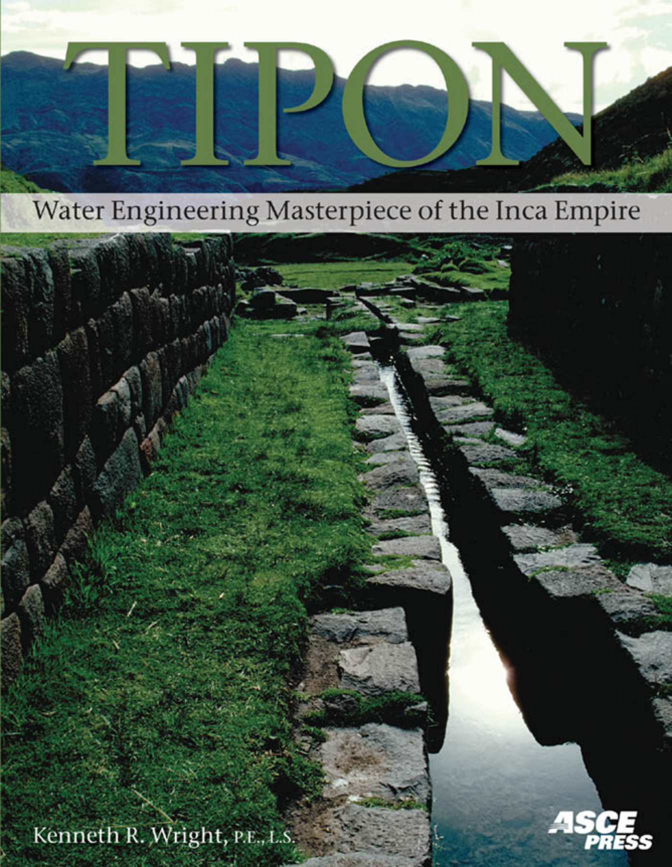
TIPON

Water Engineering Masterpiece of the Inca Empire



Kenneth R. Wright, P.E., L.S.

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Tipon

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Tipon

Water Engineering Masterpiece of the Inca Empire

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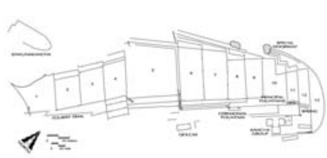
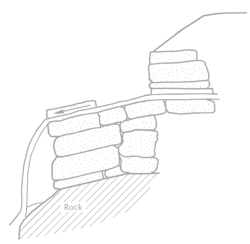




Preface

Tipon is an Inca archaeological site that is not as well known as Machu Picchu. But, like Machu Picchu, it is an engineering marvel in every sense. Much still needs to be learned about Tipon and its origins and history. What we do know is that it represents a jewel of the Inca empire from which we can benefit in knowledge and better understanding of the prehistoric Inca and their building skills.

The objective of the study of the Tipon archaeological site was to learn how the prehistoric civil engineers used and handled the site's water supply so well that all was in balance, forming a whole that was a water management masterpiece, complete with an infrastructure that created an estate for Inca nobility.

Topographic surveying, clearing, structure measurements, mapping of three long unused canals, and analysis of how the Central Terraces were irrigated by their several canal systems were performed, using the same type of engineering techniques as one might use in a modern engineering assignment for a client. What we found was startling: the Inca engineers knew a lot about the handling and beneficial use of land and water for community development.

After visiting Tipon several times in the 1995–1999 period, and after admiring the care and thoroughness given to its layout and design, Kenneth R. Wright, and his professional colleagues Christopher Crowley and Scott Marshall, selected Tipon as a research project. Dr. Alfredo Valencia was soon on board with his scholarly and expert knowledge of the Cusco valley. The Peruvian government issued a permit in 1999. Dr. Gordon McEwan of Wagner College on Staten Island also lent his scientific Andean knowledge to the effort. Dr. McEwan is a long-time, highly experienced Andean archaeologist, who has focused his entire professional life on the study of two nearby sites in the lower Cusco valley, Pikillacta and Chokepukio. Both of his research sites are close to Tipon, and he knows much about Tipon and the technological skills and culture of the predecessors of the Inca.

Fortunately, Dr. Brian Bauer had already analyzed the upper Cusco valley cultural development and made certain opinions and findings available to us for the interpretation of the Tipon archaeological site. Archaeologist Dr. Susan Niles of Lafayette College earlier studied and reported upon the Cusco valley in her scholarly publications. These were helpful in putting Tipon into its proper cultural framework.

Ruth Wright, an attorney and former Colorado state legislator, is an award-winning photographer whose work has appeared in *National Geographic Magazine*. She handled the lead photographic assignment for the Tipon project. Her *Machu Picchu Guidebook* is a best-selling publication on the subject of Machu Picchu.

Patricia Pinson and Sally Kribs helped with the research and editing and provided assistance with figure preparation and selection. Ms. Pinson participated in field exploration in Tipon in 1997 and had already gained a good understanding of Tipon. Mary Simmerman worked tirelessly to type this text and keep up with our revisions.

This book is meant to provide modern engineers and casual tourists alike with an appreciation of the Inca civilization through the analysis of the works they left behind. What they accomplished in stone and land forms can tell us more about their way of life than even written descriptions; with on-the-ground works in stone and reshaped land, there can be little exaggeration or embellishment of accomplishments, even after 500 years.

Chapter 1 takes the reader into Tipon and explains its function and setting, while Chapter 2 describes the Inca engineering planning that went into the site. Ancient climate conditions are summarized in Chapter 3. The Central Terraces that are the focal point of Tipon are described in detail in Chapter 4. The resulting hydrology of Tipon is discussed in Chapter 5. Water handling and its management, along with the Inca hydraulic engineering planning and design, are described in Chapters 6 and 7. In Chapter 8, the buildings and structures of Tipon are highlighted so that a visitor to the site can readily understand how this masterpiece of community layout functioned in an efficient manner and how the many parts fit into the whole.

Understanding what the Inca had to start with in about 1400 CE and what the earlier people of Tipon did before the Inca occupied Tipon is described in Chapter 9 in terms of ancient use of the site and the building of the colossal outer wall for the 500-acre enclosure. Especially for those scientists, engineers, and laymen interested in Inca technology, Tipon design standards, along with Inca engineering technology in general, are presented in Chapter 10.

How the Inca did so much in such a short time is answered in Dr. McEwan's scholarly Chapter 11, where he describes the long and rich Inca heritage. Modern citizens of Peru may better appreciate their long and successful cultural development via the description that is laid out in a clear and concise manner. Chapter 12, written by *Machu Picchu Guidebook* author Ruth Wright, gives detailed instructions for a self-guided walking tour of Tipon.

After you understand Tipon, and when you next visit the Cusco area, you will want to include Tipon high on your list of "must visit" places. You will not be disappointed.

Dedication and Acknowledgments

It is only fitting to dedicate this book to the people of the Inca empire of five centuries ago from whom we have much to learn in the twenty-first century. Of the millions of people of the Inca empire, we especially pay tribute to their civil engineers who fanned out all over the empire to build public works that would demonstrate prehistoric genius in planning, design, and construction. Their work in stone has left a legacy for the young people of Peru.

Then, it is necessary to herald the adventures, exploration, and accomplishments of Yale University history professor, Hiram Bingham, who in 1911 and 1912 made many unusual discoveries of Inca settlements and works, and then was able to eloquently describe his discoveries in the April 1913 issue of *National Geographic Magazine* in graphic detail for an international audience. We thank Hiram Bingham especially for his early visit to Tipon and his photographs that show it at that time. Thanks to *National Geographic Magazine* we were able to use some of Bingham's photographs to illustrate the Tipon of almost a century ago.

The civil engineers of modern Peru belong to a proud profession. This book is also dedicated to them. Their work and accomplishments, to a large extent, stem from the distinguished Universidad Nacional Ingeniería (UNI) in Lima, Peru, that holds high the cultural heritage left by the Inca civil engineers. UNI has trained thousands of young people who are descended from the Inca empire.

Senator Timothy Wirth, former Undersecretary of State for Global Affairs, was instrumental in our study of paleohydrology in Peru by assisting in obtaining our first Inca research permit in 1994. To him, this book is also dedicated.

This dedication extends to several generous and knowledgeable Andean scientists such as John Rowe and Pat Lyon of the University of California, Berkeley, Richard Burger and Lucy Salazar of Yale University, our colleague Alfredo Valencia Zegarra of Cusco, and Frank Eddy of the University of Colorado for their counsel and advice that led to the study of Tipon. We must also include architects Vincent Lee and Jean-Pierre Protzen for their long-term scholarly analysis and technical leadership in Inca construction research.

The Instituto Nacional de Cultura of Cusco and Lima, and particularly archaeologist Arminda Gibaja Ovieda of the Cusco offices, has been generous in its 11 years of cooperation and assistance to our paleohydrology studies in Peru, and we appreciate its generosity in making Tipon available for this paleohydrological research.

Finally, we dedicate this book to the staff of Wright Water Engineers, Inc., especially Christopher Crowley and Scott Marshall, who assisted in field exploration and provided the necessary technical support.

A PERFECT SETTING

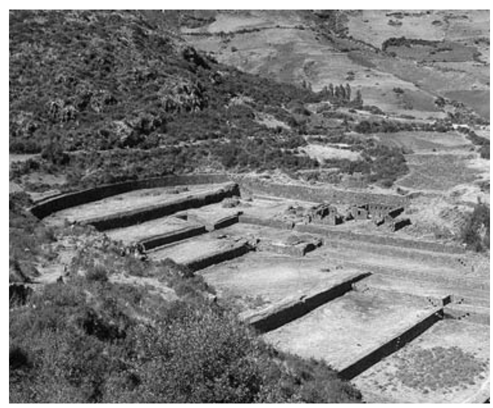
Tipon was important to the Andean people for thousands of years before the arrival of the Spanish conquistadors because of its geographical setting, soil, and reliable water supply. For the same reasons, it was not abandoned with the collapse of the Inca empire; Quechua Indians remained in Tipon and continued to enjoy the benevolence of the Tipon Spring. The structures at Tipon today are distinctly Imperial Inca. The civil engineering and public works at Tipon are a joy to behold; not even five centuries of farming activity since the first arrival of the Europeans has erased the abundant evidence of the masterful work of a legion of builders and planners who knew about hydrology and water supply, irrigation, foundations, and sturdy walls built for an eternity.

The civil engineer and casual tourist alike marvel at the public works left by the Inca. Prestigious irrigated terraces abound at Tipon, but the real miracle of Tipon is understood only when the site is viewed in its entirety. Tipon, as a whole, represents a masterful job of integration of natural resources and civil engineering genius into a self-contained royal estate.

Chapter 1

Tipon: Estate for Inca Nobility

Tipon, and all its parts, represents a prehistoric civil engineering marvel that functioned holistically before Columbus sailed for America. The Tipon archaeological site is a 500-acre, self-contained, walled settlement of the Inca empire that served as an estate for Inca nobility. It is conveniently located only 13 miles down the Huatanay River Valley from the Inca capital of Cusco. Its dramatic visual focal point is a set of 13 large, integrated, central terraces that stairstep down a former ravine, the terraces formed by handsome, carefully designed stone walls that are judged to be among the finest in all of Peru. At the head of the ravine, the life-giving perennial Tipon Spring issues from the base of a volcanic rock deposit, enhanced by elegant Inca headworks. The spring is ideally located to supply irrigation water by gravity to nearly all of the central terraces. But before the water was routed to the irrigated land, the Inca engineers constructed a remarkable fountain, now restored, with four enticing jet streams.



The beautiful irrigated Central Terraces of Tipon stairstepping down a former ravine provide a focal point for wise and efficient use of water and land. These high-status terraces showcase the Inca standard of care for the handling and management of water.

Overlooking the central terraces is a set of handsome buildings for the nobles, a nearby two-story grain storehouse, and a military complex. A long irrigation canal from a distant valley encircles the terraces on three sides.

Some 600 feet northwest of the central terraces are the Ceremonial Plaza, a long aqueduct, and a religious complex that is called the “Intiwatana.” From there, about 3,000 feet to the north, is the urban area of Pukara that housed the nobles and their retinue, likely estate managers and craftsmen. Many

The ancient Tipon Spring at the head of the Central Terrace ravine collects life-giving groundwater derived from limestone at the base of the volcanic rock deposit that is then distributed to ceremonial fountains and to the irrigated land via canals and hydraulic drop structures.

This Tipon fountain was designed and built to showcase the remarkable water supply and to provide the amenity of flowing water, as well as to help demonstrate the power of the Inca.

A long surface water canal from a distant stream operated in harmony with the groundwater supply to provide conjunctive use of two water sources and to irrigate lands lying above the Tipon Spring.

irrigated terraces border Pukara, and three canals traverse the steep hillside above.

The very highest point in Tipon, at some 13,000 feet in elevation, is the Cruzmoqo, where ancient petroglyphs from before 2000 BCE still decorate the volcanic rocks on the summit (B. S. Bauer, personal correspondence to Ken Wright, 2003). The Cruzmoqo served as a military observation point and a structure with religious significance (*huaca*).

The balance of Tipon is mostly covered by walled terraces for both irrigated and dry land farming. The exceptions are some upper slopes too steep for terraces and a huge, smooth, volcanic rock slab that is so steep that it will not hold topsoil.

The massive outer wall of Tipon, 15 to 20 feet high and nearly 4 miles long, encircles the community. The wall provided security and firmly established the perimeter of this estate.

Tipon was a perfect location for the Inca nobility to construct an estate. Its perennial spring, adjacent streams on the east and west, and fertile volcanic soils were coupled with an already-walled agricultural enclosure built by earlier people of the Cusco Valley.

Inca heritage

Modern visitors to Tipon stand in awe at the great engineering works of the Inca and the achievements there that transformed the remote mountainside into an engineering marvel. Visitors wonder how the Inca could have known the appropriate technology and accomplished so much in such a short time.

What we now know is that the Inca empire did not develop and prosper in a technological and cultural vacuum. The Inca were able to draw upon thousands of years of cultural and

technical development from remarkable earlier Andean civilizations (Moseley 1992). The Andean people today can look back more than 4,000 years and trace their cultural heritage that evolved from the early days of civilization up and down the Pacific Coast.

You will learn about the extraordinary heritage of the Inca empire in Chapter 11, written by Andean scholar, Dr. Gordon McEwan.

Engineering features

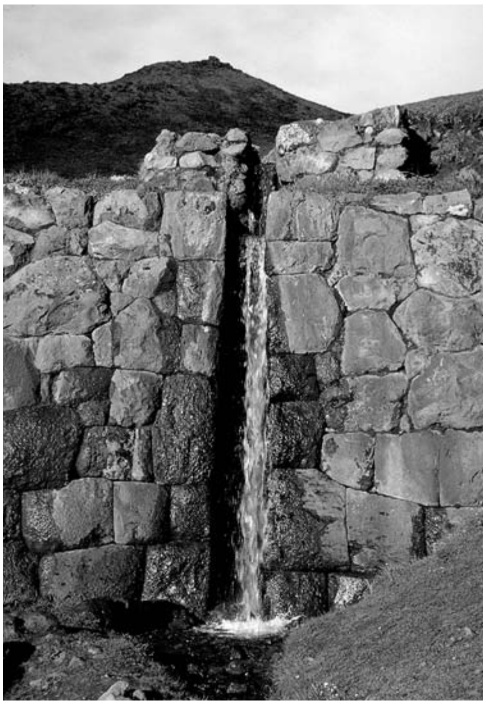
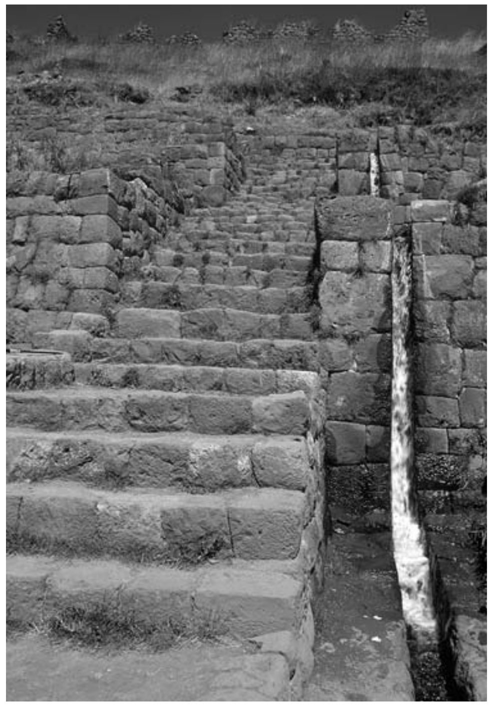
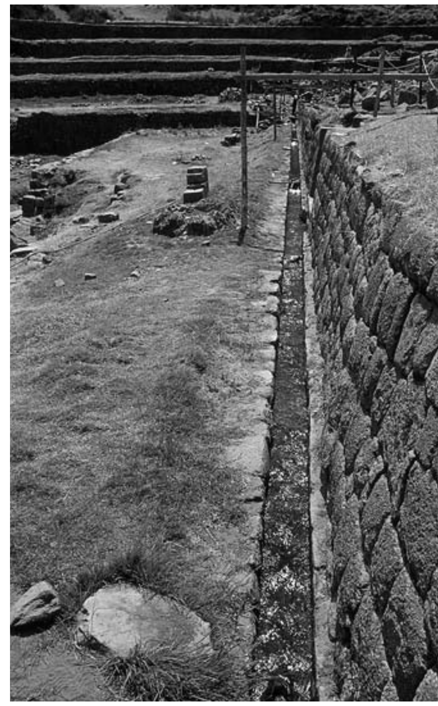
Upon entering the Tipon complex, one almost immediately recognizes that hydraulic engineering genius was at work many centuries ago. Unique hydraulic drop structures abound; they are integrated into the high walls of the central terraces. Then, further upgradient near the middle of the terrace complex, elaborate drop structures in series provide the invigorating sight and sound of cascading water. A ceremonial fountain on an upper terrace lies opposite Terrace No. 8 and was a suitable place for holding ceremonies. Finally, after proceeding further upgradient along the stairstepping terraces, the beautiful four-jet fountain of the Tipon Spring comes into view, again providing the visual and auditory delight of falling water. Along the way, the several longitudinal canals can be admired, some of which are designed for supercritical, high-velocity flow.

From the high ground adjacent to the central terraces, the extent of the agricultural and civil engineering effort is apparent. It included filling the ravine, building many walls and terraces, handling water flow, and distributing it in an aesthetically pleasing manner. This monumental set of terraces will be discussed more in Chapter 4.

A huge volcanic slab on the mountainside is steep and smooth. It does not easily hold topsoil. Stone quarrying did not mar its scenic attributes, and it was not terraced.

High up on the Tipon Mountain, at nearly 13,000 feet, remains of the massive outer wall still exist at the edge of the steep cliff. The wall helped provide security for Tipon.

High upon the Tipon Mountain, the Cruzmoqo provided a security observation point and signal station that commanded the view of the entire valley. It has mysterious petroglyphs.


Immediately east of the central terraces, the huge, flat, mesa top served as the borrow area for the thousands of cubic yards of material used to fill the ravine. Ancient stone-lined canal sections can be found on the gently sloped mesa that also provided suitable land for agriculture.

The long canal that traverses the hillside just north of the uppermost terrace can be followed along a tortuous route up the hill to the west through the Intiwatana, and then north across the 200-foot-long, masterfully designed and built aqueduct adjacent to the huge ceremonial plaza. Going westward, the canal can be followed upstream over rolling terrain and then over a steep hillside to the Pukara River, where it passes through the massive perimeter wall to a water diversion that filled the canal.

The layout of the Pukara settlement below three irrigation canals with adjacent agricultural terraces represents good city planning. Various structures in Pukara demonstrate the typical Inca engineering care for detail, function, and fitting development into the natural environment.

Certainly, the massive perimeter wall represents a major construction achievement that required enormous effort by many hundreds of workers and their overseers, plus trained engineers to ensure a sound and continuous defensive wall that encircled the entire site. But, detailed examination of the wall tells us that earlier people built the wall prior to the Inca empire.

Taken as a whole, Tipon represents a major civil engineering achievement by prehistoric Americans who were masters of irrigation and hydraulic technology and who designed buildings, water works, and massive structures to be visually and functionally in harmony with the natural environment.

CLOCKWISE FROM TOP, LEFT

Hydraulically efficient and visually aesthetic restored drop structures are combined with the beautiful high-status walls of the Central Terraces. Water is carefully delivered from one elevation to another via these structures.

The triple drop structures near the middle of the Central Terraces play an important water delivery role, while providing a water amenity adjacent to an important staircase.

A longitudinal canal designed for a supercritical flow regime delivers water quickly downstream to the large terraces via a series of three hydraulic drop structures.

A ceremonial fountain is strategically located near Terrace No. 8.

CLOCKWISE FROM TOP, LEFT

The buildings and terraces of ancient Pukara tell a story of Inca engineering and city planning.

The Inca mastery of public works is exemplified by the 200-foot-long aqueduct that carried surface water in a canal, from far away, to the Intiwatana in the background before circling back to the Central Terraces. The Ceremonial Plaza is on the left.

Canal stones mark the route of Canal C on the East Mesa near Patallaqta. The open, flat meadow of the mesa lies beyond the ancient stones.

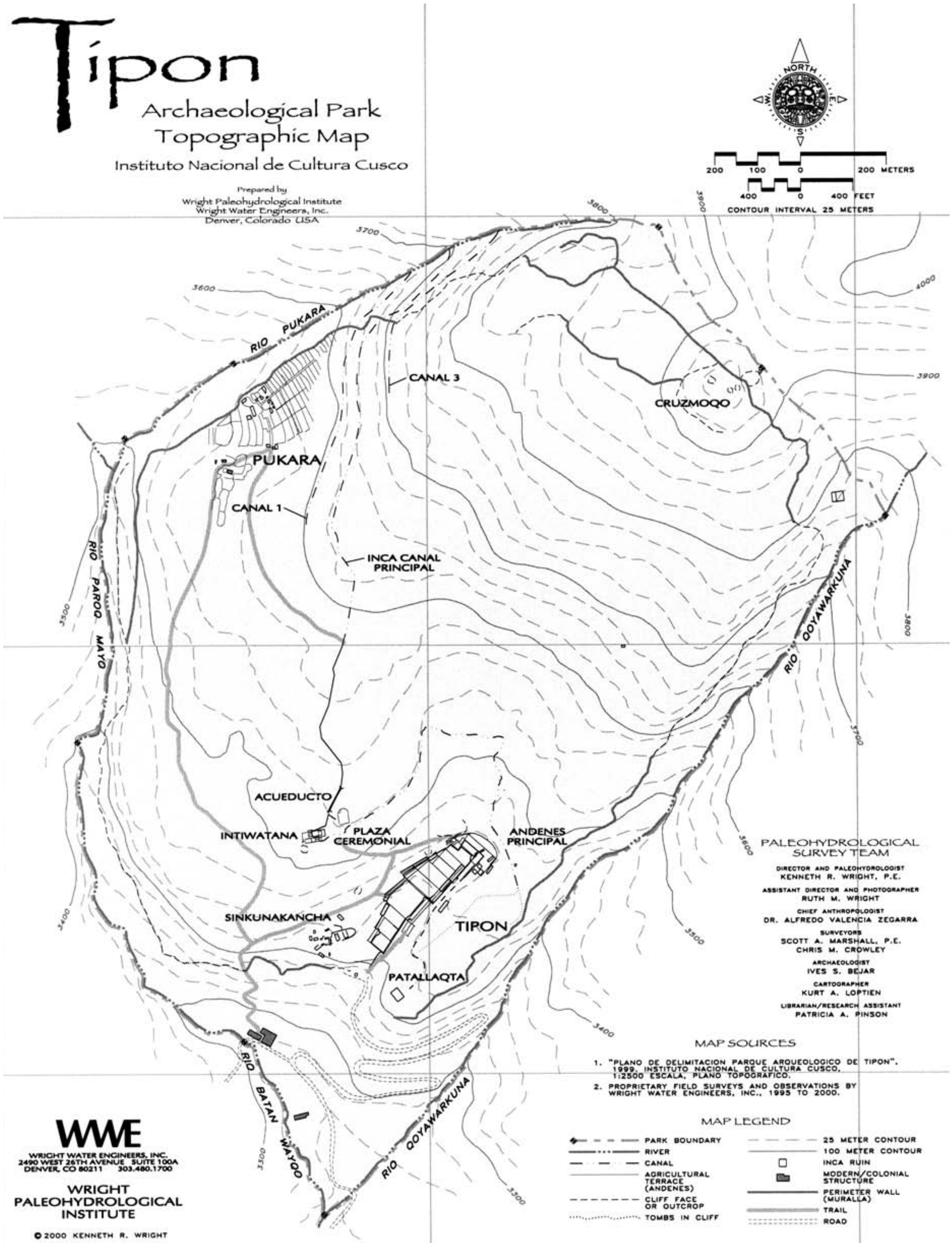
The long, massive outer wall of Tipon was a major construction achievement built by predecessors to the Inca. Construction methods used are similar to known Wari walls.

Site location

Tipon is part of the recently created Tipon archaeological park that lies 13 miles east of Cusco in the Cusco Valley at an elevation ranging from 12,000 to 13,000 feet above mean sea level. The site is at latitude 13°34’ south, longitude 71°47’ west. The archaeological park of Tipon is located in the department of Cusco. In terms of local jurisdiction, it is in the Choquepata community. It is situated on the left flank of the Huatanay Valley. Its boundaries can be identified on National Map 28S-IV-EN-1972 (Cumpa 1999). The reader is also referred to the Carta Nacional 1:100,000 topographic map “Cuzco,” HOJA 28-5, for hydrographic data. The site, in relation to San Jeronimo, Saylla, and Oropesa, is shown on the location map. The Tipon archaeological park is depicted in two figures, one a topographic map and the other an aerial photo.

The earlier people

The prehistoric cultural heritage of Tipon is well established. University of Illinois-Chicago archaeologist Brian Bauer found nearby hillside lithic evidence of campsites dating from 6000 to 4000 BCE (Bauer 2004). Dr. Gordon McEwan has traced continuous occupation of down-valley Chokepukio from 350 BCE to



Tipon
Archaeological Park
Topographic Map
Instituto Nacional de Cultura Cusco
Prepared by
Wright Paleohydrological Institute
Wright Water Engineers, Inc.
Denver, Colorado USA
NORTH
200 100 0 200 METERS
400 0 400 FEET
CONTOUR INTERVAL 25 METERS
RIO PUKARA
CANAL 3
CRUZMOQO
PUKARA
CANAL 1
INCA CANAL PRINCIPAL
RIO PAROQ MAYO
RIO QOYAWARKUNA
ACUEDUCTO
INTIWATANA
PLAZA CEREMONIAL
ANDENES PRINCIPAL
SINKUNAKANCHA
TIPON
PATALLAQTA
RIO BATAN WAYQO
RIO QOYAWARKUNA
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ARCHAEOLOGIST
IVES S. BEJAR
CARTOGRAPHER
KURT A. LOPTIEN
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MAP SOURCES
1. "PLANO DE DELIMITACION PARQUE ARQUEOLOGICO DE TIPON", 1999, INSTITUTO NACIONAL DE CULTURA CUSCO, 1:2500 ESCALA, PLANO TOPOGRAFICO.
2. PROPRIETARY FIELD SURVEYS AND OBSERVATIONS BY WRIGHT WATER ENGINEERS, INC., 1995 TO 2000.
MAP LEGEND
PARK BOUNDARY
RIVER
CANAL
AGRICULTURAL TERRACE (ANDENES)
CLIFF FACE OR OUTCROP
TOMBS IN CLIFF
25 METER CONTOUR
100 METER CONTOUR
INCA RUIN
MODERN/COLONIAL STRUCTURE
PERIMETER WALL (MURALLA)
TRAIL
ROAD
WWE
WRIGHT WATER ENGINEERS, INC.
2490 WEST 26TH AVENUE SUITE 100A
DENVER, CO 80211 303.480.1700
WRIGHT PALEOHYDROLOGICAL INSTITUTE
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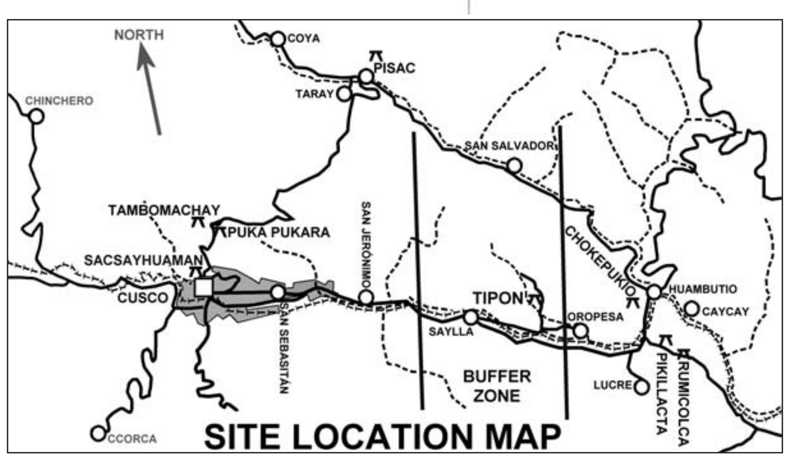
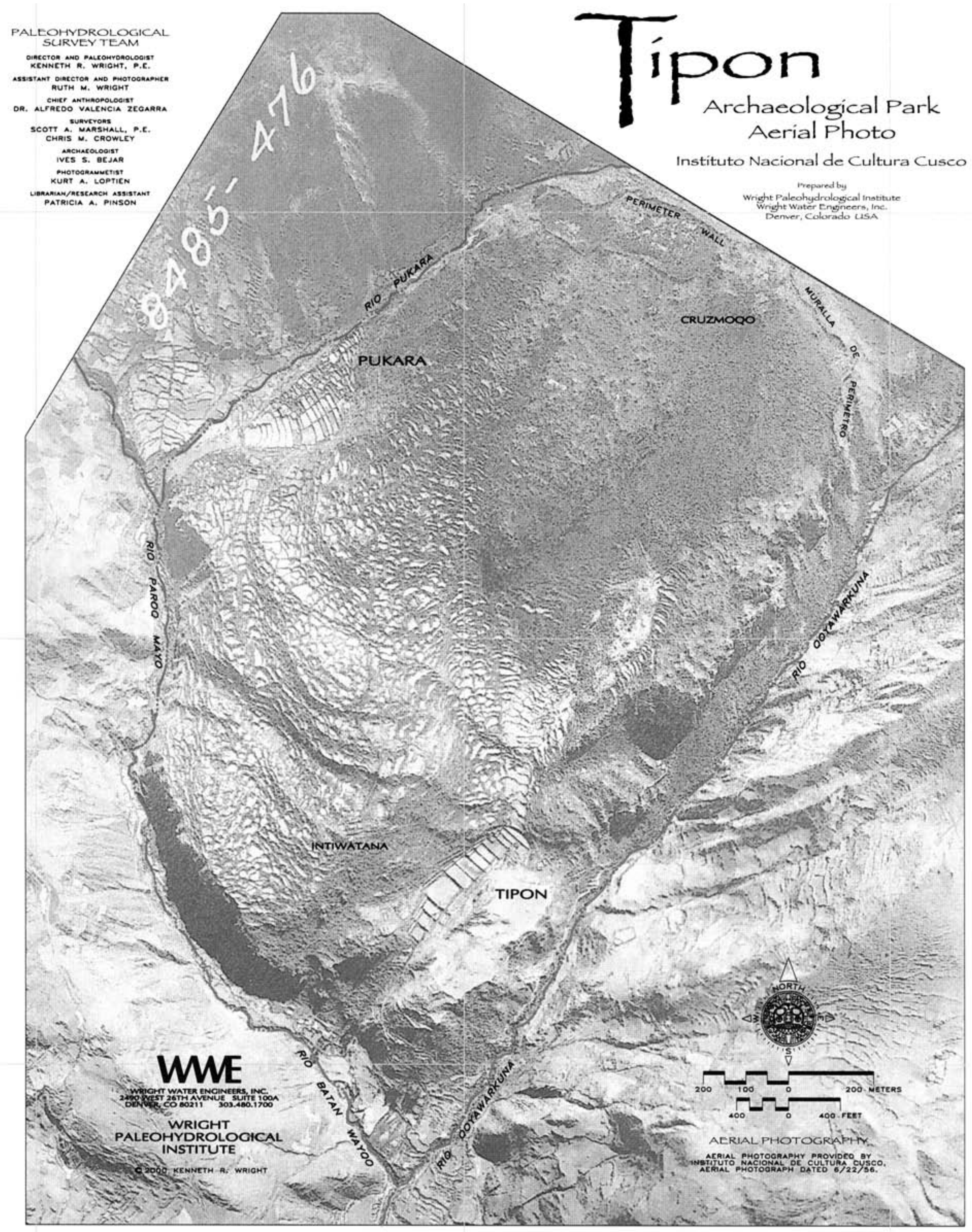


NORTH
COYA
PISAC
TARAY
CHINCHERO
SAN SALVADOR
TAMBOMACHAY
PUKA PUKARA
SAN JERONIMO
CHOKEPUKIO
SACSAYHUAMAN
CUSCO
SAN SEBASITAN
TIPON
HUAMBUTIO
CAYCAY
SAYLLA
OROPESA
BUFFER ZONE
LUCRE
PIKILLACTA
RUMICOLCA
CCORCA
SITE LOCATION MAP



OPPOSITE PAGE

This map of Tipon illustrates the outer wall, major cultural features, and the manner in which the Inca were able to capitalize on natural topography.

The Cusco Valley extends easterly down to the Lucre area along the Huatanay River. In pre-Inca times, Tipon was in a Wari buffer zone. Present archaeological sites are illustrated with a picnic table symbol.

This 1955 aerial photo shows the hundreds of outlying Inca terraces and the many other features of Tipon that made it suitable for an estate for Inca nobility.

Long before the Inca empire, the Wari empire ruled the lower Cusco valley. They built this huge aqueduct in the sixth century to carry water to their administrative center of Pikillacta. Archaeologists long thought the structure was a gateway because the pre-Inca or Inca later modified the Wari works to form a gate with the shaped stones in the foreground. Our surveys proved the original function was an aqueduct.

classical Inca times (McEwan 2002). Chokepukio lies only 4 miles east of Tipon. McEwan's earlier studies of Pikillacta, a stone's throw across the valley bottom from Chokepukio and an early major regional administrative site of the Wari empire, showed continuous occupation from 500 to 1000 CE (McEwan 1987).

Declining rainfall coupled with a long-term climate change spelled the end of the Wari empire, likely in about 1000 CE (Wright 2002). The Wari administrative center of Pikillacta was carefully abandoned; the entrances were methodically sealed as if the occupants expected to someday return. But even today, the entrances remain walled shut; the Wari never returned, and their empire disappeared as its central authority ceased to function (McEwan 1987). Likely, the Wari empire was no longer able to provide adequate food and security to its subjects, and its purpose was lost. But people continued to live in the Cusco Valley and in the Tipon area, as is described further in Chapter 2. Later, the Inca exerted their influence in Cusco. By 1200 CE, the Inca were controlling activities in the Tipon area (Bauer and Covey 2002), but it was not until the fifteenth century that classical Inca construction changed the face and character of Tipon into an estate for Inca nobility.

Who built the Tipon wall?

There was pre-Incan occupation of Tipon, and future studies may show that the wall construction extended back to Wari times because there are architectural similarities in wall construction (G. F. McEwan, personal correspondence to Ken Wright, 2003).

Scholarly research by Brian Bauer and Alan Covey (2002) describes disruption of valley bottom settlements in the lower Cusco Valley and in the Lucre Basin in about 1000 CE. A single settlement was then established at Tipon, and a huge defensive wall was constructed to enclose its agricultural lands and water supply. According to Bauer and Covey, the Tipon area fell under Cusco domination, and the fortified site of Tipon was transformed into a royal estate for Viracocha Inca.

We know that the huge Tipon wall is pre-Inca; the question of whether or not it was built before 1000 CE by the Wari or between then and 1200 CE is the subject of future field research by archaeologists who will make the determination based on tools, on pottery, and by carbon dating of any wood found within the wall. The important matter for us to consider is that the perimeter wall existed prior to the Inca empire and that Tipon was an active site well before Machu Picchu was built and before Tipon was made an Inca estate. The origin of the wall is discussed further in Chapter 9.

Population

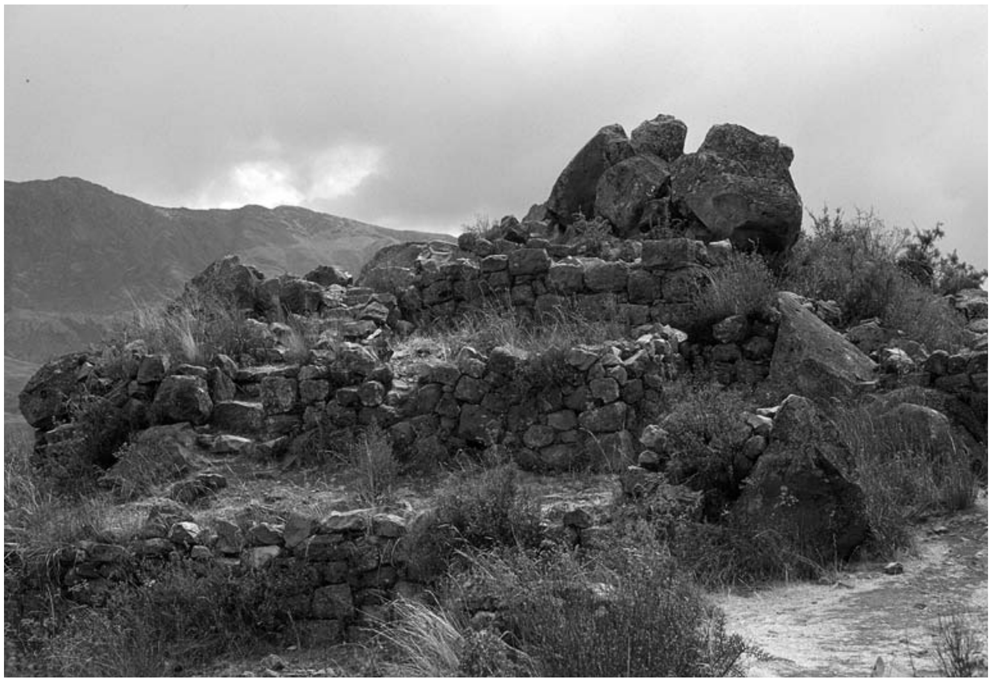
Being an estate for Inca nobility, Tipon had a small resident population. To tend to the fields, maintain the canals, and provide support services, daytime workers were brought in from nearby villages.

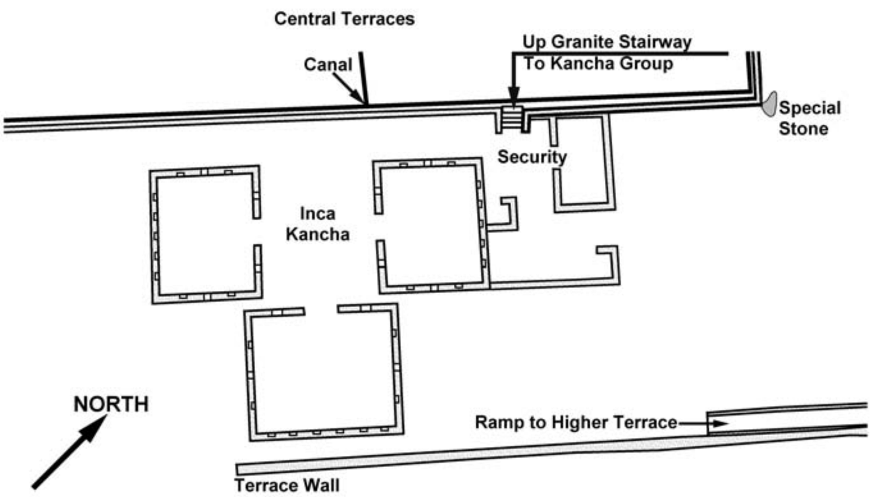
The Tipon archaeological park is divided into different areas with regard to residences. Based on field estimates by Dr. Alfredo Valencia in 2000, about 50 people lived in the Sinkunakancha area near the entrance. Approximately 20 to 30 people lived in the fine structures of the Kancha Group built on the terrace near the spring. The Intiwatana is at a higher level, with urban dwellings for about 40 people. Pukara was a larger community (with more than 100 people) where noble Inca families lived. They were coupled with a transient population (of perhaps 1,500) that included the Mitimas, agricultural workers who the Inca brought in to cultivate the land, as well as artisans who specialized in textiles, ceramics, stone, metal, and cultivation of plants. Most of the Mitimas lived outside the walls.

Tipon climate

For an Andean site at 12,000 feet of elevation, the climate was reasonable. While the winters were dry and nighttime frosts were common from October to early May, there was good rainfall and moderate temperatures, as described more fully in Chapter 3. To help manage the cold winter nights, the Inca designed the Tipon central terraces in a manner so as to conserve the sun's heat and to ward off frost (Frost 1999).

The Sinkunakancha complex overlooks the entrance and Central Terraces of Tipon. The large, oval-shaped platform coupled with its strategic location indicated that the complex might have been a military installation.





The "Intiwatana" complex of buildings, its fine stonework, and a subterranean canal focus attention on this terraced pyramid that represents a sacred place. It was a symbol of government and power.

The Inca Kancha with three high-status buildings facing a small plaza was built with geometric perfection with the placement of niches, windows, and entrances. The buildings overlook the Central Terraces from an elevated terrace.

Geology

Tipon owes its success as an estate for Inca nobility and its long period of occupation to a convergence of two geologic formations. One formation is the Cretaceous limestone, and the second is the Quaternary andesite rock of volcanic origin (Cumpa 1999).

The molten volcanic rock spread out over the limestone deposit to provide a cap on the limestone below. Subsequent cooling of the hot and molten volcanic rock resulted in fracturing that provided vertical permeability. Then, weathering of the andesite over many thousands of years created rich topsoil.

The limestone contains solution cavities caused by water seeping through its cracks and joints; the water slowly dissolved the limestone adjacent to the cracks and joints forming underground channels. Fortunately, the system of solution cavities in the limestone carries percolated water under the andesite to the location of the Tipon Spring. We know that the water of the spring has flowed through limestone on the basis of water quality analyses showing high calcium and hardness.

Peruvian geologists estimate that the volcanic deposit is at least 600,000 years old (Bejar and León 1989). They have identified this same rock throughout the area, including Pikillacta, the Rumicolca Aqueduct, and closer at Oropesa. Further to the south, breccias are common that were caused by the advance of the lava over colluvial debris.

The surface area of the Tipon archaeological site is also characterized by western lying glacial moraines, easterly Cretaceous limestone layers, alluvial gravel deposits to the south, and colluvium derived from disintegration of volcanic rock.

Building stones

The building stone of Tipon is andesite of dark grayish color containing feldspar with other components such as augite, hornblende, hypersthene, or biotite.

Because of its appearance at Tipon, the andesite can be confused with limestone. This is often the case in the Cusco Valley because there are many Inca projects that did utilize limestone for building (Niles 1999).

Fortunately, a simple acid test can be made in the field to identify limestone; the acid causes the limestone to fizz as the calcium carbonate is converted to carbon dioxide gas. Andesite is not affected by acid.

Summary

The sum of all the parts of Tipon represents a civil engineering marvel because, while the parts themselves demonstrate good engineering, the combination of the parts has created a 500-acre jewel of the Inca empire. For example, the manner in which the beautiful central terraces are fitted into a ravine at just the right location to capitalize on the Tipon Spring flow for irrigation, the use of flowing and falling water for aesthetic purposes, and the method used to bring surface water in to supplement the spring flow on the two higher terraces illustrate notable engineering planning. The Intiwatana, the aqueduct, the Ceremonial Plaza, the outer wall, and the layout of Pukara all add up to a remarkable engineering achievement by these talented prehistoric South Americans.

There was no shortage of andesite quarry rock at Tipon. Here, Dr. Gordon McEwan leads a crew to a portion of the outer wall of Tipon, shown in the left center; above, there is a huge rock outcrop.

The wall of the Ceremonial Plaza is of finely shaped stones with joints so perfect that a knife blade cannot be slipped into the joints.

WORK BEGINS

The Inca civil engineers found much to work with at Tipon and must have known the site's development potential because it already was a walled enclave with a focus on water and agriculture. The people of the lower Cusco Valley had capitalized on its land and water resources hundreds of years earlier.

Inca emperor Viracocha, shortly after 1400 CE, took control of Tipon and sent in his engineers to reshape the eastern hill and fill in the ravine below the Tipon Spring to create a showpiece of "modern" agriculture. Falling water was used to dramatize the new and exquisite high-status terrace walls and glorify the gods that provided the flowing water that issued so reliably from the earth.

Ancient canals from the west were examined for rehabilitation with stone linings and aqueducts, then the Intiwatana was laid out on a hill; it was here that a square, stepped structure was provided. It was an elegant, raised platform that served as a ceremonial site where prayers were made. It was a place that represented Inca power and authority.

The civil engineers selected an existing site near the west wall for the Pukara living quarters, fine terraces near the spring for the royal residence, and constructed trails and numerous irrigation laterals.

Being respectful of the holy nature of the summit of the Tipon Mountain that contained the rock art of long ago people, little was planned for the summit other than to ensure its suitability as a security viewpoint and a likely place from which to send signals.

The engineering planning included the use of imperial Inca building standards and design throughout the enclave, except for the already existing massive outer wall. The final product provided special agricultural terraces where new crops were tested, high-status maize was grown and harvested, and the sun's energy was stored in the stone walls to help ward off nighttime crop-killing frosts.

Chapter 2

Civil Engineering Planning

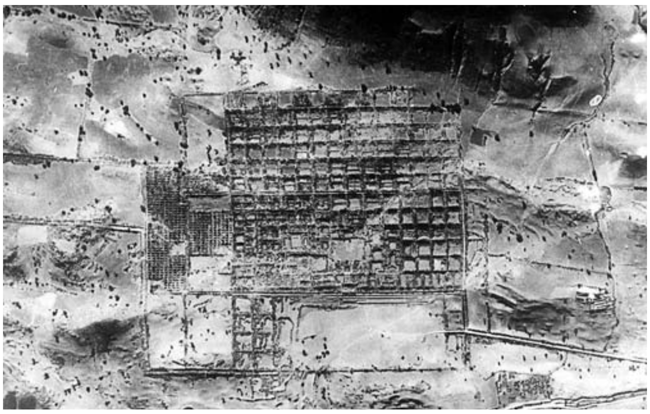
The monumental Imperial Inca works of Tipon were created by Inca civil engineers after 1400 CE (Bauer and Dearborn 1995). The Inca, however, in contrast to their work at Machu Picchu, did not start Tipon with a clean slate. Tipon was not commenced in a remote mountain wilderness; the land and water resources of Tipon had long been an attraction to the local inhabitants.

The Inca stonework poetry of the fifteenth century provided a showcase for hydraulic engineering perfection. Here, engineered canal drop structures lower water from one terrace to another.

What the Inca started with

Even though the petroglyphs of Cruzmoqo, consisting of many interesting spirals carved into dozens of large andesite boulders, were likely already there some 4,000 years ago, and the Tipon Spring had been known and used for ages by early peoples, formalized settlement of Tipon likely began shortly before or after 1000 CE (Bauer and Covey 2002). Settlement possibly commenced by 1200 CE, and well before the Inca Imperial Period of 1400 to 1534 CE.

Once the Wari empire declined in about 1000 CE, and the nearby Wari administrative center of Pikillacta was formally abandoned with the bricking up of its entrances and access to its interior spaces blocked, there was a major disruption in the settlement pattern of the area (Bauer and Covey 2002). Most smaller valley bottom settlements were abandoned; Tipon was established well above the valley floor. The people of the powerful Wari empire knew how to build irrigation canals, stable terraces, and aqueducts (Valencia 1997). The Inca engineers were able to draw upon this rich engineering legacy for their work at Tipon.



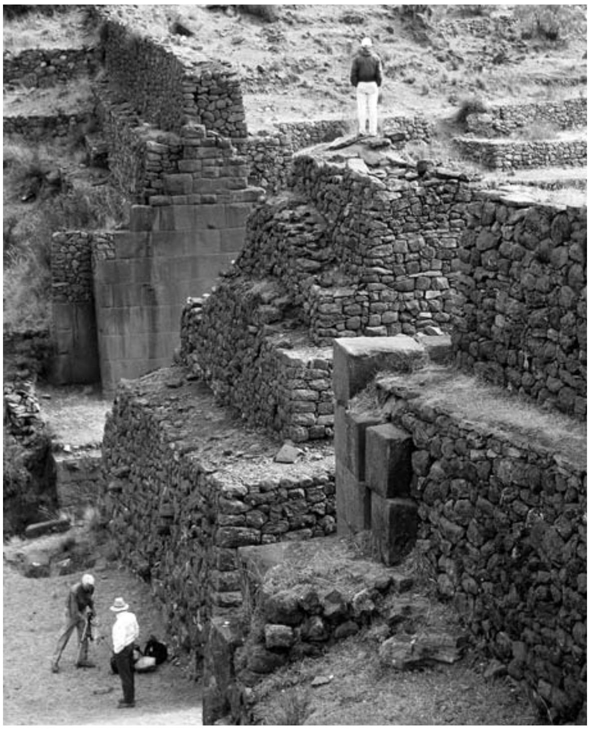
Early Andean people from 4,000 years ago visited Tipon. They left their markings high up on the Tipon Mountain. These types of petroglyphs abound at the summit from where the entire valley can be viewed.

The ancient Wari administrative center of Pikillacta, a few miles from Tipon, was abandoned in about 1000 CE, when the Wari empire collapsed.

The Wari lived in Pikillacta for about 400 years before it was abandoned with care. As if expecting to return, the Wari methodically stoned up its entrances.

The canal that furnished water to the Wari city of Pikillacta was excavated by Dr. Alfredo Valencia. Here, downstream of the aqueduct, engineers from Wright Water Engineers measure the width and depth of the canal that preceded the Inca works at Tipon by about 800 years.

Dr. Alfredo Valencia points to Wari canal remains that likely date to the sixth century. This portion of the canal lies upstream of the monumental Rumicolca Aqueduct. This was the water supply for Pikillacta.



Who built Tipon?

The people who started Tipon, as we know it, could have been the Wari as early as 600 CE to 1000 CE or one of the Late Intermediate Period peoples (900 CE to 1476 CE) such as the Ayarmacas or even the Pinagua that are known historically to have occupied the area (Julien 2000; Espinosa 1976). The nearby settlement of Chokepukio, with deep stratified deposits that are extensively radiocarbon dated, indicates that occupation in the area started as early as 400 BCE in the Early Intermediate Period (McEwan 2002). Chokepukio's occupants were familiar with the Tipon Spring water source.

The Wari or possibly the Ayarmaca, certainly by 1200 CE, surrounded the Tipon spring and agricultural lands with a huge defensive wall built of rough andesite fieldstone and mud mortar. The 15- to 25-foot-high wall with a somewhat equally sized width at the base was a massive undertaking by these early people, the wall being a total of nearly 4 miles long with full advantage taken of sheer cliffs that helped block access to the site.

Finally, in about 1400 CE, the Inca, under the leadership of Viracocha Inca, took control of Tipon. A transformation of Tipon was then begun to create a royal estate for Viracocha and his descendants. Viracocha's estate became an estate for Inca nobility. The ordinary people who helped resettle the Tipon area were Inca colonists that we know as Mitmaqkuna, who were given valley lands but who were also to work the lands in Tipon for the Inca elite (Bauer and Covey 2002).

The Rumicolca Aqueduct of about 600 CE was instrumental in the development of Pikillacta of the Wari empire. The water supply canal crossed the valley on top of the structure. The finely cut stones shown may be of pre-Inca or Inca origin when they converted the aqueduct to a huge, defensible gateway to the Cusco valley.

Many years before the Inca occupation of Tipon, earlier people built a massive outer wall encircling Tipon that was 3.7 miles in length. Even high up on the Tipon Mountain, portions of the wall remain for modern engineers to admire.

Inca engineering planning

The Inca civil engineers who came to Tipon recognized the potential of the high yielding spring with a pure, reliable base flow of

nearly 300 gallons per minute, the adjacent streams on the east and west, the rich volcanic soil, and the south-facing slope. They appreciated the already constructed perimeter wall for security and Tipon's land for its agricultural potential.

For planning of Inca Tipon, the engineers probably utilized knotted strings called *quipus* and clay models to express design concepts (Lee 1996) for the reshaping of the topography and layout of the buildings. Along with the need for hillside stability, they must have considered the potential hazard of debris flow down the main ravine because they filled it in from the reshaping of the ridge top to the east.

The Inca, as children of the Sun, knew about storing daytime solar energy in high, stone retaining walls that would later radiate heat during the cooler nights and keep crops from freezing. Such techniques were developed long before, near Lake Titicaca (Kolata 1993). The Central Terraces in the ravine were ideal for growing the high-status crops of maize, flowers, and herbs, as well as providing an excellent location for experimental strains of maize, potatoes, and other useful foodstuffs.

Housing for the Inca emperor and nobles was established next to the Central Terraces with a view of the terraces and close to the Inca Spring that flowed from bedrock. Near the Kancha Group, they used an oven (*hornopata*) to fire ceramics.

Up on the hill to the southwest was the Intiwatana and a nearby Ceremonial Plaza, both served by the main Inca Canal from the Rio Pukara that crossed a topographic depression on a long stone aqueduct that also served as a formal trail. Security was ensured by a military area overlooking the Central Terraces, near the main entrance and outer wall.

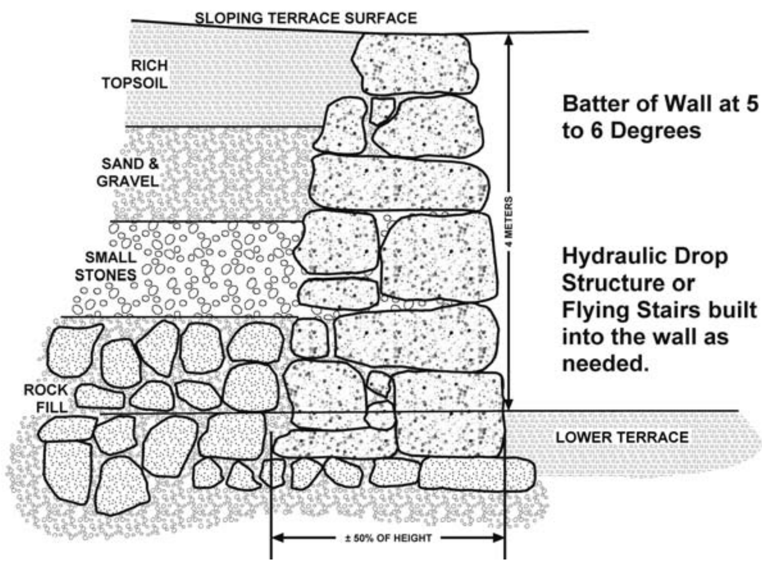
Central Terraces with high-status walls were laid out in a ravine in a manner to create beauty, geometric excellence, and agricultural land. The terraces are irrigated mostly with water from the Tipon Spring; higher terraces were supplied with surface water brought to the site via a long canal.

Housing was far to the west near the outer wall at Pukara, where irrigated terraces were created for more agricultural production. High up above on the Tipon Mountain was the Cruzmoqo that served as a security lookout post and signal station where

a complete viewing could be made of the entire area.

Full use was made of the existing outer wall and rough irrigation ditches that diverted directly out of the Rio Pukara. On the other hand, the lower flows of the Rio Qoyawarkuna to the east were not tapped into because of the steep terrain and the difficulty of constructing canals.

A storehouse of two stories was built overlooking the terraces in a location that all could see; the storehouse showed that there was plentiful food for the next year, and, certainly, this impressed visitors and workers alike.



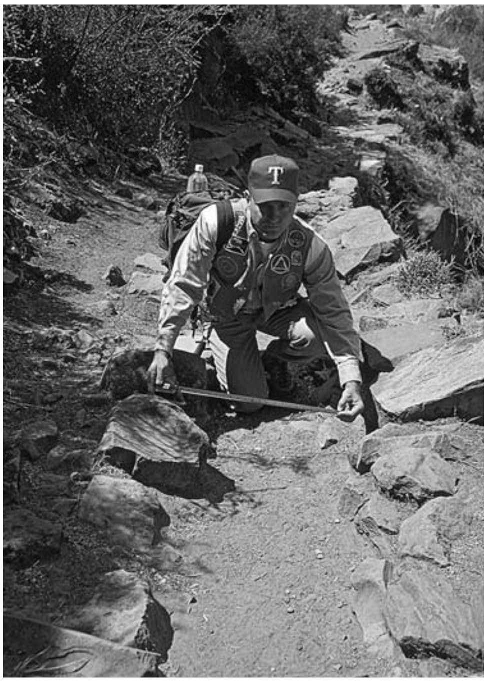
Central Terraces

First of all, to create a focal point that incorporated the spring, the Inca engineers likely filled in the valley below the spring with rock and soil taken from the adjacent hill to the east, the hill then becoming a large mesa suitable for additional agriculture. Here, the engineers shaped the mesa with a slope to the south of 12 percent that was more than adequate to allow the irrigation water to flow by gravity from one end to the other.

In the ravine, they placed boulders and rock fill to provide for good subsurface drainage to help ensure the long-term integrity of the overlying terraces. On top of the rock fill, smaller stones were placed, and on top of those were placed gravel and sand to form a huge, deep inverse filter. Finally, deep, rich topsoil was placed that was suitable for special plants and various strains of high-status crops such as maize, the seeds of which could be exported throughout the empire.

The massive engineering feat of the Inca at Tipon is illustrated in the view of the shaved down East Mesa (left) and the Central Terraces in the center, as seen from the summit of the Tipon Mountain. The East Mesa was irrigated by surface water brought from the Rio Pukara.

The high stone walls that form the Central Terraces were especially massive so as to resist soil pressures and earthquakes. The reverse filter meant that irrigation water and rainfall would easily percolate downward without creating added hydraulic pressure. Stonemason Bruce Davis provided the details for this cross section.



The remains of the 1.75-mile-long canal from the Rio Pukara still lie in its prehistoric alignment to the East Mesa. Here, Christopher Crowley is measuring the bottom width of the stone-lined cross section. The canal continues in the background.

Flying stairs were built into the Inca walls so that agricultural workers could quickly move from one terrace to another.

Special hydraulic structures were incorporated into the Tipon terrace walls so that irrigation water could be lowered from one terrace to another.

Planning for the Central Terraces included comprehensive water management to incorporate the use of both groundwater from the spring and surface water brought to the site by a canal; modern engineers call this conjunctive use.

To form the terraces, the civil engineers built tall, solid, lateral walls of volcanic rock to capture and hold the heat of the sun through the chilly nights. Longitudinal terraces formed the edges of the terrace system; some of these were built 13 feet high. In building the walls, they incorporated “flying stairs” for the workmen so that they could rapidly move from one terrace level to another.

To make the Central Terrace system a showcase suitable for an Inca emperor or nobleman, the engineers built fountains with many special qualities, as described in Chapter 7, and they constructed special hydraulic drop structures that enhanced the visual impact of Inca irrigation engineering.

Building materials

There was no shortage of good stone building blocks. The volcanic flow of lava that was deposited on Tipon long ago, during geologic time, provided andesite rock that could be shaped in a variety of forms using hammerstone brought in from the glacial deposits and regional stream channels; however, the hammerstones had to be of rock harder than the andesite and preferably rounded for ease of use.

Labor

Agricultural field workers at Tipon during the Inca occupation did not live within the walled enclosure, but returned at night to their nearby villages of Choquepata and Oropesa, bordering the Huatanay River. This meant that housing was not provided for the 1,500 or so workers within the walls.

The convenient Inca system of requiring labor from its citizens in lieu of taxes meant that an adequate labor force was available, as needed (Moseley 1992).

Fortunately, the valley of the Huatanay River has a wide floodplain that provided ample land near the villages for food production, well beyond that needed for local subsistence.

The plan

A square mile of Inca development may have been planned, perhaps with the use of clay models, to create an estate not far from Cusco, yet remote enough from the Huatanay Valley to provide a quiet and inspiring location for visitors and residents alike. The enclosure was secure, having a high and massive outer wall, and access could be readily controlled by the resident security force.

Within the Tipon wall was a self-sustaining community with about 500 residents and many acres of irrigated land with fields of varying elevations.

Summary

The Inca civil engineers, just like their modern counterparts, knew how to conceptualize, plan, design, and build. They knew how to translate imperial policy and design standards into stone and earth structures. They knew how important it was to the administrators in Cusco to design in harmony with nature to take advantage of the environment and to incorporate views. Most of all, they knew the importance of being stewards of the soil; for without soil, there would be no agriculture (Wright and others 1997b). Without agriculture, there would be no Inca empire.

In planning for the redevelopment of Tipon, the Inca had as their goal a place where water, soil, agriculture, and topographic relief would be integrated. What they planned turned out to be a virtual water garden that impressed all who saw it.

Engineer Scott Marshall examines an original and unrestored 13-foot-high Tipon retaining wall that formed one of the lateral boundaries of the Central Terraces. Note the excellent stonework.

THE INCA LEARNED FROM THE PAST

An empire that owed its success to providing agricultural surpluses and eliminating subsistence farming knew about climate and its vagaries. The Inca learned about climate, El Niño, rainfall patterns, and floods from their long line of predecessors. Evidence shows that Andean people were irrigating crops on a substantial scale some 3,800 years ago. Their livelihood depended on irrigation.

Just what was the ancient climate like? Ice cores tell a 1,500-year story of rising and falling fortunes in the Andes and along the Pacific coast as preceding empires rose to greatness and then declined as the climate changed. Floods demolished early cities such as that of the Moche kingdom along the north coast.

The Inca were able to live with the unpredictable rainfall and climatic variations. This chapter tells the story of a 1,500-year climatic record that was etched in the ice of the Quelccaya Ice Cap halfway between Tipon and Lake Titicaca.

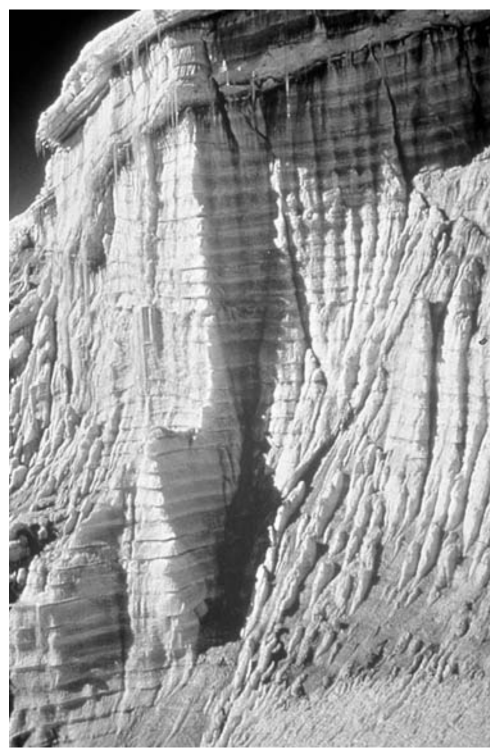
Chapter 3

Ancient Climate

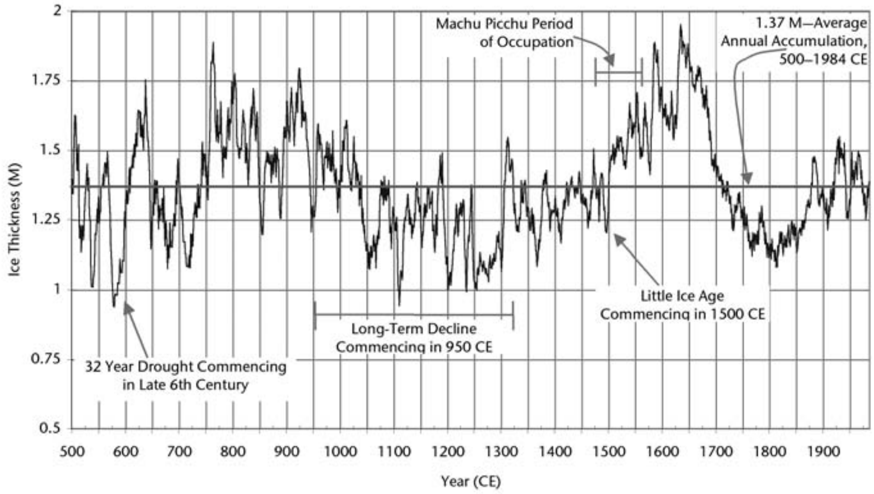
To better understand the Inca and their brilliant work at Tipon, it is important to consider the role of the Andean climate and its effect upon the many preceding civilizations from which the Inca adopted water handling technology and agricultural know-how. When one considers Andean climate, it is also necessary to understand the role of the El Niño phenomenon (Wright 2002).

The history of Andean civilization stretches back some 3,800 years to the Initial Period (Moseley 1992). Lacking the scrolls and clay tablets found at digs in the Middle East, Andean scholars in the past have been forced to rely on physical evidence found in and amongst the ruins to understand irrigation, urban planning, water supply, agriculture, and the rise and fall of empires.

This is no longer the case. During the past several decades, glaciologists, meteorologists, geologists, marine scientists, oceanographers, and hydrogeologists have probed the great ice caps and glaciers of the Andes, studied floodplain deposits, and measured ocean temperatures (Thompson and others 1985). The role of climate in ancient history is etched in glacial layers, in cores taken from Lake Titicaca, and in the rings of ancient trees. This information makes possible solid correlations with new and credible data linking droughts and floods to specific periods. The result of this continuing research is a climatological record of Andean weather, dating back not just a century or two, but spanning 1,500 years (Thompson and others 1985).



Etched in ice, climate records were deciphered by Professor Lonnie Thompson of The Ohio State University. Here, the Quelccaya Ice Cap, halfway to Lake Titicaca, shows its layer-cake-like climate record, with each layer representing 1 year. It provided 1,500 years of data on precipitation, temperature, and dust accumulation.



Fifteen hundred years of ice thickness records from the Quelccaya Ice Cap tell a story of rising and falling fortunes of early Andean civilizations. The great climate swings and events can be correlated with on-the-ground archaeological findings.

El Niño

Long before man arrived in the Americas, storms buffeted the Andes, floods inundated coastal plains, and prolonged droughts parched the land. All the meteorological phenomena that we read about in newspapers, see on The Weather Channel, or experience today—floods, drought, storms, winds—occurred in the past. Natural weather cycles, such as El Niño, and all the climate extremes inevitably repeat themselves over time (Diaz and Kiladis 1992).

What is El Niño? It is the warming of the Pacific coastal surface water off South America. Typically, the onset of El Niño occurs during the Christmas season, hence the name “El Niño,” the Spanish word for “Christ child.” The warming of surface waters is significant, ranging between 4 and 14 degrees Fahrenheit, and may last a full year. The Pacific Ocean thermocline (layer of water between the warm surface and a layer of colder water underneath) deepens, causing a reversal of coastal current flow from north to south. The nutrient supply to the photic zone, or water zone into which sunlight penetrates, decreases. Then, too, El Niño disrupts the winds that sweep Northern Peru and bring about the upwelling of deep, nutrient-rich waters. When this happens, the usually vast shoals of fish off Peru disappear.

In Peru, El Niño can be a time when great rivers roar down from the Andes, gushing onto the coastal plains. At the same time, drought may scorch immense areas in the Southern Andes. El Niño is also associated with an atmospheric phenomenon first recognized by G. T. Walker over 70 years ago. This atmospheric condition is known in scientific circles as the Southern Oscillation (SO), hence the term El Niño/Southern Oscillation (ENSO). Simply stated, ENSO represents the single major cause of international climate variation on a worldwide scale, including the Andes (Diaz and Kiladis 1992).

La Niña

To a lesser extent, the La Niña phenomenon has also impacted climate conditions in South America. The counterpart ENSO cycle to El Niño, La Niña is the cooling of ocean temperatures in the equatorial Pacific. La Niña conditions cause the eastern Pacific to be cooler than usual and the cooler water to move farther westward. The impacts of La Niña are most noticeable in the winter and generally occur after an El Niño event. La Niña is less common than El Niño, however.

The ancient climate record

The rise of great Andean empires depended on food production. High agricultural yield meant power—to feed armies and control far-flung peoples often a thousand miles from the throne. Most of all, surplus food freed up enormous energy—human labor—to build monumental stone structures, defend the empire, and create works of art. On the other hand, mighty empires could be brought to their knees or even toppled by changes in climate. Prolonged droughts or repeated floods crippled food supply. Whole communities went hungry and lost faith in their rulers.

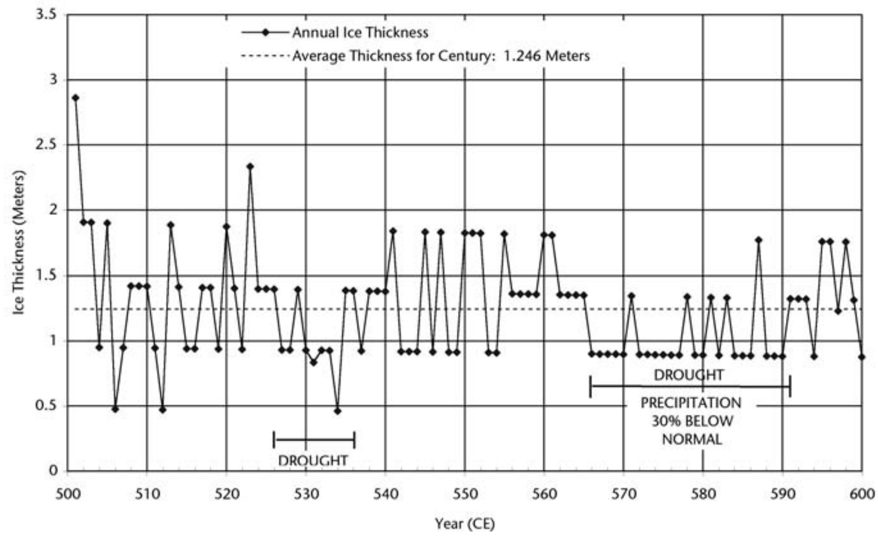
The Quelccaya Ice Cap is located in the Cordillera Oriental mountain range of southern Peru approximately 125 miles northwest of Lake Titicaca. During the 1980s, scientists drilled and analyzed ice cores from the ice cap (Thompson and others 1985). Their work has given us a record of the climate dating from 500 to 1984 CE. Like layers in a cake, each slab of the ice record reveals yearly accumulations of ice along with dust particles and oxygen isotopes. A layer's thickness represents annual precipitation.

The oxygen isotope is a guide to temperature, while dust in the ice from parched agricultural fields was blown by the wind, some of it settling on the glacier. These dust particle concentrations are used to estimate the severity of drought conditions and to identify periods of massive earthmoving. The variations in ice cap layers corresponding to the years 1935 to 1985 correlate well with known twentieth-century periods of El Niño (Table 3-1).

Ice cap data also support archaeological fieldwork. At a variety of archaeological sites, physical evidence of great flooding, drought, and destruction has been found, dated, and correlated with ice core data and Professor Kolata's (1993) sediment cores from Lake Titicaca. Over time, the particulars of El Niño's impacts on ancient civilizations are being unraveled. For example, cores from the Quelccaya Ice Cap provide "ground truth" or confirmation of suspected floods and droughts, including one particularly dry period viewed as the "granddaddy" drought that occurred during the sixth century. The climate tended to be more moderate during the seventh and early eighth centuries with well above

TABLE 3-1. El Niño and La Niña Seasons During Recent Years
Based on Data from the National Oceanic and Atmospheric Administration

Year	El Niño	La Niña
1901	■	
1903	■	
1904		■
1906	■	
1907		■
1909		■
1912	■	
1915	■	
1917		■
1919	■	
1921		■
1924	■	
1925		■
1926	■	
1931	■	
1932		■
1933	■	
1939		■
1940	■	
1941	■	
1942	■	
1943	■	
1947	■	
1950		■
1952	■	
1954	■	
1955		■
1958	■	
1964	■	
1965		■
1966		■
1970	■	
1971		■
1973	■	
1974		■
1976		■
1978	■	
1983	■	
1989		■
1997	■	
1998		■
1999		■
2000		■
2001		■
2002	■	
2003	■	
2004	■	
2005	■	



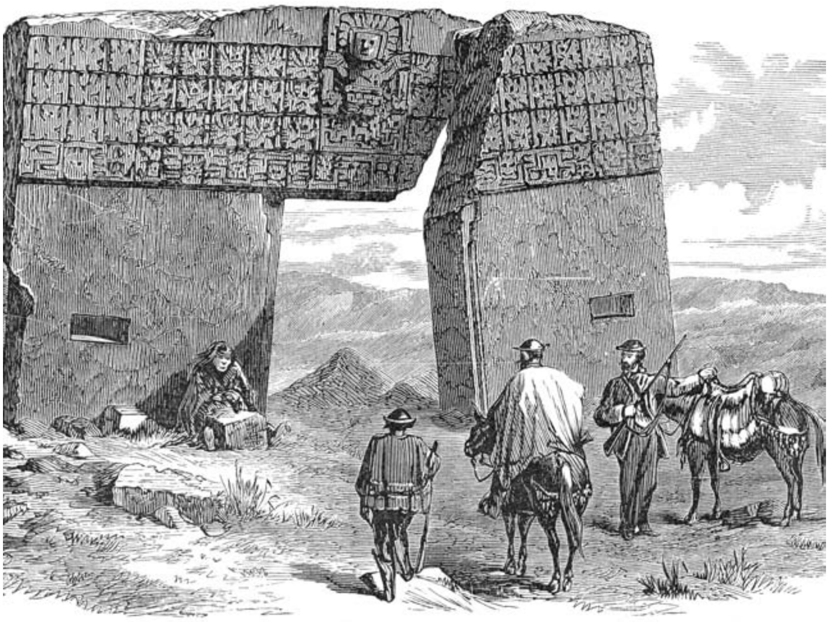
average precipitation from about 740 to 950 CE. This was followed by some 350 years of progressively drier weather with each passing century.

Moche kingdom

Professor and Moche scholar Michael E. Moseley (1992) has written that the Moche kingdom represents a remarkable achievement in statecraft. For the first time, the coastal populations were forged together in one nation. Under the Moche, the arts flourished. Peace and prosperity reigned. Alas, it did not endure. Shortly before 600 CE the Moche River, repeatedly swollen by heavy rains, swept down from the mountains, thundering toward the metropolis built of adobe. The seething water gouged away whole sections of urban landscape, gutted agricultural fields, and stripped away layers of ground to depths of 6 feet. And then, at last, after the vast work of reconstruction was finally completed, the skies cleared. Then for weeks and months on end, no rain fell. Drought settled over the land and the winds picked up. The soil washed out to the sea by the great floods returned to the beaches as sand and was then blown inland. Strong winds carried clouds of sand, burying the Moche capital and surrounding fields under massive dunes.

From 1988 until his death, Thor Heyerdahl studied the pyramids of Tucume in the Lambayeque Valley of northern Peru about 19 miles inland from the Pacific Coast (Heyerdahl and others 1995). It was here the Moche flourished in the nearby Moche Valley, with their capital flanked by two large pyramids—Huaca del Sol and Huaca de la Luna—that dominated the sandy plains. Heyerdahl found archaeological evidence of catastrophes between 500 and 600 CE. He also uncovered signs of a prolonged

The great droughts of the sixth century resulted in the complete makeover of agricultural technology by the Tiwanaku empire in about 600 CE, when they converted to the raised-field system near Lake Titicaca.



FRONT OF GREAT MONOLITHIC GATE-WAY.

and severe drought during the sixth century interrupted by periods of rain brought on by El Niño.

Ice core data confirm the archaeological fieldwork—El Niño struck the Moche capital in 511 to 512, 546, 576 CE, and again in 600 CE. Core samples also point to a great drought that began in 563 CE and continued until 594 CE. During this period, rainfall dropped 30 percent below normal.

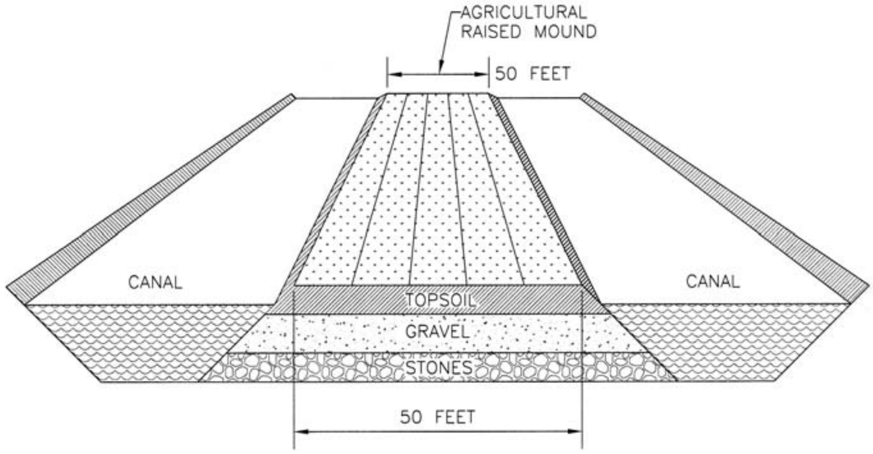
To their credit, the Moche survived years of drought, only to be undone by the floods that followed. After the floods circa 600 CE, their fields stripped of topsoil and covered with dunes of sand, the Moche abandoned their capital, and moved their city north to Pampa Grande in the Lambayeque Valley, another floodplain. Here, they carried on in their new city until 700 CE when archaeological evidence shows fire leveled the capital. It is not known if the Moche, unable to cope with recurrent floods, abandoned Pampa Grande or if the empire fell apart from myriad causes.

Nearby, in northern Peru, the Sican culture rose up after the Moche collapse. Occupying an immense area in the present-day Lambayeque province with more than a dozen pyramids, the Sican people built their capital, Batan Grande, in the Leche Valley. They, too, experienced the effects of El Niño when floods devastated Batan Grande around 1100 CE. The catastrophe doomed Batan Grande forever (Moseley 1992).

Tiwanaku empire

Around 400 CE, concurrently with the Moche IV Kingdom, the Tiwanaku empire near Lake Titicaca had learned to live with the thin air and temperature extremes at 12,000 feet. From its capital near the south shore of the lake, Tiwanaku expanded rapidly. In just two centuries it had become an economic and political power spreading across what is now southern Peru, northern Chile, and

The well-known Gate of the Sun of the Tiwanaku empire near Lake Titicaca is shown here as it looked in 1862 to the explorer George Squier. It speaks of the grandeur of the empire.



Bolivia. Like other empires, Tiwanaku expansion depended on abundant food production, and, for over seven centuries, it regularly produced food surpluses.

The German adventurer Arthur Posnansky explored Tiwanaku in 1904 and, in his monumental two-volume book on Tiwanaku (1945), attributed its decline to "malign climate conditions." Indeed, the historical record confirms that the Andean climate can be malignant. A 32-year-long drought from 563 to 594 CE caused widespread devastation across the empire. There is evidence, however, that a lesson was learned. The rulers took the catastrophe as a warning. They revolutionized their agriculture, instituting a totally new system, which we believe allowed the empire to prosper for 400 more years. In any event, Tiwanaku agricultural surpluses after the drought can be attributed to the raised-field system. Water surrounded raised agricultural mounds. Warmed during the day, the water kept the crops from freezing during the cold Andean nights and even extended the growing season. Raised-field agriculture grew to encompass an immense area, at least 47,000 acres. Studies show that land cultivated in this manner could yield 9 tons of potatoes per acre. Construction of the raised-field system no doubt required major earth moving operations. Interestingly, high dust concentrations, perhaps from the construction activity, show up in the Quelccaya Ice Cap core around 600 CE when the system was being built (Thompson and others 1989).

From about 950 CE on, a long-term decline in rainfall set in. After 1000 CE, crops withered in the field; hunger gripped the empire. Drought seared the south-central Andes, lasting for 300 years. The abundant harvests of the past were now only memories. Unable to feed the hungry, the royal dynasty of Tiwanaku tottered and fell.

The Tiwanaku developed the raised-field system of agriculture following the great drought of the sixth century. Such agricultural methods were used on nearly 50,000 acres that could yield an estimated 9 tons per acre of potatoes.

Wari empire

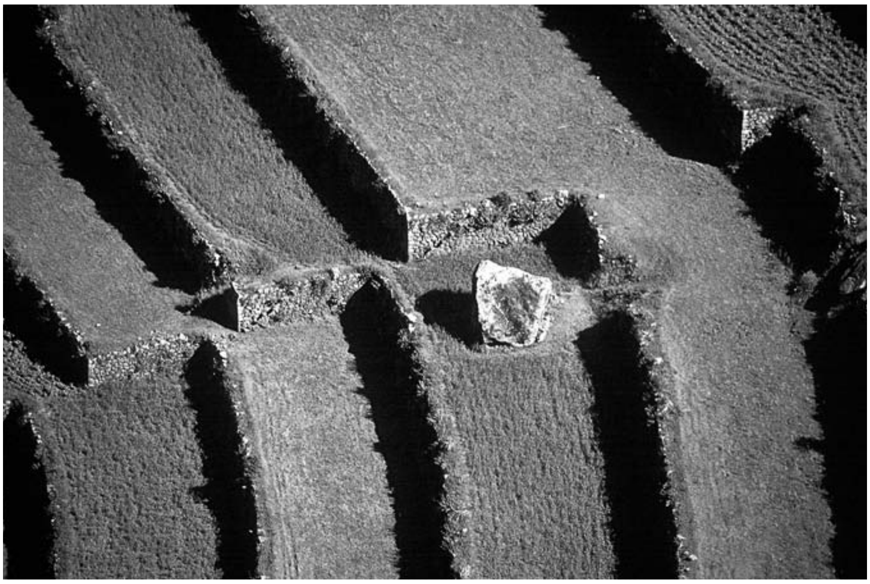
While the Moche wrestled with floods and droughts, the Wari empire spread in the southern Andes 16 miles north of present-day Ayacucho. The Wari flourished, Michael Moseley (1992) thinks, because of agricultural practices they adopted from the Huarpa, an earlier civilization that inhabited the Ayacucho area. The Huarpa are thought to have invented terrace farming. Terraces allowed them to farm the steep mountainsides, using primary and secondary canals for irrigation. Building terraces demanded intensive labor, but, once built, terraces provided steady food production by establishing fields outside of the floodplain.

The Wari added their knowledge of maize varieties with Huarpa technology to produce high grain yields. The Wari surrounded their capital with irrigated terraces, and, over time, introduced terraces throughout their empire.

Irrigated terraces allowed the early Wari to survive the 30-year drought that, in the sixth century, struck the Moche with such devastating impact. Terraced hillsides, moreover, remained unaffected by El Niño flooding. The floods that leveled crops on the Moche floodplain caused little damage to Wari agriculture. For some 400 years, the Wari empire successfully countered the vagaries of nature.

But Wari ingenuity could not cope with the steady decline in rainfall that started about 950 CE and continued for several centuries. The Wari empire entered a period of decline much like the Tiwanaku culture. According to Wari scholar Gordon McEwan, the Wari, over time, slowly ceased to function as a society (McEwan 1998). Archaeological evidence reveals entrances carefully blocked up, like houses boarded up against a storm, and administrative centers such as Pikillacta purposefully closed down. All these measures were done with care, as if the Wari planned to return. The collapse most likely took place in a gradual and orderly way, but, in the end, centuries of drought proved too much for the Wari empire.

The Inca empire spanned 2,500 miles from north to south along the west coast of South America. Its success was based on efficient agricultural production, so as to eliminate subsistence farming.



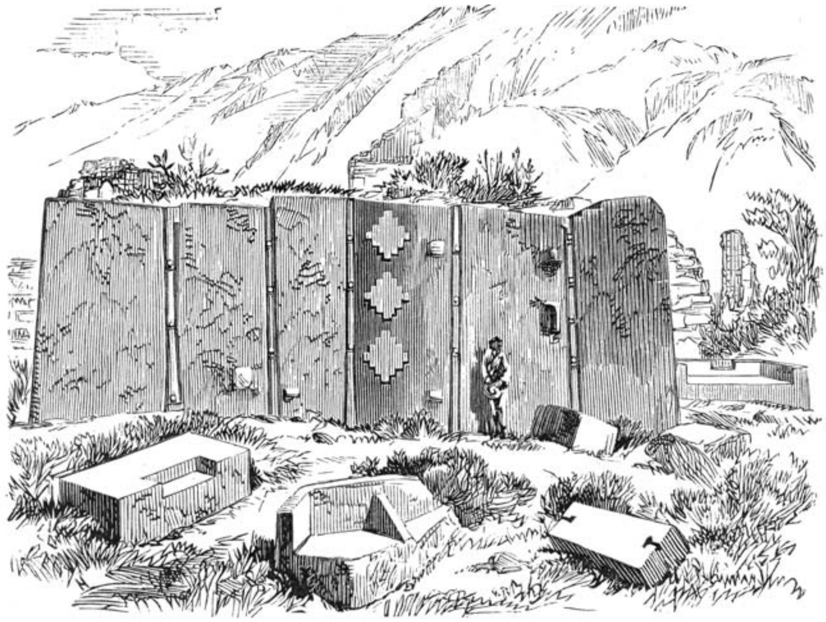
Inca empire

Some three or four centuries later, in about 1400 CE, the Inca people rose to prominence. As it grew, the Inca state successfully absorbed far-flung peoples into an empire, which at its height spanned 2,500 miles from north to south. The Inca's rapid rise hinged on agricultural surpluses, which they stored in countless stone food warehouses conspicuously dotting the hillsides in view of the lower-lying communities. The abundant food freed up a portion of the population of ten million for the military as well as for public works such as the construction of canals, roads, buildings, monuments, and temples. This they achieved through their mastery of land and water.

The Inca employed agricultural techniques formerly developed by their predecessors while readily adopting new methods from the peoples they conquered. They quickly learned to build irrigation systems and flood resistant terraces on steep mountainsides. They also perfected vertical agricultural zones, planting at different elevations crops that thrive at particular altitudes, thereby maximizing harvests. The length of the Inca empire straddled several El Niño zones. From this they learned flexibility in dealing with a variety of climatic conditions such as heavy rains in the north and drought-parched southern highlands.

Over time, the Inca empire endured wide environmental extremes as described by Huaman Poma in 1613 CE. Poma describes volcanic eruptions, the destruction of Arequipa, earthquakes, frosts, hailstorms, and a 10-year drought. Nevertheless, the Inca empire held together and was able to employ a significant portion of its population for military purposes and public works. The Inca's dedication to experiment with new technology and improve their knowledge of agriculture is illustrated by their

Terraces at Pisac in the Sacred Valley near Cusco were masterfully built into the hillsides to provide agricultural land and to stabilize the steep slopes. The rock is from a post-Inca rockfall from the mountainside.



PORPHYRY SLABS, FORTRESS OF OLLANTAYTAMBO.

success at food production. There is evidence the Inca also understood microclimatology. At Moray, the Inca used several huge natural circular depressions, building many terraces stepping downward deep into the earth (Pumaccahua 2001). At Tipon, the Inca constructed magnificent terraces in a ravine. Stone terraces and walls, together with rock outcrops jutting from the sides of the valley, capture the sun's heat during the day and radiate warmth during the cold nights. Also, in this narrow valley at Tipon, warm air currents from the main valley below flow up and across the agricultural terraces, extending the growing season beyond that of valleys not so fortuitously situated.

If further proof of Inca agricultural prowess were needed, it can be found in the fact that the Inca empire housed and fed an estimated ten million people, with energy and manpower left over to construct the "crown jewels" such as Pisac, Ollantaytambo, and Machu Picchu, along with elaborate feats of engineering.

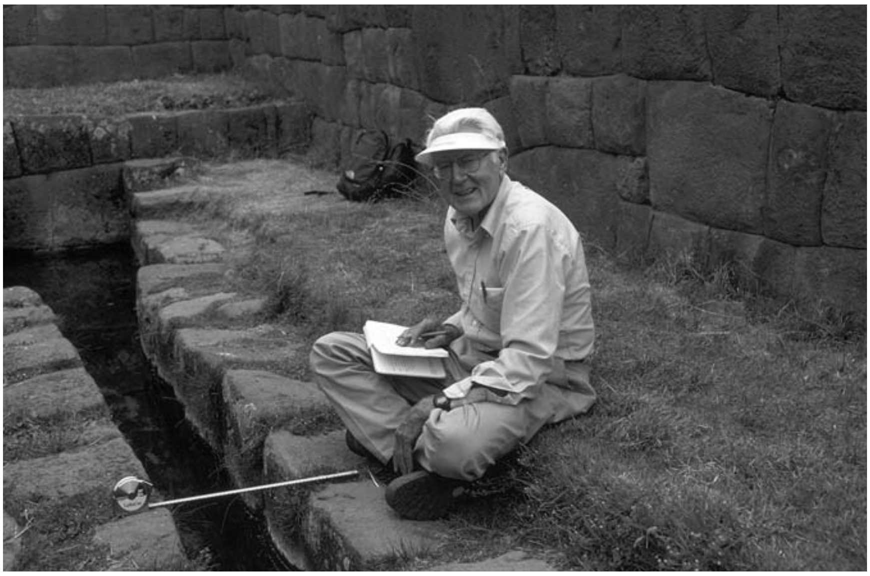
The Inca empire successfully overcame the challenges of drought and flood, efficiently making use of the land and achieving high levels of food production.

Tipon, an estate for Inca nobility, could have provided ample opportunity for the Inca agricultural experts to test special crops and cultivation methods to help counter the challenges of natural climatic variations and to learn about microclimatology management.

Summary

What kind of weather did the Inca deal with at Tipon? What about their Cusco Valley predecessors? To find out, we turned to the 1,500-year-long climate record etched in the Quelccaya Ice Cap that Lonnie Thompson of The Ohio State University deciphered (Thompson and others 1985).

The porphyry slabs at Ollantaytambo are fitted together tightly and represent exquisite Inca stonework. Squier saw the slabs in 1862 and had them sketched.



What we found was that the pre-Inca Tipon climate had wide swings. There were floods and droughts, hundreds of years of moderate climate that allowed settlements in the lower Cusco Valley to grow and flourish, and then in 950 CE, a steady decline in precipitation started. Another drought period began in 1240 CE, lasting until 1300 CE. Then, the precipitation held steady until 1500 CE, when the average precipitation rose significantly and the Little Ice Age began.

Tipon, at 12,000 to 13,000 feet in elevation, experienced frost and occasional cold temperatures from about May through August. The cooler weather coincided with the winter dry season when hardly any rainfall could be expected. From October through April, the rainy summer season helped make the higher dry, agriculture land flourish; potatoes, for which the Inca are famous, provided lots of nutrients. The rainfall in the months of December, January, and February averaged about 6 inches per month.

The Tipon Spring headworks, a masterpiece of civil and hydrological engineering, issues from limestone at the base of the volcanic rock to provide water for ceremonial fountains, domestic use, and irrigation. Here, Ken Wright is measuring spring flow that issues from numerous rock-lined conduits that penetrate into the mountainside to capture flow that otherwise would be dispersed.

TABLE 3-2. Estimate of Tipon's Inca-Period Average Precipitation and Temperature

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Max °C	20	21	21	22	21	21	21	21	22	22	23	22	21
Max °F	68	70	70	72	70	70	70	70	72	72	73	72	71
Min °C	7	7	7	4	2	1	-1	1	4	6	6	7	4
Min °F	45	45	45	39	36	34	30	34	39	43	43	45	40
Rain mm	163	150	109	51	15	5	5	10	25	66	76	137	812 **Total**
Rain inches	6.5	6	4.4	2	0.6	0.2	0.2	0.4	1	2.6	3	5.5	32 **Total**

Annually, Tipon received about 32 inches of precipitation, and had an average temperature of about 55 degrees Fahrenheit. Temperature maximums tended to be 70 degrees Fahrenheit all year long, but average minimum temperature ranged from the low 30s in the winter to 45 degrees Fahrenheit in the summer. Overall, Tipon had a rather pleasant climate that was significantly enhanced by its orientation to the sun's rays. Our estimate of climate during the Inca period is summarized in Table 3-2.

Because Tipon was blessed with an underground water source that issued from the hillside at the base of the Tipon volcanic rock, the people of Tipon tended to be somewhat less susceptible to drought than others. The spring flowed night and day, year in and year out. This natural water supply is the likely reason that Tipon became a center of activity in the lower valley of Cusco.

DESIGN WITH NATURE

Tipon is rightfully known for its 13 high-status terraces that were designed and built for beauty, soil stewardship, and special agricultural purposes. The volcanic rock stonework of the terrace walls represents the finest such construction in the Inca empire.

As if the quality of the stone walls and the flat agricultural land supported by the walls did not, in themselves, provide enough of a visual statement of power and success for the Inca nobility of Tipon and their visitors, the Inca civil engineers outdid themselves with hydraulic structures. There are 43 nearly vertical, high drop structures, two ceremonial fountains, three supercritical flow canals, a fine spring headworks, and many dozens of terrace walls with geometrically placed flying stairs to provide an appropriate structural setting for the hydraulic masterpieces.

Aesthetically, the Central Terraces represent well-planned environmental design. The complex fills the ravine from side to side. From the standpoint of soil stewardship, the Central Terraces have provided for soil stability and protection against erosion and sudden debris flows.

One can only marvel that the terraces have endured in the ravine bottom for five centuries without failing. Indeed, the Central Terraces represent a civil and geotechnical engineering masterpiece.

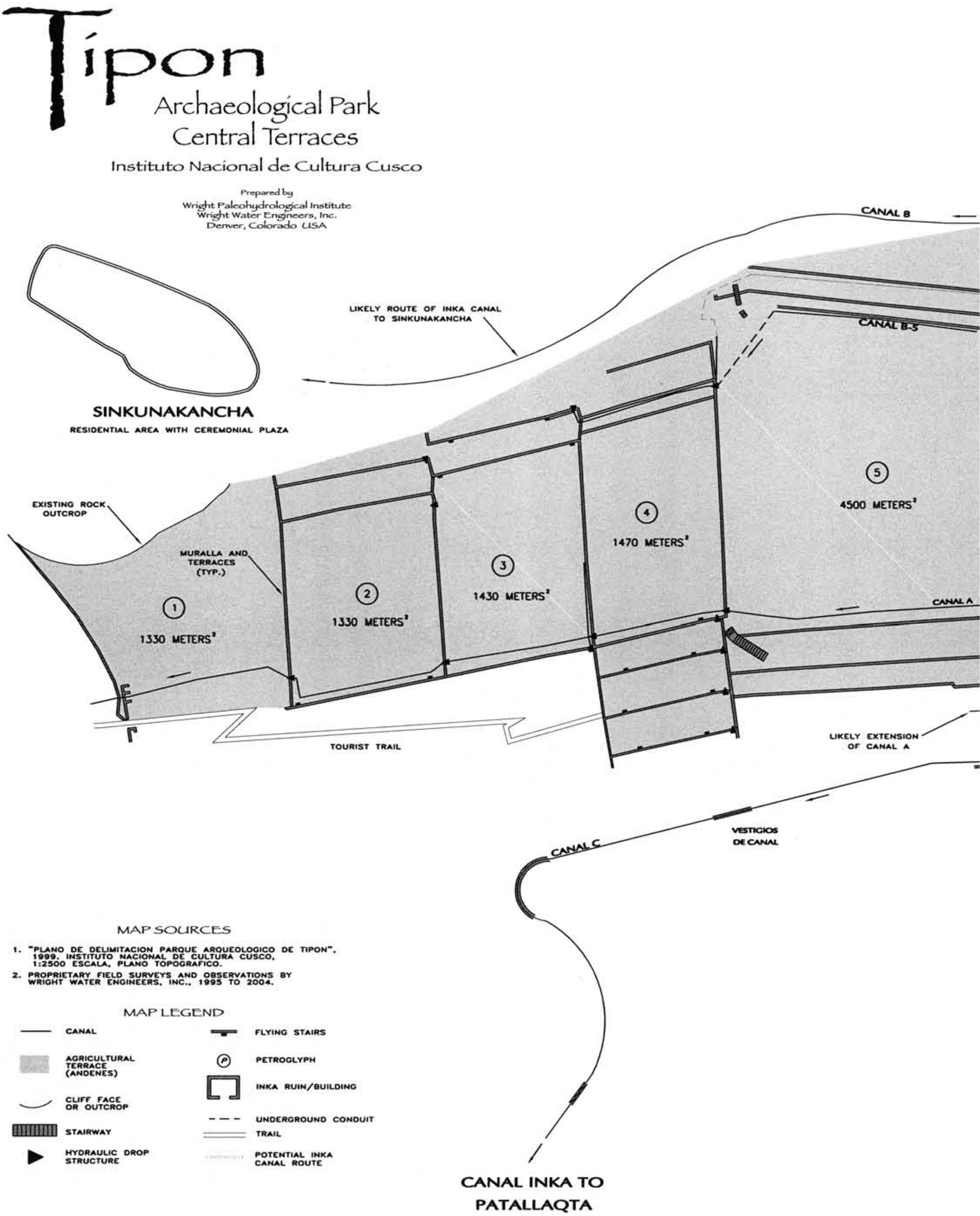
Chapter 4

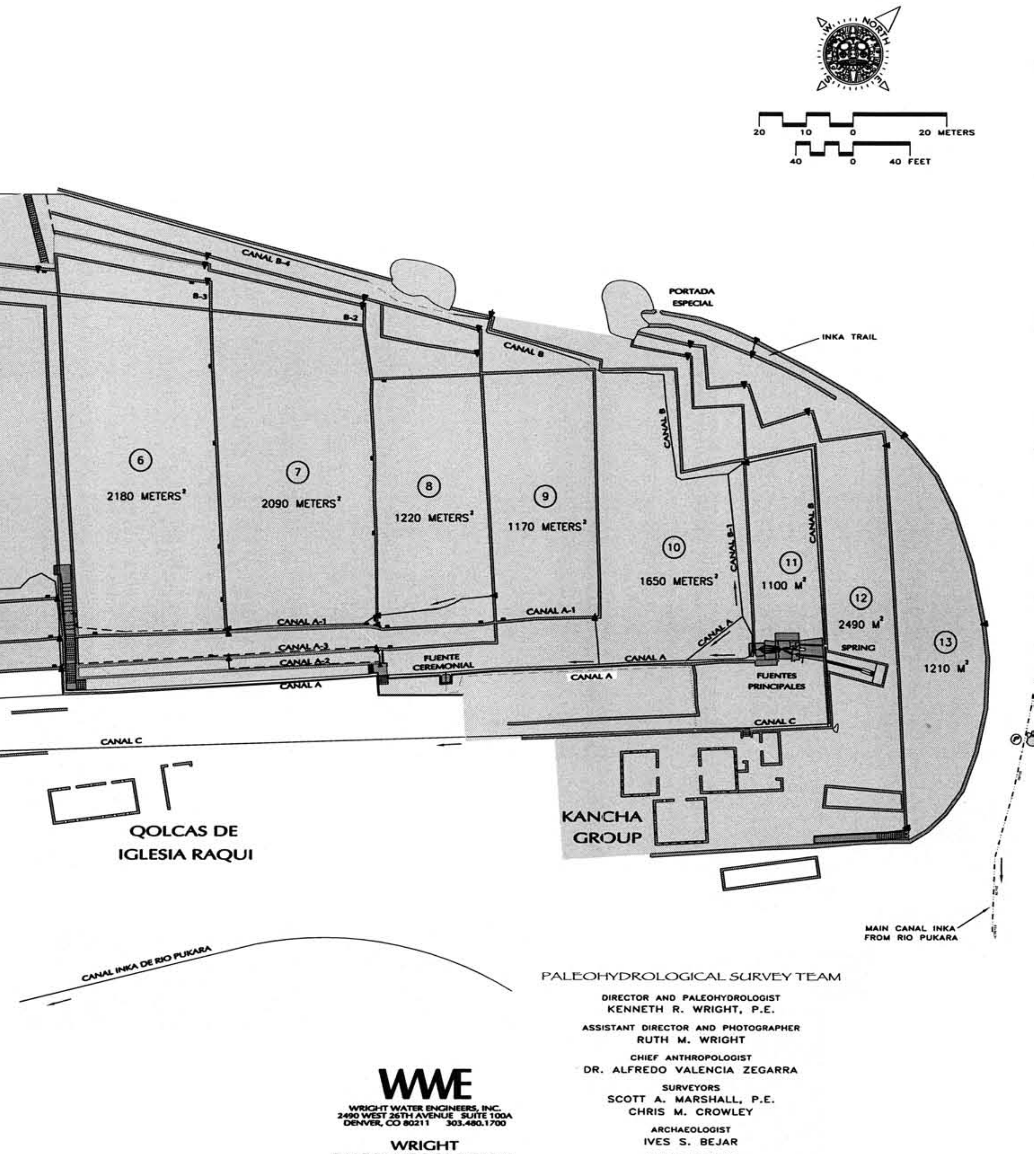
The Central Terraces

Tipon's engineering and environmental focal point, for which it is most known, is the set of 13 high-status terraces that stretch up a ravine 1,300 feet. These terraces begin right at the ancient entry to Tipon (where modern visitors park their automobiles) and are continuous all the way to the Tipon Spring that furnished the huge terrace system with irrigation water. A map of these terraces is shown on the double page map of the Central Terraces.

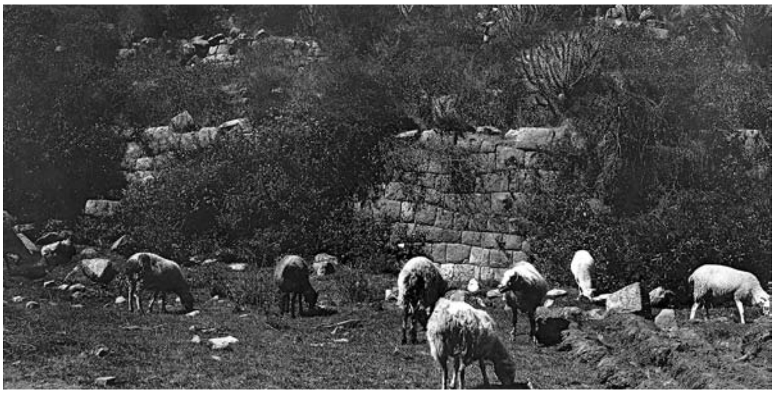
The 13 high-status terraces of Tipon are the site's focal point because of their fine stonework and hydraulics. The East Mesa is shown beyond.

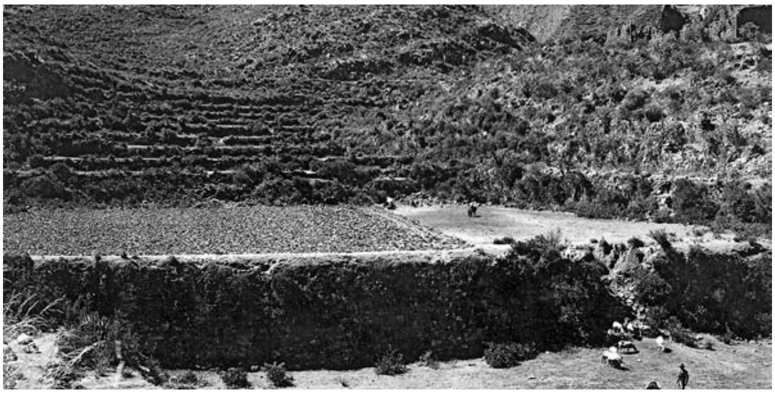
The Tipon Spring issues from beneath the volcanic rock covering most of the site. In the background the stone wall helps to concentrate the subterranean flow at a single point. A bifurcation structure in the foreground sends water both left and right.


Tipon
Archaeological Park
Central Terraces
Instituto Nacional de Cultura Cusco
Prepared by
Wright Paleohydrological Institute
Wright Water Engineers, Inc.
Denver, Colorado USA
CANAL B
LIKELY ROUTE OF INKA CANAL TO SINKUNAKANCHA
CANAL B-5
SINKUNAKANCHA
RESIDENTIAL AREA WITH CEREMONIAL PLAZA
EXISTING ROCK OUTCROP
MURALLA AND TERRACES (TYP.)
1
1330 METERS²
2
1330 METERS²
3
1430 METERS²
4
1470 METERS²
5
4500 METERS²
CANAL A
TOURIST TRAIL
LIKELY EXTENSION OF CANAL A
VESTIGIOS DE CANAL
CANAL C
MAP SOURCES
1. "PLANO DE DELIMITACION PARQUE ARQUEOLOGICO DE TIPON", 1999. INSTITUTO NACIONAL DE CULTURA CUSCO, 1:2500 ESCALA, PLANO TOPOGRAFICO.
2. PROPRIETARY FIELD SURVEYS AND OBSERVATIONS BY WRIGHT WATER ENGINEERS, INC., 1995 TO 2004.
MAP LEGEND
CANAL
AGRICULTURAL TERRACE (ANDENES)
CLIFF FACE OR OUTCROP
STAIRWAY
HYDRAULIC DROP STRUCTURE
FLYING STAIRS
PETROGLYPH
P
INKA RUIN/BUILDING
UNDERGROUND CONDUIT
TRAIL
POTENTIAL INKA CANAL ROUTE
CANAL INKA TO PATALLAQTA



The 13 Central Terraces of Tipon are stair-stepped down the ravine from right to left, a distance of 1,300 feet. The three canal systems are labeled so that the reader can trace out the flow of water from one location to another to be able to appreciate the Inca water management genius.





The large 49,000-square-foot Terrace No. 5 provided a grand platform in the center of the terrace complex. High above on the mountaintop is the Cruzmoqo.

Hiram Bingham inspected Tipon in 1912 and found the beautiful terrace walls to be relatively intact after nearly four centuries of continual use of the site by local farmers.

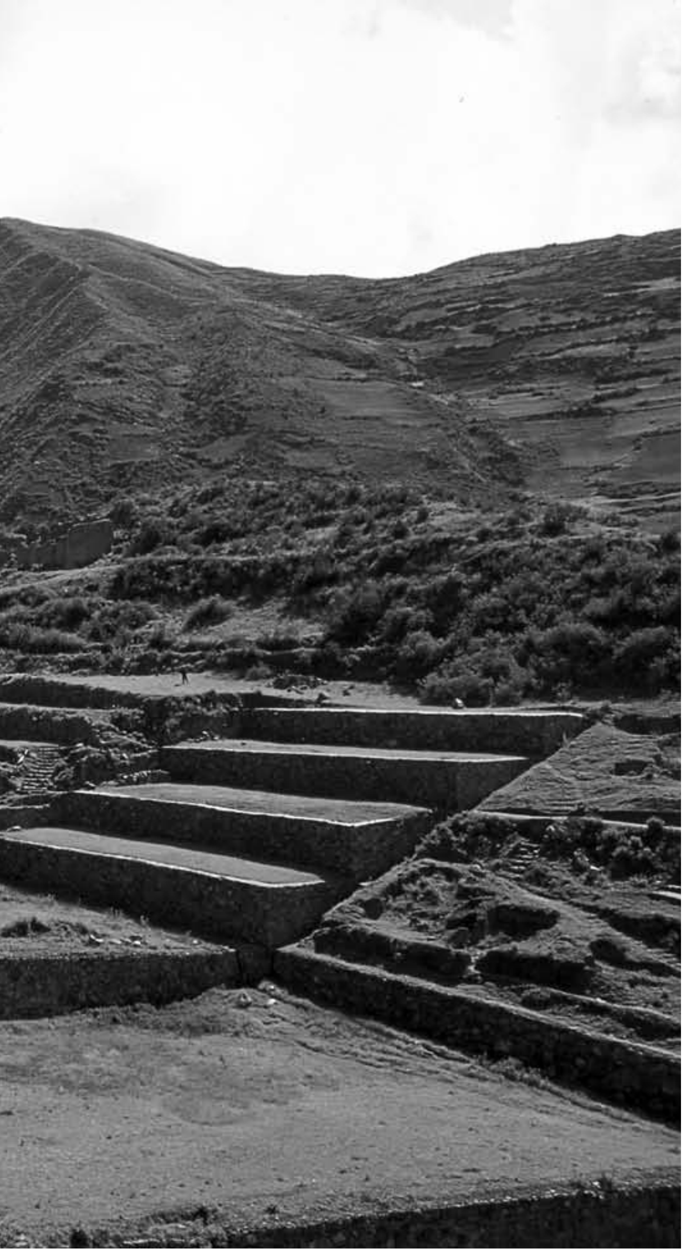
The Central Terraces in 1912 were much as we see them today. Grazing land and a potato field evidence local irrigated farming. Two of Hiram Bingham's horses are in the foreground.

The Inca Kancha (or Kancha group) buildings were in good condition in 1912 when Hiram Bingham took this photo while exploring the Cusco Valley. Note the ridge and furrow irrigated field in the right center.

The civil engineer can envision the massive earthmoving and careful design needed to ensure that the terraces were optimally integrated into the topographic setting with full consideration of the spring elevation and its flow rate. Using the map for reference purposes, the following notable features are identified.

1. High-status terrace stone walls ranging from 6 to 15 feet in height. These walls, many restored within the last decade, remain true to their original construction, as evidenced by the 1912 Hiram Bingham photographs that are archived with the National Geographic Society (Bingham 1913).

2. Hydraulic drop structures that are inset into the terrace walls. They are designed in a manner to create an astonishing



sense of continuity with the walls. The sizing of the drop structures relates well to the flow of the central spring, neither too large nor too small, to create the stunning amenity of flowing water over the entire 1,300-foot length.

3. Longitudinal terraces are on both sides; they carry the visual theme of the Central Terrace into the two hillsides in a stepped, aesthetic manner.

4. The large and grand Terrace No. 5, which is nearly square, contains 1.12 acres and is bordered on its northeast side (uphill) with a wide walkway served by a wide, rocked staircase that in turn is part of a trail system leading to the well-placed Kancha group of buildings that overlook the terraces.

The hydraulic drop structure is integrated into the terrace wall to the right of Patricia Pinson in this 1997 photograph. High above is the grain storehouse that is known as a *qolca*.

Four restored sidewalls of the Central Terraces illustrate the aesthetic and geometric patterns that are characteristic of Inca design. The protruding stones are access stairs also know as “flying stairs.” Three hydraulic drop structures are on the left.

The Inca Kancha is on its own private terrace overlooking Terrace No. 10 in the foreground. The Tipon Fountain and Spring are to the left of the photograph.

5. Two upper terraces, No. 12 and No. 13, are too high to receive water from the spring, but are served with water independently by a long canal carrying surface water from a far-off stream.

6. The upper terminus high wall is oval shaped in a manner that fits well with the natural topography of the northeastern hillside, creating a logical and eye-pleasing separation between the rough hillside and the formal nature of the terrace area.

7. Terrace No. 11 contains the Principal Fountain, a masterpiece of hydraulic engineering, beauty, symmetry, and function. The fountain is supplied with water from the Terrace No. 12 spring.

Terrace areas

Part of the work of the survey team from Wright Water Engineers, Inc., and ourselves was to carefully measure the areas and elevations of each of the components of the Central Terraces, determine how each terrace was irrigated, and determine how the Inca managed the water systems to ensure proper water delivery. The area and irrigation source of each of the terraces are presented in Table 4-1.

Modern engineers identified the ancient canal work of the Inca civil engineers on the hillside for measuring and examination. This canal traversed steep side slopes, crossed gullies, and brought water for irrigation and domestic uses.

The Principal Fountain of Tipon has a total of six jets that exemplify the Inca engineering mastery of landscape architecture. The two jets shown here were restored in 1999.

The oval-shaped upper terrace wall provides an eye-pleasing separation between the rugged mountain slope and the terrace complex.

Irrigation water needs

The method of irrigation on Tipon's main terraces was flood irrigation, or the ridge and furrow method, for which an adequate water supply existed. The assumed crop for purposes of estimating crop water requirements for the main terraces is maize (corn),

TABLE 4-1. Irrigated Main Terraces
(See figure on pages 34–35)

Irrigation Source	Terrace Complex	Area (Acres)
Rio Pukara	13	0.37
	12	0.67
	11-NW	0.10
Subtotal		1.14
Main Spring	1	0.32
	2	0.32
	3	0.35
	4	0.37
	5	1.11
	6	0.54
	7	0.52
	8	0.30
	9	0.30
	10	0.42
	11	0.25
	Side terraces (NW)	0.57
	Side terraces (SW)	0.69
Subtotal		6.06
Total Area		**7.20**

with a growing period of approximately five to six months between planting and harvesting (Wright 1997b). The Inca people were able to grow two crops of maize per year. Assuming a planting date of early August, the harvesting date would be January of the following year. The second maize harvest would then be in July. The annual consumptive use of water at Tipon by the two-crop maize pattern totaled 22 inches of depth, as shown in Table 4-2. The duty of irrigation water is estimated to be 30 to 40 acres per cubic foot per second, demonstrating that the yield of Tipon's spring was capable of irrigating an area many times the area of the terraces. Even though the high-status terraces were not used for pastureland, Table 4-2 shows the consumptive use and water needs for pasture for comparison with the consumptive use for corn.

Central Terrace water handling

If you are a civil engineer or irrigation engineer, this part of the chapter will convince you that the prehistoric engineers of the Inca empire had special insight into the challenges of water handling! There are three canal systems, A, B, and C. If modern water engineers were laying out the water distribution system, they, too, might use the same layout that the Inca engineers used. The three canal systems had the capability to furnish water to

TABLE 4-2. **Consumptive Use (CU) for Two Crops at Tipon**

MAIZE (CORN)				PASTURE			
Month	**CU (inches)**	**Effective Precipitation (inches)**	**Net Irrigation CU (inches)[1]**	**Month**	**CU (inches)**	**Effective Precipitation (inches)**	**Net Irrigation CU (inches)[1]**
July	0	0	0	July	2.27	0.08	2.19
August	0.81	0.22	0.59	August	2.44	0.24	2.19
September	1.78	0.65	1.13	September	3.82	0.72	3.10
October	4.92	1.90	3.02	October	4.45	1.85	2.6
November	6.77	2.39	4.38	November	5.16	2.18	2.98
December	5.55	3.72	1.82	December	5.00	3.61	1.39
January	1.44	1.66	0	January	4.47	4.07	0.4
February	2.19	3.34	0	February	4.64	3.82	0.82
March	2.77	2.62	0.16	March	4.16	2.83	1.33
April	5.94	1.60	4.34	April	4.04	1.44	2.61
May	5.22	0.46	4.76	May	3.01	0.41	2.61
June	1.72	0.04	1.68	June	2.52	0.08	2.44
Total	**39.10**	**18.59**	**21.88**	**Total**	**45.98**	**21.33**	**24.65**

1. Net consumptive use requirement = CU – effective precipitation. (Because of rounding of numbers the total irrigation requirement number may vary slightly.)

the entire terrace system lying below the Tipon Spring, the upper two terraces being served by gravity flow from the main canal. Note that Canal C also ran offsite below the *qolca* (storehouse), around the ridge, and to Patallaqta.

The three-canal layout of the water distribution system provided the prehistoric water managers with the capability to route water to the entire Central Terrace system lying below the spring, as well as to supply water directly to Patallaqta and to Sinkunakancha. The three canals could be operated independently or jointly, depending upon the desires of the Inca canal operator.

The discharge of the Tipon Spring flows 26 feet to a point of bifurcation where the water can flow either right or left. The left flow goes to the C system, and the right flow is a combination of the A and B systems. The canal then bifurcates again to create separate A and B systems.

How do we know the Inca canal system operated this way? The evidence tells us. In the field, one can examine the canal structures built into the terrace walls. Each structure is shown as a black triangle on the map. This tells us that hydraulic structures were built into the walls at just the right location and elevation so that when the 1,300-foot-long Central Terraces were complete, the well-planned three-canal system worked as described. The Inca engineers were able to build to predetermined elevations and slopes for the specific hydraulic drop structures and canal alignments.

Canal extensions

Canal A is the most important of the three main canals. At the stairway between Terraces No. 5 and No. 6, evidence exists of Canal A extending to the southwest, where it furnished irrigation water to the three higher elevation lateral terraces adjacent to Terrace No. 4.

Canal B, at its highest level, was extended to the enclave of Sinkunakancha; however, clear field evidence of the canal no longer exists. Canal B was designed to irrigate the lateral terraces along the lower northwest side of the Central Terrace complex, while the numerous hydraulic drop structures built into the upper multitude of walls brought surface water from above. This represents advanced conjunctive use of water that could easily have been designed by the best of modern hydraulic engineers.

The route of the extension of Canal C to Patallaqta, a distance of some 1,400 feet in length, was identified by five remaining canal sections that show the manner of construction.

Irrigation of Terraces No. 12 and No. 13

The northwesternmost, higher Terraces No. 12 and No. 13 were constructed at an elevation above the Tipon Spring, and, for that reason, an independent water supply was used. The Inca extended the Main Canal from the Rio Pukara so that it passed just uphill of the Main Terrace complex. There are ten drop structures built into the walls to bring the Main Canal water to these two sets of terraces.

The bifurcation of flow near the Tipon Fountain provided opportunities for routing water to numerous locations.

Microclimate management

Some archaeologists have long considered the Tipon Central Terraces to potentially represent an Inca experimental agricultural research station where crops were developed for specific uses; however, there is no evidence to support this theory, only conjecture. On the other hand, there is evidence to show that the terraces are laid out and constructed to take advantage of the irrigation water supply and the summer sun. Tall walls of weathered brown andesite rock face the afternoon sun, and many tall walls on the terrace edges are designed to catch the early and late day sun. The warmth absorbed by the stone walls during the warm winter days radiated heat out onto the terrace soil surfaces during the often-cold nights. This phenomenon warded off chilling frosts to extend the growing season or even to keep the frost at bay in some years.

The concept of storing the heat of the day to enhance agricultural potential could have been adopted from the Tiwanaku empire, where such techniques were developed and widely used in the early seventh century, south of Lake Titicaca (Kolata 1993), where raised fields surrounded by water served the same purpose. The water absorbed the sun's rays and was warmed, creating a microclimate.

Summary

If you go to Cusco, do not miss the Tipon Central Terraces, even if you have only one-half day to spare. Here, at Tipon, you can view and enjoy a remarkable achievement of pre-Columbian civil engineers in planning, design, and construction of high-status terraces and an irrigation system that is comprehensive and unique. It is a tribute to these early people of America. You will want to have this book in hand and turn to the map of the Central Terraces to trace out the canals and to examine the spectacular hydraulic structures and the exquisite stonework. The walking tour included as Chapter 12 can help you find everything.

LIVING WITH THE ENVIRONMENT

Modern engineers marvel at the uncanny ability the prehistoric Americans had for formally developing and managing water supplies. Tipon is a good example of the use of this attribute.

Colorado water engineers thought they were advanced in the 1960s, when conjunctive use of surface water and groundwater was put forth as an answer to water shortages. They would have learned a lot from the Inca engineers at Tipon. We have come to know that studying history (in this case, prehistory) is the way to learn and to avoid the mistakes of the past.

From Inca water handling practices, we can learn much about soil stewardship; care of the precious land is a hallmark of conscientious and thoughtful people. Here the Inca excelled.

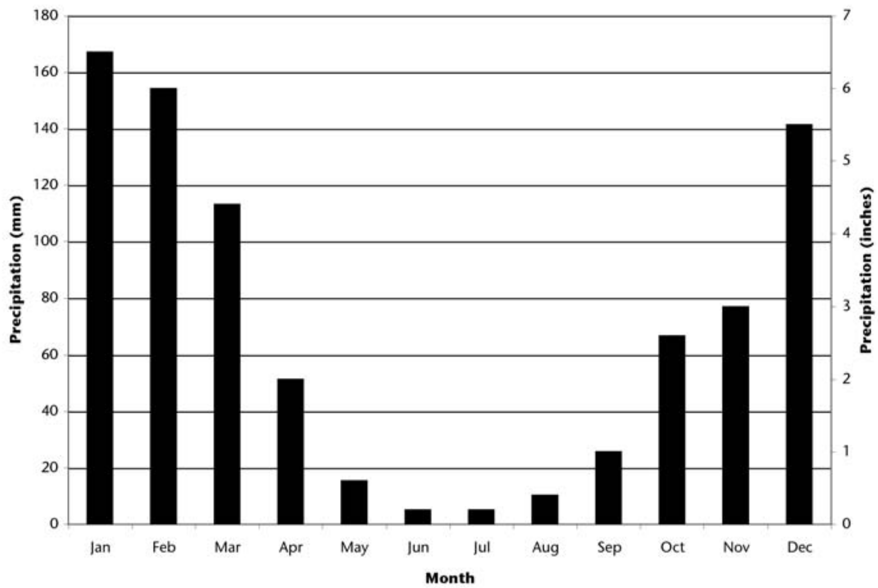
Chapter 5

Hydrology of Tipon

In Inca times, Tipon had a distinct agricultural focus with both high-status terraces to be admired and hundreds of acres of utilitarian terraces within its walls that generated plentiful foodstuffs. With about 250 acres of agricultural land cultivated and an annual precipitation of a modest 32 inches per year that was not well distributed on a monthly basis, irrigation of crops was generally necessary. There were also many terraces that were dryland farmed.

Fortunately, Tipon is well endowed with two water supply sources that were utilized conjunctively to provide optimal irrigation water. One source, today the most striking, is the renowned Tipon Spring. This groundwater supply is mostly derived from precipitation that falls on its drainage basin, volcanic rock, and its soil derivative, and then percolates downward to begin the long journey to its outlet, upon which the Inca engineers capitalized. The other water source is the adjacent Pukara River that has a perennial flow, but it is a supply that rises and falls in a manner more closely related to precipitation than the groundwater source. As a result of the good infiltration of precipitation that produces ample groundwater supplies, the overland storm runoff at Tipon is minimal and the soil erosion almost nonexistent. During our Tipon field studies, we inventoried the Tipon enclosure for gullying and sheet erosion and found little—an outcome not only of the soil and rock character, but the Inca genius for soil stewardship, the benefits of which are evident even after nearly 500 years.

Hundreds of agricultural terraces were built at Tipon where large amounts of produce were harvested before, during, and after the Inca period. These terraces were irrigated from the Rio Pukara.



The 32 inches of rainfall were not well distributed throughout the year, with monthly precipitation ranging from more than 6 inches in the summer to only a small amount during the dry winter season months of June and July.

One of the few manifestations of surface runoff erosion at Tipon is below the large volcanic slab where storm runoff is higher. During Inca times, this channel was incorporated into the main Inca canal from the Rio Pukara. There is little erosion at Tipon. The East Mesa and Central Terraces can be seen in the background.

In considering the hydrology of prehistoric Tipon, our studies also had to look at water needs for irrigation and domestic use. Then, because our civil engineering research was probing back into time some five and six centuries (and more for the Killke use of the site), we turned to the long-term climate record described in Chapter 3.

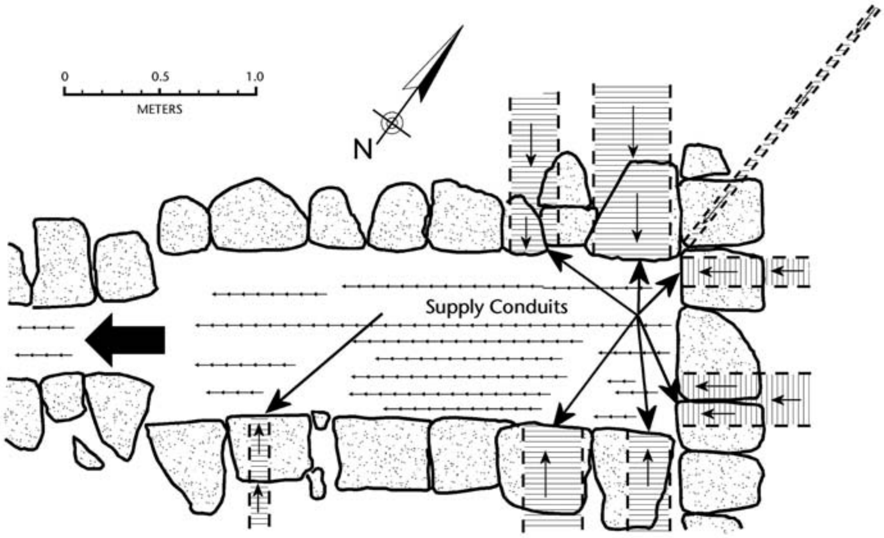
What we found out about Tipon paleohydrology told us that the Inca had an uncanny ability to recognize natural resource potential and to utilize that potential for the development of beneficial uses of water and land in a manner compatible with environmental constraints.

Spring yield

The Tipon Spring, at an elevation of 11,310 feet, discharges at the base of the volcanic Cruzmoqo slope rising 1,700 feet to the northeast. The spring's topographic tributary drainage basin is only 160 acres in size, though the geologic drainage basin is likely greater by a factor of perhaps five due to fracturing and jointing of the volcanic bedrock and solution cavities in the underlying limestone. The spring discharges at the base of the long volcanic slope, on the top of the limestone formation.

During our September 2000 hydrological survey of the spring, we found that Inca-formed stone conduits of the Tipon spring extended back into the hillside. We examined them as to relative size and direction. Eight separate conduits were noted that served to collect the subsurface flow so that it could be concentrated in one location for ease of handling and distribution.

In our examination of the spring collection headworks, it became evident that the Inca engineers knew about the fundamentals of groundwater flow. They created a milestone of hydraulic engineering that was effective and efficient in



concentrating the discharge of the subsurface flow and, at the same time, allowed for an aesthetic water source structure.

The discharge of the Tipon Spring was measured on September 21, 2000, using the wet-area cross-section and velocity method that is common to irrigation engineers and hydrologists (ASCE 1992). The discharge in 2000, based on duplicate sets of measurements, was 283 gallons per minute. Computations were as follows, using the formula:

$Q = AV$

where
Q = discharge in cfs
A = area in ft^2
V = velocity in fps

Test 1

$Q = A \times V$
$= 0.75\ \text{ft}^2 \times 0.91$ fps
$= 0.68$ cfs

$A = 0.75$ ft^2
$V = 0.91$ fps

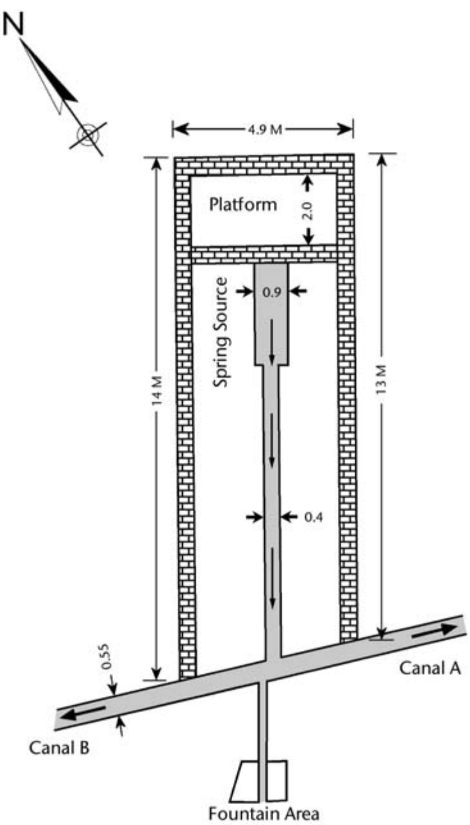
Test 2

$Q = A \times V$
$= 0.62\ \text{ft}^2 \times 0.94$ fps
$= 0.58$ cfs

$A = 0.62$ ft^2
$V = 0.94$ fps

Average Discharge Measurement

Test 1	0.68 cfs
Test 2	0.58 cfs
Average	0.63 cfs
Equivalent to	283 gpm

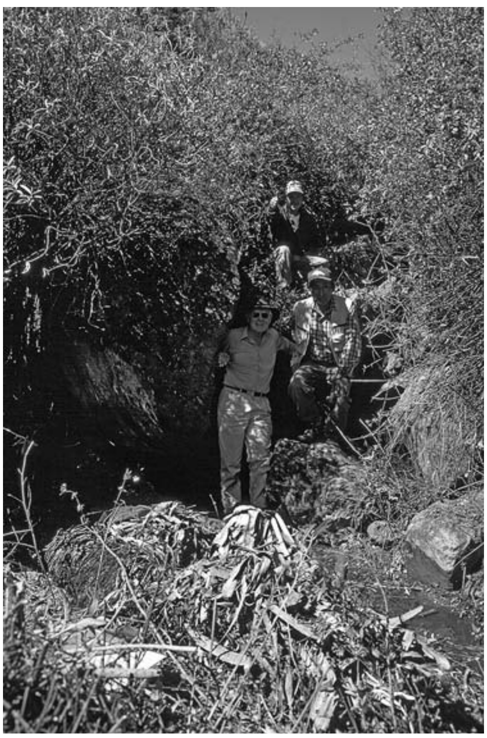


The Inca spring headwork is designed to collect and concentrate underground flow to a single point. The eight conduits that extend into the mountainside represent special hydrologic techniques for capturing groundwater.

The overall spring headwork was carefully measured in the field so that its engineering layout could be more fully appreciated.

TABLE 5-1. 2000 Precipitation at Cusco, Peru

Month	Precipitation (inches)
January	5.86
February	5.39
March	5.35
April	0.24
May	0.20
June	0.21
July	0.11
August	0.32
September 1–21	0.00



The Rio Pukara point of diversion for the main Inca surface water canal at Tipon (Canal No. 2) is at a steep reach of the stream, where rockfalls have plugged the ravine. For this reason, local Indians have sometimes thought that the water source was a spring. Our research team is shown at the diversion point.

Based on a flow of 0.63 cubic feet per second, the annual yield would be about 450 acre-feet per year, or approximately 1,800 acre-feet per square mile per year for the topographic drainage basin; this is too high given the annual rainfall of 32 inches and depletions caused by the vegetation and annual evapotranspiration. It is for that reason that we believe the geologic drainage basin must be substantially greater in size than the 160-acre topographic basin. The spring flow measurement on September 21, 2000, followed minimal precipitation for 5.75 months, as illustrated in Table 5-1.

One might conclude that the September 21, 2000, flow of the spring would be a base flow with natural seasonal variations such that the April through June flow would be significantly greater. However, this was not the case as evidenced by Wright's measurement on June 13, 2004, when the spring flow was gauged at 238 gpm (0.53 cfs).

Rio Pukara yield

The Inca point of diversion out of the Rio Pukara for their main canal is at an elevation of 12,106 feet. The tributary drainage basin for this surface water supply is 1.3 square miles. The diversion point is on the left bank of the Rio Pukara, just below a rock fall in the bed of the river through which the water flows. We estimated the flow of the Rio Pukara at 340 gallons per minute, or 0.76 cubic feet per second, in mid-September 2000, following 5.75 months of little precipitation. During and following the summer rainy season when the precipitation averages about 5 to 6 inches per month, the flow of the Rio Pukara likely peaks in the 5 to 10 cubic feet per second range. Yield of the Rio Pukara is sustained by considerable upstream flow from groundwater through the extensive volcanic rock deposits that cover much of the drainage basin.

Water quality

A sample of water from the Tipon Spring was collected on September 26, 2000, and carried to Denver for laboratory testing by Evergreen Analytical Laboratory, a U.S. Environmental Protection Agency (USEPA) approved laboratory.

Dr. E. R. Weiner of Wright Water Engineers, Inc., describes results of the laboratory testing as follows:

> Water quality data from a sample WWE collected from the Tipon Spring on September 26, 2000 is presented in Table 5-2. Evergreen Analytical Laboratory of Wheat Ridge, Colorado, analyzed the water sample following standard and accepted protocols. For those parameters regulated by USEPA, the primary or secondary standards are shown.
>
> The Tipon Spring had a flow of approximately 280 gallons per minute when measured on September 26, 2000. The water was of good quality for drinking and irrigation purposes.

TABLE 5-2. Water Quality Data from the Inca Spring at Tipon, Peru

Parameter	Unit	Measured Value Inca Spring, Tipon (Sampled 9/26/00)	USEPA Primary or Secondary* Drinking Water Standards (if applicable)
Aluminum (Al) (total/dissolved)	mg/L	<0.09[1]	0.05–0.2*
Ammonia-Nitrogen	mg/L	<0.8	—
Bicarbonate[2]	mg $CaCO_3$/L	85.3	—
Calcium (Ca) (total/dissolved)	mg/L	364	—
Chloride	mg/L	28.9	250*
Copper (Cu) (total/dissolved)	mg/L	0.0018[1]	1.3
Hardness[3]	mg $CaCO_3$/L	140	—
Iron (Fe) (total/dissolved)	mg/L	0.44	0.3*
Magnesium (Mg) (total/dissolved)	mg/L	124	—
Manganese (Mn) (total/dissolved)	mg/L	<0.01[1]	0.05*
pH	su	7.99	6.5–8.5*
Potassium (K) (total/dissolved)	mg/L	3.8[1]	—
Sodium (Na) (total/dissolved)	mg/L	3.8[1]	—
Sodium Absorption Ratio[4]	—	1.4	—
Sulfate	mg/L	88.7	250*
Total Alkalinity	mg $CaCO_3$/L	85.3	—
Total Dissolved Solids	mg/L	257	500*
Zinc (Zn) (total/dissolved)	mg/L	<0.0018[1]	5*

1 Turbidity in the sample was less than 1 NTU. Therefore, total and dissolved metal concentrations are equal.

2 Not reported by the laboratory. Calculated from alkalinity and pH values.

3 Calculated from Ca and Mg concentrations.

4 Calculated from Na, Ca, and Mg dissolved concentrations.

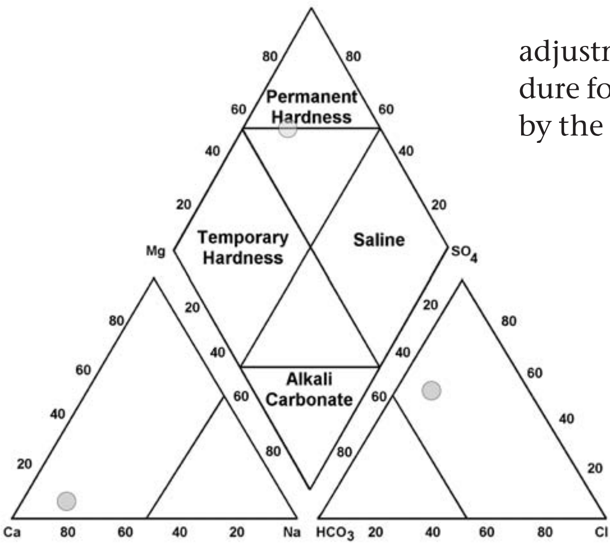
The water was very clear and contained no measurable suspended solids (NTU < 1). All measured constituents were well below USEPA primary drinking water standards. Only iron (0.4 mg/L) exceeded its secondary drinking water standard of 0.3 mg/L. Total dissolved solids at 257 mg/L were about one-half the USEPA's secondary drinking water standard (500 mg/L) (USEPA 2003). The sodium absorption ratio was low (1.4), and the water is satisfactory for crop irrigation.

The Piper diagram indicates that the Inca Spring is moderately high in sulfate and chloride, which imparts a degree of permanent hardness (not removed by softening). The total hardness is high, at 140 mg/L. The excess of total hardness over alkalinity (140 – 85.3 = 54.7 mg/L) is the permanent hardness.

Irrigation water requirements

For purposes of balancing water needs versus supply, hydrologists need to know irrigation water requirements in terms of crop evapotranspiration and application rates. These data, when coupled with the area of irrigated crops, can be used to estimate the likely duty of water.

Consumptive use (CU), also referred to as evapotranspiration, of two assumed irrigated crops (corn and pasture) was determined using the climatological data presented in Table 3-2 and the U.S. Soil Conservation Service's TR-21 version of the Blaney-Criddle formula with the American Society of Civil Engineers'



adjustment for elevation (Jensen and others 1990). The procedure for computing the monthly consumptive use is represented by the following formula.

$$CU = k_t k_c \frac{tp}{100}$$

where
k_t = temperature coefficient
k_c = crop coefficient
t = temperature
p = hours of sunlight

The results of the CU determination are presented in Table 4-2. The data are based upon two plantings of corn and continuous growing of hay or pasture grass with harvesting or llama rotated from field to field. While hay was not grown on the Central Terraces, it likely was grown on some of the outlying irrigated agricultural zones.

Drainage and flood control

To understand the Inca civil engineering work at Tipon in the field of flood control and drainage, observations were made of the surface drainage with specific attention paid to gullying.

During the past five centuries since the main terraces were constructed, the surface evidence indicates that no major destructive floods have occurred. During reconnaissance surveys of the drainage basin, only one slightly eroding ravine was noted. It lies to the northwest of the lower slope of the gray lava flow of Ajawasi and is a result of the approximately 12 acres of exposed bedrock that has a higher than normal runoff coefficient. Evidence of the lack of erosion and significant flood occurrences is provided in Hiram Bingham's 1912 photographs presented in Chapter 4 of this book.

The outlying utilitarian terraces that represent most of the Tipon agricultural land are mostly intact except for the normal toll taken by five centuries since the end of the Inca empire. Erosion and gullying were nearly nonexistent due to the high permeability of the ground surface and the almost flat terraced land. Infiltration of rainfall was high and surface runoff low.

In accordance with standard Inca technology as found at Machu Picchu (Wright and Valencia 1999), the main terraces and outlying terraces were constructed with placement of underlying stone layers beneath gravel and sand layers with topsoil in the uppermost level. This provided for good subsurface drainage.

Soil stewardship

The Inca were good stewards of the soil, and the archaeological remains of their works attest to this fact. Minimal gullying and soil erosion, combined with terrace walls and flat terraces as well as good subsurface drainage provisions, tell us that the Inca soil

The Piper diagram defines the water quality of the Tipon Spring as being of high hardness with significant calcium. The chemistry tells us that the water has traveled through the limestone that underlies the volcanic rock.

stewardship at Tipon was important to them and that they were successful at it.

The study by Alberto José Martínez Vargas (1999) of the National Engineering University (Lima, Peru) on the Inca treatment of potential mud and rock flows found that the Inca civil engineers set a high standard for modern engineers to emulate. In particular, Professor Martínez Vargas focused on the planning, design, and construction of the Tipon Central Terraces that have fully controlled and stabilized the central ravine, to the extent that in over five centuries there has been no significant failure of the public works. The prerestoration 1912 photos by Hiram Bingham (Chapter 4) confirm the lack of significant erosional damage. Professor Vargas opines that modern Peruvian engineers should study the successful works of the Inca.

Summary

The Inca were masters of agriculture; they were preceded by Andean civilizations that practiced extensive and successful irrigation for more than 3,000 years prior to the Inca effort at Tipon. Archaeologists have identified irrigation works dating back to 1800 BCE in Peru (Moseley 1992) and to 2400 BCE at the Caral archaeological site.

The hydrology of Tipon is a result of natural phenomena on which the Inca were able to capitalize. Even though earlier people utilized Tipon and its water and soil resources, the Tipon site that exists today is a product of Imperial Inca classical planning and engineering.

The Inca were able to develop the Tipon Spring and harness the flow of the Rio Pukara for beneficial purposes. They, likewise, were able to care for the soil and runoff to the extent that, even today, modern Peruvian scientists identify Inca engineering works as examples that are fit for use elsewhere in modern Peru.

The terrace-filled ravine is an outstanding soil conservation success in that it has not been damaged by flooding or debris flows since the time of the Inca empire.

BOUNTIFUL WATER

The interlacing of Tipon with canals meant that the extensive areas of rich, volcanic soil and the people of Tipon did not want for water. But, as an added benefit, the ambiance of flowing and falling water added an aesthetic dimension to Tipon that impressed visiting dignitaries and helped demonstrate the Inca power over land and water.

Irrigation canals and spring headworks are usually fairly utilitarian in the modern world, but not so in the land of the Inca. In Tipon, water provided an opportunity for the engineers to showcase their hydraulic skills, to create symbols of control over flowing water, and to create a form of hydraulic art.

The hydrological development of Tipon rested on natural resources and their thoughtful use. The Inca capitalized on what they found in nature, and they developed these assets for future generations, building works for the long-term.

The yield of the natural spring and the flow of the nearby river at Tipon represent two water sources that made it possible to create an estate for Inca nobility. But then, it was also management of storm runoff and soil stewardship that helped to make Tipon a jewel of the Inca empire, a place where the best features of the water, mountains, land, buildings, and people could be optimized.

Chapter 6

Tipon's Canal System

Tipon is a spectacular achievement of surface water development and distribution. It was accomplished on difficult terrain and steep topography. The canal system from the Rio Pukara supplies irrigation and domestic water over a widespread area.

Outside the perimeter wall, the main canal route is shown with canal stones that have slipped down the steep slope. The perimeter wall is visible in the background.

Surface water handling and management

Three irrigation canals diverted water from the Rio Pukara upstream of Pukara, approximately 0.84 mile north of Tipon's Central Terraces. The points of diversion for the three canals lie outside of the wall that encircles Tipon, with the canals passing under and through the wall at locations and elevations controlled by the steep topography. The main canal diverted water at elevation 12,106 feet directly from the bed of the Rio Pukara at a rockfall that tended to plug the stream. During low-flow times, the point of diversion could be mistaken for a mountain spring.

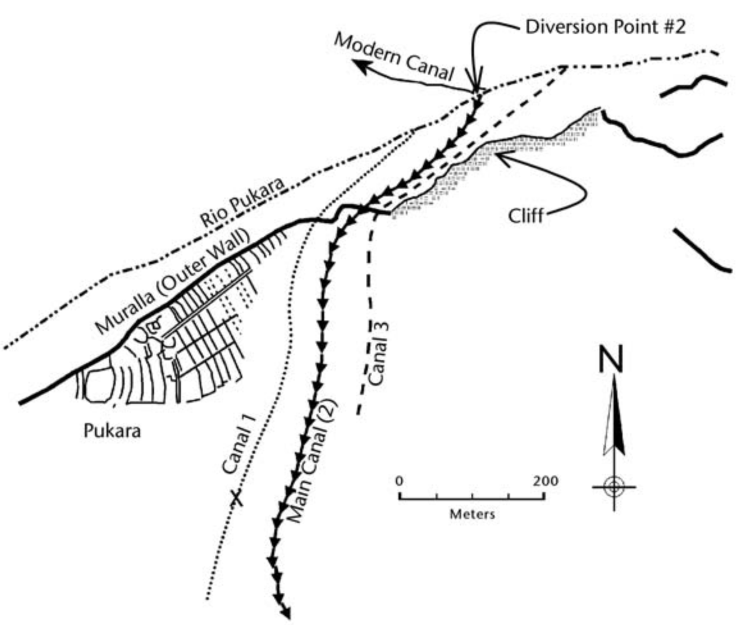
For the purpose of description, we have divided the main canal into six sections, as shown in Table 6-1.

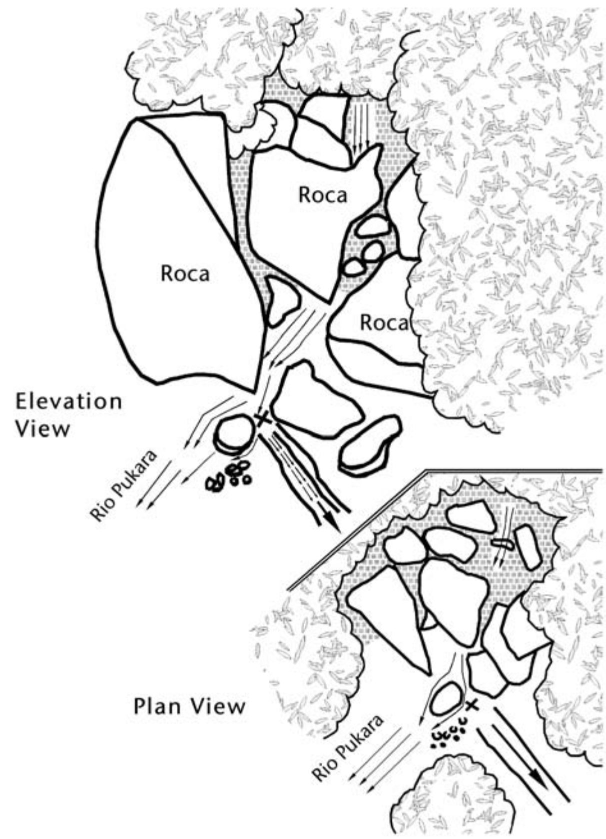
Within the enclave, and south of the outer wall, the route of the main canal tends to follow the contours on the steep hillside. The canal rights-of-way are formed via terrace rock walls and cut and fill sections in Sections 1 and 2 and continue until the topography changes to the south, that is, about 2,600 feet from the Rio Pukara point of diversion.

The main canal is used to furnish water to extensive areas of agricultural land extending to near the Intiwatana and Ceremonial Plaza. Beyond the Intiwatana the main canal follows a relatively gentle and uniform slope to the valley north of the Central

TABLE 6-1. Main Canal Sections

Section	Stationing (in feet) Start	End	Description
1	0+00	7+08	Rio Pukara to Wall: Very steep hillside with canal on contour
2	7+08	17+78	Wall to Sulluqaqa: Very steep hillside with earth slides and much damage to canal
3	17+78±	26+17	Sulluqaqa to Restored Canal: Modest slope in upstream portion and low slope for last 200 meters
4	26+17	47+89	Restored Channel to Intiwatana: Restored canal with special features and aqueduct; rolling terrain
5	47+89	76+65	Intiwatana to Main Terraces: Modest grade for 650 meters, then steep to main terraces
6	76+65	92+17	Main Terraces to Patallaqta: Gently sloping canal on Eastern Mesa





The three Inca canals that diverted from the Rio Pukara traverse a steep side slope, pass through the outer wall, and continue on into Tipon where they provided much needed water supplies. Modern farmers now divert the flowing water onto right bank lands.

The point of diversion for the main Inca canal (Canal No. 2) takes water from the Rio Pukara at a rockfall that tends to create the appearance of a spring.

Terraces and then down a steep slope in a southwesterly direction to north of Tipon's terraces and then to Patallaqta.

Surface water canals

The layout of the three canals is illustrated on the topographic map of the archaeological park. The main canal is shown from its points of diversion all the way to its terminus at Patallaqta. The cross-sectional areas range from 2.6 square feet to 0.56 square foot, with a characteristic area of about 0.65 square foot common downstream of the Pinchamoqo Andenes terraces. Slopes vary widely depending upon the topography, with steep slopes being common down rolling hills and other slopes as low as 2 to 3 percent existing where the topography is gentler.

Hydraulic structures

Several hydraulic structures exist in the surface water supply canals that traverse the Tipon site from the Rio Pukara from north to south, with the main canal terminating at Patallaqta. One is an irrigation conduit turnout, another is an open irrigation lateral turnout, and the third is a sharp bend. A drop structure at the Intiwatana follows a subsurface channel that passes through the building complex.

Canal capacities

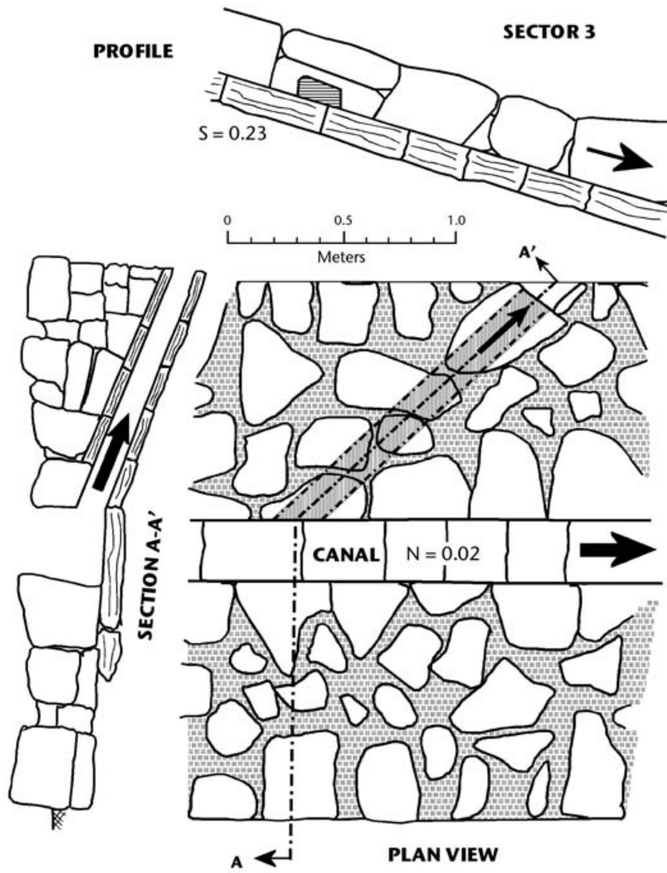
The carrying capacity of the canals diverting from the Rio Pukara has been estimated using hydraulic engineering principles, taking into consideration the following characteristics that vary from location to location:

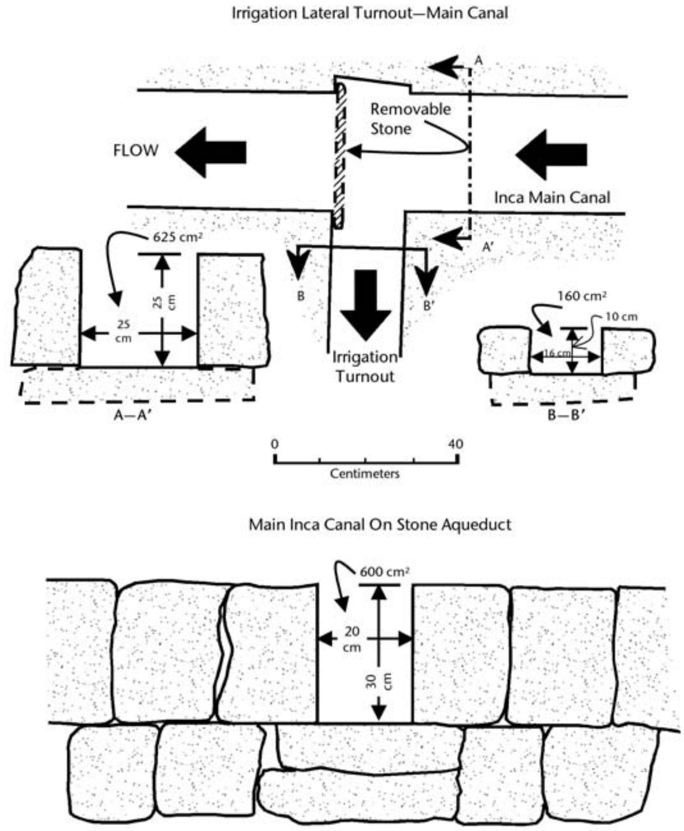
- Cross-sectional area of the canal in square feet
- Hydraulic slopes in terms of feet/foot

Remains of the main canal provide clear evidence of the high standard of care used in the design and construction of the canal sections and its smooth curves.

The main canal gently curves towards the Central Terraces. In the background, one can see the East Mesa, the terminus of the canal.

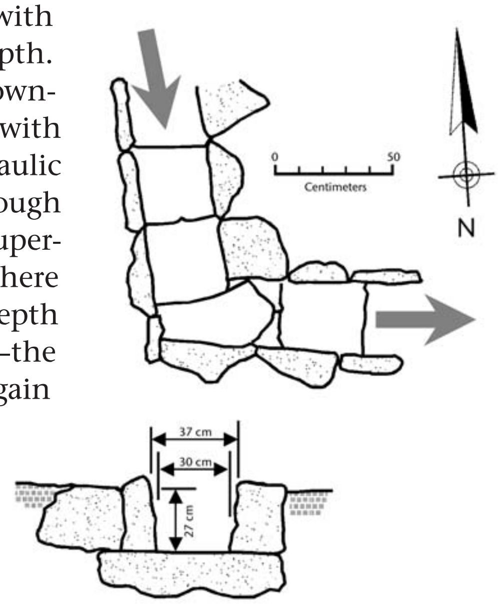
A steep portion of the main canal is paralleled by an Inca trail. Research archivist Patricia Pinson is examining the canal at the top of the 30 percent slope.





- Roughness coefficient expressed as Manning's "*n*"
- Velocity in terms of feet per second
- Discharge in cubic feet per second

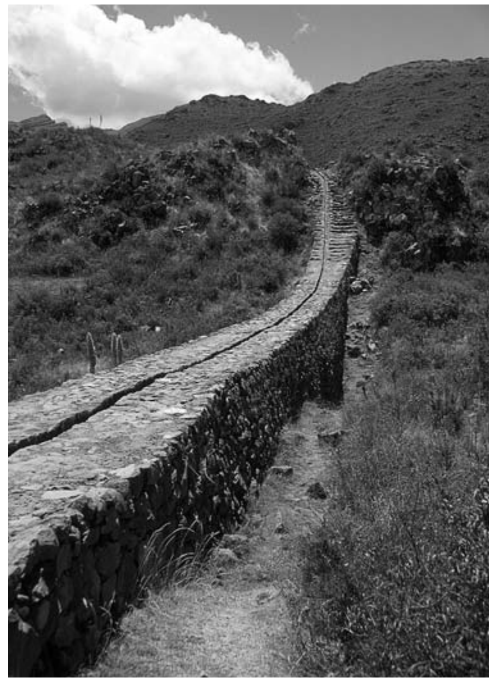
Because of the fact that the canals change slope significantly for downhill routing, the governing flow capacity estimates are based upon the assumption that the minimum slope reached full flow depth. On steeper slopes (some reaching slopes of 30 percent), the canal flow is supercritical, with high velocities and shallow depth. Where the slope decreases downstream, the velocity decreases with rising depths, often with a hydraulic jump. Where the flow goes through a hydraulic jump (i.e., from supercritical to subcritical flow), there is often an abrupt increase in depth with significant turbulence—the downstream depth once again reaching approximately the full potential depth of the canal section at that location.



An irrigation lateral turnout conduit is illustrated in plan and two sections to demonstrate Inca hydraulic engineering techniques.

Turnout structures in the main canal were important features for water distribution.

A near-right angle bend in the main canal is an enigma because the Inca typically used more hydraulically efficient curves.



Main Canal Section 1

The main canal diverts from the Rio Pukara at a point located 1,700 feet northeast of Pukara at an elevation of 12,106 feet. The length of the canal upstream of the outer wall is 808 feet, with an average slope of nearly 10 percent, but with some flatter portions. It passes through the wall at an elevation of 12,027 feet.

Where the Main Canal Section 1 bends around a rock, the cross-sectional area is 1.8 square feet; however, we judged the adjacent typical canal cross-sectional area to be about 2.2 square feet.

The typical estimated hydraulic character of the canal in Sections 1 and 2 is as follows:

Area	=	2.2 square feet
Roughness	=	0.030 (Manning's *n,* no unit)
Width	=	1.64 feet
Depth	=	1.31 feet
Minimum slope	=	5 percent

Using Manning's equation

$$Q = \frac{1.49}{n} \times A \times R^{2/3} \times S^{1/2}$$

where
Q = discharge in cfs
A = area in ft^2
R = hydraulic radius (in feet)
S = slope in ft/ft
n = roughness coefficient (no units)

The maximum carrying capacity was computed as follows:

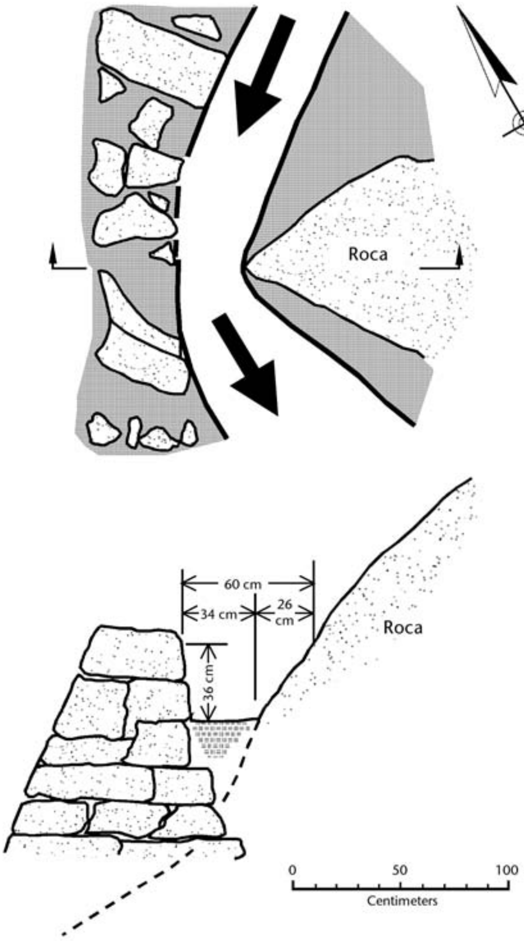
$$Q = \frac{1.49}{0.03} \times 2.2 \times (0.49)^{2/3} \times (0.05)^{1/2}$$

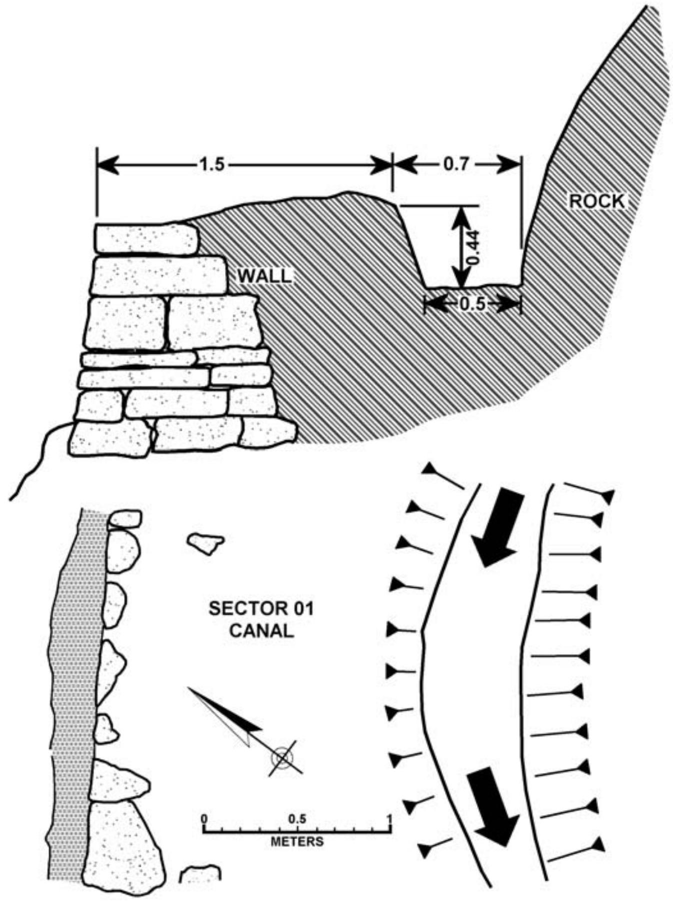
$$= 15 \text{ cfs}$$

This main canal double-notched feature may have been used for blocking canal flow, but its exact function is unknown.

The sharp bend in the main canal was carefully constructed with tight fitting stones.

A 200-foot-long restored aqueduct carries water over a ravine near the Ceremonial Plaza. By maintaining elevation, the Inca were able to serve the Intiwatana by gravity flow.





Main Canal Section 2

Inside the wall the main canal continues in a southerly course at an overall slope of over 10 percent across a very steep side slope that is subject to landslides and where portions of the canal no longer exist. Some portions of the canal are flatter. At one location a tomb with a partial skeleton exists on the left bank of the canal. Typically the canal cross-sectional area is about 2.2 square feet.

The canal in Section 2 crosses a steep and precarious topography, and it was evident that canal stones had tumbled down the mountainside. Above the main canal, we found traces of Canal No. 3.

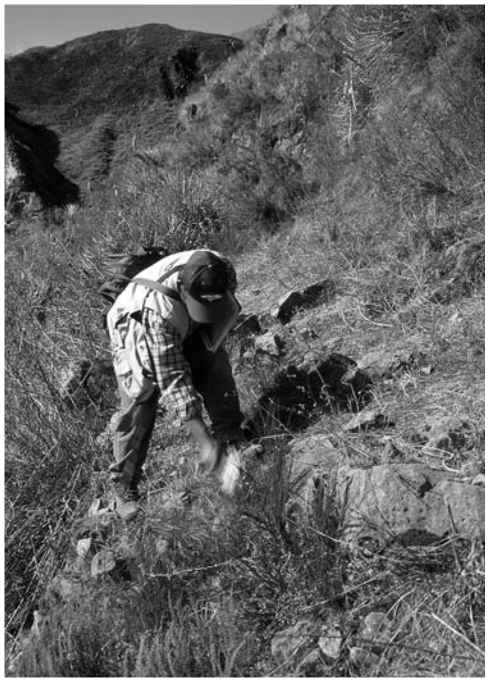
The capacity and characteristics of the main canal in Section 2 here tended to be similar to that of canal Section 1 where intact sections were measured.

Beyond the outer wall and not far from the Rio Pukara, this canal section encountered a large rock where a bend in the canal was essential.

Inside the perimeter wall, the main canal (Section 2) crosses steep and sometimes unstable slopes where the outside canal bank was formed using a low rockwall and earth fill to provide a cross-sectional area of 2.2 square feet.

Main Canal Section 3

The Section 3 portion of the main canal is on a more modest surveyed slope of 7 percent in its upstream portion but flat at about 3 percent for its downstream 660 feet, where it connects to the restored canal of Section 4. The canal route contains many existing examples of Inca construction.



Main Canal Section 4

The Main Canal Section 4 begins at the upper end of the restored canal and continues south for 2,170 feet to the Intiwatana. This portion of the canal has several unusual features including

1. A sharp (near 90°) turn to the left.
2. A survey marker.
3. Steep, supercritical slopes.
4. An aqueduct.
5. An irrigation turnout to a conduit.
6. An irrigation turnout to an open lateral.
7. Intiwatana conduits and drop structure.

The restored main canal in Section 4 has slopes ranging from 6 to about 16 percent, an estimated Manning's *n* roughness coefficient of 0.020, width from 0.65 to 0.8 foot, and depths of 0.8 to 1.0 foot (with a cross-sectional area of 0.65 foot). Table 6-2 represents the approximate discharge of the canal. Cumpa (1999) reported that the aqueduct was in reasonably good condition prior to its restoration. The cross-sectional area of the restored canal is similar to the downstream, unrestored canal. Evidence of this was provided by Dr. Gordon McEwan in his prerestoration photograph taken when he long ago visited the canal.

Considering the variable slopes of the canal and the hydraulic jump at the base of the steeply sloped canal followed by typically flatter canal slopes of 2 percent, we determined that the practical capacity of the main canal in Section 4 is 4.2 cubic feet per second.

The route of the ancient main canal has been subject to earth slides with canal stones having fallen down the mountainside.

Archaeologist Ives Bejar Mendoza examines Canal No. 3 stones not far from the outer wall. This canal lies above the main canal and served higher elevation irrigated terraced land. The canal route was lost as we proceeded downstream.

The rocky and rugged slope of the mountainside provided clear evidence of the main canal route. In the foreground, the section of the canal is clearly evident with both the right and left banks nearly intact.

Section 3 of the main canal from the Rio Pukara flowed on a flatter slope as it coursed on a surveyed route eastward on the hillside above the Pukara community. Only a few canal stones remain in this area.

TABLE 6-2. Rating Table for Restored Channel, Section 4

Project Description

Flow Element	Rectangular Channel
Method	Manning's Formula
Solve For	Discharge

Constant Data

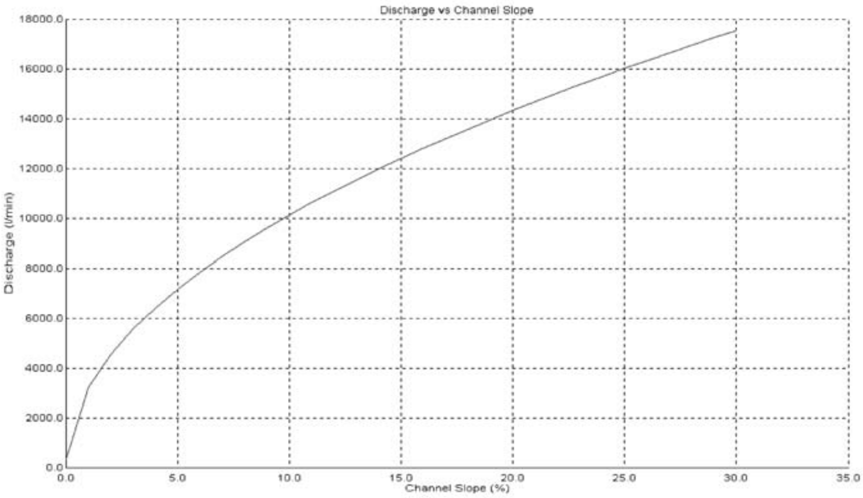
Manning's Coefficient	0.020
Bottom Width	8 inches

Input Data

	Minimum	Maximum
Channel Slope	1%	30%
Depth	2 inches	23 inches

Depth (inches)	Channel Slope (%)	Discharge (cfs)	Velocity (fps)
2	1.0	0.18	1.7
2	5.0	0.41	3.8
2	10.0	0.58	5.4
2	15.0	0.71	6.6
2	20.0	0.82	7.6
2	25.0	0.92	8.5
2	30.0	1.00	9.3
4	1.0	0.48	2.2
4	5.0	1.07	5.0
4	10.0	1.51	7.0
4	15.0	1.86	8.6
4	20.0	2.14	9.9
4	25.0	2.4	11.1
4	30.0	2.62	12.2
6	1.0	0.81	2.5
6	5.0	1.82	5.6
6	10.0	2.57	8.0
6	15.0	3.14	9.7
6	20.0	3.63	11.2
6	25.0	4.01	12.6
6	30.0	4.45	13.8
8	1.0	1.16	2.7
8	5.0	2.60	6.0
8	10.0	3.67	8.5
8	15.0	4.50	10.4
8	20.0	5.19	12.0
8	25.0	5.80	13.5
8	30.0	6.36	14.8
10	1.0	1.52	2.8
10	5.0	3.40	6.3
10	10.0	4.80	8.9
10	15.0	5.89	11.00
10	20.0	6.80	12.7
10	25.0	7.60	14.12
10	30.0	8.32	15.5
12	1.0	1.89	2.9
12	5.0	4.21	6.5
12	10.0	5.96	9.2
12	15.0	7.30	11.3
12	20.0	8.43	13.0
12	25.0	9.42	14.6
12	30.0	10.32	16.0

This sharp stone was placed adjacent to the main canal, likely to serve as an Inca survey route marker. Engineer/surveyor Scott Marshall of our team examined the placement of the setting of the stone and found it suitable for sighting from far-off locations.

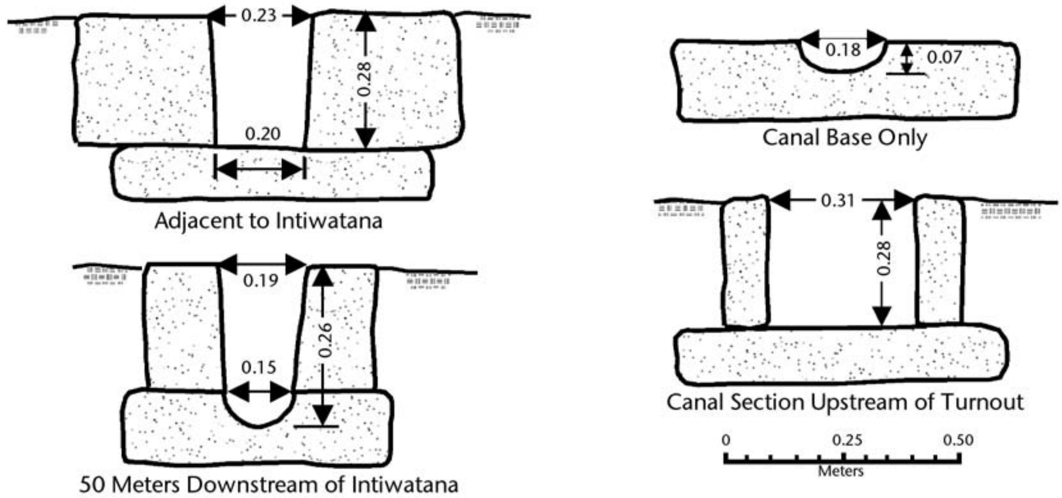


Scientific advisor Dr. Gordon McEwan, a long-time, experienced Andean scholar and author of Chapter 11, examines the 200-foot-long aqueduct of the main canal.

The main canal passes under the floor of the Intiwatana and exits at the well-designed canal outlet where it abruptly turns and flows to the right until it reaches a drop structure.

Dr. Gordon McEwan examined and photographed the approach to the aqueduct prior to restoration and found it to be in good condition. This generally confirmed the report of Cumpa (1999) that the aqueduct itself had not substantially deteriorated before it was restored.

Section 4 of the restored main canal has a wide range of slopes, but a relatively constant cross-sectional area of 0.65 square foot. Its theoretical capacity at 30 percent slope ranges up to 10 cubic feet per second; however, it would not have carried more than about one-third of that amount.



Main Canal Section 5

From the Intiwatana drop structure to near the north end of Tipon's Central Terraces, the Main Canal Section 5 is 2,690 feet long with a drop in elevation of 215 feet. Slopes of the canal range from about 2 to 30 percent.

Typical cross-sections of the canal represent areas of 0.56 to 0.93 square foot. We estimate the practical capacity to be about 3.5 cubic feet per second.

This section of the main canal contains a tunnel and an irrigation turnout. The construction of this canal is at a modest slope for 1,837 feet, and then it has a steeper slope downstream.

Main Canal Section 6

It is from the northeast edge of Tipon's terraces that the main canal enters onto the large mesa, farmed since the fall of the Inca empire, southeast of Tipon's terraces. For that reason, the route of the canal on the mesa is not proven and never will be. However, it is likely that the main canal reached Patallaqta via a final right-of-way coincident with Canal C from the Tipon Spring. A good section of canal that was 8 inches wide was observed just northeast of Patallaqta.

Three canals from Rio Pukara

During the course of archaeological exploration by Ives Bejar Mendoza, three Inca canals were recorded that diverted from the Rio Pukara.

Fortunately, while descending from the Cruzmoqo, high upon the Tipon Mountain, Ken Wright found the remains of Canal 3 on September 18, 2000. Earlier, while on a reconnaissance survey, Canal 1 was identified. The routes of Canals 1 and 3 were not fully defined because of deterioration over the centuries and the resulting lack of field evidence.

The excellent Inca canal stonework of the unrestored main canal in Section 5 is illustrated in these four sketches of field evidence downstream of the Intiwatana prior to recent construction (with dimensions expressed in meters).

Portions of the remains of the original Inca main canal are in good condition. The method of construction in Section 5 of the canal was consistent though different from that for the upstream sections.

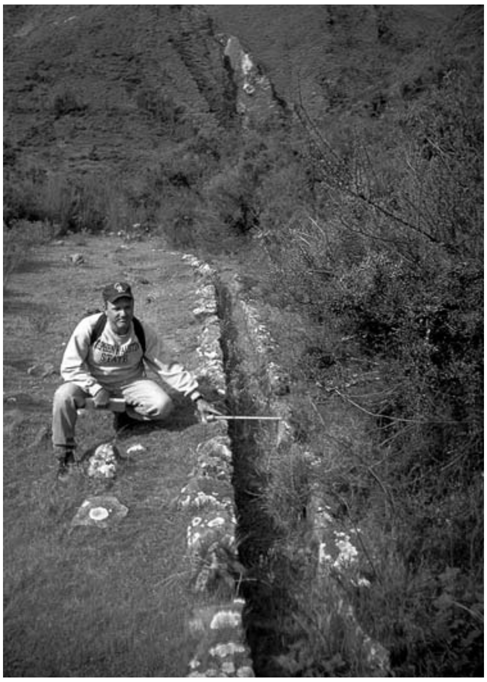
Surface water utilization

The development of three surface water canals diverting from the Rio Pukara provided the Inca enclosure of Tipon with the ability to irrigate an extensive system of terraces from the Pukara area all the way to the relatively flat mesa to the east, where excess water was discharged at Patallaqta, overlooking the valley below.

But the surface water canals also provided domestic water supplies to Pukara, to the many farm workers, and to important facilities along the course of the canals, such as the Intiwatana and the Ceremonial Plaza.

To help make the Central Terraces function as planned at elevations above the Tipon Spring, the main canal was used judiciously via the wall-integrated hydraulic drop structures.

Overall, Tipon's surface water supply was complementary to the spring water supply, besides bringing water to an otherwise arid area of the Tipon complex.



Summary

The hydraulic parameters provided above represent more than test velocities, flow depths, and discharges. They represent an Inca canal system that was properly designed to operate, as it was needed, without the modern benefits of computer models and design software.

The canals described are just a portion of the solid engineering work that was employed in Tipon, but this engineering role was essential. Without these well-designed canals, Tipon never could have functioned as an extensive irrigated agricultural enclave and, at the same time, served as a suitable estate for Inca nobility.

Coming down from the Cruzmoqo, Ken Wright came across Canal No. 3, the uppermost of the three canals.

Canal No. 1 was judged to be in excellent condition by engineer Christopher Crowley. He is measuring its width. This section of the unrestored prehistoric canal lies south of Pukara.

WATERWORKS WONDERS

A 500-acre enclosure built nearly 800 years ago in a remote side valley of the Huatanay River became a premier agricultural estate for Inca nobility, but it would have been just ordinary had it not been for the exquisite design and construction of its waterworks.

The Tipon waterworks are exceptional because the hydraulic engineering is coupled with environmental design. The overall impact of the works is worthy of America's top landscape design university departments. Water at Tipon serves utilitarian purposes while creating special environmental amenities.

Here at Tipon, hydraulic drop structures are integrated into high-status walls. Meanwhile, the hydraulic design allows for smooth stream lines with no errant currents. Some drop structures lower the stream as much as 11 feet without allowing excess splashing at the point of impact.

The joy of hydraulic investigation at Tipon lies in the fact that the planning, design, and construction were performed by prehistoric Americans who were part of a civilization that appreciated the beauty of hydraulic excellence in both function and appearance. No detail seemed too much for them as they moved water from use to use in an efficient manner that helped create a remarkable estate for Inca nobility.

Chapter 7

Hydraulic Engineering

The hydraulic engineering abilities of the Inca are well documented at Tipon for modern engineers; the evidence lies in the waterworks themselves rather than in written documents—the Inca had no written language. To analyze the hydraulic works, assign roughness factors, determine trajectories, and compute carrying capacities in either metric or English units takes the investigator back 500 years into the day-to-day technical challenges with which the Inca engineers worked. For instance, with a ceremonial fountain where an *aryballo* (water bottle) needed to be filled, the jet size and trajectory must be suitable to enter the small opening at the top of a rather large-diameter ceramic vessel. The jet could not fall too close to the wall or jet out too far horizontally. While this may seem like a simple matter to the layman, it is not so when the rate of flow varies and when one uses building stones.

Then, when a canal splits into three channels and the irrigation engineers need total flexibility in routing the water evenly in all three branches, or all the water in just one, the hydraulics need to be well balanced and the individual channels must be sized for a wide variety of discharges. To this challenge can be added both subcritical and supercritical flow with provisions made for hydraulic jumps that could cause channel sides to otherwise be overtopped. The Inca engineers were masters of such challenges.

An *aryballo* water bottle was the vessel used by the Inca for collecting water from a fountain. Its special design allowed it to be set on the floor, to be carried, or to hang from wall pegs.

Central Terrace hydraulics

The hydraulic network of the three canal systems includes numerous hydraulic structures that serve important functions, but at the same time the structures are designed and built for beauty, interest, and the creation of the aesthetic environment of flowing and falling water. The hydraulic perfection of the Central Terrace water handling is one of the primary factors in making Tipon an estate suitable for Inca nobility. It was impressive to important visitors who were invited into the compound and to the workmen viewing the works from a distance.

First of all, let us review the canal system laid out on the Central Terrace as was described in Chapter 4, with the flow of the Tipon Spring at 0.63 cubic foot per second or 283 gallons per minute. All the flow of the spring, or only a portion, could be routed to Canal A.

Main fountain

The main fountain is at the head of the Canal A system. As restored by the Instituto Nacional de Cultura (INC) in Peru in 1999, the water is divided into two jets and then again into four jets.

The measurement and plan view of the fountain prior to its restoration by INC personnel (designated as M.R.C. and R.P.V.) was prepared on August 14, 1999. Restoration of the main fountain created a masterful focal point of hydraulic engineering and landscape design. The fountain provided a convenient domestic water supply for the nearby noble residents of the Inca Kancha Group prior to use of the water for any other purpose. This first use of water by nobles is like that at Machu Picchu and Wiñay Wayna where the Inca residences are adjacent to the highest and first fountain.

The restored main fountain below the Tipon Spring represents special aesthetic hydraulic design to provide both function and beauty. The handhold to the right provided convenience as well.

Canal flow measurement

The slope of some of the longer reaches of stone-lined canals results in supercritical flow. In one long reach of Canal A to the southwest of Terrace No. 6 (restored by the INC), we impeded the flow to create a hydraulic jump that then moved upstream until an equilibrium was reached.

Several measurements of the actual flow were made on various days in the restored Canal A to the southwest of Terrace No. 6. Measurements of velocity were made over a length of 56 feet, having a slope of 0.032. The velocity was determined to be 4.0 feet per second. The wet cross-sectional area averaged 0.12 square foot. The discharge was determined as follows:

$$Q = AV$$

where
Q = discharge in cfs
A = area in ft^2
V = velocity in fps

$$\begin{aligned} Q &= A \times V \\ &= 0.12\ ft^2 \times 4.0\ fps \\ &= 0.48\ cfs\ \text{or}\ 216\ gpm \end{aligned}$$

Based upon the discharge measurement of the flow in the supercritical stage, a determination was made of the restored canal roughness using Manning's equation and solving for roughness *n*.

$$n = \frac{1.49 \times R^{2/3} \times S^{1/2}}{V}$$

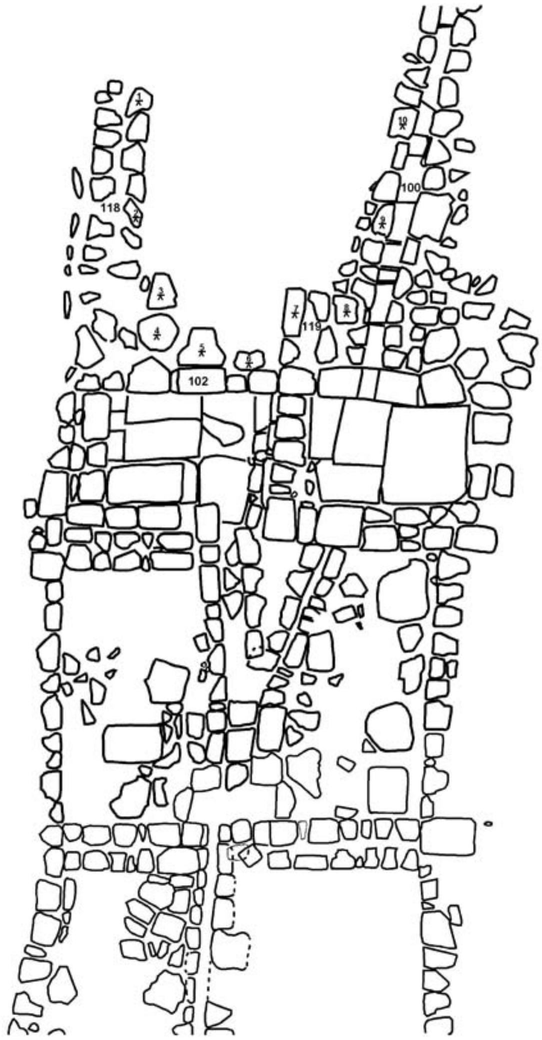
where
R = hydraulic radius in ft
S = slope in ft/ft
V = velocity in fps

$$n = \frac{1.49 \times 0.093^{2/3} \times 0.034^{1/2}}{4.0\ fps}$$

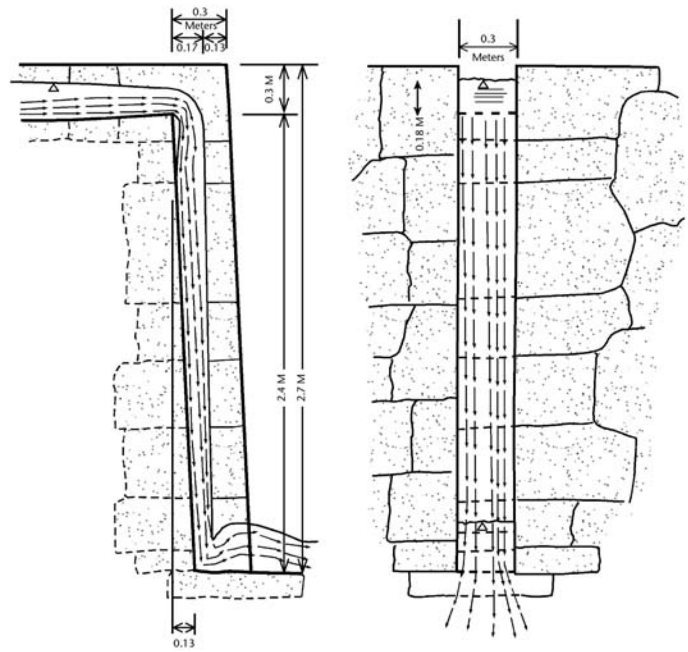
$$n = \frac{1.49 \times 0.205 \times 0.184}{4.0}$$

$$n = 0.014$$

The Manning roughness coefficient (*n*) of 0.014 represents a highly efficient smoothness; however, this canal was restored by careful workmen and does not necessarily represent the smoothness of the original Inca canal of some 500 years ago. We did note that when the canal flow was impeded, the resulting hydraulic jump was a Type I jump, and there was no canal overtopping of the resulting subcritical flow. During the Inca period of canal operation, the *n* coefficient was more likely as high as 0.02.



The diagram of the remains of the main fountain of Tipon shows that the restoration work of 1999–2000 was performed with reliability true to the original work of the Inca engineers.



Drop structures

The Central Terraces stepped down from northeast to southwest a total of about 160 feet from Terrace No. 13 to Terrace No. 1 with elevation differences between individual terraces being as much as 15 feet. Here, the Inca engineers were faced with hydraulic energy dissipation challenges because the drops needed to meet environmental design standards of controlled splash, pleasant appearance, and complete integration into the high-status stonework of the walls.

The solution was to use unique near-vertical channels inset into the walls. The resulting design is a visual highlight of the terraces and an extraordinary engineering achievement.

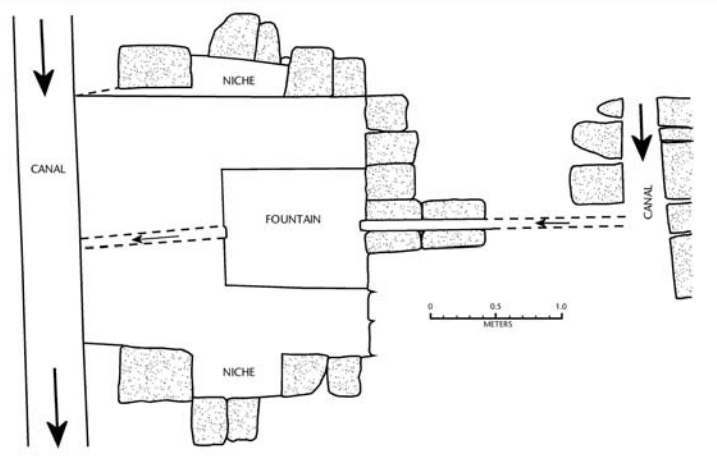
One presently operating restored drop structure of Canal A was analyzed in the field. It has dimensions as follows:

- Approach check channel length: 1.0 foot
- Approach check channel depth: 0.8 foot
- Total vertical drop: 8.9 feet
- Vertical channel inset into wall: 1.0 foot

Observations of the flow of water into and through the drop structures conveyed a feeling of order and harmony; the smooth stream lines throughout the entire 8.9 feet of vertical drop were contrasted with the controlled point of impact at the bottom, where splash was limited laterally because of the inset channel. The controlled rush of flowing and falling water have helped demonstrate the power of the Inca over land and water, as well as their capabilities in creating hydraulic poetry.

Field measurements and examination of numerous hydraulic drop structures showed a remarkable design and construction consistency. Ruth Wright documented this nearly 9-foot drop in September 2000.

The Inca were masters of hydraulic engineering. This near-vertical drop structure view, looking straight down, shows typical minimal splash even though some drops were 15 feet high.



The Tipon Ceremonial Fountain following restoration in 2000. It lacked the usual privacy wall that is typical for Inca fountains. However, by June 2004 the wall had been installed as it was originally.

Prior to the 2000 restoration, the Ceremonial Fountain operated smoothly as illustrated in this 1997 photograph. Note the remains of the privacy wall in front, the good interlocking of the stones, and an outlet in the far background.

A strategically placed ceremonial fountain above Terrace No. 8 was supplied via a stone conduit. This field sketch was prepared in September 2000 following partial restoration. Even prior to restoration, the fountain was in excellent condition.

Ceremonial fountain

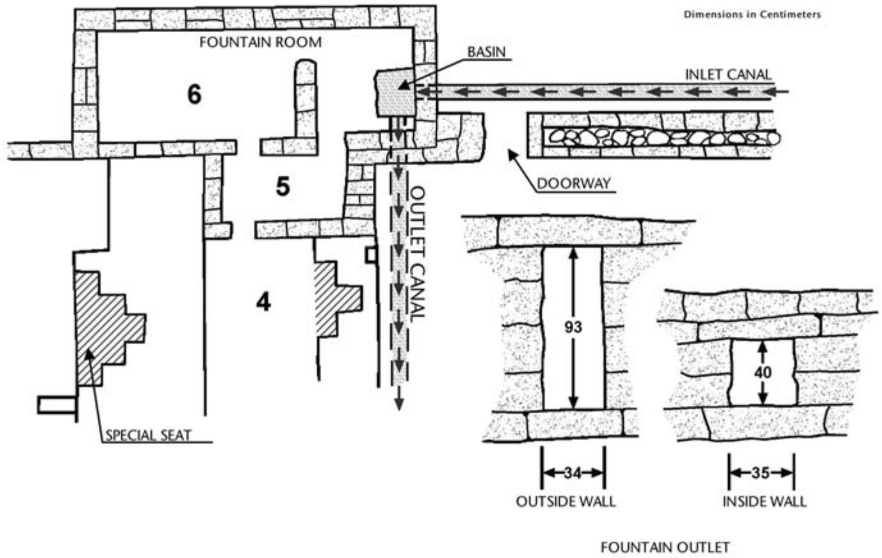
A ceremonial fountain on the southeast side of Terrace No. 8 is supplied by Canal A and a conduit at that location. The approach channel is 6 feet long where the jet drops to a stone basin, from where the water is discharged to the Canal A system.

The original fountain was initially documented in 1997 by Ken Wright, Alfredo Valencia Zegarra, and Ruth Wright, with additional work in 2000 and 2004. This fountain was designed and strategically located to provide a convenient water source enclosure for both special ceremonies and drinking. Water entering the fountain is not yet used for irrigation, and therefore it was pure enough for domestic use purposes.

Intiwatana hydraulics

Routing of the Inca main canal to the Intiwatana and then under its floor and finally out of the far side wall represents a special task of incorporating architectural design and control using the strict canal hydraulic constraints of slope, route location, and cross section. The result was one of full integration, the canal providing a fresh supply of Rio Pukara water to the Intiwatana building interior either via a floor opening or more likely from the fountain located on the north side of the building.

Upon exiting the Intiwatana via an opening in the south wall, the canal makes an abrupt turn and then flows parallel to the outside wall of Room 12, where the canal elevation then drops vertically about 4 feet via a drop structure. From the drop structure, the canal flows unimpeded down the rocky hillside through a short tunnel, past the north side of the Central Terraces, then across



The fountain of the Intiwatana received the full flow of the main canal; it is an online hydraulic structure. The fountain outlet details expressed in centimeters represent opening areas of 3.4 and 1.5 square feet, consistent with the online character of the fountain.

Most canal bends or abrupt changes in canal direction were constructed by the Inca to avoid hydraulic problems. The canal bank stones are missing in the foreground and the carved bottom stones illustrate the design procedure used.

the East Mesa top joining Canal C, and then to the several buildings of Patallaqta. From here, the water is discharged through the perimeter wall of Tipon to the valley below.

The cross sections of the stone-formed and stone-lined main canal from the Intiwatana down the rocky hillside west of the Central Terraces are varied, as illustrated previously. Further downstream, the canal section is also of stone, where a curve occurs. The estimated roughness coefficient is 0.02. The canal cross-sectional areas range between 0.56 and 0.93 square foot, with maximum capacity of about 3.5 cubic feet per second, and are remarkably constructed to transport water for optimized beneficial use.

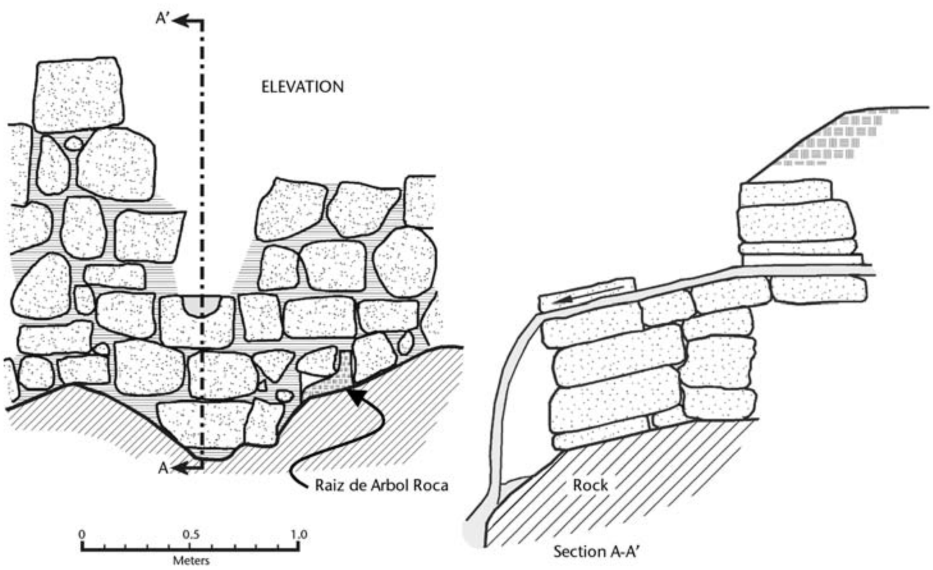
It is a pleasure for the engineer to view this portion of the canal that has not yet been restored, but remains as it was left by the Inca, where the smoothness, shape, and variety of canal stones can be fully appreciated.

Main canal turnouts and bends

A canal needs turnouts to provide water for adjacent uses such as for the Ceremonial Plaza or a nearby irrigated field. The two examples upstream of the Intiwatana in a restored portion of the canal are portrayed. One is represented by an orifice feeding a rock-lined conduit, while the second is a standard right angle channel outlet that has a feature for easy placement of a canal check. While the main canal has an area of 0.67 square foot, the branch has a cross-sectional area of 0.17 square foot.

Abrupt changes in canal direction were handled by bends; however, such bends can create hydraulic problems, while more gentle curves tend to have been preferred. A sharp bend is unusual, but the one used at Tipon may have served a flow limitation function.

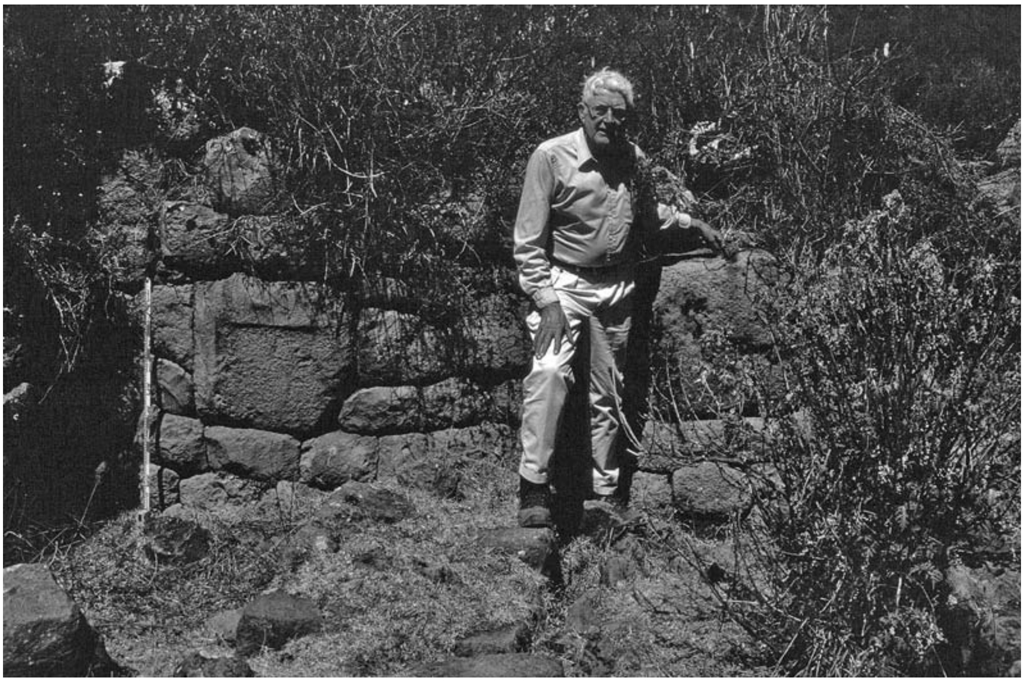
Ceremonial Plaza fountain



For years, archaeologists judged the Ceremonial Plaza to be a reservoir, but this opinion did not ring true upon closer inspection by the INC and Ken Wright, Alfredo Valencia Zegarra, and Ruth Wright. The reservoir theory seemed plausible because nearby and higher in elevation was the main canal, and there was a turnout to the structure. Within the plaza was an outlet that seemingly could fill the enclosure with water. However, closer inspection showed that the Ceremonial Plaza walls were not able to hold water, even though the wall stones were tightly fitted. The exquisite niches were not carved to be underwater, and, finally, we concluded that the outlet was part of a fountain. In the fountain area, we noted the remains of a room. Downstream from the fountain was an outlet from the room to the main plaza area. This use of water in a ceremonial plaza is similar to what Gordon McEwan found and reported upon at the earlier and nearby Chokepukio site. This 115-foot-long enclosure, earlier thought to be a reservoir, was actually a beautiful ceremonial plaza that complemented the nearby Intiwatana that contained an *usnu,* or shrine.

The Ceremonial Plaza hydraulic design included an interior fountain, the inlet conduit of which is illustrated above. The water inlet is one of the reasons why some scientists previously judged the Ceremonial Plaza to be a reservoir.

This detail drawn by team member archaeologist Ives Bejar Mendoza shows the inlet works for the Ceremonial Plaza fountain. The approach conduit was fed from a turnout off of the main canal at the aqueduct.



Pukara fountain

The archaeological ruins of Pukara lie below three Inca canals that divert out of the Rio Pukara, and, here, the water supply was abundant. In one area of Pukara, Ken Wright is shown at a fountain pointing to the shaped-stone inlet channel that is waist-high above the receiving basin. Shaping a channel into a solid rock was a stone working technique for which the Inca had special talent. Here, the water would jet out to form a suitable flowing column of water, falling about 3 feet into a stone basin below. If the jet flow was too fast, the water would splash out beyond the basin; if too slow, it would run down the stone facing of the fountain. But Inca fountains were designed within known flow limits so that water jugs could be easily filled before being carried off to a nearby residence. When not being used for filling jugs, the fountain provided a sight and sound amenity.

Ken Wright is shown at a Pukara double fountain pointing to the inlet channel for the right fountain; a jet of water would plunge into the stone basin below.

Summary

Tipon could be called an Inca water garden because of its hydraulics and related features of terraces, fountains, and drop structures. We can be thankful that the Inca were able to draw upon the technology of past empires and especially from nearby then-ancient settlements of the Wari and other Intermediate Period people (Valencia 1997). They then built upon and refined the techniques and empirical engineering successes that they had borrowed.

Described here are only the highlights of the hydraulic engineering accomplishments of the Inca at Tipon, those that characterize the marvels that exist there. More than just appreciating the individual hydraulic structures, one needs to consider the overall system of water handling that fits the topography, hydrology, and water needs to make Tipon a special place. Water was an important part of the whole. Without careful planning and the harmonious execution of all of its components, Tipon could have been an ordinary walled agricultural enclosure.

PUBLIC WORKS

Public works engineering in modern times is a noble profession that benefits and impacts citizens in many ways. To the Inca, good public works engineering was essential to the rulers of the empire who allocated untold economic and manpower resources to public works construction up and down the spine of the Andes for 2,500 miles.

Buildings and structures ranged from ceremonial plazas to terraces; grain storehouses, canals, and fountains were built with a surprisingly consistent style from north to south.

The quality of the Inca construction was aimed at longevity, as well as beauty, function, and compatibility with the environment. The care used by Inca engineers and construction craftsmen tells us much about these prehistoric people and their remarkable culture.

The Inca engineers did not have available to them a set of American Society of Civil Engineers design and construction manuals, nor did they have a modern engineering department, but close examination of their remaining legacy of public works makes one think they had the equivalent.

Chapter 8

Buildings and Structures

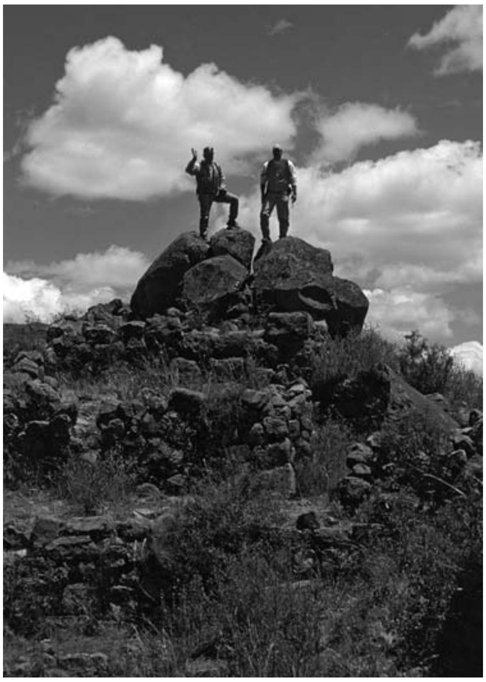
A visit to Tipon is a treat, not only for civil engineers, but also for architects, stonemasons, environmentalists, and landscape architects, too. The buildings, terraces, and hydraulic structures have withstood five centuries of climatic wear and tear, coupled with five centuries of local agricultural use of the site since the collapse of the Inca world in 1533 CE (McEwan 2006). Yet, the scenic grandeur and engineering makeup of Tipon was clearly apparent when Hiram Bingham of Yale University visited and photographed the site in 1912 (Bingham 1930). The variety of structures is wide.

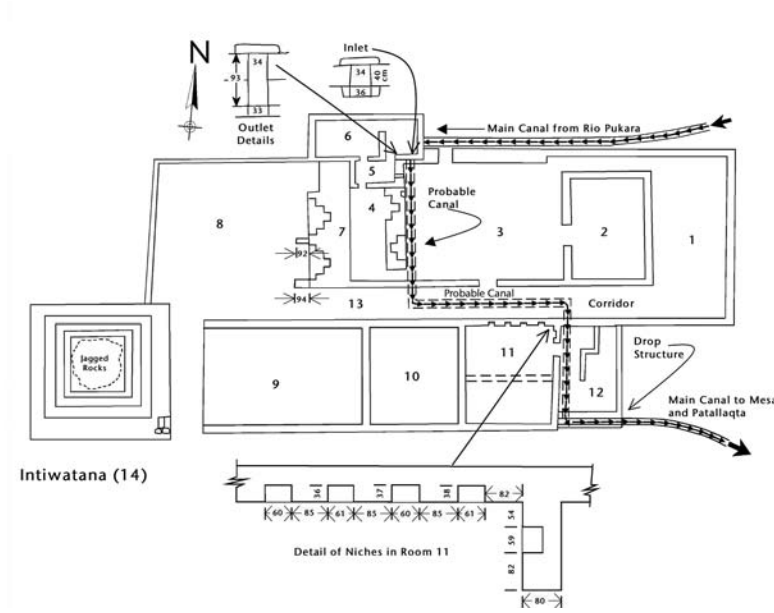
The buildings, terraces, and hydraulic structures of Tipon amply pay tribute to the skill of Inca civil engineers. This restored three-tiered hydraulic drop structure carries water of Canal A to the large terrace. The huge structure illustrates the Inca mastery over hydraulic engineering challenges.

Variety of sites

To give you a good idea of the variety, as well as the significance and aesthetics of Tipon, we can now visit the parts of the enclave that help make up the whole. Let us first examine the Intiwatana for its special location, stonework, its *usnu,* and the underground canal that passes through its middle. Then, to other focal points that include

- Ceremonial Plaza (with fine stonework)
- Kancha Group (or Inca Kancha)
- Hornopata (oven)
- Patallaqta (small group of buildings)
- Sinkunakancha (military center)





The terraced Intiwatana pyramid with jagged rock exposed at the top is likely an *usnu*. An *usnu* symbolizes government and was a place for administrating decrees and justice. Here, research team members Christopher Crowley and Scott Marshall provide scale for judging the pyramid height.

The Intiwatana complex at Tipon has many facets ranging from the terraced Intiwatana pyramid, special stairways, and fine architecture to a fountain and an underground canal. It is an important ceremonial center of Tipon.

The stairway leading into a room of the Intiwatana is of the finest stonework. Design and construction of the Intiwatana represented good craftsmanship.

- Iglesia Raqui (storehouse)
- Eastern Terraces (steep terraces)
- Qoyay Oqwayqo (gently sloping terraces)
- Pukara (urban area)

Intiwatana

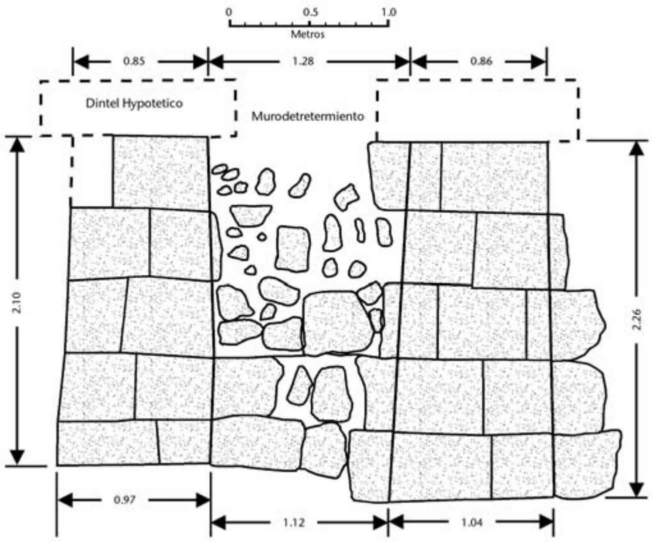
This site represents the focal point of Inca religion at Tipon with exquisite stonework, a flowing water supply on its north and south sides, a canal that ran under its center, a fountain, and, above all, a square, stepped structure to the west that is the Intiwatana.

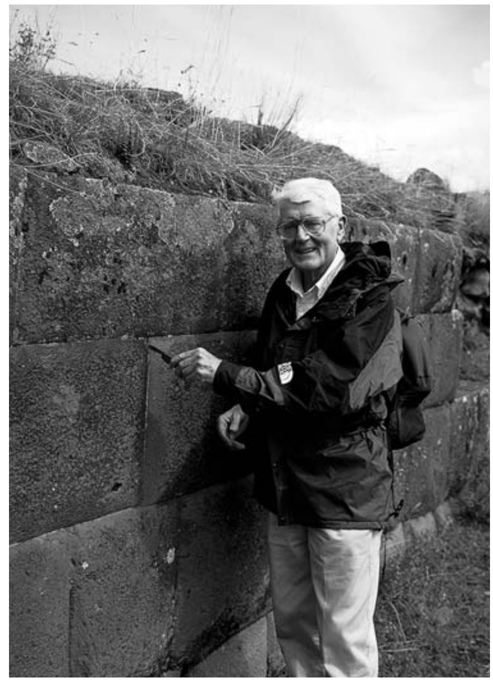
Northeast of the Intiwatana are two special seats that are related to the square, stepped structure. The square, stepped structure is an elegantly raised platform of a pyramidal shape, probably used by the Inca or a nobleman for diverse purposes such as an altar, a place of prayer and sacrifice, a throne and seat, and a place for someone who governs to hold court and dispense justice. It is a symbol of power and government of the Inca.

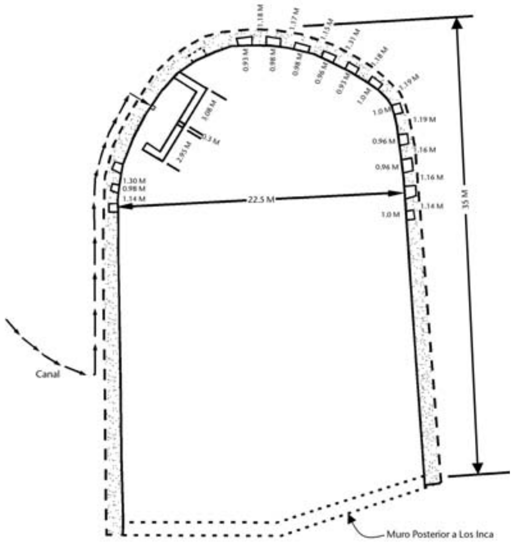
When visiting the Intiwatana, be sure to examine Room 11 and note the fine geometrical configuration of the five wall niches, examine the canal outlet on the south, the fountain configuration on the north, and follow the route of the underfloor canal. Then, imagine the work of the Inca civil engineers and other specialists in planning and designing this complex.

Ceremonial Plaza

The Ceremonial Plaza is 115 feet long and 75 feet wide in a half oval shape containing 7,500 square feet, with the opening facing south. The original andesite stonework of the Ceremonial Plaza is excellent. A layout of the Ceremonial Plaza prepared by archaeologist Ives Bejar Mendoza and a diagram of two of the

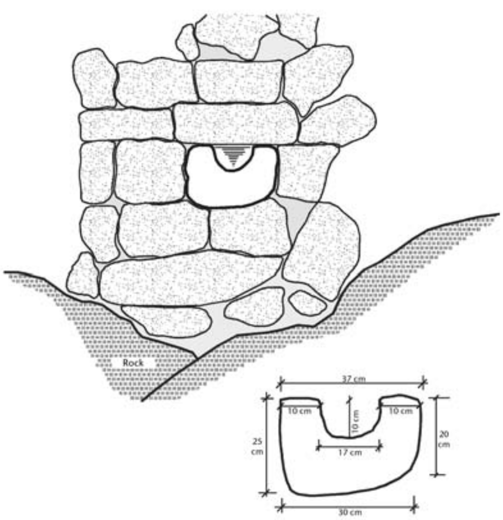






niches help us to visualize this grand plaza that provided an appropriate location for ceremonies. A branch canal off the main canal leads to the Ceremonial Plaza, and good field evidence exists for documentation of the water supply aspects of this structure.

As described in Chapter 7, some scientists had concluded that the Ceremonial Plaza was a high-style reservoir and that a southern wall formed the end wall of the reservoir (Niles 1987). We, therefore, began with the hypothesis that the structure was a ceremonial reservoir. However, detailed study of the site failed to prove the hypothesis that it served a water storage function. Site investigations provided substantial evidence of it being a ceremonial plaza, as judged by the Instituto Nacional de Cultura (INC) (1999) on their topographic survey map of the site and by Cumpa (1999), by Peter Frost, and as described below.



Stonework of two of the many niches in the Ceremonial Plaza shows the high standard of care utilized in this special structure. The measurements shown are expressed in meters.

The exquisite stonework of the Ceremonial Plaza was shaped and placed in a manner reserved for high-status buildings. Here, Ken Wright is demonstrating its tight-fitting joints where a knife blade would not penetrate.

Archaeological documentation of the Ceremonial Plaza by Ives Bejar Mendoza defined the huge and well-planned enclosure that lies near the important Intiwatana and below the 200-foot-long aqueduct of the main canal.

Remains of a canal in the Ceremonial Plaza illustrate the important function of water in carrying out the original purpose of this building.

A water delivery stone for the Ceremonial Plaza is shaped with a channel that is 4 inches deep and 6.7 inches wide. The resulting jet of water fell into a stone basin and was suitable for filling water bottles.

A fountain leads into an enclosure (not directly into the open plaza) in the northwest portion of the Ceremonial Plaza, which indicates that the fountain served an internal function for the room, not necessarily a reservoir supply function. The exquisite stonework of the interior of the Ceremonial Plaza, along with beautiful niches, is not consistent with a reservoir function and long-term storage of water. Water would leak out through the joints, and rising and falling water levels damaged the veneer of andesite stone that is cut and carefully carved to cover a rough fieldstone wall. A rapidly falling water level would create pore pressure on the inside of the veneer walls, which would cause the sections to loosen. We noted no such damage to the fine stone veneer.

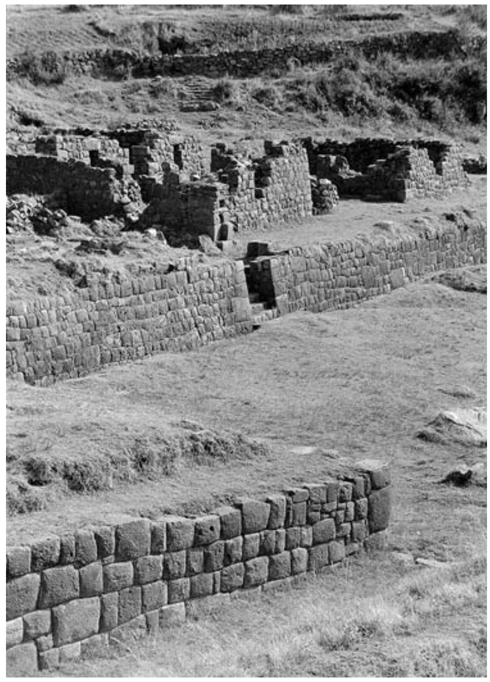
A freestanding wall on the south would not have good impervious qualities to keep the water from leaking out, both under and through the wall. An evaluation of the southern wall of the Ceremonial Plaza by Ives Bejar Mendoza and Ken Wright indicated that the wall is likely from the colonial period and not of Inca origin. The evidence is clear that water was routed to the Ceremonial Plaza. It is only the purpose for which the water was used that is challenged. In summary, we agree with the INC and Cumpa that the Ceremonial Plaza was not a "high-status reservoir." It is well located to serve as a Ceremonial Plaza. Be sure to visit this structure and admire the excellent stone wall and niches. You will find offerings made by modern Quechua Indians in one or more of the niches.

Three buildings of the Kancha Group sit on a high terrace so as to provide a dramatic view to the Central Terraces below for the Inca nobles and their families. A 1912 view of the Kancha by Hiram Bingham shows little change.

Team archaeologist Ives Bejar Mendoza carefully documented the fine stonework of the niches of the Ceremonial Plaza. Note the corner stone of the upper right that illustrates the special care that this niche received.

Kancha Group

This group of four buildings lies adjacent to Tipon's Terrace No. 12 near the spring. Three of the buildings face a central patio. Trapezoidal niches exist in all the buildings, but the one to the east is best preserved. Initial restoration of the Kancha Group



prior to 1996 was not performed adequately; it has been partially corrected with later restoration in 2000.

Bingham photographed this group of buildings in 1912 and then, in the 1995–1997 period, Ken Wright photographed some early preservation work at the Kancha Group. The more recent restoration of the Kancha Group helps to illustrate the original architecture.

Hornopata

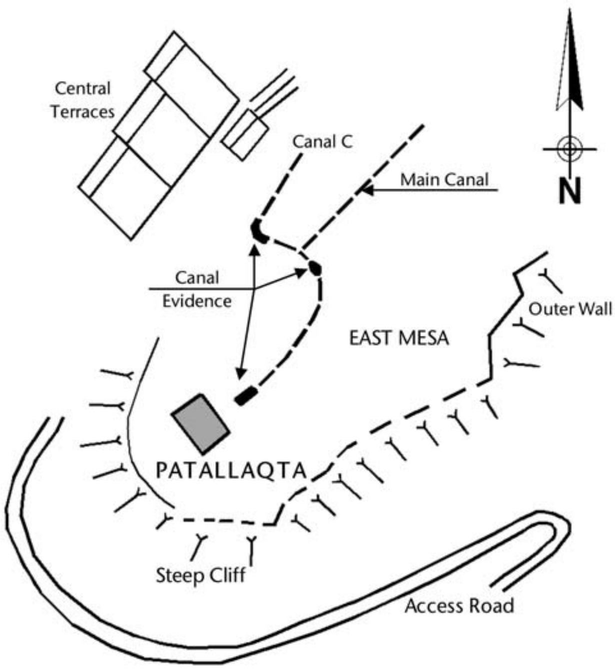
Near the Kancha Group is a circular structure that was likely an oven or incinerator. The structure is partially buried. An arched opening is at the bottom. We determined the stonework to be pre-Hispanic, not necessarily Inca. In 1995, 1997, and 2000, the Hornopata was filled with trash, indicating that it had not been recently studied. Along with the INC, we believe the structure to be a kiln for firing ceramics.

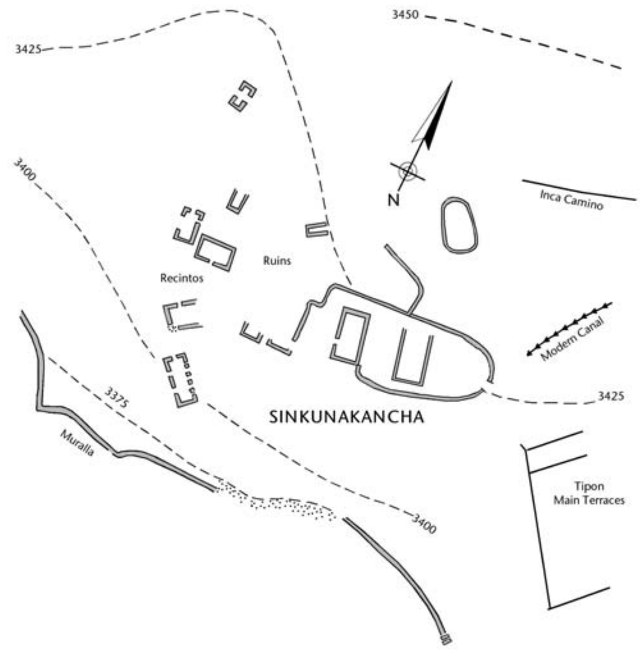
The Kancha Group for Inca nobles was well situated with its own terrace, privacy, convenient access to the water supply, and a pleasant view.

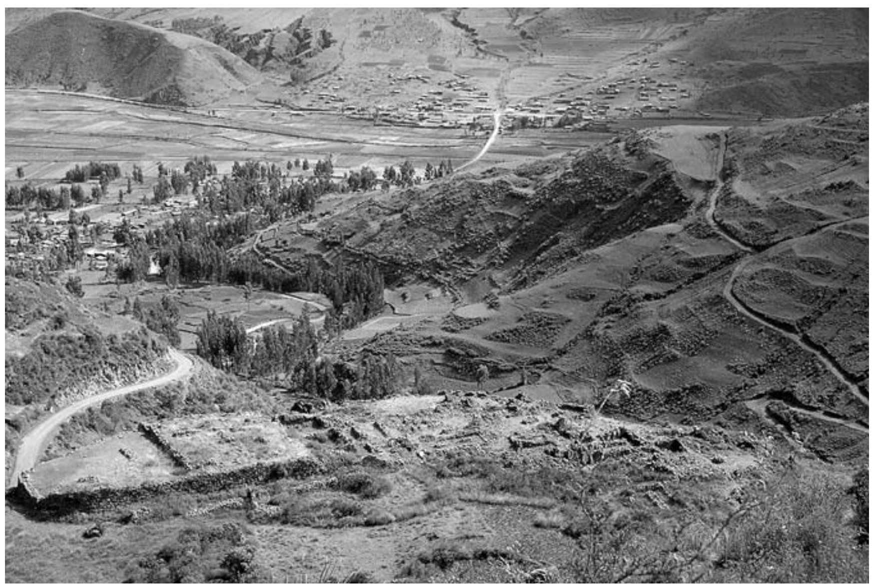
This 1995–1997 period photograph of the Kancha Group shows early preservation work that was later modified in 2000.

This 2000 frontal view of the northernmost Kancha Group building illustrates the higher terrace setting of the buildings.

The Inca use of geometric layout is illustrated in this 1997 view through the doorway of one of the buildings of the Kancha Group. The overuse of mortar in the joints of the stone represents questionable restoration.







The Patallaqta is the terminal of both the main canal from the Rio Pukara and the Canal C from the Tipon Spring. It is set on the edge of the cliff forming the East Mesa.

This 1999 layout of the Sinkunakancha by the INC shows the outer wall below, the huge oval-shaped platform, and housing for about 50 people.

The two-story storehouse that is known as the Iglesia Raqui lies east of the Central Terraces on a high and secluded bench of the East Mesa.

The Sinkunakancha, perhaps the security center for Tipon, is strategically situated to overlook the entrance to Tipon and all of the Central Terraces.

Patallaqta

This is a small enclosure located on top of a bluff at the far southern end of Tipon's walled enclosure. It is significant to paleohydrology because it is the terminal of both Canal C's system from Tipon's spring and the main canal from the Rio Pukara.

Sinkunakancha

This complex of structures (situated above and only 100 feet from Tipon's Terrace No. 1) stretches from east to west some 300 feet, with a half oval-shaped, massive wall. This Inca settlement likely housed about 50 people, based upon the number of rooms.

Canal B's water supply canal would have been extended to Sinkunakancha, although we found no field evidence to verify this assumption, probably because a modern canal for irrigation from Tipon's spring likely follows the same general course. Local

people presently use the functioning modern canal to irrigate small tracts of agricultural land. The original purpose of this site may have been for the use of the Inca military.

Iglesia Raqui

Adjacent to Tipon's terraces, just to the east of Terrace No. 6, is a *qolca* (storehouse) containing doorways, windows, and niches. It forms an important part of the scenic view of Tipon's terraces, especially from the northwest hill route to the Intiwatana.

Eastern Terraces

This long, narrow area of many terraces lies 1,200 feet northeast of Tipon's Central Terraces at an average elevation of 12,000 feet. These terraces lie just east of the gray bedrock slope that is visible from Tipon's Central Terraces and that provides a picture of a smooth volcanic flow void of any topsoil or vegetation. The 1956 aerial photograph tends to show that some of the volcanic flow surface was covered with topsoil and vegetation. To the east of the terraces some 400 feet, lie the remains of the outer wall.

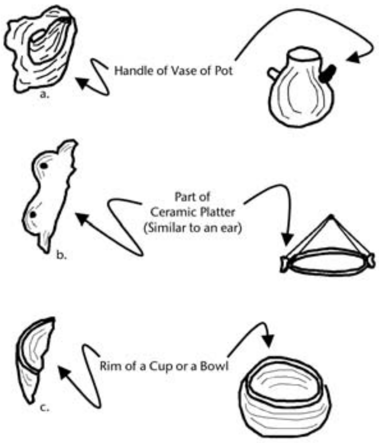
Some of the eastern terraces are in a reasonable state of preservation, even though one expects them to be gone because of earth slides and erosion. The terraces are presently partially used for growing tubers, although much of the area is thickly wooded. The terraces stretch down the steep slope about 1,000 feet. A high cliff lies near the terraces.

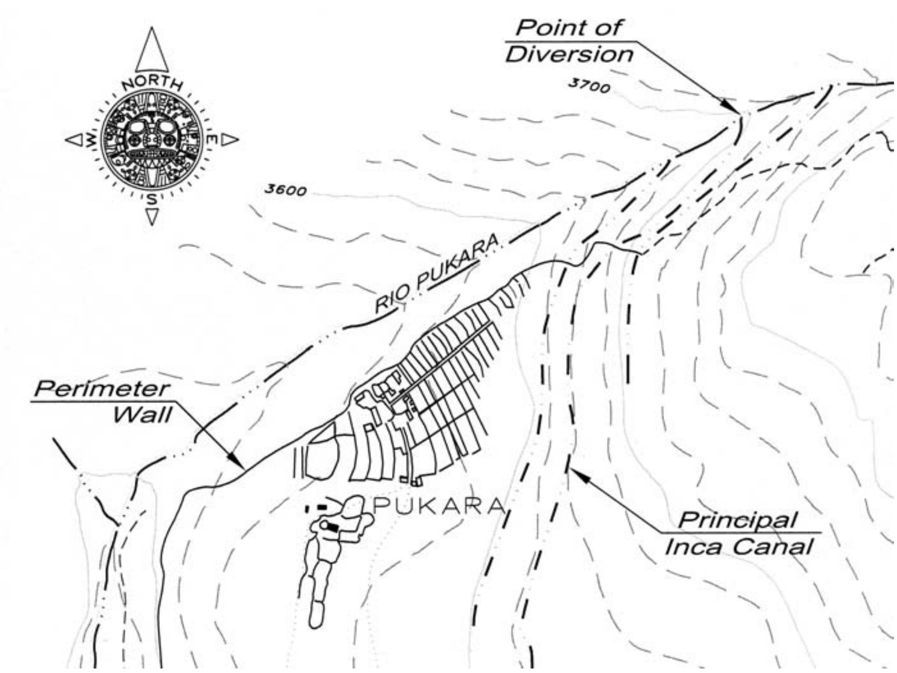
Qoyay Oqwayqo

A series of gently sloping terraces stretching over a north/south length of 600 feet lies north of Tipon's central terraces and is partially served by the main Inca canal from the Rio Pukara.

Predecessors of the Inca built the impressive outer wall of Tipon. This 3.7-mile-long wall has Wari construction characteristics that can be compared to a Wari aqueduct shown previously in Chapter 2.

An early aerial view of Tipon shows the steep Eastern Terraces (top arrow) that are adjacent to the large volcanic slab. The black arrow points to the Central Terraces. The middle arrow shows Qoyay Oqwayqo.





Ancient potsherds abound on the surface of the ground at Pukara. The sherds represent a pot, a platter, and a bowl.

The residential area of Pukara lies mostly untouched by visitors, though modern local farmers still work the adjacent fields.

Pukara, a community for about 100 people, lies adjacent to the outer wall and near the Rio Pukara. It is situated near irrigated agriculture on its many terraces.

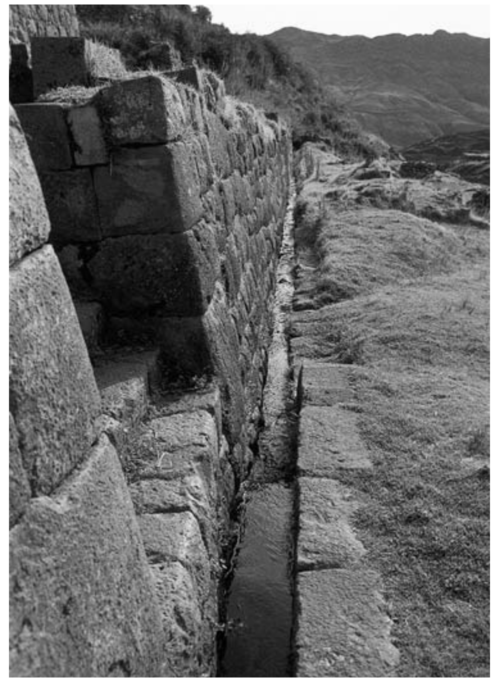
Pukara

The Inca urban area of Pukara is 0.6 mile north of the Intiwatana and is inside of and adjacent to the northwest outer wall and about 150 feet from the Rio Pukara at a typical elevation of about 11,700 feet. Pukara served as a residence for about 100 people and is made up of buildings and terraces. Likely, it was a pre-Inca site that was improved and enhanced by the Inca.

Pukara was noted to have Inca and Killke potsherds scattered over its site, many of which are decorated. The village site is in remarkably good condition considering that the general area likely has been continuously farmed since the Inca period. A portion of Pukara lies on a 20 percent slope from northeast to southeast. A double-jamb doorway that was observed after clearing away dense vegetation told us that something important lay beyond. The remains of a fountain demonstrated the use of canal water for drinking purposes.

Central Terrace walls

The Central Terrace walls represent public works construction objectives in that they were built for longevity and environmental enhancement, yet their utility and function were not compromised. Today, they would be a source of pride for any modern city.



Restoration

When one examines Tipon now, the recent restoration work by the INC is evident. The building and structure restoration is meant to improve the experience of the casual tourist. Even for the visiting engineer, the restoration can help to better understand the Inca objectives in melding intense development into the natural landscape.

Central Terrace canals

The interlacing and integrated network of three restored water distribution canal systems represents public works planning in its finest sense. The canals are laid out to highlight the Central Terraces with the beautiful view and relaxing background sound of flowing water, and, yet, they provide utilitarian delivery of water to fountains and to thirsty lands for the production of specialized high-status agriculture.

Inca canal aqueduct

The 200-foot-long and 15-foot-high aqueduct upstream of the Intiwatana and adjacent to the Ceremonial Plaza has stood for centuries as an Inca engineering achievement. Even before its restoration, the aqueduct was intact, even over the pedestrian underpass at its center.

Summary

Tipon represents a wide variety of prehistoric public works engineering achievements ranging from agricultural terraces and buildings to hydraulic structures. The public works approach to construction by the Inca sets a high standard of planning, design, and construction for modern public works engineers.

The aqueduct that carries the main canal from the Rio Pukara is built with a pedestrian underpass, but it also serves to allow any floodwater to pass unimpeded.

The high-status terrace walls of Tipon are beautiful and are further enhanced with features such as Canal C and the fine staircase leading to the Kancha Group.

Near and downhill from Pukara, this important double-jamb doorway represents an enigma that would be suitable for further research.

EARLY TIPON

When the Inca emperor Viracocha decided to take over the agricultural enclave of Tipon in the early fifteenth century, he found a center of irrigated agriculture, an active community, and a 500-acre enclave surrounded by a massive perimeter wall.

This outer wall is remarkable for its length, height, and stability. Just who built the wall, and when, is not known, but we do know it preceded the Inca. Future research by experienced archaeologists will tell us about the who and when using pottery and tools left by the workers within the stonework and carbon dating of wood and grass that is likely to be found among the interior rubble fill. For now, we can marvel at the Herculean effort that resulted in the outer wall planning and construction.

While the outer wall represents a puzzle, the Cruzmoqo on the mountaintop represents a mystery that may never be solved. High on the mountaintop overlooking the Tipon site are petroglyphs that Brian Bauer (Personal correspondence to Ken Wright, 2003) judges to be archaic, that is, earlier than the chronological period, perhaps up to 5,000 years old. Near the petroglyphs are Inca remains of terraces, a platform, and even a small bath-like stone carving that was likely used for religious ceremonies and perhaps for temporary drinking water collection and storage for the Inca outpost security personnel.

The outer wall and the Cruzmoqo help tell us of the remarkable legacy of the Inca. The many dimensions of Tipon contribute to making the Inca the greatest of the Andean civilizations.

Chapter 9

Outer Wall and Cruzmoqo

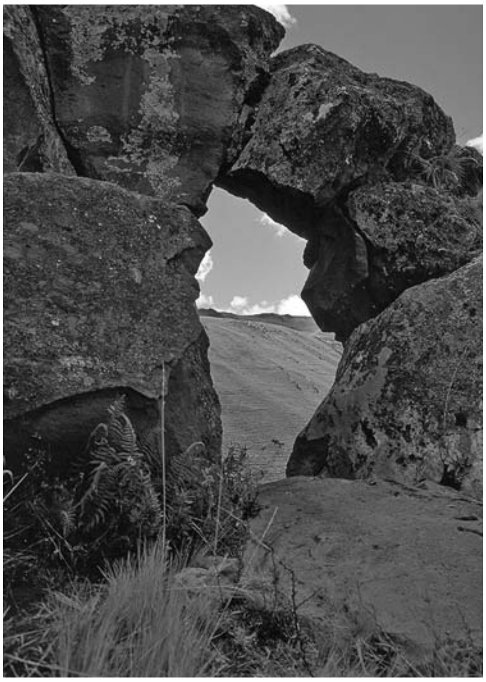
Few visitors have examined much of the outer wall of Tipon because the remaining sections of the wall are somewhat remote as they circle the site, and there are so many other things to see at Tipon. However, sections of the wall are visible right from the parking lot. The wall is older than the Inca empire, but just who built it represents a question that has not yet been answered. More about that later.

The Tipon perimeter wall was typically 15 to 20 feet high, but sometimes higher, with a base width of about 10 to 15 feet. Its length is a total of 3.7 miles. The wall is built from large, rough, unfinished andesite rock found on site, the rock providing sturdy outside wall faces, filled in-between with rubble stone. There are lots of wall sections to be sure, though in some places not much more remains than rubble from the wall and its base.

Like the work of most good civil engineers, the wall was planned and designed to take advantage of natural topography such as cliffs. A portion of the wall is built at the top of a rocky cliff to provide a better defensive position.

The massive nature of the stones available for the wall construction meant that hauling of stones took significant time and energy. The wall is at an elevation of about 12,500 feet on the eastern boundary of the enclosure. A convenient place to view the wall exists to the east, just across the mesa at the edge of the cliff, rising up some 300 feet above the Rio Qoyawarkuna. However, for the casual visitor, the easiest location to view the wall

The 3.7-mile-long outer wall of Tipon encircles the Tipon site. Here, the wall is taller than usual and has been integrated into a cliffside.



Large stones were available to construct the outer wall of Tipon. Here a type of entrance exists along the eastern portion of the site.

High up on the Tipon Mountain, the ancient outer wall swings across the rugged landscape to define the perimeter and provide security.

The arrow points to a well-preserved section of the wall. Portions of the wall also lead down to near the formal entrance to Tipon.

The north edge of Tipon was protected with a double outer wall, the purpose of which is unknown unless it was a prehistoric design change to take better advantage of the topography.

is from the vicinity of the parking lot by looking west along the steep cliff that drops down into the valley of Rio Batan Wayqo.

From about 12,500 feet in elevation on the far east, the wall winds up the hill towards the Cruzmoqo, passing it by on the north. Beyond the Cruzmoqo, to the northwest, there is an unexplained double wall with a separation of about 500 feet.

Uphill of Pukara, the wall crosses the three canals that divert out of the Rio Pukara. Here, the wall has a height of about 20 to 25 feet and is in better condition.

Cruzmoqo

From anywhere in Tipon, and even from the valley of Rio Huatanay, one can see the summit of the Tipon Mountain that reaches up to about 13,000 feet. The rectangular-shaped object on the summit is the Cruzmoqo that served as an important *huaca* (revered site).

In a study of the Inca *ceque* system, Bauer and Dearborn (1995) concluded that the Cruzmoqo was a possible shrine, but that it was not a part of the *ceque* system of lines radiating out of Cusco, as suggested by Tom Zuidema (1981).

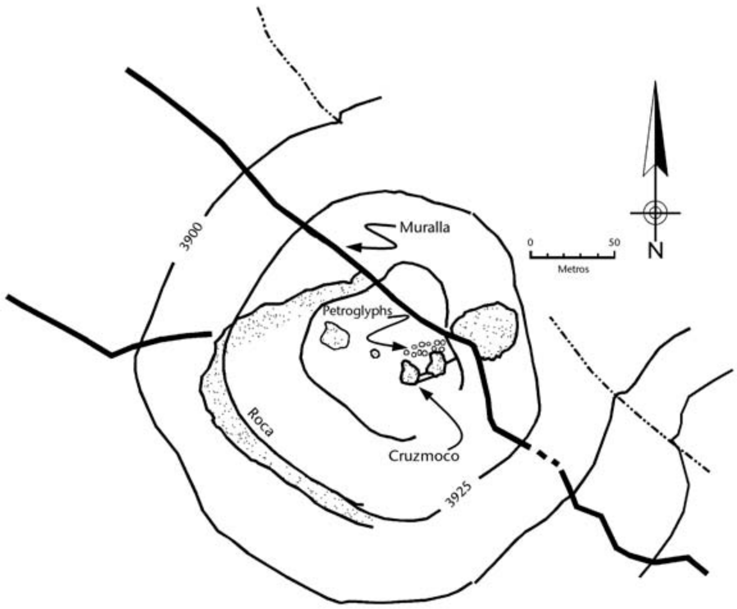
The very old use of the Tipon mountain summit is a mystery; the ancient petroglyph stones at the summit raise questions, but provide no answers. They have not been seriously studied by scientists as to their meaning or purpose, but Brian Bauer (2003) has opined that they were carved by very early people before 2000 BCE. Bauer made drawings of the petroglyphs, but has not yet analyzed them.

South of the many petroglyphs is the structure of the Cruzmoqo on a huge volcanic rock outcrop that is joined with a second rock outcrop about 30 feet to the northeast, the two rock outcrops being joined by a terrace wall. If you hike up to the Cruzmoqo (see Chapter 12), allow enough time to soak in the ambiance, enjoy the unparalleled views, and examine the many details near the summit. Be sure to give attention to the perimeter wall nearby. This mountain top is filled with ancient works of man going back more than 4,000 years, and the evidence is right in front of your eyes. For instance, one enigmatic, large stone at the summit has a 3-foot-long smooth basin carved into its top. Because of its having a low point in its polished bottom, one could first assume that the basin was for water collection purposes to provide drinking water on the dry summit for the Inca security personnel during their long watches. However, the basin was likely used for ceremonial purposes consistent with the significance of the Cruzmoqo for religious purposes.

The pre-Inca massive outer wall is shown where it overlooks the Rio Pukara. It was at this location that Ken Wright found the highest of the three canals, Canal No. 3.

Ancient petroglyphs that are 4,000 years old, or more, dot the summit area north of the Cruzmoqo. Carved spirals are common among early people. They attest to the fact that Tipon was known in ancient times due to its perennial spring.

The Cruzmoqo (arrow) is situated at the summit of the Tipon Mountain. It commands a wide view of all of Tipon and the valley beyond. A terrace wall connects the two summit rock outcrops. Note the huge volcanic rock slab in the lower right.



Who built the outer wall?

No one really knows who built the Tipon perimeter wall, a monumental accomplishment by prehistoric people. We know that the Inca did not build it, but who did?

In the summer of 2003, we requested archaeologist and Inca scholar Gordon McEwan and the distinguished Peruvian archaeologist Arminda Gibaja Ovieda of the Instituto Nacional de Cultura to inspect the wall, to judge its age, and to determine who built it. Dr. McEwan reported (Personal correspondence to Ken Wright, 2003) “there was a pre-Inca occupation of Tipon that future investigations may show extended back to Wari times, since there are architectural similarities in the wall construction.” He went on to say “the only way we will ever know Tipon’s true history is by excavating in the occupied areas of the site.” Dr. McEwan has excavated in the lower Cusco Valley within a few miles of Tipon for over two decades and continues to develop questions on the origin of the wall; it is clear that we do not have answers to Tipon’s mysteries.

Brian Bauer and Alan Covey (2002) studied the process of state formation in the Cusco Valley between 1000 and 1400 CE. Both are well experienced in Andean archaeology and have done much research in the Inca heartland.

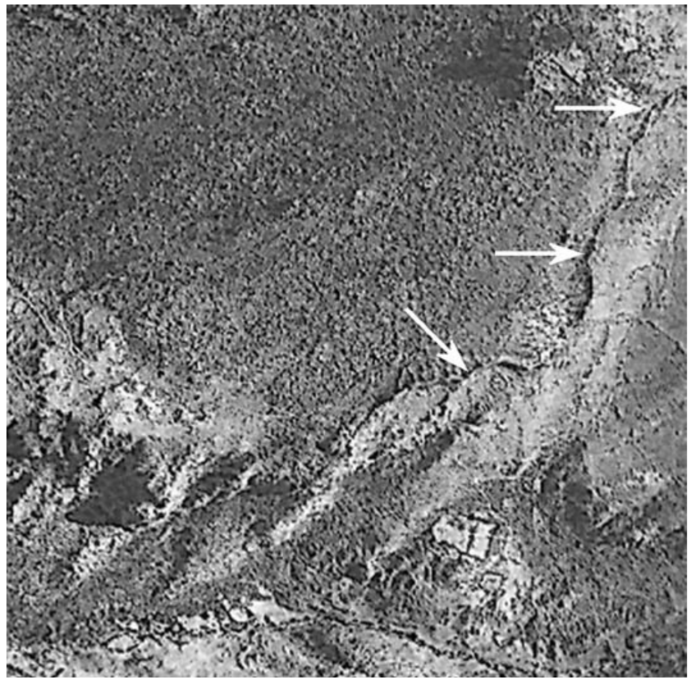
Bauer and Covey report that the Wari did not disrupt an existing network of villages along the southern side of the Cusco Valley close to good agricultural lands during the Wari settlement at Pikillacta between 600 and 1000 CE. This was in the valley below and just downstream of Tipon. They suggest that the site lay in a buffer zone. With the decline of the Wari at Pikillacta, the north slope of the valley was dramatically transformed with more population and irrigation works, but later it was depopulated, except for Tipon.

Finally, according to Bauer and Covey (2002), Tipon fell under the control of the Inca at Cusco through efforts of

This map of the summit of Tipon Mountain shows many special features: the outer wall, petroglyphs, Cruzmoqo, a bath-like carved stone, and features yet to be identified.

Joining the two rock outcrops of the Cruzmoqo is a terrace that provided a sizable flat area.

Adjacent to the Cruzmoqo is this finely carved basin that was likely used for ceremonial purposes, although some theorize that its low point would make ladling of collected rainwater easy.



Viracocha Inca, who transformed it into a royal estate. Therefore, based on their information, the wall was built after 1000 CE, after the Wari influence, and perhaps as late as 1200 CE.

Dr. McEwan disagrees with this interpretation however, pointing out that the notion of a depopulated buffer zone is contradicted by the presence of the ancient settlements beneath Oropesa and the large Late Intermediate Period site on the hilltop above the modern town of Pinagua, both squarely within the supposed depopulated zone. Furthermore there is evidence from the numerous Wari sites in the upper Cuzco valley that the Wari tightly controlled the entire region and were responsible for initiating the massive hydraulic infrastructure throughout the entire valley. Although the Spanish chronicles suggest that the first Inca to control the site of Tipon was Viracocha Inca, we cannot directly tie any particular construction at the site to this emperor. The best estimate for a date of construction, if in fact it was initiated by Viracocha Inca, would be sometime between 1380 and 1438 CE. This is based on the fact that Viracocha was the father of Pachacuti and was an old man when Pachacuti succeeded him in 1438 CE.

Dr. Alfredo Valencia asserts (Personal correspondence to Ken Wright, 2003) that evidence of Tipon settlements by the people using the Killke style (possibly the Ayarmacas) tie to an 1200 CE period, but that all the architecture and engineering at Tipon that we see today are of the Inca imperial period (Late Horizon of 1476 CE).

As for who built the massive Tipon perimeter wall, we have concluded that this question will linger, but it is pre-Inca, and its character tends to be Wari. Bauer and Valencia believe that the wall is Late Intermediate Period from about 1200 CE. We have agreed that the wall is a product of the Wari or Late Intermediate Period peoples, well before the Inca empire of about 1400 CE.

The massive outer wall, nearly 4 miles long, represented a remarkable construction effort for the early builders who preceded the Inca occupation by hundreds of years. Who built the wall is a question not yet answered.

The outer wall of Tipon (arrows) that one can partially follow up to the Cruzmoqo is shown in this aerial photograph.

With the outer wall in the background, this portion of the main canal leads from the Rio Pukara (behind the camera) to the wall where it entered the secure area of Tipon to irrigate plentiful agricultural terraces.

DESIGN STANDARDS

Somehow, over a 2,500-mile-long empire that stretched along the Andean spine, and without a written language for conveying specifications and orders from the center of power, Inca design standards were relatively uniform. The building construction details at Tipon demonstrate this consistent engineering that followed Imperial Inca standards. Even distant from the capital of Cusco, one can quickly recognize Inca public works.

Building groups, individual buildings, entrances, and niches at Tipon help tell a story of centralized authority. Building designs that are thousands of miles apart have been well documented by Inca scholars as to shape, style, and spacing. Thus, the strict Inca design standards are recognized even today, after 500 years.

The uniform batter of Inca walls helped to ensure stability. The placement of stone in a course to avoid planes of weakness also contributed to soundness and longevity, but the Inca investment in geotechnical site preparation and foundations was the most important reason why the public works construction has endured.

The Inca transportation system included paved trails, stone stairways, tunnels, retaining walls, and hanging bridges over rivers and gulches for which abutments still exist. Then, high above the trails, the Inca built storehouses for foodstuffs, so that a traveling military legion or the local people did not go hungry. The Tipon storehouse is a good example of how the Inca used agricultural production to help create loyalty among its population and diminish their uncertainty.

It is the uniformity and consistency of Inca-engineered construction that tells us much about the control of the central authority in Cusco, the capital and seat of power.

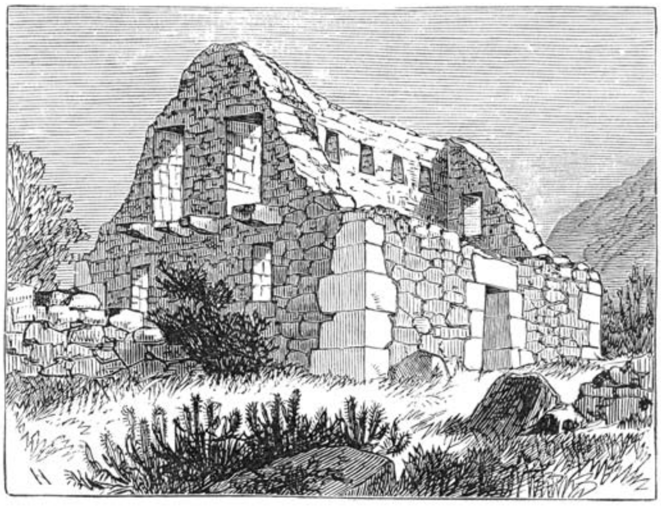
Chapter 10

Inca Design and Construction Technology

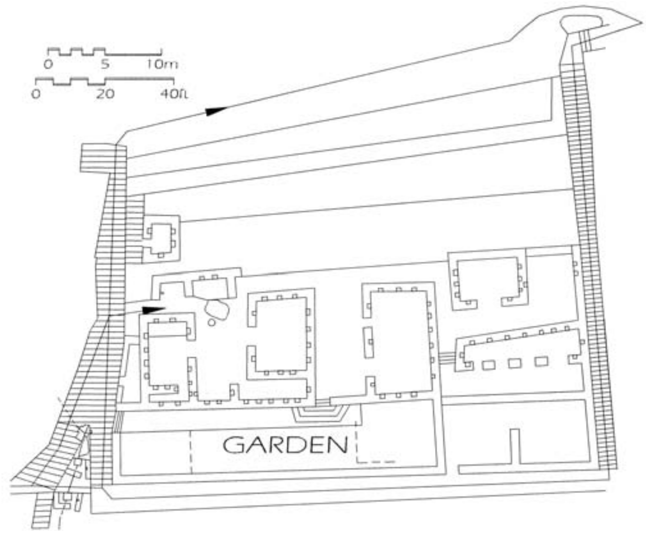
As the Inca empire expanded north and south along the Andes and from the Amazon lowlands to the Pacific Ocean, its legions of engineers followed the military to undertake massive construction programs. The Inca engineers had an abundant labor force available because the Inca were masters of corporate agriculture; people had been freed from subsistence farming, and taxes were often paid with labor. Their highway program, irrigation canals, and terracing of hillsides are most impressive from the standpoint of sheer construction volume. But their buildings, sensitive environmental design, and specialized hydraulic structures left a legacy of attention to detail. The Inca high standard of care now serves as an inspiration to the young people of Peru.

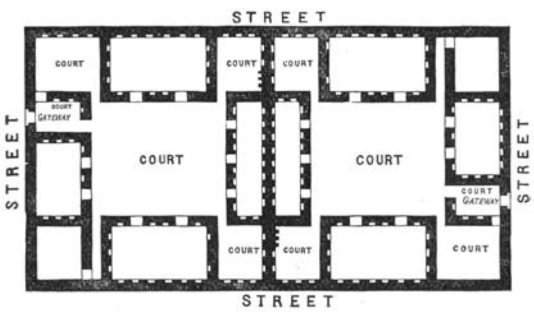
When it comes to Inca construction technology, architectural design, and the analysis of how the Inca achieved what they did, there are no better experts than Jean-Pierre Protzen and Vincent Lee, both of whom are scientific researchers and distinguished architects. Protzen is chairman of the School of Architecture at the University of California at Berkeley, while Lee has his office in Cortez, Colorado, and has done considerable exploration at many sites. Both have devoted time and energy to better understanding Inca construction technology. Their publications (Protzen 1993) (Lee 1988, 1999) are reliable resources for the engineer or casual observer with an interest in the building methods of the Inca. We have studied their publications when analyzing our engineering field data.

Pisac terraces, not far from Cusco, represent the form and function of classical Inca hillside stabilization. The Inca were good stewards of the soil.



INCA BUILDINGS, OLLANTAYTAMBO.





AN ANCIENT BLOCK IN OLLANTAYTAMBO.

In this chapter, you will get a small taste of the Inca design and construction technology that was brought to bear at Tipon and other sites where the engineers, architects, and craftsmen of the empire were employed. This technology was adopted from their predecessors and conquered peoples and then honed to perfection by the Inca. Archaeologists have labeled the construction technology and its final work products as imperial Inca. One can recognize Inca design throughout the empire because of its geometry and uniformity in design style.

Conjuntos

Peruvian archaeologists use the term *"conjunto"* to represent an enclosure of several buildings or even a specific area of terraces. At Tipon, the Intiwatana represents a good example of a *conjunto*. In Spanish, it means "as a whole, altogether, suite." The word is well suited to describe a grouping of buildings within a walled space as found all over the Inca Empire. Some *conjuntos* have only one entrance to better provide for security and limit access.

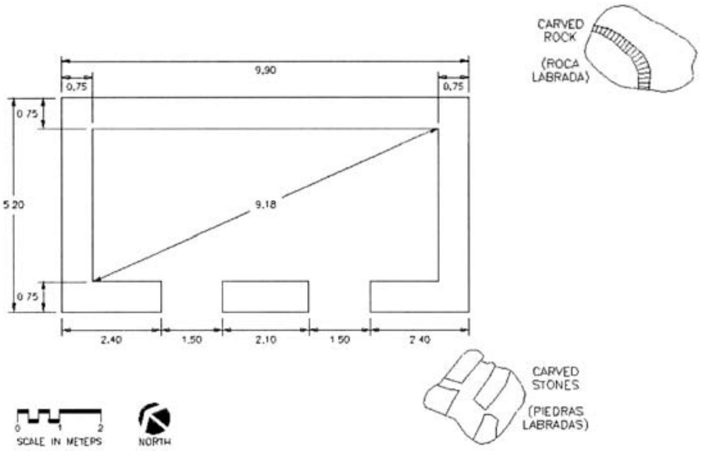
The Kancha Group (*conjunto*) at Tipon represents a typical cluster of three buildings that are laid out to complement one another. The buildings of a Kancha often face a common courtyard. Sometimes the Kancha is enclosed with a wall for privacy, though such a wall was not needed here at Tipon because of its placement on a limited access terrace.

The Tipon buildings are good examples of a classical Inca Kancha that represents geometric perfection in terms of mirror image buildings on the north and south with one larger building of the same basic design. It has a lone entrance facing out onto the courtyard, with a view of the central terraces. The nearby terrace wall contains a fine stairway leading into an area built for security personnel; the stairway does not lead directly into the courtyard.

A rural two-story building, as seen through Squier's eyes in 1862, contains many imperial Inca design components. It is at Ollantaytambo.

This *conjunto* represents classical Inca planning for privacy, security, and convenience for the Inca nobility.

This much-described *conjunto* in Ollantaytambo was first measured and mapped out by Squier during his 1862 travels.



DOOR-WAY TO CORRIDOR, OLLANTAYTAMBO.

To illustrate the common Inca design, a *kancha,* or walled compound, from Ollantaytambo (Squier 1877) is an excellent choice for comparison.

Buildings

Individual buildings usually have one or more entrances on the long side, with geometrically situated windows and niches, and often have wall pegs. Symmetry is a characteristic of Inca building design, along with the use of the trapezoid for the doors, windows, and niches. The building containing Room 11 at Tipon's Intiwatana is an example of Inca geometry.

Inca outside walls are typically constructed with a 5 to 6 degree batter for stability. Significant care is exercised on the foundations; the walls rest on a prepared surface, sometimes of small stones or rock, to provide suitable bearing.

A simple building in the agricultural field of Mandor Pampa along the Urubamba River represents ordinary small building construction. This building housed Melchor Arteaga, whom Hiram Bingham met the night before his discovery of Machu Picchu on July 24, 1911. Bingham described it as Arteaga's hut (Bingham 1913). Ken and Ruth Wright and Alfredo Valencia examined Arteaga's hut in 2000 during the archaeological exploration of the Inca Trail that led to the Urubamba River from Machu Picchu and learned that Arteaga's hut was actually an Inca building.

E. George Squier saw much of Peru in 1862 during his several months of travel (Squier 1877). His artist companion made sketches of what they encountered at the time that the United States was engaged in its Civil War.

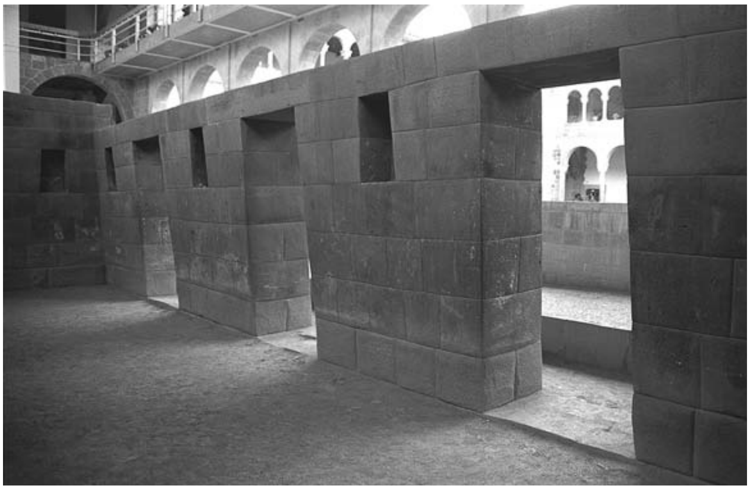
Doorways

Inca entrances are trapezoidal with a lintel beam spanning the top. A double-jamb doorway announces to a visitor that something very special lies beyond. Such entrances are seen in Tipon sites.

Hiram Bingham mentioned "Arteaga's hut" at Mandor Pampa. Actually, the hut was an ancient Inca building, likely for field workers. Bingham met Arteaga in 1911 at Mandor Pampa, and it was Arteaga who told Bingham about Machu Picchu. The next morning, Bingham rediscovered the Lost City of the Inca.

In 1862, Squier noted this trapezoidal door leading into Ollantaytambo and the series of niches on the left side of the road.

Double-jamb doorways are a trademark of the Inca. Such doorways signaled that something very important was on the other side.



An important entrance often has a means for closing. The inside would have bar holds on each side and a stone ring over the doorway. We still do not know for sure how the Inca used the appurtenances.

Entrances were important components of a building. The Tipon entrances of the Kancha group (or Inca Kancha) follow the typical standard of Imperial Inca design.

Windows and niches

At Tipon, as elsewhere, the Inca used windows and niches in an exquisite manner; the geometrical perfection adequately conveyed the sense that here was a civilization based on order, pattern, and an appreciation of aesthetics. The windows and niches echo the trapezoidal shape of the doorways.

Wall pegs

There was no use of wooden shelves or cabinets at Tipon (Lee 1988). To keep things off the floor and a room orderly, items were hung on wall pegs. Wall pegs evolved into an Inca architectural feature so that even in special rooms that were for purposes other than living, wall pegs were installed in a geometric fashion.

Roofs

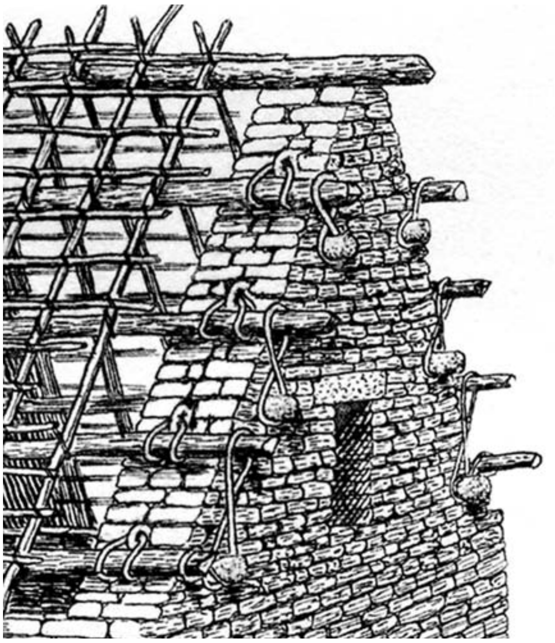
A lot needs to be learned about Inca roof construction at Tipon; the study of Inca roof structures is an evolving one. Widespread clues were left by the Inca civil engineers, and the interpretation of roof structures has tantalized many investigators.

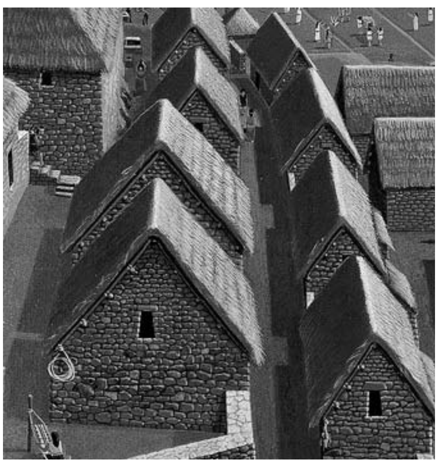
We now know that the roof thatch was thick, at about 3 feet, and heavy. Had early investigators known the weight to be supported, their theories would have been more appropriate. Vincent Lee studied roof structures based on load calculations and use of widespread evidence. It was Lee's theory that was used for the *National Geographic Magazine* portrayal of Machu Picchu in May 2002, though the timbers used would have been thicker.

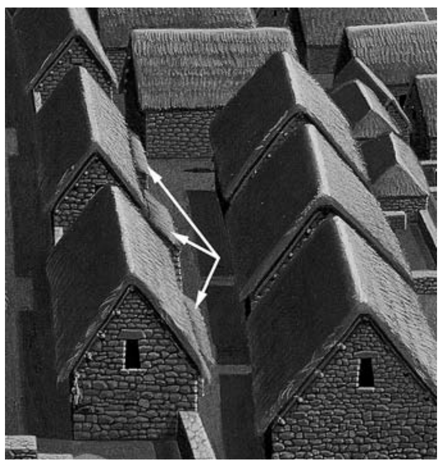
The studies of Ken Wright, Dr. Alfredo Valencia, and Ruth Wright have shown five types of roofs in use by the Inca: gable, hip, shed, wayrona, and conical.

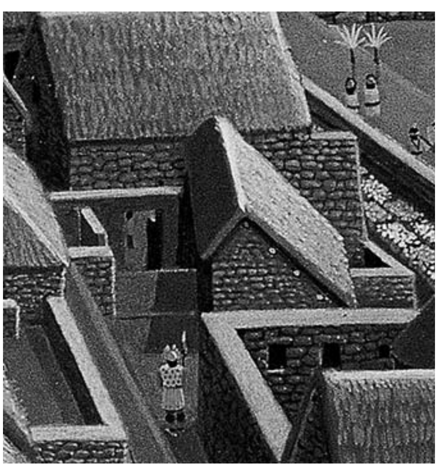
Nowhere in the Andes can Inca dedication to geometric proportions and careful stonework be better illustrated than at the Coricancha in Cusco. One might think that he/she is looking at an Egyptian temple.

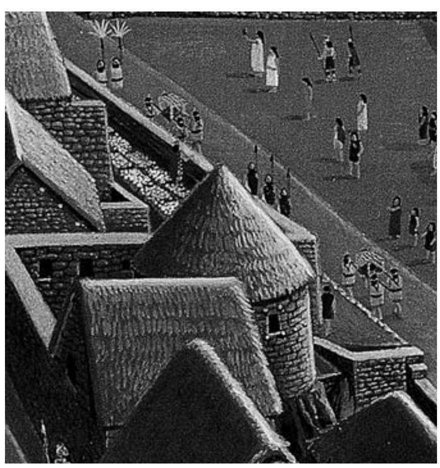
Wall pegs in this building are special; the stones for these pegs were brought from far away. Note the former niche that was stoned-in as a result of an Inca design change when the right wall was moved several feet as evidenced by a former foundation on the outside.

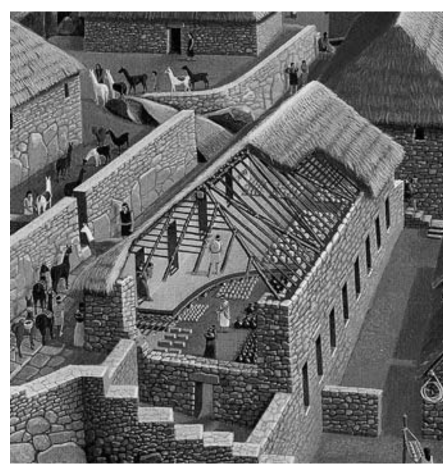












Modern investigators such as Vincent Lee have superseded the Hiram Bingham 1912 theory of Inca roof construction.

Inca gable roof structures were covered with thatch.

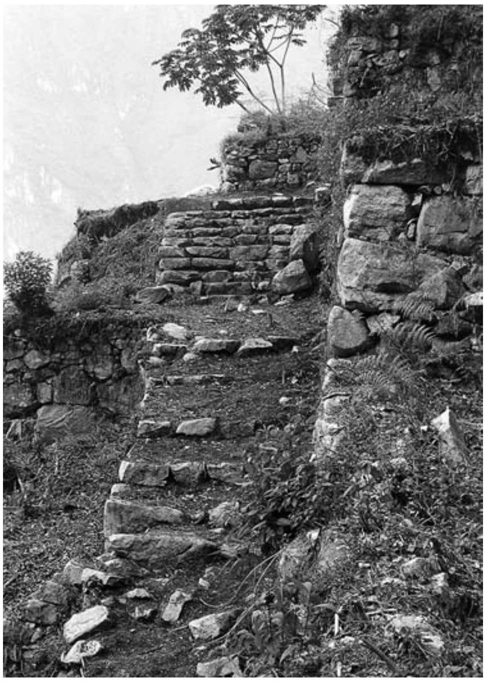
The wayrona roof was ideally suited for a three-sided building.

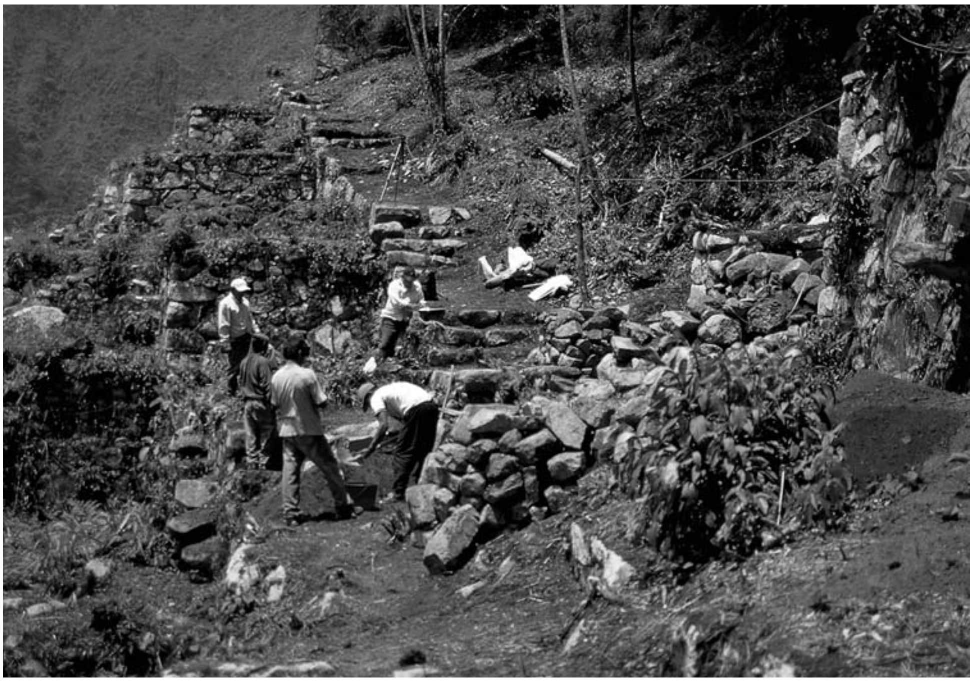
Shed roofs were used occasionally for special purposes.

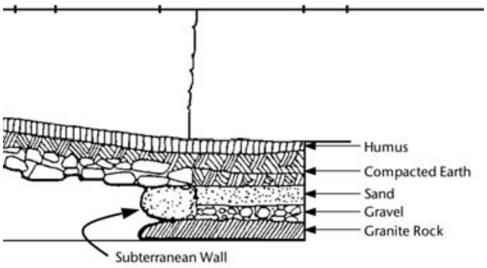
Conical roofs were used on circular structures such as this temple, but also for small temporary workmen's living enclosures.

An Inca gable with pegs and eye bonders provides tantalizing hints for architects and structural engineers who still opine about the Inca design techniques used to support 3-foot-thick thatched roofs.

A four-sided Inca roof is known as a hip roof. Quadripods were used to help support the heavy thatch.







These Inca Trail stairways are solid, uniform, and as much as 9 feet wide.

Archaeological exploration and excavations on the Inca Trail helped define the extent to which Inca engineers went to ensure slope stability for their important roadways. Stairways of the trail are shown leading up the slope to the rear.

Inca foundation construction was carefully prepared using granite rock, gravel, sand, and compacted earth.

The tantalizing clues to Inca roof design consist of roof pegs and eye bonders incorporated into the gables that still exist all over Peru. Architects are still pondering how the Inca supported thatch that was 3 feet thick.

Foundations

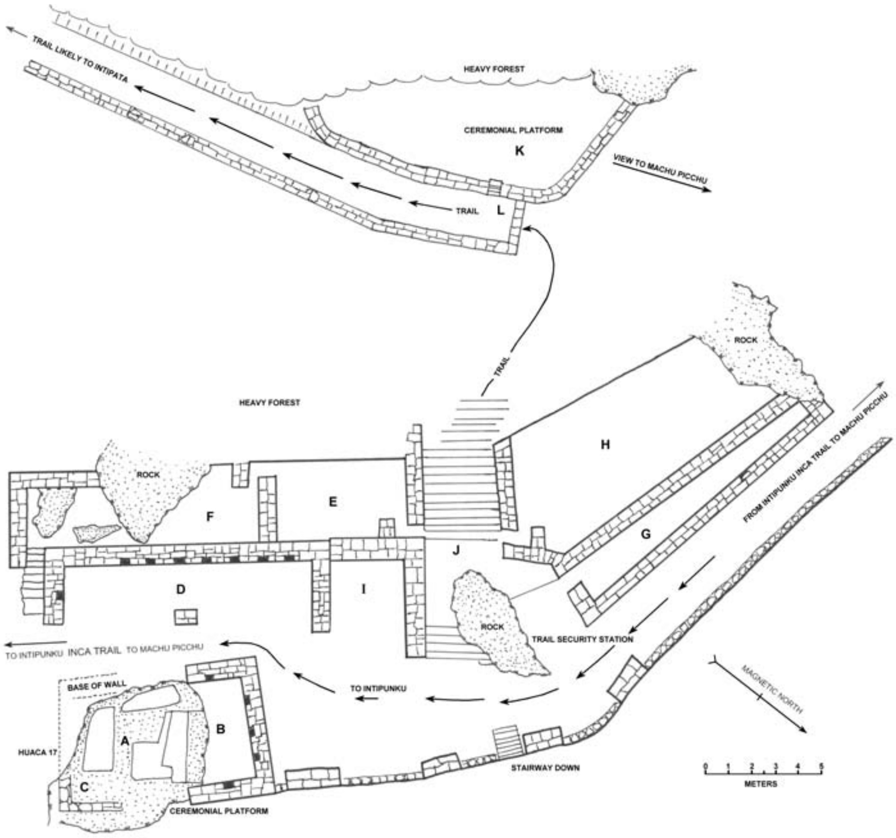
The Inca knew about the importance of good site preparation and foundations. As a result, much of the work on terraces, buildings, and hydraulic structures was focused on the underground preparation. It is for this reason that so much of the prehistoric construction has endured to modern times, such as the Tipon Central Terraces. While documented cases of Inca foundation failures exist, they are the exception. Archaeologists are especially interested in foundations because their form can tell a lot about the people's standard of care.

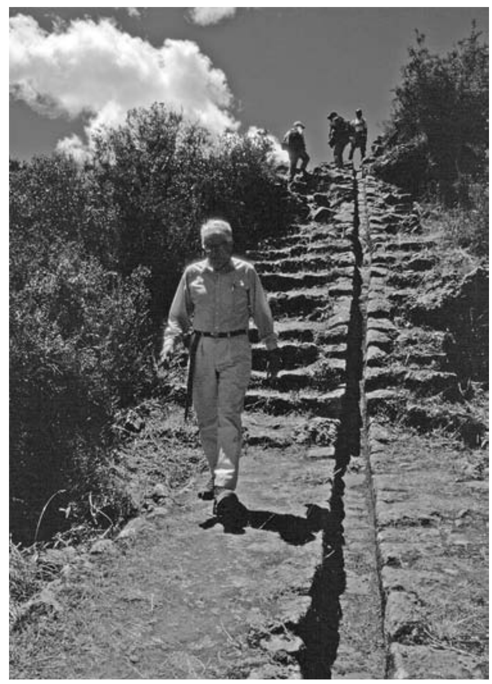
Inca trails

A good example of the design and construction of an important Inca trail is on the east flank of Machu Picchu that we and our colleagues cleared and excavated in 1999 (Wright and others 2000b). The trail lay under forest litter and an accumulation of earth for some 450 years.

Remains of original classical Inca trails at Tipon are few and far between because of the continuous use of the site by the local people following the collapse of the empire. An important Inca trail at Tipon was incorporated into the canal construction.

Examples of Inca trails show care, preparation, and attention to detail so a runner could speed from location to location, the military could move at will, and llama caravans could move goods.





The Inca trails contained security control points so travel could be limited and control of movement exercised. There were several at Tipon. To further exercise control of the road network, there were security lookout points.

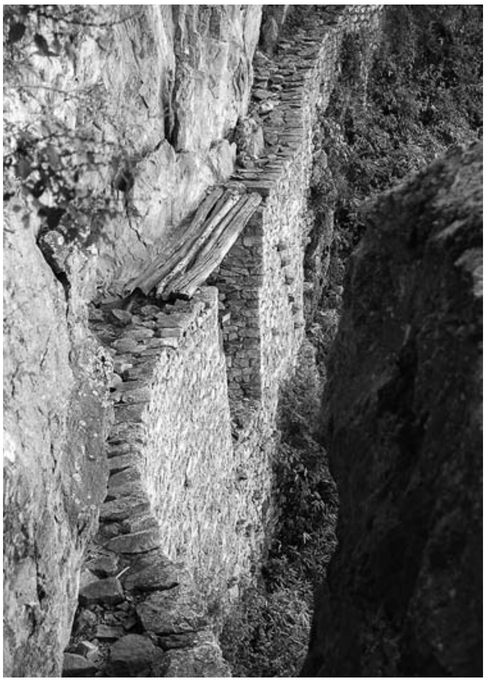
Retractable bridges provided additional security. For these bridges, a gap was created, with timbers spanning the opening when passage was permitted. With the timbers removed, there could be no passage.

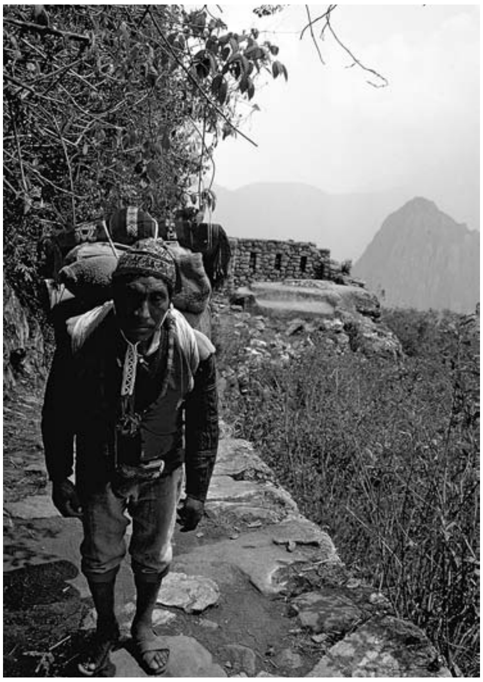
Security along the Inca roadways was tight. Checkpoints along the trails housed military personnel. This station along an Inca Trail has elaborate structures, including a ceremonial or viewing platform. The platform was excavated in 2004 as part of ongoing research.

This long segment of a Tipon trail leads to the Intiwatana from Pukara.

Ken Wright is shown walking on a Tipon trail that parallels the main canal. Note the twin staircase in the background with fellow research team members.

A spectacular lookout point high up on a mountain provided a wide view of the entire valley.





This view of an Inca drawbridge shows the careful construction that went into the structure, even to the extent of providing outside flying stairs for maintenance purposes. Roadways received the highest attention of Inca civil engineers.

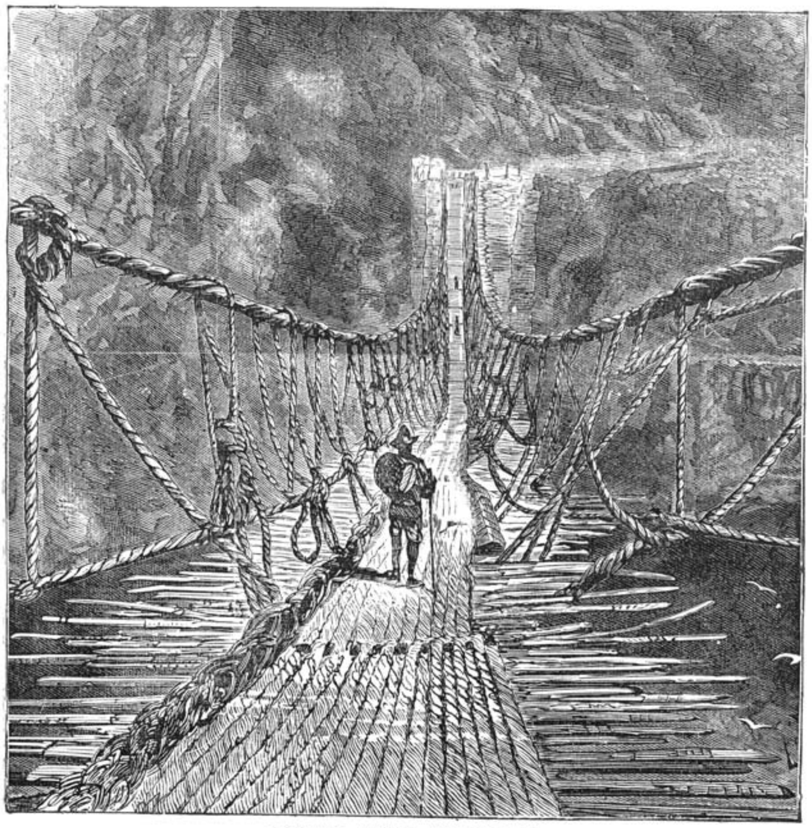
Seeking clues to Inca wall technology, stonemason Bruce Davis examined the high and sturdy terrace walls of Tipon. He found them to be of massive width to provide adequate resistance to the earth's pressure.

Inca trails are now used by tourist porters to carry heavy loads by foot. The Inca trails were usually paved.

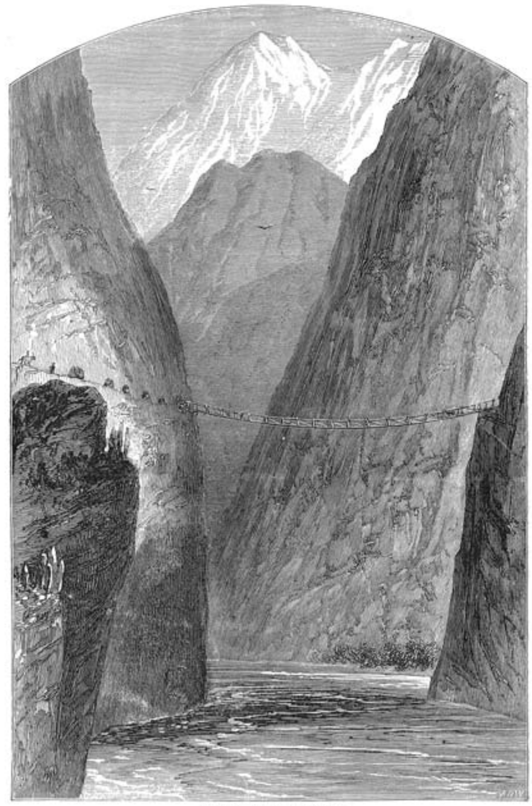
Inca bridges

The Inca bridges across streams and rivers still baffle modern structural engineers. Felipe Huamán Poma was an Inca noble in the early seventeenth century. A letter he sent to the King of Spain included a sketch of a bridge (Huamán 1978). Similar bridges were viewed by Squier in 1862 (Squier 1877). In fact, in remote areas of the Andes, people of the Quechua Indian villages completed a hanging bridge across a ravine or canyon with a deep rushing river in three to four days using spun local grasses to form the cables. Squier's work in 1862 resulted in good documentation of several bridges that reflect such Inca technology.

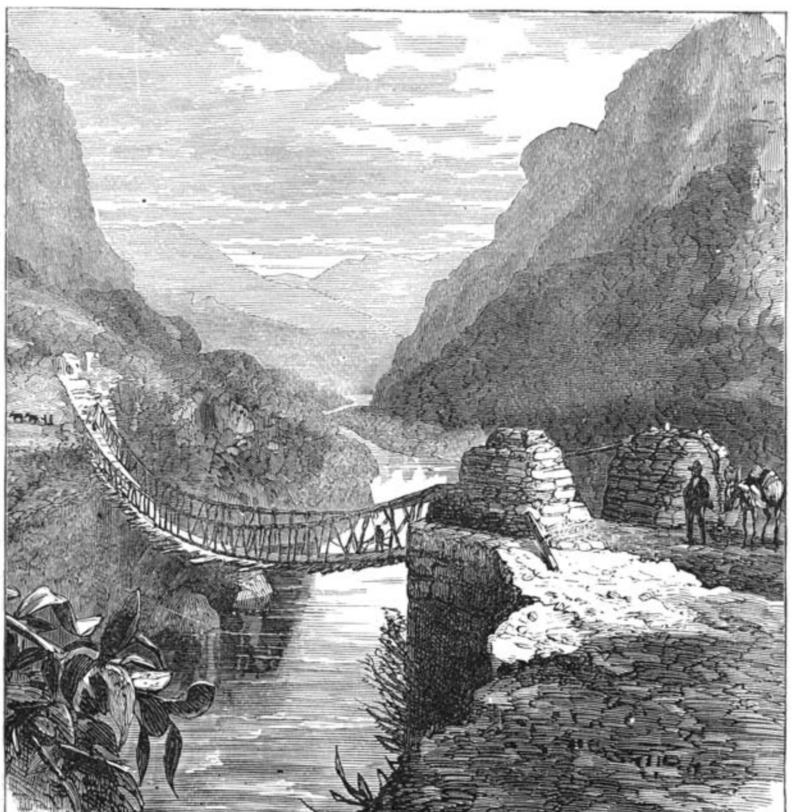
Inca bridges used spun grass cables that no longer exist, but abutments are plentiful even though subjected to floods. We were faced with the field evidence problem in 2000 when we reached the base of the Machu Picchu east flank Inca trail at the Urubamba River. Our team of archaeologists, civil engineers, and Quechua Indian macheteros spent a half day searching for the evidence of a river crossing in the neighborhood of the trail landing area and found none, even though good evidence existed for the landing itself. The stairway to the landing and the river walls were still in good condition. Farther down river, huge boulders, up to 15 feet in size at a rushing cascade, told us where the bridge might have been. Nevertheless, we found no evidence of a bridge. We reached the conclusion that either a great flood washed out the original structures or that the trail continued along the left bank to another location downstream that we were unable to locate. The bridge is a matter for future exploration.



LOOKING ACROSS THE BRIDGE.



BRIDGE OF THE APURIMAC.

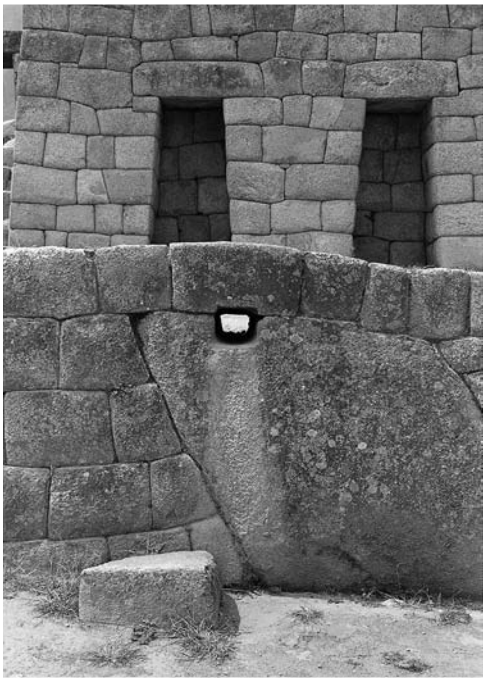


HANGING BRIDGE OVER THE RIO PAMPAS.

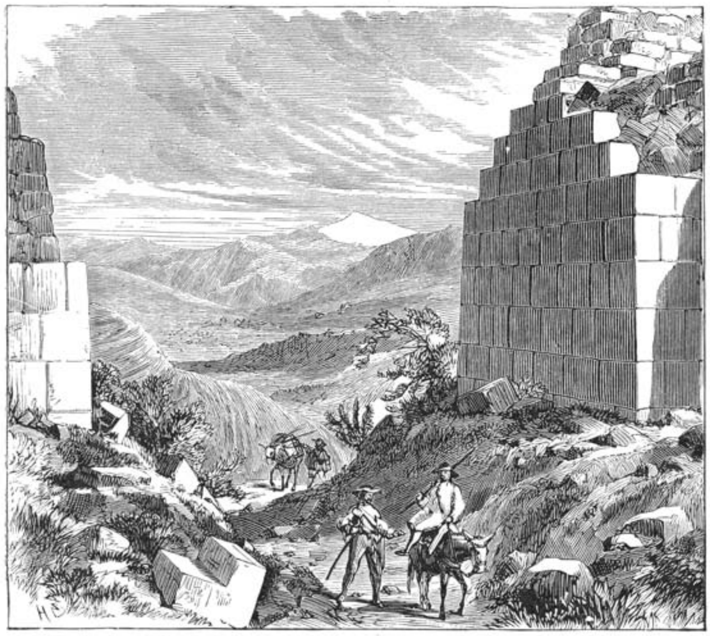
In 1862, Squier documented this then-modern bridge supported by local grass-woven cable. It was built at an ancient Inca crossing using the original abutments.

Squier sketched a high bridge crossing in 1862. It represents Inca bridge technology of the fifteenth and sixteenth centuries.

A hanging bridge in 1862 over the Rio Pampas used the ancient Inca stone abutments. The spun-grass cables were relied upon for their strength.



Urban drainage was a high priority for Inca civil engineers, as illustrated by this drainage outlet carved into the huge boulder.



Aqueduct technology did not originate with the Inca. The Rumicolca aqueduct near Tipon, as it appeared in 1862, was built some 800 years prior to the Inca empire. The evenly shaped blocks may be of Intermediate Period or Inca origin when they used the aqueduct as a gateway to the lower Cusco valley.

TABLE 10-1. Example of Inca Urban Surface Runoff Criteria for Wall Drainage Outlets

Primary	Magnitude
Tributary area per drainage outlet	2,200 square feet
Drainage outlet size, typical	4 inches by 5 inches
Drainage outlet capacity, maximum	0.4 cubic foot per second
Design rainfall intensity	8 inches per hour
Rational formula runoff "C"	0.8
Design flow per drainage outlet	0.3 cubic foot per second

Terrace walls

The high-status terrace walls of Tipon were analyzed by Bruce Davis, an experienced rock contractor from Brighton, Colorado. Fortunately, he was on site in Tipon while wall restoration work was underway by the Instituto Nacional de Cultura and was able to observe and document the original Inca terrace wall cross section and construction used at Tipon.

The Tipon terrace walls are unique and received extra care. Terrace walls elsewhere were simpler in construction even though they, too, showed remarkable resilience from the deteriorating forces of nature and climate. Terrace walls are battered at about 10 percent to provide stability and longevity.

Drainage

We can thank the site preparation and drainage work of the Inca for the fact that so much of their work has endured into the twenty-first century. The Inca surface and subsurface drainage works were extensive and effective. They used empirical relationships between area and runoff to locate and size drainage outlets in their walls. For instance, we found that the parameters for surface drainage at one site were reliable and reasonable, as shown in Table 10-1 (Wright and Valencia 2000a).

At Tipon, the fact that the Central Terraces have remained whole, while being in a defined ravine, is a testament to the effective Inca handling of surface and subsurface runoff.

Canals

Inca canals include a wide variety of construction techniques and cross sections to suit specific locations and needs. Even for the same canal, there are changes in cross sections from reach

to reach. For instance, the Tipon main canal ranges from earth-lined to stone-lined, from carved stone sections to the canal being combined with a trail. Hydraulically, the canal velocities range from subcritical to supercritical flow.

As a result of the wide variety of canal characteristics, even at one site, it can be concluded that the Imperial Inca centralized design control did not extend to canals. On the other hand, the Inca standards were likely related to the duty of water in terms of rate and volume of irrigation water for a unit of land, hydraulic jumps, suitable canal slopes, and empirical relationships between roughness, cross section, and slope. Certainly, standards controlled many of the fountains inspected.

One thing we know from the evidence is that the Inca were master water engineers. Perhaps the central authority felt it best to permit old-fashioned site-specific field know-how to prevail when it came to transporting water.

Aqueducts

Nothing captures the imagination of a civil engineer like an ancient aqueduct. The Inca used aqueducts for their canals to cross ravines. They had plenty of technology to draw upon. For instance, within a few miles of Tipon, there was the aqueduct at Chokepukio that we studied in 2000 while consulting for archaeologist Dr. Gordon McEwan on the local water supply source.

Also near Tipon is the imposing Rumicolca Aqueduct that was built by the Wari, likely about the seventh century. Their structure was erroneously identified by Squier (1877) and Bingham (1913) as a gate or portal to the lower Cusco Valley. Even as late as 1996, archaeologists and guidebook authors described it as a gateway and portal used by the Inca. Dr. Alfredo Valencia, during his doctoral dissertation studies, judged it to be an aqueduct,

The Tipon aqueduct is similar to many Andean crossings of gullies. Here, the pedestrian underpass is visible at the center. To the left is the Ceremonial Plaza that contains the remains of a fountain supplied by water from the canal on the aqueduct.

A clay model on display at the Cusco Museum in the Admiral's Palace indicates the type of models that would be used by the Inca designers to convey their concepts to the field.

The *quipu* was a tool that Inca designers could use to transmit building instructions to the construction workers. Knots would define geometric proportions and measurements. A *yupanas* (lower left) with small pebbles may also have been used for design purposes.

but his views resulted in extended controversy. Level surveys by team member William Lorah and further surveys and detailed fieldwork by Ken Wright, Alfredo Valencia Zegarra, and Ruth Wright showed that the prehistoric canal tied in perfectly with the aqueduct and that the canal then led into the well-known Wari administrative center of Pikillacta (Valencia 1997). While there is evidence that the Inca modified the structure, it was, indeed, originally an aqueduct, not a gateway, and Valencia was fully vindicated after his hydraulic hypothesis was proven with detailed level surveys.

Transporting and lifting rocks

The careful analyses of architects Jean-Pierre Protzen (1993) and Vincent Lee (1999) of ancient quarries and stone transporting routes provide insight into the transportation of large stones. Our studies at Tipon showed that while plentiful andesite rock was conveniently located, movement and placement of the quarried stones required great effort and good technology. My observations of how modern Quechua Indians moved stones while participating in archaeological excavations showed their wise use of wooden poles, both as levers and as inclined planes. A single Quechua Indian raised and moved stones ranging from 220 to 330 pounds, with nothing more than a wooden pole serving as a lever and alternately as an inclined plane.

The Inca workmen used slides to move large rocks downhill and inclined planes for transporting rocks uphill. To raise a large stone in elevation at a wall, they may also have employed a "teetering" process, using levers, and placing timbers and rocks underneath. Transporting large rocks required manpower and perhaps ropes. On the other hand, Lee (1999) surmises that log runners and sleds were also used. The movement of the stones resulted from multiple levers being applied in unison. How they moved and placed the massive stones like at Sacsayhuaman is still a mystery and the subject of conjecture.

Design and construction plans

We all know that the Inca engineers were careful planners and meticulous builders and that they had a design basis that was geometrical and orderly; this is known because the evidence in Peru is everywhere. Even a casual visitor to Tipon can instantly recognize imperial Inca architecture.

How did the Inca communicate their designs over the empire? With no written language, without a metric or English unit measuring stick, and likely without two-dimensional plans, the Inca achieved a building process that makes admirers out of even the most jaded of modern design and construction professionals.

Fortunately, scholar Vincent Lee of Cortez, Colorado, has studied Inca design; he concluded that they designed by the numbers (Lee 1996) and used clay models and *quipus* to convey the design to the field.

We know that the Inca had clay and stone models because some of them still exist and can be seen at the Cusco Archaeological Museum. There is no evidence of drawings; lines drawn on the soil surface may have been the limit of two-dimensional portrayals of a design. Units of Inca measure were likely body parts such as the foot, the arm, a long step, or a hand width.

Something that we do know about is the *quipu* (a fringe of ropes to which knots were added or removed), some 300 of which survived Spanish destruction. *Quipus* could have been used for communicating designs in terms of geometric proportions. Finally, according to Lee (1996), *yupanas* were used for calculating, using small pebbles. These might have been the methods of design control utilized at Tipon.

Stones of adoration

Huacas are religious symbols that come in many forms. Natural *huacas* can be rivers and special mountains. The man-made *huacas* are often carved stones or shaped in situ outcropped rocks, such as the centerpiece of the Tipon Intiwatana. A favorite that was excavated by Valencia in 1969 is the Sacred Rock at Machu Picchu that is still used for religious services by local Peruvians, as well as by some modern visiting tourists.

Tourists sometimes feel that they gain spiritual benefits from this carved image rock though the Inca likely did not use the stone in this manner. Nevertheless, modern local people gather here on Christian religious holidays.

Geometric perfection

Little needs to be said about the prehistoric geometric perfection of the Inca designs and construction; diagrams and photos say it all.

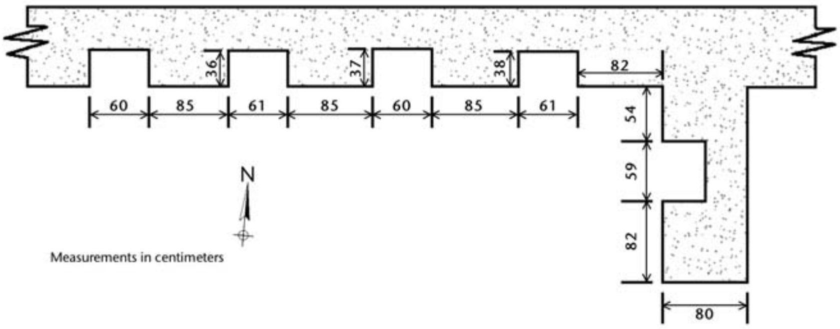
Let us examine a *kancha* at Pisac, the Coricancha in Cusco, and the Intiwatana *conjunto* at Tipon.

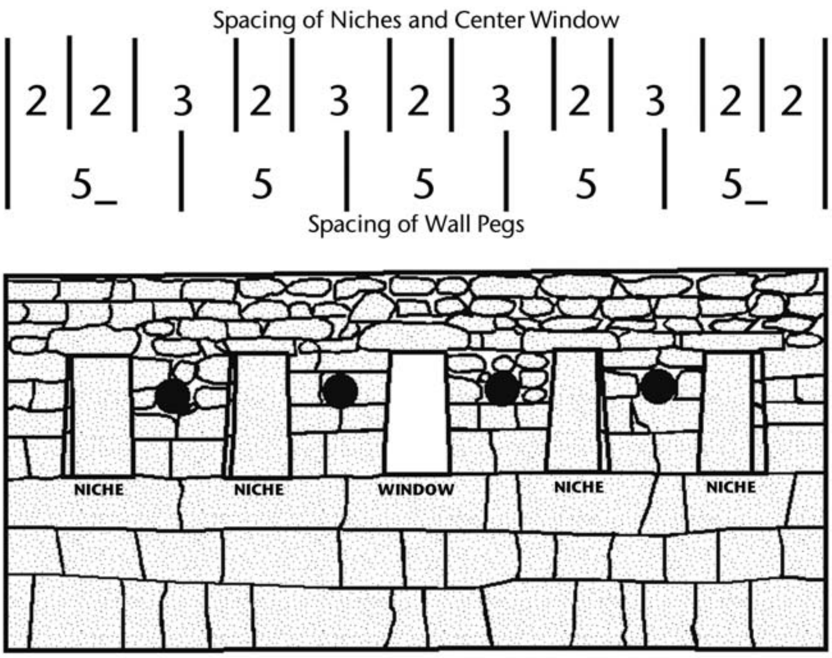
The typical geometric proportions, with spacing numbers ranging from 1, 2, 3, or more, are typical. As for a layout with geometric proportions, one can appreciate the historic drawing made by Squier (1877). The publication *Inca Architecture* by Gasparini and Marolies (1980) that was brilliantly translated by Patricia Lyon contains an early discussion of Inca design. The Inca used a decimal system calculated on their *quipus* (Lee 1996).

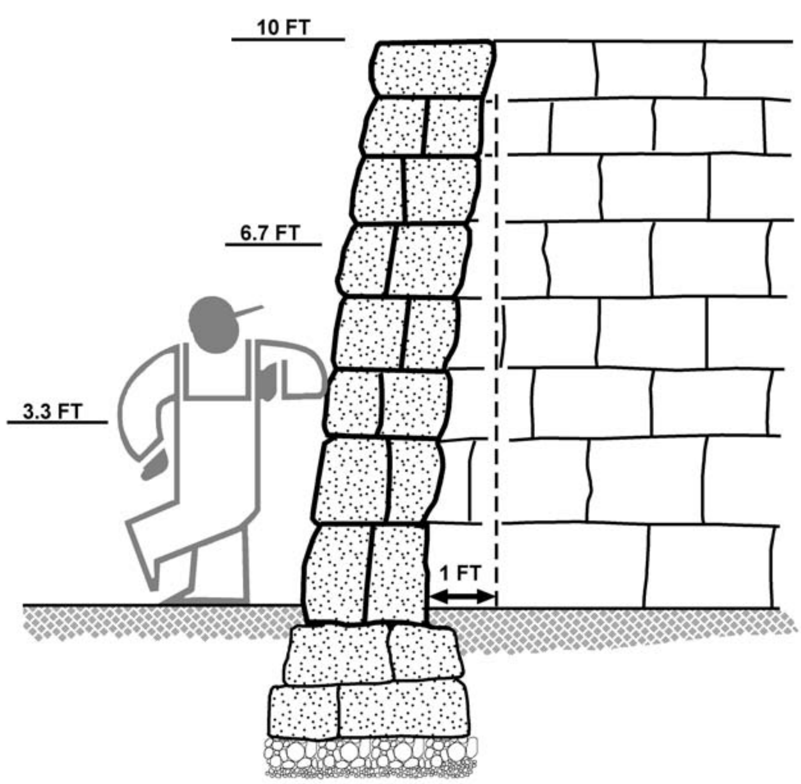
Summary

To fully appreciate the order, society, and achievements of the Inca, one must understand Inca design and construction technology, for otherwise, only a part of their culture is apparent. For a pre-Columbian civilization to have established such a high standard for their public works design and construction required organization, control, good communication, and a plentiful supply of skilled workers. The latter could have been achieved only through agricultural genius that freed people from subsistence farming to fill the needed legions of skilled craftsmen and laborers. Then, technology transfer and training was utilized to span thousands of miles and many generations.

Geometric perfection and order of the Inca builders is illustrated by this building at Pisac in the Sacred Valley.







The Tipon Intiwatana complex contains walls showing niches that are designed according to specific geometry, consistent with the Inca spacing rules.

Spacing by the numbers to create a form that expresses orderliness was a basic rule of Inca building designers. Here, the uniformity of spacing follows a prescribed pattern that could be conveyed to the field using a *quipu*. The units likely had been the length of the engineer's forearm.

The Inca building design batter of stone walls is at a 10 percent slope, an angle of 5 to 6 degrees from the vertical.

A LONG AND RICH HERITAGE

In creating the greatest of pre-Columbian empires, the Inca wove together the disparate elements of many Andean cultures using military might, statecraft, and ideology. They drew upon thousands of years of rich cultural inheritance from up and down the Pacific coast. The Inca borrowed the best ideas and methods from their conquered people. They were adept at technology transfer and its adaptation as their own.

The true secret of the Inca empire's success is corporate agriculture, for without food enough to feed ten million subjects and the ability to store it to overcome the potential of bad harvests, they would not have been able to staff their military or to build their public works. The Inca started early with good agricultural knowledge gleaned from past civilizations and conquered tribes; upon this, they applied organizational skills of the first order. Weaving, metallurgy, ceramics, and stonework were major attributes of the Inca that were developed by earlier Andean civilizations and then improved upon while being given an imperial Inca stamp.

Chapter 11

The Inca Heritage

Gordon F. McEwan

The unique Moray irrigated terraces of the Sacred Valley represent the advanced character of the Inca engineering surveying. Note the perfect circles deep into the ground.

The cultural and technical heritage of the Incas is rich and varied. The Inca empire did not develop in a vacuum, but from a long line of preceding empires and kingdoms that were populated by talented and industrious people. From these ancestors the Incas inherited highly developed agriculture, statecraft and social engineering techniques, and construction technology. Most importantly the agricultural base inherited by the Incas enabled them to produce sufficient surpluses that they were ensured against famines and were able to free up the manpower needed to undertake enormous military and public works projects without harming the economy of the empire.

This chapter outlines the 4,000-year-long heritage upon which the Inca were able to capitalize.

Ancient Peru

In the popular imagination the concept of ancient Peru often consists of images of lost cities, gold, Incas, and Spanish conquistadors. But these images suggest only a small part of the rich history of the Peruvian Andes where many complex societies rose and fell over the course of thousands of years. Of these many societies, only a few are known to us today. The peoples that the Spaniards encountered in the sixteenth century are known from fragmentary written descriptions and chronicles. Other earlier cultures have only recently come to light through archaeological studies. Unlike the pre-Columbian Mesoamericans, the ancient peoples of the Peruvian Andes lacked a system of writing, so that

no preconquest native accounts of their history or literature exist. Nevertheless, the products of these civilizations, their magnificent works of art, textiles, architecture, temples and cities, agricultural terraces and irrigation works, and sometimes the people themselves in the form of bones and mummified remains, have survived to provide a wealth of information. Through study of these varied remains, archaeologists and art historians can reconstruct the prehistory of Andean South America.

The unique cultures of the Andean area were shaped in large part by the rigorous environment to which humans had to adapt. Isolation from the developments in the rest of the world also played a role in forcing the native peoples of the Americas to find their own solutions and adaptations to the problems of human societies.

Andean culture

The population of the Andes was in ancient times and is today composed of many different ethnic groups. These peoples originally spoke their own languages and had their own distinct cultural practices. The Spanish conquest had a homogenizing effect in that much of the linguistic diversity disappeared. Most of the population of the Andes now speaks one or more of only three languages: Quechua, Aymara, or Spanish. While even today there is much ethnic diversity, certain commonalities bind these people into an Andean culture. Much of this Andean culture is shaped by the universal basic subsistence activities of farming, fishing, and herding. The difficulty of farming the steep Andean slopes and desert river valleys made cooperative efforts essential. With no draft animals, plowing had to be done by hand. A group of farmers each digging one furrow could plow a field much more efficiently than a single farmer. In areas where irrigation was

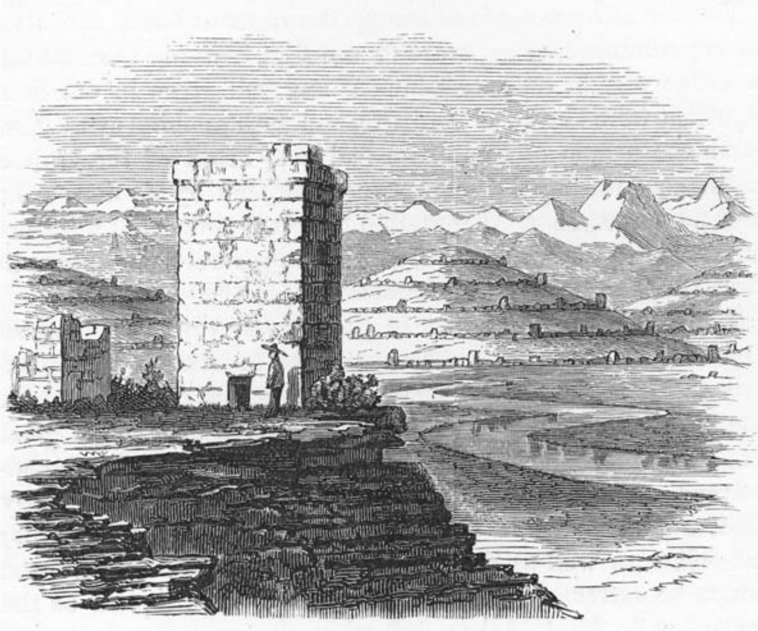
The alpine environment of the Andean mountains provided a challenge to the Inca, yet the varied surroundings offered a wealth of opportunities.

required, construction and maintenance of canals could be carried out only by large groups cooperating and coordinating their labor. The reciprocal obligation to help neighbors or kinsmen with their labors in return for their help became a key feature of Andean society.

Communal holding of land and its surplus was also an important feature of many Andean societies. In Inca times surplus food was stored in warehouses by the state for insurance against times of want. In times of famine this food was redistributed to those in need. On a community level, widows, orphans, the sick, and people too old for work were taken care of by the surpluses of their kin groups or had their lands worked for them. The storage and redistribution of surpluses, together with farming strategies involving the use of multiple different econiches, were the main means by which the Andean population could cope with the unpredictability of their environment.

The religious beliefs of the Andean societies reflected a deep concern with ensuring fertility and water, as well as warding off disease. Inca religion recognized two distinct categories of supernaturals. The pantheon of gods included deities such as Inti the sun, Pachamama the earth mother, Illapa the god of thunder, Mama Cocha the sea goddess, and Mama Qilla the moon goddess. These deities were directly related to the necessities of agriculture, fishing, and cyclic activities of life. The Inca maintained a hierarchically organized priesthood to serve the temples and shrines of the gods. An elaborate ritual calendar was observed, and religious considerations governed most aspects of life. A separate category of supernaturals was animistic spirits called *huacas* that inhabited everything in nature. They could be found in mountain peaks, unusual natural phenomena, odd-shaped stone outcrops, stone idols, and mummies. *Huacas* were honored

Agricultural terraces provided additional farming land, while at the same time stabilizing steep hillsides.



AYMARÁ CHULPA, OR BURIAL-TOWER, AND HILL FORT, AT ESCOMA.

with shrines and offerings. Great care was taken of them since an angered *huaca* could cause drought, famine, or other disaster.

Although knowledge of pre-Inca religious beliefs is very limited, archaeological and iconographical studies suggest that the basic concerns with fertility and the agricultural cycle are very ancient. Certain animal images—jaguars and pumas, caymans, and raptorial birds—are believed to have been associated with water, fertility, and the supernatural. These images continuously reoccur through time in the religious art and temples of the ancient Andes.

Treatment of the dead in Andean societies varied through time and between cultures. Archaeological evidence indicates that most ancient Andean peoples believed in an afterlife. Bodies were typically buried with grave offerings of ceramic vessels—sometimes containing food, clothing, ornaments, and other items used in life. High ranking, wealthy individuals had more and better quality objects included in their graves. It is not uncommon to find mummies wrapped in many layers of well-preserved fine textiles. The arid desert coast of Peru preserved the contents of many of these tombs in near perfect condition.

In Andean society at the time of the Spanish conquest, the dead were considered to have considerable influence over events affecting the living. The mummies of the dead Inca emperors were never buried but continued to preside over their households and property as if still alive. Dressed, fed, and entertained, these corpses continued to function in society as if they had suffered only a slight change in status. They were considered to be powerful *huacas,* and their advice was sought on matters of importance. How far back into the past this practice was observed is unknown, but the rich furnishings of many of the well preserved coastal tombs indicates that the dead were highly regarded and well cared for even in ancient times.

The Aymara people of the Inca empire were descendants of great builders and provided important resources. This burial tower illustrates their building acumen.

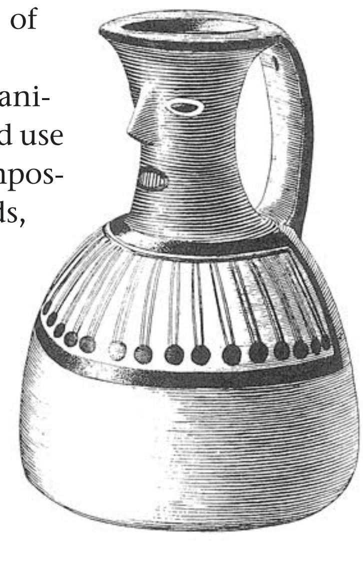
Andean technology

One of the most distinctive aspects of Andean culture is the esteem in which cloth was held. Finely woven textiles were prized above all else. Cloth was important to Andean peoples because of the vast amount and varied types of labor involved in its production. Fine textiles were a symbol of wealth and prestige. Rulers rewarded deserving members of society with grants of fine cloth. Wealthy and important people took their finest clothing into the grave wrapped in large mummy bundles. The extreme value invested in textiles is characteristic of Andean culture.

Complex societies evolved in the Andes without the knowledge of a well-developed writing system. Instead, records and accounts, history, and literature were recorded and remembered through use of a unique mnemonic device, a type of memory aid, called a *quipu*. Consisting of knotted strings and cords of various colors, joined together in a particular order, a *quipu* allowed its maker to remember and record a large body of complex information. Typically, Inca *quipus* held statistical records of production, storage, and redistribution, as well as census data. Historical information, such as the succession of rulers or famous events, could also be stored on a *quipu*. The limitation of this device was that only its maker could interpret it. Quantities were indicated by use of varying types of knots. Additional meaning was relayed through the position of the knot on the cord and through the color of the cord.

Other technological innovations in the Andes were governed by the raw materials and resources found in the natural environment. The manufacture of hard metals such as iron and steel was never discovered, but the softer precious metals, gold and silver, were relatively abundant, as was copper. These were widely exploited, and bronze produced by mixing copper, arsenic, and tin became the hardest metal known to ancient Andean peoples. Good quality clay was also readily available in the Andes, and manufacture of fine ceramics was widespread.

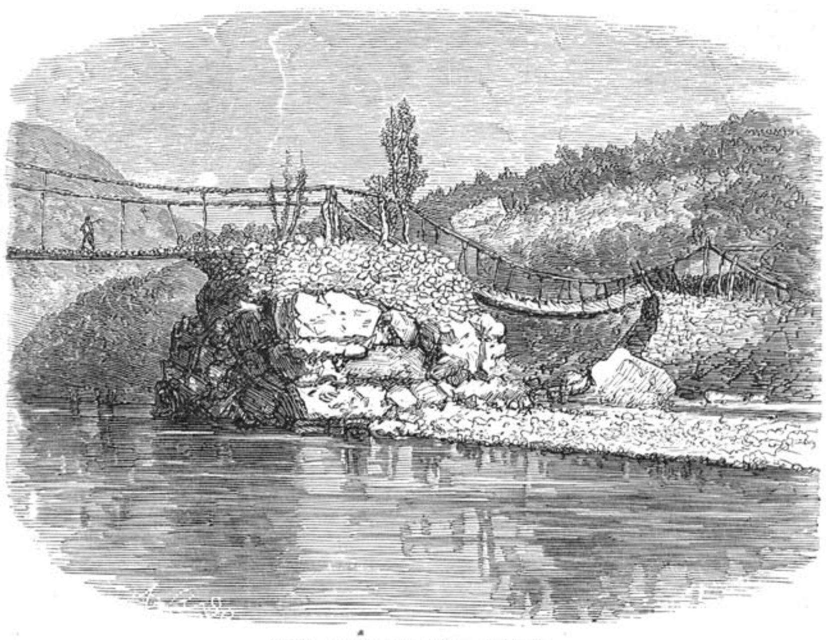
The lack of large domesticated animals that humans could ride or could use to pull vehicles, coupled with the impossibly steep terrain of the highlands, discouraged the development and use of the wheel. With all traffic on foot, roads and bridges assumed a distinctive form. Long, steep staircases are a common feature in prehistoric Andean roads. Narrow, hanging suspension bridges made of rope were well adapted



A backstrap loom was the most common type used by Inca weavers.

Ruth Wright holds an example of Inca gold, a bracelet found in 1995 and located at the Cusco Regional Museum.

An Inca ceramic vessel.



INCA BRIDGE, OLLANTAYTAMBO.

The Inca foot plow was an ingenious digging stick. Noblemen are lined up using this digging stick as part of a ceremony.

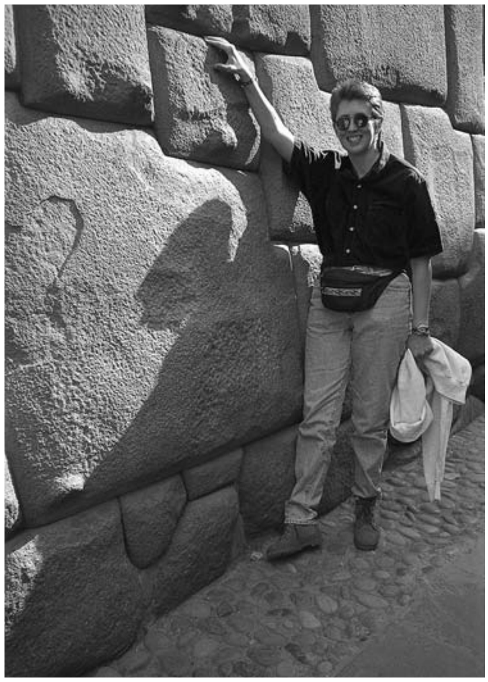
The adventurous Squier observed this Inca bridge structure in 1862 at Ollantaytambo.

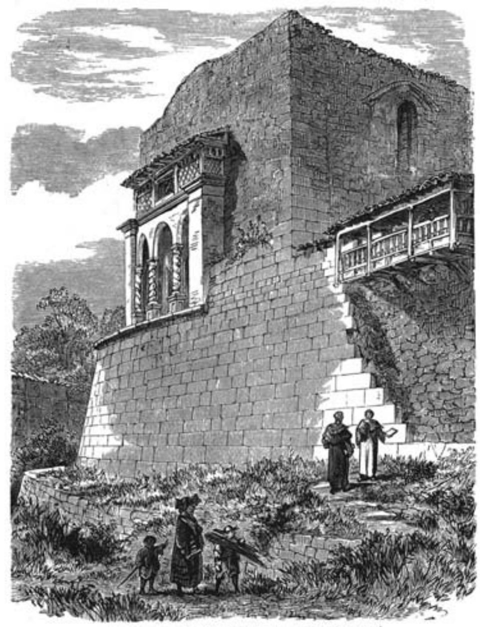
to foot traffic. Steep ravines and swift rivers could be crossed by these lightweight, easily manufactured bridges, where a vehicular bridge would have been impossible. Without draft animals, farm labor had to be performed by hand. An ingenious foot plow, a type of digging stick, was developed that allowed a person or group of people, lined up in a row with each producing one furrow, to plow a field effectively. On the coast and shores of the highland lakes where timber for boats was not available, the people learned to build fishing boats of reeds.

The ancient Andeans became master stonemasons using tools of stone and bronze. Great works of architecture involving complex engineering skills were accomplished without the precision instruments known in the Old World. Enormous temples, palaces, and fortresses were built of adobe bricks or stone. Remarkably straight roads were laid over the most difficult terrain. Even the landscape was sculpted to suit human needs, with agricultural terraces constructed to conform to the topography for aesthetic as well as functional purposes.

Pre-Inca history

Prior to the rise of the Inca, a multitude of cultures flourished and died out in ancient Peru, each one adding its unique contributions to the Andean cultural legacy inherited by the Incas. Only a few of these are well known and have been studied by archaeologists. The earliest widespread cultural influence is manifested in the style associated with the religious cult of Chavín.





END WALL OF THE TEMPLE OF THE SUN, CUZCO.

Chavín

By 1400 BCE, this new religious movement began to spread across northern Peru. It incorporated elements from older Peruvian coastal religions and combined them with religious elements such as the cayman and jaguar from the tropical forests of the *montaña* and Amazon basin. Although named for the site of Chavín de Huantar, a ceremonial center and temple complex on the eastern watershed of the North Central Highlands, the cult seems to have originated throughout a broad area of northern Peru and represents a synthesis of a variety of traditional religious beliefs. By 500 BCE Chavín influence extended from the modern cities of Cajamarca in the north to Ayacucho in the south.

The local Cusco culture at this time is called Marcavalle and is named for the site where it was discovered. Very little is yet known about these people. They seem to have been farmers who probably occupied a number of villages and lived under a relatively simple political system. Although direct Chavín influence does not appear to have reached the Cusco region at this time, it appears to have profoundly influenced the peoples of the Ayacucho region who later invaded and occupied the valley of Cusco during the Wari imperial expansion of the Middle Horizon Period.

Moche and Nazca

Following the heyday of the Chavín cult, which corresponds basically to the Early Horizon time period (ca. 1500 to 370 BCE), archaeologists believe that there was a florescence of numerous strong regional cultures. The best known of these are the Moche of the north Peruvian coast and the Nazca who lived on

The Inca trail system was developed from the Wari road network.

Inca stone masons conjoined huge stones almost seamlessly. Archivist Patricia Pinson provides a scale for the massive rocks.

The beautiful stonework of the Coricancha in Cusco attests to the importance of the Temple of the Sun.

the south coast. During the Early Intermediate Period (370 BCE to 540 CE), the Moche and the Nazca achieved a high degree of civilization. Building on the Chavín religious tradition, these societies became increasingly complexly organized and in the case of the Moche may have developed into centrally governed states.

Chanapata

In the Cusco region at this time there was a culture called Chanapata by archaeologists. Chanapata peoples are very poorly known and seem to be in many respects a continuation of the preceding Marcavalle culture. Recent excavations have shown that they lived in villages of small rectangular houses and made their living as farmers. They seem to have had a well-developed ceramic art style showing some similarities to the styles of the peoples living farther south towards Lake Titicaca. Little or no influence of other cultures can yet be detected in the cultural remains of these people.

Highlands

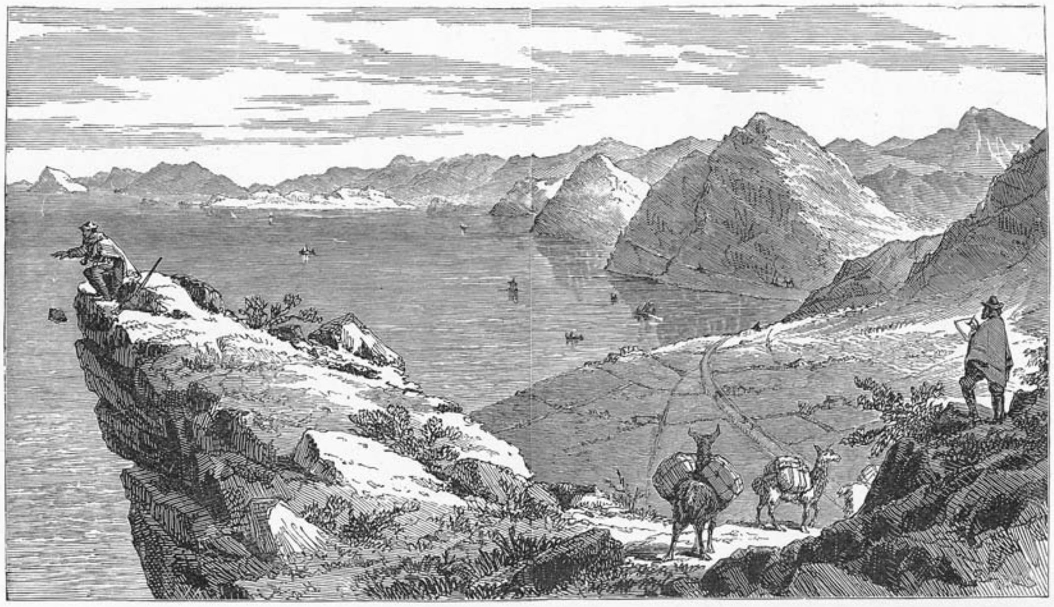
During the time that the Nazca and Moche peoples were achieving their greatest development on the Peruvian coast, other cultures were beginning to rise in the highlands of Peru and Bolivia. These highland cultures expanded their influence until it encompassed most of the Andean world. After dominating the Andes for several centuries, their cultural legacy greatly influenced succeeding cultures and the course of Andean prehistory until the Spanish Conquest.

Tiwanaku

In the southern Andes, in what is today Bolivia, a large ceremonial center developed on the shores of Lake Titicaca. This magnificent city, called Tiwanaku, was built at an elevation of 12,512 feet above sea level on the cold, treeless plateau called the *altiplano*. Although this severe environment seems hostile, in prehistoric times this area supported one of the densest population concentrations in the ancient New World. Population estimates for the city of Tiwanaku alone range between 20,000 and 40,000 people.

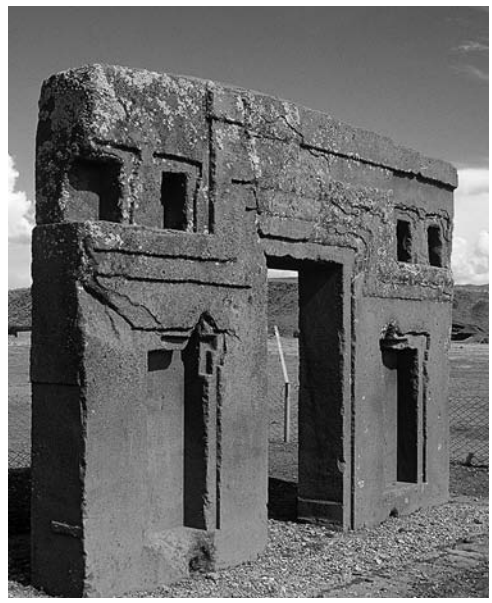
First settled around 1000 BCE, the site of Tiwanaku was occupied for nearly 2,000 years. It began as a small farming village, but around 100 CE the Tiwanakans began to construct monumental architecture, and the site grew to be the capital city of an empire that dominated the southern Andes between 500 and 1000 CE. Then, for reasons that are not well understood, but likely climate change, the Tiwanaku culture disappeared and the city of Tiwanaku was abruptly abandoned.

A great flood damaged the Pyramid of Moche some 800 years before the Inca empire.



VIEW OF THE BAY OF COPACABANA, LAKE TITICACA.

The city of Tiwanaku is dominated by its pyramids and temples. Other monumental structures at Tiwanaku include large, rectangular, stone-walled enclosures and semi-subterranean temples. All of these structures were built of fine cut stone. Entrance to these elaborate buildings and ceremonial precincts was made through monumental gateways, the most famous being the so-called Gate of the Sun.



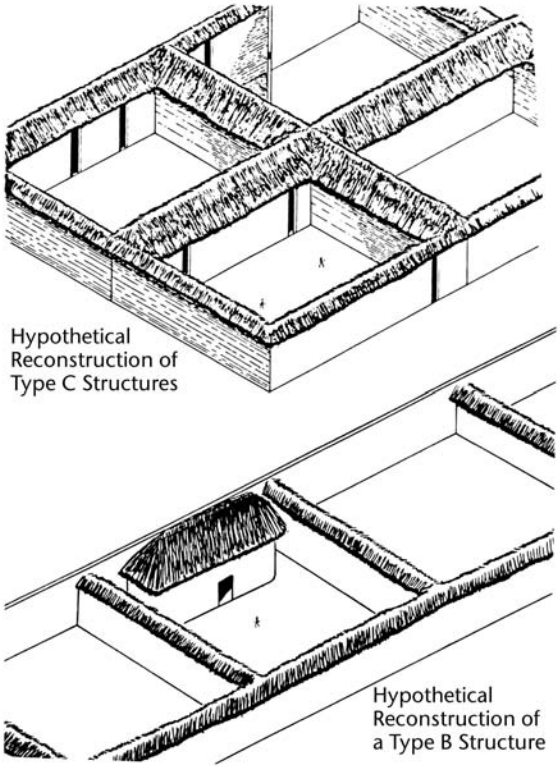
Wari

The other great culture of the Middle Horizon Period is that of the Wari. About 600 miles to the north of Tiwanaku, the Wari capital was located in the Ayacucho Valley of the central Peruvian Andes, at an elevation of 9,000 feet. The Wari empire is represented archaeologically by large architectural complexes found throughout the Peruvian highlands. Wari and Tiwanaku shared some of the same religious iconography, but they seem to have been separate entities. There is no evidence, either, that one ever dominated the other, although the exact nature of their relationship remains unknown.

The site of Wari was first occupied around 200 BCE and, like Tiwanaku, was only a small settlement until around 500 CE. Between 500 and 900 CE, however, the site grew very rapidly to become one of the largest urban centers in South America. Ultimately a city of roughly 1,235 acres, it was occupied by a population ranging between 35,000 and 70,000 people. Unlike Tiwanaku, the city of Wari had almost no finely cut stonework. Most of its buildings were constructed of field stone set in mud mortar and were then covered with smooth coats of clay and gypsum plaster. The scale was monumental with walls 3 to 6 feet thick standing to heights of 30 to 40 feet and supporting two and three stories. Many residential buildings, some as long as 120 feet

Lake Titicaca was an important natural feature for the Inca where they built an important ceremonial center.

The Gate of the Sun at Tiwanaku tells a story of a great early empire.



on a side, consisted of rectangular enclosures with central courtyards.

A new religion is presumed to have been introduced to the Wari through contact with the Tiwanakans, but little is yet understood about this religion. As with most agricultural societies, the Wari religion was undoubtedly much concerned with ensuring fertility and water supply, as well as protecting against natural disasters such as drought or flood. Religious iconography suggests that there were several deities in a ranked hierarchy, some with several aspects.

Human sacrifice seems to have been practiced. Offering caches were discovered containing the bodies of sacrificed young women and ritually broken, elaborately painted pottery. Other caches contain high-status goods including objects of gold, bronze, and shell as well as human skulls. Two temples have been excavated at Wari, but the rituals that took place within them are not yet understood to any great extent.

Following the introduction of the new religion, the site of Wari soon emerged as the center of an expansionist movement and embarked on a series of conquests. Although the motive for this expansion is unclear, an environmental deterioration may have caused the Wari to conquer their neighbors in an attempt to gain more arable land in a greater variety of ecological zones in order to ensure against universal crop failure. Whatever the cause, the Wari appear to have organized one of the first, if not *the* first, conquest empires in the Andes. Between 540 and 650 CE, the Wari conquered the Central and Southern Highlands and Central and South Coast of Peru. Around 650 CE the empire appears to have suffered a severe crisis, possibly a revolt or epidemic (reflected in the archaeological record by changes in settlement distribution and burial patterns). This crisis was successfully overcome, and a second expansion very rapidly encompassed most of what is today highland and coastal Peru.

The Wari imperial economy was based on agriculture and herding. A great variety of foodstuffs were produced. Long distance exchange also supplied scarce luxury goods such as Spondylus shells from Ecuador and feathers from the Amazon jungles.

The empire seems to have been divided into regions governed by subcapitals and administrative centers. The two largest provincial capitals are the sites of Pikillacta, near Cusco in the Southern Highlands, and Viracocha Pampa near Huamachuco in the North Highlands. Smaller Wari administrative complexes exist at Jincamocco in the Southwest Highlands, at Azangaro and Wari Wilka in the Central Highlands, and at Honco Pampa in the North Highlands. On the coast, the Wari occupied the huge

Wari buildings made use of thatched roofs long before the Inca empire.

shrine and oracle at Pachacamac just south of the modern city of Lima. Many elaborate, high-status burials were interred in the sacred ground around the temple at Pachacamac. Other coastal valleys also received Wari administrative centers such as Cerro Baul in the Moquegua Valley and Maymi in the Pisco Valley. On the North Coast, the Wari seem to have been responsible for the collapse of the Moche culture. It is unclear whether this was by outright conquest, or by taking advantage of an internal Moche collapse caused by severe environmental disruptions.

The largest and best preserved of these provincial capitals or administrative centers is the site of Pikillacta, located in the valley of Cusco, near Tipon. Pikillacta and its numerous satellite sites indicate that the Wari directly ruled the Cusco region during the Middle Horizon for a period that spans the years 600 to 1000 CE. During this time, the settlement system of the valley of Cusco was reorganized, and a number of large scale and monumental works were undertaken.

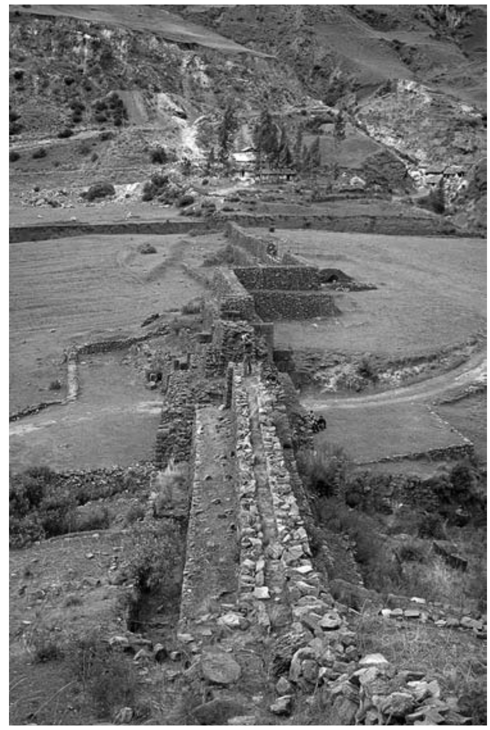
Wari imperial power lasted for more than 300 years, until sometime between 900 and 1000 CE, when it rapidly disintegrated. The exact reasons are unknown, but the Wari state seems to have suffered from severe over-centralization and adverse climate.

Although the Wari empire dissolved, like the Tiwanakans, they left an enduring legacy. Throughout much of the Peruvian Andes they introduced the concept of the imperial state. Many peoples undoubtedly increased their cultural complexity under the Wari and were now ready to try their own experiments in statecraft. The Wari, then, set the stage for the formation of numerous predatory states that competed among each other to fill the power vacuum left by the imperial collapse. Out of this ferment eventually arose the empire of the Inca.

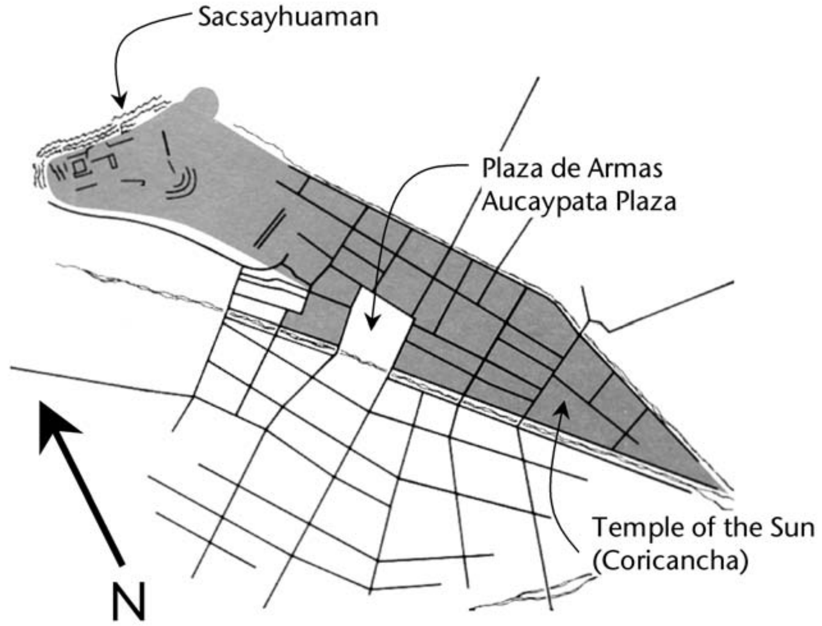
Inca history

According to legend, around the year 1200 CE, a small band of highlanders migrated into the valley of Cusco in the southern Peruvian sierra. Over the next few centuries, the huge empire of the Inca grew from this small group. According to Inca legends, their place of origin was the town of Pacariqtambo, a few miles to the southwest of Cusco, where their ancestors came forth into the world from three caves. This original group was led by the first Inca ruler, Manco Capac, and was composed of his three brothers and four sisters.

Following their arrival in Cusco the Incas slowly increased their influence through intermarriage and by military raiding against their neighbors. The city of Cusco grew from a small settlement, but, through the reign of the eighth Inca, it was little more than an ordinary Andean highland town. The turning



The Wari people built large hydraulic works. This aqueduct crossed a valley at Rumicolca.



point in the history of the city and the Incas themselves was the great Chanca crisis near the end of the reign of Inca Viracocha (1438 CE). By this time, the Incas had increased their domain to include the whole of the valley of Cusco, including the Oropesa and Lucre basins, and a large part of the neighboring Urubamba Valley. A powerful warlike confederation known as the Chanca began to expand to the south, probably from the Ayacucho basin, the earlier Wari imperial seat. They threatened Cusco and very nearly defeated the Incas. The Inca Viracocha abandoned the city and fled to the neighboring valley, but, at the last moment, one of the royal sons, Inca Yupanqui, rallied the Inca armies and, in a heroic effort, defeated the Chanca forces. Following this victory he deposed his father, Inca Viracocha, whose failure to defend Cusco was viewed as a disgrace. Inca Yupanqui took the name Pachacuti and assumed the throne to become the first of the great Inca emperors.

Pachacuti

The name Pachacuti, or Pachacutec as it is sometimes given in the chronicles, means "he who shakes the earth" or "cataclysm" in Quechua, the language of the Incas. It was an appropriate name for a man who literally reorganized the Inca world. His first acts as emperor included subduing the neighboring peoples in the Cusco region. Whereas they had previously been associated rather loosely with the Incas, mostly by persuasion and family ties, they were now firmly brought under control as vassals of the lords of Cusco. He then launched a series of conquests that rapidly evolved what had been the tiny Inca domain into an expanding empire.

Puma-shaped Cusco, the Inca capital, assimilates Sacsayhuaman as its head.

Cusco

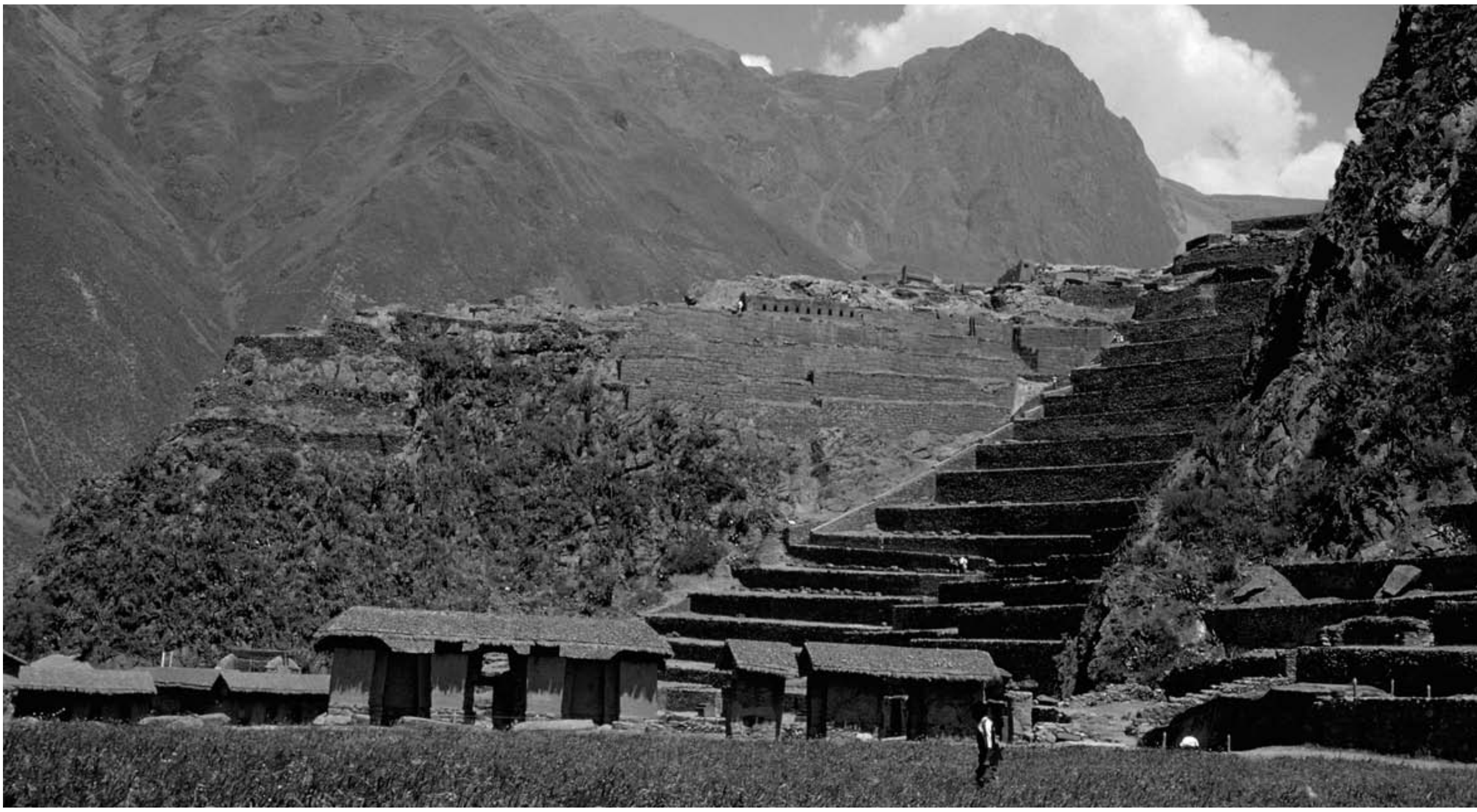
Pachacuti set himself the task of reconstructing Cusco as a suitable capital for the empire he envisioned. The city was constructed in the form of a puma, incorporating the fortress-temple of Sacsayhuaman as its head. The body comprised residential buildings and palaces laid out in a grid between the Tullumayo and Saphi rivers. Like so many New World peoples, the Incas held felines, especially the puma or mountain lion, to be sacred. The basic building unit of the city plan was an architectural form called the Kancha that comprised a series of small houses arranged within a rectangular enclosure. The Kancha form and grid plan of the city may have been derived from the old Wari imperial administrative center of Pikillacta, located in the lower end of the valley of Cusco.

The city of Cusco was conceived as the center of the empire where the four quarters into which it was divided came symbolically and physically together. Four highways coming from each of the four quarters or *suyus* converged in the great central plaza of the city. From this four-part division the empire took its name of Tawantinsuyu, meaning “the land of four quarters.”

Building Projects

In addition to rebuilding Cusco, Pachacuti also initiated building projects in the environs of Cusco and on his royal estates in the Urubamba Valley. The most famous of these is the so-called “lost city” of Machu Picchu, but he also built royal estates at Ollantaytambo, Patallaqta, and many smaller sites in the valley.

The fortress-temple of Sacsayhuaman represents the public works heritage handed down to the Inca from earlier civilizations, as does Tipon.



Other building projects initiated by Pachacuti included the famous royal highway of the Inca. It provided for communication within the expanding empire and supplied a means of rapidly moving the army to wherever it was needed. Following and expanding the routes of the old highways of the earlier Wari empire, standardized highways, often walled and paved, linked the various regions of the growing empire to Cusco. Storehouses (*qolca*) and rest stops (*tambos*) were built to provision and serve the army as it marched. A system of relay runners (*chasqui*) formed an effective postal system for the transmission of verbal messages and instructions. Towns and provincial administrative centers were also built by Pachacuti and his successors in the various conquered territories as the empire expanded.

Empire expansion

Pachacuti's son and successor, Topa Inca, succeeded him as emperor in 1471 CE and continued to expand the empire. Topa Inca moved the imperial frontier north into what is now Ecuador and south into what are now Bolivia, northern Chile, and northwestern Argentina. Topa Inca reigned until 1493 CE and was succeeded in turn by his son Huayna Capac.

Huayna Capac continued to expand the boundaries of the empire to the north and east. Compared to his father, however, his conquests were modest. Huayna Capac spent so much time on his difficult northern campaign that severe strains began to grow in the social fabric of the empire. He was absent for many years at a time. Surrogates had to stand in for him at important festivals and ceremonies, and the people of Cusco began to feel out of

Inca Ollantaytambo was a royal estate for an Inca emperor. The nearby town has been continually occupied since Inca times.

touch with their emperor. A new and potentially rival court even grew up around him at his northern headquarters at Tomebamba in Ecuador. Administratively the empire had become difficult to govern.

Civil war

A severe crisis finally came when Huayna Capac suddenly died of what may have been smallpox in 1527 CE. The disease, introduced by Europeans arriving in the New World, preceded the Spanish conquistadors as they journeyed across South America. Thousands died in a very short space of time, including Huayna Capac's appointed heir, who survived his father by only a few days. The confusion about the succession created even more strain on Inca society, and finally a civil war broke out between two brothers who were rival claimants for the throne. One of the brothers, Huascar, had succeeded to the throne in Cusco in 1527 CE. He was challenged by Atahuallpa; a large part of the army rallied behind Atahuallpa, and a bloody war ensued. Taking the city of Cusco in 1532 CE, the forces of Atahuallpa eventually prevailed.

The Spanish conquest

As Atahuallpa moved south to Cusco with a large army, he was met by the Spanish forces led by Francisco Pizarro in the northern highlands. In a stunning surprise move, Pizarro and his small band of 168 men attacked and captured Atahuallpa in the midst of his huge army. Pizarro held the emperor captive for nearly eight months, eventually having him killed in July of 1533. With the death of Atahuallpa, the last of the independent Inca rulers had fallen. The Incas continued to resist the Spanish for many years thereafter, but the Inca empire ceased to exist.

Inca culture

Inca culture was the culmination of thousands of years of Andean civilization. From their predecessors they had inherited a body of statecraft and much of the physical infrastructure for the empire. They had also inherited and participated in a great Andean culture based on religious ideas that were thousands of years old. That they were the inheritors of this great tradition does not in any way diminish their own achievement, however. It was the peculiar Inca genius for organization that allowed them to make profitable use of their cultural inheritance. They alone of the late Andean societies were able to weave together the disparate elements of the many Andean cultures through military prowess, ideology, and extraordinary statecraft by drawing on thousands of years of cultural inheritance. In terms of geographical extension, military power, and political organization, the Inca created the greatest of the pre-Columbian empires.

TIPON, UP CLOSE AND PERSONAL

To appreciate firsthand the extraordinary public works accomplishments of the Inca engineers and craftsmen of Tipon is a treat not to be missed. This ancient estate for Inca nobility is great for a quick two hour visit but exquisite for an all day inspection.

You will marvel at the Central Terraces that, year around, provide the music of falling water, the sight of controlled water drops, and the beauty and color of the finest terrace walls in all of the Andes. The Tipon fountains and the rushing water in open channels provide excellent photo opportunities.

For the engineering purist there are many original canal sections, buildings, and terraces that endured for the last 500 years even though the local people kept farming there until the 1990s. It is a pleasure to inspect an untouched reach of canal, an ancient fountain, or a still plastered building wall and then imagine the pre-Columbian workers building it, stone by stone.

To visit Tipon is to step back in time, to before the Conquistadors sailed from Spain, and see the creativity of early Americans as they worked to build communities and to learn about their wise use of land and water.

Observe the site's melding of Inca craftsmanship with the work of previous inhabitants, marvel at the precision of the Tipon fountain, and rejoice at the breathtaking views. By taking the initiative to get off the beaten trail and climb up to the Cruzmoqo or to hike over to Pukara, you will be rewarded with an experience few have had.

There is so much to be seen, enjoyed, and learned, but so much more still to be discovered about these talented people.

Chapter 12

Walking Tour of Tipon

Ruth M. Wright

Getting there

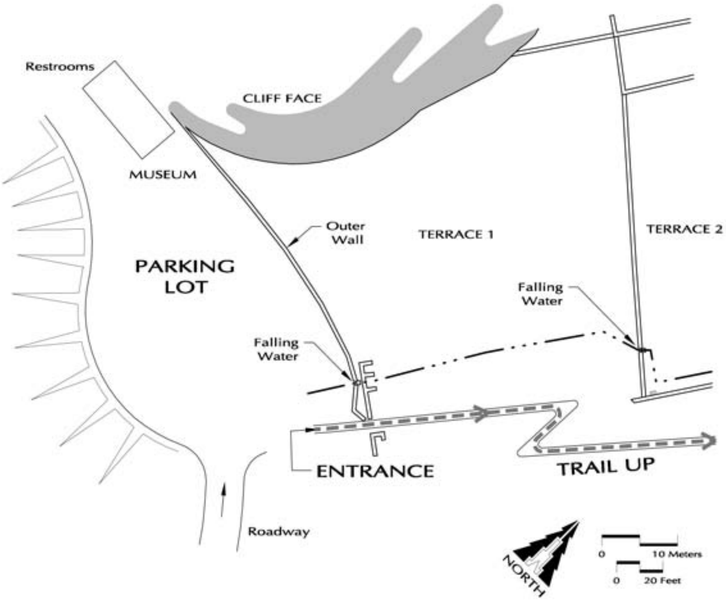
You can hire a taxi from Cusco to drive to Tipon. It will be a round trip, and you should determine the price in advance. Bring along all of the items you need for a day in the hills—rain gear, food, water, cameras, etc. The taxi will take the road east downvalley, through the towns of San Sebastian and San Jeronimo, about 14 miles to an Instituto Nacional de Cultura sign on the left for Tipon. A country road takes you through farm fields and a village for about 2½ miles, the last portion fairly steeply uphill to Tipon. Tipon ranges in elevation from 10,700 to 13,000 feet. See the site location map in Chapter 1.

Tipon Entrance

Arriving at the small parking lot, the first thing you will notice is a high wall constructed of fine Inca stonework with a drop structure with water rushing down it. High up on the hill beyond is the famous knob called the Cruzmoqo (more about this important site is in the Side Trips section later). This is your introduction to magnificent Tipon, sometimes called a "water garden" because of the extensive water features and sound of rushing water.

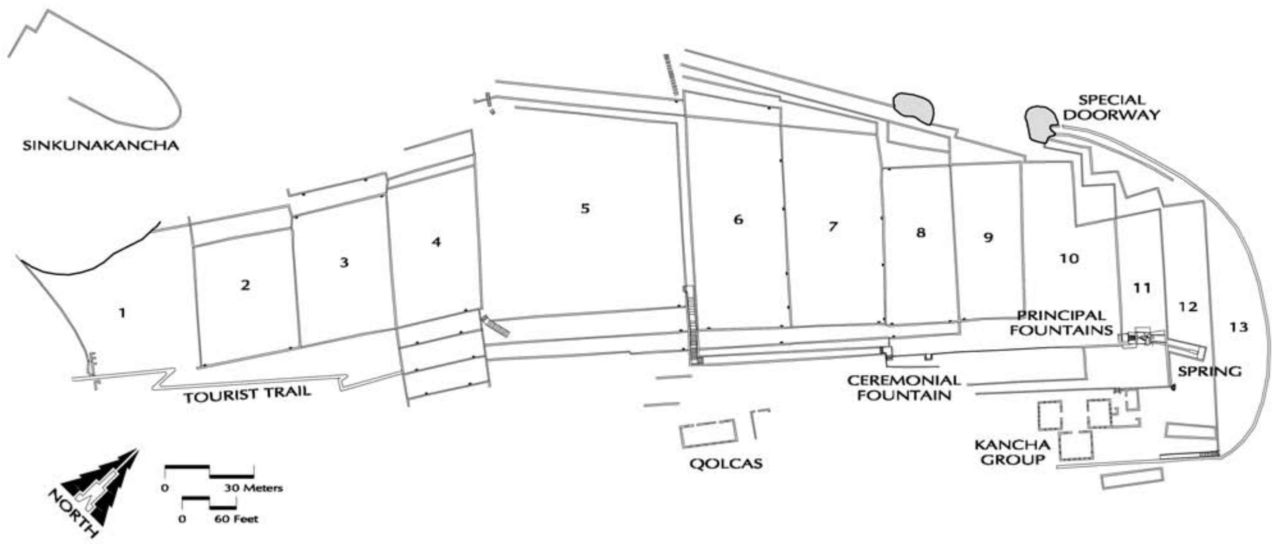
See the Tipon Archaeological Park Topographical Map in Chapter 1 that shows the park's size, its topography, and the features you will be visiting. This is "big sky" country—a 500-acre tract, still partially surrounded by a wall, with huge agricultural terraces with interlacing water canals, drop structures, stairs, various structures for residences, ceremonial areas, storehouses, an

The Inca terrace wall and drop structure at the entrance, with water cascading down. Note the hill in the background with a knob called the Cruzmoqo.



aqueduct, and possibly a military compound. While most of the structures you see today date from imperial Inca times, this is an older site. The spring, which has flowed since time immemorial, and the rich volcanic soils attracted ancient people. Neolithic sites have been discovered up on the hills to the west. The outer wall was built before the Inca, maybe by the earlier Wari civilization, as was the large Wari administrative site at Pikillacta farther down the valley. While archaeologists are still piecing together its history, we can enjoy its current features.

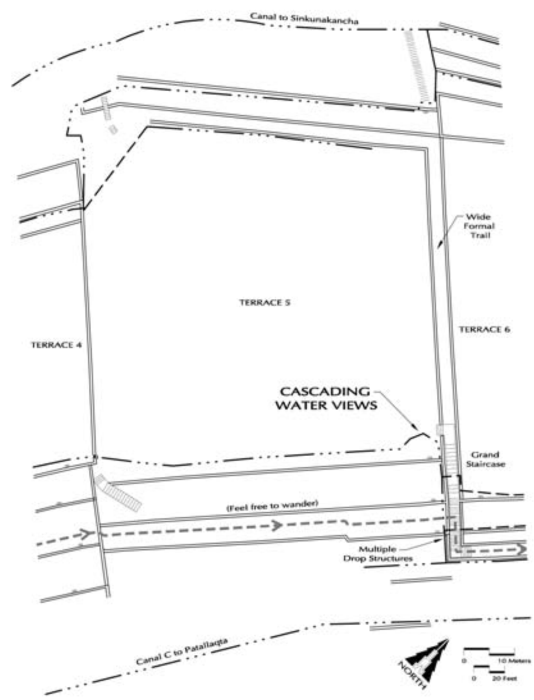
You can see from the map above that you are at the southernmost edge of Tipon. There is a small museum here that is in an early stage of development and may have some artifacts. The building also houses restrooms. If you go behind the building, you can see part of the outer wall. There is a small charge to enter the site. Before you go up the trail, be sure to take everything with you for your day at Tipon—food, water, camera, guidebook, hat, sunscreen, etc. You are at nearly 11,000 feet, the trail goes up, up, up, and you do not want to lose any elevation you have gained by having to go back to the car.



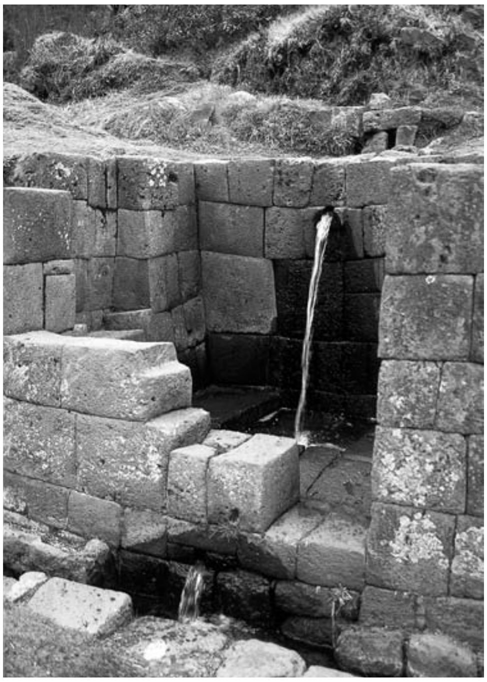
Central Terraces and main area sites

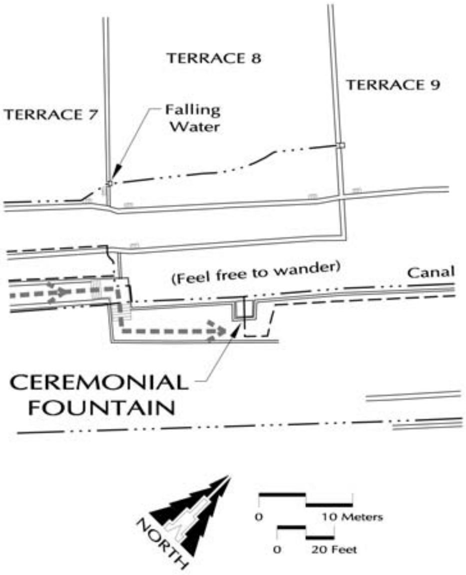
Central Terraces

First you will notice that you are in a valley that has been partially filled in to make the terracing for farming possible. The miracle here is that, in spite of a large drainage basin above, the terrace walls were built so well that there was never a major washout in 500 years. As you go up the trail, notice the beauty of the terrace walls, the flying stairs, the canals, and the drop structures, which are an integral part of the irrigation system, but which are of such beauty that the aesthetics of the site are astonishing. The sight and sound of rushing water accompany you as you move upward toward the focal point of Tipon—its justly famous spring. We have numbered the terraces for easy identification. The main text of this book, of course, gives you much more detail than this walking tour, so pause to read chapters that interest you on the way. The index at the back orients you to the text and illustrations.



The Central Terraces leading up to the Main Spring.





At Terrace No. 5 you may wish to go down the grand staircase and see and hear the water cascading down the elegant fountains. Note the stepping stones jutting out from the wall that we call flying stairs. It makes one wonder whether this particular large square terrace with its path crossing to the other side may have been used for ceremonial purposes. Go back up to visit the Ceremonial Fountain at Terrace No. 8. It is small but carefully constructed with fine stonework. Water was one of the most important features in Inca cosmology, especially here at Tipon where irrigation was a necessary component in the success of agricultural crops.

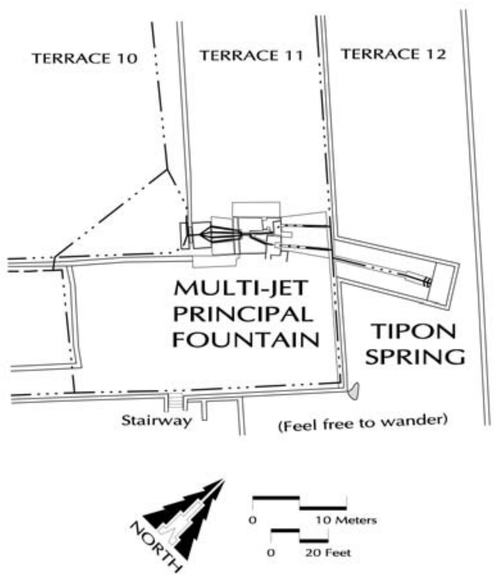
The terraces (No. 1 through No. 11) leading up to the spring are all irrigated by the spring. The areas above the spring (Terraces No. 12 and No. 13) were fed by water diverted from the Pukara River, over an aqueduct, and in water canals across agricultural areas. Modern engineers call this conjunctive use—groundwater from the spring augmented by surface water from the stream. The volume of water from the spring was more than enough to irrigate the terraced fields, and the water from the river was also a virtually unlimited source.

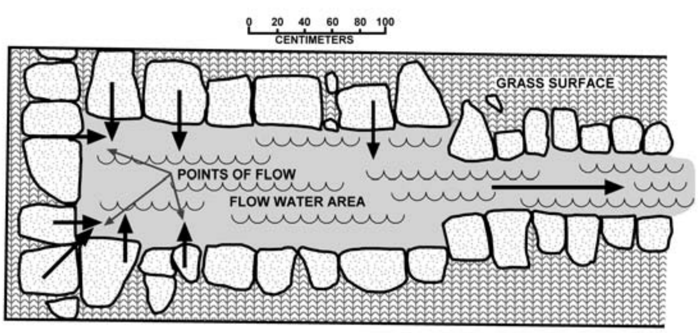
The Ceremonial Fountain above Terrace No. 8. Note the fine stonework and ingenious use of water.

The stairway at Terrace No. 5 with side channels of cascading spring water and "flying stairs" on the right.

Main Spring and Principal Fountain

You are now approaching the Fuentes Principales, the Main Spring and Principal Fountain. The spring is a masterpiece of engineering and architecture. The Inca loved to show their mastery over land and water, and since Tipon was also a ceremonial site, the extraordinary thought and energy that produced such beauty was also a tribute to their gods. The perennial spring issues forth from the base of a huge volcanic rock deposit. The water is clean and clear and of superb quality. As restored by the Institute of Culture, the water pouring out of the spring is directed to two jets, and then again to four jets. As usual the Inca combined successful engineering with fountains that are a feast for both eyes and ears. Note the diagram that depicts the intricacies of the underground development of the spring. From here the canal system and drop structures are masterfully designed to flow both on the surface and underground to fulfill the needs of irrigation, domestic water for the inhabitants, and ceremonial purposes. In the main text we have divided the flows into Canals A, B, and C, and subsets of each. They also are indicated on the Tipon Layout map earlier in this chapter.



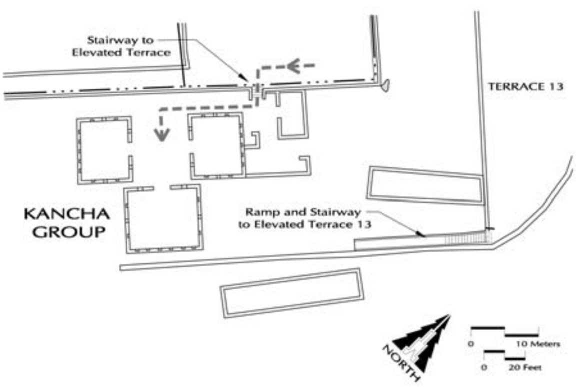


The Main Spring and Principal Fountain. Water issues forth from the volcanic rock and is directed first to two jets, which then split into four jets and into a pool.

A diagram of the Main Spring shows water issue arrows and flow from left to right towards the distribution canals and Principal Fountain.

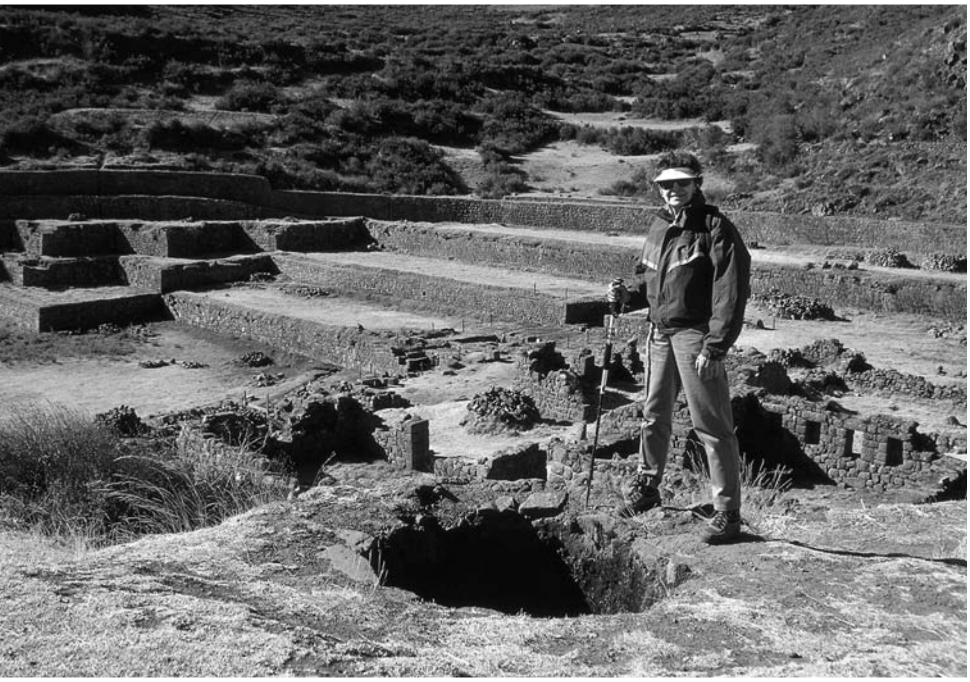
Kancha Group

Now go east and up to the Kancha Group. It was a residential complex for Inca nobility. From here they could oversee their domain and have a grand view of the site and the surrounding terrain. At this location, its residents also had first use of the pure spring water for domestic use. The diagram shows the classical

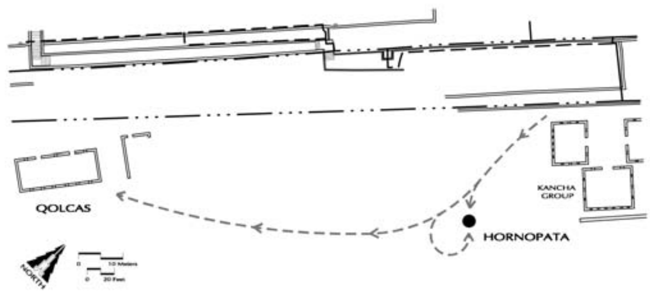


kancha design with buildings facing a courtyard, and doorways, windows, and niches with a more or less trapezoidal shape. Previous restoration efforts of the Kancha Group were not carried out well as illustrated by the considerable use of mortar between the stones. There is a fine stairway entrance to the site. The small building close to the stairway may have been a security station for the Kancha Group. It should be mentioned that most of the farmers and other workers lived outside of Tipon in neighboring villages and came in for the day.

The Kancha Group, the residential area for Inca nobility with a stairway entrance in the foreground.

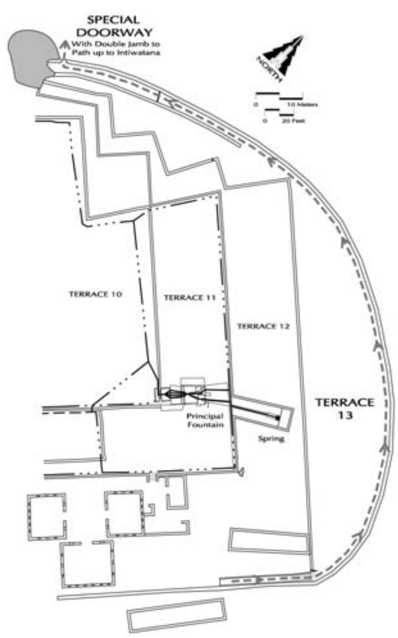


Hornopata and qolcas



Higher up is a small structure called the Hornopata that is pre-Hispanic, though not necessarily Inca. It is likely an oven, perhaps a kiln for firing ceramics. The structures farther to the south, just east of Terrace No. 6 are called the Qolcas de Iglesia Raqui. *Qolcas* are storehouses, and some of the produce was likely stored here.

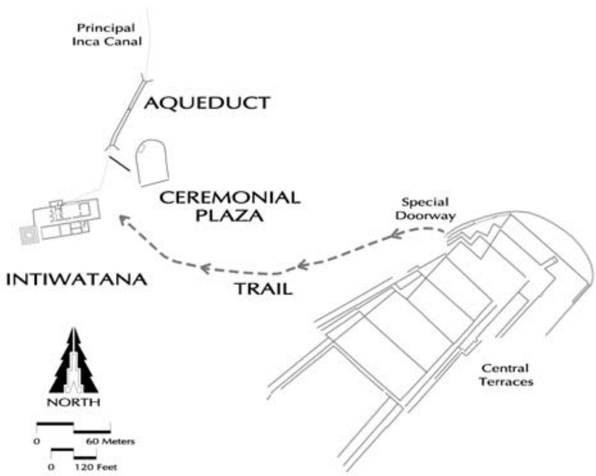
Now take the stairway that goes up onto Terrace No. 13 with a semicircular retaining wall. This is a great spot for a picnic with one of the most pleasant views in all of the Inca empire. Continuing along the wall takes you to the Portada Especial, an opening with a double jamb. A double-jamb doorway usually announces a special place beyond, in this case, the Intiwatana farther up the trail. From this point, look back to the Spring, the Kancha Group, the *qolcas,* and the whole Tipon Central Terraces to fully experience the Inca master plan.

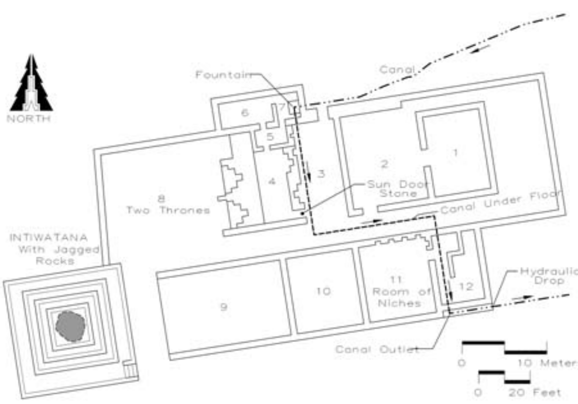


Ruth Wright at the Hornopata opening, with the Kancha Group below and beyond to the right. The Hornopata was an oven, likely for ceramics.

The *qolcas* (storehouses) above and just east of Terrace No. 6.

The Portada Especial, a doorway with double jambs announcing a special place beyond: the Intiwatana.





Intiwatana

There is now a trail below much of the canal from the Rio Pukara. You will remember that this canal supplied Terraces No. 12 and No. 13 with irrigation water by gravity flow. It also flowed to outlying fields. The canal itself is stone lined. Stones on the downside of the canal had openings to temporarily let water flow downhill to a specific field. Near the complex called the Intiwatana you will join the Inca canal.

You will be astonished to see that the canal takes you directly to an orifice and drop structure in the Intiwatana and that the canal actually flowed through and under this complex. The Intiwatana is Tipon's most intricate and sacred ceremonial site. Intiwatana is a modern term, first used (incorrectly, according to Professor John Rowe) for the stone protuberance at a temple in Pisac, then by Hiram Bingham for the carved stone at the top of the natural pyramid at Machu Picchu. The Intiwatana here is perhaps so named because of the square terraced structure topped by jagged rocks on the western side, or simply to denote it as a sacred

The Intiwatana complex as seen from near the *huaca/usnu*.

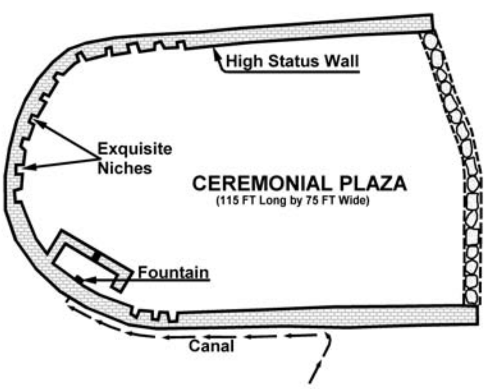
site. On the north side there are remains of a fountain, inlet, and outlet. Whether this source of water was tapped for ceremonial use in the structure in Inca times is unknown, but it certainly shows a reverence for water to bring it through the site in this fashion. In the central area is a stone stairway that is formed and finished to perfection. Wander through the site and notice the niches in Room 11 and especially the triangular seats on the eastern wall in Room 8. At an angle to the southwest of the seats is the square structure made of narrow, stepped terraces with jagged rocks jutting upwards. It has been surmised that the Inca nobility were seated in Room 8 facing west to view and participate in ceremonies at this structure, which was likely a *huaca* (shrine) and/or an *usnu*. An *usnu* has been described as a small but significant structure, sometimes pyramidal in shape, at times with a water feature, used for diverse purposes: a throne and seat for the Inca, or other authority figure, to hold court and dispense justice; also an altar, a place for prayer and sacrifice, and a symbol of power and government. One need only to sit here in the late afternoon witnessing a spectacular sunset to imagine ceremonies to the god Inti. In any case, this wonderful site certainly deserves careful restoration.

The *huaca/usnu* with terraces, steps, and jagged rocks at the top.

The finest stone stairway in the Intiwatana. Use your hand to feel the smoothness.

Aqueduct

We follow the canal once again; this time our destination is the aqueduct. It is 200 feet long and 15 feet high and was intact even before its restoration—a tremendous engineering feat. It even has a pedestrian underpass at its center. It has an easy ramp and stairs to the top, where once again you have an unparalleled view. If you have enough time, about two extra hours, you can go to the ancient village of Pukara, another Inca residential area. (See Side Trip Ancient Pukara.)



Ceremonial Plaza

From this location you can look over to the Ceremonial Plaza, our next stop, once thought to be a reservoir. It has the shape of a horseshoe, and a rough wall appears to exist at the southern end. A side canal of the main canal does go to the Plaza, but the stones at the foot of the "horseshoe" are just roughly placed and may have created an enclosure for llama or other animals in colonial times. As you can imagine, after the collapse of the Inca empire, Tipon was a choice agricultural site that continued to be productive and was never abandoned by local farmers.

The aqueduct that carried water from the Rio Pukara to the Ceremonial Plaza, the Intiwatana, outlying fields, and Terraces No. 12 and No. 13 of the Central Terraces.

Diagram of the Ceremonial Plaza. Note the canal, which delivered water to the waterspout and fountain.

The canal leads to an opening and waterspout in the wall and a fountain in the circular end that is surrounded by a small enclosure, so water was available here for ceremonies. The niches and the stonework are of the highest caliber, supporting the theory that this was a ceremonial plaza. Because some of the surface stones have fallen off, we can examine the construction of the wall. The smooth outer surface is a facade covering a rough wall and was done with such care that it is impossible to slip a knife between the stones. We saw candles and other small offerings placed in the niches, showing a continuing reverence for the site.

From here you can simply head down the way you came up or take side trips as described below.

The Ceremonial Plaza to the east of the aqueduct. The two rows of stones inside the plaza are merely stored there and were once part of the Plaza walls.

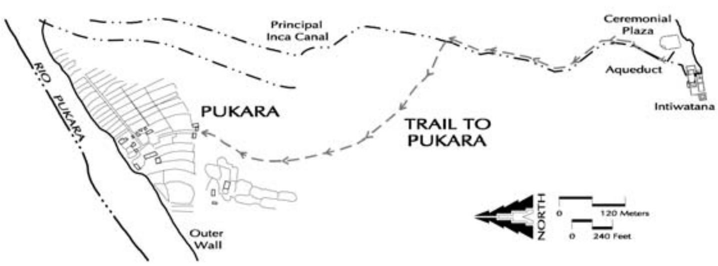
The waterspout in the Ceremonial Plaza.

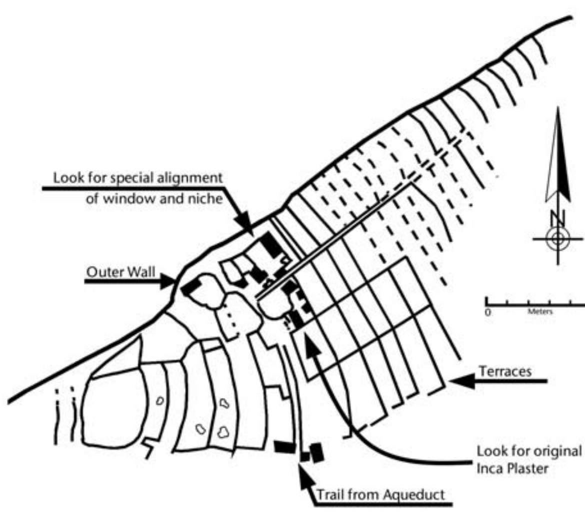
Archaeologists measured the stones of the niches on the circular end of the Ceremonial Plaza. The rough wall of stones was covered by a façade of smooth, finely worked stones. A small modern ceramic pot offering is shown between the two men.

Side trips

Ancient Pukara

If you have about two hours to spare, do not miss Pukara. It is an easy trip of about ⅔ mile from the top of the aqueduct. It lies due north of the Intiwatana, and much of the route to Pukara is via the canal that provides for easy walking. The canal served as an Inca trail. Starting at the north end of the aqueduct, follow the canal trail for about 1,100 feet with an elevation gain of about 150 feet. You will come to near the end of the restored canal where there is a trail leaving the canal route at right angles to the left (westerly). From the trail junction, there is a near horizontal footpath that will lead you right to Pukara where the ancient ruins and terraces will stretch out before you.





An overview of Pukara with ancient terraces still being farmed.

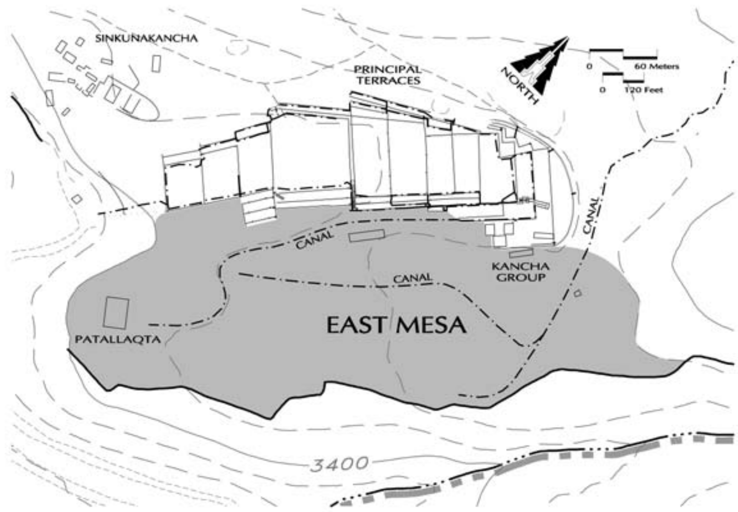
Diagram of the enclave of Pukara showing the location of the outer wall and a number of features to look for as you tour the site.

Some Pukara terraces have been restored, and some are farmed by nearby villagers who live to the north beyond Tipon's outer wall. You may even encounter farmers tending their fields. Take your time at Pukara and look over the fine Inca construction of walls, windows, and niches. You will even see original plaster on some of the walls. The northwest boundary of Pukara is the outer wall of Tipon. Terraces stairstep up the mountain slope to the northeast. Far up on the mountainside, you can see the outer wall where three canals passed through it during the Inca period and likely were used during the Colonial period until they fell into disrepair.

There is a lot to see and appreciate at Pukara, but do not pick up any artifacts or climb on the fragile walls. Pukara is a gem of an archaeological site that still needs to be seriously studied and to have determined its early inhabitants that preceded the Inca empire. Once you have visited Pukara and appreciated the ancient remains of an Inca village that is part of the Tipon Archaeological Park, you will have a better idea of how this self-contained estate for Inca nobility functioned only 14 miles east of the Inca capital of Cusco.

We suggest you return the same way you came in, even though there is a westerly lying trail leading to the Intiwatana area and the outer wall even farther west that parallels the Rio Paroq Mayo.

Pukara walls with niches; the protruding walls have windows that are aligned with each other and finally with a niche on the far left.



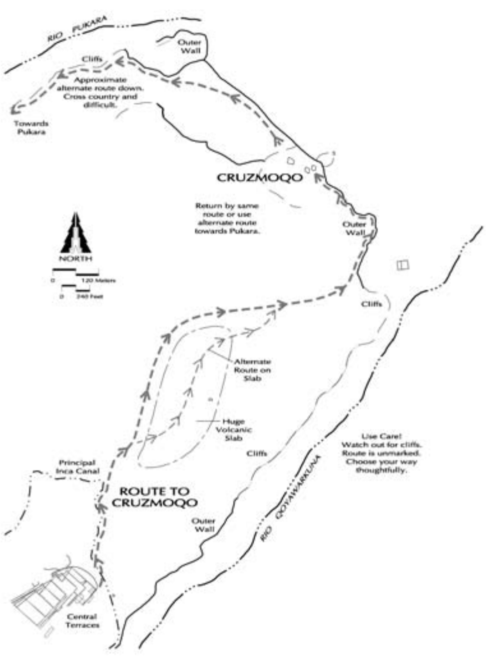
East Mesa/Patallaqta

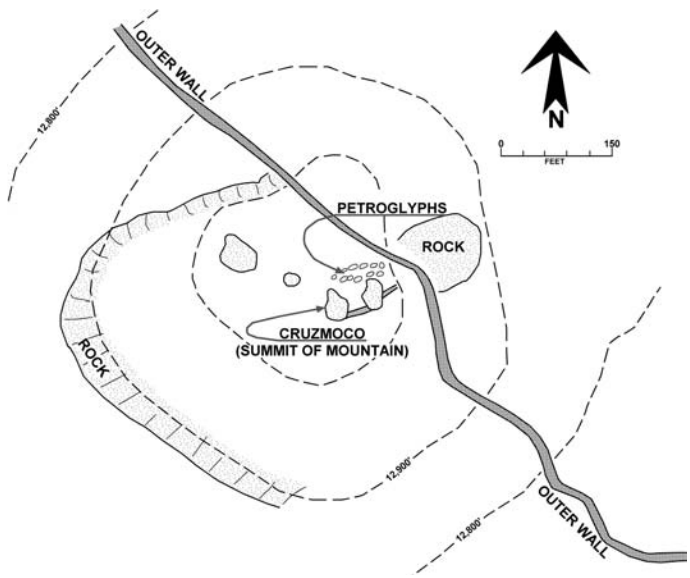
Do not hesitate to take 30 minutes to walk over to the East Mesa and Patallaqta, which lies at the south end of the mesa, a rather flat field about ¼ mile long. Start at the Kancha Group of buildings and head southeast across the mesa top to inspect the remains of the outer wall and to check out the deep canyon on its far side. Then proceed southwest down the mesa slope. As you near Patallaqta, look for the remains of the ancient Inca canal that carried water from the Tipon Spring. For your return, you might try following a portion of the Inca canal that comes from the northwest. Upstream it passes just below the food storehouse that is called Qolcas de Iglesia Raqui. The canal route is on rough slopes, and you may find it preferable to seek an easier walking route once you check out some of the canal remains.

Cruzmoqo

Hiking up to the summit of Tipon Mountain to explore the Cruzmoqo is a special treat. It is for the more adventurous visitors who might want to absorb more than the usual amount of ambiance of ancient Tipon. You will also be entering the pre-Inca world of mystery and unanswered questions.

The Cruzmoqo is special. One distinguished American Andean archaeologist makes it a point to climb up the mountainside to visit the Cruzmoqo on nearly each trip he makes to the Cusco area. If you are serious about Inca and pre-Inca cultures or are spiritually inclined, as well as have good knees and hiking shoes, do not miss it. However, the routes up and down the mountain are remote, so do not travel alone because an injury may leave you stranded and alone without rescue parties standing by.





The Cruzmoqo knob, the highest point on the Tipon Mountain.

Diagram of the 13,000-foot-high Cruzmoqo showing the location of the outer wall and the archaic petroglyphs.

Start at the Kancha Group of buildings at the upper end of the Central Terraces. Have a water bottle and a small lunch. Walk up the hill to the south to just above the elevation of the uppermost terrace wall at the Hornopata and then head northwest to the Inca canal. Follow the canal northerly (left) for the length of a football field to the ancient terraces that step up the hillside. Leave the canal route, walk up the series of terraces for about 1,000 feet with an elevation gain of 250 to 300 feet, and then meander to the right to reach the huge barren rock slab that is easy climbing. Proceed up the slab until near its upper end and then hike northwest, angling over to the outer wall. Once you reach the outer wall, follow it uphill towards the Cruzmoqo along the rather open slopes to the mountain summit. From the Kancha Group to the summit, you will have gained about 1,500 feet of vertical elevation over a distance of nearly 1 mile. Allow 1½ hours for the trip up.

First, upon reaching the summit area, head over to the Cruzmoqo to enjoy the marvelous view down the slope to the Central Terraces, the mesa to the left, and then the expanse of ancient terraces covering the mountainside to the right. One eminent archaeologist considers the Cruzmoqo to be part of the Cusco *ceque* system. The *ceque* system consists of abstract lines radiating from Cusco to hundreds of *huacas* and was part of the sacred landscape of the Inca heartland. Brian Bauer conducted outstanding research and field work, which tells us that this elaborate *ceque* network was maintained by *ayllus* (kinship groups) making offerings to the *huacas* under their jurisdiction, and that the system had social, political, and territorial ramifications. The *ceques* near Tipon start in the San Jeronimo area, not central Cusco. There is still speculation whether or not the Cruzmoqo is part of the system, and additional research is required. In any case, the

Cruzmoqo has also been called a “super *huaca*.” The reason is that there are three, and possibly four, *apus* (holy mountains) in the four cardinal directions from the Cruzmoqo. These are Ausangate to the south, Pachatusan to the east, Mutu to the west, and perhaps Mamasimon to the north. After you have soaked in the view in all directions, go over to the second rock outcrop to the northwest, about 100 feet, checking out the old wall that connects the two. Look for the carved-rock basin, likely used for water for ceremonial purposes at this super *huaca*.

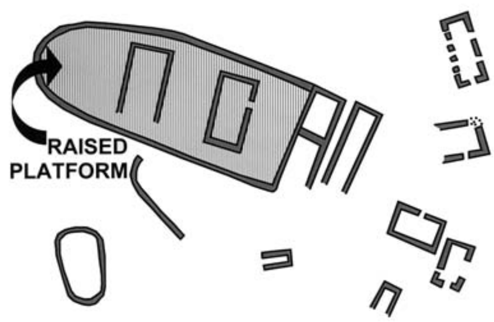
Now it is time for your journey back in time some 4,000 to 5,000 years. Look for the nearby archaic petroglyphs of spirals and arrows carved on rocks to the north. They are numerous and are everywhere you look. Their meaning and interpretation have been lost in antiquity. This was an ancient and important place for early peoples. One can imagine rituals taking place here, but little if any research has been done on this mysterious site.

Note the outer wall remains to the northwest. By this time, you have used about two hours since you left the Kancha Group. For your return trip you have two choices, the way you came up or the Pukara overlook route. If you choose the latter, allow an extra hour. From the summit, walk downslope to the west, noting the two outer walls below you and the large rocks on the summit slope area as you descend. Proceed down the average 25 to 30 percent slope traveling generally due west, but picking your route through the vegetation and later across the hundreds of old terraces. Take your time, but keep heading due west for the most part. After ½ mile and a 1,000 foot elevation drop, you will reach the ancient Inca canal that carried water from the Rio Pukara. At this location you will have a great view of the Pukara enclave, its terraces, and buildings. You also will see the outer wall paralleling the Rio Pukara. Follow the canal to the left (south) back to

The carved-rock basin, likely used for water for ceremonial purposes at this “super *huaca*.”

One of the archaic petroglyphs that may date 4,000 to 5,000 years ago; the meaning of these petroglyphs has not been interpreted.

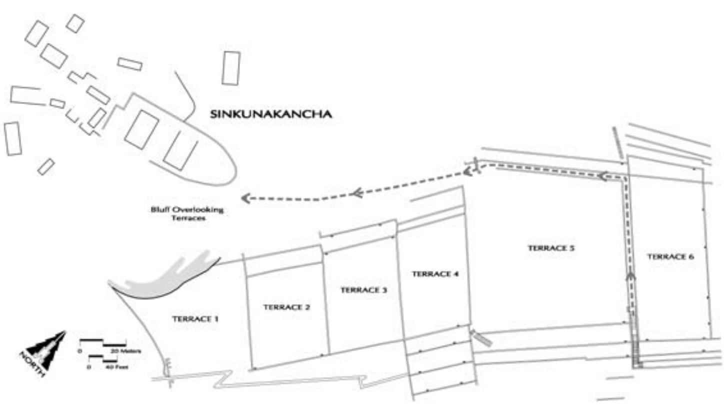
the Intiwatana area. If you miss the Inca canal, just keep heading downhill to the west until you intercept a north-to-south trail that will take you to the Intiwatana. Slopes are steep here; thus, the rock cliffs might mean a detour to one side or another, and vegetation can be an impediment to free and easy hiking. Upon your return from this side trip, you will have joined a select group of Tipon fans that consist of famous archaeologists and serious students of Andean culture.



Sinkunakancha

This complex should not be missed. It is readily accessible from the northwest side of the Central Terraces where Canal B had its route. There are numerous structures there in various stages of disrepair. The highlight of the ruins is the huge, half-oval-shaped platform. While you are there, you might want to speculate just what purpose this structure served during Inca times. Our best estimate is that it was part of the military component of Tipon because of its strategic location overlooking the Tipon entrance area, yet being isolated from the Inca residences and the religious shrines. Now you can pick your way across the lower terraces to return to the parking lot.

We hope that you have enjoyed your walking tour of Tipon.



The Sinkunakancha showing its location at the lower end of Tipon and the large raised platform.

Diagram of Sinkunakancha, which may have been a military complex.

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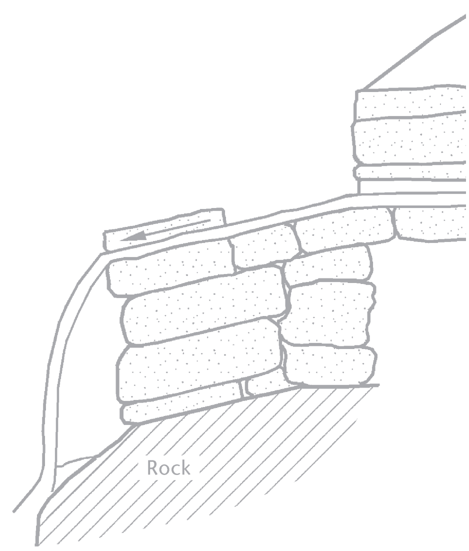

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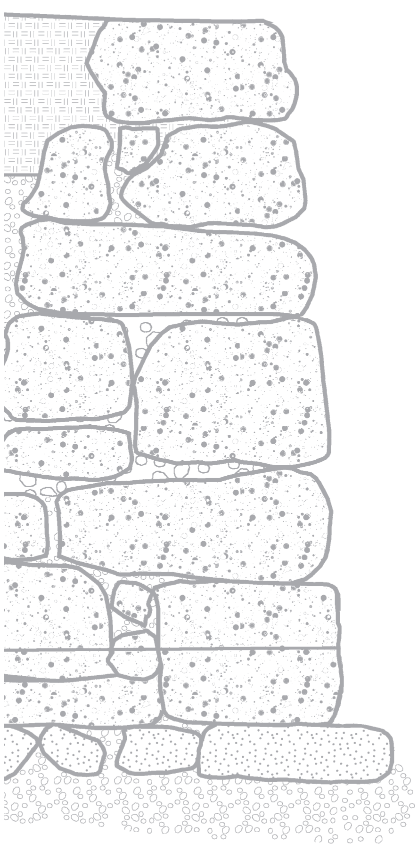

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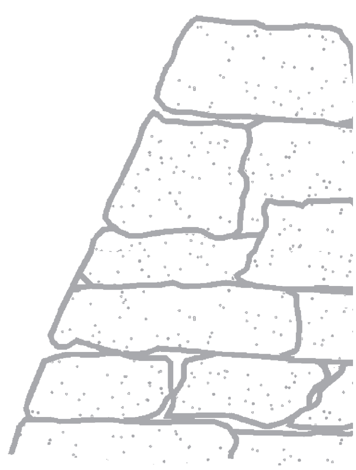

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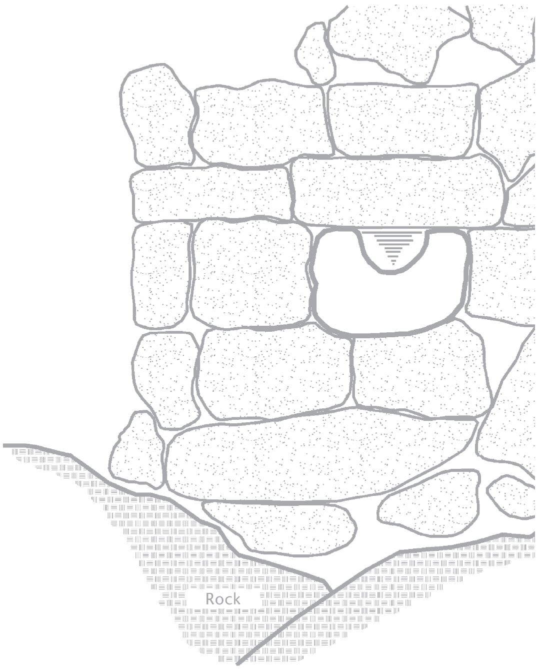

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About the Authors

Kenneth R. Wright, P.E., L.S., Hon. M.ASCE, is founder and chief engineer of Wright Water Engineers, Inc., a Denver consulting firm specializing in water resources and municipal utility design. His interest in ancient civilizations stems from a five-year foreign assignment as a construction engineer with the Arabian American Oil Company in Saudi Arabia. There, he learned to appreciate the engineering work of ancient cultures.

Wright's long-term paleohydrology research at Mesa Verde National Park and Machu Picchu led to his studies at Tipon and, later, at the archaeological site of Moray in Peru. He is a graduate of the University of Wisconsin engineering and business schools, is a registered professional engineer in 12 states, and is active in numerous professional societies.

The Universidad Nacional de Ingeniería (UNI) in Lima, Peru, awarded him an honorary professorship in 2002 for his Machu Picchu engineering research. He received the Distinguished Service Award from the University of Wisconsin School of Engineering that same year and the ASCE History and Heritage Award in 2001 for his original research.

Gordon McEwan, Ph.D., is a professor at Wagner College on Staten Island in New York. As a highly respected Andean scholar, he has led archaeological research projects in Peru over the course of 23 field seasons at Pikillacta and Chokepukio. He received his doctorate in anthropology from the University of Texas in 1984. Dr. McEwan has served as curator at Dumbarton Oaks and at the Denver Art Museum. His current research focuses on the origins of the Inca.

Ruth M. Wright, J.D., is a graduate of Marquette University and the University of Colorado Law School. She served in the Colorado House of Representatives for 14 years, with six years as House Minority Leader. With a major in history and philosophy at Marquette, Dr. Wright understands the value of studying ancient people and their technical prowess. She is an award-winning photographer, with photos appearing in the *National Geographic Magazine* and other publications. She has participated in work on numerous archaeology projects in Peru and in Mesa Verde National Park.

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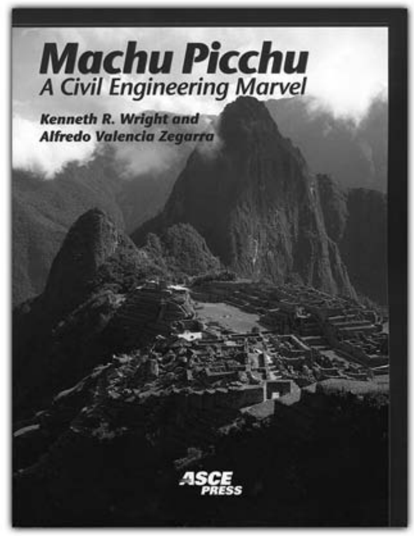
Also by Kenneth R. Wright and Alfredo Valencia Zegarra

Machu Picchu: A Civil Engineering Marvel



This book takes readers inside the Lost City of the Incas for a groundbreaking perspective never before seen by tourists or archeologists. Built high in the Andes on a seemingly impossible site, Machu Picchu stands as a testament to early Native Americans and their ability to plan and build. How was it possible to create a mountaintop city complete with running water, drainage systems, food production, and stone structures so advanced they have endured for over 500 years? Authors Kenneth R. Wright and Alfredo Valencia Zegarra explain these and other mysteries, based on their original engineering and scientific research. A fascinating book, *Machu Picchu: A Civil Engineering Marvel* is a must-have for civil engineers, archeologists, armchair travelers, and tourists alike. An illustrated walking guide and detailed map allow readers to become familiar with each building and pathway, and numerous photographs take readers on a breathtaking pictorial adventure.

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Remarkably, the aqueduct constructed by the Inca civil engineers withstood the ravages of time and climate for well over 500 years following the collapse of the Inca empire.

The rugged countryside at Tipon provided gravity flow challenges to the Inca hydraulic engineers. Aqueducts were common to the Andean people long before the Inca established their empire. Note the opening in the center of the aqueduct that served the dual purpose of passing floodwaters and allowing pedestrians to pass through.

The ancient aqueduct at Tipon, which carries the main canal across a ravine, also serves as an Inca trail. Note the stair-steps in the background.

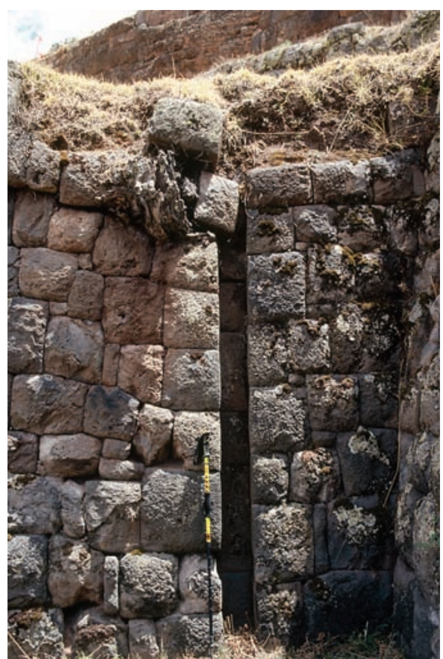
The Tipon aqueduct flood flow and pedestrian opening still serves its original function well because of the high standard of care used by the Inca engineers near the beginning of the 15th century.

The Kancha Group served as the residence for the Inca noblemen and ladies. The stone stairway leading up from the terrace attests to the importance of these buildings.

The Inca stonework standard of care is best represented by the excellent work on windows and doorways. Note the large lintel beam and the fine view of the beautiful terrace walls.

The setting of the Kancha Group is spectacular; it overlooks the Central Terraces while at the same time providing inspiring views of the countryside.

Somehow the stonework of the Kancha Group survived fairly intact over nearly five centuries even though Tipon continued to be used and farmed by local Indians until the 1990s.



Inca hydraulic drop structures are a beauty to behold because of the properly designed hydraulics and the Inca standards for aesthetics and geometric proportions.

Tipon is well known for the flowing water in carefully formed channels and drops. The water here is delivered from the Tipon spring.

This inset unrestored hydraulic drop structure is a testament to the care of the Inca engineers. Ruth Wright's walking stick can be used for estimating the height of the water drop.

This restored Inca fountain has four jets plunging into a pool. Note the use of proportion and geometry by the Inca engineers.

The average visitor to Tipon can experience the joys of walking along ancient canals to inspect the high quality work of the Inca.

The long main canal at Tipon traversed variable topography, curved, and dropped in elevation to carry the much needed water safely to the various places of use. This unrestored Inca canal was well built and well designed to serve its function.

A bifurcation structure divides the Tipon spring water flow so that the water can be routed, at will, to three separate canal systems.

The Inca hydraulic engineers were not adverse to using super-critical flow velocities in their canals. However, they well knew the need for erosion protection and how to manage hydraulic jumps.

Groundwater is collected by a series of underground conduits at the far end and brought to the Tipon spring headworks to create this orderly and handsome water source structure that has flowed with pure water for century after century.

The importance of food storehouses is shown by the strategic setting of this two-story *qolca* above the grand staircase where all could see it. The *qolca* remains in good condition even today.

The stonework of the *qolca* is well laid and permanent, even though its roughness is in stark contrast to the exquisite walls of the Central Terraces.

Strategically situated above the Tipon main entrance and isolated from the Central Terraces, the Sinkunakancha is considered to be an Inca security base. Its oval-shaped platform supported several buildings.

The Central Terraces of Tipon contain the finest terrace walls in all of the Andes. Their many incorporated hydraulic structures provide a joy for all to experience.