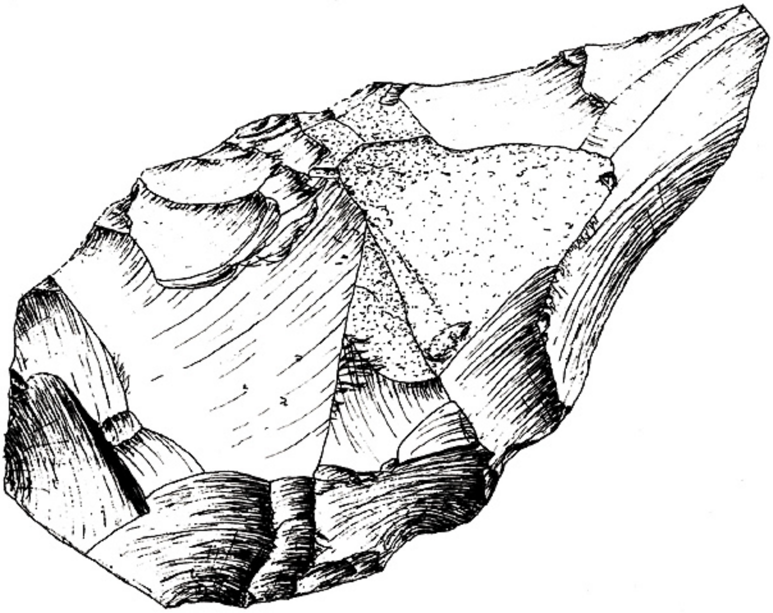
Early Human Behaviour in Global Context

The Rise and Diversity of the Lower Palaeolithic Record



Edited by Michael D. Petraglia and Ravi Korisettar

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EARLY HUMAN BEHAVIOUR IN GLOBAL CONTEXT

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EARLY HUMAN BEHAVIOUR IN GLOBAL CONTEXT

The Rise and Diversity of the Lower Palaeolithic Record

Edited by

Michael D.Petraglia and Ravi Korisettar

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Preface

Palaeoanthropology has made tremendous progress during the present century, both in accumulating data and in formulating more secure frameworks for interpreting human behaviour and evolution. The intermingled archaeological and human palaeontological record and its variable geological and environmental deposits are a testament to the major events that marked the origins of our ancestors and the processes by which hominids evolved. Those interested in human evolutionary forces and processes have sought to understand the profound behavioural changes that occurred during the course of the Plio-Pleistocene. *Early Human Behaviour in Global Context: The Rise and Diversity of the Lower Palaeolithic Record* draws together researchers who are interested in documenting and comprehending early behaviour from the complex array of material in archaeological context. Whilst the contributions in this volume mainly centre on study and interpretation of archaeological phenomena, the researchers do not limit themselves to artefactual residues, but draw upon core information from the biological and the natural sciences, thereby enriching behavioural interpretations.

Early Human Behaviour in Global Context covers a period referred to by archaeologists as the Lower or Early Palaeolithic, a holistic term usually meant to describe contexts where diverse core-flake and bifacial stone tool industries are recovered. The beginning of this period starts with the first recognizable stone artefact assemblages in the Late Pliocene at around 2.5 myr, although lines of evidence from archaeology and insights gained from modern tool use by primates suggest that this age may have to be extended further back with future investigations and discoveries. The end point of the Lower Palaeolithic is also rather arbitrary; the terminus is marked by the introduction of prepared core and retouched flake tool assemblages characteristic of the Middle Palaeolithic. These assemblages are introduced at different times in various geographic areas, although their first appearance is recorded in Africa. In conventional archaeological terms, then, the Lower Palaeolithic record spans the Late Pliocene to the end of the Middle Pleistocene, a range covering about 95 per cent of humanity's material record. Because this research context is broad, modern researchers are often dissatisfied with the 'Lower Palaeolithic' label, and thus use the term as a matter of convenience, perceiving that there is probably enormous variability in the technology, subsistence, settlement and social practices of Plio-Pleistocene hominids separated by tens of thousands of generations and spanning several continents. However inadequate it is for understanding dynamics at particular times and places, persistent use of the Lower Palaeolithic framework does appear to have some sustained research value, assisting in the organization of data and providing a context to examine some long-term patterns that indicate that there is morphological stability in certain species (e.g. *Homo erectus*) and some recurring trends in activity and technology (e.g. Acheulian Technocomplex).

Since chipped stone dominates the Plio-Pleistocene artefact record, archaeologists have devoted much attention to understanding how this material may be used to discern temporal and spatial trends and functional relationships. Not surprisingly, then, contributors in the current volume utilize the stone artefact record to examine an array of palaeolithic events and behaviours. As revealed in the following pages, stone artefact assemblages play a central role in modern studies, providing evidence for the documentation and evaluation of the origin and duration of regional occupation, changes in manufacturing technologies and reduction techniques through time, relationships between stone tool assemblages and particular habitats and resource bases, and variations in the distribution and attributes of materials as a reflection of activity and mobility. Examination of stone tools at many research scales will therefore continue to play a vital role in recording evidence and formulating hypotheses about ancestral behaviours.

Most palaeoanthropologists would probably agree that one of the most significant events that occurred during the course of the Plio-Pleistocene was the expansion of the geographic range of hominids across the African continent, eventually culminating in the colonization of the Near East, eastern Asia and Europe, where hominids encountered new and changing environments. *Early Human Behaviour in Global Context* provides a forum for examining the colonization process and the diverse regional records across the Old World. While certain researchers maintain that palaeoanthropologists must study regional records in exhaustive detail, understanding special circumstances in each particular place, other investigators contend that certain evolutionary and behavioural processes transcend regional dynamics, and thus broad processes and extra-regional comparisons are necessary. The current volume will hopefully demonstrate that both approaches are vital and necessary components of current research.

The 3rd World Archaeological Congress (WAC-3) meetings, held in New Delhi, India, in December 1994, provided the forum for gathering international specialists in palaeoanthropology. Contributions appearing in *Early Human Behaviour in Global Context* were drawn from the overall theme, ‘The Neogene and the Quaternary’, organized by V.N.Misra and S.N.Rajaguru of Deccan College, Pune, India. The theme was a compilation of a range of sub-themes devoted to the environmental, biological and cultural records over the last 20 million years. With the endorsement of the theme organizers, the editors of the current work approached Peter Ucko, Series Editor of the One World Archaeology books, about a proposal to formulate a volume. After several subsequent exchanges on proposed subjects, the editors concluded with a volume dedicated to the analysis of the Lower Palaeolithic around the world. Chapters for this volume were selected from particular sub-themes, mainly ‘Environment and Chronology’, ‘Dating the Past’, ‘Colonization’ and ‘Settlement and Technology’. To enhance this volume, several chapters were solicited from the outside to add substantive coverage and to fill in some key geographic gaps. We believe that the outcome of this effort was successful in uniting scholars interested in tackling issues and problems centring on the Lower Palaeolithic, and we are pleased that the editorial team and the list of contributors represents a satisfactory combination of researchers from the industrial and developing worlds, fulfilling a central goal of the World Archaeological Congress and the One World Archaeology series. The collection and representation of a diverse set of international workers devoted to study of the Lower Palaeolithic is unique, and may reflect, in part, the increase of scholars engaged in Lower Palaeolithic research and the greater level of intellectual exchanges occurring since the demise of the Cold War. In some small measure, we hope that this volume helps to foster international interactions among scholars, stimulating and encouraging collaborative, multidisciplinary efforts.

Given the growing number of practitioners involved in global Lower Palaeolithic research, this volume does not pretend to cover the full range of potential topics and regional studies. We do hope, however, that the contributors show how to draw upon past scientific accomplishments, transcend some previous limitations, and advance a more holistic and fruitful interpretation of the extant archaeological data base, providing further stimulation to other practitioners. As with any wide-ranging compilation of researchers from different countries, institutions and intellectual backgrounds, this volume does contain some contradictions of fact, terminology and substantive view-points. These inconsistencies do not, however, mean that there are not certain shared goals. In fact, a general reading will show that researchers are united in their desire to address a common set of questions about Plio-Pleistocene hominids, including examination of the relationship between environments and adaptations, the timing and extent of global and regional colonization, the meaning of the similarities and differences in stone tool assemblages, and the methodological problems encountered in dealing with the earliest traces of archaeological evidence.

While palaeoanthropologists place central emphasis on learning about human evolution and behaviours, it will be apparent to the reader that the current evidence for interpretation of the Lower Palaeolithic is fragmentary and far from complete. Much global evidence spanning the period is yet to be compiled. Moreover, detailed, multidisciplinary palaeoanthropological studies are still rare, and thus generalizations are often made about the behaviour of Lower Palaeolithic hominids from limited evidence. Future palaeoanthropological investigations in many areas must concentrate on how our ancestors made a living in unique situations and how they may have coped with synchronic and diachronic changes in local and regional environments. Collection of this data will help us to understand how past populations adjusted their economic and social systems in response to these environmental shifts. As studies progress, palaeoanthropologists will have a much richer data base to interpret behaviour.

Early Human Behaviour in Global Context would not have been produced without the support and guidance of Peter Ucko, Series Editor. His courtesy during Korisettar's subsequent visit to the Institute of Archaeology, University of London, in June 1996, was generous, helping further to promote the production of this volume. During the long and tedious editorial process, Petraglia continued to receive support from the Smithsonian Institution's Human Origins Program, directed by Rick Potts. Korisettar derived support from Karnatak University, Dharwad, India, and the Ancient India and Iran Trust, Cambridge, UK. A note of appreciation is extended to Dennis Knepper, who illustrated the Isampur handaxe on the cover of this volume. Our wives, Ly Nguyen Pham-Petraglia and Visalakshi Vajragiri-Korisettar, deserve special recognition for their unrelenting patience during our time spent away from home and during our struggle to formulate this volume over many a night and weekend. Our gratitude is also extended to the participants of WAC-3 for their cooperation, despite the many logistical difficulties encountered during the New Delhi sessions. Rhys Jones of the Australian National University, Canberra, admirably led the final discussion, soothing the inconveniences endured by many. We hope that this volume reflects a positive outcome of the evidence and ideas expressed in the sub-theme sessions.

Michael D.Petraglia
Ravi Korisettar

1

The archaeology of the Lower Palaeolithic: background and overview

RAVI KORISETTAR AND MICHAEL D.PETRAGLIA

INTRODUCTION

The last half century of palaeoanthropological exploration has experienced a tremendous increase in our knowledge about the 2.4 million year long artefactual record commonly referred to as the Lower or Early Palaeolithic. The growing number of discoveries of plio-pleistocene localities have been accompanied by paradigm shifts in palaeoanthropology and concomitant changes in the way in which early human behaviour is viewed (e.g. Dart 1953; Clark 1960; Leakey 1967; Binford and Binford 1968a, 1968b; Binford 1972, 1981, 1985; Ardrey 1976; Isaac 1977, 1984; Bunn *et al.* 1980; Potts 1994). During the last few years there has been a torrent of discoveries throughout the Old World, forcing investigators to re-evaluate earlier positions and previous consensus. The new dates for hominid fossil occurrences in Spain (Carbonell *et al.* 1995a; Parés and Pérez-Gonzàlez 1995), Georgia (Gabunia and Vekua 1995), China (Huang *et al.* 1995) and Indonesia (Swisher *et al.* 1994) have created controversy, potentially stretching the time-depth of hominid presence in Early Pleistocene contexts outside of Africa. At the same time, Africa's pre-eminence as the cradle of mankind continues to be continually strengthened by new discoveries, including the identification of Late Pliocene forms *Ardipithecus ramidus* and *Australopithecus anamensis* in East Africa (White *et al.* 1994; WoldeGabriel *et al.* 1994; Leakey *et al.* 1995). To date, there is no strong evidence of australopithecines in any other part of the Old World, and the recent suggestion that pre-*erectus* hominids are present in eastern Asia (Huang *et al.* 1995) is arguable.

Most firmly recognizable archaeological occurrences appear at about 2.5 myr, beginning with the Oldowan or Mode I industries in Africa (Harris 1983; Semaw *et al.* 1997). Most Mode I stone tool assemblages are attributed to *Homo habilis,* although archaeological and fossil evidence indicates that the australopithecines may have been involved in tool manufacture (Susman 1991). Although human palaeontologists agree that the split between the *Homo* and australopithecine lineages occurs at about 3 to 2.5 myr, the evolutionary path of the *Homo* lineage is still vigorously debated (e.g. Chamberlain 1991; Klein 1995). In addition to

Homo habilis populations at 1.8 myr, there is a possibility that another species, *Homo rudolfensis,* occurs at this time (Wood 1992). In addition, the long-surviving *Homo erectus* populations show distinct anatomical variations among African and east Asian forms, the early African forms possibly separable as *Homo ergaster*. The emergent and long-lasting *Homo erectus* populations coincide with the development of Mode II industries, including the standardized bifacial industries commonly referred to as 'Acheulian'. During the course of the Early Pleistocene, *Homo erectus* greatly expanded its territorial range, spreading to many other African environments and colonizing areas outside of the African continent (Rightmire 1990, 1991; Gamble 1993; Klein 1995). Debate still surrounds the stylistic meaning, adaptive significance and technological relationships of Mode I, Mode II and Acheulian industries found in Early and Middle Pleistocene contexts around the Old World (e.g. Isaac 1984; Binford 1985; Wynn 1989; Davidson and Noble 1993; Toth and Schick 1993; Belfer-Cohen and GorenInbar 1994; Clark 1994; Klein 1994; Schick 1994). During the Middle Pleistocene, archaic *Homo sapiens* emerge, overlapping with more developed Acheulian biface industries and prepared core techniques at 200 kyr. Prepared core technologies increase in use and level of sophistication in later periods, eventually characterizing the Middle Stone Age of Africa and the Middle Palaeolithic of Europe and the Levant (Klein 1995).

The application of DNA studies has added new dimensions to the debate on the multiregional hypothesis versus the replacement or 'out of Africa' model for modern humans (e.g. Mellars and Stringer 1989; Bräuer and Smith 1992; Clark 1995; Tobias 1995). Multiregionalists have held that modern humans have evolved in their respective geographic zones over a long period of time from their ancestral *Homo erectus* and archaic *Homo sapiens* populations, thereby essentially reflecting regional continuity (e.g. Prayer *et al.* 1993, 1994; Wolpoff *et al.* 1994). On the other hand, advances in molecular biology have led to the emergence of an 'out of Africa' model that argues for population replacements of evolved *Homo erectus/*archaic *Homo sapiens* by advancing *Homo sapiens* populations from Africa (e.g. Bräuer 1992; Stringer and Gamble 1993; Stringer and Bräuer 1994). This has led to reassessments of the archaeological evidence of this time period (Klein 1995), thus forming questions about the relationship of the hominid and archaeological record.

The aim of the following overview is briefly to characterize the Lower and Middle Pleistocene archaeological record found over a number of geographic areas of the Old World. Of course, no single review could possibly cover all material findings, as each region contains a plethora of studies in a number of languages. Rather, this overview simply aims to provide the reader with a broad sketch of the status of palaeoanthropological research as a context for examining the chapters in this volume. For study of the more detailed literature, the reader is referred to the reviews and regional works cited here and to the chapters and references forming this volume.

AFRICA

Africa contains the earliest and longest human palaeontological and archaeological records, as amply discussed in numerous reviews (e.g. Harris 1983; Isaac 1984; Toth and Schick 1986; Clark 1994; Klein 1994). The earliest stone tools, often referred to as the Oldowan industry, date from *c.* 2.5 to 1.5 myr. Oldowan artefacts were usually produced from pebbles and cobbles and simply flaked into unifacial and bifacial pieces, termed as choppers, discoids, scrapers and polyhedrons (Leakey 1971). The tool categories are considered to represent a continuum of flaking, and not necessarily target designs (Toth 1985; Potts 1991). The earliest Oldowan or Mode I assemblages have been identified from localities in East Africa (e.g. Member F Omo, Gona, Senga-5), and later from open air localities in East Africa (e.g. Member E Omo, Koobi Fora, Olduvai) and cave breccia contexts in South Africa (e.g. Swartkrans, Sterkfontein). While a number of Mode I localities have been identified, the known frequency of early occurrences is very low compared to later Acheulian sites (Gowlett 1990). The utilization of modified stone is viewed as a significant behavioural change in early hominid lifeways, and the increasing use of tools generally coincides with significant environmental changes around 2.5 myr, a time marked by extensive northern latitude Arctic glaciation, triggering great changes in terrestrial biomes, including the tropics. The Sahara expanded in area, and open and desertic environments and grassland habitats appeared in eastern Africa with a reduction in temperatures and rainfall (Clark 1995; Vrba 1996).

Among the group of Early Pleistocene hominids, *Homo erectus* coincides with the appearance of a stone tool industry characterized by the production of standardized bifacial forms (e.g. handaxes, cleavers), commonly referred to as the Acheulian industry. The majority of Early Acheulian sites in Africa date from about 1.6–1.5 myr onward into the Late Middle Pleistocene, when a more evolved technology is found (Clark 1994). The abundant African fossil and archaeological evidence from this period is generally recovered from semi-arid savanna-woodland transition zones. During this long time span, stone knapping techniques became increasingly diversified. It is assumed that the Acheulian in East and Southern Africa gradually spread into most other habitats. The Acheulian sites from the Sahara are generally considered to be Late Acheulian, based on absolute dates and classificatory schemes. In the western deserts, these sites are associated with fossil springs, where occupations came to an end with the onset of drier conditions, leading to the drying up of the spring-lakes. The presence of diminutive bifaces and prepared core techniques are characteristics that distinguish Late Acheulian occurrences from earlier Acheulian bifaces and the later mousterian flake tool assemblages (Clark 1982, 1995).

During the 1960s, there was a major shift in the orientation of Lower Palaeolithic research, ushering in an era of anthropological archaeology. While taxonomists and culture-historians were preoccupied with the reconstruction of biological and technological stages, anthropological archaeology emphasized the reconstruction of hominid adaptations through time and across diverse ecosystems. Documention of finds across occupation surfaces to discern settlement patterns was of major concern. The excavations at Isimila, Kalambo Falls, Olduvai and Olorgesailie provided novel information about hominid behaviour (Howell *et al.* 1962; Clark 1969; Leakey 1971; Isaac 1977). Accumulations of artefacts and bones together in sediments were considered to be intact manifestations of cultural behaviour; thus, for example, living floors and butchery and kill sites were recognized (Leakey 1971) and home bases with reciprocal food sharing was surmised (Isaac 1977).

More than any other study of its time, the Koobi Fora investigation set the stage for subsequent behavioural approaches in Palaeolithic archaeology (Isaac *et al.* 1976; Isaac 1978). Emphasis was laid on the reorientation of prevailing theoretical and methodological frameworks for a better understanding of early human economy, ecology and demography. A major focus of research centred on socio-cultural evolutionary processes, determining the degree to which early humans were involved in the gathering of plant resources, the hunting and transport of meat, and the reciprocal sharing of foodstuffs. This research was oriented towards:

1 the determination of the overall distribution of artefacts and faunal remains on ancient landsurfaces,
2 the recovery of palaeoenvironmental data,
3 the quantification of material evidence relevant in the reconstruction of subsistence economy and social configurations, and
4 the comparison of morphological parameters of artefacts to draw inferences about distinctive styles and social entities.

Variability among and within places occupied by hominids was demonstrated by differences in artefactual contents and spatial configurations (Isaac and Harris 1978; Isaac and Crader 1981). A major conclusion of this research was the identification of home bases, with implications for organized hominid movement around a spatial focus (Isaac 1977, 1978). Although the role of scavenging in the hominid diet was recognized early on in this research, the hunting of meat and reciprocal sharing were considered key traits in proto-human behaviour.

Inferences about early human behaviour set in motion debates about the accuracy of these interpretations, eventually leading to reappraisals and sometimes dramatic changes in the way in which early hominid lifeways were viewed (e.g. Binford 1981, 1983, 1985; Isaac 1981, 1983, 1984; Blumenschine 1986; Potts 1988, 1991). To determine the degree to which early hominids possessed predatory and social behaviours, much research has been expended on determining the role of meat eating and scavenging in the hominid diet (e.g. Bunn *et al.* 1980; Binford 1981, 1984; Potts and Shipman 1981; Shipman *et al.* 1981, 1982; Potts 1983, 1984, 1987; Shipman 1983, 1986; Shipman and Rose 1983; Blumenschine 1986, 1995; Bunn and Kroll 1986, 1988; Blumenschine and

Cavallo 1992; Blumenschine and Marean 1993; Oliver 1994; Monahan 1996; Rose and Marshall 1996). Taphonomic research has also focused on assessing the role of human and non-human agencies in the formation of archaeological occurrences (e.g. Behrensmeyer and Hill 1980; Bunn *et al.* 1980; Blumenschine 1986; Schick 1986). Studies have been conducted to examine the role of natural processes in contributing to the formation of artefact and faunal distributions (e.g. Bunn *et al.* 1980; Brain 1981, 1993; Schick 1986, 1987, 1992; Potts 1988; Schick and Toth 1993; Kroll 1994; Kuman 1994; Petraglia and Potts 1994). Analysis of the temporal resolution of early occurrences has been performed to determine whether artefact distributions represented short- or long-term activity (e.g. Bunn 1982; Kroll and Isaac 1984; Potts 1988) or variable combinations and rates of geological and cultural processes (e.g. Binford 1981; Potts 1986, 1994; Blumenschine and Masao 1991; Stern 1993, 1994). To understand the activity and ranging behaviours of hominids, the frequency and distribution of stone artefact types, sizes and raw materials have been examined (Schick 1987, 1991; Toth 1987; Potts 1988, 1991; Stiles 1991; Schick and Toth 1993; Bunn 1994; Rogers *et al.* 1994).

Current research has begun to stress the importance of examining geographic and temporal variability in environments and shifts in hominid activity and resource use (Potts 1994, 1996). The initial movement of tools over the landscape and the new ways of exploiting resources has been viewed as a critical shift in hominid behaviour, culminating in a large-bodied and diurnal hominid that engaged in long-distance walking (Potts 1991, 1993). Habitat disruption in Africa, both synchronic and diachronic, may have led to the occupation of novel environments, thereby accounting for the ability to adapt to new situations and to cope with unpredictable and marginal environments (Potts 1993; Cachel and Harris 1995).

THE NEAR EAST

The Near East constitutes a plausible geographic transit of hominids between Africa and Eurasia and beyond. An understanding of the diverse geographic environments of the Near East is likely to play a key role in examining the record of early hominid adaptations and dispersal processes. The Mode I industry of ‘Ubeidiya is characterized by the high incidence of core-choppers, polyhedrons and crude bifaces comparable to the simple core industries of East Africa (Bar-Yosef and Goren-Inbar 1993; Bar-Yosef 1994). Biostratigraphic correlations of the fauna from ‘Ubeidiya indicates an age of about 1.4 to 1.0 myr (Bar-Yosef 1994). At Dmanisi, a hominid mandible and a non-bifacial industry consisting of core-choppers is associated with Lower Pleistocene fauna in a stratified context overlying a lava flow, which has a K-Ar age of 1.8 myr (Bar-Yosef 1994; Gabunia and Vekua 1995). Morphological analysis of the Dmanisi mandible suggests that the hominid possessed relatively evolved features, indicating an age consistent with the existing scenario of hominid dispersal out of Africa (Dean and Delson 1995; Klein 1995). Some are not convinced of the early age range of the Near Eastern localities, favouring younger dates of 0.7 to 1 myr (Gamble 1993: 127–8).

Absolute and stratigraphic dating of Lower Palaeolithic occurrences suggests that there was a second migratory wave of hominids out of Africa about 700 to 500 kyr, in this case hominids carrying Acheulian technologies (Bar Yosef 1994). Latamne is one of the early sites where faunal analysis suggests an age dating to the Mindel-Riss interglacial (Clark 1967). The Lower Palaeolithic site of Gesher Benot Ya'aqov contains a galerian fauna that replaced the late villafranchian fauna around 900–700 kyr, and K-Ar dating of the basal lava to 900 kyr also supports these date estimates. The Middle Acheulian sites in the southern Levant have radiometric age estimates of 500–400 kyr (BarYosef 1994).

The identification of numerous Acheulian sites in the Near East has led to the establishment of a typological scheme, classifying assemblages into Lower, Middle and Upper stages based on changes of stone tool forms and technologies (Bar Yosef 1994). The earliest stages of the Acheulian are represented by localities such as 'Ubeidiya, which contains high frequencies of core-chopers, polyhedrons, spheroids and crude handaxes. The Middle Acheulian of the region comprises two broad groups of assemblages: the inland sites containing core-choppers and polyhedrons, lanceolate bifaces and picks, and the coastal sites generally containing amygdaloid and oval bifaces. Gesher Benot Ya'aqov is cited as an instance where Middle Acheulian assemblages share strong similarity with those of Africa (Bar-Yosef 1994). Upper Acheulian sites are dominantly composed of symmetrical handaxes and the employment of the Levallois technique. Whilst it has been possible to study technological evolution among these Lower Palaeolithic localities, many of the identified sites have been heavily influenced by natural disturbances, with few localities meriting focused attention on artefact distributions to study activities and settlement patterns, and few sites contain functionally associated fauna and artefacts allowing for interpretation of subsistence (Bar Yosef 1980, 1993; Goren-Inbar *et al.* 1992).

EUROPE

The timing of the initial colonization of Europe continues as an intense debate, with researchers favouring either a lengthy chronology reaching into the Early Pleistocene or a shorter chronology dating to the Middle Pleistocene (e.g. Dennell 1983; Rolland 1992; Roebroeks and van Kolfschoten 1994; Carbonell *et al.* 1995b; Dennell and Roebroeks 1996). In addition to solid Early Middle Pleistocene evidence from localities such as Isernia, in Italy (Coltorti *et al.* 1982), and Přezletice, in Czechoslovakia (Svoboda 1989), recent discoveries in Spain have further challenged the 'short' chronology. At the karstic cave of Cueva Vittoria, there is claim that a hominid phalanx dates to the Early Pleistocene (Palmqvist *et al.* 1996). Moreover, hominid remains of *Homo heidelbergensis* occurring in association with faunal material in the pleistocene cave of Gran Dolina (TD), Sierra de Atapuerca, have been dated by palaeomagnetism to >780 kyr, suggesting that western Europe was occupied by the Late Early Pleistocene (Carbonell *et al.* 1995a; Parés and Pérez-González 1995). A number of other localities in western and central Europe have been claimed to be of Early Middle Pleistocene or Early Pleistocene date, but some lack definite evidence of hominid presence and others are being redated upwards (e.g. Santonja and Villa 1990; Villa 1991; Roebroeks and van Kolfschoten 1994; Carbonell *et al.* 1995b; Roberts *et al.* 1995). Most solid evidence indicates that Europe was not occupied until the Middle Pleistocene, with the majority of the localities dating to 500 kyr or younger, perhaps representing a major colonization of Europe at that time (e.g. Villa 1991; Roebroeks and van Kolfschoten 1994). The close resemblance of Middle Pleistocene *Homo erectus* fossils from Europe and Africa may represent population movement (Klein 1995). Indeed, the Acheulian assemblages in Europe between 500 kyr and the last interglacial (125 kyr) are similar to the Late Acheulian assemblages of Africa.

Whatever the date of the initial occupation of Europe, hominids certainly encountered a cold, arid landscape that presented a unique set of environmental circumstances and challenges to economic adaptations (Dennell 1983; Gamble 1986). The rarity of archaeological sites prior to 500 kyr and the abundance of sites thereafter may be connected to a faunal turnover, marked by a decline in carnivores and hyenas, and an increase in deer, bovid, horse and rhino populations (Turner 1992). Based on these environmental circumstances and the characteristics of the archaeological record, variation in landscape resources and biomass were viewed as central forces in conditioning hominid economies and social behaviours (Gamble 1993). Some sites are associated with interglacial faunal and floral material revealing adaptations to wide-ranging environments during all climatic phases, including glacial, inter-stadial, interglacial, and subarctic (Roebroeks *et al.* 1992; Gamble 1995). The Middle Pleistocene site of Boxgrove is an example of occupation throughout the interglacial Oxygen Isotope Stage 13 and into the subsequent major cold phase (Anglian/Elsterian) (Roberts *et al.* 1995).

Based on differences in tool types, archaeologists have divided Lower Palaeolithic industries into regional classifications such as the Acheulian, Clactonian and Levallois (Wymer 1982). However, the meaning of some of these divisions is becoming increasingly complicated, and some critics have argued that the distinction between the British Clactonian and Acheulian industries cannot be maintained (Ohel 1979). Within Acheulian occurrences in western Europe, typological and technological studies indicate that there are temporal trends in artefact manufacture in the later stages (i.e. more refined flaking techniques, increased standardization in forms, use of prepared techniques, use of soft hammer technique, greater range of tool types). Whilst some directional changes have been identified in the Acheulian biface industries (Roe 1982), the relationship of these industries in an absolute temporal scale remains to be determined (Roberts *et al.* 1995). The Levallois technique is present in the late phases of the Middle Pleistocene, showing consistency with Middle Palaeolithic industries (e.g. Tuffreau 1982; Villa 1991). Researchers have emphasized that it is important to consider that temporal trends in flaking patterns are not always progressive, and that variations of Lower Palaeolithic types may be due to a variety of factors, including raw materials, activity and reduction variation (Villa 1983, 1991; Santonja and Villa 1990). Recent finds of handaxes in clactonian assemblages indicate that the traditional division may be in need of revision, and researchers suggest that formal assemblage variations are the result of hominid activities and raw material differences (Ashton *et al.* 1994; McNabb 1996). Unlike western Europe, the Middle Pleistocene period of central Europe is dominated by a pebble tool industry (Svoboda 1987, 1989; Kretzoi and Dobosi 1990). Bifaces, attributed to the Acheulian, though not abundant, are present later in central Europe (Valoch 1982; Svoboda 1989). Southern margin zones such as the mainland of Greece continue to be poorly known, but localities with Mode I and biface assemblages have been identified (Reisch 1982; Runnels and Andel 1993a, 1993b; Bailey 1995; Runnels 1995).

Like studies in Africa, behavioural approaches in Europe gained serious attention in the 1960s (e.g. Howell 1965; Freeman and Butzer 1966; de Lumley 1969). After initial behavioural reconstructions about hominid hunting and settlement were formulated, more sophisticated taphonomic and distributional studies were conducted, leading to the realization that localities were the product of hominid behaviours, animal interactions and geomorphological processes (Villa 1982, 1983; Binford 1987a, 1987b; Klein 1987; Santonja and Villa 1990). More realistic interpretations are now being advanced about Lower Palaeolithic behaviour, including assessments concerning the butchery and processing of large and small animals, identification of activity zones including artefact manufacture and reduction, and the transport of raw materials from local and distant sources (Roebroeks and van Kolfschoten 1995).

ASIA

South Asia

Lower Palaeolithic archaeological occurrences are abundant in India. Surveys and excavations have recovered Mode I (i.e. Soan) and Acheulian assemblages (e.g. Paddayya 1984; Misra 1987; Mishra 1994). Determination of the initial occupation of the region remains uncertain, owing to problems with geomorphological contexts, artefact identification and dating. The oldest potential locality in India, Kukdi, remains fraught with uncertainties, owing to conflicting dates, with various techniques dating the tephra to 1.38 myr and 75 kyr (e.g. Korisettar 1994; Mishra *et al.* 1995; Shane *et al.* 1995). In Pakistan, well known but controversial dates place Mode I assemblages to 2 myr (Rendell *et al.* 1989). Acheulian occurrences are well known in India, ranging from >350 to *c.* 150 kyr (see Mishra 1992:Table 1). In Pakistan, Acheulian sites date from 700–400 kyr (Dennell and Rendell 1991; Allchin 1995). Only one locality, Hathnora in the Narmada Valley, has yielded a hominid fossil, originally cast as a *Homo erectus* but later reclassified as an archaic *Homo sapiens* (Sonakia 1985; Kennedy *et al.* 1991).

Mode I or Soan pebble tool assemblages are commonly found in the sub-Himalayan region, and they are occasionally reported from the Upper Siwalik formations (Sharma 1977; Verma 1991) and on the Siwalik surfaces (Gaillard 1995). Pebble artefacts elsewhere in India have been treated as an adjunct of a Lower Palaeolithic industry (Joshi 1978). There are few temporal or stratigraphic controls on these Mode I sites, hence their age is difficult to assess. The technological characteristics of Acheulian assemblages are consistent with assemblages found in Africa and Europe. Although both Early and Late stages of the Acheulian have been identified (Misra 1987), stratigraphic profiles showing the sequential development are absent, and the role of other factors, such as raw material variability for stone tool manufacture, has not been thoroughly examined. Sporadic but vital evidence of Acheulian bifaces is being reported from the central Himalayan plateau (Sharma 1995) and in the Dang and Deokhuri valleys of Nepal (Corvinus 1995).

Palaeoenvironmental research has been conducted in recent years, indicating the relationship between climatic and geomorphological changes and hominid responses (e.g. Wadia *et al.* 1995). The Thar Desert investigations have documented changes in fluvial, aeolian and lacustrine environments and their effects on hominid settlement (Misra 1995), and surveys in several valleys have revealed Acheulian settlement patterns over large areas (Paddayya 1982; Jacobson 1985). Given the location and characteristics of hominid settlements in the Hunsgi-Baichbal Valley, and an inferred palaeomonsoonal and semi-arid landscape on the subcontinent, a model of dry season aggregation and wet season dispersal has been hypothesized (Paddayya 1982). Analysis of artefact assemblages has shown that the formation of Acheulian localities was influenced by a variety of geomorphological processes, but that certain technological and spatial distributions were the product of hominid behaviours (Paddayya 1987; Paddayya and Petraglia 1993; Petraglia 1995).

Eastern Asia

A significant number of Palaeolithic occurrences and fossil *Homo erectus* and *Homo sapiens* localities have been identified in eastern Asia (e.g. Wu and Olsen 1985; Rightmire 1990; Schick and Dong 1993). Unlike finds in Africa or Indonesia, the Chinese hominid localities are not associated with volcanic material, hence chronology has been based on biostratigraphic, lithostratigraphic and magnetic stratigraphy. The great majority of the archaeological and human palaeontological evidence from China strongly reaffirms occupation during the

Middle Pleistocene (Chen and Zhang 1991). Although dates exceeding 1 myr have been reported, the earliest reliable contexts are the Nihewan sites and Lantian, where hominid and archaeological finds date to >780 kyr (e.g. Wu 1985; Schick and Dong 1993). The recent dating of the Longgupo hominid and artefacts to *c.* 1.9 to 1.7 myr (Huang *et al.* 1995) is controversial, but it has opened renewed discussion on the earliest phases of the colonization of East and Southeast Asia.

Although hominid remains in island Southeast Asia occur in volcanic and mineralized deposits, sometimes in faunal-rich sequences, no consensus has been reached regarding their precise age. The first K-Ar dating of the Modjokerto infant calvaria to 1.9 myr and the recent $^{40}Ar/^{39}Ar$ dates of 1.8 myr (Ninkovitch and Burckle 1978; De Vos *et al.* 1994; Swisher *et al.* 1994) have not been completely accepted; some argue that the localities are certainly no older than 1.3 myr and more likely 1 myr or younger (e.g. Pope 1988; Pope and Keates 1994). In support of the latter argument, others argue that hominids are absent in deposits dated to between 2 and 1.5 myr, and further, that *Homo erectus* was able to reach Java only during the period between *c.* 1.2 and 0.9 myr, at times of low sea levels (Bergh *et al.* 1996a). If the recent 1.8 myr date for the presence of *Homo erectus* in Indonesia is accurate, however, it would have a profound implication for understanding the distribution of Lower Palaeolithic technology, as it suggests that Mode I assemblages may have been carried to eastern Asia prior to the advent of bifacial industries in Africa at about 1.6 myr. Although a case has been made that there is no reliable stone tool industry in Indonesia dating to the Early and Middle Pleistocene (Bartstra 1983), recent evidence suggests the possibility that a flake industry is present (Bergh *et al.* 1996b; Simanjutak and Semah 1996).

The East Asian ‘Chopper-Chopping Tool’ terminology for the Lower Palaeolithic of China is being revised, and two broad groups of industries have been recognized: Mode I core-flake tool assemblages and Mode II biface assemblages (Clark 1994; Schick 1994). Mode I assemblages constitute cores, flakes and modified pieces derived from Early and Middle Pleistocene contexts. The presence of bifaces across the ‘Movius Line’ is being reported from different localities in East and Southeast Asia (Yi and Clark 1983; Huang 1989; Pokee 1991). These have been grouped as Mode II occurrences, constituting bifaces made on cobbles and large flakes. However, there has been some reluctance in classifying these as Acheulian, because the relatively rare bifaces lack the characteristic forms, symmetry and technologies that are representative of this industry (Clark 1994; Schick 1994). The dominance of Mode I occurrences throughout the course of the Middle Pleistocene is thought to reflect the particular environments of eastern Asia, with hominids relying on resources such as bamboo for tool use (e.g. Harrisson 1978; Pope 1989).

Zhoukoudian cave, with its hominid finds, abundant artefacts and ecofacts, and its evidence of fire, has provided for most behavioural reconstructions, and traditional interpretations centre on the role of hominids in forming the deposits (e.g. Jia and Huang 1990). Reassessments of the Zhoukoudian deposits have indicated that the role of hominids in contributing to patterning could not be taken for granted; instead, some material evidence and associations were interpreted to be the result of non-hominid agencies (Binford and Ho 1985; Binford and Stone 1986, 1987a, 1987b). While detailed spatial approaches have not been taken to Early and Middle Pleistocene occurrences in East Asia, it is clear that preservation conditions among localities likely range from wholly transported to well preserved, with some showing significant evidence for hominid involvement in forming artefact and faunal associations (Clark and Schick 1988; Schick *et al.* 1991; Pope and Keates 1994).

DISCUSSION

An overview of the state of the art of Lower Palaeolithic research indicates that significant strides have been made in documenting and understanding the behaviour of our ancestors over the course of the Plio-Pleistocene. In examining these investigations, a number of particular issues come to the forefront that merit the scrutiny of future researchers.

1 Palaeoanthropologists have the opportunity to examine Lower Palaeolithic assemblages from the perspective of stasis and change throughout a period lasting over 2 million years. The breakthrough that occurred some 2.5 myr ago in the consistent use of stone tools profoundly influenced hominid adaptations and helped to set in motion a series of biological, behavioural, and sociological changes and feedback mechanisms. The development of Acheulian technologies at 1.6 myr ago is often implicated as a second major shift in hominid technological advances. While palaeoanthropologists have recognized the importance of these technological shifts, comparative studies must be conducted to address the influence of these technological milestones on behavioural evolution.

2 The Lower Palaeolithic provides the context to examine the hominid colonization process, and thus greater attention must be given to this issue. Critical to this analysis, dating methods will need to be improved and applied to a variety of depositional contexts throughout the Old World. Systematic dating of Lower Palaeolithic assemblages will provide an opportunity to address the timing of radiation(s) out of Africa, as well as the record of continuity and abandonment of certain regions.

3 Major questions remain regarding the meaning of stylistic and quantitative differences among regional stone tool assemblages. Studies devoted to lithic technology are of utmost importance in addressing a multitude of behavioural questions; thus detailed analyses of lithics are needed to understand the meaning and relationships among Mode I, Mode II and Acheulian industries.

4. More emphasis needs to be placed on examining the ecological context of Lower Palaeolithic occurrences. By examining the relationship between Lower Palaeolithic occurrences and ecological contexts, a more informed understanding of hominid adaptations and adjustments through time can be made. Once distributions and relationships are better known within habitats, inter-regional comparisons may be examined to assess variability.
5. Despite a lengthy period of investigation of Lower Palaeolithic sites, little is still known about hominid activities in many parts of the Old World. Greater efforts must be made to examine lateral artefact distributions and co-occurrences and associations between stone artefacts, fauna and ecofacts. Compilation of this data will allow archaeologists to make inferences about intra- and intersite activities and, furthermore, it will be possible to generalize about hominid adaptations.
6. Archaeologists must continue to focus attention on understanding geomorphic contexts and formation processes. Of the behavioural reconstructions that have been attempted, many have been called into question because of the lack of attention paid to geological and biological processes. The role of natural processes in contributing to the formation of deposits and artefact associations must be systematically addressed.
7. The Lower to Middle Palaeolithic transition is a significant boundary, as profound behavioural changes are thought to have occurred during this interval. Whilst an enormous amount of attention has been placed on examining the Middle to Upper Palaeolithic transition, a similar level of comparison has not been generally made of the Lower to Middle Palaeolithic transition. Evaluations of the similarities and differences in the structure and content of the archaeological record will provide useful comparative information for assessing variations in behaviours.

The foregoing overview has hopefully shown that the Lower Palaeolithic provides an opportunity to examine a number of fascinating palaeoanthropological topics. Whilst some of the foregoing outlined issues are covered in the current volume, some are only touched upon, partially on account of the inadequacy of our data base. However, there is reason to remain optimistic that continued improvement will be made to address data gaps in the near future. Over the last two decades, positive scientific reorientations in behavioural research have occurred, and the increasing interactions among foreign scholars can only lead to further advances. We conclude with the belief that the twenty-first century will provide an unprecedented opportunity to examine the behaviour of our ancestors and the attributes that characterize ourselves.

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2

Techniques for the chronometry of the Palaeolithic: evidence for global colonization

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INTRODUCTION

This chapter aims to provide an overview of the basic principles that govern some key physical and chemical methods relevant in dating humanity's past. It complements monographs and articles that review the ever increasing and improving chronometric methods available to researchers (e.g. Faure 1986; Aitken 1990; Geyh and Schleicher 1990; Aitken *et al.* 1992; Wagner 1995; Wintle 1996). Although early archaeological and geological research recognized the importance of stratigraphy in establishing relative chronology, absolute chronology has remained a daunting task for reconstructing cultural evolution in time and space. The intensity of the debate between the 'multiregional evolution' and the 'out of Africa' hypotheses (Figure 2.1) have warranted not only new technological tools to finger-print DNA, but also higher precision in numerical dating techniques (see Aitken *et al.* 1992).

The earliest concept of dating was based on the law of superposition, which reasons that the deeper the stratum in the stratigraphic sequence, the older it is. This provides a chrono-sequence of events. Faunal markers were used, wherever possible, to correlate stratigraphic sequences, but the paucity of unambiguous evidence, compounded by poor preservation of organic materials, rendered this task difficult. Later developments involved somewhat more quantitative (but still relative) dating techniques that utilized chemical changes in the organic remains due to oxidation/degeneration. Thus techniques such as the fluorine to phosphate (f/p) ratio and sequential growth of hydration layers on obsidian became applicable in dating. Among relative dating methods, an important application came from the delineation of palaeomagnetic stratigraphy of sedimentary deposits.

Although Rutherford first conceived the idea of the applicability of natural radioactivity for dating as early as 1905, it was Libby who laid the firm foundation of radiometric chronology with his radiocarbon revolution in the late 1940s. Ever since, numerous archaeological samples have been dated (Libby 1952). The radiocarbon revolution in archaeology formed the basis of dating younger archaeological situations. The first radiometric assays for hominid

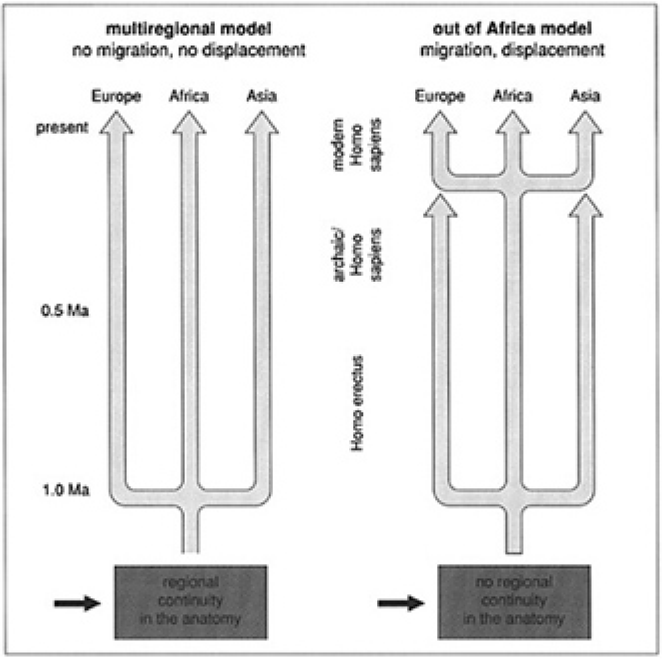


Figure 2.1 Alternative evolutionary scenarios of hominid evolution.

Source: Lewin 1989

localities can be credited to von Koenigswald *et al.* (1961), who gave the first set of K-Ar ages on the basal flows in Olduvai Gorge, and soon after additional K-Ar ages were also quoted by Leakey *et al.* (1961) for the same site (see also Leakey 1965). In addition, other chronometric techniques have been developed to date Palaeolithic and later prehistoric sites (Table 2.1).

Stratigraphic and numerical dating methods are independent approaches, yet they are mutually complementary. The Stratigraphic approach leads to a relative age framework of layers and associated material remains. The second approach provides quantitative ages to individual horizons. A *chronology* results

Table 2.1 Physical and chemical methods of dating in archaeology.

Method	*Age Range (a)*	*Dated event*	*Materials*
Physical dating methods			
Potassium-Argon	$>10^4$	Rock and mineral formation, last heating event	Volcanic ash falls, lava flows, feldspar, biotite

Method	*Age Range (a)*	*Dated event*	*Materials*
Fission-track	$>10^3$	Rock and mineral formation, last heating	Natural glass (obsidian, pumice), artificial glass, zircon, sphene, apatite
Alpha recoil tracks	10^3–10^6	Surface exposures	Rock varnish
Luminescence	10^2–10^5–(10^6)	Most recent heating, most recent burial, sedimentation, mineral formation	Heated pottery, slags, lava flows, volcanic ash, daylight bleached sediments, quartz, feldspars, flint, obsidian
Electron spin resonance	10^4–10^6	Mineral formation, mineral heating events	Silicates, carbonates, bones and other organic material
Uranium series	10^2–4×10^5	Calcium carbonate precipitation	Coral, bones, teeth, travertines, stalagmites
Radiocarbon	$<4\times10^4$	Death of an organism	Wood, charcoal, seeds, nuts, peat, ivory, bones, shells
Other cosmic ray produced isotopes	10^3–10^6	Exposure of a surface to cosmic rays	Rock surface, sediments
Chemical dating methods			
Hydration	10^2–10^6	Fracturing	Obsidian
Fluorine-Uranium-Nitrogen tests	qualitative and large age differences	Death and subsequent burial	Bones, antler, teeth
Amino acid racemization	10–10^6	Death and subsequent burial	Bones, teeth, ivory
Cation ratio method	10^3–10^6		
Relative dating methods			
Palaeomagnetism	In principle unlimited $>10^2$	Sedimentation, volcanism	Sediments deposited under non-turbulent conditions, basalts

from attaching numerical age data to stratigraphic sequences (Figure 2.2). This may be expressed by the formula:

$$\text{Stratigraphy} + \text{Chronometry} = \text{Chronology} \qquad (1)$$

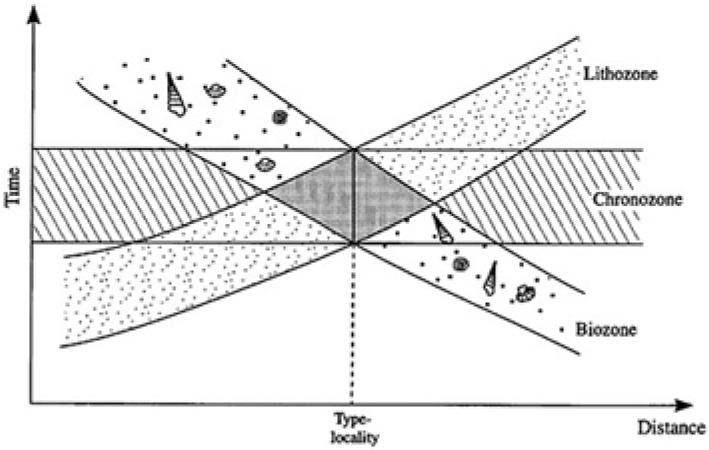


Figure 2.2 The stratigraphic units lithozone, biozone and chronozone are based on palaeontological, lithological and chronometric criteria respectively. Biozones and lithozones might be time-transgressive.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

BASIS FOR NUMERICAL DATING

All physical and chemical dating methods are based on the measurement of a parameter (P) that evolves with time in a continuous and predictable manner. This could be the annual growth of tree-rings or the radioactive decay or growth of a radioactive isotope whose decay or growth rates are known. A simple analogy for any dating method is the case of a beaker being filled or emptied through a leak (Figure 2.3). The estimation of chronometric age T (or the time needed to fill/empty the beaker) is given by the notional relation:

$$T = (P_f - P_i)/E \qquad (2)$$

where P_f is the final value of the parameter P, P_i is the initial value of the parameter P and E is the rate of change.

An important factor in the application of this equation is the assumption of the closed system behaviour of the sample being examined with respect to the parameter P. It is therefore necessary to establish that during time evolution of P, no latent sources or sinks, apart from those defined by time evolution function E, existed that could have altered its value. Typical examples of violation of the closed system behaviour are the case of missing tree-rings in dendrochronology and the contamination of a radiocarbon sample by modern carbon or by 'dead' carbon through the limestone dilution effect. Thus, in every single chronometric application it is crucial to establish that the system indeed exhibited a closed system behaviour.

Crucial to chronometric studies is the identification of the event that is being dated by a particular method. Not only do different methods date different events in the history of the sample, but the same method in the same sequence can provide ages of different episodes. Thus, for example, luminescence ages from different strata within a loess-palaeosol sequence may date very different events. The analysis of the B-horizon normally provides the date of deposition of loess, whereas the analysis of the A-horizon gives the average age of soil formation; thus the two could be separated by several thousand years (kyr). This implies that one need not unduly seek concordance between different methods or unduly despair from the lack of it. In effect, physical and chemical dating methods provide pieces of scientific evidence of an event in the history of the sample. To decipher whether it reflects the age of an event or whether it reflects an average age of yet another geochemical/physical phenomenon calls for general analytical rigour on the part of the investigator.

RADIOCARBON DATING

Radiocarbon, or ^{14}C, dating is perhaps the most frequently used method in archaeology. The useful time range of the method is about 40 kyr; beyond this a routine assay is difficult owing to problems arising from low signal to instrumental noise ratio. The basis of ^{14}C dating can be summarized as shown in Figure 2.4. Cosmic rays produce ^{14}C through the nuclear interaction:

$$^{14}N\ (n,p)\ ^{14}C$$

The radioactive carbon (^{14}C) so produced is heavier compared to its stable isotope counterparts ^{12}C and ^{13}C but has identical chemical properties. The ^{14}C combines with oxygen to form radioactive carbon dioxide ($^{14}CO_2$), which then enters the biosphere (and the food chain) and hydrosphere through photosynthesis and as dissolved carbonates respectively. Owing to the equilibrium between production and decay, the ^{14}C concentration in the atmosphere remains constant with a ratio of $^{14}C/^{12}C$ being 10^{-12} (Figure 2.5). The equilibrium concentration of ^{14}C in systems with continuous exchange with the atmosphere remains the same. 'Death', i.e. on removal from this cycle, leads to a termination of the supply of ^{14}C. The ^{14}C present in the sample (equal to the equilibrium value) then starts depleting by its radioactive decay, with its characteristic half-life of 5,730 years. With the passage of time, the ^{14}C content of the samples continually keeps decreasing until the measurement limit is reached. The basic laws of radioactive decay permit calculation of the time that is needed to reduce the ^{14}C activity of a sample from its equilibrium value to the observed present-day value. The age T is calculable by the relation:

$$T = (t_{1/2} \times \ln (C_i/C_f)) / 0.693 \qquad (3)$$

where (C_f) is the ^{14}C concentration of the sample at the present time and (C_i) is the assumed concentration at time t=0 (equal to the equilibrium value) and $t_{1/2}$ is the half-life of ^{14}C (5,730 years as compared to the conventional value of 5,568 suggested originally by Libby). A ^{14}C assay involves a measurement of ^{14}C activity (i.e. the number of radioactive decays per second of a standard), the activity of a sample, and instrumental background. The measurement involves

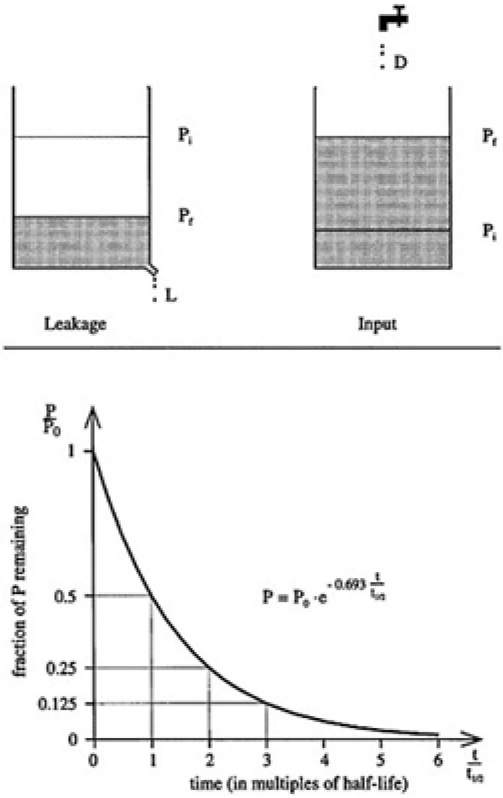


Figure 2.3 *Upper:* The conceptual basis of age determination. The parameter P (the level of liquid in the beaker in this case) changes through time due to leakage or input. If the time evolution function E (i.e. the leak rate L or the drop rate D) is known, then the time T taken to reach to a final level P_f from a given initial level P_i can be estimated, provided, of course, that no perturbation in E occurs during T. *Lower:* A typical time evolution function for the decay of radioactive species. Here the x-axis is plotted as a multiple of the half-life, which is the time needed for the species to decay to half its initial value. The half-lives of radioactive species can range from sub milliseconds to billions of years. An appropriate choice of the radioactive isotope enables dating in a desired time range with an acceptable precision.

preparation of the sample by combustion in a pure oxygen atmosphere, preparation of pure carbon dioxide, its reduction into benzene or methane, chemical purification of these (either methane or benzene), and finally the measurement of their specific activity by the coincidence nuclear gas counting or the scintillation counting techniques. A heavy lead-shield houses the equipment to reduce the interference from signals produced by radioactivity within the laboratory walls. About two decades ago, a significant step forward in the technology was achieved by the concept of atom counting which provided exceptional improvement in the detection levels. The basic difference of this

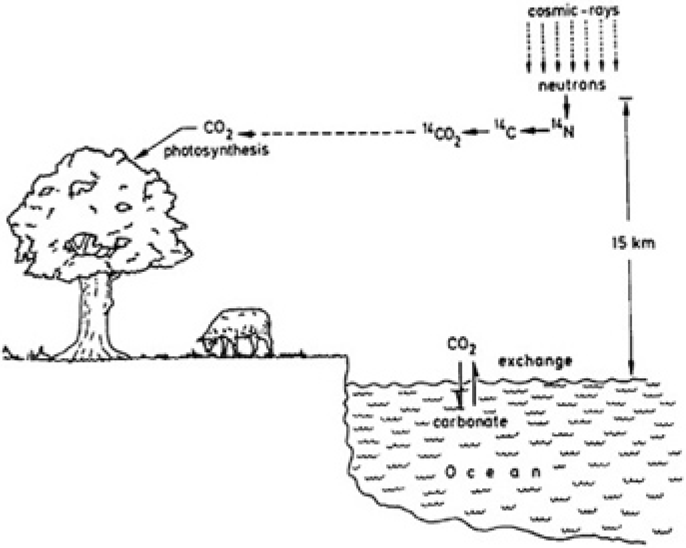


Figure 2.4 The carbon exchange reservoir. The ^{14}C forms in the upper atmosphere and converts into radioactive carbon dioxide ($^{14}CO_2$). This carbon dioxide enters the biosphere through photosynthesis. All living species get ^{14}C-labelled by the food chain.

Source: Aitken 1990 (Reproduced by permission of Addison-Wesley Longman Ltd)

method is that instead of counting the relatively few decaying atoms, one determines the total number of ^{14}C atoms directly with a sophisticated accelerator with mass separation capabilities. This significantly improves the detection efficiency, thereby enabling very small (sub-milligram) samples to be counted with equal or higher precision (Harris 1987; Hedges 1987; Litherland 1987).

The simplicity of the ^{14}C method is somewhat diluted in a real-life situation on account of several factors. These include mainly the variation in ^{14}C production through time, isotopic fractionation effects, and reservoir ages. It was soon realized that Libby's assumption of a constant ^{14}C concentration through time was not valid, due to changes in cosmic ray fluxes on account of the variable geomagnetic field and solar activity. A way out of this was to calibrate the ^{14}C ages to calendar ages by analysing annual tree-rings from bristle cone pines and oak trees (Figure 2.6). This calibration (up to the past 11 kyr) is achieved by using the standard procedure of Stuiver and Reimer (1993). Bjoerk *et al.* (1996) provide the most recent calibration curve which allows conversion of ^{14}C ages to calendar ages. More recently, annually varved lake sediments have been used to extend the calibration range to 15 kyr (see Goslar *et al.* 1995). Beyond that, some effort has been made by Bard *et al.* (1990, 1992) to use corals, dated precisely by uranium series isotopes. These studies suggest that a ^{14}C age of 18 kyr corresponds to a calendar age of approximately 21.5 kyr, i.e. a difference of

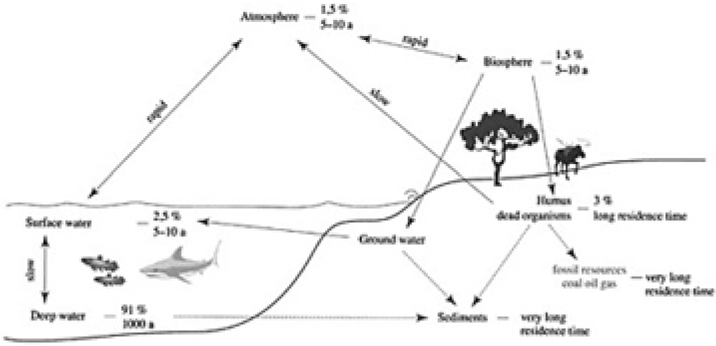


Figure 2.5 Carbon cycle in nature. Given are the fractions (in %) of total carbon content and the mean residence times (in years expressed as annum—a) within the various reservoirs.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

about 15 per cent. Calibration of even higher ^{14}C ages is not yet possible, and thus the ages are provided in ^{14}C years only. Several laboratories still quote the ages with the earlier half-life of 5,568 years, which causes a systematic 3 per cent age-underestimation compared to the new half-life estimate of 5,730 years. Thus these aspects need to be kept in mind when comparing such uncalibrated radio-carbon ages with other independent ages.

Besides these issues, there is an effect introduced due to mass dependent isotopic fractionation on account of ^{14}C being marginally heavier than ^{12}C. This implies that small but significant shifts due to mass dependent fractionation occur during the formation process of molecules, radicals and compounds, and this needs to be accounted for. This is normally done by the measurement of the ratio of ^{13}C with respect to ^{12}C and extending it to the fractionation between ^{12}C and ^{14}C using standard physical considerations. Another aspect that merits consideration is the reservoir effect arising out of the fact that not all the materials have the ^{14}C concentration at the time t=0, as is normally assumed. Small but finite differences can and do occur. Thus, for example, mixing up of old waters of glacier melt into oceans can cause an average higher initial age of up to a few hundred years to about 1–2 kyr. On the more recent time scales, fossil fuel burning and nuclear weapons testing have introduced finite amounts of dead and modern carbon, and these have to be taken into account. The burning of fossil fuel, such as coal and oil, puts into the atmosphere significant amounts of ‘dead’ carbon. Suess (1955) demonstrated that ^{14}C activity in a wood sample dating to 1950 was less than that of a AD 1850 sample, by about 3 per cent.

The ^{14}C method has made an important contribution towards establishing the chronology of the Upper Palaeolithic. Radiocarbon dating of the youngest phases of the Palaeolithic are particularly useful when they overlie older archaeological deposits of the Middle and Lower Palaeolithic, since an over-lying age limit can be delimited. Radiocarbon dating is usually done by establishing the age of

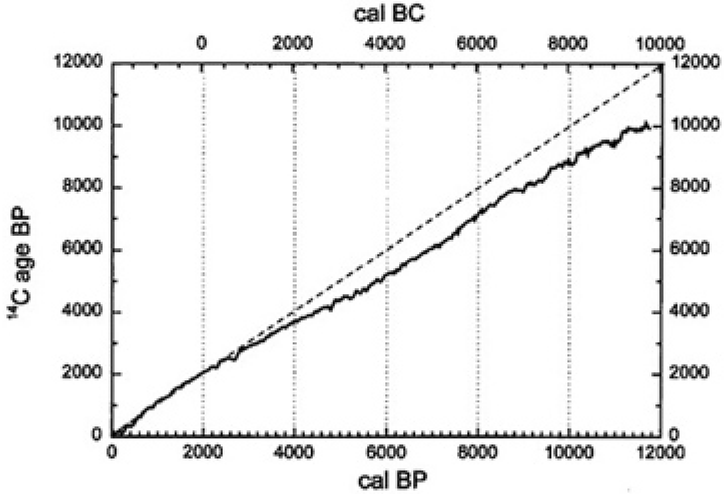


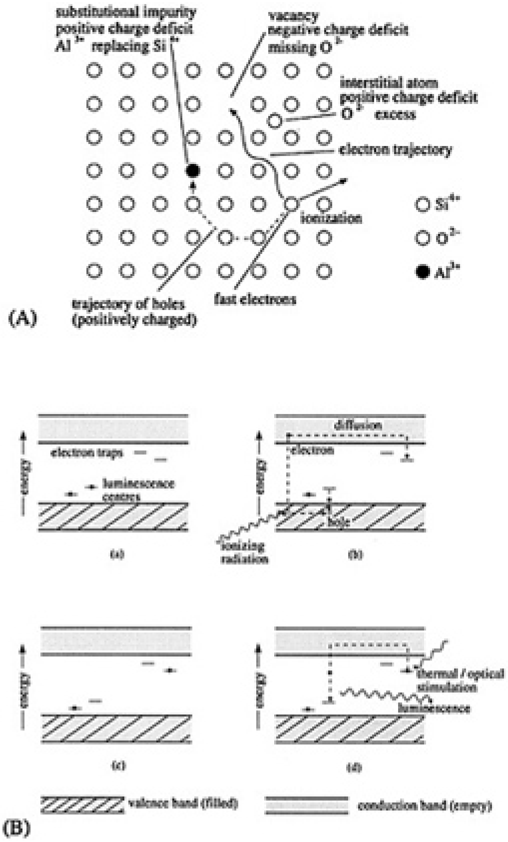
Figure 2.6 A plot of radiocarbon ages with calender ages on tree-rings in oak and pine. The x-axis is the calender age based on tree-ring counting. Cal BP implies years before present with respect to 1950 as the baseline. The Y-axis gives the corresponding radiocarbon ages.

Source: Bjoerk *et al.* 1996 (Reproduced with permission from *Science* © Copyright 1996 American Association for the Advancement of Science)

bones and organic fragments. It is important to point out that these ages are uncalibrated ^{14}C ages, which implies that the true antiquity of the artefacts is higher. A major difficulty has also been in the humid tropical environment, where environmental factors conspire against the preservation of samples. Further, ^{14}C ages on inorganic carbonates are generally notorious for their open system behaviour and ages on them are either too young, due to modern carbon coming in through present-day precipitation, or too old, due to limestone dilution effects in a lime-rich terrain.

LUMINESCENCE DATING

Luminescence dating methods, namely thermoluminescence (TL) and optically stimulated luminescence (OSL), basically depend on the ability of minerals (such as quartz, feldspars and zircons) to serve as dosimeters for the natural radiation environment. This radiation environment arises from the natural radioactivity of ^{238}U, ^{232}Th and ^{40}K, along with a minor contribution by cosmic rays. When minerals are exposed to such ionizing radiations they suffer ionization, resulting in an avalanche of free charges (electrons and holes), most of which instantaneously recombine during their journey through the crystal lattice (Figure 2.7a, b). A small fraction gets trapped at lattice defects. The nature of lattice defects determines the mean residence time of the trapped charges. These



could range from 10^7–10^8 years. The trapped charges, however, can be detrapped from the lattice defects through an appropriate thermal or optical stimulus. The detrapped charges again wander through the crystal, and a small fraction of these radiatively recombine to produce luminescence that is generally in the ultraviolet to the visible region of the electromagnetic spectrum. An important aspect of this luminescence is that, despite being a multistage process involving *ionization, charge trapping, storage, thermal/optical stimulation, detrapping/recombination and luminescence emission,* the net luminescence intensity bears a direct proportional relationship to the initial radiation dose (measured as total energy deposited in the material and expressed as Grays [Gy]) until a saturation or equilibrium value is reached (Figure 2.7c). This aspect, coupled to the near constancy of the natural radiation field (in view of substantially longer half-lives of the natural radionuclides), provides the basis of a dating application. The age T is given by the relation:

$$T = P/D \qquad (4)$$

(C)

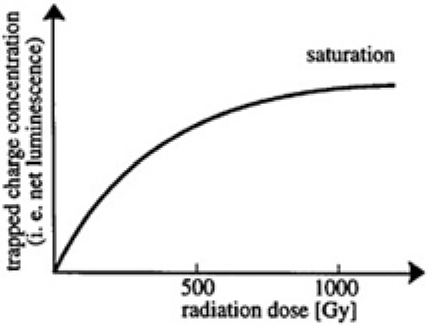


Figure 2.7 (A) Schematic presentation of a typical crystal structure and the lattice defects. The lattice defects could be missing atoms, interstitial atoms and substitutional impurities.

(B) a. The luminescence induction process in the energy band formalism of the crystal structure; b. irradiation with ionizing radiation results in creation of free charges which diffuse through the lattice; c. some of these free charges get trapped at the lattice defects and can remain trapped over long time periods; d. the charges can be released with a supply of energy (thermal or optical). After their release, the charges are free again and wander through the crystal. Some of them radiatively recombine to produce luminescence.

(C) Growth of luminescence signal with dose. The nature of growth is sample dependent. The saturation dose and the dose-rate, together determine the maximum age that can be obtained in a given situation.

Source: after Wagner 1995

where P is the laboratory irradiation that induces in a sample a TL or OSL level equal to that in a natural sample and D is the annual radiation dose rate. High precision photon counting systems are used to measure the luminescence from mineral separates or the fine silt extracted from the sample, and appropriate laboratory calibration procedures allow a conversion of the luminescence intensity into the equivalent radiation dose P.Computation of the annual dose is done by a measurement of elemental concentration of U and Th (both typically at mg/g level) and K (at per cent level), gamma-ray spectroscopy, alpha spectroscopy and/or alpha counting. In complex stratigraphic sequences, on-site gamma-ray spectrometry or gamma dosimetric measurements are used. In these cases, sensitive TL dosimeters at the sample locations are necessary.

The event that is dated with luminescence is either the thermal or the optical *zeroing* event that reduced the pre-existing luminescence (called geological luminescence) of the minerals to a zero or a near zero residual value. On subsequent burial, the reaccumulation of luminescence is initiated, and this continues unabated until excavation and laboratory analysis.

Innovation of direct dating of sediments using TL in the late 1970s opened up new possibilities for Palaeolithic chronologies (Wintle and Huntley 1982). This was because of the fact that Palaeolithic artefacts were often found in sedimentary deposits such as dune sands and loess that were conventionally considered undatable. The dating of such burial contexts is now possible and can be used directly to determine the age of most archaeological horizons (Aitken 1985; Chawla and Singhvi 1989). The basic premise of luminescence dating application to sediments is that, during their predepositional transport, minerals get exposed to sunlight and their geological TL gets photo-bleached to a small unbleachable residual level. A new approach of optically stimulated luminescence (OSL) was first demonstrated by Huntley *et al.* (1985), who used an optical stimulus to excite the latent luminescence, as against the thermal stimulus used in conventional TL. The use of an optical stimulus not only circumvents the need to correct for the residual TL but also eliminates the need for heating of the sample, as is necessary for TL dating. The bleaching duration required for total zeroing is about two to three orders of magnitude lower. Consequently, the condition for complete resetting is more readily achieved, and even poorly sun-bleached fluvial sediments can be analysed. Presently the technique has two variants, the green light stimulated luminescence (GLSL) and the infrared stimulated luminescence (IRSL), depending upon the colour of the stimulating light (Figure 2.8).

With respect to Palaeolithic chronology, luminescence applications can be grouped into two categories, namely *direct* and *indirect* dating, depending on whether the artefact itself is dated or the dating is achieved through the age estimation of the context (Figure 2.9). Methodologically, the luminescence age determination involves an experimental tedium of about one week for experimental procedures of sample preparation and analysis. More specifically, the laboratory analysis calls for:

1. The practical realization of the heterogeneity of irradiation conditions in nature. Heterogeneity arises due to the fact that, a) the natural radiation field comprises three types of radiation (, ,) with significantly different ranges, and b) the sample comprises a variety of grain sizes of different minerals with varying luminescence sensitivities and with different levels of internal radioactivity. Thus different minerals and grain size fractions experience a different annual radiation dose.
2. The radiation dosimetry has to take into account the presence of water in the matrix. Water, by itself devoid of radioactivity, effectively attenuates the radiation flux through it. The attenuation factor is approximately proportional to the water fraction by weight, implying thereby that an inappropriate choice of the average water content during antiquity would cause significant systematic deviations in age estimations.
3. The measurement of the annual dose has to contend with different luminescence production efficiencies of - as compared to the (- and -rays. It is also necessary to check for loss in the dose-rate due to chemical fractionation of the members of the decay chain of U and Th.

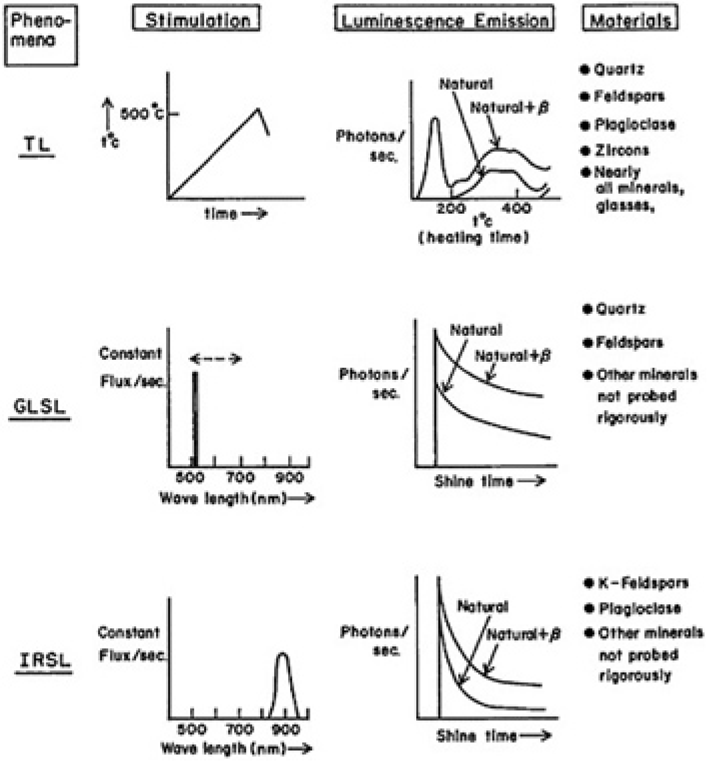


Figure 2.8 Scheme of the thermoluminescence TL and optically stimulated luminescence OSL. GLSL and IRSL are variants of OSL and specify the colour of the stimulation, i.e. green and infra-red, respectively. It is, however, possible to use other wave-lengths for optical stimulation as is indicated in the figure. The luminescence emission is termed in case of TL as glow-curve (plot of TL intensity against heating temperature) and in case of OSL as shinedown-curve (OSL intensity against duration of optical stimulation). The type of mineral used is also indicated.

4 Measurements of equivalent radiation dose P must take into account non-linear effects in the luminescence growth, presence of unstable signals (the anomalous fading), and occasional effects such as age under-estimation effects. A practical realization of predepositional sun exposure in laboratory simulation is also necessary.

Aitken (1985, 1990), Singhvi and Wagner (1986) and Berger (1996) provide detailed discussion of the methodological aspects of luminescence dating.

In the case of heated objects, the most effective use of luminescence has been the dating of burnt flint. Flint and chert were fired by hominids, and in the process the geological TL was reset. Considerable effort has been made in the use of burnt flint for the dating of archaeological sites. Low internal radioactivity of flints implies that the dose-rate is small (Mercier *et al.* 1995; Mercier and

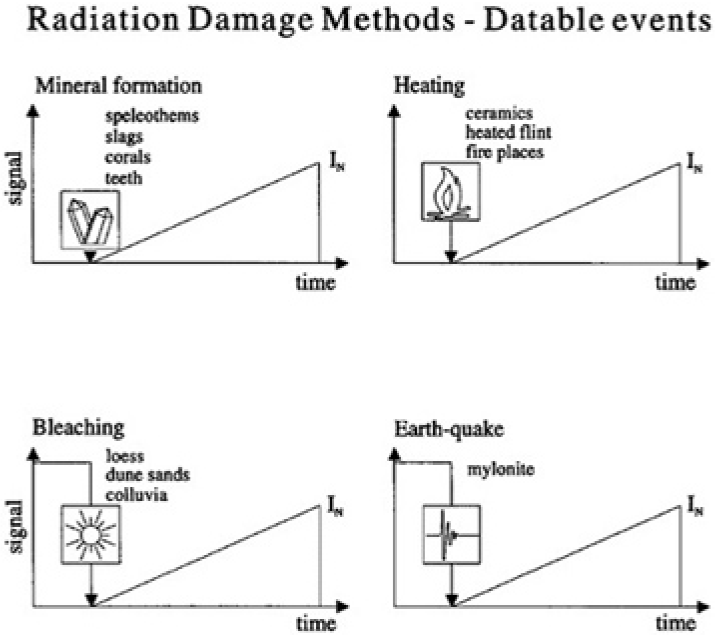


Figure 2.9 Various geological and archaeological events datable by luminescence.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

Valladas 1996). This in turn implies that the dating range of the samples can be extended considerably without encountering saturation in the growth of the TL signal. Low internal activity also implies that the -dose from the ambient strata and the cosmic rays need a careful measurement, and onsite dosimetry is necessary.

The most important application of luminescence dating of sediments from various Palaeolithic sites are summarized in Table 2.2. It is also possible to use TL to date stalagmites associated with archaeological floors (Debenham and Aitken 1984), but these applications have been limited principally due to the difficulties associated with luminescence measurements and dosimetry.

Table 2.2 Compilation of luminescence ages based on dating of burial contexts.

Site	*Strata*	*Technique*	*Age Range (kyr)*	*Reference*
Bir Tarwafi, Sahara	Lacustrine	OSL	40–50 70–130	Stokes 1994
Wadi Kubenia, Sahara	Dune sand	TL	31–89	Bluszcz 1994
Dzierzyslaw, Silesia, Poland	Loess	TL	38–42	Bluszcz *et al.* 1994

Site	*Strata*	*Technique*	*Age Range (kyr)*	*Reference*
Plaidter Hummerich, Germany	Loess	TL	80–130	Singhvi *et al.* 1986
Tonchensberg, Germany	Loess	TL	110	Zoeller *et al.* 1991
Schwalbenberg, Germany	Loess	TL	31.3±2.6	Zoeller *et al.* 1991
Mauer, Germany	Sand	TL	552±155	Zoeller 1996
Wallertheim, Germany	Colluvial loess, loess	TL	75–118	Preuss *et al.* 1996
Lichtenberg, Germany	Sand	TL	57±6	Veil *et al.* 1994
Schobendorf, Germany	Sand	TL	13.3±2.6	Baray 1994
Gamsenberg, Germany	Loess	TL	62±5	Schaefer and Zoeller, pers. comm.
Weimar-Ehringsdorf, Germany	Loess	TL	>166	Zoeller, pers. comm.
Rosenhof, Regensburg, Germany	Loess, sand	TL	>13, <16	Zoeller, pers. comm.; Buch and Zoeller 1990
Rheindahlen, Germany	Loess	TL	167±15	Zoeller *et al.* 1988
Willendorf, Austria	Loess	TL	23–46	Zoeller, pers. comm.
Stratzing, Austria	Loess	TL	30.2±3.5	Zoeller *et al.* 1994
Grubgraben, Austria	Loess	TL	20–22	Zoeller, pers. comm.

ELECTRON SPIN RESONANCE

The conceptual basis of electron spin resonance (ESR) or electron paramagnetic resonance dating is identical to that of luminescence dating. Both the techniques are related to detection of the concentration of trapped charges. In luminescence dating, these are measured by thermal or optical release of these charges and emission of luminescence consequent upon recombination at a different site. Luminescence dating thus involves two types of trapped charges. ESR dating, on the other hand, aims at detecting the trapped charge concentration by utilizing the fact that some of the trapped charges can be detected directly. Based on this fact, some sites with trapped charges act as free magnets, and these can be detected by placing the sample under a magnetic field. In the simplest case, these individual magnets can occupy two energy states when placed in a magnetic field, and it is in general possible to cause an energy transition of these magnets from an overall low energy state to an overall high energy state, using appropriate micro-wave energy. The amount of microwave energy absorbed is proportional to trapped charge concentration. The nature of the charge environment of individual magnets (and the nature of their own intrinsic magnetism) decides the details of the ESR absorption spectra. The ESR spectra is characteristic for individual types of trapping states. Figure 2.10 indicates a typical ESR spectra and is generally plotted as a derivative spectrum for ease of analysis.

Each type of trapped charge 'magnet' has its characteristic spectrum determined solely by its own magnetic properties and the charge environment around it. Thus signals from different defects in a mineral or from different phases in a sample can be readily identified. This implies that, besides minor effort in sample crushing, no other effort is needed to prepare the sample. Another aspect that merits mention is the fact that in general no heating is required and consequently even organic materials such as bones and teeth can be readily analysed. However, some low temperature (<200°C) preannealling is needed to estimate and isolate stable signals. The age equation for ESR dating is identical to that of luminescence dating, and the only difference is in respect of the fact that the equivalent dose is estimated using ESR as opposed to luminescence measurements.

The measurement of ESR is done by placing the sample under a high magnetic field which allows the separation of possible magnetic energy levels. The sample is placed in a cavity. Microwave energy travels through the sample without being affected, except under situations where the microwave energy exactly equals the difference of energy between the magnetic levels. The sample then absorbs energy and this is detected by sensitive power meters. The extent of absorption depends on the total number of magnetic states (i.e. trapped charges concentration), and hence the intensity of absorption provides a direct measure of the trapped charges, which can be calibrated in terms of equivalent dose. The materials that can be dated by the ESR method are speleothems, travertines, mollusc shells, tooth enamel, corals, bones and burnt flints. In all these cases, a specific centre is used for the dating analysis. Recent reviews by Ikeya (1993) and Wagner (1995) provide a good account of ESR materials and methodology.

In ESR dating, the radiation dosimetry plays an important part and involves some basic assumptions in certain cases. Thus, for example, in the case of tooth enamel, the post mortem uptake of uranium implies that the present-day value of uranium cannot be taken *per se* for dose-rate calculation. Instead, depending on the nature of the sample and the site, the dose is calculated on the basis of either the linear uptake (where the rate of uranium increase in the samples is assumed as constant) or an early uptake (where most U is assumed to have been taken up immediately after burial). A good discussion of this aspect is provided by Blackwell (1995), Ikeya (1993), Grüm (1989) and Schwarcz (1989).

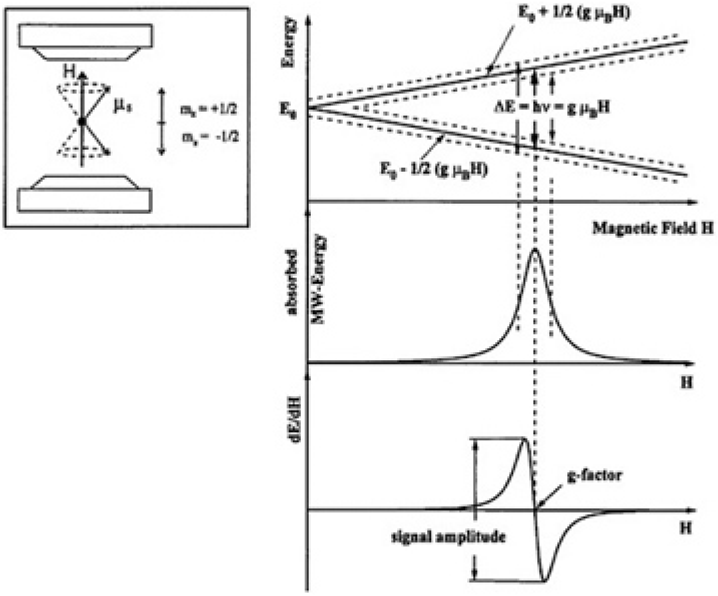


Figure 2.10 Schematic presentation of the two magnetic energy levels of a single ‘electronic’ magnet placed in a magnetic field.

Top: the energy separation between the magnetic levels of the electronic magnet increases with the increase in the applied magnetic field.

Middle: the absorption of microwave energy occurs when this is equal to the energy separation between the magnetic energy levels.

Bottom: the derivative (dE/dH) of the absorption spectra that is normally for the ease of analysis.

The dating range of ESR spans several million years and is ideally suited to directly date organic remains, provided the dosimetry is established unambiguously. Quite often, the ages based on the linear uptake and the early uptake are both quoted so that the user can estimate the accuracy of ages. Nevertheless, ESR dating is well suited to the examination of Lower Palaeolithic localities around the world.

PARTICLE-TRACKS

Etchable tracks left by the passage of heavy ions through minerals are the base of two dating methods, namely the fission-track and alpha recoil track techniques. Whereas fission-tracks have already found many applications in Palaeolithic research, the alpha recoil method is still in its infancy and, thus, less known, but it bears a great potential for tephrochronology.

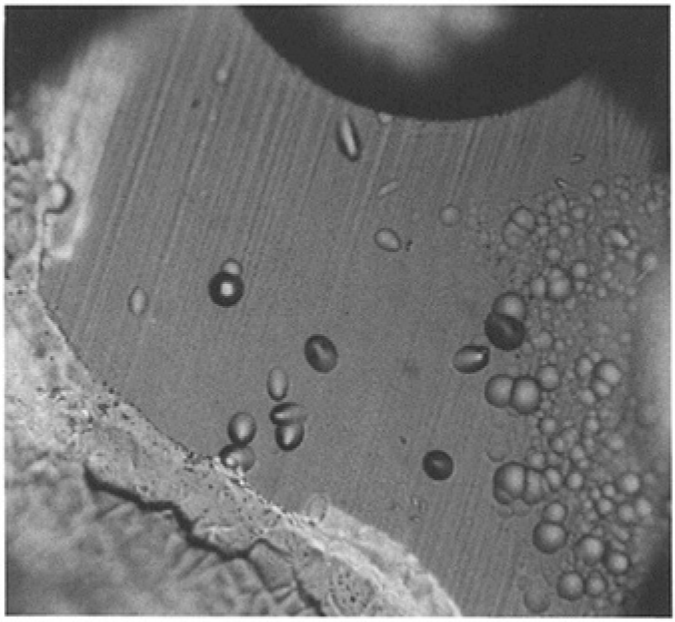


Figure 2.11 Induced fission-tracks in glass shard from Banks Island tephra, Canada, etched for 110 seconds at 23°C in 24% HF.

Source: courtesy of J.A.Westgate

Fission-tracks

A fission-track (FT) is the radiation-damaged path left by two heavy fragments of uranium-fission. By chemical etching it is enlarged to a microscopically visible size of about 15 µm length (Figure 2.11). One distinguishes between *spontaneous* and *induced* fission-tracks. The spontaneous tracks are formed by the spontaneous fission of uranium-238 with a half-life of 8.2×10^{15} a. The tracks accumulate with time, and consequently their number is a measure of the elapsed time, i.e. the age of the material. Because the number of stored tracks depends also on uranium content, it is necessary to determine the induced tracks also. This is done by counting induced fission-tracks that are artificially formed by irradiating the sample with thermal neutrons, whereby uranium-235 undergoes induced fission. Because natural uranium consists of two isotopes, ^{235}U (0.7 per cent) and ^{238}U (99.3 per cent) with fixed abundance-ratio, the number of induced fission-tracks reveals implicitly the ^{238}U-content. This means that fission-track dating depends essentially on counting tracks before and after a neutron irradiation. The tracks are counted under a petrographic microscope at high magnification.

Although many minerals and glasses contain fossil fission-tracks, only a few of them, mainly zircon, sphene and various glasses, are of practical interest for the prehistoric periods, because the uranium content needs to be high enough in order to produce a sufficient number of fission-tracks in the available 10^4 to 10^6 years. The mineral and glass grains or fragments, which are usually 100 to 300 μm in size, are concentrated by standard mineral separation techniques. After being ground and polished, internal faces of the grains are etched. The fission-track age-precision is typically between 5 and 10 per cent. Methodological aspects are described in detail by Wagner and Van den haute (1992).

The clue for interpreting fission-track ages is the stability of tracks. As with other types of radiation damage (see also luminescence), unetched fission-tracks are ultimately unstable, a phenomenon known as *fading*. Elevated temperatures accelerate the fading process, and fading causes shortening of the etchable track-length. The resulting track-loss tends to lower the apparent fission-track age. The track retention-properties vary with the material. Tracks in zircon are more stable than those in glass, for which the track stability increases generally with the silica content. Fading is recognized by comparing the sizes of etched spontaneous and induced fission-tracks. If both types of tracks have on average equal sizes, the fission-track age may be interpreted as the formation age of the sample. Smaller spontaneous tracks indicate partial fading. Such samples have apparently lowered ages that can be corrected. For glasses there exist two correction-procedures: the track-size and the plateau techniques. The high thermal sensitivity of tracks allows us to date secondary heating events, such as volcanic eruptions or hominid activities. If the heating temperature was sufficiently high to anneal all former fission-tracks, then the fission-track clock is reset and the subsequently accumulated fission-tracks date this event.

One of the materials well suited to archaeological application of the fission-track method is volcanic glass, such as obsidian. Because of its restricted geographical occurrence, obsidian as a raw material is often transported. During artefact use, the material may become subjected to heat, which results in track annealing. FT-analysis can answer questions about *geographic provenance* of the material and the *age of manufacture*. The geological fission-track age of unheated artefacts, as well as their uranium content, is often specific for a certain source area (e.g. Bigazzi *et al.* 1990), and thus by matching the artefacts with potential source areas, one may trace back the raw material. However, in quaternary volcanic glasses, ambient surface-temperatures commonly cause significant track fading which requires age-correction. If the artefacts were sufficiently heated by humans, the FT-age dates the time of manufacture or use (see Miller and Wagner 1981 for a demonstration). For complete removal of fission-tracks, obsidian requires 300–400°C. Glass is also a common constituent of tephra. Microscopic glass shards allow the dating of distal tephra occurrences that are otherwise hardly datable. There are many applications of FT-dating to glass fragments from tephra layers in pleistocene sedimentary sequences in various parts of the world (see, for example, Westgate 1988).

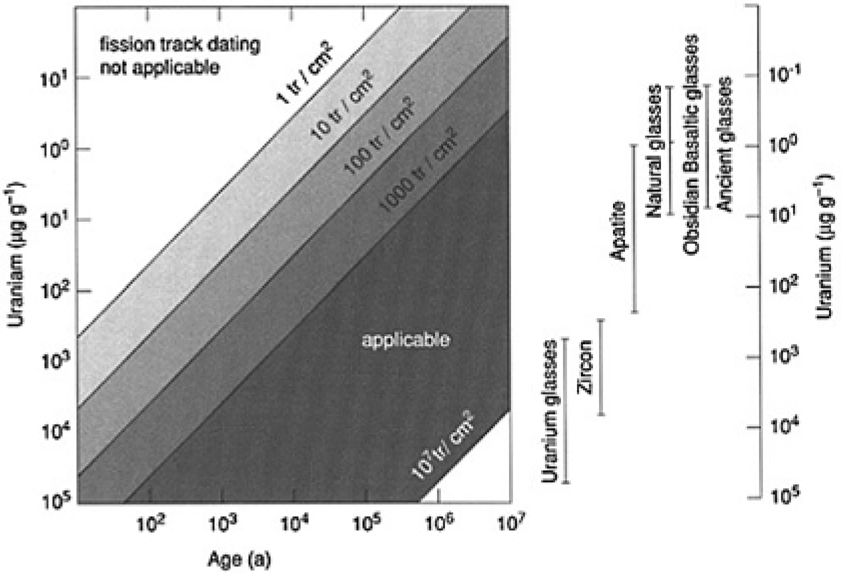


Figure 2.12 Range of applicability of fission-track dating for various minerals.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

Figure 2.12 provides a summary of the suitability of different minerals in fission-track dating. Mineral inclusions in heated rocks and baked soils can also be used to date the heating event. In order to reset the fission-track clock completely, generally heating to at least 500°C for one hour is necessary. An example is the age determination of the *Homo erectus* locality at Zhoukoudian. Several hundred sphene-grains between 50 and 300 µm in size were collected from ash deposits. Track-length criteria were used in order to select only those grains whose fission-track clocks had been completely reset by fire. For two stratigraphically different ash bearing layers, ages of 462±45 kyr and 306±56 kyr were determined (Guo *et al.* 1990). A most important application in palaeoanthropology is the dating of artefact and hominid bearing stratigraphic sequences that contain datable tuffaceous marker-beds. For dating tephra, uranium-rich minerals such as zircon are of great advantage, since the fission-track technique is grain-discrete. This allows us to account for contaminating grains mixed into the tephra layer due to secondary processes, such as redeposition by water or wind, creeping, slumping, cryoturbation and bioturbation. Several zircon-populations are commonly observed in volcanic ash layers. Important contributions to the tephrochronology of various areas adjacent to Plio-Pleistocene volcanism have been achieved by zircon fission-track studies, especially from the sedimentary deposits in East Africa. The KBS Tuff at Lake

Turkana, Kenya, was originally dated to 1.87±0.04 myr, for example (Gleadow 1980).

Alpha-recoil-tracks

During the alpha-decay of uranium and thorium, as well as of their decay products, the heavy nucleus is recoiled. It traverses several 10 µm through the crystal lattice, leaving a radiation-damaged trail: the alpha-recoil-track. The number of alpha-recoil-tracks is analogous to fission-tracks, a measure of the elapsed time. So far, etchable alpha-recoil-tracks have been observed only in micas. Due to the many contributing nuclides, alpha-recoil-track dating is methodologically more complex than fission-track dating. For this reason, there exist only a few studies dealing with this method. However, recent investigations on biotites from chronologically known quaternary tephra layers in Eifel revealed a large potential for dating in the age range between 10^4 to 10^6 years (Gögen and Wagner, in preparation). It seems that even tiny mica flakes of less than 1 mm in size are suitable for this technique, which is an important prerequisite for dating distal tephra occurrences.

URANIUM-SERIES DATING

Uranium series methods exploit the phenomenon of radioactive equilibrium within the decay chains of ^{235}U and ^{238}U. Both these isotopes decay naturally to stable lead isotopes via various radioactive nuclides with different half-lives and different chemical properties (Figure 2.13). It can be easily seen that, if undisturbed for a long period, the different members of the decay chain reach a state of secular equilibrium, such that the activity of the parent and the progeny is the same all through the chain. If this chain is somehow disturbed chemically, or if a parent nuclide is deposited without the supporting daughter radionuclide, then, after the chemical event, the decay of parent nuclei with the passage of time re-establishes the equilibrium. The time needed for this to happen is decided by the half-life of the daughter. Actually, after about five half-lives, the radioactive equilibrium is re-established. From the degree to which the equilibrium is reached, the time elapsed since the event of disturbance can be readily calculated. The age represents the time of geochernical fractionation. In uranium, basically three types of isotope systems can be used. These are, $^{230}Th/^{234}U$, $^{231}Pa/^{235}U$ and $^{234}U/^{238}U$. The system $^{230}Th/^{234}U$ has been most extensively used in archaeological research and is discussed below (see also Table 2.3) (Schwarcz 1980, 1989, 1996; Ivanovich and Harmon 1992).

Figure 2.14 provides a simplified introduction to the use of disturbance in a radioactive series for chronometric applications. Calcium carbonate deposits such as travertines and stalactites contain uranium but not thorium, due to the insolubility of thorium in groundwater. Thus ^{234}U enters the carbonate

Table 2.3 Dating methods based on uranium series isotopes.

Isotope ratio measured	*Analytical method*	*Age range (kyr)*	*Materials*
$^{230}Th/^{234}U$	Alpha spectrometry Thermal ionization mass spectrometry (TIMS)	1–350	Carbonates, phosphates, organic material
$^{231}Pa/^{235}U$	Alpha spectrometry Thermal ionization mass spectrometry	1–300	Carbonates, phosphates teeth, bones
$^{234}U/^{238}U$	Alpha spectrometry Thermal ionization mass spectrometry	100–1000	Carbonates, phosphates teeth, bones
U-trend	Alpha spectrometry	10–1000(?)	Detrital sediment
226_{Ra}	Alpha spectrometry 226Rn-alphas	0.5–10	Carbonates
$^{230}Th/^{232}Th$ (excess)	Alpha spectrometry	5–300	Marine sediment
$^{231}Pa/^{230}Th$ (excess)	Alpha spectrometry	5–300	Marine sediment
$^{4}He/U$	Mass spectrometry	20–1000	Corals

Source: After Schwarz (1989)

matrix unsupported by its daughter nuclide ^{230}Th, and a build-up of ^{230}Th starts. This levels off at about 350 kyr; the freshly formed ^{230}Th also decays with a half-life of 75 kyr. The activity ratio $^{230}Th/^{234}U$ provides a direct measure of age. Estimation of the activity ratio involves chemical digestion of the sample and extraction using ion-exchange procedures, and then a measurement of radioactivity using an alpha-spectrometer. Another possibility is to use high-resolution gamma ray spectrometry by estimating ^{238}U and ^{230}Th and assuming that the original $^{234}U/^{238}U$ is known and is close to unity. A third and the most promising approach is the use of thermal ionization mass spectrometry (TIMS), which measures directly the isotopic composition of uranium and thorium and enhances the detection sensitivity by almost two orders of magnitude (Edwards *et al.* 1986–7). Consequently, a high-precision analysis of very small samples and various phases of the same sample can be obtained.

This method assumes that, at the time of deposition, the sample had no detrital ^{230}Th. Such clean samples are rare, and consequently a major source of analytical difficulty arises from the presence of finite amount of detrital thorium, contributed by the parent sediments, the air borne dust or the parent limestone itself. These sources provide additional ^{230}Th signals, despite their having nothing to do with the formation age of the sample. The presence of detrital Th is detected by measuring ^{232}Th. The higher the $^{230}Th/^{232}Th$ ratio, the better the reliability. Another complication that arises is redissolution and reprecipitation of carbonates and possible migration of uranium from the matrix. In such an open system behaviour, the ages are likely to be erroneous. Though some check

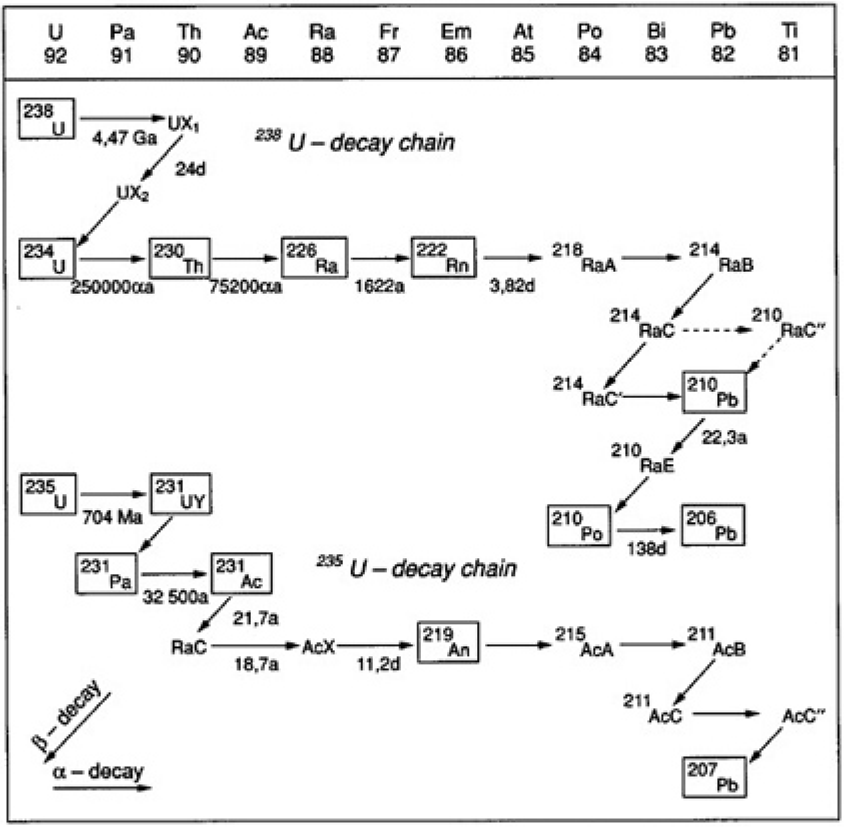


Figure 2.13 Radioactive decay-series of ^{238}U and ^{235}U. Both nuclides decay through various radioactive species finally to the stable end members ^{206}Pb and ^{207}Pb, respectively. After several half-lives radioactive equilibrium is established among the decay-members.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

on this can be made by using ^{231}Pa, the errors in such corrections compound, and ages are in general unreliable. The development of TIMS can help, since the small sample requirement allows microscopic examination, so that the pristine phases can be identified and cored to obtain the true ages on the micro-samples that are unaffected by post-depositional processes.

Uranium series dating is well suited for travertines, speleothems and pedogenic carbonates, some of which appear as occupational floors. Table 2.4 provides a brief representative summary of the recent dates on the Palaeolithic sites obtained by this method.

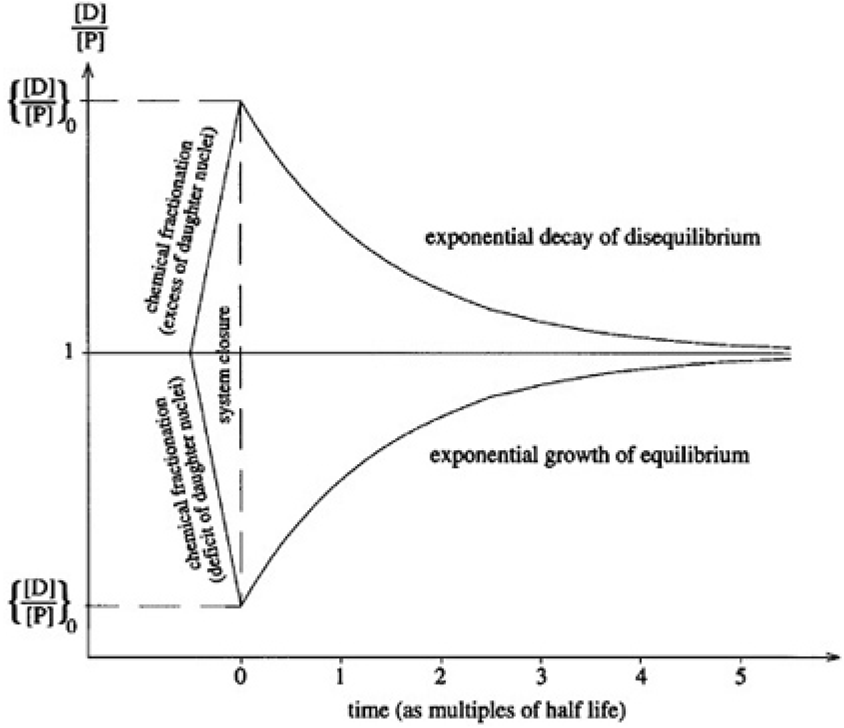


Figure 2.14 A radioactive system in equilibrium has a daughter (D) to parent (P) ratio ((D)/(P)) of unity. In the case of chemical, physical and biological disturbance, this ratio deviates from unity. The radioactive equilibrium is nearly re-established in about five half-lives. The decay and growth of the ratio ((D)/(P)) is used for chronometry.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

K-Ar DATING

The potassium-argon method was developed some forty-five years ago and has been extensively used in geochronology. This method is perhaps the most simple and direct application of the radioactive decay, comprising a 'parent'

Table 2.4 A representative collection of recent uranium series dates on the Palaeolithic.

Site	*Samples*	*Age range (kyr)*	*Reference*
Europe			
Prince Cave	Travertine	79–160	Guanjun 1986
Banylos	Travertine	45±4	Julia and Bishoff 1991
Bilzingsleben	Travertine	319–>350	Schwarcz *et al.* 1988

Site	*Samples*	*Age range (kyr)*	*Reference*
La Chaise de Vouthon	Calcitic flowstones	245^{+45}_{-28}, 97±6, 101	Blackwell *et al.* 1983
Petralona	Calcite	160^{+27}_{-24}	Latham and Schwarcz 1992
Vértesszöllös	Travertines, Tuffa	185±25	Schwarcz and Latham 1984
Tata	Travertine	101–120	Schwarcz and Skoflek 1982
Asia			
Nahal Jin, Israel	Travertine	47±3	Marks 1976
Ein Aqev, Israel	Travertine	80±10	Marks 1976
Tabun, Qafzeh Skhul, Israel	Dental fragments	50.69–168.1	McDermott *et al.* 1993
Gujarat, India	Miliolites	>65, >190	Baskaran *et al.* 1986
Hunsgi Valley India	Travertine, teeth	166, 174, 290, >350,	Szabo *et al.* 1990
South China	Teeth, bones, travertines	18–312	Sixun 1986
North China	Teeth, bones, travertines	21–251	Sixun 1986
Africa			
Bir Tarwafi	Ostrich egg shells, marl, calcite	122–136, 56–156	Wendorf *et al.* 1994

nucleus decaying into a ‘daughter’ nucleus. Potassium (K) has a small radioactive component, ^{40}K, which has a half-life of 1.2 billion years. ^{40}K decays by two possible modes, namely ^{40}Ar and ^{40}Ca. Being an inert gas, ^{40}Ar keeps accumulating in the lattice of potassium bearing mineral and does not form any chemical bonds. In suitable cases, Ar gas can remain in the lattice over geological time. This gas can be extracted by heating the mineral and can be measured using sensitive mass spectrometers. The estimation of K can be done using chemical analytical methods, and the time needed (i.e. the age T) for the mineral to accumulate the observed concentration of ^{40}Ar can be estimated using the simple relation:

$$T = t_{1/2} \log_e \{(^{40}Ar^*/^{40}K)(1/B) + 1\}$$

where T is the age, $t_{1/2}$ is the half-life of ^{40}K, and B is a constant called branching ratio that provides the fraction of ^{40}K that decays into ^{40}Ar* (* denotes radiogenic origin). As is true for all numerical dating techniques, there are several assumptions involved in the use of this age equation. The foremost is the assumption of the closed system, in that the ^{40}Ar* present in a mineral sample is due only to the decay of ^{40}K. It needs to be ascertained that no contribution from any inherited ^{40}Ar, as also that no loss of radiogenic ^{40}Ar, occurs during the storage of the sample (due either to the ambient temperature or due to a later metamorphic event). A K-Ar age reflects the event when the mineral cooled below the retention temperature, which is the temperature below which the loss of Ar through thermal diffusion becomes negligible, and this is mineral dependent. The determination of an age comprises the measurement of the release of Ar as the sample is heated in steps. Such a step-wise heating helps in evaluating the validity of an age *vis-à-vis* the loss by diffusion. In the measurement of Ar, appropriate techniques such as spiking the sample with ^{38}Ar are employed to evaluate non-radiogenic components. K is estimated using standard analysis techniques. A major source of uncertainty arises in cases where the distribution of K is inhomogeneous. This is because of the fact that the estimations of both Ar and K are non-destructive, and thus two separate sample fractions are used to evaluate them, with the assumption that the two sample fractions are identical in respect of their Ar and K distributions. Any deviation results in erroneous ages. An introductory discussion on the method is provided by Faure (1986).

An innovative way to circumvent this problem of inhomogeneity was provided with the development of the ^{39}Ar–^{40}Ar method (Merrihue and Turner 1966). In this technique, the evaluation of K is made on the same sample fraction by converting some of the ^{39}K into ^{39}Ar via a nuclear re-action by irradiating samples in a nuclear reactor. As ^{39} K bears a constant abundance ratio in K, ^{39}Ar so produced provides a direct measure of potassium and is measured simultaneously with ^{40}Ar. This eliminates the ambiguities due to uneven distribution of K. The step-wise heating approach helps in the estimation of the reliability of the data. Further improvement in this technique has been the innovation of laser ablation techniques during the past decade. In this approach, the precision of a laser in heating a single mineral grain is used, which allows a grain-by-grain analysis of the samples. This not only enables an age based on single grains but also provides for a reduction of labour in the separation of individual grains and in identification of detrital grains (Bogaard *et al.* 1987; Layer *et al.* 1987). The most commonly employed minerals are sanidine, hornblende, plagioclase, biotite and muscovite. Typical errors in the age estimation can be as low as a few per cent for a young sample of 10 kyr. The new techniques of laser ablation have recently been extended to the Holocene, thereby providing a complementary technique to radiocarbon (Hu *et al.* 1994). We refer to more detailed accounts by Hall and York (1984), Flish (1986), Hammerschmidt (1986) and Wagner (1995) on methodological aspects.

The half-life of ^{40}K allows dating of any deposit encompassing the human past. The only limitation arises due to measurement accuracy of Ar in the presence of any contaminating signal. Most of the applications have been based on the dating of different tephra layers (see Figure 2.15) that occur in between archaeological layers. Consequently, this method yields ages of the archaeological remains indirectly by providing ages to the strata that bracket the record. One of the recent applications has been the dating of the earliest hominid in Java (Swisher *et al.* 1994). The step-wise heating ^{39}Ar–^{40}Ar technique was applied to hornblende samples extracted from pumice at two hominid sites in Java, and mean ages of 1.81±0.04 and 1.66±04 myr were obtained. As discussed later, these ages triggered a fresh debate on the timing of the movement of *Homo erectus* outside of Africa. In another study based on ^{39}Ar–^{40}Ar dating, feldspar samples provided an age of 4.4 myr for Aramis hominids in Ethiopia (WoldeGabriel *et al.* 1994).

COSMIC-RAY PRODUCED ISOTOPES

Interaction of cosmic ray particles with rocks and sediments on the earth produces radioactive nuclides such as ^{10}Be, $^{26}A1$ and $^{36}A1$ (Figure 2.16). These nuclides decay with their characteristic half-lives, and attempts are being made to date various geomorphological situations using this technique. The key factors in the application of these isotopes for dating are:

1. constancy of irradiation geometry through time;
2. previous knowledge of the irradiation history of rocks; and
3. constancy of cosmic ray flux through time.

The effect of variation of cosmic ray fluxes through time is to some extent overcome by using the ratio of two isotopes as a time marker, such as the system $^{10}Be/^{26}Al$. Direct dating of burnt flint may be possible in the years to come. An introductory discussion of this method is given by Nishizumi *et al.* (1993).

PALAEOMAGNETISM

Studies on the magnetization direction of rocks and ocean magma conclusively established that the earth's magnetic polarity reverses periodically over time scales ranging from a few hundred thousand to a million years. These polarity reversals with longer duration are called Epochs, and these are occasionally punctuated by shorter time scale Events and Excursions; for instance, the Blake Event covered a time span of a few thousand years beginning at 115 kyr. These reversed and normal magnetic polarity Epochs have been documented from rocks and constrained either by K-Ar or fission-track dating of volcanic ashes interbedded in the sedimentary strata. Palaeomagnetic dating is based on the fact that, during deposition of sediments, the constituent minerals record the direction of the ambient magnetic field by orienting their own magnetic vector. This orientation predominantly occurs during the sinking of particles under quiet air or water columns. Upon sedimentation, the magnetic polarity acquired by the magnetic minerals is fixed, and subsequent reversals do not have any effect on the magnetization of the grains. This is known as detrital remanent magnetism (DRM) (Figure 2.17). Thus in a long, continuously deposited sedimentary

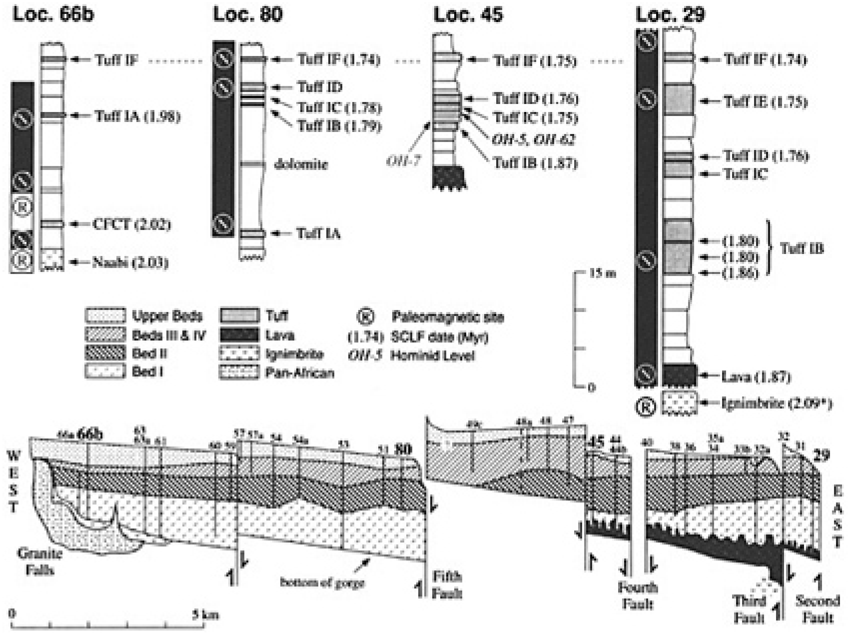


Figure 2.15 The stratigraphic sequence at the Olduvai Gorge, Tanzania.

Source: Walter *et al.* 1991

sequence, a series of stratigraphic zones of normal and reversed polarity occur. A faunal or radiometrically dated horizon then allows identification of a particular normal or reversed polarity epoch, or a boundary in the sedimentary sequence, and allows for its correlation with the standard global magnetic polarity time scale (MPTS). Based on this correlation, an age assignment to all other horizons is made provided that the sequence being dated represents a continuous sedimentary record. Further, if it can be assumed that the sedimentation rate remained constant through time, then it is possible to date any layer by simple interpolation. Figures 2.18 and 2.19 present a scheme of palaeomagnetic dating and the standard global magnetic polarity time scale, respectively.

The measurement of magnetic polarity begins with a careful sampling that comprises picking up undisturbed oriented blocks of rocks and carefully documented details of any evidence of their post-depositional tilting or rotation. The magnetic polarity of the samples is then read in either a spinner magnetometer or a cryogenic superconducting quantum interference device (SQUID) magnetometer. These instruments work on the principle that a rotating magnetic field can induce currents in the neighbouring coils, such that the magnitude and direction of current depends on the magnet itself. Here the sample is the magnet. Subsequent to this measurement, the sample is checked for secondary magnetizations. Secondary magnetization is the magnetization that a

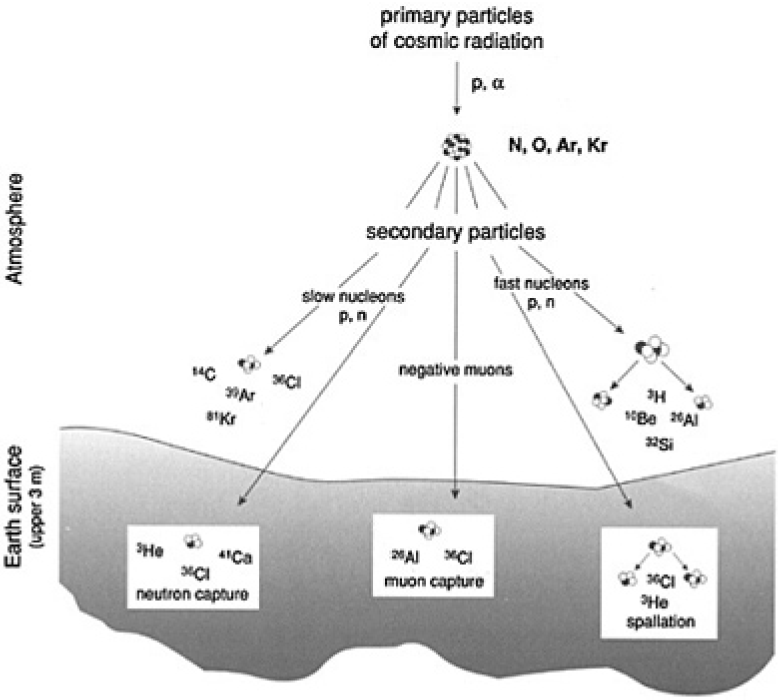


Figure 2.16 Scheme of cosmogenic nuclides produced by the interaction of cosmic rays with rocks on the earth's surface.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

sample may acquire during diagenesis. Techniques such as thermal or alternating demagnetization cleaning are used. Such procedures allow isolation of the pristine magnetic vector. The magnetic vector comprises the intensity, declination (indicating the horizontal deviation of the magnetic field from the geographic north) and inclination (the deviation angle of the magnetic field from horizontal).

This is useful for establishing a Palaeolithic chronology, since a large number of Palaeolithic sites are preserved in sedimentary contexts. The Olduvai Normal Polarity Event is named after Olduvai Gorge in Tanzania, a well known location in East Africa (Figure 2.18). For anthropological and archaeological applications of palaeomagnetism, we refer to Kappleman (1993).

CHEMICAL REACTIONS

Chemical dating methods are based on reactions such as diffusion, ion exchange and oxidation of known rate. From the progress of chemical reaction, one infers elapsed time as the thickness of weathering and hydration rims, the fluor

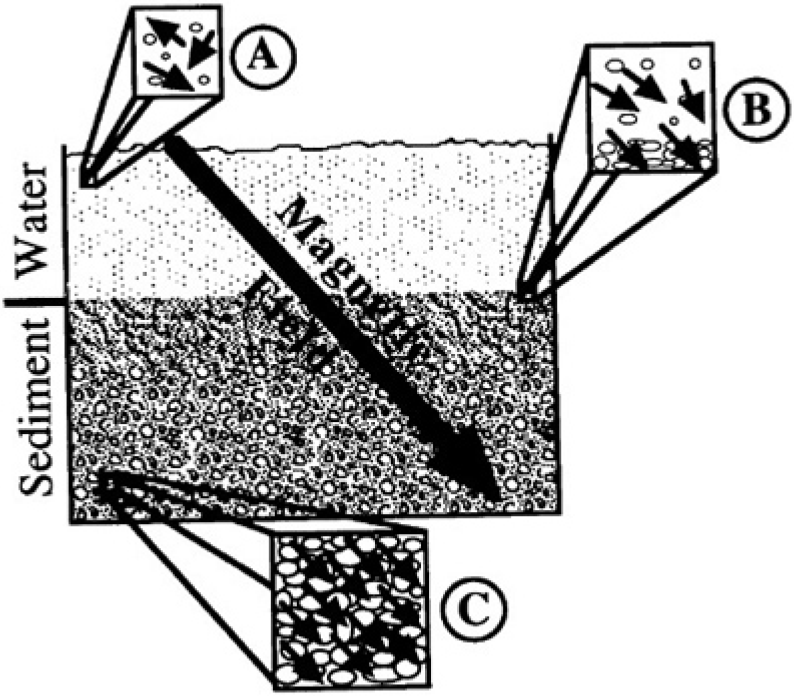


Figure 2.17 Schematic acquisition of remanent magnetism by sediments. Magnetic particles settling in air or water experience a force due to the earth's magnetic field which results in a net alignment of their magnetic vector in the direction of the earth's magnetic field. A) During their transport, the turbulence of the media results in a randomly oriented magnetic vectors of sediments magnetic grains; B) The grains acquire a similar orientation of their magnetic vectors while settling under a still condition; C) After sedimentation, the magnetic orientation of the grains remains locked in.

Source: Kappelman 1993 (Reproduced by permission of Wiley-Liss Inc.)

diffusion into the surface, the cation ratio in rock varnish. The fluor, uranium and nitrogen contents, as well as the amino acid racemization of bones are used as time dependent parameters. The principal difficulty that all these methods have in common is the influence of environmental factors, especially the effects of temperature on the reaction rate. Therefore site and sample specific reaction rates have to be established, which are achieved mostly by calibration. This makes the methods susceptible to uncertainties, and consequently these methods are of only limited use in chronometry, but they may sensitively reveal relative age differences.

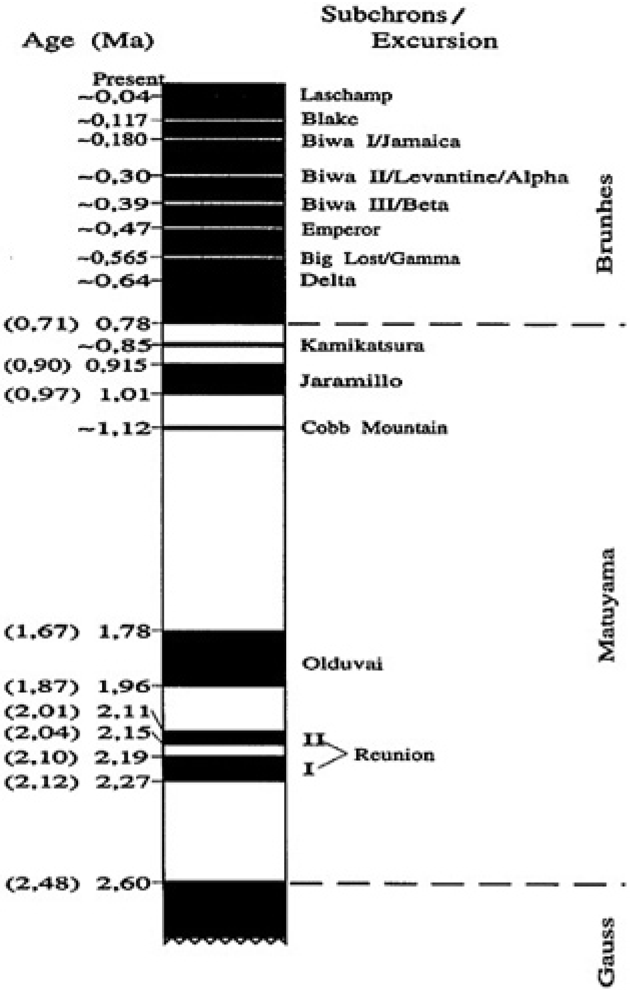


Figure 2.18 Geomagnetic polarity scale of the last 2.8 myr. As per convention, the normal polarity epochs are shown in black and the reversed are indicated in white.

Source: Wagner 1995 (Reproduced by permission of Ferdinand Enke Verlag)

Weathering rims

The measurement of the thickness of weathering crusts is one of the earliest attempts to estimate the age of rock surfaces. Under humid conditions, weathering agents corrode freshly exposed natural or artificial surfaces of rocks. Often there is a distinct reaction front that penetrates with time up to a few centimetres into the fresh matrix of the rock (Figure 2.20). The phenomenon is also known as *patination,* and thin weathering crusts are called *patina*. The processes involved are complex and not fully understood. Apart from the

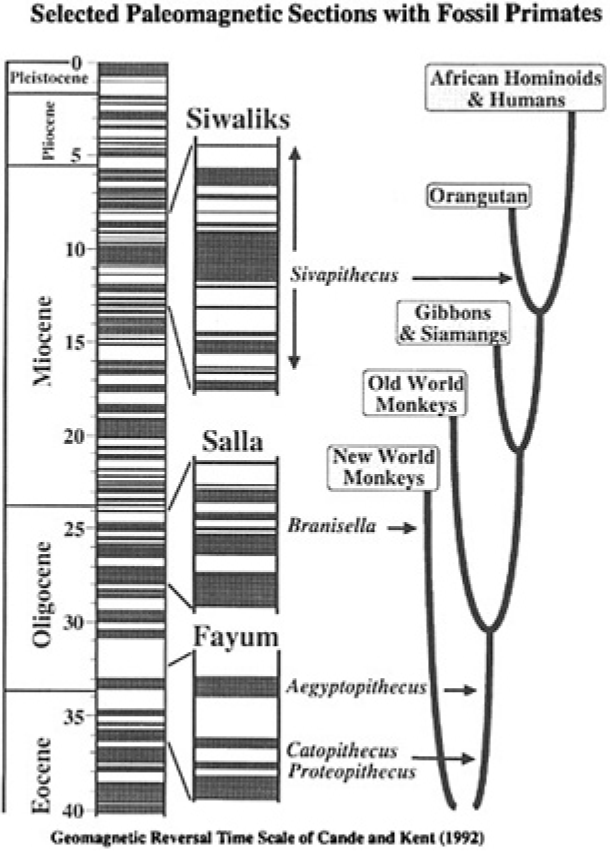


Figure 2.19 Selected palaeomagnetic sections with branching events in primate evolution.

Source: Kappleman 1993 (Reproduced by permission of Wiley-Liss Inc.)

chemical and mineralogical composition of the rock, soil chemistry, humidity and temperature determine reactions. The method has occasionally been applied to flint artefacts (Purdy and Clark 1987) and basaltic rock fragments (Cernohouz and Sole 1966), but the validity of the weathering crust as a quantitative age indicator has been questioned (e.g. Rottländer 1989).

Hydration

A fresh surface of obsidian slowly absorbs water from its environment. Water content increases from about 0.1–0.3 to 3–4 per cent. This phenomenon, known as hydration, involves exchange of the alkali ions from the glassy matrix. The hydration front penetrates gradually with time up to about 50 µm deep into the glass. In a thin section, cut perpendicular to the surface, the hydration front can be

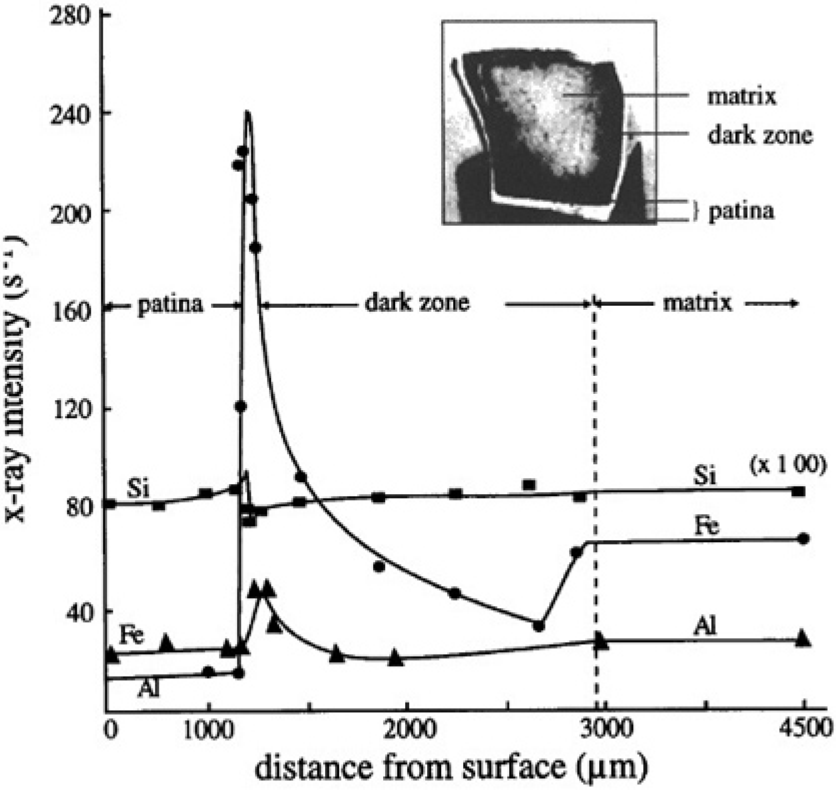


Figure 2.20 Chemical profile through the weathering crust of a chert from Florida

Source: Purdy and Clark 1987.

seen under the optical microscope as a sharp, thin line. The thickness of the hydrated rim is a measure of exposure time. If the surface is still the original one when the obsidian solidified from the magma, the hydration age dates this volcanic event (Friedman and Obradovich 1981). More interesting in archaeological contexts are secondary surfaces created by humans during tool making from obsidian raw material. In such cases one is able to determine the time of artefact production.

The conversion of the hydration depth into an explicit age value presupposes our knowledge of the hydration rate. Hydration rate is controlled by the chemical composition of the obsidian and temperature (Figure 2.21). Since it can be assumed that the chemical composition is sufficiently homogeneous within each obsidian flow, but differs from flow to flow, hydration dating requires some kind of source identification of the sample material. Due to the strong thermal effect on the hydration rate, the ambient temperature at the site needs to be known precisely. In particular, data on the variation of temperature and the duration of its variation over time are needed. This is a prerequisite not easily met. There are two approaches to overcome these problems. One is to use independently known ages, for instance ^{14}C dates of accompanying organic materials, and to derive from them the hydration rate for each site with its specific temperature history. The rates need to be established for the various raw materials at the site. The other approach is the experimental determination of the hydration rate. Since at higher temperatures hydration is accelerated, hydration rims can be attained artificially over shorter times. The laboratory values are then extrapolated from the hot, experimental to the natural, ambient temperature conditions using laws of reaction kinetics. The site's ambient temperature has to be assessed independently. Its secular and annual fluctuations are taken into account by the concept of a continuously fixed *effective hydration temperature* that would result in the observed rate.

There have been numerous successful attempts of dating obsidian artefacts from various archaeological periods. Actually, since the hydration rim measurements are easy and rapid, over the years a large body of data has been accumulated in all major volcanic belts, such as for Acheulian obsidian implements at Prospect Farm in East Africa (Michels *et al.* 1983). The age range covered by hydration dating extends from several hundred years up to 1 million years. In cases where the hydration rate is unknown, the depth of hydration on objects from the same site and deriving from the same source can still be used to establish a relative age sequence of various surfaces (Michels and Tsong 1980).

Fluorine diffusion

Fluorine dissolved in groundwater diffuses into the rock surface during burial. The depth of the migration front below the surface has been tentatively taken as an age indicator. High fluorine contents up to 900 µg/g have been observed at least down to 1.2 mm below the surface of various rocks, among them dacite, trachyte and quartzite (Taylor 1975). Fluorine can be detected with a nuclear resonance technique. Although reasonable ages for a few artefacts from California (USA) have been reported, the dating potential of the method is difficult to assess in view of the limited understanding of the underlying physico-chemical processes. It seems that at best it may serve as a relative dating technique of rock artefacts from the same site.

Cation ratio

Under arid conditions, rock surfaces become covered with a dark coating called *rock varnish*. It is composed of a mixture of oxides and hydroxides of manganese and iron and of clay minerals. Instead of thickness, it is the chemical composition of the varnish that has been exploited for determining the duration of surface exposure. Dating is based on the concept that certain cations in the varnish are

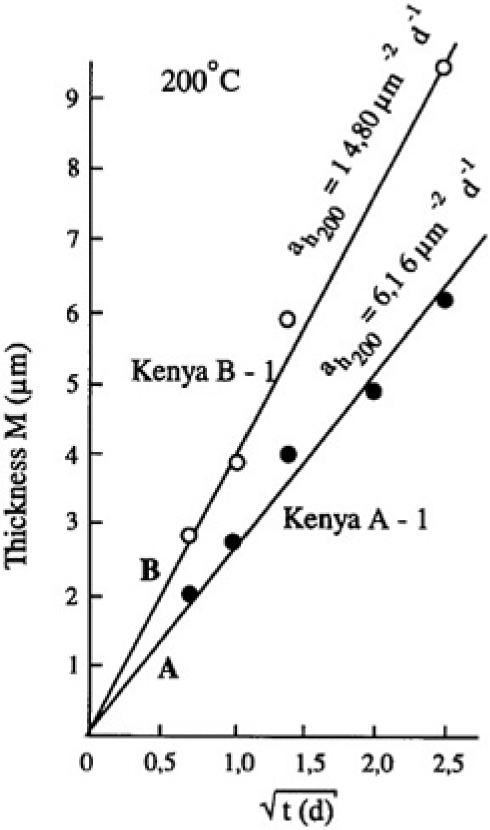


Figure 2.21 Experimental determination of hydration rates for two chemically different obsidian samples from Kenya. In this experiment, fresh obsidian surfaces were hydrated at 200°C in water.

Source: Michels *et al.* 1983 (Reproduced with permission from *Science*. Copyright 1983 American Association for the Advancement of Science)

exchanged due to weathering processes, whereby the cations of sodium and potassium are more mobile than titanium. Consequently, as time elapses, the ratio decreases. When calibrated against surfaces of independently known age, the cation ratio can be transformed into a chronometric age. The method seems to have a potential of numerical dating extending up to 1 million years (Figure 2.22). Since the ion-exchange reactions are controlled by (micro-) environmental factors, such calibration curves are valid for only certain conditions and regions. Apart from geomorphological applications the method is especially interesting for dating petroglyphs (Dorn and Whitley 1983; Dorn *et al.* 1986).

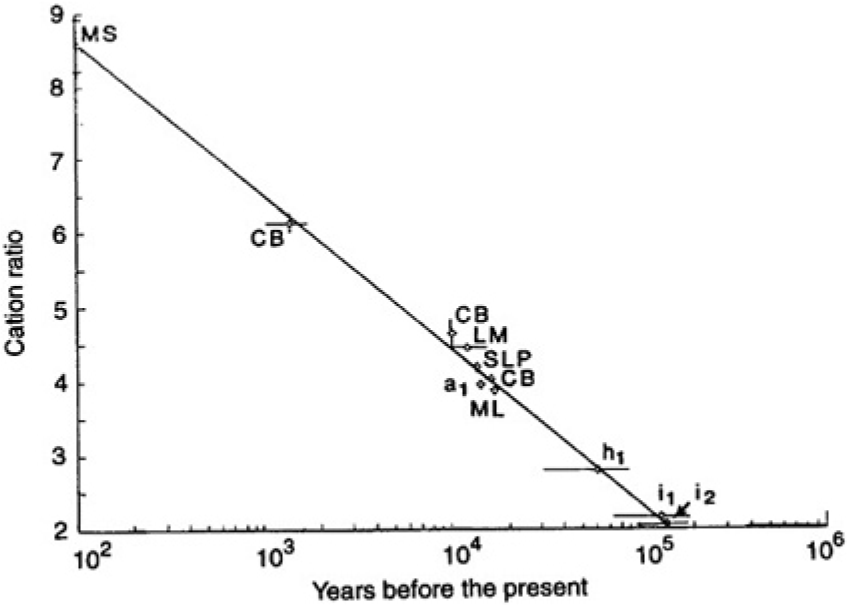


Figure 2.22 The calibration curve for cation ratio. The cation ratio is plotted against independently known ages.

FUN test

Buried bones and teeth absorb in their mineral matter fluorine (F) and uranium (U) from groundwater. With burial time, the contents of these elements may increase by two or three orders of magnitude. At the same time, organic matter, indicated by the nitrogen (N) content of the bones, decays. Therefore, the analysis of the elements F, U and N may be used as an approximate indicator of the age of fossil bones and teeth (Figure 2.23). Since the rates of the underlying chemical reactions are strongly controlled by the matrix and environmental factors, the FUN technique cannot be considered as a chronometric method. At best, it reveals relative antiquity when the F, U and N contents of skeletal specimens of similar matrix and from a particular site are compared with each other. In this way, it has been shown that the Piltdown mandible and cranial bones were considerably younger than the accompanying pleistocene fossils, thereby helping to expose the fraud. Many early hominid bearing sites were investigated with FUN testing, among them Mauer with the remains of *Homo heidelbergensis* (Oakley 1980).

Amino acid racemization

Amino acids exist in two configurations, the L- and D-enantiomer. The protein of living organisms contains exclusively L-type amino acids. Such a system is

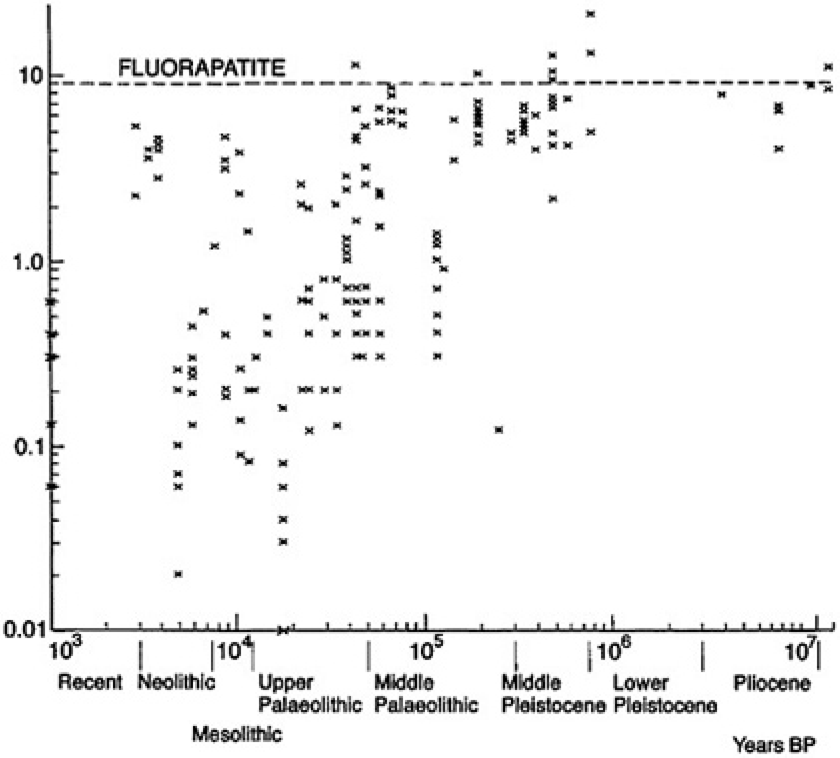


Figure 2.23 Fluorine to phosphate ratios in fossil skeletal samples from Europe plotted against stratigraphic age. Notice that the ordinate is in a logarithmic scale. Also notice the large range of values in the ratios.

Source: Oakley 1980

thermodynamically unstable, and so the protein transforms until chemical equilibrium sets in, with L- and D-enantiomer amino acids present in equal amounts. The gradual conversion of a L-type system into an equal mixture of L- and D-enantiomers is called *racemization*. Since racemization is a first-order reaction, it can be mathematically described by an exponential decay, analogous to the radioactive decay but with the difference that its half-life is temperature-dependent. Amino acid racemization dating is based on the ratio D/L of both enantiomers in the bone samples. It is a great advantage that the protein contains various types of amino acids with different racemization rates (Figure 2.24). The most important ones are asparagin, alanin, glutamin, leucin and isoleucin. Their combined application allows amino acid racemization dating to cover a wide range from recent times to several million years ago.

The major difficulty of racemization dating is the strong temperature-dependence of the racemization rate. There are two methodological approaches, first, the site-specific calibration of the rate with independently known ages, and second, the experimental determination of the rate under high temperature conditions and extrapolating to the ambient temperature at the site. In the latter approach, the concept of the *effective reaction temperature* (see hydration dating) is used. Other environmental factors, in particular the soil chemistry, also need to be taken into account while evaluating the racemization rate. The enantiomers of the various amino acids are detected with gas chromatographic techniques.

For bone dating, mostly the asparagin (up to 100 kyr) and isoleucine (up to myr) amino acids are taken. The originally determined high asparagin racemization ages of 40 to 60 kyr for the Palaeoindian bones from Del Mar and Sunnyvale, California, had to be revised to holocene values, based on independent ^{14}C calibration of the racemization rate (Bada *et al.* 1974; Taylor 1983). A more successful attempt was the dating of hominid and mammal bones from various Lower Palaeolithic and mesolithic sites in southern Italy (Belluomini 1981). Csapo *et al.* (1991) recommended separation of at least two or three amino acids as an internal check while dating bones. With isoleucine tooth enamel, the Lower Pleistocene stratigraphic sections of Olduvai Gorge have been dated and calibrated using the independently known radiometric age of Bed I (Bada 1985). Molluscs are suitable for isoleucine amino acid racemization dating. In view of the uncertainties involved in the evaluation of the racemization rates, explicit ages often cannot be calculated, and the racemization ratios are given alternatively. Their comparison allows relative dating *(amino acid stratigraphy)* within larger data sets, as demonstrated for the mollusc *Glycymeris* from the interglacial coast lines throughout the western Mediterranean (Figure 2.25; Hearty *et al.* 1986).

CASE STUDIES

The purpose of the following section is to review certain regions to indicate the diversity of dating methods being used, and to show how local circumstances dictate the application of certain methods. In addition, the following section also illustrates how dating may contribute to revisions about issues surrounding human palaeontology and archaeology or how the paucity of dates limits behavioural inferences. It is by no means considered to be a comprehensive list of dates or issues; rather, this section is intended to illustrate the importance of techniques for assessing potential palaeoanthropological issues, particularly the record of the colonization and occupation of the Old World.

Africa

Beginning in the early part of this century, the South African Transvaal caves were known to yield hominid fossils. Due to the absence of appropriate methods and dateable materials, however, these could be placed in the ‘Basal’ Pleistocene

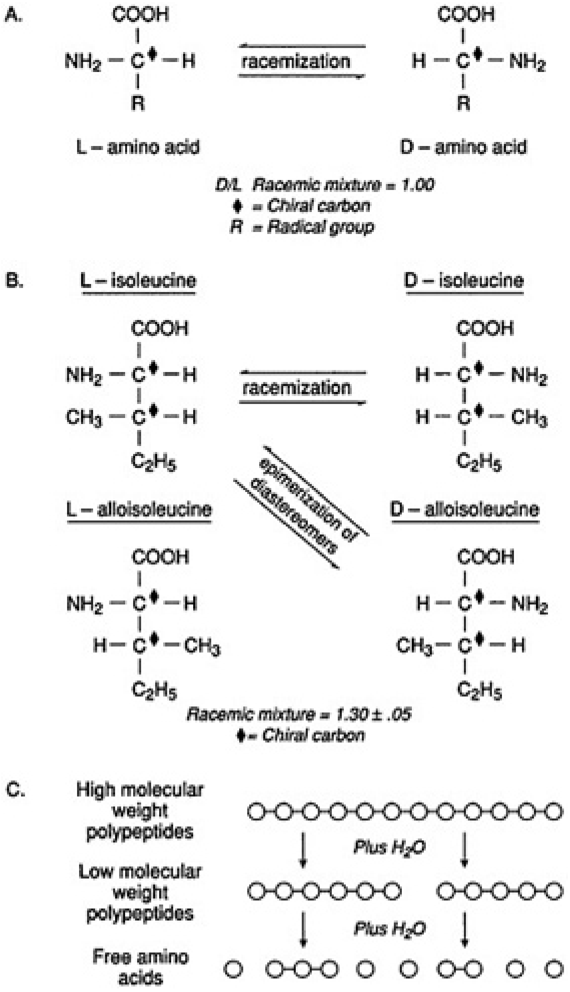


Figure 2.24 Diagentic reactions commonly used in ammo-acid geochronology: A) Racemization of L- and D-enantiomers with a single chiral carbon (e.g. leucine, bonds yielding lower molecular weight polypeptide with five ammo-acids. As the racemization/ epimerization rates differ depending on the position of amino-acid in the peptide chain, the rate of hydrolysis influences the rate of racemization.

Source: Miller and Brigham-Grette 1989 (Reproduced by permission of *Quaternary International*)

only on the basis of biostratigraphy. Real advances in dating began in the early 1960s in East Africa, where there was considerable dating activity. This enabled palaeoanthropologists to establish a provisional sequence of hominid fossil localities, thereby placing hominids in the Plio-Pleistocene, supported by a new

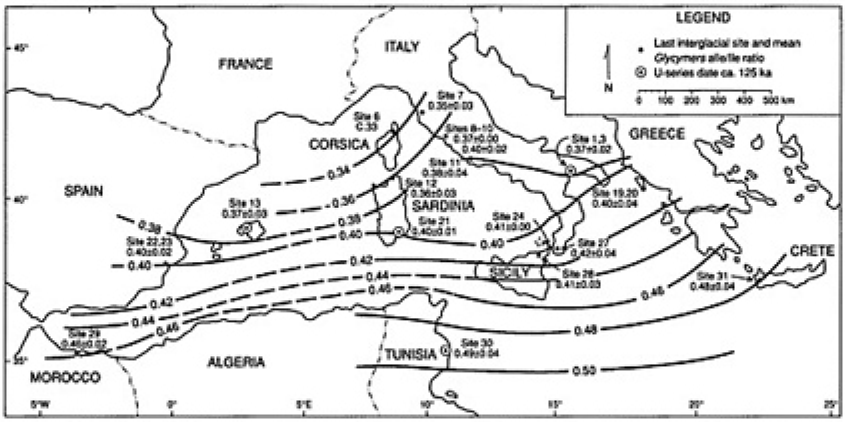


Figure 2.25 Contour plot of amino acid ratios of the fossil mollusc *Glycymeris* from raised sea-level shore during the last interglacial in the western Mediterranean.

Source: after Hearty *et al.* 1986 (Reproduced by permission of Geological Society of America)

radiometric chronology, mainly K-Ar and fission-track on volcanic ash and tuff (e.g. Howell 1969; Clark 1970). These chronometric techniques were often used in combination with biostratigraphic and palaeomagnetic sequences. Whilst increasing advances in dating and discovery of new hominid localities were considered a blessing for interpretation, the appearance of ‘inconvenient’ dates and fossils opened up serious debates about phylogeny, hominization and the temporal framework (e.g. Leakey and Walker 1976).

Among important localities associated with early radiometric dates was Laetoli, Tanzania, where *Australopithecus afarensis* fossils were identified and where hominid footprints were preserved in a volcanic ash (e.g. Leakey *et al.* 1976; Leakey and Hay 1979). The two units of the Laetoli Beds, and the hominid fossils and footprints (Tuff 7), were bracketed by two K-Ar dates of 3.8 and 3.5 myr. Complementing the Laetoli discoveries, among spectacular specimens and significant dates for hominds was the discovery of *Australopithecus afarensis* specimens at Hadar, Ethiopia, which were placed to 3.9–3.0 myr (Johanson and White 1979; White *et al.* 1981).

While radiometric dates continued to show the antiquity of hominids in Africa, increasing scrutiny was brought to bear on placing various hominds in a precise temporal sequence. In particular, great attention was paid to establishing the age of *Homo habilis.* A series of methods was used to date deposits yielding *Homo habilis* fossils, including K-Ar, fission-track, palaeomagnetism, tephrostratigraphy, and palaeontology (Drake *et al.* 1980; McDougall *et al.* 1980), the evidence converging to date the specimen to *c.* 1.9 myr.

The greater number of localities dated by K-Ar and fission-track enabled intersite correlation, which was a significant advancement since comparisons could be made among localities and regions. Thus, for example, the KBS Tuff at Koobi Fora was placed at 1.8±0.02 myr and Tuff IB at Olduvai was dated to 1.79 ±0.03 myr. In both instances, *Australopithecus boisei* and *Homo habilis* fossils and early tool industries were dated, thereby indicating the contemporaneity of the two hominids. Converging lines of dateable evidence therefore showed the potential of tephrochronology for connecting regions, particularly Olduvai Bed I, the Shungura Formation and the KBS Tuff (Ceding *et al.* 1979; Drake *et al.* 1980; Brown *et al.* 1989).

In recent years, there have been dramatic new finds of hominid specimens, and dating of these has been paramount in situating these ancestors. The composite stratigraphic section of the Hadar Formation was supported by a suite of Ar/Ar dates that are additionally constrained by the magnetic polarity studies. These dates indicated the initiation of the Hadar Formation at 3.4 myr. Lucy was placed at 3.18 myr and the AL-333 hominid assemblage at 3.2 myr (Kimbel *et al.* 1994). The 3.9 myr old Belohdelie cranial frontal, with its morphological similarity with *Australopithecus afarensis* (frontal from KH member) of the Hadar Formation, was also placed in the same hypodigm. This comprised the largest corpus of *Australopithecus afarensis* remains in the time range from 3.9 to 3.0 myr ago—a time span of almost a million years (Kimbel *et al.* 1994). These finds extended the temporal range of hominid evolution and further supported an African ancestry for hominids.

Yet another fossil representing *Australopithecus afarensis,* 2,500 km west of the Rift Valley, in Chad, has added a new spatial dimension to the species (Brunet *et al.* 1995). According to the investigators, the hominid's mandible from Chad is morphologically similar to *afarensis*. Among the seventeen new sites in the region of Bahr el Ghazal, the locality KT 12 has yielded an australopithecine mandible associated with a fauna biochronologically estimated to belong to the period 3.0 to 3.5 myr ago (Brunei *et al.* 1995). Based on previous expectations, biochronology has been used to assign a relative age measure, yet radiometric dates will be likely to play a central role in further assessing the placement and significance of these localities.

Further extending hominid ancestry in Africa, seventeen *Australopithecus/ Ardipithecus ramidus* fossils were collected from the Middle Awash region of Ethiopia (White *et al.* 1994, 1995). The discovery of *Ardipithecus ramidus* and its association with volcanic eruptives suggest that both human antiquity and bipedalism are still older by another 500 kyr. Sites like Maka and Belohdelie, yielding *Australopithecus afarensis* dating back to between 3.4 and 3.8 myr, are also situated in the Middle Awash region (White *et al.* 1993). The geological context of Maka and Belohdelie fossil sites is well defined in the Awash region. The sedimentary sequence yielding the fossil material is capped by a volcanic ash, the VT-1/Moiti Tuff, dated to 3.9 myr.

Similarly, crucial to dating the *Ardipithecus ramidus* hominid was its association with volcanics. This fossil horizon is also sandwiched by two volcanic tuffs. The fossils, though they are surface finds, were recovered from the surface within 3 m of the Daam Aatu Basalt Tuff (DABT) and from the layer immediately above the underlying Gaala Vitric Tuff Complex (GATC). One of the specimens was from stratified context, between DABT and GATC. GATC has a secure Ar/Ar date of 4.4 myr. This is also constrained by magnetostratigraphy. The reversed polarity of DABT suggested a time span between 4.5 and 4.3 myr. This hominid's morphological dissimilarity has been considered typical for the new genus *Ardipithecus,* and a species of hominine rather than hominid (White *et al.* 1995).

Although *Ardipithecus ramidus* is the oldest hominid, dating back to 4.4 myr, new finds at Kanapoi have added to the species' diversity in the *Australopithecus* hypodigm. Kanapoi has yielded a new fossil type designated *Australopithecus anamensis* (Leakey *et al.* 1995). These fossils came from a horizon lying between two pumiceous tephra beds, dated using Ar/Ar chronometry to 4.167±0. 004 myr and 4.121±0.004 myr. The sedimentary sequence containing the fossil hominids and mammals is capped by the Kalokwanya basalt, with a whole-rock K-Ar age of 3.4 myr. Leakey *et al.* (1995) have suggested that the hominid fossils from Kanapoi represent an age interval of 4.2–3.9 myr.

Among the more significant early archaeological occurrences associated with dates are the Gona localities in Ethiopia (Semaw *et al.* 1997). At Gona, stone tool assemblages were identified using radioisotopic age control and a magnetic polarity stratigraphy. The archaeological assemblages were placed to 2.6– 2.5 myr by Ar/Ar, thereby placing them as the oldest assemblages in the world and indicating a long period of technological stasis in the Oldowan.

Europe

Although the frequency of Lower Palaeolithic sites in Europe is relatively high, the lack of radiometrically datable contexts has been the major problem of reconstructing evolutionary changes in a time-space framework. The majority of age estimates are based on biostratigraphic zonation. In recent years, the situation has improved, and hominid and archaeological localities of Europe have been examined using a variety of alternative techniques, including biostratigraphy, geochronology, Oxygen Isotopic Stage correlations, and palaeomagnetic sequences (e.g. Roebroeks *et al.* 1992; Roebroeks and van Kolfschoten 1994, 1995). Uranium series and thermoluminescence dating techniques have also been applied for dating sediments, secondary limestones and burnt flints for somewhat younger deposits.

Recent chronologies, based on pollen analysis and correlation with the deep sea Oxygen Isotope Stages, indicate that most Middle Pleistocene sites pre-date Oxygen Isotope Stage 7 (see Roebroeks *et al.* 1992; Roebroeks 1994). This chronological framework placed the initial European colonization to *c.* 750–500 kyr ago. The European record therefore indicates that hominids bearing achuelian assemblages took nearly 1 million years to reach Europe after the initial emergence of this technology in East Africa. However, the probability of hominids entering Europe much earlier than the Middle Pleistocene cannot be ruled out as yet. Recently, the discovery of hominids just before the Brunhes/ Matuyama boundary, i.e. older than 780 kyr, were announced from Atapuerca in Spain, where *Homo heidelbergensis* is tentatively identified (Carbonell *et al.* 1995a, 1995b). Recent chronometric efforts of dating the Mauer *Homo heidelbergensis* specimen, using TL, ESR, uranium series, and palaeomagnetic dating in conjunction with biostratigraphy, place this find in an interglacial that correlates with either Oxygen Isotope Stage 13 or 15, i.e. 621–568 kyr or 528–474 kyr, respectively (Beinhauer and Wagner 1992). Excavations at Boxgrove have confirmed that Europe was occupied during the Middle Pleistocene (Roberts 1986; Roberts *et al.* 1994). A hominid tibia, identified as *Homo heidelbergensis,* is associated with Acheulian artefacts and other time sensitive mammalian fauna. The fauna represents a major temperate or interglacial stage that was equated with Oxygen Isotope Stage 13 (see Gamble 1994).

Near-East

The Lower Palaeolithic of the Near East has been difficult to place in precise chronological context, since most dates centre on geological correlations and biostratigraphy. The earliest archaeological assemblages have been placed to *c.* 1. 4–1.0 myr (see Bar-Yosef, this volume). The later phases of the Palaeolithic have been radiometrically dated utilizing luminescence of burnt flints from stratified contexts (Figure 2.26). This has provided age determinations on some Late Acheulian sites (e.g. Tabun) and provided ages for Lower-Middle Palaeolithic transitional sites. Among significant sites in the Near East, Dzaparidze *et al.* (1983) reported an early *Homo erectus* in Georgia, Caucasus. The find comprises a human mandible, lithics, and faunal and floral remains. The site occurs over a lava flow dated by the K-Ar method to 2.0–1.8 myr. Palaeomagnetic analysis of the lava flow revealed normal polarity, and accordingly was ascribed to the Olduvai event. Since the layer occurs stratigraphically above the lava flow, the K-Ar age provided the upper limit of the *Homo erectus* find. The fauna belongs to the Upper Villafranchian, which is ascribed to the Lower Pleistocene. Since the find layer is also normally polarized, it was argued that it also belonged to the Olduvai event; however, it is in principle possible to ascribe it to the Brunhes epoch.

The Indian sub-continent

In the Indian subcontinent, prospects of dating Palaeolithic artefact assemblages from the Neogene-Quaternary sediments in the Potwar region appear bright (Allchin 1995). In the 1980s, magnetic polarity stratigraphy of the Neogene

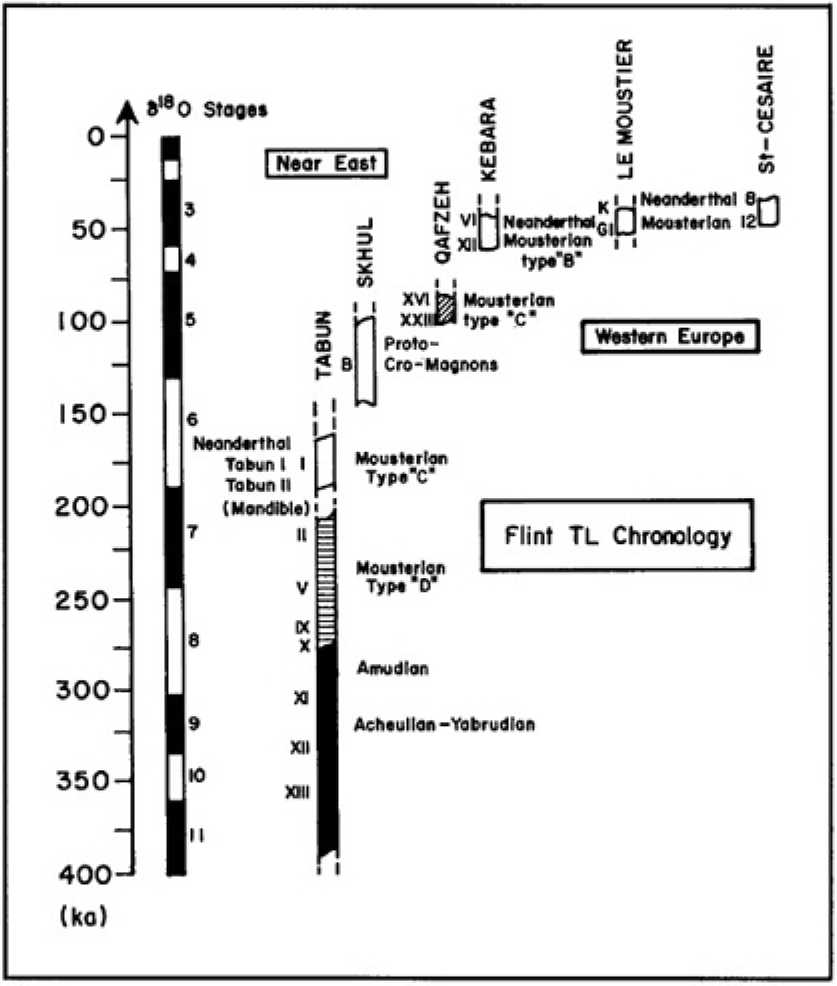


Figure 2.26 The TL flint chronology of selected Near Eastern and west European sites. Dark shading designates the Lower Palaeolithic, whilst lighter shades are used to indicate several types of Mousterian industries represented in the Near East. The numerals or letters to the left of each bar identify the archaeological levels.

Source: Mercier *et al.* 1996 (Reproduced by permission of the authors)

sediments and tephrochronology of the interbedded tuffs (bentonites) of the Himalayan foreland basins resulted in the delineation of a structural evolution of the basins, tectonics and sedimentation (Burbank and Raynolds 1984; Burbank *et al.* 1986; Johnson *et al.* 1986). Fission-track chronology of the bentonites helped correlation of the magnetic polarity time scale with faunal and climatic changes (Keller *et al.* 1977; Barry *et al.* 1982; Opdyke *et al.* 1982; Zeitler *et al.* 1982;

Agrawal *et al.* 1989). The Palaeolithic material reported from these basins is still atypical, and can be categorized as a Mode I assemblage. The Palaeolithic sites from Riwat and Pabbi Hills have acquired renewed significance, as they anticipate prospects of dating hominid expansion into South Asia to 2 myr (Dennell *et al.* 1988a, 1988b; Rendell *et al.* 1989; Dennell 1993; Dennell, this volume).

In peninsular India, suspected Palaeolithic implements within a volcanic ash horizon at Bori (near Pune) in the Deccan Volcanic Province have been dated by the K-Ar method. A bulk sample K-Ar age was originally estimated to be 1.4 myr (Korisettar *et al.* 1989). This was considered erroneous, as demonstrated by subsequent fission-track and K-Ar ages by Horn *et al.* (1993), who placed this age at 600 kyr. Subsequent analysis using Ar-Ar methodology supported the age of 600 kyr (Mishra *et al.* 1995). On the other hand, bulk geochemical analysis by Acharyya and Basu (1993) and subsequent grain specific geochemical finger printing matched with the 75 kyr youngest Toba tuff (Shane *et al.* 1995). The apparent inconsistencies in the stratigraphic reconstruction of the alluvial sequences in the Kukdi Valley and the stratigraphic location of the Bori ash bed led to a currently unresolved situation (Mishra and Rajaguru 1997; Shane *et al.* 1997).

Most Acheulian occurrences in India have been placed using relative age estimates in the later phases of the Acheulian, most presumably dating to the second half of the Middle Pleistocene and to the Late Pleistocene. A set of uranium series dates places Acheulian sites comfortably to >350 kyr and to *c.* 150 kyr (see Mishra 1992: Table 1; Petraglia, this volume).

East and Southeast Asia

Hominid bearing localities in Indonesia have been subject to K-Ar, fission-track and palaeomagnetic dating (Sortono 1982; Djubiantono and Semah 1991). The youngest Notoporo Formation has a fission-track date bracket of 250–70 kyr. Hominid remains recovered from the Kabuh Formation have been dated to 500 kyr by the K-Ar method. Similarly, the older Pucangan Formation containing Jetis fauna has a K-Ar date of 1.9±0.4 myr (Jacob and Curtis 1974; Jacob 1972; Day and Molleson 1973). Based on the recent Ar/Ar dating of two hominid localities in Java, an early date for *Homo erectus* has been further advocated, with samples yielding weighted mean ages of 1.81±0.04 and 1.6±0.04 myr (Swisher *et al.* 1994).

The Indo-China region occupies an intermediate position between China in the north and Indonesia in the south. The region has recently produced dated pleistocene sites, bridging gaps in our knowledge of hominid evolution and their movements in this north-south transect. The cave complex at Lang Tang in northern Vietnam has yielded a record of pleistocene faunal remains in association with hominid fossils. Middle Pleistocene breccia samples, containing hominid dental remains, were ESR dated to 480±2 kyr (Ciochon and Olson 1991).

In China, at least 400 Palaeolithic and hominid sites are known, many of which have been temporally placed based on biostratigraphy and palaeomagnetic correlation (Wu 1985; Schick and Dong 1993). The absence of volcanic ash beds has precluded the use of the fission-track and K-Ar methods. Dates exceeding 1 myr have been advanced, but these are considered controversial or in need of further verification. The most reliable hominid and archaeological sites may be placed to >780 kyr by palaeomagnetism and biostratigraphic correlation (Wu 1985; Schick and Dong 1993). The Longgupo locality has recently placed homind finds and artefacts to *c.* 1.9 to 1.7 myr (Huang *et al.* 1995), although identifications and dates have not been roundly accepted. Most localities in China are clearly datable to the Middle Pleistocene. In the Zhoukoudian cave locality in China, sphene was separated from burnt ash deposits (in layers 4 and 10), and these were dated to 462±45 and 306±56 kyr, respectively, suggesting that this site was inhabited for a duration of 156 kyr (Guo *et al.* 1980). The majority of published dates are U series ages on fossil bones and teeth in which uranium is present in relatively high concentration, i.e. 1 to 1,000 (µg/g. The closed system approximation, however, is rarely fulfilled. Nonetheless, the U series dating of the Chinese Palaeolithic has dated many localities to a range of 190–50 kyr.

CONCLUSION

Though the first significant palaeoanthropological discoveries were made in the last quarter of the previous century in Java, it is only during the last seventy years that the intensive search for hominids is being made, especially in Africa. In the earliest African studies, the focus was on the limestone caves in South Africa and the East African Rift. An increasing number of sites in these areas competed with one another in providing older and newer hominid fossils. The great number of finds in well established chronological contexts led to recognizing East Africa as the original habitat of hominids. This gave rise to the 'East African Rift Centric' (EARC) theory of human origin, based on a reasonably secure foundation of numerical dates.

Reinvestigation of Longgupo cave in central China has fuelled the debate on the timing of the movement of *Homo* out of Africa, and supported the idea of multiregional evolution (Huang *et al.* 1995). Based on these new finds and their associated dates, it appears that the spread of *Homo* may have happened much earlier than has been assumed today. The ESR dates, the palaeomagnetic sequence, and the fauna of the Longgupo cave deposits have placed the hominid bearing levels to the earliest Pleistocene. Age determinations suggest that hominids were established in Asia just after 2 myr, and, given the primitive nature of the hominid dentition from Longgupo, it is possible that the first hominids to occupy Asia may have been *erectus* variants such as *Homo ergaster* or perhaps *Homo habilis* (see also Wood and Turner 1995). The dental remains share morphological similarity with the early representatives of the genus *Homo* in Africa, and the stone tools share similarity with the earliest Oldowan technologies of East Africa. These results indirectly support an early age of the Javanese *Homo erectus* fossils (Swisher *et al.* 1994).

The basic question of 'When did hominids move out of Africa?' still remains enigmatic (Figure 2.27). At this stage, the most probable answer is that hominids migrated out of Africa at the *erectus* stage. On the basis of the fore-going discussion on the chronometry of the Lower Palaeolithic, it appears that early technology began in Africa, evolved slowly, and eventually spread widely in the Old World.

Review of the Palaeolithic record reveals that a significant amount of chronometric and palaeoanthropological research has been carried out in Africa, followed by Europe. Although application of radiometric techniques is not as plentiful in Europe as in Africa, quaternary biostratigraphic and climatic records of the Middle Pleistocene are correlated to deep sea oxygen isotopic records, which aid the reconstruction of Palaeolithic chronology and environment. Unfortunately, similar investigations in the tropical south and Southeast Asia are generally lacking to this day; once these are conducted, further clues and perhaps surprises about colonization are bound to emerge.

The foregoing account reveals the successful efforts of scientists in developing a variety of dating methods that have been useful in chronology building. Chronometric dating has organized a complex array of data into a sequence tracing the rise of modern humans (Figure 2.28). While chronometric methods sometimes add to the clarity of our understanding of hominid evolution, 'unanticipated' dates may also lead to debates and to reassesssments of prior hypotheses. In this sense, the continued use and improvement of chronometric methods for palaeoanthropological investigations are of great advantage in reaching a truer understanding of human evolutionary processes.

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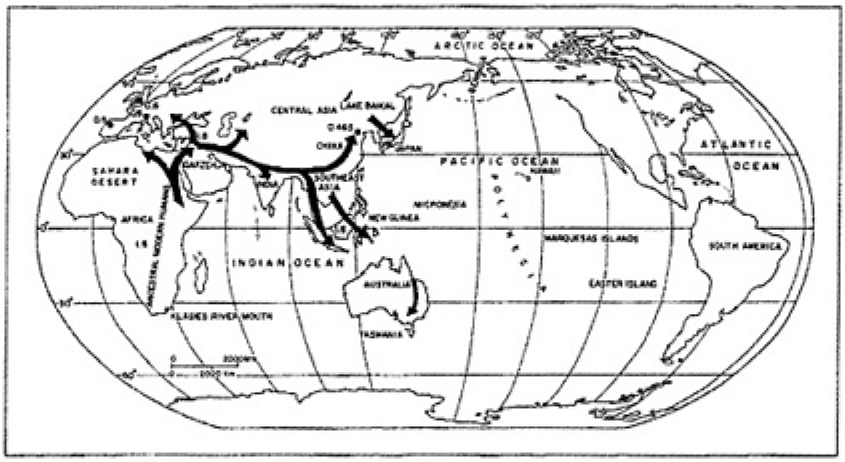

Figure 2.27 Possible scenarios of migration of *Homo erectus*.

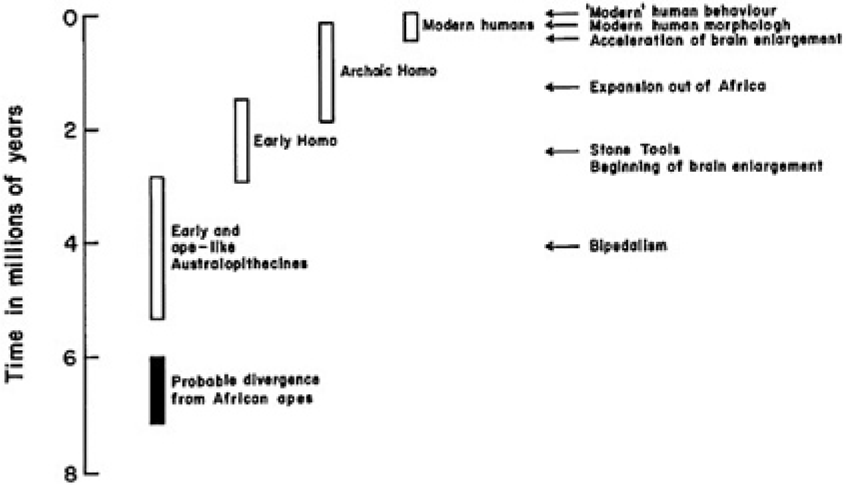

Figure 2.28 Summary of the landmarks in the evolution of hominids.

Source: Foley 1996 (Reproduced by permission of Blackwell Publishers Ltd)

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3

Towards a technological reassessment of East African Plio-Pleistocene lithic assemblages

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INTRODUCTION

Much hominid behavioural research being carried out today still utilizes traditional typologically based frameworks, despite the fact that these typologies were not designed to provide data on issues such as hominid cognitive capacities, manual abilities, ranging patterns or land use. In Plio-Pleistocene artefact studies, the typology devised by Mary Leakey (1971) is still the predominant method of lithic analysis. This is surprising in the light of research that has shown the advantages offered by experimental approaches (Jones 1979, 1980, 1981; Stiles 1979; Keeley 1980; Toth 1982, 1985a, 1985b, 1987, 1991). As a general rule, however, the use of actualistic data in early hominid research is still the exception rather than the rule.

Recognizing that the conventional methods of analysis were inappropriate for investigating early hominid behavioural questions, Isaac and Harris (in press) devised a concise technologically based approach to the archaeological record (see also Harris 1978). This involved dividing lithic assemblages strictly according to their condition, i.e. flaked, detached or pounded, and served to categorize cores and flakes into gross analytical units. This technique eliminated the need for highly subjective typological categories and allowed for a strictly technological assessment of hominid produced lithic assemblages. While ideal for making basic technological evaluations of lithic assemblages, in the long run this methodology proved somewhat imprecise and not necessarily suitable for addressing complex hominid behavioural issues.

This chapter is based on a currently on-going, experimentally constructed study carried out primarily to contribute new data and insights into four main early hominid related research topics:

1 the validity of typologically defined ‘cultural’ entities (e.g. Oldowan, Developed Oldowan, Acheulian, Karari),
2 the effects of knapper proficiency and handedness on lithic assemblage character,
3 the existence of pre-Acheulian artefact standardization, and

4 the technological differences between ‘scatters’ and ‘patches’.

Whilst experimentation may not be a panacea for all that ails lithic studies, by utilizing a series of variables derived mainly from actualistic programmes (Toth 1982; Ludwig 1992), these issues can be addressed from a more objective standing as opposed to the frequently subjective findings relying on typological methodologies.

Summary statistical data are not yet available and the findings presented here can only be considered preliminary. However, it is apparent that the application of this actualistic methodology to Plio-Pleistocene assemblages by the senior author, a skilled lithic technologist, has already provided important insights into hominid behavioural patterns. This data has important implications regarding hominid cognitive and physical development, technological and subsistence systems, ranging patterns and how the Plio-Pleistocene as a whole is perceived from an archaeological perspective.

SITE CHRONOLOGY AND CONTEXT

A total of forty-three excavated archaeological lithic assemblages were directly analysed or otherwise considered for inclusion in this study (Figure 3.1, Table 3.1). Typologically, these collections comprise a number of lithic industries including the Oldowan, Developed Oldowan A and B, Karari, KBS and Acheulian. Temporally, they span a period in excess of 1 million years, from the threshold of implement manufacture at approximately 2.5 myr through to the beginnings of the traditionally defined Acheulian some 1.5 myr ago. These assemblages were recovered from various depositional contexts at East and West Turkana, Ileret and Chesowanja in Kenya (Harris 1978; Harris and Gowlett 1980; Isaac *et al.* 1980; Gowlett *et al.* 1981; Isaac 1984; Kibunjia *et al.* 1992; Kibunjia 1994; Isaac and Harris, in press), Olduvai Gorge in Tanzania (M.D.Leakey 1971, 1975; Potts 1988), the Omo and Gona rivers in Ethiopia (Merrick 1976; Merrick and Merrick 1976; Howell *et al.* 1988; Semaw 1996; Semaw *et al.* 1997) and from along the Semliki River in Zaire (Harris *et al.* 1987, 1990).

STUDY METHODOLOGY AND APPROACH

This research has employed a methodology which, although firmly grounded in an experimental perspective, utilizes analytical variables from typological, technological as well as actualistically based approaches. Standard observations found in typological analyses, such as general artefact dimensions and raw material type, are utilized as well as those found in technologically oriented studies such as flake shape, degree of core reduction and the presence of cortex on flakes and cores. While the contributions of these methodologies are certainly important and, if analysed properly, can contribute to behaviourally focused

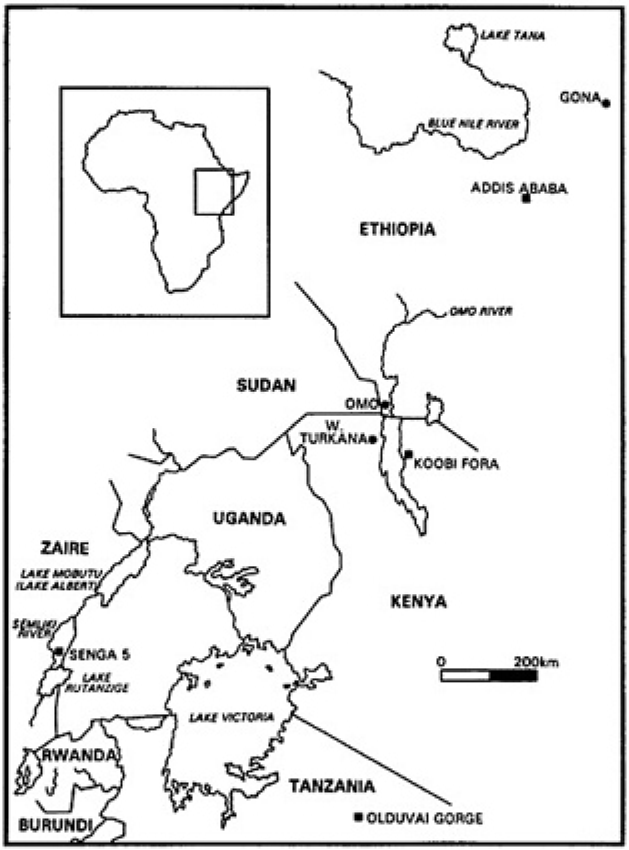

Figure 3.1 Map of East Africa showing the locations of sites included in this study.

studies, in general, it is the factors derived from experimentation that have proven to be the most useful in this research.

Table 3.1 Sites included in this study, with date ranges and associated typologically designated lithic industries.

Dates (myr)	*Associated industries*	*Lithic assemblages*
2.5–2.0	Indeterminate	*Gona* 10, 12; *Omo* 84, 57, 123, FtJi 1, 2, 5; *W.Turkana* GaJh 5; *Zaire* Senga 5
2.0–1.7	Oldowan, KBS	*Koobi Fora* FxJj 1, 3, 10; *Olduvai* DK, FLK 22, FLKN 1/2–6, Deino.; *W.Turkana* FxJh 5
1.7–1.4	Developed Oldowan, Karari	*Koobi Fora* FxJj 11, 16, 17, 18GL, 18GU, 18IH, 18NS, 20E, 20AB, 23, 33, 37, 50, 64; *Ileret* FwJjl; *Chesowanja* GnJi 1/6E, 2/8,

Dates (myr)	*Associated industries*	*Lithic assemblages*
		10/5; *Olduvai* MNK Main, FLKN sand., HWKE 1–4, BK
1.4–1.2	Acheulian, indeterminate	*Koobi Fora* FxJj 63; *Olduvai* EF-HR, TK/L; *W.Turkana* FxJh 6

These include parameters such as an adaptation of the flake types defined by Toth (1982), restructured to allow for the recording of more detailed information concerning the placement of dorsal cortex on flakes, flake condition, dorsal platform angles and the presence of dorsal battering. For cores, features such as the presence or absence of the 'point and hollow' configuration (Ludwig 1992) and the number of step or hinge fractures are recorded. Other variables relying on the analysts' skill as a lithic technologist are noted as well, such as whether or not a core can be considered exhausted or rejected.

The most general topic addressed here deals with the East African Plio-Pleistocene cultural entities defined according to the conventional methods of typological classification of core and flake forms. None of these divisions has been tested as to their validity from an experimental perspective. Historically, it has always been the gross morphological variation present in stone tool kits that has received the most attention in lithic analysis. This differentiation, noted on both temporal and spatial levels, has traditionally been used to define what were thought of as distinct hominid technological systems reflecting varied cultural norms, i.e. Oldowan, Developed Oldowan and Acheulian (Leakey 1971, 1975). Lithic analysis has been structured in this manner since at least the middle of the nineteenth century, and until the last ten to fifteen years or so few Plio-Pleistocene stone tool studies were conducted that could be considered truly innovative (Jones 1979, 1980, 1981; Toth 1982, 1985a, 1985b, 1987; Schick and Toth 1994).

One area of research well beyond the approach of typological analysis involves the issues of hominid handedness and knapping skill. In the past, these have been treated as separate issues, but recent experimental investigations have shown that they are intricately interrelated in terms of their expression in the archaeological and experimental lithic records (Ludwig 1992; Ludwig and Harris 1994). Hominid skill has been approached by a number of researchers in recent years (Wynn 1979, 1981, 1983; Gowlett 1984; Isaac 1986; Roche 1989; Kibunjia 1994). None has examined this issue from an experimental perspective though, and while they all utilize quantifiable data, those data are oftentimes based on highly subjective typological observations. The most recent contribution to the hominid skill debates is the work of Kibunjia (1994) which suggests the presence of a technologically recognizable 'pre-Oldowan'.

The determination of hominid skill levels and the relation of this information to handedness necessitates that skill be considered as a combination of both mental and physical capacities. Our contention that the manifestation of flint knapping skill requires two elements, one cognitive and the other anatomical, is supported in part by the works of Marzke (1983), Marzke and Schackley (1987), Ricklan (1987) and Susman (1988, 1992). According to these studies, *Paranthropus robustus* and *Australopithecus africanus* appear to have possessed the manual dexterity necessary for tool manufacture and/or utilization. As the archaeological record is unclear as to whether or not either species engaged in such behaviour, it may be that they did not possess the cognitive abilities necessary for tool production. If this is indeed the case, a conjoining of these mental and physical capacities may have occurred only with the emergence of the genus *Homo* (see Hill *et al.* 1992).

Hominid knapping skill and handedness are related in that hand preference is strongly manifested in the lithic record only by skilled knappers according to the flake types and shapes they produce. Novice knappers work their cores unsystematically, producing patterns of flake shapes and partially cortical flakes that are highly ambiguous as to handedness (Ludwig 1992). Although the relationship is uncertain at this time and highly controversial (Holder and Senglaub 1994), it may be that the lateralized areas of the brain that control the cognitive capacities for language may influence hand preference as well (Isaac 1976; Levy 1977; Annett 1985; Falk 1987). Consequently, the identification of the initial tendency towards handedness in the archaeological record *may* indicate the initial development of cerebral lateralization and language abilities in early hominids.

Another issue further related to the development of hominid cognitive and manual capacities is the point in the archaeological record where core forms appear to loose their *ad hoc* character and instead consist of purposefully knapped arbitrary forms. Lithic artefact standardization and the imposition of form on raw stone have traditionally been thought of as having originated with the Early Acheulian. This view holds that, at about 1.4 myr, hominids began to consider mental templates in their knapping activities, and this predetermined the ultimate shape and size of the bifaces that serve to define the Acheulian (Gowlett 1979, 1986). While it may be true that Acheulian bifaces often exhibit a high degree of regularity in terms of morphology and production technique, the single platform cores (core-scrapers or ‘Karari scrapers’) found in great numbers in Karari industry assemblages starting at about 1.7 myr (Harris 1978) display the same degree of morphological and technological predictability and skilled manufacture (Ludwig and Harris 1994; Ludwig 1995). These single platform cores represent a highly efficient technology designed to provide the highest possible number offtakes from a single core. Such maximization of stone would be of great advantage to the probable producers, *Homo erectus,* as this hominid inhabited far larger and more ecologically diverse ranges than previous species (Stringer 1984; Walker and Leakey 1993; Swisher *et al.* 1994).

Aside from the variability in the character and context of East African lithic assemblages from the Plio-Pleistocene, their density and distribution across the landscape differs as well. Numerous studies have attempted to elucidate the reasons for the variability seen in the placement of artefact scatters and patches in East Africa (Howell *et al.* 1988; Potts 1988, 1994; Blumenschine and Masao 1991; Stern 1991; Rogers 1997; Isaac and Harris, in press). This differentiation in assemblage density and context has traditionally been approached from the typological perspective involving the analysis of large bone and stone assemblages (Leakey 1971, 1975). These typologically based studies have suggested primarily 'cultural' reasons for varying site size and density. Potts (1982, 1988) suggests functional reasons for this variability, and other work has suggested that it may simply be the duration and/or frequency of hominid occupation that led to variation in assemblage density and distribution (Blumenschine and Masao 1991).

It has only been fairly recently that researchers have taken into account less dramatic, low-density scatters in studying hominid ranging and subsistence patterns (Isaac 1980, 1981; Stern 1991; Rogers *et al.* 1994; Rogers 1997). These studies examine more diffuse occurrences from functional and technological perspectives in attempting to elucidate patterns of hominid land use. Until now, however, they have never been examined from the stand-point of experimental studies.

SITE SPECIFIC CASE STUDIES: RESULTS AND IMPLICATIONS

The Late Pliocene or 'Pre-Oldowan'

In recent years, a number of Late Pliocene archaeological sites have been excavated, yielding relatively large stone tool assemblages (Harris *et al.* 1987, 1990; Howell *et al.* 1988; Kibunjia *et al.* 1992; Semaw *et al.* 1997). These range in age from 2.2 myr to at least 2.5 myr, and have been recovered from a broad geographical region and in varying depositional contexts. The early hominid producers of these assemblages utilized a variety of materials including quartz, quartzite, basalt and various other types of volcanic rock. There does not appear to be any utilization of exotic materials, and the knappers were, in all likelihood, exploiting lithic sources very near the sites. On the Omo localities and at Senga 5 in Zaire, the predominant source of raw material consists of small water-worn quartz pebbles. In the Gona and at West Turkana, locally available basalts and igneous rocks of various grades were employed in the production of stone cores and flakes. In examining these early sites, it became clear that, contrary to some suggestions (Roche 1989; Kibunjia 1994), Late Pliocene knappers were in fact relatively skilled in removing usable flakes from a number of raw material types and forms.

At Senga 5 (controversially dated to approximately 2.3 myr, see Boaz 1994; de Heinzelin 1994), a total of 1,004 quartz and quartzite cores and flakes were recovered from a limonitic horizon in direct association with fauna dating to the

Late Pliocene (Harris *et al.* 1987, 1990). A detailed examination of these materials revealed the earliest documented use of the bipolar reduction technique. The vast majority of the debitage and cores were manufactured utilizing this knapping method on locally available small quartz pebbles, which were nearly the only available lithic resource. Considering the apparent lack of any other type or form of material, it is not surprising that the Senga 5 hominids utilized bipolar reduction. For the most part, 'opportune platforms' (those occurring naturally on an unworked clast or fragment) (Ludwig 1992) are not available on the rounded quartz pebbles found at Senga. The only method that a knapper can use to break into these pebbles and consistently produce sharp-edged flakes is the bipolar technique. A hammerstone and anvil are employed, examples of which have been recovered *in situ*.

Although assemblages from the Omo (sites 84, 57, 123, FtJi 1, Ftji 2, FtJi 5) have not yet been subjected to the methodology outlined in this chapter, examination of the literature seems to indicate that they were also produced utilizing bipolar knapping (Merrick and Merrick 1976; Howell *et al.* 1988). The reasons for the extensive employment of this technique at the Omo are likely to be the same as at Senga 5: the preponderance of small, rounded quartz pebbles. With other materials evidently being scarce at these sites, bipolar reduction appears to have been an early technological adaptation to a particular raw material type and form. Without large clasts of material suitable for direct percussion knapping, employment of bipolar reduction was a necessary if not inevitable solution to the constraints of a specific form of raw material.

Not only was bipolar reduction extensively employed at Senga 5, and apparently in the Omo as well, but it was also conducted in a very efficient and skilled manner. Many of the Senga cores and core fragments were heavily worked to a point where many of the obtained flakes were not more than 10–20 mm in maximum dimension (Figure 3.2). These depleted cores show little in the way of step or hinge fractures and appear to have been broken only upon exhaustion. Despite a readily available supply of raw material, the Senga 5 hominids appear to have been exploiting these cores to their absolute limit. The end product of such efficiency produced tiny, exhausted bipolar cores, strikingly similar to those found on much later sites (see Barham 1987) and identical to typologically defined *outil ecailles*.

Whilst the manufacture of such diminutive flake and core forms raises many questions as to how they might have figured in hominid subsistence strategies, such forms clearly demonstrate that the pre-classic Oldowan hominids of the Late Pliocene possessed a high degree of manual dexterity in terms of precision and power grips (Marzke 1983; Marzke and Shackley 1986; Ricklan 1987; Susman 1988, 1992).

Although the bipolar technique may be cognitively easier to employ than direct percussion, based on personal observations, it in no way reflects upon the mental abilities of the hominids from the 2.3–2.2 myr period. At the Gona sites (10, 12), dating to about 2.5 myr (Semaw *et al.* 1997), quartz was not available, and only

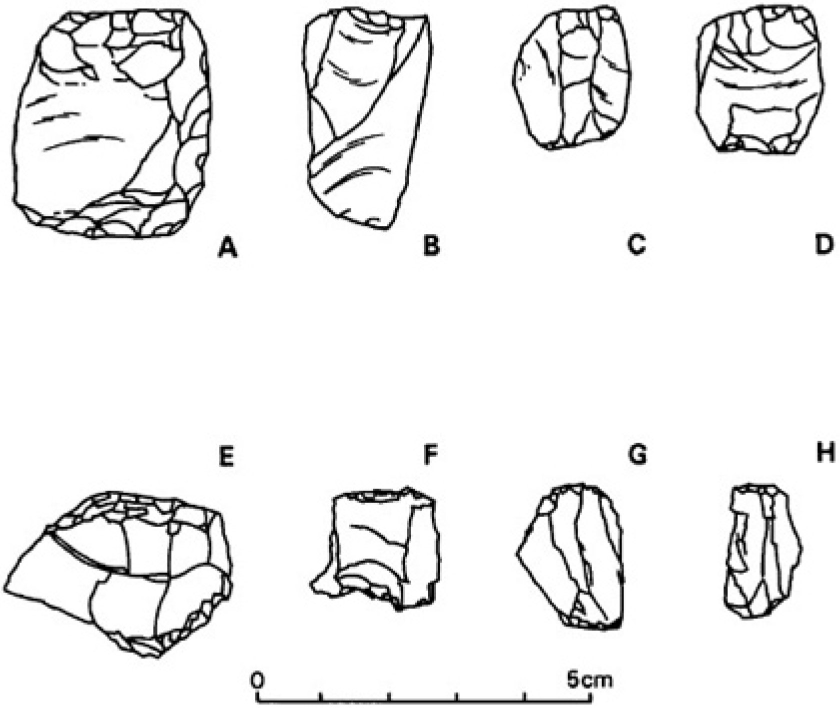

Figure 3.2 Exhausted quartz bipolar cores from BK (a–d) and Senga 5 (e–h).

various grades of volcanic rocks were employed in the direct percussion manufacture of core and flake forms. Technologically, there appears to be little difference between these tools and those produced 0.6 myr later at the classic Oldowan sites from Olduvai Gorge. All appear to be the result of the hominids obtaining usable flakes through the 'least effort' strategy as defined by Toth (1982).

Somewhat later, but still roughly contemporaneous at 2.4 myr, the site of Lokalalei from the western side of Lake Turkana also contains artefacts produced on varying grades of basalt and other volcanic rocks (Kibunjia *et al.* 1992; Kibunjia 1994). Many of these cores and flakes, although produced on different raw materials, are similar in production technique to later artefacts recovered from the eastern side of the lake. Again, the technological norm appears to have simply been the least effort strategy towards the removal of sharp-edged flakes. The ultimate form of the core appears to have been inconsequential to the Late Pliocene knappers. Unlike the Gona materials, however, the cores from Lokalalei exhibit a high incidence of stepped flakes. The Lokalalei assemblage is interpreted as being representative of a pre-Oldowan industry exhibiting features characteristic of a hominid producer that is less advanced, mentally and physically, than their later counterparts beginning around 2.0 myr (Roche 1989; Kibunjia 1994). Although analysis is not complete at this time, examination of the excavated assemblage seems to indicate that the presence of subtle raw material flaws may have played a major role in the formation of these step fractures. At earlier sites in the Gona, the incidence of stepped flake terminations is quite low and no greater than at any of the later occurrences included in this study. Consequently, the existence of a pre-Oldowan industry, defined through technological variables, is in question, and only further experimentation and analysis will satisfactorily resolve the issue.

In general, during the Late Pliocene, early hominids already possessed the full range of cognitive and manual capacities necessary for consistent, successful flake production. Their ability to exploit various raw lithic materials is also exhibited in their use of knapping techniques at times specifically suited to particular types and forms of stone. Although the archaeological sites are not nearly as dense or as extensive as later occurrences, it appears that stone tools were already playing an important role in hominid subsistence strategies.

The Classic Oldowan

The classic Oldowan industry, as defined by Mary Leakey from sites excavated at Olduvai Gorge (1971), is the benchmark by which all East African Plio-Pleistocene lithic assemblages are judged and interpreted. This industry is roughly contemporaneous at about 1.9–1.8 myr with the KBS from Koobi Fora (Isaac and Harris, in press) which contains similar core and flake forms produced almost exclusively on locally available basalts. This study incorporates data from the excavated Bed I and Lower Bed II Oldowan assemblages from DK, FLK 22, FLKN levels 1/2–6 and the 'Deinotherium' level and FxJj 1, FxJj 3 and FxJj 10 from the Lower Member Koobi Fora formation. Temporally, GaJh 5 from West Turkana is comparable to the sites from Olduvai and Koobi Fora.

In general, there appears to be little difference, technologically, between the KBS and the Oldowan at Olduvai and the earlier Late Pliocene assemblages, where simple direct percussion was the predominant mode of reduction. Local materials still prevail, and there is little doubt that the least effort solution of obtaining usable flakes was employed. However (and this is likely to be due in part to the relatively large size of the assemblages), distinct differentiation can be noted in how various grades of raw materials were being reduced at Olduvai. This is particularly noticeable at DK and FLK, which have a high incidence of what Mary Leakey terms 'utilized' or 'battered nodules and blocks'. These tend to be produced on extremely poor, often highly vesicular volcanic materials. Almost without exception, these nodules and blocks, due to their rough nature, do not show battering in the sense of pecking or pitting indicative of hammer or anvil use. Rather, they normally exhibit the removal of one or two often stepped flakes and nothing more. Finer grained materials, on the other hand, are far more heavily reduced, often to the point of exhaustion. Essentially, it appears that many of these battered blocks may, in effect, be 'test cores' rejected after the removal of one or two flakes (these cores occur to some degree in nearly every assemblage examined in this study). This is, for any flint knapper, a fairly certain way to determine the suitability of raw materials for further reduction. By removing a section of cortex, the knapper exposes the un-weathered inner matrix, and its working qualities can be better judged. Supporting this hypothesis are the numerous cores produced on finer grained, more homogenous materials that are heavily reduced to a point where further flaking is either impossible or at the very least highly impractical. Quite simply, finer materials are being exhausted whilst poor quality stone is passed over.

The highly selective nature of reduction noted at Olduvai indicates that, by the Early Pleistocene, hominids had an advanced appreciation of the working qualities of various raw materials. Considering the obviously well-developed knapping skills exhibited at 2.5 myr, this comes as no surprise. The consistent production of even the simplest cores and flakes is, cognitively and behaviourally, a complicated and demanding process. Proficient knapping necessitates that the individual conceptualize and act according to a complex equation of variables including, among other things, raw material type, form and availability. Clearly, by 1.9 myr and apparently much earlier, Plio-Pleistocene hominids had a relatively extensive grasp not only of the basic principles of fracture mechanics but also of the intricacies of raw material quality.

Selectivity of raw material is not as apparent in the KBS industry, but this is almost certainly due to the restricted nature of lithic resources in the Koobi Fora Formation (Harris 1978). Materials other than fine-grained basalt are very rare on KBS sites, and when they do occur they usually consist of very small fragments and, in one case, a small bipolar core. A single, exhausted bipolar quartz core, virtually identical to those recovered from Senga 5 and noted on several later sites from Olduvai, was recovered *in situ* at FxJj 3. The total excavated assemblage consists of 147 flakes and fragments, three cores and one hammerstone. Of that total, 143 of the flakes are of basalt with the remaining four being of green-black ignimbrite. Obviously, materials other than basalt are quite unusual and may have been curated and transported off the site except for the depleted quartz core.

At FxJj 3, there appears to be a continuation, albeit small, of the utilization of the bipolar technique in the Early Pleistocene. Despite the availability of fine-grained basalt, the exhausted bipolar core may indicate that quartz, a rare material at Koobi Fora, may have been highly desirable and consequently exploited to its full potential. Again, the question as to the functional practicality of flakes under 20 mm in maximum dimension is not necessarily apparent and remains to be tested. However, the production and utilization of such flakes demonstrates the advanced level of manual dexterity evidently possessed by Early Pleistocene hominids. This degree of dexterity, while not expressly evident in the contemporaneous assemblages from Olduvai, was almost certainly possessed by the classic Oldowan knappers who clearly maintained a solid understanding of the physical and theoretical basics of lithic fracture mechanics.

The 'Developed Oldowan' and temporally comparable assemblages

As defined by Mary Leakey, the Developed Oldowan A and B is distinguished primarily by the appearance of small chert tools and the introduction of some poorly made and generally small bifaces (Leakey 1975). Although not necessarily considered to be within the same typological series as the Developed Oldowan at Olduvai Gorge, a number of technologically comparable sites included in this study are dated to approximately the same time. These include the Koobi Fora and Ileret localities of FxJj 11, FxJj 16, FxJj 17, FxJj 18 GL, GU, IH and NS, FxJj 20 E and AB, FxJj 23, FxJj 33, FxJj 37, FxJj 50, FxJj 64 and FwJj 1. Three sites from the Chemoigut and Chesowanja formations, GnJi 1/6E, GnJi 2/8 and GnJi 10/5, are considered to be typologically similar to the Developed Oldowan A assemblages from FLKN Sandy Conglomerate, HWKE and HWKE Sandy Conglomerate and the Developed Oldowan B assemblages from MNK Main and BK at Olduvai Gorge.

Whilst these sites are set within a broad geographical range, they vary considerably in terms of the overall character of their lithic assemblages, utilization of various raw materials, their context on the landscape and their density and spatial distribution of artefacts. However, aside from their temporal affiliations and specific cases of technological or functional innovation, the stone artefacts from these sites are generally quite similar in technological terms. As with earlier assemblages from Olduvai, Koobi Fora, Zaire, the Gona and Omo, it appears that their early hominid producers were simply engaging in the least effort solution to obtain usable flakes. Typologically, similar cores are present at these later sites, and the technological variability appears to be largely related to the use of numerous raw materials. At Olduvai, the sites of HWKE, HWKE Sandy Conglomerate and FLKN Sandy Conglomerate exhibit fairly heavy utilization of the pebble cherts that became available for hominid exploitation with the recession of the lake around 1.6 myr (Leakey 1971; Hay 1976). The shrinking lake exposed strata containing small, irregular nodules of chert that would have provided the lower Bed II knappers with a large source of previously scarce, high-quality lithic material. At HWKE and FLKN, these nodules were reduced in a random fashion, producing minimally worked cores usually not conforming to conventional typological parameters. The reasons for the random nature of the chert cores are apparent when the initial raw material form and the employed knapping techniques are considered. The uneven, asymmetrical nature of the chert nodules normally offers few naturally occurring opportune striking platforms. There appears to be no evidence of the purposeful manufacture of striking platforms ('suitable' platforms) (Ludwig 1992) in order to conserve and further exploit a seemingly superior lithic material at times transported from at least 1 km away (Stiles 1991). In effect, the hominid utilization of chert did not differ from their use of other materials in that the least effort solution still applied. Only the most readily available opportune platforms were exploited, and when none remained, the core was apparently abandoned.

Typologically, small flake 'tools' of chert also occur in the Developed Oldowan at Olduvai Gorge (Leakey 1975). These consist primarily of small types such as awls and scrapers exhibiting various degrees of edge damage and flaking. Whilst a number of chert pieces display areas of fine flaking, they are normally random in their placement and highly variable in intensity. As chert is considerably more brittle than most of the volcanic rocks common at Olduvai, flakes and fragments would be more prone to edge damage through knapping procedures, trampling from hominid and faunal activity and other post-depositional effects. As at least one level (4) from the Sandy Conglomerate of HWKE appears to contain a component where numerous flakes and fragments exhibit edge rounding and evidence of tumbling (Petraglia and Potts 1994); fluvial action may have played a major role in the production of these small pieces initially interpreted as purposefully manufactured tools.

From a flint knapper's perspective, chert is a superior material compared to the quartz and lava rocks that were so available and heavily utilized at Olduvai. However, it appears that chert was not a particularly sought after or valued material at some of the sites examined in this study. Contrary to conventional wisdom regarding the disparate working qualities of quartz and chert, quartz seems to have been far more heavily utilized and conserved at MNK Main than one might expect. The large number of predominantly quartz, flaked artefacts (4, 405) indicates the degree to which quartz was obtained and employed in core and flake manufacture. Schick and Toth (1994) note the general shift from the use of lava to quartz in the Developed Oldowan at Olduvai. Additionally, there appears to have been no correlation between site distance from the primary known quartz source, Naibor Soit, and the frequency of quartz utilization. The hominid use of chert, however, does not appear to conform to this pattern of transport and curation. With the exception of MNK CFS (Stiles *et al.* 1974), chert utilization at Olduvai appears to have been highly opportunistic and expedient.

Many of the MNK Main cores are exhausted, or nearly so, and a fairly sizeable component of 'diminutive' pieces is present as well. These minuscule cores are technologically identical to their larger counterparts, having been knapped using identical techniques, i.e. bifacial, polyhedral, single platform (Figure 3.3). The exhausted nature of many cores seems peculiar, given the widespread availability of quartz within several kilometres of MNK Main and the fact that numerous cores of equal quality material are only minimally reduced. Considered along with the existence of diminutive cores (most no more than 20–30 mm in maximum dimension), questions arise as to the desirability of quartz and the function of the small flakes. Some have interpreted MNK Main as a factory site, and this may essentially be the case (Leakey 1971). Given that chert was apparently not available in the vicinity, quartz, despite its brittle nature

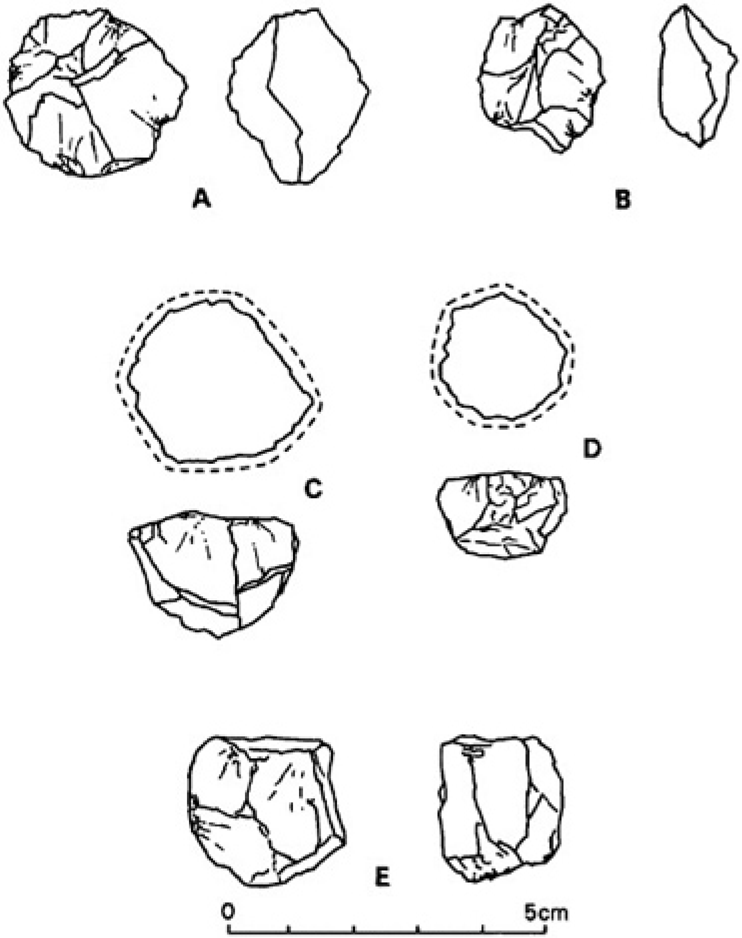

Figure 3.3 'Diminutive' quartz cores from MNK Main. Bifacial (a,b), single platform (c,d), polyhedral (e).

and inherent preferential planes of fracture, is relatively easy to work when compared to the often coarse, vesicular lava rocks otherwise available at Olduvai. In addition, functional experiments have shown that the edges of quartz flakes are much sharper than those produced on most lavas and are highly suited for cutting activities (Schick and Toth 1994). Consequently, at MNK Main, quartz appears to have been the material of choice for hominid knappers.

At BK, some cores small enough to be considered diminutive as per Mary Leakey (1971) do occur but, unlike at other Developed Oldowan sites, this assemblage contains a number of exhausted bipolar cores (typological *outil ecailles*) indistinguishable from those noted at Senga 5 and FxJj 3 (Figure 3.2).

As with the diminutive cores noted at MNK Main in particular, these exhibit maximum dimensions usually in the range of 20–30 mm. In light of the apparently plentiful supply of quartz, once again it seems peculiar that bipolar reduction would have been utilized in order to obtain the very small flakes from these cores. As the quartz found at Olduvai does not occur in pebble form as it does on earlier sites like Senga 5, the utilization of the bipolar technique probably has little to do with the initial form of available raw material. Instead, the small flakes produced with this technique may be filling a functional niche in the hominid technological system.

The only assemblage roughly contemporaneous with the Developed Oldowan containing truly convincing examples of small flake tools is from the Chesowanja site of GnJi 10/5. Unlike the diminutive single platform cores ('scrapers') from MNK Main, the implements from this site exhibit purposefully worked edges that are patterned and evenly flaked. The steep edges that were produced are highly uniform and in some cases encompass the entire circumference of the flakes on which they were produced, resulting in ovate shapes. They range in maximum dimension from 27 to 59 mm and the working edge angles vary from 59 to 73 degrees. They are manufactured on a very fine-grained volcanic rock, although the specific variety is not known. Although use-wear analysis would be necessary to confirm their use as scrapers, their morphology and manufacture technique strongly suggest that these are almost certainly the only skilfully produced flake tools noted throughout this study. As opposed to those identified typologically from many sites, these show strong evidence of skilled production and curation. Such effort, however small, exerted to produce a scraping tool is not readily apparent in earlier or even contemporaneous assemblages, and raises questions as to the role they played in the technological and subsistence systems of the hominids at GnJi 10/5.

One class of artefact recovered from Developed Oldowan sites that has received a great deal of attention is that of the 'spheroids' and 'subspheroids', which are often found in great numbers (Leakey 1971; Willoughby 1985, 1987). The experimental work of Schick and Toth (1994) clearly indicates that these artefacts represent a manufacturing continuum resulting from the reduction of irregular quartz fragments into cores and eventually roughly spherical hammerstones. The evenly rounded stone balls that serve as the typological baseline for these artefacts are in the minority, however, and most subspheroids and spheroids can, technologically, be classified into three main categories: exhausted polyhedral cores; hammerstones; and combination cores and hammerstones.

Whilst Schick and Toth's experimental work elucidates the technological and behavioural aspects of these artefacts, the implications concerning hominid cognitive capacities and assemblage variability are equally intriguing. The increased use of quartz for hammers may be viewed as a cognitive development involving an increased understanding of the general principles of lithic fracture mechanics. Specifically, the hominids' recognition of friable quartz as a superior hammer material indicates an improved knowledge of the working relationship between different types of stone. Friable quartz, as a material for hammers, is preferable in comparison with other harder stones found at Olduvai due to its ability to increase the contact time between the percussor and the striking platform. Softer or more friable stones like the Olduvai quartz tend to 'bite' or compress into the platform, thereby allowing more time for force to extend into the core, resulting in larger flakes. Harder hammerstones essentially tend to bounce off the core, generally resulting in a reflection of force away from the core and producing on average smaller flakes (personal observations; Callahan, pers. comm.). However, this is not to say that the only hammerstones to be found in the Developed Oldowan consist of quartz spheroids and subspheroids. A number of hammerstones were produced on various lava rocks, but they are worked to a far lesser extent than their spheroid counterparts.

The Karari industry, noted and described by J.W.K.Harris from sites along the Karari Escarpment at Koobi Fora, dates to about 1.7 myr and has traditionally been considered as a variant of the typologically designated Oldowan Industrial Complex (Harris 1978). More specifically, it has been interpreted as a regional and temporal counterpart of the Developed Oldowan A as defined by Mary Leakey (1971, 1975). Although polyhedral, bifacial and unifacial core forms occur in large numbers, the distinctive trait of Karari sites is the high percentage of single platform cores ('Karari scrapers') (Harris 1978). Although these forms do occur on earlier sites and in other parts of East Africa, their preponderance on Karari sites suggests that they may have played an important role in the subsistence strategies of their most likely producers, *Homo erectus*. Unlike other less uniform cores, standardized single platform cores may have offered their users considerable technological and functional advantages. Relatively large quantities of morphologically predictable flakes could be removed from these cores, resulting in a highly efficient utilization of raw material. Such efficiency may have been important for *Homo erectus,* a highly mobile hominid whose apparently wide ranging life style and land use patterns (see Rogers *et al.* 1994; Rogers 1997) took them into areas where lithic materials may have been scarce. The production of these highly portable and efficient cores may, however, have required a higher degree of planning and general flint-knapping prowess than is evident in earlier lithic assemblages (Ludwig and Harris 1994; Ludwig 1995).

Aside from their outward morphology, many Karari single platform cores were produced utilizing knapping techniques traditionally associated with the Acheulian, which occurred some 300,000 years later. The distinguishing technological hallmark of the Acheulian is the hominid knapper's apparent ability to consistently remove large flakes from boulder or outcrop sources and work them into highly standardized, typologically defined bifaces or cleavers. However, this same ability is evident among the Karari knappers, with the only difference being that bifaces and cleavers were not being subsequently manufactured. The preferred Karari core form involved the removal of flakes from the dorsal surface of the large flake blank. In some cases, the striking platform of the flake is preserved and is often off-set, as seen on many classic Acheulian bifaces (Figure 3.4). Eventually, after considerable reduction, the ultimate form evolved into the single platform cores so conspicuous on Karari archaeological sites.

In addition to the technological changes apparent in Developed Oldowan and contemporaneous sites, a marked increase in site size and density is also clear during this period. The causes of this gradual increase may be complex, and whilst no single hypothesis may offer the sole answer, artefacts from one site lend credence to one in particular. At FxJj 16, there are clear indications of multiple knappers impacting ultimate assemblage character. In this case, large clasts of basalt were initially worked, transported and eventually redeposited, then flaked a second time. This is evident in the form of differing degrees of water-induced rounding and patination exhibited on both cores and flakes. Although there is no certainty as to how far this assemblage was moved, it may have been minimal (Petraglia and Potts 1994), and this opens up the possibility that this site may have been visited repeatedly. This would support the contention of Blumenschine and Masao (1991) that one of the main factors determining differential site size and artefact density was the frequency of hominid visitation and subsequent deposition of artefactual materials.

Early Acheulian

Several Early Acheulian sites were examined as part of this study. These include TK (lower floor) and EF-HR from Olduvai and FxJj 63 from Koobi Fora. At TK/L, the majority of artefacts were produced on quartz, naturally occurring in tabular form, while at EF-HR, raw materials varied to a greater extent. This varying use of raw materials has greatly affected the character of these assemblages, as noted in Stiles' 1979 study. As nearly all of the typological bifaces recovered from TK/L were produced on quartz, and many were manufactured on tabular fragments, this site is technologically not comparable to either EF-HR or FxJj 63, where many of the cores were produced on large flakes. At FxJj 63, all but three of the cores were produced on flake blanks. In many respects, EF-HR and FxJj 63 are very similar in terms of the manufacturing techniques used to produce cores. The key difference, however, lies in how the flake blanks were further reduced.

At EF-HR and FxJj 63, there is clear evidence for the removal of large flakes (up to 164 mm maximum dimension) from boulder and/or outcrop sources and the eventual modification of those blanks through the additional removal of flakes. At FxJj 63, this reduction takes on a highly standardized and patterned nature. Although variously termed bifaces, due to their general typological appearance, and unifaces, from a purely technological perspective, these cores are in fact produced in a fashion identical to that used in the manufacture of the single platform cores so ubiquitous on sites attributed to the Karari industry (Figure 3.5) (see Harris 1978). Single platform reduction is quite different from

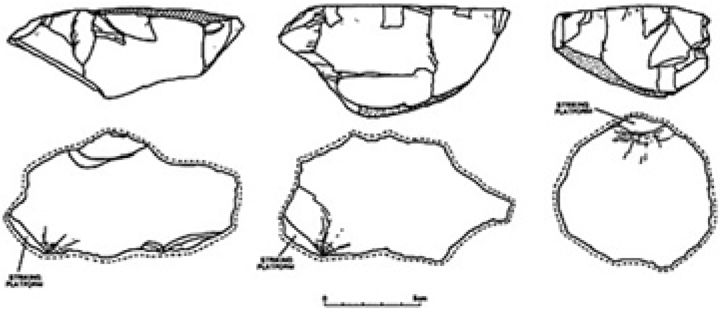

Figure 3.4 Heavily reduced single platform cores produced on large basalt flakes from FxJj 18 GSL.

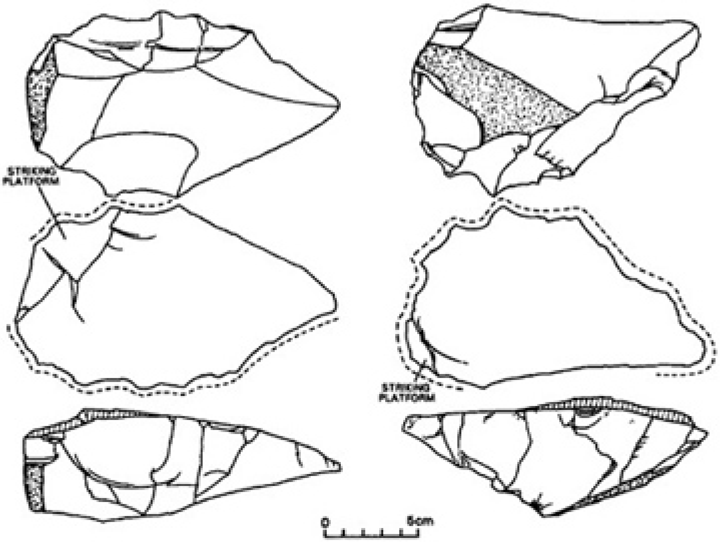

Figure 3.5 Minimally reduced single platform cores produced on large basalt flakes from FxJj 63.

bifacial or unifacial knapping. The only real difference between a biface and a uniface is the degree to which both faces of a blank have or have not been flaked. A bifacial or unifacial determination is made based on the *predominant* technique utilized. Single platform cores differ in that the surface from which flakes are removed exhibits edge angles often approaching 90 degrees. In general, working these cores bifacially would be difficult, as such reduction characteristically utilizes angles normally in the 45–70 degree range (Callahan 1979). The use of a single, broad platform area provided the easiest access to a maximum number of flakes. Unlike EF-HR, where most flake blanks were subsequently reduced in a bifacial manner, at FxJj 63, nearly all of the blanks were worked in a single platform fashion, with nearly all of the removed flakes being struck off the dorsal surface.

Many classic Karari scrapers appear to be the result of the fairly extensive reduction of large flake blanks, and a similar situation occurrs at FxJj 63, albeit to a lesser extent simply in terms of the intensity of reduction. Consequently, as there is no debate as to the Acheulian nature of 63 as defined according to the 'large flake' standard, the Karari industry itself may represent an early manifestation of the Acheulian instead of being more closely aligned with the Oldowan. This is not an altogether new assessment, as Clark (1975) articulated this position but from a predominantly typological perspective (see also Harris 1978). In this study, this assertion appears to be supported, if not fully confirmed, through actualistic data.

CONCLUSIONS

Through the application of an experimentally based methodology to a large sample of Pliocene and Early Pleistocene lithic assemblages, a clearer picture is developing of the technological nature of early hominid produced stone tools. Dating to as early as 2.5 myr, recovered Pliocene assemblages are still few and far between. Despite this scarcity, patterns of hominid material utilization, reduction technology and knapping proficiency are discernible. In general, the hominids from this period appear to be relatively skilled in terms of both manual and cognitive capacities. As seen by their tailoring of specific techniques to particular types and forms of raw material, these early hominids had at least a basic appreciation for the working qualities of various lithic resources. Their advanced manual dexterity is evident in their production of diminutive cores and flakes that, although unknown as to their functional role, indicate developed precision and power grips.

By the time of the Classic Oldowan, there is increased selectivity of raw materials for their working qualities. Vesicular, coarse or otherwise inferior stone was rarely reduced much beyond the test core stage involving the removal of one or two flakes, while finer grained and more homogenous stone was frequently worked to the point of exhaustion. This is not to say, however, that this behaviour is unique to the Oldowan or later periods. This pattern of selective reduction likely took place during the Late Pliocene as well, but the somewhat limited nature of the archaeological record may currently preclude this from being apparent.

Considerable innovation does not appear to occur in East Africa until the advent of assemblages typologically designated as the Developed Oldowan at Olduvai Gorge and the Karari from Koobi Fora. A considerable shift in reduction strategies is evident in these assemblages in the form of increased raw material selectivity, the appearance of the first small flake tools and an increased knowledge of the working relationship between different types of stone, as hypothesized with the intensive use of quartz spheroids at Olduvai.

These innovations include the apparent ability of hominids, starting around 1.7 myr, to consistently detach large flakes from cores. Traditionally surmised as being the hallmark of the Acheulian, this ability is clearly evident in the Karari industry. The main technological difference between the Karari and the classic Acheulian is in the subsequent treatment of the large flake blanks. Otherwise, the technology is markedly similar and seems to indicate that the Karari has a far greater technological affinity with the Acheulian than it does with the Oldowan. The technological changes evident at Olduvai, while not the same as those noted at Koobi Fora (due in part to raw material differentiation), have similarly important implications regarding hominid cognitive, physical and behavioural development.

For at least the initial 0.8 myr of hominid tool manufacture and use, the archaeological record appears to support the notion of a technological stasis, as articulated by Semaw *et al.* (1997). Consequently, there appears to be no justification for the division of geographically and temporally defined cultural entities. The most appropriate classificatory system reflecting the broad temporal and spatial variability of Plio-Pleistocene assemblages consists of the Mode I and Mode II 'industrial' designations, which are roughly equivalent to the Oldowan and Acheulian (respectively), as defined by G.Clark (1971). The innovations and shifts in technology occurring around 1.7 myr roughly coincide with the appearance of a bigger-bodied and larger-brained hominid species, *Homo erectus* (or *Homo ergaster*). This wide-ranging hominid was inhabiting contextually diverse locations on the ancient landscape. This increased mobility and the concurrent physical requirements may have necessitated an increased dependence on technological solutions to the difficulties of subsistence inherent in a seasonal and arid environment. Such physical developments and environmental stresses, coupled with a possible increase in cognitive capacities, may have greatly affected the nature and character of Early Pleistocene lithic assemblages.

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4

The lifeways of Homo erectus *inferred from archaeology and evolutionary ecology: a perspective from East Africa*

SUSAN CACHEL AND J.W.K.HARRIS

INTRODUCTION

The goal of this chapter is to examine the biology and behaviour of *Homo erectus, sensu lato,* and to re-evaluate the niche structure of this taxon. During this process, the origin, dispersal properties, geographic spread and evolutionary ecology of this species will be discussed. There is a great deal of variability within the hypodigm of this species, as broadly defined. Researchers have long argued about whether this variability reflects the existence of more than one species (e.g. Le Gros Clark 1964; Howell 1978; Howells 1980; Tattersall 1986, 1992; Rightmire 1990, 1996). Alternatively, some researchers, whilst recognizing the strikingly polytypic nature of the fossil material, see no distinct boundary line between *Homo erectus* and *Homo sapiens,* and inveigh against the continued use of the taxon *Homo erectus* (Wolpoff *et al.* 1994). Many physical anthropologists approach morphological variability as if it were merely a vexing problem that obscures the taxonomic allocation of fossil specimens. Many archaeologists approach behavioural variability merely by continuing to debate about lithic typologies and the definition of stone tool industries and their boundaries. Yet, natural selection on morphology and behaviour cannot occur without population-level variability, and the assessment of shifting variability through time may allow palaeoanthropologists to trace the activity of natural selection and other evolutionary processes. Hence, our emphasis here on evolutionary ecology leads us to recognize that morphological and behavioural variability in time and space are themselves data, and that these data can contribute to a fuller understanding of how evolution has affected fossil hominid populations.

THE FUNDAMENTAL HOMINID NICHE

Although the significance and even the objective reality of higher taxonomic categories is debatable, it is generally agreed that, among vertebrate animals, the family taxon signals an entrance to a major new adaptive zone (Simpson 1953). The family Hominidae conforms to this expectation, because its principal hallmark is the achievement of bipedality—a novel form of locomotion that implies new ranging and foraging strategies.

Comparative data indicate that the development of bipedality among Old World higher primates (catarrhines) was not an improbable event. In a trend documented back to 20 myr in East Africa in members of genus *Proconsul,* hominoid catarrhines acquire the following traits in a mosaic fashion: a short, laterally broad thorax and sternum; short, broad ilia; loss of the tail; shifting of the scapula to the dorsal side of the thorax; lengthening of the clavicles; and the development of a mobile forelimb by increasing mobility at the shoulder, elbow and wrist joints. These traits are generally thought to herald the development of arboreal suspensory postures and locomotion. The first fossil species to demonstrate the full suite of these traits for arboreal suspension is *Dryopithecus laietanus* (Can Llobatares, Spain), dated to 9.7–9.6 myr (Agustí *et al.* 1996; Moyà-Solà and Kohler 1996). This surprisingly recent date underscores the mosaic fashion in which these post-cranial traits, now typical of all living hominoids, were acquired. In all modern catarrhine primates, the trunk is often orthograde, because it is generally held upright in sleeping and resting postures. In addition, there is a general trend for all primates to have relatively elongated hindlimbs (particularly elongated femora) and a tendency for primates to carry more body weight on the hindlimb (i.e. the centre of gravity is shifted caudally). In combination with general catarrhine orthogrady, and perhaps accentuated by hominoid arboreal suspensory postures and locomotion, this primate hindlimb domination ensures that some form of bipedality is probably an inevitable development in catarrhines.

During bipedal locomotion, all of the body weight is carried by the hindlimbs (lower limbs), while the trunk is held upright; the forelimbs (upper limbs) do not support body weight. Bipedality does not preclude arboreality. It is possible for species to exhibit both bipedality and arboreal locomotor adaptations, as demonstrated by modern gibbons and siamangs. In theory, only a body size larger than that of the lesser apes would preclude some degree of arboreal bipedalism. Debate about the existence or degree of arbo-reality present in the earliest hominid species (australopithecines) is uncalled for, because arboreal adaptations need not compromise bipedalism. Furthermore, until hominids were able to construct artificial shelters or control fire, they would need to take shelter at night in sleeping trees or sleeping cliffs, even if they were wholly or largely terrestrial during the day.

There is some faint evidence that an early radiation of hominids occurred, and that this radiation was based on different forms of bipedality. This evidence is best seen in dichotomous foot and ankle morphology. *Australopithecus anamensis* has been described as having a distal tibial anatomy similar to that of modern humans (Leakey *et al.* 1995); the ankle joint in *Australopithecus afarensis* was apparently significantly more flexible. Foot bones possibly from *Australopithecus africanus* (Stw 573) present a mosaic of long toes and abducted hallux, combined with a modern talus anatomy (Clarke and Tobias

1995); in the OH 8 specimen *('Homo habilis'),* the toes are short and the hallux adducted, but hindfoot anatomy is less modern. If foot and ankle morphology are considered, it is possible that two distinct hominid lineages have independently evolved bipedal specializations.

Because there are significant indications of arboreal adaptations in the earliest hominids, it is probably more productive to analyse bipedality in terms of an adaptation for effortless, long-distance travel on the ground, rather than to emphasize a false arboreal/terrestrial dichotomy, or to speculate about the degrees of bipedality exhibited by different hominid species. Extensive electromyographic work on modern humans (synthesized in Basmajian [1978]) reveals that muscle activity is very low during walking at a normal pace. From this, one can infer that selection pressures mandating extensive ranging behaviour would yield bipedal locomotion, particularly since energy expenditure in this form of locomotion is virtually nil if the pace is normal, and no heavy loads are being carried. This biomechanical analysis implies that the spread of open-country environments was the principal factor triggering bipedal adaptations.

Comparative study of modern tropical environments indicates that the African continent has the richest global concentration of upland tropical grass-lands, and is impoverished with respect to tropical forests (Rosenzweig 1995: 288; Richards *et al.* 1996:10–13). The progressive general decline of global temperatures during the Miocene and accompanying secondary effects, such as changes in rainfall, had a pronounced impact on the African continent. Palaeoenvironmental evidence from a number of sources (discussed below) indicates that more open woodland and open-country grassland habitats began to spread in Africa at the expense of tropical rainforest as early as 7 myr. This trend was probably exaggerated by the messinian salinity crisis at 5.5 myr, created by global cooling and a simultaneous marine regression of 40–50 m, exaggerated by local tectonic effects. The messinian salinity crisis caused desiccation of the Mediterranean Sea, the Persian Gulf and the Red Sea (Williams *et al.* 1993). This crisis or its antecedents may in fact have initiated the hominid radiation, which was based on the evolution of bipedal adaptations, if these adaptations were triggered by the spread of open-country habitats. Increasing aridity at two subsequent time periods (2.8 and 1.7 myr) may also have influenced later hominid evolution in Africa (de Menocal 1995).

ANATOMICAL INDICATIONS OF NICHE STRUCTURE IN *HOMO ERECTUS*

In the following sections, concentration is placed upon *Homo erectus,* the first fossil hominid taxon unequivocally considered to have engaged in habitual tool behaviour, and generally thought to be associated in many areas of the Old World with a particular lithic industry, the Acheulian. In addition, this is the first member of genus *Homo* for which certain and nearly complete knowledge of post-cranial anatomy exists. Fossil specimens within the hypodigm of *Homo erectus* have recently been interpreted as evidence of multiple species (Tattersall 1986, 1992; Groves 1989; Wood 1992; Rightmire 1996). Here traditional, non-cladistic taxonomic diagnoses of this species are followed (Le Gros Clark 1964; Howell 1978; Howells 1980; Rightmire 1990). Researchers recognizing multiple species in the genus *Homo* are necessarily implying that distinct ecological niches exist for these species, although hominid taxonomists diagnosing fossil species are often unaware of this implication. Several lines of evidence (anatomy, palaeoecology, lithic technology and archaeological survey) converge to suggest that the niche of the taxon *Homo erectus* differed significantly from the niches of earlier hominid taxa. This evidence is delineated in the following sections, as an attempt is made to reconstruct the adaptive zone of this species.

A subadult specimen of *Homo erectus* from the western Kenyan site of Nariokotome (KNM-WT 15000) shows a funnel-shaped thorax, long femoral neck, small femoral neck-shaft angle, and iliac flare. Together these traits indicate that this species emerged from the australopithecine subfamily. The KNM-WT 15000 specimen is dated at 1.53 myr, and, in spite of possessing anatomical traits indicating descent from an australopithecine, the specimen shows post-cranial anatomy significantly different from the australopithecine condition (Walker and Leakey 1993). The horizontal orientation of the clavicle and glenoid cavity argue for an absence of arboreal suspensory locomotion, and hence indirectly argue for increased terrestriality. A major feature of the specimen is its modern limb proportions: the lower limb has increased in length, so that the relative proportion of upper to lower limbs is like that found in modern hominids. The relatively long legs of modern hominids are usually explained by presumed efficiency in bipedal locomotion. Yet recent experimental studies of locomotor efficiency in modern humans demonstrate that relatively longer legs have no important effect on locomotor efficiency (Steudel and Beattie 1994; Webb 1994; Steudel 1995). If leg length does not affect locomotor efficiency, then the evolution of relatively long lower limbs in *Homo erectus,* as exemplified by KNM-WT 15000, was driven by selection pressures either for speed or for heat adaptation.

Of the two, speed is unlikely to have been a factor in increasing relative length of the legs. Heat adaptation, however, was probably a major selection factor in the increasing relative length of the Nariokotome lower limb, particularly given the long distal limb segments and exaggerated ectomorphy of the whole specimen (Ruff and Walker 1993). Ruff (1991, 1994) argues that narrow pelvic bi-iliac breadth in all Plio-Pleistocene specimens complete enough to examine indicates the existence of a fundamental hominid adaptation to heat, but the greater stature and long limbs of the Nariokotome specimen indicate further adaptation to open, arid, hot environments.

Why did heat adaptation become a factor in East Africa? Increasing aridity and the spread of grasslands may have been important, because they increased the patchiness of hominid food resources. Palaeosol carbonates and organic matter from sites in the Kenya Rift Valley show that an environmental mosaic appears to have persisted for the last 15.5 myr. There is no evidence here of a shift to a dominant open grassland regime at any time (Kingston *et al.* 1994). Carbon isotope signals taken from herbivore teeth from the same succession of sites in Kenya show that C4 grasses are present in herbivore diets at 15.3 myr, although these grasses are not the primary food resource until 7 myr (Morgan *et al.* 1994). One researcher believes that modern Serengeti-type grasslands had a brief peak in East Africa at 1.7 myr, and a slightly less pronounced peak between 1.6–1.4 myr (Cerling 1992). Marine records of dust transported off the East and West African coasts show shifts toward arid, more open-country conditions at 2.8, 1.7 and 1.0 myr (de Menocal 1995). It is important to note that hominid anatomy by itself indicates climatic adaptation, irrespective of the palaeoenvironmental evidence. Narrow pelvic width demonstrates adaptation to heat (Ruff 1991, 1994), and the long legs and pronounced ectomorphy of the Nariokotome specimen imply arid, open-country adaptation.

The predicted full adult stature of the subadult Nariokotome specimen indicates large size, even by modern standards, although any prediction is affected by assumptions about the existence and degree of an adolescent growth spurt. In non-human primates, the growth spurt may not exist, or it may be sexually dimorphic; in modern humans, the adolescent growth spurt can be quite variable across populations. Certainly adult body size was larger in the Nariokotome species than in specimens of early genus *Homo* from Olduvai Gorge. This indicates a difference in nutrition, and a probable dietary shift in the Nariokotome species.

If, as seems likely, large adult body size would occur in the Nariokotome specimen, then relative brain size is affected. Relative brain size may not have been markedly larger in *Homo erectus* than in earlier hominids. Walker (1993a) uses a figure of 909 cc for the adult cranial capacity of the KNMWT 15000 specimen, and estimates the relative brain size as being equivalent to that of earlier members of genus *Homo*. Because the difference in relative brain size between early genus *Homo* and the australopithecines is not marked, this indicates that the great increase in relative brain size often thought to be characteristic of genus *Homo* is, in fact, found in this genus only after the Middle Pleistocene.

A critical and frequently overlooked factor in hominid evolutionary ecology is that the Nariokotome individual and his conspecifics coexisted with *Australopithecus boisei* and perhaps other species of the genus *Homo*. A theoretical model for the coexistence of competing species predicts that seasonal variation in resource abundance generates species diversity by creating trade-offs between maintenance and foraging efficiency (Brown 1989). Heat adaptation affects the ability to range and forage in equatorial environments, and particularly affects mid-day activity levels (Wheeler 1993). Given access to abundant, potable water, the ancestors of *Homo erectus* in East Africa may have reacted to seasonality and competition from sympatric hominid species by evolving additional morphological adaptations to dissipate heat by increasing stature, relative leg length, and ectomorphy. Thus, foraging efficiency would increase. Earlier post-cranial evidence is sparse; and knowledge of body form and limb proportions in *Homo erectus* prior to 1.53 myr is lacking. It is assumed that the spread of *Homo erectus* in the Old World was associated with the post-cranial anatomy of the Nariokotome specimen, but no comparable North African, European or Javanese specimen has been discovered.

The Nariokotome species must have had a higher quality diet and a better nutritional base to support large adult body size, in contrast to members of early genus *Homo* discovered at Olduvai Gorge. Walker (1993b) has argued that hominid stature and body weight increased when relatively habitual hunting was first established at 1.5 myr; the dispersal of *Homo erectus* from Africa was caused by new, or more efficient, hunting abilities (Walker 1984). As evidence of such hunting abilities, a partial adult skeleton of *Homo erectus* dated to 1.7 myr (KNM-ER 1808) has extensive pathological remodelling of the bone surface. This periosteal inflammation has been attributed to hyper-vitaminosis A, which Walker *et al.* (1981) suggest was caused by ingestion of an adult carnivore liver. This may at least indicate the advent of a higher quality diet in this species. The possibility of more nutritious hominid diets is borne out by archaeological evidence in Bed II, Olduvai Gorge (above the Lemuta Member, dated at 1.71 myr) and the Okote Member, Koobi Fora (dated at 1.64 myr), in strata that also contain fossil remains of *Homo erectus*. At Olduvai, recent study of fossil faunas from a wide variety of taxa associated with stone artefacts in scattered occurrences, indicates the early acquisition of vertebrate carcasses by hominids (Monahan 1996). At several archaeological occurrences, meaty limb bones are present, which indicates early access to more intact carcasses by early hominids. Moreover, as Mary Leakey (1971) and others have pointed out from Upper Bed II and later Lower Pleistocene occurrences, there are a greater proportion of large animals represented in the bone refuse (Monahan 1996). This acquisition of meat from large animals is also a feature of fossil fauna at Koobi Fora. Not only does the distribution of cut-marked bone found in a variety of habitats in the proto-Omo Basin indicate that hominids ranged widely, but the distribution also indicates that they were exploiting megafaunal carcasses, particularly hippopotamus (Bunn 1994). Finally, it may be unnecessary to invoke hunting to explain hominid dispersal. Home range size in animals increases isometrically or allometrically with body size; yet carnivorous mammals do show a greater home range size increase with body size increase than herbivorous or omnivorous mammals (Calder 1984).

PALAEOENVIRONMENTAL AND ARCHAEOLOGICAL INDICATIONS OF NICHE STRUCTURE IN *HOMO ERECTUS*

Just after the earliest occurrence of *Homo erectus* at Koobi Fora (1.8 myr), the archaeological record in East Africa becomes increasingly complex. Based upon the distributional pattern of archaeological occurrences relative to palaeogeographic features, there is a pronounced shift in hominid occupation at approximately 1.8–1.6 myr. This coincides with an arid pulse in the African palaeoclimate (de Menocal 1995). Moreover, habitat changes were also brought about by local tectonic activity and volcanism. These processes changed the physical relief, the configuration of local water resources, and vegetation patterns on emergent landscapes, as evidenced by two well-studied sedimentary basins in East Africa (Hay 1976, 1990; Feibel *et al.* 1991; Feibel 1995). The coincidence of these dates suggests that *Homo erectus* (unlike earlier or sympatric hominids) was experiencing selection pressure to exploit resources that were widely distributed across Early Pleistocene landscapes. In East Africa, increasing aridity between 1.8–1.6 myr is attested to by absolute increases in the abundance of arid-adapted bovid species (Vrba 1995b), and by carbon isotopic evidence documenting an expansion of savanna vegetation (Cerling 1992). This arid episode may have contributed to the patchy and perhaps relatively unpredictable nature of resources exploited by hominids.

By 1.7–1.5 myr, archaeological traces are found in a variety of habitats within the Lake Turkana Basin. At the same time, a major change in depositional environments occurs that transforms sediments in the basin from an earlier, predominantly lacustrine phase (2.0–1.8 myr) to a phase in which the ancient landscape is dominated by the perennial proto-Omo River (Rogers *et al.* 1994; Feibel 1995). Furthermore, during this younger time interval, the fluvial system changes from a meandering pattern to a series of smaller, braided channels. The result of this change was that the dense gallery forest surrounding the proto-Omo was significantly fragmented into narrower stands of trees along the banks of numerous but smaller river channels (Feibel 1988, 1995). The Nariokotome *Homo erectus* skeleton was recovered from a similar depositional environment (Feibel and Brown 1993). Large numbers of archaeological occurrences are found along the banks of these river channels and in adjacent floodplain settings, perhaps indicating patterned exploitation of more patchy resources. Moreover, for the first time, archaeological traces attest to the movements of hominids to the drier, more upland parts of the basin. Archaeological occurrences are found in more marginal habitats, characterized by more open scrub and grassland vegetation near ephemeral streams that were seasonally flowing off the topographic heights of the basin (Cachel and Harris 1995). This contrasts with hominid land use based upon the distribution of archaeological occurrences across this basin in earlier time ranges, when archaeological traces are found in more sheltered and protected closed habitat settings (Rogers *et al.* 1994; Cachel and Harris 1995).

Archaeological survey at different time intervals, and the more efficient exploitation of resources implied by Karari artefacts, first appearing at 1.7 myr, thus confirms the increase in home-range size and wider habitat exploitation independently suggested by the anatomy of *Homo erectus*.

In Africa, stone tool assemblages dated between 1.8–1.6 myr become highly variable, both in terms of individual artefact size and shape, as well as in densities across ancient landscapes. Such assemblages have been labelled Developed Oldowan (Leakey 1971). In the Okote Member at Koobi Fora, a local variant of the Developed Oldowan has been named the Karari industry (Harris 1978). Here there are differences in the number of archaeological occurrences and artefact densities at different points along the ancient landscape. In addition, at several places, more than one episode of occupation has been documented by the excavation of multiple stratified archaeological horizons. These features of the archaeological record could be interpreted (particularly where multiple horizons occur, and numbers of occurrences and artefact densities are highest) as preferred habitat loci or core areas.

Similarly, the archaeological record at Olduvai Gorge, Tanzania, demonstrates a shift in hominid foraging behaviour through time (Harris and Capaldo 1993). Bed I sites at Olduvai are concentrated in lake margin habitats, but sites in Bed II, in addition to occurring in the lake margins, are also located along the banks of stream channels at higher elevations in the basin. This demonstrates that Olduvai hominids occupied a greater diversity of habitats at later time ranges.

Moreover, insights into hominid foraging behaviour are provided by comparing and contrasting intersite variability of fossil fauna found associated with stone artefacts from the Okote Member (Koobi Fora) and Bed II above the Lemuta Member (Olduvai). Fossil faunal remains associated with older archaeological occurrences in both basins also yield insights into the evolution of hominid foraging behaviour. In the Okote Member (in strata also yielding the remains of *Homo erectus*), Bunn (1994) was able to demonstrate the existence of patterned differences in hominid modified bone at different points across the ancient landscape at Koobi Fora. In one area, hominids appeared to be more interested in the meaty portions of carcass limb bones; in another area, however, they had modified the bones to exploit both meat and marrow. This contrast in contemporary occurrences suggests the existence of different strategies to utilize vertebrate carcasses. In another study, Monahan (1996) was able to document what are apparently contrasting hominid foraging strategies at Olduvai from an examination of fossil faunal remains found associated with artefacts at occurrences stratified above and below the Lemuta Member in Bed II. The patterning of the bone data in the mid to upper levels of Bed II (in strata also containing fossil specimens attributed to *Homo erectus*) indicates that hominids were gaining early access to carcasses. There was a greater focus on larger animals, and a greater concentration on selection of meat-rich, rather than marrow-rich, long bones.

These examples of hominid behaviour from 1.8–1.6 myr at Koobi Fora and Olduvai Gorge clearly imply more complex ranging and foraging behaviours occurring over greater areas of the landscape, in contrast to earlier time intervals. These differences affect the dynamics of hominid social behaviour, and also impact on hominid sociality. The archaeological record appears to show that *Homo erectus* was clearly less constrained than earlier hominid species by the natural distribution of critical resources on the ancient landscape. Predation risk may have increased as hominids dispersed into arid open-country habitats, away from the refugia of gallery forests. Larger hominid body size may have functioned to reduce predation risk, besides conferring a selective advantage in competitive interactions with mammalian carnivores (Walker 1993a). Increased direct competition with mammalian carnivores for vertebrate meat, fat and marrow may have selected for larger hominid group size and more complex sociality, as cooperative foraging and resource reciprocity behaviours began to evolve.

It is against this background of greater complexity in hominid ranging behaviours and foraging strategies, as well as inferences about more complex sociality, that the increasing amount of archaeological evidence showing that hominids had acquired the technological innovation of controlled fire becomes important (Clark and Harris 1985; Brain and Sillen 1988). More recent work by Bellomo (1990, 1994) shows conclusively that controlled campfires were present at the archaeological site FxJj 20 Main, Koobi Fora. Moreover, his studies indicate that early hominids used fire as a means of predator protection and/or as sources of heat and light. In this context, the technological innovations associated with fire could have secured localities on the ground, and thus enhanced social dynamics and co-operative group behaviour. Moreover, controlled fire would have facilitated movements into the more open parts of ancient landscapes where predator risk was high. New habitats at higher elevations on the flanks of the Rift Valley could be colonized. With controlled fire, hominids could have survived freezing night temperatures, as at the site of Gadeb in the Ethiopian highlands (see discussion below).

To summarize, during the interval between 2.0–1.5 myr, the nature and distribution of archaeological traces across the ancient landscape yield evidence for hominid ranging, foraging and subsistence behaviours from such well documented localities as Olduvai Gorge Bed II and the Okote Member at Koobi Fora. Comparing the evidence, one also sees the influence of local conditions in eliciting very different hominid behavioural responses between the two areas (Potts 1988; Cachel and Harris n.d.). Controlled fire would enhance hominid dispersal properties and lead to the development of more complex sociality.

CHARACTER RELEASE AFFECTING MORPHOLOGY AND BEHAVIOUR

Natural selection affects the phenotype, which comprises both morphology and behaviour. Variability within the hypodigm of *Homo erectus* has recently been interpreted as evidence of multiple species (Tattersall 1986, 1992; Groves 1989; Wood 1992). These analyses emphasize a marked distinction between Asian and African specimens, and raise doubt about the presence of *Homo erectus* in Europe. A more parsimonious explanation for phenotypic variability in *Homo erectus* is that such variability reflects character release occurring during colonization of novel environments that offer no competition (Cachel and Harris n.d.). During ecological release (Van Valen 1965), species encountering no competitors in new environments may alter their behaviour and morphology. This may result in increasing variability of the phenotype, or phenotypic character release. The existence of character release ensures the likelihood that a widely dispersed species like *Homo erectus* would demonstrate great morphological and behavioural variability (Cachel and Harris 1995). Members of this species would often enter new regions previously uninhabited by hominids. The resulting character release would explain morphological differences within the *Homo erectus* hypodigm, which some researchers recognize by drawing taxonomic distinctions between African, European and Asian specimens.

Explaining variation in Acheulian assemblages has long been a staple of research in lithic technology (e.g. Gowlett and Crompton 1994). Character release would also explain differences in the behavioural phenotype, as seen by the evidence of stone artefact traits, and the distribution of artefacts in diverse contexts. Some examples that may illustrate this phenomenon in younger time periods during the Lower Pleistocene are regional variants of the Acheulian industry that occur on the northwest Mediterranean coast of Africa at Sidi Abderrahman and Ternifine. Other stone tool industries exist where handaxes are rare or absent. Examples in Europe are the Buda, Tayacian and Clactonian industries. Oldowan artefacts are found in association with the 1.8–1.6 myr Dmanisi mandible in Georgia (Gabunia and Vekua 1995). The hominid remains from Gran Dolina, Sierra de Atapuerca, Spain, dating to >780 kyr, are associated with tools classified as pre-Acheulian (Mode I); handaxes, cleavers and picks are absent (Carbonell *et al.* 1995; Parés and Pérez-González 1995). The Nihewan Basin in northern China has yielded several sites dated 1–0.7 myr with Oldowan artefacts (Schick and Toth 1995). Handaxes do not occur in stratigraphic context at Chinese sites (Keates 1996). The absence of the Acheulian industry, especially in the Far East (i.e. beyond 'the Movius Line'), has, since the 1940s, often been held to indicate the existence of a major cultural discontinuity between the Far East and other areas of the Old World. A recent review documents the persistence of this idea (Klein 1995/1996), and the fact that it can be used to support an interpretation of highly restricted gene flow between the Far East and other areas of the Old World, even up to the Late Pleistocene. This, in turn, can be used to imply that hominid populations in the Far East were isolated refuge populations that were unlikely to have contributed to the origins of anatomically modern humans. Yet, if migrating hominids were subject to behavioural character release, as argued here, it may be no accident that alternative tool industries or Acheulian variants are found far from tropical African habitats. The archaeological evidence thus supports character release affecting the behavioural component of the phenotype as hominids disperse into novel environments.

DISTRIBUTIONAL BARRIERS AND VARIATION

Even hominid species antecedent to *Homo erectus* may have had considerable abilities to disperse. A craniofacial fragment of *Homo erectus* has been identified from Chad, but an australopithecine mandibular fragment with affinities to *Australopithecus afarensis* has also recently been discovered in Chad (Brunet *et al.* 1995). The location of this specimen 2,500 km west of the Raft Valley argues that even australopithecines were widely distributed throughout sub-Saharan Africa; some australopithecine species may have had considerably well-developed dispersal and ranging abilities. This implies that the ranging abilities of later hominids would be even less constrained.

An important factor to consider is whether the distribution of *Homo erectus* was relatively continuous or broken by substantial geographic barriers. It has been known for a long time that animal populations that are isolated on islands may exhibit significant phenotypic and genetic differences from island to island in an archipelago, and from parent populations on a continental landmass (Mayr 1963). Habitat differences within a continental landmass may be much greater than those that occur between the continent and offshore islands; yet very little geographic variation may occur in a species continuously distributed within the continent. Hence, it is the genetic isolation of islands that causes the variability of island populations. Mayr (1963) therefore stresses the importance of major geographic barriers for speciation, because these barriers create genetic and phenotypic variability. The dispersal of small-bodied arboreal primates is highly constrained by river boundaries (Ayres and Clutton-Brock 1992). In New World primates, tributaries of major river systems often determine the boundaries between different subspecies. This is true even though all New World primates are highly arboreal, and might be expected to bridge streams and rivers in a relatively easy fashion via connecting canopy structures, at least along some portion of the waterway. The large body size and terrestriality of *Homo erectus* strongly imply a larger home range than in smaller, arboreal primates. In general, rivers and streams are unlikely to have acted as major barriers to distribution in *Homo erectus*. Probably only the largest of rivers acted as significant geographic barriers to this taxon. There is even some indication that *Homo erectus* may have reached the island of Flores in Indonesia, crossing an ocean gap and a major biogeographic boundary (Wallace's Line) at 700 kyr (Sondaar *et al.* 1994). In fact, a recent general review of the influence of body size on ecological barriers and speciation confirms that most large animals experience very little ecological isolation. Unless major geographic barriers occur, gene flow across habitats is usually sufficient to prevent the divergence of populations within large-bodied animal species (Bush 1993).

The most extreme geographic barriers are seen on islands. A well known primate example of the effects of island isolation is the St Kitts vervet monkey *(Cercopithecus aethiops),* separated on this Caribbean island from founding African populations since the early seventeenth century. In comparison to the founding populations, rare dental abnormalities are common in the St Kitts vervets; craniofacial and dental dimensions are larger in the St Kitts animals, although the variability of these dimensions is reduced; and craniofacial and dental traits show more fluctuating asymmetry in the St Kitts vervets (Ashton and Zuckerman 1950, 1951a, 1951b). These differences are equivalent to differences that otherwise separate species or subspecies of the genus *Cercopithecus*. It is particularly interesting that the St Kitts animals show less dental and craniofacial variability (Ashton and Zuckerman 1951a). This implies either a reduction in genetic diversity, or a reduction in niche variability (habitat variability) on the island. Both of these factors may operate. The St Kitts vervets underscore how dramatic the genetic and phenotypic divergence from parental stock may be in isolated primate groups with small founding populations. It is probable that, if small founding populations of *Homo erectus* experienced complete genetic isolation, they would also demonstrate similar differences from descendants of the parental population.

POPULATION SIZE AND DISPERSION

Dispersal potential is strongly affected by a population's intrinsic rate of increase. In modern humans, there is abundant evidence that the exponential increase in human populations that occurs after the adoption of agriculture is associated with a demic spread or wave of advance, as farmers colonize new areas or enter areas only sparsely inhabited by hunter-gatherers (Cavalli-Sforza *et al.* 1994). Large mammals appear to maintain higher population densities than one would expect if the relationship between body mass and density were a simple linear one (Silva and Downing 1995). In addition, it is possible that differences in subsistence and habitat use caused population sizes to increase in *Homo erectus*. Faster maturation than in modern humans would affect the intrinsic rate of population growth, as would small neonatal brain size relative to the size of the birth canal inlet, when compared to modern humans. Individuals could reproduce at a younger age, and birth would be less hazardous to both mother and infant. Although the intrinsic rate of population increase in *Homo erectus* may have been larger than in modern humans, this greater intrinsic rate may have been offset by a relative poverty in material and symbolic culture. Consequently, population sizes in *Homo erectus* were probably much less than the order of those seen in modern human hunters and gatherers. Yet, although low by the standards of modern hunter–gatherers, and certainly vastly lower than populations of agriculturalists or people in modern industrialized societies, population sizes in *Homo erectus* may have been significantly larger than in earlier hominid species.

It has recently been estimated that effective hominid population sizes in sub-Saharan Africa continuously remained about three times larger than else-where in the Old World through the course of evolutionary time (Relethford and Harpending 1995). If this is true, sub-Saharan Africa would have constantly served as a source area for dispersing hominids. Roberts (1984: 45) has proposed a palaeoenvironmental mechanism for triggering hominid dispersal from Pleistocene Africa. He argues that the alternation of wet and dry environments in the Pleistocene Sahara causes this dispersal. Wet environments draw hominid populations into the Sahara from more southern regions; Sahara desiccation then expels hominids out into circum-Mediterranean areas. Mathematical analysis confirms that persistent environmental variation or mosaicism does in fact promote the dispersal of natural populations (Holt and McPeek 1996).

In comparison to earlier hominids, *Homo erectus* had a larger body mass, and would have consequently dispersed more quickly. This is because the speed of animal travel is directly proportional to body mass raised to the power 0.17 [$(\text{body mass})^{0.17}$] (Schmidt-Nielsen 1984: 174). Larger mammals have home ranges that appear to exceed their energy requirements. Home range size scaling isometrically or with positive allometry in relation to body size, and dietary shifts involving more reliance on vertebrate meat (Calder 1984:Table 11–1), would also generate greater dispersal abilities in *Homo erectus*. Simulations of the rate of Pleistocene gene flow demonstrate that advantageous genes could diffuse through the geographic area inhabited by *Homo erectus* in 50 kyr (Livingstone 1992). A reasonable mutation rate for functionally similar alleles arising separately in other areas could have spread the advantageous genes throughout the distribution of *Homo erectus* in a substantially shorter period.

GENERAL FACTORS AFFECTING DISPERSION

Five factors probably affected hominid dispersion out of the Rift regions of East Africa.

1 Tectonic changes in East Africa, associated with the development of East African and Red Sea rifting beginning at 25 myr (Harland *et al.* 1989: Figure 7.3), contribute to the origin of regional faunas through habitat fragmentation. Regional faunas affect mammalian diversity (Flessa 1975). Events associated with tectonism or Pleistocene climatic fluctuations would therefore create regional faunas, and contribute to species diversity through habitat fragmentation.

2 It is unlikely, however, that a large-bodied mammal species like *Homo erectus* was limited even by extensive habitat fragmentation, because dispersal ability is directly proportional to body size in land mammals.
3 According to Rapoport's Rule (Stevens 1989), high-latitude species have greater latitudinal range than low-latitude species, and are less affected by the occurrence or degree of seasonality. Consequently, once hominids disperse from low latitudes, the less constrained they are likely to be in terms of range or seasonal perturbations.
4 Because the niche of a species may vary with geographic range, it is possible that the niche of *Homo erectus* in sub-Saharan Africa was different from that of *Homo erectus* in North Africa or in the Far East, simply because of the wide distribution of this taxon. A wide distribution coupled with low population sizes would ensure the operation of genetic drift. Phenotypic morphological or behavioural traits may sometimes, therefore, have been caused by random processes, rather than natural selection.
5 The phenomenon of ecological release, and consequent character release, may also have been important (Cachel and Harris 1995).

THE ORIGIN AND DISPERSAL OF *HOMO ERECTUS*

Palaeontology and archaeology demonstrate that *Homo erectus* emerged in areas of tropical sub-Saharan Africa where habitat disruption, caused by Pleistocene climatic fluctuations, tectonic movements and volcanism, was prevalent. The successful migration of *Homo erectus* out of the African tropics is not necessarily dependent upon material culture, because the Old World monkey genus *Macaca* occurs in many temperate areas during the Pleistocene (England, Germany, The Netherlands, northern China) without benefit of tool behaviour or the ability to create artificial shelters or control fire. It is suggested that *Homo erectus* (perhaps like some modern macaque [Richard *et al.* 1989] and baboon species) thrived on environmental disruption, and emerged as a 'weed' taxon in areas of tropical Africa disrupted by Pleistocene climatic and tectonic perturbations (Cachel and Harris 1995).

The properties of successful weed species have perhaps been better investigated in plants than in animals. In plants, secondary growth species appear where the primary vegetation has been disturbed. These species also colonize newly deposited volcanic sediments and naked, newly exposed river alluvium. These pioneering species have very broad geographic distributions. They have a high intrinsic rate of increase, disperse efficiently, tolerate a broad range of environmental conditions, and reproduce successfully under these conditions (Richards *et al.* 1996). The literature on naturalized mammals yields many examples of species that are introduced by humans into new areas, where they flourish, spread rapidly, and markedly alter their diet and behaviour to suit the novel environment (Lever 1985). (Although these alien species are introduced by humans, and have not invaded areas solely by virtue of their own dispersal abilities, it is important to note how their diet and behaviour rapidly respond to differences in habitat and a relative lack of competition—a demonstration of phenotypic character release under artificial circumstances.) Naturalized alien species may compete with and prey upon native species, or drive them to extinction. Successful species of naturalized mammals can tolerate a wide variety of habitats, and frequently thrive in habitats highly altered by humans. These species can disperse in a surprisingly rapid fashion: for example, the documented average advance is 135 km/yr, but a maximum advance of 300 km/yr is documented for the raccoon-dog, a medium sized carnivore 4–10 kg in body weight (Lever 1985).

Weed taxa profit from habitat fragmentation and ecosystem instability, and these factors certainly prevailed in the Pleistocene of sub-Saharan Africa. There is evidence that Pleistocene habitat fragmentation did have an effect on mammal distribution and community composition. As a direct result of climatic fluctuations, Late Pleistocene environments in the United States were significantly more heterogeneous than they were in the Holocene. This environmental heterogeneity, in turn, generated significantly more diverse mammal faunas than in the Holocene. The composition of Late Pleistocene communities in America was constantly shifting (Graham *et al.* 1996). In Africa, biogeographical analysis of modern animal species, pollen from lake basin sediments, and sedimentological evidence indicate major changes during the Pleistocene, even affecting rain forest distribution (Richards *et al.* 1996). The evidence is dramatic (e.g. sand dunes underlying the western portion of the modern rainforest in Zaire). Thus, not only was Africa subject to climatic disturbances similar to those occurring in the United States, but African tectonic disturbances also created an additional source of environmental fluctuation during the Pleistocene (Feibel 1995). Weed taxa would be likely to evolve, thrive and spread under such conditions of long-term, continuous environmental and community change.

The idea that climate has exercised a major control on mammal evolution was first outlined in the early twentieth century by Matthew (1914), and thus the idea that climate broadly affects hominid evolution is not novel. More recently, Vrba (1992, 1995a) espouses the idea that climate exercises a major role in mammal evolution, with major turnovers in mammal faunas resulting from global climatic events. Other researchers have recently advocated the idea that palaeoclimatic fluctuations have had a major direct influence on hominid evolution. Currently, Stanley (1992, 1996) argues that climatic deterioration in Africa triggered the origins of genus *Homo* by reducing forest habitat. Potts (1996) argues that continued climatic fluctuations in Africa selected for hominids that were generalists. Our argument here about Plio-Pleistocene weed taxa emphasizes that climatic fluctuations and tectonic disturbances create continual long-term habitat disturbance and community change. Under these conditions, animal species that are adapted for environmental disturbance are more likely to survive, become abundant, and disperse throughout the habitats affected by such disruption. These habitats are characterized by communities whose species composition is highly unstable. Our argument is therefore directed at the level of ancient communities. It addresses the properties that affect the survival, abundance and distribution of animal species at the level of a palaeocommunity whose internal species composition is ever-changing and plastic.

In recent years, archaeological and human palaeontological records in the Old World have been interpreted to show evidence of distinct species within the hypodigm of *Homo erectus* and the dispersal of hominids out of sub-Saharan Africa. Regardless of the minutiae of various debates, hominid dispersal from sub-Saharan Africa is a major evolutionary event, and East Africa, the Horn of Africa and the Middle East are targeted as the principal corridor for dispersal into Eurasia. Given the radiometric dating of Javan *Homo erectus* to 1.8 myr (Swisher *et al.* 1994), a date equivalent to the oldest *Homo erectus* site in Africa (Koobi Fora), and the recent suggestion that genus *Homo* is present in Longgupo, China, at 1.9 myr (Huang *et al.* 1995), it is possible that hominids began to spread from sub-Saharan Africa even before 2 myr. In spite of the equivalence of the earliest dates in Java and Koobi Fora, we consider that *Homo erectus* emerged in Africa. This is because australopithecines have been found only in sub-Saharan Africa, and not in other tropical areas of the Old World, and the Nariokotome *Homo erectus* specimen shows descent from an australopithecine.

Archaeological survey yields evidence that a variety of habitats were being occupied after 1.7 myr (Rogers *et al.* 1994). An arid climatic pulse in Africa at 1. 7 myr (de Menocal 1995) may have contributed to hominid dispersal: as prime habitats in the core of a home range become more restricted or fragmented by aridity, hominids are forced to shift their activities to more peripheral areas of their home range, or are forced to disperse to marginal or novel habitats. Long-term environmental variation or habitat mosaicism serves to promote the dispersal of natural populations (Holt and McPeek 1996). After 1.7 myr, there are indications for the first time that hominids occupied much higher elevations. In the Ethiopian highlands, sites occur just below the forest zone at 2,000 m (Clark and Harris 1985). Ethiopian sites such as Gadeb and Melka Konture experience extreme fluctuations in daily temperature, with freezing or near freezing conditions at night. It therefore appears significant that some of the earliest evidence of hominid control of fire occurs at the Gadeb site, which dates to 1.4 myr. Here hominid control of fire may have been initiated to combat nocturnal freezing, but it also facilitated the movements of hominids into new habitats, some of which were at higher elevations. The dispersal of *Homo erectus* into new and possibly marginal regions of Eurasia is a result of a weed-like ability to thrive in disrupted environments. Many researchers attribute the first control of fire to this taxon (Baiter 1995), and the use of fire by this hominid species may have contributed to local environmental disruption. If *Homo erectus* is present in Java at 1.8 myr (Swisher *et al.* 1994), hominid dispersal from sub-Saharan Africa probably occurred prior to 2 myr. A date of 1.8–1.6 myr for the

Homo erectus mandible from Dmanisi in Georgia also suggests an earlier dispersal (Mchedlidze 1993; Dean and Delson 1995; Gabunia and Vekua 1995). A 2 myr migration pre-dates the earliest Acheulian artefacts, which are found in the Ethiopian site of Konso-Gardula, dated to 1.4 myr, where abundant Acheulian artefacts occur with a mandibular specimen of *Homo erectus* (Asfaw *et al.* 1992). If hominids migrate from sub-Saharan Africa at 2 myr, this might explain the absence of the Acheulian industry in China and Java, although we consider character release to be the more probable explanation, because it accounts for both morphological and behavioural variation. Clark *et al.* (1994) argue that advanced morphological features appear first in Africa, but character release may explain morphological variation between African and Eurasian specimens of *Homo erectus*.

Various routes have been proposed for the dispersal of Lower Pleistocene hominids from Africa. It is generally considered that the most likely migration route is the current land connection between Africa and Eurasia. Hominids and other land mammals are thought to have dispersed through the Sinai Desert region, and north through the Levant, which has been well explored by palaeoanthropologists. However, we believe that the most likely route is by way of the Afar Depression, through the shallow termination of the Red Sea and across the southwestern point of the Arabian peninsula. Currently, the Strait of Bab al Mandab between Ethiopia and Yemen is 28 km wide at its narrowest point, and is as shallow as 137 m. This shallow sea floor has been created very recently, and the expansion of the southern Red Sea Basin has caused a counterclockwise rotation of the Arabian plate through the Plio-Pleistocene. Land connections in this area were probably affected by global sea level drops during the Pleistocene. During the Early and Middle Pleistocene, land today covered by the Red Sea may have been intermittently subaerially exposed to allow hominid movements between northeast Africa and the Arabian peninsula and north into the Levant and thence to Eurasia. Arguments supporting the Levantine route (the Levantine Corridor) are well known (summarized in Bar-Yosef and Goren-Inbar (1993), Bar-Yosef, this volume). The available geophysical evidence supports a possible route from East Africa through southwestern Arabia. In fact, the Asal Rift segment of the Afar Depression is now subaerially exposed, because crustal thinning and subsidence is balanced by the injection of magma (de Chabalier and Avouac 1994). This is a modern example of an emergent area in the Afar Depression created by processes presumably operating throughout the Pleistocene. Hominid dispersal into Eurasia may well have occurred in this region along a broad front. Strategic archaeological survey of the south-western Arabian peninsula might confirm this dispersal route, assuming that archaeological material could be recovered from stratified sites in primary context, and was not recovered only from surface collections.

The Israeli site of ‘Ubeidiya is crucial in understanding the timing of migration, as well as behavioural and ecological factors involved in the dispersal of hominids. The earliest artefact levels date to 1.5 myr (Tchernov 1987). The broad similarities in the lithic assemblages of ‘Ubeidiya and Olduvai Bed II suggest a stone tool tradition that may have African origins (Bar-Yosef and Goren-Inbar 1993). The dating of ‘Ubeidiya indicates that hominids had already dispersed out of Africa and established a foothold in Eurasia by 1.5 myr. Dmanisi, in Georgia (1.8–1.6 myr), also lies on the vector of dispersal through the Levant into Asia. Much later in time, during the Middle Pleistocene, the Acheulian site of Gesher Benot Ya’aqov in the northern Dead Sea region of Israel continues to demonstrate African affinities. The Gesher Benot Ya’aqov artefacts show a high degree of resemblance to the Lower Pleistocene Acheulian assemblages of Olduvai Gorge and ‘Ubeidiya. In fact, Gesher Benot Ya’aqov has been used to suggest the possibility of recurring waves of hominid dispersal from sub-Saharan Africa into the Levant through long periods of time (Goren-Inbar 1996).

A major turnover in the large mammal fauna of Europe appears to have occurred at 800 kyr (Turner 1992), which would certainly affect hominid palaeoecology. Whatever the first migration date from Africa may be, it is clear that hominid presence in Europe is largely ephemeral until about 500 kyr (Turner 1992). Two Iberian localities may precede this knickpoint: the site of Gran Dolina at Atapuerca, Spain (780 kyr), which contains both human fossils and archaeological material (Carbonell *et al.* 1995), and three more southern sites in the Orce Basin, which contain possible human fossils, as well as non-Acheulian artefacts, and which may date to as early as 1.8 myr (Dennell and Roebroeks 1996; Zihlman and Lowenstein 1996). More permanent hominid occupation of Europe after 500 kyr is certainly indicated by the Mauer and Boxgrove sites in central and northern Europe. Boxgrove contains a hominid fossil, Acheulian implements with debitage, and butchered animal remains (Roberts *et al.* 1994).

It is important to note that Acheulian artefacts do not occur at Gran Dolina (Atapuerca, Spain), which yields the earliest dated unequivocal hominid fossils in Europe (Carbonell *et al.* 1995). Preliminary analysis indicates that the hominid fossil material is attributable to genus *Homo,* although the species status is uncertain. The evidence from Gran Dolina implies two things. First, that phenotypic character release, affecting both the morphological and behavioural components of the phenotype, was operating. Second, that it is unlikely that the Straits of Gibraltar were the route of hominid dispersal across the Mediterranean from Africa into Spain and the rest of Europe (contra Freeman 1975). If this were so, one might expect that the hominid fossils from Gran Dolina would resemble hominid material in Africa. Instead, there is some resemblance to later European material. Later hominid fossils from Atapuerca (300 kyr) are either Neanderthals, or clearly antecedent to this group. Furthermore, one might expect to see classic Acheulian implements at Gran Dolina, if a dispersal route from Africa were in such proximity. The earlier artefacts from the sites at Orce, Spain, which may date to as early as 1.8 myr, are also not Acheulian artefacts.

SUGGESTED TESTS OF THE ADAPTIVE ZONE INFERRED FOR *HOMO ERECTUS*

Finally, we believe that the combined archaeological and palaeontological records in East Africa and the Middle East may be dense enough, and dated well enough, to begin to test some of the ideas developed here about the adaptive zone of *Homo erectus*. For example, if we are correct in identifying the origin and dispersal of this species with the spread of grasslands, palaeoecological analysis should reveal a statistically significant association between fossils of this taxon and open-country environments. If the ability to occupy disrupted habitats is typical of this species, one would expect to see a broader array of habitats exploited compared to earlier or sympatric hominid species. Palaeoecological evidence in East Africa has already begun to show a non-random occupation of ecotones, areas of secondary succession, landscapes altered by volcanic activity or fire, disturbed floodplains, or braided streams. Archaeological survey from different time intervals in the Turkana Basin documents that archaeological traces in earlier time ranges are found in more sheltered and protected, closed habitat settings; later hominids move to drier, more upland parts of the basin. Later archaeological occurrences are found in more marginal habitats, near ephemeral streams that were seasonally flowing off the topographic heights of the basin (Rogers *et al.* 1994; Cachel and Harris 1995). Modern plants and animals known to be weed species should occur with *Homo erectus*. Estimates of ranging behaviour based on the distribution of lithic raw materials should reveal more exploitation of distant resources by *Homo erectus*. Perhaps more patterning to the exploitation of lithic raw materials exists, if the ability to survey and exploit such resources were an habitual facet of behaviour. Once *Homo erectus* emerges into temperate environments and higher latitudes, range size should increase, and niche structure should become more generalized. This might be demonstrated by a comparison of sites from low versus temperate latitudes.

CONCLUSION

The fundamental hominid niche is characterized by bipedal locomotion and heat adaptation seen in a narrow bi-iliac breadth. Catarrhine primates in general may be pre-adapted for evolving bipedal specializations; this may be accentuated in hominoid catarrhines. It is possible that a very early radiation of hominids occurred that was based on bipedality. There is evidence that at least two hominid lineages independently developed bipedal adaptations.

Because of its novel adaptive zone, *Homo erectus* was the first widely dispersed hominid species, and its dispersal occurred at an early date. This is the earliest hominid species unequivocally thought regularly to manufacture and utilize stone artefacts. The density of the archaeological record increases with the advent of this taxon. This is also the first member of genus *Homo* for which virtually complete post-cranial anatomy can be reconstructed from fossil evidence. A number of factors can be inferred to have operated during the evolution of *Homo erectus*. Among these are large body size (associated with larger home range size, K-selection and dietary diversity), the influence of food as a limiting factor on population size, and dietary change as a major selection factor. Tool behaviour associated with food acquisition and processing implies occupation of a niche distinctive for primates.

The first occurrence of *Homo erectus* in sub-Saharan Africa documents larger body size and pronounced arid, open-country adaptations. Home range size was probably larger than in other hominid species, with a wider variety of habitats being exploited. The date of 1.8 myr marks the earliest occurrence of *Homo erectus* at Koobi Fora. At 1.7 myr, the archaeological record of East Africa becomes highly variable, with artefact occurrences that are generally referred to as the Developed Oldowan. The coincidence of these dates suggests that *Homo erectus* (unlike earlier or sympatric hominids) was experiencing selection pressure to exploit resources that were becoming increasingly widely distributed across Pleistocene landscapes. This inference is supported by marine dust records off the African coasts: a major shift towards arid, open-country conditions is signalled at 1.7 myr (de Menocal 1995).

Because modern temperate species have larger ranges and generalized niches than tropical species, one might infer that an increase in range size and the acquisition of a more generalized niche structure was associated with the emergence of *Homo erectus* into temperate regions of the Old World. The invasion of novel environments by *Homo erectus* could lead to character release, which might increase variability in the morphological and behavioural phenotype.

The successful migration of *Homo erectus* out of the African tropics is not necessarily dependent upon material culture. We suggest that *Homo erectus* (perhaps like baboons and macaques) thrived on environmental disruption, and emerged as a 'weed' taxon in areas of tropical Africa disrupted by Pleistocene climatic and tectonic perturbations.

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5

Raw material as evidence for human behaviour in the Lower Pleistocene: the Olduvai case

DANIEL STILES

INTRODUCTION

Plio-Pleistocene archaeological 'sites', or concentrations of debris, have usually been interpreted to be the result of various processual phenomena. The most common interpretation is that stone and bone accumulations are predominately the result of hominid behaviour. Based on various processual findings, a current popular archaeology text book states that, 'We know that the hominids transported toolmaking stone and portions of animal carcasses from one place to another…. All archaeology currently tells us is that the early Olduvai sites were places to which stone and food resources were carried' (Pagan 1992:105). In contrast, some maintain that accumulations are not the result of hominid behaviour, and thus they cannot be used to reconstruct early ways of life (Binford 1981; Stern 1993). Other interpretations of the early archaeological record have shown that this interpretive dichotomy is likely to be simplistic. More realistic is that geomorphological, taphonomic and hominid behaviours interact to produce various site conditions relating to depositional and post-depositional processes (e.g. Behrensmeyer 1983; Isaac 1983; Potts 1984; Bunn and Kroll 1986; Schick 1986; Toth 1987; Goldberg *et al.* 1993; Paddayya and Petraglia 1993; Petraglia and Potts 1994). Therefore, it is now recognized that archaeological sites vary considerably as a consequence of the multiple processes that interact to deposit the material that will later be recovered in excavation. Moreover, once deposited, material remains are variably preserved by natural factors, such as disturbance by moving water after deposition. This chapter presents the results of a study carried out at Olduvai Gorge, Tanzania. A main conclusion of this study is that even fluvially disturbed accumulations of archaeological debris can offer evidence of important hominid behaviour patterns. The study provides evidence for hominid selection of a certain category and size of stone raw material, and its manufacture and intentional transport of stone from one place to another. The application of intentional choice in selection of tool type for future use by hominids, followed by their transport, indicates that relatively complex thought processes were at work that could be characterized as typically human as opposed to pongid. This analytical approach to archaeological materials has global relevance to the study of both site formation processes and human behavioural evolution in a variety of contexts.

THEORETICAL BACKGROUND

It has been long recognized that there are alternative modes of transport and accumulation that could explain the co-occurrence of different types of debris in excavated Plio-Pleistocene archaeological sites. They can basically be divided into two types: physical and biological. The main physical forces that can move stones and bones from one place and deposit them in another are moving water and gravity on slopes. Other forces that could move archaeological material, such as volcanic eruptions, earthquakes or hurricane force winds, need not concern us at the general level because of their rarity in the archaeological record. Biological agents, including animals and plants, may alter archaeological sites. Burrowing rodents, insects, plant roots and other agents can move objects *in situ,* but they are highly unlikely to collect different types of objects from different loci and accumulate them in one place. The biological agents that can move and deposit objects are primates, including hominids, and carnivores. It is unlikely that any other type of animal could transport objects that would leave debris resembling archaeological sites, though the scavenging and 'tool' manipulation behaviours of porcupines, sea otters, Egyptian vultures and other non-primates/ non-carnivores are well documented (Oakley 1972).

Therefore, when archaeologists find stones and bones in association in discrete accumulations, scientific methods must be employed to decide the agent(s) that brought them together. If water and gravity can be ruled out, then the possibility of hominids and carnivores, either independently or in conjunction, must be explored. Carnivores have never been observed to transport stones and accumulate them in one spot, which is why most of the literature on site formation focuses on bones (e.g. Behrensmeyer 1978, 1983; Binford 1981, 1988; Brain 1981; Hill 1984; Potts 1984, 1986; Bunn 1986; Bunn and Kroll 1986; Blumenschine and Masao 1991). Chimpanzees have been observed to transport stone objects for use up to 500 m, and to use one place more than once for an activity involving tool use (Boesch and Boesch 1984, 1990; Matsuzawa 1991; Toth *et al.* 1993), but the activities do not produce a material pattern that resembles any Plio-Pleistocene archaeological site. In addition, chimpanzees have never been observed to manufacture and use a stone tool in activities related to hunting or meat processing.

Some believe that the earliest tool making hominids were at a chimp-like grade of behaviour, and that they did not have planning depth or live in repeatedly used camps or central places (Binford 1985; Foley 1988; Wynn and McGrew 1989; Wynn 1993). A comparison of chimpanzee behaviour and the Oldowan archaeological record by Wynn and McGrew (1989) concluded that there is nothing in this record that could not have been chimpanzee produced. This comparison, however, did not consider early hominid archaeological evidence from Olduvai Gorge, which clearly falls outside of any observed pongid grade type of behaviour (Stiles *et al.* 1974), which will be discussed in detail below. An elaboration of this study concluded that hominids were the most probable agent of transport of selected tool forms and raw materials found at certain Olduvai lower Bed II sites, demonstrating planning depth and cognitive ability by early hominids (Stiles 1991), thought by some to be lacking at such an early period, *c.* 1.7 myr ago (Binford 1981; Foley 1988; Wynn and McGrew 1989). Taking the analysis of the Olduvai data further, this chapter proposes that raw material evidence can be used to support the hypothesis that human as opposed to ape grade behaviour emerged at approximately 1.7 myr.

THE OLDUVAI CASE STUDY

Background

Olduvai Gorge is located in northern Tanzania in the Serengeti Plains at the western margin of the Eastern Rift Valley. The gorge has been cut by flowing water into a thickness of 50–80 m of Plio-Pleistocene sediments that overlie a trachyte welded tuff and precambrian basement rocks. The sediments were deposited in a broad, shallow basin that lay east of a series of volcanoes of the Eastern Rift Valley. Periodic eruptions of volcanoes, which deposited sediments capable of potassium-argon dating, have permitted the establishment of one of the most complete and reliable Plio-Pleistocene dating sequences in the world from approximately 1.9 myr ago. The sediments contain abundant remains of hominid activities in the form of stone and bone artefacts and animal food remains. The deposits were first studied by Reck and L.S.B.Leakey in the 1930s (Leakey 1951), and subsequently by other researchers (M.D. Leakey 1971; Hay 1976).

Archaeological Sites

Two sites were analysed in this study: the MNK Chert Factory Site (CFS) and HWK East, Levels 3 and 4 (HWK E 3–4). These sites are located in lower Bed II immediately above Tuff IIA, dated to approximately 1.7 myr ago (Hay 1976: 64), and they are stratigraphically equivalent (Figure 5.1). MNK CFS is located in a natural chert bearing layer that is found exposed in various parts of Olduvai Gorge today. MNK CFS is the oldest special activity site yet known, and features an extremely high density of lithic debris which is characteristic of stone artefact manufacture. The overall pattern of the remains was so distinctive, and the intensive use of natural chert exposures so evident, that the excavated occurrence was termed a ‘factory site’ (Stiles *et al.* 1974).

During the time that Bed I was formed (1.9–1.75 myr), there was a permanent saline, alkaline lake that fluctuated in size due to climatic and tectonic influences.

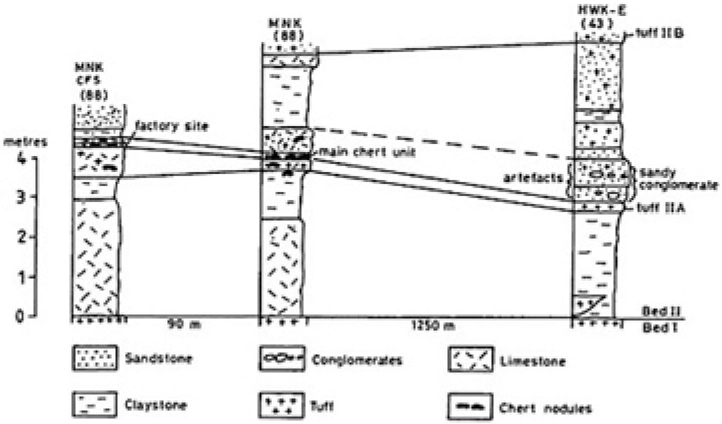

Figure 5.1 Stratigraphical relationship between the MNK CFS and HWK E 3–4.

After the formation of the chert on the floor of this lake, the water retreated to expose it (Hay 1976). During this period, hominids came to work the chert. The lake then expanded again to cover the chert. During the same period that MNK CFS was exposed and active, chert appears in relatively high frequencies at HWK E and FLK North, both approximately 1 km from the factory site. These assemblages have been termed the Developed Oldowan A (Leakey 1971). Chert has also been observed at unexcavated sites eroding in the gorge such as PEK, SHK and at Localities 201 and 202, some 5 km north of the gorge along the Fifth Fault (see also Hay 1976) (Figure 5.2).

An attribute analysis of chert whole flakes was carried out by the author, and differential frequencies of raw materials in relation to certain artefact categories were ascertained at the two sites, with the objective of testing the hypothesis that chert was being transported to HWK E. Other assemblages with chert were not included because of the dearth of excavated material. There were 400 chert whole flakes sampled at MNK CFS, and 110 constituted the total number of whole flakes at HWK E 3–4. Chert modified pieces and cores were too few to provide statistically valid results.[1] Whole flakes were chosen for detailed study because ethnographic and experimental studies have shown that this lithic category is the most desired in a number of processing activities (Wilmsen 1968; Strathern 1969; White and Thomas 1972; Jones 1980; Toth 1985). Specifically, the hypotheses being tested were:

1 If chert was being flaked from nodules at both MNK CFS and HWK E, the attributes of the chert flakes and flaking waste should show similar patterns in the two assemblages.
2 If hominids were selecting flakes from a factory site such as MNK CFS and transporting them to HWK E 3–4, the transported flakes should differ from

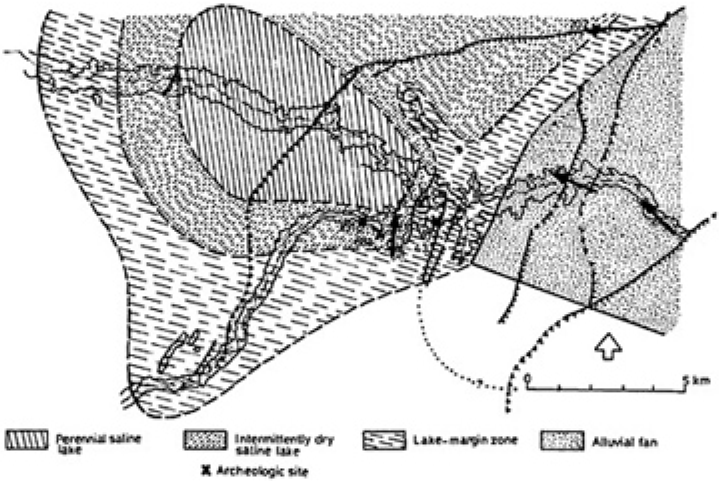

Figure 5.2 Location of MNK CFS (88a), HWK E 3–4 (43), FLK N (45a), SHK (91) and Locality 202.

those at the factory site, reflecting those attributes that were preferred for utilization by the makers. Flaking waste categories should also be different, with disproportionately higher numbers of whole flakes to other debitage categories at HWK E 3–4.

3 If all lithic artefacts found at HWK E 3–4 were being manufactured there, then the debitage categories of all raw materials should be similar.

The MNK CFS assemblage numbers more than 30,000 pieces excavated from a 5×2 m area, 20 cm in depth. The excavator, Marie-Louise Harms, divided the material into ten levels of 2 cm each. A sample of 7,373 chert pieces was made by the author, consisting of all material from four of the metre squares and six of the levels in each square. Two lava hammerstones and a large gneiss block that showed clear signs of having been used as an anvil were also part of the sample. The material is distributed through a bed of soft to hard sandy limestone 5–8 cm thick, overlain by 10–15 cm of sandy claystone in which some chert is also found. The sedimentary levels are horizontally layered and there is no evidence of a slope.

The HWK E 3–4 assemblages were excavated by M.D.Leakey from 60 cm of sandy sediments in an area of approximately 4.6×2.3 m, and a small proportion of the artefacts display signs of water action (Leakey 1971:96). The material was not in primary context, but the lack both of orientation of the material and of evidence for water sorting (i.e. very small and large pieces were randomly scattered), as well as the fresh condition of the whole flakes, indicate that the material is most likely from discrete site accumulations that were located at or near their excavated position. Level 3, in fact, was still discrete enough that it was plotted (Leakey 1971:Figure 49). Petraglia and Potts (1994:247) concluded that artefacts from Level 4, the most disturbed level, were most likely transported by water for only a short distance from their original location.

Methods and Analytical Results

The attributes recorded for whole flakes were flake length, maximum thickness, striking platform width, number of dorsal surface scars, number of platform facets, dorsal scar pattern, flake shape and the type of flake release surface (see Stiles *et al.* 1974 for definitions).

The dorsal scar patterns, flake shapes and flake release surface types in the two assemblages showed almost identical patterns (Stiles *et al.* 1974: Figures 10–12). This suggests that the flaking technology was similar in the production of the flakes. The percentage of cortex dorsal surface, i.e. primary flakes, was 15.8 per cent at MNK CFS and only 4.7 per cent at HWK E 3–4— a more than threefold difference. A chi-square test showed this difference to be significant in excess of the 0.01 probability level. Flakes with cortex dorsal surfaces, i.e. primary flakes struck from a core, are the first to be worked, and an almost 16 per cent representation at MNK CFS indicates a high degree of on-site flaking (Toth 1987).

More significantly, the flake lengths and maximum thicknesses showed very different patterns between the two assemblages (Figures 5.3 and 5.4). HWK E flakes were longer and thinner on average than those at MNK CFS, and the distribution was much more restricted around an ‘ideal type’ measuring about 3 cm long and 8 mm thick (Stiles 1991:10). The most common whole flake at MNK CFS was a small one under 1 cm in length. This is also a characteristic of on-site flaking, and the MNK CFS size frequency distribution approximates closely the debitage size frequency distributions obtained in flaking experiments (Schick 1986:23–4). There were no chert flakes present at HWK E 3–4 measuring less than 1 cm in length.

Interpretation

The flake attribute study supports the hypothesis that there is a functional difference between the populations of whole flakes at MNK CFS and HWK E 3–4. The factory site flakes show a much wider range of attribute values and a significantly higher proportion of primary flakes. The restricted range of flake length and width at HWK E 3–4 supports the hypothesis that they were selected, and the dearth of primary flakes supports the hypothesis that chert was not flaked as much there as at MNK CFS. Both of these findings are consistent with the hypothesis that chert was transported to the site.

Selection by moving water was considered as an alternative to hominid transport. The other flaking waste categories at HWK E were examined. There

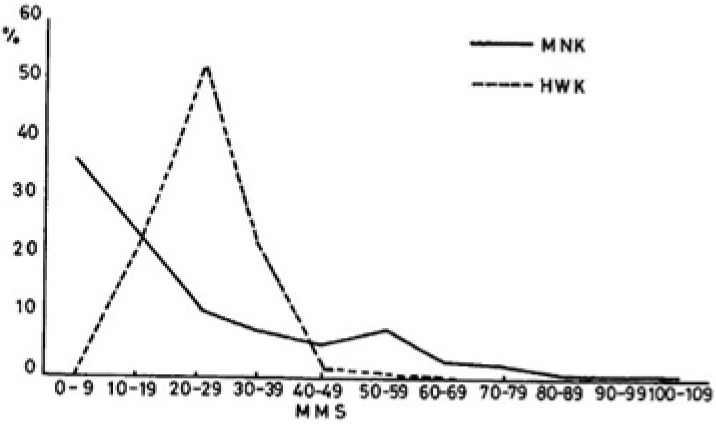

Figure 5.3 Frequency distribution of flake length at MNK CFS and HWK E 3–4.

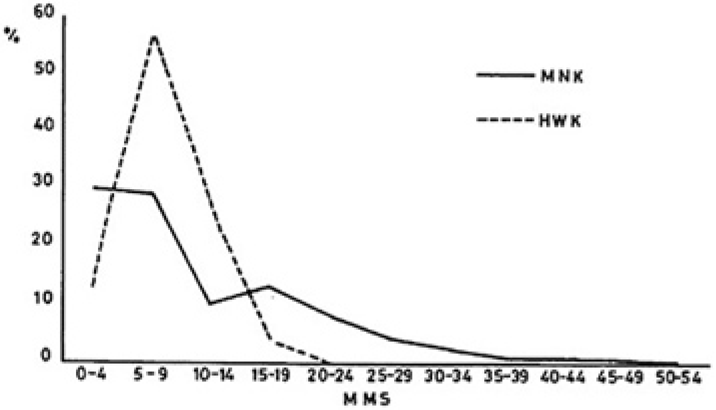

Figure 5.4 Frequency distribution offtake thickness at MNK CFS and HWK E 3–4.

were almost 1,000 very small chips, broken flakes and core fragments, representing some 59 per cent of the total assemblage. If these small pieces were present, water was not washing out any small chert flakes of the <1 cm type seen at MNK CFS that might have been present. The average size of the lava flakes was significantly larger than the chert flakes at HWK E 3–4 (Leakey 1971:108), thus if water sorting had occurred, any larger chert flakes originally present should still have been there along with the lava flakes. Another possibility to explain the lack of large chert flakes at HWK E 3–4 is that the chert was flaked there from nodules or cores that were small. This would still be an indication of selection and transport of small nodules, however, as large chert nodules are available at MNK CFS and in the chert horizon elsewhere. The lack of a single

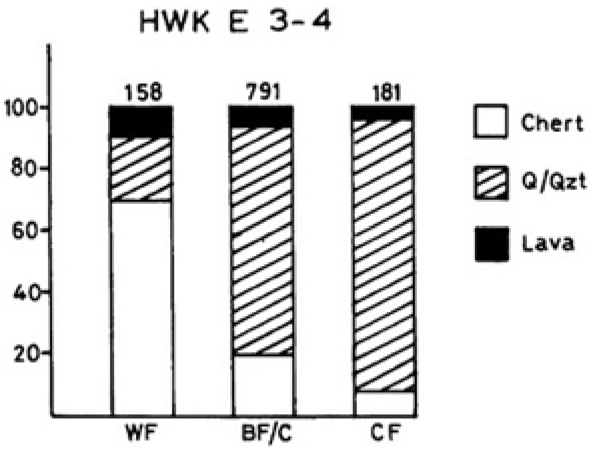

Figure 5.5 Proportions of chert, lava and quartz/quartzite raw materials in the debitage at HWK E 3–4 (see Table 5.1).

Key: WF=whole flake; BF/C=broken flake/chip; CF=core fragment.

chert nodule at HWK E does not support this possibility. There is thus no evidence that the restricted size range of the chert flakes was due to water sorting.

At HWK E 3–4, the chert whole flakes make up almost 70 per cent of that category, with the remaining 30 per cent being lava or quartz/quartzite. If flaking of all raw materials was being done equally on the site(s), one would expect a similar ratio in the other waste categories. However, almost 80 per cent of other waste is lava and quartz/quartzite, and only some 22 per cent is chert (Figure 5.5). Thus we see about a 3:1 ratio of chert flakes to other waste, and almost a 1:4 ratio of these categories with the other raw materials (Table 5.1). It is unlikely that differential water transport could explain this dramatic difference. Chert whole flakes would have to be transported in a completely opposite way to other chert debitage in relation to other raw materials. In addition, there were no chert flakes that could be refitted with other chert artefacts (Yuki Kimura, pers. comm.). Another important factor

Table 5.1 Flaking waste raw materials at HWK E 3–4.

Raw material	*Whole flakes (%)*	*Broken flakes /chips (%)*	*Core fragments (%)*
Lava	8.9	2.1	1.1
Quartz/quartzite	21.5	75	91.7
Chert	69.8	22.9	7.2
Total (N)	158	791	181

Source: Leakey 1971: 104, 108

to consider is that HWK E is upstream from the known chert sources in the former lake, and thus chert could not have been brought there by moving water from this source (Hay 1976).

Referring back to the three hypotheses presented above, the lithic study indicates that:

1 Chert was not being flaked from nodules at HWK E 3–4 in the same way as at MNK CFS, because the flake attributes and chert flaking waste show very different patterns in the two assemblages. MNK CFS displays patterns that would be expected from *in situ* flaking, i.e. a high proportion of primary flakes, a wide range of flake attributes, and a very high proportion of small debris to whole flakes. HWK E 3–4 has few primary chert flakes, a very restricted range of flake size and thickness, and a low proportion of flaking waste to whole flakes.
2 Flake selection and transport were occurring at HWK E 3–4, supported by the evidence provided in 1 above.
3 Not all lithic artefacts seen at HWK E 3–4 were manufactured there. The debitage categories of chert are opposite those of quartz/quartzite. The high proportion of quartz/quartzite debitage, including core fragments, to whole flakes at HWK E 3–4 is suggestive of a high degree of working of this raw material on the site. The reverse pattern with chert supports the hypothesis that chert whole flakes were not produced often on the site, but rather they were transported in.

DISCUSSION

One can conclude that the MNK CFS represents a place where hominids went recurrently to flake chert. The dense concentration of *in situ* nodules, flaking waste and modified chert pieces in lake margin (not stream channel) sediments would be difficult to explain in any other way. There were extremely few bone pieces, suggesting that animal carcasses were not brought there for butchery. The fact that chert artefacts were found at sites away from the chert sources means that they were transported there. The lack of evidence for water transport or sorting, and the fact that the sites are upstream from the chert sources, supports the hypothesis of hominids as the transport agency. This hypothesis is further supported by good evidence for selection of a certain size and thickness of chert flake to transport for raw material provisioning purposes at another site or sites. The distance of transport is irrelevant in respect of the cognitive behaviour interpreted to have occurred. Hominids were planning ahead for the future use of stone artefacts that displayed a specific and restricted range of attributes. Presumably the functional activity for which these artefacts would be used was also planned.

The archaeological record described here matches behaviour observed ethnographically in the Western Desert of Australia. Gould *et al.* (1971)

observed Aborigines creating a ‘chert factory site’. To work chert nodules, an Aborigine uses small boulders to smash them. He then:

> selects the flakes he wants from the resulting pile of chippings and debris. Working in this way, a man can leave behind as many as 200 waste flakes for each flake he actually chooses. Behaviour like this accounts for the tremendous quantities of unused stone flakes [and presumably other waste] which one characteristically finds on the surface of Aboriginal quarries…. Sometimes he performs a little preliminary trimming by percussion-flaking on the spot; but more commonly, he carries the selected flakes away with him.
>
> (Gould *et al.* 1971:160–1)

The two anvils found at MNK CFS correspond to the Aborigines’ ‘small boulders’ and the hammerstones suggest that some trimming was done at the factory site. Retouched chert pieces were in fact found at both MNK CFS and HWK E 3–4. This ethnographic observation is so strikingly analogous to what may have occurred at Olduvai Gorge that the author here has risked the criticism for making a facile ethnographic analogy. The purpose is simply to show that such behaviour is part of the hominid behavioural repertoire involving stone tool manufacture and transport.

There were other raw materials represented in the assemblage as well. Some 50 per cent of the choppers were made of lava from Sadiman, an extinct volcano, gneiss artefacts came from Kelogi hill, and quartzite came from the inselberg of Naibor Soit. Table 5.2 and Figure 5.5 show the raw material sources and distances from HWK E. Neither water nor non-hominid primates can plausibly be hypothesized as agents of transport for raw materials originating from such a wide distribution of sources. This stone transport is not as significant as that concerning the chert, however, as there is presently no evidence that certain forms were manufactured at source to be transported elsewhere for a predetermined use.

Stern’s (1993) explanation of HWK E 3–4 would presumably be that the stones and bones found in association represented a time-averaged palimpsest

Table 5.2 Raw material sources and distances from HWK E.

Raw material	*Locality*	*Distance from HWK-E (km)*
Chert	Main chert unit	1
Phonolite	Engelosin	9
	North Sadiman	12
Trachytic lava	Ngorongoro	11
Olivine basalt	North Lemagrut	10
Quartz/quartzite	Naibor Soit	2
Gneiss	Kelogi	8

of materials that had a variety of taphonomic and geomorphological histories. In the past, the pieces would have been scattered here and there, but by chance they ended up being buried in a concentration, later to be partially exposed by erosion and eventually excavated. This explanation avoids identifying the agent that created the concentration. If it was not hominids, was it moving water, a slope, or carnivores? It has already been shown that none of those agencies can adequately explain the pattern observed for the HWK E raw materials.

It is possible that water influenced their immediate history association, however. That is, the pieces were lying in the general vicinity of each other in a scatter, or scatters, of unknown density when at some point in time the stream entering the Bed II lake brought the pieces together. The freshness of most of the material and the lack of sorting or orientation argues that water action would have been brief and of low energy, a conclusion similar to that of Petraglia and Potts (1994) for Level 4. The original association of the diverse materials would still need to be explained by hominid transport, however. The archaeological value of the site would be reduced because spatial analysis would not be valid. That does not, however, invalidate the conclusion that the material represents hominid behaviour, and other information can be derived from the data.

The problem raised by Stern (1993) of the contemporaneity of the material cannot be answered at present. It certainly appears unlikely, given the thickness of deposits in which the material was found at HWK E 3–4, that the same group of hominids produced all of it. The material most likely represents the results of the behaviour of many different hominids over many years. This does not invalidate the general conclusions, however, that hominids in one place were manufacturing stone tools to take to another place for use. In fact, the evidence suggests that this activity was being carried out over a long period of time and thus was part of the normal repertoire of hominid behaviour at this time.

The evidence presented here says some very important things about hominid behaviour some 1.7 myr ago:

1 Hominids were repeatedly going to one place to work intensively a high-value raw material—chert. This is the earliest evidence of such behaviour.
2 Hominids were manufacturing and selecting a certain type of chert flake to transport to a functionally different type of site.
3 Raw material transport distances measured several kilometres.
4 Early hominids displayed planning depth previously thought by some to be lacking.
5 The manufacture and *selection* of a certain type of chert flake, and transport of those flakes to another place for subsequent repeated use, is outside the range of any observed ape behaviour, and thus marks the earliest unequivocal human behaviour in the archaeological record, as indicated by advanced cognitive capabilities.

Another site that could provide further information was briefly tested by the author in 1972 at Locality 202 on the Fifth Fault, a little under 5 km north of the main gorge (Figure 5.6). A 9 m^3 surface collection yielded 172 stone artefacts, 127 of them of chert, and six bone fragments. A 5 cm deep spit in two of the square metres produced a total of 78 chert, 49 quartz, seven lava, one phonolite, and one feldspar pieces, as well as 41 bone fragments and three teeth. At least one flake could be refitted to its core. The material was concentrated in an approximately 10 cm thick band in a thin lens of pyroxene sand at the top of Tuff IF. A geologist studying Olduvai Gorge (Hay 1976) interpreted the sand as being all of what remained after the glass in Tuff IIA weathered to clay (Hay, pers. comm.). The deposits between Tuffs IF and IIA were eroded away before the archaeological material was deposited. The interpretation, therefore, is that the material is an *in situ* accumulation of residues of a discrete period of hominid activity that was covered by the volcanic ash of Tuff IIA.

If the geological interpretation is correct, it would appear that this site represents a ‘living floor’ broadly contemporaneous with MNK CFS and HWK E 3–4. This raises a fundamental weakness in Stern’s (1993) main thesis. She compared materials from surface scatters with excavated (i.e. buried) accumulations. She did not compare surface scatters with surface accumulations or buried scatters with buried accumulations, which would have been a more logical approach if analogy is the main analytical methodology. Stern ignores sites that on geomorphological grounds represent brief periods of time. For example, at FxJj 1 at Koobi Fora there was a definite ‘floor’ of material lying on a tuffaceous sand, situated in a fine-grained unbedded tuff silt. The material found on that floor should be contemporaneous, unless one argues that it was accumulated by water over time from surface scatters before burial. That would be difficult to do, however, as there were leaf casts and tiny bone fragments in the silt (Isaac 1976) indicating sediment deposition in an extremely low-energy environment. In fine-grained deposits on relatively flat land, what agency would have accumulated the material? Hominids would seem to be the only viable agency.

CONCLUSIONS

Several investigators have presented arguments that concentrated accumulations of archaeological debris from the Plio-Pleistocene are not the result of pene-contemporaneous hominid behaviour focused at one place. Most archaeologists would agree that in some situations this is true, for example in high-energy fluvial contexts and former carnivore lairs. In low- or no-energy fluvial contexts, and when large quantities of stones, bones and other materials or structures are found in association, however, one must offer an agency of transport alternative to hominids to explain the accumulation. Stern (1993: 215) argues that the patches of excavated archaeological debris are stochastic accumulations on the

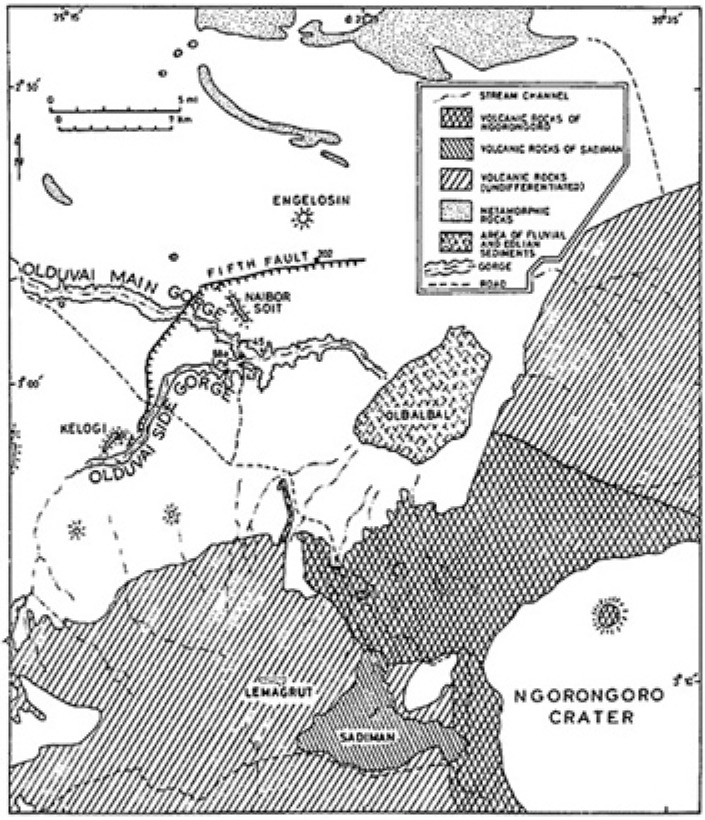

Figure 5.6 The locations of various sources of raw materials found in the artefacts of HWK E 3–4 (see Table 5.2).

surface of a landscape that were subsequently buried. Binford (1981, 1985) makes arguments with similar conclusions that factors other than hominids can explain the artefact and bone patterns observed. If their arguments are true, why did neither of them find contemporary preburial surface accumulations similar to the excavated sites? An obvious answer is that it is because there are no longer hominids transporting and accumulating the material. No one has been able to provide contemporary analogues to the archaeological occurrences, except in an ethnographic context involving human behaviour.

Ethnoarchaeological studies have shown that surface material can be buried with minimal disturbance and relatively quickly (Gifford and Behrensmeyer 1977; Yellen 1977). To accept the time-averaged model, we would have to believe that *all* similar prehistoric buried sites were eroded and the material randomly dispersed, then new accumulations were made over a long period of time, then reburied and re-eroded to be found by the archaeologist. In addition, surface scatter material would be mixed in before the final reburial. Whilst this process would be possible, even probable, with some of the sites excavated to date at Olduvai Gorge, Koobi Fora and elsewhere, it would be highly improbable at other sites, such as MNK CFS and HWK E 3–4, for the reasons presented above.

The Olduvai Gorge raw material study supports the hypothesis that at least some accumulations of archaeological lithic debris were brought into the same locus by hominid transport. It is unnecessarily pessimistic to conclude that all archaeological accumulations are stochastic, long-term events. Stern, Binford and others have only strengthened warnings made by many archaeologists over the years that geomorphological context should guide the archaeologist as to what behavioural inferences can legitimately be derived from the evidence. The analytical approach taken in this study (i.e. differential proportions of raw material types, stone sizes, and shape attributes) can be used to add information relevant to interpreting Palaeolithic site formation processes in a variety of geographical and depositional contexts.

NOTE

1 Cores are not dealt with here, as M.D.Leakey classified all core-type objects under her tool categories. These would have to be studied in order to introduce this variable into the analysis.

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6

The earliest South African industries

KATHLEEN KUMAN

INTRODUCTION

Archaeological sites spanning the Plio-Pleistocene boundary are rare in South Africa. This is not because they may have been absent on the landscape, but rather because the conditions for their preservation are rarely met. From 2.5 myr, when the first cultural remains are recorded in East Africa, until the time when hominids began to occupy caves, the open nature of the earliest sites and the restricted circumstances needed to seal and preserve them mean that we must be content with rather fragmentary glimpses of the earliest prehistory in southernmost Africa. Currently the best documented artefacts older than 1.5 myr found in informative contexts are from sealed underground cave deposits in dolomitic limestone at Swartkrans (Clark 1993) and Sterkfontein (Mason 1962a, 1962b; Kuman 1994a, 1994b). It is likely that Oldowan tools are also distributed in open, disturbed alluvial sediments and gravels, but their informal character has made them typologically invisible. Only associated fauna would provide a framework for identifying such early occurrences, and such ancient fossils are rarely preserved in open contexts in South Africa.

We can reasonably expect that Oldowan hominids were widespread in other parts of southern and south central Africa beyond the Gauteng (southern Transvaal) caves. In Malawi, artefacts from Mwimbi, originally thought to be at least 1.6 myr old, are now considered to be reworked from younger sediments (Kaufulu and Stern 1987; Juwayeyi and Betzler 1995). However, the discovery of a hominid mandible 2.5–2.3 myr old at Uraha suggests that *in situ* assemblages may in time be found with the on-going geological mapping of tool bearing sediments (Schrenck *et al.* 1993; Juwayeyi 1995). At Senga in Zaire, artefacts associated with fauna 2.3–2.0 myr old are considered to be an Oldowan assemblage redeposited in younger sediments (Harris *et al.* 1990; Boaz *et al.* 1992). At Koanaka, in Botswana, flakes of non-local quartzite have been identifed in an Early Pleistocene karst cave infill (Pickford 1990; Pickford *et al.* 1994). On the Angolan coast south of Luanda, tools in a conglomerate are considered to be Developed Oldowan in age (Clark 1990). Thus, given the limited distribution of appropriate deposits even in East Africa, these indications in distant parts of southern and south central Africa should be regarded as potentially valuable evidence.

Early Acheulian tool types have long been documented in South Africa at Sterkfontein (Mason 1962a, 1962b, 1976; Clarke 1985). In river gravel contexts in southern Gauteng, two series of artefacts were excavated at Three Rivers and Klipplaatdrif (Mason 1962b). Although these alluvial assemblages are in poor context and without fauna, the technology is comparable to the artefacts at Sterkfontein, and they are considered to be Early Acheulian. Acheulian bifaces from lime miners' dumps at Swartkrans have been published (Leakey 1970), although they cannot be reliably associated with the *in situ* breccias dated by fauna. They may have derived from Member 3, which is estimated at *c.* 1 myr, or they may be younger, and thus technically cannot be termed 'early'. In southern Mozambique, sites with bifaces similar to those found in South Africa are currently being studied (Meneses 1995), which should shed light on the antiquity of Acheulian occupation in the southeast.

This handful of Developed Oldowan or Early Acheulian sites thus far provides only limited data for the southern part of Africa, but it is suggestive of fairly widespread hominid occupation by about 1.5 myr. By later Acheulian times, artefacts in both open and sealed cave contexts are well documented, especially in South Africa. Large geological concentrations of tools associated with bifaces and some with prepared core technology have been published for the lower Vaal River Basin (Goodwin 1928, 1933; Goodwin and Van Riet Lowe 1929; Van Riet Lowe 1937, 1945, 1952; Malan 1947; Humphreys 1969; Helgren 1978), and a number of open sites in alluvial and colluvial contexts have been recently investigated (Beaumont and Morris 1990). Many other open sites across the country have been recorded but not studied or published, because of their disturbed contexts. Better preserved open Acheulian sites occur in low-energy pan-margin or spring settings, such as Doornlaagte, Kathu Pan, Rooidam, and Amanzi, or in deflation hollow contexts as at Elandsfontein (Singer and Wymer 1968; Deacon 1970; Butzer 1974; Klein 1978; Mason 1988a). Quarry and other open sites have been published mainly for the Orange River Basin and the adjacent Seacow Valley (Sampson 1972, 1985), whilst many elsewhere have been recorded in unpublished archives. However, one partly sealed factory site on the Dry Harts River near Taung has been analysed in detail because it provides documentation of the Victoria West prepared core technology (Kuman n.d.). Another type of open site excavated by Mason (1962b) is Wonderboom, a hillslope rubble rich in Acheulian tools. Finally, cave sites with later Acheulian strata are few, but these are spread across different regions: Wonderwerk in the northwest (Malan and Wells 1943; Beaumont and Morris 1990; Binneman and Beaumont 1992), Montagu Cave in the south (Keller 1973), and Olieboompoort and Cave of Hearths in the north (Mason 1962b, 1988b).

Such an expansion in the numbers of archaeological and geological sites following the Early Acheulian reasonably suggests a large population increase. Nonetheless, it is clear that the underground cave deposits that preserve the earliest artefacts are only a limited sample of occupations that existed during the Oldowan and Developed Oldowan/Early Acheulian, and many of these cave sites are also not fully tested.

THE EARLIEST SOUTH AFRICAN SITES

The Transvaal caves are not living sites but underground caverns that preserve traces of surface occupations within the catchment of a cave opening (Brain 1958, 1981; Partridge 1978; Vrba 1981; Kuman 1994a). The one exception that has been suggested most likely to represent a habitable cave is Swartkrans during the accumulation of the Member 3 infill (Brain 1993:262–3). Here, fire management has been proposed based on the chemical analysis of burnt bone and its configuration in the deposit, although the artefact accumulation is limited and does not reflect occupation debris (Clark 1993:167). Even if Member 3 does not represent a major occupation of the cave at this early date, cut- and chop-marked bones attest to surface occupations with significant human involvement in the faunal assemblage (Brain 1993:261–3). This has not been demonstrated for the preceding faunal assemblages from Swartkrans, nor for Sterkfontein or other less well-studied caves in the region. Estimated at *c.* 1 myr old, Swartkrans Member 3 is one of the youngest infills under study.

Cave shape and surface features evolve over time, and each infill within a single cave must be evaluated separately for the taphonomic history of its fauna and the site formation processes revealed by artefacts and sediments. Of some thirteen Plio-Pleistocene caves worked to date in South Africa, only Sterkfontein, Swartkrans and Kromdraai have at this time been verified to contain stone tools (Table 6.1). Of the remaining ten sites, only Taung does not appear to have infills of the right age. Buffalo Cave, Haasgat and Coopers B are broadly placed in time, and at least the latter two sites have carnivore-accumulated assemblages. Modified stones from the Early Pleistocene Member 5 at Makapansgat are generally not accepted as artefacts. The remaining five sites of Plovers Lake, Gladysvale, Gondolin, Bolt's Farm and Drimolen have Late Pliocene to Middle Pleistocene infills, but do not appear to have been in geographic settings attractive for hominid use. These facts highlight the restricted physical circumstances required for the preservation of early cultural materials in South Africa. It is not coincidental that the three proven arte-fact sites lie within a 3 km line of one another, and all are within the same geological formation and close to the raw material sources of the Blauubank River gravels.

Sterkfontein is the most intensively worked of the cave sites yielding early stone tools. Its tool bearing deposits were excavated by Brain, Mason and Robinson between 1957 and 1958 and then continuously since 1966 by

Table 6.1 Plio-Pleistocene cave sites in South Africa.

Site	*Age estimate*	*Hominid/s*	*Stone artefacts*	*Selected references**
Taung	3.0–2.4 myr	X	–	Delson 1984; McKee 1993, 1995; McKee and Tobias 1994; McKee *et al.* 1995
Makapansgat Members 3–4	3.2–2.9 myr	X	–	McFadden *et al.* 1979; Vrba 1982, 1985; Maguire 1985
Makapansgat disturbed Member 5 and overburden	*c.* 1.7 myr	–	?	Vrba 1987
Sterkfontein Members 1–3	3.5–3.0 myr	X	–	Partridge 1978; Clarke and Tobias 1995
Sterkfontein Member 4	2.8–2.6 myr	X	–	Partridge 1978; Vrba 1975, 1985; Clarke 1994
Sterkfontein Member 5 sequence	2.0–1.5 myr	X	X	Partridge 1978; Vrba 1985; Clarke 1994; Kuman 1994a, 1994b
Kromdraai B decalcified	2.0+–1.7 myr	X	X	Brain 1958; Vrba 1985; McKee *et al.* 1995; F.
Kromdraai A decalcified	2.0–1.0 myr	–	X	Kuman *et al.* 1997
Swartkrans				
Member 1	1.8/1.7–1.5 myr	X	X	Vrba 1985; Brain *et al.* 1988; Brain 1993; Clark 1993
Member 2	1.5 myr	X	X	
Member 3	1.0 myr	X	X	
Bolt's Farm: mixed sites	*c.* 2.0 myr and 3.5–3.0 myr	–	–	Cooke 1991, 1993a, 1993b
Gondolin	*c.* 2.0 myr more	–	–	Watson 1993
	recent deposit?	X	–	
Haasgat	<1.5 myr	–	–	Keyser 1991; Plug and Keyser 1994
Drimolen	Late Pliocene	X	–	Keyser, p.c. 1995
Coopers B	Plio-Pleistocene	X	–	Brain 1958; Berger *et al.* 1995
Gladysvale				Berger 1993;

			Stone	
Site	*Age estimate*	*Hominid/s*	*artefacts*	*Selected references**
Pink breccia	Mid-Pleistocene	X	_	Berger and Tobias 1994;
Stony breccia	Mid-Pleistocene	–	–	Berger *et al.* 1993;
Australopith breccia dump	Late Pliocene	X	–	updated: L.Berger, p.c. 1995
Plovers Lake	*c.* 1.0 myr	–	–	Thackeray and Watson 1994
Buffalo Cave	Pleistocene?	–	–	Kuykendall *et al.* 1995

Note: *References are not comprehensive but have been selected for information on dating or other topics discussed in this chapter, (p.c.=personal communication)

Tobias and Hughes (to 1991) and Tobias and Clarke (from late 1991 to the present). This long stretch of uninterrupted excavation is partly responsible for the large number of artefacts, which exceeds 9,000 tools and manuports, if all cultural periods are totalled. Nevertheless, Sterkfontein was also the most attractive venue for tool making hominids through time, with a quantity of artefacts roughly tenfold that recovered from Swartkrans during Brain's twenty-five years of excavation.

As these caves are underground receptacles for debris from surface occupations, there would have had to be some landscape features that attracted hominids to each site. At Sterkfontein, this most reasonably would have been the shade trees that commonly grow at openings to underground caves where more moisture is present, as well as the outcrops of dolomitic limestone in which the avens to the caves have formed (Kuman 1994a). Some projections of dolomite in the area today are waist-high, and even such low outcrops provide good shelter on windy days. Other important attractions would have been gravels for raw materials, which lay within easy reach of the site (Kuman 1996), and possibly also standing water in the form of karstic pools (Stiles and Partridge 1979), as well as the vantage point afforded by high ground. The highly varied nature of analogous sites on the modern landscape suggests that the most comfortable localities would have been attractive in prehistoric times and visited frequently.

The earliest archaeological infill yet discovered at Sterkfontein contains Oldowan artefacts *c.* 2.0–1.7 myr old, although an underground talus under-lies this deposit and still must be tested.[1] This large assemblage of 2,800 pieces is succeeded in time by artefacts estimated roughly at ±1.5 myr. The next section provides a full discussion of the Sterkfontein artefacts, which constitute the most informative archaeological assemblages among the early South African sites. Swartkrans, which lies about 1 km west of Sterkfontein, is the next most prolific tool bearing site which has three geological members with early artefact assemblages (Brain *et al.* 1988; Brain 1993). Member 1 is dated to (at most) 1.8

or 1.7 myr, but not younger than 1.5 myr, which is the probable age of Member 2. Members 1 and 2 contain 402 and 403 artefacts respectively. Member 3, which is *c.* 1 myr, has only 72 artefacts. None of the three assemblages is considered to represent *in situ* flaking activities, either from cave or surface occupations, as the full size range of flaking debris is absent (Brain *et al.* 1988; Clark 1993). Artefacts accumulated in the cave deposits by gravitation or flooding through an aven from the surface. Clark believes that all the assemblages are similar and, based on the generally larger sizes of the chopper cores, that all material can be classed as Developed Oldowan, with some suggestion of Acheulian technology in the small Member 3 assemblage. His criterion for the latter is the presence of some bifacial flaking, as well as a few handaxes and cleavers found earlier in unprovenanced dumps (Leakey 1970). Although Clark distinguishes the Developed Oldowan and the Early Acheulian as industries, he puts emphasis on the importance of activity differences in creating such varied assemblages.

Sixty-eight bone tools have also been reported from the three Swartkrans members (Brain and Shipman 1993). Comparisons with experimental bone tools suggest that most have been used for digging in the stony ground typical of dolomitic sites, whilst a smaller number was also used for rubbing some soft material, and one appears to have been used as an awl for piercing. It is difficult to explain the localized tapering and polished ends of many of these items by natural processes alone, particularly if one examines the actual bones rather than photographs of them. Swartkrans is particularly rich in *Paranthropus* fossils, which suggests that this hominid living in the Sterkfontein Valley may have geared its tool culture more to underground food sources than other species. A higher degree of grit in their diet could explain some of the microwear pattern on paranthropine teeth observed by Robinson (1963) and Grine (1981, 1987). However, *Homo* fossils are also present at Swartkrans (Clarke *et al.* 1970; Clarke 1994b), and the stone tool assemblages cannot be attributed to any particular species.

Kromdraai lies about 1.7 km to the east of Sterkfontein. It consists of a faunal deposit known as Kromdraai A (KA), and a somewhat older deposit, Kromdraai B (KB), which has yielded hominid material, including the type specimen of *Paranthropus robustus*. One certain chert flake artefact, three less certain chert flakes, and one broken quartzite pebble have been published (Brain 1958, 1981: 261), all of which came from decalcified parts of KB and are unlikely to be *in situ*. Excavations renewed by Thackeray in 1993 have now produced one quartzite core from the KB overburden and a number of artefacts from decalcified sediment in KA. The KA tools lie together with well-mineralized bone, and Thackeray's aim is to determine if the newly excavated artefacts are *in situ* in the decalcified breccia or derive from the overburden. Ninety-nine artefacts and manuports have now been excavated from decalcified KA breccia and one good flake from hard breccia (Kuman *et al.* 1997). It is possible that all the pieces derive from an *in situ* deposit, but this remains to be demonstrated.

Nevertheless, they are an interesting addition to the small inventory of early cultural assemblages. KA and KB may be close in age, but KB is considered older and is also thought to be older than Swartkrans Member 1 (Vrba 1981, 1982; Vrba and Panagos 1983; McKee 1995; McKee *et al.* 1995). Less is known about the age of KA, although McKee *et al.* (1995) suggest it is near to Swartkrans Member 1 in time. Although KA is richer in bovids and KB in primates, both faunal assemblages are primarily carnivore-accumulated (Brain 1981). This could explain the relative paucity of artefacts, if surface features at Kromdraai were less attractive to hominid occupation than at Sterkfontein and Swartkrans.

The many thousands of stone artefacts at Sterkfontein contrast with the smaller assemblages from Swartkrans and the even smaller collection from Kromdraai, yet they are all close neighbouring sites along the same river. One clue to this difference may lie in some rare specimens of fauna. Both Swartkrans and Kromdraai have yielded hippo, whilst KB has also produced a crocodile specimen (Vrba 1981; Brain *et al.* 1988, Brain 1993). Neither of these water-dependent species has yet been found at Sterkfontein, which could indicate that the river was slightly more distant from the site when the archaeological deposits were accumulating, although it was still within easy access. The difference may also have been due to better topographic features at Sterkfontein which attracted hominid tool users more frequently.

The only site outside the Sterkfontein Valley that has been argued to contain early stone tools is Makapansgat in the northern Transvaal (now Northern Province). This site is best known for its ancient infills *c.* 3 myr old which, until 1994, had yielded the oldest South African australopithecines.[2] Member 5, however, is of Early Pleistocene age and thus young enough for artefacts (Vrba 1987). Thousands of natural cherts, cherty dolomites and quartzites were recovered from collapsed parts of Members 4 and 5 and from overburden and solution pockets in the expectation that crude early artefacts would be found, but it was concluded that this collection consisted of naturally modified stone and stone fragments (Maguire 1965, 1968; Mason 1965). Maguire (1980) meticulously excavated Member 5 overburden and solution pockets and located a number of quartzites *in situ* in hard breccia. Of the vast amount of stone from this site, the Member 5 quartzites were generally considered more likely to be manuports and artefacts, although natural quartzite pebbles do also occur on occasion in the older members. Mason and M.D.Leakey both recognized that some flakes among the many natural pieces did exhibit conchoidal fracture more typical of artificial than natural fracture (Mason 1965; Maguire 1980). However, the context of these few items among many thousands of natural stones does not seem convincing. If there are true artefacts in Member 5, the published data indicates that they are very rare and not in good archaeological context, but derive from gravels and hillside rubble. Until the day when intact Member 5 breccia may be studied systematically, it seems more reasonable to regard the question of artefacts at Makapansgat as an open question.

HOMINID ASSOCIATIONS

With the foregoing discussion, I have tried to demonstrate that the limited nature of early cultural remains in South Africa is determined by the special circumstances required for their accumulation and preservation. With an increased level of research activity this decade, we can only hope that more finds will surface, particularly more finds associated with hominids, as we know very little about the species responsible for artefacts older than 1.5 myr. At Sterkfontein, tool making has been attributed either to *Telanthropus* (Robinson 1958), now referred to as *Homo ergaster,* or more recently to *Homo habilis,* due to the discovery of the StW 53 cranium at the southern end of the archaeological deposits, Member 5 (Hughes and Tobias 1977; and see Figure 6.1). However, new excavations now suggest that the stratigraphy in this area of the site should be reinterpreted (Clarke 1994a). We now believe that some artefacts 'associated' with the cranium actually belong to a later breccia lying in contact with the StW 53 infill, whilst others appear to have infiltrated the deposit through the soft decalcified sediments of a solution pocket that contained part of the cranium. Our recent excavation of cemented, intact StW 53 breccia has not uncovered any artefacts in true association with the hominid (Kuman and Clarke 1996; Clarke, in press). As this breccia appears to be the first infill to succeed the australopithecine bearing Member 4 breccia (Clarke 1994a), it should fall somewhere in time between 2.6 and 2.0 myr.

The artefact-bearing Oldowan infill (2.0–1.7 myr) lies in Member 5 East. From here, the only hominid specimens are three teeth of *Paranthropus robustus* and an ulna shaft. From Kromdraai B, there is also *Paranthropus robustus,* but no artefacts proven to be *in situ,* while KA has not yet produced hominid fossils. At Swartkans, both *Homo* and *Paranthropus* are associated with the artefacts, including those from Member 1. However, a slightly younger age than the Sterkfontein Oldowan infill is indicated by the more derived or specialized features of the *Paranthropus* teeth, which Howell (1978), Grine (1982) and Clarke (pers. comm.) would assign to *Paranthropus crassidens*. Clarke (1977, 1990) also believes that the *Homo* from Swartkrans Member 1 is more evolved than *Homo habilis,* and he now assigns it to *Homo ergaster* (i.e. African *Homo erectus*). At Sterkfontein, the post-Oldowan assemblages are associated with a handful of hominid fossils. Most are either fragmentary or non-diagnostic of species, but StW 80–83 is cf. *Homo ergaster* (Clarke 1985, 1994b: 216–17; but see Kuman and Clarke n.d.).

THE STERKFONTEIN INDUSTRIES

The Sterkfontein Formation has been described by Partridge (1978) as consisting of six geological members. The three earliest members are visible only in the underground Silberburg Grotto and are dated on geological grounds to between 3. 5 and 3.0 myr. Member 2, which has now produced the oldest South African

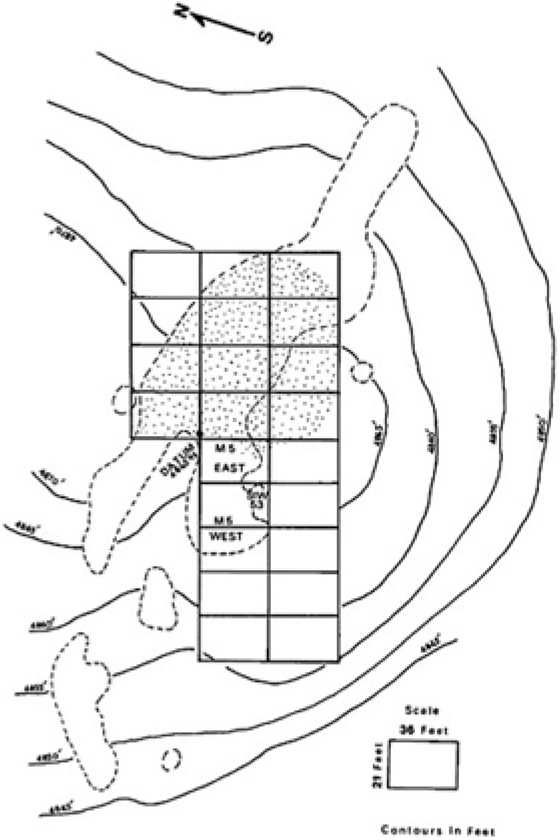

Figure 6.1 The Sterkfontein site, with the grid over Members 4 and 5, adapted from a plan by A.R.Hughes. Member 4 with *Australopithecus* lies within the stippled area. Member 5 with artefacts is indicated by die labels: M5 East=Member 5 East, M5 West=Member 5 West, StW 53=the southern part of the member with a cranium assigned by Tobias to *Homo habilis*. Dashed lines indicate cave entrances, quarried areas and deeper excavations.

hominid, is the best studied of these infills. It contains large parts of articulated skeletons, mainly of primates and carnivores, which resulted largely from natural deaths of the animals living around the caves (Clarke 1994a; Clarke and Tobias 1995). Such a death-trap situation is not uncommonly found in caves with narrow openings. In this circumstance, the opening that links the cavern's shaft with the surface may be newly formed, and the entrance is relatively small and dangerous if obscured by thick bush. As the dolomite continues to erode over time with dissolution in the slight acidity of ground and rainwater, the opening can become considerably larger. Blocks of roof rock detach and become incorporated as rubble in the cave's infill, which is consolidated as breccia with lime dissolved from the dolomite. This is the situation that prevailed during accumulation of Member 4, now estimated at 2.8 to 2.6 myr old.[3] The cavern was very large. Hundreds of fragments of fossilized lianas distributed in the southern end of the Member 4 deposits show that a sizeable opening was present in the south where these vines were able to grow down into the cave. Roof rubble of dolomite and chert occur throughout the infill, with the largest blocks of dolomite occuring also in the south where, due to the dip of the dolomite, the cave roof outcropped and was weakest.

The age of 2.8–2.6 myr for Member 4 pre-dates the earliest occurrence of artefacts in East Africa, and this appears to explain why tools are absent. Only australopithecine fossils occur in Member 4, which include *Australopithecus africanus* and a yet unnamed species of *Australopithecus* that Clarke (1989) believes is ancestral to *Paranthropus robustus*. Although we do not know which hominid made the earliest tools at 2.5 myr, the absence of artefacts in Member 4 does not rule out *Australopithecus* as a tool maker. We have to consider that this cave was the haunt of dangerous carnivores, who were responsible for the many hundreds of monkey and hominid fossil remains. It would not have been an attractive living site for hominids, and the surface features of the cave may have been more awkward for hominids than for carnivores and monkeys. Brooks and Laden (1995) have also argued that, prior to 2.5 myr, when moist, closed habitats were more extensive in Africa, hominid activity would have been more dispersed on the landscape, thus making it less likely that archaeologically visible sites would accumulate. In Member 4, the fossil wood fragments are dominated by a species of liana today restricted to central Africa, while a second species is a shrubby plant now restricted to forest margins along and inland from the east and south-east coast of the country (Bamford in press). As grasslands predominate in the Sterkfontein region today, Bamford envisions (at the least) a dense, humid gallery forest refugia in Member 4 times.

At some stage when the Member 4 cave had filled, the deposits may have been largely sealed with final roof collapse. The next episode in the cave's history was a period of erosion or collapse that affected the western flank of the Member 4 deposits (Partridge 1978; Partridge and Watt 1991). Eventually, new surface openings formed in the west through complex processes: dissolution of the dolomite roof which allowed solution channels to erode into older breccia, and collapse of breccia into lower chambers which created voids. The Member 5 infills entered, banked against the western flank of Member 4. Thus the contact between the artefact-bearing Member 5 and the Member 4 australopithecine breccias is an unconformity, with the contact well delineated by the eastern limit of the artefact distributions in Member 5 (Partridge 1978; Partridge *et al.* 1991; and see figures in Clarke 1985; Kuman 1994b).

The Member 5 breccias are difficult to interpret because they consist of a series of fills not well distinguished by lithology, and complicated by later episodes of decalcification affecting both the colour and the consolidation of the deposits. Clarke (1994a) believes that the StW 53 breccia in the south was admitted through the first opening, but this infill was later destabilized by collapse into a lower lying cave. Much of the StW 53 breccia would have been lost through collapse into this lower chamber. Later, a void left in Member 5 East filled with the breccia that contained the Oldowan assemblage. The exact history of the subsequent Member 5 infills is still under study, as are the assemblges that have been referred to both the Developed Oldowan and the Early Acheulian.

As underground receptacles, the South African caves contain what may be called an 'erosional mix' of sediments from many past environments represented in the surrounding landscape (Butzer 1971; Brain, pers. comm.). Deposits take the form of consolidated sloped tali, and there are few horizontal strata and no palaeosols to aid traditional stratigraphic interpretation. Distinctions based on laboratory study of the sediments can also differ (e.g. Partridge 1978 *v.* Butzer 1984). Add to this further interpretive problems: solution channels that invade older fills and later admit younger sediments in complex physical relationships (e.g. the Hanging Remnant in Swartkrans Member 1, Brain 1993), or solution pockets that may admit younger material to lie in false association with an older breccia's contents. These intricacies make long-term study of deposits and testing and revision of interpretation a necessity. It is often easier to be confident when dealing with the centre of an infill where matters are clearest, but caution is needed in describing contact zones or areas that may be affected by collapse or decalcification. One of the better clues to distinguishing infills at Sterkfontein is differences in site formation processes between the Oldowan and the post-Oldowan deposits, which are the next subject of discussion.

The Oldowan

Deep levels of Member 5 East contain an infill distinct from all other arte-fact bearing deposits yet excavated. The artefact assemblage is assigned to the Oldowan industry and consists of 2,800 artefacts and manuports, 83 per cent of which is flakes and chips under 20 mm maximum length (Table 6.2; Kuman 1994b). With a majority of pieces in fresh condition, this assemblage points to a period of accumulation when the landscape adjacent to the cave entrance was relatively stable compared with the later assemblages. Fossil equid, ostrich and springhare indicate a much drier habitat than the tropical gallery forest of Member 4 times. However, the Oldowan sediments have a higher clay and silt content than the subsequent Member 5 infills, which may indicate a relatively moister climate in the early stages of Member 5 (Partridge 1993).

Table 6.2 The oldowan assemblage from Member 5.

Category	*N*	*%*
Complete flakes >20 mm	146	5.2
Incomplete flakes >20 cm	165	6.0
Retouched tools	4	0.1

Category	*N*	*%*
Flakes, chips, chunks <20 mm	2,314	82.6
Chunks >20 mm	122	4.4
Cores and core tools	23	0.8
Protobiface (1)		
Casual cores (2)		
Chopper-cores (4)		
Discoid core (1)		
Polyhedral or irregular polyhedral cores (9)		
Bipolar-flaked cores/chunks (6)		
Natural stones	20	0.7
Split pebbles	6	0.2
TOTAL	2,800	100%

Notes: Three pieces have been added to the list since its first publication (Kuman 1994b). The spits assigned to the oldowan infill have been identified conservatively at this time because of the complicated stratigraphy. Further additions may be made following future excavations and analysis.

The capture of so much small debitage in good condition and the full range of artefact sizes indicate that material was not significantly transported on the surface before the assemblage was introduced into the cave.

This infill is estimated at 2.0–1.7 myr on the presence of *Phacochoerus modestus,* which compares best to specimens from Olduvai at 1.8–1.7 myr (Cooke 1994), and also on Clarke's comparison of the *Paranthropus* teeth with those from Kromdraai B and Swartkrans (Kuman 1994b). The ostrich fossil is a giant species that is also recorded at Olduvai, FLK Site 39, which pre-dates the Early Acheulian at 1.6 myr (Leakey 1967; Leakey 1971). The fauna shows no obvious signs of hominid involvement, such as cut-marks.

All artefacts from Sterkfontein are the result of relatively long-term accumulations, or what Stern (1993) calls 'time-averaged' assemblages. This fact, and not the intensity of occupation, is responsible for the large number of pieces in the Oldowan infill (Kuman 1994a). Another factor is that 91 per cent of the assemblage consists of vein quartz, which shatters readily and produces a high proportion of small chipping debris. Quartzite and chert make up the remaining 9 per cent. Certain features of the industry show that stone was used in a more casual way than in Developed Oldowan assemblages. Quartz was preferred over the other rocks, even though quartzite is much more abundant in the gravels. Flaking experiments with the local rocks suggest the reason (Kuman 1996). Quartz is brittle and more easily chipped than the other materials. One easy means to obtain sharp flakes and fragments of quartz is with the bipolar technique, which six of the twenty-three cores show was well known to these

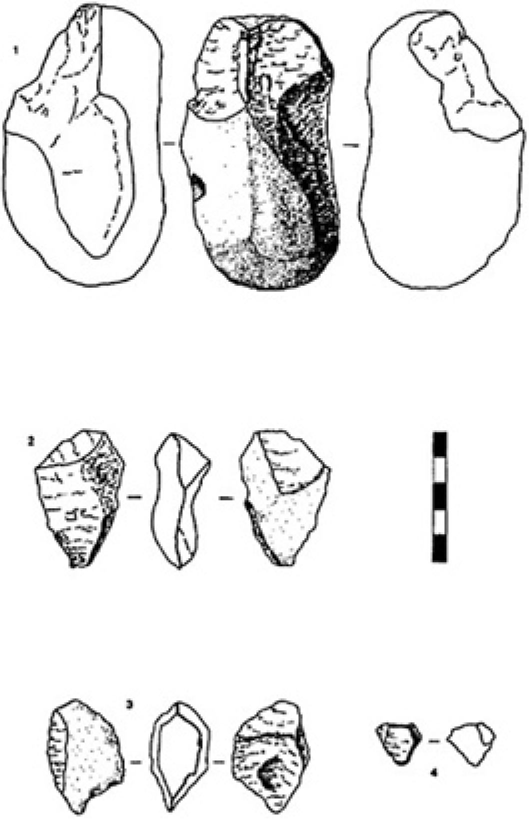

Figure 6.2 Bipolar-flaked cores and chunks from the Sterkfontein Oldowan, Member 5. All are made of quartz.

hominids. Bipolar flaking is often recorded in assemblages of varied ages that rely on small quartz pebbles that are difficult to hold in free-hand percussion (e.g. Chavaillon 1976; Barham 1987). At Sterkfontein, it is used on both small and large pieces (see Figure 6.2). My experiments show that the more rounded quartz cobbles are most easily flaked in this manner.

When quartzite was used, it may have been worked in the easiest manner. Of the five quartzite core-forms, four show splits or irregular fractures prior to flaking. Personal experiments show that throwing is an easy means of initiating fracture in the local quartzites. Quartzite cobbles thrown against an anvil or an outcrop of dolomite rock are almost always fractured within several throws. The first throws usually create or follow an internal fracture, whilst subsequent throws weaken the piece and eventually remove a large fragment or flake or break the piece into two or more parts. Bipolar flaking of quartzite takes greater physical effort, but it usually splits the piece or produces fragments. Throwing and splitting quartzite produce scars that are distinct from free-hand, hard-hammer percussion. The scars can be quite irregular as they follow weaknesses or irregularities within the stone, or they may be planed and resemble natural fractures. In other examples, they may terminate in a curved fracture at the distal end.

Thus, for both quartz and quartzite, the easiest techniques suited to flaking each type of stone are potential features of the Sterkfontein Oldowan. To use a concept recently proposed by Harris (1995), stone use tends to be more expedient in industries older than 1.5 myr. Despite the expedient character of such old assemblages, however, there are still signs of quite sophisticated cognition capable of evaluating the properties of individual raw materials and finding the most suitable approach. Whilst such traits continue to be seen in later assemblages, other aspects of stone use change with time and reflect a less expedient or less casual approach typical of the Oldowan.

Of the twenty-three Oldowan core-forms at Sterkfontein, eighteen are in quartz and five in quartzite (Table 6.3). Both these materials derive from gravels of the Blaaubank River, which today is within 500 m of the site. Remnant gravels are recorded within 300 m of the site, but closer gravels may have existed, the traces of which have been removed by hillslope erosion (Partridge, pers. comm.). The quartzites derive from the Witwatersrand Supergroup and Black Reef Formation, and the quartz from veins within the quartzites and shales of these rocks and the Chunniespoort Group of dolomites. With the main source of the Blaaubank being near Randfontein to the south, the river traverses about 21 km before reaching Sterkfontein, which subjects the rocks to only limited rolling and abrasion. Thus the blocky forms of the original quartzite and quartz cobbles found in the river gravels have not on average been very heavily rolled by the time they reach Sterkfontein. Cobbles tend to be polyhedral and faceted and include a variety of angular, blocky to more rolled polyhedral shapes. Few discoidal and spheroidal shapes occur, as these are formed by more extensive abrasion. There is also much variety in the size of pieces from pebble to cobble grade, as well as occasional boulders.

These raw material features have influenced the character of the assemblage. From such forms we would expect fewer of the classic Oldowan chopper-cores made on well-rolled cobbles that are so common at Olduvai (Leakey 1971). Instead, polyhedral cores in quartz are the most common

Table 6.3 Raw materials used in the oldowan assemblage from Member 5.

Category	*Qt*	*Qe*	*Ch*	*Db*
Complete flakes >20 mm	106	27	13	0
Incomplete flakes >20 mm	129	30	6	0
Retouched tools	3	0	1	0
Flakes, chips, chunks <20 mm	2,178	6	130	0
Chunks <20 mm	110	10	2	0

Category	*Qt*	*Qe*	*Ch*	*Db*
Protobiface	0	1	0	0
Casual cores	2	0	0	0
Chopper-cores	1	3	0	0
Discoid core	1	0	0	0
Polyhedral or irregular polyhedral cores	8	1	0	0
Bipolar flaked cores/chunks	6	0	0	0
Natural stones	8	2	7	3
Split pebbles	1	1	4	0
TOTAL	2,553	81	163	3
PERCENTAGE	91%	3%	6%	

Notes: Qt=Quartz; Qe=Quartzite; Ch=Chert; Db=Diabase.

type. The irregular manner in which vein quartz tends to fracture also contributes to the multifaceted shapes of these cores. With grainier materials, polyhedral cobbles may result in chopper-cores as well as polyhedral cores (Toth 1985). Both core types occur among the abundant quartzites in the post-Oldowan industry at Sterkfontein, but in the case of the Oldowan there are only five quartzite cores. Four show irregular fractures suggestive of splitting or throwing prior to flaking. Three of these were then made into chopper-cores and one into an irregular polyhedral core. The fifth quartzite is a proto-biface which was probably a pointed tool rather than a core.

The casual appearance of the industry is striking because the hominids have not selected for any particular cobble shapes or sizes. Thus there is selectivity for the type of raw material favoured (easily fractured vein quartz), but a lack of selectivity for rock shape. This is probably because rocks were chipped primarily for their flakes, rather than to create specific core-tools (Toth 1985). At sites in East Africa where Oldowan hominids flaked lava, there was careful selection for the quality of lava chosen and also sometimes for the size of cobbles (Schick 1987: 792; Schick and Toth 1993:126).

Figures 6.2 to 6.7 illustrate the types of core-forms in the Sterkfontein Oldowan. The types are described below in order of their frequency.

Polyhedral cores (n=5, Figures 6.3–6.4) are worked on all or nearly all faces, while *irregular polyhedral cores* (n=4) are less completely worked, but have too many removals to be termed *casual cores*. Eight are made in quartz and one in quartzite, the latter showing irregular scars possibly produced by throwing (Figure 6.3, bottom). These cores vary greatly in size, with a range of sizes from 35 to 119 mm.

Bipolar-flaked cores and *chunks* (n=6, Figure 6.2) are the second most frequent type, and all are made in quartz. No. 1 is an elongated rolled cobble with two scars probably produced by the same blow. At 102 mm long, this cobble would have been easy to hold, and was probably flaked with the bipolar method

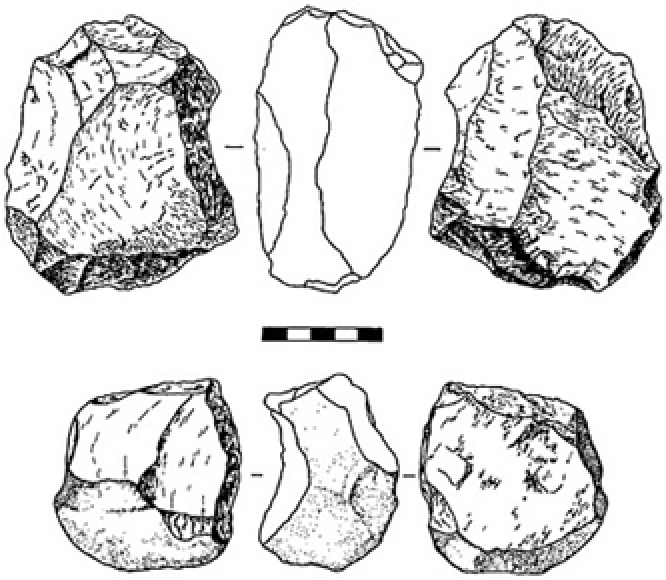

Figure 6.3 Polyhedral cores from the Sterkfontein Oldowan, Member 5. Top: a large polyhedral core in quartz. Bottom: an irregular polyhedral core in quartzite. Two scars on this piece were produced by throwing.

because of its rounded edges, which are more difficult to flake free-hand. Another piece is a flaked pebble, two are large chunks that may have come from split pebbles, and two are like tiny polyhedrons with signs of battering. These latter two are the ‘chunks’ referred to above, and because one cannot know if they were used as tools or cores, the cores and chunks have been grouped together as one type. Sizes range from 20 to 102 mm.

Chopper-cores (n=4, Figure 6.5) are cores with a series of contiguous removals but with no damage to indicate that they were used as tools. What defines these pieces as chopper shaped is the series of removals on at least one edge, but none resembles the classic type of chopper made on a well-rolled cobble or pebble. Each of the three cores made in quartzite has an irregular fracture of some sort. The fourth piece is made in quartz. Two are predominantly unifacial and two are bifacial. The number of free-hand flake scars ranges from four to fourteen and sizes range from 65 to 93 mm.

Casual cores (n=2, Figure 6.6) have only one or two free-hand removals, and both are made in quartz. Both pieces are made on forms with more angled edges, which experiments show are most suitable for free-hand, hard-hammer percussion. Sizes are 66 and 101 mm.

Discoid cores (n=1, Figure 6.7, top) are rare, probably because flat or bi-pyramidal forms that lend themselves to radial flaking are rare in the gravels. The one example is made in quartz with twelve facets and a maximum length of 43 mm.

Figure 6.4 Polyhedral and irregular polyhedral cores in quartz from the Sterkfontein Oldowan, Member 5.

Proto-bifaces (n=1, Figure 6.7, bottom) are presumed to be core-tools with a form intermediate between a chopper and a biface (Leakey 1971:5). They are not so well made as handaxes, but can have a pointed business end. The one example (106 mm) is made in quartzite on a very rolled polyhedral cobble, the distal end of which was probably well angled enough to allow free-hand flake removals without prior throwing or splitting.

SUMMARY

The Sterkfontein Oldowan thus has its own industrial character, with features clearly related to the type of available raw materials. Quartz was selected for its ease of fracture, and was flaked free-hand when suitable edges were present, but the bipolar method is common, apparently when forms were small or had more rounded edges. The tendency of quartz to flake and shatter readily has created

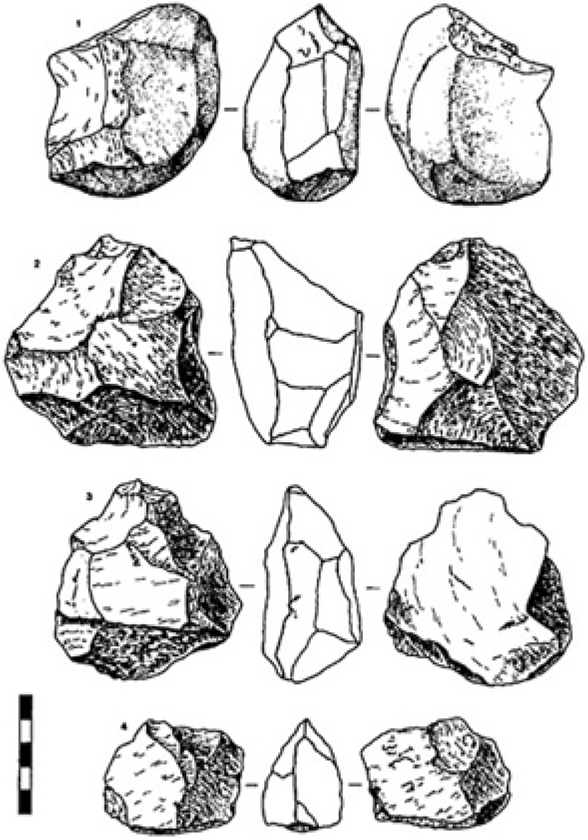

Figure 6.5 Chopper-cores from the Sterkfontein Oldowan, Member 5. No. 1: a quartzite unifacial side-chopper-core with four scars and one irregular fracture (right view, top). No. 2: a well-made quartzite bifacial chopper-core with fourteen removals in a near-radial fashion and one planed scar (right view). No. 3: a predominantly unifacial quartzite chopper-core with a split or ventral surface (right view) indicating that the piece was thrown or split. No. 4: a quartz bifacial chopper-core with 10 facets.

the large majority of small chipping debris, which was well preserved from surface occupations during the early formation of the Member 5 deposits. Quartzites may have been thrown or split to make flaking of the polyhedral forms easier. The most common core type is the polyhedron, but the principle of radial flake removal was well understood, as is evident in the discoid core and three of the chopper-cores. The dominant feature of this industry is its opportunistic, casual nature, which is probably due to the expedient nature of stone use common in the Oldowan prior to 1.5 myr (Harris 1995). However, there are signs of relatively sophisticated cognition evident in the ability to judge raw materials and adapt flaking techniques to them, and in the ability to flake

Figure 6.6 Casual cores in quartz from the Sterkfontein Oldowan, Member 5. Top: two removals are placed bifacially on a near-right-angled edge of a blocky cobble. Bottom: one stepped flake (left view) was removed from an acute-angled edge on a chunk.

radially or to succeed in removing a large number of flakes, which is evident in some of the choppers and polyhedrons.

The Post-Oldowan industry

The presence of an Oldowan industry this far south in the continent is a recent discovery, but slightly younger tools from Sterkfontein have been known since 1956 (Robinson and Mason 1957; Robinson 1962). These were termed Earlier Acheulian by Mason (1962a) but 'Developed Oldowan' by M.D.Leakey (1970). Later, the Developed Oldowan was formally distinguished from the Acheulian on its low percentage of bifaces, which were more crudely made (Leakey 1971, 1975). Mason (1976) did not agree with this quantitative approach. For him, the number of bifaces was less important than the appearance of more sophisticated flaking techniques. Debates have followed on the significance of the differences between the Acheulian and Developed Oldowan industries, with most theories drifting away from M.D.Leakey's original emphasis on different hominids or cultural traditions. Some researchers have emphasized raw material differences as the causal factor (Stiles 1979, 1980, 1991), whilst others have argued for activity differences (Kleindienst 1961; Clark 1987; Gowlett 1988), or for random variation (Isaac 1972). Most recently, Developed Oldowan bifaces have been proposed to be only more reduced, resharpened versions of their Acheulian counterparts (Jones 1994).

Whatever the explanation favoured, assemblages comparable in age to the Early Acheulian do occur that have few or no bifaces but show other more

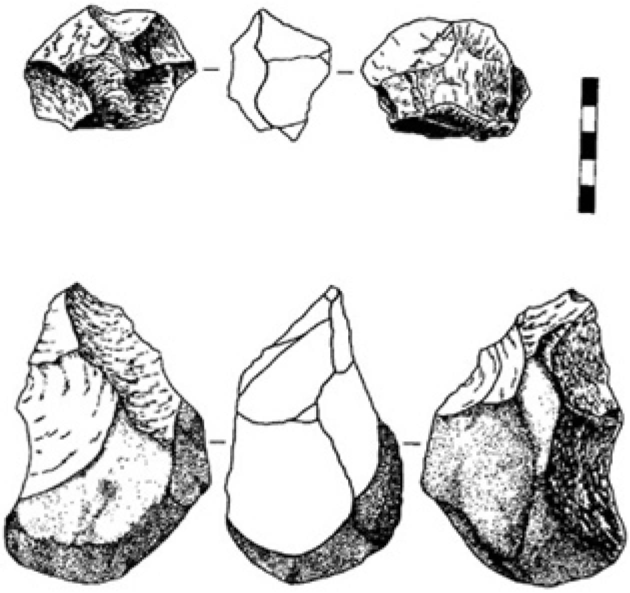

Figure 6.7 Two core-forms from the Sterkfontein Oldowan, Member 5. Top: a discoid core in quartz with twelve facets and a thick cross-section. Bottom: a proto-biface in quartzite which was probably a tool rather than a core.

evolved features, such as more spheroids, larger tool and core sizes, and greater variety of retouched tools. M.D.Leakey (1976) objected to the use of bifaces as a tool type diagnostic of the Acheulian, and stressed the increasing complexity of the Developed Oldowan toolkit. If both the Developed Oldowan and Early Acheulian are comparably complex, and other explanations (than hominid taxa) for their differences can be invoked, then the Developed Oldowan–Early Acheulian dichotomy is still maintained essentially for historical reasons and for ease of nomenclature. For example, it does not seem appropriate to term a developed assemblage Acheulian if it lacks bifaces, yet the absence of bifaces may relate only to the size or nature of the sample.

The 1996 Sterkfontein excavation makes a compelling case study in this debate about the Developed Oldowan, because here we do not have the complicating factor of differing raw materials or distance to raw material sources through time. Although the Blaaubank River may have migrated further from the site by 1.5 myr ago at the estimated time of the post-Oldowan infill, the difference is unlikely to have been more than a few hundred metres, and remnant gravels would have been available at even less distance. With this relative control over the ‘raw materials variable’, we are able to focus more on explanations related to sample size, random variation and activity differences, as well as those related to changes in hominid behaviour, as the following section explores.

New findings

Much of this decade of excavation at Sterkfontein has been devoted to clarifying the stratigraphic sequence in Member 5 as a necessary prerequisite to accurate identification of assemblages, spatially and chronologically. In the previous two decades, A.R.Hughes had excavated a large area of Member 5 East that contained much debitage thought to be associated with what are clearly Early Acheulian handaxes and cleavers, made on both large flakes and cores (Figures 6.8 and 6.9). However, large parts of this breccia were problematic because of the extent of decalcification in its upper 7 m. We thus concluded that the upper two-thirds of Member 5 East were contaminated in places with younger material filtering into the Acheulian breccia through solution pockets (Kuman 1994b). As only material excavated from the more consolidated parts of Member 5 could reliably be considered an *in situ* assemblage, we began more systematic excavation in Member 5 West where the breccia is well consolidated. Figure 6.1 shows the situation: Member 5 East, with debitage, is decalcified in large areas, and only below 7 m is the material reliably *in situ*. The base of the current excavation is at 10 m. Member 5 West has large, intact areas of hard breccia and no debitage. Further to the south is the StW 53 infill, which presents another research problem not relevant to this discussion. At the northern end of Member 5 West, there is also an area of soft sediment of the Middle Stone Age, not shown in this figure. The complexity of Member 5 illustrates the extreme caution with which assemblages must be defined in underground cavern infills, especially in deposits that lithologically do not appear to have separate beds or units.

The new, uncontaminated samples emerging from Member 5 West reveal an assemblage that clearly entered the cave under different depositional conditions from those that prevailed for the Oldowan infill. There is a total absence of small flaking debris (under 20 mm), and there are also very few flakes over 20 mm. Instead, the breccia is rich in cores, large chunks and stone fragments, and manuports or natural stones. As of June 1996, 349 artefacts and stones have been excavated here by Hughes and Clarke. To this figure must be added the 286 items excavated by Robinson in the 1950s, which are housed in the Transvaal Museum. Since cores normally comprise only a minor percentage of any undisturbed assemblage, this total of over 635 large arte-facts and stones is clearly only the remnant of a much larger assemblage of artefacts and manuports. The debitage, lighter tools and tool fragments have been winnowed from the occupation surface before material entered the cave. No gravels are present in the Member 5 West sediment, which argues against a stream-deposited assemblage. It is most logical to assume that continued erosion of the hillslope over time has winnowed the surface occupations of small elements before they became incorporated in the cave infill.

The new assemblage is identical to Robinson's excavated material, which includes one handaxe and two broken artefacts that could have been bifaces,

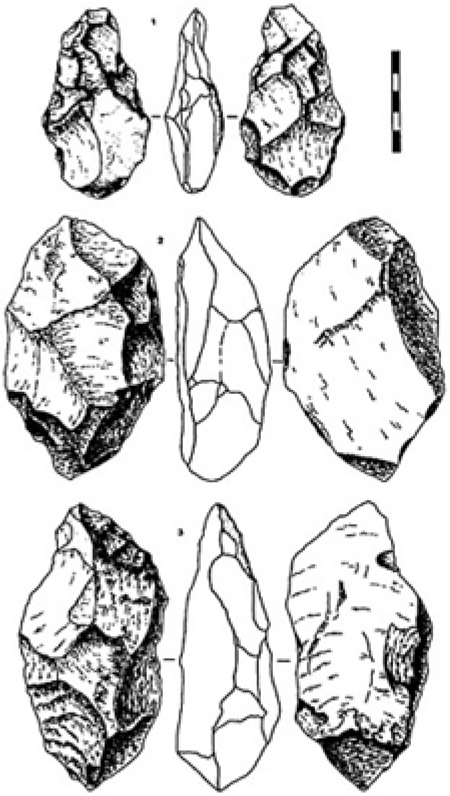

Figure 6.8 Diagnostic acheulian types from Sterkfontein, Member 5 East. No. 1: a chert bifacial handaxe. No. 2: a quartzite unifacial handaxe made on a large side-struck flake. No. 3: a quartzite unifacial handaxe made on a large end-struck flake.

according to Mason (1962a, 1962b). However, Robinson's catalogue in the Transvaal Museum records that the handaxe came not from solid breccia but from a decalcified pit. All handaxes and cleavers recovered by Hughes since 1966 derived either from Member 5 East or from lime miners' dumps, overburden and soft superficial deposits. This suggested to us that all definite bifaces had come either from Member 5 East or from decalcified and disturbed sediment in the rest of the member, which could have admited later artefacts. It thus became important to establish whether the consolidated breccia of Member 5 West held a separate industry, lacking bifaces, that might have preceded the undated Acheulian assemblage in Member 5 East. If this were the case, then Sterkfontein would prove to have a sequence of three industries in time: Oldowan, Developed Oldowan A without bifaces, as at Olduvai (Leakey 1971, 1975, 1976), and Early Acheulian equivalent to Developed Oldowan B.

Figure 6.10 shows some examples from the Member 5 West industry, which contrasts with the Oldowan in three important respects. First is the much larger

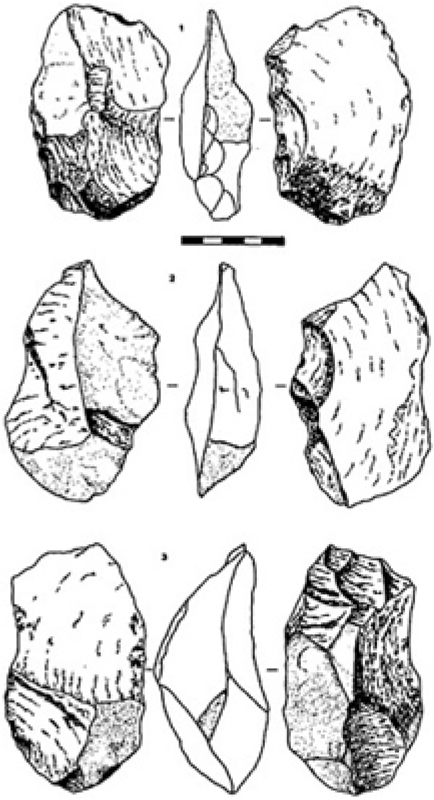

Figure 6.9 Diagnostic acheulian types from Sterkfontein, Member 5 East. No. 1: a quartzite cleaver made on a large side-struck flake with bulbar flaking. No. 2: a quartzite cleaver made on a large side-struck flake with bulbar flaking. No. 3: a mint-sharp quartzite cleaver fashioned on a cobble.

number of cores and unworked cobbles. This reflects a less expedient and more habitual use of stone suggested for many Developed Oldowan sites (Harris 1995). Second, igneous rocks are flaked for the first time. It is not yet clear whether two diabase spheroids, a type argued to be used as hammerstones (Jones 1994:282; Schick and Toth 1994), are stratigraphically associated. Third, there is a shift to much greater use of quartzite, accompanied by a general increase in core and manuport sizes. Quartz is still well represented, and quartzite continues to show irregular fractures (e.g. Figure 6.10, No. 3). However, this increased reliance on quartzite, which is more difficult to flake, is probably related to the more habitual use of stone in an evolving hominid culture. Quartz produces very sharp edges, but quartzite flakes will have more robust edges. The shift to quartzite may also relate to additional functions for which stone tools were wanted. The majority of the Member 5 bifaces are also made in quartzite.

As a whole, the Member 5 West assemblage appears quite crude, with many chunks and fragments. Many cores are only partly worked, presumably because raw materials were readily available, and this lends to the impression of crudity. Yet the upper limits of skills are apparent in occasional cores, such as No. 1 in Figure 6.10, which are more heavily worked. Perhaps such cores are worked further because of the quality of the quartzite, which varies a great deal, or perhaps because of the preference or skill of the individual knapper. Because there are many variables that influence each collection of artefacts, it cannot be over-emphasized that such rare items reveal more about evolving flaking skills than does the overall character of an assemblage. The upper limits of tool making abilities are only rarely revealed in early technologies.

Figure 6.10 Core forms from the Member 5 West breccia currently being excavated. No. 1: a well-made quartzite discoid core with thick cross-section. No. 2: a quartzite protobiface. No. 3: a quartzite cobble with irregular fractures.

This fact was even more amply demonstrated by a find made in May 1996 in Member 5 West (Figure 6.11). Just when the sample size of some 635 pieces seemed large enough to verify our hypothesis of a Developed Oldowan A industry lacking in cleavers and handaxes, a well-made cleaver emerged from the solid breccia. It is undoubtedly part of the assemblage, even being well cemented with breccia to a crude quartzite core. The skill evident in this cleaver is worth highlighting. It is made on a large flake, and the ventral side shows several well-directed removals that have reduced and shaped the base of the tool. Use-wear is also quite clear. The distal end or bit shows some large stepped scars that would have been produced by a hacking action, whilst the left dorsal edge shows the kind of unifacial wear found on scrapers. This particular cleaver thus appears to be a wood working (rather than a butchery) tool. Such use-wear on cleaver bits has been noted at Olorgesailie (Isaac 1977:88–9) and reproduced experimentally

Figure 6.11 A quartzite cleaver from solid breccia in Member 5 West.

in the chopping and shaping of tree branches (Toth 1982:241, Figure 5.67; Isaac 1984:129).

The new cleaver also has significance for the Developed Oldowan– Acheulian debate. It underlines the necessity of very large sample sizes for accurate classification. Without this new type, the Member 5 West assemblage could justifiably have been grouped with the pre-Acheulian, Developed Oldowan A industry; but with the discovery of such a sophisticated type, the industry must be considered Early Acheulian or Developed Oldowan B. Because there are a handful of other Acheulian-style bifaces from Member 5 as a whole, including some made on large flakes, it seems preferable to refer the post-Oldowan to the Early Acheulian. There is as yet no reason to differentiate the Member 5 West and East assemblages. Unless subsequent faunal analysis suggests a difference in time or mode of accumulation, we assume that they are associated.

Dating

The age of the Acheulian breccia will not be refined until new faunal analyses are completed, but previous estimates for these levels are 1.5±0.3 myr (Stiles and Partridge 1979) and <2.0 myr (Vrba 1985). We expect that a somewhat younger age relative to the Oldowan infill will eventually be established because of differences in the fauna, as well as the artefact assemblages. Another difference that suggests the passage of time is the winnowing of small artefacts from the site catchment zone, in contrast with the Oldowan. This would appear to indicate continuing surface erosion, which eventually resulted in the gently rolling hilly landscape we see today. Whilst Member 4 has moisture loving vegetation and a mix of forest and grassland fauna, the Oldowan fauna points to a drier, more open landscape, but nevertheless a site catchment with good retention of material from surface occupations. For the Acheulian assemblage to be winnowed of small material, the landscape surrounding the cave entrance should have been less vegetated and less stable, with a higher degree of run-off. Although this implies continued erosion, there is also the possibility that the differences are site-specific or even seasonal. Any firm conclusions on climatic changes must, however, await the faunal analyses.

CONCLUSION

An important advantage of the Sterkfontein industrial sequence is the relative constancy of raw material types, sizes and availability. Thus the shifts over time in artefact types and in choice and size of raw materials have fairly direct implications for hominid behaviour. The earliest Sterkfontein assemblage fits the pattern of an expedient Early Oldowan industry (Harris 1995), yet it still attests to an impressive level of cognition able to evaluate different raw material qualities and shapes and to adapt the most appropriate flaking techniques. The succeeding Acheulian assemblage also fits the pattern of behavioural change evident at sites closer to 1.5 myr: the more difficult quartzites are chosen more often, resulting in larger average tool and core sizes, as well as the occasional large flake for biface production; the increased number of cores and manuports implies a more focused or habitual dependence on stone that is unlikely to be due only to sampling limitations, and is more likely to be due to the emergence of *Homo ergaster*. This increasing complexity in cultural remains is mirrored in the East African record by the expansion of archaeological sites into a greater variety of geographic settings by 1.6 myr (Rogers *et al.* 1994).

Another conclusion to emphasize from the Sterkfontein scenario is the importance of large sample sizes for appropriate industrial taxonomy. Given all the variables that may influence the character of an assemblage, i.e. raw material distance, form and flaking properties, activity differences, random variation and curation, we should not assign too much importance to classificatory schemes. Rather it is more important to discuss patterns of site size and complexity (Harris 1995), the overall pattern of land use (Rogers *et al.* 1994), and certain aspects of decision making that can be analysed in stone use (Kuman 1996).

Moreover, it is the upper limits of flaking technology that should be stressed. Among all the variables that influence an assemblage, we should also consider the individual interest and motivation of the hominid(s) responsible. Blanket statements about an assemblage based on its overall character are less useful than appreciation of its upper limits. Even the very early assemblages *c.* 2.4–2.3 myr from Omo and Lokalalei include some examples of well-flaked cores, despite their rather crude overall character that may relate more to the expedient, casual use of stone than to flaking abilities (see Chavaillon 1976; Kibunjia 1994). If Brooks and Laden (1995) are correct that occurrences older than 2.5 myr may not be archaeologically visible as sites, we may never locate the very first steps in tool making in East Africa. The restricted settings that preserve artefacts in cave sites suggest the same for South Africa, but let us hope that the heightened level of research during this decade may dig up some surprises.

NOTES

1 This talus lies in the Name Chamber of the Tourist Cave and contains a collapsed portion of older breccia that yielded several artefacts (Robinson 1962; Clarke 1994a).

2 Member 2 at Sterkfontein is considered older than 3.5–3.0 myr and has now produced twelve foot and leg bones of one hominid (Clarke and Tobias 1995; Clarke, pers. comm.).

3 The revised age for Member 4 is discussed in Clarke and Tobias (1995: footnote 27) and in their response to McKee (1996), based on information provided by Partridge. The unconformity between Members 4 and 5 appears to coincide with a shift away from a more closed environment (indicated by fauna and fossil wood) and towards a drier grassland fauna. Such a faunal turnover is dated in East Africa to between 2.7–2.5 myr. In addition, the overall dating of the Sterkfontein Formation is based on sedimentation rates at Makapansgat and the recalibrated palaeomagnetic time scale.

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7

The Lower Palaeolithic settlement of Eurasia, with special reference to Europe

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INTRODUCTION

Human colonization of the Old World has attracted periodic attention and discussions throughout this century. Archaeological discoveries have rapidly accumulated over the past few decades, providing information on the timing of human presence in Eurasia. The volume of publications from colloquia and special journal issues devoted to the first occupants of Eurasia, particularly Europe, testifies to a renewed and growing interest in this topic (Bordes and Thibault 1977; Bonifay 1981; Dreiman 1983; Ripoll 1983; Piperno *et al.* 1985; Bosinski and Kröger 1988; de Lumley *et al.* 1988; Bonifay and Vandermeersch 1991; Peretto 1992).

Pioneering researches about establishing human antiquity and realizing the human species' natural historical origin began in Europe. Before the turn of the century, it became evident that these issues required investigation beyond Europe for tracing the hominid cradle (Teilhard de Chardin 1953). This meant that, although the occupation of Europe was ancient, it was the outcome of population movements originating elsewhere.

This chapter surveys the Lower Palaeolithic period, along with relevant palaeoanthropological and environmental evidence relating especially to the peopling of Europe. It will be essential to devote considerable and detailed attention to evidence and issues pertaining to the initial hominid dispersal out of Africa and into Eurasia, since Europe represents a special case of that event. Eurasia, as defined here, includes major geographic regions such as the Near East, the Indian subcontinent, continental and peninsular Southeast Asia, the Far East, central Asia, Siberia and Europe (Figure 7.1).

THEMES AND MAJOR ISSUES

The human peopling of Eurasia represents the first of a series of major intercontinental colonization events, the others being the Upper Pleistocene peopling of Australasia or Sahul, and the Americas, and the Holocene maritime colonization of the Pacific. All colonizing events constitute major investigation

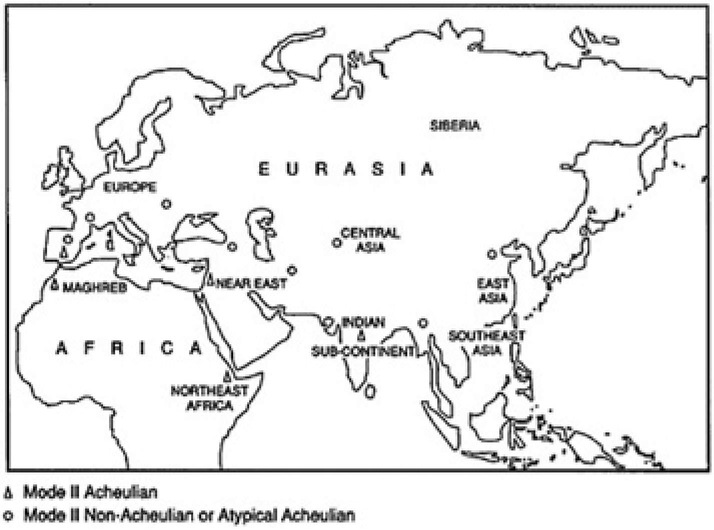

Figure 7.1 Map of Eurasia and northern Africa, showing major regions and some key lower palaeolithic occurrences.

themes of prehistory, and thus are of paramount importance to our understanding of hominid adaptations to new environments and regions. The initial settling of Eurasia shares with subsequent colonizing events a number of problems, including dating, identifying archaeological evidence, and establishing dispersal routes. Of these, the latter remains the least understood, as this must be based on secure data sets.

Of special significance is the fact that the colonization of Eurasia virtually doubled the area occupied by hominids by the Late Middle Pleistocene, involving a gradual adaptation to middle and higher latitude temperate and boreal climatic conditions, and contrasting seasonal variations (Dennell 1983; Rolland 1992). A majority view is that this expansion was achieved by populations belonging to the same *Homo erectus* species, without reproductive isolation sufficient to produce speciation.

All Pleistocene colonization events involved fossil human population movements, but the initial occupation of most of Eurasia was achieved by more archaic palaeospecies. Whilst it is reasonable to assume that subsequent dispersal and colonization episodes were achieved by human groups possessing basic biocultural parameters identical to those of modern populations, this does not apply automatically to Late Pliocene/Early Pleistocene evolutionary groups. The colonization of Europe, for instance, may have occurred more than once, possibly by different species or grades of *Homo*. This awareness opens up additional investigation issues about hominid biocultural adaptations.

The prevailing view of the early occupation of Eurasia, indicated by human palaeontology and Lower Palaeolithic archaeology, is that hominids had simpler technologies and levels of social organization. Human adaptation was constrained more severely by external and natural environmental conditions when ancient humans began moving into Eurasia's less familiar habitats (Howell 1960, 1966; Dennell 1983; Perlès 1987).

Europe, as noted above, illustrates special conditions and situations within the broader context of the peopling of Eurasia. Though closer to Africa, the locus of human origins, it remains separated from it by maritime and topographic barriers. It forms a comparatively narrow, and generally more maritime, higher latitude temperate extension of the Asian landmass.

This chapter concentrates on a set of questions arising from a review of direct evidence represented by the anthropic record, i.e. fossil hominids and Lower Palaeolithic occurrences. The European Lower Palaeolithic contains a comparatively much richer record than is currently available from the rest of Eurasia, due to a longer research history, more intensive field work, and growing interest in the theme of initial occupation. Most of the discussions, however, have focused on this record's validity, i.e. provenance, identification and dating, almost to the exclusion of broader and more basic issues. These concerns represent a necessary operational level for achieving resolutions, but remain preliminary steps, insufficient as such in a balanced, more holistic research design.

Other significant research topics include migration and adaptation processes, reconstructing early hominid socio-ecology and behavioural repertoires. Unfortunately, these topics have received comparatively little attention in the context of dispersal and colonization, although there have been a few exceptions (Turner 1982, 1992; Dennell 1983; Gamble 1986). Systematic studies of human migrations from methodological and theoretical perspectives have been confined to more recent chapters of prehistory (e.g. Inskeep 1976; Bellwood 1978; Rouse 1986). Biogeography and animal palaeontology have developed their own concepts about animal population dispersals (Darlington 1957; Simpson and Beck 1965; Geist 1971; Lindsay *et al.* 1980; Guthrie 1984). These possess a heuristic usefulness for understanding major human colonization events. The peopling of Eurasia, from this standpoint, may be seen as the expansion of a single primate species, native of the Ethiopian faunal region, into the oriental and palaearctic regions.

Below is a summary of the key developments concerning human origins and biocultural beginnings in sub-Saharan Africa; these are the formative steps that provide antecedents for human dispersals. After this summary, we address the following issues, and survey the available evidence concerning them, focusing on Europe:

1 the causes for early hominid dispersal beyond sub-Saharan Africa;
2 dating the earliest anthropic record beyond sub-Saharan Africa;

3. the fossil hominid specie(s) involved in this dispersal;
4. the number and kinds of Lower Palaeolithic tool making repertoires represented in Eurasia;
5. reconstructing early hominid behavioural parameters as dispersal factors;
6. identifying dispersal routes involved in colonizing Eurasia and, more particularly, Europe.

The questions do not exhaust investigative possibilities, and answers to any of them will remain unavoidably provisional and incomplete at best.

AFRICAN ANTHROPOGENESIS: EARLY FORMATIVE STAGES

Several lines of evidence, ranging from mammalian palaeontology, primatology and palaeoanthropology, concur in making a compelling case for sub-Saharan Africa as the cradle of the human species. Precise causes for human emergence are still obscure, but detailed information from palaeoenvironments and fossil mammals in East Africa, and in the Omo Valley in particular, show that conditions for hominid appearance began during the Miocene (Coppens 1994). This appearance was initiated by large-scale tectonic uplift causing the Rift Valley formation, and the gradual prevalence of more open, semi-arid landscapes supporting a dense biomass of gregarious herbivores (Bourlière 1963). These trends isolated ancestral hominoid primates, along with quadrupedal ground-living cercopithecids, in relict forest habitats, while other forest dwelling species survived elsewhere in the denser African forest biomes.

Fragmentary hominid remains reach back from 5.5 to 4.0 myr (Kanapoi, Lothagam, Belohdelie) (Johanson and Taieb 1976; Asfaw 1987; Leakey and Harris 1987). Anatomical identifications include *Australopithecus ramidus,* at 4. 5 myr, *Australopithecus anamensis,* at 4.1 myr, followed by *Australopithecus afarensis,* from 3.7 to 3.4 myr, confirming the appearance of a primitive bipedalism stage, adapted initially to forest/woodland environments, as an energy saving locomotion mode (Rodman and McHenry 1980; Wood 1993).

Early hominization stages were followed by adaptive radiation episodes between 3 and 2 myr, leading to diverging hominid lineages, *Paranthropus* and early *Homo* representatives, by 2.5–2.4 myr (Hill *et al.* 1992). Regular lithic tool making appears around the same time, e.g. Kada Gona at 2.6 myr (?) and the Shungura Formation at 2.3 myr, although their hominoid and earliest hominid forebears must have been tool users. Evidence supporting this is both archaeological (Oldowan artefacts) and anatomical, with the human hand displaying both power and precision grip capabilities (Susman 1994). Stone chipping enabled humans to process carcasses of medium and largesized herbivores. Evidence for a significantly more carnivorous diet is synchronous with these indications for skill. They mark the inception of the archaeological record, or the Palaeolithic, as an additional source of behavioural information, beginning with the Oldowan Complex or the Mode I technological stage (Toth 1985).

Fossil remains point to the presence of at least two larger-brained representatives of the genus *Homo (habilis* and *rudolfensis)* by 2 myr. These species became more fully bipedal compared with their predecessors. The preceding forest-adapted bipedalism stage provided a preadaptation for this subsequent stage, linked with locomotion and sustained high-energy activity in arid, open tropical landscapes, concomitant with body hairlessness and a more efficient thermoregulatory (perspiring/cooling) system (Wheeler 1985, 1991, 1992). The large-sized *Homo erectus,* e.g. Nariokotome by 1.6 myr, displays accelerated encephalization—a trend related perhaps to increased reliance on animal food as major energy source (Ambrose 1986). *Homo erectus* became the dominant, and eventually the only surviving, hominid group. The Palaeolithic record shows a linear development from Mode I Oldowan to Mode II Acheulian. The latter introduced a more specialized and standardized large cutting implement form, the handaxe, to the Oldowan paraphernalia. This development illustrates the first cumulative, progressive technological innovation in prehistory (and perhaps, in natural history).

The link between tool making and a greater reliance on meat eating, probably represents the development of a wider adaptive system by hominids inserted into the faunal communities of East and central Africa, and involved a long-term coevolution with carnivore species since 4 myr (Turner 1982; Tunnel 1989). This adaptive reorientation seems to have been fostered by the exceptionally rich animal food biomass of the region, presenting early humans with a hitherto unexploited food niche (Foley 1982).

There have been recent debates concerning whether predation or scavenging prevailed as the procurement method among Plio-Pleistocene hominids. Scavenging models based on direct evidence (bone remains patterns) or actualistic observations (extant wildlife studies) range from marginal participation in securing carcasses or refuse from carnivore kills (Binford 1981) to active hominid involvement (Potts 1984; Bunn and Kroll 1986; Blumenschine and Cavallo 1992; Bunn and Ezzo 1993). Certain models can be classified into those postulating an initial, pre-predatory stage, because predation was beyond early human anatomical or technological capabilities for preying and competing with major carnivore species, such as lions, leopards, hyenas and wild dogs (Binford 1983); conversely, others emphasize favourable situational factors in terms of scavenging opportunities in the rich biomass context of East and central Africa, making predation superfluous (Tunnell 1989). Shifts to predation and/or increased plant collecting could have been triggered by prolonged drought cycles reducing animal food biomass, or in regional contexts with diminished scavenging opportunities, e.g. South Africa (Turner 1988).

An alternative predation model does not regard scavenging as a stable, viable adaptation. Zoological observations about predation among primates (Butynski 1982) indicate a continuous strategy spectrum from scavenging to predation.

Most carnivores can modify their procurement tactics opportunistically, from scavenging to predation, or the reverse, according to circumstances. The view that early humans were incapable technologically or organizationally of directly exploiting medium or large herbivores has been challenged (Schüle 1991): bipedal hominids, with fully 'liberated' hands, physiologically equipped for stealth and sustained activity in open, semi-arid savanna/woodlands, could have pursued medium-sized prey and even mega-herbivores (over 1,000 kg) and killed them with simple but lethal wooden thrusting weapons. Some large mammals, such as extinct species of African elephants and rhinos, without natural predators and consequently not having flight or fight responses, would have become especially vulnerable to hominid predation (Owen-Smith 1987).

Whatever the merits of either scenario, it must be emphasized that ancient humans shared the same habitats as other carnivores. Initially, hominids coexisted symbiotically with extinct large felids such as sabertooth cats in forested core areas (Marean 1989). After these species' disappearance, hominids became involved in more confrontational, competitive interactions with extant species such as lions, leopards, spotted hyenas or wild dogs. Wildlife studies suggest that essentially ground living, socially organized more carnivorous primates, including early hominids, could have ranked highly in an inter-carnivorous competitive hierarchy (Eaton 1979), either as predominately scavengers or as predators.

CAUSES FOR HOMINID DISPERSAL

Population pressure and/or environmental change have been regarded as major causes for animal migration (Darlington 1957:25, 549). Similarly, hominid migration may be tied to these factors. Hominids share with most other primates the adaptive characteristic of single birth and prolonged post-natal care, but stand out as being more successful reproductively. This reproductive success and resulting increase in population pressure may explain in part why humans became more easily migratory than other primates, due to greater strain on habitat carrying capacity. Another factor for hominid migration may relate to major environmental change. Drier cycles, marked by large-scale mammalian species turnover between 1.6 and 1.0 myr (Maglio 1978:612; Bonnefille 1979; Kappelman 1984), may have led to hominid migration.

A third major cause that may account for the initial hominid dispersal could be their increased carnivorous propensities. A meat eating diet entails adaptive advantages, because animal protein retains basic nutritional properties, regardless of latitude or climate, in contrast with plant foods. Thus, carnivores tend to be generalists, adjusting to varying conditions (Foley 1987). As a result, initial human dispersals could have been part of a wider event involving other African carnivores (e.g. lions, leopards, spotted hyena) moving into Eurasia (Turner 1982).

This hominid dietary and behavioural transformation, ‘primate by phylogeny but carnivore by vocation’ (Schaller 1973), remains rare, with few natural historical analogues (Shipman 1993). Once actualized, however, it would be subjected to new pressures for surviving. One of the conceivable responses would be migration. This dual evolutionary nature of hominids implied two characteristics: retaining a primate-like sociality, requiring a need for comparatively sizeable local groups for safety, as is the case of ground living species; and combining this constraint with the need for carnivores to maintain low predator/prey densities. These conditions, added to others already mentioned such as reproductive success, prolonged drought cycles that reduced scavenging opportunities, coevolution with African carnivore species, and participating in their large-scale dispersal events, would result in expanding hominid home ranges, making migration a likely outcome and an identifiable cause for the peopling of Eurasia.

THE EARLIEST ANTHROPIC RECORD BEYOND SUB-SAHARAN AFRICA

Establishing a datum line from earliest human traces requires resolving the following methodological problems:

1 obtaining reliable anthropic identification,
2 excercising adequate provenance control
3 establishing secure dating.

The first requirement applies to archaeological remains such as stone artefacts, non-lithic artefacts, and activity traces (e.g. butchering, occupation structures), in addition to fossil human discoveries. Much progress has been achieved in discriminating between artificial and natural modification of lithic objects, but many ambiguities persist when dealing with isolated pieces or objects from non-isotropic materials. Provenance may indicate whether some artefacts are out of context, derived, or from dubious sources (disturbed, coarse matrix), creating uncertainties with respect to identification and dating.

Satisfactory time-placement calls for several concurring lines of time-stratigraphic evidence, complemented coherently by calibration methods (geomagnetism, tephrochronology, radiometric methods). Litho-stratigraphy from well-studied regions, e.g. central Spain, can provide a broad framework, while biochronology, especially when based on microtine fauna, e.g. in Europe (van Kolfschoten 1988), is beginning to yield reliable and detailed successions. Thermoluminescence dating in excess of 500–300 kyr may be questionable, but potassium/argon (K/Ar) dating, fission-track and electron spin resonance (ESR) have become increasingly reliable.

Our survey will cover *datum* lines from North Africa, and beyond Africa into Eurasia, centring on Europe in particular. This should enable comparisons for investigating to what extent initial occupations in different major areas were synchronous or indicate some time lag. We note competing hypotheses for all major areas, implying either a ‘long’ chronology (back to the Upper Pliocene) or a ‘short’ one (Lower or Middle Pleistocene). The weight of evidence presently favours the ‘short’ chronology, suggesting that hominids did not disperse beyond sub-Saharan Africa much before 1.25 myr. It also emerges that Europe may have been colonized significantly later than North Africa or Asia.

North Africa

Recent lithostratigraphic researches in Atlantic Morocco (Texier *et al.* 1985), as well as biochronological findings from Algeria, at Tighenif and Ain Hanech (Geraads *et al.* 1986), point to an early human presence ranging from 1.0 to 0.75 myr. This contrasts with previous conclusions from Atlantic Morocco (Biberson 1963), outlining a protracted, long-lasting Quaternary and Lower Palaeolithic succession reaching back to the Upper Pliocene, and paralleling much of East Africa’s master sequence.

Asia

A string of recent finds from the Levant and into the Transcaucasus, and from the Far East and northeast Asia, claim a Pliocene age for the first human presence outside Africa (Table 7.1, Figure 7.1). All, however, need confirmation with respect to their anthropic identification, provenance or dating, until they can be accepted as established *datum* lines. They include a possible pebble tool from Erq al Ahmar, datable to 1.8 myr, and the Yiron Plateau artefacts, datable by crossdating to at least 2.4 myr, both in Israel (Ronen 1991; Verosub and Tchernov 1991); the Dmanisi occurrence, with artefacts and *Homo erectus* remains, in Georgia, with a proposed dating from biochronology, K/Ar and geomagnetism to 1.8 myr (Gabunia and Vekua 1995); the Riwat artefacts Pakistan (Dennell *et al.* 1988); the argon dating of the Modjokerto and Sangiran *Homo erectus* remains, at 1.8 and 1.6 myr respectively, in Java (Gibbons 1994); a mandibular fragment attributed to *Homo habilis,* datable to 1.8 myr, at Longgupo, China (Menon 1996); and a proposed Pliocene age for the Diring Yuriakh quarry site artefacts, in Yakutia (Sakha), Russia (Mochanov 1992).

The artefactual identity of the Erq al Ahmar and Yiron objects needs verification and confirmation. The Diring assemblage, and some of the Riwat pieces, appears undoubtedly anthropic, but their dating, and the provenance of the Riwat finds, remain open to doubt or need independent confirmation. Dating Dmanisi is also problematic, with conflicting biochronological verdicts (e.g. Vekua 1986: 87). The actual provenance of the Java early hominids has to be established, while the taxonomic and chronological positions of the Longgupo fragment also require definitive studies. The ‘long

Table 7.1 Major early anthropic occurrences in Europe and Asia.

Europe	*Near East, central Asia*	*Southern and eastern Asia*
600–500 kyr	*1.25 myr–600 kyr*	*1 myr–400 kyr*
Kents Cavern, Boxgrove, High Lodge, Abbeville, Mauer, Miesenheim, Gerassimovka, Visogliano, Ranuccio, Castro dei Volsci, Venosa-Loreto, Pinedo, Cúllar-Baza, Irsina, Colle Marino	Latamne, Jubb Janine, Kul'dara, Sitt Markho, Jebel Idriss, Khattab, Sheikh Muhamad, Kashafrud, 'Ubeidiya	Zhoukoudian, Yuanmou, Guanyindong, Gongwangling, Donggutuo, Xiaochangliang, Xihedou*
*900–600 kyr**	*1.8 myr–400 kyr*	*1.9–1.8 myr*
Stránská skála, Korolevo, Cerveny Kopec, Monte Peglia, Isernia la Pineta, Monte Poggiolo, Atapuerca,+ Soleihac, Vallonet, Sandalja, Cueva Victoria	Dmanisi, Erq al Ahmar, Yiron	Longgupo, Sangiran, Modjokerto, Riwat

*Occurrences not confirmed with respect to identification, provenance or dating
+Occurrence confirmed

chronology', i.e. Pliocene age, for anthropic finds across Asia, must consequently be treated with reserve.

The shorter chronology for Asia is based on the earliest confirmed dates for a human presence beyond sub-Saharan Africa: the 'Ubeidiya Early Acheulian occurrence, in Israel, with a minimum geomagnetic, radiometric (K/Ar) and biochronological age determination around 1.25 myr (Tchernov 1988), along with other similar, though less precisely dated finds from the northern Levant (Hours 1975; Muhesen 1988); other hominids from Java have a minimum age of 1.2 to 1.0 myr (Pope *et al.* 1987); the Nihewan Basin sites, e.g. Donggutuo and Xiaochangliang, associated with a Sanmenian fauna, are datable to 1 myr (Lanpo and Qi 1987; Schick and Dong 1993); the artefacts from the PK11 and PK12 horizons at Kul'dara, Tadzhikistan, are datable to 850–750 kyr (Ranov *et al.* 1987).

In summary, the earliest human presence in western Asia predates 1 myr, and is only slightly earlier than that of the Far East. These conclusions, unless superseded by earlier finds, suggest that hominids moved beyond sub-Saharan Africa somewhat before they reached the Maghreb and crossed the Sahara.

Europe

The notion of tertiary (Miocene or Pliocene) humans in Europe has been debated inconclusively throughout this century, exemplified especially by the Piltdown fraud and the 'eoliths' controversy (Oakley 1964; Bourdier 1968; Coles 1968).

They implied that Europe was either part of the original hominization geographical realm, or had been settled quite early, prior to the Lower or Middle Pleistocene. A revival of this opinion has been illustrated by field investigations focused on well-dated fossil mammal occurrences from the Massif Central, in France (Bonifay 1981, 1989), e.g. Perrier-les-Etouaires, St-Eble/Le Coupet, La Rochelambert, or Senèze. These reportedly would contain artefactual objects and other material traces attributed to human activity, calibrated between 2.6 and 1.8 myr, or the Late Pliocene. These reports have, however, been received sceptically so far (de Lumley *et al.* 1988; Delson 1989). None of the sites has yielded fossil humans, in spite of good faunal preservation. The artefactual identity is also questionable. If established, this 'long' chronology model for the human occupation of Europe would actually extend to the earliest genus *Homo* representatives, and tool making beginnings in East Africa.

Another 'long' chronological model, though within the Pleistocene boundary, i.e. Jaramillo or late Matuyama geomagnetic *datum* lines (e.g. Piperno *et al.* 1985; de Lumley *et al.* 1988; Rolland 1992), had gained more acceptance, until recently. It would include calibrated localities and findspots such as Vallonet, Soleihac, Kärlich A, Korolevo, Irsina, Colle Marino, Cerveny Kopec, Isernia la Pineta, Ferme de Grace and Monte Peglia, ranging between 950 and >750 kyr (Table 7.1).

Many of these sites meet criteria of anthropic identification, except perhaps Kärlich A, Vallonet and Ferme de Grâce, but their dating is regarded as problematic, with different lines of evidence conflicting with one another (e.g. Isernia la Pineta, Soleihac), and these may not be older than 600 kyr (Roebroeks 1994). Others have been redated radiometrically upwards to the Middle Pleistocene (Colle Marino, Irsina), whilst provenance control may be at issue for some, e.g. Monte Peglia, according to recent conclusions emerging from the Tautavel meeting of The Network on the Palaeolithic Occupation of Europe (Roebroeks and van Kolfschocen 1994). Critical reevaluations discussed at that meeting stressed the contrasts between the quality and reliability of most occurrences prior to a tentative 500 kyr boundary date, the latter corresponding approximately with the biochronological *Arvicola terrestris cantiana* lower limit (Roebroeks and van Kolfschoten 1994: Figure 7.2).

These new conclusions support better the 'short' chronology model, i.e. well into the Middle Pleistocene, for the first settlement of Europe. It coincides also with reliably dated anthropic occurrences such as Mauer, Boxgrove, Fontana Ranuccio, Venosa-Loreto, High Lodge, Abbeville and Visogliano, some of which contain fossil human remains, as well as Isernia la Pineta and Soleihac. Some artefact-rich localities such as Monte Poggiolo or Korolevo are devoid of biochronological associations, making their claimed Lower Pleistocene age difficult to confirm. The only possible remaining exception, containing both human fossil fragments and undoubted artefacts, comes from the TD4 and TD6 horizons from the Gran Dolina of Atapuerca cave, in Old Castile, Spain. These could date to the Late Matuyama, on the strength of biochronological and geomagnetic evidence (Gil and Sese 1991; Carbonell *et al.* 1994, 1995).

To conclude, it appears that the European portion of Eurasia may have been settled significantly later, i.e. 600–500 kyr, than Asia (1.25 myr) or North Africa (*c.* 1 myr). Whatever the final verdict concerning the initial date for a human presence in Europe, the Middle Pleistocene 600–500 kyr boundary appears to retain the best empirical support, for the time being. The implied time lag resulting from this conclusion raises fundamental questions about it (Roebroeks 1994:303). The peopling of Europe may have resulted from either a separate dispersal event, or was a delayed episode of a single, more protracted one, unfolding gradually in different directions.

HOMINID SPECIES INVOLVED IN EARLY DISPERSALS

Palaeoanthropologists wish to determine whether one or more hominid palaeospecies participated in hominid migrations beyond sub-Saharan Africa, as well as to identify which hominization grade or evolutionary group may have been represented. Chronological resolution once again plays a decisive role in reaching a verdict: if, as argued by some, dispersals began as early as 2.5–2.4 myr, on the basis of artefact finds in the Levant and Europe, this must imply that pre-*erectus* populations were involved in these initial movements. They would coincide in time with the earliest anatomical, i.e. hand morphology, and archaeological evidence known for tool making in Africa, although confirmed fossil human finds older than 2 myr are lacking for the time being in both North Africa and Eurasia. If recent argon dating from Java and hominid fragments from China are indeed 1.8 myr, this could mean that either *Homo habilis* or *Homo rudolfensis* were present in Eurasia, since *Homo erectus* appears around 1.6 myr in Africa. The Dmanisi *Homo erectus* mandible probably represents a comparatively evolved grade, despite its proposed 1.8 myr age. On the other hand, all the known *Homo erectus* finds beyond sub-Saharan Africa, e.g. in the Maghreb (Tighenif, Sidi-abd-er-Rahman, Carrière Thomas), or in the Far East all appear to post-date the African *datum* line for *erectus* emergence.

A debate re-emerging periodically, regardless of chronological resolution issues, revolves around whether several ancient hominid species occupied different regions inside Eurasia during the Middle Pleistocene. Palaeoanthropologists have proposed alternative scenarios:

1 *Homo erectus/ergaster* was already present in sub-Saharan Africa; *Homo erectus* moved to the Far East and persisted there in isolation; *Homo heidelbergensis,* a more evolved group more closely related to African hominids, colonized western Eurasia, including Europe (Rightmire 1990; Delson 1991; Carbonell *et al.* 1995).

2 A single but variable *erectus* species, originating in Africa, occupied all of Eurasia (Bräuer and Mbua 1992).

Having eliminated as misdiagnosed the so-called Orce cranial fragment (Moyá-Solá and Agustí 1989), originally attributed to *Homo habilis,* and believed to date to 1 myr (Agustí *et al.* 1983), we are left with fossil human remains found in Europe that include Boxgrove, Mauer, Vergranne and Visogliano. All are given an age of less than 600 kyr, although the recent Atapuerca TD1 find could be older. The dating of the Dmanisi find, at the edge of Europe, perhaps also older, remains to be worked out.

The idea of more than a single species being present across Eurasia, or, more concretely, the notion that *Homo heidelbergensis* rather than *Homo erectus* occupied Europe, remains open. In sub-Saharan Africa, several archaic palaeospecies (several grades of *Australopithecus, Paranthropus,* early *Homo*) differed by more contrasting adaptive traits, suggesting episodes of adaptive radiation (Wood 1992). The Middle Pleistocene fossil hominid record in Eurasia, though variable, presents morphological patterns whose taxonomic diagnosis makes 'splitting' more problematic from a populationist viewpoint. They may simply indicate intra-specific or isolated variations, comparable to the range of those observed among living human populations (Bräuer and Mbua 1992). This does not, however, invalidate, the notion that, after their arrival, the first occupants of Europe began to display precociously some of the autapomorphic traits leading eventually to the Neandertal populations (Delson 1991), indicative perhaps of some degree of reproductive isolation.

LOWER PALAEOLITHIC TOOL MAKING REPERTOIRES

The classificatory diagnosis of tool making repertoires, or the formal variations of stone tool types and flaking techniques, has received little systematic attention, except in the case of the Far East. This aspect remains crucially important, inasmuch as it may contribute independently to pointing out specific dispersal routes leading to the colonization of Europe in particular. Lower Palaeolithic industry types have undergone some repertoire modifications, before and after the hominid dispersal out of Africa and throughout Eurasia.

'Long' versus 'short' chronological resolution again plays a decisive part on assemblage type diagnosis. If some archaeological occurrences in Asia actually date to as early as 2.4 myr (Yiron) or to 1.9–1.8 myr (e.g. Erq al Ahmar, Dmanisi, Riwat), the conclusion, with reference to a *terminus ante quem* established by the Palaeolithic developments represented by the East African master sequence, that these must represent a Mode I technological horizon, or 'pebble-culture' *sensu lato* (Vértes 1969), becomes compelling, given that Mode II Acheulian does not emerge until 1.5 myr in East Africa. The 'short' chronological alternative, i.e. from 1.25 myr in Eurasia, indicates that all Lower

Palaeolithic occurrences found beyond sub-Saharan Africa belong to Mode II, as the null hypothesis, because the first hominid dispersal would post-date the earliest Acheulian record in East Africa.

A major methodological issue confronts the task of taxonomic diagnosis of Lower Palaeolithic repertoires in both North Africa and Eurasia: how to interpret inter-assemblage variability, given the above considerations. The record displays an array of occurrences, some containing handaxes (and cleavers), others without such tools. Handaxe frequencies, furthermore, range from isolated but diagnostic finds, through small numbers, to dozens, hundreds or even thousands of pieces. Their mere presence suffices for making a Mode II Acheulian assemblage type diagnosis, regardless of whether particular occurrences may be dominated by flake implements, by choppers or by handaxes; those lacking handaxes/cleavers may also vary in terms of relative frequencies or dominance by non-handaxe artefact class composition or assemblage size.

Artefact class composition lacking handaxes may result from distinct causes and situations, such as sampling factors, brief occupations or halts, or taphonomic processes, including partial site destruction. Absence of handaxes/cleavers does not necessarily correspond with small assemblage sizes, since some large occurrences remain entirely devoid of that implement category, although this does not necessarily rule its Acheulian taxonomic identity.

Time and geographical patterning can assist in making diagnosis: the African Oldowan represents an archaic Mode I technological horizon entirely devoid of true handaxes or cleavers confined to sub-Saharan Africa. Lower Palaeolithic occurrences in Eurasia whose age would demonstrably predate 1.5 myr, however, would constitute conclusive proof that a ‘pre-Acheulian’ or ‘pebble-culture’ repertoire (Mode I) diffused out of Africa through hominid migration. The geographically clustered Chopper and Flake Tool Complex in the Far East (Movius 1948) was previously thought to be an instance of Mode I (née Oldowan) survival (Sieveking 1962). Current interpretations, however, taking into account up-to-date chronological evidence that supports a time boundary not exceeding 1.2–1.0 myr, imply that this complex corresponds instead with a secondarily modified, specialized techno-ecological version of Mode II technology, following adaptation to the Indo-Malaysian tropical forest and bamboo/karst habitat mosaic, without handaxes (Watanabe 1985; Pope 1989; Schick and Dong 1993). Diagnosis thus becomes a ‘non-Acheulian’ Mode II technological pattern.

Diagnosis becomes less straightforward when dealing with regions such as the Maghreb, the Levant, India or Europe, where handaxe and non-handaxe occurrences overlap in time and space. Setting aside taphonomic or sampling distortions, one is still left with assemblages entirely without handaxes. Two interpretations may be conceived. First, occurrences with sufficiently abundant artefacts, though still without handaxes, may express separate tool making repertoires where handaxe manufacture never developed or became phased out, perhaps as a consequence of long-lasting adaptive shifts or idiosyncratic drift, making these ‘non-Acheulian’ Mode II assemblage types. This inter-pretation is problematic and creates more problems than it would resolve. It requires demonstrating the presence of autonomous palaeosocieties forming isolated mating networks, rather than being geographically distant from other populations, and persisting as such despite geographical overlap. This scenario is made improbable by the assumption that Lower Palaeolithic social units constituted low-density, dispersed groupings, with ‘anucleated’ types of social formations (Yellen and Harpending 1972: Figure 15), namely open socio-demographic entities. Second, assemblages without handaxes reflect the internal elasticity (frequency variations of different artefact classes) of the Acheulian as a polythetic complex. Non-handaxe occurrences would illustrate situational variations such as quarry and factory sites, raw material circumstances, or activities correlated with specific environments (Rolland 1996).

The case of Europe

Putting to rest most of the Massif Central sites as non-anthropic occurrences, we note a definite time lag when comparing the (‘short’) chronological positions of Europe’s earliest Lower Palaeolithic evidence with that of the remainder of Eurasia (Figure 7.2). Considering again the ‘long’ (Late Matuyama or 900 kyr) versus the ‘short’ chronologies, repertoires diagnosis of inter-assemblage variability would involve two alternative hypotheses:

First, should Europe’s earliest Palaeolithic occurrences date indeed to the Late Matuyama, one observes that none of these appears to belong to the Acheulian (Vallonet, Soleihac, Atapuerca, Monte Poggiolo, Isernia la Pineta, Irsina, Cerveny Kopec, Korolevo), being consistently without handaxes, and should be diagnosed instead as belonging to a European ‘pre-Acheulian’ (Broglio *et al.* 1982; Rolland 1992; Carbonell *et al.* 1995).

The concept of a separate non-handaxe tradition, either older or penecontemporaneous with the Acheulian, inside Europe is not new, and has been an object of debate throughout this century, with different scenarios proposed for its origin (Breuil 1932; Bordes 1950; McBurney 1950; Narr 1953; Kretzoi and Vértes 1965; Howell 1966; Collins 1969). A ‘long’ chronology model, vindicating the notion of a ‘pre-Acheulian’, also preempts the difficult issue of explaining the coexistence of two separate Lower Palaeolithic assemblage types, by fitting them into separate tool making horizons. It leaves open the issue, however, of accounting for its origin and isolated persistence in Europe long after the appearance of the Acheulian in adjacent regions, namely the Mahgreb and the Levant, by 1.25 and 1 myr respectively. This would appear to rule out the possibility that the European ‘pre-Acheulian’ would represent a belated Mode I (‘pebble-culture’), since its earliest datable presence in Europe does not predate 900 kyr.

Second, the ‘short’ chronological perspective concludes instead that the earliest Palaeolithic record in Europe includes both Acheulian, e.g. Boxgrove,

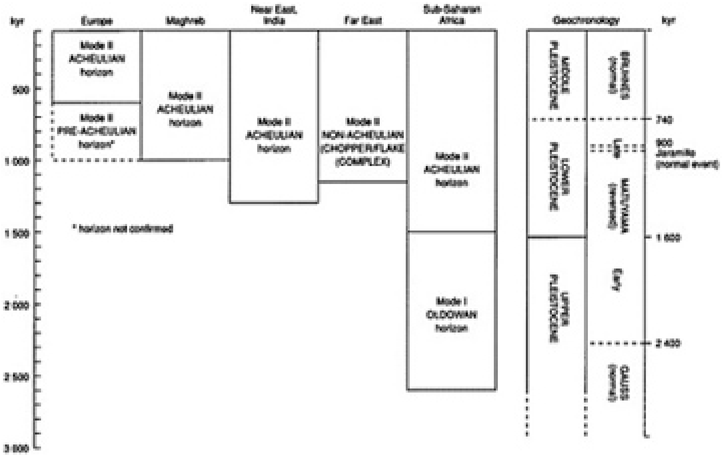

Figure 7.2 Tool making repertoire diagnoses

Kent’s Cavern, Abbeville, Fontana Ranuccio, as well as non-handaxe occurrences, e.g. Isernia la Pineta, Venosa-Loreto, none datable before 600–500 kyr. This has the consequence of removing the notion of a preceding ‘pre-Acheulian’ from further consideration. Non-handaxe assemblages thus become either ‘non-Acheulian’ Mode II repertoire, e.g. ‘Clactonian’ *sensu lato,* analogous to the Chopper and Flake Complex in the Far East, or, more likely, atypical variants or facies of the Acheulian. Some writers have proposed *in situ,* i.e. intra-European, adaptive developments to widespread interglacial temperate woodland habitats, subsequent to the colonization of Europe, to explain the origin of a ‘non-Acheulian’ tradition (McBurney 1950; Narr 1953; Collins 1969), although the palaeoclimatic record is not entirely consistent in terms of showing correlations with these non-handaxe occurrences, with the possible exception of the Clactonian strictly speaking. We have already emphasized that palaeosocietal, palaeodemographic and palaeoecological conditions were probably not conducive to the formation of distinct socio-cultural groupings within the confines of Europe, during the Lower Palaeolithic. A diagnosis of non-handaxe occurrences as atypical facies of the Acheulian, relating to different contextual or situational factors, remains more plausible.

EARLY HOMINID BEHAVIOURAL PARAMETERS AS DISPERSAL FACTORS

Early hominid behavioural activities are poorly understood, despite their intrinsic importance (e.g. Dennell 1983). Available information is fragmentary, incomplete and open to several interpretations. Discussion of hominid behaviour will be restricted to two particular themes bearing on hominid dispersal: the role of carnivorous diet and fire production. Whilst nothing conclusive will emerge from this coverage, it will serve the purpose of emphasizing their potential significance for an in-depth appreciation of key conditions and processes involved in ancient hominid colonization, as well as the need for systematic research. Our discussion will concentrate more on the European portion of the Eurasian record.

Carnivorous diet

Dependence on animal food staples would provide a preadaptive advantage for migrating. This meat eating propensity would become particularly suited for dispersal movements into higher temperate and boreal latitudes, where plant food availability is no longer year-round. *Homo erectus* populations had already succeeded in surviving under Mediterranean bioclimatic conditions of southern Africa, an antecedent that made relatively easy the settlement of lowland regions of the Near East and Mediterranean Europe.

Adjusting survival strategies to the unfamiliar conditions of temperate Eurasia and its distinct seasonal variations raises the issue of how year-round subsistence could be organized, on the strength of the record indicating that hominids were already occupying northern China and Europe beyond the Mediterranean. Determining whether scavenging or predation represented the dominant meat procurement system becomes a crucial question. There is evidence for specific carcass processing methods, such as extracting bison brain as a valuable dietary element, exemplified at Isernia la Pineta (Sala 1983), or the butchering techniques reconstructed at Soleihac (Fosse and Bonifay 1991), which are reminiscent of those employed during later prehistoric times or among extant foraging populations. None of these enables us to determine which procurement technique was used, however.

Turner (1982) concludes that ancient hominids, relying primarily on scavenging, remained unable to compete with other carnivorous species in Europe, under the guild conditions, i.e. a group of species exploiting a resource in a similar way, until well into the Middle Pleistocene. This point brings up the need to evaluate animal biomass conditions prevailing in Europe at the time, since opportunities for regular scavenging increase with a rich biomass, such as is evidenced in East and central Africa (Bourlière 1963; Turner 1988). Localized circumstances would provide intermittent opportunities for this, as suggested by animal food refuse from Isernia la Pineta, where butchered bison remains dominate. This could have resulted from episodic large-scale seasonal flooding, causing mass animal drowning, a situation analogous to current observations from the Wood Buffalo Park, northern Canada (Carbyn *et al.* 1993:34). This recurrent opportunistic strategy, however, should not imply that scavenging constituted the major procurement system during earlier hominid occupation phases in Europe.

In summary, it remains more realistic to perceive hominid dietary patterns as versatile rather than primarily contingent on scavenging opportunities on a regular basis, especially in the context of colder latitudes and long winters, where dependence on animal proteins and related nutritional requirements increases.

Fire production

Various fire use applications would play an important role for human dispersals, particularly in the case of colonizing temperate and colder zones; bush burning for making fire signals while exploring unfamiliar localities; fire as a source of heat; for producing light during darkness (especially during long winters); for meat cooking; and for protection against predators or competitors during the night.

Two perspectives currently compete about fire making antiquity: a deliberate use and regular production of fire could reach back into the Late Pliocene/Early Pleistocene, involving various uses, including game driving (Clark and Harris 1985; Schüle 1990,1992); or this technology developed comparatively later, well into the Middle Pleistocene, approximately 400– 300 kyr (James 1987; Perlès 1987). It cannot be assumed, however, that all of the different applications of fire were actualized simultaneously, or that fire production could be mastered as early as fire using. Pyrogenic environments such as the semi-arid subtropical or tropical vegetation of East and South Africa, India and the Mediterranean would have supplied natural conditions favouring an expedient use of that energy source at an early date and, consequently, the emergence of an important technical element for early human migrations. Much remains to be done, however, despite significant analytical progress (e.g. Barbetti 1986), in discriminating between:

1 material evidence for fire, as distinct from other natural phenomena,
2 whether *bona fide* evidence for fire can be traced to human agencies, and
3 expedient use, as distinct from actual fire-production.

Several reports mention evidence for early fire use or production in sub-Saharan Africa, e.g. Chesowanja, Koobi Fora, Gadeb, Swartkrans (Clark and Harris 1985; Brain and Sillen 1988; Bellomo 1994). All this evidence does indicate a presence of fire, but whether any or all of this is anthropic remains debated (Isaac 1982; Perlès 1987).

The oldest and most widely accepted evidence in Eurasia comes from Zhoukoudian. The earliest ones mentioned in Europe include L'Escale cave (Bonifay and Bonifay 1963), Isernia la Pineta (Peretto *et al.* 1983) and Stránská Skála (in Musil 1971), ranging in time between over 750 kyr to about 500 kyr, but conclusive proofs about a human origin are not available yet. Unambiguous evidence, otherwise, does not predate by much 400 kyr, e.g. Ménéz-Drégan (Monnier *et al.* 1994), Vértesszöllös, Bilzingsleben, Achenheim 'sol 81'

(Rolland, in press), all coinciding in time with the Lower Palaeolithic final phases in Europe. Subsequently, occurrences containing hearths, fire-pits or other straightforward evidence become commonplace. Henceforth, regular fire making must have had a varied and profound impact on ancient hominid life, including perhaps a major shift in settlement systems, and the appearance of home bases *sensu stricto* (Perlès 1987; Rolland, in press). It would seem, from the preceding, that definite evidence for fire production post-dates the time of initial human occupation throughout Eurasia, ruling out this technology as a decisive factor but raising for the same reason the question of human adaptation to temperate latitudes without it.

DISPERSAL ROUTES

Establishing which dispersal routes were followed by hominids out of Africa into Eurasia, and eventually into Europe, represents one of the most important but challenging issues facing palaeoanthropological researchers. This topic has received minimal, and mostly incidental attention, with few exceptions (Howell 1960; Chard 1963), in contrast with discussions concerning the colonizations of Australasia, the Americas or the Pacific Islands. Most references to the peopling of Eurasia remain schematic (e.g. Vértes 1969; Roe 1981; Gladilin and Ranov 1986; Foley 1987: Figure 10.1).

The problem requires considering and weighing several variables. These comprise:

1 environmental, geographic (topographic, bioclimatic) and palaeoclimatic variables, informing about possible natural barriers and dispersal routes;
2 chronology, by reference to the African master sequence for biocultural developments as antecedents and *datum* lines;
3 Lower Palaeolithic horizons and repertoires, with reference to diagnosis in terms of Mode I (Oldowan or 'pebble-culture') or Mode II (Acheulian, atypical Acheulian, and non-Acheulian) assemblage types, and their African origins or antecedents;
4 other behavioural variables, including concepts adapted from bio-geography, hominid socio-ecology, and what can be reconstructed concerning ancient hominid technologies and adaptations. Available information concerning this last group of variables is admittedly tentative and limited in terms of information content.

Combining available direct and indirect information concerning all these factors will constitute a body of evidence contributing progressively to resolution, by considering alternative scenarios. Mammalian historical bio-geography (Simpson 1962) supplies heuristic guidelines about migration probabilities. *Corridors* refer to conditions involving few natural barriers and a high probability of migration for most species, e.g. the Eurasian palaearctic corridor. *Filters* conditions imply more limited migration probabilities, restricted to fewer species, e.g. the Sahara filter. *Sweepstake routes* refer to barriers impeding migrations by all but very few species, due to major natural barriers, e.g. human movements during the Pleistocene between Southeast Asia and Australasia. We shall examine the record as it applies to barriers and dispersal probabilities between:

1 sub-Saharan Africa and North Africa,
2 Africa, and Asia, and
3 those concerning more particularly the peopling of Europe.

Beyond the Sahara

The vast stretches of the Sahara have created a major natural obstacle that separates, with varying degrees of effectiveness, sub-Saharan Africa, the locus of human origins, and North Africa. Episodic climatic fluctuations, governed especially by changing precipitation and marine current regimens, have influenced the expansion and contraction of major vegetation belts, i.e. Mediterranean and tropical forests, woodlands, savanna and Sahel, creating intermittently oasis refugia, passage trails and contact zones, or absolute barriers, throughout the Quaternary, between north and south.

Anthropic evidence containing either *Homo erectus* and/or Lower Palaeolithic (Acheulian) remains suggests that the Sahara filter route was probably breached around 1 myr ago. The Maghreb actually constituted an Ethiopian biogeographic island throughout most of the Quaternary. A Nile Valley dispersal route appears unlikely until about 500 kyr or less, when sediments begin to indicate that this river started flowing directly north, instead of into the Red Sea. Acheulian finds in Upper Egypt do not predate 400–300 kyr (McHugh *et al.* 1988). Colonizing movements into the Maghreb probably took place further west, through some of the episodic filter trails (Hoggar, Tibesti, Saoura Valley, Mauritanian corridor), during wetter cycles.

From Africa into Eurasia

The earliest securely dated and confirmed Lower Palaeolithic in the Levant, best represented by ‘Ubeidiya, predates somewhat (1.25 myr) that of the Maghreb (1 myr). This rules out a colonization of western Asia through a North African dispersal route involving either the Nile Valley or the south Mediterranean coastline. It suggests as well that the settlement of North Africa was a separate, lateral and somewhat later branch of population movement events, initially from sub-Saharan Africa into the Near East. Circumstantial evidence from Quaternary research (de Chabalier and Avouac 1994) supports the model of a peopling directly through the Horn of Africa across a Red Sea filter route, during Early Pleistocene glacio-eustatic low sea level episodes (Caton–Thompson 1953). The Early Acheulian site of Barogali, Djibouti, dated to 1.4 myr, could exemplify this scenario. Further migratory movements into the Arabian peninsula, along the more hospitable, wetter foothills of inland Yemen, would eventually reach the Levant northwards, up to coastal Anatolia.

This dispersal and colonization model for initial hominid migratory movements out of Africa, while still largely hypothetical, remains essentially the same (though better documented in parts) from the one outlined decades ago (Howell 1960). It takes into consideration the role of topographic obstacles lying further north inside Eurasia, comprising a west to east trending line of mountains and plateau, stretching from the Taurus to the Qinling range in China. Human groups would therefore follow a more familiar range of subtropical and tropical habitats, from southwest Asia, south of the Taurus, toward the Indian subcontinent, where Acheulian Mode II occurrences are common (Mishra *et al.* 1995).

Hominids apparently adapted successfully to the ecological transition that was represented by the filter constituted by the Indo-Malaysian tropical forest complex (Sieveking 1962; Watanabe 1985), coinciding during the Pleistocene with the oriental faunal region boundary between the Indian subcontinent and Southeast Asia. This expansion into unfamiliar bamboo/karst habitats corresponds with the occurrences of a Mode II non-Acheulian technology, representing a simplified but specialized modification of Acheulian repertoire, with abandonment of handaxe/cleaver manufacture. This Far Eastern Chopper and Flake Tool Complex prevailed throughout the tropical, wet subtropical, and temperate broadleaf biomes of East Asia, reaching latitudes at the edge of inland Asia's steppic environments, in the Nihewan Basin. A possible westward extension into inner Asia from northern China (Chard 1974:10) may be illustrated by the Kul'dara occurrence in Tadjikistan (Ranov *et al.* 1987), as another example of Mode II non-Acheulian, around 850 kyr, through a filter route across western China (Xinjiang), when Lower Pleistocene bioclimatic conditions were less inhospitable (Rolland 1992).

It should be noted, on the other hand, that another penetration route into central Asia and/or the Far East has been suggested, which would imply that a precocious breaching of the interior mountains/plateau barrier had been achieved from the Near East (Vértes 1969; Luchterhand 1984; Gladilin and Ranov 1986). This last model, while plausible, implies that Lower Palaeolithic hominids had developed a vertical transhumance land use system much earlier than current evidence indicates (e.g. Smith 1986).

In summary, and if we adhere to the short chronology model, early humans, represented by the *Homo erectus* palaeospecies and manufacturing a Mode II technology, moved into North Africa and western Asia by 1.25 and 1 myr respectively. Hominids then reached the Far East through a southern route not later than 1 myr, and, perhaps from there, central Asia around 850 kyr. In western Asia and the Indian subcontinent, the Mode II technological horizon is Acheulian, while in the Far East and central Asia it becomes the derived and simplified non-Acheulian variant, following a techno-ecological adaptation to Southeast Asia's Indo-Malaysian and bamboo/karst forest habitat mosaic.

The colonization of Europe

This subcontinental portion of Eurasia is closest to Africa but could not be reached easily and directly from there because of several natural barriers. These include marine obstacles (e.g. the Mediterranean), for which evidence of Pleistocene glacio-eustatic landbridges have not been established, orographic obstacles, with the Taurus, Zagros and Armenian Knot ranges, and, to a lesser degree, bioclimatic ones, with the need for adapting to temperate or colder environments.

For identifying dispersal and colonization routes into Europe, it is necessary to consider together three key lines of evidence and conditions: natural barriers to overcome; the implications of 'long' and 'short' chronologies for Europe's earliest occupation; and diagnosing Lower Palaeolithic assemblage types in terms of the presence of Acheulian and atypical or non-Acheulian repertoires or facies. Hypotheses about dispersal routes leading to the peopling of Europe can be grouped into two sets, within the framework of 'long' and 'short' chronological models.

THE 'LONG' CHRONOLOGICAL MODEL

Europe

The oldest dated evidence for an Acheulian horizon in Europe does not exceed the 600–500 kyr *datum* line. Any archaeological occurrences with a proposed dating earlier than this, namely back to between 900 and 600 kyr, such as Atapuerca, Monte Poggiolo, Korolevo, Isernia la Pineta, would constitute a 'pre-Acheulian' horizon, in view of both their chronological position and, their artefact class composition, i.e. absolute absence of handaxes/cleavers.

Accepting as an empirical generalization that occurrences allegedly older than 600 kyr must belong to a 'pre-Acheulian' horizon raises important inter-pretative issues. The first one relates to the fact that such a repertoire would represent an isolated cluster throughout Europe, adjacent to regions (North Africa and the Near East) where the only known Lower Palaeolithic is the Acheulian and its atypical facies, actually present there before the appearance of a 'pre-Acheulian' horizon in Europe. The next issue pertains to the origin of this 'Pre-Acheulian', and thereby identifying the dispersal route into Europe.

One solution would be to regard the European 'Pre-Acheulian' as a lingering variant of an archaic, Mode I technological horizon, or 'pebbleculture,' with occurrences in Asia such as Yiron, Erq al Ahmar, Dmanisi and Riwat being its forerunners, thereby implying that the initial hominid colonization of Eurasia took place by at least 2 myr ago. The European record would illustrate a belated persistence of this event. This scenario, however, contains a logical flaw, because the Acheulian in adjacent regions precedes the most commonly accepted earliest dates for the 'Pre-Acheulian' in Europe: 1.25–1.0, against 900–600 kyr. The only option left, if one accepts the existence in Europe of a 'pre-Acheulian' horizon, is to diagnose it as derived or modified Mode II technology. Determining the 'Pre-Acheulian's' geographic origin, and, through this, the hominid dispersal route into Europe, brings up three alternatives: the Near East, the Maghreb, and the Far East through central Asia.

Near East

The region contains the earliest securely dated anthropic (Palaeolithic) remains beyond sub-Saharan Africa. It provides, as such, a plausible stage area for further population movements towards both the remainder of Asia and Europe. A Near Eastern origin for the 'Pre-Acheulian' faces a major objection, however, due to the fact that its earliest occurrence, 'Ubeidiya, is Acheulian.

One could argue that the European 'Pre-Acheulian' is actually derived from the Acheulian in the Levant, through adaptive modification, a process analogous to what happened when hominids moved into Southeast Asia. Habitat differences between Europe and the Near East, whilst not identical, do not present the contrasts found between the arid or semi-arid regions of western Asia and the dense equatorial or monsoon forests and woodlands of Southeast Asia. Europe also contains its own Mediterranean biomes. Furthermore, the 'Pre-Acheulian' in Europe is distributed across a variety of biomes, hardly suggestive of adaptive modifications.

An additional difficulty in considering a Near Eastern origin refers to physical barriers north of the Levant, with the mountain ranges of Anatolia, and those of the Balkans, which could have acted as filters (Bailey 1995:22), especially during much of the Lower Palaeolithic, thus delaying human movements or durable settlement until the Late Acheulian, i.e. 400–300 kyr (Howell 1960; Rolland 1992:90–1).

Maghreb

This region's greater proximity to Europe, being separated from the Iberian peninsula only by the Strait of Gibraltar, has often been regarded as a likely point of origin for either the Acheulian (Chard 1963; Alimen 1975) or for the 'pre-Acheulian' (Bordes and Thibault 1977; Santonja 1983), especially if the great antiquity of the North African 'pebble-culture' was treated as a given.

This archaeological argument concerning the 'pre-Acheulian's' origin is no longer tenable, since the very existence of the 'pebble-culture' in the Maghreb is now in doubt. Arguments of geographic proximity are also problematic: both marine and continental faunal evidence show that North Africa and southwestern

Europe remained apart throughout the Quaternary (Biberson 1968:124–5; Bonifay 1975: note 3), without biogeographic indications for faunal exchanges across the Strait. Furthermore, lower glacio-eustatic sea levels do not appear to have created landbridges at any time (Stanley 1972).

Central Asia

This region has been mentioned as both an outpost of the Far Eastern Chopper and Flake Tool Complex (Chard 1974:10), or even as a connecting route for its diffusion into Europe (Bordes 1968:69). A model of the peopling of Europe through a narrow inland palaearctic filter route, as the only alternative left to account for the 'Pre-Acheulian's' origin, has been discussed in detail (Rolland 1992). The hypothesis, outlined in Figure 7.3, describes a continuous and chronologically more or less coherent relay of non-Acheulian occurrences stretching from north China (Nihewan sites), through inner Asia (Kul'dara, Kashafrud Basin) and the Transcaucasus (Azykh, Dmanisi), and into Europe (Gerasimovka, Korolevo, Monte Poggiolo, Isernia la Pineta, Soleihac, Atapuerca). A prime mover for this protracted hominid population movement could have been the End-Villafranchian/Galerian Dispersal Event (Azzaroli 1983; Guthrie 1984)—a turnover pulse of massive scale involving large-scale extinctions and rapid evolutionary change and replacements in palaearctic Eurasia, triggered by climatic deteriorations during the Late Matuyama (1.0–0.9 myr).

This hypothesis, while possible, can no longer be regarded as proven, in view of recent conclusions supporting the 'short' chronology for the peopling of Europe, which also weaken or invalidate the concept of a 'pre-Acheulian' as an earlier horizon. Non-handaxe occurrences now appear to be penecontemporaneous with Acheulian ones. The most reasonable diagnosis is to regard them as atypical variants. The reality of the End-Villafranchian/Galerian Dispersal Event as a turnover pulse (see Vrba 1985 for the concept) is also being questioned (Roebroeks and van Kolfschoten 1994).

THE 'SHORT' CHRONOLOGICAL MODEL

This other set of hypotheses comprises fewer alternatives.

Near East

The Early Acheulian found in the Levant provides a logical antecedent for the eventual appearance of the same repertoire in Europe, on grounds of phyletic affinities and chronological priority, besides the fact that this region is in a neighbouring position with Europe. This possible point of origin remains plausible, therefore, but empirical considerations against it still apply: the natural barriers, already mentioned, for ancient hominid population movements; furthermore, besides a late dating for the Acheulian north of the Levant, in

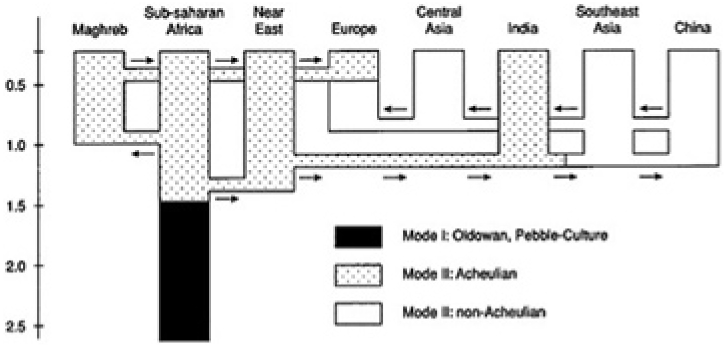

Figure 7.3 Long chronology model showing the peopling of Europe with a pre-acheulian horizon and a central Asia dispersal route. Mode I is confined to sub Saharan Africa. Mode II Acheulian is a linear development from the Oldowan and the only tool making repertoire involved in the initial hominid dispersal out of Africa, diffusing into the Maghreb, Near East and the Indian subcontinent. It undergoes a techno-ecological modification by adaptation to the Indo-Malaysian and bamboo/karst habitats. Further dispersal along coastal China, retaining Mode II non-acheulian characteristics, reaching the edge of temperate continental Asia's steppe conditions, bypassing in a loop-shaped movement to the north, inner Asia's mountains and plateaux barrier. The peopling of Europe takes place during the Late Matuyama, through a Palaearctic filter route connecting central Asia, northern Iranian plateau, the Transcaucasus, northern Anatolia, and both Black Sea coastlines, into the Balkans, involving the diffusion of Mode II non-Acheulian (pre-Acheulian, in Europe). This dispersal is linked with the end-villafranchian/galerian turnover pulse and dispersal event. The pre-acheulian horizon's phyletic affinities are actually with the Acheulian of Asia from which it derives, despite morphological analogies with Mode I Oldowan. The Acheulian is present in the Near East and the Maghreb prior to the appearance of the pre-Acheulian in Europe. The subsequent acheulian horizon in Europe represents a stratified, rather than linear event, originating probably from the Maghreb by diffusion into an already settled region (Iberia).

Anatolia and the Balkans, Lower Palaeolithic occurrences in central and eastern Europe show appreciably lower densities than further west, and most of them tend to comprise assemblages containing fewer artefacts, virtually all being atypical Acheulian. By contrast, the Acheulian in western Europe contains typical and atypical occurrences, with often rich assemblages containing at times a great abundance of handaxes. This geographic clustering could have a bearing on identifying a point of origin and a direction of hominid dispersals.

Maghreb

Several researchers have argued in favour of a Maghreb origin for the Acheulian in Europe, on the basis of both its concentration on both sides of the Gibraltar Strait, and of detailed techno-typological similarities (van Riet Lowe 1945; Chard 1963; Alimen 1975; Freeman 1975). In the absence of biogeographic evidence testifying for episodic Pleistocene landbridges, human migrations

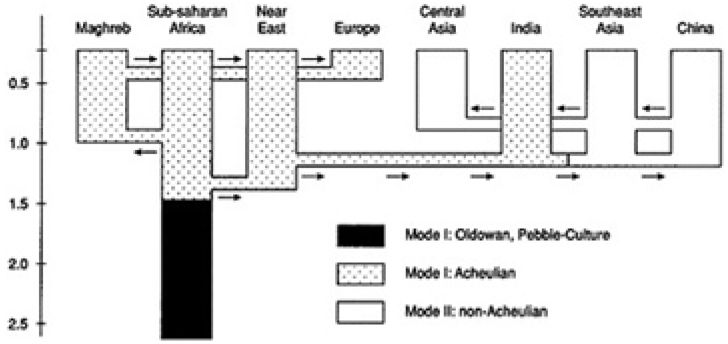

Figure 7.4 Short chronology model showing the peopling of Europe with acheulian colonization through the Gibraltar sweepstake route. Same antecedents and dispersal patterns as described for Africa and Asia. The colonization of Europe takes place during the Middle Pleistocene, originating in the Maghreb, when glacio-eustatic low sea levels were most favourable. Pre-acheulian occurrences are contemporaneous with the Acheulian which represents Europe's earliest palaeolithic horizon, making the pre-Acheulian an atypical facies of the Acheulian, rather than a preceding horizon.

would have required a crossing of the Strait (Bordes and Thibault 1977). This model, summarized in Figure 7.4, becomes the last alternative to consider within the framework of a 'short' chronology perspective. It would also document an early instance of a sweepstake dispersal route among Palaeolithic populations, with the colonization of the Sahul palaeocontinent being a classic Upper Pleistocene example. This biogeographic model may answer hypothetically why Europe was occupied much later than Asia. Other explanations (bioclimatic adaptation, carnivore guild competition) lack conclusive empirical support.

The remaining task will be to attempt reconstructing precisely the Quaternary conditions that might have enabled the first occupants of Europe to move across Gibraltar. The absence of indications from mammalian palaeontology for dry land movements across the Strait underscores this natural barrier's effectiveness, leaving a sweepstake dispersal route pattern as the only option left. This model, however, places the burden of pinpointing specific palaeogeographic conditions of short duration, as limited windows of opportunity, that made it feasible for ancient humans to penetrate into Iberia. These conditions, nevertheless, would have remained insufficient for creating even tenuous landbridges permitting exchanges between the Ethiopian fauna from the Maghreb, and the palaearctic one from southwestern Europe. Bathymetric studies show that crossings would have been hazardous during lower glacio-eustatic sea levels, despite narrower inter-coastal distances in Gibraltar, because *deep current* speed increased (Stanley 1972).

Recent findings bearing on coastal palaeogeographic reconstructions for the Last Glacial Maximum modify this verdict, however (Shackleton *et al.* 1984: 310). They conclude that the Strait narrowed to 8 km, producing a condition that, combined with more evenly balanced water temperature and salinity between the Atlantic and the Mediterranean, would not result in *surface current* acceleration. It becomes reasonable, on the strength of these conclusions, to extrapolate these processes back to some earlier, Middle Pleistocene, low sea level glacio-eustatic episodes, coinciding with Isotopic Stages 12 (443– 440 kyr) and 16 (627–592 kyr), known to have been of much greater intensity and depth (Shackleton 1987). They would have introduced uniquely optimal circumstantial conditions for hominid sweepstake-like migratory movements across Gibraltar, assisted by rudimentary navigational means (e.g. floating logs of tree trunks), at a time of enhanced across-shore visibility, and narrowest inter-coastal distances. This model, whilst not conflicting with the 'short' chronology model, provides situational evidence for the notion of an 'artificial' crossing (Chard 1963; Bordes and Thibault 1977).

Much is left unresolved concerning the peopling of Eurasia in general, and Europe in particular, even if more concrete indications are beginning to emerge about a possible dispersal route. The 'long' chronology model will require more abundant and better quality evidence, before it can be given further consideration. The archaeological period whose proposed chronology would fit within the 900–600 kyr time (Late Matuyama) will need a substantial body of occurrences, consistently without handaxes/cleavers, before it can be accepted as representing a Mode II 'pre-Acheulian' industry, rather than merely an atypical facies of the Acheulian, not to mention a firmer chronological and provenance background. Even if future finds result in lowering the time boundary for an initial human occupation of Europe, this does not necessarily imply the existence of a 'pre-Acheulian', keeping in mind that the Acheulian was already present between 1. 25 and 1 myr in adjacent regions. The alternative hypothesis of a Central (and ultimately, Ear Eastern) Asian origin for a Mode II repertoire without handaxes also calls for a considerably more robust data base.

With respect to this last model, two scenarios are conceivable: rapid colonization of Europe from the East, across the central Asia filter route, linked with the end-villafranchian/galerian turnover pulse (Rolland 1992); or a series of sporadic, perhaps abortive, founder population movements, never consolidating into durable occupation (e.g. Dennell 1983:37–9).

The 'short' chronology model remains the one with the most solid documentary support. The most likely hypothesis involves a 'sweepstake' colonization route from the Maghreb into Iberia, when Isotopic Stage 16 (or Stage 12) palaeoclimatic conditions created optimal opportunities. Anthropic evidence, besides some fossil remains, would be provided by Mode II Acheulian, with typical and atypical occurrences. The comparatively abundant, widespread and sudden appearance of *bona fide* anthropic evidence, clustered in western Europe, around 600–500 kyr, also concurs with demographic models for colonization, as well as with biogeography for barrier breaching (Simpson 1940:Figure 3).

Finally, constituent elements of both 'long' and 'short' chronologies need not be mutually exclusive, and could be integrated into a more comprehensive explanatory synthesis, by allowing for an initial series of discrete probing migratory episodes originating in the East, followed by a major, sudden and durable colonization wave originating in the Maghreb.

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8

Early colonizations and cultural continuities in the Lower Palaeolithic of western Asia

OFER BAR-YOSEF

INTRODUCTION

Western Asia occupies a central geographic location between Africa, Asia and Europe. It is the only secure terrestrial road through which animals could have crossed between the continents during the Pliocene and Pleistocene. The currently available information from the Lower Palaeolithic of southeast Spain (Freeman 1975; Gibert 1992; Raposo and Santoja 1995; Roe 1995) may indicate that early crossings from Africa to Mediterranean Europe could have taken place through the Gibraltar Straits. Another potential pathway across the Mediterranean could have been by way of Sicily (Alimen 1979), as indicated by the spread of the Acheulian in Italy and the presence of core-chopper assemblages in localities such as Monte Poggiolo and Isernia la Pineta (e.g. Peretto 1991, 1994; Mussi 1995). However, although certain morphological traits of the Spanish and Italian Acheulian assemblages could be related to similar African industries, sound evidence for early crossings of the Mediterranean is still missing from both regions.

One may speculate that successful colonization of western Asia by hominids encouraged their movement farther into Southeast Asia as well as into the European temperate belt. As a result, a great emphasis must be placed on locating the earliest sites in western Asia that mark the path of *Homo erectus* populations in the process of colonizing various regions of Eurasia. Such an investigation will enable us to ask questions concerning the frequency of the ‘out of Africa’ movements during the Lower and Middle Pleistocene. In addition, we may gain insights into the rate of survival of early hominid groups that ventured beyond their original habitat. Having emerged from essentially tropical and subtropical ecosystems, hominids succeeded, probably following numerous failures, in surviving in the Mediterranean and Asian temperate belts. Any review of Lower Palaeolithic sites in western Asia must begin by posing questions concerning the potential causes that led early *Homo erectus* to leave behind their African homeland. This homeland, in which several human species of *Homo habilis* evolved from 3.7 to 2.0 myr ago (Wood 1992), is on a continental scale limited to a relatively narrow ecological province (Figure 8.1). It is currently

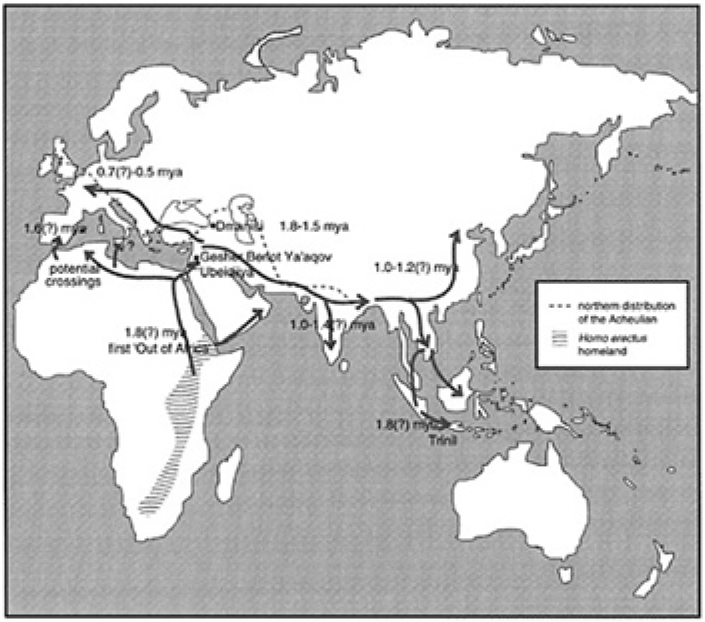

Figure 8.1 A map indicating early sorties and dispersals of *Homo erectus,* including some proposed crossings of waterways.

Source: Bar-Yosef 1994

assumed that *Homo erectus* was the only species from this region to succeed in invading other regions, crossing the boundaries of variable vegetational belts and facing different faunal communities that posed previously unknown hazards (Dennell 1983; Rightmire 1990).

In this context, the archaeological and fossil evidence from Eurasia raises several questions concerning the African records that need to be addressed in future research. These are as follows:

1 When did *Homo erectus* or the earlier *Homo ergaster* emerge as a new species, and what were the adaptational capacities that made these hominids more successful than any of the earlier species of *Homo habilis?*
2 What caused groups of *Homo erectus* to migrate out of Africa at different times? Were these movements motivated by human curiosity, by environmental pressures, expressed in terms of food shortages due to shifts in spatial distribution of resources, and/or by enhanced inter-species or inter-group competition?
3 Were migrations of *Homo erectus* groups incremental, perhaps driven by a slow population increase, or did they take the form of a series of episodic

events, interspersed with periods when humans did not leave the African continent?

4. What were the skills or capacities developed by *Homo erectus* populations, while in Africa, that enabled them to occupy Eurasia, or did they simply adapt by 'trial and error'? Did they only follow the migrating carnivores, as Turner (1992) proposed, on whom as scavengers they could rely for meat supplies?
5. Are lineage extinctions a phenomenon that could be expected to occur in the new lands, evidenced by proven gaps in the archaeological regional sequences?

Answering these questions in full is beyond the scope of this chapter. However, examining the Lower Palaeolithic records of western Asia offers us certain insights into the behavioural capacities of *Homo erectus* as the colonizing species.

The Javanese *Homo erectus* is currently believed to have arrived in Southeast Asia some 1.8 myr ago (Swisher *et al.* 1994). This date is earlier than the 1 myr date that had been upheld by numerous scholars until recently. An age earlier than 1 myr was already suggested by several geochronological observations in southwestern Asia:

1. the presence of early stone industries on the Israeli coastal plain, the Lebanese shorelines and the Syrian fluvial deposits (Hours 1975, 1981; Horowitz 1979; Sanlaville *et al.* 1993);
2. the detailed analysis of faunal collections from 'Ubeidiya (Tchernov 1986, 1987, 1992a);
3. the recently published reports on Dmanisi, a Lower Palaeolithic site in Georgia (Dzaparidze *et al.* 1989), where a *Homo erectus* jaw was discovered (Gabunia and Vekua 1995).

When taken together, the distribution of Lower Palaeolithic sites in western Asia, including the Caucasus and the intermontane valleys of the Taurus–Zagros junction, presents several potential routes of *Homo erectus* into Eurasia, as shown in Figure 8.2. It is generally accepted that major evolutionary events during the Miocene, Pliocene and Lower Pleistocene were driven by climatic fluctuations that resulted in environmental changes (e.g. Wood 1992; Vrba 1995). *Homo erectus,* as a new species, first emerged in Africa (e.g. Rightmire 1990). However, due to the large geographic gap between the African and the East Asian sites, the detailed evolution of the various kinds of *Homo erectus* is still debatable. If the Javanese dates are correct, then *Homo erectus* first appeared during or immediately after the Olduvai subchron—a major palaeomagnetic event currently dated to 2.01/1.98– 1.75 myr. A major climatic shift from a humid environment to drier conditions, lasting 10,000 years, marked the end of the Olduvai subchron (Hay 1976; Walter *et al.* 1991; Leakey and Roe 1994).

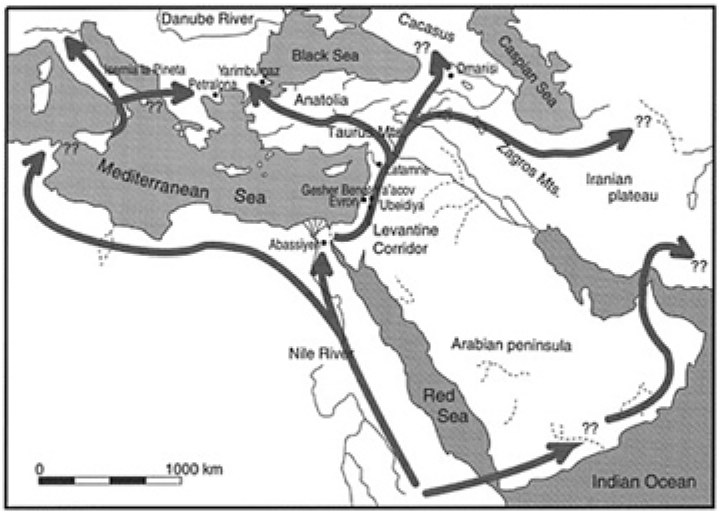

Figure 8.2 A map of northeast Africa and western Asia with the main routes of potential early dispersals of *Homo erectus* and archaic *Homo sapiens*.

On a global scale, the Olduvai subchron also indicates the increased severity of glacial cycles. It is suggested that early dispersals of *Homo erectus* or perhaps *Homo ergaster* could have begun immediately after 1.8 myr, and that the first occupations could have been in North Africa and western Asia. Therefore, the period 1.8–1.4 myr was probably the crucial formative period for *Homo erectus* populations in the new lands. Unfortunately, ambiguities in the dating of the early sites in North Africa (e.g. Biberson 1961; Jaeger 1975; Raynal *et al.* 1995) hamper the secure dating of the first human occupations in this vast region. In addition, the chronological relationship between the human occupation of the Maghreb and the movements along the Syro-African Rift (known as the Dead Sea System) is unclear. It is not impossible that the Levantine Corridor, as identified by palaeontologists (e.g. Thomas 1985), saw the arrival of humans before the Maghreb did—a proposal supported by the current dates for the first occupations in Atlantic Morocco (Raynal *et al.* 1995).

The basic assumption in this chapter is that several *Homo erectus* lineages became extinct during the Lower Pleistocene and even the early part of the Middle Pleistocene. These extinctions are, in my view, expressed in recorded gaps in the archaeological sequences of the regions where humans tried to survive. A somewhat similar view is held by the proposal that the colonization of temperate Europe took longer than previously estimated (Roebroeks and van Kolfschoten 1995). The current interpretation is that hominids occupied the temperate belt only by 500 kyr ago (Roebroeks and van Kolfschoten 1995). This assertion does not preclude the possibility that hominids ventured into the Mediterranean belt of Europe at much earlier times (Dennell and Roebroeks

1996). The evidence from early sites such as Monte Poggiolo and Isernia la Pineta in Italy, and Orce (Fuente Nueva 3 and Barranco) and TD6 in Atapuerca in Spain, indicate that this is a viable possibility (e.g. Gibert 1992; Perreto 1994; Carbonell *et al.* 1995; Roe 1995; Dennell and Roebroeks 1996).

Undoubtedly, we lack better dating of known sites, but we are also missing a sufficient understanding of the behavioural aspects, including technical skills, and the social organization of *Homo erectus* and archaic *Homo sapiens* populations. Preliminary efforts to fill this weakness indicate that archaeological data are prone to contradicting interpretations. The common approaches to behavioural models draw their basic premises from studies of either modern hunter-gatherers or primates. New efforts aiming to fill the gap between the two and to provide a new model were recently published (e.g. Tooby and DeVore 1987; Wynn 1993; Belfer-Cohen and Goren-Inbar 1994; Gamble 1994; Mithen 1994).

The technical abilities of African *Homo erectus* populations as producers of stone tools are well documented (e.g. Gowlett 1986, 1990; Isaac 1986; Leakey and Roe 1994; Schick and Toth 1994; Roche and Texier 1995). However, the paucity of evidence concerning group size, inter- and intra-group social organization, and elements of group identity (if they ever existed and/or can be detected from archaeological remains), together with the limited interpretations of excavated Late Pliocene and Lower Pleistocene sites, hamper a better understanding of the social skills of this species. Nonetheless, lithic industry studies that are based on pattern recognition of both technological and morphological (typological) attributes can perhaps be employed to identify archaeologically those groups with lasting traditions. It seems quite probable that the mental templates of *Homo erectus* differed from those of the primates, as we know them today, and that they also differed from the modern hunter-gatherers. Let us briefly examine both.

Non-human primates demonstrate a degree of ‘choices’ (e.g. McGrew 1992; McGrew 1994) and the ability to predict and therefore influence the behaviour of other individuals in the group (Tomasello 1994). Social learning is based on imitative learning, defined as the process through which an individual acquires a new skill by understanding another individual’s activities and their goal (Tomasello 1990, 1994). Tool making and tool usage are known from both studies of primates and of other animals (Boesch and Boesch 1990), such as birds and otters. However, in comparison to humans, the apparent limitations of primates in making and using stone tools have been demonstrated in experimental studies (Toth *et al.* 1993). Thus the main difference between humans and chimpanzees is that the latter do not demonstrate, as far as is known from systematic observations, the generational transmission of knowledge for tool production. In brief, primates do not create lithic assemblages or scatters similar to those found in the archaeological records of the African Late Pliocene/ Early Pleistocene. The suggestion to view the Oldowan, also referred to as Mode I (Toth and Schick 1993; Schick and Toth 1994), as an industry produced by a chimp-like hominid (Wynn and McGrew 1989) is interesting, as long as we accept that this hominid does not have analogies in the modern world of primate societies. The differences between the lithic industries of *Homo habilis* and chimpanzees are a matter not only of kind but also of degree. The producers of the Oldowan assemblages from 2.5 to 1.8 myr could have been chimp-like hominids who, due to limitations in generational learning and social organization, could never have ventured to leave their original habitats. Crossing phytogeographical boundaries and facing different game communities and different sets of parasites probably required the skills of *Homo erectus*. Short-term teaching, mostly horizontal, seems to have been replaced by additional vertical learning within the social group.

A slight increase in lithic skills required the acquisition of knowledge, and the result is seen in the appearance of Acheulian assemblages perhaps some 1.7–1.4 myr ago. However, neither the Early Acheulian nor the Developed Oldowan, as defined by Leakey (1971) (see also Leakey and Roe 1994), demonstrate the presence of a complex operational sequence *(chaîne opératoire)* when compared to the later stages of the Acheulian (e.g. Gowlett 1990; Belfer-Cohen and Goren-Inbar 1994; Roche and Texier 1995) or to the complexity of the Levallois methods (e.g. Boëda 1995; Meignen 1995). If the emergence of *Homo erectus* occurred some 1.9–1.8 myr ago, certain groups continued to produce Oldowan or core-chopper industries, whereas other groups began, around 1.7 myr, to shape the Acheulian or the biface industries. A variety of the latter is present among the Developed Oldowan, and especially in the Developed Oldowan B assemblages (Bar-Yosef and Goren-Inbar 1993; Leakey and Roe 1994). Thus *Homo erectus* groups were the bearers of both Acheulian as well as core-chopper industries. Identifying *Homo erectus* solely with the Acheulian is absolutely erroneous. The evidence from beyond the 'Movius Line' indicates that several *Homo erectus* populations and later archaic *Homo sapiens* held distinct operational sequences for making core-choppers and never made bifaces. This assertion is supported by experiments aimed at replicating stone chipping methods. Studies of operational sequences demonstrate that the dominant artefact forms resulted from different learned behavioural traditions, ignoring in many instances the constraints of the locally available raw materials (e.g. Bordes 1977; Boëda 1995; Roche and Texier 1995). This issue will be exemplified further in the following pages.

Past field work in Africa indicated that early hominids were essentially opportunistic scavengers and gatherers of plant food. They favoured riverine and patchy woodland/parkland associations where carnivore activities left behind numerous carcasses. Local hard rocks, available on beaches and dry river bed channels, were picked for making artefacts that enabled the hominids to process animal tissues (e.g. Binford 1981; Isaac 1984; Potts 1988; Blumenschine 1991; Sept 1992; Stern 1993; Rose and Marshall 1996). The direct evidence for the use of stone tools in treating vegetal components is rare, although 'pitted anvils' (Leakey and Roe 1994) are interpreted as nut cracking stones, similar to those used by chimpanzee groups in West Africa. The debate concerning early hominid use of a base camp ('central place foraging'), which resulted in the accumulation of transported stone artefacts, animal tissues and other organic substances, is still not fully resolved (e.g. Rose and Marshall 1996). Whether humans slept on the ground and/or in trees is unknown. The resolution of these questions is hampered by the partial understanding of site formation processes, although major progress has been made in recent years (e.g. Petraglia and Potts 1994). Field work in Africa often concentrated on identifying the natural agencies that were responsible for the accumulations of bones, stones and their modifications (e.g. Schick 1987; Stern 1993). However, the lack of micromorphological analyses (e.g. Courty *et al.* 1989), which has demonstrated the potential to provide the necessary information concerning biogenic contributions in well-preserved sites, requires attention (Bar-Yosef 1993).

WESTERN ASIAN ENVIRONMENTS

This chapter deals with western Asia (Figure 8.2). The main geographic features of this region include the topographic combination of mountains, plateaux, and alluvial plains. The coastal plains are narrow in comparison with those found on other continents. The Anatolian plateau is bounded by the Pontian mountains to the north and the Taurus mountains to the south, with each range spanning about 1,500 km in length. Both join the northwestern end of the 1,800 km long Zagros chain which, together with the Caucasus mountains, comprises the deeply dissected landmass. The Iranian Plateau is bounded by the Zagros mountains to the west and south, the Elburz and Kopet Dagh mountains to the north, and the Khurasan and Baluchistan mountains to the east. The Mesopotamian Plain stretches and descends from the foothills of the Zagros and Taurus into the Persian Gulf. It is bounded to the west by the Syro-Arabian Desert, which stretches into the Arabian peninsula (Figure 8.2). The Mediterranean Levant is a special zone within western Asia, covering an area about 1,100 km long and 250–350 km wide. Topographically, it includes the coastal mountain range, the Dead Sea System or the Rift of the Orontes-Jordan valleys, inland mountain ranges such as the Anti-Lebanon mountains, and an eastward sloping plateau, dissected by many wadis flowing into the Syro-Arabian Desert and spotted by oases (El-Kowm, Palmyra, Azraq).

Today, the climate of western Asia is dominated by two distinct seasons: cool, rainy winters and hot, dry summers. Winter temperatures are milder in the coastal ranges and more severe inland or at higher elevations. Precipitation is affected by distance from the sea and by altitude, with the central Anatolian and Iranian plateaux the Syro-Arabian Desert and Mesopotamia being the driest zones. In the Mediterranean Levant, rainfall decreases in a north-south direction from the Taurus mountains to the Sinai peninsula. The current distribution of the phytogeographic belts was affected by human activities during the Holocene, especially during the last five millennia. Today, Eu-Mediterranean vegetation, consisting of woodlands or open parklands, prevails along the coastal ranges.

Dwarf shrubland and steppic vegetation (Irano-Turanian) dominate the eastern Anatolian plateau, forming a wide arching belt from northern Mesopotamia into Sinai. In the semi-arid and arid region, xeromorphic dwarf shrubland and desert plant associations (Sahara-Arabian) cover most areas.

The current complex climatic system of western Asia makes it difficult to reconstruct the patterns of the past. Palynological sequences and lake levels have demonstrated that Upper Pleistocene rainfall distributions were some-what similar to those of today. Decadal and centennial fluctuations in the amount of precipitation, rather than temperature changes, were responsible for the expansion and contraction of vegetational belts (e.g. Roberts and Wright 1993). The distribution of past mammalian fauna, as well as birds and reptiles, is poorly known, and most of the information is gathered from animal bone collections retrieved from excavations across the region.

THE CHRONOLOGY OF THE QUATERNARY

The geochronology of the western Asian Quaternary is based on the correlation of coastal, marine and inland fluvio-lacustrine sequences. Calculations of the relative ages of the different formations are often based on their bio-stratigraphic positions, interpretations of their palaeoclimates and possible correlations with the curve of the Oxygen Isotope Stages. In the past, Quaternary terminology was adopted from the Alpine sequence generally correlated with the central European loess cycles (e.g. Kukla 1975; Horowitz 1979; Besançon 1981; Sanlaville 1981).

Obtaining secure dates for this region is problematic due to the rare presence of tuffs and lava flows, which are necessary for radiopotassium dating techniques. A sufficient number of palaeomagnetic readings is not yet available for large areas of western Asia. Therefore, the Quaternary subdivisions are based on local sequences of marine shorelines and inland fluvial sequences in river valleys. Their chronologies are derived from either correlations with known palaeoclimatic chronologies, such as the Oxygen Isotope Stages, or the European terrestrial faunal sequences (e.g. Horowitz 1979; Sanlaville 1981; Tchernov 1986, 1987).

Given the variability of the western Asian landscape, Quaternary cycles were identified in marine and coastal sequences, on the one hand, and terrestrial sequences, on the other (e.g. Horowitz 1979; Issar 1979; Sanlaville 1981). Inland sequences are often based on the study of wadi and river terraces, such as Nahr el-Kebir, the Orontes, the Middle Euphrates (e.g. Besançon 1981; Sanlaville *et al.* 1993), the Jordan Valley and adjacent wadis (Goldberg 1994; Schuldenrein and Clark 1994), a few riverine and wadi localities in Turkey (e.g. Albrecht and Müller-Beck 1994) and the Kura Valley in Georgia (Liubin and Bosinski 1995). Inland basins outside the Rift Valley accommodated lakes, but their Lower and Middle Pleistocene history is still poorly known (Copeland and Hours 1989).

The existing lakes in western Asia are often located in tectonic basins. Major tectonic movements took place during the Plio-Pleistocene, but later, minor ones had additional effects on the landscape. In particular, the role of tectonic movements can be observed in the formation and subsequent changes along the Syro-African Rift Valley. These movements caused older lakes to disappear and new ones to form (e.g. Horowitz 1979; Sanlaville 1988). Thus, the efforts to correlate marine coastal cycles with inland fluvial-lacustrine cycles are often tenuous.

Palaeoclimatic correlations of these formations with the Oxygen Isotope Stages may not always be feasible until new or improved techniques make possible the dating of stratified sequences where volcanic tuffs and lava flows are absent. Without a chronological control, the subdivision of the Lower and Middle Pleistocene is still a puzzle composed of stratigraphy, relative chronology based on general subdivisions of faunas into bio-zones, and pollen assemblages classified into pallynozones.

Table 8.1 presents the suggested correlations between marine cycles and fluvial and lacustrine cycles in the Levant. It is based on the works of Picard (1965), Horowitz (1979), Issar (1979), Sanlaville (1979, 1981), Besançon (1981) and Tchernov (1986, 1987, 1992a, 1992b). It should be noted that

Table 8.1 Chronological chart of pleistocene formations and lithic industries in the Levant.

Israeli coastal ingressions	*Lebanese coast*	*Nahl El-Kebir*	*Orontes Valley*	*Euphrates Valley*	*Southeast Turkey*	*Jordan Valley formations*		*Main excavations*	*Industries*	*Approx. date (myr)*
						North	*South*			
	'Naamean'					Ayeleth	Lisan	Kebara		0.075
Poleg	'Enfean II'	Jraimaqiye				Hashahar		Qafzeh	Mousterian	
Ramat Gan		Ech Chir a, b	Sarout	Abu Chaari	Cedide			Yabrud I, 1–10		
Kurkar				a, b, c				Tabun D-B		
								Hayonim		0.20
	'Enfean I					Dan		Zuttiyeh Tabun E	Acheulo-	

Israeli coastal ingressions	*Lebanese coast*	*Nahl El-Kebir*	*Orontes Valley*	*Euphrates Valley*	*Southeast Turkey*	*Jordan Valley formations*		*Main excavations*	*Industries*	*Approx. date (myr)*
						North	*South*			
Holon*	Transgression’				Travertine		Yabrud I	Yabrudian		
Hamra	Koura	Jinderiyé*	Jrabiyate*	Abou Jemaa*	Nizip					
	Regression	(Fl.)						Gharmachi Ib		
	Sequence							Berekhat Ram		
							Naharayim	Nadaouiyeh		
Azor	Jbailian I, II	Hennadi (M.)	Erosion	Erosion				Ras Beirut Ib		
Gedera	Transgressions	Khellalé (Fl.-M)						Wadi Aabet	Upper	
Kurkar								Ruhama Holon Tabun F Umm Qatafa D,E	Acheulian	
						Gesher*		Gesher Benot		
Dorot* Hamra	Regression Sequence	Berzine* (Fl.)	Latamne	Chniné	Kale Köy	Benot Ya’aqov Yarda +		Ya’aqov	Core-chopper industries Middle	

Israeli coastal ingressions	*Lebanese coast*	*Nahl El-Kebir*	*Orontes Valley*	*Euphrates Valley*	*Southeast Turkey*	*Jordan Valley formations*		*Main excavations*	*Industries*	*Approx. date (myr)*
						North	*South*			
						Yarmuk B				
En Besor	Zaqrounian	Baksa (M.)*						Latamne	Acheulian	−0.70
Tell Fara	I, II, III	Jabal Idriss	Erosion							
Kurkar	Transgression	(F1.-M.)						Evron-Quarry		
						Mishmar*				
Hasi Hamra	Regression Sequence	Sitt Markho* (Fl.)	Khattab*		Tilmgara	Hayarden		Joub Jannine II		
Eyal Gerar		Mcherfet es-Samouk			Hancagiz		‘Ubeidiya*		Lower Acheulian	~1.00±
Kurkar								‘Ubeidiya		
Zeelim									Core-chopper industries	
Hamra	‘Chabian’ or ‘Mcherfian’						Erq El-Ahmar			
‘Calabrian’										1.70 –

Israeli coastal ingressions	*Lebanese coast*	*Nahl El-Kebir*	*Orontes Valley*	*Euphrates Valley*	*Southeast Turkey*	*Jordan Valley formations*		*Main excavations*	*Industries*	*Approx. date (myr)*
						North	*South*			
Haruvit K.					II Dagi					2.00

Key: Fl. = Flluvial deposits M M. = Marine depoosits* = Sites

marine transgressions and regressions played different roles along the Syrian-Lebanese coast from on the Israeli coast. While the latter is relatively flat and the changes in sea level affected the width of the coastal plain, shore lines along the mountainous coastal strip of Syria and Lebanon are often expressed in series of terraces. However, the main sediments, whether the kurkar (sand-stone) dunes, the sandy beaches or the hamra (red loam deposits), are present everywhere along the Mediterranean shores.

The chrono-stratigraphy of the Israeli coast was unfortunately based on the assumption that the Mousterian is solely of the last (Würm) glaciation. Currently, electron spin resonance (ESR) and thermoluminescence (TL) dates indicate that this industry is at least as old as Oxygen Isotope Stage 7 age, or even Oxygen Isotope Stage 8 (Mercier and Valladas 1994; Schwarcz 1994; Mercier *et al.* 1995). Therefore, the Lower Palaeolithic in western Asia began with the first colonizations of *Homo erectus,* 1.8–1.4 myr, and lasted until the end of the Acheulo-Yabrudian, around 300–250 kyr.

The topographic and climatic heterogeneity of western Asia is demonstrated by its faunal history (e.g. Tchernov 1988). Given its location on the crossroads of the palaeoarctic, oriental and African zoogeographic zones, the region has preserved a mixture of mammals, reptiles, birds and molluscs, demonstrating the coexistence of various species. A number of species characterize the Mediterranean Basin, where local climatic conditions facilitated the emergence of endemic species, especially during the heights of the glacial periods when the desertic belts reached their maximum expansion. Today, the results of field work allow the subdivision of the Quaternary into biozones based on two areas alone: the Caucasus (e.g. Vekua 1987) and the central Levant (e.g. Tchernov 1986, 1992a, 1992b).

SAMPLING PROBLEMS, TECHNO-TYPOLOGY AND TERMINOLOGY

Due to geo-political conditions in modern western Asia, not every country has been open for systematic field research. Therefore, the following summary is undoubtedly biased, as it represents only those parts of the region that have received the attention of archaeologists during the last fifty years or so.

Lower Palaeolithic artefacts, particularly handaxes, were first noted by European travellers during the late nineteenth century, and surface collections accumulated during this time in institutions in Beirut, Damascus and Jerusalem. However, the main thrust for prehistoric research took place between the two World Wars and since 1960. Intensive surveys and excavations have been carried out since the early 1950s, mainly in Israel, Lebanon, Syria and Jordan, with fewer in the Arabian peninsula (Figure 8.3) (Garrod and Bate 1937; Rust 1950; Stekelis 1960; Clark 1967, 1969; Solecki 1968; Bar-Yosef 1975, 1980, 1994; Sanlaville 1979; Copeland and Hours 1981, 1989; Hours 1981; Rollefson 1981, 1983; Besançon *et al.* 1982; Whalen *et al.* 1983, 1984; Goren-Inbar 1985, 1995; Muhesen 1985, 1993; Solecki and Solecki 1986; Abdul-Nayeem 1990; Ohel 1991; Ronen 1991; Goren-Inbar *et al.* 1992a, 1992b; Bar-Yosef and Goren-Inbar 1993; Sanlaville *et al.* 1993).

Field research in Iraq, Iran and Turkey was more limited (e.g. Yalçinkaya 1981; Smith 1986; Albrecht and Müller-Beck 1994). Field work in Georgia and Armenia was done mostly after the Second World War by local and Russian scholars, but was poorly known in the West until recent changes in the political atmosphere enabled better communication (e.g. Dzaparidze *et al.* 1989; Liubin 1989, 1993; Liubin and Bosinski 1995).

Most of our current knowledge concerning Lower Palaeolithic sites is derived from surface collections, accidental samples from wadi and river terraces, and a small number of excavations in open-air sites and caves. The majority of the stratified occurrences and find spots were related by their stratigraphic position and typological characteristics to industries that range from pre-Acheulian or Oldowan to Late Acheulian, Acheulo-Yabrudian and Mousterian. In many cases, the artefacts were rolled and heavily patinated. Few of the collected assemblages ever surpassed a total of 500 pieces. Only a few exposures, such as the Upper Acheulian assemblages from Ouadi Aabet and Ras Beyrouth (Fleisch and Sanlaville 1974), both on the Lebanese coast, and inland sites such as the Middle Acheulian of Joub Jannine II (Besançon *et al.* 1982) and Upper Acheulian of Ma'ayan Baruch (Ronen *et al.* 1980), were subject to efforts of many years of systematic collections, yielding large samples. Systematic surface collections in the Galilee were done by Ohel (1990).

The various Lower Palaeolithic lithic assemblages in western Asia can be grouped into the following basic types: core-chopper industries and assemblages with bifaces, often known as the Early Acheulian, Middle Acheulian (only in the Levant), Upper Acheulian and Acheulo-Yabrudian.

Technological studies and typological determinations of the artefacts followed the schemes suggested by Bordes (1961) and Roe (1964), as well as the attribute analyses proposed by Leakey (1971) and Isaac (1986). Subdivision of the Acheulian sequence was done on the basis of the degree of elaboration of

Figure 8.3 A map of excavated Lower Palaeolithic sites in the Levant.

handaxe manufacture (e.g. Gilead 1970), but also takes into account relative and radiometric chronology.

The terminological subdivisions of the Lower Palaeolithic assemblages are, however, subject to controversy. Western Asian prehistorians followed both European and African terminologies. Thus, in Lebanon and Syria, the Early Acheulian or the 'early Lower Palaeolithic', as defined by Hours (1975, 1981), is an industry with high frequencies of core-choppers and some crude, large handaxes exhibiting large scars and twisted edges. Several find-spots were proved to be problematic in their cultural assignment, as only a few core-choppers and flakes were found. Further field work is usually needed in order to increase the sample and to indicate whether an occurrence could be related more accurately to an Oldowan type or core-chopper industry or to the Early Acheulian, which is defined by the presence of even a few bifaces (Bar-Yosef and Goren-Inbar 1993).

Occurrences assigned to the Middle Acheulian (or the 'Middle Lower Palaeolithic' by Hours) in Lebanon and Syria contain two 'facies'. The sites along the coast, such as Berzine, Ouadi Aabet and Ras Beirut Ib, produced more amygdaloid and oval bifaces, while the inland sites, such as Latamne and Joub

Jannine II, exhibited more lanceolates and trihedral picks. It is unknown whether this typological diversity could have arisen from chronological or raw material differences or both (Hours 1981; Copeland and Hours 1993).

The Upper Acheulian is better known from numerous sites, and its assemblages can be divided into those where the oval forms dominate and those with more pointed forms, as well as 'fades' with and without the use of the Levallois technique. Apparently, the intentional use of the Levallois technique is a subject for debate (e.g. Copeland 1995), although it is documented from the excavated assemblage of Berekhat Ram (Goren-Inbar 1985), where a human figurine was also found (Goren-Inbar 1986). Most researchers agree that the workmanship of Upper Acheulian bifaces is considerably more symmetrical and refined compared to the older assemblages. The youngest entity included in this review is the Acheulo-Yabrudian (Rust 1950; Garrod 1956), named the Mugharan Tradition by Jelinek (1981). Under the influence of Bordes, who saw a striking similarity between the thick Yabrudian scrapers and the Quina scrapers, the Acheulo-Yabrudian was included within the Mousterian sequence (e.g. Bordes 1977; Jelinek 1981). TL dates from Tabun cave (Mercier *et al.* 1995), and its stratigraphic position in El-Kowm, Adlun, Zuttiyeh cave and Yabrud rockshelter I, indicate that this entity precedes the Mousterian in the northern and central Levant and can be regrouped with the Lower Palaeolithic assemblages. Nevertheless, this is merely a terminological game, given that the separation between the Middle and the Lower Palaeolithic was never established as a major dividing line, except when the Mousterian was thought to begin only with the last (Würm) glaciation. Otherwise, it was often seen simply as a convenient subdivision. In addition, there is a growing awareness in recent times that the Mousterian period began in western Asia, Europe and probably in East Africa (McBrearty *et al.* 1996) some 250 kyr ago. It would be practical, therefore, to include the Acheulo-Yabrudian within the Lower Palaeolithic. As in Africa, core-chopper (Oldowan type) and Acheulian industries in western Asia can be interspersed in time and space. The only industry with a well-defined territory is the Acheulo-Yabrudian, which seems to have been an entirely local Levantine entity, perhaps originating in the Taurus region.

Table 8.1 summarizes the chronology of the Lower Palaeolithic. In the following pages, each of the main Early Palaeolithic sites, or local sequences, are presented briefly. The descriptive section begins with the best evidence for the earliest human occupation in western Asia, according to today's publications.

EARLY LOWER PALAEOLITHIC SITES

Dmanisi

The site of Dmanisi is a Medieval town, located on a basaltic block bordered by two tributaries of the larger Kura River. The prehistoric deposits were uncovered under the houses and in their cellars and, since the 1980s, have become a target for systematic excavations (Vekua 1987; Dzaparidze *et al.* 1989; Gabunia and Vekua 1990, 1995; Liubin and Bosinski 1995). The palaeoenvironment is reconstructed on the basis of pollen preserved in coprolites and the association of the different mammalian species. The pollen indicates that the area around the site was forested with the following types of trees: beech, pine, hornbean, walnut, chestnut, basswood, birch, hornbeam, rare elm and willow. The bushes included rhododendron, corylus and myrtle, while the herbaceous vegetation was dominated by *Cyperaceae, Graminae* and *Polygonaceae*. The association of these species indicates a region of high mountains with Alpine vegetation and the well-watered woodland of an inland basin. This general reconstruction is supported by a faunal list (Dzaparidze *et al.* 1989) that includes the following species: *Struthio dmanisensis; Ursus etruscus; Canis etruscus; Pachycrocuta* sp.; *Homotherium* sp.; *Megantereon* cf. *megantereon; Archidiscodon meridionalis; Equus* cf. *stenonis; Equus* cf. *altidens; Dicerorhinus etruscus etruscus; Sus* sp.; *Dama* cf. *nestii; Census* sp.; *Dmanisibos georgicus; Caprini* gen.; *Ovis* sp.; *Leporinae* gen.; *Cricetulus* sp.; *Marmota* sp.

Originally, the fauna from Dmanisi was attributed to the Upper Apscheronian or the Upper Villafranchian, as defined in the western Mediterranean Basin (Gabunia and Vekua 1990). While re-evaluating the assemblage following the discovery of the hominid mandible, investigators made comparisons with faunal assemblages from Europe and the site of 'Ubeidiya (in the Jordan Valley) (Dzaparidze *et al.* 1989). The results led them to suggest that the Dmanisi assemblage is slightly earlier than the faunas of Senèze and Le Coupet, and thus somewhat earlier than 'Ubeidiya as reported by Tchernov (1986, 1987). They concluded that Dmanisi could be dated to the Olduvai subchron. In addition, the *Megantereon* cf. *megantereon* are currently identified as *Megantereon whitei,* an African Maicharodont whose dispersal from Africa to Europe through western Asia is dated to the Plio-Pleistocene boundary, about 1.8–1.6 myr (Martinez Navarro 1995). According to the excavators, the age of the site is indicated by the normal polarity of the lower layers, the K/Ar date of 1.8±0.1 myr, and the Ar^{40}/Ar^{39} age of 2±0.1 myr for the lava flow under the bone bearing layers (Bosinski 1995; Liubin and Bosinski 1995). Direct dating of the bone bearing layers and additional palaeomagnetic readings are currently in progress.

The human jaw is considered by Gabunia and Vekua (1995) to represent a specimen with progressive features, though the excavators indicate its age to be that of early *Homo erectus*. A detailed morphological analysis concluded that the advanced traits of the jaw would cluster with other late *Homo erectus* remains (Bräuer and Schultz 1996).

The lithic industry of Dmanisi consists primarily of core-choppers (Dzaparidze *et al.* 1989). The reported flakes include retouched pieces that can be classified as scrapers (Figure 8.4). According to the excavators, a few bone objects were used by humans. The Dmanisi core-chopper industry marks the presence of a *Homo erectus* group that did not practise the production of

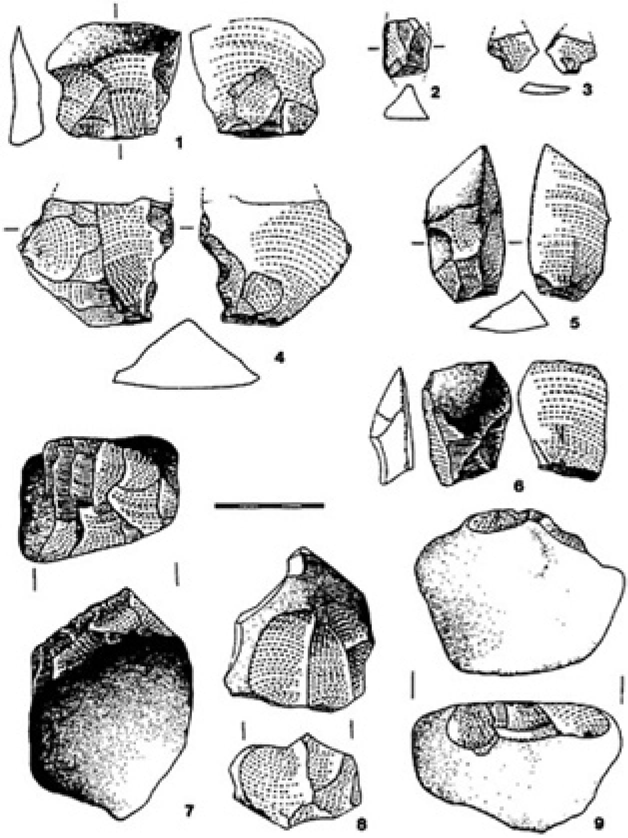

Figure 8.4 Artefacts from Dmanisi including flakes, retouched flakes and core choppers.

Source: Liubin and Bosinski 1995

handaxes. It therefore signifies the presence of hominids who either left Africa before bifaces became a common tool-type or originated in an African population that did not produce bifaces, even after the earliest manifestations of the Early Acheulian.

'Ubeidiya

The site of 'Ubeidiya is situated on the edge of the western escarpment of the Jordan Rift Valley. The geological structure is an anticline with several undulations disturbed by a few faults (Bar-Yosef and Tchernov 1972). The exposed tilted layers were numbered from those observed earliest to latest, over a total thickness of 154 m. The sequence was subdivided into four cycles: two mostly limnic (Li and Lu) and two essentially terrestrial (Fi and Fu), as explained below (Figure 8.5).

The Li-cycle, characterized by clays, silts and limestone, terminates with laminated silts, rich with freshwater molluscs and fish remains. One layer (III-12) contained mammalian bones and some artefacts including core-choppers and flakes. The only pollen spectrum collected in this layer indicates that an oak forest covered the flanks of the Jordan Valley (Bar-Yosef and Tchernov 1972; Horowitz 1979; Tchernov 1986; Bar-Yosef and Goren-Inbar 1993).

The Fi-cycle is an accumulation of clays and conglomerates, mainly beach, marshy and wadi deposits. Most of the archaeological finds and faunal remains were excavated from this member, from layer II-21 through to III-64 (Bar-Yosef and Goren-Inbar 1993).

The Lu-cycle is the upper limnic member and is essentially composed of clays and chalks overlaid by silty series. Only a few artefacts were found in this unit.

The Fu-cycle consists mainly of conglomerates, some of which are large basalt boulders. No artefacts or molluscs were found in this member. It probably represents the regression or even total disappearance of Lake ‘Ubeidiya due to the onset of a tectonic movement. This member is overlain by a Pliocene overthrusted block within which the basaltic flow was K/Ar dated to 3.6 myr (Curtis 1967).

The changes in the palaeoenvironments of ‘Ubeidiya were reconstructed on the basis of the different lithologies as well as the indications provided by the malacological and faunal assemblages (Bar-Yosef and Tchernov 1972; Figure 8.6). The results demonstrate that the lithic and bone assemblages accumulated within a sequence of complex alluvial and deltaic deposits in which lake shore fluctuations played an important role as the lake advanced and regressed. During the early phase, the lake reached almost as far as the escarpment of the Jordan Rift (the Li member). Later, the lake receded (Fi), and early humans camped on the gravelly lake shores, at the edges of the alluvial fan, and on mud flats or temporarily dried swamps. From the hilly area, several lithic assemblages were washed and redeposited within a wadi channel infilling (in particular layers K-29, K-30 and III-34, 35). The lake transgressed again (Lu), and then regressed (Fu) (Figure 8.6).

The excavations at ‘Ubeidiya uncovered numerous layers with artefacts (Bar-Yosef and Goren-Inbar 1993). Several layers could be traced on both sides of the main anticline, but in order to avoid unfounded correlations, the layers were numbered separately in relation to each geological trench. Of the sixty-three observed layers, thirteen can be considered as major archaeological horizons containing 7,956 artefacts (Bar-Yosef and Goren-Inbar 1993: Table 8.3). While a large portion of the artefacts in each of these layers was in mint condition, the frequencies of abraded pieces are up to *c.* 30 per cent (similar value to Latamne; see below). These were excavated from sufficiently large exposures and provided a fairly good idea about the nature of the lithic assemblages.

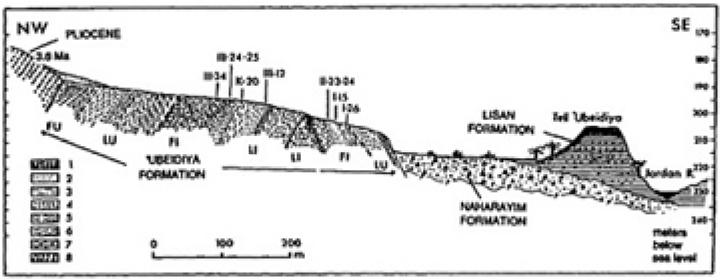

Figure 8.5 A schematic geological section at the site of 'Ubeidiya indicating the position of the richest layers within the Li and Fi members.

Source: Bar-Yosef and Tchernov 1972

Considering the depositional environment of the assemblages, regardless of the number of recovered artefacts, the following subdivision was proposed:

1 Assemblages within or on top of a swampy layer, with very few naturally transported pebbles or cobbles, include layers K-12 (also identified as III-12), III-20-22, II-23, II-24, II-25, II-36 and K-20.
2 Assemblages incorporated with naturally transported pebbles and cobbles on lake beaches, and their lateral extension into lacustrine or swampy deposit, are found in layers I–15 (also identified as II-26), II-28, I-26d, I-26c, I-26b and I-26a.
3 Assemblages incorporated within a fluvial conglomerate were uncovered in layers K-29, K-30, and III-34.

Occasional artefacts were encountered in different layers, reminiscent of the sparse finds in FLK, Olduvai Gorge, above the *Zinjanthropus* floor (Leakey 1971:58–60) and directly related to the study of the 'scatter between the patches' (Isaac 1986; Stern 1993). While this phenomenon seems to indicate the presence of hominids in the area, the tilted nature of the 'Ubeidiya layers will make it difficult to expose large surfaces and to offer a significant contribution to the discussion concerning the nature of these occurrences (e.g. Stern 1993).

The raw materials used for manufacturing artefacts were lava (basalt), flint and limestone. The basalt occurs as pebbles, cobbles, boulders and scree components; the limestone appears as cobbles within the beach and wadi deposits; and the flint is found in the same environments as small pebbles and cobbles. The 'Ubeidiya hominids used each type of rock to form a different kind of tool (Bar-Yosef and Goren-Inbar 1993). Core-choppers and light-duty tools were made of flint, spheroids mainly of limestone, and the handaxe group from basalt, with a few of flint and limestone. There is a direct correlation between the size of the tool category and the type of common raw material. Basalt is the most common rock, found in every litho-logical facies at 'Ubeidiya. However, the most abundant tool type is the core-chopper, which is made of flint. Needless to

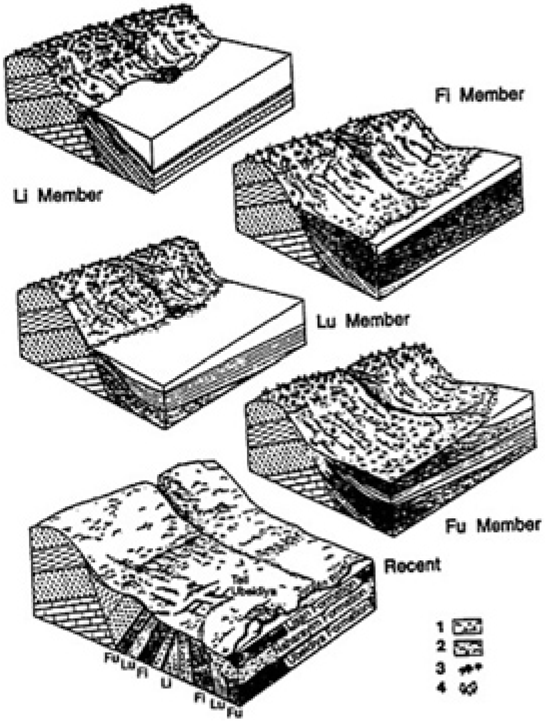

Figure 8.6 Reconstructions of four environmental situations during the Li, Fi and Lu, Fu members of the ‘Ubeidiya formation and the current geological situation.

Key: 1 – marshland; 2 – grassland; 3 – oak trees; 4 – pistachio trees

Source: Bar-Yosef and Tchernov 1972

say, flint provides a generally more stable sharp edge than basalt or limestone. The lithic assemblages were reported by using a modified type list that followed the original proposal of Leakey (1971) with additional attribute analysis (see Bar-Yosef and Goren-Inbar 1993 for details). Figure 8.7 presents the varying frequencies of artefact groups in a stratigraphic order. Most variable are the percentages of bifaces. Even a recalculation of the frequencies of choppers, bifaces, polyhedrons and spheroids would indicate that the gravelly layer K-30 is the richest in bifaces. However, the underlying layer (in the same wadi fill), K-29, produced very few bifaces. It seems that certain activities carried out in the more forested areas, from which the more abraded assemblage of K-30 was derived, were less important in the riparine environment. The almost total disappearance of bifaces in the later assemblages at ‘Ubeidiya is also noticeable, and as yet unexplained.

Following the basic contentions presented in the introductory remarks, it seems that the lithic assemblages from layers K/III-12, III-20 to 22, II-23 and 24,

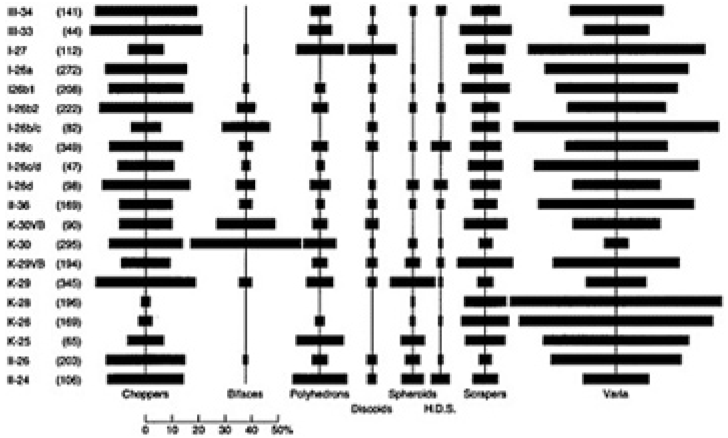

Figure 8.7 Frequencies of artefact classes of major assemblages at ‘Ubeidiya.

Source: Bar-Yosef and Goren-Inbar 1993

which contain an abundance of core-choppers, polyhedrons and spheroids but lack bifaces, except for one trihedral, deserve a speculative interpretation. The samples (Figure 8.7) are large enough to suggest that they may indicate the presence of an early group of *Homo erectus* that did not produce bifaces. The overlying assemblages contain bifaces in varying frequencies and can be called Early Acheulian (Bar-Yosef and Goren-Inbar 1993; Figures 8.8 to 8.9). Using the Olduvai terminology, assemblages with a few bifaces would fall into the category of the Developed Oldowan. In spite of the considerable similarity between the non-Acheulian and Acheulian assemblages in the basic knapping technique for the production of core-choppers and poly-hedrons, the presence or absence of bifaces is taken to designate different groups of hominids.

The dating of ‘Ubeidiya is currently based on the revised faunal studies by Tchernov and his associates, which concluded that the site should be dated to 1. 4–1.0 myr (Tchernov 1986, 1987, 1992a, 1992b), with higher probability of a date around 1.4 myr. Chronological considerations are based on the following observations and/or age determinations of geologic formations below and above the site.

1. The major tectonic activities that formed the Jordan Rift Valley (Dead Sea Rift System) post-date the deposition of the Cover Basalt. This complex formation, around Lake Kinneret (Sea of Galilee), is currently dated to 3.11 ±0.18 myr (Mor and Steinitz 1985).
2. The lacustrine and fluvial sediments of the Erq el-Ahmar Formation were recently dated by palaeomagnetic reversals (Verosoub and Tchernov 1991) to have lasted from the late Gilbert chron through the early part of the

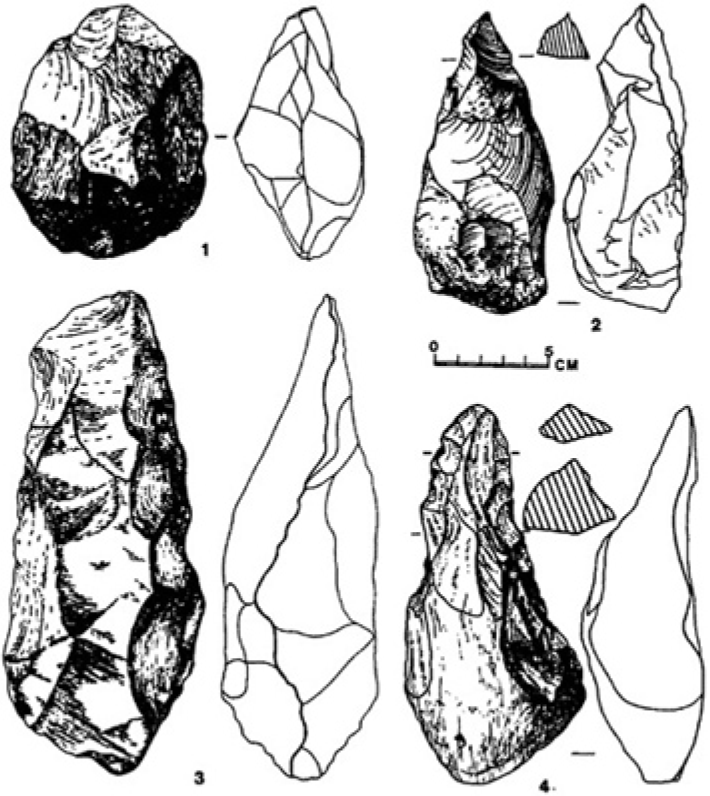

Figure 8.8 Selected bifaces (1, 3, 4) and a trihedral (2) from ‘Ubeidiya.

Sources: Stekelis *et al.* 1969; Bar-Yosef and Goren-Inbar 1993

Matuyama chron. A few core-choppers and flakes were found in its upper part, which is considered to be slightly later than the Olduvai subchron.

3 The Erq el-Ahmar Formation was dated to the Late Pliocene by the presence of *Hydrobia acuta* and *Dreissena chantrei* in its molluscan assemblage. Furthermore, it contained eight extinct species of molluscs not found in ‘Ubeidiya or in later localities (Tchernov 1986), therefore indicating a chronological and physical gap between these two fresh-water lake formations.

4 The ‘Ubeidiya Formation was deposited following a tectonic movement that contorted the Erq el-Ahmar Formation. The deposition of the ‘Ubeidiya Formation was halted by another tectonic movement that folded and faulted the formation and was possibly the cause for the eruption of the Yarmuk Basalt.

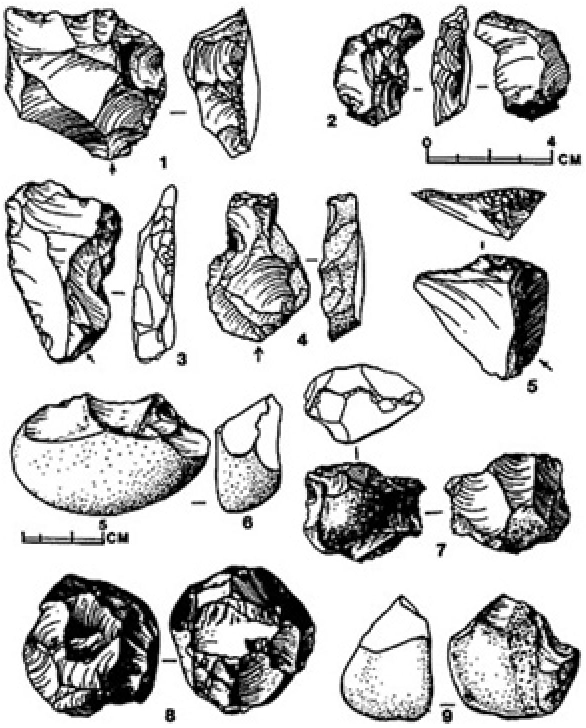

Figure 8.9 Selected retouched flakes including a scraper, core-choppers and a spheroid from ‘Ubeidiya.

Source: Bar-Yosef and Goren-Inbar 1993

5 The lava flows of the Yarmuk Basalt unfortunately do not lie directly over the ‘Ubeidiya Formation. Nevertheless, this formation is considered to post-date the latter on the basis of geologic correlations (Horowitz 1979). It was first K/Ar dated to 0.6±0.05 and 0.64± 0.12 myr, and later nine samples were averaged to a date of 0.79 ±0.17 myr (Mor and Steinitz 1985). Given the date of 0.78 myr for the Bruhnes/Matuyama boundary, it is not surprising that researchers reported normal polarity for flows of the Yarmuk Basalt. The reversed palaeomagnetic situation at ‘Ubeidiya only indicates an age within the Matuyama chron (Opdyke *et al.* 1985).

The current dating of ‘Ubeidiya relies on faunal correlations with European assemblages of known ages (Tchernov 1986, 1987, 1992a; Guérin and Faure 1988; Guérin *et al.* 1996). The subdivisions of the biozones and the dates as proposed by Guérin (1982) were as follows:

Zone 16: Lower Villafranchian, 3.2–2.5 myr
Zone 17: Middle Villafranchian, 2.5–1.9 myr
Zone 18: Upper Villafranchian, 1.9–1.4 myr
Zone 19: Final Villafranchian, 1.4–1.0 myr
Zone 20: 'Gunz', 1.0–0.6 myr
Zone 21: 'Cromerian', 0.6–0.5 myr
Zone 22: 'Mindel', 0.5–0.35 myr

Additional radiometric dates during the last fifteen years led to certain modifications of this scheme. Thus, for example, Villafranchian faunas such as Le Coupet and St Vallier are placed between 2.1 and 1.8 myr (e.g. Bonifay 1990).

The following is the list of the species as identified at 'Ubeidiya, arranged into two lists. The first indicates the relatively younger species and the second indicates the older ones. Zones as defined by Guérin (1982) are given on the basis of the major publication of the faunal assemblages (Tchernov 1986).

1 The younger species (since Zone 19) include the following:
   - *Lagurodon arankae* (Zone 19)
   - *Mammuthus meridionalis* cf. *tamanensis* (Zone 19 and early 20)
   - *Canis amensis* (Zones 19–20)
   - *Pelorovis oldowayensis* (from mid-Bed II through Bed III in Olduvai, 1.4–0.7 myr)
   - *Apodemus (Sylvaticus) sylvaticus* (reached Europe by Mid-Pleistocene from western Asia)
   - *Apodemus flavicollis* (same as *A.sylvaticus*)

2 The older species (Zone 18) include the following:
   - *Dicerorhinus etruscus* (Zones 16–20)
   - *Praemegaceros verticomis* (Zones 18–20)
   - *Panthera gombaszoegensis* (Zones 18–20)
   - *Kolpochoerus oldowayensis* (in Shungura G and Olduvai I–IV)
   - *Hippopotamus gorgops* (present in the entire sequence of Olduvai)
   - *Hippopotamus behemoth* (endemic species; Faure 1986)
   - *Hypolagus brachygmathus* (Zones 16–20)
   - *Allocricetus bursae* (in Eurasia from Zones 17–21, seemingly survived later in western Asia)
   - *Cricetus cricetus* (from Zone 17)
   - *Gazellospira torticornis* (throughout the entire Villafranchian)
   - *Sus strozzii* (Zones 16–20)
   - *Ursus etruscus* (throughout the entire Villafranchian)
   - *Pannonictis ardea* (throughout the entire Villafranchian into the Mid-Pleistocene)
   - *Megantereon cultridens* (Zones 16–19)
   - *Crocuta crocuta* (from Shungura B)

Herpestes sp. (from the Pliocene in Africa)

In sum, the fauna of 'Ubeidiya is essentially late villafranchian with a few galerian elements. Whilst African species are present, Eurasian species dominate the overall assemblage (Tchernov 1986).

From a regional view point, 'Ubeidiya and Dmanisi seem to mark two different stations in human dispersals from Africa into Eurasia (Bar-Yosef 1987, 1994; Goren-Inbar and Sargusti 1996). Such movements occurred along the 'Levantine Corridor', as defined by palaeontologists (e.g. Thomas 1985). This corridor is often reconstructed as leading from the Afar Rift into the south-eastern corner of the Arabian peninsula, across the straits of Bab el Mandeb. From there it could have taken two paths. One leads through the southern edges of the Arabian peninsula into Iran (especially when the sea level dropped in the Persian Gulf). A second path continues along the Red Sea into the Levant and extends from there both eastward and westward. The existence of the Saharan desertic belt, since the end of the Miocene, excludes the interior of the Arabian peninsula from the 'Levantine Corridor'. Under interglacial conditions, the northern penetration of the monsoonal system drastically changed the potential for increasing amounts of resources in the eastern Sahara (e.g. Neumann 1989), and could have enabled an alternative route for *Homo erectus* or archaic *Homo sapiens* groups along the western shores of the Red Sea. The Lower Palaeolithic assemblages in el-Abassieh in Cairo (Bovier-Lapierre 1926), therefore, may also indicate that the Nile Valley should not be excluded as a possible migration route.

LOWER PLEISTOCENE LEVANTINE COASTAL OCCURRENCES

Surveys along the Levantine coast located a few occurrences that appear to be of Early Pleistocene age, although dating, in most cases, is rather tenuous due to lack of datable substances. Shorelines were dated on the basis of their elevation above sea level, whilst the known relative ages of foraminifera and marine shell assemblages were also incorporated into these figures. Along the Syrian-Lebanese-Israeli mountainous front, artefacts were sometimes found on terraces as high as 120 m above sea level.

Among the find-spots on the high Lebanese shorelines, the occurrence of Borj Qinnarit contained a few core-choppers and flakes. Originally named 'Para-Acheulian' (Hours 1975), it was later recognized that sampling biases may have caused the absence of bifaces. This and additional assemblages were therefore grouped as 'early Lower Palaeolithic' (Hours 1981). If future research demonstrates that the absence of bifaces is real, as in Dmanisi, such assemblages may represent an early sortie of core-chopper bearing *Homo erectus* hominids from Africa.

Kefar Menachem, although not well dated, is a site that contains such an industry. The site, situated in the Israeli plain, was tested in a location named Halulim (Gilead and Israel 1975; and see Figure 8.4). The lithic industry is embedded in red loam assigned by Horowitz (1979) to Dorot Hamra. In the absence of faunal remains or palaeomagnetic readings, correlation with other sites is unfounded. Only the overall geological position of the site indicates a Lower Pleistocene age. The lithic assemblage of the Halulim site is composed of numerous core-choppers, flakes and some flake-tools (classified as end-scrapers, side scrapers, burins, notches and denticulates). The use of direct hard hammer percussion is dominant. To date, a few bifaces have been found on the surface, but their attribution to the excavated sample is doubtful. These bifaces are described as irregular ovates, picks, long lanceolates and backed bifaces (Gilead and Israel 1975). The excavators tentatively related this industry to the Early Acheulian. Currently the entire collection is under restudy (M.Chazan, pers. comm.).

Evron-Quarry

The site of Evron-Quarry, situated in the coastal plain of the western Galilee, was discovered when a sandstone quarry was opened in the 1960s. Systematic excavations (Ronen 1991) exposed a sequence of alternating deposits of sandstone *(kurkar),* sometimes up to 3 m thick, and red-brown loams *(hamra),* either as isolated lenses or as layers up to about 1–4 m thick. The layer that contained the Middle Acheulian horizon was separated by another deep red, loamy clay layer. This layer had two distinct horizons of calcareous concretions, occasional artefacts, and sandy clay lenses with pebbles (2–3 m thick) from the dark brown-black clay (2 m thick) that contained Upper Acheulian artefacts and a few animal bones.

The archaeological layer contained small pebbles of quartz, limestone and flint, with most of the artefacts made of flint. No bifaces were found in the excavated areas, although earlier searches in the quarry dumps recovered twenty bifaces, probably due to the small area of excavations (Figure 8.10). These are large in size (140–220 mm) and demonstrate a relatively crude workmanship that resembles that of the Latamne site (Ronen 1991). The artefacts within the archaeological horizon were distributed over an area 15–25 cm deep—a phenomenon interpreted as the result of repeated occupations. The large cobbles from which the bifaces were made, along with a group of hard calcite geodes, the heaviest of which was 580 gm, were brought to the site by the occupants from about 5 km away. The spatial distribution within the main excavation area does not indicate any effects of water flow, although it seems that a lower level that was exposed during the last season (1985) was affected by over-bank flooding (Ronen 1991).

The fragmentary animal bone assemblage from the excavations, in which an elephant tusk 1 m in length was found (Tchernov *et al.* 1994), includes the

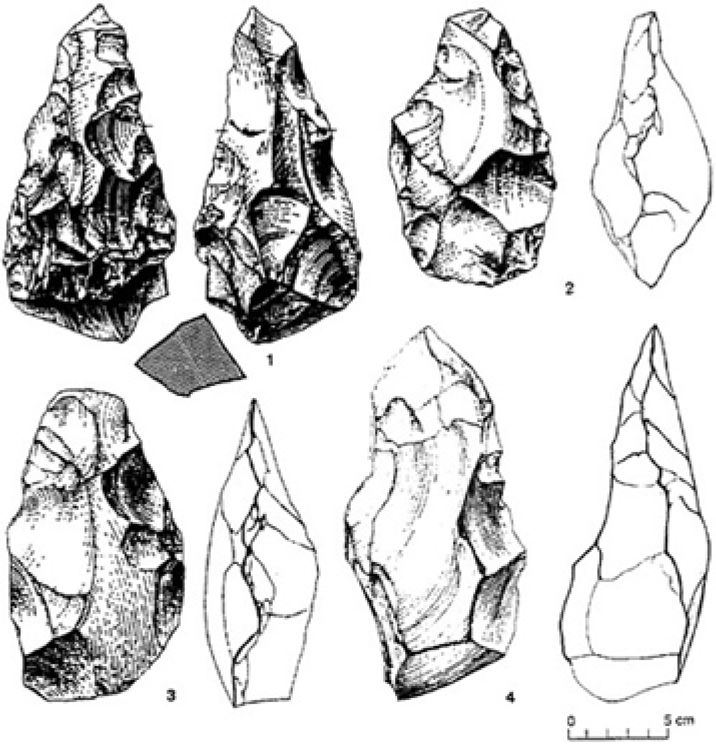

Figure 8.10 Selected bifaces from Evron-Quarry.

Source: Gilead and Ronen 1997

following species: *Elephas* sp.; *Stegodon* sp.; *Hippopotamus* sp.; *Kolpochoerus everonensis; Cervus* (?) *elaphus; Capreolus* sp.; *Bos primigenius; Alcelaphus* sp.; *Gazella gazella; Crocuta* or *Hyaena; Gerbillus* sp. (cf. *dasyurus*); and *Trionyx* sp. Biogeographically, there is a marked oriental stamp on this faunal assemblage that seems to have been caused by an influx of South Asian species. The African species are considered as stragglers from post-'Ubeidiya times.

The faunal assemblage reflects a mixed habitat incorporating woodland and riparine environments with a few rocky exposures. Chronologically, it is assigned to a post-'Ubeidiya age, and is perhaps contemporaneous with the Latamne site in Syria (*c.* 1.0–0.6 myr).

INLAND LOWER PALAEOLITHIC SITES

Latamne

Earlier surveys of the terraces of the Orontes River provided a sparsely distributed core-chopper assemblage, collected in the gravels of the Khattab Formation and at the site of Latamne (Sanlaville *et al.* 1993). The earlier assemblage was called 'Khattabian', and compared to both 'Ubeidiya and the site of Sitt Markho in the Nahr el Kebir terraces. The site of Latamne, discovered in the 1960s by W.J.van Liere, was excavated by Clark (1967, 1969), and additional field work was done by Sanlaville and his associates (1993).

The archaeological horizon of Latamne lay in the mid-sequence of the Latamne Formation (de Heinzelin, in Clark 1969). It contained the Latamne 'occupation floor'—a silty layer only a few centimetres thick (up to 10 cm) capped by sandy-silty bedding with traces of rootlets. The sequence was interrupted by erosion and was overlaid by a fluvial sandy deposit, capped by a lacustrine layer. Palynological samples from the Latamne Formation indicate that the mountain slopes were forested by broad-leafed trees such as oak, hornbeam, linden (basswood), walnut, elm, hazel birch and by coniferous species such as pines and cypress (Sanlaville *et al.* 1993).

Geomorphological observations indicate that the archaeological horizon of Latamne resulted from a low-energy water flow that was responsible for the deposition of the artefacts and their pattern of spatial distribution. About one-third of the total 3,724 recorded artefacts were classified as slightly abraded or abraded. Water activity in leaching the sediments, as well as diagenesis, destroyed most of the bones. Most of the well-preserved identifiable bones were collected from the gravels underneath the archaeological site. These were first identified by Hooijer (1962) and were later restudied by Guérin *et al.* (1993) who, together with Mein and Besançon (1993), added the newly found micromammals to create the following list: *Stegodon* cf. *trigonocephalus; Ekphas trogontherii,* currently classified as *Mammuthus trogontherii; Equus* cf. *altidens; Dicerorhinus* cf. *hemitoechus; Hippopotamus amphibius,* reclassified as *Hippopotamus* cf. *behemoth; Orthogonocerus verticomis,* currently classified as *Praemegaceros verticomis; Camelus* sp.; *Giraffa camelopardalis,* an undetermined antelope, perhaps *Pontoceros; Bos primigenius; Bison* cf. *priscus* (the earliest positively identified in the Levant); *Canis aureus; Crocuta crocuta,* the insectivore *Crocidura sauveolis* and rodents including *Apodemus flavicollis; Arvicola jordanica; Meriones maghrebianus;* and *Lagurodon arankae*. During the excavations of the archaeological horizon, the most common bone fragments seemed to belong to the equids and elephant-types, although the presence of two additional species was suggested: *Dama mesopotamica* and *Gazelle soemmeringi*.

Hooijer (1962) originally assigned the overall assemblage to the 'Mindel-Riss' Interglacial, in relation to the western European faunal bio-stratigraphy. The re-

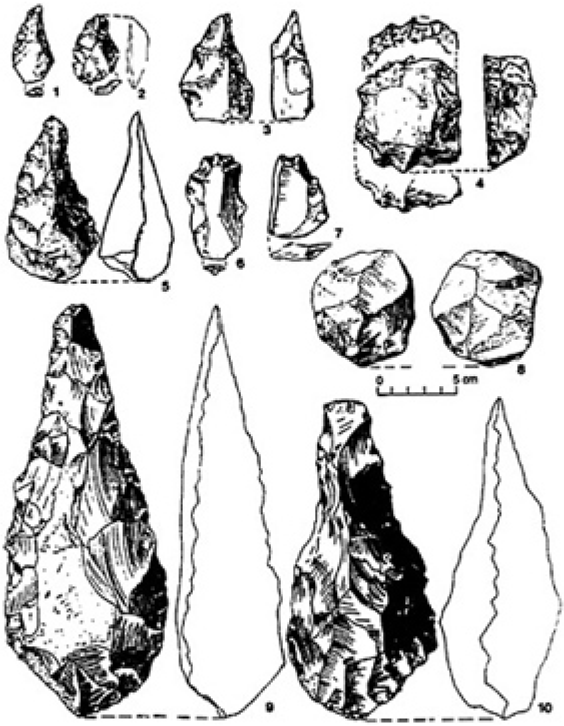

Figure 8.11 Retouched flakes, denticulates, scrapers and bifaces from Latamne.

Source: Clark 1967, 1969

examination of the material and the newly discovered rodents (Guérin *et al.* 1993; Mein and Besançon 1993) suggest that there is greater similarity than was previously thought between the faunas from Latamne and 'Ubeidiya. At the same time, however, the authors view 500 kyr as the latest potential date for the site. With a single TL date of 560 kyr for the Latamne Formation, the proposed dates for the entire sequence would be 700–500 kyr (Sanlaville 1988; Sanlaville *et al.* 1993).

Clark noted that most of the artefacts from Latamne were made of raw materials available on site, such as flint, limestone and basalt. Large flint cobbles could easily have been knapped, generally by hard hammer percussion, although scars on several bifaces indicate the occasional use of the soft hammer technique (Figure 8.11).

The tool classes can be roughly divided into thirds according to tool type: a collection of bifaces; a group of light-duty scrapers; and a category including heavy-duty tools, a few spheroids, and others. Among the handaxes, there are a few trihedral picks, similar to those found at 'Ubeidiya. Several spheroids were

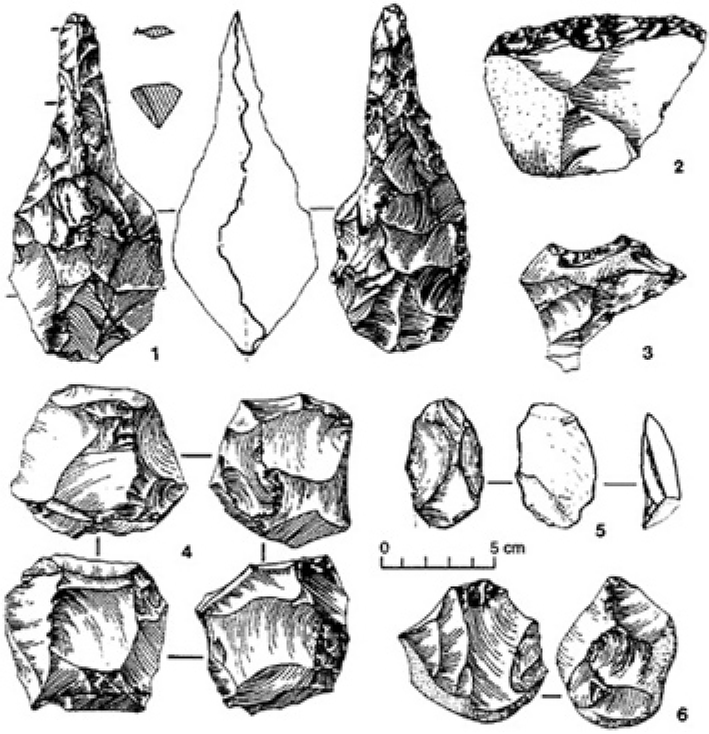

Figure 8.12 A biface, scraper, retouched flakes, polyhedron and a core chopper from Joub Janine II.

Source: Hours 1975

made of limestone and basalt. Choppers comprise only 4.3 per cent of the core-choppers, but this percentage would increase to 27.5 per cent if we broaden the category to include the polyhedrons and cores. This shift in frequencies would bring the Latamne assemblage closer to some of the ‘Ubeidiya assemblages.

Other Middle Acheulian sites include Joub Jannine II and Berzine (Copeland and Hours 1993), though unfortunately these assemblages were surface collected and therefore there are no *in situ* deposits (Besançon *et al.* 1982). The lithic assemblage of Joub Jannine II (Figure 8.12) is composed of high frequencies of bifaces and picks, along with polyhedrons (26 per cent) and core-choppers. Like the spheroids at ‘Ubeidiya, these were made of lime-stone cobbles (Besançon *et al.* 1982).

Gesher Benot Ya'aqov

The site of Gesher Benot Ya'aqov lies on the eastern edge of a vast, basalt-covered area (Gebel Druz and the Black Desert) within southern Syria and northern Jordan. It is unique in the context of the western Asian Lower Palaeolithic. The excavations in the 1930s by M.Stekelis, and recently by Goren-Inbar and her associates (Goren-Inbar *et al.* 1991, 1992a, 1992b; Goren-Inbar and Saragusti 1996), provided an African-type assemblage of cleavers and bifaces that is unlike any of the other 170 Acheulian sites, including both surface and excavated occurrences (e.g. Gilead 1970; Hours 1975, 1981; Bar-Yosef 1987; Goren-Inbar 1995). Gesher Benot Ya'aqov is located in the gorge of the River Jordan in the Hula Valley. The nature of the deposits and the malacological assemblages, dominated by *Viviparus apameae,* indicate that the archaeological assemblages accumulated on the shores of an expanding lake that flooded the gorge (Horowitz 1979; Goren-Inbar *et al.* 1991, 1992a, 1992b; Goren-Inbar and Saragusti 1996). The complex stratigraphic sequence, first exposed by Stekelis (1960), contains early layers with an Acheulian industry (Stekelis layers VI–V) dominated by the production of cleavers and bifaces from basalt, although recently flint and limestone tools were also uncovered in these layers. The cleavers were fabricated by the Kumbewa technique (Goren-Inbar *et al.* 1991, 1992a; Goren-Inbar and Saragusti 1996; see Figure 8.13). The upper layers in the Stekelis excavations (IV–II) contained bifaces made of flint that are similar in form to other known Upper Acheulian assemblages in the Levant (Stekelis 1960). Despite the fact that other parts of the Levant (such as the Hauran-Golan-Gebel Druz area, parts of southern and eastern Jordan and the eastern Galilee in Israel) are also covered by lava flows, it should be emphasized that lava-made Acheulian assemblages have not been noted in any of the surface surveys of these areas. On the contrary, in most cases flint nodules that derived from isolated limestone and chalky outcrops, often of eocene age, served as a raw material for fabricating handaxes (e.g. Goren 1979; Goren-Inbar 1985; Ohel 1991). The exceptionally good preservation in this water logged site provided a wealth of plant remains, including seeds, fruit, etc., as well as numerous pieces of wood. In addition, the site produced the only known shaped wooden object (Belitzky *et al.* 1991).

The archaeological horizons of Gesher Benot Ya'aqov are embedded in a depositional sequence that accumulated above a lava flow with normal polarity. The lava flow, designated as the Yarda Basalt, was first K/Ar dated to 0.68 ±0.12 myr (Horowitz 1979) and later to 0.9±0.15 myr (Goren-Inbar *et al.* 1992a). The fauna that derived from the lower layers of the Stekelis excavations in the 1930s, as well as from the new excavations, was restudied, and the following is an updated list: *Elephas antiquus; Stegodon* sp.; *Hippopotamus* (?) *amphibius; Dicerorhinus hemitoechus; Equus* sp.; *Sus scrofa; Cervus* cf. *elaphus; Dama* cf. *mesopotamica; Bos* sp.; *Copra* sp.; *Gazella* cf. *gazella; Gerbillus* cf. *dsyurus* (Geraads and Tchernov 1983; Goren-Inbar 1992b). This assemblage falls within

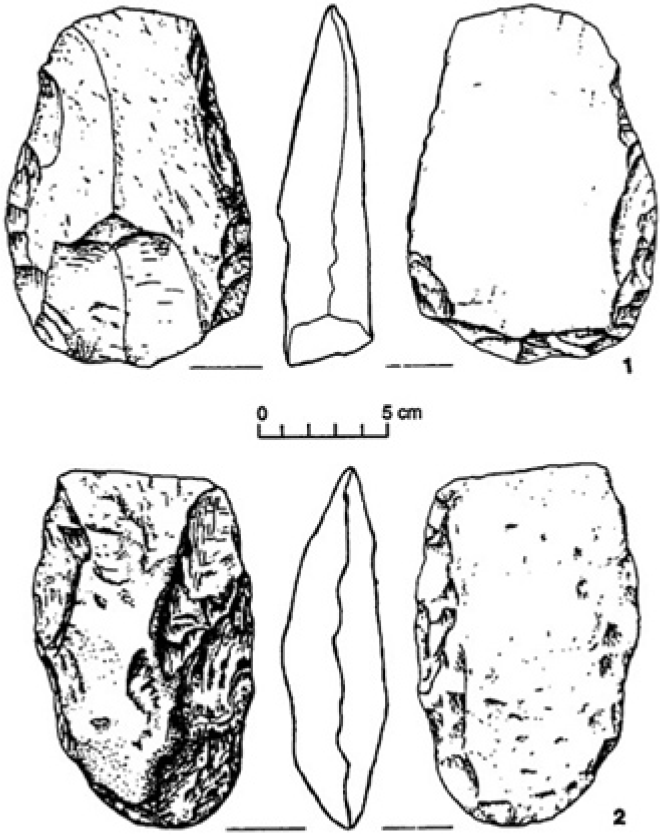

Figure 8.13 Two basalt cleavers from Gesher Benot Ya'aqov.

Source: Goren-Inbar *et al.* 1992b

the general definition of the galerian fauna that replaced the late villafranchian association around 0.9–0.7 myr (Azzaroli *et al.* 1988). It should be noted that two broken human leg bones, of which the exact provenance within the site is unknown, were attributed to *Homo erectus* (Geraads and Tchernov 1983).

The site of Gesher Benot Ya'aqov is interpreted to be the archaeological remains of a group of hominids that migrated from Africa (Bar-Yosef 1987; Goren-Inbar and Saragusti 1996). It has been suggested (Bar-Yosef 1994, 1995) that this move was triggered by environmental change that occurred around the Jaramillo subchron or the Brunhes/Matuyama boundary. Palaeoclimatic conditions in the northern hemisphere, as recorded by deep sea cores and terrestrial fauna, reflect a clear increase in the intensity of the glacial cycles. This cumulative climatic change probably resulted in increased periods of aridity on the African continent. Given the level of the available food acquisition techniques of Late Lower or Early Middle Pleistocene groups, a major palaeoenvironmental deterioration probably led to an intense competition for resources that forced certain groups to seek alternative foraging grounds. The exact place of origin within the African continent of the producers of the Gesher Benot Ya'aqov assemblages remains unknown. It could be East Africa, given that the Acheulian sequence began there earlier. North Africa is also a possible candidate, given its long tradition of cleaver production, but the current dates for human occupation in this region are uncertain (Raynal *et al.* 1995). At any rate, one may speculate that, after a period of undetermined length, the Gesher Benot Ya'aqov hominids either died out, assimilated among other western Asian contemporary groups, or adopted the common local techniques for producing handaxes from flint.

THE MIDDLE ACHEULIAN IN THE NORTHERN LEVANT

As has been mentioned above, most of what is known from the areas of Lebanon and Syria was obtained through the study of the terraces of Nahr el Kebir, the Orontes and the Middle Euphrates (e.g. Hours 1975, 1981; Sanlaville 1988; Muhesen 1993; Sanlaville *et al.* 1993). The majority of the sites were classified as belonging to the Early and Middle Acheulian, first on stratigraphical grounds and later upon consideration of their typological characteristics. All samples were collected from gravel deposits along the Nahr el Kebir and the Orontes rivers and the coastal shorelines. Rare finds were retrieved from exposures along the valley of the Euphrates River and in several localities in the Beqa'a Valley. Chronologically, they were assigned to the Qf IV–III, Qm III–II stages (see Table 8.1), or in other words, to the Lower and Middle Pleistocene. Unfortunately, no radiometric dates or palaeo-magnetic readings are available to support this chronological scale. The main sites include Berzine, Ouadi Aabet and Ras Beyrouth, both on the Lebanese coast, and Latamne and Joub Jannine II, which were described above (e.g. Clark 1967, 1969; Besançon *et al.* 1970, 1982; Fleisch and Sanlaville 1974).

The lithic studies of the Middle Acheulian assemblages identified two geographic fades. The sites along the coast, such as Berzine and Ouadi Aabet, contain essentially amygdaloid and oval bifaces, while the inland sites (Joub Jannine II and Latamne) have more lanceolates and trihedral picks. Recent work along the Nizip River (Minzoni-Deroche and Sanlaville 1988), a tributary of the Euphrates in Turkey, recognized a similar distribution with the Middle Acheulian artefacts in the Qf III deposits. It is unknown to what extent this typological diversity between the coastal and inland sites arises either from diachronic differences (the inland sites being earlier), or simply from the use of raw material of different sizes. The gravel quarries in Latamne and the size of cobbles near Joub Jannine (the Beqa'a Valley) convey the impression that the actual variability stems from the differences between the large eocene flint cobbles and the somewhat smaller Jurassic and cenomanianturonian cobbles employed along the coast.

THE MIDDLE ACHEULIAN AND CORE-CHOPPER INDUSTRIES IN THE SOUTHERN LEVANT

The Middle Acheulian has rarely been used as a designation in the literature of the southern Levant. Assemblages that seem to fall within this category on the basis of the dominant biface forms can also be attributed by their elaborated shaping and by the flake industry to the Upper Acheulian. Assemblages like Holon provide a fair idea about the various aspects of an open-air Acheulian site, temporarily classified as 'Middle Acheulian' following the definition of the rich assemblages in Umm Qatafa layer E (Neuville 1951; Yizraeli 1967). In addition, it should be stressed that the layers in this site below the Acheulian contained a core-chopper assemblage that was called 'Tayacian (or Clactonian)' by the excavator.

The site of Holon is embedded in marshy deposits overlying an abraded kurkar ridge, dated by Horowitz (1979) to the 'Rissian' pluvial, potentially around 500–400 kyr. The site contained more than one level, but the available preliminary report describes artefacts obtained from the main level only. The bifaces are mostly of pointed and rounded aspects; the flake industry contains racloirs, denticulates and notches, along with cores and debitage products. The assemblage is currently under study (Chazan, pers. comm., 1995). ESR and luminescence dating suggested for the archaeological horizon a date of *c.* 215 kyr and *c.* 220 kyr respectively. The ESR date is comparable to ESR readings from teeth from Garrod's excavations in Tabun layer E (the Acheulo-Yabrudian). However, TL dates of burnt flint pieces from this layer indicate an age older than 270 kyr (Mercier *et al.* 1995). This would mean either that the Holon Acheulian was contemporary with the Early Mousterian (TL dated to 270–170 kyr), which is untenable, or that there is a systematic difference between luminescence dates of quartz grains and TL of burnt flints.

The animal bones were preliminarily identified primarily as elephant (including an entire tusk), hippopotamus, wild oxen, equids, deer and fragments of *Trionyx* sp. shell (a fresh water turtle). The mixture of large and medium-sized animals may have resulted from human scavenging and hunting in an environment where both carcasses and free-ranging animals were in abundance. Nonetheless, despite the lack of plant remains, it can be assumed that gathering was probably the main source of calories in such an environment.

Another site, tested only by Gilead and as yet not published, is located near Tel Hesi. The industry found there contained many core-choppers but was wrongly assigned by Issar (1979) to the 'pebble-culture.' Broken tips of typical Upper Acheulian bifaces were found *in situ,* along with fragmentary bones of equids. The deposit in which the cluster of artefacts and bones were embedded is a sandy-clayish layer, situated, like Holon, near the course of a major wadi. A special industry was reported from Ruhama (Figure 8.3), where numerous core-choppers, debitage products and retouched flakes were surface collected from an outcrop of paludine facies of the so-called Holon Member (Horowitz 1979:111). A systematic excavation was initiated in 1996 (Ronen, pers. comm.). No bifaces were found, and the bones from the original surface collection were identified as deer, equids and elephants. This non-Acheulian industry was first named Nagilan by Ronen (1979; Lamdan *et al.* 1977).

Two additional assemblages without bifaces were discovered by Garrod in Tabun (Garrod and Bate 1937; Layer G) and by Neuville (1951) in Umm Qatafa (Layers E-G). Both were first called Tayacian, following the common European terminology, and later Tabunian by Howell (1959). The Umm Qatafa lithics were not a subject for re-examination, as in the case of Tabun, where Jelinek (1982a) suggested to view both sites as belonging to the Acheulian. The presence of non-biface industries to which the Shemsi assemblage, excavated by Solecki (1968) in Yabrud IV, should be added, indicates that this issue requires a new, in-depth study.

THE UPPER ACHEULIAN IN THE NORTHERN LEVANT

A large number of find-spots and a few major occurrences were located in the northern Levant (Hours 1981; Muhesen 1985, 1993), mainly in the lower reaches of Nahr el-Kebir, the Sajour (a tributary of the Euphrates), the Middle Euphrates and the Orontes rivers. Nadaouiyeh in the El-Kowm Basin (Hours *et al.* 1983; Le Tensorer *et al.* 1993) and Yabrud rockshelter I provided stratified collections. One open-air site (Gharmachi Ib; Figure 8.14) was tested and excavated (Muhesen 1993).

The observed general technological tendency is towards the greater use of soft hammer percussion and the appearance of the Levallois technique. However, in no one assemblage does the percentage of the products detached by the Levallois technique surpass 12 per cent, although Levallois cores may be more numerous among the core category (Copeland and Hours 1981).

Typologically, the almost total disappearance of core-choppers is noticeable. The cordiform and amygdaloid bifaces outnumber the ovates. The length of the handaxes decreases in general—a tendency that was already noted by Gilead (1970) for the southern Levantine samples. A special facies of the Late Acheulian was recognized near the outlet of Nahr el-Kebir. Four localities produced small choppers, small bifaces (45–90 mm in length) and a large number of cores. The Levallois technique was apparent in 40 per cent of the cores and 20 per cent of the products (Muhesen 1985). The patina was the same for all the pieces, and the artefacts were reported to be in fresh condition. The industry was named Samoukian, following the name of the type-site Mchairfet es-Samouk. It seems that the pebbly raw material, in this specific situation where

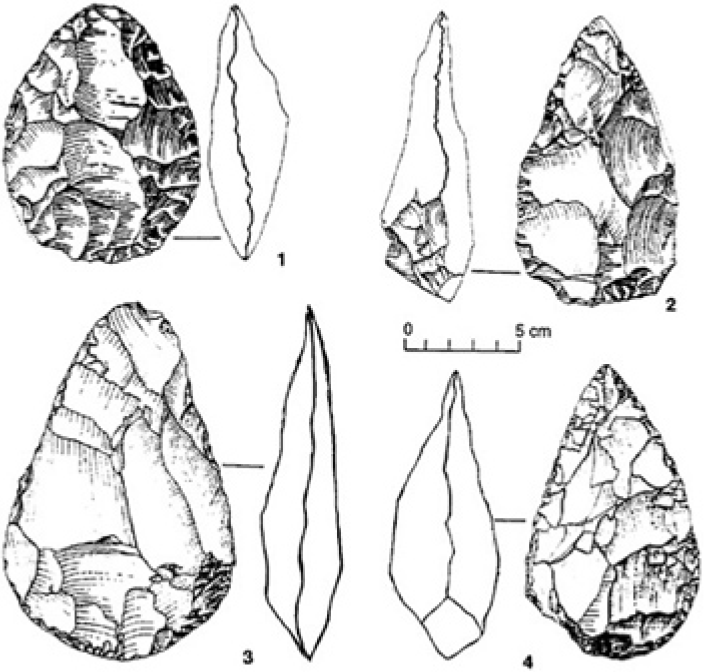

Figure 8.14 Bifaces from Gharmachi IB (1, 2) and Ma'ayan Baruch (3, 4).

Sources: Stekelis and Gilead 1966; Hours 1981

fluviatile terraces intermingle with marine terraces, had its influence on the composition of the industry.

The site of Gharmachi Ib is located in the mid-Orontes Valley, within the Jraibiyat Formation, and was a subject for systematic excavation (Muhesen 1985, 1993). Unfortunately, bones were not preserved, but the rich lithic assemblage provided a large sample of bifaces, choppers and some products of the Levallois technique. The bifaces are ovoid and amygdaloid in shape.

Intriguing reports exist concerning several assemblages, mostly surface collected in the same area, that presumably originated in the Saroute Formation. These assemblages are composed of ovate bifaces, and often small and relatively rare Levallois elements. Following the name of the main factory site, Tulu Defai, the industry was named Defaian.

Nadaouiyeh I, a Late Acheulian site discovered in the El-Kowm Basin (Hours *et al.* 1983; Le Tensorer *et al.* 1993), was found to have several occupational horizons. This site is composed of an accumulation of alternating clayish and sandy layers near an artesian spring. The stratigraphy is a complex one, marked by slumping and erosion. The systematic excavations demonstrated the presence of *in situ* Acheulian assemblages. The bifaces, generally amygdaloid, were accompanied by a rich flake industry in every one of the six tested layers. The presence of the Levallois technique was noted in low frequencies. Unfortunately, no bones were preserved. In addition, the Nadaouiyeh site contains yabrudian and hummalian (an early mousterian industry) assemblages.

Given the uncertainties in the detailed intra-regional geochronological correlations across the Levant, it is safest to assume for the time being that the various facies of the Upper/Late Acheulian preceded the Acheulo-Yabrudian industry sequence. This interpretation raises the possibility of an apparent discontinuity between the Late Acheulian assemblages which, according to several authors, contain the evidence for the use of the Levallois technique, and the Levantine Mousterian, in which this technique was generally dominant. Unfortunately, the lack of radiometric dates precludes further affirmations. The current debate on the definition of the various Levallois methods requires clearer resolutions concerning the use of this technique within Late Acheulian assemblages (e.g. Dibble and Bar-Yosef 1995 and references therein).

THE UPPER ACHEULIAN IN THE SOUTHERN LEVANT

The basic techno-morphological study by Gilead (1970) still serves as a framework for seriating the Upper Acheulian in the southern Levant (Bar-Yosef 1980; Goren-Inbar 1995). Using a large series of surface collections in which bifaces were the main artefact class, Gilead (1970) subdivided the Acheulian into several groups as follows:

1 The Ma’ayan Barukh group (MB) is characterized by the dominance of the cordiform aspect (including amygdaloids, cordiforms and subtri-angulars), up to 40–50 per cent. Ovoids form 20–25 per cent, along with a few pointed bifaces and some cleavers (Figure 8.14). The assemblage of Umm Qatafa D2 is included.

2 The Evron-Kissufim group (EK) is, on the basis of stratigraphic evidence, later than the MB group. It contains a richer flake tool component, up to 30–60 per cent, with clear evidence for the manipulation of the Levallois technique. The bifaces show a decrease in rounded aspects (ovates and discoids) and a slight increase in the pointed forms.

3 The Sahel el-Khoussin-Yiron group (SY) are those assemblages that are mostly surface collected in the hilly areas and flanks. The bifaces are somewhat cruder than those of the other groups, with an occasional dominance of the rounded aspect over the cordiform aspect (e.g. Yiron, Beith Uziel, Baqaa-Rafaim). As in the EK group, the Levallois technique was practised in some sites. It is worth noting that, despite the hilly distribution, these assemblages are not present in the three caves where Upper Acheulian layers were uncovered (Tabun F, Abu Sif, Umm Qatafa D).

It seems that, in part, the variability in metrical attributes among the sites reflects differences in the size of the raw materials available in the vicinity of the sites. Many, although not all, of the assemblages of the SY group are made on the so-called 'brecciated' campagnian (senonian) flint. This flint is more difficult to knap due to its uneven consistency, and the resulting tools contain various irregular breakages. The frequencies of refinement index (thickness/breadth×100) demonstrates the differences among the sites. The same is probably true when the mean length among Upper Acheulian sites is considered. Wherever large cobbles were available, there was a tendency towards larger bifaces. However, a general tendency for decrease in biface length could indicate increasing efficiency of resharpening (perhaps longer curation?) during the Upper Acheulian.

The flake industry of most of the Upper Acheulian occurrences is not very well known. In some places, the number of flakes cannot account for their manufacture. For instance, the thousands of bifaces found in Ma'ayan Barukh may have been produced in an area further north, near the Litani River. The flakes collected from the same surface clusters could indicate some resharpening (although small flakes and chips are not easy to retrieve in the deep red soil of these hills). It seems that the concentration of bifaces near the Hula Lake shores on the interfluves of freshwater creeks may represent repeated butchering activities in a pristine environment. A unique Upper Acheulian site, embedded between a lava flow dated to 233±3 kyr and an older lava dated to 800 kyr, was excavated on the edge of the crater lake known as Berekhat Ram on the Golan Plateau (Goren-Inbar 1985). The rich assemblage contains 6,045 artefacts, mostly in excellent condition, with 404 retouched pieces, including eight small bifaces (Figure 8.15). The makers of the industry employed the Levallois centripetal (radial) technique. A special find is a human figurine (Goren-Inbar 1986) that recently received much attention in the debate concerning the capacities of archaic *Homo sapiens* or late *Homo erectus* (e.g. Marshack, in press). The actual date of the site is unknown, but given the current TL dates of the Acheulo-Yabrudian and the approximate date for Gesher Benot Ya'aqov, it should be placed during the time span of 500–350 kyr.

At other sites, such as the Baram-Yiron Plateau (Ohel 1986, 1990), in Evron-Zinat (Gilead and Ronen 1977) or in Kissufim (Ronen *et al.* 1972), the flake industry is quite variable and is often made by the Levallois technique. Unfortunately, in many of the coastal occurrences, it is difficult to ascertain to what extent they could have been mixtures of mousterian artefacts with earlier Upper Acheulian assemblages. In general, Upper Acheulian sites can be found across the Near East in every environment, including the coastal plain, hilly areas, intermontane valleys and oases. The best example to date from an oasis situation is the series of Upper Acheulian assemblages that is characterized by high frequencies of bifacial cleavers, uncovered in the Azraq Basin (Copeland and Hours 1989). Among these, the sounding at Lion Spring provided stratified lithic assemblages that are characterized by ovate, amygdaloid and cordiform

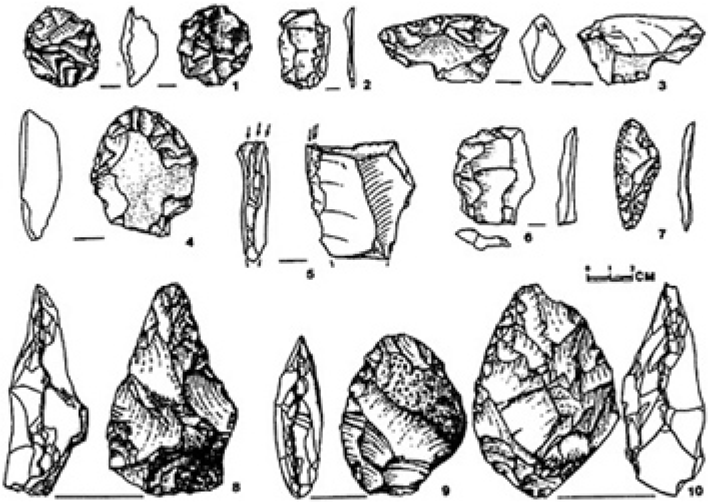

Figure 8.15 Selected artefacts from Berekhat Ram including scrapers, a burin and bifaces.

Source: Goren-Inbar 1985

bifaces, with a rich flake industry. In the absence of precise dating and on the basis of comparisons with the occupations of other oases in the Near East in later periods, it seems that all Upper Acheulian occupations should be correlated to periods of wetter conditions.

THE LOWER PALAEOLITHIC OF IRAQ, IRAN AND TRANSCAUCASIA

The vast geographic area summarized here is generally poorly known. The scanty evidence from Turkey on one end of the region and India on the other, including a few recorded find spots from Iran (Smith 1986) and from the Arabian peninsula (Zarins *et al.* 1979, 1980, 1982; Whalen *et al.* 1983, 1984; Abdul Nayeem 1990), indicate that bifaces can be found everywhere. The distribution toward the northern edges of the Near East has implications for the re-examination of the 'Movius Line'.

In Iraq, little is known beyond the site of Barda Balka, located in the Chemchemal Valley in Kurdistan, which was collected and excavated by Howe (Braidwood and Ho we 1960). This predominantly flake assemblage may be of Middle Palaeolithic age. Iranian finds are also few and far apart. In Khorasan, on the edge of a dried-up lake, quartzite and andesite core-choppers were collected (Ariai and Thibault 1975/7). In the absence of dates, the investigators related the assemblage to the Late Pliocene on typological grounds. Isolated bifaces have been collected in various places in Iran (Smith 1986). The Ladizian industry in

Baluchistan (Hume 1976) to the east should be mentioned briefly. It is defined on the basis of scatters of lithics on old river terraces, and it is a core-chopper industry with retouched pieces but no bifaces. Hume (1976) has proposed a Late Middle Pleistocene age for the Ladizian.

Early and Upper Acheulian sites in Transcaucasia were either surface collected or excavated (see Liubin and Bosinski 1995 for a detailed survey). Among the surface sites, some of the interesting collections were done in Cikiani, near Paravani in southern Georgia, where cleavers and handaxes were found (Kikodze 1986). The bifaces (Figure 8.16:1) were made of andesite, but most of the cores were made of obsidian. Persati, another surface site that is yet unpublished, is located on top of a volcanic plateau that is apparently the continuation of the Dzavacheti range in southern Georgia, about 2,100 m above sea level (Kikodze, pers. comm.). The artefacts were found at the edge of lacustrine sediments, dated to the Neogene. One of the find-spots seems to be eroding from these lake deposits, but radiometric dates are not available. A few of the bifaces are included in Figure 8.16.

Acheulian industries were uncovered in four excavated caves: Azych, Kudaro I and III, and Tsona. The lithic industry in Azych, located 800 m above sea level, is subdivided on the basis of the observed stratigraphy into several phases of the Acheulian. The earliest levels produced a few core-choppers, but they are without clear attribution to a prehistoric entity (Liubin and Boskinski 1995). The richest assemblages were uncovered in layers VI and V, including mainly Upper Acheulian bifaces with distinct use of the Levallois technique. In layer V, a fragment of a hominid mandible was found.

Kudaro I is situated 1,600 m above sea level. Layer 5 contained Acheulian artefacts made from local raw material. The entire assemblage is characterized by a high frequency of retouched pieces, including numerous side scrapers. Core-choppers and bifaces (Figure 8.16:2–3), mostly of elongated shapes, assign this assemblage to the Upper Acheulian. The presence of flake cleavers was noted by the excavator. Three human teeth were also found in this context. Dates suggest a range of 300–250 kyr, though TL readings indicate a slightly earlier time of 360 ±90 kyr and 350±70 kyr. However, a reversed palaeo-magnetic situation identified in level 6 immediately below the Acheulian assemblage, with the fauna of several galerian elements, hints that the Acheulian in layer 5 is perhaps of an older age (Liubin and Bosinski 1995).

Kudaro III produced a more restricted Acheulian collection in layers 6–8 with bifaces and flake tools. Layers 7 and 8 contain fauna dominated by bear remains *(Ursus deningeri praekudarensis; Spelaeus deningeri praekudarensis)*. A TL date of level 8a was 560±112 kyr, while layer 5 produced dates of 252± 51 kyr and 245±49 kyr.

Tsona, at an altitude of 2,150 m above sea level, and just about 5–6 km south of Kudaro, is a very large cave. The Acheulian industries were derived from layers 6–7a. Preliminary reports indicate that the lower assemblages (layer 7), which that were originally considered to be Early Acheulian, produced only a small

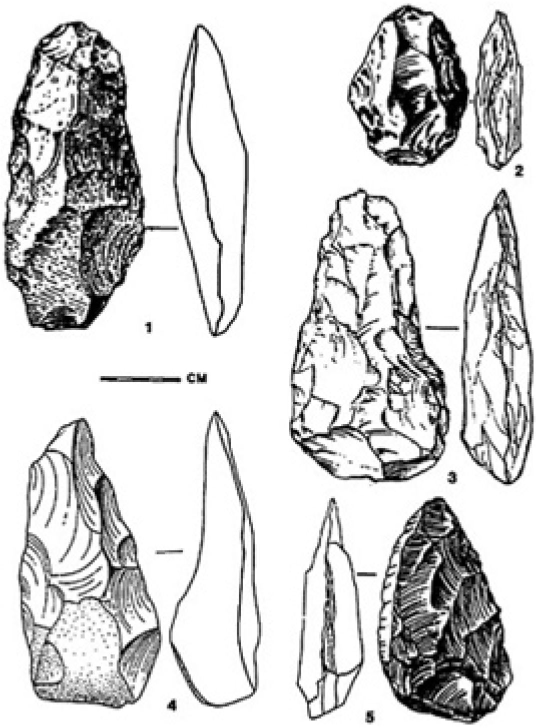

Figure 8.16 Selected bifaces from Persati, Kudaro cave and Tsona cave, Transcaucasia.

Sources: after Kikodze, unpublished; Liubin and Bosinski 1995

sample. The assemblage of layer 6 assigned to the Upper Acheulian contained about 100 artefacts, including twenty-nine bifaces (Figure 8.16: 4–5) made from local raw material, mostly retrieved in the form of pebbles. The chronological position of this Acheulian industry is not well known, although it seems that this cave, like others at high altitudes, could have been occupied only during interglacial times and that, in most cases, these caves were possibly only seasonal hunting camps. At least two other cave sites on the northern flanks of the Caucasus are known to contain Upper Acheulian remains.

In sum, the distribution of the Acheulian industries in western Asia is essentially limited to Transcaucasia, eastern Anatolia and the Levant. Unfortunately, the information from Iran, as mentioned above, is not sufficient, but it is known that the distribution of the Acheulian continues into India (see Petraglia, this volume). Thus, the 'Movius Line', which distinguishes between the Acheulian and the non-biface industries, divides Turkey. Western Anatolia belongs to the same world of core-chopper industries that dominates most of eastern and central Europe.

THE ARABIAN PENINSULA

Regional surveys in the Arabian peninsula have led to the identification of find-spots and the collection of lithic assemblages with and without bifaces. Bifaces are reported solely from the western subzones, where they are made on a variety of raw materials such as flint, basalt and metamorphic rocks. No bifaces have yet been found in that part of eastern Arabia that borders the Persian Gulf, known also as the Arabian Shelf. Of special interest are the reports concerning sites or find-spots along the Red Sea, another potential route of *Homo erectus*. The excavation at Saffaqah (Whalen *et al.* 1983, 1984) provided a rich Middle Acheulian assemblage made primarily of andesite, with bifaces, cleavers and numerous flakes. The depth of the deposits that contain artefacts, amounting to about 90 cm, indicates numerous repeated occupations. Farther south in Yemen, excavations of open-air sites embedded in Pleistocene formations, many of which are rich in gravels or angular rock fragments, unearthed several series of core-chopper and biface assemblages without animal bones (Amirkhanov 1991). In addition, surface collections clearly indicate the presence of an Upper Acheulian industry.

HUMAN REMAINS AND SUBSISTENCE

It is unfortunate that the Lower Palaeolithic sequence of the Near East is known mainly from the limited lithic assemblages described above. Only a small number of sites produced assemblages of animal bones, and even fewer revealed fragmentary hominid remains. The available human remains from this long period are scanty, and a few are surface finds. At ‘Ubeidiya, only one tooth, an incisor, was unearthed during the excavations; the other pieces are surface finds (Tobias 1966) that could not be clearly identified with a particular hominid type. Two broken femora from Gesher Benot Ya’aqov (Geraads and Tchernov 1983), attributed to *Homo erectus,* were identified in the collections of animal bones made at the site when the deepening of the Jordan River channel took place. A broken femur was uncovered in Tabun cave layer E (McCown and Keith 1939) within the acheulo-yabrudian assemblage. It thus occupies the same stratigraphic and chronological position as the fragmentary skull from Zuttiyeh (Gisis and Bar-Yosef 1974). The latter is considered as an example of an archaic *Homo sapiens* (Vandermeersch 1995), and could have been one of the potential ancestors of the later Qafzeh-Skhul group. Recently, this fragmentary skull has been compared to the Zhoukoudian human remains, and interpreted as belonging to a generalized Middle Pleistocene Asian population (Sohn and Wolpoff 1993).

Similarly, there is little evidence concerning subsistence activities of early hominids in the Near East. Animal bones in most sites are taken to indicate the procurement of animal tissues. As in most African sites of that period, cut-marks on bones at ‘Ubeidiya may indicate scavenging. Bone assemblages from Upper/later Acheulian sites are few and far between, with the rich cave sites of the

Caucasus, such as Koudaro, serving as the only current exceptions. Only small faunal assemblages have been recovered from the caves of Tabun (layer F) and Umm Qatafa and from the open-air sites of Evron-Quarry and Holon (see above). As such, food acquisition techniques such as scavenging, hunting and gathering cannot be identified and studied in detail because we lack sufficiently large samples. Only acheulo-yabrudian sites such as Zuttiyeh, Masloukh and the Adlun caves produced somewhat larger assemblages (e.g. Garrard 1983). These faunal lists may indicate some attention to medium- and large-sized animals in Masloukh, but Abri Zumoffen and Tabun E produced assemblages that do not difFer from those of the mousterian ones (Bar-Yosef 1989).

Nothing is known yet about plant gathering, although in Mediterranean environments, basic survival probably relied on the gathering of fruits, seeds, leaves and a few tubers. The well-preserved plant assemblage at Gesher Benot Ya'aqov promises to be informative in this respect (Goren-Inbar *et al.* 1992a, 1992b).

THE ACHEULO-YABRUDIAN

The Acheulo-Yabrudian, renamed the Mugharan tradition by Jelinek (1981, 1982a, 1982b), has a definite geographic distribution: acheulo-yabrudian assemblages are known only from the northern and central Levant (Figures 8.3 and 8.17). Despite intensive surveys, none of the typical artefacts by which this entity is defined was found in either the Negev and Sinai or the desert region of southern Jordan. Three facies that some investigators considered as independent industries were identified on the basis of quantitative studies, as detailed below (Jelinek 1982a, 1982b; Copeland and Hours 1983):

1. The yabrudian facies contains numerous side-scrapers, often made on thick flakes including canted ones, thus resulting in relatively high-frequencies of Quina and demi-Quina retouch, with a few Upper Palaeolithic tools and rare blades. Although typologically, Levallois type products have sometimes been mentioned, the reconstruction of operational sequences has not yielded a well-identified Levallois method.
2. The Acheulian facies is considered by Jelinek (1982a, 1982b) to consist of up to 15 per cent bifaces, with numerous scrapers fashioned in the same manner as the yabrudian ones.
3. The amudian facies is characterized by end scrapers, burins, backed knives and rare bifaces, and was therefore originally called pre-Aurignacian in the sense of being pre-Upper Palaeolithic. What is sometimes forgotten is that, until the 1940s, the term Aurignacian was used to refer to all early Upper Palaeolithic industries in western Asia, following the European example. The amudian facies, following the Tabun excavations, seems to be closer typologically to the Acheulian than to the Yabrudian, and contains evidence for limited practice of the Levallois technique (Jelinek 1982a, 1982b). The

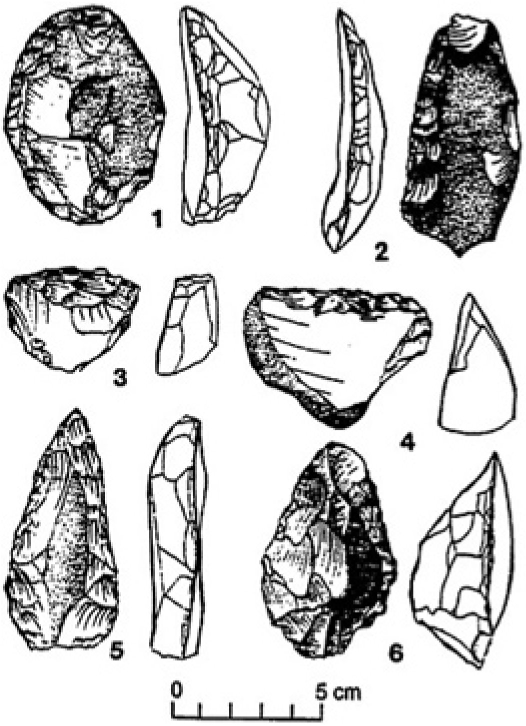

Figure 8.17 Acheulo-Yabrudian scrapers from Zuttiyeh.

Source: Gisis and Bar-Yosef 1974

> pre-Aurignacian in Yabrud I and Abri Zumoffen are richer in 'Upper Palaeolithic' elements.

The question of how to define the various methods of the Levallois technique is essentially beyond the scope of this chapter (see references in Dibble and Bar-Yosef 1995). The current literature of western Asia promotes the identification of Levallois methods on the basis of operational sequences. These are defined on the basis of systematic refittings or detailed study of the various products that designate the phases of each operational sequence.

Observations concerning the potential relationship between the different acheulo-yabrudian facies and the contemporaneous climatic conditions (Jelinek 1982a, 1982b) need to be reviewed in light of the TL chronology for Tabun cave (Mercier *et al.* 1995). Despite various efforts, correlations between shifting environmental conditions and the emergence of different kinds of stone tool assemblages (e.g. Collins 1969; Mithen 1994) have never been demonstrated to be real in western Asia.

CONCLUSION

The emergence of *Homo erectus* in Africa seems to have been triggered by the climatic changes that occurred at the time of the Olduvai subchron, around 1.8 myr. This was followed by a series of outward migrations into North Africa and Eurasia, as evidenced by the appearance of the various Lower Palaeolithic industries known in Eurasia.

If we assert that groups of early hominids enjoyed rigid, modular, mental templates in the production of stone tools, then it is possible to theorize that the first groups of *Homo erectus* who left their homeland were the bearers of a core-chopper industry and not the manufacturers of the Acheulian bifaces. Sub-Saharan early hominids produced both industries commonly known as the Oldowan and Early Acheulian. In Koobi Fora, the post-Oldowan non-biface industry, called the Karari industry, was dated to *c.* 1.3 myr. Therefore, one may expect that bearers of core-choppers and Acheulian tool-kits could have dispersed from Africa into Eurasia at any time from 1.8 myr onwards.

Producers of core-choppers could have colonized the Maghreb, if the sequence established by Biberson (1961) is supported by further field work (Raynal *et al.* 1995). Similar groups could have been among the first to colonize western and Southeast Asia (Schick and Dong 1993) or among those who ventured to colonize Mediterranean western Europe (Roe 1995). Although the earliest dates for the colonization of temperate Europe are debatable (Dennell and Roebroeks 1996), the Middle Pleistocene inhabitants of central and east-ern Europe who made core-choppers could have been late migrants from Africa or from a region where such a core-chopper tradition lasted longer, such as East Asia (see Rolland, this volume). On the other hand, Acheulian bearers could have ventured into East Asia. Isolated occurrences of bifaces were reported from China (Schick and Dong 1993; Huang and Wang 1995), but their age is unknown. The distribution of long-lasting core-chopper assemblages beyond the Eurasian ‘Movius Line’ (Figure 8.1) stands in contrast to western Europe and western Asia, where Acheulian occurrences dominate, although they are stratigraphically interspersed in several subregions with core-chopper industries (known by various labels such as Clactonian and Tayacian).

The earliest Lower Palaeolithic occupations in western Asia are poorly known. Claims for occurrences around 2 myr or immediately post-Olduvai subchron are not yet supported by convincing geochronological and archaeological evidence. The artefacts, small in number and sometimes of uncertain provenances, do not compare well with sites rich in fauna and artefacts. These sites, such as Dmanisi and ‘Ubeidiya, are currently dated to 1.8–1.4 myr, but undoubtedly require further investigations in order to establish a more precise chronology.

The Acheulian industry in western Asia is generally subdivided into the Early Acheulian and Upper/Late Acheulian. Field work in Syria and Lebanon has demonstrated the potential for additional chronological subdivision. A group of assemblages that could be defined as ‘Early Upper Acheulian’ by one system is named in the Levantine literature as ‘Middle Acheulian’. This entity (e.g. Latamne, Joub Jannine II), chronologically placed between the Early Acheulian (e.g. ‘Ubeidiya) and the Upper/Late Acheulian (e.g. Gharmachi I, Ma’ayn Baruch, Tabun F), is also characterized by various researchers according to a set of the specific morphological and technological attributes of bifaces described above.

Among the Acheulian assemblages, the basalt cleaver/biface industry of Gesher Benot Ya’aqov stands out as an exception. Despite the fact that large portions of western Asia are covered with lava flows, no similar industry has yet been reported. In areas such as the Golan, Upper Acheulian assemblages are generally made of flint (e.g. Goren-Inbar 1985). It was therefore suggested that the assemblages of Gesher Benot Ya’aqov, like those of ‘Ubeidiya, represent an additional migration out of Africa (Bar-Yosef 1987; Goren-Inbar and Saragusti 1996). Another assemblage conveying the same impression, produced from andesite, was uncovered in Saffaqah near the Red Sea (Whalen *et al.* 1984).

The ephemeral use of basalt during the entire Acheulian sequence does not mean that differences in size and perhaps in the quality of workmanship cannot be discerned in all other Acheulian occurrences, where local flint/chert was exploited. Biface resharpening would account for some changes in the forms, but not for all. The dichotomy between the clusters of the dominantly pointed and oval bifaces, which share the same size distribution, cannot be explained by the availability and accessibility of raw material or even by the amount of resharpening. The Acheulo-Yabrudian can be considered as a local west Asian entity, with a definite geographic distribution within the region. It seems to emerge from the Taurus region and to spread across northern and central Levant. No Acheulo-Yabrudian artefacts were found south of Mt Carmel. The characteristic *chaîne opératoire* for making the scrapers (similar to the Quina scrapers) is not related to raw material, and the southern boundary does not follow an environmental ecotone. It probably means that this entity was contemporary with a certain Late Acheulian entity. Little evidence exists concerning the subsistence activities of early hominids in western Asia. Microwear and edge damage analyses are not available, as they depend on recovery from well-preserved contexts. Animal bones in most sites are taken to indicate the procurement of animal tissues, and, as in African sites, cut-marks on bones at ‘Ubeidiya may indicate scavenging. However, bone assemblages from the Upper/late Acheulian sites are few. In most cases, only large and medium-sized mammals are represented. In open-air sites such as ‘Ubeidiya, taphonomic studies are still unavailable.

Levantine caves such as Umm Qatafa and Tabun produced small bone assemblages. The few cave sites of the Caucasus, such as Koudaro and Tsona, are richer. Unfortunately, aspects of game acquisition techniques, such as scavenging and hunting, are still poorly researched. Acheulo-Yabrudian sites such as Zuttiyeh, Masloukh and the Adlun caves produced somewhat larger assemblages (e.g. Garrard 1983). Their faunal lists may indicate continuous attention to medium and large-sized animals. At least two sites, Abri Zumoffen and Tabun E, produced assemblages that do not differ from the mousterian faunal collections (Bar-Yosef 1989). Recent work on the African sites demonstrated that both hunting and scavenging provided meat and marrow. Thus, the explanation that viewed the success of *Homo erectus* in colonizing Eurasia as based on the development of communication and assisted by hunting, is most likely to be irrefutable.

In spite of constraints imposed by seasonal availability, plant food gathering in Mediterranean environments was the most optimal survival strategy, given the number of exploitable fruits, seeds, leaves and rare tubers. Except for during a short winter (late November to early February), early hominids could subsist on plant food alone. This general observation, derived from Late Pleistocene and Holocene studies, is not yet supported by plant remains from early sites. The only exception is the well-preserved plant assemblage at Gesher Benot Ya'aqov, which holds promise (Goren-Inbar *et al.* 1992a, 1992b).

In sum, the entire Lower Palaeolithic sequence of western Asia preserves evidence for several events of 'out of Africa' movements by *Homo erectus* and perhaps archaic *Homo sapiens* groups. Three identifiable examples of these sorties are: the preliminary dating of the earliest core-choppers assemblages to *c.* 1.8–1.6 myr (e.g. Dmanisi); the *c.* 1.4–1.0 myr dates of the Early Acheulian at 'Ubeidiya (which could be even earlier); and the dating of *c.* 0.6 myr for the Gesher Benot Ya'aqov industry. The apparent continuity of several Acheulian complexes, taken together with archaeological evidence from Mediterranean Europe and east Asia, testify to an increasing number of successful colonizations by early hominids, without ignoring temporary regional failures.

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9

Grasslands, tool making and the hominid colonization of southern Asia: a reconsideration

ROBIN W.DENNELL

INTRODUCTION

One of the most basic assumptions in palaeoanthropology is that hominids evolved in Africa, and then colonized Asia and Europe. How much later is fiercely debated. The prevalent view in recent decades has been that hominids did not colonize Asia before a million or so years ago; the site of ‘Ubeidiya in Israel, which is probably between 1.4 and 1.0 myr old (Tchernov 1989; Bar-Yosef 1994; Bar-Yosef, this volume), has often been cited as the earliest evidence of hominids outside Africa. Given this model, the over-riding questions are why hominids were confined to Africa for so long, and how they then colonized Asia and later Europe with no apparent breakthrough in anatomy, behaviour or technology, and under similar environmental conditions to those that had existed previously. This dominant model has been challenged in recent years by claims of hominid remains and/or stone tools considerably older than 1 myr from both Europe and Asia (Table 9.1). Of particular relevance to this chapter are the stone artefacts from Riwat, Pakistan, which were dated to a minimum of 1.9 myr (Rendell *et al.* 1987; Dennell *et al.* 1988), and subsequently to a probable age of 2.5 myr (Rendell *et al.,* in press). This anomalous discovery has recently been joined by other claims that hominids were in Eurasia before 1.5 myr ago, notably in Java by 1.8–1.6 myr (Swisher *et al.* 1994); at Dmanisi in Georgia at 1.8 myr (Gabunia and Vekua 1995); at Longgupo, China, at 1.9 myr (Huang *et al.* 1995); and at Orce, Spain, at 1.8 myr (Gibert 1992; Roe 1995). If any one of these Asian claims is correct, there must be sites in southwest Asia that are older than ‘Ubeidiya. Early Eurasian dates are therefore back on the agenda, raising the possibility that hominids dispersed out of Africa much earlier than was once thought.

Before we review the evidence from northern Pakistan, three issues will be examined that are pertinent to the broader theme of early human evolution in southern and southwestern Asia:

Table 9.1 Some claimed occurrences for early hominids in Eurasia before 1 myr.

Site	*Age (myr)*	*Contents*	*Source*
Bori, India	1.4	Artefacts	Korisettar *et al.* 1989
Diring, Siberia	3.2	Artefacts	Mochanov and Penkov 1989
Dmanisi, Georgia	1.8	Artefacts, hominid	Gabunia and Vekua 1995
Longgupo, China	1.9	Artefacts, hominid	Huang *et al.* 1995
Orce, Spain	1.8	Artefacts, hominids	Gibert 1992; Roe 1995
Riwat, Pakistan	>1.9	Artefacts	Dennell *et al.* 1988
Sangiran/ Modjokerto, Indonesia	1.8	Hominids	Swisher *et al.* 1994
St Eble, France	>2	Artefacts	Bonifay 1989
‘Ubeidiya, Israel	1.4	Artefacts	Bar-Yosef 1994

Notes: The list is not exhaustive, and several European claims have been omitted. All the claims on this list are contentious in terms of the identification of material as hominid or archaeological, their context and/or dating. ‘Ubeidiya is probably the least contentious at present; Diring in Siberia is probably late pleistocene (Kuzumin and Kribonogov 1994), and the least convincing in this list.

1. the weaknesses of our current knowledge of human evolution from the Pliocene to Middle Pleistocene;
2. the likely extent of the grassland environments inhabited by early hominids; and,
3. whether the ability to make stone tools would have been characteristic of all extinct hominids, and not just the genus *Homo*.

Current data on early human evolution

In general terms, the area about which most is known concerning early human evolution prior to the Middle Pleistocene is East Africa, followed by the cave sequences of southern Africa, and the poorly dated hominid remains from Java. Western Europe has the best documented fossil and archaeological record for the Middle Pleistocene.

EAST AFRICA AND WESTERN EUROPE: HOW WELL KNOWN?

Even in the two best-documented areas in palaeoanthropology, East Africa and western Europe, we have clearly not reached the point at which we are acquiring only redundant information. New discoveries are constantly forcing reappraisal of earlier views, and helping to fill substantial gaps in our knowledge. For example, new types of hominids are still being found in East Africa: first, *Australopithecus ramidus* (White *et al.* 1994), the alleged ancestor of all later hominids, which was reclassified within six months as a hominoid, *Ardipithecus ramidus* (White *et al.* 1995); and second, *Australopithecus anamensis* (Leakey *et al.* 1995), another 'new' ancestor of all later hominids. Recent discoveries of *Australopithecus afarensis* in Chad at 3.5 myr (Brunet *et al.* 1995), and of *Homo rudolfensis* (another type of hominid not recognized even ten years ago) in Malawi at 2.4 myr (Schrenk *et al.* 1993) also show our uncertainty over how much of Africa was occupied by hominids in the Pliocene, and by which types. Western Europe has also shown that there is still room for 'big surprises' in well-researched regions. As recent examples, the fossil hominid remains and stone tools in the TD6 horizon at Atapuerca, Spain (Carbonell *et al.* 1995) that are dated palaeomagnetically to >780 kyr raise the possibility that hominids were in southern Europe considerably before 500 kyr, as advocated by proponents of the 'long' chronology (e.g. Dennell 1983; Roebroeks and van Kolfschoten 1994; Dennell and Roebroeks 1996). The discovery of a puncture-mark on a 500 kyr old horse scapula that was almost certainly caused by a thrown spear at Boxgrove (Roberts, pers. comm. 1996), and of complete wooden spears over 2 m long and 400–380 kyr old at Schoningen, Germany (Thieme and Maier 1995; Thieme 1997), indicate that big-game hunting is once again much more probable for the European Early Palaeolithic than the type of opportunistic scavenging that has dominated most syntheses of the last fifteen years (e.g. Binford 1989; Gamble 1994). In other words, both the duration and nature of the early fossil hominid record in East Africa, and the Early Palaeolithic record in Europe are still uncertain, and changing substantially from year to year. If that is true for the best known areas in the world, how much more true might it be for Asia?

ASIA, THE UNKNOWN CONTINENT

Both the number and the density of well-dated sites in Asia with early hominid remains and/or early stone artefacts are extremely low, especially when set against the enormity of the Asian landmass. This point is made clear in Table 9.2, which shows the distance between the main early hominid localities in the Old World. To make some simple points about the size of Asia: Boxgrove (UK) is the same distance from Swartkrans (South Africa) as 'Ubeidiya (Israel) is from Sangiran (Indonesia); Riwat (Pakistan) is closer to Olduvai Gorge than to Sangiran; and Boxgrove is closer to Olduvai than 'Ubeidiya is to Zhoukoudian.

Enormous areas of Asia are still wholly devoid of evidence. This is particularly true of the area between the 'Ubeidiya in Israel; Dmanisi in Georgia; and Riwat in Pakistan. As Table 9.3 shows, this area is larger than East Africa (Kenya, Tanzania, Ethiopia) and the countries of the European Community combined, or larger than the whole of Europe west of the former Soviet Union. Southwest Asia should be a key link between Africa, Europe and eastern Asia;

however, apart from 'Ubeidiya, its earliest occupation is wholly unrecorded. There is, therefore, almost no information against which individual claims, such as Riwat (Pakistan) or Longgupo (China), can be checked. Indeed, west of Riwat, the nearest reasonably well-dated Lower Pleistocene sites are Dmanisi, 1,600 miles to the northwest, and 'Ubeidiya, 2,200 miles to the west. In contrast, the *maximum* distances between European localities (e.g. Boxgrove or Atapuerca to Petralona) is only 1,300 miles, and in East

Table 9.2 Direct distances (in miles) between principal early hominid localities in Asia, Africa and Europe.

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1) 'Ubeidiya (Jerusalem)	**0**											
2) Dmanisi (Tblisi)	***864***	0										
3) Riwat (Islamabad)	***2,201***	***1,643***	0									
4) Zhoukoudian (Beijing)	***4,433***	***3,644***	***2,411***	0								
5) Sangiran (Yogyakarta)	***5,643***	***5,356***	***3,755***	***3,306***	***0***							
6) Omo (Addis Ababa)	1,580	2,279	2,772	5,173	5,072	0						
7) Oldu	2,275	2,999	3,373	5,736	5,086	721	0					

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
vai (Nairobi)												
8) Swartkrans (Jo’burg)	4,014	4,792	5,073	7,267	5,511	2,525	1,809	0				
9) Atapuerca (Bilbao)	2,220	2,407	4,038	5,573	7,759	3,441	3,933	5,170	0			
10) Swanscome (London)	2,246	2,202	3,762	5,071	7,517	3,568	4,228	5,617	**585**	0		
11) Petralona (Thessaloniki)	918	1,137	2,755	4,675	6,435	2,381	3,014	4,609	**1,341**	**1,329**	**0**	

Source: Fitzpatrick and Modlin 1986.

Notes: The distances in this table are a reminder of how little we know about the early hominid record of the Asian landmass. Few sites in Europe are more than 1,300 miles apart (see distances bottom right in **bold**); those in East Africa between Addis Ababa and Nairobi are less than 700 miles apart (see distance in *italic* at intersection of column 6 and row 7). In contrast, distances between the few Asian localities found to date (distances top left in ***bold italic***) are commonly between 2,000 and 5,000 miles apart. Absence of evidence is not necessarily evidence of absence.

Table 9.3 Some comparisons of the size of Southwest Asia, East Africa, the European Community (EC), and Europe west of the former Soviet Union.

Region	*Square miles*
Southwest Asia	2,362,400
East Africa	977,000
The European Community (EC)	1,084,760
The EC and East Africa	2,061,760
Europe west of the former Soviet Union	1,720,760

Region	*Square miles*

Notes: Southwest Asia comprises the countries encompassed by the three largest: Saudi Arabia (927,000 sq. miles), Iran (628,000 sq. miles) and Turkey (296,000 sq. miles). East Africa comprises Tanzania (362,000 sq. miles) (included because of Olduvai Gorge on its northern border), Kenya (220,000 sq. miles) and Ethiopia (395,000 sq. miles). The four largest European countries west of the former Soviet Union are France (213,000 sq. miles), Spain (195,000 sq. miles), Sweden (173,000 sq. miles) and Germany (138,000 sq. miles). East Africa and Europe contain abundant evidence for when these areas were first occupied. In contrast, 'Ubeidiya in Israel is the only site in southwest Asia that usefully documents when that region was first colonized.

Africa, all the localities between Laetoli and Olduvai in Tanzania and the Omo Research Area in Ethiopia lie along a strip only 600 miles long.

The enormous distances between key early hominid and archaeological localities in Asia are critically important to the level of confidence that can be attached to assessments of when Asia was first colonized. Not only is there no means of predicting the age of the earliest sites, but there is no secure means of assessing new evidence. This point is clearer if set in European terms. Enough is now known for it to be a reasonable prediction that any new discoveries of fossil hominids or archaeological sites in northern Europe will be less than 500 kyr, given the amount of evidence indicating the *absence* of hominids before that time as well as their *presence* thereafter. Anomalous claims from any one part of northern Europe can thus be constrained on the basis that 'any colonisation of one region of Europe could only be colonised if it was colonised at the same time as most of the others' (Gamble 1995: 290). The same approach cannot be applied with the same degree of confidence in Asia, where too few sites are known from a much greater landmass to indicate the latest absence of hominids as well as their first appearance.

Grasslands and early hominids

There is little disagreement that hominids evolved in the grasslands of Africa, and acquired bipedalism, an increasingly large brain, and the ability to make stone tools and acquire substantial amounts of animal protein as adaptations to that type of environment. The main issues are when hominids first colonized the grasslands outside the Rift Valley, and the extent and duration of these grasslands.

The recent discovery of a mandible of *Australopithecus afarensis* in Chad, 1,500 miles west of the Rift Valley and *c.* 3.5 myr in age (Brunet *et al.* 1995), shows that hominids had already dispersed a considerable distance from the Rift Valley by the mid-Pliocene (if it is assumed that that was where they originated). As Brunet *et al.* (1995:274) stress, the new discovery from Chad implies that, by 3.5 myr ago, 'hominids were distributed throughout the

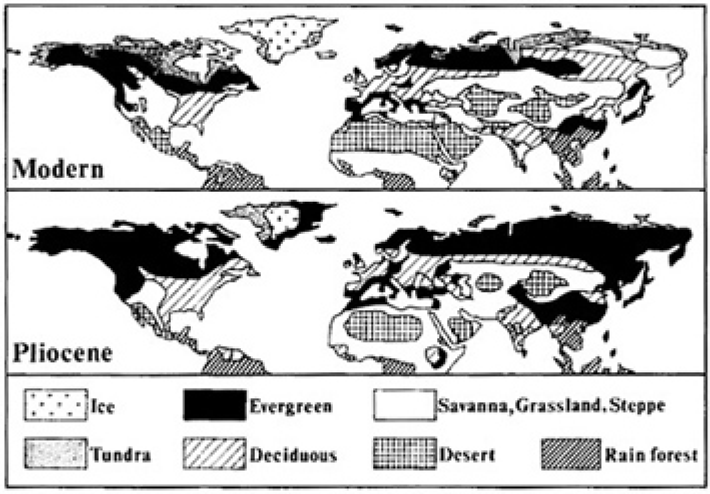

Figure 9.1 Northern hemisphere grasslands 3 myr and now. If australopithecineswere grassland creatures, there was no Saharan barrier in the Late Pliocene to prevent them from colonizing large areas of Asia.

Source: Dowsett *et al.* 1994.

woodland and savannah belt from the Atlantic Ocean across the Sahel through eastern Africa to the Cape of Good Hope'. They further point out that while current evidence suggests an East African origin for the hominids 'this inference is based entirely on the fact that comparably aged sediments are either absent from or have not yet been located in southern, central and western Africa' (Brunet *et al.* 1995: 274). The same argument can be adduced for western Asia.

Recent reconstructions of global climate during the Pliocene indicate that grasslands were far more extensive 3 myr ago than today (Dowsett *et al.* 1994). As Figure 9.1 shows, it would have been possible to remain within a grassland environment almost anywhere within an enormous area between the Atlantic Ocean and northeast China, and between central Asia and southern Africa. The Asian grasslands are especially long-standing: those of southern Asia have existed for the last 6 myr (Quade *et al.* 1989). Most significantly of all, *the Saharan barrier between Africa and Asia did not then exist.* This point may have profound implications for palaeoanthropology. If hominids were already 1,500 miles west of the Rift Valley 3.5 myr ago, there is no obvious reason why they were not in Israel, the same distance to the north; and indeed, there was no obvious barrier preventing them from occupying the Asian grasslands as far east as northern China. To repeat, but to develop further, the argument of Brunet *et al.* (1995: 274), 'if the origins of hominids occurred rapidly, followed by rapid range extension, as seems likely, it may be as futile to seek a specific and localized place of origin for hominids as it is for any other group'. What our currently

African-dominated fossil hominid record may therefore indicate is merely the fortuitous outcomes of good preservation, intensive field work and well-deserved luck.

Stone tools—why so recent, and why so special?

The oldest stone tools so far discovered are those from Kada Gona, Ethiopia, probably dated to *c.* 2.7–2.5 myr (Seman *et al.* 1997). Other East African localities, such as the Omo Valley, Ethiopia, and Koobi Fora, Kenya, indicate the deliberate flaking of stone between 2.5 and 2.0 myr (Toth and Schick 1986). These antedate the first appearance of *Homo habilis* around 1.8 myr ago, and those dating to after 2.4 myr may have been made by either the closely related *Homo rudolfensis* or by *Paranthropus*. The latter possibility is reasonable in the light of Sussman's (1988) assessment of the manual capabilities of *Paranthropus,* as evidenced by the hand bones from Swartkrans, South Africa. As *Homo rudolfensis* and *Paranthropus* are not known from contexts prior to 2.4 myr, neither could have made the 2.9 myr old stone tools at Kadar Goma, Hadar. It is therefore possible that *Australopithecus afarensis,* the only East African hominid evidenced at this time, might also have been a tool maker. Alternatively, *Homo* and other putative contemporaneous tool makers may extend further back in time than currently realized.

The implications of the stone working abilities of modern, non-human primates, particularly the chimpanzee, should be borne in mind. Numerous studies now document their ability to make and use stone tools, whether in the wild (McGrew 1992) or under zoo conditions (Toth *et al.* 1993). These tools include hammers, anvils and a variety of flakes. Orangutans can also be persuaded to make stone tools (Wright 1972), although they do not normally seem to use this ability. More recently, Westergaard and Suomi (1995) have shown that capuchin monkeys *(Cebus)* can flake stone, albeit extremely crudely.

In archaeological terms, the central problem raised by these studies is whether the tool making abilities of chimpanzees (and other primates) are the result of shared ancestry or independent discovery. Given the number of other similarities between chimpanzees and humans regarding genetic make-up and anatomy in particular, but also language, predation and social behaviour, it appears a reasonable supposition that the tool making abilities of chimpanzees also result from a shared ancestry with humans. If that is the case, 'the earliest lithic technology may…have preceded the divergence of hominids from the African apes' (Westergaard and Suomi 1995: 403) some 8–6 myr ago.

If that is the case, palaeoanthropologists should also expect other Pliocene hominids, such as *Australopithecus africanus, Australopithecus afarensis* and *Australopithecus anamensis,* to have had the ability to flake stone, even if they lacked the refined manipulation of later hominids (Sussman 1991). Likewise, if orangutans can make stone tools, so might have *Ramapithecus,* their putative ancestor, the latest of which is dated to *c.* 5.5 myr ago (Sankhyan 1985), or even the Middle Pleistocene Asian hominid, *Gigantopithecus*. On these grounds, the question 'when does stone tool making first begin?' changes into 'why do we not find a recognizable archaeological record until after 3 or even 2.5 million years ago?'. Possible answers are: that very simple examples of intentionally flaked stone are most easily recognized as such when found in clusters; and/or when they are sufficiently distinctive to be recognized as intentionally struck; and/or there is no reason why hominid remains, the main focus of Pliocene palaeoanthropological field work, need be found near any stone tools that may have been discarded. If (as with chimpanzees) stone tools were made and discarded in very low frequencies, and rarely in the same places, its would be very hard to detect then when looking for fossil remains. What may be evidenced after 2.5 myr ago in East Africa are changes in the frequency of use and the pattern of discard of flaked stone, rather than the advent of the ability to flake stone. Earlier claims of deliberately flaked stone in contexts 14 myr old at Fort Ternan, Kenya (Leakey 1968), or 9 myr old and in association with *Ramapithecus* in India (Prasad 1982), may not be as improbable as is usually thought.

If hominids (and perhaps other primates) were making stone tools before 3 myr ago, how might these be recognized, especially if they are likely to be crudely made and discarded in low frequencies? The problem is one of distinguishing 'signal' from 'noise', as any stone that may have been deliberately flaked will be a minute fraction of the total number of stones in the surrounding landscape, and may even have been derived from a later context. For these reasons, both the context and the characteristics of flaked stone in very ancient contexts needs to be assessed.

Several approaches might be tried that are realistic within the context of surveying large areas of fossil bearing strata. The first is to record the abundance, distribution and type of stone, whether flaked or not, along fossil bearing strata, especially those that indicate low-energy conditions under which the fluvial transport of large clasts can be excluded. If stones are found on the erosional surfaces of fossil bearing strata, it is then necessary to consider where they might have come from. Possible sources are later strata via downslope transport; deflation from strata that have now been eroded; or modern human activity, such as throwing stones when herding animals or as a defence against dogs and other animals. If these possibilities are thought unlikely, they may have been derived from the geological horizon on the surface of which they were found.

At that point, it is necessary to consider how stones in that layer might have been fractured or flaked by agencies other than primates or hominids. For that reason, the characteristics of any fractured pieces need to be considered: the degree of abrasion and roundedness of flake scars; the numbers of flakes removed, the number of directions in which they were removed; the type of flake scars; the amount of cortex remaining; and evidence of edge modification. It is those features that will constitute the 'signal' of deliberate flaking against the 'noise' of naturally flaked stone across a Pliocene (or earlier) landscape.

However, the ‘signal’ is likely to be weak: it is doubtful, for example, how much of Kanzi’s stone flaking (Toth *et al.* 1993) would be recognized as such if found in Pliocene contexts in the Rift Valley.

Discussion

The previous sections have highlighted the inadequacy of our knowledge concerning early human evolution in even well-known areas such as East Africa and Europe, and especially in Asia, where far too little is known to allow reliable predictions of what might later be found. It has also been pointed out that the African grasslands were occupied by hominids at least 3.5 myr ago, and that these grasslands then extended without interruption across most of Asia. On *a priori* grounds, the remains of Pliocene hominids might be expected to be found in areas of former grassland in both Africa and Asia, even if the point of origin cannot be established. Regarding stone tools, it is likely that these have been made by the ancestors of both humans and chimpanzees for the last 8–6 myr, and quite possibly by other primates. Stone tools on their own are not therefore reliable indicators of the presence of *Homo,* unless it is known to be the only local primate with the necessary technological proficiency. With these reflections in mind, the earliest evidence from northern Pakistan can be considered.

NORTHERN PAKISTAN

The Siwaliks of northern Pakistan and India are one of the most continuous and well-dated terrestrial sequences in the world for the last 15 myr. They comprise several kilometres of fluvial sediments that were deposited by the rivers flowing southwards from the Karakorum and Himalayas over a broad, 1,900 kilometre front extending from the west bank of the Indus to the Bay of the Ganges. These rivers are generally very large (Figure 9.2), and are often laterally unstable, and prone to major shifts in their channels. They also have a strongly seasonal flow because of the summer monsoon, which has been in place for at least 2 myr (Wang *et al.* 1982).

The best Siwalik exposures tend to lie in what is now Pakistan, and have been investigated intermittently for over 150 years. In the British period, most of these investigations were undertaken by the Geological Survey of India, but important fossil collections were also acquired by Dubois in the 1890s, and by various American teams in the interwar years, including the Yale Expedition of 1934–5. Little further research was undertaken into the Siwaliks after Independence in 1947 until the 1970s, when the Yale-Harvard group began an ongoing project in the Chinji area of the Salt Range in collaboration with the Geological Survey of Pakistan (e.g. Badgley 1986; Rose 1989), and an important palaeomagnetic dating programme was initiated by geologists based at Peshawar and in the USA.

Most of the research to date has concentrated on the Miocene exposures of the Lower and Middle Siwaliks (e.g. Badgley and Behrensmeyer 1980; Barry *et al.*

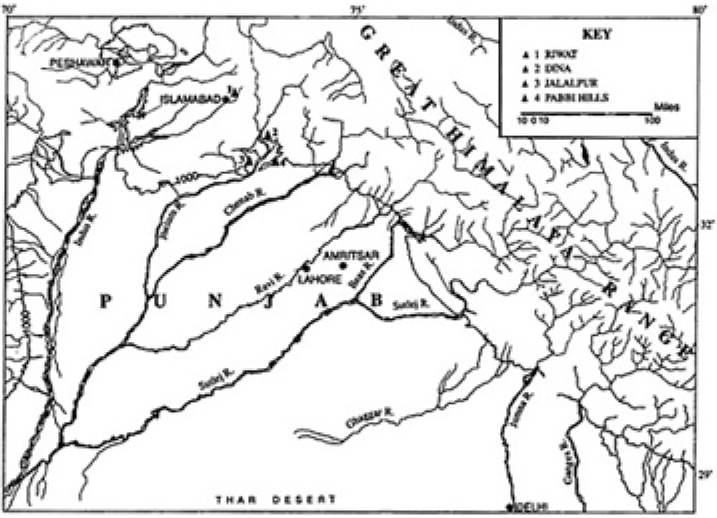

Figure 9.2 The Punjab of northern India and Pakistan. This figure shows the size of the area's drainage system; the 1,000 m contour-line approximates to the southern front of the Siwaliks. Symbols 1–4 indicate the areas investigated by the British Archaeological Mission to Pakistan in the 1980s. Large areas remain unexplored in both northern Pakistan and India.

Source: Colbert 1935

1982; Behrensmeyer and Tauxe 1982), not least because of interest in the Miocene hominoids such as *Ramapithecus,* once regarded as a hominid, but now a possible ancestor of the orangutan. In contrast, the Upper Siwaliks have received far less attention, and much less is known of the Pliocene and Lower Pleistocene. The most often quoted Pleistocene study is still that of de Terra and Paterson (1939), who conducted a six-week survey in the Soan Valley in 1935 before moving on to Kashmir, the Narmada Valley and the Madras area. After a forty-five-year hiatus, their work was followed in the 1980s by that of the British Archaeological Mission to Pakistan (Allchin 1995). Most of this research was on a very small scale, particularly if the size of area is taken into account. Salim's (1985) work in the Soan Valley, although useful, was also on a small scale, as were the palaeontological investigations of Pliocene deposits in the Mirpur area by the Dutch in the 1980s (Steensma and Husain 1992). Although the Upper Siwaliks are now well dated, our knowledge of their palaeontological and archaeological record is probably comparable to that of East Africa in the 1930s. What is known is summarized below.

Geology and chronology

The geochronology of the Siwaliks is now based on several detailed palaeomagnetic and stratigraphic investigations by American and Pakistani geologists. These initially focused on the uplift of the Karakorum and Himalayas, and the associated tectonic changes in the forelands to the south (e.g. Raynolds 1980; Burbank and Johnson 1982; G.D.Johnson *et al.* 1982; N.M.Johnson *et al.* 1982; Burbank and Raynolds 1983, 1984; Raynolds and Johnson 1985). Other studies refined and amplified this general framework, and also examined the evolution of individual drainage systems (e.g. Keller *et al.* 1977; Opdyke *et al.* 1979). The main results are shown in Figure 9.3. What this broadly shows is a series of major river systems flowing southwards of the Karakorum and Himalayan mountains from the Miocene period onwards. As these mountains rose and extended southwards, so these rivers were increasingly confined to a series of river basins through complex, interlinked tectonic processes involving uplift, folding and deformation.

Two outcomes of this research are particularly relevant to the Pleistocene of this region, since they contradict the sequence proposed by de Terra and Paterson, and followed by numerous subsequent investigators. The first is that these local sequences are entirely tectonically driven, and are not directly a consequence of changes in sea level brought about by changes in global ice volume. Upper Siwalik fluvial deposits cannot therefore be correlated with any Pleistocene glaciations or interglacials. The second is that these tectonic processes are often time-transgressive and did not occur synchronously. An important example is the Boulder Conglomerate a large, clast-supported unit that caps many local sequences, and has been used as a major 'marker' horizon for the onset of the Middle Pleistocene. However, this is not a synchronous, climatically induced deposit, but one brought about tectonically at different times in different places (e.g. Rendell *et al.* 1989: 35–49).

Palaeontology

Whilst the fauna of the Miocene Lower and Middle Siwaliks is now known in considerable detail at generic and often specific level, the same is less true of the Upper Siwaliks, despite the excellent efforts of many Indian palaeontologists. Many key taxa are still poorly defined, notably the bovids, cervids, suids and many smaller mammals, and often based on poorly provenanced specimens. The already mentioned Dutch work began to clarify some taxa for the Middle Pliocene (e.g. de Vos *et al.* 1987; Hussain *et al.* 1992). The British Archaeological Mission to Pakistan collected *c.* 40,000 Lower Pleistocene fossil specimens (including undiagnostics) in the Pabbi Hills between 1986 and 1990 (Ashfaque and ul-Haq 1988; Jenkinson *et al.* 1989), and detailed study of some of this material may help resolve some of the prevailing taxonomic uncertainty.

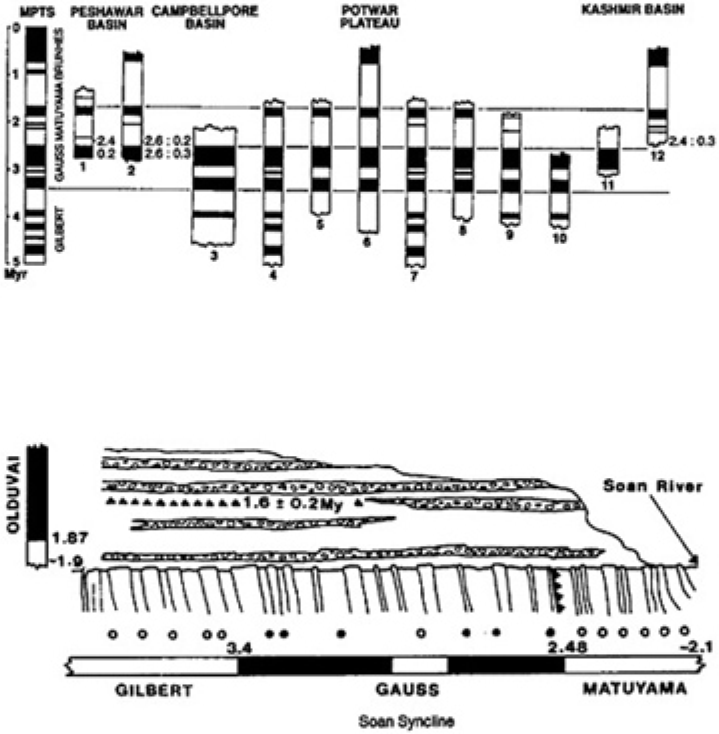

Figure 9.3 The palaeomagnetic stratigraphy of northern Pakistan, (a) *Top:* magnetic-polarity stratigraphies across northern Pakistan. The Upper Siwaliks are well dated, even if largely unexplored archaeologically: the Soan Syncline (no. 3, and the widest of the vertical bars) is part of a broad picture of late pliocene sedimentation across this area being truncated by the onset of folding, (b) *Bottom:* the northern limb of the Soan Syncline, where nearly vertical strata of Siwalik sediments are truncated and overlain by the generally undeformed Lei conglomerate. The magnetostratigraphy indicates that the youngest Siwalik sediments extend into the Lower Matuyama chron, probably to *c.* 2.1 myr. The overlying Lei conglomerate includes an ash date of 1.6±0.2 myr, on the basis of which the normal polarity magnetozone is interpreted as the Olduvai subchron. The artefacts reported here were found in the younger part of the Siwalik strata in the gently sloping southern limb of the Soan Syncline.

Source: Burbank and Raynolds 1984: Figure 3

Two points are relevant to this chapter. The first is that the Upper Siwalik faunal types confirm carbonate analyses of palaeosols that indicate the prevalence of grasslands after Late Miocene times (Quade *et al.* 1989). Elephant, rhinoceros and horse are common, as are several types of bovids and cervids (e.g. Keller *et al.* 1977; Opdyke *et al.* 1979). The second, resulting from the detailed surveys in the Pabbi Hills, is that the faunal assemblages from Upper Siwalik fluvial palaeolandscapes are strongly biased towards taxa with a body weight of

>60 kg, due to the taphonomic processes that resulted in the preservation of fossils. This factor may go some way to explaining the absence of primates (including hominids) from Upper Siwalik deposits, in addition to the lack of research.

Archaeology

De Terra and Paterson (1939) proposed that the Palaeolithic of the Soan Valley comprised a Soan Flake Tradition, which began in the Middle Pleistocene, and developed internally through a series of stages. An Acheulian component, which they saw as intrusive, also existed periodically during this time. Following detailed re-examination of their field observations, their conclusions have been heavily criticized in several publications (e.g. Rendell *et al.* 1989; Dennell and Rendell 1991). The two main reasons are first, that de Terra's geological sequence for the Scan Valley is invalid in the light of recent studies (both prior to and including those of the British Mission) and second, that Paterson's Soan culture cannot be related to the formation of the deposits on which these assemblages are found. For these reasons, Palaeolithic investigations must start afresh, and within the geological framework established in the last twenty years through palaeomagnetic investigations.

The British Archaeological Mission to Pakistan's field work deliberately took advantage of the previous American-Pakistani palaeomagnetic studies mentioned above, by selecting for study only those areas that had already been dated: the Soan Valley; Rohtas, Jalalpur and Dina in the Jhelum Basin; and the Pabbi Hills (Figure 9.2). These were also chosen for ease of access and, in the case of the Pabbi Hills, because of the quality of fossil remains already recorded in the American-Pakistani work of the 1970s (Opdyke *et al.* 1979).

With the exception of the Rohtas Anticline, where the Mission spent ten days in 1985, significant archaeological discoveries were made in each of the other areas, and (with the partial exception of the Pabbi Hills) by a small field team of four to six people. Similarly important discoveries might also be expected in any other area of northern Pakistan dated palaeomagnetically to the Late Pliocene or Lower Pleistocene, and others might accrue in areas already investigated by the Mission. Palaeontological and archaeological field work to date has done little more than scratch the surface of an enormous landscape spanning 2 myr. The results obtained so far need to be seen in that perspective.

The Soan Valley

As is well known, there are some highly controversial pieces of flaked stone from a conglomerate horizon at Riwat, southeast of Rawalpindi (Dennell *et al.* 1988; Rendell *et al.* 1989). The most distinctive pieces are shown in Figure 9.4. The main one (R83/001) is a large green/brown quartzite cobble (167×118×74 mm) with the remnants of eight or nine substantial flake scars (at least three of which

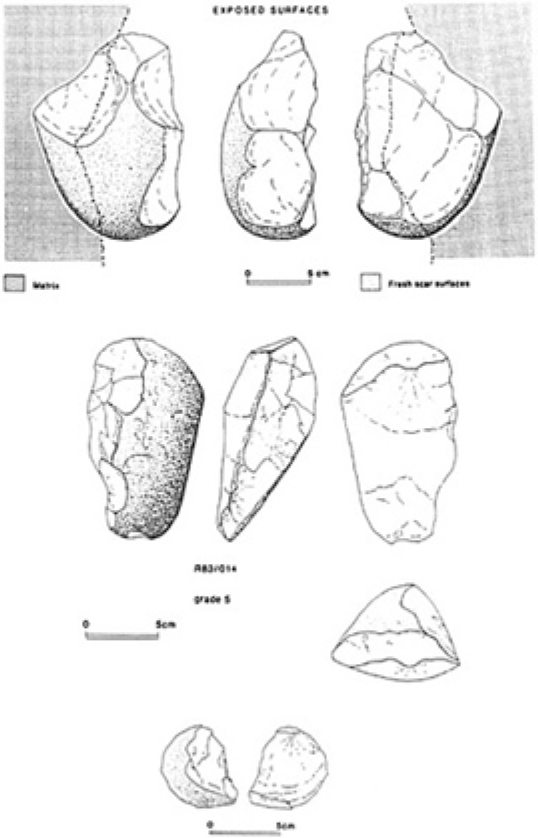

Figure 9.4 The artefacts from the lower conglomerate horizon, Riwat, Scan Valley.

show clear flake features) resulting from flaking in five different directions. Fortunately, a resin replica was made in Pakistan, and the numerous Palaeolithic archaeologists who have seen it have no doubts that it was deliberately flaked. At least two other pieces are regarded as equally convincing (Figure 9.4). One (R83/014) is a large grey-green quartzite flake (132×79×58 mm) with a prominent bulb of percussion and associated ripple marks. It was struck from a core, and transversely flaked on one side, creating an edge that is straight in side view. A total of eight scar surfaces can be seen resulting from flaking in three directions; the edges and scar surfaces are all rounded. The other (R88/1) is a fresh quartzite flake (59×45×20 mm), with a pronounced bulb of percussion on the ventral face, and half the dorsal face covered by cortex. However, there is no cortex on the platform. The piece shows evidence of flaking in three directions (Dennell and Hurcombe 1989:115–16).

Distinguishing deliberately struck stone from geologically struck stone is a long-standing issue in Palaeolithic studies that extends back to the controversy over ‘eoliths’ in the early part of this century (e.g. Warren 1920) and over the Kafuan industry of East Africa in the 1930s (e.g. Wayland 1934; Clark 1958). Such problems still persist, as over the alleged 34 kyr old stone tool assemblage from Pedra Fuerada, Brazil (Meltzer *et al.* 1995), the alleged Late Pliocene artefacts from St Eble, France, that may be tephrofacts (Raynal *et al.* 1995), and the claimed 1 myr old assemblage from Le Vallonet, France, which may also be natural (Roebroeks and van Kolfschoten 1994). In the case of the Riwat assemblage, the investigators paid particular attention to all the stone in the exposed sections of the lower conglomerate horizon, as well as the flaking characteristics of flaked pieces. Contra Klein (1989: 207), the pieces regarded as deliberately struck (especially R83/001, R83/014 and R88/1) are totally unlike the 1,264 other stones in the 50 m section between pieces R83/001 and R88/1 (Dennell and Hurcombe 1989:115–16 and Figure 7:16). Of those 1,264 pieces, only one was fractured, but had no flake features. In this instance, it is not a case of arbitrarily selecting a few convincing pieces out of a continuum of flaked material. Moreover, only eight pieces were found that may have been deliberately flaked out of *c.* 120,000 clasts along 4 km of exposed sections of the same conglomerate horizon.

The flaked stone from Riwat was examined in terms of length, breadth and thickness; scar surfaces with and without clear flake features; number of directions in which flakes were removed; the percentage of the total surface area that had been flaked; the amount of surface covered by cortex, positive and negative scars; evidence of retouch; edge-roundedness; and any obviously post depositional damage. Given the problems of distinguishing between geological and hominid flaking of coarse-grained material such as quartzite, each piece was also given an overall ranking, from grade 0 to 5, to indicate the probable agency of flaking. A ranking of 0 implies that the piece is natural; one of 5 implies that it is an unequivocal example of a humanly struck piece. The critical divisions are between grades 2 and 3: between ‘probably natural’, with few scar surfaces and little evidence of flake features, and ‘hominid or naturally flaked’, with a shape suggestive of an artefact and with little cortex remaining but without clear flake features. A score of 4 was reserved for those pieces showing clear flake features, with scars indicating flake removal from several directions and little cortex remaining. Given the controversies surrounding any assemblage of flaked stone more than 1 myr old outside Africa, the ranking of any material at grades 4 and 5 was done with great caution (see Dennell and Hurcombe 1989:105–22). Finally, natural flaking by percussion (as when one stone falls onto another) can be excluded as a possible agency. Dennell and Hurcombe (1995) attempted to flake quartzite by throwing 100 quartzite cobbles as hard as possible down a 10 m high concrete embankment, and failed to fracture a single piece. Multidirectional flaking of the type seen in at least three pieces from the lower conglomerate horizon at Riwat is almost certain to have been the result of deliberate flaking. The main issues at Riwat are thus ones of context and dating.

Regarding context, the sandstone adjacent to and more distant from the place where R001/83 was found was sampled for evidence of reworking, and none was found. The horizon itself has been exposed in only the last 10,000 years, as the overlying sequence of sands and silts is capped by a Late Pleistocene loess (Rendell *et al.* 1989:64–75). The dating has been accomplished by palaeomagnetic and stratigraphic means, drawing upon earlier work (Moragne 1979; Raynolds 1980; Burbank and Raynolds 1983, 1984; Raynolds and Johnson 1985). They showed that the Soan Syncline is strongly asymmetrical: the southern limb (containing the artefacts) dips gently at 10–15 degrees, where the northern limb rears up almost vertically, and is capped by horizontal fluvial deposits. These contain an ash that they dated to 1.6 myr; this has a normal polarity, and is thus consistent with the Olduvai event. On the basis that the folding of the syncline, the erosion of the northern limb and the deposition of the overlying horizontal deposits took at least 300 kyr, Burbank and Raynolds (1983, 1984) argued that the folding of the syncline occurred around 1.9 myr.

Rendell (Rendell *et al.* 1989; Rendell *et al.,* in press) undertook highly detailed palaeomagnetic sampling of the Soan Syncline, using a sampling interval as little as 0.5 m and averaging only 1.7 m, instead of the 27 m interval of Raynolds (1980), and has broadly confirmed but also refined earlier conclusions. First, she has shown that the rotation of the syncline (including the artefact bearing horizon) had ceased by the time the folding was completed, and was somewhat greater than calculated by Burbank and Johnson. Second, her re-examination of the probable rates of deposition, folding and erosion has led her to conclude that the *probable* age of the artefact bearing horizon is around 2.5 myr, rather than the *minimum* age of 1.9 myr that was initially argued (Burbank and Raynolds 1983, 1984; Rendell *et al.* 1987). (This estimate takes into account the redating of the palaeomagnetic timescale [McDougall *et al.* 1992], which affects the dating of *all* sites within this time range; ignoring that complication, the revised age estimate is 2.35 myr in the old timescale.) The new age estimate is likely to be even less acceptable to most palaeoanthropologists than the earlier one of >1.9 myr; unfortunately, the age of individual synclines cannot be manipulated because of their archaeological contents without profound geological consequences!

The Pabbi Hills

The anticline of the Pabbi Hills was dated palaeomagnetically by Keller *et al.* (1977), who showed that it had 1 km thick sequence of fine-grained fluvial deposits that spanned Early Matuyama to Early Brunhes (2.5–0.8 myr), before it was folded into a low anticline in the last half million years. Opdyke *et al.* (1979) also showed that it contained a very wide range of fossil vertebrate taxa. The British Archaeological Mission to Pakistan worked there extensively between 1986–90, looking for fossil animal (including hominid) remains and stone tools, as well as acquiring comparative fossil specimens for the Geological Survey of Pakistan (e.g. Jenkinson *et al.* 1989; Ashfaque and ul-Haq 1988).

In the course of fossil collecting, some 350 stone artefacts were found on the surface of fossil bearing deposits between 2 and 1 myr old. In 1990, one was found in context in a horizon 1.4–1.2 myr old (Dennell *et al.* 1992). The deposits in the Pabbi Hills are generally unconsolidated, and experience very high rates of erosion, especially during the spring rains and the monsoon. Consequently, neither fossil remains nor stone tools are likely to remain on erosional surfaces for more than a few years before being washed downslope and eventually out of the area. The artefacts found so far are very simple, and of quartzite. Core preparation, edge retouch and standardized forms are rare. Interestingly, the highly visible types of stone tools (e.g. handaxes, cleavers, prepared cores, blades) that are often found on Middle and Upper Pleistocene surfaces elsewhere in northern Pakistan are lacking. For this reason, we do not feel that the artefacts that were recovered were discarded and then deflated onto the erosional surfaces where they were found. Instead, it is thought that these tools eroded from Lower Pleistocene fossil bearing deposits. Interestingly, they are not Acheulian. We would hesitate to regard them as Soanian, as this is too poorly defined; we would also be reluctant to call them Oldowan until more is known. Nevertheless, it does provide some support for a pre- (or at least non-) Acheulian in northern Pakistan during the Lower Pleistocene (Hurcombe and Dennell 1992), as suggested for elsewhere in Eurasia by Rolland (1992; see Rolland, this volume).

Dina and Jalalpur

In 1983, a team of five spent ten days in the Jhelum Basin, enduring much heavy rain and looking for stone artefacts in previously dated sections. At both Dina and Jalalpur, Acheulian-type handaxes were found in fluvial contexts shortly above the Brunhes-Matuyama boundary, i.e. <780 kyr (Rendell and Dennell 1985). Although only three were found in securely dated contexts at Dina and Jalalpur, they are an important part of a broader pattern, of an Acheulian in Europe after 500 kyr, a little earlier in India/Pakistan, but substantially later than the earliest in East Africa, where it first occurs around 1.4 myr (Asfaw *et al.* 1992). It is worth noting that, at Dina and Jalalpur, flaked stones were found that are accepted as artefacts; they were found in a sandstone conglomerate unit, and dated palaeomagnetically. In contrast, the same type of evidence from Riwat, found in the same type of context and dated in the same way, is generally regarded as unacceptable. This is clearly not because of the intrinsic nature of the evidence itself, but because the dating does not accord with prior expectations.

CONCLUSION

Some of the issues raised in this chapter can now be drawn together. In the first part, the point was made that even in well-researched areas, such as western Europe and East Africa, palaeoanthropologists are still far from acquiring redundant data that adds nothing or very little to previous knowledge. In a region as poorly known as northern India and Pakistan, the scope for being surprised is so much the greater because little is known, particularly if we include it in a larger province the size of Europe, extending eastwards to Pakistan from the Red Sea and the Mediterranean. The point was also made that if hominids were already occupying grasslands throughout Africa by 3.5 myr, there would have been no reason why they were not also in the comparable (and longer established) grasslands of Asia, as there was no effective barrier (as now) between the two continents. Third, stone tool making is not unique to *Homo* or even hominids; if behavioural similarities between us and chimpanzees result from a shared ancestry, it follows that both the ancestors of both have been making stone tools since they diverged 8–6 myr ago.

The second part of this chapter reviewed the little new material that has been found since the 1980s: a small Late Pliocene assemblage from Riwat, a surface collection that may be Lower Pleistocene in age from the Pabbi Hills, and three securely dated handaxes from Early Middle Pleistocene contexts at Dina and Jalalpur. We can now add to this exiguous evidence some other Asian data: the mandible and stone artefacts from Dmanisi, Georgia, which may be 1.8 myr old; the similar evidence from Longgupo, China, of the same age range; and the new dates of 1.8–1.6 myr for the earliest hominids in Java. All these are controversial, and each can be challenged in terms of the dating, context and/or identification of material. However, they at least raise the possibility that hominids were in Asia by 2 myr, which in itself removes one major obstacle to acceptance of the Riwat evidence.

There are a number of ways of explaining current evidence from northern Pakistan and the rest of Asia. One is to accept the probability that hominids occupied grasslands in both Africa and Asia during the Pliocene, even if to date knowledge of them outside the Rift Valley and South Africa is minimal, and prior to 3 myr, evidenced only by the recent discovery in Chad. This proposition would also imply that present knowledge from the Rift Valley owes most to the combination of excellent, and often predictable preservation in lakeside and stream environments, combined with substantial expenditures of funding and time. It also suggests that the twenty-first century could be as exciting as the late twentieth century has been, if and when these enormous expanses of grasslands outside East Africa are investigated between the Atlantic Ocean and China. A second possibility is that the archaeological record in the form of stone tools is far longer than so far identified, and extends back to when chimpanzees and humans shared a common ancestor. Indeed, there is no inherent reason why very simple stone tools of the type found at Riwat or other early East African localities had to be made by *Homo,* unless there is incontrovertible evidence that it was the only potential tool maker in the area at that time.

On these arguments, it would not be surprising if stone artefacts were found in contexts both in and outside Africa before 2 myr ago: first, because there is no reason why hominids were not in extensive areas of both continents before 3 myr ago (Dennell 1995); second, because they are likely to have been tool makers; and third, because primates other than hominids can make such artefacts. Finally, the imperfections and unevenness of the fossil hominid and early archaeological record need to be recognized more explicitly. Given the rate at which our views on early human evolution change in even the best known areas, new data from poorly known areas such as southern Asia are likely to be even less predictable. In particular, palaeoanthropologists cannot afford to be dogmatic about human origins when a wholly unexplored area the size of Europe, or the European Community and East Africa combined, lies between our two best data sets of Europe and East Africa. The most exciting developments in palaeoanthropology may yet occur in areas of former grasslands such as those in Africa outside the Rift Valley, or those of southwest Asia and the Siwaliks.

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10

Quaternary stratigraphy, palaeoclimate and the Lower Palaeolithic of India

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INTRODUCTION

The development of Quaternary studies in the context of Palaeolithic research in India can be seen in two major phases: first, from 1863 to 1964, and second, from 1964 to the present. During the first phase, many type areas for reconstructing prehistoric culture successions were identified in various river valleys of peninsular India. Inferences regarding palaeoclimates and palaeoenvironments were based on the characteristics of lithological units (such as coarse-grained and fine-grained clastic sediments) and faunal material contained in these deposits. Methodological and interpretative frameworks that were current in Europe were applied to the Indian situation. Much of the early Indian research was conducted by European scholars endeavouring to reinforce European models in India. Between 1940 and 1960, many regional surveys were carried out to bridge geographical gaps concerning Pleistocene chronology and cultural succession, allowing for inter-regional correlations. The 1960s were a decade of major methodological and theoretical changes in the earth sciences and archaeology. The new perspectives necessitated a revision of the existing models and the application of new scientific techniques. Many new areas for investigation were identified, including littoral, aeolian, lacustrine and off-shore environments. Since 1970, Quaternary research in India has steadily increased, producing excellent data to fit into the global climatic framework. Three other chapters in this volume (Singhvi *et al.,* R.Dennell and M.D.Petraglia) deal with aspects such as the initial occupation of South Asia, the problems and prospects therein, and the potential of non-alluvial Lower Palaeolithic contexts for behavioural and site formation studies, dating and environments. This chapter reviews the progress of Indian Lower Palaeolithic research from the perspective of Quaternary geology.

THE FIRST RESEARCH PHASE (1863±1964)

Integrated geological, climatological and Palaeolithic studies in India date back to the earliest investigations, beginning with the first discoveries by Robert Bruce Foote on 30 May 1863 (Foote 1866). While describing the momentous discovery of Lower Palaeolithic artefacts at Pallavaram near Madras, Foote made a graphic description of the geological context of the stone tools. Furthermore, he attempted to fix their age as well as the contemporary climatic conditions. Although much prehistoric research was subsequently carried out, there were few attempts to reconstruct palaeoclimates or palaeoenvironments until the 1920s.

Old concepts: glacials versus pluvials

Fresh impetus for palaeoclimatic research in the context of stone age studies was provided by Cammiade and Burkitt (1930). They closely followed Foote's work along the southeast coast and identified a large body of Palaeolithic evidence. From this, they made fresh geological observations that not only filled the gaps in Foote's (1916) fourfold framework, but also provided a climatic background to the evolution of stone age cultures, an alternating succession of wet and dry periods (Cammiade and Burkitt 1930). Whilst their organization of stone age material into Series I, II, III and IV cultures was equal to the European subdivision of pre-neolithic cultures, their concept of alternating wet and dry climatic cycles was based on the East African model of pluvial-interpluvial cycles, implying cyclic variation in the intensity of rainfall. At that time, L.S.B.Leakey (Wayland 1929; Leakey 1929 quoted in 1931:11–12) had been using this model for East Africa, where the pluvial phase was defined as a period of heavy rainfall concurrent with the glacial climate of the northern latitudes, suggesting a shifting of climatic belts. The interpluvial was considered to be a relatively dry phase. In the following decades, Leakey's model was widely accepted in southern Indian prehistoric research. Richards *et al.* (1932) made a detailed survey of the region around Manjan Karani on the Kortallaiyar (also Kortalayar or Old Palar) River, north-east of Madras, and at Kannapuram in the Godavari Valley. At the latter site, they documented a sequence of alluvial sediments and also reported the occurrence of Lower Palaeolithic tools in the basal gravel conglomerate, which came to be the ubiquitous source of Lower Palaeolithic material. Further, they attributed the Manjan Karani (also Manjankaranai) palaeoliths to the late Series I or early Series II culture. However, Cammiade and Burkitt (1930) and Richards *et al.* (1932) were clear about the fact that peninsular India did not experience glaciation in the past. Table 10.1 summarizes their findings, representing a root paradigm in the culture history of the Indian Stone Age.

It was suggested that the Mesolithic was the only period that flourished during a wet phase, whereas all early cultures appeared during dry phases (Cammiade and Burkitt 1930). These researchers made an explicit comparison of the tool industries with the African material, and concluded that 'all

Table 10.1 The geological and climatological succession of Series I–IV cultures in southeast India.

Phase	*Climate*	*Prehistoric culture*
Laterite formation I	Humid dense forest	No human occupation
Disintegration of laterite II	Dry	First human occupation (handaxes) Series I
Denudation of disintegrated laterite and artefacts III	Humid but not intensive enough to form laterite	Humans moved out of the region
Stable land surface IV	Dry	Flake culture Series II
Deposition by rivers	Wet, but less intense than Phases I and II	Blade tools Series II
–	Dry	Series III
–	Wet	Series IV

tool industries of southeast India have exact counterparts in Africa, especially in South Africa'. They also emphasized the close connection between the two widely separated regions from the Early Palaeolithic to Mesolithic (Cammiade and Burkitt 1930:337). Subsequently, typo-technological comparisons between the Indian and the Vaal River cultural material became an important aspect of palaeoclimatic research in India. Krishnaswami (1938) carried out detailed documentation of the stratigraphy at Vadamadurai, Attirampakkam, and Manjankaranai in the Kortalayar Valley, and utilized Cammiade and Burkitt's inferences. Coherence between several climatic stages and the Himalayan glacial-interglacial cycles was emphasized. The Vadamadurai Boulder Conglomerate was correlated with the Boulder Conglomerate of the II glacial period and the Middle Pleistocene fossil beds of the Narmada (Krishnaswami 1947).

In the 1930s, the Yale-Cambridge expedition was launched in India by de Terra and Paterson (1939). Their primary goal was to look for evidence of Pleistocene glaciation in the Himalayan region and to highlight its impact on early human cultures. The expedition was not, however, limited to the Himalayan region alone, but was also extended to central India and around Madras. These were the areas where prehistoric as well as palaeontological research had been occasionally carried out between 1880 and 1920 (see Movius 1944). Following their field work in the Kashmir Valley (Jhelum), on the Potwar plateau (Soan Valley), in the central Narmada Valley (between the towns of Hoshangabad and Narsinghpur) and around Madras they arrived at a fourfold glacial-interglacial model for northwest India that was correlated with the Alpine glacial-interglacial model of Penck and Brückner (1909). The basis for their model was provided by the terraces in the Soan Valley (now in Pakistan) and the Jhelum in Kashmir (India). The possible correlation between the Alpine and Himalayan glacial-interglacial terrace sequences was adopted by Movius (1944) and was further extended to the Pleistocene sequence in northern Burma, northern China and equatorial Java.

This glacial-interglacial scheme became a standard yardstick for prehistoric and Pleistocene research in India for at least forty years. Like Cammiade and Burkitt (1930), de Terra and Paterson (1939) were the first to highlight the evidence for climate-related deposits in the Soan Valley. This enabled them to relate such deposits to glaciation in the Himalayan region. The Siwalik Boulder Conglomerate was assigned to the period of Mindel glaciation, and this provided a chronological basis for reconstructing the glacial sequence for the Subcontinent. In their classic monograph, *Studies on the Ice Age in India and Associated Human Cultures* (1939), de Terra and Paterson documented evidence for four principal glacial and three interglacial stages during the Pleistocene, as shown in Table 10.2. While Pinjore and Tatrot zones were placed in the Lower Pleistocene, the Boulder Conglomerate and the terraces were assigned to the Middle and Upper Pleistocene. Despite varying climatic, tectonic and sedimentary environments in the diverse physiographic zones of India, de Terra and Paterson attempted a correlation of Pleistocene sequences. The sedimentary stratigraphy of the Narmada Valley was equated with the Potwar depositional and erosional features, and, in addition, they extended stone age terminology to include core cultures. Table 10.3 presents the correlation, which was based on climatic and lithic evidence. Evidence for Middle Pleistocene mammal fossils was recorded from the basal conglomerate of the Lower Group,

Table 10.2 The classical glacial—interglacial succession in the Himalayas.

Depositional unit	*Terrace sequence*	*Glacial and culture sequence*
Pink loam/silt/gravel	Terrace 4	Fourth glacial (Würm)
Thin loam Late Soan industry	Terrace 3	Third interglacial (Riss-Würm),
Loessic silt industry	Terrace 2	Third glacial (Riss), Late Soan
Upper Terrace gravel	Terrace 1	Second interglacial, (Middle-Riss) Chelles-Acheul and Early Soan I industry
—erosion and tilting—		
Boulder Conglomerate flake industry (pre-Soan)		Second glacial (Mindel), oldest
—erosion and tilting—		
Pinjor zone		First interglacial (Gunz-Mindel)
Tatrot zone		First glacial (Gunz)
—unconformity—		
Dhok Pathan		

Table 10.3 Correlation of the Narmada Valley and Soan Valley climatic and cultural sequences.

Lithic industry	*Narmada Valley*	*Soan Valley*	*Climate*
—	Black cotton soil or Regur	Terrace 5	Interglacial= Holocene
Upper Group			
	Pink clay	Terrace 4	Glacial=Last glacial
Late Soan	Sand	Terrace 3	Interglacial=Last interglacial
Lower Group			
Upper Acheulian	Pink clay	Terrace 2	Glacial=3rd glacial
Early Soan-Abbevillo-Acheulian	Conglomerate and sand	Terrace 1	Interglacial=2nd interglacial
No human occupation	Bedrock: laterite		2nd glacial

which also yielded crude, rolled bifaces. Typical Upper Acheulian artefacts came from the fine sediment of the Lower Group. Late Scan artefacts and faunal material (e.g. *Bos namadicus, Bubalus, Hexaprotodon, Elephas namadicus*) came from the Upper Group. Further south in the Madras area, de Terra and Paterson worked out a Pleistocene stratigraphy that was comparable to the Narmada sequence both in terms of culture and sedimentary succession. The 'Kortalyar' (Kortallaiyar) sequence is shown in Table 10.4.

On the west coast, Todd (1932) pioneered both prehistoric and Pleistocene research. He primarily extended the east coast model, and described the Pleistocene and cultural stratigraphy and climate succession on the basis of a depositional sequence on the Kandivli Nala in the Bombay area. The basal gravel formation yielding Acheulian artefacts was attributed to a pluvial phase (Todd 1932, 1939). Further survey on the west coast did not produce much Acheulian material but for a few more mesolithic sites (Todd 1950). However, sporadic occurrence of Acheulian artefacts was reported from the north Konkan

Table 10.4 Thepleistocene stratigraphy in the Madras area.

Climate	*Terrace*	*Lithofacies*	*Stage*
	Terrace 3	Modern alluvium	
	Terrace 2	Fine sand, silts, and pellety lateritic gravel	Levallois-like flakes
	Terrace 1	Erosion of TD sand and gravel	Late Acheulian material
Post 3rd glacial	—	Detrital laterite grit and sand	—
3rd glacial	TD (depositional Boulder Conglomerate terrace)		Middle and Late Acheulian

(Malik 1959, 1963). Re-examination of the Kandivli section by Sankalia (1962) revealed no evidence of the Acheulian as well as the succession of sediments, and thus the entire Kandivli assemblage was considered to be post-Acheulian.

In the northwest of the Indian subcontinent, there was no follow up of de Terra and Paterson's work in the ensuing several decades, as much attention was drawn to the unravelling of the Indus bronze age civilization. However, the pervasive influence of their work continued to hold sway in central and peninsular India, and there ensued a continuing debate on whether the Soanian and Acheulian periods were two separate geographic entities. The Boulder Conglomerate zone of the Potwar was considered a marker unit in the Quaternary correlations in India, first by Krishnaswami (1947) and later by Khatri (1961). Furthermore, there were efforts either to refute or to subscribe to their Pleistocene stratigraphic model. This is clearly reflected in the works of Krishnaswami (1947), Zeuner (1950), Soundara Rajan (1952, 1958), Khatri (1961), Sankalia (1963) and Wainwright (1964). This gradually led to a plethora of climatic interpretations presenting a confused picture of the Pleistocene period in India (e.g. see the chart showing the Quaternary sequence in northwest Pakistan, Kashmir and the Narmada based on de Terra and Paterson's [1939] ice age model [Krishnaswami 1947: plate XIV]). While Soundara Rajan (1958) assigned silt deposition to wet conditions and gravels to a dry climate, Sankalia (1964) assigned silt deposition to a dry climate. Previously, Cammiade and Burkitt (1930) had very clearly emphasized that both silt and gravel deposition took place during a wet phase, and that during dry phases, weathering of the previously deposited sediments took place. In these works, the presence or absence of laterites was an essential issue, and it provided the basis for the Pleistocene climatic stratigraphy. Another striking aspect of these studies was that they primarily based their inferences on field observation of vertical lithofacies variations and on the construction of composite lithostratigraphic columns, without attempting to identify erosional unconformity and depositional processes operating in each of these areas.

Both Zeuner (1950) and Wainwright (1964) were successful in showing that evidence for more than four cycles of wet and dry phases existed in the peninsular rivers, provided that one could read the records carefully. The question of whether these corresponded with the glacial-interglacial or pluvial-interpluvial oscillations loomed large, and yet remained unresolved. Further confusion was added by Movius (1944) and Khatri (1958), who used the pluvial concept without clearly explaining its implications and applicability. In the context of their time, the pluvial climate was conceived as a period of very heavy rainfall in tropical areas, synchronous with cool and dry conditions of the temperate zone (see Wayland 1929).

Zeuner (1950, 1963) was the first well trained environmental archaeologist to work in western India, and he gave a scientific footing to Pleistocene research in India. His field work in the 1940s culminated in the publication of *Stone Age and Pleistocene Chronology of Gujarat* (1950). He outlined a sequence of three wet and dry cycles and contemporary cultures in the Sabarmati Valley (Table 10.5).

Further noteworthy work in the south Gujarat area was carried out by Wainwright (1964), whose focus was the lower reaches of the Narmada adjacent to the area of the Sabarmati River. In addition to field documentation of the lithostratigraphy, he carried out a micromorphological study of buried soils interbedded in the fluvial sediments. His study was further extended to establish a relationship between fluctuations in sea levels and continental glacial-interglacial cycles. This was perhaps the first attempt to relate stone age cultures to sea level fluctuations on the west coast of India. Wainwright developed a scheme in terms of stream response to sea level changes (Table 10.6). On the basis of a comparative study with the Sabarmati sections, Wainwright (1964) suggested that the lateritic weathering that led to the formation of lateritic crusts could be of third glacial age, and that all the three Pleistocene soils corresponded with the three glacial maxima of the last glaciation (Wainwright 1964; see also Zeuner 1959:54).

Khatri (1961) surveyed the central Narmada Valley and revisited most of de Terra and Paterson's (1939) sites, and he developed fresh observations on the cultural stratigraphy of the region. Khatri placed the Lower Group sediments and the pre-Acheulian assemblages in the Middle Pleistocene, and equated it with an interpluvial climatic phase (i.e. similar to present-day climatic conditions). The Upper Group represented a pluvial phase of very

Table 10.5 Climatic and cultural succession in the Sabarmati Valley.

Formation	*Climate*	*Stage*
Stable dune surface	Relatively wet	Microlithic
Sand dune activity	Dry	–
Erosional phase	Somewhat damper conditions	–
Fine silt and windblown sands	Main dry phase	Aeolian activity strong, no human activity
Red soil	Wetter conditions	Alluvial silt, no palaeolithic material
Silt	Onset of drier climate	Steeper gradient, palaeolithic material present
Cemented gravel	Rainfall heavier than today	Seasonal flood deposition, palaeolithic material present
Mottled clay	Relatively less humid	Establishment of the ancient course of the Sabarmati
Laterite weathering	More humid than today	No human occupation

Table 10.6 The lower Narmada Valley lithostratigraphic and climatic succession.

Phase	*Lithofacies*	*Interpretation*
Phase I	Modern soil surface	Present river level
Phase II	Aggradation: deposition of sands and aeolian dust	Seasonal monsoon floods
Phase III	Low sea level, erosion, soil formation on older deposits	Dry phase
Phase IV	Aggradation: sand, silt and clays	Wet phase
Phase V	Erosion: low sea level, soil formation on older deposits	Dry phase
Phase VI	Aggradation: high sea level	Wet phase
Phase VII	Erosion: low sea level, soil formation on the older deposits	Dry phase
Phase VIII	Lower Series—clays, silts and sands — high sea level aggradation	Wet phase, lower palaeolithic man present
Phase IX	Low sea level—erosion	Dry
	—Unconformity—	
Phase X	Aggradation: lower clay	
	—Base not exposed—	

wet conditions, during which time both Early to Late Acheulian industries existed, where Series II cultures flourished. He differed with de Terra and Paterson regarding the Soanian intrusion into the valley, and suggested an *in situ* development of the Acheulian. Although Khatri (1958) worked out a revised Pleistocene stratigraphy for the central Narmada, his emphasis was more on locating laterite exposures and evolving his own terminology for the artefact assemblages, such as the Mahadevian (Khatri 1962; see also Supekar 1985), which was comparable to the Oldowan. He basically disagreed with de Terra and Paterson's idea that the Narmada was a meeting ground of the Soanian pebble tool culture and the madrasian handaxe culture. He suggested a date of Lower Pleistocene pluvial age for the laterite, and provided a pluvial-interpluvial sequence for the Pléistocène deposits in the Narmada Valley, as shown in Table 10.7. Perhaps in order to demonstrate that the Acheulian evolved independent of the Soanian and that the Narmada was the original place of its development, he presented a comparative scheme of the Pleistocene sequence from the Godavari, Shivna and Narmada (Khatri 1957, 1961), wherein the 'boulder conglomerate' of the Narmada was shown to be the oldest of the deposits that contained Chellian artefacts. By assigning a Middle Pleistocene age to the Narmada Boulder Conglomerate, he did not suspect the possibility of identifying the gravel along the Shivna, a tributary

Table 10.7 Pleistocene stratigraphy and cultural succession in the central Narmada Valley.

Period	*Lithofacies*	*Climate*	*Stage*
Holocene	Black cotton soil	Interpluvial	
	Yellow brown silt with concretions	present-day conditions	Microlithic
	Cross-bedded sand		Series II
Upper Pleistocene	sands, fossils	Pluvial	Late Acheulian
	Gravel conglomerate		Early Acheulian Chellian
–Unconformity–			
Middle Pleistocene	Boulder conglomerate fossils	Interpluvial present-day conditions	Early Chellian
Lower Pleistocene	Laterite(?)	Pluvial	

stream of the Narmada, to be of Middle Pleistocene age. Table 10.8 shows Khatri's comparative scheme.

Retrospect

As far back as the 1940s, Zeuner was aware of the tenuous character of the correlations of the northwest Indian glacial-interglacial sequence with the Alpine one. He had, however, provisionally shown contemporaneity between the Early Acheulian in Europe and India (penultimate interglacial stage 1). Many regional studies on the Pleistocene climatic and cultural succession in India were subsequently conducted, including the work of Bose and Sen (1948) in Mayurbhanj (also Bose *et al.* 1958); Krishnaswami and Soundara Rajan (1951) in the Singrauli Basin, Uttar Pradesh; Soundara Rajan (1952) in the Gundlakama Valley, Andhra Pradesh; Subbarao (1952) in the Mahi, Orsang and Karjan Valleys, central Gujarat; Joshi (1955) in the Malaprabha Valley, Karnataka; Sankalia (1956) in the Godavari and Pravara River valleys in upland Deccan, Maharashtra; and Mohapatra (1962) in the Brahmani Valley, Orissa. Inevitably, certain regional interpretations of the evidence attained importance, and interregional correlation was also made.

The above account of empirical records of Pleistocene sediments produced by various workers betrays ambiguities in the reconstruction of past climates. The Lower Palaeolithic evidence was generally preserved in the basal gravel conglomerates, commonly designated Gravel I, and in some cases was under-lain by a clay horizon. Terms like Soanian, madrasian, mahadevian, abbevillian, clactonian, chellian and Acheulian were freely used for random collections of Palaeolithic artefacts made from riverine sections, without going into their

Table 10.8 Comparison of Pleistocene stratigraphy in the Pravara, Narmada and Shivna Valleys.

Pravara (Godavari Valley)	*Narmada*	*Shivna (Narmada Valley)*
Sandy gravel-III Microliths	Black cotton soil Microliths	Black cotton soil Microliths
Yellow silt	Yellow brown silt with concretions	Brown silt
Cross-bedded gravel-II Series II and Acheulian	Cross-bedded sand, fossils, Late Acheulian	Fine cemented gravel, Yellow silt and Series II
Fissured clay		
Pebbly gravel-I Middle Acheulian Late Chellian	Cemented sandy gravel fossils, Early Acheulian/ Late Chellian	Pebbly gravel Acheulian Late Chellian
Bed rock	–Unconformity–	Bed rock
	Boulder conglomerate fossils, Early Chellian	
	Red clay, Early Chellian	

typo-technological and chronological implications. There was an apparent lack of uniformity in interpreting the climatic significance of various alluvial deposits, while the ubiquitous nature of the geological and sedimentological context of the Lower Palaeolithic certainly warranted a unified approach. The indiscriminate use of the term Boulder Conglomerate for the basal gravel of the Narmada also implied its similarity with the Scan sediment (Khatri 1961). Outside the Siwalik region, gravels of comparable size and thickness are not encountered. Although Zeuner (1959) had no opportunity to do field work in the Soan Valley, he was not convinced of the climatic succession of northwest India that was based on the linkages of river terraces with moraines in the Soan Valley (for a summary of the data see also Krishnaswami 1947).

THE SECOND RESEARCH PHASE (AFTER 1964)

Regional studies continued to be made in the 1960s. The Kortalayar Valley continued to receive the attention of both geologists and archaeologists. Wainwright and Malik (1967) outlined the problems of archaeology and Quaternary chronology in peninsular India on the basis of their work near Madras. Around the same time, Banerjee (1964–5, 1965–6) carried out a series of excavations in this area, and established the existence of river terraces at elevations of 73 m, 45 m and 17 m above mean sea level. Though a detailed report was never published, brief comments on the Middle Acheulian character of the Lower Palaeolithic industry were made in the absence of stratigraphic development. However, it is not clear whether base level changes and corresponding sea levels were taken into account while identifying terraces at various elevations.

After brief collaborative research with F.E.Zeuner of the Institute of Archaeology, University of London, Sankalia (1963) produced *Prehistory and Protohistory in India and Pakistan,* wherein he brought together the regional alluvial and cultural sequences as having developed under the influence of alternating wet and dry climatic cycles. In 1974, he updated it by including new data produced during the intervening decade (Sankalia 1974). *The Roots of Ancient India* by Fairservis (1971) also included an Appendix by Possehl (1971), who suggested relatively secure correlations of empirical data from various river valleys in the peninsular region. This was true as far as the lithological sequence was concerned, but not in terms of the Pleistocene chronology. He treated Zeuner's Sabarmati Pleistocene sequence as a frame of reference, and placed the upper three soils in the Narmada (Wainwright 1964) and Sabarmati (Zeuner 1950) against the three glacial maxima of the last (Würm) glacial, and assigned the implement bearing gravels to the last interglacial. Further, he suggested a third glacial or penultimate glacial age to the laterite of southern India as per Wainwright (1964). This considerably altered the chronology of the Indian Stone Age and implied a very late arrival of Early Palaeolithic hominids in India. While assigning laterites to the Middle Pleistocene third glacial, he was perhaps not clear about climatic implications. A great deal of caution needs to be exercised in using implements as 'fossil zones' when drawing parallels in the Pleistocene chronology between diverse physiographic zones of India. Early palaeoclimatic reconstructions were based on simplistic assumptions that gravels were deposited in high energy fluvial regimes, and hence heavier rainfall was a prerequisite; conversely, as light sediments, silts were considered to be deposited under low energy conditions, and under a dry climate.

Since the 1960s, there have been a series of methodological developments in both geology and archaeology that have had a profound effect on Indian Palaeolithic studies. The theory of plate tectonics made a resounding revival as a result of oceanographic expeditions and palaeomagnetic anomaly studies of rocks and sediments. The deep sea oxygen isotope stratigraphy and the continental loess-palaeosol stratigraphy in central Europe (Kukla 1977) and China (Kukla and Zhisheng 1989) have now become standard frames of reference for Quaternary correlation. Greater emphasis was laid on the application of laboratory procedures for the sedimentology and petrology, as well as radiometric dating of Quaternary deposits (e.g. Rajaguru 1970; Lele 1972; Pappu 1974; Guzder 1974, published in 1980). An increasing number of radiometric and other dating techniques have facilitated the reconstruction of Quaternary history in a secure timeframe. Multidisciplinary data from the diverse regions of the world could now be synthesized to provide a unified picture of Quaternary environmental changes and their effect on the human community.

New concepts: land, sea and the Quaternary climate

The awareness that the Pleistocene was a period of major environmental changes, stretching over a far greater time depth than had been known from previous studies, led to new avenues of research (Bowen 1978; Imbrie and Imbrie 1979). The oxygen isotope stratigraphy from deep sea cores has helped immensely in land-sea correlation and in revealing the pattern of glacial and interglacial climatic phases (Shackleton 1975). The continental loess-palaeosol stratigraphy, supported by the palaeomagnetic time scale and radiocarbon dating, led to the revision of fourfold Alpine glacial sequence; as a result, other palaeoclimate models based on this collapsed. There have been at least eight glaciations during the Middle Pleistocene (since 700 kyr), and since 1.6 myr ago there were at least seventeen major glacial cycles. The classical Alpine glacial cycles are now bracketed between 550 and 20 kyr (Kukla 1975). The sequence of glacial-interglacial cycles based on terrace sequences on land have been proved incomplete and discontinuous. Oceanic and ice cores have shown that climate change in the tropics was also in tune with the temperate and subtemparate regions, and was similar if not identical.

The fall of the classical Alpine model

The availability of continuous deep sea oxygen isotope records providing uninterrupted evidence of global climatic change, necessitated its correlation with the terrestrial evidence of glacial and interglacial cycles propounded by Penck and Bruckner (1909) for the Alpine region and from north Europe and America. Deep loess-palaeosol sequences on land also provided an alternative continuous record. These in turn could be correlated with each other. Since the classical model was based on a sequence of strata with specific climatic signatures, and given the fact that gross changes in climate are globally synchronous, testing the validity of the Alpine model as representing a continuous situation became imminent. Kukla (1978) made a thorough study of the Alpine terrace stratigraphy and its climatic interpretation in comparison with the deep sea and loess-palaeosol records. This brought out the long gaps in the continental terrace sequence and the associated deposits as well as errors in climatic interpretations. It was evident that sediments ascribed to ‘glacial’ stages were formed during both glacial and interglacial climates, and that ‘interglacial’ stages probably represented increased crustal movements. He further recommended discontinuing the use of classical terminology in Quaternary correlations, and basing the chronostratigraphic subdivision of the Pleistocene on the Oxygen Isotopic Stages from the deep sea.

Limnological and oceanic research

The formerly held belief that the cool and dry glacials of the temperate areas were accompanied by pluvials of hot and wet climate in the tropics has been shown to be unfounded. Evidence for this came from the dating of tropical African 'pluvial' lakes. A number of lakes in East Africa showed high lake levels in the Early Holocene based on radiocarbon dating (Butzer *et al.* 1972). The marine pollen diagram from the Arabian Sea off the East African coast showed periodic fluctuation in monsoon conditions that correlated with glacial climatic changes as revealed by Oxygen Isotope Stages. Glacial periods were arid because of decreased monsoon flow, and during early interglacial stages, the SW monsoon flow was intense, resulting in the rise of lake levels in the tropics (Van Campo *et al.* 1982). An increase in rainfall between 10 and 5 kyr was also recorded from lakes in Australia and India. Temperate regions of Australia and China have shown records of major fluctuations in lake levels in response to the onset of glacial aridity during the Last Glacial Maximum, during 25–16 kyr ago. At the end of the Ice Age, 10 kyr ago, these lakes were restored to levels a little higher than today (Bowler *et al.* 1995). Similar evidence of climatic fluctuations is also reflected in the Nilgiri peat (Sukumar *et al.* 1993) and the Didwana lake in the Thar Desert of India (Singh *et al.* 1971, 1974; Wasson *et al.* 1983, 1984). Such changes in lake levels in both hemi-spheres can now be shown as uniform and synchronous events (Wasson 1995).

It is now well established that the global climate operates as a single, inter-connected system (Bowler *et al.* 1995). For instance, the major deglacial intensification of the SW monsoon over the subcontinent, marking the end of the Pleistocene, was synchronous with the major climatic transition recorded in the Greenland ice core. An earlier event at 16 kyr is also recorded in the Atlantic core (Sirocko *et al.* 1996; see also Broekker 1996). It should therefore be expected that all the regions of the world, with or without long-term proxy records, must have experienced synchronous climatic changes in the past, influencing human evolutionary and cultural processes. Quaternary climates in the unglaciated regions also oscillated in accordance with the glaciated regions, even in terms of magnitude. Considerable evidence has accumulated that points to the fact that vegetation changes in the tropics took place in response to glacial and interglacial cycles. The expansion of tropical savannas and the opening of tropical forests occurred during the Last Glacial Maximum. The equatorial Atlantic cores show an increase in diatoms at regular intervals derived from continental lakes, indicating low lake levels during periods of aridity. These periods were identified with those at 115–110, 95–84, 68–60 and 23–15 kyr, which are arid phases of the last glacial cycle (for a detailed account on tropical climates, see Thomas 1994). Without a multidisciplinary programme of research, reconstruction of Quaternary climates and palaeoenvironments is a difficult task, and correlation of cultural stratigraphy to the glacial and inter-glacial chronology based on imprecise indices is problematic. Outside India, there was a spate of radiocarbon dates facilitating correlation of Quaternary events in time and space. The geomorphic and biological investigations into the archaeological sites in Africa emphasized the need for new field methods and laboratory techniques. At this time, much of Quaternary research in India was restricted to riverine situations. These locations proved themselves discontinuous and attenuated in their record of floral and faunal material. Even the pollen profiles drawn for the northwest Indian lakes did not go beyond the Early Holocene–Terminal Pleistocene.

Prospect

Since the 1950s, a new beginning has been made in palaeoenvironmental and chronological research in India. The basic problem of dating proxy records of climate in absolute years was resolved with the application of radiometric and other dating techniques, though it was mainly confined to the Late Quaternary. With increasing opportunities for a better reconstruction of Indian Quaternary history, old concepts were dropped. However, the lack of establishing a long-term geological record has been a major limitation, especially for the Middle and Lower Pleistocene, where Lower Palaeolithic sites are generally preserved.

With the availability of radiocarbon dates for the Late Quaternary, correlations may be made between fluvial and marine mineral sequences and the deep sea oxygen isotope stratigraphy. Although a large number of surface and subsurface sediments from the Arabian Sea have been analysed for reconstructing palaeomonsoon fluctuations over the Indian region, this research is generally confined to the period of the Last Glacial Maximum and the latest interglacial. Duplessy (1982) inferred that the climate was very arid about 22–18 kyr ago, and that the Asian summer monsoon was weaker during the Last Glacial Maximum than it is today, whereas the winter monsoon was stronger. The palynological study of marine cores of the southwest coast of India has revealed two phases of the monsoon. The low mangrove pollen frequency is dated to a dry climatic phase between 22 and 18 kyr ago, followed by a humid phase at the early post-glacial period (Van Campo 1986). Mineralogical study of the Arabian sea shelf sediments has also shown aridity around 11 kyr ago during the Younger Dryas (Nigam and Hashimi 1995). Another significant development in the Indian Ocean region is the availability of the climatic record for the Middle Pleistocene from the DSDP sites, 800 km off the southwestern coast of India. These cores show marked fluctuation in the population of planktonic foraminifera *Globorotalia menardii*. This species is most sensitive to changes in sea surface temperature, and therefore the cyclic variation in the abundance of the foraminifera at these sites is a good record of temperature changes during the Pleistocene. At least three glacial-interglacial cycles from the Upper Pleistocene to Holocene have been identified in these cores (Sarkar and Guha 1993). Recently, Somayajulu (1990) has made a survey of geochemical and geochronological methods for the reconstruction of Quaternary climates and has also presented a synopsis of findings in these areas in India.

Laterites revisited

Krishnaswami's (1947) account of stone age India indicates some degree of confusion and uncertainty regarding the age of laterites. Whilst emphasizing their importance in climatic and stratigraphic reconstructions and correlation of Quaternary sequences, he assigned laterites to both Lower Pleistocene (pre-human) and Middle Pleistocene periods, and later work by Wainwright (1964) did not break new ground on this issue. The presence or absence of archaeological evidence on laterite surfaces was considered crucial to its dating. This situation prevailed until Guzder (1980) carried out a detailed study of laterites and stone age cultures in the Konkan region of western India. This work was a systematic study of laterites in terms of types and their relationship to planation surfaces, mode of formation, palaeoclimate and chronology. Konkan laterites were classified into three types,

1. laterite with a typical three-layered structure of lithomarge, lateritic clay and crust,
2. a homogeneous or massive laterite, and
3. detrital laterite.

Whilst the first two are considered primary, the third variety is a secondary deposit or a sediment of weathered laterite, but relateritized. This classification of laterites into primary and secondary does not conform to the high and low level laterites identified by Medlicot and Blandford (1879). The term sedimentary laterite appears more appropriate, and lateritic gravels can also be included in this. In the context of stone age studies, Kale (1983) systematically documented laterites in Goa, further south of Konkan (Maharashtra). Guzder (1980) further observed that primary laterites (including plateau and coastal formations) predate valley formations, and the lateritic gravels are products of Middle to Late Pleistocene fluvial processes. The occurrence of Lower Palaeolithic tools on the surface of 45–90 m terraces suggests that the terrace formation predates the Lower Palaeolithic occupation of the area, and the evidence of lateritic gravels at various elevations and the alluvial cut and fill sequences are in response to local or regional (Quaternary glacio-eustatic) base level changes.

Mature, well developed laterites situated on the crest of the Western Ghats and on higher denudational surfaces in the peninsular region are dated to the Early Tertiary (Kumar 1986). There are no typical laterite profiles datable to the Early Quaternary. The Indian laterite formed under the influence of a tropical monsoon and equatorial regime, with longer rainy seasons, supported by peneplanation processes when the Indian plate was crossing over the Equator. Atypical laterites common on the pediments flanking the river valleys in peninsular India are considered to be of Quaternary age. This is more appropriately termed ferricrete rather than laterite. However, two broad distinctions are made in the laterite profile. One is a commercial variety and the other is nodular or pisolitic material. Although there are two generations of laterite situated at different altitudes, the highest or plateau laterite dates to the K-T boundary, and the lower one is placed in the Late Tertiary on the basis of palaeomagnetism (Kumar 1986; Ollier and Rajaguru 1989; Sahasrabudhe and Rajaguru 1990; Ollier 1995).

The monsoon

After the work of de Terra and Paterson (1939), there was very little interdisciplinary research conducted in the Potwar region. On the basis of field observations, Porter (1970) suggested that a thorough re-evaluation of the fourfold sequence was needed in the light of modern developments in Quaternary processes, sediments and chronology. Later, Joshi *et al.* (1974) found evidence of only one glaciation during the Middle Pleistocene in this area. Since the 1980s, the magnetic polarity stratigraphy of the Siwalik and Karewa morasses and tephrochronology of the interbedded bentonites has facilitated an impressive delineation of the structural evolution of these basins. This has led to a new understanding of the structural evolution of the Himalayan fore-land basins, their tectonic structure, the nature of fluvial terraces and the evolution of cenozoic climate and environment (Burbank *et al.* 1986; Johnson *et al.* 1986; Singhvi *et al.* 1987; Agrawal *et al.* 1989; Bronger and Heinkele 1995). The role of Himalayan tectonics in the evolution of Siwalik and Karewa molasses and the effects of the rise of the Tibetan plateau to its present height and its impact in the establishment of a monsoon climate over the subcontinent, added new dimensions to Quaternary palaeoclimatic and environmental research in the diverse physiographic regions of India. Geological evidence from Tibet shows that the ultimate collision of the Indian plate with the Eurasian took place in the Miocene, and subsequent episodic uplift of the plateau resulted in the gradual development of monsoon climate over the Asian landmass. The uplift of Tibet created a barrier between the airmass of north and south Asia and divided them into two flows. Tibet became a quasi-permanent high pressure zone with a permanent ice cover changing the Earth's albedo. This resulted in strengthening the high pressure cell in Siberia and low pressure over central India and the Thar Desert. The Himalayas have been regulating the movement of both the jetstream and the monsoon. The seasonality of the monsoon is controlled by the annual heating and cooling of the continental area: the plateau anchors a summer heat low over northern India and causes a strong inflow of the SW monsoon. Chinese Quaternary research in Tibet also attests to the initiation of monsoon conditions, at least in the Late Neogene (Sheng and Ding 1993; Xu 1993).

That the subcontinent basically enjoyed a monsoon climate during the Pleistocene and even earlier has been amply demonstrated by the work of

Retallack (1995) on the Siwalik palaeosols. While the Siwalik monsoon records go back to the Miocene period, the palaeomonsoon reconstructions outside the sub-Himalayan region in the Indo-Ganga plains and on the Deccan plateau are likely to be Late Quaternary. That fluctuations in the intensity of monsoon affected the ecology and habitats is also reflected by the archaeological record. During the last interglacial, relatively wetter conditions prevailed in the Thar (Rajasthan) as well as Surashtra peninsula (Gujarat), supporting Middle Palaeolithic populations. That the Indian summer monsoon causes large-scale seasonal changes in the environments of both eastern Africa and the Arabia Sea is shown by Prell and Van Campo (1986). From the Arabian Sea cores they selected pollen records for a monsoon pollen index (MPI) and foraminiferal records for a monsoonal upwelling index (MUI), in order to identify the frequencies of their variability and coherence and the phase of the terrestrial and marine responses to monsoonal circulation during the last 140 kyr. Higher values of the MUI coincided with increased precipitation, vegetation and pollen production on land, and vice versa. Two distinctive modes of monsoon variability have been interpreted, first, an interglacial mode with a strong monsoon, and second, a glacial mode with a weaker monsoon. Both MPI and MUI are 'coherent and in phase at periodicities near the precession of the Earth's rotational axis (23 kyr)' (Prell and Van Campo 1986: 526).

REGIONAL INVESTIGATIONS

Since the publication of a general survey of Quaternary deposits by Biswas *et al.* (1971), much new multidisciplinary research has been carried out in India, marking the coming of age of international collaboration, and resulting in major new findings and areas of research on early hominids and the Pleistocene environment.

The fall of the Potwar glacial-interglacial model

The British Archaeological Mission to Pakistan in the 1980s has shown that none of de Terra and Paterson's (1939) findings can be sustained (Rendell *et al.* 1989; Dennell and Rendell 1991). The oldest stone tools belonging to the pre-Soan industry of the Boulder Conglomerate horizon are now found to be natural in origin. The Early Soan industry associated with terraces Tl and T2 has been questioned on the basis of a cultural taxonomy. The Late Soan industry is now said to be a combination of Levallois-Mousterian and pebble tools (Dennell and Rendell 1991). The palaeomagnetic stratigraphy has helped in dating some new Palaeolithic discoveries in the time range of 500 to 400 kyr ago. These sites are associated with the Lei Conglomerate, which is much younger than the Boulder Conglomerate of the Upper Siwaliks.

Rendell *et al.* (1989) have now advanced a revised stratigraphy of the Pleistocene sequence (Table 10.9). There is no evidence of terraces in the Soan

Valley (cf. Table 10.2) nor evidence for glacigenic deposits. The Middle Pleistocene periglacial environment may be altered by loess deposition. Rendell *et al.* (1989) also argue that there is no evidence for the existence of independent Acheulian and Soanian technological traditions in the Potwar region. The majority of prehistoric sites are located on the surface of the Lei and Siwalik conglomerates, which are covered by loess. A couple of Acheulian sites are clearly datable to between 700 and 400 kyr (Rendell and Dennell 1985). In the light of this work, the Quaternary sequence on the Indian side of the Punjab needs to be reinvestigated, as the works of Lal (1956), Mohapatra (1976) and Karir (1985) are in conformity with de Terra and Paterson's stratigraphy. Joshi (1970), on the other hand, did not find evidence for glaciation in the Kangra Valley of Himachal Pradesh. Similarly, in the Madras region, the suggested terrace sequence is difficult to establish.

Table 10.9 Chronology of Siwalik and post-Siwalik formations and associated cultural stages.

Depositional unit (thickness in the Soan Valley in parentheses)	*Age (myr)*	*Cultural Stages*
Erosion/deposition		
Loess (0–8m)		
Disconformity/warping		Middle Palaeolithic
Lei conglomerate complex (valley fill) includes deposition of loess/ uplift partly contemporaneous		Lower Palaeolithic
uplift/ folding/start of erosion	0.7–0.5	
SIWALIK GROUP		
Upper Siwalik Conglomerate (900 m)	1.9	
Pinjor beds (1,070 m) Soan Formation		Pebble artefacts
Tatrot beds	2.5	(Sharma 1977; Rendell and Dennell 1985; Verma 1991)
Disconformity	3.0	
Dhok Patan (400 m)	8.6	
Nagri stage (665 m), Dhok Pathan Formation		
Chinji stage (1,525 m)	10.2	

Proxy records of the monsoon

CENTRAL NARMADA BASIN AND UPLAND DECCAN

In the Indo-Ganga plains, the Narmada Basin, the Thar Desert, and in the peninsular river basins, fluctuation in monsoon intensity during glacial-interglacial cycles is recorded by rubbles, calcic palaeosols, calcarinites, silica dune formations, interdunal marls, fanglomerates, loess-like silts, fluvial gravels and silts. Some amount of success has been achieved in dating some of these deposits by radiocarbon, thermoluminescence, fluorine-phosphate ratios and uranium-thorium dates, especially for the western Indian and north Karnataka sites. While the radiocarbon dates are useful in the time range of 40–30 kyr, the thermoluminescence dates now cover the last 200 kyr, i.e. the later part of the Middle Pleistocene. Radiocarbon dates for the fluvial sequences in the southern peninsular region are not as yet available. This region is replete with Acheulian sites, and some of the open-air sites in the Hunsgi Valley have yielded radiometric ages (for details on dates see Petraglia, this volume). From the mid-1970s onwards, considerable reorganization of the Quaternary stratigraphy and Pleistocene chronology of the Narmada in central India, and upland river valleys in western Deccan, has been carried out. Tables 10.10 and 10.11 provide a synopsis of the work on the Middle and Late Quaternary stratigraphy that has been carried out in these regions. These are the two regions where a marker tephra bed has been well documented and subject to radiometric dating.

Since 1990, field and laboratory studies were carried out on the sediments from the upland river basins. On the basis of geomorphological and chrono-stratigraphic data, a detailed lithological, cultural and climatological sequence

Table 10.10 Pleistocene stratigraphy and cultural succession in the central Narmada region.

Period	*Lithostratigraphy*	*Stages*
Holocene to Terminal	Jhalon Formation. Fine member (30 m)/ Netankheri Formation	Upper Palaeolithic
	Depositional Terrace Tl (upper), mainly silt, fine sand, incipient calcification, mammal fossils low and fragmentary	
	Dissection and lateral accretion	
Late Pleistocene	Jhalon Formation, Coarse Member (10–15 m)/Nimsarya Formation Depositional Terrace Tl (lower), mainly coarse sand with silt, clay, carbonaceous clay with shells	Middle and Upper Palaeolithic
	Tephra: 75 kyr old (Acharyya and Basu 1993)	
	calcretes, lime cement present abundant mammal fossils	
	Dissection and alluviation	

Period	*Lithostratigraphy*	*Stages*
Middle Pleistocene	Devakachar Formation (30 m)/ Dhansi Formation	Late Acheulian
	Depositional Terrace T2 fining upward alluvial sequence top 10–15 m oxidized, calcretes common mammal fossils abundant archaic *Homo sapiens* fossil (Sonakia 1985)	
	Dissection, erosion level T3	
	Narsinghpur Formation (10 m)/ Tuguria Formation	Early Acheulian
	Depositional Terrace T4 oxidized silt, clay, sand, gravel, iron stone band	
	Shobhapur Formation (150 m), blue, yellow, brown clay with minor silt and sand	
	Bedrock	

Source: based on Acharyya and Basu (1993)

Table 10.11 Quaternary stratigraphy in the upland rivers, Maharashtra (from base upwards).

Kajale et al. 1976	*Corvinus 1981*	*Kale and Rajaguru 1987*	*Korisettar et al. 1989*
Upper Bhima Formation	*Lower Pravara Beds*	*Upper Bhima Formation*	
Colluvial gravel Acheulian	Chirki rubble	Rubble with few artefacts, brown silt, tephra	
Bouldery pebbly gravel	Cobble boulder gravel	Bouldery pebbly gravel	Sandy-pebbly gravel
Sandy pebbly gravel	Cobble boulder gravel	Sandy-pebbly gravel	Acheulian gravel: fossils
Acheulian		Acheulian	
Tephra not recorded	Tephra not recorded	Tephra not recorded	Tephra recorded (Korisettar *et al.* 1989a, 1989b) Tephra dated to 75 kyr (Shane *et al.* 1995) and to 600 kyr (Mishra *et al.* 1995)
Fine sands and silts	Compact yellow silts Unconformity	Yellow brown, reddish brown silts	Fissured clay

Kajale et al. 1976	*Corvinus 1981*	*Kale and Rajaguru 1987*	*Korisettar et al. 1989*
	Upper Pravara Beds Yellow silts, calcium carbonate in the form of root casts, microliths tools present 'Salt pepper' gravel, microliths		
Vertisol	not recorded	Black soil	Black soil
Post Black Soil Formation	*Late Holocene Beds*	*Post Black Soil Formation*	
Brownish less calcareous Early Historic	Dark grey sandy silts	Non-calcareous dark laminated silt inset into UBF older, inset terrace gravels brown silts with gravelly lenses	
Chalcolithic Early Historic	Brown clayey sandy silts		

has been worked out, and an attempt has been made to correlate this with the deep sea Oxygen Isotope Stages (Rajaguru and Mishra, in press). This has substantially increased our understanding of the Quaternary history of the region since the early work of Sankalia (1956). Two broad groups of sediments are now recognized, first, colluvial sediments, and second, alluvial sediments, in order of succession. This sequence has been worked out as a response to the changing intensity of the monsoon since the Middle Pleistocene (Table 10.12). Thus the fluvial sequences representing aggradation and erosion geomorphic environments are attributed to a fluctuating SW monsoon. As elsewhere, the Acheulian is associated with the oldest deposits, dating from the Middle Pleistocene. Though Todd's Kandivli section could not be rediscovered, fluvial stratigraphy from other sectors of the west coast, particularly from Konkan and Goa, are comparable to that of upland rivers. Guzder (1980) documented two sets of cut-and-fill terraces in the Konkan River valleys. The older and higher one is generally about 10 m above the present bed level; the younger inset terrace is about 3 m high. The sediments associated with these terraces are one or more gravel conglomerates with highly acidic brownish silts; the upper part of the alluvium is generally silty. The occurrence of gravelly lenses in the upper part of the sequence and general intercalated nature of the gravels and silts is suggestive of a braided stream network with low sinuosity.

THE THAR DESERT AND LITTORAL AND MAINLAND GUJARAT

In the Thar Desert of Rajasthan, records of integrated high-energy fluvial systems dating back to the Late Tertiary and Early Pleistocene have been documented. Other fluvial and aeolian sediments of Late Middle Pleistocene age that appear to overlap with each other have provided abundant evidence of stone age occupation of the area.

In the region south of the Aravallis, Mewar, along the tributaries of the Chambal, Acheulian artefacts have been recorded from the bouldery deposits. Not much work has gone into the Quaternary stratigraphy since Misra (1967). His climatic sequence for the Berach Basin was necessarily based on the standard schemes provided by previous workers. He was, however, conscious of the need for detailed palaeogeographic research to be able to arrive at a systematic correlation of the Quaternary deposits.

Allchin *et al.* (1978) established a comprehensive account of their decade-long interdisciplinary research in the Thar, centring their research on Quaternary palaeogeography, environments and prehistory. The region covered by their project included north Gujarat, Kathiawar, and the Pushkar Basin in Rajasthan (Allchin and Goudie 1974). The investigators observed a sparsity of Palaeolithic sites along the eastern margin of the Thar. The arte-fact scatters were associated with hill wash scree buried under later aeolian sands, which were generally situated in the vicinity of lakes and streams. Table 10.13 shows the stratigraphic scheme covering the Later Pleistocene and Holocene.

Table 10.12 Proxy records of the monsoon in the upland rivers, western Deccan.

Period	*Lithofacies*	*Geomorphic environment*	*Radiometric dates*	*Cultural sequence*	*Monsoon intensity*
Middle Pleistocene	Colluvial gravels	Aggradation active in the piedmont zone	U series >350 kyr	Early Acheulian	Fluctuation between weak and strong discharge
	Alluvial sandy pebbly gravel	As above		Acheulian	As above
	Soil formation or silty alluvium	Erosion	Oxygen Isotope Stage 3 40–25 kyr		Relatively strong monsoon
LGM	Gravels at Kalas, Chandoli and Nevasa	Aggradation and accumulation of colluvium	C-14 date 18–11 kyr	Microliths	Weak monsoon

Period	*Lithofacies*	*Geomorphic environment*	*Radiometric dates*	*Cultural sequence*	*Monsoon intensity*
Terminal Pleistocene	Gravel at Nevasa, Inamgaon, Gargoan and Alsa	Aggradation dominant	C-14 date 13–10 kyr Younger Dryas	Microliths	Weak monsoon, episodic floods
Mid-Holocene	Soil Formation on pleistocene silts	Erosion	6–4 kyr	Microliths	Good monsoon
Late Holocene	Sandy silt deposition inset fill terrace gully erosion	Minor aggradation within the Holocene onwards	3 kyr	Chalcolithic	Weak monsoon

Table 10.13 Climatic and cultural succession along the eastern margin of the Thar Desert.

Lithology	*Stage*	*Climate*
Slope wash scree	Lower Palaeolithic	Semi-arid
Sand sheet	—	Arid
Buried soil (deep rotlehm type soil)	Middle and Upper Palaeolithic	Moist
Sand sheet	—	Arid
Calcification and rootcast development	—	Arid
Modern land surface (reactivated sand surface)	Microliths	Semi-arid

Subsequent work by Misra and Rajaguru (1987) in the Nagaur district of Rajasthan demonstrated that environmental conditions were suitable during Palaeolithic occupation and that aridity set in during the Late Pleistocene, leading to the expansion of the desert. This is one of the few areas where multiple dating techniques have been applied (Table 10.14). Multidisciplinary studies on the playas and dune sediments around Didwana have helped in reconstructing the evolutionary history of the Thar Desert along its eastern margins. The antiquity of dune forming processes in this region reaches as far back as 100 kyr ago, and the major dune field of the Thar seems to have formed between 15 and 12 kyr ago, not during the Last Glacial Maximum, but during the transitional phase of Terminal and Early Holocene (Dhir *et al.* 1994). Mapping of Quaternaries in the Kantli-Ghaggar and Luni Basins, the Sambar Lake and Jaipur area has been carried out. An informal sequence of formations has been documented from this region. A succession of five distinctive formations has been identified, including Bikaner, Churu, Sambar, Jaipur and Luni. The sequence overlies either a laterite or calcrete pediment surface (Sundaram *et al.* 1996). Unfortunately, this work did not attempt a correlation with the Quaternary sequence of the Nagaur district of Rajasthan (Misra and Rajaguru 1987) before proposing a new nomenclature.

Gujarat is an area where Quaternary deposits have been documented from marine, fluvial and aeolian environments (Chamyal and Merh 1995). The marine sequences are confined to the littoral zones of Kachchh, Saurashtra and mainland Gujarat. The fluvial and aeolian sequences are best exposed in the valleys of Sabarmati, Mahi and Narmada. The lithological sequences date back to the Middle Pleistocene. Miliolites are the conspicuous littoral and aeolian formations and represent transgressive-regressive phases of the sea during the Middle to Late Pleistocene. Beach rocks, raised mud flats, raised beaches and inland ridges represent a Holocene transgressive sea. The *ranns* of Kachchh also represent a Holocene fluvio-transitional environment.

Table 10.14 Quaternary stratigraphy and cultural succession in the Thar Desert.

Formation	*Lithofacies*	*Stage*	*Age*	*Environment*
	Colluvial gravels in the piedmont of the Aravallis	Early Acheulian	Age of the sediment probably Late Middle Pleistocene	Arid
Jayal	Boulder Conglomerate well cemented	Early Acheulian on the surface of the Jayal Formation	Sediment age: Late Tertiary	High-energy streams, integrated drainage, humid
Amarpura	Tectonic uplift unconformity Marly sediments (40 m)	Early Acheulian, Late Middle Palaeolithic, Upper Palaeolithic	Middle Pleistocene	Low-energy fluvial systems, relatively dry
Didwana	Dune sands (20m) palaeosols calc bands	Upper and Middle Palaeolithic	A span of 400 to 6 kyr BP Middle Palaeolithic TL date from 163–21 kyr	Streams extinct, dry

Lele (1972) and Marathe (1981) have established the relationship of sea level changes with the stone age occupation in Saurashtra, determining that the chronology of the Lower Palaeolithic is interlinked with the miliolite formation. During the mid-Quaternary the rivers were flowing 10–15 m below their present bed levels, and Lower Palaeolithic occupations took place at this time, as recorded by Acheulian artefacts in the gravel conglomerates of buried channels. The fluvial gravel containing Acheulian artefacts was buried under the sediments of a major transgressive phase of the sea, represented by miliolite M-I, occurring at an elevation of 40–60 m above mean sea level. This phase was followed by a rejuvenation of streams (3–5 m below the present bed of the rivers) at the time of a low sea level. The gravels overlying M-I have yielded Middle Palaeolithic tools. These gravels are in turn overlain by miliolite M-II, representing yet another phase of transgressive sea. Uranium-thorium dating of the miliolites suggests that the Lower Palaeolithic occupation took place around 190 kyr ago, and the Middle Palaeolithic around 56 kyr ago (Baskaran *et al.* 1986). Later, Baskaran *et al.* (1989) dated three episodes of miliolite formations, M-I (70–56 kyr), M-II (115–75 kyr) and M-III (210–140 kyr). Interruptions in the deposition of miliolite, and sedimentary and diagenetic features in it, are interpreted as a consequence of palaeoclimate changes. In a summary of research on miliolites in Gujarat, Patel and Bhat (1996) have identified several palaeoclimatic signatures preserved in them.

Following earlier investigations (Foote 1898; Zeuner 1950; Subbarao 1952), Pant and Chamyal (1990) carried out detailed mapping of the fluvial sequence in the Mahi Valley. The composite lithostratigraphy reveals a succession of units with intervening conglomerate beds. Unit I comprises fine clay (with lateral extent of nearly 30 km) with marly bands and carbonate pipes, overlain by Gravel I containing Lower Palaeolithic artefacts. Unit II is a fractured mud overlain by Gravel II. Unit III is a fine laminated mud. A carbonate crust separates Unit III and IV (fractured mud). Yet another carbonate layer separates Unit IV and V (aeolian silt), which is overlain by Gravel III followed by aeolian silt (Unit VI) and dunal sands (Unit VII) towards the top. Within the section, a succession of buried layers or palaeosols has also been logged. Gravel I yielding Acheulian artefacts has been correlated with the Hiran Valley Acheulian gravel (dated to around 190 kyr). The Mahi Valley red palaeosol (Unit V) is equated to Oxygen Isotope Stage 5e, and is being considered a marker bed because of its ubiquitous presence in the alluvial sequences of southern Gujarat. A detailed pedogenetic analysis of various lithounits in the Mahi Valley by Khadkikar *et al.* (1996) has resulted in the identification of a series of palaeosols reflecting cyclic changes in climate between arid and humid phases, but with varying intensity, during the last 300 kyr. The lower age limit of the basal clay is extrapolated from the Sabarmati Valley (Sareen *et al.* 1992). Recently, Chamyal and Merh (1995) have made a comprehensive account of the Quaternary sequences in this region. For this purpose, however, we present here an update on the Sabarmati sequence carried out by Sareen and Tandon (1995) as representative of the Quaternary history of the region. This work is a continuation of Zeuner's work after a gap of nearly forty years (Table 10.15). In other river sections, two or more generations of gravel conglomerates are noticed. There is a general correlation between the alluvial sequences of the Mahi, Sabarmati and Narmada rivers. The oldest fluvial deposit is a gravel conglomerate that has yielded Lower Palaeolithic tools and is assigned to the Middle Pleistocene (Chamyal and Merh 1995).

Table 10.15 Quaternary stratigraphy of the Sabarmati Basin, Gujarat.

Formation	*Member*	*Thickness (m)*	*Climate*
Sabarmati	Aeolian sand	07	Semi-arid
	Fluvial sand	04	
Akhaj	Fine sand	15	Semi-arid (dry phase)
Mahesana	Upper sand	12	Fluvial, floodplain
	Lower sand	10	Semi-arid (also pedogenic phase)
Waghpur	Sand	20	Fluvial semi-arid
	Conglomerate	05	Semi-arid fan

Table 10.16 Quaternary alluvial formation in the Son Valley, Madhya Pradesh.

Formation	*Lithounits*	*Stage*	*Age*
Khetaunhi	Fine sands silts and clays	Neolithic	
Baghor	Silts and clays coarse sands calcreted gravels	Mesolithic Upper Palaeolithic Some Middle Palaeolithic	Holocene Upper Pleistocene
Patpara	Granule sands gravelly clays red-brown clayey gravels	Transitional Lower to Middle Palaeolithic Upper Pleistocene to	Late Mid- Pleistocene
Sihawal	Fine sandy clay colluvial-alluvial gravels fanglomerates	Lower Palaeolithic	Middle Pleistocene TL date 103 kyr (Clark and Williams 1986)

NORTH CENTRAL INDIA

In north central India along the Son and Belan rivers, three widespread alluvial formations have been documented. They range in age from the Middle Pleistocene to the Holocene. As in the Sabarmati Valley, the three oldest formations are capped by aeolian deposits. There is abundant evidence of stone age assemblages contained in these formations. On the basis of a summary of Quaternary investigation by Williams and Clarke (1995), Tables 10.16 and 10.17 present the Pleistocene sequences in the Son and Belan valleys. In the Belan Valley, a similar sequence of sediments has been documented, but formal designations have not been assigned.

Table 10.17 Quaternary alluvial stratigraphy in the Belan Valley. Uttar Pradesh.

Lithofacies	*Stage*	*Age*
Tabular conglomerate	Lower Palaeolithic	Probably Middle Pleistocene
Calcareous brown clay loam	—	(?) Mid-Pleistocene
Cross-bedded gravels	Middle Palaeolithic	Late Middle to Early Upper Pleistocene
Sandy clays	—	(?) Upper Pleistocene
Shell-bearing gravels	Upper Palaeolithic (*c.* 25 to 19 kyr)	Upper Pleistocene
Calcareous clay loams and sandy gravels, sandy loams	Upper to Epipalaeo-lithic (25 to 10 kyr) and Mesolithic	Upper Pleistocene
Clays, loams and alluvial sands	Mesolithic Neolithic	—

KARNATAKA PLATEAU

Since the work of Joshi (1955), the Quaternary sections in the Malaprabha Valley in the Kaladgi Basin have not been intensively studied. While Pappu and Deo (1994) carried out a morphometric analysis of the landforms of the Ghataprabha Valley in the northern parts of the Kaladgi Basin, their Quaternary stratigraphy corresponded with the upland rivers of the Deccan. Recent field investigations in the Kaladgi Basin have revealed that the Lower Palaeolithic yielding gravel bodies along the middle course of the Malaprabha and Ghataprabha are a series of coalescent alluvial fans, and that the stratigraphic sequence based on the traditional framework is not applicable (Korisettar and Petraglia 1993; Korisettar *et al.* 1993, n.d.). It is observed that an extensive calcrete surface developed over the older laterite surface, followed by the Late Quaternary alluvial sequence. The artefact-bearing conglomerates exposed in the bed of the Malaprabha (Kaladgi Basin, north Karnataka) can be traced away from the channels up into the piedmont region away from the river. These represent former alluvial fan systems originating from the Kaladgi ridges, upon which the Late Quaternary alluvial deposits are superimposed, in part burying the cultural material. The material is preserved across palaeoland-scapes, with Acheulian occupation post-dating fan deposition. The Acheulian sites do not correspond to the present drainage network, as supported by artefact size, material distributions, and the low level of rounded edges on artefacts. This seems to be the case with the majority of Acheulian sites in peninsular India. Artefact scatters away from the reach of pediment alluviation remained exposed on the surface and suffered *in situ* weathering, whereas those artefacts buried under alluvium are unweathered but show wearing on the surface exposed to aerial processes. It is observed that both Lower and Middle Palaeolithic artefact distributions on the pediment surfaces are associated with ponds and lacustral clays and fine-grained silts that were deposited by the now extinct water courses. It is also noted that hominid activity loci were not related to channel networks as seen at present (see also Korisettar 1995). With this working hypothesis, a detailed survey of the Quaternary deposits in a palaeogeographic perspective is being undertaken to be able to reconstruct hominid adaptations as well as the natural and cultural site formation processes operating in the past.

OVERVIEW

As the above account demonstrates, confusion was created by assigning the alluvial sedimentary facies to different climatic phases; in addition, there were discrepancies in the climatic interpretations of alluvial deposits. By the 1950s, there was a greater level of clarity in terms of describing lithofacies and stratigraphic profiles. However, geochronology and interbasinal correlation remained ill-founded, circumscribed by uncertainty and controversy. Until now, the only way of establishing age estimates for Palaeolithic assemblages was through use of weathering indices of rocks and gravels from which Palaeolithic tools were manufactured and by fluorine/phosphate ratios of associated fossil material (Mishra *et al.* 1988; Kshirsagar 1993). Fortunately, a tephra marker bed was recently documented from alluvial sections in central and peninsular India (Korisettar *et al.* 1989a; Acharyya and Basu 1993). Efforts at radiometric dating of the tephra and its relevance in the chronology of the Lower Palaeolithic have, unfortunately, been problematic. This tephra was initially dated to about 1.4 myr ago (Korisettar *et al.* 1989a, 1989b), but subsequent Ar-Ar dating and grain specific geochemical fingerprinting based on electron micro probe data have resulted in divergent dates (Acharyya and Basu 1993; Mishra *et al.* 1995; Shane *et al.* 1995), rendering it difficult to arrive at a definite age for the Acheulian (see also Korisettar 1994). A renewed start at reconstructing composite lithostratigraphic columns for all the tephra associated with Lower Palaeolithic sites is of immediate necessity. However, it should be considered a significant step forward in the direction of obtaining a radiometric chronology for both Quaternary sedimentary deposits and stone age successions in India.

The Pleistocene chronology, without exception, is based on sedimentary piles rarely exceeding 50 m. Delineation of inter-relationship between depositional and erosional events was greatly hindered by cut-and-fill activity. This is further compounded by the distinctive lack of well-defined datum beds, either biotic or abiotic. Until the middle of the 1960s, radiocarbon dates were not available. Despite three decades of intensive research in the region outside the sub-Himalayan region, the Quaternary records tend to be weak for the Early and Middle Pleistocene. There are some breakthroughs in over-coming this barrier by thermoluminescence dating of dune sands from Rajasthan, where the archaeological material is preserved in aeolian context. In Kashmir, thermoluminescence dating of loess has extended deposition to the Middle

Pleistocene, but unfortunately these sediments are sterile of Palaeolithic evidence. Uranium-thorium dates for the Acheulian artefact-bearing calcrete with cemented conglomerates from Nevasa (Pravara Basin), Yedurwadi (Krishna Basin) and Bori (Bhima Basin) are suggestive of Early Middle Pleistocene (200 kyr ago) (Rajaguru *et al.* 1993). Uranium-thorium dates and fluorine-phosphate ratios for calcretes and fossils respectively have now been available from the gravels containing Middle Palaeolithic tools, which have dated to the early part of the last glacial. There is now a thermo-luminescence date for Middle Palaeolithic in the context of a sand dune in Rajasthan, dating to >100 kyr (A.K.Singhvi, pers. comm. 1996). This also supports the stratigraphic dating and the suggested Middle Pleistocene age of the Acheulian (Rajaguru 1985).

Uranium series dating of a few Lower Palaeolithic sites associated with the travertine in central Deccan (Karnataka), miliolite in Saurashtra (Gujurat), calcrete in the Thar Desert (Rajasthan) and calcrete cement of the alluvial conglomerates has provided some encouraging results. At Kaldevanhalli in the Hunsgi Valley (Karnataka), the Acheulian assemblages form the upper part (15–25 cm) of a travertine. This suggests that the travertine formation post-dates the Acheulian occupation of the area and that the travertine formed around an extinct spring. In other words, the Acheulian occupation took place while the spring was active. The geochemical age of 150 kyr appears to be the minimum age estimate of the Acheulian at this locality. Fossils of *Bos, Elephas* and *Equus* occurring in association with Acheulian assemblages elsewhere in the Hunsgi Valley have uranium-thorium dates in the range of 300 kyr (Szabo *et al.* 1990).

Other chemical dating methods providing relative age estimates have also been applied, and these support the uranium series and radiocarbon dates. However, there is sometimes a problem of internal consistency in the age of fossils coming from various deposits. The determination of flourine-phosphate ratios and percentage of uranium present in bones coming from the same horizon should help to resolve temporal relationships. Thus chemical dating by determining fluorine-phosphate ratios on bone samples from a variety of Quaternary and prehistoric sites has compensated for the dearth of radio-metric dates. In many instances, the ratio has provided a relative age estimate for geological and archaeological events. Kshirsagar's (1993) comprehensive list of fluorine-phosphate ratios for a wide range of prehistoric and Quaternary sites from diverse physiographic environments betrays the lack of internal consistency between and among them. On the other hand, although the fossils could be grouped together in terms of fluorine-phosphate ratios as Middle and Upper Pleistocene, on the other they are not constrained by finite radiometric dates. The bone samples from Acheulian contexts show a range of fluorine-phosphate ratios, between 6.738 and 8.39, and 8.11 and 8.28, the latter very close to the saturation value. In some cases, these values support the uranium series dates. The ratios close to the saturation value do not provide a finite lower age limit. This inevitably leads to the problem of temporal relationships between fossils and the gravel conglomerates. Fossils of *Elephas, Bos* and *Equus* that belong to a single gravel conglomerate deposit probably betray variation in their fluorine-phosphate ratios and indicate discrete time intervals in their incorporation into the gravel bodies that contain them. In some cases, there are incongruities between fluorine-phosphate ratios and uranium-thorium dates on fossil bones. The bone sample from the Krishna River deposits at Shirguppi (Karnataka) show fluorine-phosphate ratios of 4.44 and 6.29, whereas the calcrete associated with the same Acheulian conglomerate gives a uranium-thorium date of 350 kyr (Kale *et al.* 1988). Similar dates are also available for the Acheulian gravel at Nevasa-on-Pravara in the northern Deccan (Maharashtra). Therefore, in spite of several numerical dates and fluorine-phosphate ratios for fossil bones, absolute chronometry continues to be problematic.

The recent publication of *Quaternary Environments and Geoarchaeology of India* (Wadia *et al.* 1995) reflects the current status of our understanding as well as the state of art of South Asian Quaternary research. The Indian Lower Palaeolithic still proves difficult to place in a definite time frame; however, the regional stratigraphic schemes that are presented in the foregoing help make regional correlations, despite the fact that glacial and interglacial records vary from one region to another in terms of their potential for a global Quaternary correlation. Older sediments in the peninsular river basins where much prehistoric material is preserved are largely undated. The general feeling that major parts of peninsular India form an erosional landscape wanting in depositional records is also being proved erroneous (Korisettar 1994; Petraglia, this volume). A large majority of Palaeolithic sites are associated with pools and ponded environments with potential for palaeoenvironmental and palaeogeographic reconstruction. Future research in these situations is likely to fill the gaps in our knowledge of the Quaternary. To the present, the pre-Late Quaternary history of the region remains uneven.

Although the Lower Palaeolithic evidence in the majority of cases comes from Middle Pleistocene contexts, it is not as yet possible to assign the Lower Palaeolithic occupations at these sites to a particular glacial or interglacial stage. The present evidence points to a gross correlation to savanna ecosystems. Site-specific geoarchaeological studies and geochronology are still wanting. Moreover, the Palaeolithic record is quite unevenly distributed in time and space in the subcontinent (Rendell and Dennell 1985; Acharyya and Basu 1993; Mishra *et al* 1995; Shane *et al.* 1995). A large majority of sites are surface or plough-zone situations, lacking in complementary data for a palaeoenvironmental reconstruction. Although for some time alluvial sites came to be treated as secondary and unsuitable for provenance studies, there is increasing realization that many of them indeed represent spot provenance situations with potential for behavioural studies (Paddayya and Petraglia 1993, 1995). To date, excavated Lower Palaeolithic sites are very few in India (Corvinus 1982; Kenoyer and Pal 1982; Paddayya 1982; Sharma and Clark 1983; Misra 1985; Pant and Jayaswal 1991).

Evidence for Lower Palaeolithic occupation on the west coast has remained uneven. The absence of Lower Palaeolithic artefacts in Todd's collection and a single evidence of a chopper from the Manori cemented river gravel leaves much of the material as surface occurrences. Goudeller and Korisettar (1993) have made a claim for the Acheulian occupation of the west coast, but the evidence again comes from the surface of fluvial gravels in the Dudhsagar and Mandai river valleys of Goa. A quartz chopper assemblage is also reported from Kerala, and a couple of bifaces have been found in coastal Karnataka (Rajendran 1979, 1990). Guzder (1980) treats the Lower Palaeolithic assemblages from Borande on the Vaitarna, and from Malvan, together with the collections made by others (Todd 1939; Malik 1963; Joshi and Bopardikar 1972), as representing a 'regional cultural group', but it is difficult as yet to establish detailed stratigraphy on individual sites, as the majority are surface occurrences. During the last three decades, Lower Palaeolithic occurrences in the basal conglomerates have been reported from different sectors of the east coast (see Thimma Reddy 1994 for a summary), though significant data pertaining to Quaternary stratigraphy and climate is not forthcoming. The region south of the Kaveri into Sri Lanka continues to draw a blank in regard to Lower Palaeolithic occupation. Until recently, the central Himalayan region was not known to yield evidence for Lower Palaeolithic occupation. In the sub-Himalayan region, however, the Upper Siwalik strata are now known to yield Lower Palaeolithic evidence (Mohapatra 1976; Verma 1991). Sharma (1995) mentions the discovery of Early Palaeolithic tools from below a tuffaceous bed dated to 2.5 myr ago in the Upper Siwalik beds. Details regarding typology and technology are not available as yet. Although such an early date is doubted, it certainly deserves serious attention of both geologists and prehistorians to establish the context and nature of the industry (Sharma 1995). Prospects for finding Early Palaeolithic tools in the Ladakh region appear to be bright. As far back as 1934, a solitary palaeolith was reported from this area. In view of the paucity of the evidence, its provenance was doubted. In recent years, more evidence of indubitable local provenance is known from this area (Ota 1992). These artefacts were made from locally occurring fine-grained volcanics and cherty tuffs. One site is located in the Indus Valley at Alchi Village and another is a rock-shelter at Hunder Dok in the Shyok Valley. These two finds are, however, surface occurrences (Sharma 1995). The Kashmir Valley draws a blank in terms of Lower Palaeolithic occupation, and the situation is no better than in 1947 (Krishnaswami 1947). Joshi *et al.* (1974) found evidence of only one glaciation at a lower altitude of 2,100 m around Pahalgam, and although some Palaeolithic artefacts were collected, later surveys have not produced additional evidence anywhere in Kashmir. This is one of the best investigated regions in India, both for geological and climatic history of the Cenozoic period (Agrawal *et al.* 1989). In eastern India, Early Quaternary deposits are represented by ferruginous conglomerates with occasional Palaeolithic material.

On the basis of our current knowledge of Pleistocene stratigraphy across the subcontinent, one notices an apparent similarity of geomorphic processes operating under the influence of a fluctuating monsoon. The regional environments fluctuated in accordance with these changes between savanna and woodland ecosystems, affecting hominid occupation of the areas. The lithological successions suggest that, during the Middle Pleistocene, bedrock erosion and pedimentation were the dominant processes leading to the formation of debris flow, rubble and colluvial deposits, and fan gravels prior to hominid occupation. Subsequently, some of these materials were incorporated into alluvial systems, in the early stages of drainage evolution, and integrated perhaps in the Late Quaternary. Changes in depositional environments are reflected by the silts and sands overlying the older gravel bodies, and, as a result, Lower Palaeolithic evidence comes from two different contexts.

If Late Quaternary palaeoclimatic inferences are any guide, it should be possible to extrapolate the same to the rest of the Quaternary. Multidisciplinary palaeoclimate studies carried out on continental and off-shore deposits in southern India are suggestive of variation in vegetation cover of the Western Ghats between tropical evergreen and savanna ecosystems. While the evergreen forests were associated with stable humid conditions, the spread of savanna vegetation took place during arid to semi-arid transitions. During the lateritic phase, the existence of a tropical woodland ecosystem can be envisaged. The rise of the Western Ghats effectively changed the peninsular ecosystem from tropical woodland to a network of savanna ecosystems between the west coast and the plateau. The savanna ecosystem became well defined in the rocky tri-angle between the Western and Eastern Ghats. This orographic configuration resulted in a progressive decrease in the intensity of rainfall along the path of the SW monsoon, which is the basic element controlling the habitability of the area. Obviously, the structure of food resources between the coastal, upland and plateau ecosystems was very different, and the key controlling factor would have been the secular variation in the intensity of the SW monsoon across the peninsular region. A close examination of the archaeological and palaeontological evidence from the riverine deposits in southern and central India reveals an assemblage of fossil ungulates in the proximity of Lower Palaeolithic sites, and attests to the prevalence of savanna habitats and riverine gallery forests. The distribution pattern of Palaeolithic sites are indicative of the preference for savanna habitats. Precise radiometric dating of the earliest phases of the Lower Palaeolithic occupation is as yet frustrating, although the Middle Pleistocene age sequence is evident.

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11

The Lower Palaeolithic of India and its bearing on the Asian record

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INTRODUCTION

India preserves an important Lower Palaeolithic record which can convey significant information about hominid adaptation to a unique geographic and environmental region of the Old World. Despite the vast size of the Indian landmass and the range of environments, palaeoanthropologists have not gained an appreciation for the significance of the existing and potential data base. Whilst archaeologists have recently outlined the importance of the Lower Palaeolithic record of Africa, the Near East and eastern Asia in relation to hominid adaptations and behaviour (Toth and Schick 1986; Schick and Dong 1993; Bar-Yosef 1994; Clark 1994; Schick 1994), the Indian record has not been placed in a similar palaeoanthropological context. Reviews describing the Indian material evidence have clearly shown that a large number and variety of Lower Palaeolithic occurrences and complexes are present in many regions (Sankalia 1974; Jacobson 1979; Paddayya 1984; Misra 1987, 1989; Sali 1990; Mishra 1994), although the sketchiness of the overall work described in these syntheses also demonstrates that much fundamental palaeoanthropo-logical research remains to be conducted.

This chapter aims to demonstrate that the material record of India can provide an opportunity to examine how hominids utilized and adapted to diverse environments and resource bases. Some of the most significant regional investigations are described first. This regional description is followed by a discussion centring on the Lower Palaeolithic chronology, stone tool typology and technology, and settlement patterning. Whilst a review of the current data base will demonstrate that significant contributions have been made by various practitioners, problems with certain approaches will be raised, indicating areas for more productive research in the future.

Unfortunately, most western scientists rarely cite the Indian Palaeolithic literature in overviews, and most introductory textbooks and encyclopedias of global human prehistory virtually ignore the abundant archaeological data base (e.g. Tattersall *et al.* 1988; Klein 1989). This information gap is a major problem if analysts wish to understand the range and complexities of hominid adaptations in a significant portion of the Old World, echoing a point made by western scientists working in eastern Asia (Schick and Dong 1993; Pope and Keates 1994). The lack of knowledge or interest about the Indian record appears to be due to limited access to publications, and *a priori* judgements about the quality of the record. Whilst some accessible reviews have been published by western presses (e.g. Misra 1987), most western scientists are not familiar with the major Indian publishers or anthropological journals, such as *Man and Environment* and the *Bulletin of the Deccan College Postgraduate and Research Institute*. More problematic is the underlying presumption that Lower Palaeolithic occurrences in India are in 'disturbed' contexts and that these sites and site complexes therefore do not provide relevant behavioural information. This notion probably stems from traditional survey methods that emphasized techno-typological reconstructions from riverine sections (see Korisettar and Rajaguru, this volume, for a history of research emphasis). However, during the last two and a half decades, important information has been gathered from surveys and excavations in a variety of depositional settings, and investigators have proven that the country preserves an abundant material record that may contribute to an understanding of global issues in palaeoanthropology.

THE INDIAN LOWER PALAEOLITHIC

Background

Much of the current intellectual framework surrounding study of the Indian Lower Palaeolithic was formulated by earlier investigations that delineated two stone tool 'cultures' or 'traditions', one dominated by unifacial core or pebble tools, termed the 'Soan', and the other consisting of shaped bifacial implements, or handaxes, later known as the 'Acheulian'. The first discovery of Palaeolithic artefacts was by the British geologist, Robert Bruce Foote (1866), who recognized that shaped bifaces were similar to finds of great antiquity in Europe. Subsequent discoveries of archaeological assemblages led to the establishment of culture-historic frameworks based on typo-technological variations (Foote 1916; Cammiade and Burkitt 1930). The biface industry was found to consist of a suite of recognizable forms, now classified as handaxes, cleavers, knives, choppers, chopping tools, polyhedrons, spheroids, discoids, scrapers, denticulates, flakes and blades. In addition to the discovery of a Palaeolithic bifacial tool industry, a Soan core tool industry was identified as a result of de Terra and Paterson's (1939) investigations in the Potwar region of West Punjab (now Pakistan). Soan tools were found to occur as unifaces and simply struck bifaces, with the cores deriving from cobbles, pebbles or nodules, and the flake byproducts were occasionally retouched into tools.

Recognition of the two stone tool industries in India was a key component of Movius' (1948) synthetic work on the geographic distribution of Early

Palaeolithic cultures. Movius recognized two broad culture areas: the handaxe or Acheulian area, from Africa and Europe eastward across South Asia to peninsular India, and the Chopper-Chopping Tool area (core and flake industries inclusive of the Soan), extending further into eastern and southeastern Asia. The Chopper-Chopping Tool industries were believed to be broadly contemporaneous with each other and with Acheulian industries to the West. The geographic segregation between the two major stone tool industries eventually became known as the 'Movius Line'. The lack of technological diffusion of the Acheulian technology to eastern Asia was suggested to be a consequence of a major geographic barrier, such as the Himalayas or the southern rainforest, producing a separation between populations and causing isolation of the eastern groups.

To this day, typo-technological and culture history studies have played a central role in Indian Palaeolithic investigations, and the majority of the research has been devoted towards understanding the meaning of the technological differences displayed by the two Lower Palaeolithic stone tool traditions. A departure from this research perspective began in the 1970s, when increasing attention was turned towards investigating Pleistocene environments and hominid settlement patterns from non-transported situations, and the application of absolute dating methods to define the record of regional occupation.

Environments

Lower Palaeolithic occurrences have been found in the Himalayan mountains and the Siwalik frontal range in the north and the Deccan Plateau in the central and southern parts of the country. The Himalayan rivers, with their discharge of water and sediment, have formed the vast Indo-Gangetic plain in the northwest—an alluvial landscape that has not yielded many Lower Palaeolithic occurrences due to aggradation. The Deccan Plateau is an ancient continental shield, consisting of mountains, plateaux and coastal plains. Landforms within each of these physiographic zones are shaped by alluvial processes. Geological evidence indicates that tectonics played a role in shaping and uplifting the Himalayan region during the Quaternary, although the peninsular Indian landmass was generally structurally stable, showing no evidence of major folding and faulting (e.g. Korisettar 1994; Mishra 1994). Tectonic episodes are observed, however, as reactivated faults and lineaments. Sporadic seismic disturbances may have led to some landscape deformations playing a role in riverine aggradation and erosion (e.g. Rajaguru 1969).

The physiographic configuration of the subcontinent controls the movement of both the southwest and the northeast monsoons (during summer and winter respectively). The physiographic zones do not necessarily coincide with natural ecosystems, the characteristics of which are strongly influenced by the monsoons. From the distribution of the rainfall patterns, a variety of ecosystems are formed, including deciduous woodlands, tropical evergreen forests, savannas, semi-arid to arid scrub lands, and deserts. Palaeoclimatic research in

India has shown that, during the Quaternary, the intensity of the monsoon fluctuated in accordance with global oscillations and the prevalence of wet and dry cycles, thereby controlling floral communities (Joshi 1970; Agrawal 1992; Bowler *et al.* 1995). The present-day Thar Desert experienced wetter conditions during the Pleistocene (Misra 1987), and forests in the mountains along the western border of the country fluctuated between woodland and savanna ecosystems, in turn affecting habitats across the Deccan Plateau. A variety of Middle and Late Pleistocene faunal remains (e.g. *Sus namadicus, Bos namadicus, Elephas hysudricus, Equus namadicus, Hexaprotodon namadicus, Hexaprotodon palaeindicus, Stegodon insignis-ganesa, Cervus* sp.) indicate both forest and open grassland habitats during the Pleistocene (Badam 1984; Misra 1989).

REGIONAL INVESTIGATIONS

The following section briefly summarizes the findings of some of the most significant and sustained Lower Palaeolithic investigations that have been conducted throughout the Indian subcontinent (Figure 11.1). This section is provided to show the level to which Lower Palaeolithic studies have been conducted. Whilst the general level of research and knowledge is reviewed, it should be recognized that the regional presentations vary owing to differences in research orientation and intensity of field effort.

Potwar Plateau

The Potwar Plateau, situated between the Indus and the Jhelum rivers, in northern Punjab, was surveyed by de Terra and Paterson (1939), resulting in the identification of simple core assemblages, termed the Soan industry. The investigators indicated that the Soan industries were in a Boulder Conglomerate and four terraces (T1–4) of the Soan River. The terrace sequence led to the establishment of a technological classification of assemblages developing from the pre-Soan to the Late Soan. In some cases, Early Soan and Acheulian tools were identified in the same deposits, implying contemporaneity to the investigators. Approximately forty years later, renewed studies were undertaken in the Potwar Plateau to reanalyse the Palaeolithic chronological sequence (Allchin 1981). The main conclusion of the modern investigations was that de Terra and Paterson's geological and archaeological sequence was untenable, and that the so-called Soan terraces were in fact not primary deposits but erosional features (Dennell and Rendell 1991). Although this research contradicted earlier findings, the renewed investigations indicated the potential of the area for containing Lower Palaeolithic assemblages. In one location, Riwat, near Rawalpindi, northeast Pakistan, the investigators claimed to find three flaked quartzite cobbles and two quartzite flakes beneath 65 m of silts and conglomerates. These deposits were dated to *c.* 2 myr by palaeomagnetism and fission-track (Rendell *et al.* 1987; Dennell *et al.* 1988a, 1988b). At a second

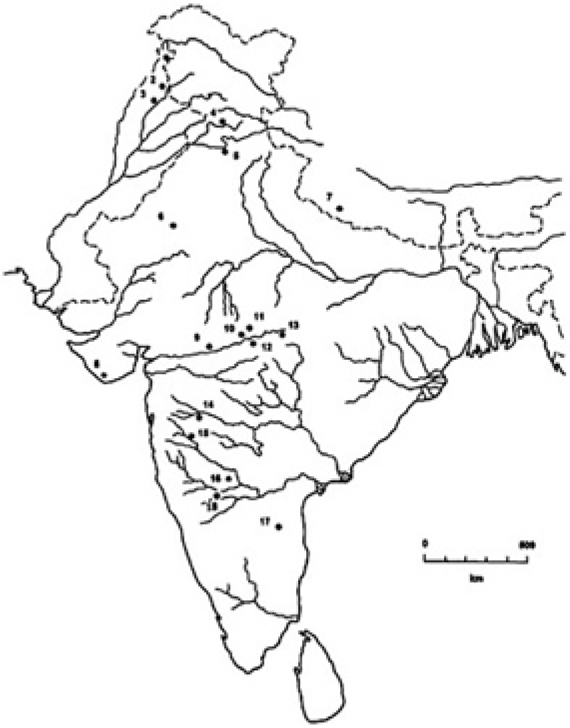

Figure 11.1 Map of India and Himalayan province showing principal lower palaeolithic localities mentioned. 1. Riwat; 2. Jalalpur; 3. Dina; 4. Beas-Banganga; 5. Sirsa; 6. Thar Desert Complex; 7. Dang Valley; 8. Umrethi; 9. Durkadi; 10. Bhimbetka; 11. Raisen Complex; 12. Adamgarh; 13. Mahadeo Piparia; 14. Chirki-Nevasa; 15. Kukdi; 16. Hunsgi-Baichbal Valley Complex; 17. Gunjana; 18. Malaprabha Valley.

location, Dina, a handaxe was found within and underlying a quartzite conglomerate, and at another location, Jalalpur, fourteen artefacts, including two handaxes, were recovered. The investigators correlated handaxe-bearing horizons with deposits dating to 700–400 kyr by palaeomagnetism (Rendell and Dennell 1985).

Sirsa and Beas-Banganga valleys

The Sirsa Valley in Haryana and the Beas-Banganga Valley in Himachal Pradesh, in the Himalayan foothill zone, have yielded assemblages attributed to the Soan and the Acheulian (e.g. Mohapatra 1974, 1976, 1989). Based on stratigraphic evidence in the two valleys, an Early to Evolved Soan sequence was surmised. Stratigraphic evidence and palaeomagnetic dates implied that the Soan industries dated to *c.* 400–200 kyr. Quartzite pebble tool assemblages in the

Beas-Banganga complex were identified as Early Soan, consisting of simply flaked unifacial choppers, bifacial chopping tools, core tools, flake tools, and other tool types (Figure 11.2). An excavation at Dehragopipur on the third terrace of the Beas River produced over 100 artefacts in a context that was thought to be intact (Mohapatra 1966). On the upper and middle terraces of the Sirsa Valley, more refined pebble tool assemblages were identified, classified as choppers, chopping tools, small side scrapers, borers, and prepared and unprepared flakes. Over twenty Acheulian occurrences were identified in valleys of the Himalayan flank, apart from Soan localities on the surfaces of the Siwalik Frontal Range (Mohapatra 1976, 1981). The Soan and Acheulian assemblages were noted to be in different topographic contexts, and thus they were viewed as contemporaneous industries exploiting different ecological niches. Technological analysis of the Soan material from surface and excavated contexts implied that processing sequences were similar to Early Acheulian tool forms (Gaillard 1995).

Thar Desert

Comprehensive archaeological and palaeoenvironmental investigations in the Thar Desert, Rajasthan, identified Lower Palaeolithic occurrences in diverse Pleistocene settings (Allchin *et al.* 1978; Misra 1987; Misra and Rajaguru 1989). Simple core assemblages were identified at various surface locations (Allchin *et al.* 1978). At Singi Talav, an Acheulian assemblage was excavated in a calcareous silty clay (Misra 1989). Sedimentary evidence indicated that the climate was semi-arid, with fluctuating cool-dry and warm-wet phases (Misra 1989). During cool-dry phases, laterally extensive and thick depositions of sand sheets and sand dunes formed, whilst during wet and humid phases, pedogenization of dune surfaces occurred. The Singi Talav assemblage was classified as handaxes, cleavers, choppers, hammerstones, polyhedrons, spheroids, cores, flake tools and flakes, made from quartz and quartzite (Gaillard *et al.* 1983, 1985, 1986) (Figure 11.3). The assemblage was attributed to the Early Acheulian, based on the predominance of core tools, the large, thick and incomplete character of the handaxes, the low level in refinement of cleavers, the high proportion of handaxes to cleavers, and the absence of the levallois technique. Horizontal distributions of the artefacts from excavated contexts indicated discrete clusters in certain places, leading the investigators to surmise that the artefacts were not significantly displaced since initial discard (Misra 1995). Another locality, the 16R dune, was trenched to the extraordinary depth of 20 m, producing a series of five major palaeosols, sixteen calcrete bands, and archaeological horizons dating from the Lower Palaeolithic to the Mesolithic (Figure 11.4). The assemblages in the lowermost basal horizons totalled only forty-five pieces, but produced items classified as cores, flakes, a side scraper and a chopper. A calcrete band just below this level was dated to an uncorrected age of 390 kyr, beyond the U/Th range (Raghavan *et al.* 1989). The investigators

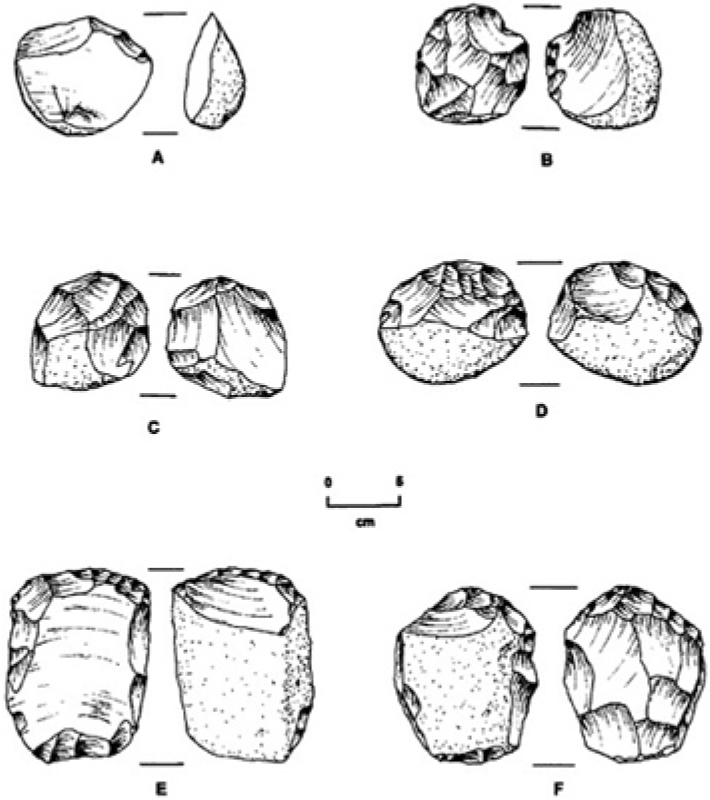

Figure 11.2 Soan pebble tools from the Beas terraces: (a, b) unifacial choppers; (c, d) bifacial chopping tools; (e) cleaver-like tool; (f) discoidal core.

Source: after Gaillard 1995

identified Acheulian assemblages on the surface of the nearby Jayal gravel beds, where raw material was available from quartzite and quartz gravels. Higher elevations of the formations yielded Lower Palaeolithic assemblages that were attributed to the Late Acheulian, based on the presence of symmetrical handaxes, levallois flakes, and scrapers.

Narmada Valley

The Narmada Valley, a major alluvial course which traverses a distance of 1,000 km east to west across the middle part of the subcontinent, has been the subject of numerous palaeontological and archaeological investigations since the nineteenth century (Sankalia 1974; Badam 1984). The stratigraphy of the alluvium in the central Narmada Valley, Madhya Pradesh, has been described as consisting of a Lower Group, a basal conglomerate and clay, and an Upper

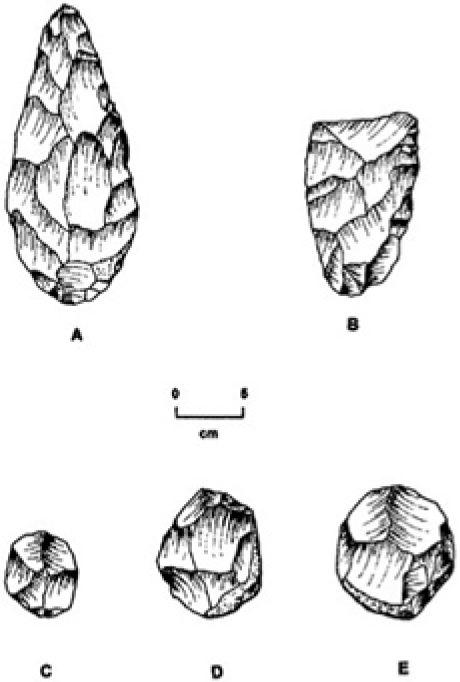

Figure 11.3 Early Acheulian from Singi Talav: (a) handaxe; (b) cleaver; (c) chopper; (d) hammerstone; (e) polyhedron.

Source: after Misra 1987

Group, of gravel and sand (Misra 1987). The Narmada Valley has produced some of the best available Pleistocene fossil evidence from peninsular India (Badam 1984). Among the mammals identified in the Lower Group were *Sus namadicus, Bos namadicus, Elephas hysudricus, Equus namadicus, Hexaprotodon namadicus, Stegodon insignis* and *Stegodon ganesa,* and in the Upper Group were *Equus namadicus, Bos namadicus, Hexaprotodon palaeindicus, Elephas hysudricus, Stegodon insignis, Stegodon ganesa* and *Cervus* sp. These species occur in both Middle and Late Pleistocene contexts. One fossil hominid calvarium was identified at Hathnora in a secondary basal gravel of the Lower Group (Sonakia 1984, 1985; H.de Lumley and Sonakia 1985; M-A.de Lumley and Sonakia 1985). The calvarium was originally classified as an advanced *Homo erectus,* although re-evaluation indicated that it may be an archaic form of *Homo sapiens* (Kennedy *et al.* 1991). The calvarium has recently been joined by the discovery of a possible hominid clavicle from the same deposit (Sankhyan 1997). Excavations at Mahadeo Piparia recovered pebble tools in the lower stratigraphic unit and Acheulian in the Upper Group, taken as support for a developmental sequence of the two industries (Khatri 1962a, 1962b). This developmental trend was challenged by later excavations which indicated

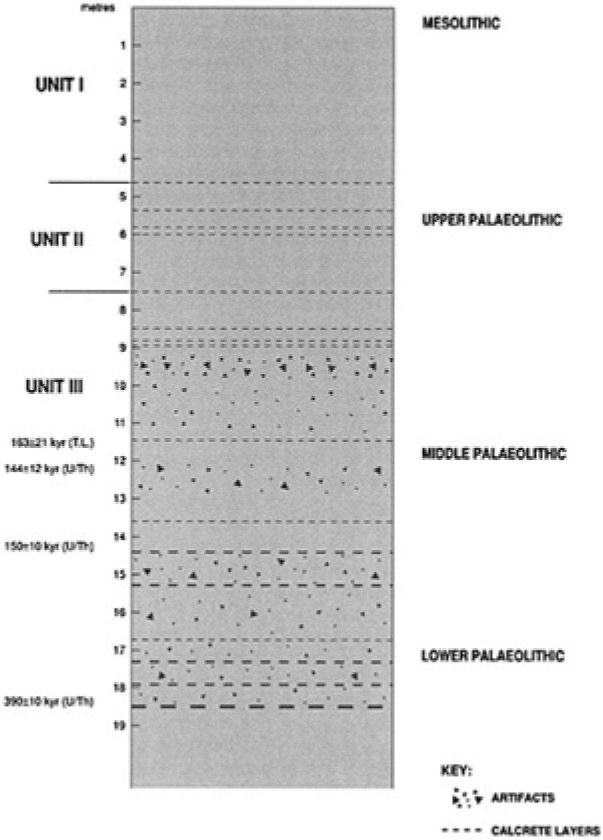

Figure 11.4 Vertical section of Didwana 16R Dune showing absolute dates and stone tool assemblage succession.

Source: after Misra 1989

that the lower unit also contained an Early Acheulian industry (Supekar 1968, 1985), thus the deposits were viewed as fluvially transported and mixed (Armand 1983). Excavations at Durkadi, considered to be a primary context, yielded a quartzite pebble tool industry with handaxes attributed to the Early Acheulian (Armand 1983). Based on these stratigraphic observations, a general Acheulian developmental sequence was posited: the Lower Group was to found contain a simply flaked bifacial industry that was argued to be characteristic of the Early Acheulian, whereas the Upper Group contained an industry that showed more refinement, and was classifiable as Late Acheulian (Misra 1987).

Adamgarh

The Adamgarh rockshelters are located on a sandstone and quartzitic hill in Madhya Pradesh. Excavation of trenches at various locations revealed stone tool assemblages up to 3 m in depth, and a stratigraphic sequence ranging from the Lower Palaeolithic to the Mesolithic (Joshi 1978). The basal layer consisted of a laterite, overlain by a sandy gravel and a red clay. Within and overlying the gravel and clay was a bifacial tool assemblage identified as Early Acheulian, based on their large size and their low level of refinement. The artefacts were classified as handaxes, cleavers, points, scrapers, choppers, cores and picks. The majority of the materials were noted to be in an unfinished state, indicative of the initial stages of tool manufacture. The artefacts were made of sandstone and quartzite blocks from the local scree deposits. Pebbles, derived from the nearby river, were believed to be used as hammerstones or were flaked to fashion unifacial or bifacial choppers— the most dominant tool types in the shelters. The pebble tools were not considered to be separable from the bifacial tools, hence these assemblages were viewed as adjuncts of a general Lower Palaeolithic industry.

Bhimbetka

The Bhimbetka sandstone hills in Madhya Pradesh contain hundreds of caves and rockshelters above perennial springs and seasonal streams in the foothill zone. Excavations have been conducted at one cave (III-F-24) and two rock-shelters (III-A-29 and 30; III-F-23). Three trenches in the cave identified a stratigraphic sequence with assemblages attributed to the Lower and Middle Palaeolithic. In one of the trenches, separable Lower Palaeolithic assemblages were noted, consisting of a basal lateritic deposit yielding pebble tools, a sterile layer, and an Acheulian level (Wakankar 1973). One rockshelter, III-F-23, produced a 4 m sequence, ranging from the Lower Palaeolithic to the Mesolithic (Misra 1985, 1987). The assemblages attributed to the Lower Palaeolithic totalled >19,000 artefacts, about 30 per cent of which were shaped tools (Figure 11.5). Most cleavers and handaxes were made on large flakes, and secondary flaking was done by the soft hammer technique. Cleavers were more than twice as numerous as handaxes. Many finely retouched flake tools were present, including side scrapers, endscrapers, notched tools, truncated flakes, denticulates and knives. Massive cores weighing more than 20 kg, as well as small, carefully prepared levallois and discoid cores, were present. The advanced technological state of the assemblages was considered to be representative of the Late Acheulian. Artefact densities varied horizontally and vertically, suggesting activity variation. The presence of manufacturing debris and shaped tools indicated that the shelter was used for both stone tool production and use. Floors paved with stone blocks and slabs in several levels suggested architectural preparation. The complete absence of large cores and a high proportion of shaped tools at open-air localities suggested that many tools in the Raisen District were made in or near the rockshelters and transported to certain spots, where they were used and discarded.

Raisen District

The Raisen complex, located in Madhya Pradesh, consists of over ninety open-air localities attributed to the Acheulian (Jacobson 1975, 1985). The assemblages are situated in an undulating upland region (175 km^2) not connected with any major water courses. The area forms part of the Malwa Plateau, a peneplained surface broken up by numerous low sandstone and quartzite hills of the Vindhyan range. The location of these assemblages at higher elevations suggests that the sites were in forests close to small seasonal rivulets or ponds, where fresh water resources would have been available during the palaeomonsoon or during the early winter seasons. The localities were situated on the surface or in near-surface contexts, and measured from 1,500 to 4,500 m^2 in horizontal extent. Seven localities at Minarawala Kund contained *c.* 50,000 artefacts, three-quarters of which consisted of shaped tools. The main tool categories were classified as bifaces, scrapers, knives and choppers. Among bifaces, cleavers were nine times more numerous than handaxes and six times more numerous than picks. Large cores were absent, suggesting that the flake tools were manufactured at the source of the raw material. Levallois and discoid core techniques were represented in cores and flakes. Based on these technological characteristics, the assemblages were attributed to the Late Acheulian.

Pravara River

A number of Palaeolithic occurrences were identified along cliff sections of the Pravara River, in Upland Maharashtra (Sankalia 1974). At Nevasa, a gravel layer lying unconformably on bedrock yielded assemblages attributed to the Acheulian. Horizontal excavations at Chirki-Nevasa produced 2,400 artefacts across an area of 64 m^2 (Corvinus 1968, 1973, 1981, 1983). The assemblage was dominated by shaped tools, but included cores and flakes of various sizes. The tools were classified as handaxes, choppers, polyhedrons, cleavers, knives and picks. The assemblage was considered to be Early Acheulian, based on the high proportion of core tools, the predominant use of the stone hammer technique, and the absence of a levallois technology. The unit contained faunal remains, including *Bos namadicus, Equus namadicus* and *Elephas namadicus,* as well as pieces of fossil wood, suggesting a thin forest along the riverbanks. The cement from the gravel at Nevasa was dated to >350 kyr (Kale 1990; Mishra 1992).

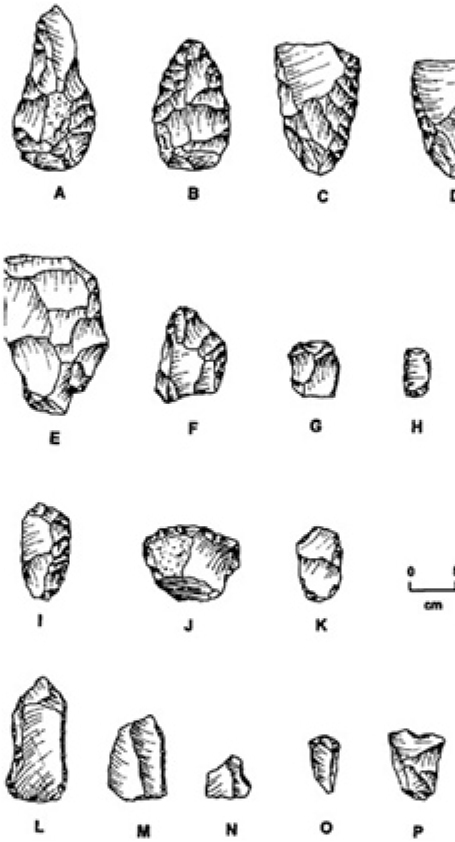

Figure 11.5 Late Acheulian from Bhimbetka: (a, b) handaxes; (c, d) cleavers; (e-n) side scrapers; (o) end scraper; (p) notch.

Source: after Misra 1987

Hunsgi-Baichbal Valley

Systematic surveys and excavations have been conducted in the Hunsgi-Baichbal Valley, Karnataka, revealing the presence of over 100 Acheulian occurrences in an erosional basin measuring 500 km^2 (Paddayya 1977a, 1977b, 1982, 1989). Uranium series dates placed occupations minimally from the Late Middle Pleistocene to the Early Late Pleistocene (Szabo *et al.* 1990). The localities occurred in a variety of depositional contexts, situated on the valley floor, along the plateau edge, in pediments and along streams (Paddayya and Petraglia 1993). Although there are a variety of differing preservation contexts, a number of surface and buried localities were considered to be in original context, and not transported by natural processes. The localities consisted of assemblages with artefacts classifiable as handaxes, choppers, cleavers, picks, knives, polyhedrons, scrapers, discoids and unifaces. A variety of locally available raw materials were used for tool manufacture, including limestone, quartzite, granite, dolerite, basalt and schist. Variability in use of hard hammer and soft hammer techniques could be observed between the localities. Use of soft hammer manufacturing techniques was delimited by the presence of finely flaked, symmetrical pieces, and prepared cores and debitage. In some cases, the technological variation of the tool forms and depositional contexts suggested a division of the Acheulian into early and late stages. Specialized localities were identified, including a cluster of handaxes interpreted as a cache, and dense concentrations of basalt and limestone manufacturing debris at geological outcrops, interpreted as sources for tool manufacture (Petraglia *et al.* 1997). Based on the distribution of archaeological occurrences, the inferred monsoonal palaeoclimate, and the identification of seasonal springs and ponds, an Acheulian settlement model was proposed, consisting of wet season dispersal of groups and dry season aggregation of populations (Paddayya 1982). Recent multidisciplinary investigations have been conducted in the Hunsgi-Baichbal Valley, including geomorphological and geological research. Test excavations and observations of sedimentary profiles have shown that Acheulian occurrences may be found in buried contexts, with varying sedimentary substrates indicative of different micro-environments. Testing and mapping has been recently conducted at Isampur, a buried locality that contains primary limestone outcrops exploited by Acheulian groups for stone tool manufacture. Excavations at the locality showed that the site contained large slabs and cores of limestone that were flaked and fashioned into handaxes and cleavers and other tool types. The flake waste was of high density and of variable sizes, showing the entire sequence from initial procurement of material, through initial stages of reduction, to thinning of bifaces.

Malaprabha Valley

Lower Palaeolithic occurrences were first identified in the Malaprabha Valley as concentrations along the major stream (Joshi 1955). Later survey efforts identified Palaeolithic occurrences in a number of palaeogeomorphic settings (Pappu 1981, 1984). As part of a comprehensive survey effort in the Kaladgi Basin, encompassing the Malaprabha, R.S.Pappu and Deo (1994) aimed to reconstruct Quaternary alluvial stratigraphy, landforms and palaeoclimates and to map archaeological site distributions. These investigations showed that a variety of Lower Palaeolithic occurrences could be identified, containing handaxes and cleavers, predominately made from quartzite. Site distributions were tied to inferred courses of the Malaprabha River, demarcating variable zones of hominid activity. Renewed investigations on the Lower Palaeolithic sites have been conducted in the Malaprabha Valley (Korisettar and Petraglia 1993; Korisettar *et al.* 1993; Korisettar 1995; see also Korisettar and Rajaguru, this volume). Preliminary observations have shown that a Quaternary stratigraphy is preserved, consisting of an extensive lateritic surface overlain by a calcrete and fluvial formations. Based on sedimentary and archaeological observations, it has been argued that the Lower Palaeolithic sites exposed along the Malaprabha River are not alluvial occurrences, but rather these are situated on an ancient series of coalescent fans that have been cross-cut by more recent stream action. Test excavations of Lower Palaeolithic artefact occurrences around Lakhmapur, and studies of other localities away from the Malaprabha, have led to the recognition of buried sites and landscapes that have not been subject to heavy reworking or transport by natural processes, although surfaces are likely to be the result of repeated hominid activity and slow rates of sedimentation. The Lower Palaeolithic occupation apparently took place on the lateritic surface, which was later sealed by low-energy processes. The extensive distribution of primary quartzite outcrops and secondary cobble sources were utilized by Acheulian groups, resulting in a wide-ranging artefact distribution over several kilometres. In some cases, Lower Palaeolithic occurrences are associated with dried-up pond situations and shallow water sources.

DISCUSSION

The foregoing summary indicates that India contains a rich array of Lower Palaeolithic occurrences in diverse settings. The following discussion high-lights results derived from the regional investigations, supplemented by some specific data collected from other archaeological studies. The findings raised from the Indian investigations are compared to evidence from other parts of the Old World, particularly Asia. The main goal of the following discussion is to determine the degree to which the Lower Palaeolithic record of India can contribute to a broader understanding of the colonization process and hominid behaviours. Another aim of this section is to identify research gaps and problems, thus providing recommendations for future investigations.

Chronology

An intriguing question that remains unresolved to this day centres on the timing of the colonization of the Indian subcontinent. Archaeologists working in India have traditionally relied on relative dating methods, although in recent years absolute dating techniques have been increasingly applied to Lower Palaeolithic contexts. Archaeologists have used typological classifications to identify Lower Palaeolithic industries. In some cases, the position of these industries within stratigraphic deposits has been used to establish temporal successions. The application of absolute methods has clearly shown that India was occupied by the mid- to Late Middle Pleistocene, although chronometric evidence from the Near East and eastern Asia indicates that Lower Palaeolithic assemblages should be present that date to the Early Pleistocene. The following two subsections discuss the positive results and the problems associated with relative and absolute methods for dating Lower Palaeolithic occurrences.

RELATIVE METHODS

Stratigraphic and typological correlation have been central to estimating the age range of archaeological occurrences in India. Archaeologists have placed much emphasis on showing the relationship of artefact type variations within stratigraphic columns (e.g. Sankalia 1974; Rajaguru 1985; Misra 1987). Based on changes in artefact types in alluvial and rockshelter stratigraphies, Lower, Middle and Upper Palaeolithic sequences have been identified; the changes in artefact forms seemed to conform to the classificatory sequence found in other parts of the Old World. Whilst relative dating techniques may be used to place Lower Palaeolithic assemblages in a general, relative sequence, reliance on stratigraphic and typological methods has resulted in a low level of temporal precision. Moreover, many studies have been based on alluvial sequences, where it is difficult to establish secure chronological controls. In these cases, cross-correlation of deposits may be tenuous, and regional marker horizons often cannot be identified, which limits the usefulness of the information for dating occurrences. For these reasons, archaeologists are often uncertain about the temporal relationship between Lower Palaeolithic industries in different regions or the relative contemporaneity of multiple occurrences in the same valley.

Biostratigraphic research has been conducted in India that shows abundant evidence of taxonomic change during the Plio-Pleistocene, although no index fossils have been identified for subdividing the Pleistocene (Badam 1979). Fluorine/phosphate ratios on bone and fossils have been applied to many archaeological occurrences, in an attempt to supplement stratigraphic evidence and to differentiate Middle and Late Pleistocene localities (Kshirsagar 1993). Whilst chemical ratios may be useful in further supplementing stratigraphic evidence, the accuracy of these measures is undetermined, since little is known about palaeoenvironments and depositional conditions, and further, few correlations have been made with absolute dates.

Based on concepts and techniques developed on African and European assemblages, archaeologists working in India have divided stone tool industries by typology and manufacturing techniques (Sankalia 1974). Most investigators have assumed that there should be changes in artefact types through time, and, as a result, researchers have placed emphasis on determining the chronological relationship between Soan and Acheulian biface industries. The Soan and Acheulian industries were originally seen to be contemporaneous, since they co-occurred together (de Terra and Paterson 1939; Movius 1948). There have been claims that attempted to demonstrate that pebble tools preceded the Acheulian, as was demonstrated in one Narmada excavation (Khatri 1962a, 1962b). Renewed excavations in the same locality, however, indicated that the industries could not be temporally subdivided, due to evidence for redeposition and mixture

(Supekar 1968; Armand 1983). The separation between pebble tools and handaxes in other contexts has been observed, and has been interpreted as evidence for a developmental scheme (Armand 1983). Based on finding pebble tools with handaxes in the same stratigraphic context, however, others have considered these associations to be functional associations of an Early Palaeolithic stage (Joshi 1978). None of the temporal or developmental schemes based on variations in typed assemblages has stood up to close scrutiny, mainly due to the lack of superimposed stratigraphies. As a result, any temporal association between simple core tool assemblages and bifacial industries remains unresolved. In Pakistan and eastern Asia, however, there have been claims that Mode I tools may be found in Late Pliocene or Early Pleistocene contexts, preceding the date of the Acheulian or bifacial industries in Africa (Dennell *et al.* 1988a, 1988b; Huang *et al.* 1995; Dennell, this volume). In this view, *Homo erectus* may have carried simple core tools out of Africa before the advent of bifacial industries at *c.* 1.6 myr (Swisher *et al.* 1994).

With regard to the development of the Soan tool industry itself, de Terra and Paterson (1939) posited an evolutionary sequence consisting of ‘pre’, ‘Early’, ‘Late’ and ‘Evolved’ stages, based on associations of artefact forms with terrace deposits. The sequence was used by archaeologists for nearly half a century, accommodating new finds of core assemblages into the sequence (e.g. Mohapatra 1976, 1989). However, recent research has indicated that the standard Soan developmental sequence was faulty and not based on secure stratigraphic evidence (Dennell and Rendell 1991). Thus, whilst the simple core industries (i.e. Mode I) are still recognized as a potentially discrete industry apart from the Acheulian, most researchers no longer hazard to subdivide core industries of the ‘Soan’ into developmental stages.

Of the two Lower Palaeolithic industries in India, the bifacial industry is better known, because numerous localities from the period have been identified and these occurrences have been more intensively investigated. Most practitioners working in India still view the concept of the ‘Acheulian’ as a useful classificatory device, arguing that a variety of characteristic stone tool forms may be consistently identified (Misra 1987). Archaeologists working in other parts of the Old World have subdivided the Acheulian into Early, Middle and Late stages, based on changes in artefact forms, manufacturing techniques and tool type frequencies (e.g. Bar Yosef 1994; Clark 1994). In India, two main phases have been indicated for the Acheulian: an Early Acheulian and a Late Acheulian (Paddayya 1984; Misra 1987; Sali 1990). The subdivision was based on variability in the frequencies of particular tool types and metric attributes. Handaxes have been discriminated into types that are considered to be representative of developmental stages (e.g. Joshi and Marathe 1985; Gaillard *et al.* 1986; Raju 1988). Localities such as Singi Talav and Chirki-Nevasa were considered to be Early Acheulian, since they contained handaxes that were large and thick, with massive butts, and were ovate or triangular in shape. Other localities, such as Bhimbetka, fell into a later stage, based on smaller, symmetrically shaped handaxes, with a large number of flake scars and refined trimming, and use of soft hammer and prepared core techniques, together with a greater range of tool types made on cores and flakes. In the Hunsgi-Baichbal Valley investigations, a general link has been observed between sedimentary deposits and assemblage characteristics (Paddayya 1982, 1991; Paddayya and Petraglia 1993). Pleistocene sedimentary deposits, which are considered to be the youngest, contain more refined flaking patterns on bifaces (e.g. removal of large numbers of flakes, control of flakes using soft hammer technique, greater symmetry of forms) and an increase in the variety of forms and reduction techniques (e.g. increase in retouched flakes, introduction of prepared core techniques).

Whilst there may be some merit in subdividing Acheulian technology chronologically, the hypothesis that refinement should equate with age has been widely adopted in India without much critical forethought and without secure stratigraphic controls. Comparison of the metric analysis of handaxes from two localities, Gunjana and Chirki, demonstrates the point. Variation in handaxes from the two Lower Palaeolithic complexes was shown in mean length (120 vs. 138 mm), weight (337 vs. 539 gm), thickness:breadth ratios (0.46 vs. 0.64), and number of flake scars (24 vs. 10) (Raju 1988). Based on the belief that there is a relationship between age and handaxe refinement through time, the Gunjana industry was typed as 'Late Acheulian' and the Chirki assemblage was typed as 'Early Acheulian'. Typical of other metrical studies, this example does not provide stratigraphic controls and it does not seriously consider the role of other important variables, such as tool functions, raw material variability or manufacturing stages, in influencing size measures. Whilst there may indeed be broad assemblage characteristics that set earlier and later phases of the Acheulian apart, analysts have accepted evolutionary typological assumptions uncritically, and the relationships drawn between chronology and handaxe refinement have become circular in reasoning. As a consequence, researchers should remain cautious about temporal-typological trends until more secure sequences from stratified contexts are established, preferably accompanied by absolute- dating.

ABSOLUTE METHODS

The relatively recent application of absolute dating methods has had a profound effect on Palaeolithic studies in India, providing more precise ages and pushing the potential age of the Lower Palaeolithic further back into the Pleistocene. Lower Palaeolithic occurrences have been dated from >150 to >350 kyr by a number of uranium series samples and a single thermoluminescence sample (Table 11.1). Chronological sequences through stratigraphic profiles are rare, although the Didwana flake assemblage was dated between a bracket of >150 and <390 kyr through a 19 m column (Figure 11.4). Absolute dates from other contexts in India were derived from single depositional units or from fossils derived from particular deposits. The youngest reliable dates for the Acheulian occurs at two localities: Umrethi, which was dated to >190 kyr, and in the Hunsgi Valley, where the terminus of the Kaldevanhalli travertines was dated to 166 and 174 kyr (indicating that the associated Acheulian assemblages were contemporary with an earlier humid phase). Middle Pleistocene age ranges were obtained from fossils associated with Acheulian assemblages in the Hunsgi-Baichbal Valley, where they were dated to 287 and 290 kyr (Teggihalli and Sadab). Three dates exceed 350 kyr from three different geographic contexts, showing that the Acheulian extends beyond the maximum dating range of the uranium series technique. In all,

Table 11.1 Absolute dates obtained for the Indian Lower Palaeolithic.

Location	*Material*	*Technique*	*Date (kyr)*	*Notes*
Umrethi[1]	miliolite	Th^{230}/U^{234}	190 +29/−22	Miliolite overlying acheulian handaxes
Kaldevanhalli[2]	travertine	Th^{230}/U^{234}	174±35 166 +15/−13	Acheulian assemblages overly travertine; dates represent terminus of seep spring formation
Sadab[2]	*Elephas* sp. molar	Th^{230}/U^{234}	290 +21/−18	Associated with acheulian assemblage
Teggihalli[2]	*Bos* sp. Molar *Elephas* sp. molar	Th^{230}/U^{234}	287+27/−22 > 350	Associated with acheulian assemblage
Didwana (16R) [3]	calcrete	Th^{230}/U^{234}	150±10	Overlying undifferentiated palaeolithic assemblage
Lower Didwana (16R) [3]	quartz grains	TL	163±21	Associated with undifferentiated lower palaeolithic assemblage
Didwana (16R) [3]	calcrete	Th^{230}/U^{234}	>390	Underlying undifferentiated lower palaeolithic assemblage
Yedurwadi[4]	calcrete	Th^{230}/U^{234}	>350	Associated with Acheulian assemblage

Location	*Material*	*Technique*	*Date (kyr)*	*Notes*
Nevasa[4]	calcrete	Th^{230}/U^{234}	>350	Overlying Acheulian assemblage
Kukdi[5]	tephra	K/Ar	1,380±240	Mean age from whole samples Locality 1, one flake in gravel underlying tephra Locality 4, Early Acheulian in gravel which rests disconformably with tephra on silt
Kukdi[6]	tephra	Stratigraphic	74	Estimate based on correlation with youngest toba ash
Kukdi[7]	tephra	Geochemical	74	Electron microprobe analysis
Kukdi[8]	tephra	Ar^{39}/Ar^{40}	680±30 540±30 660±10	Locality 2, one flake in gravel underlying tephra Locality 2, second dated sample considered less reliable Locality 5, tephra rests disconformably with gravel on silt, no artefacts
Kukdi[9]	tephra	K/Ar Fission-track	538±47 640±290	Estimates provided in oral communication

Notes: ‘Baskaran *et al.* 1986; [2]Szabo *et al.* 1990; [3]Misra and Rajaguru 1989, Raghavan *et al.* 1989; [4]Kale 1990, Mishra 1992; [5]Korisettar *et al.* 1989a, 1989b; [6]Acharyya and Basu 1993; [7]Shane *et al.* 1995; [8]Mishra *et al.* 1995; [9]Korisettar 1994

the uranium series evidence therefore indicates that the terminus of Acheulian assemblages dates to *c.* >150 kyr, and the earliest evidence ranges beyond 350 kyr, in agreement with temporal evidence from other parts of the Old World.

Whilst Lower Palaeolithic assemblages were bracketed between *c.* 150 to >350 kyr using uranium series dating, the samples were called into question and rejected in favour of an older sequence (Mishra 1992). All uranium series dates younger than 350 kyr were interpreted to stem from age errors or contextual problems such as redeposition (Mishra 1992:325). However, the argument that all dates younger than 350 kyr should be rejected in favour of a older chronology appears tenuous in the face of the available chronometric and depositional evidence. Whilst the Umrethi date indicates that the Acheulian is older than 190 kyr, it does not necessarily imply that it is beyond or as old as 350 kyr. The Didwana section brackets inferred Lower Palaeolithic assemblages between >150 and <390 kyr, and not necessarily beyond the range of uranium series, as interpreted by Mishra (1992:327). The Kaldevanhalli travertines produced age estimates of 166 and 174 kyr, dating the terminus of seep spring formation. Although the possibility for redeposition of the Acheulian occurrences at Kaldevanhalli was raised (Mishra 1992: 326), no supporting evidence is marshalled, and in fact, recent stratigraphic work indicates the relative integrity of the association between the Acheulian assemblages and the seep springs (Petraglia *et al.* 1997). Finally, finite dates of 287 and 290 kyr on associated molars from the Hunsgi-Baichbal Valley occurrences can not be rejected just because one sample produced a date of >350 kyr (Mishra 1992:327). Although it is agreed that the Lower Palaeolithic likely ranges beyond 350 kyr in India, much of the currently available evidence supports the fact that assemblages are younger than 350 kyr, hence rejection of all the samples in favour of an older age range is unrealistic.

During the 1980s, a number of volcanic ash beds or tephras were identified in various parts of India, providing the unparalleled opportunity to date deposits containing archaeological and palaeontological assemblages (Williams and Clarke 1984, 1995; Korisettar *et al.* 1989a, 1989b). The first radiometric age determination was on the Bori tephra from the Kukdi Valley, producing an average age of 1.38 myr by K/Ar (Korisettar *et al.* 1989a, 1989b). The date of the Kukdi ash was of great importance, given an association between an inferred Early Acheulian assemblage and the tephra, as well as supposed flakes underlying the tephra (Figure 11.6). However, the radiometric age of the Kukdi ash was rejected by geologists, who argued that it was probably correlated with the youngest Toba ash eruption, dated to *c.* 74 kyr from deep sea cores (Acharyya and Basu 1993). This discrepancy generated considerable debate and re-evaluations (Acharyya and Basu 1994; Badam and Rajaguru 1994; Korisettar 1994; Mishra and Rajaguru 1994), eventually leading to rejection of the 1.38 myr date by some of the original proponents (Korisettar 1994; Mishra *et al.* 1995). In a recent reassessment, geochemical sampling from various localities, including Kukdi, has provided support for the 74 kyr age of the tephras (Shane *et al.* 1995). However, other recently reported dates do not agree with this young estimate: radiometric age estimates from K/Ar on glass and feldspars produced a date of 538 kyr, and a fission-track date on glass separates produced a date of

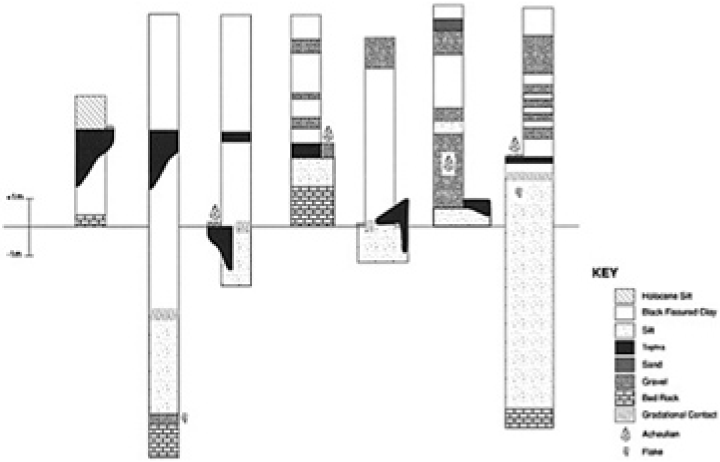

Figure 11.6 Vertical profiles of Kukdi sections showing relationship of deposits and artefact assemblages.

Source: after Mishra *et al.* 1995

640 kyr (Korisettar 1994). Three Ar/Ar dates were also recently obtained, with two samples resulting in ages of 680 and 660 kyr (Mishra *et al.* 1995).

The discovery of tephra deposits at a number of locations is clearly of significance for assisting in the establishment of an absolute chronology for the Indian Palaeolithic. Unfortunately, however, most of the Indian tephras and associated sediments have not been petrographically analysed or characterized, and samples have not yet been dated with a high degree of confidence. Moreover, the exact stratigraphic provenance of Lower Palaeolithic artefact assemblages in relation to tephra deposits has not been positively established. Whilst the Kukdi tephra was originally interpreted to be situated below the Acheulian gravel (Korisettar *et al.* 1989a, 1989b), others then argued for a contemporaneity of the two facies (Mishra *et al.* 1995) (see Figure 11.6). The divergence of interpretation demonstrates the limitations of constructing composite lithostratigraphic columns in this context. In view of the fact that Kukdi tephra is preserved in a fluvial context, contamination of the tephra is suspected. This is likely to be revealed by the discordant dates so far produced for various samples. Whilst geologists and archaeologists involved in the tephra debate have clung to particular age estimates, the possibility also exists that tephras across India are of variable ages. As a consequence, better sampling and temporal precision measures are needed, which are available through techniques such as single crystal ^{40}Ar/^{39}Ar dating (e.g. Deino and Potts 1990).

Overall, in the limited cases where absolute dates have been obtained, too few dates have been sought for making reliable judgements about occupation. To establish the antiquity and duration of Lower Palaeolithic assemblages in India, investigators will need to obtain multiple and precise dates from secure contexts, ideally from columnar samples in superimposed stratigraphic contexts. Dating methods such as electron spin resonance (ESR.) and palaeo-magnetism, which range over the Early and Lower Middle Pleistocene, must be applied to resolve questions about the colonization of India.

Although chronological evidence for the Lower Palaeolithic of India is just emerging, comparisons with evidence from the Near East and eastern Asia indicate the potential age of the assemblages. Evidence for Lower Palaeolithic localities in India from 150 to >350 kyr is highly plausible, and probably a very conservative age estimate, in light of secure evidence that dates localities between 200 kyr and 1 myr or more in the Near East (Bar-Yosef 1994), to >780 kyr, and possibly >1 myr in China (Schick and Dong 1993), to *c.* 1 myr in Indonesia (Pope and Cronin 1984; Pope 1985, 1988), and from 700 to 400 kyr in Pakistan (Rendell and Dennell 1985). More controversial dates place hominid occupation to *c.* 2 myr in Pakistan (Dennell *et al.* 1988a, 1988b; Rendell *et al.* 1987; Dennell, this volume), *c.* 2 myr in China (Huang *et al.* 1995), and to *c.* 1.8 myr in Java (Swisher *et al.* 1994). If hominids travelled a southern route to reach eastern Asia by 1.8 myr or more, it would imply that Mode I tools should be present in India by that time or earlier. Based on the securest Old World evidence, the dates imply that the earliest archaeological occurrences in India must date to 1 myr or more, which would be likely to include Mode I and/or Acheulian assemblages of Early Pleistocene date.

Stone tool technology

Stone tools are, by far, the most abundant class of material evidence for the existence of the Lower Palaeolithic in India. Stone tool typology, technology and reduction patterning may elucidate important aspects about the relationship of hominid populations, adaptations to environments and resource bases, and activities over the landscape. Since typological classification of stone tools has played a central role in traditional and current studies, the following section examines the utility of this approach for assigning meaning to industrial variations. Given that palaeoanthropologists are interested in understanding hominid adaptations, the following section also explores the role that stone tool attribute variations may play in understanding behaviour.

GENUINE ARTEFACTS?

Before any technological study is initiated, lithic analysts must consider whether fractured rock pieces are the consequence of natural modifications or deliberate reduction by hominids. In attempting to address the question of the first entry of hominids in Asia, analysts may be confronted with localities containing relatively few artefacts which are simply produced and are frequently reminiscent of naturally fractured rocks. If hominids in Asia produced only simply flaked core tools prior to the advent of the Acheulian, artefact recognition may be a problem, since only one to several flakes may be struck from a core. This is even more problematic if occasional artefacts were produced by hominoids (see Dennell, this volume).

Analysts have questioned the genuine nature of some simply flaked assemblages attributed to the Soan (Stiles 1978). The pre-Soan, consisting of massive boulder flakes and associated with Boulder Conglomerates, has been considered non-artefactual by some, especially given the lithological character of the deposits, where naturally flaked pieces can occur (Mohapatra 1989; Dennell and Rendell 1991). In addition, it has been pointed out that many pebble tools show apparent signs of post-depositional modifications, including rolling and patination, thereby creating problems in identifying bona fide artefacts (Armand 1985).

In the case of the supposed 2 myr Riwat assemblages, analysts have attempted to use a combination of criteria to separate naturally produced items from culturally reduced artefacts (e.g. cortical percentage, number of flake removals, numbers of planes for flake removals, presence of bulbs of percussion) (Dennell *et al.* 1988a, 1988b). Based on these criteria, five of twenty-three collected quartzite specimens were considered to be hominid-struck, seven were equivocal, and the remainder were considered suspect or geologically produced. Whilst the analysts have made their inferences as clear as possible, the definitive cultural attribution of the pieces has been questioned on the basis of the amorphous character of the flaked pieces and the context of the finds, situated in heavy clastic sediments where natural percussion was possible (Mohapatra 1989).

On the basis of two 'simple flakes' from gravel and silt deposits under-lying the dated Kukdi tephra (Figure 11.6), claims have been made about the early occupation of the Indian subcontinent (Mishra *et al.* 1995). One artefact is a large flake made on coarse-grained basalt with a number of dorsal flake scars. The other is a small flake in a colluvial lag, which is abraded and patinated. The low number of pieces, the presence of one item in a gravel deposit, and the ambiguous nature of the pieces coming from below the tephra, however, call into question the behavioural nature of the specimens.

Since archaeologists are well aware that naturally fractured rock may sometimes mimic artefacts produced through hand-held percussion (e.g. Nash 1993; see Dennell, this volume), analysts should remain sceptical about claims for the artefactual status of a few pieces. The distinguishing criteria for artefacts and naturefacts remain a major problem in lithic technology, and this problem is compounded by recovering small numbers of simply flaked pieces. Clearly, before major revisions of the Asian Lower Palaeolithic chronology are accepted, a larger number of artefacts from many primary depositional contexts are required.

STONE TOOL MORPHOLOGY

The typological and technological distinction between simple core industries (i.e. Mode I) and those of the Acheulian is still recognized by most analysts, with differences marked on the basis of the relative frequency of representative tool types and the employment of certain reduction techniques and strategies. Mode I assemblages have been classified on the basis of shared attributes, usually consisting of pebbles and cobbles that have been unifacially and sometimes bifacially struck along their edges. The degree to which unifacial and simply struck bifacial tools are regularly made leaves some question as to whether these pieces were intentional morphological designs on the part of the tool manufacturer. Similarities and differences of stone tool 'forms' in these assemblages may simply represent variations of flaking produced through hard hammer percussion to stone, and not be representative of 'mental templates', regional 'cultures', or shared norms in tool making (Toth 1985; Schick 1994; Toth and Schick 1993). As a consequence, some analysts now prefer to abandon the traditional, culturally loaded terminology used to designate these assemblages (e.g. Chopper-Chopping Tool, Soan), instead preferring to classify these assemblages as 'core/flake' or Mode I technological classifications (e.g. Clark 1994; Schick 1994).

Most archaeologists working in the Old World have adhered to the notion of an 'Acheulian', believing that this industry shares similar manufacturing methods and resultant stone tool forms that can be isolated over time and space. Shaped bifaces of the Acheulian are considered to be more sophisticated in employment of reduction techniques compared to Mode I assemblages, requiring the ability to predict geometric designs through systematic and careful flaking. Complex procedures in the manufacture of Acheulian bifaces have been recognized, consisting of a rigid and elaborate set of rules in technology to control shape. Preparatory stages consist of selecting a clast for tool manufacture, shaping a nodule or flake bifacially, directing blows to set up striking platforms to thin a piece, developing and maintaining a bilateral symmetry, and final shaping and thinning (Schick 1994: 584–5). Acheulian assemblages therefore contain stone tool forms (e.g. handaxes, cleavers) that apparently share broad stylistic traits equating with the manufacturers' intentions (e.g. Wynn 1989; Toth and Schick 1993; Clark 1994; Schick 1994). Maintenance of material patterns or technological traditions is usually interpreted to be the result of shared or learned rules among populations, which can be evidenced over space and time (Wynn 1989; Schick 1994:570).

Although many analysts accept the 'standardization' of morphological tool forms as a hallmark of the Acheulian, problems are raised with respect to the typological classifications. For example, studies in fact show that there is some range of shape variation in so-called 'similar' forms of 'handaxes' within and between geographic regions, which is possibly the result of manufacturing trends over time or raw material differences (e.g. Roe 1981; Wynn and Tierson 1990). Analysts have also indicated that differences in Acheulian biface shapes and sizes may be the result of varying degrees of use, and thus, similarities in the final products are not necessarily intentional on the part of the tool manufacturer (Davidson and Noble 1993). In support of this argument, elongated biface types have been argued to represent earlier stages of reduction, and smaller, rounded types to represent later stages (McPherron 1994). Moreover, it has also been pointed out that archaeological classifications that appear to demonstrate uniformity in handaxe dimensions may be an artifice of the typology system itself; for example, 'handaxes' are always defined on the basis of similar attributes (i.e. relations among length, width and thickness), and if observed to be dissimilar by the typologist, the pieces are reassigned to other artefact classes (e.g. cores). Whilst the reduction variability arguments are at the forefront of current lithic classificatory debates, they do not necessarily disprove the notion that certain tool forms may have been intentional designs (see Dibble 1995 and Mellars 1996 for a discussion of the Middle Palaeolithic typological debate). As a consequence, there is no resolution as to whether Mode I or Acheulian stone tool types and variations represent definable emic rules in tool making in time and space, stochastic shaping convergence and divergence, or differences in function, raw materials or reduction. Whilst the meaning of typological variability is not readily apparent, the Lower Palaeolithic industries of India and Asia may be examined in light of these arguments.

LOWER PALAEOLITHIC INDUSTRIES IN INDIA AND ASIA

Palaeoanthropologists working in eastern Asia still observe a basic morphological dichotomy between Mode I and Acheulian assemblages (e.g. Pope 1988; Clark 1994; Schick 1994). In recent reappraisals of the geographic distribution of the Lower Palaeolithic industries in Asia versus those in the West, certain analysts still indicate support for the reality of the 'Movius Line' (Pope 1988), although the geographic separation of the industries is considered an 'enigma' (Schick 1994:593). The discovery of Mode II bifaces in eastern Asia over the last two decades has been construed by some investigators as a breakdown of the geographic dichotomy between the Mode I and Acheulian industries (Yi and Clark 1983; Huang 1989) (Figure 11.7a–b). Whilst the geographic dichotomy for biface production may not be as well defined as originally observed, the presence of an 'Acheulian' industry in eastern Asia has not been generally accepted. Most investigators do not evidence a systematically produced Acheulian biface industry, characterized by certain tool forms (e.g. handaxes, cleavers) and reduction techniques (e.g. soft hammer, Levallois). Some analysts have argued that bifaces in eastern Asia are rarer than those found at localities in the West, and the true morphological resemblance of these 'Mode II' bifaces to Acheulian bifaces is not clear, because the former assemblages lack consistently produced forms and systematic flaking techniques (Clark 1994, this volume; Schick 1994). Contemporary investigations show that the most northeasterly lying extension of accepted 'Acheulian' bifaces is in the Dang Valley, Nepal (Corvinus 1994, 1995, this volume) (Figure 11.7c–d).

Conventional interpretation of the Indian Lower Palaeolithic indicates that there is a basic typological and technological difference between the Mode I (i.e. Soan) and Acheulian industries (e.g. Sankalia 1974; Paddayya 1984; Misra 1987, 1989). Differences among the two Lower Palaeolithic assemblages are defined on the basis of stone tool morphologies, with the Soan typically consisting of unifacial and bifacial pebble tools and cores, whereas the Acheulian is usually defined on the basis of bifaces (i.e. handaxes, cleavers), unifacial and bifacial pebble tools, together with an increasing number of unifacial tool types, including scrapers and notched pieces produced from flakes (compare Figures 11.2–3 and 11.5). The distinctive characteristics of Acheulian stone tool forms throughout India continue to support the notion that these assemblages are separable assemblage units. Support for the planned technological design of Acheulian stone tool forms comes from recent work at the Isampur locality in the Hunsgi Valley. Examination of the attributes of bifaces indicated that handaxes and cleavers were made in a systematic and predictable fashion, with forethought about the morphology of pieces. Moreover, a proportion of small to moderate size bifaces are likely to be designed pieces (representing discarded pieces and not necessarily end-products after continuous use and reduction).

Whilst analysts may argue that gross assemblage variations can be defined, separating the Soan and the Acheulian, the question becomes to what degree can the dichotomy be maintained? Are the assemblages indeed unique entities, or are they simply ranges of a contemporary stone tool industry? Recent comparison of Soan artefacts from the Siwaliks with Acheulian materials from Singi Talav concluded with the observation that there were close overlaps and parallels in the processing sequences and forms of the two industries (Gaillard 1994, 1995).[1] In this view, Soan assemblages contain pebbles and cobbles that were trimmed along their edges both unifacially and bifacially, with some forms reminiscent of tools associated with Acheulian assemblages, including 'cleavers' (Figure 11.2e), bifaces and 'handaxes' (Figure 11.2f, Figure 11.7e–f). These observations may be supported by examination of 'Acheulian' assemblages that contain bifaces that are only roughly trimmed, retaining characteristics of the original clast (Figure 11.7g–h). From a processing viewpoint, it may therefore be argued that the Soan and Acheulian forms may show convergences in the striking and trimming of pieces (Gaillard 1995). As a consequence of overlapping and varying techniques and bifacial tool forms, the absolute distinction between the two Lower Palaeolithic tool forms may become more difficult to sustain. This may imply that some assemblages are not easily divisible into the traditional dichotomy.

If an overlapping or potentially wider range of variation is present in the Indian assemblages, comparison to Lower Palaeolithic assemblages of eastern Asia seems further to exacerbate typological problems. Figure 11.8 portrays the current division between Lower Palaeolithic assemblages, which fall on either

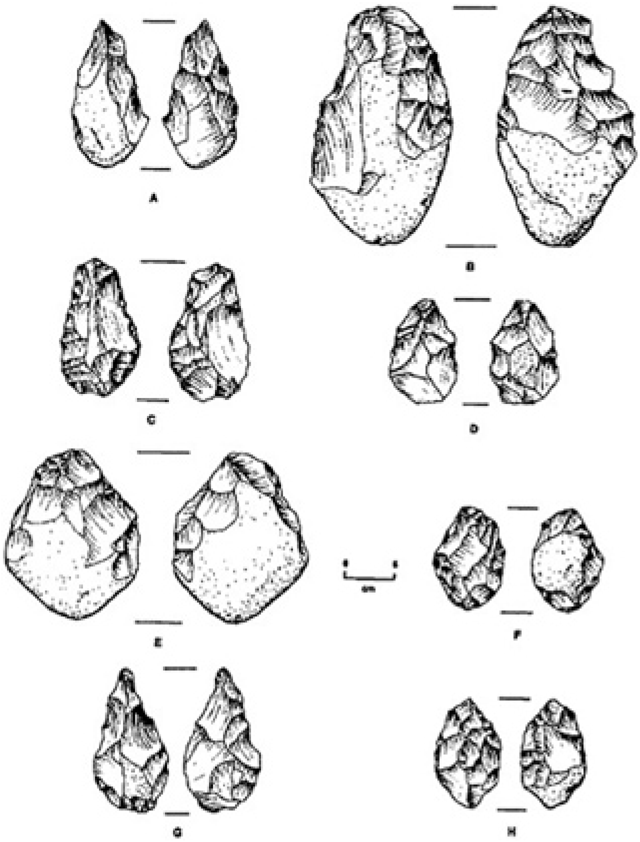

Figure 11.7 Bifacial implements from Asia, (a, b) Pingliang and Baise, China; (c, d) Dang Valley, Nepal; (e, f) Beas, India; (g, h) Chirki, India.

Sources: after Corvinus 1995; Huang 1989; Gaillard 1995; Misra 1987

side of the ‘Movius Line’. The assemblages from eastern Asia are usually typed as Mode I (i.e. Chopper-Chopping Tool) (Figure 11.8a–b), although there is some evidence that Mode II forms are present (Figure 11.8c). Assemblages from India may be classified as ‘Soan’ (Figure 11.8a–b) or as variable ranges of Acheulian assemblages (Figure 11.8d–f). However, as indicated above, a problem is raised concerning how to treat Indian Lower Palaeolithic assemblages that include mixtures of unifacial assemblages with simple bifaces and occasional bifaces (Figure 11.8c). In these cases, it is not readily apparent whether assemblages should be assigned to the ‘Soan’ or the ‘Acheulian’. This presents a potentially perplexing situation for those that adhere to the traditional typological classifications of Indian assemblages. The possibility is raised that certain Indian assemblages share characteristics with Chinese assemblages

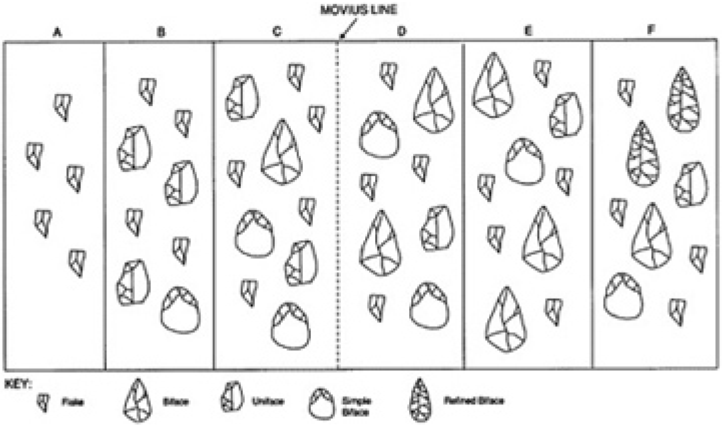

Figure 11.8 Variations among lower palaeolithic biface assemblages of eastern Asia and south Asia. The dashed line represents the Movius Line, the traditional demarkation between Mode I (i.e. Chopper-Chopping Tool) industries and the Acheulian.

classified as Mode II. That is, if the Chinese Mode II is legitimate (Figure 11.8c), and the same classificatory and typological logic is employed for the Indian assemblages, it would have to be argued that there is a Mode II in India apart from the Acheulian (unless the Mode II of China were typed as Acheulian). If this were the case, this would imply that India would contain Mode I, Mode II and Acheulian industries. The triparate splitting of assemblages would clearly raise classificatory and explanatory problems for those who assign meaning to typological distinctions. This is reminiscent of the problems encountered in Africa, where assemblages have been split into Oldowan, Developed Oldowan and Acheulian. Regardless of the ultimate meaning of typological classifications, the foregoing illustrations show that a clear Lower Palaeolithic dichotomy for India and Asia is becoming more difficult to maintain, because assemblages consisting of a larger range of variation than was previously emphasized.

Although it could be argued that archaeologists should completely reject the traditional typological dichotomy (i.e. Soan, Acheulian) in favour of technological modes (i.e. Mode I and II) or reduction sequences (often used for inferences about activity and behaviour), these arguments would not help to explain some technological patterns of lingering interest. For example, if it is accepted that there are some recurring and systematically produced biface forms (e.g. handaxes, cleavers), as the result of deliberate manufacturing methods, the occurrence of these types in certain geographic areas and their absence in other regions is clearly of interest in understanding an element of hominid behaviour that transcends economic interpretation. Abandonment of classificatory schemes in favour of reduction sequences, or classification of all Lower Palaeolithic bifaces under the general rubric of Mode II, would, in fact, hide biface variability, blending any potential distinction between bifaces that occur occasionally in assemblages and those that are consistently and systematically produced.

This discussion of Lower Palaeolithic stone tool morphology indicates that archaeologists working on both sides of the 'Movius Line' are still left with major problematic issues: first, whether the common set of attributes that distinguish Mode I, Mode II and Acheulian industries are in fact useful taxonomic devices, and second, whether these industrial distinctions are the result of biology, culture, cognition, environments, norms in tool making, functional variations, or combinations thereof. The foregoing discussion implies that the Lower Palaeolithic of India and Asia is more complicated than the current typological dichotomy suggests, as it contains variable mixtures of artefact types. This is not to imply that some interesting typological differences among Mode I and Acheulian assemblages do not exist. It simply means that we have not satisfactorily characterized assemblage variations under the current technological rubric nor fully comprehended their meanings. Whilst further research on the meaning of industrial typologies is of interest for future investigation of hominid cognition, etc., the following sections will attempt to show the importance in considering the relationship and connections between stone tool typologies, reduction, raw materials and activity variations over landscapes.

Stone tools and raw materials

Archaeologists have long held that there are likely to be strong relationships between raw materials and Lower Palaeolithic artefact forms. The availability and properties of lithic raw materials are thought to influence stone tool technological choices and resultant artefact forms. In studies of Mode I and Mode II assemblages in Asia, a close relationship was demonstrated between tool types and raw material types, shapes and availability (Leng 1992; Gaillard 1994). In certain regions, raw materials may be widely distributed in secondary deposits as pebbles and cobbles, whereas in other areas clast occurs in primary bedrock locations, showing a large variation in their mineralogical and percussive characteristics. The presence of Soan assemblages predominately produced from quartz pebbles and cobbles may therefore be attributed to resource type and abundance, with the Himalayan foothills and outwash of northern India containing extensive gravel deposits. In this situation, the shape of the initial clast directly affected the size and form of the implements. By contrast, in certain areas primary outcrops of variable raw materials may be available for biface production. Biface forms may, however, vary as a consequence of the particular size, shape and fracture mechanics of these raw materials. For example, in the Hunsgi-Baichbal Valley, biface (i.e. handaxe) sizes show variation as a consequence of raw material types (Figure 11.9).

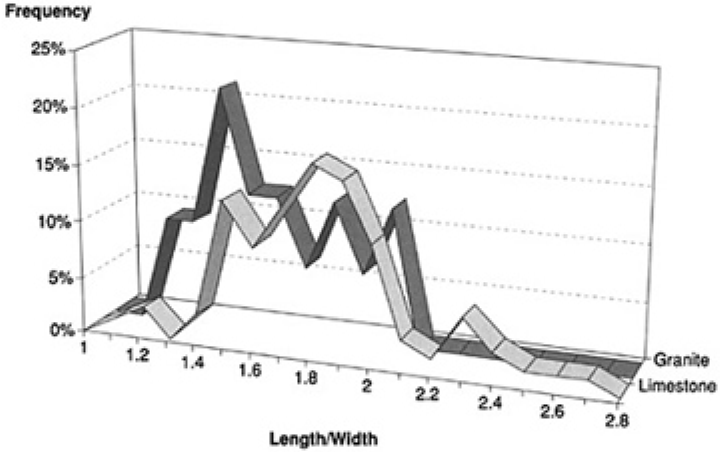

Figure 11.9 Biface sizes by raw material for Hunsgi-Baichbal Valley occurrences.

Limestone slabs of variable sizes are widely available, leading to a diversity of biface sizes. On the other hand, granite spalls selected for biface production have a restricted size range, limiting biface sizes towards a shorter and wider range. Moreover, the limestone pieces allow for predictable flake removals, and thus highly refined bifaces may be produced. By contrast, percussion flaking on granite is less predictable, and soft hammer percussion on this material is difficult, thus producing ‘cruder’ forms (i.e. fewer and wider flake scars). In this case, raw material differences account for some typological and technological differences, demonstrating the inherent danger in assigning ages or cultural/ cognitive meanings to artefacts solely based on size and number of flake removals.

Archaeological distributions

The distribution of stone tool assemblages in various ecological settings provides information about hominid behaviours and activities, and this approach is widely adopted by investigators working on the earliest occurrences in East Africa (e.g. Isaac 1984; Schick 1987; Toth 1987; Potts 1988). Identification of the distribution of archaeological occurrences can lead to an understanding of the organization of hominid activities across landscapes, and how they may have changed in response to local and regional environmental variations. Whilst some interesting settlement pattern studies are beginning to emerge in India, archaeologists generally have not made a concerted or systematic effort to analyse the behavioural meaning of stone assemblage distributions over space. The following subsections emphasize the importance of examining the formation and distribution of archaeological assemblages.

CONTEXTS AND FORMATION PROCESSES

Before inferences about hominid settlement behaviour are made, archaeologists must first examine the integrity of stratigraphic deposits and artefact distributions. Traditionally, most Lower Palaeolithic localities in India were identified as a result of surveys and excavations in major alluvial deposits made in an attempt to identify techno-typological successions (Sankalia 1974). Within the last two decades, however, interest has steadily turned away from establishing major culture-histories in favour of the investigation of Palaeolithic behaviours through survey of Pleistocene landforms, where primary sedimentary deposits and occurrences may be identified (Paddayya 1978). As a consequence, a number of Lower Palaeolithic localities are now known to occur in a variety of Quaternary geomorphic contexts, including mountainous terrain, hillslopes, pediments, alluvial settings, coastal plains and in rock-shelters (Pappu 1985, 1995; Mishra 1994). The current evidence clearly shows that hominids inhabited diverse environments and settings, each with variable resource bases.

Whilst many Lower Palaeolithic occurrences are known in various contexts, few controlled studies have been made to survey and document the relation of material patterns and hominid activities. The number of systematic, and laterally extensive excavations in gentle depositional contexts is still small. Excavations in primary contexts where hominid occupation occurred (e.g. Adamgarh, 16R dune, Bhimbetka) placed little emphasis on understanding space use or activities (Joshi 1978; Misra 1987). Whilst some laterally extensive excavations in open-air contexts have been conducted with an aim to study behaviour, the selected contexts were not the most ideal to identify original spatial patterns (Paddayya 1977a; Corvinus 1983). There have been some hints that certain sites may contain areas of original stone tool reduction (Misra 1987:109, 1989: Figure 7) and areas of architectural preparation (Misra 1987:109). Despite the fact that there are probably a great number of buried Lower Palaeolithic occurrences in India, the great majority of the collections are known as surface collections without any subsurface testing. The surface assemblages are therefore likely to contain material from several periods of activity, potentially spanning lengthy periods. There are very few collections that have been amassed under controlled conditions, and thus there is little confidence that all recovered material is representative.

There have been relatively few attempts to examine the meaning of spatial distributions from the perspective of formation processes. A case has been made that Palaeolithic occurrences must be examined from the perspective of the variable combinations that may arise as a result of hominid activities and natural processes (Paddayya 1987; Petraglia 1995; Pappu 1996). In the Hunsgi-Baichbal Valley, depositional and analytical studies indicate that the formation of Lower Palaeolithic artefact distributions ranged from transported and redeposited assemblages to areas where Acheulian activities could be identified (Paddayya and Petraglia 1993, 1995). Although some localities were considered to be in their original depositional contexts, retaining ‘spot provenance’, many of these same localities were shown to lack ‘point provenance’, where artefacts could be considered to be in positions where they were originally discarded.

In the Malaprabha Valley, recent investigations have shown that a buried and extensive surface of Acheulian assemblages exist, with variable densities of materials in certain areas. This landscape is representative of a stable surface that probably resulted from slow rates of deposition and a complex combination of behavioural processes and sorting by natural processes. With respect to time resolution, some artefact distributions may represent short-term events, whereas others are accumulations of repeated activities over a lengthy period, exemplified by variable combinations of rounding of dorsal and ventral faces of artefacts. Materials over laterally extensive surfaces are also shown to be variably sorted, with small and large objects differentially occurring on hill-crests, slopes and low spots, with some preferred orientations and inclinations of objects as a consequence of natural rearrangements.

SETTLEMENT PATTERNING

The abundance of Lower Palaeolithic occurrences throughout India provides an opportunity to examine the relationship between ecological contexts and settlement patterns. Many Pleistocene sections are exposed, and Palaeolithic localities occur on or near the surface, not deeply buried by major geological events such as glacial advance, as in Europe, or found in deeply buried lacustrine settings, as in East Africa. The Thar Desert investigations clearly indicate that ecological contexts and changes in environments through time can be examined. The surveys and excavations show that Acheulian occupations occurred near shallow water pans or on floodplains, associated with playas or low-energy anastomizing channels, and stabilized dune surfaces along lakes (Misra and Rajaguru 1989; Misra 1995). Sometime later, during the course of the Late Middle Pleistocene, hominids adjusted to environmental changes, including a decline in rainfall, deposition of wind-blown sediments on alluvial plains due to increasing aridity, and the gradual infilling of basins by fluvial sediments.

Several regional surveys have shown how hominid occurrences are distributed over the landscape, and the position of the occurrences in relation to particular ecological contexts. Surveys have revealed the presence of more than ninety Acheulian occurrences over 175 km^2 in the Raisen District (Jacobson 1975, 1985) and more than 100 occurrences over 500 km^2 in the Hunsgi-Baichbal Valley (Paddayya 1982, 1991), forming the densest accumulations of Lower Palaeolithic localities known in India, and possibly worldwide. Generally, surveys have shown that assemblages may be horizontally dispersed throughout basins (Figure 11.10). In some cases, recent geomorphological research suggests that multiple clusters may be part of intact Pleistocene landscapes measuring over several square kilometres, although relative contemporaneity among occurrences is not yet well controlled (Petraglia *et al.* 1997). Whilst the occurrences may be

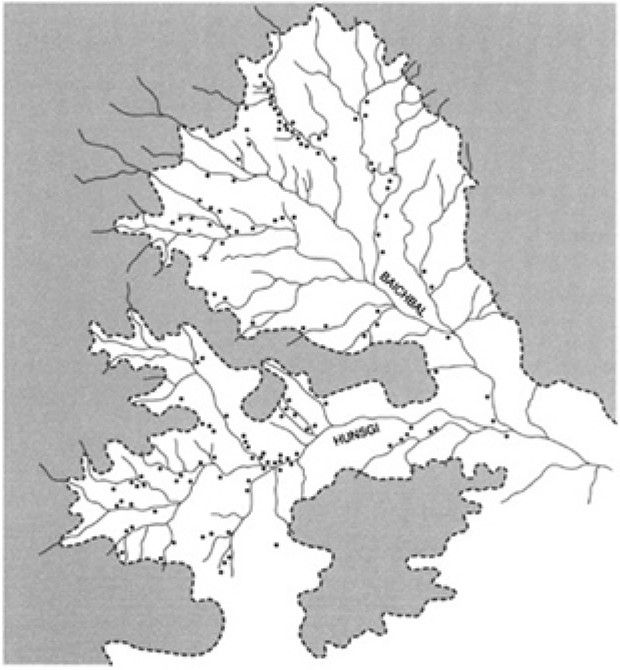

Figure 11.10 Regional map of the Hunsgi-Baichbal Valley showing location of Acheulian occurrences. Dots may represent a single occurrence or multiple occurrences in close proximity.

found as bounded concentrations of variable sizes, strict artefact boundaries are sometimes difficult to ascertain, as material occurs as diffuse areal distributions between clusters. When horizontal boundaries may be established from surface observations, most occurrences range from 1,500 to 4,500 m^2 in the Raisen District and from 400 to 5,000 m^2 in the Hunsgi-Baichbal Valley (Figure 11.11). In a restricted number of other cases, occurrences are much smaller, measuring only *c.* 50 m^2. In terms of numbers of objects, three-quarters of the Hunsgi-Baichbal occurrences contained 200 objects or less. The remainder of the occurrences consisted of small scatters of few objects or concentrations of several hundred to several thousand pieces. Habitats with a perennial water supply appear to have been intensively or repeatedly visited, as is indicated by the high density of occurrences, the large horizontal size of these localities, and the high number and range of artefact types produced from a variety of locally available and distant raw materials (Paddayya and Petraglia 1993). Other occurrences near seasonal streams and ponds tend to be smaller in horizontal size, with lower numbers and ranges of stone tools, which suggests limited use. Based on inferred seasonal changes in the distribution of water, plants and animal resources, induced by the periodicity of the monsoon, two behavioural patterns were hypothesized: dry season coalescence of groups around scarce water bodies (e.g.

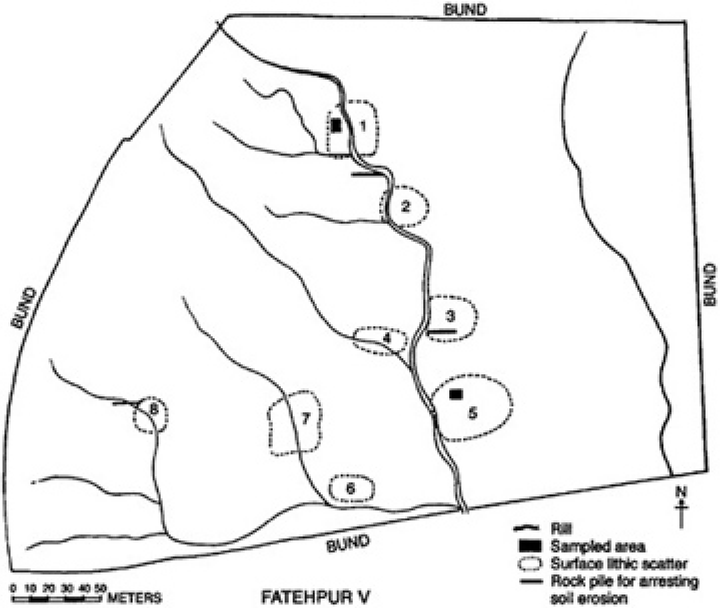

Figure 11.11 The Fatehpur V Locality showing multiple occurrences.

springs), and group dispersion during wet periods, when a diversity of resources were present (Paddayya 1982). Recent testing at the Isampur locality in the Hunsgi Valley suggests that hominids may have been attracted to areas where vital resources overlapped. In this particular spot, high-grade limestone for stone tool manufacture was present, coupled with natural springs. Uneven spatial distributions of occurrences and varying artefact densities and types in the Hunsgi-Baichbal Valley may therefore represent, in many circumstances, hominid activities across varying local habitats. This may be supported by examining the variation in lithic artefact attributes. At Isampur, the limestone artefact assemblage was dominated by primary stage reduction pieces, including large flakes and large and unfinished bifacial handaxes and cleavers. At a basalt source, boulders appear to have been split, resulting in large flake production. By contrast, occurrences away from particular raw material sources tend to contain intermediate and final stage reduction debris, and a larger range and varying frequency of raw materials and stone tool types (Paddayya and Petraglia 1993) (Figures 11.12–13). For example, large limestone bifaces have been found at outcrop sources and as a concentration in a confined area some distance from the outcrop; the latter case was interpreted to represent a cache (Figure 11.14a). This contrasts with more common bifaces of intermediate and small size found throughout the valley, which may represent intermediate and final stages of rejuvenation and use (Figure 11.14b–c).

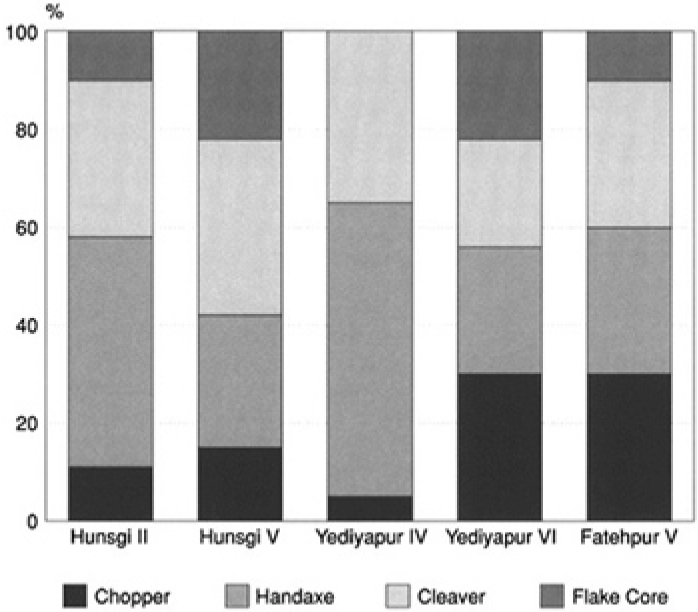

Figure 11.12 Percentages of artefact types for Hunsgi-Baichbal Valley occurrences.

Recent survey and testing in the Malaprabha Valley have shown that an extensive Pleistocene landscape with acheulain assemblages is preserved over several kilometres. The Malaprabha investigations have shown that buried assemblages occur in deposits associated with colluvium at the base of quartzite outcrops and active springs. The extensive nature of the Acheulian assemblages shows that these were favourable environments, where both raw material and fresh water converge. Whilst much more rigorous study needs to be concentrated on examining artefact distributions across palaeolandscapes, the foregoing investigations have shown that Pleistocene land surfaces may be defined, the distribution of Lower Palaeolithic artefact assemblages may be identified, and associations between occurrences and palaeohabitats may be established.

CONCLUSION

This review has attempted to demonstrate that the Lower Palaeolithic record of India is a testament to the colonization and adaptation of hominids to a unique and significant area of the Old World. Whilst an attempt has been made to synthesize the most significant research on the Pleistocene of India, it should be kept in mind that India is a large geographic landmass, as large as Europe or the East African Rift Valley. As a consequence, future studies should be directed towards highlighting the palaeoanthropological and environmental diversity that was probably present in India's physiographic provinces.

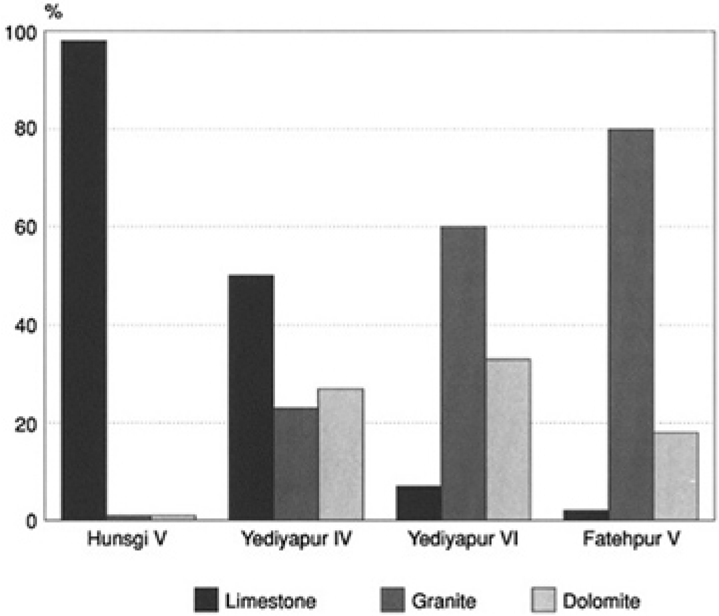

Figure 11.13 Percentages of raw material types for Hunsgi-Baichbal Valley occurrences.

Important in assessing the earliest colonization of India, accumulating archaeological and fossil evidence indicates that hominids radiated out of Africa sometime during the Late Pliocene to Early Pleistocene. The most secure record of occupation of India currently places hominids there by the middle part of the Middle Pleistocene (Figure 11.15). However, tantalizing data from India suggest a lengthier chronology, perhaps into the early stages of the Middle Pleistocene. Fossil and archaeological evidence from the Near East, eastern Asia and Indonesia combine to suggest an older chronology for the colonization of India, possibly in the Early Pleistocene. If preservation conditions or archaeological sampling are shown not to be the cause for the absence of early sites, it is also possible that the lack of identified occurrences in Early Pleistocene or Early Middle Pleistocene contexts, and the wealth of sites in the mid-Middle Pleistocene, may be due to population variances or the relative success of hominids in adapting to environments. Another possibility is that migrations occurred later in India compared to western and eastern Asia, with geographic barriers, such as the Himalayas, preventing southerly advances. Fossil evidence from primary Pleistocene deposits is currently meagre, although this review suggests that, with systematic and careful surveys of low-energy settings (e.g. travertines, paludal deposits), it may be possible to identify mammalian and hominid fossils in good context (see also Kennedy 1980).

There is evidence for Mode I core/flake industries in India, although the current archaeological evidence is not entirely secure, and the precise temporal

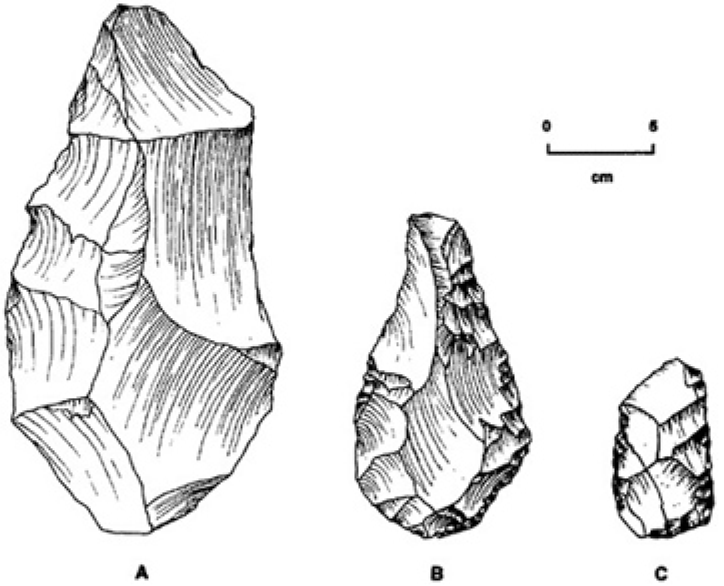

Figure 11.14 Limestone bifaces from the Hunsgi-Baichbal Valley showing size variations.

and spatial relationship of these assemblages to the Acheulian, or to those industries of the Near East and eastern Asia, remains unknown. The existence of Mode I industries may be the product of early stages of human occupation prior to the advent of the biface industries, functional aspects of a biface industry, or a different industry for which a relationship to the bi-facial technocomplex cannot currently be drawn. It is abundantly clear that a widespread biface industry is present in India, and the artefact forms are representative of Acheulian technocomplexes found also in Africa, the Near East and Europe. As elsewhere in the Old World, it appears that this bifacial stone tool technology changed through time, employing more sophisticated flaking techniques and utilizing the soft hammer technique more frequently in later stages. The diversity of Mode I and Mode II assemblages in India raises a number of questions about the relationship and meaning of these industries. In some respects, the Indian stone tool assemblages show similarities to those of the Near East, inclusive of both the Mode I and Acheulian, as well as Mode I and Mode II industries in China. As a consequence, this review suggests that the traditional Mode I–Acheulian dichotomy may not be entirely satisfactory for characterizing assemblages in India and Asia. Due to the array of technologies present in India, major questions therefore remain concerning the relationship of industries with the colonization process and with cognitive and adaptive evolutionary processes. India plays a central role in investigating technological relationships because the landmass is at

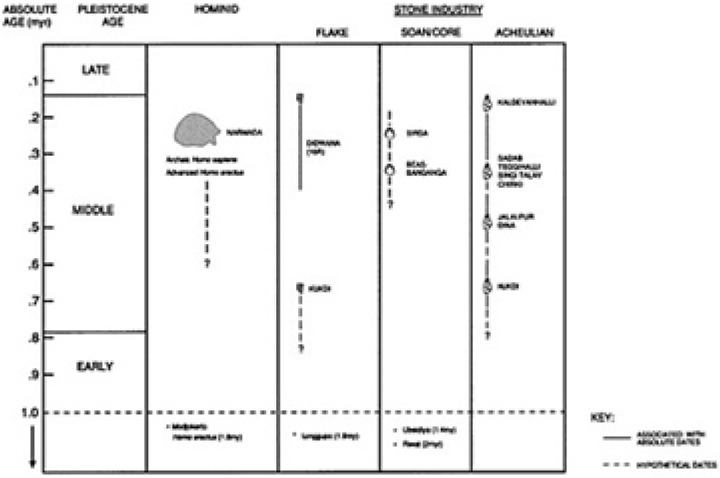

Figure 11.15 Composite chart showing chronology, hominid find, and archaeological evidence from India and Pakistan. The earliest evidence from the Near East and Asia indicates the potential age of India's record.

the cross-roads between continents and forms the dividing ground between traditionally recognized core flake and biface industries. As demonstrated in this review, research must be devoted to the relationships between activity, raw materials and stone tool industries, prior to interpreting Lower Palaeolithic typologies from the perspective of regional stylistic variations or cognitive abilities. Certain technological evidence indicated that archaeologists must be careful not to make simplistic correlations between artefact types and hominids, ages, cognitive abilities, etc. For example, the connection made between raw material and biface size and shape parameters in the Hunsgi-Baichbal Valley is significant, indicating that factors having to do with settlement and economic activities must be dealt with before sweeping biological and behavioural generalizations can be made.

Regardless of the meaning of typological patterns, it is certain that during the mid- to Late Middle Pleistocene, hominid populations occupied all geographic areas of India, adjusting to a variety of environments and local ecological settings. The abundance of stone tool assemblages over local Pleistocene landscapes shows that hominids adapted to an ecological mosaic. Diachronic shifts in palaeoclimates, longitudinal and latitudinal fluctuations in the palaeomonsoon, and marked annual seasonal changes in rainfall would have had a profound effect on long- and short-term hominid adaptation. Environmental changes of the Thar Desert have been demonstrated, for example, thereby influencing ecological adaptations made by hominids. Since India preserves unique Quaternary habitats, physiographic landscapes and resource bases, archaeologists should be able to study successfully hominid landscape foraging and activities in different settings. The distribution and variability of Lower Palaeolithic occurrences and stone tool assemblages should prove to be productive for studying hominid adjustments to local resource bases. The variability among valleys and basins in resources such as raw materials is dramatic; thus, local circumstances are likely to have strongly influenced patterns of economic behaviour. India preserves a variety of Lower Palaeolithic sites in various contexts, including rockshelter and open-air contexts. Both contexts have demonstrated that sites may be preserved intact, with buried localities having been identified in some areas (e.g. Bhimbetka, 16R dune, Hunsgi-Baichbal Valley, Malaprabha Valley). Buried localities and intact surface or near-surface occurrences have the ability to produce data on settlement and mobility patterning. Further, certain occurrences have shown that intra-site patterning exists, and these may be the result of activity-set differentiation.

In sum, the Indian evidence offers a wide range of research opportunities for palaeoanthropologists. Given India's central geographic position between Africa, the Near East and eastern Asia, the country should play a key role in elucidating important aspects about the colonization process and subsequent failures and successful adaptations to changing environments. Whilst significant data have been gathered during the past several decades, much information about the Lower Palaeolithic remains to be collected, and specifics about hominid behaviours and activities remain to be addressed. Future research must be devoted towards reconstructing chronologies, past environments, technological patterns and hominid activities across time and space. This will require focused and long-term multidisciplinary projects, employing systematic surveys over wide areas and careful excavations in sound contexts.

NOTE

1 A similar argument has been made in a comparison of the Chopper-Chopping Tool industry of China and the Acheulian of India (Leng 1992).

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Phil LaPorta are acknowledged. In this wide review of the Asian evidence, there are bound to be errors of fact and representation, thus my apologies to all those whom I offend or whose data I may have mischaracterized.

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12

Lower Palaeolithic occupations in Nepal in relation to South Asia

GUDRUN CORVINUS

INTRODUCTION

Nepal was, until recently, a blank page on the world prehistory map, apart from a few polished stone axes found without stratigraphic context (Banner) ee and Sharma 1969; Sharma 1983). Although Joshi (1964) conducted prehistoric investigations in the Kathmandu Valley, and Bannerjee (1969) recorded artefacts in Chitwan in the southern part of the country, it transpired that the items were natural river-worked pieces and not artefacts. These were, however, the first attempts at looking into Nepal's prehistoric past.

Nepal's neighbouring country, India, is rich in prehistoric records from the Lower Palaeolithic onwards, and much research has been carried out there (see Korisettar and Rajaguru; Petraglia, this volume). Nepal is separated from the Indian peninsula 'mainland', from where most of the prehistoric occupations are recorded, by the wide expanse of the Indo-Gangetic Plains, which is filled with young alluvial sediments. Any remains of older prehistoric occupations that once may have existed in this area have therefore been deeply buried under sediments. This has created a natural hiatus in the record of older Palaeolithic occupations in this wide strip of area between the peninsula and Nepal, but settlements and migrations certainly must have taken place there, and further it may be assumed that Nepal, particularly in the Himalayan foothill valleys and the mountainous foothills, was prehistorically occupied.

With the idea that Nepal should preserve a prehistoric record, the author conducted geological and archaeological investigations in the Siwalik foothills, beginning in 1984. The result was, apart from the biostratigraphical data published elsewhere, the discovery of a great wealth of prehistoric sites from the Lower Palaeolithic to the Neolithic periods in various parts of the country (Corvinus 1985, 1993, 1995a). Prior to the Nepal investigations, the author worked on the Lower Palaeolithic in India and excavated an extensive Acheulian site at Chirki-on-Pravara (Corvinus 1983). Therefore it was particularly intriguing to determine whether Lower Palaeolithic populations, especially handaxe producing groups, crossed the Indo-Gangetic Plains and entered the Himalayan foothills in Nepal. A number of large tectonic dun valleys occur within the Siwalik belt of the Lower Himalayas, which nowadays have a mild climate and lush vegetation, making them very favourable for human occupation. A survey was therefore undertaken to determine whether prehistoric environments conducive to Palaeolithic occupation were present.

THE GEOLOGICAL BACKGROUND

The areas under investigation lie within the Siwalik belt of the Himalayan foothills in Nepal, which stretch along the entire Himalayan mountain front from Pakistan to Assam. The Siwaliks contain a 5,000 m thick sequence of molasse deposits of Late Miocene to Early Pleistocene age, which were deposited into the foredeep in front of the rising Himalayas. These foreland deposits were then folded and fractured in geologically very young times in the earlier Pleistocene, and were uplifted to form the youngest and southern-most Himalayan range of mountains: the Siwalik foothills.

Large, so-called dun valleys were formed during tectonic movements within the Siwaliks and these were later, in Pleistocene and Holocene times, filled up by thick alluvial sediments of lacustrine and fluvial deposits, and still later by swamp environment deposits. Prior to the current study, the stratigraphy of the dun valley alluvium was not known. Basic research had to be carried out to establish the stratigraphic background of the valleys for the interpretation of the prehistoric findings. The geology is only briefly discussed here (Table 12.1) but treated in greater detail elsewhere (Corvinus 1995a).

The two large dun valleys of Dang and Deokhuri (Figures 12.1 and 12.2) both measure about 50 km in length and between 10 and 17 km in maximum width. The valleys are seperated by the Siwalik hills from the young, flat Indo-Gangetic Plains, and are drained by E–W running rivers, the Babai and the Rapti Rivers respectively. A smaller valley, the Tui Valley, is an appendix to the large Dang Valley and reflects very similar alluvial strata. The Dang and Tui valleys lie at an elevation of an average of 650 m above sea level, and Deokhuri lies considerably lower, at 250 m.

The valleys were filled in during the Pleistocene by thick alluvial, stratified deposits of the so-called Babai Formation (Corvinus 1995a), accompanied along the marginal flanks at the foot of the hills by unstratified fan-like silt deposits. The deposits of the Babai Formation form the older infilling of the valley, with terrace elevations of 20–40 m above river level in the southern Dang and in the Tui Valley (Figure 12.3). The deposits consist predominantly of stratified lacustrine sediments and to a lesser degree of fluvial deposits as lateral influxes from the Siwalik hills. The southern part of the Dang Valley, and also the Tui Valley, must have been occupied by a lake or lakes during the later part of the Pleistocene; the water bodies were probably formed by blockage of river drainage due to tectonic movements.

Table 12.1 Chronological succession of Nepal industries.

Period	*Industry*	*Stratigraphic context*
	Polished axes, cord-marked pottery (Brakhuti, Gadari)	In terrace-top grey soil. Date at Gadari: 1.6 kyr
Microlithic industry (of chert and quartz), no pottery (Lamahi, Bhatarkund, Ammapur)	In subsurface of 30m terrace in Deokhuri dun valley	
Patu industry of adzes and choppers at Patu, East Nepal	In red soil of 60 to 80 m terrace of Rato River; date: 7 kyr	
Chabeni industry of unifacial adzes	Alluvial terrace at Siwalik Hill foot	
Brakhuti industries with flakes, choppers and core-scrapers, made of quartzite, very common (Gidhiniya, Brakhuti, Gadari, Masuria, Lalmatia, Gairakhuti and other sites)	Upper 30 m levels of colluvial silts and alluvial clay/silts of Babai Formation in Dang and Tui and 60–80 m river terraces of Arjun and Mashot River	
Arjun 3 industry of prepared flakes, blades, points, scrapers and Levallois-like cores	At base of 8 m alluvial silt of 30 m terrace of Arjun River in Deokhuri dun valley; older than 30 kyr	
End-chopper and heavy duty industry of quartzite (Lape, Sampmarg)	Below red soil of the 25 m terrace of Babai River in Deokhuri dun	
Brakhuti-West flake site, with large flakes, cores up to 30 cm in size and a uniface	In basal cobble-boulder gravel below banded silt succession in the Tui Valley	
Gadari handaxe industry with handaxes, cleavers, flakes, made of quartzite	In basal gravel above bedrock below banded clay/silt succession in Dang dun valley	
Satpati handaxe site	In folded alluvial sandstones at the Himalayan foot, folded by the last tectonic event	

A younger alluvial sequence is present, the Sitalpur Formation, consisting of fluvial sediments and swamp environment black clays and lignites. This deposit is inset into the older alluvium and forms the lower, widespread surface of 10 to 15 m above river level, which constitutes the major cultivated part of the valley and which so far has not yielded any prehistoric remains. A lignite/clay profile at Sitalpur in southern Dang has yielded radio-carbon dates with ages of 13,270

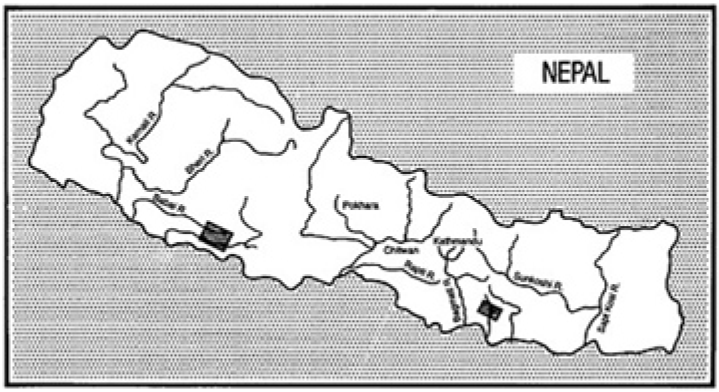

Figure 12.1 Map of Nepal showing areas of investigation.

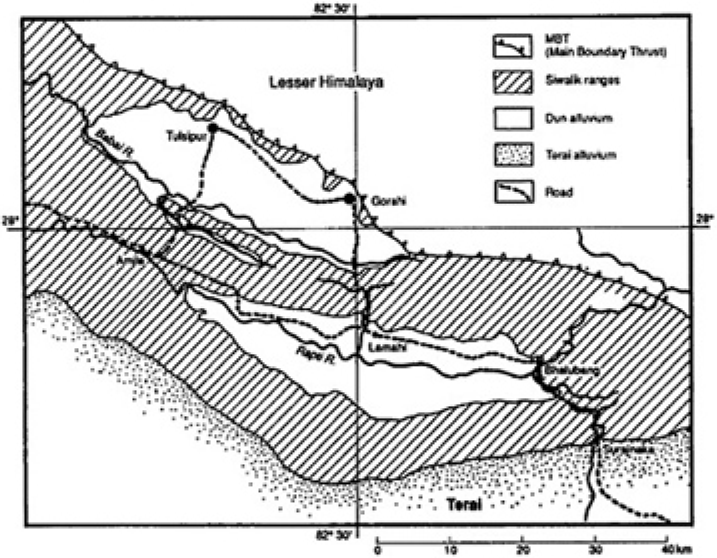

Figure 12.2 Map of the two dun valleys of Dang and Deokhuri in western Nepal.

±190 (BSIP No. BS-1008) from 1.8 m below the terrace surface, and 15,320±280 (BSIP No. BS-1009) from 3.3 m below the surface (Sarkar, pers. comm. 1995).

As the sediments of the Babai Formation are quite unconsolidated, and as recent erosion induced by the indiscriminate deforestation is very strong, the alluvium along the valley flanks has been dissected to such an extent that a desert-like badland topography has developed. The erosion has washed away much of the sediment and thus has exposed many prehistoric sites that had been embedded in the valley alluvium. Prehistoric occupation of the valleys appears to have been abundant, as a great number of sites found during the survey have their stratigraphical position in these sediments. Most of the sites come from the

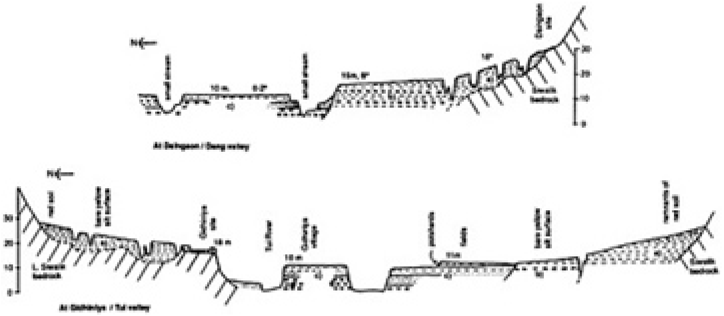

Figure 12.3 Cross-section of the Dang Valley at Daingaon (above) and the Tui Valley at Gidhiniya (below). Above: a) and b) Babai Formation; c) Sitalpur Formation. Below: a) the unstratified marginal silts along the Siwalik slopes; b) the stratified clay/silt succession of the older alluvium; c) the inset, younger 10–15 m terrace alluvium of black clays, lignites and overlying sands.

uppermost part of the clay-silt succession, as well as from the unstratified silts along the foot of the hill slopes in all three valleys of Dang-Deokhuri. It seems that prehistoric occupation was concentrated on the bank of the lakes and streams on the southern border of the Dang Valley and in the Tui Valley, as well as along the northern and southern margins of the Deokhuri Valley. The oldest horizon of the Dang Valley alluvium seems to reach back into the Middle Pleistocene, as bifaces in the Indian handaxe tradition could be recorded from a basal gravel above bedrock below the older alluvium of the Babai Formation.

THE PREHISTORIC RECORD FROM THE DANG AND DEOKHURI VALLEYS

The establishment of a geological succession was considered to be an important goal for placing archaeological assemblages in proper context. During the course of the survey more than seventy localities of Palaeolithic to neolithic origin were located in the Dang-Deokhuri area (Figure 12.4), twenty-three in Dang, fifteen in Tui, thirty-three in Deokhuri and five in Mashot. Of these, the majority belong to a late to terminal Pleistocene industry, and only a few date to the Lower Palaeolithic. Most sites were discovered on the surface, but these are, in fact, eroding out from strati-graphic contexts within the older alluvium. Erosion is both exposing and destroying the sites. The erosion is of a badland type, with vertical cliffs, cut down to bedrock, destroying the original terrace surfaces. The block in Figure 12.5 is now sensationally perched on a preserved silt column of the original terrace.

Below the dissected alluvium of silts and clays on bedrock, there is, at places, a gravel which at Gadari in Dang has yielded handaxes. These handaxes would have remained undetected without the strong erosion. Though most of the

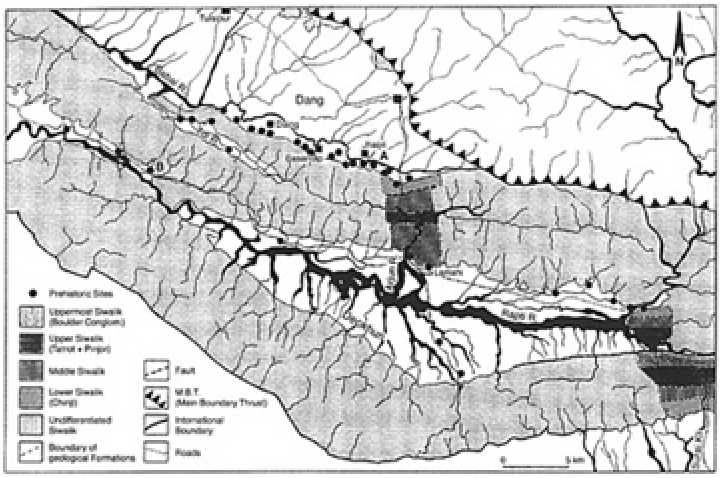

Figure 12.4 Part of the Dang and Deokhuri valleys with sites indicated.

artefacts of this assemblage are now found on the surface, one arte-fact was still embedded in the gravel (Figure 12.6). Based on these finds, it is certain that Lower Palaeolithic occupation occurred here, before the alluviation of the Babai Formation, on the bank of the ancient Babai River. The bedrock of the ancient river bed disclosed fossil water-cut rills. The site was later buried by the lacustrine and fluvial sediments of the Babai beds, which filled the valleys up to the rim. The extent of this infilling can still be seen when one descends from the southern hills into the Dang Valley (Figure 12.7).

In the Tui Valley, an industry of very large flakes and cores without handaxes was recovered from the basal alluvium of a quartzite cobble-boulder gravel. The artefacts occurred below the stratified silts and clays of the Babai Formation at Brakhuti W, and became exposed recently by erosion. In the eastern Deokhuri Valley, the Palaeolithic site of Sanpmarg on the Rapti River was found *in situ* within the older terrace deposits of the Rapti River. The terrace surface has been dissected to a great degree, exposing a site with predominantly large, unifacial end-choppers, made on large, oblong cobbles of quartzite. They derive from a level within the silts below the red soil cover, some 5 m below the terrace surface where a red-brown palaeosol underlies a yellow silt. It is from the top part of the lower red-brown palaeosol that artefacts of possible Lower Palaeolithic age were recovered. Thermoluminescence (TL) samples have been taken recently from this site, but dates are not yet available. In the Deokhuri Valley, the site of Arjun 3 was recovered, which appears typologically to belong to the Middle Palaeolithic, with prepared Levallois-like cores and blades and flakes from prepared cores. The artefacts (Figure 12.8) occur eroding out from the base of an 8 m thick alluvial silt of the oldest 30 m terrace deposits of the Arjun River. The silt is overlying fluvial gravels and bedrock and is covered by a deep-red, weathered soil on its surface. TL dates from the soil profile at Arjun 3 gave

Figure 12.5 Badland topography of the dissected alluvium of the Babai Formation in Dang. The large block of Siwalik sandstone prevented the erosion of the underlying silt.

preliminary ages from 29.5 to 10 kyr (Zoeller, pers. comm. 1995) at respective depths of 20 cm and 2.50 m below the red surface. These preliminary dates indicate a considerably older age for the Arjun 3 site at a depth of 8 m.

A more continuous occupation is apparent from the Late Pleistocene onwards, but this will not be discussed here, except to note that it includes heavy-duty cobble tools, which in northwest India have always been interpreted to be a characteristic of the Lower Palaeolithic. The majority of these localities in Nepal, however, belong to a younger Palaeolithic industry, as they derive from the uppermost level of the succession of the Babai beds (see Figure 12.9). This industry, the Brakhuti industry, invariably exhibits the same characteristics, with rather unrefined, unretouched flakes and with cobble tools of unifacial choppers and core-scrapers, but with very few flake tools. The flakes are always associated with large cobble tools of choppers and core-scrapers, and the flakes seem to be predominantly manufacturing flakes for the large cobble tools. Collectively, these sites belong to populations who had very similar lithic requirements and manufacturing techniques. These groups needed heavy-duty choppers and core-scrapers and rough flake assemblages employing distinct techniques. It seems apparent that their tool kit reflects heavy wood and bamboo work. The sites are so abundant that it is assumed that the population was much denser than during the earlier Palaeolithic period. The occupations occurred in the Himalayan foothills when the climate must have been cooler and the vegetation less thick than during the Holocene, though a forested habitat is envisaged, judging by the heavy-duty cobble tools. Very similar industries with unrefined flakes and choppers (but apparently without core-scrapers) have been recorded from the Soan industry in the foothills of northwest India, though not in stratified contexts. In Nepal, however, it appears that these assemblages are of much later age, as

Figure 12.6 The Gadarai handaxe site, Dang: a core *in situ* in the basal gravel.

indicated by their stratigraphic position in uppermost terrace deposits that just predate the microlithic advent. The cultural material from these levels seems to date from the later Pleistocene in the Dang, Tui and Deokhuri valleys, considering the Terminal Pleistocene age of the lignites of the Sitalpur beds of the lower 10–15 m terrace. TL samples have recently been taken from the upper silts of the Babai succession in Dang and Deokhuri in order to establish a time frame for the deposits in which the occupations of the Brakhuti industry occur, and in order to understand the ages of the heavy-duty cobble tools in comparison with those from northwest India. A number of sites in all three valleys are of a microlithic industry, and they exhibit elements of the Indian microlithic tradition without pottery. It is probable that these microlithic sites belong to the later Pleistocene and not the Holocene. The youngest prehistoric occupation of the Dang-Deokhuri valleys dates to the Neolithic.

The sites discovered during the survey show a wide temporal and geographic range. As opposed to the previously unknown prehistoric record, Nepal now proves to be a region with a rich heritage. The survey of the last twelve years shows that Nepal was occupied from the Lower Palaeolithic to the Neolithic (see Table 12.1).

Figure 12.7 View into the Dang Valley, Dang.

LOWER PALAEOLITHIC OCCUPATION IN NEPAL WITH REFERENCE TO NORTHWEST INDIA AND NORTH PAKISTAN

The earliest occupations in Nepal are marked by characteristic bifacial handaxes. These localities are rare, however, as only two sites have been recorded, one in Dang Valley and one at the Himalayan front, at Satpati near Benighat, where the Narayani River merges into the plains. The handaxes from Dang were located near the Gadari temple and opposite the Jhaijri village on the south bank of the Babai River in the southern Dang Valley. Their position is in the basal gravels of the Dang alluvium, and they therefore belong to the oldest period of the dun valleys. The gravels are overlain by heavily dissected silts which belong to the stratified alluvial sediments of the Babai Formation (Figure 12.10). The bedrock below the handaxe-bearing gravel is uneven, and indicates dissection by erosion prior to the deposition of the gravel. The groups would have lived close to the ancient river bank.

The Dang handaxes were made from quartzite cobbles or large flakes by large primary and smaller step flaking. One biface is a small oval handaxe, with a jagged bifacial edge around the circumference, and a rounded point with some cortex left on its upper face (Figure 12.11, below). Another handaxe is a larger, flat biface made on a flake and trimmed with shallow primary flaking and smaller step-flaking, producing a rather straight edge around the circumference (Figure 12.11, above). The oval, flat handaxe is made with fine, very shallow primary and secondary flaking over the upper face, and it has a straight, bifacial edge along the circumference. An oval, unfinished handaxe, a pick, a large cleaver, and a number of large cores and flakes have also been found. The assemblage is small, yet it indicates the diversity of tool types of this Lower Palaeolithic assemblage. The handaxes are made in the Indian Acheulian

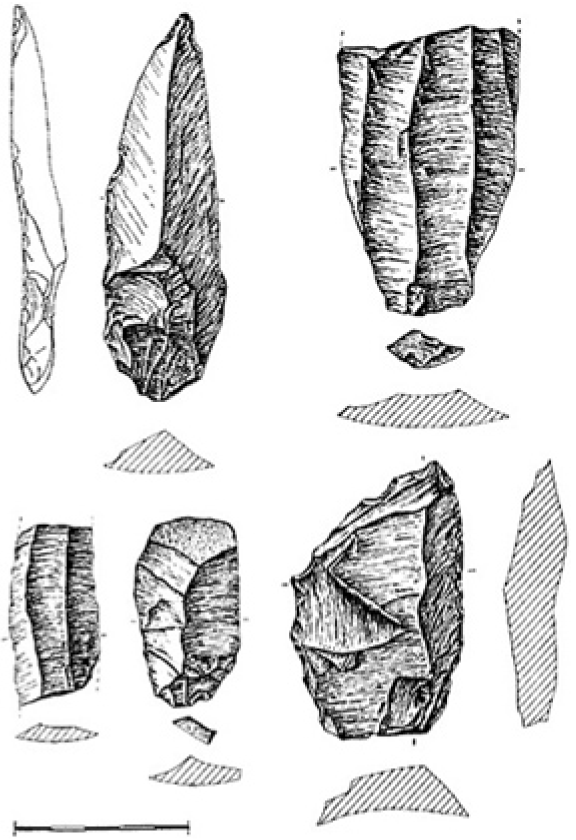

Figure 12.8 Artefacts from the Arjun 3 site, Deokhuri.

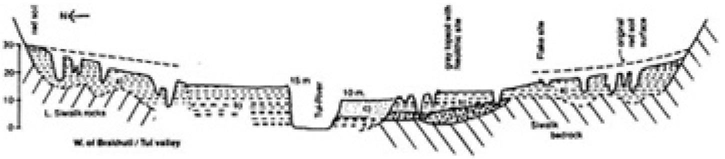

Figure 12.9 Cross-section of the Tui Valley at the Brakhuti site, a) the unstratified marginal silts along the Siwalik slopes; b) the stratified clay/silt succession of the older alluvium; c) the inset, younger 10–15 m terrace alluvium of black clays, lignites and overlying sands.

tradition, suggesting migrations from India. In spite of the systematic search for prehistoric occupations in Dang-Deokhuri, this is the only Lower Palaeolithic biface site in the area.

The Satpati handaxe site is situated at the very foot of the Siwalik range, in Lumbini District, west of the Narayani River where it emerges from the

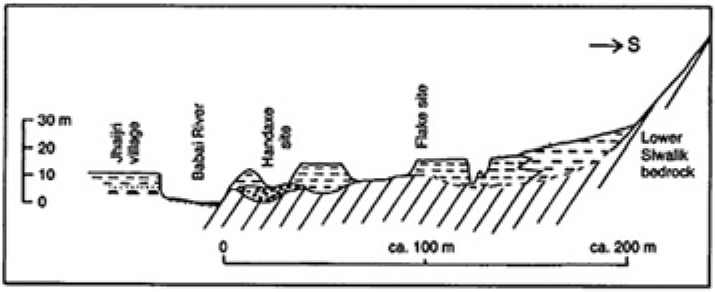

Figure 12.10 Profile at the Gadari handaxe site, Dang.

mountains into the Terai plains. This site was discovered in 1991 in folded alluvial sandstones and gravels of the Gangetic alluvium, which was included into the tectonic activities of the last phase of the Himalayan uplift and folding, thus becoming exposed by the folding (Figure 12.12). The original locality of the occupation, before it became uplifted, was on the plains near the mountain front, some 200 m below the recent alluvial surface of the plains, where it was buried by later alluvial sediments. The site became exposed from its buried position only due to the tectonic uplifting and folding movements of the Himalayas in very recent times, most probably in the Late Pleistocene. The bifaces (Figure 12.13) are made from quartzite, and are similar to those fashioned from the same materials in India. Altogether, eighteen Palaeolithic artefacts have been collected from the slope of the Satpati Hill deposits, together with a tooth of *Bos namadicus* and some unidentified limb bone fragments with a matrix of micaceous sandstone in their cavities. One of the bifaces was extracted *in situ* from the sandstone. The artefacts have been described in detail elsewhere (Corvinus 1995b). The assemblage is not large, but it is important as it is the first incident known where Palaeolithic material from the Indo-Gangetic Plains has been involved in orogenetic movement. In addition, it has established the fact that these tectonic movements are young.

A large flake-core industry of probable Lower Palaeolithic age, occurring within a basal cobble gravel below the alluvial stratified silts and clays in the Tui Valley at Brakhuti (Figure 12.14), is enigmatic. It does not seem to be related to the handaxe occupations or to any other population in the Dang-Deokhuri. Its position in a gravel below the stratified silts makes it older than all the other sites from Tui. The artefacts are all made in quartzite and comprise unusually large, unretouched flakes and huge cores, as well as a well-made uniface, and a few large scrapers (Figure 12.14). Of the forty flakes collected from this site, 13 per cent are larger than 20 cm and 68 per cent are larger than 10 cm. Similar artefacts are recovered almost everywhere in the Tui Valley where this cobble-boulder gravel is exposed above bedrock and below silt.

These definite, though scanty records of Lower Palaeolithic populations in the Himalayan foothills in Nepal indicate that Lower Palaeolithic groups probably

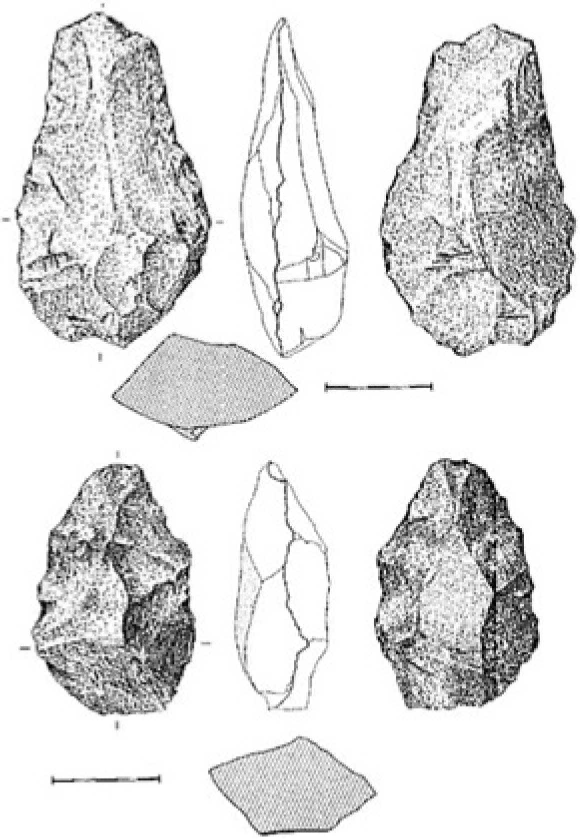

Figure 12.11 Handaxes of the Gadari site, Dang.

crossed the Gangetic Plains and migrated into the Himalayan foothills. These incidences show that Palaeolithic populations occupied the lower Himalayan mountains as Early as the Middle Pleistocene, although an absolute age cannot yet be given to these assemblages. Handaxe production is supposed to have ended by about 100 kyr ago in Africa and probably also in India. Such a datum line may give an indication of the approximate age of the oldest definite prehistoric occupations in Nepal during the early post-Siwalik alluviation of the dun valleys.

The occurrence of handaxes in the Siwalik Hills in Nepal shows that Palaeolithic occupation has a greater antiquity than hitherto expected. The industries point to connections with the handaxe industries in India, where they are abundant. They are the northeastern-most handaxe occurrences of the Indian subcontinent. These Lower Palaeolithic handaxe occurrences are situated well within the lower Himalayan mountain ranges, and they indicate that Lower Palaeolithic groups not only migrated to the foot of the mountains but penetrated

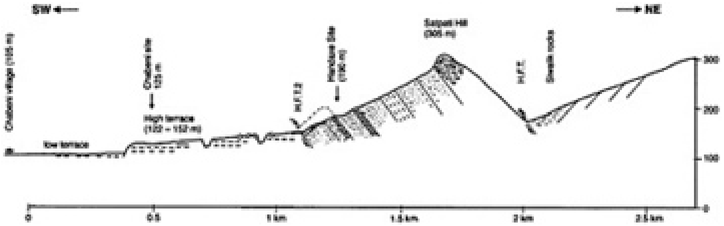

Figure 12.12 Profile of the handaxe locality of Satpati Hill.

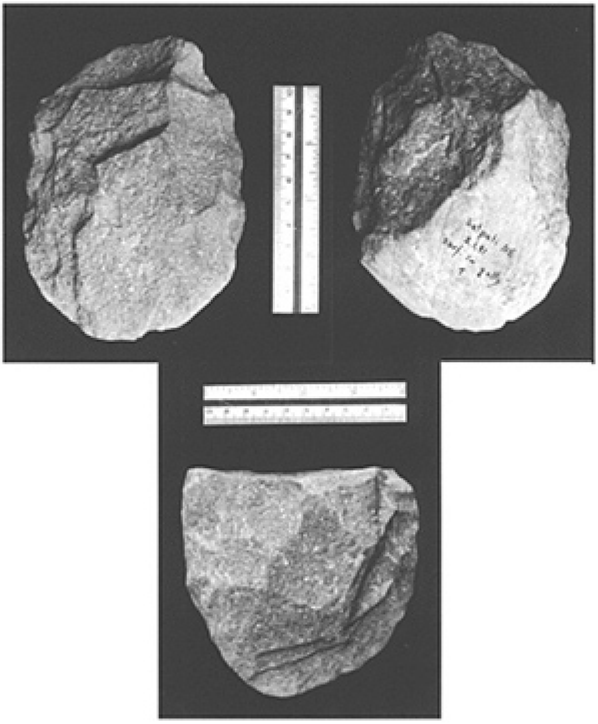

Figure 12.13 Bifacial tools from Satpati.

into them. The climate and vegetation must have been favourable during those migrations. This may have occurred during the last-but-one glacial period, when the Himalayan front was not so densely forested as it must have been during interglacial periods. The high Himalayan snow range to the north formed the northern impenetrable boundary of the extension of the handaxe cultures of the African and Indian tradition.

In India, the Acheulian handaxe industry is very widely distributed in the subcontinent south of the Indo-Gangetic Plains. The northern-most occurrences of Acheulian bifaces south of the Gangetic plains are those recorded recently by A.K.Sharma (1993) just south of Delhi. In northwest India, along the Himalayan

Figure 12.14 The cobble gravel at Brakhuti W, Tui Valley, containing large flakes and cores (above and centre). The large flakes and cores within the gravel (below).

foothills in Himachal Pradesh and Haryana, which is the area of the chopper-dominated Soan industry (de Terra and Paterson 1939), Acheulian bifaces are rare and in fact have only recently been reported (Mohapatra 1981, 1982) in the area north of Hoshiarpur and near Pinjor north of Chandigarh (Kumar 1995). J.C.Sharma (1977) also reports handaxes and cleavers from Upper Siwalik conglomerates 10 km northwest from Chandigarh near Mullanpur, but Mohapatra (1981) refutes these discoveries as being without substance.

Acheulian occurrences have also been reported recently from the Himalayan foothills in the Potwar area in Pakistan, where the Soan River valley is the type location of the Soan (de Terra and Paterson 1939). Recently, teams have resumed intensive investigations there, and have reported handaxes in geological context, dating them to 700–400 kyr (Rendell and Dennell 1985; Rendell *et al.* 1989). Apart from these recently identifed Acheulian occurrences, sites in the Himalayan front in northwest India and Pakistan have, since de Terra and Paterson (1939), been described as being the home of populations who manufactured the Soan Chopper-Chopping tools with associated simple flakes. This concept has to be reconsidered in light of the recent biface discoveries.

In the foothills along the Himalayas in northwest India, artefacts of the Soan industry have been reported by a number of researchers (Sen 1955; Lal 1956, 1979/80; Mohapatra 1966; Joshi 1968; Sharma 1977). The Early Soan, as described by Sen (1955) and Mohapatra (1966), consists of mainly unifacial but also bifacial choppers of medium size and usually round shape, which show occasionally well-controlled flaking. They are accompanied by simple, unrefined and unretouched flakes with wide platform angles. Their platforms are unprepared, and Sen mentions them to be predominantly cortical, whilst the dorsal faces retain much cortex. The Early Soan is supposed to be of Lower Palaeolithic age, though there is no stratigraphic or dating control. They are recorded from the surface of the higher river terraces, including along the Beas, Banganga and Sirsa rivers. Mohapatra (1966) describes an advanced Soan industry from the Sirsa Valley, also from the surface, with smaller and better trimmed, usually round choppers and prepared flakes and thick blades, a fine uniface and bifacial discoids. He also records an industry, made of chert and not of quartzite, with prepared but unretouched flakes, made from small pebbles/ cobbles that resemble miniature choppers, again in association with choppers. He describes this latter industry as ‘a regional manifestation of the Soan pebble tool tradition at its very late stage’ (Mohapatra 1966:229). All these occurrences were without Acheulian bifaces, though Gaillard (1994) regards some of the large flake tools from the Beas terraces as ‘cleavers’.

Mohapatra (1981, 1990) later recorded handaxes along the Siwalik foothills near Hoshiarpur and near Pinjor. In the Hoshiarpur Siwaliks, he reports bifaces on ‘various types of Siwalik surfaces (Upper Siwalik formations Tatrot, Pinjor and Boulder Conglomerate) in handful numbers lacking any stratified context’ (Mohapatra 1981:434) on both sides of the range’s crestline. Whilst ‘Soanian artefacts are either few or absent where Acheulian ones are numerous’, Soanian artefacts are found abundantly in the adjacent dun valleys with no Acheulian element at all. He speaks, therefore, of two distinct ecozones for the Acheulian and the Soanian and also concludes that ‘the Acheulian penetration appears to have taken place much later than the period of the Early Soanian’, though nothing was found in stratified context (Mohapatra 1981:435). Lal (1979/80:8) comments that ‘the handaxe-cleaver element is not indigenous to the area but represents an intrusion’ from outside into the chopper-dominated Soan culture along the Himalayan mountains. Kumar (1995:7) comments, however, that ‘in the whole frontal region both these traditions…flourished side by side’, and that the Acheulian element is not an intruder in the region. Unfortunately, there is no stratigraphic control for the handaxe finds in the foothills of northwest India, and thus their age must wait until further research yields datable occurrences.

In Nepal, the evidence is quite different, with the most important fact being that the recorded industries are usually stratigraphically controlled and that a chronological order can be more or less securely established. The evidence indicates that the Acheulian handaxe industry is in fact confined to the stratigraphically oldest horizon in the alluvial sediments of the duns. The handaxes are not associated with choppers, though the assemblage is still scanty. Assemblages with choppers, core-scrapers and simple unretouched flakes (they are not described here as Soan, though they resemble it to some extent) become very common only in later periods higher up in the sedimentary dun deposits. Core-scrapers, as this author has described them from Nepal, seem to be absent in northwest India. The earliest occurrence in Nepal of unifacial choppers of the Soan type (but not of core-scrapers, which appear later) is with a Middle Palaeolithic assemblage at Arjun 3 in the Deokhuri Valley, where they occur together with a prepared flake- and flake-blade industry of a Levallois-like technique. This industry is found in sediments younger than the Acheulian level. All later industries in Nepal contain, as a definite element, unifacial choppers and core-scrapers, and they seem to continue even into the Holocene, as evidenced at Patu in east Nepal, where they occur in association with Hoabinhian-like adzes.

The Brakhuti industry of choppers and core-scrapers, always in association with simple, unrefined and unretouched flakes, is the most common industry in Nepal and is found abundantly everywhere in the dun valleys. It seems to be of a Late Pleistocene age, according to the stratigraphical level in the dun sediments. The chopper/core-scraper element is, in the author's opinion, an indication of the special requirement for heavy-duty tools in a forested habitat along the Himalayan front and in the intermontane dun valleys within the Siwalik foothills during the Late Pleistocene and Early Holocene.

The Lower Palaeolithic chopper industry of the Banganga-Beas valleys is essentially a unifacial industry (Lal 1979/80) as is the Late Pleistocene chopper/core-scraper industry in Nepal. There are very few bifacial choppers, and the core-scrapers are always unifacial. The major question is whether the Early Soan industry of northwest India is indeed of Lower Palaeolithic age, since it has never been found in stratified context. Whether it precedes the Acheulian, or whether it is much younger than the Lower Palaeolithic industries remains speculative. In peninsular India, cobble tools have been found by themselves and in Acheulian contexts (Soundara Rajan 1952; Sen and Ghosh 1960; Sankalia 1978; Jayaswal 1982; Paddayya 1982; Corvinus 1983; Mishra 1994), as well as in later contexts. In Southeast Asia, they form a common tool type from the Pleistocene to the Holocene. It is therefore time to redefine the Soan industry in India and to locate stratified contexts.

From the Pabbi Hills in Pakistan, Dennell *et al.* (1991) and Hurcombe and Dennell (1992) have recorded a pre-Acheulian industry from the Lower Pleistocene of little standardization and little retouch, which the investigators believe to resemble the Soan industry, although they do not, rightly, classify them as such. The investigators claim that this industry is of Lower Pleistocene age, between 1–2 myr, on the grounds that the artefacts, like the fossils, have been found on erosional surfaces of fossiliferous Upper Siwalik deposits that have an age between 0.7 to 2 myr. None has come from *in situ* contexts, and it is noted 'that some of the stone artefacts have eroded from the fossil-bearing horizon and are thus between 1 and 2 myr' (Dennell *et al.* 1991:58). In the absence of profiles or sections some doubt surrounds the geomorphological situation. The investigators record that the artefacts from the older erosional surfaces consist 'predominantly [of] flaked pebbles, cortical flakes, disc cores and flakes with 25% of their cortex remaining' (Dennell *et al.* 1991:53). It does not appear that there are formal tools, bifaces, blades or prepared cores, and it is not certain whether there are choppers as traditionally defined. A conglomerate to pebbly sandstone, which is exposed at several places along the hill flank, 'contains quartzite stones large enough (average 6 cm) to be used for making stone tools' (Dennell *et al.* 1991:58). This restricted size range seems to be too small for making Lower Palaeolithic stone tools. The investigators admit that the artefacts are not necessarily as old as the conglomerate and that 'the stone tools could easily have been made and discarded at conglomerate exposures long after the conglomerate was deposited' (Dennell *et al.* 1991:60). Nevertheless, they believe that the artefacts derive from the fossil bearing Siwalik strata.

Mohapatra (1981) reports Acheulian handaxes on Upper Siwalik surfaces on the hill slopes in the Hoshiarpur Siwaliks that lack any stratified context, but he does not conclude that the bifaces come from the Upper Siwalik deposits. In Nepal, the author has also found quartzite artefacts of simple flakes and core/core-scrapers on surfaces of Siwalik outcrops on slopes and even on hill tops (for example at Raimandal Hill in east Nepal on Upper Siwalik pebbly sandstones) and south of Sanpmarg (in Deokhuri Valley on a hill of Lower Siwalik strata). These artefacts certainly did not derive from the Siwalik deposits, even if one site was on Upper Siwalik strata. No other, younger deposits could have been deposited on these hill tops. A conclusion was that these artefacts were surface finds, maybe of a rather young age, especially since they do not exhibit any classifiable features (they do not contain any formal tools except core-scrapers).

Dennell *et al.* (1988a, 1988b) also reported a few artefacts *in situ* in a gritstone supposed to be older than 1.9 myr, near Riwat on the Soan River, southeast of Rawalpindi. The gritstone horizon from which these artefacts were protruding is within the Upper Siwalik sequence of the gently dipping southern limb of the Soan Anticline. Horizontal beds, including an ash layer dated to 1.6 myr, overlie the Upper Siwalik beds, not on the artefact-bearing southern limb, but on the steeply dipping northern limb of the Soan Anticline some 5 km away, and therefore the underlying dipping beds are assumed to be older than 1.6 myr. The question becomes: can the artefact-bearing horizon on the southern limb be correlated to the dated strata of the northern limb 5 km away? The section with the artefact-bearing horizon has reversed polarity and must therefore be older than 0.7 myr. The folding of the Soan Anticline is supposed to have happened between 2.1 and 1.9 myr according to Johnson *et al.* (1982), and therefore the sediments of the anticline, including the artefact-bearing horizon, must have a minimum age of 1.9 myr. As the strata just below the artefact-bearing horizon have normal polarity, and are supposed to be of the 2.01 myr old Reunion Event, the investigators came to the conclusion that the artefacts are 2 myr old. The situation is complicated, though convincing, apart from the fact that 5 km is a large distance for correlations. The geological situation of the artefact-bearing horizon itself, too, appears convincing according to the monograph plates (Rendell *et al.* 1989), indicating that it is not a reworked horizon. The question remains, however, as to whether the few artefacts, in fact only three, are really humanly made without any doubt.

The evidence from Pakistan certainly challenges traditional notions about the 'out of Africa' colonization model. Similar questions have influenced this author during her last eleven years of geological and prehistorical research in the Nepal Siwaliks. Yet no evidence of artefacts within the Siwalik deposits has come forward, and this fact is certainly not for lack of searching during the twenty-two months of field work in these eleven years. The data obtained by Rendell *et al.* (1989) are also the result of a long research programme, derived from six years of research with twelve months of field work, but they will allow us our doubts until other convincing data have come from other areas in South Asia. There is simply not enough research in South Asia as compared to East Africa, and research missions, like the British work in Pakistan, are desperately needed.

What we can ascertain after the survey of the last eleven years is that the foothills in Nepal were occupied from the Lower Palaeolithic onwards, through various prehistoric periods of the Palaeolithic, Mesolithic and Neolithic. Whether these occupations were continuous or sporadic, interrupted by long gaps of non-occupation, cannot be determined before the results of the analysis of the vast cultural material is finished and further work is done. As far as the data reveal at present, it seems that Lower Palaeolithic occupants were sporadic inhabitants, who migrated from the Indian subcontinent only from time to time during the Lower Palaeolithic. This was probably sometime during the Middle Pleistocene and probably during a cooler climatic period which permitted groups to cross the forested Indo-Gangetic Plains.

CONCLUSION

The Palaeolithic survey of the last eleven years has put Nepal on to the world map of prehistoric occupation. Nepal proves to have been occupied by Palaeolithic populations from the Lower Palaeolithic onwards. This begins with handaxe assemblages in the Indian tradition found in stratigraphic contexts in the basal alluvium of the Dang-Deokhuri dun valleys, and in tectonically folded and uplifted Quaternary alluvium, which became involved in the last phase of the Himalayan orogeny. The Lower Palaeolithic occurrences in the Himalayan foothills in Nepal indicate that there was a link to India in the Pleistocene with migrations of Acheulian groups to the hills. The Himalayas formed the northern boundary of the extention of the classic handaxe industries of the African and Indian tradition.

The relationship between Acheulian occurrences in Nepal and those from the foothills in northwest India as well as from the Pakistan Siwaliks has been reviewed. The controversial issue of Lower Palaeolithic artefacts as old as 1.9

myr in Siwalik deposits in Pakistan has been discussed. In Nepal, no arte-facts have been found in Upper Siwalik deposits, in spite of a determined search. A sequence of Palaeolithic industries could be established in chronological order that would prove that occupation continued through time, but towards the end of the Pleistocene the prehistoric record is more continuous and less interrupted with material and temporal gaps. A wealth of sites proves the presence of a chopper/core-scraper/flake industry in the dun valleys of the Siwalik foothills. The chopper industry is comparable with the Soan industry of northwest India. It is is not, however, of a Lower Palaeolithic age, but much later in time. The earliest choppers of the Soan type in Nepal were found together with a Middle Palaeolithic industry in stratified context. As a consequence of this long-term study, important gaps have been filled in the Palaeolithic occupation of an important geographic area.

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13

Early Palaeolithic quartz industries in China

JIAN LENG

INTRODUCTION

During a significant period of the Pleistocene in China, Early Palaeolithic populations used local quartz cobbles to fashion stone tools. The repeated use of cobbles and pebbles was so pervasive that the whole Early and Middle Pleistocene suite of tool use has been characterized as belonging to a homogeneous 'Chopper-Chopping Tool' industry. Whilst quartz was commonly used to produce Early Palaeolithic tools, the material is not the most desirable type of stone for manufacture, since it fractures in unpredictable ways and options for reduction are limited due to size constraints and its properties. Nevertheless, cobble experiments have demonstrated that quartz is easier to flake and split than are quartzite and sandstone cobbles, making it an attractive raw material (Leng 1992). Because of its unpredictability in fracturing, however, choosing the proper quartz cobble for tool manufacture is of utmost importance.

In this chapter the tool making characteristics of quartz with reference to a number of lithic data sets from Early Palaeolithic industries in China are assessed (Figure 13.1). This topic is of some significance, since quartz tool industries are not rare or unusual in the Chinese Early Palaeolithic. In fact, at certain archaeological localities, e.g. Zhoukoudian, quartz was the preferred raw material. At other sites, however, e.g. Lantian, quartz was used together with other raw materials. Two Early Palaeolithic archaeological localities in which quartz was used as a raw material (i.e. Zhoukoudian and Donggutuo) are discussed first. Four stone tool assemblages (i.e. Lantian, Liangshan, Shilongtou and Bose) are then discussed for which the quartz industry was replicated, using the same local raw material as the Early Palaeolithic knappers. This chapter aims to show variations of stone tool types and techniques among these sites, with special emphasis on examining the relationship between types and techniques on the one hand, and the sizes of the quartz raw material available in each area on the other. This chapter also examines the relationships among quartz industries from diverse locales in two contrasting geological contexts: sedimentary deposits formed along ancient river systems (i.e. Lantian, Ba River; Liangshan, Hanshui

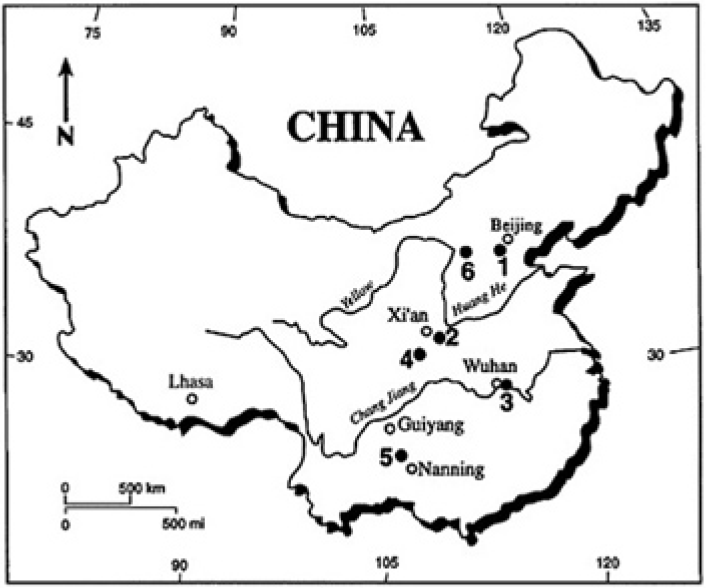

Figure 13.1 Map of China showing site locations. 1. Zhoukoudian; 2. Lantian; 3. Shilongtou; 4. Liangshan; 5. Bose; 6. Donggutuo.

River; Bose, You River; and Nihewan, Sanggan River), and sediment deposits in limestone caves (i.e. Zhoukoudian, Shilongtou).

The major focus of this study was on the tools themselves, so the primary concerns were the stone tool collections and the supporting archival materials in local museums, archaeological laboratories, and store rooms. Access to complete collections was not always possible, and this limitation is acknowledged. Unfortunately, many of the limitations placed on access to the collections are political in nature and will confront all researchers in the foreseeable future. As much information as possible was elicited from the material available, however, and whilst some of the individual samples are small, the sum total of observations makes a persuasive argument.

Geological thin-section analysis was performed on the lithic data sets to furnish information on the type, name, origin, mineralogical make-up and structure of materials, and, most importantly, on how the structural characteristics of the rock enhance or degrade its tool making potential (Osburn 1992:332). The mineral vein-variety of certain quartz cobbles exhibits large interlocked crystals broken by intensive fracture sets. The shape of the grain is angular with crystal boundaries, and its mineral content is uniform pure quartz with many fractures. Pure quartz is tough and strong, but fractures make breaking unpredictable. The ease of fracture creates a problem when it comes to distinguishing purposeful human activity from natural occurrences that alter the shapes of stones. This is especially true for the tools of the Early Palaeolithic period, such as those from the Zhoukoudian cave site, some 50 km southwest of Beijing.

ZHOUKOUDIAN

It has been seventy-five years since the Swedish geologist Andersson (1934) discovered this site in 1921. Since then, Zhoukoudian has become one of the most valuable places in the world for the study of early human ancestry. The chronological position of Zhoukoudian was recently recalibrated by uranium series dating of two calcite samples taken from a stalagmitic flow-stone layer intercalated in 1–2 layers. Based on the weighted mean of three measurements performed on the purer one, the upper age limit of this site is 421 kyr, which is much older than the former evaluation of 230 kyr based on uranium series dating of fossil bones (Shen and Jin 1993). As of 1989, more than fifty articles and books in Chinese, and at least thirty-five in English had been published about the Zhoukoudian cave site (Wu *et al.* 1989). In 1990, the most recent book about Zhoukoudian appeared, bringing together much of what we know about the nature of the site, including a systematic history of the entire Zhoukoudian excavation (Jia and Huang 1990). In 1994, the earliest standard reference of the 1934 excavation report by Pei Wenzhong was republished (Dong and Zheng 1994). Yet, among all these Zhoukoudian publications, only a few focus upon the stone tool technologies from the site, and most of these are in Chinese (de Chardin and Pei 1932; Pei 1932, 1939; Jia 1956, 1960, 1961; Zhang 1962, 1963, 1987; Pei and Zhang 1985).

Much of the knowledge we have of hominid behaviour at Zhoukoudian is based on the investigation of tool technologies. According to the original excavation report, more than 10,000 stone tools have been recovered since the site was first excavated in 1921. Forty-four different raw materials were used by the ancient inhabitants of the cave, and 89 per cent of this raw material is quartz. The remainder of the raw materials used include 5 per cent rock crystal, 3 per cent sandstone, 2 per cent chert and 1 per cent ‘other’ kinds of raw materials. The quartz was quarried from a marble and granite source about 2 km from the site. The rest of the raw materials can easily be found in the ‘Lower Gravel Layer’ at the foot of Longgushan (Dragon Bone Hill). The ancient knappers selected raw materials from near the home site, perhaps because of local environmental conditions and the limitation of the stone types in the immediate area. The quality of the local quartz is not uniform, hence some cobbles were better suited to tool manufacture than others, and about 50 per cent of the specimens found at Zhoukoudian are waste pieces from the manufacturing process (Zhang 1989:107).

The main method used to produce quartz flakes at Zhoukoudian was the bipolar technique (Figure 13.2a). Flake lengths range from 89 to 14 mm, breadths from 65 to 7 mm, and the thicknesses from 30 to 3 mm. Most of the flakes are small: in general, the length/breadth/thickness measurements are 20/10/

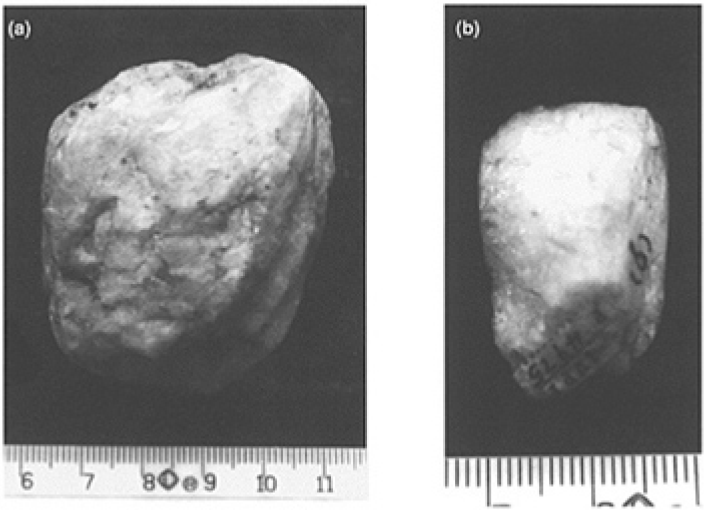

Figure 13.2 Zhoukoudian, (a) quartz core (P3512) produced by the bipolar technique; (b) quartz flake (P4975) produced by the bipolar technique.

5 or 40/20/10 mm (Figure 13.2b). Experiments show that if a stone is too small to hold in one hand, then the bipolar technique is the best way to break it into flakes of maximum size (Leng 1992:322). Because the quartz cobbles or pebbles selected to make stone tools at Zhoukoudian are generally small, the bipolar technique would be the most efficacious. The quartz tools of Zhoukoudian may be classified as mostly points (Figure 13.3a) and scrapers (Figure 13.3b).

Zhang (1987:17) indicates that the Zhoukoudian stone tool assemblages show continuity and improvement over time. Their common characteristics from the lower to the upper levels include: continual use of the bipolar technique, small flake tools making up the main part of the stone tool assemblage, and retouch from ventral face to dorsal. Zhang characterizes technique development at Zhoukoudian with reference to Early, Middle and Late stages and notes the following trends:

1. analysis and selection of raw material improves over time, e.g. there is more good quality quartz in the upper layers than in the lower layers;
2. use of the block-on-block technique found in the early stage decreases in each subsequent stage as the bipolar flake production technique becomes more common;
3. the percentage of flake tools increases gradually; and
4. the stone tools become smaller over time, and retouching improves at each stage.

(Zhang 1987:17)

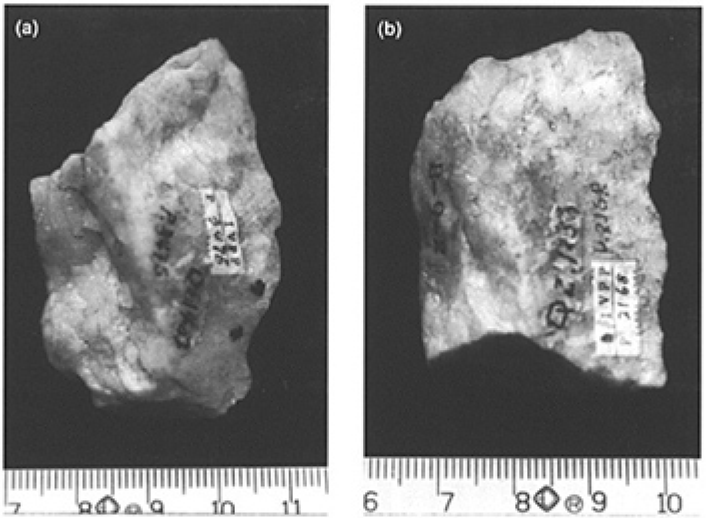

Figure 13.3 Zhoukoudian, (a) quartz point (P3475); (b) quartz scraper (P2168).

DONGGUTUO

Donggutuo is in the Nihewan Basin, which is about 150 km west of Beijing. The Sanggan River cuts through the eastern portion of the basin, near the village of Nihewan. Since 1924, when the American geologist Barbour (1925) investigated the area and named the Nihewan Beds, there have been more than 100 articles and books published about this area (Wei and Xie 1989). In 1990, J.Desmond Clark led a team from the University of California, Berkeley, in a collaborative effort with the Institute of Vertebrate Paleontology, China, to investigate Palaeolithic localities of the Early Pleistocene period in the Nihewan Basin. The investigation mainly focused on the Nihewan Bed formation around the area of Donggutuo (Schick *et al.* 1991). The Nihewan Beds contain a long sequence of lacustrine and fluvial sediments from the Late Pliocene to the Late Pleistocene.

The quartz tools the Berkeley team examined recently are from one of the oldest localities, Donggutuo, which provides materials from the 1 myr old, Lower Pleistocene Nihewan Formation. Wei (1985, 1991) excavated 1,000 square meters of the site in 1981. He obtained 1,443 stone specimens, made of volcanic rock, flint, quartz, and a few of limestone and agate. These raw materials were widely distributed on the older local sediments. Although quartz is not the major material for stone tool industries at this site, the quartz tools here are thought to be the earliest in China. According to the original report, the sizes of the tools indicate possible use of the bipolar technique.

In the Donggutuo assemblage studied in 1994, there are 152 cores (10.5 per cent), 839 flakes (58.1 per cent) and 452 tools (31.3 per cent). Eighty-six per cent (391 specimens) of stone tools are scrapers, made on flakes. The tools are small, with average length measurements being 20–40 mm. Retouch is basically from ventral face to dorsal, and the edge angles are 65 to 85 degrees (Figure 13.4a). Fifty-two specimens (11.5 per cent) are small points, also made on flakes (Figure 13.4b). The length/breadth measurements are 76/57 to 21/ 15 mm. The points are retouched carefully, usually bifacially. The points are irregular in shape, and some are considerably longer than others.

The bipolar technique was used to produce most of the flakes. The flakes are small, and their average weight is 8.4 gm. The measurements of the largest flake produced by the bipolar technique are 40.4×38.7×9 mm (P5657), and the smallest one is 34.7×14.7×12.4 mm (P5665). The dorsal faces of the flakes show evidence of the bipolar technique: some flakes are outer flakes that retain cortex, others are inner flakes showing several flaking scars. They might have been struck two or three times in order to break the core, and then retouched by the hard hammer technique. The manufacturing details of the small tools indicate that the Nihewan hominids were technically adept and experienced at working quartz.

There are similarities between the quartz industries of the Zhoukoudian cave site and those of the Donggutuo locality. For example, the bipolar technique was used to produce flakes at both places, and therefore the sizes of the quartz cobbles and pebbles are closely related to the sizes of the core tools and flake tools at both sites. The most common tools are scrapers and points made on flakes; and the edges of the scrapers are retouched from ventral face to dorsal. The edges and the points of the tools were carefully shaped by hard hammer retouch. The difference between these two localities is that quartz was the major source of

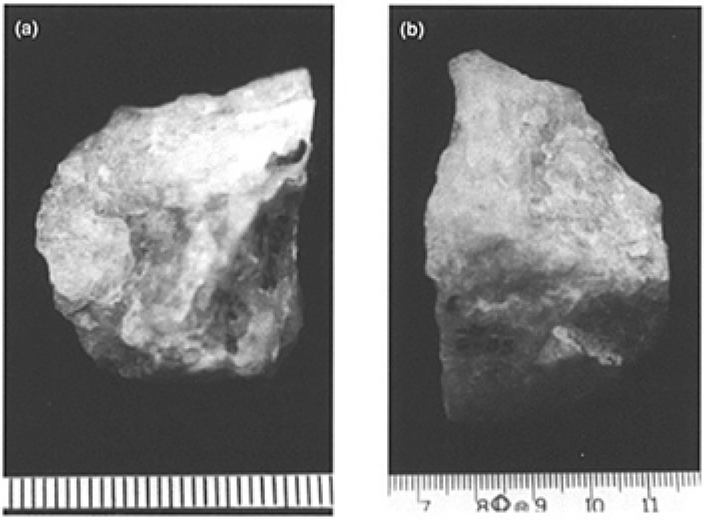

Figure 13.4 Dongguituo, (a) quartz scraper; (b) quartz point.

lithic material for the Zhoukoudian populations, but was not for the Nihewan knappers, although the exact percentage of quartz used in the Nihewan assemblage is not known. Personal stone tool manufacturing experiences indicate that volcanic rock has better characteristics for tool making than quartz. Volcanic rock was available for the Nihewan populations, but it was not present at Zhoukoudian. It would seem that, in both cases, the ancient hominids chose the best lithic material available to make their stone tools.

LANTIAN

In the summer of 1964, the Institute of Vertebrate Palaeontology and Palaeoanthropology (IVPP) and the Institute of Archaeology of Shaanxi Province unearthed a fossil human cranium during a comprehensive survey at Gongwangling (Wu *et al.* 1966). The fossil was named *Homo erectus lantianensis,* popularly called ‘Lantian Man’. The mammalian fossils found together with the human remains are called the ‘Gongwangling Fauna’. According to the most recent report, the cranium found in the fossil-bearing strata at Gongwangling is about 1.15 myr old, whereas the remains found at the Chenjiawo locality in Middle Pleistocene loess are about 0.65 myr old (An and Ho 1989:213).

Gongwangling is bordered to the south and southeast by the Qinling Mountains, the Wei River is to the north and the Chan River to the west. Since the discovery of the site, several articles on the Early Palaeolithic artefacts have been published (Dai and Chi 1964; Wu *et al.* 1966; Dai and Xu 1973; Gai and You 1976). Over

200 stone artefacts from the Lantian area (twenty-seven localities) were found *in situ,* twenty-eight of which were recently examined at the IVPP (Leng 1992). The lithic materials used by the Lantian hominids are quartzite, quartz and sandstone gravel. There are two main sources of these lithic materials, and both are still accessible: one is the gravel stratum at the Gongwangling hill, and the other is along the Ba River bed. The sizes, colours and types of lithic materials are similar at both sources, with the only difference being that some of the quartzite boulders along the Ba River approach 2 m in height, and thus are too large to have been transported by the river. Quartz cobbles are comparatively small at both sources, at around 90×80×60 mm.

There are three specimens made in quartz in the collection. Example P3465 is a core with a single bifacial edge (Figure 13.5a). A single edge has been bifacially flaked, and the flake scars are rather shallow. The length/ breadth/ thickness measurement of P3465 is 48×44×34 mm, which makes it among the smallest core tools in the collection (dimensions of the core tools range from 210×113×111 mm to 48×44×34 mm, with an average of 142×115×78 mm). Two unmodified flakes are quartz (P3855 and P3856). P3855 was made from a small quartz pebble and was not heavily damaged. The cross-section of this flake is roughly triangular (32×49×21 mm) (Figure 13.5b). P3856 was made from a subspheroid, and has a concave ventral surface. One flake was taken off prior to this one, so only half the dorsal surface is covered by cortex (55×59×20 mm) (Figure 13.5c). The angle of the striking platform of P3855 is 101 degrees; for P3856 it is 126 degrees. The weight of P3855 is 50 gm, and P3856 is 40 gm (the average weight of flake specimens is 49 gm). These two flake specimens were probably struck off the corners of a large, angular quartz cobble by direct, free-hand percussion. If they were not removed in this way, then they must have been obtained by the bipolar technique, because they are too small to be held and still allow access to a striking platform.

LIANGSHAN

In July 1951, Yu Shiyuan of the Department of Geology of Northwest University, Xian, recovered some Palaeolithic artefacts from the Lianshan area of Shaanxi Province. Since then, Yan Jiaqi of Xian Mining College, Huang Weiwen of the IVPP, and the Archaeological Institute of Shaanxi Province have collected artefacts from twenty-eight more localities in the Hanshui River valley (Yan 1980, 1983, 1988; Huang and Qi 1987; Tang and Zong 1987). The Liangshan site is located in the third terrace of the upper reaches of the Han River, a terrace that was made up of yellow-reddish sandy clay containing concretions and some mammalian fossils. The site is situated in the quarry of the Longangsi brick kiln. These investigators came to the conclusion that the fossils associated with the palaeoliths belong to the *AiluropodaStegodon* fauna, so that the Palaeolithic age can be attributed to the Middle Pleistocene (Tang and Zong 1987:60).

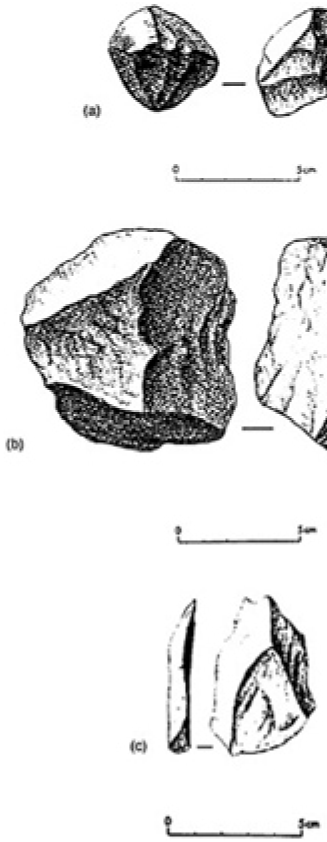

Figure 13.5 Lantian, (a) quartz core with single bifacial edge (P3465); (b) quartz unmodified flake (P3855); (c) quartz unmodified flake (P3856).

Ninety-one examples of stone artefacts from the 2,000 specimens in the collections of the IVPP and the Shaanxi Province Archaeological Institute were recorded. An overview of the lithic materials used for the ninety-one specimens indicates that there are thirty-five specimens (38 per cent) of volcanic rock, thirty-four specimens (37 per cent) of quartz, and twenty-two specimens (24 per cent) of quartzite.

An analysis of the dimensions of these three raw materials highlights the similarities and differences between them. Average dimensions of the volcanic rock specimens are as follows: core tools (twenty-one specimens) 132×97 ×69 mm and flake tools (fourteen specimens) 85×86×43 mm. Average dimensions of the quartzite cobble specimens are: core tools (fifteen specimens) 129×97×69 mm and flake tools (seven specimens) 102×95×37 mm. The average dimensions of the core tools are similar, with the differences being among the dimensions of the flake tools: the volcanic flakes are smaller and thicker than the quartzite flakes. It is possible that this results from the shapes of the volcanic rocks, which are usually rounder than the quartzite cobbles, making it comparatively easier to produce smaller flakes from them.

Average dimensions of quartz cobble specimens are: core tools (twenty-six specimens) 89×82×61 mm and flake tools (eight specimens) 55×60 ×22 mm. The quartz specimens are obviously much smaller than the tools in the other two lithic materials. The small size is due to the nature of the quartz:

1 quartz is much easier to break into flakes (but one has to be very careful to avoid striking quartz too hard and so smashing the platform);
2 quartz cobbles (99×93×56 mm) from the local area are somewhat smaller than cobbles of other materials, so most of them can be held in one hand for use as a hammer stone; and
3 the interlocking granular structure of quartz tends to break along natural fissures and cracks, requiring the knapper to be a keen observer in order to choose a useful cobble.

Within the quartz tool industry, seven of the core tools (27 per cent) have single unifacial edges. Quartz constitutes 47 per cent of the lithic materials used for this type of tool. Ten of the core tools (38 per cent) have single bifacial edges, and quartz makes up 62 per cent of the lithic materials used for this core type. Hence, tool manufacture on the edge seems to dominate the main body of the quartz industry in the Liangshan assemblage. The single edge, made either unifacially or bifacially, is on the side or end of the cobble, which is usually the area that can best serve as a percussion platform. Most of these cores are trimmed for less than 50 per cent of the circumference. The single edges are generally jagged and exhibit edge damage (Figure 13.6a). There are five other quartz specimens of miscellaneous shapes, constituting 63 per cent of the lithic materials in this category. The edges of these core tools are made by flaking from different directions. All the specimens are rolled, and the surfaces of most of them have also been extensively damaged (Figure 13.6b). The average dimensions (83×74×78 mm) and weight (688 gm) of these tools suggest that they were used as hammers by the ancient manufacturers. The average size and weight of quartz cobbles in the Liangshan area indicate hard hammer technique on volcanic rock and quartzite cobbles.

There are nine quartz flake specimens (26 per cent) in the collection. As already noted, they are small. Specimen P6275 is a flake with a unifacial proximal end, the proximal platform having been almost entirely removed by trimming from the ventral face to the dorsal. There are two, large, shallow flake scars on the proximal end, and two steep scars on the lateral edge. There is edge damage present on the distal edge. The profile of the flake is curved towards the ventral face. The dimensions of the tool are 76×74× 26 mm, the angle of the platform is 91 degrees, and the weight is 45 gm (Figure 13.6c). The shallow flake scars on the proximal end, and edge damage on the distal end, could be the result of the bipolar technique. Retouch scars on the lateral edge suggest edge usage. There are several other cases indicating use of the bipolar technique for quartz materials by the Liangshan population.

Liangshan knappers changed their techniques according to the different dimensions of the various raw materials: hard hammer technique for the volcanic rocks and quartzite cobbles, and bipolar technique for quartz. Furthermore, quartz cobbles also functioned as hard hammers for making stone tools of other raw materials.

SHILONGTOU

In 1971–2, archaeologists of the IVPP and the Hubei Provincial Museum excavated a limestone cave site on top of the Shilongtou hill in the Zhang Mountains of Hubei Province (Li *et al.* 1974). The Yangtze River is 4 km northeast of the cave, and on the southwest side of the cave is Daye Lake. From the excavation, they uncovered some stone tools *in situ* in a fissure, together with mammalian fossils that resemble the typical *Ailuropoda-Stegodon* fauna. The geological-palaeontological age of these finds has been determined to be Middle Pleistocene.

There are twenty-four tools in the collection. The raw materials selected include quartzite (83 per cent), breccia (8 per cent), chert (4 per cent) and quartz (4 per cent). The sources of these raw materials are unknown, as there is rice growing in the Daye Lake basin today. If there was a source of gravel cobbles on the bank of the lake in the Middle Pleistocene, it is not present now, perhaps having been covered by lacustrine deposits. The area was investigated from the cave to the Yangtze River, and along the south bank of the Yangtze. The river dykes are very high, and there is no floodplain with any gravels, large or small. Above 15–20 km northeast of the cave, the Yangtze River branches and flows around several towns. The water in these branches is shallow, and here there are large cobbles on the river bed, covered by river mud. Quartzite and sandstone cobbles are most abundant, and quartz is less common. This is also the case in the portion of the stone tool assemblage studied, which contains only one quartz flake tool (P3830).

Specimen P3830 is a thin, oblong flake with one flake scar on the platform, and a single lateral, unifacial edge. A previous flake was removed from the dorsal face. There is one retouch scar on the thick lateral edge, which was also flaked from ventral surface to dorsal. Another lateral edge is naturally sharp, and shows heavy edge damage. There is cortex on the platform and the back of the distal edge. The distal edge also shows heavy edge damage. The tool is 79×62×20 mm, the angle of the platform is 120 degrees, and the weight is 100 gm (Figure 13.7).

A total of fifty-five lithic cobbles were measured in the Yangtze River area northeast of the cave. The sizes are regular, and the length/breadth/thickness measurements range from 178×126×80 mm to 96×82×50 mm, with an average

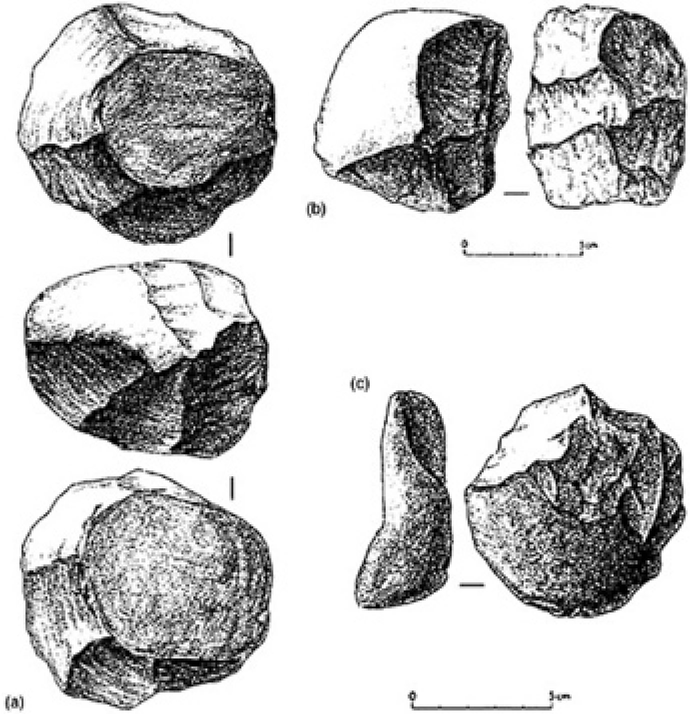

Figure 13.6 Liangshan, (a) quartz core with single bifacial edge (P6213); (b) quartz specimen of miscellaneous shape (P6299); (c) quartz flake with a unifacial proximal end (P6275).

of 135×104×65 mm. The weight range is 500–1200 gm, with an average of 595 gm. These lithic materials are quite hard to work, and it is especially difficult to produce a long flake on quartz material, like specimen P3830. The angle of the platform of specimen P3830 is 120 degrees, which is the smallest angle in the lithic industry. The angles of the platforms on the flake specimens in the collection range from 132 degrees to 120 degrees, with an average of 127 degrees. Hard hammer is the best technique for producing these large-angled flakes with one percussion bulb on each flake, hence replication work at Shilongtou was conducted using hard hammer direct percussion.

BOSE

In 1973, the IVPP, the museum of the Guangxi Zhuang Autonomous Region and the prospecting team of Guangxi Zhuang Autonomous Region investigated the palaeontology of the Bose basin. They found a lithic locality at Shangsong village, Bose County (Li 1975). Since then, joint teams have continued to work around the area, amassing about 2,000 Palaeolithic stone specimens on both

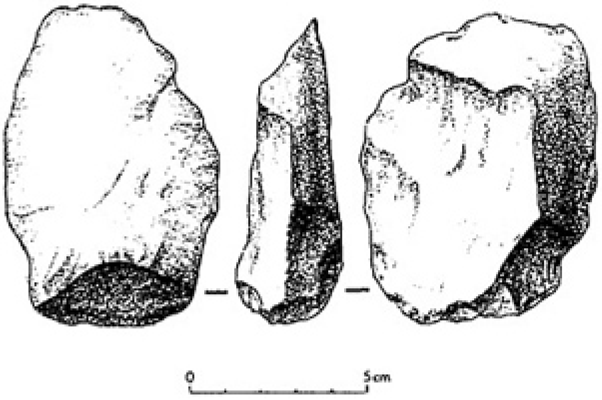

Figure 13.7 Shilongtou, quartz flake with single lateral unifacial edge (P3830).

sides of the You River (Zen 1983; He and Qu 1987). In the winter of 1988, a small excavation was organized by the IVPP, the Museum of Guangxi Zhuang Autonomous Region and the Bose Museum of Cultural Relics at Posuan village, Tiandong County. Sixty-nine stone specimens were unearthed from the primary laterite in the fourth terrace on the north bank of the You River. The age of the lateritized fans in Guangxi was compared to the 'Yuhuatai Beds' of the Lower Yangtze River, which have been recognized as probably belonging to the Late Pliocene (de Chardin *et al.* 1935). The stone tools are made of silicified limestone, sandstone, and quartz cobbles, and these lithic materials are abundantly distributed adjacent to the You River today (Huang *et al.* 1990).

A total of forty-two specimens from the local collection was recorded. The lithic materials selected to make these stone tools include silicified limestone (72 per cent), sandstone (26 per cent) and quartz (2 per cent). Specimen Shangsong 1, made on a quartz cobble, is a core with a unifacial leaf-shaped end. The cross-section of the tool is biconvex, the butt end is rounded cortex, the lateral edges are roughly even and symmetrical, and the distal end is somewhat pointed. The location of the use damage is on the cortex. The dimensions of the tool are 151×124×80 mm, and the weight is 2,000 gm (Figure 13.8a). The dimensions of the tool are similar to the average measurements of the core tools (thirty-three specimens, all of silicified lime-stone or sandstone), which are 153×118×72 mm, and the weight is much heavier than the average weight of 1,345 gm.

The Shangsong 1 specimen was replicated at the site. The following account of experimental work with this quartz material is offered: the length/ breath/ thickness measurement of the quartz cobble used was 255×154× 80 mm, the weight was 3,636 gm. The cobble was wide and oblong. The hard hammer technique was used, alternately flaking both lateral edges to replicate the bifacial edges and to form a point at one end. The butt and centre of both surfaces retain cortex. The flake scars, which are large and shallow, resulted in a shape commonly referred to as a 'handaxe'. The type of the finished tool was a core with one bifacial leaf-shaped end (Figure 13.8b). The dimensions are 220×130×80 mm, and the weight is 2,727 gm. About thirty-two small fragments of debitage were produced, and nineteen flakes. The edge of the tool is very sharp with a jagged edge. Comparison of the replicated specimen with the ancient tools suggests that the freehand, hard hammer technique was employed by the Bose hominids.

CONCLUSION

The combinations of raw materials available to the ancient knappers at the six archaeological sites differ somewhat. We know, for example, that forty-four different raw materials were used by the ancient inhabitants of the Zhoukoudian cave site, and that 89 per cent of the tools were made of quartz, and the remainder included rock crystal, sandstone, chert and other materials. Zhoukoudian is the only site for which we have information about the percentage of quartz in the total raw material used. For the rest of the sites, we know that quartz was selected as one of the raw materials in the stone tool industry, but we do not have exact percentages for the different raw materials (we have only the percentages of quartz tools in my study samples). This situation makes it difficult to infer selection criteria concerning the quartz that was used in the other sites. We know that in one case, the Donggutuo site, there are better raw materials than quartz available, such as volcanic rocks, flint and limestone. At other sites, e.g. Lantian, Langshan, Shilongtou and Bose, there are much tougher materials than quartz to work with, such as quartzite, sandstone and silicified limestone. From personal experiences at these sites, it was observed that there were always some raw materials that were easier and more difficult to flake than the available quartz, but if it was available, quartz was always selected, although with varying frequency.

Ancient knappers used quartz wherever it was available, and they discovered quite early on how to use it. One million years ago, some of these ancient flintknappers began to employ the bipolar technique for tool production. This technique was used at four archaeological sites: Donggutuo, Zhoukoudian, Lantian and Liangshan. The average dimensions of quartz tools at these four sites are 50×38×24 mm. The hard hammer technique was used at Shilongtou and Bose. The average dimensions of the specimens at these two sites are 115×84×40 mm. Thus, the average dimensions of the specimens made by the hard hammer technique are almost twice those of the specimens made with the bipolar technique. These quartz industries come from two contrasting geological contexts: those manufactured by the bipolar technique include one limestone cave site (Zhoukoudian) and three riverine floodplain sites (Donggoutuo, Lantian and Liangshan) for hard hammer industries, there is one cave site (Shilongtou) and one river valley site (Bose). Hence there is no necessary relationship between the locale context and the techniques selected. There is, however, a strong relationship between the size of the local quartz clasts and the choice of production technique, and the resultant artefact sizes. The bipolar technique is

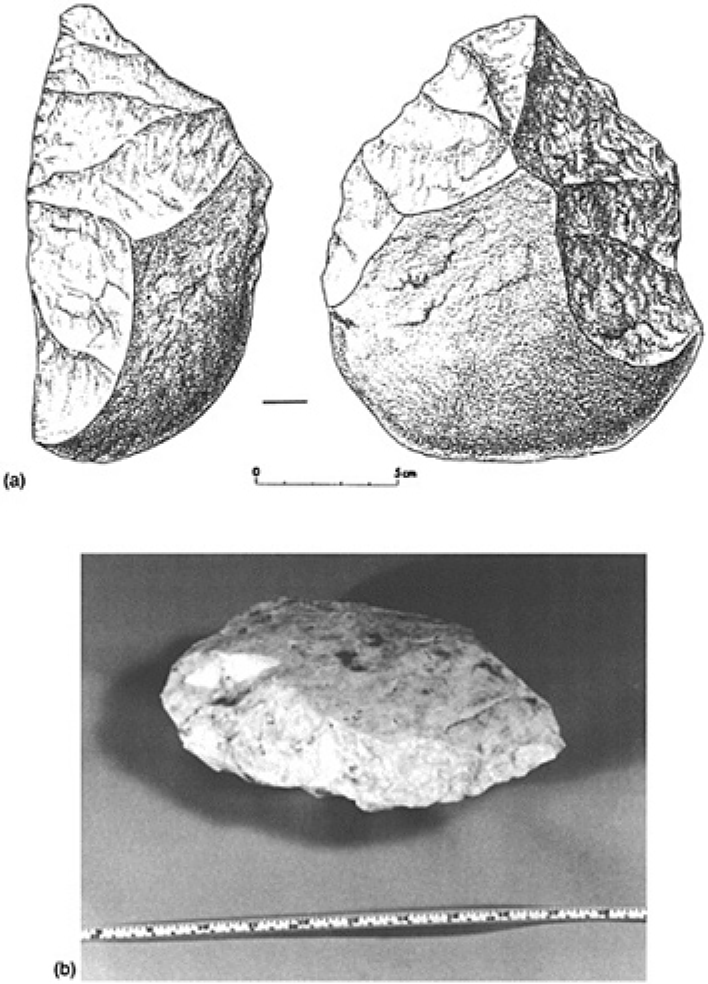

Figure 13.8 Bose, (a) quartz core with a unifacial leaf-shaped end (Shangsong 1); (b) replicated tool made from Bose quartz.

used when quartz cobbles are too small to be held in one hand. Since quartz is easy to fracture, a knapper experienced in using the bipolar technique requires only controlled strength to strike the core and obtain flakes of the necessary sizes, while avoiding smashing the platform.

At Zhoukoudian, there was improvement in quartz tool production techniques from the lower to the upper levels. This is especially true in the selection of the most appropriate quartz raw material at any one time. Zhang's (1987) study provides statistical information indicating that stone tools become smaller over time, and that the percentage of flake tools gradually increases. Zhang's analysis of the Zhoukoudian quartz industry is, in fact, a pointed rejoinder to Binford and Ho's (1985) comments, which cast suspicion on the original interpretation of the site and the behaviour of the hominids who lived there. When they examined the Zhoukoudian collection, Binford and Ho (1985:429) could see 'no evidence that the form and composition of the tool assemblage is changing at any greater rate than the anatomy of the hominids themselves'. This led Binford and Ho (1985: 429) to conclude that, 'what we are dealing with is not a culture-based behavioural system but a tool-aided, semantically transmitted and conditioned behavioural system—a noncultural form of adaptation that is strongly tool-assisted'. Ikawa-Smith's (1985:432) comment on the Binford and Ho position is a simple, cogent response: 'How can we compare the rate of anatomical change with that of changes in tool assemblages?' I ask further, how can one speak of the developments found in tool technology at Zhoukoudian as a 'noncultural form of adaptation'? As we have noted above, the Zhoukoudian knappers progressively selected better quality quartz as their main raw material from other lesser quality quartz materials (as seen in the lower levels) as well as from forty-four different raw material sources they could have used. Moreover, these early tool makers increasingly used the bipolar technique to produce perfect flakes, and they skilfully chose the quartz pebbles or cobbles, using smaller and smaller sizes at each stage. They used a hard hammer technique to refine the points, and the single or double lateral edges of the small quartz flakes to make efficient little points and scrapers. All the above demonstrates improvement in technology over generations of Zhoukoudian knappers. It is a very limited definition of culture that excludes preferences in raw material, the improved selection from that material, and evolving technical expertise in efficiently producing tools from that material, as exhibited by the early knappers of Zhoukoudian.

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14

The Early Palaeolithic of the eastern region of the Old World in comparison to the West

J.DESMOND CLARK

INTRODUCTION

Beginning about 1.6 myr or before, the large stone artefacts of the Acheulian Industrial Complex (comprising handaxes and cleavers) were introduced, supplementing the former Oldowan chopper and small flake tool assemblages. This second technological development was more or less contemporary with the appearance of the first large-sized hominid, *Homo erectus*. This hominid spread into all ecological habitats in Africa other than the tropical forests, and about 1.4 myr or before exploded into Eurasia, bringing the artefact assemblages that combine the core-chopper and biface technologies (Figure 14.1). Mostly found in Africa, these are inseparable parts of single assemblages, but sometimes one or other tradition is found separately. The meaning of this is unclear, but may be sex or age related or may represent the equipment requirements for the terrain. In western and southern Asia, the core-chopper and Acheulian industries are generally but not always associated, and sometimes occur alone as they do in Africa. In western Europe, the pattern is the same, but with the dominance of one or other of these technologies. In eastern Europe, central, eastern and southeastern Asia, on the other hand, only the core-chopper and flake technology (Oldowan) is found. Here, the clue to understanding this patterning must be more specifically ecological, and more precise dating and environmental evidence is an essential beginning to the recognition of significant behavioural differences in resources and their utilization.

The Acheulian Industrial Complex appears about 1.6–1.4 myr in Africa (Konso-Gardula, Olduvai, Bouri) (Klein 1989; Asfaw *et al.* 1992; Schick and Toth 1993:233–35), and is associated there with *Homo erectus,* who first appeared in Africa 1.8–1.6 myr (Brown *et al.* 1985; Walker and Leakey 1993). The Acheulian is characterized by the first large bifacial stone tools (hand-axes and cleavers) (Figure 14.2). It developed slowly and lasted until c. 300 kyr (Clark 1994). The later Acheulian spread into a wide range of ecological habitats (Clark 1967). It evolved technological innovations and skills (proto-Levallois; Tachengit; Kombewa; throwing [anvil] technique) to produce the large flakes for bifaces where necessary (van Riet Lowe 1945; Tixier 1957; Balout 1967;

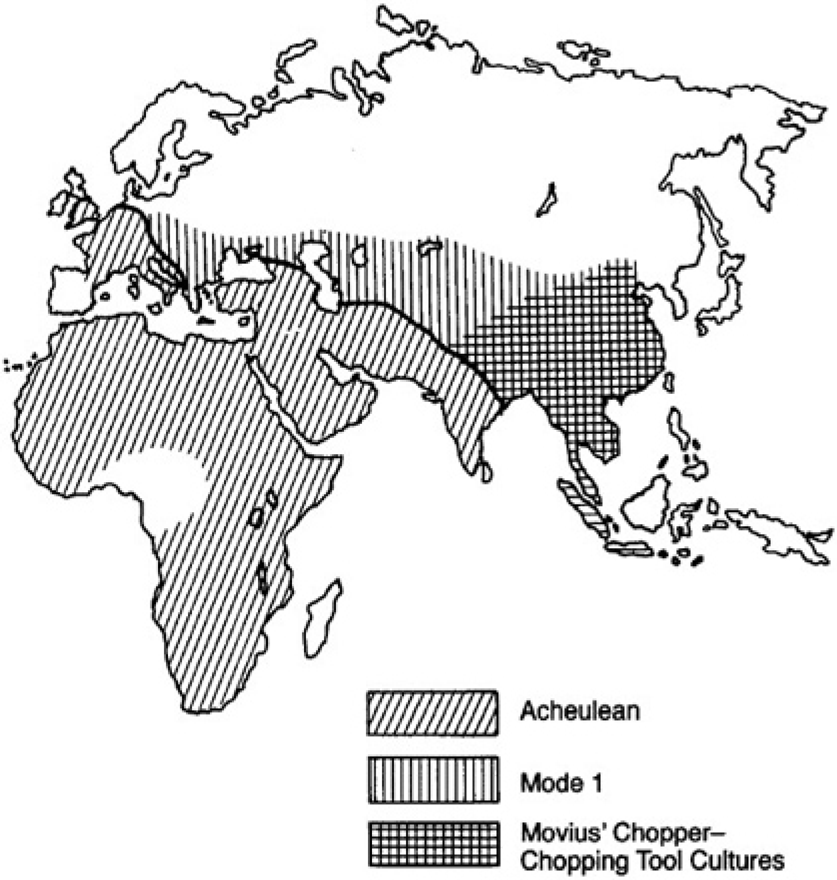

Figure 14.1 Map showing the regional distribution of the acheulian biface and core/ flake complexes during the Middle Pleistocene. Distribution of Movius' Chopping Tool Complex shown by cross hatching.

Source: after Schick 1994: Figure 26(1)

Brezillon 1968) (Figure 14.3). From its beginning, the Acheulian was associated with a core-chopper and flake component that had appeared earlier, *c.* 2.6–2.4 myr in Africa (Hay 1971:13–15), where it is known as the Oldowan Industrial Complex. This tradition—Oldowan or Mode I—continues and is an integral part of the African Acheulian (Leakey 1975; Harris 1983) as well as of the Acheulian in the Levant, India and southern Europe (Clark 1975, 1992, 1994). Percentages of bifaces and of core-chopper-flake forms are very variable, and there are also sometimes sites with only bifaces and others with only core-choppers and flakes. Mostly, however, bifaces and core-flakes are found together (Klein 1989; Clark 1992). Elsewhere in the Old World—in central Europe, the Caucasus, central Asia (Tadjikistan, Uzbekistan), the Far East and Southeast Asia—only

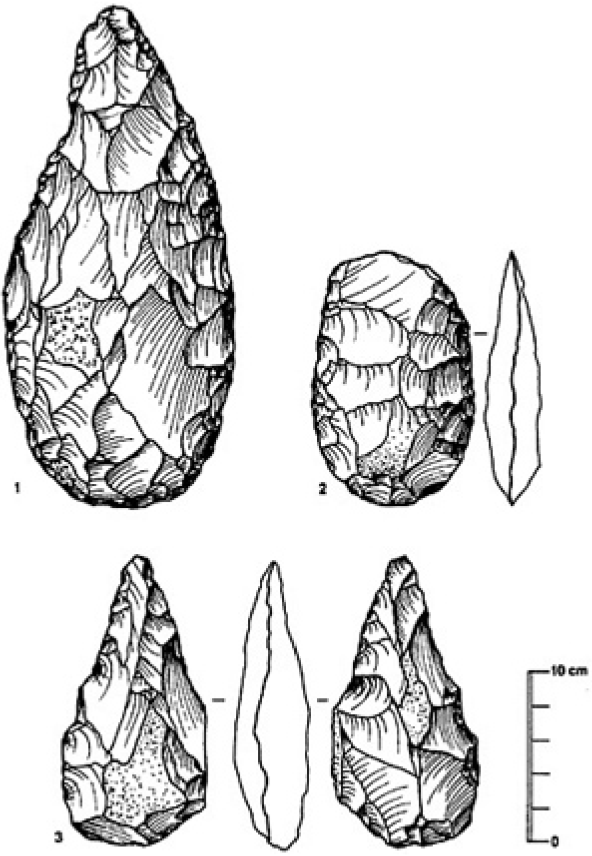

Figure 14.2 (1) Acheulian asymmetric handaxe in welded tuff; 2) parallel-sided basalt cleaver. Both artefacts from Locality 8, excavation 8E at Gadeb, Southeast Plateau, Ethiopia; 3) Acheulian handaxe from Nakjhar Khurd excavation, Middle Son Valley, Madhya Pradesh, India.

Sources: (2) after Clark and Kurashina 1979: Figure 5, nos. 6 and 8; (3) after Sharma and Clark 1983: Figure 5, no. 4

the core-chopper and flake assemblages occur and the true Acheulian biface is absent (Schick 1994). A legitimate question that can be asked is how can we explain the variable geographical distributions of the two great lithic technocomplexes of this time? Various possibilities come to mind—climatic, geographical, biological and cultural phenomena some of which will be discussed below. First, however, we need to examine the composition of the components of the Acheulian and core-chopper-flake traditions.

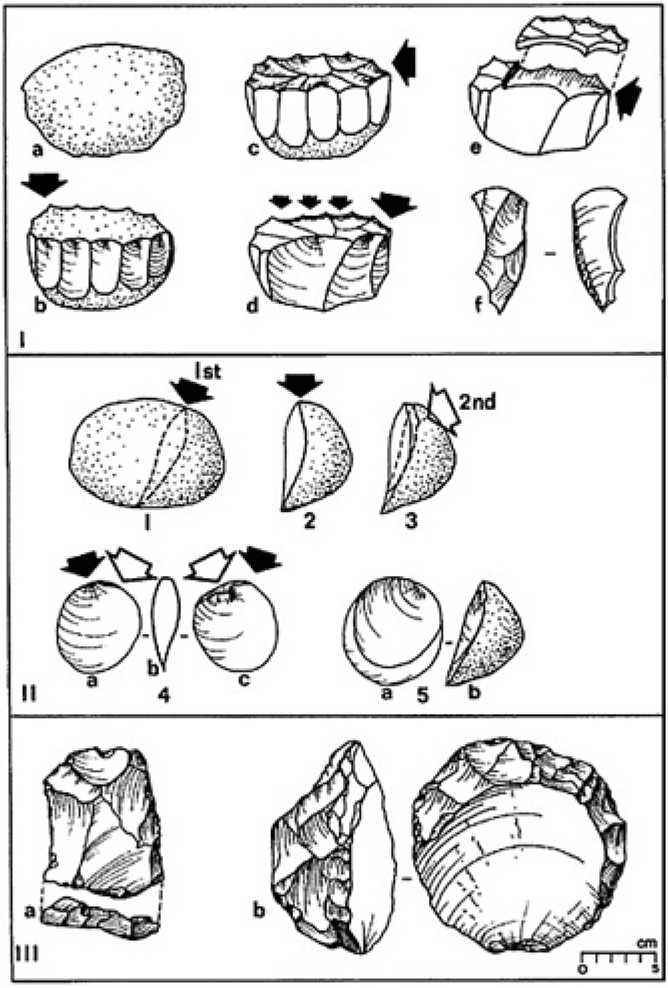

Figure 14.3 Acheulian methods of flake production. I) Tabalbalat-Tachengit technique; II) Kombewa technique producing Janus flakes; III) Proto-Levallois core and flake, Older Tug Gravels, Site H12, Hargeisa, Somalia.

Sources: (I) after Tixier 1957:920; (II) after Balout 1967, Figure 72; (III) after Clark 1954: Plate 6, no. 8; Plate 7, no. 6

THE ACHEULIAN COMPLEX

The Acheulian is characterized by biface industries. These are the earliest large stone tools in the archaeological record and they are very often made from large primary flakes struck from boulder cores or outcrops of the raw material. Two forms predominate: the handaxe, of which the plan form varies from lanceolate through ovate to, especially in the earlier Acheulian, long, pointed and trihedral pick-like forms; and the cleaver, which has a straight, axe-like cutting edge that may be at right angles or oblique to the long axis of the tool. Both the handaxes and cleavers are retouched as is necessary to produce a regular, symmetric plan form and a biconvex or planoconvex cross-section. These handaxe tools usually also exhibit fully, or parti-bifacial retouch, although unifacial forms sometimes occur, as also do trihedral picks. Where the raw material occurred in the form of cobbles, the biface was made by direct percussion and reduction of the cobble form. This is especially the case in those parts of Europe where flint was the most common raw material (Villa 1991); elsewhere, as in the Garonne Valley in southwestern France (Schick and Toth 1994) and in the Iberian Peninsula (Villa 1991) where quartzite was used, the technology resembles that seen in Africa.

Other tool forms are the polyhedron, subspheroid and spheroid, which are most common where large primary flakes are needed for the manufacture of bifaces and other large tools (Kleindienst 1962). The polyhedrons are probably discarded or worked-out core forms, but the spheroids have recently been shown to be the end-product in hammerstone uses (Schick and Toth 1994). In addition, a wide range of cobble-size cores and the detached flakes are usually associated with and have sometimes been retouched as heavy-duty scrapers and light flake-scrapers; the modified edges show various kinds of regular and denticulate retouch as scrapers or modification as naturally backed knives (Figure 14.3) (Clark and Kurashina 1979), with one or more edges showing use-wear. In later Acheulian times, these flake-scrapers closely resemble the mousterian *racloirs* of the Middle Palaeolithic.

THE CORE-CHOPPER AND FLAKE COMPLEX

The core-chopper and the flake forms and retouch that belong to the later Mode I (Developed Oldowan) tradition (Clark 1977:22) cannot be distinguished from those with the Acheulian, except that they are sometimes associated with smaller, more crudely made bifaces. However, the degree of designed symmetry and careful retouch found with some of the scraper forms seen in the later Acheulian assemblages is generally absent in these later core-chopper-flake assemblages. Denticulate pieces are always well represented.

There would seem to be no significant or consistent differences between any of the Mode I assemblages of the later Lower and Middle Pleistocene wherever they occur, except for ‘cruder’ and smaller bifaces at some African sites, and the presence sometimes of ‘scaled pieces’ as at the Olduvai Gorge Upper Bed IV (Jones 1994:283–84) and in the Chinese cave site at Zhoukoudian (Pei and Zhang 1985) where quartz was the most common raw material see Leng, this volume. It is an efficient lithic tool-kit that provides knives, scraping tools and ‘choppers’, together sometimes with spheroids.

THE MIDDLE PALAEOLITHIC/MIDDLE STONE AGE

By 300 kyr, or thereabouts, in Africa, Europe, the Levant and western Asia, the Acheulian bifaces fall away and the descendent assemblages are typically Middle Palaeolithic/middle stone age, based on the Levallois and discoid core methods of flake and blade production. A range of adapted Middle Palaeolithic, regional industries is found which continue, with some innovative modifications, up to replacement by the Upper Palaeolithic around 40 kyr (Bordes 1968:98–120; Clark 1992:205, Figure 1). Regional Middle Palaeolithic, based on the discoid and modified Levallois methods, also emerges from the Mode I ancestral technology in central Asia, and has more in common with the western than the eastern parts of the continent (Larichev *et al.* 1987; Islamov 1990). In Southeast Asia, the situation is uncertain, since no unequivocal stratified artefact assemblages have been found in earlier Pleistocene sediments, despite claims to the contrary (Bartstra 1982).

EASTERN ASIA

The Mode I techno-complex was apparently present in China shortly before 1 myr, and it is best represented by the northern Chinese site of Donggutuo in the Nihewan Basin (Figure 14.4) (Schick *et al.* 1991), and later, by the assemblages from Locality 1 at Zhoukoudian, ranging in time between *c.* 500 and 240 kyr (Liu *et al.* 1977; Liu 1985). The associated hominid is *Homo erectus*, but by 100 kyr this had undergone morphological change, and fossils assigned to archaic *Homo sapiens* are found at sites such as Jinyushan, Dali and Yunxian (Huang *et al.* 1987; Jones *et al.* 1992:250; Etler and Li 1994). The associated lithic assemblages, where such exist, are an extension of the Mode I/Oldowan industry, but now sometimes include small retouched scrapers that are clearly within the Middle Palaeolithic period, in particular the retouch of side-scrapers and borers. This is well seen at Xujiayao, Ban Jing and Locality 15 at Zhoukoudian (Jia and Qi 1976; Jia 1980). Levallois and discoid core methods are not found and are nowhere clearly demonstrated to be present in the Far East. The significant characteristic about the Lower and Middle Palaeolithic of northern China is that it is essentially a *small tool complex*. ‘Choppers’ and core-scrapers occur, as also do large flakes, hammerstones and bipolar anvils at Zhoukoudian, but in appreciably smaller percentages. The bipolar technique, well seen at Zhoukoudian Locality 1, is not common at the sites in the Nihewan Basin, where direct percussion by hard hammer was the method used.

There are, however, some assemblages from southern China, as also from northern China and Korea, where a large tool component is present. This component has sometimes been called Acheulian, but these large tools do not have the hallmark features of the Acheulian bifaces described earlier. At Chongokni in South Korea, some are bifacial but most are unifacial (Bae 1988). This is also the case at the Fen Valley terrace sites at Dingcun (ten sites) (Wang

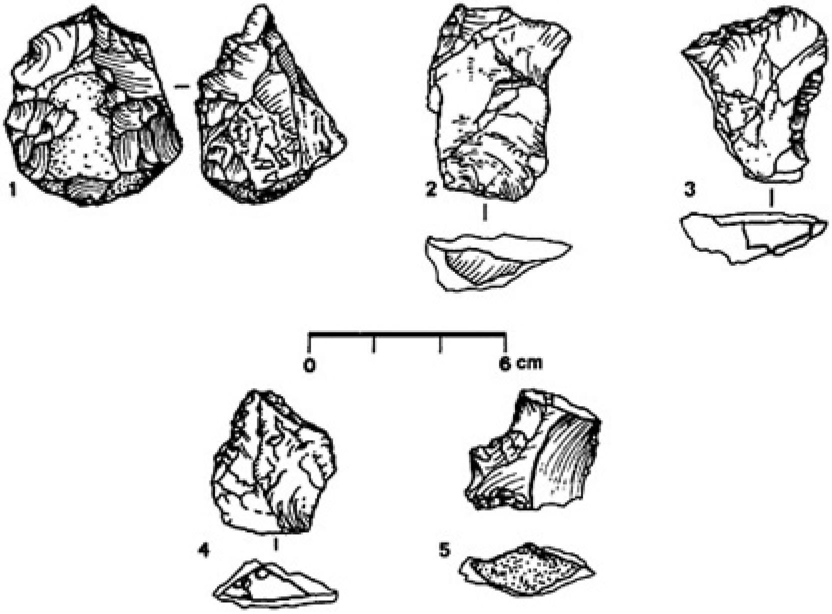

Figure 14.4 Lower palaeolithic core-chopper and modified/retouched flakes from 1990 excavations at Donggutuo, Nihewan Basin, Hebei Province, China.

Source: after Schick *et al.* 1991: Figure 3

et al. 1994) and at the southern China sites such as Baise (Bose), where numbers of these tools occur eroding from sediments overlying the upper terraces of the rivers (Huang 1990; Huang *et al.* 1990). The term used in China to describe these heavy-duty tools is 'point tool' (Figure 14.5). They are usually elongate, pointed tools worked at the point and down most of both side edges. The butt is generally unworked and they are more unifacial, resembling trihedral picks. Those that have bifacial retouch super-ficially resemble an early, rather than Late, Acheulian handaxe. The only cleaver-like pieces come from Chongokni in quartzite and from Dingcun in indurated shale. It remains uncertain, however, whether these from Dingcun come from Middle or Early later Pleistocene sedimentary contexts, and are distinct from those that are 'roughouts' and come from very interesting neolithic quarry sites. At the Korean sites, the large tools are associated with a typical small tool component, usually in quartz, and well seen in the Chongokni excavations (Bae 1988). The extent of the small tool component at Dingcun is difficult to know on account of fluvial winnowing. Huang Wei Wen's (pers. comm.) excavation in southern China uncovered a horizon with a number of flakes and cores, but the full range of this component remains unknown. The only 'Acheulian' biface observed by the author is from

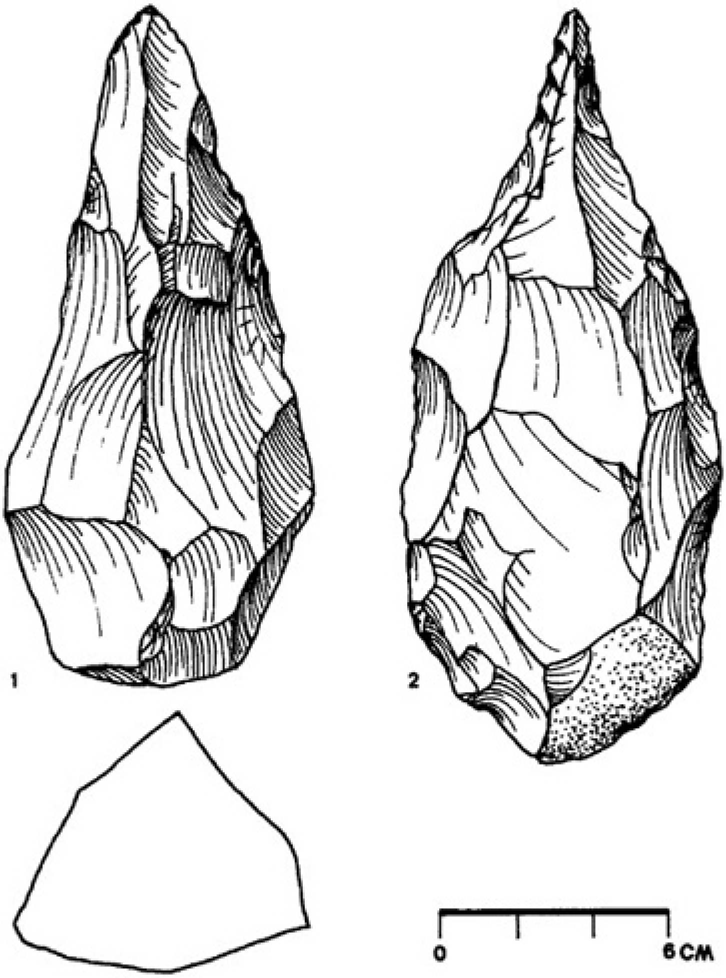

Figure 14.5 Two trihedral 'point tools' in hornfels from Dingcun, Shanxi Province, China.

Source: after Wu and Olsen 1985:10, 3

Lantian; again, it resembles an earlier not a later Acheulian biface, and is a unique piece.

The age of Lantian is, on uranium series, between 1.2–0.8 myr; Baise is thought to be as old as 400 kyr, but there is no associated fauna or radiometric date to confirm this. Mostly, these assemblages with point tools are thought to date to between 200 and 100 kyr. The only site with a radiometric date is Dingcun, which has a uranium series age of 210–160 kyr (Wang *et al.* 1994). Indeed, these heavy-duty artefacts resemble the Sangoan of Africa, which has a similar time range, more than they do the Acheulian. In this connection, it is of interest to know the age range of the Acheulian in the Indian subcontinent where it is associated with archaic *Homo sapiens* or evolved *Homo erectus* at Hathnora (Gaillard 1985; H.de Lumley and Sonakia 1985; M.-A.de Lumley and Sonakia 1985; Sonakia 1985). Most of the Indian assemblages appear to be later rather than earlier Acheulian. Acheulian bifaces have now also been found in Nepal (Corvinus 1990; Corvinus, this volume) and, if the Acheulian did penetrate or influence the Palaeolithic stone technology in China, it is, perhaps, likely to have done so via the Tibetan plateau, at that time considerably lower in elevation than it is today, as is also the case with Nepal, taking into account the on-going elevation of the Himalayas.

The most likely hypothesis to explain the Chinese/Asian point tool assemblages is that they are a functional answer to the equipment needs of hominids living in a tree-covered environment. As yet, we are not in a position to know with any certainty what form of ecosystem prevailed, although it would seem unlikely that it was a closed, evergreen tropical forest. It is, perhaps, not unlikely that there was an expansion of a woodland system of conifers with broad-leafed, semi-deciduous trees, such as is present today in the mountains of southern Yunnan.

In Southeast Asia, the Acheulian stops abruptly at the western edge of the tropical evergreen forest in eastern India. East of this boundary, only chopper-flake artefacts occur for which, again, a functional explanation could be advanced: namely that the Acheulian biface was redundant (as it was, for example, in central Europe) for processing resources in the habitats of Southeast Asia and so ceased to be made when migration continued east-ward. If, however, the Mode I (Oldowan) tradition had *already* penetrated and been established in southeast Asia, as the new dates recently associated with *Homo erectus* suggest (Swisher *et al.* 1994), then these populations could have been well adapted to the tropical ecosystem(s), whether evergreen forest or other ecosystems, prior to the arrival of the makers of the Acheulian techno-complex in India. Clearly, more artefact assemblages and fossils in well-dated contexts are needed before it will be possible to test this model. It remains an intriguing and not unlikely hypothesis, if the new dates from Java are accepted. If the Southeast Asian hominids had evolved, as they clearly had, a very effective way of life, it is not reflected in the lithic assemblages. This is on the basis of surface collections, as no clear, *in situ,* earlier Pleistocene assemblages are known, except for some artefacts from Sangiran (Sémah *et al.* 1992).

MODE I AND ACTUALISTIC EXPERIMENTS

Experiment shows the Mode I industry to be a perfectly adequate lithic tool-kit, if these artefacts were simply the basic equipment needed for processing some other material from which the actual tools of the foragers were made. For a while now, it has been thought that bamboo might be an alternative raw material (Hommel 1969:222–28; Wang and Shen 1987), and recent work has proved that this is, indeed, so. In the late summer of 1991, an American-Chinese team (J.Desmond Clark, Nicholas Toth, Kathy Schick and Peng Nanlin) visited the Kuchung, a minor ethnic group in the high-lands of southern Yunnan. The Kuchung were mainly foragers but also very competent hunters; they use a number of wild plant resources and are now also marginal cultivators. The team witnessed the way in which bamboo was used to provide most of the needed equipment. All processing was done with a short steel machete. Nicholas Toth brought a large block of flint from which he made a chopper and a number of flakes. With these stone implements, he was able to do everything that the Kuchung did with their machete: cut down the bamboo (chopper); saw it into lengths (flakes); split the lengths into sections (using flakes as wedges), and cut the sections into finer and finer splints (using flakes and his own thumbnail). Bamboo provides points for projectile weapons, digging sticks, containers for water and for cooking, splints for making baskets, machetes for cutting vegetation and the frameworks for houses, and a range of other pieces of equipment of which the most important are bamboo knives which are still used for processing meat by the New Guinea highlanders (Toth *et al.* 1992). At times in the past, the ‘bamboo zone’ in China probably extended north of the present limit, stretching from south of Xian in the west to Beijing. Of course, in other regions, other woods of various kinds can be expected to have been used, but none was as versatile as the bamboo reed.

The actualistic work is of obvious relevance and importance to an understanding of the Mode I industries, which may have been developed in South and Southeast Asia as a consequence of the use of bamboo. To examine this issue, it would be necessary to find phytoliths of bamboo, which are very distinctive, on the edges of stone tools. In addition, it is not impossible that bamboo and other perishable materials may be found in permanently water-logged situations. Many questions and problems remain to be researched to provide the hard data on which behavioural adaptations might be identified. Was the composition of the tropical forest in the Middle Pleistocene as it is today? If not, what was there instead? Were the mountain ranges of Asia the barriers to easy movement from south to north and vice versa that they are today? (Clark 1992:207, Figure 4, map).

CONCLUSION

A large number of the East and South Asian assemblages are selected aggregates from the surface, and are therefore of little or no value in attempting to understand how they relate to the behaviour of their makers. Where arte-facts are eroding, excavation should provide a representative assemblage of tool forms and (hopefully) associated faunal remains as well, for these provide the best way of assessing whether an artefact assemblage belongs to the Lower, Middle or

Upper Pleistocene. Uranium series dating of tooth enamel could provide an important means of correlating with climatic and environmental history and chronology from deep sea cores. However, whilst in western Eurasia and in some parts of Africa such dating and correlations have provided broad palaeoclimatic sequences, archaeologists are still slow to understand what a primary context assemblage means in terms of activity behaviour, in relation to the habitat background. Such sealed primary sites are the basis for any attempt to recognize behaviour, and the distribution patterns have very important information about activities. When examined in conjunction with analyses of use-wear and organic trace elements, new data will exist that, when joined with experimental feasibility studies, can provide some confidence for any testable scenarios or models that emerge. Sealed primary context sites with fauna are rare, and need a very careful search to ensure that the maximum results expected can be obtained from the available funding. They certainly exist, but they have to be found, and investigators need to be outstanding specialists to deal with the problems that will be encountered. It is high time that the search is more rigorously pursued, as there is no longer room for the subjective speculations that have dominated the Palaeolithic field in eastern and South Asia for so long.

Southeast Asia and, indeed, India are ready for the kind of carbon isotope work on fossil soils that can identify the vegetation communities of a traced archaeological horizon in a dated locality. A firm chronology needs to be established; *in situ* artefact assemblages need to be found, analysed, and their contexts determined. The interest is surely there to develop more intensive teamwork by groups of specialists working *together* in the field, each concerned with his or her own special problems and the ways in which these interrelate to develop scenarios that can be tested by the related sets of data.

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15

Concluding remarks: archaeology's fifth big question

CLIVE GAMBLE

INTRODUCTION

Archaeology has very few big global questions that have stood the test of time. Three of them concern the origins of civilization, agriculture and modern humans, whilst hominid origins and evolution form a fourth. Research into these questions goes through a regular cycle. First they become a hot topic fuelled by international conferences, the formation of opposed sides, heated exchanges in the press as the topic catches public attention, and an escalation of papers, books and especially peer review comment. Then, gradually, the topic grows cold for several years until it re-emerges again on the front-burner of research.

Ten years ago, the hot topic in Palaeolithic research became the origins of modern humans, or the fate of the Neanderthals and other late archaic *Homo sapiens* populations. Results from new dating techniques, provocative conclusions from genetic studies and a re-evaluation of fossil and archaeological data led to a lively and productive debate. I currently detect some cooling in this research area partly because the available data have been squeezed about as far as they will go, and also because the main conclusion to emerge is that we need to go back in time to understand what was happening during the so-called human revolution. First, we need to know how ancient were some of the Middle Palaeolithic behaviours that seem to have been replaced or substantially modified after the end of the last interglacial, 75 kyr ago. In other words, were there earlier examples of *The Human Revolution* (Mellars and Stringer 1989) as identified in the Middle to Upper Palaeolithic transition in western Eurasia? Second, we need to know what the geographical variation was in fundamental aspects such as subsistence, settlement, technology and society. How far could the diversity in these behaviours be attributed to either environmental factors or regional traditions?

Both issues are directly addressed in this volume. In terms of approach, it follows the global syntheses of the Upper Palaeolithic at the Last Glacial Maximum (Gamble and Soffer 1990; Soffer and Gamble 1990) and during the late glacial (Straus *et al.* 1996). Similar comprehensiveness is what we have come to expect in the One World Archaeology Series, and, as the editors point out in their preface and introductory chapter, such a global view identifies the specific questions about which we need to know more. Chronologically, the chapters in the volume start with the earliest stone tools at 2.5 myr and finish sometime in the Middle Pleistocene between 500– 250 kyr. It is not a volume about human origins but, by considering 2 myr of global hominid behaviour, we are treated to a much more interesting account of this question than is normally the case. In particular, by examining this 2 myr span, many of these chapters identify a fifth big question for archaeology: why did some hominids become colonizing species? The capability to expand geographically makes early hominids distinctive from all primates, with the possible exception of the macaque, and certainly distinguishes us from all the great apes. Old World colonization in the period 2.5–0.25 myr summarizes very effectively the unintended consequences of evolution for basic behaviours that included bipedalism, encephalization, tool use, foraging ranges, diet and a social life based on repeated absence rather than continual co-presence.

Hominids as colonizers has been a much ignored topic for reasons I have discussed elsewhere (Gamble 1993a, 1993b). The chapters in this volume, which deal with ancient rather than more recent Palaeolithic and prehistoric dispersals, demonstrate why hominid colonization is now widely recognized as archaeology's fifth big question. The current claim to hot topic status can be found simmering in many of the chapters, and from this disputation and polarized debate will follow. The pot is stirred by concerns over dating, the importance of climatic or environmental forcing, and hominid capabilities. I will now briefly discuss each concern in turn.

DATING

The chapters reveal long and short chronologies for most regions. India and Europe are presented as having had a short Middle Pleistocene chronology, whilst Pakistan, the Near East and Southeast Asia have advocates for a long Lower Pleistocene age. China might go either way. Other authors writing about the same regions would probably have seen it differently. Basic to these long and short chronologies for dispersal are the two dates from sub-Saharan Africa for the earliest technology so far discovered at 2.5 myr (Semaw *et al.* 1997) and the earliest appearance of the Acheulian at c. 1.6 myr (Clark, this volume).

The archaeological evidence for many of the long chronologies is invariably a small number of pebble tools and flakes, often from disturbed contexts and dated by new science-based techniques that are still being evaluated (Schick and Dong 1993). This last point was recently demonstrated at Atapuerca, Spain, where, within the space of twelve months, the oldest part of the site gained an additional 500 kyr thanks to revisions in the geomagnetic age estimates (compare Carbonell *et al.* 1995 with Carbonell and Rodríguez 1994). A long rather than a short chronology for Europe now hinges on the reliability of this revision (Rolland, this volume).

The difficulty of finding scarce, old artefacts is a familiar one, but it should not lead us to accept all claims on the grounds that not accepting them blinds us to the realities of the archaeological record (Roebroeks and van Kolfschoten 1994; Gamble 1995a). Moreover, whilst the argument that vast areas remain unexplored by Palaeolithic archaeologists is persuasive (Dennell, this volume), it seems strange, even so, that nobody has yet turned up a large collection of well-stratified, refutable artefacts outside of sub-Saharan Africa prior to 1.6 myr and maybe not even prior to 'Ubeidiya at 1.4–1.0 myr ago (Bar-Yosef, this volume). As Roebroeks (1996) has recently pointed out, the eolith debate, which once mightily exercised British archaeologists, was finally resolved. There is currently no evidence for occupation older than the Middle Pleistocene in this small corner of the Old World (Roberts *et al.* 1995). However, I can imagine that if, seventy years ago, the eolith supporters had the undreamt-of techniques of scientific dating that we now possess, they too would have had 'handy man' at 2 myr in the Cromer Forest Bed. The dates would have been used to support the 'archaeology', even though we now know the evidence to be geofacts.

Currently, the strongest evidence for an early dispersal before 1.4 myr rests on the two dated fossils from Dmanisi (Dzaparidze *et al.* 1989) and Sangiran (Swisher *et al.* 1994). These two dates have performed a similar function for the fifth big question as a few thermoluminescence dates achieved for the modern human debate (Bar-Yosef 1989). The Qafzeh and Kebara dates first appeared in 1987 and turned the temperature up under the topic of modern human origins. However, in the case of Qafzeh and Kebara, other dates from other sites have been forthcoming to confirm the pattern (Stringer and Gamble 1993: Appendix 221–5). This is unlikely to happen with the same speed for the earlier material because of the rarity of fossil finds. This places even more emphasis on dating the problematic stone tools from other widely scattered localities in the Old World.

Of course, raising doubts rather than presenting evidence does not dismiss the long chronology, but it does let us put its importance for investigating the fifth question into context. The current problem of resolving the issue suggests that we need working hypotheses to assess new data rather than fixed positions. In this regard, I have always found the 'tracks of life' championed by the vicariance biogeographer Croizat a useful heuristic device for reconciling the different views within an evolutionary framework (Figure 15.1). His view on evolution basically linked speciation to tectonic processes, since these separated populations (Gamble 1993b:77–8, 92–3). The continental plate margins provide not only the necessary conditions for archaeologists to find uplifted and exposed sediments, but equally a mechanism by which allopatric, or geographical, speciation and dispersal can regularly occur. We should not be surprised then that the early hominid track, as traced for example through Dmanisi, 'Ubeidiya, Riwat, Sangiran and other localities, also matches the plate margins of the Old World, or that Europe and India have no reliable old tools and fossils. Neither should we be surprised that the Movius Line, to which many chapters in this volume refer,

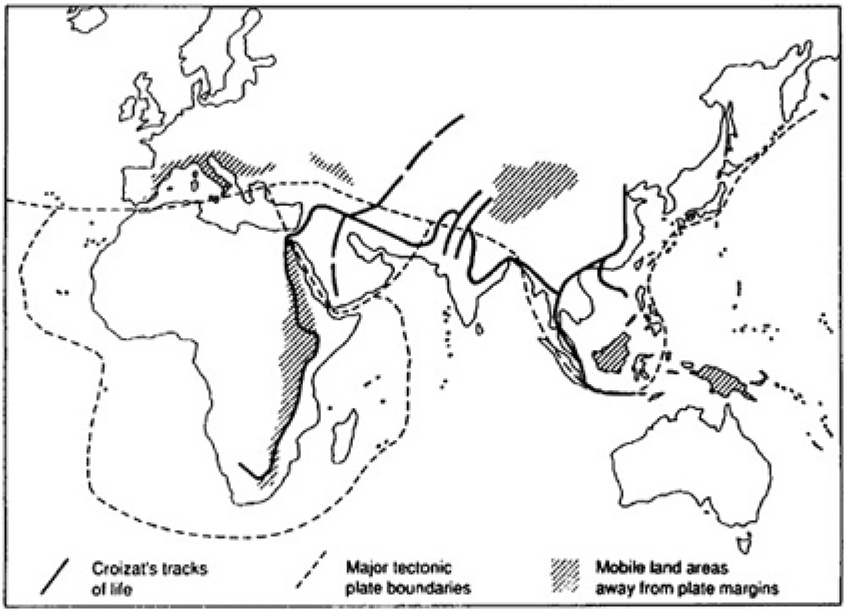

Figure 15.1 Croizat's tracks of life along which *in situ* evolution took place for all species, hominids included. Notice how the tracks follow tectonically active areas, including the plate margins and earthquake areas.

Source: after Gamble 1993c: Figure 5.2

also follows tectonic activity, since the uplift of the Himalayas and Tibetan plateau has been a Pliocene/Pleistocene process creating different climates and regions. On an evolutionary time scale and at a global geographical scale, we need to remember that the taphonomy controlling our evidence is intimately locked into the mechanisms producing change, either speciation or dispersal, which we seek to unravel from our data.

The working hypothesis therefore is to keep, within reason, an open mind on these questions of age and authenticity and to improve our models concerning the evolutionary processes themselves. This is why the fifth question is so interesting for the development of archaeology, precisely because it is framed not in the traditional terms of origins research, but rather with regard to the process and mechanisms of hominid evolution. These are necessary if we are to understand what made us into a variety of species with different colonizing capabilities.

From this perspective, the debate over which chronology we should follow becomes less polarized, because both sides will have things to explain, whoever is eventually correct. For example, there are knock-on implications for supporters of the short chronology. If a late date, after 1.4 myr, is accepted for the first series of dispersals out of sub-Saharan Africa, then why are India and Europe not reached for either another half or one million years, depending on which regional chronology—long or short—is supported? Is it a question of taphonomy or one of social and environmental obstacles to expansion? Similarly, the long chronology has to balance a global view on the age of the first dispersal with regional variation. One global view would be that sometime before or around 2 myr, populations dispersed and rapidly established the boundaries of hominid distribution within the Old World. These boundaries then lasted until *c.* 60 kyr (Gamble 1993b:203). Another equally possible scenario would be that dispersals started at 2 myr, but reached only selected parts of the Old World. They followed a track of specialized environments rather than covered a world of many diverse habitats. The boundaries of the Old World distribution of early hominids (e.g. Europe, India and perhaps China) were then only reached much later, either at, or sometime after, 1 myr ago. The hominid *track* (Figure 15.1) then became, sometime after 1 myr ago, the hominid *world,* in the sense of filling up large geographical areas away from preferred habitats. The differences that summarize the variety of views expressed in these chapters are shown schematically in Figure 15.2. Whichever model wins favour will substantially alter the way in which we appreciate the subtitle of this volume—the rise and diversity of the Lower Palaeolithic period.

CLIMATIC AND ENVIRONMENTAL FORCING

A major implication of these different chronologies concerns the role of climate and environment in forcing along the pace of speciation through exaptive radiation and the subsequent colonization of new habitats. These views are most closely associated with the work of Vrba (1988, 1989, 1996), whose emphasis is on turnover pulses as shown by the appearance of new species in the fossil record. In her opinion, these were linked to changes in global climate (see Gamble 1993b:81–91 for discussion, and Geist 1978 for a similar model). It appears, however, that even here in sub-Saharan Africa there is a long and a short chronology for such turnover. Vrba (1996:6) identifies a major pulse in bovid species 2.9–2.7 myr ago and two smaller ones at 1.9–1.8 myr and 0.9–0.6 myr ago. However, Spencer (1997) has shown that the secondary grasslands, which are associated with the first appearance of key East African bovids such as wildebeest, came into existence only around 2 myr ago. Secondary grasslands are those where tree and shrub growth is prevented by either fire or grazing. They are extremely productive, because they represent an arrested stage in the natural cycle of vegetation which, if uninterrupted, would lead to forest conditions. They must be distinguished from edaphic grasslands, which have existed for far longer, but over much smaller areas, in East Africa, and where waterlogging checked the cycle. The importance of secondary grasslands for hominid evolution is made by Cachel and Harris (this volume), where disturbance and productivity are linked to the adaptation to disperse.

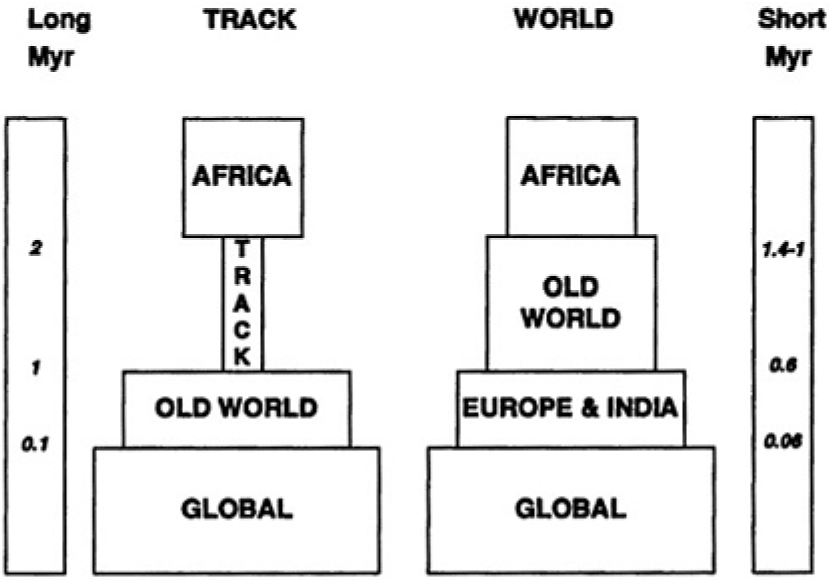

Figure 15.2 'Track' and 'World': two views of global colonization. The long and short chronologies in millions of years before the present can apply to either model.

Just how productive the secondary grasslands are has been examined by Kelly (1983). His approach is to list three basic measures for the ten major global habitats (Table 15.1). These are *net primary production,* measured in grams of matter per m^2 per annum, which represents the amount of energy in vegetation remaining from photosynthesis. This energy is what herbivores and humans can use. The second measure is *primary biomass,* which refers to the total amount of standing plant material in a habitat. Apart from primary production, much of this is inedible for humans, since it consists of tree trunks. The third measure, *secondary biomass,* consists of animals.

The purpose in listing these estimates, and Kelly admits that some of them are very approximate, is to see how accessible each habitat is for omnivorous, mobile humans. Kelly (1983:283) defines resource accessibility as the amount of time and effort required to extract either plant or animal resources from a habitat. This is assessed through a series of simple relative measures.

Table 15.1 The distribution of energy in global habitats.

	Primary production g/m2/yr (1)	*Primary biomass g/ m2* (2)	*Secondary biomass g/ m2* (3)	*Primary production/ primary biomass* (1/2)	*Secondary biomass/ primary biomass* (*10^{-3}) (3/2)
Tundra	140	600	0.4	0.23	0.7
Boreal forest	800	20,000	5	0.04	0.2
Temperate deciduous forest	1,200	30,000	16	0.04	0.5
Temperate evergreen forest	1,300	35,000	10	0.04	0.2
Temperate grassland	600	1,600	7	0.38	4.3
Woodland/ scrubland	700	6,000	5	0.12	0.8
Desert/semi-desert	90	700	0.5	0.13	0.7
Tropical savanna	900	4,000	15	0.23	3.8
Tropical seasonal forest	1,600	35,000	12	0.05	0.3
Tropical rain forest	2,200	45,000	19	0.05	0.4

Source: Kelly 1983: Table 3

In the first place, net primary production is divided by primary biomass (Table 15.1). This compares the relative amount of plants available for grazing by herbivores in each habitat. Notice how the very high values for production and biomass in the tropical rain forests fail to convert into usable resources. This is because the trees and plants are competing for space and light and so little is produced for the herbivores. By contrast, the temperate grasslands, tundras and tropical savannas stand out as the best grazing habitats. The second calculation deals with the availability of animal resources for use by humans, which is done by dividing the secondary biomass by the primary biomass. In particular, this changes the assessment of tundra, which now drops in terms of ease of accessibility against the grasslands and savannas.

In Table 15.2, I have further simplified these assessments. All the habitats are compared proportionately against the grasslands, which are the most productive habitat. This allows us to see which environments are easiest for hominids to inhabit. Significant differences in the ease with which major habitats can be exploited is emphasized on a transect taken from the equator to the poles. The two most accessible environments for hominids—grass-lands and savannas—are highlighted. This is not unexpected, since it is largely within these that both the hominid turnover pulse and the Old World expansion occurred.

The marked differences between the habitats shown in Table 15.2 suggest that, unless secondary grasslands were widespread throughout the Old World, hominid dispersal would indeed follow the hominid *track* model (Figure 15.2). The hominid *world* model would then occur much later, as appropriate strategies evolved to cope with the uncertainty and difficulty of securing subsistence within environments other than the temperate and tropical savanna/grasslands. In Eurasia, for example, the short chronology of 500 kyr for Europe might be explained by the late appearance of the very productive mammoth steppe, which eventually extended from France to Alaska (Guthrie 1982, 1984, 1990) and which appears sometime after 500 kyr ago (Gamble 1995a; Pettitt, pers. comm.).

Table 15.2 Accessibility of environments: the higher the percentage, the more accessible.

Habitat	*Ease of exploiting plants by animals (%)*	*Ease of exploiting animals by humans (%)*
Tundra	61	16
Boreal forest	11	5
Temperate deciduous forest	11	12
Temperate evergreen forest	11	5
Temperate grassland	**100**	**100**
Woodland/scrubland	32	19
Desert/semi-desert	34	16
Tropical savanna	**61**	**88**
Tropical seasonal forest	13	7
Tropical rain forest	13	9

Source: After Kelly 1983: Table 3

Notes: Plant exploitation derived from Table 15.1, column (1/2) and animal exploitation from Table 15.1, column (3/2)

Finally, at a global scale, Table 15.2 might be used to predict the sequence of major habitat colonization during the course of hominid evolution (Gamble 1993b:8–12). For example, it is in this context that the issue of when the tropical rain forests were first colonized (Bailey *et al.* 1989; Politis and Gamble 1994) becomes relevant, in terms of understanding something about archaeology's fifth big question. If the predictions fail, then we need either to develop more sensitive comparisons between habitats or to attribute the environment with less influence in determining the pattern of hominid expansion.

THE BACKGROUND TO EARLY COLONIZATION

The key period for early colonization, which emerges from the African chapters in this volume, centres on the half million years between 1.8 and 1.3 myr ago. During this time, and well after any immediate climatic forcing could be claimed, the elements in the behavioural/anatomical package, as shown in Table 15.3, appear.

This package of changes represents the evolution of some core hominid behaviour. The inter-related causes and consequences are very well summarized in the expensive-tissue hypothesis as outlined by Aiello and Wheeler (1995). This model starts from the observation that in modern humans our brains account for 2 per cent of our body weight but consume 20 per cent of all our energy intake. Moreover, in order to manage energy budgets without dramatically increasing body size, the process of encephalization can have been achieved only by downsizing another organ. This organ appears to have been the gut. So, as brains increased in size guts decreased proportionately. Aiello and Wheeler propose that this could only occur with a shift to higher quality diets and, in particular, animal protein. The move would therefore be from herbivory (as best exemplified by the megadont robust Australopithecines) to omnivory, where meat played a larger part in the diet to compensate for the smaller gut.[1] Novel behaviours to compensate for the reduced processing power of the gut would be selected. Among these, cooking of meat, the equivalent of an external digestive system (Aiello and Wheeler 1995), would be particularly advantageous. Such a dietary change would in turn entail a shift from a primate to a carnivore pattern of range behaviour and where larger territories would be covered. There would also be social costs associated with this new scale of land use with longer periods of separation. Traditional patterns of maintaining social

Table 15.3 An important 500,000 years in hominid evolution.

Myr	*Occurrence*
1.8	*Earliest* first expansion from sub-Saharan Africa (Sangiran)
1.7	Change in food management strategies to securing carcasses rather than just cracking bones for marrow; predator defence implied Encephalization reaches 800 cc
1.6	*Homo rudolfensis, Homo erectus, Homo ergaster* either appear or are well established Acheulian bifaces, meat processing and gut reduction Raw material transfers indicate a carnivore range pattern Episodic use of landscapes leads to artifact concentrations
1.5	Chimp/Bonobo split Fire recorded from burnt bone (Sterkfontein)
1.4	*Later* first expansion from sub-Saharan Africa ('Ubeidiya)
1.3	Last robust *Australopithecus* in East Africa

alliances through constant, or at best very frequent, interaction involving mechanisms such as social grooming would have to change.

No single factor led the way in the development of this package, although social life provided the decisive context for selection (Gamble 1993b:108–16). However, it was during the period 1.8–1.3 myr ago that the package characterized by the selection for expensive tissues came together (Table 15.3). Brain sizes increase in *Homo* to 800cc (Aiello and Dunbar 1993) which, although still far short of later populations, such as Neanderthals and anatomically modern humans, are nonetheless a considerable increase on the early *Homo/* Australopithecine baseline of 500cc. Within Africa, *Homo ergaster* appears by at least 1.6 myr ago (Wood 1992), whilst *Homo rudolfensis* is probably much earlier. Spencer (1997), for example, argues that *Homo erectus* appeared because of the massive increase in secondary grasslands after 2 myr ago. By 1.7 myr in Olduvai Bed II, there is evidence from the animal bones that hominids were now securing carcasses and protecting them against carnivores (Monahan 1996). Acheulian bifaces made on flakes are known from 1.6 myr, as documented by several chapters in this volume (Cachel and Harris; Clark). Their close association with carcasses and cutting meat now seems well established. The first convincing traces of fire-altered bones are present in Sterkfontein by maybe 1.5 myr (Brain and Sillen 1988). Traces of controlled burning are also present in the Early Pleistocene open location of FxJj20 at Koobi Fora. However, the lack of burnt bone makes it difficult to be certain about cooking meat (Bellomo 1994: 177). Finally, it is noticeable that the raw materials used in biface manufacture were often transferred over longer distances (Féblot-Augustins 1990) than was the case with the earlier Oldowan pebble tools (Potts 1993).

Therefore, by 1.3 myr we have a number of good archaeological measures for a suite of behaviours that operated at a scale that I have described elsewhere as a local hominid network (Gamble 1993c, 1995b, 1996).[2] This network encompasses both social and subsistence behaviour, and contains other hominids, non-hominid competitors and resources. It is centred on the individual and the decisions he/she must make in the course of the negotiation and reproduction of social life. Using data from studies of raw material transfers (Geneste 1988, 1989; Féblot-Augustins 1990, 1993; Floss 1994), we discover that range activity in a local hominid network regularly takes place within a radius of 40 km and with an upper limit of 100 km (Gamble 1993c).

An independent check on these archaeological data is provided by Steele's (1996) calculations of group size from brain size—a technique proposed by Aiello and Dunbar (1993) using the neocortex and home range size calculated from body weight data. The results are compared in Table 15.4, with predictions from primates and carnivores (Grant *et al.* 1992). These data translate the raw material transfer data obtained by archaeologists into the carnivore rather than primate model of home range size. Moreover, the data possibly suggest that the major change in later hominid evolution after 300 kyr ago is related to group size and the mechanisms of interaction (Dunbar 1996) rather than to basic range behaviour.

Exapted for, adapted, or dispersal?

The half million years 1.8–1.3 myr ago, sees the development of a behavioural package that, when compared to the preceding 1 million years, has several novel elements. Since it is a highly inter-related package, it is difficult to put its evolution down to any simple prime-mover such as climatic forcing. This being the case, the question that then has to be asked is was this package necessary for dispersal out of sub-Saharan Africa and into the very productive and accessible mid-latitude grasslands (Tables 15.1 and 15.2)? In other words, was it an adaptive solution to the problems limiting dispersal, or was the subsequent and spectacular colonization of the Old World an unintended consequence, an exaptation (Gamble 1993b), of these behavioural changes?

Table 15.4 Selected predictions for average group size and for home range diameters for group sizes in the range 25–300.

	Average group size	*Home range diameters (km)*	
	Predicted from group size/ total brain and body weight	*Primate model*	*Carnivore model*
Homo habilis	91.3	3–8.5	26.2–78
Homo rudolfensis	74.7	3.6–10.4	32.4–96.2
Homo erectus	107.6	3.7–10.6	32.9–97.9
Neanderthal	308.7	3.6–10.5	32.6–96.8
early *Homo sapiens*	312.1	3.8–11	34.4–102.2

Source: Steele 1996: Tables 8.7 and 8.8

The chapters in this volume disagree as to how the fifth question illuminates our understanding of the mechanisms involved in human evolution. This is often due to the length of time scale they favour for colonization. A long chronology favours a gradual view of human evolution and an adaptive explanation. The short chronology can be used to support a contingent interpretation. In this case, the hominids found themselves exapted for dispersal and evolutionary success in the northern part of their Old World range. On reading these chapters, however, it seems unlikely that these dispersals just relied on a friendly environment to push them through the Sahara or across the straits of Bab-el-Mandeb. Such lucky contingency does not seem to be the issue here. Rather, in my view, the hominids co-opted those elements of behaviour that dealt with migration on an immediate ecological time scale and turned them into the trail of colonization (Gamble 1993b: 95). Colonization was thus an unintended consequence of our evolutionary history. It is for these reasons that I favour a short chronology after this package has been assembled. The long chronology is not impossible, but suggests a very different type of hominid dispersal pattern from that associated with *Homo erectus/ergaster*.

CAPABILITIES AND DIVERSITY

This brings me to a consideration of capabilities. One of the great values of this volume is that it allows us to examine the diversity of the global record for these early hominids. There is certainly diversity in technology, as measured geographically and chronologically. This is particularly well demonstrated by Clark and Ludwig and Harris. There is also a stability to the behavioural package that we see so clearly in the well documented African record between 1.8 and 1.3 myr ago. Rather than document this through the distribution of bifaces and pebble tools, since it has been done far more elegantly in the preceding chapters, let me instead take two points on a time-slice transect through the Old World distribution of early hominids. This comparison allows us to establish the role, if any, of ecology on variation in forager lifestyles, as has been demonstrated for contemporary hunters and gatherers (Kelly 1995).

The transect runs from the equator to 51 degrees north, from the Masek Beds of Olduvai Gorge (Leakey and Roe 1994) to Swanscombe (Conway *et al.* 1996), a lower Thames terrace site on the outskirts of London. These two sites are approximately the same Middle Pleistocene age equivalent to Oxygen Isotope Stage 11, some 400 kyr ago.

The FLK excavation in the Masek Beds uncovered a stream channel that contained a hominid mandible (OH 23) and 2,465 stone artefacts, of which 193 were tools, from an area of approximately 38 m^2 (Leakey and Roe 1994: Figure 6.2). The scatter of bones and stone tools reveals no special patterning that might be attributable to hominids, although it is noted that 'there was no apparent evidence of water-alignment and most of the artefacts, particularly the large bifaces made from quartzite, were in unusually fresh condition' (Leakey and Roe 1994:118). Twenty-two whole bifaces were recovered. They are very similar in size and pointed in form, which suggests that they may have been the work of a single craftsman; this is supported by metrical analysis of the material (Leakey and Roe 1994:119, 207). Finally, the FLK site produced sixteen mammalian taxa (Leakey and Roe 1994: Table 7.2).

At a latitude of 51 degrees to the north, the site of Swanscombe also has evidence of human occupation associated with stream channels and banks. The oldest part of the sequence, the lower loams and lower gravels, were last excavated between 1968 and 1972 (Conway *et al.* 1996). According to the excavator, the lower loams produced some 375 stone artefacts from 200 m^2 whilst from the lower gravels 104 artefacts came from an excavated area of 62.5 m^2 (Waechter *et al.* 1970). The artefact densities have been recalculated as cubic measurements by Ashton and McNabb (in Conway *et al.* 1996:228) and give a range of 3–7.2 per m^3 for the lower gravels and 31.2 per m^3 for the knapping floor in the lower loam. Twenty-eight mammalian taxa have been identified from the lower gravel and lower loams (Schreeve, in Conway *et al.* 1996:150).

The indications are that these deposits have much lower densities of arte-facts than the FLK Masek site. However, this site might be more comparable to the Upper Middle Gravels at Swanscombe, where large numbers of slightly rolled, pointed handaxes have been found, although few are from controlled excavations (Roe 1981:75). This gravel unit also produced the three sections of the Swanscombe skull.

Several points of comparison are worth making. At Swanscombe, a wide range of depositional and preservational conditions have been found. These include horizons within the lower loam where animal footprints are preserved (Davis and Walker, in Conway *et al.* 1996), as well as artefacts incorporated into fluvial gravels. The same range of micro-habitats, with their varying opportunities for preservation of hominid activity, are also present in the Masek Beds and in the underlying deposits of Olduvai Bed IV.

However, despite all these opportunities to find differences in the archaeological record that might relate to the effects of latitude on ecological productivity, the overwhelming impression from the two locations is one of similarity. The wide range of mammal species points to the richness of the secondary grasslands, even though they are separated by 50 degrees of latitude, and the impact this must have had on seasonality. The northern grasslands were possibly even richer in secondary biomass than their tropical counterparts. Even so, the Swanscombe hominids would have been faced with the severe limiting factor, even during an interglacial, of how to make a living during the long winters in this northern locality. The absence at both sites of hearths, post holes (which could have been preserved, like the footprints, in the Swanscombe loams) or indeed any structured activity other than flint knapping or carcasses butchery is striking. How different indeed, in terms of technology, settlement systems and camp-site organization, is the situation along a similar latitudinal transect among modern foraging peoples (Kelly 1995).

How are we to interpret such similarity in the scale and dimensions of the Masek and Swanscombe local hominid networks? Is this a situation where *generic skills* were applied to different ecological conditions? If this was the case, then we should expect the tolerance of hominids to vary with the pattern of amplitude changes in those conditions. Hence the ebb and flow of population, as measured at a regional scale, might provide the strongest archaeological signature of variation in behaviour. Alternatively, we might be looking for the development of *specific skills* along that transect. Storage techniques, for example, might be developed to cope with the long northern winters.

Bifaces and raw material

All the evidence in this volume points to a generic skills model. This can even be extended to an east-west transect, where stone is apparently 'replaced' by bamboo on the Movius frontier. The evidence supporting a generic skills model can be demonstrated through considering raw material.

White (1995) has demonstrated for the British end of the transect that the flaking quality of local raw materials had a role to play in determining biface shape. The preference was for a circumferential working edge, with an ovate form representing the optimal shape. Experiments show that this provides an efficient implement for cutting meat from large animal carcasses. Moreover, ovate-dominated biface assemblages are invariably found near good supplies of raw material. In the English examples studied by White, those assemblages dominated by pointed handaxes used local supplies of much poorer fluvial gravels. As a result,

> [Biface] shape does not form a template but is rather the result of rhythmic repetition of an adaptable technological repertoire. Therefore, it is the highly localised, situational nature of the Lower Palaeolithic which makes biface assemblages vary. Biface manufacture is strongly correlated to raw material sources and these dictate the technological responses employed by the hominids.
>
> (White and Pettitt 1995:32)

Whilst this seems a convincing explanation for understanding variability among British assemblages (Roe 1981) and even, I would suggest, provides support for the local, situational use of bamboo/stone to the east of the Movius Line, how does White's principle work at the other end of our north–south transect?

The FLK site in the Masek Beds provides the comparison. The twenty-two bifaces are made from Naibor Soit white quartzite which, according to Jones (in Leakey and Roe 1994:256), is found within 5 kms of the site and is common as slabs of up to 5 kg in weight. This raw material was used almost 'exclusively and extensively' for small, light-duty tools, although Jones qualifies this by reporting that in Bed IV and at Masek FLK the biface assemblages were all dominated by this material (Leakey and Roe 1994:267). The naturally serrated edges of the quartzite bifaces (Leakey and Roe 1994: Plates 20–1) were particularly useful in experiments on skin and meat cutting carried out by Jones.

Roe's metrical analysis of biface shape for the FLK material reveals a predominantly ovate pattern in comparison to the Middle Gravels from Swanscombe, where the assemblage is dominated by pointed forms (Table 15.5). At Swanscombe, the raw material in the middle gravels was poor in quality and derived from the river beach (White 1995:3). By contrast, the raw materials available to hominids in the upper loams was of higher quality, hence the difference in biface shape between the two assemblages.

There is, of course, much more to compare between these assemblages, such as flake scar counts and the percentage of the biface covered by cortex (Callow, in Leakey and Roe 1994). What is needed is an in-depth study of biface morphology and raw material between a site such as Swanscombe, with access to flint, and Olduvai, where the raw materials might superficially be regarded as of poorer quality. The point of such an analysis, made possible by Roe's standard analysis, would be to examine White's model from the perspective of a generic, or transferable, skills model for Lower Palaeolithic hominid behaviour. The initial indications are that variation in this aspect of technology can be explained by local conditions where generic skills are exapted rather than adapted to meet new situations. These biface-making and using skills operate in the survival context of aspects of meat management linked to the selective pressures of changes in expensive tissues.

Table 15.5 A comparison of biface shape groups based on metrical analyses performed by Roe which separates specimens into three groups.

Locality	*Cleaver (%)*	*Ovate (%)*	*Pointed (%)*	*Total no.*
FLK Masek	15	65	20	20
Swanscombe Middle Gravels	1.3	18.8	79.9	159
Swanscombe Upper Loam	0	66.7	33.3	18

CONCLUSION

The standardized approach to biface variation pioneered by Roe is an example of the sort of studies we need if the degree of diversity among early hominids is to be assessed. This volume assembles these data so that such an approach can now proceed on a global and regional basis. As a result, many interesting patterns to do with subsistence, settlement and technology will emerge. However, having read all the chapters, what I am struck by is the conclusion that the rise and diversity of the Lower Palaeolithic probably has more to do with those elements we are trying to infer beyond statements about land use and feeding strategies, in other words hominid social life as a context for selection. Here diversity takes on a different aspect, as individual hominids varied enormously in their capability to construct networks, pursue alliances and attain social goals. The package of behaviours that led to colonization does, however, seem to have been very transferable. Such generic skills were part of the local hominid network, and their very repetition allowed the intricacies of social life to proceed. The research challenges that now face archaeologists interested in this period lie not only in improving chronologies and documenting more accurately the lifestyles of the last 2.5 myr, but also putting such skills into the context of the fifth big question and asking how, seemingly, such small variation could have led to such massive geographical expansion. Why was the diversity of the world not immediately matched by the diversity of the species that made it its own?

NOTES

1 The change in growing seasons and day length in northern latitudes would have accentuated the move to higher quality diets, as originally discussed by Dennell (1983).

2 This does not imply that local hominid networks appeared for the first time by this date. All hominids past and present had and have such networks.

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