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Zhijie Liao

Thermal Springs and Geothermal Energy in the Qinghai-Tibetan Plateau and the Surroundings

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Preface

Geothermal energy is one of the new and alternative energy resources that have not yet rivaled the main energy resources (hydropower, coal, petroleum, natural gas, or even nuclear). Nevertheless, the Earth is a huge heat reservoir with abundant geothermal energy, which has the potential to impact the energy demand of many countries throughout the world. Due to the difficulty in development and the demanding huge investment, the use of geothermal energy has been very slow before the 1970s. The petroleum crisis in early 1970s was one major factor affecting the study and development of the geothermal energy. During that period, many provinces of China began to investigate in large-scale use of geothermal energy and went beyond the balneology of thermal springs. The Geothermal Research Section of Geology Department of Peking University emerged at the time of 1970, when I was fortunate to join this Section. We collaborated with the power system to construct a pilot station of 200 kW using 79 °C hot water. The station has become one of the seven pilot plants on the east of China mainland. But our goals were Larderello, Wairakei and The Geysers. Our Section decided to visit Tengchong volcanic area in Yunnan Province to seek high-temperature geothermal fields from 1973 winter to 1974 spring.

Qinghai-Tibetan (hereinafter called Qingzang) Plateau is a collision zone of continent crust between the Eurasian and Indian plates, where there are many high-temperature areas owing to its unique tectonic setting. How many thermal springs are there in this region? How many high-temperature hydrothermal systems? How high are the temperatures? The answers were unknown before 1970s. To find the answers, the Chinese Academy Science formed Qinghai-Tibetan Plateau Scientific Expedition in 1973, a Geothermal Project Group emerges as that time. Our Geothermal Research Section joined the Expedition in 1975 and became the main force of Geothermal Group.

This book in English is the generalization and summarization of field survey data of Geothermal Project Group of Qinghai-Tibetan Plateau Comprehensive Scientific Expedition of Chinese Academy of Sciences (CAS) from 1973 to 1989. It presents readers rich and various thermal springs distributed over the Qingzang Plateau and its surrounding areas, which are steadily manifesting due to the convergence of the two continental plates. The thermal springs over there are 1684 in total, of which 1380 springs have geochemical data for calculations of temperatures of the reservoirs. The author of this book provides a wealth of data on boiling and hot springs, including their locations, elevations, temperatures, geological data, and the analytical results of water samples, and also tables on warm and tepid springs with low temperatures. The author of this book considers that this research area is the sole high-temperature geothermal belt on Chinese mainland, called Himalayan geothermal belt or Yunnan–Tibetan Geothermal belt. Lastly, this book discusses the relationship between geothermal energy and other energies, and claims that geothermal energy could be an important supplement to the rich hydroelectric resources in the remote southwest China.

The foundation of this book is the following five monographs (in Chinese with English abstract) published over the years by the author of this book and his colleagues.

Wei T, Mingtao Z et al. (1981) Geothermics beneath Xizang (Tibet) Plateau. Science Press, Beijing.

Geothermal Reserch Section of Department of Geology of Peking University (1989) Geothermics in Tengchong, Science Press, Beijing.

Wei T, Mingtao Z compiled, Writers: Guoying G, Zhijie L, Shibin L et al. (1994) Thermal Springs in Hengduan (Traverse) Mountain, Science Press, Beijing.

Zhijie L, Ping Z (1999) Yunnan-Tibet Geothermal Belt—Geothermal Resources and Typical Geothermal Systems, Science Press, Beijing.

Wei T, Zhijie L et al. (2000) Thermal Springs in Tibet, Science Press, Beijing.

These monographs are written based on fieldworks, especially those done by the Geothermal Project Group of Qinghai-Tibet Plateau Comprehensive Scientific Expedition of CAS. This book is the summary and condensation of these monographs. Ever since the Qingzang Expedition ended, during the following over 20 years, the amount of thermal springs in this area has not changed much, but the development of geothermal fields makes a bit headway.

The author of this book thanks our stellar researcher-writers, without whom this book would be a pile of blank pages. The wealth of data in books are taken from field researchers of the Geothermal Group, who overcame plateau reactions and every difficulty. Their outstanding work will always be cherished in my memory. Over the years, the following scientists have participated in the geothermal fieldwork: Wei Tong, Zhifei Zhang, Zhijie Liao, Maozhen You, Meixiang Zhu, Guoying Guo, Minzi Shen, Shibin Liu (the staffs of Geothermal Research Section of Peking University, during 1975–1989), Dexin Wang, Zhiguo Mu and Baoshan Deng (from teacher of Department of Geology and Department of Geography, in 1975 or 1976), Shaonan Dai, Changyi Jiang, Jincai Lu, Fengtong Wang, Xiangmin Wang (in 1975), Baimin Chen, Xiuping Li, Jiapin Tang, Xiaohuan Xi, Shaoping Yang (1976) (more for the high grade students of Department of Geology and Department of Geograph of Peking University), Mingtao Zhang, Changjtn Zhou, Yaxin Zheng (from Commission for Integrated Survey of Natural Resources, CAS), Li Zhu, Shutang Xiao, Shaozhuo Xu, Longlin

Wu, Honglin Song, Xinhua Wang (from Chinese Geology University (Wuhan) during 1973–1974).

Many experts have been working hard in the Plateau for a long time. Though they did not participate in our study tours, they played invaluable roles in the completions of the above monographs. These experts are: Mianping Zheng (from Chinese Academy of Geological Science, Academician of Chinese Academy of Engineering), Dorjee (Academician of Chinese Academy of Engineering), Tingli Liang and others (from Tibet Geothermal Geological Brigade), Dengzhujiacan and others (from Tibet Geothermal Development Company), Fangzhi Wu (from Ministry of Power Industry), Xizhi Jia and Xiyi Jia (from the Second Hydrogeology and Engineering Geology Brigade of Yunnan Geology and Mineral Resources Bureau), Prof. Mei Luo and Prof. Shuyuan Jia (from Chendu GeologY Institute and PLA00933 Troops). They also provided a wealth of information of local thermal springs.

Unfortunate, my colleagues Prof. Wei Tong and Prof. Zhifei Zhang, whose calm guidance in fieldwork and writing made a daunting project possible, and Mr. Shibin Liu, have passed away. Their contributions to Chinese geothermal development would be forever memorized.

Lastly, the author of this book wishes to thank Dr. Yujie Wu, my American friend, who proofread my first draft in English, without his help there would inevitably be many language errors. The author of this book also wishes to thank Ms. Ying Wang and Ms. Haijie Jin, as well as Higher Education Press, for their help to typeset all figures. These works are very difficult for me, an 80 years old man.

Beijing, China Zhijie Liao

The original version of the book was revised: For detailed information please see Erratum. The erratum to the book is available at https://doi.org/10.1007/978-981-10-3485-5_11

Contents

Chapter 1
Classification of Thermal Springs

Abstract This chapter discusses the definition and classification of thermal springs. Based on the boiling temperature of local elevation, the annual mean maximum temperature of the earth and local annual average temperature, thermal springs can be divided into four categories: boiling spring, hot spring, warm spring, and tepid spring.

Keywords Definition of thermal spring · Boiling spring · Hot spring · Warm spring · Tepid spring

One of the largest characteristics of modern active volcanoes is to discharge a large number of thermal springs, which are, however, not limited to the volcanic area. Our ancestors left us large historical documents, where the report of volcanoes was rare, but of thermal springs abundant. These thermal springs reports are far better than those common cold seeps, maybe for the reason that the thermal spring water is hot, and this has the function of disease treatment.

The temperature of thermal springs overflowing on the surface varies dramatically. Some thermal springs give off boiling fog, flying like smoke; some only trickle; some release unbearable stinky smells with the rising heat, while some are so clear, colorless, and tasteless that you can see to the bottom. Despite the differences, thermal springs are all warm groundwater discharged from underneath the ground. But how high the temperature of the groundwater is to count as a thermal spring? And what is the highest temperature that thermal springs at natural emissions can reach? For the first question, the various national standards exist. For example, Germany and Britain's standard says it is higher than 20 °C, while Japanese standard requires it to be higher than 25 °C. Our country's (China's) recent standard sets it to 25 °C. These values are not strictly scientific standard. In fact, as early as 1875 American Gilbert made a scientific definition of thermal spring: A local spring is called a thermal or hot spring if its water temperature is higher than the annual average temperature by 15 °F. In other words, if the temperature of the natural spring water is higher than the annual average temperature of 8.3 °C, then local springs can be counted as thermal springs. This sets the lower

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limit of the temperature of thermal springs. For some countries, topography varies so greatly, that the annual average temperature is different at different regions, and, so the lower limit of the temperature of thermal springs is not the same everywhere. In northern Tibet, the annual average temperature is roughly 0 °C, and so the spring with water temperature only 8–9 °C should be counted as a thermal spring. The annual average temperature in Beijing is 11.6 °C, and so a 20 °C spring can be counted as a thermal spring. In Southern China, Guangdong's annual average temperature is 21 °C, and so the spring water temperature must reach at least 30 °C to be counted as the thermal spring. When a country has a small land area where the terrain change is not dramatic. It can reasonably take a single temperature value as the national standard, but China's territory is huge, and has complex terrain, a united temperature standard for thermal springs is not scientific. As of now with 25 °C being the criterion. A lot of tepid springs (<25 to 10 °C) in the Qingzang Plateau may be excluded from the thermal springs, where as in Guangdong, Hainan and Guangxi, some cold spring (>25 to 30 °C) are counted as thermal springs.

What is the highest degree that the temperature of thermal springs can reach? If you read some information about thermal springs, you will probably see that people have reported varied records. For example, the temperature of the Pingdong thermal spring in Taiwan was as high as 140 °C; the temperature of Big Roll of Liuhuangtang in Tengchong up to 104 °C, and Mt. Tanggula in Tibet has the thermal springs of 100 °C. You may be marveled at these reports, where the temperature of thermal springs is very high! But if you have the basic knowledge of physics, you would think that these reports about the temperature values are wrong. Boiling is basically the gasification phenomenon within liquid, that is to say the water changes from the liquid state into a gas state. Boiling only happens at fixed temperature under a given pressure. This temperature is called the boiling point. The water that reached the boiling point is called saturated water. Under one atmospheric pressure, the boiling point of water is 100 °C. When pressure rises, boiling point will increase and vice versa. On the surface, pressure in each area does not remain the same, as the elevation of a region increases, the atmospheric pressure drops, the boiling point goes lower (Fig. 1.1). In the Tibet Plateau, if the altitude is 4000 m, the boiling point of water is 87.5 °C, when the altitude increased to 5000 m, the boiling point goes down to 85 °C. In the Liuhuangtang of Tengchong County in Yunnan Province, the elevation is 1600 m, and the boiling point is 95 °C. In the conditions where the surface pressure is certain, the water discharged from the underground is saturated water corresponding to the local elevation. Therefore, a thermal spring's temperature is generally not higher than local boiling temperature (Fig. 1.1).

This means that in the Tibet Plateau with its elevation 5000 m, the highest temperature of thermal spring is 85 °C, whereas in the Liuhuangtang of Tengchong with 1600 m elevation, the highest temperature of thermal springs is 95 °C. At these temperatures, thermal springs can be called boiling springs. The discharging of boiling springs is always accompanied by steam around the spring. Such steam is vapor containing saturated water, also known as wet steam. The temperature of wet steam will not exceed the saturation temperature. Someone called boiling spring as

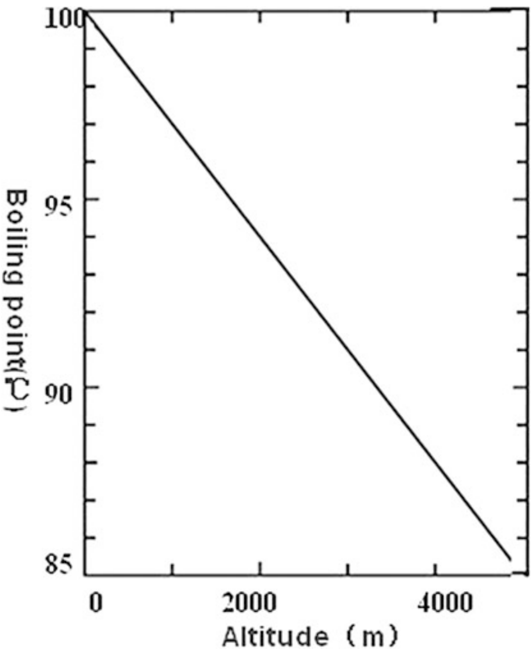

Fig. 1.1 The relation between boiling point and elevation

overheated springs, but that is a misconception. Because the water in boiling spring is not superheated water, but saturated water. Sometimes due to the presence of a large amount of steam, boiling spring temperature may be slightly more than the boiling point, but no more than 1–2 °C. People reported that the hot water temperature in Big Roll Pan of Liuhuangtang in Tengchong Country reaches 104 °C. But that is unbelievable. In 1973, we measured the temperature of Big Roll Pan to be 95 °C, and the temperature of the water 1.5 m deep in a jet of northwest corner of Big Roll Pan to be 96.6 °C, only 1.6 °C higher than the local boiling point. In the same spring area, the measured temperature often varied quite dramatically, the reason is that on the one hand the measuring instrument was alcohol thermometer, which is not very accurate under high temperature; on the other hand, the temperature probe often went deeply down into the internal of springs, the temperature readings thus did not reflect those at the spring outlet. According to the above analysis and investigation, we can say that the minimum temperature of the thermal spring is higher than the annual average temperature of 8 °C. And the highest temperature that a thermal spring can reach should be the boiling point in the local elevation, or at most 1–2 °C higher.

In history, the springs with a temperature higher than the local cold groundwater were called warm springs in China, while in other counties they are called thermal springs. With the advance of science, our understanding of the nature has been gradually deepening and advancing. Therefore, we need to make scientific classification of thermal springs. In the early stage of human history, people's understanding of thermal springs is limited to comparing the spring's temperature with that of the surrounding environment or human's feeling of hotness or coldness. But each individual has a (sometimes very) different sensation of the temperature. For example, some young people are very comfortable to bath in thermal springs at 37 °C, but this temperature would feel quite cold for many senior people. Therefore, the boundaries between warm and hot are not clear and strict.

With the advance of science, people in the field of studying and utilizing thermal springs has noticed three important temperature boundaries: the annual average temperature of the local region, the average annual maximum temperature of the earth (35 °C), and the boiling temperature at the local elevation. When the water is discharged onto the surface of the ground, if its temperature is higher than the annual average temperature of 8 °C and lower than the local earth annual mean maximum temperature of 35 °C, it can be called the tepid springs; if its temperature is higher than 35 °C, and less than 45 °C, it can be called thermal springs or warm springs; The temperature value 45 °C can be used as a boundaries between warm springs and hot springs, because human beings cannot directly bath in a spring where the water temperature is higher than 45 °C. The water of hot spring can be directly sent into people's living facilities or for industrial and agricultural production. The upper limit of hot springs' temperature should be lower than the boiling point of local elevation. If the spring's temperature reached the boiling point, it should be called boiling spring. If boiling spring emits both boiling water and steam, it can be called fumaroles. If there is no spring in an area, but there is steam spurting out from the ground, the area is called steaming ground. Boiling springs, fumaroles, and steaming ground are all high-temperature hydrothermal activity areas with two-phase manifestations, and they often have many impressive geothermal landscapes.

Chapter 2
Thermal Springs in China

Abstract This chapter introduces the quantity and distribution of thermal springs in China, Based on the investigation of whole country in 1970s, the total number of thermal springs of whole nation was 3398, including Taiwan Province 94. The most concentrated region of thermal spring is Yunnan and Tibet in the first, Fujian and Guangdong second. The biggest distribution density is Taiwan. The boiling spring only emerges in Tibet, west Sichuan, Southwest Yunnan, and Taiwan, Qinghai is only one.

Keywords Quantity of thermal spring · Distribution of thermal spring · Concentrated region

How many thermal springs are there in China? Prior to 1970 it is unclear. The most senior Chinese geologist Hongzhao Zhang wrote a booklet "Compilation of Chinese Thermal Springs" in 1956 (Zhang 1956). This booklet records approximately 972 thermal springs. In 1970s, most of the provinces or autonomous regions made geothermal reconnaissance survey. Meanwhile, the Qinghai–Tibet Plateau Comprehensive Scientific Expedition of Chinese Academic of Science (its geothermal group's main members: Geothermal Research Section of Department of Geology of Peking University), and the PLA 00933 Troops in the Qingzang Plateau and Hengduan Mountains (West Sichuan and southwest Yunnan) have done geothermal study, found only in this region the number of thermal springs reached 1600. The estimate of the total thermal springs of whole country could be between 2500 and 3000. The statistical number of thermal spring of whole nation was 3398, including Taiwan Province 94 by Geothermal Professional Committee of China Energy Research Society in 1986.

According to present irrefutable data, the most concentrated region of thermal springs is Yunnan Province and Xizang (Tibet) Autonomous Region in the first place, Guangdong Province and Fujian Province second. But according to density of distribution of thermal springs, Taiwan is first.

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The real number of thermal spring in Tibet is 645, in which Ngari Prefecture has 88, Xigaze 117, Lhasa City 34, Nagqu Prefecture 187, Shangnan Prefecture 44, Nyingchi Prefecture 49 and Qamdo Prefecture 126. From the geological structure, they are mainly distributed in both north and south sides of Yarlung Zangbo suture, from where go northward into the Chang Tang plateau, and southward across the Himalayas, the number of thermal springs immediately reduce. In the Tibetan plateau, the average altitude is over 4000 m, the boiling point is very low, at around 86 °C. Where the annual average temperature is at 0 °C. According to the definition of science, the temperature of spring reaching 8 °C can be called thermal springs at Tibet Plateau, The number of boiling spring (>86 °C) has 48 in Tibet; accounting for 7.5% of the total thermal spring; hot springs (<86 to 45 °C) area has 179, making up 27.8% of the total thermal spring; warm spring(<45 to 35 °C) area is 294, amount to 45.1% of the total thermal spring; tepid spring (<35 to 8 °C) area is 127, accounting for 19.7% of total number of hot springs. Tibet's boiling spring mainly exposed in the vicinity of the Yarlung Zangbo suture, so Xigaze Prefecture is at most, up to 21, followed by Ngari Prefecture, reaching 10, Shangnan Prefecture 7, Lhasa City 6 and each 2 for Nyingchi Prefecture and Nagqu Prefecture. Hot springs of 51 appear in Nagqu Prefecture being the most, Xigaze Prefecture followed for 34, Qamdo Prefecture has 27, Nyingchi Prefecture has 20, Ngari Prefecture 19, Shangnan Prefecture 16, and Lhasa City 12. Warm springs are concentrated in Nagqu Prefecture (98) and Qamdo Prefecture (64), where there is the upstream of the three rivers (Nujiang river, Lancangjia ng river and Jinshajiang river). The springs here account for 55.9% of all warm springs in Tibet Autonomous Region. In addition there are more warm springs. Xigaze (49) and Ngali Prefecture (35). Tepid spring at are mostly found in Nagqu Prefecture (36) and Qamdo Prefecture (35) (Tong et al. 1981, 2000).

Qinghai–Tibet Plateau Comprehensive Scientific Expedition of Chinese Academy of Sciences in Tibet has inspected the 354 thermal springs and samplings and analysis were done from 1973 to 1976. Most of boiling springs found in Tibet discharge sodium chloride type of water that is also boron rich. Some boiling springs discharge Cl–HCO_3–Na type water or HCO_3–Cl–Na type water due to blending of different degrees of cold water. Thermal springs in Tibet are high in salinity regardless the temperature level, however, with the increase in bicarbonate component, their TDS values will decline.

Yunnan Province is the largest province in terms of number of thermal springs in China. The number of springs with temperature >25 °C reached 862 in Yunnan. Among these springs, 20 are boiling springs, 314 hot springs, 208 worm springs, 321 tepid spring. The 20 boiling springs in Yunnan Province all appear in the south Yunnan and the west Yunnan to the southwest of the Red River fault zone, where Lincang City has 6, Baoshan City 4, Dehong Dai and Jingpo Autonomous Prefecture 4, Xishuangbanna Dai Autonomous Prefecture 3, the Puer City, the Dali Bai Autonomous Prefecture and Honghe Hani and Dai Prefecture each 1. In the 20 boiling springs, only Rehai (Hot Sea) Geothermal field of Tengchong County discharges sodium chloride type of water, the rest discharge sodium bicarbonate type of water. But all these high temperature boiling springs have high F content but low B content. For relatively lower temperature hot springs and warm springs, especially tepid springs, their water chemistry type is basically HCO_3–Ca or HCO_3–Mg type. TDS value of Yunnan Springs are very low, Except the Rehai (Hot Sea) geothermal field of Tengchong County is higher than 1 g/L, but all of them are <1 g/L. The rest thermal spring is also no exception. In other words, Yunnan's thermal spring except Tengchong's Rehai Geothermal field, their discharging thermal water all discharge freshwater (Tong et al. 1989, 1994).

The western Sichuan (including Garze Tibetan Autonomous Prefecture, Aba Tibet and Qiang Autonomous Prefecture, Liangshan Yi Autonomous Prefecture and Pangzhihua City), in fact, is the eastern part of Qingzang Plateau, where there are 290 thermal springs. The thermal springs of western Sichuan mainly (70% and high temperature spas) are distributed in Ganzi Tibetan Autonomous Prefecture, which has 205, including 7 boiling springs. Aba Tibetan and Qiang Autonomous Prefecture has only 20 thermal springs, including 14 tepid springs. But there is one boiling spring in Aba County, where altitude is 4500 m and temperature is 85 °C. The chemical type of boiling spring water in western Sichuan mainly is HCO_3–Na type, except Yulinhe of Tardo County, which is Cl–HCO_3–Na type. There are 55 thermal springs in Liangshan Yi Autonomous Prefecture, where the highest temperature is 75 °C in Nanhua County (Tong et al. 1994).

Qinghai Province is located in the northern part of Qingzang Plateau. In total, 52 thermal springs are found in this province (Huang 1993). Among these springs, 4 have temperature >80 °C, 6 at 61–79 °C, 10 at 41–60 °C, and up to 29 at 20–40 °C. The temperature of 9 mineral springs is <20 °C, the temperature of remaining 3 springs is unknown. Among the 4 springs with temperature higher than 80 °C, Reshuigou of Guide County has the highest temperature, reaching 93.5 °C. The most special is a boiling spring located on the east slop of Bouguer Daban peak (6860 m) of Kunlun Mountains. The temperature of this spring is higher than 85 °C, and the boiling water gushed from till before valley glacier tongue. The salinity of this boiling spring's water is very low, thus, it could be steam-heated fresh water.

Southeast coastal provinces are another area of concentrated distribution of thermal springs. Both Guangdong and Fujian provinces take precedence in the number of thermal springs, but Taiwan get ahead in the distribution density of thermal springs.

Guangdong Province has 257 thermal springs (>25), sixteen of which are >80 °C, only making up 6% of the total number of thermal springs. The temperatures of the bulk of thermal springs in Guangdong are between 40 and 80 °C, accounting for 70%. There are no boiling springs in this province. The highest temperature of springs is 97 °C in Hengganzi of Yangjiang County near the seashore (Chen et al. 1994).

Hainan Province has 30 thermal springs, two of which are >80 °C, amounting to 6.7% of the total number. They are Qishenling hot spring (94 °C) in Baoting County and Lanyang Farm (82 °C) in Danzhou City. The temperatures of 25 thermal springs are between 40 and 79 °C, making up 83% of the total number.

Thermal springs (>25 °C) in Fujian Province emerge in 184 sites, eight of which are >80 °C, accounting for 4% of the total. The highest temperature is 89 °C in Nancheng of Dehua County. The temperatures of 70% thermal springs in Fujian are between 40 and 80 °C. And the temperatures of a quarter of thermal springs are less than 40 °C (Zhuang 2010).

The distributions of thermal springs in both Guangdong and Fujian are determined by geological structures, mainly in the intersect point of pressure faults of the North-East trending with the tension fault of the North-West treading. The chemistry type of water in these springs is mainly bicarbonate type, but those at seashore has are sodium chloride type owing to the contamination of sea water.

Taiwan Province has the highest distribution density of thermal spring in China. The number of thermal springs per unit area is up to 35.6. The total number of springs is between 80 and 100. Spring water temperatures fall into the following two intervals 38−70 and 84–99 °C. The boiling springs are mainly located in Taiwan northernmost Datun volcanic area, Guishan Island in Yilan County and the deep fault zones of east side of the Central Mountain Range. The springs of Datun volcanic region discharge sodium chloride–sulfur type of water, while the boiling springs along the deep fault belts discharge sodium bicarbonate type of water (Chen 1989).

Hunan is another province where the number of thermal springs is over 100, reached 138. The spring temperatures are most between 40 and 60 °C. Only two springs have temperatures exceeding 80 °C.

In eastern China, thermal springs are mostly distributed in the provinces: Jiangxi (94), Liaoning (47), Hubei (44) and Hebei (37). This is not a complete list.

The eastern part of China has vast great plains, such as the North China plain, the Northeast plain, Jianghuai plains, and Jianghan plain and Wei-Fen graben, although no springs are exposed on the ground, but there is rich underground hot water. A lot of geothermal wells have been drilled since 1970s, and they can be actually counted as artificial hot springs.

Table 2.1 is the statistics of thermal springs and geothermal wells in municipality (which are directly under the central government), provinces, and autonomous regions (Wen et al. 2010).

Table 2.1 shows that the total of the thermal springs is 3089 in the whole country, Tibet Autonomous Region takes 20.9%. Yunnan Province takes 27.9%, western Sichuan (290) 9.4%, Qinghai Province 1.4%. That is, the thermal springs in Qinghai–Tibet (hereinafter called Qingzang) Plateau and its surrounding account for 60% of the total number of thermal springs. And boiling springs are only found

Table. 2.1 The statistics of thermal springs and geothermal wells

City, Province, Autonm., Region	Num. springs	Area 10^4 km^2	Num./ 10^4 km^2	Num. Wells	City, Province, Autonm., Region	Num. Springs	Area 10^4 km^2	Num./ 10^4 km^2	Num. Wells
Beijing	3	1.7	1.76	300	Tianjin	0	1.2		251
Hebei	25	19	1.32	200	Shanxi	7	16	0.44	220
N.M.G	6	118	0.05	1	Liaoning	36	15	2.4	10
Jilin	6	19	0.32	5	Heilongj.	0	46		18
Jiangsu	5	10	0.5		Shanghai	0			
Zhejiang	6	10	0.6		Anhui	18	14	1.29	
Fujian	172	12	14.33	94	Jiangxi	82	17	4.82	22
Shandong	17	16	1.06	100	Henan	23	17	1.35	300
Hubei	53	19	2.79		Hunan	130	21	6.19	76
Guangdong	282	18	15.67	15	Guangxi	35	24	1.86	10
Hainan	35	3.4	10.29	60	Sichuan*	305	57.2	5.53	3
Guizhou	72	18	4.0	40	Yunnan	862	39	22.10	230
Tibet	645*	123	5.24	60	Shanxi	14	21	0.67	186
Gansu	14	43	0.33	3	Qinghai	44	72	0.61	10
Ningxia	2	6.6	0.32	2	Xinjiang	62	166	0.37	8
Hong Kong	0				Macao	0			
Taiwan	128	3.6	35.56	15	Total	3089			2239

Statistics data in 2010. *Data of Tibetan thermal springs are taken from “Thermal Springs in Tibet” (Tong et al. 2000), and the data* of Sichuan include Chongqing’s data (Wen et al. 2010; Liao 2012)

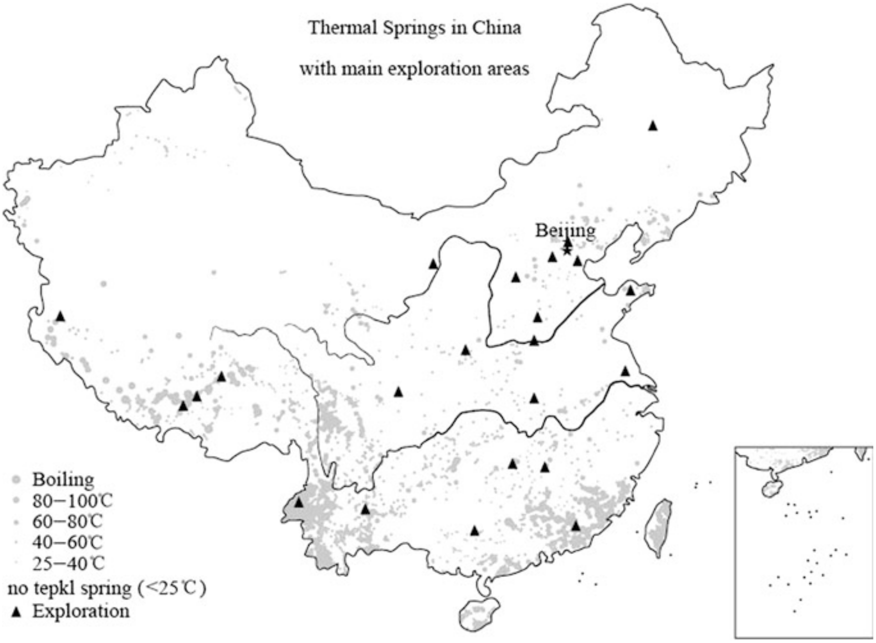

Fig. 2.1 The distribution of thermal springs in China (after Tian et al. 2006; with a bit of alteration)

in this area. Chinese southeast region has higher density of the thermal springs, Guangdong takes 9.1%, Fujian 5.56%, Hunan 4.2%, and Taiwan 4.15%, and Jiangxi 2.7%, and the sum over all these provinces is 25.7%. The remaining 24 provinces and autonomous regions account for only 14% (Fig. 2.1).

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Chapter 3
Geological Setting

Abstract This chapter analyses the geological setting of appearance of thermal springs in different provinces in China. High-temperature geothermal regions emerge on the margin of plate tectonic. Qinghai–Tibetan Plateau is a collision of continental crusts between Eurasian and Indian Plates. Taiwan is located in the Pacific Ring of Fire. Fujian and Guangdong are closed the margin of east edge of Eurasian Plate, but is not on the island arc of west pacific ocean, where is a shovel-like fracture system dip to east and short of boiling springs.

Keywords Geological setting · Collision belt of continental crusts · Island arc · Shovel-like fracture

In China, the Qingzang Plateau and its surrounding areas for about 2.5 M km^2 have 60% of the total of thermal springs, and the southeast coast for about 0.54 M km^2 distributed 23% of the total of thermal springs, while the remaining 6.6 M km^2 distributed only 17% of the total of thermal springs. Such a pattern is obviously affected by China's geological structure.

According to the theory of plate tectonics, China is located in the southeast edge of the Eurasian Plate. Adjacent to the east side of Chinese mainland is the Philippine Micro Plate of the Pacific Plate and the southern part of Qingzang Plateau is a collision zone between the Indian Plate and Eurasian Plate. Logically it should appear two high-temperature geothermal belts to the southeast and southwest of China. But, the reality is not so.

Qingzang Plateau is a continental crust–continental crust collision zone, its development has gone through a long process. The beginning of the Eocene epoch, which is between 60 and 45 Ma, is the "soft collision" period, during which the northern oceanic crust of the Indian plate subduct to underneath the Eurasian plate, and its northward drift velocity then dropped from 17 cm/a down to 10 cm/a. After 45 Ma, the Indian plate began to migrate northward. And this is the "hard collision" phase, and the speed was further down to 6 cm/a. The oceanic crust of northern part of the Indian plate slowly disappears in the process (Lee and Lawver 1995; Aitchison and Davis 2001).

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During the late Paleogene epoch (about 37–30 Ma), the collision of continental crusts between the Indian and Eurasian Plates occurred, forming the Yarlung Zangbo Collision Zone and making the oceanic crust disappear. Further convergence in the Neogene led to the development of the Himalayan Thrust Zone to the south, with shortening in a "thin-skinned" tectonic system. There are three major thrusts from south to north: the Main Boundary Thrust (MBT), or the Main Central Thrust (MCT) or Main Himalaya Thrust (MHT), and the Main North Thrust (MNT) or Kangmar Thrust (KT). The Main Boundary Thrust and the Main Central Thrust appear to the south of the watershed of the Himalayan Mountain in Nepal, Bhutan and India (Tapponnier et al. 1981; Allegre et al. 1984; Wan 2004).

The main thrust planes of Himalayan Thrust Zone all dip to the north at low or intermediate angles. With the hanging wall over thrust toward the south, the thrusting took place between 23.5 and 16.8 Ma during the early Himalayan orogenic period.

Based on the results of INDEPTH project, the deep seismic profiling across the Main Himalayan Thrust Zone makes it clear that the footwall of the thrust zone has been subducted northwards for more than 200 km, reaching a depth of 15 km. At the deepest level the fault plane dips to the north at only 5°, and the depth of Mohorovicic Discontinuity is around 23 km, and a zone of partial melting is recognized beneath the Yarlung Zangbo Suture, where the thickness of crust increases to 60–74 km (Zeng et al. 1995; Zhao et al. 1997; Teng et al. 2003).

Deformation in the Himalayan Stage (23–0.78 Ma) produced a large-scale, thin-skinned thrust zone in western China. The western margin of this system is formed by the Altun sinistral strike-slip fault and the eastern margin lies in the Daxueshan–Xiaojiang Foothills, along a dextral strike-slip and a normal fault zone. Within this area a series of WNW trending fault form imbricate thrust system, such as the Bangongco-Nujiang thrust, the Kongela-Wenquan-Tanggula thrust, the Jinshajiang-Honghe thrust, the Central Kunlun thrust, up to the northern margin of the North Qilianshan thrust. This thin-skinned tectonic system, with a displacement of ten to hundreds of kilometers, was developed mainly in the upper crust, with a major detachment at a depth of 30 km along the low velocity layer in the low crust (Fig. 3.1) (Burchfied et al. 1989, 1992; Royden and Burchfied 1997).

The Qingzang thin-skinned tectonic system developed in the tectonic stress field was caused by the northeastwards subduction and compression by the Indian Plate, making use of preexisting faults.

The deformation of the Qingzang Plateau was three dimensional. There was a large-scale shortening from the end of the Neogene epoch, and in the Early Pleistocene epoch there was vertical thickening, with uplift of the ground surface and E-W extension, especially during the past 3 Ma (Ma et al. 1998).

Crustal shortening was accompanied magmatism: there was intraplate potassium-rich volcanic rocks and muscovite granites formed by crustal remelting, which gives isotopic ages younger than 20 Ma (BGMRXAR 1993).

In the Qingzang Plateau, as a result of main compressive stress with the north-south trending appeared, the E-W extension of Tibetan crust began and many

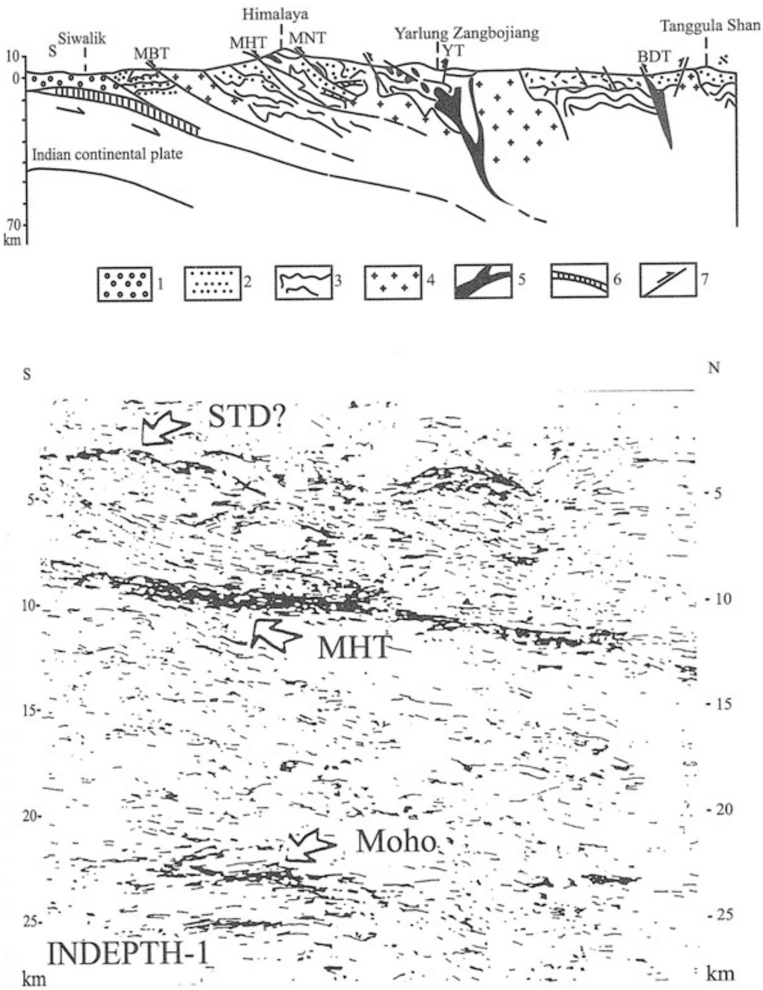

Fig. 3.1 Geological section and INDEPTH seismic profile across the Himalayan Collision Zone (after Zhao et al. 1993, 1997; Wan 2004). **Upper section**: *1* Cenozoic molasse formation; *2* sedimentary cover; *3* crystalline basement; *4* granite; *5* ultra-mafic rocks; *6* subduction zone; *7* thrust zone; *MBT* main boundary thrust; *MHT* main Himalayan thrust; *MNT* main northern thrust; *YT* Yarlun Zangbo fault zone; *BDT* Bangonghu-Dengqen thrust. **Lower Section**: *MHT* main Himalayan thrust; *Moho* mohorovicic siscontinuity, *STD* south Tibet detachment (Zhao et al. 1993, 1997)

north-south grabens took shape in the Neogene. The molten material intruded upwardly into some places of graben and its surrounding, which became the heat source of some high-temperature hydrothermal systems in the vicinity of the Yarlung Zangbo Suture. Most of these high-temperature hydrothermal systems are located in the N-S graben (Fig. 3.2).

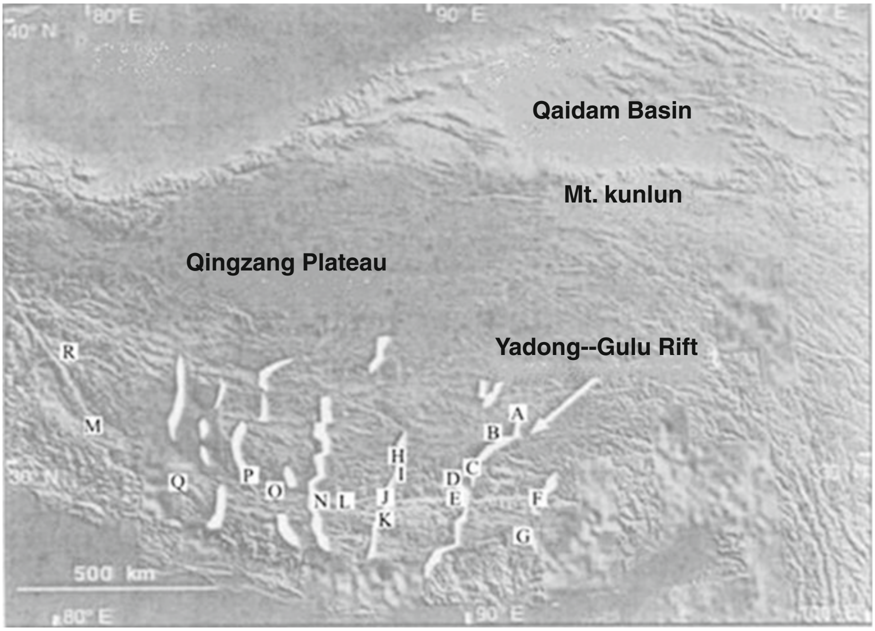

Fig. 3.2 Main rifts of Neogene-Pleistocene in Qingzang Plateau (Zhao and Zhang 2002) and main geothermal areas. *A* Golug; *B* Qucain; *C* Yangbajain; *D* Yangyi; *E* Xumai; *F* Chabmaise; *G* Gobdu; *H* Capu; *I* Qangbugqabka; *J* Lhawangze; *K* Kawu; *L* Buloba; *N* Samig; *O* Daggyai; *P* Ruggog; *Q* Qucain Lungba; *M* Sogdoi; *R* Largju

Due to the mosaic, collision, and subduction between the Indian plate and Eurasian plates, southern Tibet has experienced a very complex tectonic evolution, especially the subduction of Indian plate are still undergoing. Heat flow measurements have discovered that: the fluctuations of heat flow value in the south of the Yarlung Zangbo suture (Himalayan Tethys belt) are between 66 and 106 mW/m^2, in the north of the suture (Gangdise belt) are between 106 and 364 mW/m^2. That indicates the differences between the two thermo-physical mechanisms. The former is the result of heating of tectonic movement, while the latter is that the heat background of tectonic superimposed effect of partial melting or semi-molten magma chambers. At Gangdise belt, the researchers of INDEPTH found many deep reflection highlights in the depth of 15 km, which could belong to the crust remelting type of magma source region. And they also found locally pear-shaped shallow high-conductor in the depth of more than 10 km, which could be molten or semi-molten state magma chamber of late tectonic intrusion. The magmatism at continental crust–continent crustal collision zone is a special type, which is different from island arc and also from the hot and expansion centers. It should be relatively small size and new type.

Although east China is located in eastern edge of the Eurasian plate, but the Chinese mainland is not in direct contact with the Pacific Plate. In the northeast China, the edge of the Eurasian plate is the Japanese island arc. The gap between the Japanese island arc and Asia mainland is Japan Sea. In the central China, the Pacific Plate is adjacent to the Ryukyu island arc, in the west of which is the East China Sea basin. In the southern China, South China Sea basin is between Hainan Province and Philippines. These marginal seas have been interpreted as back-arc basins, forming part of the western Pacific trench-arc-basin system (Uyeda 1977). In this model, all the components of the parallel trench-arc-basin system were formed at the same time. In fact, they are not the product of the same period, the Japan-Ryukyu–Taiwan–Philippine island arc-trench system was formed at a latter epoch in the Paleogene Period (40–30 Ma), the rifting of Japan Sea was in late Miocene and the expansion of the South China Sea was in the Oligocene (32–20 Ma). Therefore, there is no relationship between the expansion of the Japan Sea and the South China Sea and the formation mechanism of the arc-trench system (Wan 2004).

Japanese island arc, Ryukyu arc (the Taipei area is at its western end), and Luzon arc have a strong geothermal activities, which are closely related to a strong volcanic activities and magmatic activities. Therefore, it is not surprising that the Japanese archipelago, the Philippines, Indonesia, and Taiwan of China are rich in high-temperature geothermal resources.

In the east of China mainland, a great number of thermal springs emerge in Guangdong and Fujian provinces. Both their temperature and the flow rates are high. But high-temperature hydrothermal system with magmatic heat source has not been found. This is also determined by the local geological structure. Taiwan is the connection point between the Ryukyu and Luzon arcs. Taiwan is also the contact belt of the Eurasian Plate and the Philippine Sea plate (Fig. 3.3). Philippine Sea plate is a small plate on the west side of the huge Pacific plate. Hall and Blundell (1995) pointed out that during the Neogene epoch the Philippine Sea Plate moved northwards at a rate of 8 cm/a. From 30 to 15 Ma the eastern basin extended E-W at a rate of 2.8 cm/year, to form the Shikoka and Parece Basins, to the south of the Japanese Islands. In the late Neogene and the Early Pleistocene (4–2 Ma), the Philippine Sea Plate was subducted to the north along the Ryukyu Trench and the Nankai Trough, at a rate of 4 cm/year. Taking Taiwan's Hualien as a boundary, on its north, the Philippine Sea Plate with 45° dip angle to the northwest along the Ryukyu Trench subducted below the Ryukyu island arc during the period from the late Neogene to Pleistocene (4–2 Ma), when the submerged depth of slab reached 150 km, the volcanoes appear above the arc, such as Okinawa, Datun, Keelung, and so on. In the south of Taiwan's Taidong, there is an eastward tilt Benioff zone with dip angle of 55°–60°, between 21°N and 22°N, the submerged depth reached 180 km, and it became shallow northwards; at 23°N the Benioff zone disappears.

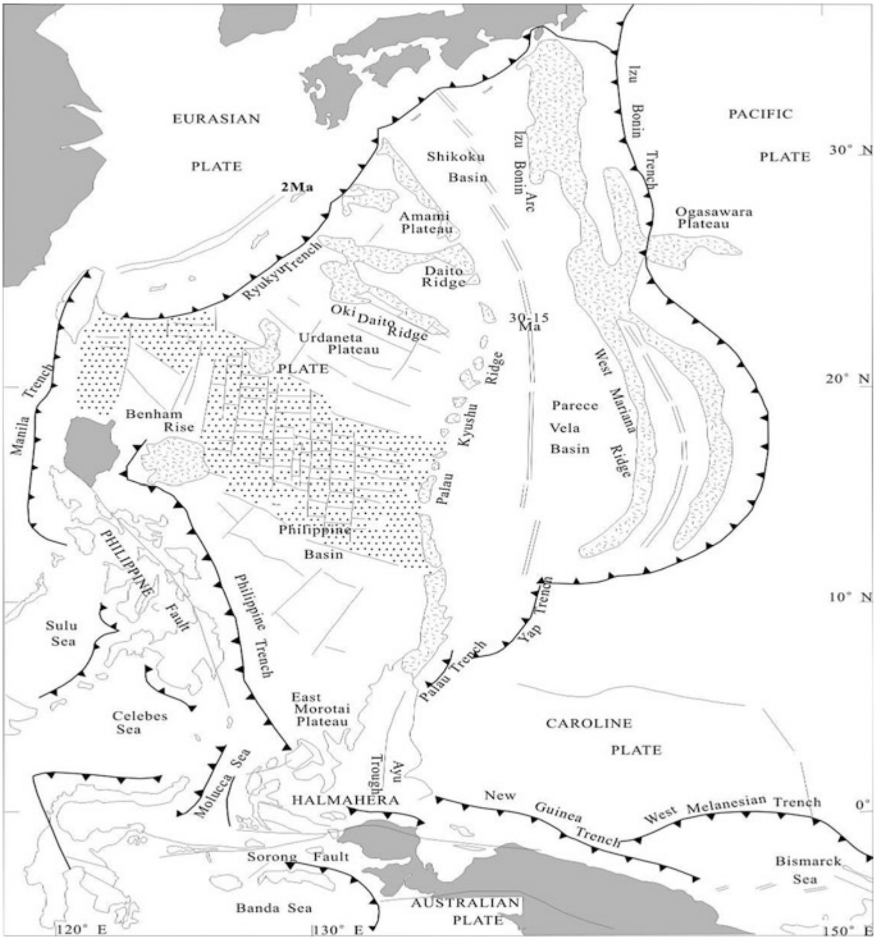

Fig. 3.3 Geotectonic between the eastern edge of Eurasian Plate and Philippine Plate (Hall and Blundell 1995)

At the south of Taiwan, the Eurasian plate along with the early Cenozoic opened Southern China Sea Basin from Manila Trench subducted beneath the Philippine Sea Plate. The andesite at Green Island, and Orchid Island is a northward extension of the Luzon volcanic arc, but they was extruded at Neogene age older than Luzon Islands volcanic rocks. Thus convergent is from north to south development. In the Neogene, between 14 and 2.6 Ma, the west Philippine–Batan–Babuyan—East Taiwan longitudinal valley fault zone changed to a normal fault with sinistral strick-slip, which is the boundary between Eurasian Plate and Philippine Sea Plate. The Taiwan Island suffers strong squeeze from the Philippine Sea Plate westwards, leading to frequent earthquakes over there. This force goes westwards across the Taiwan Strait and affects Fujian. From east to west, seismic intensity goes weaker, and the number of earthquake decreases. Compared with the number of earthquakes in Taiwan, the number in Fujian is less by one order of magnitude. The energy released by earthquakes in Fujian is only one ten thousandth of that in Taiwan. All earthquakes in Fujian-Taiwan region are located on a gently eastwards inclined plane with a dip 4°–10°, Wan and Chu (1987) called it as Fujian-Taiwan shovel-like fracture systems. Because Fujian is not the obduction plate at ocean-continental convergence region, massive calc-alkaline magmatism is impossible, and therefore high-temperature hydrothermal system with a magmatic heat source can not form (Fig. 3.4) (Liao 2012).

In Eastern China, high-temperature hydrothermal system with magmatic heat source could be discovered in Changbai Mountain of Jilin Province. Tianchi volcano as the center of the Changbai Mountain volcanic region occupied about 30,000 km^2, the volcanic rocks spouted out in the Tumen River–Hunchun graben. Spouting began in the Miocene period. The dominant rock is basalt. The trachyte and alkaline rhyolite at Tianchi volcano have only a very small percentage. It is the product of a mantle basalt contaminated by crustal material in crustal magma chambers. Basaltic magma coming from mantle arises because the oceanic crust of Pacific Plate along the Japan Trench subducts westwards under the Japan island arc, resulting in a deep earthquakes in the vicinity of the volcanoes, but also makes the molten mantle material again, and then the eruption occurs in extension system of arc-back (Figs. 3.5 and 3.6).

It should be mentioned that some high-temperature hydrothermal systems may not have magma heat source, but they are distributed in the vicinity of deep faults, geothermal fluid along the fault goes through the deep circulation. For example, Qingshui and Tuchang of Yilan County of Taiwan, they are distributed along Suao-Beidawu Mountain fault zone. Qingshui's first geothermal hole is 2200 m deep, and the temperature at the bottom is of 205 °C. The discharged geothermal fluid is HCO_3–Na type of water, not Cl–Na type volcano water. Western Yunnan have even more of this type of springs, The Ruili geothermal field of Yunnan Province is one example, its appearance obviously was controlled by Longlin–Ruili fracture zone. The waters in both Peacock Springs and the one thousand meters deep hole in Ruili County are of the HCO_3–Na type.

According to the geological setting of spring's formation in China, 60% spas appear in the southwest China, namely the Tibetan Plateau and its surroundings. The second is in the southeast coast, accounting for 23% of the total. But high-temperature hydrothermal systems can produce secondary energy, especially those with magmatic heat source systems, which are mainly in Tibet, western Yunnan, western Sichuan and Taiwan, and some may also be in the Changbai Mountain. The deep cycle high-temperature systems mainly emerge in Yunnan and western Sichuan. Guangdong and Fujian could also have a small amount.

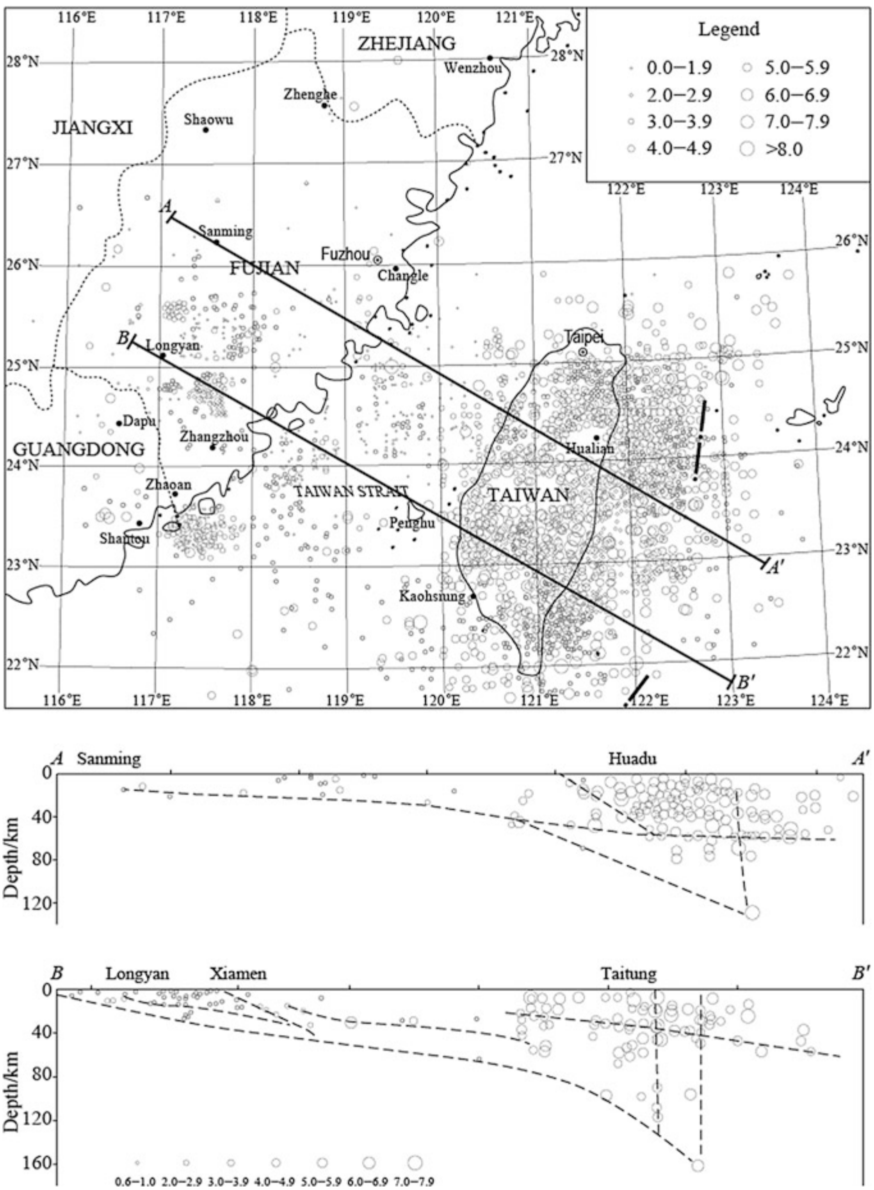

Fig. 3.4 Plans and sections (1067–1982) of seismic source distribution in Fujian and Taiwan (after Wan and Chu 1987, Wan 2004; Liao 2012)

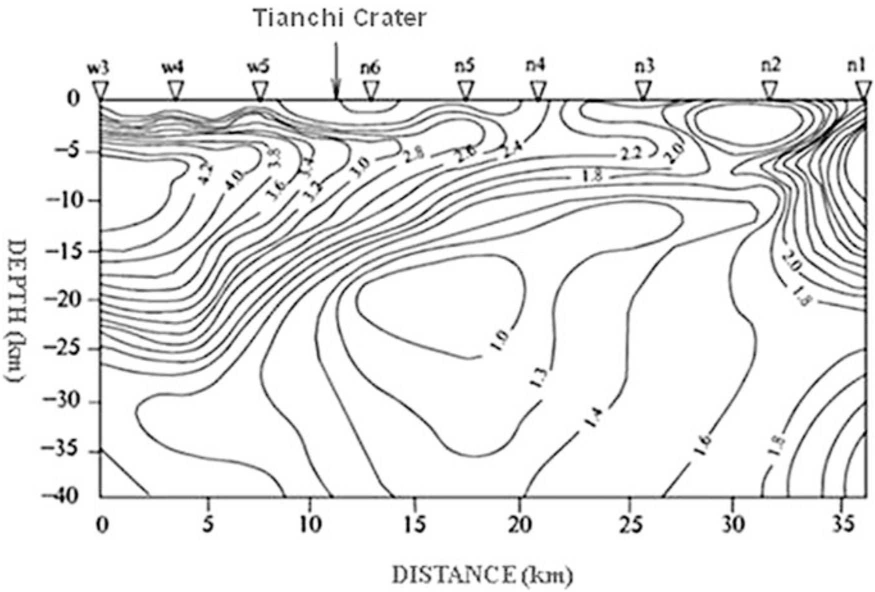

Fig. 3.5 The two-dimensional inversion of the measured MT section with NNE trend across Tianchi volcano of Mt. Changbaishan (Tang et al. 1998)

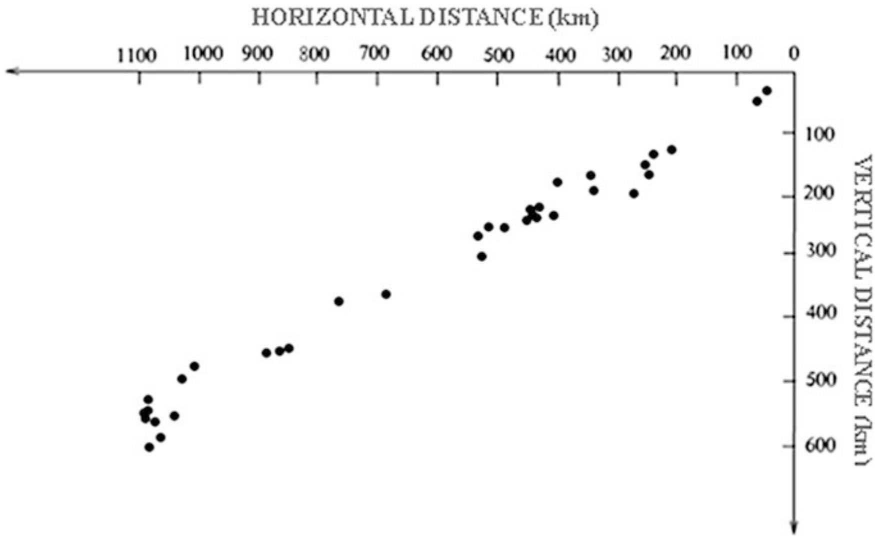

Fig. 3.6 The projection section of focus of earthquakes across Japanese Sea from Japan to Hunchun deep earthquake area (Zhang and Tang 1983)

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Chapter 4
General Survey of Thermal Springs of Qingzang Plateau and Its Surrounding Areas

Abstract This chapter tabulates statistics of thermal springs in Tibet Autonomous Region, west Sichuan Province and southwest Yunnan Province. There are different opinions concerning the amount of thermal springs in Tibet. According to "national standard", it is only 304; Considering low annual temperature at plateau, it could be more than 600. According to preliminary statistics in this book, the amount of thermal springs in Tibet is 645, in which 223 spas lack on-the-spot investigation. The west Sichuan is eastern end of Qingzang Plateau, where there are 334 thermal springs, in which 34 spas lack of temperature and water chemical data.

Keywords Tibet autonomous region · West Sichuan Province · Southwest Yunnan Province

4.1 The Thermal Springs in Tibet Autonomous Region

How many thermal springs are there in Tibet? There are two different opinions. 304 by Wen et al. (2010), whereas 677 by Tong et al. (2000). Apparently, the former researchers do not include spas below 25 °C in accordance with the "national standard". The latter researchers divided spas into the following eight categories in their statistics, (1) boiling spring: whose temperature are greater or equal to the boiling point of local elevation; (2) sub-boiling spring: roughly 81 °C—the local boiling point; (3) hot springs: 46–80 °C; (4) warm spring: 36–45 °C; (5) low-temperature thermal springs: 21–35 °C; (6) tepid springs: 20 to >5 °C high than the local annual average temperature; (7) nine poison springs found on the topographic map but without field inspection; (8) 24 traces of thermal springs, which include some large sinters, but without spring waters spilling.

This book compiles 645 thermal springs in total (Table 2.1). The differences of this table from the book "Thermal Springs in Tibet" (Tong et al. 2000) are as follows: (1) It removes the sub-boiling springs which are in fact high-temperature hot springs; (2) the low-temperature warm springs and tepid springs in "Thermal Springs in Tibet"

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are merged into tepid springs (<35 to 5 °C); (3) It removes "poison springs"; (4) It removes the "traces of thermal springs"; (5) it adds "geological settings".

Nevertheless, the authors of the present book hold identical views as Tong et al. The land of China is a vast and undulating terrain with dramatic changes in the annual average temperature in different locations, and therefore we should not use 25 °C as the national lower limit of temperature of thermal springs. The Qingzang Plateau is a good example, where annual average temperature is about 0 °C. Spas with 5–6 °C temperature are exothermic bodies toward space, and they should be categorized to thermal spring. In contrast, the annual average temperature in Guangdong is 26.1 °C. A spring of 30 °C is only a cold one and cannot be counted as a thermal spa.

Of the more than 1300 separate thermal springs listed in Fig. 4.1 during a regional inventory, Tibet Autonomous Region has 634 (Table 4.1), the three autonomous prefecture and one city of western Sichuan Province has 334 (Table 4.2), two autonomous prefecture and one city of northern Yunnan Province 105 (1, 2, 5 in Table 4.3) and Qinghai Province 44. In Fig. 4.1, It also shows the thermal springs in southern periphery of Tibetan Plateau, including Bhutan, Nepal, and northern India (Waring 1965; Bhattarai 1980). The scope of Fig. 4.1 is lack of western and southern Yunnan Province, where a numerous boiling and hot springs will put on Fig. 4.2.

According to the data in Table 4.1, the amount of thermal spring in Tibet with definite temperature data is only 423, and 222 thermal springs are short of temperature data, of which warm springs account for 90%. That is 70% warm springs in Tibet non on-the-spot investigation due to their low temperature or a long way to go.

As we can see from Table 4.1, the Tibet's boiling springs only make up 7.5% of the total thermal springs, hot springs account for 27.8%, warm springs 45.2%, and

Fig. 4.1 Distribution of the thermal springs on Qinghai–Tibetan Plateau (after Liao 2000)

Table 4.1 Thermal springs of Tibetan Autonomous Region

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
1	2	3	4	5	6	7
1. *Ngari prefecture*						
Rutog	North of Bangong–Nu Fault	9 (1)	2 (1)	1		12 (1)
Gar	Near Yarlung Zangbo Suture	3	3 (3)	4 (1)	4	14 (4)
Zanda	South of Yarlung Zangbo suture	4	2 (2)	4 (1)	1 (1)	11 (4)
Ge'gya	Near Bangong–Nu fault	3 (1)	5 (4)	2 (1)		10 (5)
Burang	Near Yarlung Zangbo suture		1 (1)	3	3	7 (1)
Gerze	North of Bangong–Nu fault	5	17 (13)	3	1	26(13)
Coqen	North of Yarlung Zangbo suture		5 (5)	2	1	8 (5)
Brief summary		24 (2)	35 (29)	19 (3)	10 (1)	88 (35)
2. *Xigaze prefecture*						
Zhongba	Both sides of Yarlung Zangbo suture	1	10 (10)		3	14 (10)
Saga	Both sides of Yarlung Zangbo suture				3	3
Gyirong	South of Yarlung Zangbo sutute	1	1 (1)			2 (1)
Nyalam	Valley of Himalayan Mountain	1		1		2
Ngamring	Both sides of Yarlung Zangbo suture	1	9 (6)	6	5	21 (6)
Tingri	South of Yarlung Zangbo suture	1	4 (3)	3	1	9 (3)
Lhaze	Yarlung Zangbo suture nearby	1	3 (2)	2		6 (2)
Xaitongmoin	North of Yarlung Zangbo suture		8 (5)	10	3	21 (5)
Sagaya	South of Yarlung Zangbo suture		1		1	2
Dinggye	South of Yarlung Zangbo suture		1 (1)	1		2 (1)
Kamba	South of Yarlung Zangbo suture			1	2	3
Namling	North of Yarlung Zangbo suture	3	6 (5)	5	3	17 (5)
Bainang	South of Yarlung Zangbo suture		1 (1)			1 (1)

(continued)

Table 4.1 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
1	2	3	4	5	6	7
Gyangze	South of Yarlung Zangbo suture		1	1		2
Kamgmar	South of Yarlung Zangbo suture	2	2 (1)	1		5 (1)
Yadong	South of Yarlung Zangbo suture	2		1		3
Rinbung	South of Yarlung Zangbo suture		2 (2)	2		4 (2)
Brief summary		13	49 (37)	34	21	117 (37)
3. *Lhasa City*						
Damxung	North of Yarlung Zangbo suture	1	3 (1)	6	4	14 (1)
Nyem	North of Yarlung Zangbo suture		2	4	1	7
Doilungdeqen	North of Yarlung Zangbo suture	2	1			3
Lhasa Urban	North of Yarlung Zangbo suture	1				1
Lhunzhub	North of Yarlung Zangbo suture	2	1 (1)			3 (1)
Maizhokunggar	North of Yarlung Zangbo suture	1	2 (1)	2	1	6 (1)
Brief summary		7	9 (3)	12	6	34 (3)
4. *Nagqu prefecture*						
Nyima	North of Bangong-Nu fault	8	8 (4)	6		22 (4)
Shuanghu	North of Bangong-Nu fault	5	11 (2)	2		18 (2)
Xainza	South of Bangong–Nu fault	1	9 (6)	4		14 (6)
Bangoin	South of Bangong–Nu fault		9 (9)	8		17 (9)
Amdo	South of Mt. Tanggula	6	16 (16)	4		26 (16)
Nagqu	Bangong–Nu fault nearby	2 (1)	14 (13)	3	2	21 (13)
Nyainrong	Bangong–Nu fault nearby	4	1	5		10
Jiali	South of Bangong–Nu fault	3	5 (4)	1		9 (4)
Biru	Bangong–Nu fault nearby		11 (9)	7		18 (9)

(continued)

Table 4.1 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
1	2	3	4	5	6	7
Sog	Bangong–Nu fault nearby	1 (1)	5 (4)	1		7 (4)
Baqen	Bangong–Nu fault nearby	6 (1)	9 (5)	10		25 (5)
Brief summary		36 (3)	98 (72)	51	2	187 (75)
5. *Shannan prefecture*						
Nagarze	South of Yarlung Zangbo suture	1	1	1		3
Konggar	South of Yarlung Zangbo suture	1				1
Lhozhag	South of Yarlung Zangbo suture			5		5
Chanang	South of Yarlung Zangbo suture					0
Nedong	South of Yarlung Zangbo suture	1				1
Sangri	South of Yarlung Zangbo suture	1		1		2
Qusun	South of Yarlung Zangbo suture			2		2
Comai	South of Yarlung Zangbo suture	2	1 (1)	2	5	10 (1)
Cona	South of Yarlung Zangbo suture		10 (6)	1	1	12 (6)
Gyaca	South of Yarlung Zangbo suture					0
Lhunze	South of Yarlung Zangbo suture		3 (3)	4	1	8 (3)
Brief summary		6	15 (10)	16	7	44 (10)
6. *Nyingchi prefecture*						
Gongbo'gyamda	North of Yarlung Zangbo suture		2	1		3
Nyingchi	Yarlung Zangbo suture nearby			2	1	3
Mainling	Yarlung Zangbo suture nearby	1		1		2
Medog	Yarlung Zangbo suture nearby	2	4 (2)	1		7 (2)
Bome	Yarlung Zangbo suture nearby	3	4	2	1	10
Zayu	Yarlung Zangbo suture nearby		11 (8)	13 (7)		24 (15)

(continued)

Table 4.1 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
1	2	3	4	5	6	7
Brief summary		6	21 (10)	20 (7)	2	49 (17)
7. *Qamdo prefecture*						
Dengqen	Nu fault and Lancang fault	6	6 (1)			12 (1)
Lhorong	Nu fault nearby	2	1			3
Riwoge	Nu fault and Lancang fault	4	3 (2)			7 (2)
Qamdo	Lancang fault nearby	8	6 (4)	1		15 (4)
Baxio	Nu fault nearby	4 (2)	10 (6)	7		21 (8)
Chagyab	Lancang fault nearby	4 (1)	4 (2)	4		12 (3)
Zogang	Lancang fault nearby	3 (1)	8 (6)	8 (1)		19 (8)
Jomda	Between Nu and Lancang faults		6 (5)	1		7 (5)
Kongjo	Between Nu and Lancang faults		7 (7)			7 (7)
Markam	Between Nu and Lancang faults	4 (1)	13 (5)	6 (1)		23 (8)
Brief summary		35 (5)	64 (38)	27 (2)		126 (45)
Sum up of Tibet (The numerals in brackets are the amount of spas lack of irrefutable temperature data)	127 (10)	290 (199)	179 (12)	48 (1)	645 (222)	

Table 4.2 Thermal springs in western Sichuan

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boi-ling springs	Sum up
1. *Garze Zang (Tibet) nation autonomous prefecture*						
Serxu	Between Jinsha and Xianshuihe faults	2		3		8 (4)
Dega	Between Jinsha and Xianshuihe faults	7	5	9		21
Baiyu	Between Jinsha and Xianshuihe faults	9	1	5		16 (1)
Garze	Between Jinsha and Xianshuihe faults	5	3	2	1	15 (4)
Nyagrong	Between Jinsha and Xianshuihe faults	7	3	3		14 (1)
Sertar	Xianshuihe fault nearby		2			4 (2)
Chaggo	Xianshuihe fault nearby	8	2			10
Dawu	Xianshuihe fault nearby	10	1	7		19 (1)
Rongchag	North of Xianshuihe fault	6	1	1		8
Batang	East of Jinsha R. fault	2	4	7	3	16
Litang	Between Jinsha and Xianshuihe faults	6	7	21	3	39 (2)
Derong	East of Jinsha R. fault		1			1
Qazheng	Between Jinsha and Xianshuihe faults	5	6	4		16 (1)
Dabba	Between Jinsha and Xianshuihe faults			1		8 (7)
Nyqu	Yalung R. fault nearby	3	1	2		7 (1)
Tardo	Xianshuihe fault nearby	8	3	9		23 (3)
Gyaisi	Between Yalung and Xianshuihe faults		2	1		3
Luding	East of Xianshuihe fault	2	2	3		7
Brief summary		79	44	78	7	235 (27)
2. *Aba (Ngawa) Zang (Tibet) and Qiang nations autonomous prefecture*						
Gamda	Songpan massif (NE of Xianshuihw fault)	2				2
Aba(Ngawa)	Songpan massif (NE of Xianshuihw fault)				1	3 (2)
Barkam	Songpan massif (NE of Xianshuihw fault)	2		1		4 (1)

(continued)

Table 4.2 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boi-ling springs	Sum up
Jinchuan	Songpan massif (NE of Xianshuihw fault)	1				1
Zoige	Songpan massif (NE of Xianshuihw fault)	1	1			2
Jiuzhaigou	Songpan massif (NE of Xianshuihw fault)	1				1
Songpan.	Songpan massif (NE of Xianshuihw fault)	4				4
Heishui	Songpan massif (NE of Xianshuihw fault)		1			1
Li Xian	Songpan massif (NE of Xianshuihw fault)	1	1	1		3
Maoxian	Longmenshan fault nearby	1				1
Wenchuan	Songpan massif (NE of Xianshuihw fault)	2				2
Brief summary		15	3	2	1	24 (3)
3. *Liangshan Yi nation autonomous prefecture*						
Muli	South end of Longmenshan fault	4	7	3		14
Yanyuan	Yangzi Platform		1			1
Mianning	Yangzi Platform	1				1
Xichang	Yangzi Platform	1	1			2
Xide	Yangzi Platform			2		2
Zhaojue	Yangzi Platform	3	1	1		5
Butuo	Yangzi Platform	1				1
Puge	Yangzi Platform		1	1		2
Ningnan	Yangzi Platform	1	1	3		5
Huili	Yangzi Platform	1		1		2
Huidong	Yangzi Platform	4		2		6
Leibo	Yangzi Platform			3		3
Jinyang	Yangzi Platform	1	2	1		4
Yuexi	Yangzi Platform	1	2			3

(continued)

Table 4.2 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boi-ling springs	Sum up
Ganluo	Yangzi Platform	2	1	1		4
Brief summary		20	17	18		55
4. *Panzhihua City*						
Yanbian	Yangzi Platform	3		1		5 (1)
Miyi	Yangzi Platform		3			4 (1)
Dukou	Yangzi Platform	2		1		3
Brief summary		5	3	2		12 (2)
5. *Some adjacent counties*						
Shimian	East of Xianshuihe fault	1	2	2		5
Mabian	Yangzi Platform	2				2
Ebian	Yangzi Platform			1		1
Brief summary		3	2	3		8
Sum up to western Sichuan		120	69	103	8	332 (32)

Parenthesized in "sum" column are number of springs lack of temperature data

Table 4.3 Thermal springs in southwestern Yunnan

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
1. *Deqen Zangzu autonomous prefecture*						
Deqen	Between Lancang and Jinshajiang faults	1	8	6		15
Weixi	Lancang fault nearby	3	1	3		7
Shangri-la	East of Jinshajiang	8	2	4		14
Brief summary		12	11	13		36
2. *Nujiang Lisu nation autonomous prefecture*						
Gongshan	Nu fault nearby	4	1			5
Fugong	Nu fault nearby	2				2
Bijiang	Nu fault nearby	6	2	1		9
Lushui	Nu fault nearby	4	2	7		13
Lanping	East of Lancang fault	3	3	2		8
Brief summary		19	8	10		38
3. *Dehong Dai and Jingpo nations autonomous prefecture*						
Yingjiang	Tengchong massif	1	10	6	2	19
Longchuan	Tengchong massif	2	3	6		11
Ruili	Ruili basin on Tengchong massif	2	3		1	6
Wandiing	Ruili basin on Tengchong massif	1				1
Lianghe	Tengchong massif	1	3	10	1	15
Luxi	Longlin-Ruili fault nearby	2	6	11		19
Brief summary		9	25	33	4	71
4. *Baoshan City*						
Tengchong	Cenozoic volcanic region	19	16	20	3	58
Longling	Longlin–Ruili fault nearby	12	7	22	1	42
Longyang District	Baoshsn synclinore	7	8	12		27

(continued)

Table 4.3 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
Shidian	Baoshsn synclinore	2	1	5		8
Changning	Changning–Menglian suture zone	3	6	10		19
Brief summary		43	38	69	4	153
5. *Lijiang prefecture*						
Lijiang	East of Jinsha fault	11	1	3		15
Ninglang	Yangzi platform	5	2			7
Yongsheng	Yangzi platform	2	1	3		6
Huaping	Yangzi platform	3				3
Brief summary		21	4	6		31
6. *Dali Bai nation autonomous prefecture*						
Yunlong	East of Lancangjiang fault	6	5	10	1	22
Jiangchuan	Jinsha fault nearby		3			3
Heqing	East of Jinsha fault	1		4		5
Eryuan	Jinsha fault nearby	5	3	6		14
Yangbi	West of Jinsha fault	2	3	2		7
Yongping	East of Lancang fault	3	2	1		6
Dali	Linkup of Honghe and Jinsha faults			2		2
Weishan	South of Honghe fault	2		2		4
Nanjian	South of Honghe fault	4	2			6
Midu	Honghe fault nearby	5	3	4		12
Binchuan	Yangzi platform	9				9
Xiangyun	Yangzi Platform, close to Honghe F.	4		2		6
Brief summary		41	21	33	1	96

(continued)

Table 4.3 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
7. *Lincang City*						
Zhenkang	Baoshsn synclinore	1		3		4
Yongde	Baoshsn synclinore	1	5	8		14
Gengma	Baoshsn synclinore	1	1	3		5
Cangyuan	Baoshsn synclinore			1		1
Fengqing	West of Lancang fault	3	2	6	2	13
Yunxian	West of Lancang fault	2		5	4	11
Linxiang D.	West of Lancang fault	1		3		4
Shuangjiang	West of Lancang fault	0		2		2
Brief summary		9	8	31	6	54
8. *Pu'er City*						
Ximeng	Changning–Menglian suture nearby					
Menglian	Changning–Menglian suture nearby			5		5
Lancang	Changning–Menglian suture nearby	14	12	19	1	46
Jingdong	Lanping-Simao Mesozoic trough	1	1			2
Zhenyuan	Lanping-Simao Mesozoic trough	4	1	1		6
Jinggu	Lanping-Simao Mesozoic trough	2	2	3		7
Pu'er	Lanping-Simao Mesozoic trough	4	1	1		6
Ning;er	Lanping-Simao Mesozoic trough	4		1		5
Mojiang	Southwesh of Ailaoshan Anticlinoria	1	3	4		8
Jiangcheng	Lanping–Simao Mesozoic trough		3	1		4
Brief summary		30	23	35	1	89

(continued)

Table 4.3 (continued)

County	Geological setting	Tepid springs	Warm springs	Hot springs	Boiling springs	Sum
9. *Xishuangbanna Dai nation autonomous prefecture*						
Menghai	Liancang Granite zone	5	9	16	2	32
Jinghong	West of Lancang fault		10	8	1	20
Mengla	Lanping–Simao Mesozoic trough	1	1			2
Brief summary		6	20	24	3	53
10. *Many counties at the southwest bank of Honghe (Red River)*						
Xingping	Ailaoshan Anticlinoria	2	2	1		5
Yuanjiang	Ailaoshan Anticlinoria		2	2		4
Honghe	Ailaoshan Anticlinoria	3				3
Luchun	Ailaoshan Anticlinoria	1	3			4
Yuanyang	Ailaoshan Anticlinoria	1	4	4		9
Jinping	Ailaoshan Anticlinoria	4	6	5	1	16
Brief summary		9	19	12	1	41
Sum up to the western Yunnan		199	178	266	20	663

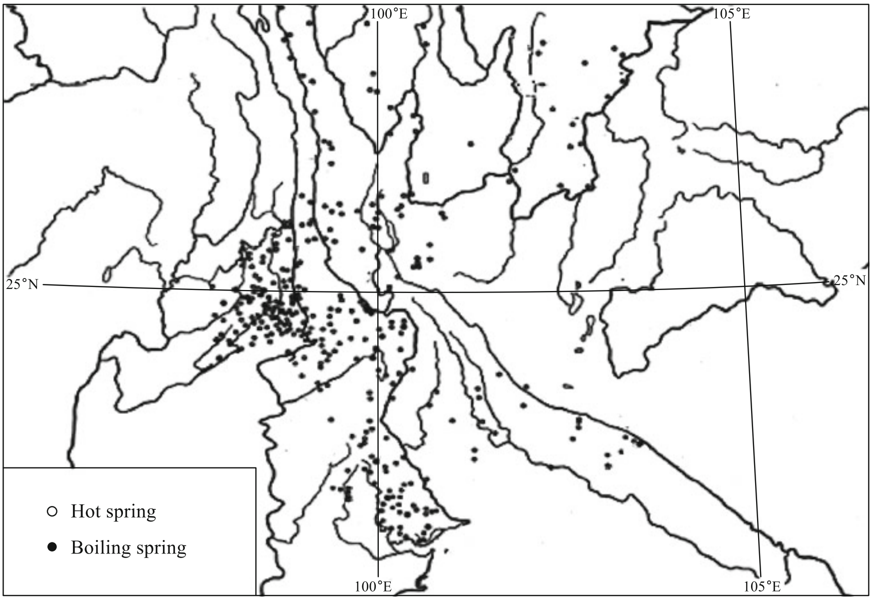

Fig. 4.2 Boiling springs and hot springs southwestern Yunnan

Tepid springs 19.6%. Tibet's boiling springs are mainly exposed in Lhasa-Gandise belt at the north of the Yarlung Zangbo suture and in Himalayan Tethyan belt at south of the south of the Yarlung Zangbo suture. The location of boiling springs is situated in the rift with S-N trend cutting the suture at the E-W direction. By the occurrence rate, the Xigaze Prefecture accounts for 18%, Lhasa City 17.6% and Shannan Prefecture 16%. Gar and Burang Counties of Ngari Prefecture near the suture have six boiling springs. For low-temperature hot springs and tepid springs, the areas with the highest occurrence rate are Qamdo Prefecture (79%) and Nagqu Prefecture (72%).

4.2 Thermal Springs in Western Sichuan Provence

There are 332 thermal springs in total in western Sichuan (Table 4.2), including 8 boiling springs, 103 hot springs, 69 warm springs and 120 tepid springs, 32 thermal springs are lack of temperature data.

As we can see from Table 4.2 boiling springs in the western Sichuan only make up of 2.4% of the total thermal springs, whereas hot springs account for 30.8%, warm springs 20.7% and tepid spring 35.9% Roughly 10% spas are lack of temperature data. These spas could be low-temperature thermal springs. The boiling springs in western Sichuan mainly distributed in Garze Zangzu Autonomous Prefecture along the large faults. Aba Zangzu and Qiangzu Autonomous Prefecture are located at Songpan Massif, and Liangshan Yizu Autonomous Prefecture and Pangzhihua City are located at the northwestern corner of Yangzi Platform. Both Songpan massif and Yangzi Platform are all relatively stable tectonic region, and there are less number of thermal springs with relatively low temperature.

4.3 Thermal Springs in Southwestern Yunnan Province

The amount of thermal springs in Yunnan Province is first in China, reaching 862 (Wen et al. 2010). This book only includes those in the southwestern Yunnan and the quantity of thermal spring reaches 663, accounting for 77% of whole Province. All boiling springs and high-temperature hot springs (≥ 80 °C) are over there. Table 4.3 shows the thermal springs in the southwestern Yunnan.

As we can see from Table 4.3 the western Yunnan Province has 20 boiling springs, only making up only 3%. There are 266 hot springs, accounting for 40% of total amount, and 178 warm springs account for 27% of the total amount. The rest (30%) is tepid spring. As far as I know that there are 17 spas short of temperature data, they could be all tepid springs and counted out from total.

4.4 Thermal Springs in Qinghai Provence

Geothermal survey work for me and my colleagues at the Peking University have not set foot in Qinghai Province. The data of thermal springs in Qinghai Province were only taken from the hydrogeological survey report of this region. Their divided standard of hot springs is 25 °C. According to the results of their research, Qinghai Province has a total of 44 thermal springs. The low-temperature thermal springs (≥ 25 to <40 °C) have 21, accounting for 47.73% of the total number of thermal spring; the medium temperature thermal springs (≥ 40 to <60 °C) 10, accounting for 22.73%; the intermediate high temperature (≥ 60 to <80 °C) 9, accounting for 20.45%; the high temperature (≥ 80 to <boiling point) 3, accounting for 6.82%; and Boiling spring only one, for 2.27% (Huang 1993). Here this no longer list.

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Chapter 5
Boiling Springs in the Southwest China

Abstract This chapter describes varied and colorful 77 boiling springs in great detail. The types of geothermal manifestation include geysers, hydrothermal exploration, fumaroles, steaming ground, silica sinter, travertine, hot water lake, and intense hydrothermal alteration, and so on. Daggy, Capu in Tibet, and Caluparseng Qumig in Sichuan are three famous geysers. The strongest hydrothermal exploration took place at Qucain Lungba (Qubug) of Burang County in Tibet. The Yangbajain geothermal field and The Rehai geothermal field are the biggest high-temperature hydrothermal convective systems in southwestern China.

Keywords Boiling spring · Geysers · Hydrothermal exploration · Fumaroles · Geothermal field

Boiling springs are characterized by high water temperature and rich geothermal phenomenon and thus attracted many scholars, and forever we left lager number of history literatures, which are valuable information to study trends and changes in the boiling spring areas. These boiling spring areas may also be important high-temperature geothermal area and thus be one of the important bases for industrial developments

According to the existing data, the Tibet Autonomous Region has 48 boiling springs, west Sichuan area 8, Yunnan province 20, and Qinghai province 1. Below we will give a detailed introduction to these boiling springs.

5.1 Boiling Springs in Tibet Autonomous Region

Boiling springs in the Tibet Autonomous Region are mainly found in the southern Tibet, to both the north and the south of the Yarlung Zangbo river. Their distribution range include: Gar and Burang Counties of Ngari Prefecture; Zhongba, Sega,

The original version of this chapter was revised: A new sentence has been included near Fig. 5.5 citation. The erratum to this chapter is available at https://doi.org/10.1007/978-981-10-3485-5_11

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https://doi.org/10.1007/978-981-10-3485-5_5

Ngamring, Tingri, Xaitongmoin, Sa'gya, Kanba, and Namling Counties of Xigaze Prefecture; Damxung, Nyemy, and Maizhokunggar Counties of Lhasa City, Comai, Cona and Lhunze Counties of Shangnan Prefecture; Nyingchi and Bome Counties of Nyingchi Prefecture. Also one boiling spring is found in each of the following counties: Gerze County and Coqen County of Ngari Prefecture and Nagqu County of Nagqu Prefecture (Tong et al. 2000).

The function of thermal spring depends on its thermal energy and chemical compositions. Thus, both temperature data and the results of chemical analysis are very important. Under given conditions, we need as far as possible to obtain these data for each thermal spring, among which "t" is sampling temperature; "pHf" is field pH value; "pHl" is laboratory value; "TDS" is total dissolved solids, unit: g/L; the units of each compositions are mg/L; "na" indicates not.

5.1.1 There Are 10 Boiling Springs in Ngari Prefecture

Tb01, Namru boiling spring is located in Namru township of Kunsha District of Gar County and at the Kunsha township government NEE down, 2 km away. Latitude and longitude are: 80° 09′ 56″E′, 31° 55′ 17″N, respectively. 4400 m above the sea level. Spring is exposed in the Gar Zangbo river on the left bank of the level terrace. The temperatures of three springs are 85, 84, and 66 °C respectively. No travertine deposition or silica sinter, but the ground is clothed with florescence. On July 5, 1976, water samples were collected and analysed, and the results are as follows: t 84 °C, pHf 7, pHl 7, TDS 0.79, Na 230, K 5.5, Ca 9.86, Mg nd, Li 0.85, Rb 0.10, Cs 0.1, NH_4 na, CO_3 nd, HCO_3 188, SO_4 158, Cl 179, F 15.0, SiO_2 87.3, HBO_2 74.1, As 4.13, Cl–SO_4–HCO_3–Na type of water.

Tb02, Bar boiling spring (Abunabu Qucai) is located in the Abunabu grand canyon of Ayila mountain of Bar pasture of Sogdoi village of Moincer District of Gar County Latitude and longitude: 80° 24′ 18″E', 31° 26′ 43″N, 4700 m above the sea level. Along the foot of Ayila Mountain with NW direction, there is a big fault with same trend, which was cut off by a NNE strike fault, along which formed the Abunabu grand canyon. The west wall of NNE fault has a branch fault with NE trend. In the geothermal area at intersection of two faults, there are more than 10 thermal springs. The main manifestation is a boiling fountain which spurts 93 °C boiling water and reaches height of 14 m. The others are very small with lower temperatures around 75 °C. Travertine is more than silica sinter. Sulfur crystal has emerged in the field. The mountain is formed of Triassic black slate, which intruded by the ultrabasic rock at the foot of range. In July of 1976, I planned to visit this spring, but could not make it due to the lack of guides. I had a brief stopover in the grand canyon owing to obstacles of many falls. The place that I stayed was about 500 m and I measured the temperature of rivulet water. It was 21 °C, higher than that of common rivers by 10 °C. The flow rate of rivulet was 0.5 m^3/s, and so the heat flow of rivulet was about 20.9 $MW_{t.}$ The temperature of water coming from fractures was about 35 °C and the temperature of the rocks at the rivulet bank was warmer than hands.

Tb03, Molo'gyam (Sogdoi 2) boiling spring is located in the south of Molo'gyam (a pasture of Sogdoi village) of Moincer District of Gar County, where there is a low watershed between the Moincer river and Gar Zangbo at the northeast foot of Mt. Ayila. Latitude and longitude: 80° 25′ 16″E, 31° 21′ 00″N. Elevation: 4900 m. The spring is discharging from slope sediment and has four spa mouths. Main spa mouth is a small pit that bubbles intensively, discharged boiling water at 85.5 °C. The guide told me: The water there could cure eye diseases. I thought that it might be related with high boron content in the water. The analysis results of water samples collected on July 29, 1976 are as follows: t 85.5 °C, pHl 8.5, TDS 6.24, Na 1060, K 120, Ca 9.86, Mg 1.50, Li 50, Rb 1.85, Cs 30.6, NH_4 na, CO_3 303, HCO_3 75, SO_4 83.2, Cl 1560, F 16, SiO_2 120, HBO_2 1917, As 125.6, Cl–Na type. The TDS of this water was too high with 6.24 g/L that could be small flow rate of 0.5 L/s of the pit by evaporation enrichment.

Tb04, Molo'pu (Sogdoi 1) boiling spring is located approximately 500 m in the southeast Sogdoi 2. Both separated by a low hills consisting by purple conglomerate. Latitude and longitude: 80° 30′ 06″E, 31° 20′ 54″N. Altitude: 4850 m. Springs issue out from the Carboniferous-Permian metamorphic gray-green greywacke, with dense cleavages. There were 15 springs, the temperatures of 5 of which reached boiling point of local altitude roughly 84 °C. The flow rate of single spring is not large, the total flow is estimated to 3 L/s. Take too watery, but the water vial during transport is penetrated by nails, causing water out and the bottle is empty. According to the guide, spring water here could cure stomach ailments.

Tb05, Hala boiling spring is located in a deep gorge of Langqen Zangbo river in Zanda County. The topography is very precipitous and too difficult to reach. The river water never frozens in the winter. Latitude and longitude: 80° 16′ 4″E, 31° 37′ 3″N. Altitude: 4240 m.

Mapam Yumco Geothermal System is located in the southeast of Mapam Yumco of 5.5–8 km, where three boiling springs and one hot spring are found on both sides of Zaqu Zangbu river (Tage Qu) (Fig. 5.1). According to the water chemistry data of the four springs, their Cl/B molecular ratio basically is consistent. For this reason, they should have a unified geothermal reservoir underground.

Tb06, Abug (Lungba) boiling spring is located in southwest of Gongzhu Village of Burang County, which is located within a tributary (Abug Lungba) at the right bank of Zaqu Zangbu, which flow from southeast to west into Mapam Yumco Latitude and Longitude: 81° 35′ 06″E, 30° 36′ 09″N. Altitude: 4650 m. In the tributary, spa clouds, hot water flows from the lake sediments. The flow rate of hot water is very small. The total flow of hot water is about 20 L/s. In the tributary head, there is a boiling spring, water temperature is 85 °C. Also there locates a large pond, which may be a product of hydrothermal explosion. The analysis results of water samples collected on July 22, 1976 as follows: t 85 °C, pHf 8, TDS 1.23, Na 343, K 34, Ca 3.78, Mg 5.98, Li 1.77, Rb 0.25, Cs 2.0, CO_3 123, HCO_3 549, SO_4 66.9, Cl 119, F 9.0, SiO_2 87.3, HBO_2 126, As 0.087, HCO_3–Na water. Boron than chlorine molecule ratio is 1.149.

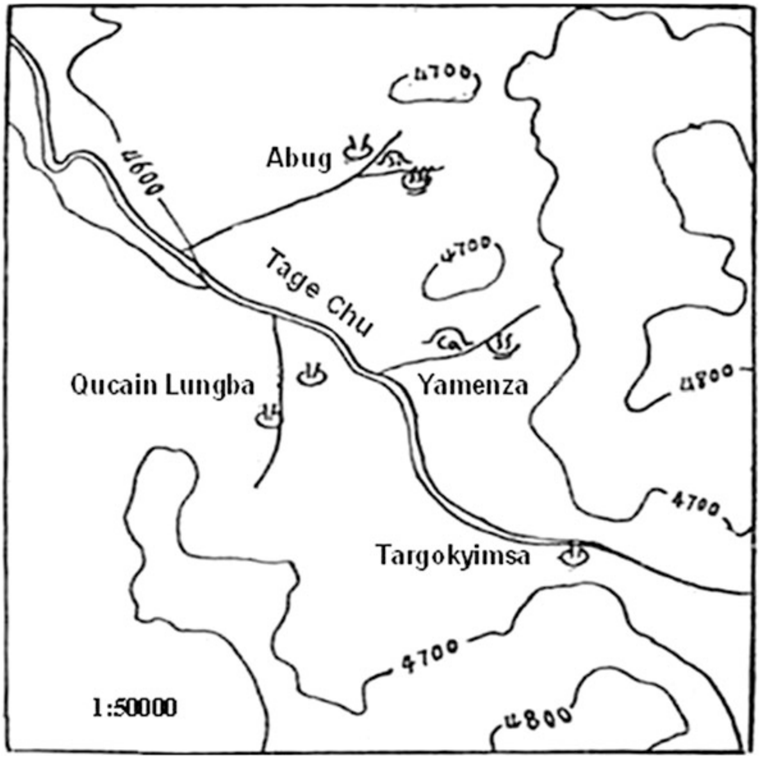

Fig. 5.1 The distribution of four thermal springs of Mapam Yumco geothermal system

Tb07, Qucain Lungba hydrothermal explosion area is located at left bank of Zaqu Zangbu river, 81° 34′ 4″E, 30° 35′ 23″N. Altitude: 4580 m. It was also called Qubug on the 1976 map and was called Tagpotong by S. Pranavanande in 1937. This boiling spring area approximately is 1.5 km^2. In the middle is a 20 m high hill, composed by hydrothermal explosion breccia cemented by gray silica sinter. Around the hill, there are many hydrothermal explosion lakes, caves, boiling fountains, boiling springs, hot springs, thermal springs, hot water streams, water marshes, fumalores, and steaming grounds. The maximum temperature of fountain is of 95 °C, and the total water inflow is 80 L/s. The number of hydrothermal explosion caves reached more than 10 with the diameter in the range of 20–80 m The times when explosion caves were formed vary. According to the visitation of local herdsman, the latest explosion occurred in 1974 (Fig. 5.2).

Indian Pranavananda (1939) visited here in 1937. He has just written that 3 or 4 miles away from Lake Manasarova, Tagpotong on the left bank of Tage Chu, are several hot springs. Their temperatures vary from tepid up to local boiling point. There are hot water streams into Tage Chu. But he did not mention those very conspicuous hydrothermal explosions.

Fig. 5.2 The biggest hydrothermal exploration caves in Qucain Lungba (after Tong et al. 1981)

The total emissions of hot water in Qucain Lungba are up to 80 L/s. But a lot of heat in this area is discharged through the steaming ground and heating ground. The thermal power was 167.2 MW_t by the measurement of natural heat flow in 1977.

Latitude and longitude: 81° 34′ 45″E, 30° 35′ 23″N. Altitude: 4580 m.

The analysis results of water samples collected on July 21, 1976 are as follows: t 95 °C, pHl 8.63, TDS 1.23, Na 384, K 41.2, Ca nd, Mg, nd, Li <1, Rb 0.29, Cs 1.53, NH_4 2.03, Fe 0.12, Mn <0.001, Al 0.037, Cu 0.0044, Pb 0.0057, Zn 0.09, CO_3 81.8, HCO_3 417.6, SO_4 79.9, Cl 150.6, F 6.38, Br 3.11, I 0.0122, SiO_2 107.1, H_3PO_4 0.822, HBO_2 160, As 0.32, HCO_3–Cl–Na type. The molecule ratio of Boron than Chlorine is 1.145.

Tb08, Targokyimsa boiling spring is also located at the left bank of Zaqu Zangbu river and in the southeast 1.3 km away from the Qucain Lungba. The geographical coordinates are: 81° 35′ 40″ and 30° 34′ 36″N. The altitude is 4680 m. Indian S. Pranavanande called it the Tomomopo in 1939. The geothermal manifestation area is located in the south bank of the river, where is a lower floodplain with width of less than 100 m There is a hot water pool 30 m long and 5–15 m wide. The plane is dumbbell-shaped with it long axis in east-west direction, and it is actually composed of three hydrothermal explosions caves in linear connection. Eastern pool is largest, followed by the west one, and the smallest one is in between. Eastern end of the pond and intermediate reservoirs are full of gray-black silt pouring boiling water. The water gushing was very violent, particularly in the middle pond. And paroxysm have erratic at high tide the water column leaps more than 1 m from the pond surface. The pool body has a funnel-shaped hole at the bottom more than 2 m deep. The water temperature is of 86 °C. But I found the middle of the pond to stop water gushing in the next day. The analysis results of water samples collected on July 21, 1976 are as follows: t 86 °C, pH 7–8, TDS 1.27, Na 335, K 34, Ca 5.26, Mg 2.49, Li 1.83, Rb 0.30, Cs 2.0, NH_4 na, CO_3 59.3, HCO_3 629, SO_4 82.4, Cl 119, SiO_2 120, HBO_2 132.5, As 0.24, HCO_3–Na type. Cl/B is 1.093.

Tb09, Canyoi (Charu) Qucain is located at Chima Village of Coqen District of Coqen County. 85° 41′ 10″, 30° 04′ 18″N. Altitude: 5160 m. According to information of Bureau of Geological and Mineral Resources of Tibet, Temperature of the spring is 83 °C, and its flow rate is 25.7 L/s. The country rock is a quartz diorite little rock strains of Himalayan stage The chemical composition of spring: pH 8, TDS 0.96, Na 293.04, K 23.58, Ca 12.9, Mg 3.01, Li 1.66, CO_3 79.63, HCO_3 419.31, SO_4 87.26, Cl 93.41, F 2.55, SiO_2 na, HBO_2 153.75. HCO_3–Na type of water.

Tb10, **Tuoheping Co** is located in the north to Jiacu Village of Wuma District of Gêrzê County, in the northwest 30 km away from the Tuoheping Co and the southeast 10 km from the Yazi Lake. 82° 54′ 40″E, 34° 22′ 18″N. Altitude: 5135 m. The spring area was covered by Quaternary system over an area of about 50 km^2. The bedrock is quartz sandstone, pebbly slate, and phyllite of Carboniferous system. Some black cryptocrystal multi-vesicular basalt emerged around the springs. This is the only one boiling spring in the center of the Plateau of Northern Tibet far away from the Yarlung Zangbo suture. There are 10 springs in this manifestation area. The highest temperature reached 90 °C. The boiling water gushed out with total flow rate of 100–150 L/s. There are silica sinter and travertine, as well as awful H_2S smell. The analysis results of water sample are as follows: pH 8.74, TDS 2.575, Na 917, K 81.13, Ca 1.34, Mg 1.73, Li 2.91, NH4 3.80, CO_3 96.12, HCO_3 2123.94, SO_4 85.82, Cl 121.49, F 6.50, H_3PO_4 0.02, NO_3 0.11, SiO_2 146.8, HBO_2 47.84. HCO_3–Na type of water.

5.1.2 Xigaze Profecture Have 21 Boiling Spring, of Which 16 Have a Chemical Analysis Information, and the Other Four Only Had Temperature Measurement Data

Tb11, Janggu Malung boiling spring is located in the most west part of Zhongba County, where is river head (Janggu Lungba) of Yarlung Zangbo river at the southern foot of Mt. Gangdise 82° 43′ 50″E, 30° 35′ 24″N. Altitude: 4255 m. Temperature: 109 °C(furnished by Prof. Zhao P in 2000).

Tb12, Zuolong boiling spring is also located in the most west part of Zhongba County, where is river head of Yarlung Zangbo river at the southern foot of Mt. Gangdise. 82° 34′ 58″E, 30° 32′ 58″N, Altitude: 5131 m. Temperature: 82 °C (Zhao P offered in 2000).

Tb13, Yulung Lungba thermal springs are also located in the most west part of Zhongba County, where is the river head of the Yarlung Zangbo river at the southern foot of Mt. Gangdise. 82° 56′ 57″–82° 57′ 05″E, 30° 29′ 26″N. Altitude: 4950 m. There are a lot of thermal springs in a tributary, along which the thermal springs stretches right to 700 m. The temperature was measured from 74 to 81.5 °C by Zhao P in 2000.

Tb14, Rugyog boiling spring or **Donagqucain** is located in a wide valley of 800 m to the northwest 21 km away from the Rugyog Village of Saga County. Latitude and longitude: 84° 47′ 35″E and 29° 54′ 50″N. Altitude: 5000 m. A magnificent travertine body 800 m long, 80 m wide, and 20 m high spans this wide valley. There are three main springs on the travertine. Their temperatures are 83.5, 83.5, and 80 °C. The last one is surface temperature of the boiling pool and the temperature at its bottom is 85 °C. Some fast, strong of gas, liquid, and steam forced out of some small opening up to 2 m high. A river with flow rate of 1 m^3/s passes through the spring area. The water temperature of upper reaches of river (before enter spring area) is roughly 12 °C and the water temperature after cutting across the spring areas goes up to 22.2 °C. The analysis results of water samples collected on July 28, 1975 are as follows: t 85 °C, pH 7.7, TDS 1.61, Na + K 491.5, Ca 16.8, Mg 4.28, NH_4 0.30, Fe 0.04, Al 0.05, CO_3 nd, HCO_3 714, SO_4 152, Cl 286, F 7.80, SiO_2 12.5, HBO_2 255, HCO_3–Cl–Na water.

Tb15, Dagze Quicain or **Kangleg I** boiling spring is located to the west of Dagze Village of Saga Country on the north shore of Yarlung Zangbo river. 86° 15′ 05″E, 29° 30′ 00″N. Altitude: 4240 m. The springs area is 1000 m 100 m. There are five main vents, three of which are boiling springs at 87 °C, two of fumaroles at 88 °C. Silica sinter was massive with opal-based. Travertine is layered calcite. There are sulfur crystals. Marshland occupies a half of the springs area. The total flow is roughly 3 L/s. The surrounding rock is mica-plagioclase gneiss. The analysis results of water samples collected on August 2, 1975 are as follows: t 85 °C, pH 8.0, TDS 1.12, Na + K 410.8, Ca 74.04, Mg 7.91, NH_4 43.0, Fe 13.0, Al 0.02, CO_3 nd, HCO_3 144, SO_4 935.38, Cl 9.57, F 3.75, SiO_2 33.4, HBO_2 1.10, As 0.02, SO_4–Na water.

Tb16, **Kangleg** boiling spring is located in the Kangleg Village of Saga County on the Yarlung Zangbo river. 86° 15′ 00″E, 29° 10′ 20″N. Altitude: 4240 m. The springs area is 3000 m × 200 m. There are four vents. According to our visit on August 2, 1975, the two vents were flooded and two vents departed from the water only 10 m. Temperatures were 45 and 55 °C. During the dry season the measured temperature is 86 °C. Sinters extend up along the shore of 3 km, thick 30 m. There are fresh sulfur crystals and strong odor of hydrogen sulfide. The analysis results of water samples collected on August 2, 1975 as follows: t 55 °C, pH 7.0, TDS 0.87, Na 134, K 19.5, Ca 56.6, Mg 4.57, NH_4 3.70, Fe 13.0, Al 0.02, CO_3 nd, HCO_3 396, SO_4 54.1, Cl 88.4, F 5.5, SiO_2 113, HBO_2 195, As 0.452, HCO_3–Cl–Na–Ca water.

Tb17, Daggyai geyser is located to the west of Qieye Township of Sang Sang District of Ngamring County, where is a vast valley with a north–south trend in Duoxiong Zangbo river source. Latitude and longitude: 85° 44′ 45″E, 29° 36′ 00″–20″N. Altitude: 4970–5140 m. The springs area is the southern foot of Mount

Gandise. Both sides of the springs area are exposed Cretaceous and Dazhuka group of Tertiary sandstone–conglomerate with volcanic rocks. The whole area of geysers is located at a silica sinter terrace 1000 m long, 500 m wide in north, and 1200 m wide in the south. There are four geysers on the terrace. The main one is located at south end of terrace, 15 m above the river water. The vent's circular diameter is about 30 cm. Its eruption has ebb and flow. When surliness reached a steam water column of 2 m, the spray height is about 20 m (Fig. 5.3). According to the local herder's presentation, stimulated spray had four times a day, in the morning, noon, evening, and midnight (Liao and Zhang 1984). The analysis results of water samples collected on August 2, 1975 are as follows: t 85.5 °C, pHl 9.0, TDS 1.57, Na 365, K 41, Ca 7.21, Mg 1.87, Li 7.25, Rb 0.80, Cs 6.45, NH_4 1.20, Fe 0.12, CO_3 234, HCO_3 261, SO_4 132, Cl 165, F 25, SiO_2 22.7., HBO_2 440, As 5.4, CO_3–Cl–HCO_3–SO_4–Na type.

Fig. 5.3 Water vapor column spurted out from Daggyai geyser (after Kang 1985)

After 1975, many experts came to Daggyai for visiting and investigations. One of the most important is the study of the silica sinter by Academician Mianping Zheng. He believes that silica sinter can be divided into new and old two kinds and found cesium-bearing opal. They mainly exist among the new silica sinter., Its chemical molecular formula is $[SiO_2 \cdot nH_2O]mCs$. Old silica sinter was divided in two types. The upper section of old silica sinter is very dense with color of green/red and white or light gray, 7 m thick. The majority of lower section is silica breccia Zheng et al. (1989) think that the main difference between the old and new silica sinters is different dilute alkali metal content, such as Cs content: new silica sinter: 5233.33 ppm; old silica sinter: 1479.29 ppm. B content: new one: 1620 ppm; old one: 544.86 ppm. The older a silica sinter, the less the content of cesium opal. Zheng Mianping et al. determined the age of silica sinter with the ESR measurement method. The surface layer of silica sinter of 0–10 cm is 0.62×10^4 years, the top silica sinter is 1.70×10^4 years old, the age of the upper part of old silica sinter at terraces is 8.21×10^4 years, middle part is 40.33×10^4 years.

Tb18, Nandumu boiling spring or **Chazi** boiling spring is located on the SSE 8.5 km away from the Chazi Vallage of Chazi District of Ngamring County and is on the west margin of the mountain basin. 86° 28′ 30″E, 30° 00′ 05″N. Altitude: 4820 m. The area of this hydrothermal region is 1.5 km × 1 km. There are countless vents, among which 8 hot water ponds of 50 m^2 are formed by hydrothermal explosion. One of the largest boiling pond areas is 50 m × 15 m. The maximum temperature of vent is of 86 °C. The total flow is >20 L/s. The sulfur crystal emerges at surface with hydrogen sulfide odor. This spring is located in the north slope of Mt. Gandise, where the andesite appeared. According to introduction of local herders, the spa temperature was not very high in the past. Some day before March 1975, a sudden explosion in the south vent took place, when steam and water mixture entrained sand and gravel blocks sprayed up to roughly 5 m, scattered scope of 40–50 m. The explosion lasted for up to five minutes. Several subsequent explosions also took place. A boiling spring area was thus formed. The analysis results of water samples collected on August 14, 1975 are as follows: t 86 °C, pHl 7.90, TDS 1.56, Na 468, K 45, Ca 12, Mg 4.17, Li 2.2, Rb 0.60, Cs 0.55, NH_4 0.15, CO_3 nd, HCO_3 801, SO_4 144, Cl 163, F 9.75, SiO_2 145., HBO_2 170, As 0.384, HCO_3–Na type.

Tb19, Samig boiling spring is located in the Samig vallage of the Ngamring County, at both the north and the south sides of the Yarlung Zangbo river. 86° 32′ 10″E, 29° 13′ 00″N. Altitude: 4400 m. Spring area in the north shore along the river extends for 800 m. There are three vents, the vent at the eastern end of the springs area is **a**bove the river water 20 m and the boiling water at 86 °C flows out from the sinter body. Many sulfur crystals appear nearby. The middle vent is a fracture with a temperature of 58 °C. A bathroom has been completed over there. The vent located at the western end is located on the floodplain, and its temperature is 54 °C, which is characterized by non in winter and out in summer. On the high terrace ~40 m above river water appear a large number of travertine.

A boiling spring is emerging at the south bank of the river less than half a meter away. A fountain is apart from the shoreline 5 m underwater. Totally five events emerge at the south bank. Strong odor of hydrogen sulfide spread all over the springs area. The total flow rate of the north shore springs is 3 L/s. The flow rate of south bank spring far exceeds the north shore. The analysis result of water samples collected on August 11, 1975 are as follows: t 86 °C, pHl 8.65, TDS 4.34, Na 700, K 104, Ca 3.43, Mg 4.17, Li 35, Rb 2.45, Cs 51.5, NH_4 2.0, CO_3 306, HCO_3 490, SO_4 65.8, Cl 674, F 13.3, SiO_2 116.2, HBO_2 1750, As 30.8, Cl–CO_3–Na type. Samig spring is hitherto known the highest in terms of arsenic-containing and the second in cesium-containing in Tibet.

Tb20, Laboulang boiling spring is located at the south shore of the Yarlung Zangbo river to the west of Samig boiling spring of Ngamring County. 86° 32′ 06″ E, 29° 12′ 50″N. Altitude: 4400 m. The temperature of spring is 85 °C. The analysis results of water samples are as follows: t 85 °C, pH nd, TDS 4.47, Na 700, K 87, Ca nd, Mg nd, Li 23.75, Rb 2.1, Cs 58.0, NH_4 na, CO_3 361.7, HCO_3 362.9, SO_4 26.5, Cl 707.4, F 20.0, SiO_2 147.3, HBO_2 1965, As 5.66. Cl–CO_3–Na water.

Tb21, Buloba boiling spring is located in the Kaga Village of Ngamring County, at the north shore of the Duoxung Zangbo river. 87° 09′ 08″E, 29° 23′ 52″ N. Altitude: 4200 m. The springs area is roughly 150 m × 50 m, The spring water flows out from the gravel pile of the floodplain. Several vents have been flooded by the river water. The distance between vent on the shore and shoreline is of 0.5 m, above the water level by 0.2 m. Within one of the major vent, spring water rolls out like boiling, jumping as high as half a meter, yet the actual temperature is only 79.8 °C. Quartz andesite appears on both sides of the river. According to local residents, this spring was submerged in the flood season, the position of the vent frequently move from 2 km upstream to 1.5 km downstream. Sometimes they move from the north shore to the south. New vents usually occur with vapor explosion that could last for 2–3 min. The analysis results of water samples collected on August 9, 1975 are as follows: t 79.8 °C, pHl 8.0, TDS 2.21, Na 690, K 61.5, Ca 8.58, Mg 2.08, Li 9.25, Rb 0.80, Cs 0.17, NH_4 nd, CO_3 48.5, HCO_3 340, SO_4 284, Cl 693, F 7.05, SiO_2 155., HBO_2 158, As 3.05, Cl–Na type water.

Tb22, Lolo Qucain is located in the Loloqu river near the Baba Vallage of Tingri County. 87° 12′ 35″, 28° 43′ 25″N, Altitude: 4300 m. The springs area extends along the river 4 km away, and its width ranges from 100 to 300 m. There are a large travertine mound at the southwest end, under which are two springs with the temperatures of 30 °C. Three hundred meters to the north is another travertine mound. There are three hot springs, and their highest temperature is 79 °C, sulfur crystals are found over there. There are many springs with temperature of 30–65 °C. 1 km to the northeast further north, there are two boiling springs with temperature 86 °C. Sulfur crystals are also found there. A pattern seems to be this: the southern springs have relatively low temperatures and large-scale travertine; whereas the northern springs have relatively high temperature and small-scale silica sinter. Therefore, regional hydrothermal activities seem to have a tendency of transferring from the south to the north. The analysis results of water samples collected on July 13, 1975 are as follows: t 79 °C, pHl 7.40, TDS 1.57, Na 265, K 34, Ca 44.3, Mg 2.30, Li 8.25, Rb 0.70, Cs 7.55, NH_4 6.64, CO_3 nd, HCO_3 656, SO_4 69.8, Cl 192, F 8.75, SiO_2 126, HBO_2 515, As 0.424, Cl–Na type water.

Tb23, Capu geyser or **Cainpu Qucain** is in the Capu Township of Longsang District of Xaitongmoin Country. It is located at a rift with north–south trend and it is the second largest geyser in China. Latitude and longitude: 88° 24′ 00″E, 29° 45′ 30″N. Altitude: 4690–4730 m. The surrounding rocks are mainly Gangdese granite with some diorite, quartz diorite, and the Tertiary neutral–acidic volcanic rocks. Scientific Work Team on Tibet have been to this place in 1952. At that time, the primary vent erupted 4 times a day, and the height of stimulated water vapor column exceeds 10 m. In the 1975 study, there were more than 200 vents on the sinter terrace. The temperatures of 58 vents were higher than 80 °C, the maximum temperature is 86.5 °C. According to a 24 h observation of from midday of September 7, 1975 to the noon of the next day, total number of eruptions of the main vent was 208 times. Each time the eruption lasted for 4–5 min. The longest time was 6′ 40″, whereas the shortest was 1′ 20″. The intermission of two eruptions is roughly 2–3 min. During intense eruptions, the spring water's temperature can reach as high as 93 °C, during other times the temperature is 90 °C. The expedition in 1989 discovered that the eruptive activity has become very irregular and eruption height also declined. The reason is because the vent has been partially blocked. Nevertheless around 15:00 pm every day there is a large eruption, and water and steam column can shoot as high as 30–40 m. The analysis results of samples collected in 1989 are as follows: t 86 °C, pHf 9, pHl 8.9, TDS 1.60, Na 379, K 59.5, Ca 0.15, Mg 0.50, Li 11.7, Rb 1.40, Cs 11.3, NH_4 0.14, CO_3 42.7, HCO_3 477, SO_4 69.5, Cl 285, F 11.4, SiO_2 280, HBO_2 204, As 3.65, H_2S 1.36, Cl–HCO_3–Na type water.

Tb24, Kungqu boiling spring is located in the Longsan District of Xaitongmoin County at the north foot of Mt. Gangdese. 88° 43′ 05″E, 30° 03′ 10″N. Altitude: 4840 m. Local rocks are gray tuff and white silica sandstone. There are six vents discharging boiling water at 81.5–84 °C. The spring area is 30 m × 10 m. The analysis results of water samples on September 10, 1975 are as follows: t 84 °C, pHl 7.35, TDS 0.96, Na + K 239, Ca 30.9, Mg 6.23, CO_3 nd, HCO_3 552, SO_4 98.7, Cl 47.8, F 8.80, SiO_2 8.1, HCO_3–Na type.

Tb25, Chajiandang boiling spring is located in the southeast 4 km away from Chajiandang village of Chunzhe Township of Longsan District of Xaitongmoin County. 88° 33′ 40″E, 29° 41′ 45″N. Altitude: 4320 m. Springs appear in Chunzhe River center and also on the left bank of the river. A fountain emerges on the sinter terrace in the center of riverbed and the left bank of river. The water column of the fountain spurts into the air up to 3–4 m. The exact temperature of fountain is unknown. But estimated to be the boiling point about 85 °C. On the left bank of the river there is a hot water pool with diameter 3 m and depth 0.6 m and water temperature is 80 °C.

Tb26, Kawu Qucain is located in the Kawu village of Sa'gya Town of Sa'gya County. 88° 10′ 25″E, 28° 49′ 35″N. Altitude: 4620–4700 m. First expedition was on August 7, 1975. The spring area is about 1000 m × (100–200) m. Himalayan porphyry granite is distributed in the south part of this area, garnet schist in the northwest and Jurassic slate in the west. The main vent is located in the foothills of the mountain on the right bank of the Chum Qu river. A fountain sprays as high as 1.2 m, and the water temperature is 88 °C, and the flow rate is 3 L/s. On the floodplain of left bank of the Chum Qu river, there were a large number of boiling springs, fumaroles, and boiling mud pools. Hydrothermal explosions in this area occurred on several occasions. Total flow rate was about 20 L/s. My colleagues visited Kawu again on July 24, 1989. And they found that the geothermal manifestations had a very significant change. The main vent on the right bank had fully stopped and transformed into a mud pool. On the silica sinter plateau of the left bank were more than 10 boiling springs, large number of boiling fountains, boiling spring ponds, mud springs, fumaroles, and hydrothermal explosion pits. All of these were located in this narrow floodplain. Its vapor spewing sound, mist-filled air, and the pungent odor of hydrogen sulfide, make it difficult for people to stop and observe. The analysis results of water samples are as follows (the outer brackets for 1975, in brackets for 1989): t 82 °C (86 °C), pHf na(9), pHl 8.55(8.9), TDS 2.32 (2.496), Na 560(642), K 78(95.1), Ca 5.15(0.20)m, Mg 2.08(0.15), Li 19.8(21.4), Rb 1.70(3.62), Cs 0.55(27.2), NH_4 7.24(5.12), CO_3 103(165), HCO_3 505(403), SO_4 32.1(19.7), Cl 602(660), F 7.9(11.6), SiO_2 152(205), HBO_2 500(435), As 0.072 (0.221), H_2S na(2.96). Sodium chloride type water. Please note that 1975 and 1989 sampling locations may be different, analytic methods may also be different, therefore there is some inconsistency in the data. Though the two samples are separated by 14 years, the changes in the chemical composition of the spring are not as large.

Tb27, Kurme boiling spring is located in a wide valley with south–north trend of Kongma Village of Kurme Township of Kamba County. 88° 37′ 34″E, 28° 38′ 05″. Altitude: 4800 m. The spring area is about 2.5 km × (100–400) m. The main spring is located on a broken hill of diabase, 150 m long and 80 m wide. There are more than 10 craters. Most of them is 4–5 m in diameter, the biggest one has a diameter of over 10 m. The wall of the crater is roughly 1.5 m high, on which emerge a lot of sublimed sulfur and salts. The highest temperature of boiling water in exploration crater is 87.5 °C. Total flow rate is more than 8 L/s. The air is filled with pungent odor of hydrogen sulfide. Diabase body can be seen pyrite and chalcopyrite infection. The western edge of the mountain basin is of Jurassic or Cretaceous shale, sandstone, and limestone. Hydrothermal explosion in this area has very frequently occurred at least four or five times a year, sometimes up to 20 times. Each lasts 3, 4 min. Explosion occurs at random locations each time and it rarely hits the same place repeatedly. The analysis results of water samples collected on July 7, 1975 are as follows: L t 55.8 °C, pH 7.5, TDS 3.29, Na + K 784.4, Ca 27.2, Mg 2.01, NH_4 18.5, Fe 0.32, Al 0.03, CO_3 nd, HCO_3 280, SO_4 101, Cl 1050, F 6.9. Br 4.0, I 0.25, SiO_2 17, HBO_2 1139, H_3PO_4 2.70, As 0.01, H_2S 0.01, Cl–Na + K type water.

Tb28, Kogco boiling spring is located in the southeast 1.7 km from the Kogco village of Longzhong Township of Kamba County, which is between the south bank of a river and the northern foot of a low mountain. 88° 32′ 06″E, 28° 19′ 46″N.

Altitude: 4480 m. The mountain appears Cretaceous sandstone, limestone, and shale. The springs area between the mountain and the river is to the east–west trend, 3 km long and 400 m wide. A row of mount of sinter more than 15 m high appears along the foot of the hill, which is surrounded by a large number of low temperature spas. Hot and boiling springs are mainly distributed in the south side of the river floodplain. There are many hydrothermal explosion pits (Fig. 5.4). The highest temperature is 85.3 °C. The analysis results of water samples collected on July 7, 1975 are as follows: t 84 °C, pH 7.9, TDS 1.62, Na + K 525, Ca 5.44, Mg 0.46, NH_4 2.4, Fe 0.18, Mn 0.06, Al 0.02, CO_3 25.6, HCO_3 1110, SO_4 183, Cl 79.2, F 3.70, SiO_2 15, H_3PO_4 0.15, As 0.15. HCO_3–Na + K type of water.

Tb29, Bibilong boiling fountain is located in the northeast of Caiqing Village of Labupu Township of Namling Country, Southern foot of Mt. Nyqingtangula And that is both banks of upper reach of Lhabuqu. 89° 28′ 30″E, 29° 27′ 25″N. Altitude: 4510–4650 m. Three boiling fountains and one boiling spring are found at the precipitous bank of the Lhabuqu river. The temperature of boiling spring is 87 °C. Total flow rate is estimated to be 10 L/s. The analysis results of water

Fig. 5.4 Hydrothermal explosion crater in Kogco (after Tong et al. 1981)

samples collected on July 21, 1975 are as follows: t 87 °C, pH 7.5, TDS 0.75, Na + K 219.8, Ca 10.1, Mg 0.76, NH_4 nd, Fe 0.10, Al 0.06, CO_3 nd, HCO_3 459, SO_4 41.5, Cl 56.9, F 2.6. SiO_2 100, HBO_2 59.1, H_3PO_4 0.44, As 0.01, HCO_3–Na + K type of water.

Tb30, Sangmuzhai boiling spring is located in a small ravine of Oiyug mine in the north of the Oiyug village of Dazi Township of Namling County. 89° 26′ 15″E, 29° 38′ 44″N, Altitude: 4500 m. There are three main vents with the highest temperature of 84.5 °C and the lowest 41 °C. There is a small piece of warm water swamp of 20 °C. The total flow rate is of 3–5 L/s. Thick sinter layer is found on the slopes and floodplains. There is quartz andesite on the west side of ravine and andesite on the east side, The glauconite limestone and argillaceous limestone appear at the south of andesite. The analysis results of water samples collected on September 25, 1975 are as follows: t 84.5 °C, pH 6.90, TDS 1.28, Na 275, K 20.8, Ca 65.2, Mg 7.27, Li 3.30, Rb 0.25, Cs 1 95, NH_4 0.89, CO_3 nd, HCO_3 421, SO_4 218, Cl 167, F 2.60, SiO_2 92.0, HBO_2 217, As, 1.73. HCO_3–Cl–SO_4–Na type water.

Tb31, Puncoglung geyser or **Kanzho geyser** is located near Kanzho Village of Manre Township of Namling County. 89° 38′ 00″E, 29° 42′ 40″N. Altitude: 4450 m. According to introduction of the Namling Country officials, there is a geyser that sprays every 15 min and each spraying lasts for one minute. The temperature is estimated to be over 84 °C. No actual investigation has been made yet.

5.1.3 Lhasa City Has Six Boiling Springs, in Which There Are Two Exploited Geothermal Fields: Yangbajain and Yanyi

Tb32, Xumai or Molung boiling spring is located in the southwest 3 km from Xumai Township of Nyemo County and in Xuqu riverbed. 90° 15′ 00″E, 29° 26′ 40″N. Altitude: 3800 m. The temperature of a vent at easternmost foothills of the basin and under the scarp of highway is 50–81.5 °C. Hot springs converge into rivers. There are numerous small seepages at the bottom of the river, causing the flow of hot water in the river continues to increase, and the temperature of the river water is between 40 and 50 °C. In the center of the valley is a river channel, its bottom has a lot of gushing steam with temperature up to 86.5 °C. After the two hot rivers merge together, the river water temperature goes as higher as 60 °C. Confluence flow rate is 35 L/s and an outflow of water occurs in the southern end of the basin. The overall length of the spring area is 2 km from north to south, width 500–600 m. The wide east side of the valley hillside is of granodiorite, diorite, and the west side is of gneissic diorite. The analysis results of water samples collected on June 26, 1975 are as follows: t 86.5 °C, pHl 8.20, TDS 0.59, Na 140, K 7.20, Ca 10.3, Mg 2.09, Li 1.38, Rb 0.10, Cs 0.10, NH_4 0.18, CO_3 6.27, HCO_3 101, SO_4 152, Cl 81.4, F 12.8, SiO_2 84, HBO_2 44.5, As 0.304. SO_4–Cl–Na type water.

Tb33, Yangyi geothermal field is located in Yangyi Township of Damxung Country. 90° 22′ 17″E, 29° 44′ 05″N. Altitude: 4600–4900 m. The exploration work have been completed in 1991 by Tibet Geothermo–Geological Team. And they have submitted reserves report. This field is a horst structure, located in graben with a north–south trend. Yangyi's area is about 10.8 km^2, and it can divided into high-temperature area (>150 °C) of 1.6 km^2, middle temperature area (90 to <150 °C) of 3.26 km^2, and low temperature area (<90 °C) of 5.9 km^2. The high-temperature area occupies the core part of horst with south–north trend. The north–south trending faults of both sides of the horst are water overflow channel and is also the main channel of cold water injected into the ground. The transverse NEE faults are the main channel of deep hot water discharged upwards. The NEE faults should be the main target of drilling. According to drilling results, the drilled rock formations at horst above the from top to bottom are as follows: Quaternary, 27 m; Miocene trachyandesite, 101 m; Eocene–Oligocene volcanic breccia, 146 m; granitic porphyry, >112 m. Geothermal reservoir lies 295 m to the fractured belt of deep granitic porphyry. The type of geothermal fluid is HCO_3–Na with higher chlorine content. The analysis result of water samples collected on June 23, 1979 are as follows: t 91.5 °C, pHl 9.70, TDS 1.7.8, Na 450, K 30, Ca 1.0, Mg 0.1, Li 13, Rb 0.5, Cs 1.6, NH_4 nd, CO_3 200, HCO_3 357, SO_4 217, Cl 183, F 23.5, SiO_2 258, HBO_2 150, As 1.82. CO_3–HCO_3–Na type water. The highest temperature in drilled hole of Yangyi geothermal field is 208 °C, the orifice operating temperature is 190 °C. Geothermal Field reserves is 30 MWe (Fig. 5.5). The beginning of this century, Jiangxi Huadian Group built a pilot plant to use self-produced screw expander and original drillholes and achieved geothermal full flow power generation in Yangyi Field.

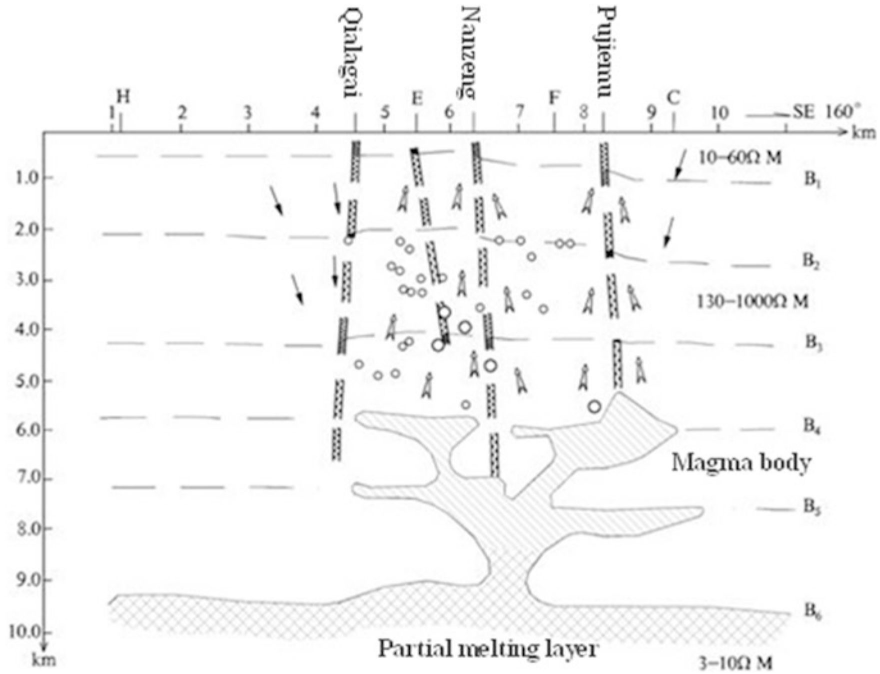

Fig. 5.5 The structure section of Yangyi geothermal field

Tb34, Gulinqu boiling spring is located at south slop of watershed of Mt. Nyainqêntanglha of Damxung County. 90° 22′ 50″E, 30° 12′ 50″N. Altitude: 4950 m. There are 3 sections in an area 500 m in length and 5 m in wide. The maximum temperature of 85 °C was found at intermediate section. The peripheral rock is granite. The analysis results of water samples collected on June 2nd 1975 are as follows: t 85 °C, pH 7.8, TDS 0.63, Na 160, K 11, Ca 17.2, Mg 2.09, Li 1.44, Rb 0.15, Cs 0.25, NH_4 0.10, CO_3 nd, HCO_3 433, SO_4 49.6, Cl 23.7, F 15.0, SiO_2 128, HBO_2, 7.7, As 0.01. HCO_3–Na type.

Tb35, Yangbajain geothermal field is first exploited high temperature hot water system in China in 1970s. It is located at south foot of Mt. Nyainqêntanglha of Damxung County. 90° 29′ 30″–90° 30′ 30″E, 30° 03′ 40″–30° 05′ 40″N. Altitude: 4200–4500 m. The area of thermal manifestation was about 7 km^2 (Fig. 5.6). Its upflow zone of the geothermal field is located in the north, below the mined Sulfur Mine. Geothermal fluids rise to the Cenozoic loose sediments and then flow south, forming a horizontal flow, and oozing out to surface along the Zangboqu river. This flow forms many boiling and hot springs and famous hot lake (Fig. 5.7). Ten years before the development of the geothermal field, exploration work mainly focused within Yangbajing basins (i.e., the southern area). Temperature measured during the exploration at that time do not exceed 170 °C. The drilling in the vicinity of Sulfur Mine began in 1987. The high temperature of 202 °C has been discovered at the 950 m deep in the hole ZK352. The hole ZK4002 in the Sulfur Mine drilled in November 1993. Its final hole depth is 2006.8 m. The measured maximum

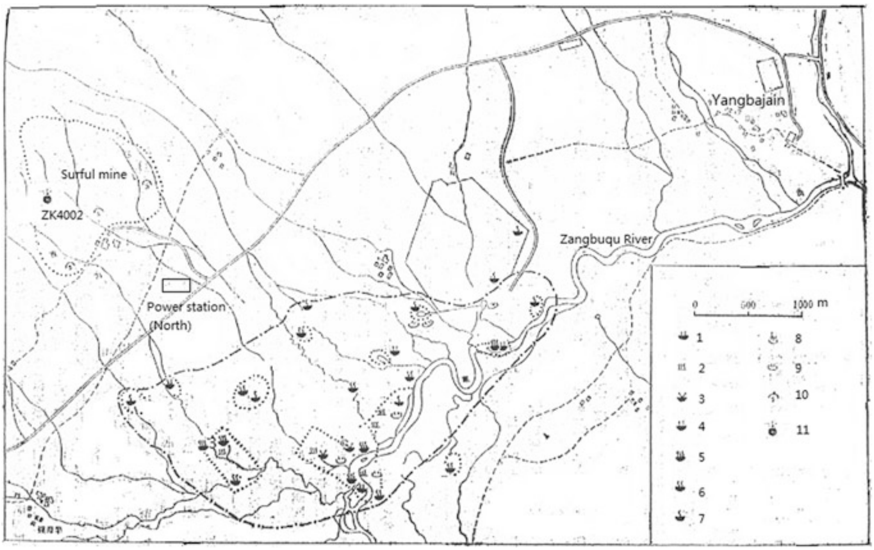

Fig. 5.6 The geothermal manifestation in the Yangbajain geothermal field before exploitation. *1* Fumaroles; *2* Steaming grand; *3* Hydrothermal exploration area; *4* Geysers; *5* Boiling springs (>85 °C); *6*Hot springs (46–85 °C); *7* Warm springs (<46 °C); *8* Hot lake; *9* Thermal marsh; *10* Sulfurin; *11* Main drillholes

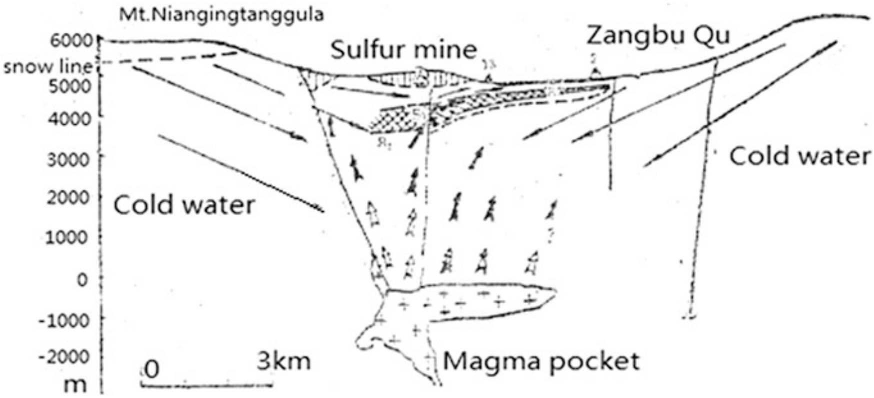

Fig. 5.7 The conceptual model of the Yangbajain geothermal field

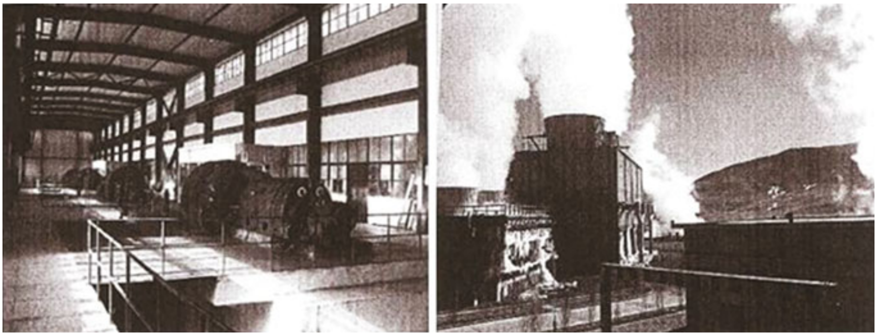

Fig. 5.8 Yangbajain geothermal power station: indoor scene of south factory (*left*) and outdoor scene of north factory

temperature was of 329.8 °C, and wellhead maximum operating temperature was of 204 °C. The drilling of the hole ZK4001 began on September 17, 1995 and completed on October 15, 1996. The hole's depth is 1459.09 m. The rock in well is fractured granite. Underground maximum temperature was 251 °C and the well-head temperature was 200 °C. The success of three deep wells lead to major changes to the view of the cause of Yangbajain geothermal field: it is not due to deep circulation, but the present of magma heat source. The water in boiling springs and shallow horizontal reservoir is Cl–HCO_3–Na type but in deep reservoir it is Cl–Na type volcanic water (Fig. 5.8).

The analysis results of water samples of No. 3 boiling spring collected 1975 are as follows.

t 90.5 °C, pHl 7.90, TDS 1.60, Na 400, K 45.5, Ca 13.8, Mg 4.18, Li 9.75, Rb 1.25, Cs 6.45, NH_4 0.36, CO_3 nd, HCO_3 439, SO_4 51.2, Cl 468, F 14.2, SiO_2 170, HBO_2 203, As 2.15. Cl–HCO_3–Na type.

The analysis results of separated water samples by separator collected in 1981 from Y23 hole are as follows: pH 8.20, TDS 1.912, Na 494.82, K 54.78, Ca 2.43, Mg 0.90, Li 13.0, Al 0.05, Fe 0.02, NH_4 0.24, CO_3 nd, HCO_3 434.43, SO_4 50.0, Cl 584.55, F 10.0, SiO_2 125, HBO_2 276.8, As 2.4. Cl–HCO_3–Na type.

Tb36, Qucain boiling spring is located in Qucain Village of Ninzhong Township of Damxung County near the Qinghai–Tibet highway. 90° 56′ 40″E, 30° 24′ 46″N. Altitude: 4250 m, The maximum temperature of main vent at silica sinter and travertine is of 87–91 °C and the flow rate of 10 L/s. The analysis results of water samples collected on June 9, 1989 are as follows: t 87 °C, pH 8.8, TDS 2.044, Na 532, K 131, Ca 0.60, Mg 2.65, Li 10.2, Rb 2.12, Cs 7.12, NH_4 0.56, CO_3 60.9, HCO_3 496, SO_4 192, Cl 512, F 7.04, SiO_2 203, HBO_2 132, As 1.672, H_2S 1.12. Cl–HCO_3–Na type water.

Tb37, Caquwo boiling spring is located on the both banks and in riverbed of Dezhongqu river. This area belongs to Dehong Village of Renduogang Township of Maixhokunggar County. 92° 10′ 20″E, 30° 06′ 45″N. Altitude: 4240 m. Maximum temperature is of 85° C, and flow rate is of 5 L/s. The analysis results of water samples collected on June 8, 1989 are as follows: t 85 °C, pH 8.6, TDS 1.779, Na 512, K 70, Ca 4.2, Mg 6.9, Li 4.7, Rb 1.50, Cs. 7.18, NH_4 0.65, CO_3 21.3, HCO_3 831, SO_4 85.9, Cl 318, F 7.14, SiO_2 163, HBO_2 159, As 0.985, H_2S 0.60. HCO_3–Cl–Na type water.

5.1.4 Nagqu Prefecture Has Two Boiling Springs, They, Together with Boiling Springs of Damxung County, Are Located Within the Same Rift with North–South Trend

Tb38, Gulu fountain and boiling spring is located in Gulu Township of Nagqu County, 90° 36′ 30″E, 30° 52′ 25″N, Altitude: 4720 m. Geologically; Gulu geothermal areas and Ningzhong boiling spring, Yangbajain geothermic fields and Yangyi geothermal field are all located in the same basin of Cenozoic rift. This rift valley here with a north–south trend cuts through the Mt. Nyainqêntanglha There are seven silica sinter hills in Gulu geothermal area. One fountain and three boiling springs emerge at a big sinter hill, The height of intense spurt of this fountain reached 5 m and maximum temperature is 86 °C. These fountain with intermittent activities are also called geysers by some researchers. But they not as spectacular as the Daggyai geysers. We conducted an investigation on September 6–9th 1975. The analysis results of water samples collected as follows: t 85 °C, pHl 8.80, TDS 3.93, Na 1050, K 117, Ca 13.7, Mg 54.1, Li 25.2, Rb 2.75, Cs 5.7, NH_4 0.28, CO_3 179.9, HCO_3 1160, SO_4 94.6, Cl 899, F nd, SiO_2 123.5, HBO_2 205, As 0.99, Cl–HCO_3–Na type water.

Tb39, Sanlai (Dongweng) boiling spring is located to south 3 km of Sanlai village of Gulu Township of Nagqu County, 91° 35′ 30″E, 30° 40′ 00″N. Altitude:

4560 m. Springs area extends along the southern slope of Mt. Nyainqêntanglha, long 120 m and wide 60 m. The temperature of the main vent is 85 °C. The total flow rate is about 15 L/s. The vent and its surrounding ground has sulfur. Rock of springs area next to the hillside is Carboniferous gray and black slate. No water samples were taken.

5.1.5 Shangnan Prefecture Is Situated in the Southern Part of Yarlung Zangbo River. There Emerge Seven Boiling Springs

Tb40, Riro boiling spring is located on the south of Riro village of Gobdu Township of Comai County. 91° 50′ 20″E, 28° 32′ 08″N. Altitude: 4440–4540 m. Springs area run from east to west, 2 km long and 0.5 km wide. The boiling springs appear at the most eastern end of springs area. The maximum temperature of springs area varies: 85.5 °C in 1975, 84 °C in 1979, and 82 °C in 1989. In this area, there are silica sinter and travertine. Sulfur and salt are also appearing on the sinter hillock. The total amount gushing is about 20 L/s. We visited there three times in 1975, 1979 and 1989 to take water samples. In 1979, we have been collected three samples on a travertine terrace, the temperature of the sample point is 84, 68 and 61 °C respectively. In this list only from the analysis results of the sample 1979, outside the bracket is 84 °C springs, in sequence (in brackets) is 68 and 61 °C springs. The analysis results are as follows: t 84 °C (68, 61 °C), pH 8.4 (8.1, 8.3), TDS 2.00, (3.07, 2.46), Na 500 (690, 600), K 58 (98, 78), Ca 23.2 (26.8, 39.7), Mg 12.1 (11.2, 8.1), Li 15.0 (35.0, 22.6), Rb 1.1 (1.9, 1.4), Cs 6.0 (9.6, 7.4), NH_4 5.42 (10.8, 8.10), Sr 2.7 (2.5, 1.3), CO_3 nd (nd, nd), HCO_3 532 (689, 609), SO_4 137 (125, 123), Cl 501 (985, 718), F 7.5 (9.40, 5.5), SiO_2 130 (126, 125), HBO_3 330 (590, 420), As 0.05 (0.03, 0.08). Cl–HCO_3–Na type water.

Gobdu geothermal systems is located on the southeast and south of Manidan Village of Gobdu Township of Comai County, where it is on the both sides of tributaries (Manidanqu) of Xiongqu river. It contains Buxionvilangu, Caka, Sagarnamka, and Babudimi four boiling areas and one hot spring. Their hydrochemical type and Cl/B the molecular ratio is the same. On the surface, they are not far apart (<1 km) from each other. So they should belong to the same hydrothermal system (Fig. 5.9). The Scientific Expedition of Qinghai–Tibet plateau of the Chinese Academy of Sciences have ever been Gobdu on-site inspection in June 1, 1975, July 24, 1979, and July 11, 1989, three times in total.

Tb41, Buxionglangu boiling spring is located to the southwest of Manidan Village and on the both banks of Manidangu. 91° 52′ 57″E, 28° 31′ 00″N. Altitude: 4400–4540 m. The area is of 0.7–1.0 km^2 rich in silica sinter and small travirtine. Many springs emerge on the sinter body. There are 23 spas with temperature of about 75 °C on 100 °m^2 surface. The maximum temperature is 85.5 °C. The type of geothermal manifestation varies, including boiling spring, fumalores,

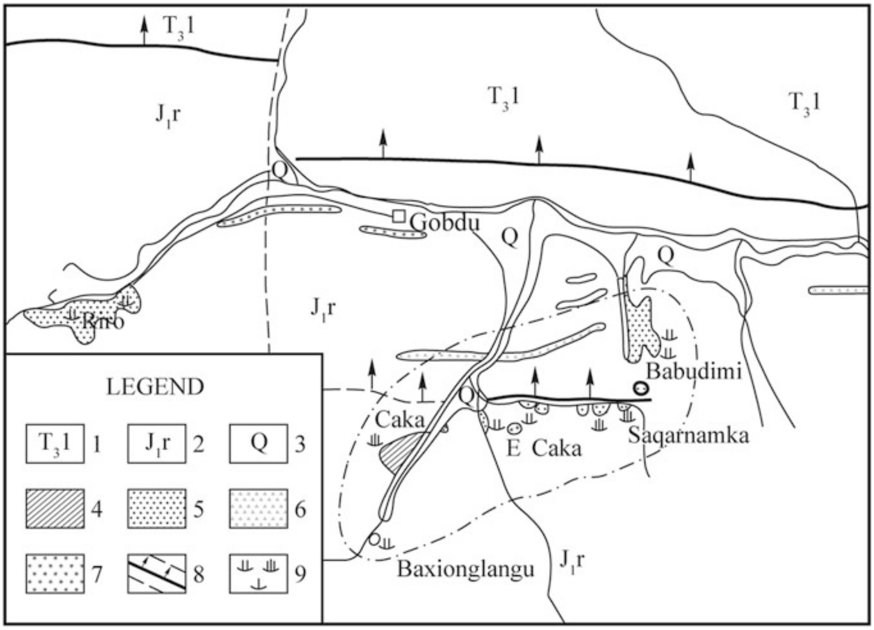

Fig. 5.9 Geological sketch of Gobdu geothermal system (Shen et al. 1981). *1* U. Triassic, *2* L. Jurassic *3* Quaternary system, *4* Silica sinter, *5* Travertine, *6* Siliceous fracture breccia, *7* Gabbro, *8*, Fault, *9* warm spring, hot spring and boiling spring

mud pool, and so on. The rock of mountain consists of mottled slate. The characteristic of silica sinter in Buxionvilangu is to take opal as the dominant mineral and lack of clastic sinter. The analysis results of water samples collected on July 11 1989 are as follows: t 85 °C, pH_F 7.5, pH_L 8.4, TDS 2.841, Na 658, K 100, Ca 0.15, Mg 0.4, Li 23.2, Rb 2.80, Cs 15.5, NH_4 2.45, CO_3 6.21, HCO_3 577, SO_4 152, Cl 729, F 13.4, SiO_2 425, HBO_2 420, As 2.012, H_2S 2.28. Cl–HCO_3–Na type water. Cl/B 1.611.

Geothermal exploration by Tibetan Geothermo–Geological Team of Bureau of Geology and Mineral Resources of Xizang (Tibet) Autonomous Region in the Buxionglangu area was begun in 2013. It comprises geological survey, electric resistivity survey, gravity survey, magnetic prospecting, rock alteration survey, and chemical analysis of thermal waters and fumaroles gases. Judging from these data, it was concluded that geothermal development in this area would be feasible. Thus a drilling of eight exploratory wells was begun in 2013 and completed in 2015. The depth of wells are about 600 m into the fracture zones of Triassic system. Temperature of the reservoir was reached more than 200 °C at a depth of 600 m (Academician Dojee furnished fresh information in November 2015).

Tb42, Caka boiling spring is located in the southeast of Manidan Village. 91° 54′ 00″E, 28° 31′ 25″N. Altitude: 4500 m. The most notable feature of this region is a huge travertine hillock with bottom area 250 m × 100 m, and there stands about 4–5 ancient sinter cones that are roughly 2 m tall. At the cone top, there is no hot water outflow, but at the cone bottom there is an 83 °C boiling spring flowing out. The flow rate is only 0.1 L/s. Roughly 10 thermal springs with temperature of 60–67 °C are discharging from the top and bottom of hillock, Total flow rate is about 2 L/s. Strong H_2S smell is all over spring area which is covered by slate and intrusive rocks. The analysis results of water samples collected on May 31, 1975 are as follows: t 83 °C, pH 7.80, TDS 2.18, Na 450, K 63.5, Ca 34.5, Mg 5.85, Li 18.75, Rb 12.5, Cs 6.45, NH_4 6.05, CO_3 nd, HCO_3 504, SO_4 139, Cl 555, F 9.0, SiO_2 176, HBO_2 458, As 1.24. Cl–HCO_3–Na type water. Cl/B 1.211.

Tb43, Sagarnamka boiling spring is also located on the southeast of Manidan Village. 91° 54′ 40″E, 28° 31′ 00″N. Altitude: 4600 m. The distribution of the thermal springs was extended along the valleys, 1 km long and 0.5 km wide. The valley slope consists of two parts. The upper part is huge sinter, but less number of hot springs, and the temperature of the springs are not high. Many boiling springs, fumalores, and hot springs are scattered over the bottom of valley and steep walls on both sides of the groove. Many sulfur crystal are widely dispersed on steep wall. The maximum temperature of springs is 85.5 °C. Total flow rate is 10–20 L/s. Temperature were measured in 1979 at 6 different points. The temperature at main boiling spring was 85.5, 86 °C at the east edge boiling spring, 86 °C at the small boiling fountains, 84 °C at the fountain of the bottom of valley, 82 °C at the rest two point. In 1989, the temperature was measured again roughly in the same pints, and the highest temperature was of 78 °C, the other temperatures were between 55 and 70 °C. The temperature at the east 4 ditches decreased obviously by as much as 20 °C. The reason for the drastic change of the temperature in the 15 years remains unknown. The analysis results of sample of main boiling spring in 1979 are as follows: t 85.5 °C, pH 8.9, TDS 2.403, Na 560, K 78, Ca 2.6, Mg 0.2, Li 21.2, Rb 1.5, Cs 5.6, NH_4 2.10, CO_3 143, HCO_3 257, SO_4 165, Cl 628, F 14.2, SiO_2 220, HBO_2 430, As 2.80, Cl–Na type water. Cl/B 1.460.

Tb44, Babudimi boiling spring area is located to the southeast of Manidan Village of Gobdu Township, 91 °55′ 10″E, 28° 32′ 20″N, Altitude: 4630–4700 m. Between Sagarnamka and Babudimi is a mountain with the elevation of 4894.9 m, named Sagarnamka peaks, where is ancient silica sinter containing flint and agate. In the southern slope of the mountain is Sagarnamka boiling spring, and in the northern slope of the mountain is Babudimi springs area which is the source of a gully with a scarp. On the top of the gully is a platform, and there is a spring area of 60 m × 40 m. More than 10 vents of boiling springs and hot springs are found over there. Boiling springs are located at the north end of spring area, and the temperature is 86.5 °C. There is no great changes in temperature from 1975 to 1979 and then to 1989. The analysis results of sample of main boiling spring in 1975, 1979, and 1989 are as follows: t 86.5, 86, 86.5 °C, pH 8.55, 8.8, 8.5, TDS 2.05, 2.091, 2.188, Na 450, 525, 558, K 67, 73, 82.4, Ca 6.89, 3.7, 0.15, Mg 1.05, 0.2, 0.45, Li 19.3, 16.3, 19.8, Rb 1.35, 1.3, 2.40, Cs 6.00, 6.4, 12.4, NH_4 3.40, 3.10, 3.75, CO_3 109, 88.54, 12.4, HCO_3 134, 282,360, SO_4 177, 144, 150, Cl 576, 566, 608, F 12.5, 13.5, 10.2, SiO_2 151, 175, 180, HBO_2 412, 332, 365, As 1.09, 2.40, 2.104, Cl–Na type water.

Cl/B 1.398.

Tb45, Quchomu boiling spring is located on the Quchomu Village of the Cona Country, Quchomu river along the east–west direction is a tributary of the east bank of the Donggaxiongqu river along a north–south direction, 91° 47′ 55″, 28° 15′ 00″ N, Altitude: 4360–4440 m. Springs area is located on both banks of Quchomu river. In the south bank of the river is a fountain group, including three fountains, temperatures were 83, 78, 70 °C, respectively. Flow rate is of 2 L/s. Three hundred and fifty meters to east of the fountain group locates a spring with temperature as high as 86.5 °C. The other springs are at 59–84.5 °C. On the northern bank of the Quchomu river, there are also several thermal springs, and the temperature range is from 49 to 66 °C. Both sides of the river exist travertine. The outcrop of rock is dark gray slate and schist, including garnet-sericite schist. The analysis results of water sample collected on July 5, 1989 are as follows: t 83 °C, pH 7.7, TDS 1.514, Na 312, K 50, Ca 105, Mg 20, Li 4.05, Rb 1.35, Cs 3.75, NH_4 2.15, CO_3 nd, HCO_3 279, SO_4 358, Cl 309, F 3.69, SiO_2 81, HBO_2 124, As 0.045, Cl–SO_4–Na type water.

Tb46, Zhangtang (or Samtang) boiling spring is located 1.3 km to east of Zhangtang Village of Rerong Township of Lhunze County. The spring is situated in the center flood of riverbed and in north river course. 92° 00′ 15″E, 28° 32′ 10″N. Altitude: 4220 m. The spring area is 400 m long and 80 m wide. Explorers have ever been this area for three times on June 10, 1975, July 19, 1979, and July 2, 1989, respectively. The temperature of main vent was 88 °C in 1975. It dropped to 78 °C in 1979, and then came back to 88 °C again in 1989. The outcrop of rock is carbonic slate and schist. The analysis results of water samples collected on July 2, 1989 are as follows: t 88 °C, pH 8.9, TDS 1.411, Na 460, K 14.2, Ca 0.25, Mg 1.50, Li 1.50, Rb 0.12, Cs 1.22, NH_4 2.28, CO_3 64.1, HCO_3 815, SO_4 62.1, Cl 181, F 2.25, SiO_2 150, HBO_2 62.7, As 0.047, HCO_3–Cl–Na type water.

5.1.6 Nyingzhi Prefecture Has Two Boiling Springs. Geothermal Examination Have Been Carried Out Twice in 1973 and 1974, But I Suspect that There Were Some Problems in the Results of Chemical Analysis

Tb47, Asideng boiling spring is located at Zhayuzhongco Village of Pailongmen Moinba Nationality Township of Nyingzhi County, where is situated at right bank of sharp bend in Yarlung Zangbu river. 95° 11′ 30″E, 29° 52′ 18″N. Altitude: 1600 m. Temperature was 94 °C and flow rate was 1 L/s. The simple analysis results of water sample of November 1973 are as follows: t 94 °C, pH 8.4, TDS 0.59, Na + K 210.45, Ca 26.17, Mg 3.46, CO_3 27.87, HCO_3 380.87, SO_4 118.54, Cl 39.07. HCO_3–SO_4–Ca–Mg type water.

Tb48, Tangmai Changning boiling spring is located 5 km to the southwest of Tangmai Village of Qingduo Township of Bome County and at both sides of the Sichuan-Tibet Highway. 95° 02′ 20″E, 30° 04′ 10″. Altitude: 2000 m. The area of thermal manifestation is 100 m length and 20 m wide with NE–SW trend. The main vents is located at an 8 m high cliffs at the northwest side of the highway. It is a boiling spring hole with diameter of roughly 1 m, and its depth is unknown. We can see strong vapor stream carrying a lot of boiling water gushing out of the hole, and smoke shooting into the sky can reach as high as 20 m. Nearby the smell of hydrogen sulfide is very strong. It is difficult for people to stay there. The simple analysis results of water sample in 1974 are as follows: t 94 °C, pHl 9.5, TDS 1.57, Na + K 391.1, Ca nd, Mg nd, NH_4 1.30, CO_3 357, HCO_3 6.10, SO_4 254, Cl 4.52, F 7.0, Br 0.99, SiO_2 175, HBO_2 88.97. CO_3–SO_4–Na + K type water.

5.2 Boiling Springs in Western Sichuan Province

The western Sichuan has three autonomous prefectures (Garze Tibetan Autonomous Prefecture, Aba Tibet-Qiang Autonomous Prefecture and Liangshan Yi Autonomous Prefecture) and one city (Pangzhihua). There are eight boiling springs over there, seven of which in Garze Tibet Autonomous Prefecture, and another one in Aba Prefecture.

This area is located between Longmenshan collision zone on the east side and Jinshajiang collision zone on the west side. The exposed formations are the Permian–Triassic sandy mudstone deposits or flysch on the bathyal and continental slope. The northern part of Jinshajiang collision zone marked by ophiolite-melange, accretionary slices and thrust zones is the zone of amalgamation between the Garze-Litang and north Qiangtang-Ningjingshan blocks. Triassic and pre-Trassic systems show extreme deformation and metamorphism, with steeply dipping foliations. Due to overprinting by later period of movement (Paleogene and Neogene) the multi-phase Jinshajiang–Red River strike-slip fault is difficulty determine. Molasse deposits of Upper Triassic, which rest unconformably on the rocks of collision zone, closure of the Jinshajiang Paleo-Ocean commenced during the Late Permian with subduction, and the sinistral transpression and the collision was completed by the end of the Middle Triassic. A syn-collision granite gave isotopic age of 255–227 Ma (Wan 2010).

5.2.1 *Garze Tibetan Autonomous Prefecture Has Seven Boiling Springs, Distributed in Garze, Batang and Litang Counties*

Sb01, Garyungo boiling spring is located in the southeast of Garze County. 100° 22′ 36″–05′ 60″E, 31° 33′ 36″–34′ 54″N. Altitude: 3300 m. The area is 400 m long and 1000 m wide. It lies along the Yalong Jiang river. It can be divided into six manifestation areas (Fig. 5.10, Table 5.1). The highest temperature is 92 °C in No. 3 area. Hydrothermal alteration is very intense. The fracture of alteration zone is filled up with native sulfur.

The analysis results of water samples collected on July 1981 are as follows: t 90 °C, pH 9, TDS 2.584, Na 956, K 95.5, Ca 0.3, Mg 032, Li 3.89, Rb 2.53, Cs 4.18, NH_4 nd, CO_3 231, HCO_3 1802, SO_4 46.1, Cl 50.0, F9.31, SiO_2 217, HBO_2 67.0, As nd, HCO_3–Na type water.

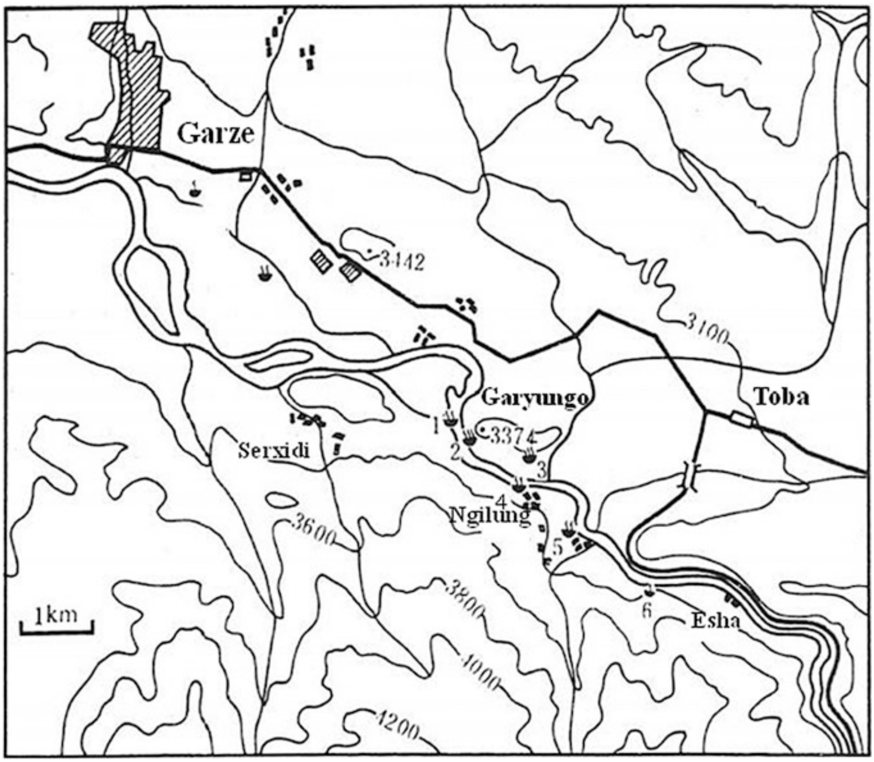

Fig. 5.10 The distribution of manifestation areas of Garungo geothermal region (after Tong and Zhang 1994)

Table 5.1 The manifestation areas of Garyungo hydrothermal system

No	Location	°C	L/s	Summary
1	West of Garyungo hill, channel bar of Yalong river	47		It has arisen at dry season
2	The southwest corner of hill	90		Flood season only 32 °C Dry season 90 °C
3	The top of southeast corner of hill	92		Steaming ground, pool of boiling mud, flood season 69 °C at foothill
4	South bank of Yalung river	52	0.2	It were inundated at flood season
5	Ditto	47	2.0	0.8 km of southeast of No. 4
6	Enter the mountain area	37	1.5	1 km of southeast of No. 5

Sb02, Kangrilung boiling spring is located in Batang County. 99 °24′ 50″–25′ 10″E, 30° 06′ 40″N, Altitude: 3950 m. The manifestation area extends about 1 km, and there are more than 10 spas. The main vent is a boiling fountain with 97 °C and flow rate 3 L/s. The rest is about 76 °C. The analysis results of water samples collected in 1982 are as follows: t 76 °C, pH 7.5, TDS 0.477, Na 116, K 9.4, Ca 10.62, Mg 5.64, CO_3 nd, HCO_3 326, SO_4 33.48, Cl 4.47, F 14, SiO_2 120, HCO_3–Na type of water.

Sb03, Caluparseng Qumig geysers is located in Batang County. 99° 22′ 52″–23′ 36″E, 30° 23′ 55″–24′ 34″N. Altitude: 3520–3600 m. The springs are extends along the river for 1 km, and its width ranges from 100 to 300 m. The area is about 0.15 km^2. Its temperature is 89 °C. There are four geysers at the sinter flat in this area. They are called Chabada, Chalima, Hunshui (Troubled water) and Chaxiong from west to east. Chabada is the biggest one, and the spray height is about 4.5 m and lasts for 15–20 min Its temperature at full display is 88.5 °C, the flow rate of hot water is 4 L/s and of steam flow rate is 622 L/s. The analysis results of water samples collected in 1982 are as follows: t 88.5 °C, pH 9.58, TDS 1.189, Na 319, K 28.6, Ca 4.32, Mg nd, Li 2.91, Rb 0.65, Cs 1.75, NH_4 7.81, CO_3 159, HCO_3 425, SO_4 34.4, Cl 43.8, F 26, SiO_2 330, HBO_2 18.1, HCO_3–CO_3–Na type of water.

Sb04, Zamkog boiling spring is located in Batang County. 99° 31′ 00″E, 30° 28′ 30″N. Altitude: 4086 m. This area is a tent hill 150 m long and 100 m wide. There are 17 vents. The temperatures range from 84 to 94 °C. The total flow rate is 2.656 L/s. There are fresh surfur crystals and strong odor of hydrogen sulfide. The analysis results of water samples are as follows: t 90 °C, pH 8.8, TDS 1.081, Na 375, K 33, Ca 1.98, Mg nd, CO_3 116.06, HCO_3 699.38, SO_4 20.0, Cl 41.8, F 14, SiO_2 120, HCO_3–Na type of water.

Sb05, Qukoilungba boiling spring is located in Litang County. 100° 07′ 47″E, 30° 04′ 56″N. Altitude: 4180 m. The Tibetan language “Qukoilungba” means boiling water valley. The geothermal manifestation appears at both sides of valley. The area is 350 m × 80 m. Main vent is located on east side of valley. Its temperature is 86.5 °C, The travertine precipitates along the vent, forming many travertine cones on the travertine terrace. The analysis results of water samples collected in 1982 are as follows: t 86.5 °C, pH 8.5, TDS 1.555, Na 485, K 52.5, Ca

9.51, Mg 7.85, Li 6.80, Rb 0.77, Cs 3.04, NH_4 20, CO_3 49, HCO_3 1260, SO_4 39.6, Cl 63.2, F 5.21, SiO_2 117, HBO_2 65.1. HCO_3–Na type of water.

Sb06, Yemucha boiling spring is located in Litang County. 100 °12′ 30″E, 29° 56′ 00″N. Altitude: 4120 m. The temperature of main vent is 83 °C, and the flow rate is 3 L/s. There are 3 hot springs of 76–80 °C around the main vent. Native sulfur appears in the overflowing place. The analysis results of water samples collected in 1982 are as follows: t 83 °C, pH 8.45, TDS 0.288, Na 65, K 3.3, Ca 2.75, Mg nd, Li 0.02, Rb nd, Cs nd, NH_4 2.36, CO_3 12.2, HCO_3 124, SO_4 25.6, Cl 10.0, F 3.3, SiO_2 99, HBO_2 2.13. HCO_3–Na type of water.

Sb07, **Garboko**i thermal springs are located in Litang County. 99° 55′ 06″–26″ E, 29° 56′ 13″–58″N. Altitude: 4160 m. This springs region includes a boiling spring area and a hot spring area. In boiling spring area, there are two vents on the top of travertine cone. One is 85 °C with flow rate of 2.396 L/s; another is 83 °C and 24.046 L/s. The hot spring areas also have two vents, one is 47 °C, and another is 70 °C. The analysis results of water samples of the latter are as follows: t 70 °C, pH6.7, TDS 0.647, Na 164, K 15, Ca 66.57, Mg 8.25, NH_4 0.80, CO_3 nd, HCO_3 0.684, SO_4 0.50, Cl 20.03, F 10, SiO_2 20. HCO_3–Na–Ca type of water.

5.2.2 Aba Tibet and Qiang Autonomous Prefecture Has Only One Boiling Spring

Sb08, **Longkequkeer** boiling spring is located in Aba County, which is the boundary between Sichuan and Qinghai. There is dispute on the geographical ownership of the spring, and Qinghai people think it is located in Zebra County, Qinghai Province. 101° 02′ 24″E, 33° 02′ 00″N. Altitude: 4500 m. There are six vents on the silica sinter.. The highest temperature is 85 °C and flow rate is 2 L/s. Country rock is Granite. The analysis results of water samples are as follows: t 85 °C, pH 7.2, TDS 0.563, Na 195, K 11.55, Ca 8.46, Mg 1.86, NH_4 nd, CO_3 nd, HCO_3 460.80, SO_4 5.00, Cl na, F 16, SiO_2 94.29. HCO_3–Na type of water.

5.3 Boiling Springs in Yunnan Province

There are 20 boiling springs in the Yunnan Province, and they are distributed over three tectonic uplift areas: Tengchong Massif, Cangning-Jinghong anticlinorium and Ailaoshan anticlinorium (Figs. 5.11 and 5.12).

Tengchong Massif is located to the west of Nujiang Fault Belt and is the most east end of Gangdise-Lasha Massif of Tibet. I have called the Tengchong micro-plate in 1995 (Fig. 5.11). There are eight boiling springs in this area. There are three in Tengchong County (Tong and Zhang 1989), two in Yingjiang County, and each one for Longling County, Lianghe County and Ruili City (Figs. 5.12 and 5.13, Table 4.3).

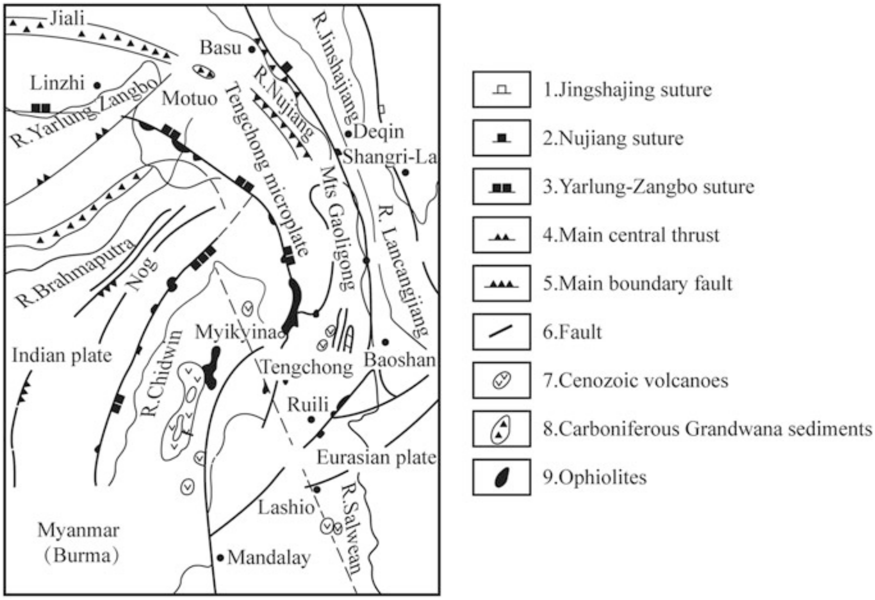

Fig. 5.11 Tectonic shetch map of Tengchong area and its surroundings (after Liao 1995)

Canning-Jinghong anticlinorium is an upland consisting of the metamorphic rock of Lancang Group on the northern part and of the Liancan Granite on the souther part. The east side of the region is Lancangjiang fault and the west side is the Changning Menglian ancient ocean basin. There are 11 boiling springs in this belt (Fig. 5.12). The north-most one is found in Yunlong County. There are two boiling springs in Fengqing County, four in Yunxian County, one in Lancang County, 2 in Mengman County, and one in Jinghong County.

There is a boiling spring in northern side of Ailaoshan anticlinorium, which is located in the Red River fault zone (Figs. 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11 and 5.12).

5.3.1 Boiling Spring in Tengchong Massif

Yb01, Rehai (Hot Sea) geothermal field is located in Tengchong County of Baoshan City. 98° 26′ 0″E, 24° 57′ 00″N. Altitude: 1500 m. The area of field is more than 10 km^2 (Fig. 5.14). The thermal manifestation includes boiling ponds, boiling springs, fumerolus, fountain, steaming grand, and strong hydrothermal alteration. Rehai geothermal field can be divided into 20 manifestation area, which

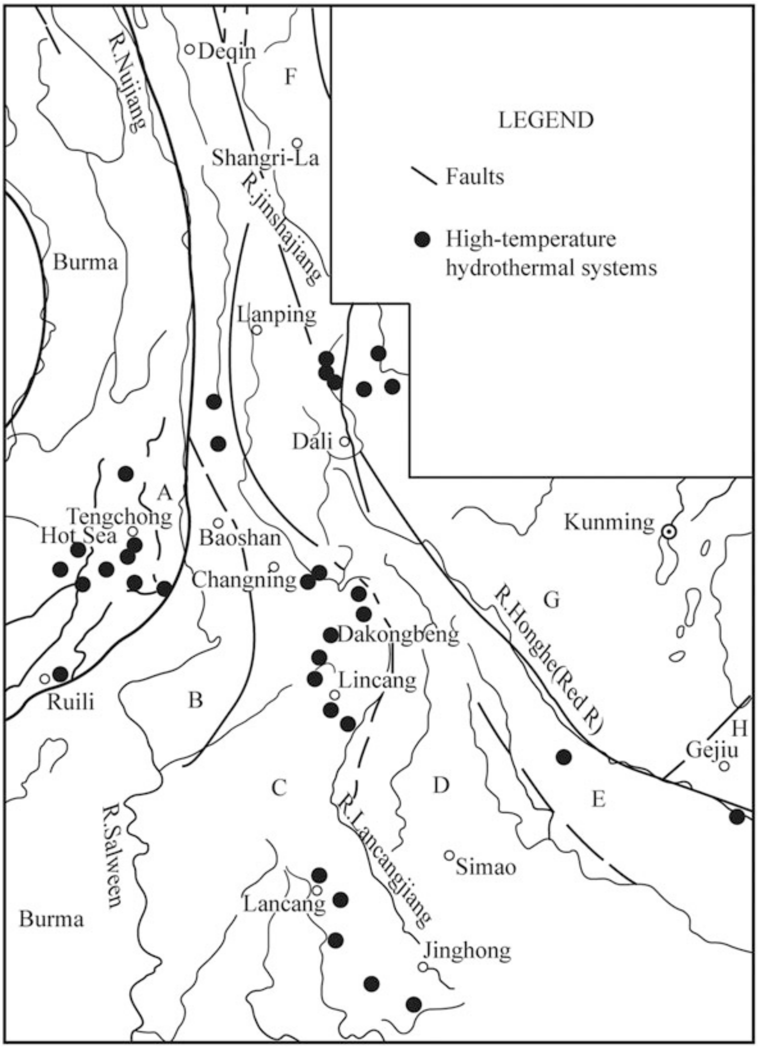

Fig. 5.12 Distribution of high-temperature hydrothermal systems in West Yunnan Province (Liao et al. 1986). *A* Tengchong-Gaoligongshan belt; *B* Baoshan belt; *C* Changning–Lancang belt; *D* Simao–Lanping belt; *E* Ailaoshan belt; *F* West Sichuan folded belt; *G* Yangzi platform; *H* SE China folded belt

is under the control of tension fault with north–south trend. Silica sinter and sulfur crystal can be found at anywhere in the field. The stratigraphic succession: Top is the Nanlin Group of Neogene, and bottom is Granite (Fig. 5.14). The hydrothermal alteration is very strong and is controlled by faults with south–north trend (Fig. 5.15). The highest temperature is 96 °C. The analysis results of

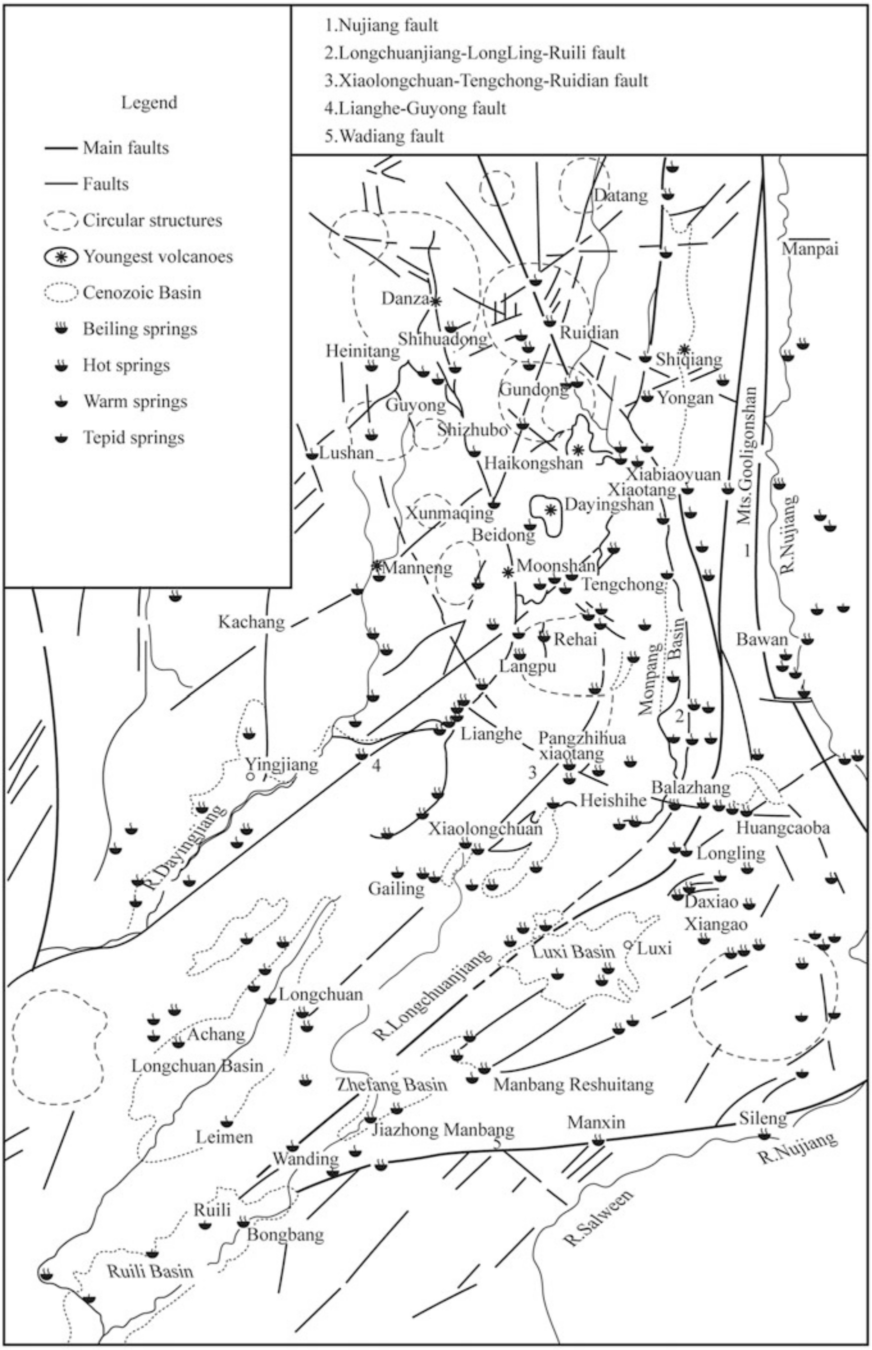

Fig. 5.13 Simplified map showing active tectonics and thermal springs distribution in Tengchong and the surround area. Heavy lines are major active faults recognized on Landsat images (Liao et al. 1986)

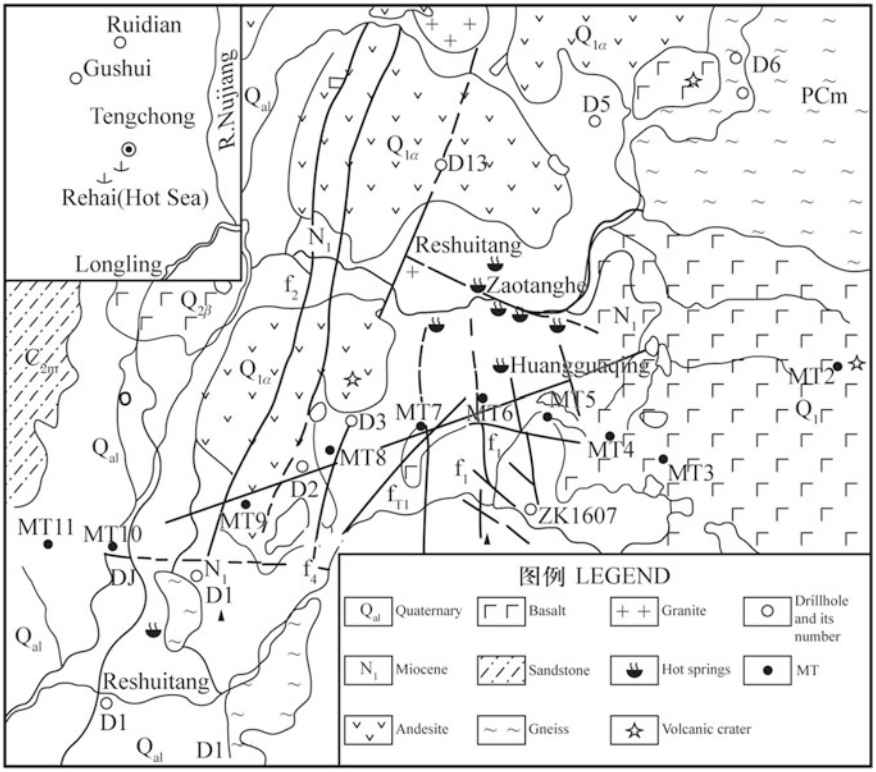

Fig. 5.14 Geological map of Rehai(hot sea) geothermal field. Q_{al} = Quatenary alluvium; $Q_{2\beta B}$ = Middle Pleistocene basalt; $Q_{1\alpha}$ = Lower Pleistocene andesite; N_1 = Miocene sandstone and conglomerate; C_{2m} = Mid Carboniferous sandston-bearing gravel; γ_5 = Late Cretaceous granite;PCm = Gaoligongshan group of Precambrian

water samples collected in 1981 are as follows: t 95.5 °C, pH 8.55, TDS 0.932, Na 340, K 61, Ca 10.7, Mg 1.79, Li 3.40, Rb 0.70, Cs 0.37, NH_4 0.80, CO_3 37, HCO_3 512, SO_4 24, Cl 269, F 7, SiO_2 170, HBO_2 18, The water chemical type is HCO3–Cl–Na.

Yb02, Langpu Reshuitang boiling spring is located in Tengchong County of Baoshan City. 98° 23′ 20″E, 24° 54′ 30″N. Altitude: 1100 m. The geothermal manifestation includes: boiling spring, boiling pond, hot springs, and big travertine hill. The hydrothermal explosion occurred in the main boiling pool. The stratum of spring area is sandstone of Gaoligongshan Group, around which is the Nanlin group of the Neogene. The temperature of boiling spring is 96 °C. The analysis results of water samples collected in 1981 are as follows: t 96 °C, pH 7.5, TDS 1.703, Na 640, K 50, Ca 1.14, Mg, 0.80, Li 2.10, Rb 0.63, Cs 0.15, NH_4 1.30, CO_3 0, HCO_3 984, SO_4 35, Cl 307, F 10.5, SiO_2 150, HBO_2 7. The chemical type of spring water is HCO_3–Cl–Na type.

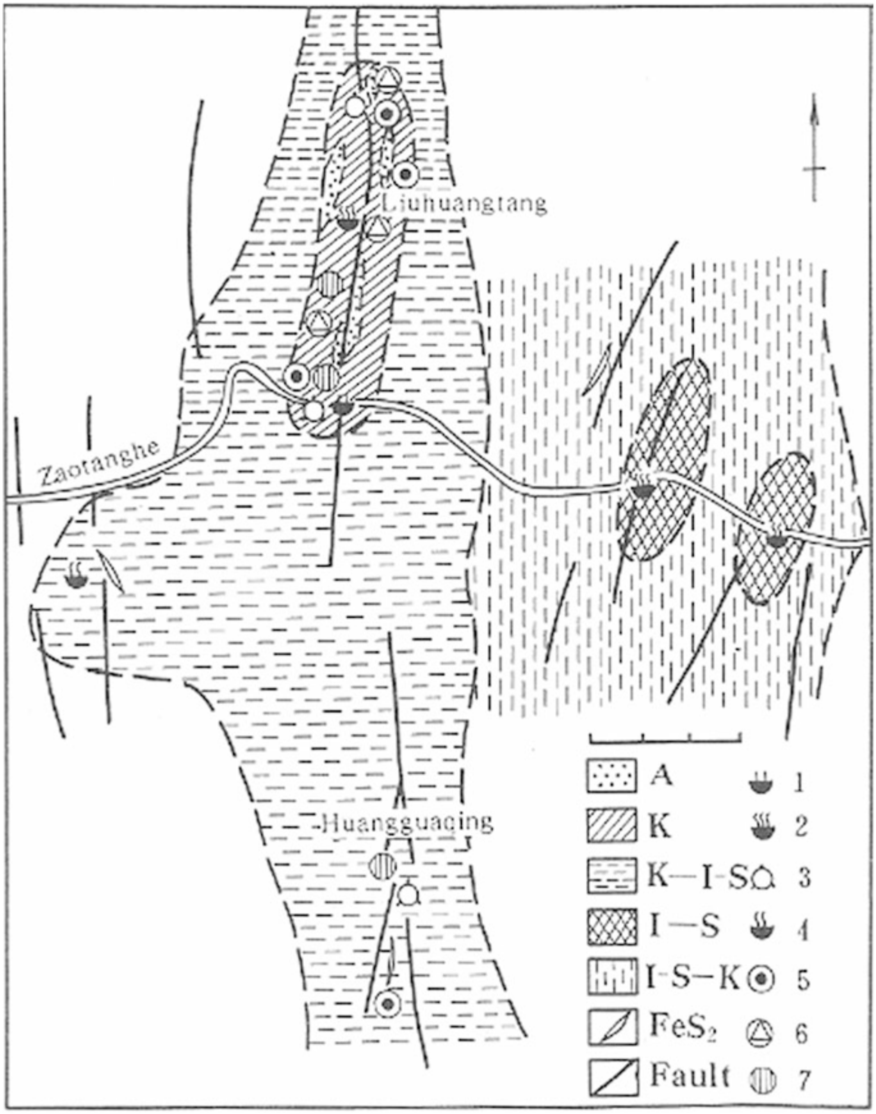

Fig. 5.15 Distribution of alteration zones at the Rehai field (after Zhu and Tong 1987) *A* alunite zone; *K* kaolinite zone; *I–S* Illite mixed mineral zone; *I–S–K* Illite–smectite mixed layer–mineral kaolinite zone; *K–I–S*: kaolinnite–illite–smectite mixed layer mineral zone; FeS_2 Pyrite vein; *F* fault; *1* spouting boiling spring; *2* boiling spring; *3* fumaroles; *4* hot springs; *5* efflorescence; *6* silica sinter; *7* native sulfurite

According to the data of MT surveys across Langpu Reshuitang and Rehai (Hot Sea) geothermal field, they share a common underground heat source (only 5Ω-m low resistivity)

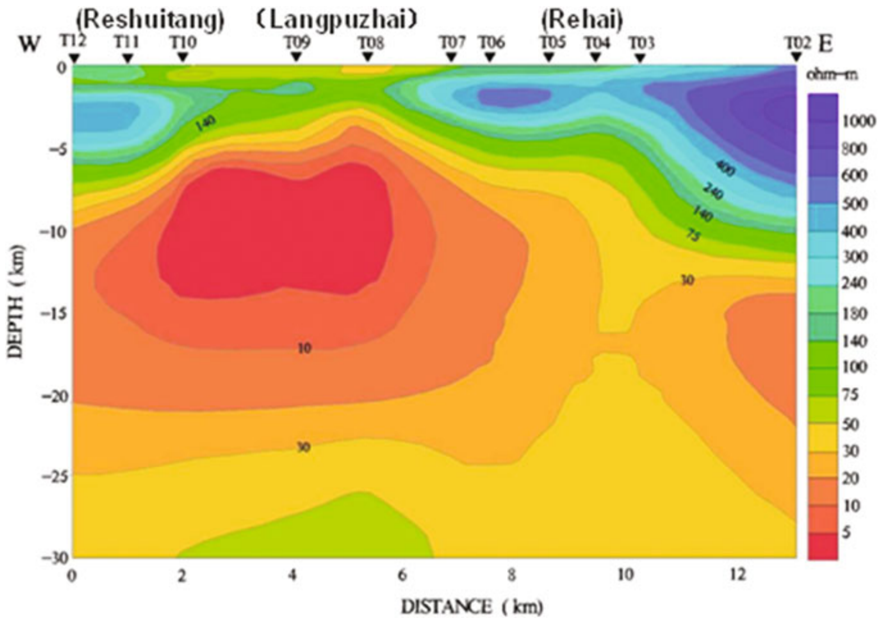

Fig. 5.16 MT 2-d profile of Rehai (Hot Sea) geothermal field (Bai et al. 1994)

6 km beneath the surface, but they are different hydrothermal systems. In other words, there are no hydraulic connector (Fig. 5.16).

Yb03, Panzhihua Xiaotang boiling spring is located in the Xinhua District of Tengchong County of Baoshan City. 98° 29′ 00″E, 24° 43′ 10″N. Altitude: 1230 m. The area is 400 m × 50 m. There are eight vents of boiling springs. The highest temperature of boiling springs is 96.8 °C. The flow rate is 1.5 L/s. The stratum of spring area is metamorphic rock of the Gaoligonshan Group. The geothermal area is located on a fracture belt with S–N trend. Hydrothermal explosion often takes place. The analysis results of water samples collected in 1981 are as follows: t 96.8 °C, pH 7.8, TDS 0.688, Na 210, K 15, Ca 2.14, Mg 0.30, Li 0.96, Rb 0.23, Cs 0.14, NH_4 7.2, CO_3 0, HCO_3 434, SO_4 12, Cl 45.0, F 11.5, SiO_2 158, HBO_2 8. The spring is discharging the HCO_3–Na type water.

Yb04, Bannazhang boiling spring area is located in Longling County of Baoshan City, where is in a tributary of left (eastern) bank of the Longchuanjiang river. 98° 39′ 00″–40′ 00″E, 24° 39′ 20″N. Altitude: 1280 m. The geothermal manifestation types include: boiling springs and large silica sinter terrace. The spring region is dispersed along the tributary into three parts from east to west. The highest temperature is 98 °C. Hydrothermal explosions often occur. The analysis results of water samples collected in 1981 are as follows: t 97 °C, pH: 9.3 ~ 8.45, TDS 0.904, Na 220, K 20, Ca 0.90, Mg 0.02, Li 2.10, Rb 0.27, Cs 0.74, $NH_4$1.0, CO_3 141, HCO_3 306, SO_4 31.2, Cl 5.0, F 20, SiO_2 295, HBO_2 14. The chemical type of water is HCO_3–Na.

Yb05, Longwozhai boiling spring is located in Lianghe County of Dehong Dai-Jingpo Autonomous Prefecture. 98° 15′ 00″E, 24° 47′ 35″N. Altitude: 1040 m. There is a boiling pool with a diameter of one meter. The temperature of spring is 96.5 °C and the flow rate is 0.5 L/s. The hot water flows into a ditch for irrigation of paddy field. Country rock could be andesite. The analysis results of water samples collected in 1981 are as follows: t 96.5 °C, pH 8, TDS 0.488, Na 148, K 7.4, Ca 5.12, Mg 4.83, Li 0.5 2, Rb <0.03, Cs <0.15, NH_4 0.32, CO_3 nd, HCO_3 250, SO_4 54.2, Cl 24.3, F 12, SiO_2 102, HBO_2 4.1. HCO_3–Na type of water.

Yb06, Humeng boiling spring is located in Yingjiang County of Dehong Dai-Jingpo Autonomous Prefecture. 97° 55′ 30″E, 24° 46′ 30″N. Altitude: 870 m. The spring is on a hill slope consisting of granite. The temperature of thermal spring is of 94 °C and the flow rate is 3.1 L/s. The analysis results of water samples collected in 1981 are as follows: t 94 °C, pH 8, TDS 0.522, Na 135, K 10.6, Ca 6.72, Mg 0.36, Li 0.5 2, Rb 0.018, Cs <0.15, NH_4 nd, CO_3 nd, HCO_3 253, SO_4 37.1, Cl 38.2, F 13, SiO_2 153, HBO_2 0.61. The discharging hot water is HCO_3–Na type water.

Yb07, Lanniba boiling spring is located in Yingjiang County of Dehong Dai-Jingpo Autonomous Prefecture. 98° 07′ 48″E, 24° 56′ 24″N. Altitude: 960 m. The spring area is in a Quaternary basin 300 m long and 30–40 m wide. The temperature of spring is 93 °C. It is very difficult to measure the flow rate. The analysis results of water samples collected in 1981 are as follows: t 93 °C, pH 8, TDS 0.353, Na 88, K 4.9, Ca 2.14, Mg 0.11, Li 0.1 2, Rb 0.05, Cs <0.15, NH_4 0.86, CO_3 nd, HCO_3 130, SO_4 32.3, Cl 2.78, F 12, SiO_2 143, HBO_2 0.62. The chemical type is HCO_3–Na water.

Yb08, Peacock spring (Bangbeng boiling spring) (Ruili geothermal field) is located in Ruili City of Dehong Dai-Jingpo Autonomous Prefecture. 97° 23′ 35″E, 24° 00′ 55″N. Altitude: 765 m. Peacock spring is natural outcrop of Ruili geothermal field. The area of Ruili geothermal field occupies more than half of the Ruili basin, which occurs along Longlin-Ruili Fracture belt with NE trend. The Cenozoic sediment in the basin is the Quaternary system and the Tertiary system which became the thermal water-bearing stratum. The basement of Ruili basin can divided into two regions: the north side of Longlin-Ruili Fault is Granite or migmatite and the southern side is slate and limestone of Perm-Triassic system (Figs. 5.17 and 5.18). The water temperature of the Peacock spring is 95 °C. The analysis results of water samples collected in 1981 are as follows: t 95 °C, pH 8, TDS 1.104, Na 380, K 31, Ca 2.98, Mg 0.63, Li 2.28, Rb 0.38, Cs 0.53, NH_4 1.4, CO_3 nd, HCO_3 874, SO_4 19.0, Cl 26.7, F 17, SiO_2 156, HBO_2 29. HCO_3–Na type of water.

5.3.2 Boiling Springs on Canning-Jinghong Anticlinorium

Yb09, Yandengshan boiling spring is located in the Yunlong County of Dali Bai Autonomous Prefecture. 99° 08′ 00″E, 25° 52′ 05″N. Altitude: 1900 m. The area is 50 m × 20 m. The springlets are innumerable. There are five large vents, and their

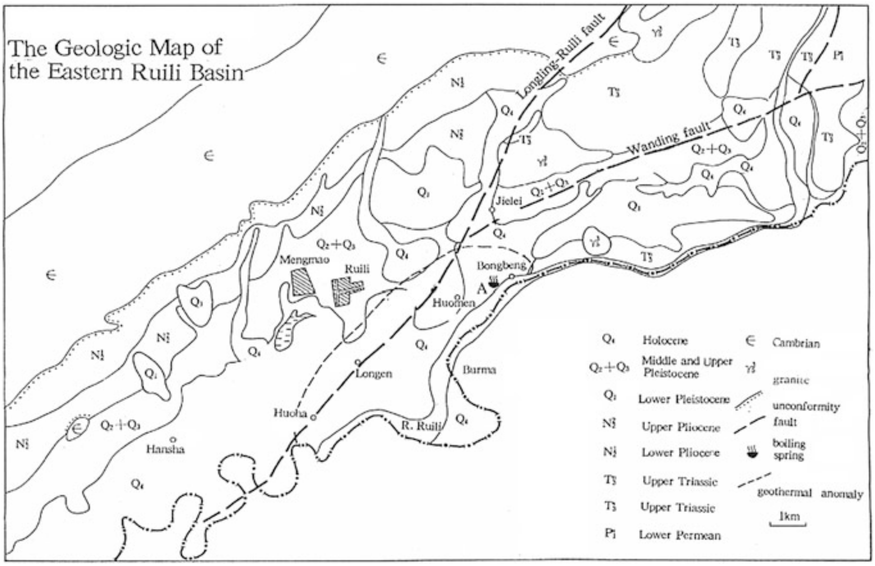

Fig. 5.17 Geological map of the eastern Ruili Basin

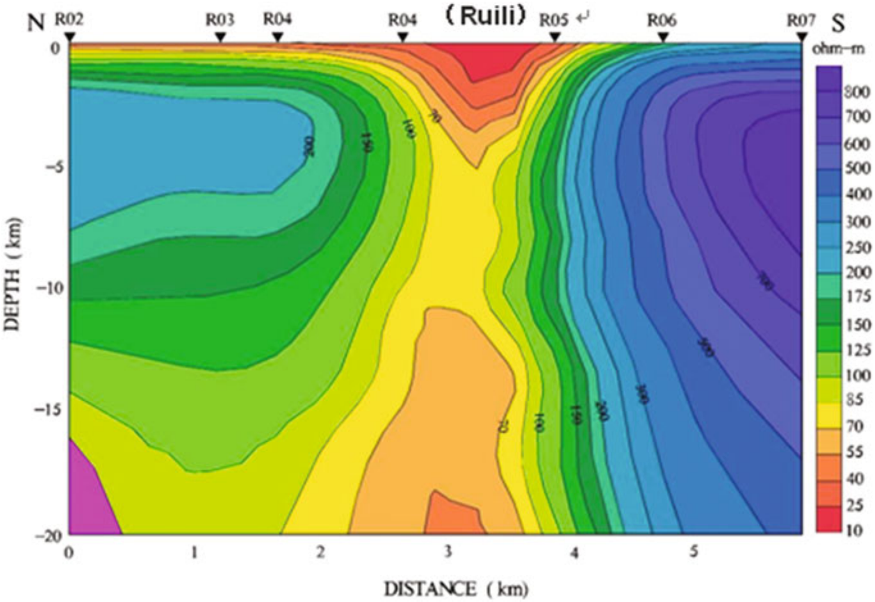

Fig. 5.18 MT 2-D profile of Ruili geothermal field

temperatures are 91, 93, 92, 94.5 and 68 °C, respectively. They are all fountains with different height. The maximum spray height is 2 m. There are travertine and native sulfur. The highest temperature of boiling spring is 94.5 °C. The analysis results of water samples collected in 1981 are as follows: t 94.5 °C, pH 8., TDS 0.75, Na 175, K 16.4, Ca 15.3, Mg 1.43, Li 0.73, Rb 0.017, Cs 0.48, NH_4 nd, CO_3 9.51, HCO_3 410, SO_4 45.1, Cl 13.7, F 5.3, SiO_2 184, HBO_2 3.16. HCO_3–Na type of water.

Yb10, Juanqiaohe boiling spring is located in Fengqing County of Lincang City, where is on the tributary of south bank of Lancang River. 99° 52′ 48″E, 24° 45′ 42″N. Altitude: 1040 m. There are two boiling spring pools, which are discharging 96 and 97 °C boiling water. The outcrop of rock is gneiss of Lancang Group of the Proterozoic Era. The analysis results of water samples collected in 1981 are as follows: t 97 °C, pH 8.92, TDS 0.370, Na 73.0.4, K 5.63, Ca 1.32, Mg 1.05, Li 0.47, Rb 0.05, Cs 0.34, NH_4 1.84, CO_3 18.8, HCO_3 102, SO_4 31.0, Cl 11.2, F 15, SiO_2 154, HBO_2 4.49. The chemical category of thermal water is HCO_3–Na type.

Yb11, Yongxin Reshuitang (hot water pool) boiling spring is located in Fengqing County of Lincang City, which is on the northern bank of Lancang River. 99° 53′ 54″E, 24° 45′ 54″N. Altitude: 1080 m. Juanqiaohe spring and Yongxin Reshuitang face each other across the river, but Yongxin Reshuitang is in the downstream 1 km away from the main river. The temperature of spring is 97 °C. The outcrop of rock is gneiss of Lancang Group of the Proterozoic Era. The analysis results of water samples collected in 1981 are as follows: t 97 °C, pH 9.02, TDS 0.399, Na 94, K 4.85, Ca 2.51, Mg 1.52, Li 0.53, Rb 0.40, Cs 0.87, NH_4 nd, CO_3 31.2, HCO_3 69.8, SO_4 38.2, Cl 28.0, F 13.6, SiO_2 144, HBO_2 4.26. The chemical category of thermal water is HCO_3–Na type

Yb12, Bingling (Xiaodingxi) boiling spring is located in the Yunxian County of Lincang City near the Yunxian-Kunming highway and a riverlet. 100° 18′ 00″E, 24° 29′ 30″N. Altitude: 1040 m. The surface manifestation has mainly hot springs and travertine. Only one small boiling spring of 94 °C is mixed with hot springs. The analysis results of water samples collected in 1981 are as follows: t 94 °C, pH 8.30, TDS 0.534, Na 140, K13.9, Ca 1.01, Mg 0.25, Li 0.06, Rb 0.09, Cs 0.18, NH_4 0.38, CO_3 nd, HCO_3 273, SO_4 41.5, Cl 25.0, F 11.0, SiO_2 160, HBO_2 4.50. The water chemical type is HCO_3–Na.

Yb13, Dakongbeng boiling fountain is located in the Yunxian County of Lincang City near the Nanqiaoke hydropower station. 100° 03′ 30″E, 24° 23′ 00″ N. Altitude: 1080–1200 m. The strength of geothermal manifestation comes second in Yunnan Province, right after the Rehai (Hot Sea) geothermal field of the Tengchong County. The geothermal manifestation type is mainly boiling fountains (Fig. 5.19). Intense hydrothermal alteration took place in this geothermal region. The rock of geothermal region is granite. The Nandinghe fault passes through this geothermal region. The temperature of fountain is 96 °C. The analysis results of water samples collected in 1981 are as follows: t 96 °C, pH 8.50, TDS 0.702, Na 177, K 23.4, Ca 0.12, Mg 0.11, Li 1.20, Rb 0.22, Cs 1.01, NH_4 0.38, CO_3 37.5,

Fig. 5.19 Dakongbeng fumaroles jetting against each other (1996)

HCO_3 329, SO_4 31.50 Cl 33.0, F 16.1, SiO_2 201, HBO_2 15.20. The water chemical kind is HCO_3–Na type.

Yb14, Xingfu boiling spring is located in Yunxian County of Lincang City. There are two display areas, 400 m apart from each other. 99° 58′ 48″E, 24° 10′ 00″N. Altitude: 951–970 m. The boiling spring area is within a valley, and its temperature is 96 °C; another one is a hot spring with temperature of about 70 °C in the vicinity of flood, This geothermal region is closed the Nandinghe Fault belt. The analysis results of water samples collected in 1981 are as follows: t 96 °C, pH 8.50, TDS 0.579, Na 126, K 13.3, Ca 0.21, Mg 0.10, Li 1.08, Rb 0.15, Cs 1.06, NH_4 2.25, CO_3 100, HCO_3 28.6, SO_4 32.60 Cl 12.2, F 18.5, SiO_2 244, HBO_2 13.20. The discharging boiling water is CO_3–Na type.

Yb15, Malutianba boiling spring is located in Yunxian County of Lincang City. 99° 56′ 36″E, 24° 07′ 12″N. Altitude: 960 m. Both Malutianba and Xingfu geothermal areas are located in a common basin with NEE trend. But it is located in the southwestern end of the basin and the Xingfu is located at the northeast end. The formation of basin is under the control of the Nandinghe fracture belt. The temperature of boiling spring is 96 °C. Hydrothermal explosion have occurred in this geothermal area. The analysis results of water samples collected in 1981 are as follows: t 96 °C, pH 7.95, TDS 0.544, Na 127, K 12.8, Ca 2.12, Mg nd, Li 0.53, Rb 0.08, Cs 0.04, NH_4 3.40 CO_3 nd, HCO_3 209, SO_4 68.2 Cl 12.6, F 20, SiO_2 181, HBO_2 11.4. The discharging thermal water is HCO_3–SO_4–Na type.

Yb16, Yunnancheng boiling spring is located in Lancang County of Puer City. 99° 58′ 30″E, 22′ 40′ 20″N, Altitude: 920 m. The temperature of main vent is 99 °C. There are many springlets at 93–98 °C. Total flow rates are about 4 L/s. Country rock is metamorphic rock of the Lancang Group. The chemical compositions of spring water are as follows: t 99 °C, pH 8.66, TDS 0.593, Na 146, K 15.6, Ca 9.50, Mg 4.52, Li 0.36, Rb 0.21, Cs 0.14, NH_4 1.74, CO_3 37.4, HCO_3 241, SO_4 50.1, Cl 44.0, F 14.0, SiO_2 136, HBO_2 12.8, As 0.04. The discharging thermal water is HCO_3–Na type.

Yb17, Mengman boiling spring is located in Menghai County of Xishuanbanna Dai Autonomous Prefecture. 100° 07′ 40″–08′ 00″E, 22° 09′ 40″–10′ 00″N. Altitude: 860 m. The area of thermal manifestation is 1000 m long and 500 m wide with northeast–southwest trend. The areal extent is 0.5 km^2. Numerous boiling springs appear in the south end. Their temperatures are 96–100 °C. There are many spring-fed pools of varying sizes.and a mass of hot marsh. The rock outcrop is granite. The chemical compositions of spring water are as follows: t 99 °C, pH 9.7, TDS 0.972, Na 265, K 30.7, Ca 1.05, Mg 0.32, Li 0.50, Rb 0.52, Cs 1.34, NH_4 2.40, CO_3 140, HCO_3 98.3, SO_4 160, Cl 56, F 25.6, SiO_2 224, HBO_2 15.7, As 0.03. The discharging thermal water is CO_3–SO_4–Na type.

Yb18, Manzhao boiling spring is located in Menghai County of Xishuanbanna Dai Autonomous Prefecture. 100° 23′ 00″E, 21° 52′ 15″N. Altitude: 1200 m. Thermal springs are distributed along both sides of a river. The temperature of thermal waters is 97 °C. The chemical compositions of hot water are as follows: t 97 °C, pH 8.35, TDS 0.476, Na 118, K 11.4, Ca 0.71, Mg 0.51, Li 0.21, Rb 0.14, Cs 0.37, NH_4 0.88, CO_3 18.7, HCO_3 212, SO_4 37.2, Cl 7.4, F 14.6, SiO_2 150, HBO_2 9.66, As 0.02. The discharging thermal water is HCO_3–Na type.

Yb19, Xiaojie Manbang boiling spring is located in Jinghong County of Xishuanbanna Dai Autonomous Prefecture. 100° 42′ 00″E, 21° 43′ 25″N. Altitude: 700 m. The geothermal manifestation area includes two places. One is boiling pool and another is a small fountain with the temperature of 101 °C. The chemical compositions of water sample are as follows: t 100.7 °C, pH 8.52, TDS 0.400, Na 90.5, K 8.03, Ca 1.01, Mg 0.11, Li 4.72, Rb 0.02, Cs 0.13, NH_4 1.85, CO_3 12.5, HCO_3 146, SO_4 27.5, Cl 11.0, F 15.3, SiO_2 154, HBO_2 4.72, As 0.02. The discharging thermal water is HCO_3–Na type.

5.3.3 Boiling Springs on Ailaoshan Anticlinorium

Yb20, Mengping boiling spring is located in Jinping County of Honghe Hani Autonomous Prefecture. 103° 29′ 15″–29′ 30″E, 22° 54′ 40″–55′ 00″N. Altitude: 160 m. The boiling spring is situated in the south bank of Hong (Red) river. The area is 150 m × 30 m with NW–SE trend. The main spring mouth is a pool, where a large of steam bubbles extrude out. The temperature of boiling water is 96–102.2 °C. The chemical compositions of water sample are as follows: t 102.2 °C, pH 8.40, TDS 0.915, Na 235, K 23, Ca 6.92, Mg 1.80, Li 0.21, Rb 1.43, Cs 0.53, NH_4 4.50, CO_3 nd, HCO_3 165, $SO_4$332, Cl 26.3, SiO_2 191, HBO_2 1.70, As 0.02. SO_4–HCO_3–Na type of water.

5.4 Boiling Springs in Qinghai Province

The north margin of Qingzang Plateau is the Qilianshan Mountain of Qinghai Province. But only one boiling spring in Qinghai Province emerges in west end of Kunlun Mountain, which lies across the center part with east–west trend.

Qb01 Bukadaban boiling spring is located on the eastern foot of Bukadaban peak (6860 m) of Kunlun Mountain, where is a no man's land. 90° 52′30″E, 35° 58′ 00″N. Altitude: about 5000 m. It was found by Hoh Xil Scientific exploration in 1990 (Zheng et al. 1992). The area of spring region is about 1000 m^2, where there are 74 fumalores and 35 boiling springs and hot springs with temperatures of 75–92 °C. The boiling water gushed from the moraine, and then quickly flows into moraine of lowland. Then it was flowed from the edge of the moraine up to surface as a thermal spring with lower temperature. The water sample was gathered in 1989 and the results are as follows: t 90 °C, pH 7.3, TDS 0.207, Na 15.9, K 1.04, Ca 11.2 Mg 2.01, Li <0.05, Rb <0.02, Cs<0.05, NH_4 33.1, CO_3 nd, HCO_3 118, SO_4 35.4, Cl 6.95, F 0.902, SiO_2 39.1, HBO_2 2.42, As 0.04. HCO_3–SO_4–Na–Ca type.

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Chapter 6
Hot Springs in Southwestern China

Abstract This chapter describes 548 hot spring in Qingzang Plateau and the surrounding, of which Tibet has 179, west Sichuan 103, and southwest Yunnan 266. A brief introduction of their geographical positions and altitude, spa's temperatures, geothermal manifestations, and the main chemical compositions of spring waters and country rocks has been done.

Keywords Hot springs · Geothermal manifestations · Chemical composition

Hot Springs is a type of thermal spring with temperatures higher than 45 °C but lower than the boiling temperature at corresponding local elevation. The total amount of hot spring in Qingzang plateau is about 560, in which Tibet has 179, western Sichuan 103, Southwest Yunnan 266, and Qinghai 12. The most hot springs have undergone on-the spot investigation and sampling for analysis due to their higher temperature. But I only show the eight main ions and SiO_2 or HBO_2 (only for Tibetan spas) for the analytic result in this chapter.

6.1 Hot Springs in Tibet Autonomous Region

According to the data of books *Thermal Springs in Tibet* (Tong et al. 2000) and *Geothermals beneath Xizang (Tibetan) Plateau* (Tong et al. 1981), there are 179 hot springs in Tibet, five of which their temperature are close that of boiling spring.

6.1.1 Hot Springs in Ngari Prefecture

Th01, Musi Qucain hot spring is located in Rutog County. 81° 52′ 25″E, 33° 24′ 25″N. Altitude: 4800 m. There are three vents on the top of trivertine. The temperature of spring's water is 60.5 °C. The country rock is Lower Permian

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limestone and quartzite. The main chemical composition (sampling time: Aug. 23 1976): pH 6–7, TDS 2.88, Na 1000, K 43, Ca 40.3, Mg 17.0, CO_3 and, HCO_3 2070, SO_4 69.0, Cl 396, F 4.4, SiO_2 76.4, HBO_2 35.6. HCO_3–Na water.

Th02, Langjiu geothermal field is located in Gar County. 80° 21′ 40″E, 32° 21′ 48″N. Altitude: 4500 m. This is a hot spring area of 400 m × 400 m. The geothermal manifestation type includes hot spring (78 °C), warm springs and silica sinter and travertine. The distance between Langjiu hot springs and Shiquanhe, the capital of prefecture, is only 30 km. Shiquanhe was lacking of electricity. In 1984 the local government decided to develop Langjiu's geothermal power. Due to the lack of detailed geological exploration, 13 wells were drilled, well spacing was than only 10 m. Depth was about 100 m. They drilled in the same funnel of precipitation with severely interfere between each other. The maximum temperature of the drilled hole was 105 °C, the lowest 91 °C. This does not meet the requirements for power generation. The chemical analysis of water sampled from 78 °C springs and several drilling holes of Langjiu geothermal field were done, I here list only the analysis results of main chemical components in Table 6.1 and the calculation results of three silica geothermometers.

The chemical type of geothermal water in Langjiu geothermal field belongs to chlorine—bicarbonate—sulfate—sodium type. Although sulfate content of some drilling drainage did not meet the naming standards, but its equivalent percentage reached 23%. Such a high sulfate content is clearly different from the common type

Table 6.1 The main chemical components of Langjiu geothermal field

	78 °C spa	No. 3 hole	No. 5 hole	No. 8 hole	No. 9 hole	No. 12 hole
TDS	2.04	2.27	2.15	2.06	2.03	2.21
Na	573	595.8	585.2	552.2	576.6	605.2
K	50	65.91	65.3	62.93	65.02	66.95
Ca	32.1	32.04	14.85	30.48	27.75	34.39
Mg	8.66	3.32	1.66	3.32	2.13	1.66
CO_3	3.75	111.7	81.90	50.40	3.15	37.80
HCO_3	445	403.63	403.64	515.76	611.68	573.41
SO_4	342	327.63	387.73	306.23	348.19	332.57
Cl	430	399.06	379.02	382.66	382.18	386.32
SiO_2	137	175	190	185	174.63	185
HBO_2	212	246.15	218.07	214.95	225.40	246.15
Water type	Cl–HCO_3–SO_4–Na	Cl–(HCO_3+CO_3)–Na	Cl–SO_4–Na	Cl–HCO_3–Na	Cl–HCO_3–SO_4–Na	Cl–HCO_3–Na
T quartz	156	161	165	164	161	164
T chalce-dony	131	149	155	153	148	153
Tα-cristo-bality	105	121	127	125	121	125

of high-temperature, sodium chloride, and certainly not low-temperature HCO_3–Ca Mg type water. Based on the content of silica in geothermal water, the quartz, chalcedony and, α-cristobalite thermometers were used to calculate the temperature of deep fluid in geothermal reservoir The temperature as calculated with the quartz thermometer shows that the geothermal fields in Langjiu is a high temperature hydrothermal system, and the temperature calculated with chalcedony thermometer is close to 150 °C. The temperature calculated with α-cristobalite thermometer shows that Langjiu field is an intermediate temperature hydrothermal system. The CSAMT measurement has been done in the Langjiu geothermal field in 2014 and 1000 m deep low resistivity body has been inferred for geothermal reservoir. Later, a 1000 m deep borehole drilled into the low resistivity body, the temperature was measured to be only 120 °C, consistent with calculated temperature by α-cristobalite thermometer, and the temperature inversion occurs in the depths. It seems the original conjecture that low resistivity zone for geothermal reservoir is wrong, it is likely due to the intense hydrothermal alteration of clay layers. It seems that the Langjiu hot springs is likely one of the intermediate hydrothermal system. But the location of the reservoir remains unknown.

Th03, Bogqen hot spring is located a pastoral point of Moincer District of Gar County. 80° 37′ 54″E, 31° 27′ 49″N. Elevation: 4800 m. The temperature of hot spring is 78 °C in 1973. Others are unknown.

Th04, Moincer hot spring is located on Moincer District of Gar County. 80° 55′ 53″E, 31° 11′ 09″N. Altitude: 4500 m. Indian Pranavananda (1939) has called this spring for the Tirthapun. It is located in the north bank Langqing Zangbo river. The spring is well-known with special development of trivertine. There are five main vents, three located on the white travertine terraces with temperature between 69.6 and 71.4 °C. Two springs (51 °C) lie on the river floodplain of west side of trivertine terraces. Sinter's development can be divided into four stages. The first phase is silica sinter, which is situated on the edge of the cliff of the travertine terraces's north side. The cliff is a NW-trending fault plane. Rock is Carboniferous–Permian quartzite. The second phase is travertine cone, white, distributed on the top of the cliff. It is 40 m higher than the river. The third period is also trivertine cone, yellow, individual large becomes a turning tower. Located on the second terrace gravels. Above the river 20 m. The fourth is white travertine terraces, an area 250 m × 170 m. High 3–4 m. The main chemical components (1976 sample) as follows: pH 7, TDS 0.964, Na 123, K 41.5, Ca 74, Mg 50.3, HCO_3 689, SO_4 88.9, Cl 18.1, SiO_2 43.7, HBO_2 21.6. Water type: HCO_3–Na–Mg–Ca.

Th05, Demqok hot spring is located in Gar County. 79° 26′ 42″E, 32° 40′ 36″N. Altitude: 4700 m. The temperature could be very high. Steam is rising above the vents. The spring water is too hot to touch with hand. It discharges hydrogen sulfide odor.

Th06, Quca hot spring is situated in Zanda County, which is on the boundary between China and India. 78° 45′E, 31° 50′N. Altitude: 3200 m. There are tree vents. The temperature of spring water is so high to cook chicken eggs, and so it should be above 70 °C.

Th07, Eboqu hot spring is situated in Zanda County. 79° 14′E, 32° 10′N. Not done fieldwork. According to the visit that, it is a fountain of hot water.

Th08, Gyarang hot spring is located in north bank of gorge of Langqing Zangbo river in Zanda County. The County government sent people to do the temperature measurement and sampling in July 1976. Analysis results were as follows: $t > 50$ °C, TDS 1.23, Na 165, K 73.5, Ca 146, Mg. 79.7, HCO_3 1110, SO_4 41.7, Cl 98.9, SiO_2 32.7, HBO_2 35.6. HCO_3–Ca–Na–Mg type water.

Th09, Kyunglung hot spring is located at most east part of Zanda County and at east (left) bank of Langqing Zangbo river. Indian Pranavananda (1939) has ever been there in 1937. 80° 32′ 45″E, 31° 03′ 43″N. Altitude: 4240 m. Travertine body is very spectacular. The highest temperature of hot spring is 55 °C. The flow rate is about 270–550 L/s. The main chemical compositions are as follows: pH 8.7, TDS 1.12, Na 265, K 118, Ca 10.3, Mg 47.9, CO_3 82.5, HCO_3 468, SO_4 191, Cl 98.3, SiO_2 36.4, HBO_2 19.1. HCO_3–Na–Mg type water.

Th10, Qangba hot spring is located in the western part of Ge'gya County, 80° 41′ 27″E, 32° 32′ 44″N. Altitude: 4400 m. The spring area is exposed under Tertiary volcanic cliffs of north (right) bank of Senge Zangbo river. Mainly a warm swamp is dispersed along the highway from Ge'gya to Siquanhe Town. The water temperature of swamp is 20 °C. There are two vents, and their higher temperature is 51 °C. The flow rate is of 1 L/s. Sampling date was collected on September 9th 1976. The main chemical components are as follows: TDS 2.60, Na 800, K 53.0, Ca 39.4, Mg 5.98, HCO_3 966, SO_4 396, Cl 381, SiO_2 109, HBO_2 137. It is HCO_3–Cl–Na type water.

Th11, Quduowa hot spring is located east end of Ge'gya County. 82° 36′ 08″E, 31° 58′ 37″N. Altitude: 5020 m. Vents are located on a sinter hill 10 m high and 100 m long and with NE60° trend. On the hill top there are two rows of vents. Along west line there list 10 sinter cones, five of which are overflowed with hot water with the maximum temperature of 58 °C and the lowest 28 °C; along the east line list four sinter cones, three of which are drainage with the maximum temperature of 61 °C. The total flow is very low, only 1 L/s. At the northern end of the sinter hill is a hot water pool with diameter of 20 m and deep of 10 m. There are a lot of bubbles bulges. Water temperature is 47 °C, discharge orifice flow 3 L/s. September 6, 1976 samples. The main chemical components are as follows: t 61 °C, pH 8.6, TDS 2.63, Na 768, K 76.5, Ca 14.7, Mg 7.45, CO_3 131.3, HCO_3 604.3, SO_4 194.5, Cl 639.1, SiO_2 94.2, HBO_2 308, As 20.0. Water type: Cl–HCO_3–Na.

Th12, Qiugoinba hot spring is located in the riverbed of spillway of the northwest corner of Mapam Yomco of Burang County. Main vent is located on the right bank of spillway. A fountain spurted hot water of 81 °C into the air reaching 50 cm high. Two sides of riverbed is huge brown sandstone and conglomerate cemented by sinter which formed a terrace. Several hot springs come out from the base of terrace. Their temperature is of 79–81 °C. Total flow rate is about 20 L/s. Country rock at northern bank of spillway is quartz sericite schist of the Palaeozoic Era. The simple analysis results of water sample of July 15th 1976 are as follows: t 81 °C, pH 8.6, TDS 3.11, Na 910, K 113, Ca 3.17, Mg 3.61, CO_3 173, HCO_3 1054, SO_4 352, Cl 624, SiO_2 152, HBO_2 310. Cl–HCO_3–Na type water.

Th13, Yamenza hot spring, located in Burang County, is one manifestation area of Mapam Yongco boiling-hot spring system. 81° 35′ 18″E, 30° 35′ 23″N. Altitude: 4680 m. It is located in the north shore Tagequ Zangbo river. The sinter hill with a big cave is famous. When we studied here in July 1976, this cave was our dwelling place. The eastern side of sinter hill is a gully flows from north to south. Cretaceous sandstone appears on the wall of gully. Two groups of hot springs appear on either side of I-grade terraces of gully. The maximum temperature is 78.6 °C. Total flow rate is 3 L/s. The main chemical components are as follows: pH 7.5, TDS 1.27, Na 335, K 35.5, Ca 18.1, Mg 2.49, CO_3 18.2, HCO_3 732, SO_4 67.8, SiO_2 131, HBO_2 117. HCO_3–Na type water.

Th14, Kunggyu hot spring is located in northeast of Burang County. and lies on a alluvial fan of the southern foot of Mt. Gangdise, which is 4.5 km south to Kunggyu Co. 82° 06′ 05″E, 30° 42′ 40″N. Elevation: 4860 m. There are two trivertine bodies 4 m high. The hot water at 71.5 °C is discharged out of the bottom outlet of trivertine body. The flow rate is about 5 L/s. The main chemical composition are as follows: pH 7–8, TDS 4.33, Na 960, K 100, Ca 25.5, Mg 12.5, CO_3 66.5, HCO_3 1430, SO_4 74.3, Cl 762, SiO_2 76.4, HBO_2 1180, As 22.49. HCO_3–Cl–Na type water.

Th15, Lugu hot spring is located in Gerze County. 84° 08′ 12″E, 33° 24′ 24″N. Elevation: 4528 m. The temperature of spring is 70 °C. The others are unknown.

Th16, Nagezhong hot spring is located in Gerze County. 84° 12′E, 32° 18′N. Altitude: 4550 m. The temperature of spring is 60 °C. The country rock is Jurassic-Cretaceous red rocks. The others are unknown.

Th17, Yarlhaingari hot spring is located in Gerze County. 86° 01′ 36″E, 33° 00′ 48″N. Altitude: 4880 m. The temperature of spring is 60 °C. The others are unknown.

Th18, Qucainmenbo or **Caiza** hot spring is located in Coqen County. 84° 45′ 06″E, 31° 20′ 20″N. Altitude: 4640 m. The temperature of spring is 75.5 °C. The flow rate is 20 L/s. The Country rack is Cretaceous system. The main chemical compositions are as follows: pH 8.25, TDS 1.013, Na 337.55, K 23.24, Ca 12.79, Mg 2.33, CO_3 299.01, HCO_3 na, SO_4 154.35, Cl 49.65, SiO_2 90.0, HBO_2 34.25. CO_3–Na type water.

Th19, Lug La hot spring is located in Coqen County. 85° 17′ 30″E, 29° 44′ 50″N. Altitude: 5200 m. The temperature of vent is 56 °C. The country rock could be granite. The main chemical compositions are as follows: pH 7.48, TDS 2.758, Na 656.55, K 69.32, Ca 18.34, Mg 3.02, HCO_3 1169.8, SO_4 155.58, Cl 356.82, SiO_2 90.0, HBO_2 802.8. HCO_3–Cl–Na type water.

6.1.2 Hot Springs in Xigaze Prefecture

Th20, Quxam Qucain hot spring is located in gorge of Mt. Himalayas of Nyalam County. 85° 59′ 55″E, 28° 04′ 54″N. Altitude: 2500 m. There are three springs within 500 m along the Boqu river. The east bank of the river is Precambrian muscovite gneiss; and the west bank is quartzite. The temperature of springs is between 57.5 and 37.5 °C. The total flow rate is about 5 L/s. The main chemical compositions are as follows: *t* 49.2 °C, pH 7.2, TDS 1.23, Na 418, K 71.5, Ca 39.6, Mg 9.36, HCO_3 1340, SO_4 33.9, Cl 85.1, SiO_2 115, HBO_2 16. HCO_3–Na type water.

TH21, Qunggo hot spring is located in Ngamring County. 86° 43′ 00″E, 29° 08′ 00″N. Altitude: 4400 m. The highest temperature of spring is 46 °C and the flow rate is 4 L/s.

Th22, **Qugu** hot spring is located in Ngamring County. 87° 05′ 50″E, 29° 19′ 27″N. Altitude: 4400 m. The highest temperature is 48.5 °C. The main chemical compositions are as follows: pH 8.9, TDS 0.377, Na 118, K 2.5, Ca 3.43, Mg 1.26, CO_3 45.7, HCO_3 227, SO_4 28.8, Cl 13.9, SiO_2 36.0, HBO_2 8.0, HCO_3–Na type water.

Th23, Mailung hot spring is located near the north bank of Yarlung Zangbo river in Ngamring County. 67° 04′ 18″E, 29° 08′ 15″N. Altitude: 4100 m. The main vent had inundated by river water in August 1975. Country rock is crystal limestone and carbonaceous phyllite. The main chemical compositions are as follows: *t* 44.2 °C (sampled point at subaqueous 5 cm), pH 7.35, TDS 1.33, Na 238, K 31, Ca 87.5, Mg 15.6, HCO_3 764, SO_4 1.63, Cl 127, SiO_2 67.5, HBO_2 110, HCO_3–Na–Ca. water.

Th24, Chala hot spring is located on the flood land of southern bank of Duoxung Zangbo river in Ngamring County. 87° 18′ 35″E, 29° 23′ 25″N. Altitude: 4220 m. There are three main vents (46.5, 47, and 52.5 °C) within an area of 1 km × 300 m along the river. The total flow rate is 25 L/s. Country rock is andesite. The main chemical compositions of sample collected on August 20 1976 are as follows: *t* 52.5 °C, pH 7.45, TDS 3.53, Na 1000, K 81, Ca 88.9, Mg 7.19, HCO_3 1160, SO_4 337, Cl 927, SiO_2 109, HBO_2 400. Cl–HCO_3–Na type water.

Th25, Longbu or **Quku** hot spring is located in a tributary of north bank of Duoxung Zangbo river in Ngamring County. 87° 27′ 00″E, 29° 24′ 25″N. Altitude: 4480 m. There are 6 vents with temperature of 63–85.2 °C and total flow rate of 5 L/s. Country rock is andesite. The main chemical compositions are as follows: pH 7.0, TDS 1.60, Na 442.5, K 26.5, Ca 53.2, Mg 9.36, HCO_3 493, SO_4 280, Cl 272, SiO_2 78.8, HBO_2 187. HCO_3–Cl–SO_4–Na type water.

Th26, Salu hot spring is located on the right bank of a tributary of south bank of Yarlung Zangbo river in Ngamring County. 87° 25′ 40″E, 29° 05′ 25″N. Altitude: 4200 m. The area of springs is 150 m × 20 m with dozens of vents. Measured temperature is from 73.5 to 76 °C and flow rate is 5 L/s. Country rock is quartz sandstone bearing pyrite. The main chemical compositions are as follows: pH 7.5, TDS 0.51, Na 125, K 12.5, Ca 34.3, Mg 8.33, HCO_3 38.1, SO_4 26.8, Cl 9.57, SiO_2 74.7, HBO_2 25. HCO_3–Na water.

Th27, Yendum Qucain hot spring is located in Tingri County. 86° 42′ 17″E, 28° 47′ 45″N. Altitude: 4450 m. The area of spring region is 1.5 km × 1 km. There are three main vents, including a fountain. The temperatures of spring are 60–67 °C and the flow rate is 8 L/s. There are six sinter cones on the hillside, the highest one reaches 3 m. The main chemical compositions are as follows: pH 7.5, TDS 1.37, Na 370, K 34.5, Ca 55.9, Mg 4.57, HCO_3 1202, SO_4 24.7, Cl 91.75, SiO_2 57.9, HBO_2 110. HCO_3–Na type water.

Th28, Jiggyob Qucain hot spring is located in Tinri County. 87° 42′ 25″E, 28° 32′ 20″N. Altitude: 4178 m. The main vent (77.5 °C)is located at a meeting point of two tributary only occupying a small area. The flow rate is very small, only 0.5–1 L/s. The main chemical compositions are as follows: pH 7.8, TDS 0.798, Na 148.4, K 8.3 Ca13.2, Mg 3.45, HCO_3 372, SO_4 53.5, Cl 40.6, HCO_3 372, SO_4 53.5, Cl 40.6, SiO_2 102, HBO_2 39.5, HCO_3–Na water.

Th29, Nyxia hot spring is located in Tingri County. 87° 43′E, 28° 32′N. Elevation: 4180 m. There is only one vent with temperature of 47 °C and flow rate of 6 L/s. The main chemical compositions are as follows: TDS 0.398, Na 110, K 3, Ca 13.6, Mg 5.49, HCO_3 290, SO_4 21.7, Cl 26.7, SiO_2 76.3, HBO_2 16.7, HCO_3–Na water.

Th30, **Mangpu** or **Mangpu Qukug** hot spring is located in Lhaze County. 87° 33′ 54″E, 28° 54′ 36″N. Altitude: 4600 m. There are five vents with temperature of 43–47 °C and flow rate of 3 L/s. The main chemical compositions are as follows: pH 8.05, TDS 0.43, Na 138, K 6.0, Ca12.0, Mg 1.05, HCO_3 282, SO4 4.13, Cl 26.3, SiO_2 57.8, HBO_2 30.5, HCO_3–Na type water.

Th31, Xiqen Qucain hot spring is located in Lhaze County. 87° 44′ 25″E, 29° 04′ 25″N. Elevation: 3995 m. It has large vents with temperature of 45.5–54 °C. The main chemical compositions sampled on July 1989 are as follows: pH 7.40, TDS 0.279, Na 51.5, K 11.5, Ca 26.4, Mg 3.60, HCO_3 205, SO_4 19.8, Cl 3.4, SiO_2 48.4, HBO_2 10.2. HCO_3–Na–Ca water.

Th32, Langna hot spring is located in Xaitongmoin County. 87° 36′ 30″E, 30° 02′ 28″N. Altitude: 4280 m. The area is 600 m × 300 m and has a huge trivertine body of 10 m high. Three hot springs with the temperature 63, 57 and 49 °C appear on the travertine body. Total flow rate is 3 L/s. The main chemical compositions are as follows: pH 7.05, TDS 2.28, Na 475, K 41, Ca 48, Mg 2.08, HCO_3 1185, SO_4 79.8, Cl 10.0, SiO_2 102, HBO_2 21.5. HCO_3–Na water.

Th33, Qungtag or **Kyungda** hot spring is located in Xaitongmoin County. 87° 43′ 30″E, 29° 57′ 05″N. Altitude: 4400 m. The temperature is 50 °C and flow rate is 2 L/s. The main chemical compositions are as follows: pH 7.4, TDS 2.08, Na 590, K 64, Ca 108, Mg 19.8, HCO_3 1600, SO_4 78.1, Cl 90.8, SiO_2 67.8, $HBO_2$120. HCO_3–Na water.

Th34, Langmado hot spring is located in Xaitongmoin County. 87° 45′ 50″E, 30° 06′ 20″N. Altitude: 4660 m. Two vents flow out from two caves. The temperature of spring in cave is estimated not more than 50 °C. The flow rate is about 3 L/s. The main chemical compositions are as follows: pH 7.7, TDS 1.15, Na 280, K 33.3, Ca 92.6, Mg 8.33, HCO_3 770, SO_4 60, Cl 158, SiO_2 69.3, HBO_2 52.5. HCO_3–Na type.

Th35, Chagla hot spring is located in Xaitongmoin County. 88° 15′ 00″E, 29° 54′ 45″N. Altitude: 4720 m. There are about 10 vents. The highest temperature is 72 °C. The main chemical compositions are as follows: pH 7.15, TDS 1.29, Na 415, K 32, Ca 41.2, Mg 4.17, HCO_3 913, SO_4 145, Cl 81.3, SiO_2 73.0, HBO_2 30.0. HCO_3–Na water.

Th36, Qabka hot spring is located in Xaitongmoin County. 88° 14′ 10″E, 29° 26′ 50″N. Altitude: 3990 m. The temperatures of three main vents are 57, 58, and 60 °C, respectively. Total flow rates are 10 L/s. The main chemical compositions are as follows: pH 9.3, TDS 0.36, Na 100, K 1.8, Ca 3.43, Mg 2.08, CO_3 51.4, HCO_3 4.80, SO_4 74.02, Cl 33.47, SiO_2 74.4, HBO_2 11.5. CO_3–SO_4–Na type.

Th37, Lhawangze hot spring is located on left bank of Yarllung Zangbo river in Xaitongmoin County. 88° 08′ 05″E, 29° 21′ 30″N. Altitude: 3910 m. There is one vent with temperature of 63.2 °C and flow rate is 1.5 L/s near the highway. The main chemical compositions are as follows: pH 7.0, TDS 2.61, Na 530, K 58.5, Ca 2.40, Mg 7.28, HCO_3 669, SO_4 151, Cl 693, SiO_2 129, HBO_2 565. Cl–HCO_3–Na water.

Th38, Qungbuqabka hot spring is located in Xaitongmoin County. 88° 18′ 50″E, 29° 29′ 25″N. Altitude: 4350 m. It is a hot water pond with temperature of 82 °C and the flow rate is 3 L/s. Country rock is cataclasite of granodiorite. The main chemical compositions are as follows: pH 8.4, TDS 0.426, Na 84.5, K 6.35, Ca 0.85, Mg 0.70, CO_3 30.5, HCO_3 71.3, SO_4 64.8, Cl 34.7, SiO_2 164, HBO_2 30.2. SO_4–HCO_3–Na water.

Th39, Dergyu hot spring is located in Xaitongmoin County. 88° 31′ 05″E, 29° 57′ 05″N. Altitude: 4500 m. Many small seepages emerge on the floodplain. The highest temperature is 59 °C and the flow rate is 1 L/s. Country rock is andesite. The main chemical composition is as follows: pH 7.75, TDS 0.86, Na 265, K 14.3, Ca 9.12, Mg 2.08, HCO_3 491, SO_4 185, Cl 23.9, SiO_2 88.7, HBO_2 17.5. HCO_3–SO_4–Na type.

Th40, Cakakambug hot spring is located in Xaitongmoin County. 88° 41′ 40″E, 30° 08′ 40″N. Altitude: 4800 m. Hot water flows out from a fault of the N–S trend. The temperatures of six vents range from 52.3 to 64.2 °C. Country rock is volcanic tuff. The main chemical compositions are as follows: pH 7.55, TDS 1.25, Na 415, K 46, Ca 34.3, Mg 3.12, HCO_3 992, SO_4 69.9, Cl 52.6, SiO_2 109, HBO_2 13.0. HCO_3–Na water.

Th41, Chaga hot spring is located in Xaitongmoin County. 88° 41′ 45″E, 29° 42′ 35″N. Altitude: 4350 m. The spring area is 2 km in length and 0.75 km in breadth. The highest temperature is 51 °C. The total flow rate is estimated to be about 5 L/s. Country rock is porphyry and quartz monzonite. The main chemical compositions are as follows: pH 7, TDS 2.04, Na 530, K 68, Ca 94.4, Mg 21.9, HCO_3 1340, SO_4 35.4, Cl 256, SiO_2 70.6, HBO_2 275. HCO_3–Na water.

Th42, Dongla hot spring is located in Dinggye County. 88° 20′ 45″E, 28° 33′ 48″N. Altitude: 4760 m. Nine vents came out from diluvium with temperature from 15.5 to 48 °C, and the total flow rate is 5 L/s. Country rocks are Carbonaceous slate and quartzite. The main chemical compositions are as follows: pH 8.15, TDS 0.26, Na 18.0, K 4.6, Ca 34.3, Mg 2.49, HCO_3 140, SO_4 18.1, Cl 4.79, SiO_2 91.8, HBO_2 3. HCO_3–Ca–Na type.

Th43, Targyai hot spring is located in Kamba County. 88° 29′ 30″E, 28° 20′ 10″N. Altitude: 4450 m. There are many vents, and their temperatures are mostly 54 °C, up to 55.2 °C. The total flow is about 10–15 L/s. The main chemical components are as follows: pH 8.7, TDS 1.34, Na + K 504.9, Ca 2.01, Mg 1.86, CO_3 163, HCO_3 716, SO_4 154.7, Cl 69.3, SiO_2 7.0, HBO_2 70.12, HCO_3–Na + K type.

Th44, Pundam hot spring is located in Namling County. 89° 06′ 20″E, 29° 55′ 50″N. Altitude: 4500 m. There are eight main vents from the diluvium of foothills logistics. Maximum temperature is 62 °C, generally 60 °C. Flow rate is 5–7 L/s. The main chemical components are as follows: pH 6.7, TDS 1.22, Na 463.66, K 30.22, Ca 42.59, Mg 10.33, CO_3 118.30, HCO_3 561.97, SO_4 66.00, Cl 144.14, SiO_2 105.39, HBO_2 65.8. HCO_3–Na type water.

Th45, Sertangcaka hot spring is located at flood land of left shore of Lhabuqu river in Caiqing Village of Labupu District of Namling County. 89° 23′ 20″E, 29° 54′ 00″N. Altitude: 4500 m. The scope of manifestation area is 500 m × 100 m. The highest temperature is 82 °C. Total flow rate is about 20 L/s. A small amount of travertine smuggle trace sulfur in the area. The analysis results of water samples are as follows (the outer brackets for 1975, in brackets for 1989): *t* 82 °C (81.2 °C), pHf na (7.5), pHl 7.75 (8.1), TDS 0.85 (1.027), Na 275 (289), K 26.8 (35.2), Ca 17.9 (0.20), Mg 2.08 (0.70), Li 2.45 (2.75), Rb 0.25 (0.41), Cs 1.12 (3.60), NH_4 nd (0.49), CO_3 nd (nd), HCO_3 528 (515), SO_4 36.0 (41.5), Cl 132 (118), F 6.20 (7.98), SiO_2 6.2 (?) (150), HBO_2 88.8 (116), As 0.73 (1.502), H_2S na (0.50). HCO_3–Cl–Na type water.

Th46, Beiqiagarba hot spring is located in Namling County. 89° 26′ 08″E, 29° 36′ 32″N. Altitude: 4500 m There are four main vents, arranged NNW340° direction, The maximum temperature is of 70 °C, whereas the lowest 41 °C. The total flow rate is 3.5 L/s. Country rock is andesitic volcaniclastic rocks. The maim chemical composition of 70 °C spring are as follows: pH 6.90, TDS 2.28, Na 465, K 35, Ca 96.07, Mg 5.20, HCO_3 917.6, SO_4 398.8, Cl 195.9, SiO_2 84.4, HBO_2 530. HCO_3–SO_4–Na type.

Th47, Nanqiagarba hot spring is located in Namling County. 89° 25′ 00″E, 29° 36′ 00″N. Altitude: 4500 m. There are five main vents, one of which is a 77.5 °C fountain. Water is spurted out from fountain up to one meter in the air. Total flow rate is 4 L/s. Country rock is quartz andesite. The main chemical compositions are as follows: pH 7.25, TDS 1.70, Na 490, K 36.5, Ca 82.3, Mg 8.33, HCO_3 871, SO_4 64.3 Cl 206, SiO_2 64.3, HBO_2 325, HCO_3–Na water.

Th48, Ringenling hot spring is located in Namling County. 89° 44′ 12″E, 29° 42′ 00″N. Altitude: 4500 m. The temperature of main spring is 65 °C and the flow rate is 0.1 L/s. The main chemical compositions of 61.5 °C spring are as follows: pH 7.1, TDS 2.30, Na + K 801.2, Ca 61.2, Mg 1.51, HCO_3 1590, SO_4 386, Cl 141, SiO_2 8.5 (?), HBO_2 95.1. HCO_3–Na + K type water.

Th49, Gyinkar Qucain hot spring is located in Gyangze County. 89° 37′ 10″E, 28° 47′ 00″N. Altitude: 4462 m. There are many vents. The highest temperature is 60 °C and the flow rate is 10 L/s. Travertine is well developed throughout the region, and the thickness reaches to 20–30 m. The main chemical compositions are as follows: pH 7.0, TDS 2.91, Na 630, K 109, Ca 185, Mg 14.4, NH_4 60.0, HCO_3 1104, SO_4 2.0, Cl 937, SiO_2 78.0, $HBO_2$315. Cl-HCO_3–Na type water.

Th50, Marza hot spring is located in Kangmar County. 89° 32′ 47″E, 28° 21′ 16″N. Altitude 4400 m. There are six main vents with temperature of 23–46.5 °C. The flow rate is about 2 L/s. There is lack of water samples.

Th51, Kambu Qucain or **Kambudoi** or **Qucainka** is located on both sides of Kambu Maqu river in Yadong County. 88° 58′ 46″E, 27° 49′ 00″N. Altitude: 4260 m. The trend of Kambu Maqu is NW 330° which is the direction of spring area with 500 m long and 200 m wide. There are 8 vents on the east bank and 4 vents in west bank. In addition to one with 38 °C, whereas the temperatures of the others are between 45.5 and 49 °C. Total flow rate is 11 L/s. Country rock is two-mica plagiogneiss. The main chemical compositions of 46.5 °C spring sample are as follows: pH 7.2, TDS 0.15, Na + K 56.6, Ca 3.18, Mg 0.76, HCO_3 71.1, SO_4 15.3, Cl 36.0, SiO_2 65, HBO_2 11.6. HCO_3–Cl–Na + K type. Water.

Th52, Sagar hot springs is located on the southern bank of Yarlung Zangbo river in Rinbung County. 90° 12′E, 29° 20′N. Altitude: 3700 m. The temperature could be between 60 and 70 °C. When we visited in June 1976, it was submerged by floodwater.

Th53, Chagba Qucain or **Qucainka** is located in Rinbung County. 90° 03′ 00″ E, 29° 06′ 35″N. Altitude: 4000 m. The spring area is distributed along a tributary of the south bank of the Yarlung Zangbo river. The area is about 1 km long and 200 m wide, where could be a rift of the N-S trend. In this region there are more than 20 vents. The highest temperature is 70 °C, the lowest 48 °C. The total flow rate is about 5 L/s. Area appears the Triassic carbonaceous slate, which had intruded by tourmaline two-mica, two-feldspar granite of the Oligocene Epoch. The main chemical compositions are as follows: pH 7.05, TDS 4.18, Na 1140, K, 108, Ca 82.3, Mg 10.4, HCO_3 1180, SO_4 28.8, Cl 1480, SiO_2 114, HBO_2 585. Cl–HCO_3–Na water.

6.1.3 Hot Springs in Lhasa City

Th54, Conyi hot spring. is located on the northeastern corner of Nam Co in Damxung County. 90° 01′ 00″E, 30° 54′ 25″N. Altitude: 4725 m. There is only one vent with temperature of 50–60 °C. It is short of water sample.

Th55, Yoirai Qu hot spring is located in south foot of Nyainqentanglha Mountain of the most eastern part of Damxung County. 91° 14′ 00″E, 30° 37′ 07″N. Altitude: 4630 m. The temperature of vent is 67 °C and the flow rate is 0.1 L/s. The main chemical compositions are as follows: pH 7.95, TDS 0.92, Na 230, K 45, Ca 26.8, Mg 7.84, CO_3 15.5, HCO_3 764, SO_4 36.2, Cl 43.7, SiO_2 70, HBO_2 36.4. HCO_3–Na water.

Th56, Guringqung hot spring is located in Guringqung of Nyainqentanglha Mountain close to shed the Guring La. 90° 20′ 20″E, 30° 14′ 00″N. Altitude: 5000 m. The diameter of the spring mouth is 5 cm, which is encircled by a trivertine wall with diameter of 25 cm and high in 30 cm. The depth of water is 20 cm. No water drains away. The temperature in wall is 54 °C. The main chemical compositions are as follows: pH 8.4, TDS 0.658, Na 190, K 10, Ca 10.9, Mg 1.3, HCO_3 439, SO_4 38.4, Cl 18.3, SiO_2 140, HBO_2 17.3. HCO_3–Na water.

Th57, Latogka hot spring is located in northeast of Yangbajain geothermal field of Damxung County. 90° 35′ 35″E, 30° 12′ 00″N. Altitude: 4480 m. The temperature is 46.5 °C and the flow rate is 5 L/s. The main chemical compositions are as follows: pH 7.2, TDS 3.75, Na 960, K 262, Ca 145, Mg 9.40, HCO_3 1130, SO_4 14.9, Cl 1550, SiO_2 80.0, HBO_2 474. Cl–HCO_3–Na type water.

Th58, Gariqiong hot spring is located in western part of Yangbajain geothermal field. 90° 21′ 08″E, 29° 58′ 50″N. Altitude: 4400 m. Springs flow out from a fault scarp with east-west trend, The temperature is 78 °C. And the flow rate is 13 L/s. The outcrop of fault scarp is volcanic tuff. The main chemical compositions are as follows: pH 7.6, TDS 1.14, Na 450, K 53.5, Ca 13.5, Mg 1.05, HCO_3 709, SO_4 57.8, Cl 65.8, SiO_2 88, HBO_2 35.6, HCO_3–Na type water.

Th59, Gyaidadargor hot spring is located in western part of Damxung County. 89° 17′ 00″E, 29° 51′ 00″N. Altitude: 4600 m. There are a lot of travertine and ancient travertine of 800 m long, 200 m wide and 25 m high in this area. Three main vents is located at the top of the travertine terraces. Their temperature is round 65 °C. Below the main vents also appear 25 vents, but the temperature is lower. The total flow rate of spring water is about 18 L/s. Cliffs on the west side is of the quartz monzonite. The main chemical components as follows: pH 6.65, TDS 1.32, Na 250, K 20.7, Ca 53.8, Mg 3.01, HCO_3 497, SO_4 187, Cl 104, SiO_2 98, HBO_2 65.8, HCO_3–SO_4–Na type water.

Th60, Deruishan hot spring is located in Nyemo County. 89° 57′ 15″E, 29° 42′ 50″N. Altitude: 4500 m. The temperature is 62 °C and flow rate is 5 L/s. The main chemical compositions are as follows: Na + K 801.19, Ca 61.1, Mg 1.51, HCO_3 1593.6, SO_4 385.47, Cl 141.39, SiO_2 11.05, HBO_2 95.01. HCO_3–Na + K type water.

Th61, Mianjiu hot spring is located on the north bank of Yarlung Zangbo river in Nyemo County. 89° 55′ 15″E, 29° 20′ 43″N. Altitude: 3750 m. There is a trivertine hill 3 m high, on the top of which there are three main vents with temperature of 76, 78 and 79 °C, respectively, and total flow rate of 5 L/s. Surrounding rock is phlogopite gabbro and migmatite. The main chemical compositions of 79 °C spring are as follows: pH 6.9, TDS 2.31, Na 690, K 31, Ca 155, Mg 2.09, HCO_3 166, SO_4 657, Cl 572, SiO_2 11.1, HBO_2 92.7. Cl–SO_4–Na type water.

Th62, Bugba hot spring is located on the north bank of Yarlung Zangbo river in Nyemo County. 89° 59′ 00″E, 29° 20′ 43″N. Altitude: 3750 m. It is located 800 m to the east of Mianjiu. The spring area is only 7 m away from shoreline. The main vents located at the top of travertine cone, which is roughly 5 m high and its bottom diameter is roughly 7 m. The temperature of spring is 69 °C, and the flow rate is approximately 3 L/s. The main chemical compositions are as follows: pH 7.7, TDS 2.75, Na + K 744.7, Ca 138, Mg 16.8, HCO_3 526, SO_4 723, Cl 611, SiO_2 115, HBO_2 120. Cl–SO_4–Na type.

Th63, Zha Qucain hot spring is located on the northern bank of Yarlung Zangbo river in Nyemo County. 90° 13′ 05″E, 29° 20′ 35″N. Altitude: 3750 m. On June 29, 1975 inspection were made, and it was found that the vents had been submerged 10 cm under the water, but the temperature still reached 60 °C. No water sample was able to collect.

Th64, Derzhom hot spring is located in Maizhokunggar County. 92° 10′ 00″E, 30° 09′ 10″N. Altitude: 4350 m. There are many vents on the both sides of a rivulet. The highest temperature is 46 °C. The main chemical compositions of 46 °C spring are as follows: pH 7.9, TDS 1.160, Na 257, K 32.2, Ca 104, Mg 24.5, HCO_3 796, SO_4 51.2, Cl 115, SiO_2 90, HBO_2 75.4, HCO_3–Na–Ca type water.

Th65, Rutog hot spring is located in Maizhokunggar County. 92° 14′ 20″E, 29° 41′ 47″N. Altitude: 4370 m. The area of spring is 600 m × 50 m, in which there are 64 springs with temperature from 52 to 81.5 °C. Total flow rate is 20 L/s. There is a large trivertine terrace, on which there are many small cones with 30 cm high. Country rock is tuff. The main chemical compositions are as follows: PH 8.2, TDS 1.350, Na 372, K 37.7, Ca 24.5, Mg 4.50, HCO_3 434, SO_4 279, Cl 168, SiO_2 94.5, HBO_2 135. HCO_3–SO_4–Cl–Na type water,

6.1.4 Hot Springs in Nagqu Prefecture

Th66, Rongma hot spring is located in Nyima County. 86° 34′ 18″E, 32° 54′ 30″N. Altitude: 4900 m. The area of spring has 680 m long and 100 m wide. The total area is about 68,000 m^2, in which the vents are more than 100. The highest temperature is 72 °C and the lowest is 18 °C. There are 35 springs with temperature above 45 °C and 30 springs from 30 to 45 °C, Rongma is famous for the travertine forest, which consists of more than 10 cones or columns 10 m high. Country rock could be the chlorite schist of the Carboniferous and Permian Systems. The main chemical compositions are as follows: pH 8.18, TDS 1.49, Na 470, K 71.0, Ca 17.1, Mg 22.4, CO_3 81.1, HCO_3 887.3, SO_4 81.1, Cl 12.9, SiO_2 68.6, HBO_2 31.8. HCO_3–Na type water.

Th67, Ligang Qucain or **Xagbai Co** hot fountain is located in Nyima County. 87° 13′ 30″E, 32° 13′ 00″N. Altitude: 4640 m. According to the Report of 1: 1,000,000 Regional Geological Survey, the water temperature is 60–70 °C, spray height is 1.7 m. There is lack of water chemistry data.

Th68, Zhuqu Co hot spring is located in Nyima County. 87° 43′ 30″E, 32° 01′ 30″N. Altitude: 4630 m. According to the Report of 1: 1,000,000 Regional Geological Survey, water temperature is 70 °C. Lack of water chemistry data.

Th69, Pongce Co hot spring is located in Nyima County. 88° 42′ 00″E, 32° 03′ 30″N. Altitude: 4550 m. According to the Report of 1: 1,000,000 Regional Geological Survey, the water temperature is 60 °C. There is lack of water chemistry data.

Th70, Zari Qucain hot spring is located in Nyima County. 86° 42′ 30″E, 31° 36′ 56″N. Altitude: 4550 m. Two vents are 5 m apart with E-W arrangement. East Spring is 55 °C, and its flow rate is 2 L/s, while west spring is 44 °C, and its flow rate of 1 L/s. Surrounding rock is limestone. The main chemical compositions of east spring are as follows: pH 6.5, TDS 0.62, Na 91.3, K 12.3, Ca 92.5, Mg 20.1, HCO_3 533, SO_4 138, Cl 14.5, SiO_2 38.2, HBO_2 34.8. HCO_3–Ca–Na type water.

Th71, Maerzhou hot spring is located in Nyima County. 86° 41′ 35″E, 31° 28′ 28″N. Altitude: 4640 m. In a long and narrow area of 220 m × 30 m, there are six vents at the top of travertine cones, four of which discharge thermal water of 40–50 °C, for the rest, the temperature of water are 19–20 °C, respectively. The main chemical compositions of 50 °C spring are as follows: pH 8.4, TDS 4.30, Na 1272, K 186, Ca 10.3, Mg 11.8, CO_3 99.8, HCO_3 1200, SO_4 831.4, Cl 1020, SiO_2 92.2, HBO_2 142. Cl–HCO_3–SO_4–Na water.

Th72, Angdaer Co hot spring is located in Shuanghu Special District of Nyima County. 89° 39′ 00″E, 32° 44′ 00″N. Altitude: 4870 m. According to the Report of 1: 1,000,000 Regional Geological Survey, water temperature is 60 °C, and there is lack of water chemistry data.

Th73, Quse or **Sobcha** hot fountain is located in Shuanghu Special District of Nyima County. 89° 56′ 25″E, 32° 31′ 35″N. Altitude: 4770 m. There are 12 main vents in this area of 1000 m in length. Four vents discharge hot water of 45–50 °C; 2 vents have 60 °C, The hot fountain is located on the top of a travertine cone of one meter high and the temperature of vent is 75 °C. Surrounding rocks are limestone and sandstone and so on. The main chemical compositions of fountain are as follows: pH 8.62, TDS 1.57, Na 510, K 34.0, Ca 6.74, Mg 16.6, CO_3 101, HCO_3 912.1, SO_4 151.9, Cl 126.0, SiO_2 83.5, HBO_2 21.7. HCO_3–Na type water.

Th74, Maryo hot spring is located in Xainza County. 88° 21′E, 31° 34′N. Altitude: 4556 m. The temperature of spring is 66 °C, and the flow rate is 32 L/s. The main chemical compositions are as follows: pH 7.45, TDS 2.22, Na 703.66, K 51.05, Ca 90.33, Mg 13.2, HCO3 1835, SO_4 252.61, Cl 75.96, SiO_2 36, HBO_2 70.08. HCO_3–Na water.

Th75, Daglungba Qucain hot spring is located in Xainza County. 88° 34′ 30″E, 30° 55′ 05″N. Altitude: 4760 m. The area of springs is 800 m in length and 150 m in wide, where there are many small trivertine cones with 0.5 m in high and diameter of 1 m. The top of each cone had a mouth out overflow, the temperature is 35–56 °C. Total flow rate is 14 L/s. The main chemical compositions are as follows: pH 6.5, TDS 1.48, Na 310, K 48.5, Ca 111, Mg 21.9, HCO_3 972, SO_4 225, Cl 156, SiO_2 76, HBO_2 42.1. HCO_3–Na–Ca water.

Th76, **Xinggun** or **Qucainchagg**o or **Kodiu** or **Nagor** hot spring is located in Xainza County. 88° 43′ 42″E, 30° 50′ 47″N. Altitude: 4680 m. The temperature of main vent is 51.5 °C. The main chemical compositions are as follows: pH 7.0, TDS 2.79, Na 970, K 73.0, Ca 50.6, Mg 22.9, HCO_3 2230, SO_4 192, Cl 328, SiO_2 54.6, HBO_2 36.3. HCO_3–Na water.

Th77, Mudig or **Dina** hot spring is located in Xainza County. 88° 43′ 40″E, 30° 43′ 25″N. Altitude: 4770 m. Main vent is situated on the top of the sole travertine cone with 1.5 m in height and 14 m in the bottom diameter. Its temperature is 79.5 °C. There are many springs with temperature of 42–53 °C. Total flow rater is 10 L/s. The main chemical compositions are as follows: pH 8.1, TDS 0.97, Na 320, K 28.5, Ca 19.03, Mg 10.82, CO_3 37.0, HCO_3 614.7, SO_4 51.5, Cl 104.5, SiO_2 60, HBO_2 14.8. HCO_3–Na type water.

Th78, **Bangoin Co No 1** hot spring is located on the southeast of Bangoin Co in Bangoin County. 89° 33′ 11″E, 31° 39′ 49″N, Altitude: 4700 m. Its temperature is 57 °C. The main chemical compositions are as follows: TDS 1.72, Na 640, K 11, Ca 51, Mg 11, CO_3 150, HCO_3 1280, SO_4 52, Cl 48, SiO_2 54.8, HBO_2 34.0. HCO_3–CO_3–Na type water (Zheng et al. 1988).

Th79, Bangoin Co No. 2 or **Nanshan of Bongoin Co** hot spring is located 12 km in the south to Bangoin Co in Bangoin County. 89° 29′ 22″E, 31° 34′ 22″N, Temperature: 70–78 °C (in July 1960), Flow rater: 15 L/s. The analysis results of water samples are as follows: pH 7.72, TDS 2.38, Na 520, K 5.02, Ca 54, Mg 26.7, CO_3 70, HCO_3 1579, SO_4 24.7, Cl nd, HCO_3–Na type water (Zheng et al. 1989).

Th80, Qucain Xong hot spring is located in Bangoin County: 89° 23′ 05″E, 31° 29′ 42″N. Altitude: 4640 m. According to the Report of 1: 1,000,000 Regional Geological Survey, water temperature is 56 °C, and the flow rate is 4 L/s. The main chemical compositions are as follows: pH 7.08, TDS 1.81, Na 641.75, K, 48.65, Ca 35.58, Mg 10.76, CO_3 134.59, HCO_3 1474.6, SO_4 40, Cl 53.35, SiO_2 61.06, HBO_2 41.1. HCO_3–Na water.

Th81, Samogoninba or **Xuru** hot spring is located in Bangoin County. 89° 51′ 35″E, 31° 10′ 10″N. Altitude: 4750 m. The springs area is a traivertine platform of 20,000 m^2 and high 10 m. The main vent's temperature is 79 °C. There are many different sizes of sinter mounds and sinter cones on the platform, most of which still discharge hot water (28–56 °C) on their top. Total flow rate is 10 L/s. The main chemical compositions are as follows: pH 8.4, TDS 1.10, Na 405, K 27.0, Ca 0.12, Mg 3.13, CO_3 52.7, HCO_3 772.7, SO_4 93.0, Cl 15.4, SiO_2 93.0, HBO_2 12.9. HCO_3–Na type water.

Th82, Xezhag hot spring is located in Bangoin County. 90° 18′ 30″E, 31° 10′ 37″N. Altitude: 4715 m. The temperature of main vent is 63 °C. The total flow rate is 5 L/s. The main chemical compositions are as follows: pH 6.5, TDS 0.803, Na 215, K 13.5, Ca 27.9, HCO_3 567, SO_4 9.61, Cl 86.8, SiO_2 142, HBO_2 29.3. HCO_3–Na type water.

Th83, Duobu hot spring is located in Bangoin County. 90° 38′ 43″E, 31° 18′ 02″N. Altitude: 4560–4593 m. The vents are in arrangement of SW240. There are eight main vents occurring within 250 m in length. The temperature are 31–50 °C, and the total water flow rate is 10.5 L/s. Duobu Hill (4593 m) is a travertine mound. There are many vent orifice on the ridge. The H_2S odor is very strong, and it is difficult to gain a foothold and there are some dead birds nearby. The main chemical composition are as follows: pH 6.5, TDS 1.25, Na 315, K 63.5, Ca 59.2, Mg 87.5, HCO_3 1440, SO_4 nd, Cl 42.7. SiO_2 49.1, HBO_2 17.2. HCO_3–Na–Mg type water.

Th84, Esucaiqu hot spring is located in Bangoin County. 90° 56′ 50″E, 31° 36′ 28″N. Altitude 4530 m. Temperature was 67 °C. The flow rate is 1 L/s Other data are unknown.

Th85, Turui or **Kabulin** hot spring is located in Bangoin County. 90° 57′ 46″E, 31° 22′ 42″N. Altitude: 4600 m. Four vents were in arrangement of NE–SW trend. Their temperature is in the range of 33–58 °C. The main chemical compositions of 56 °C spring are as follows: pH 6.5, TDS 1.98, Na 660, K 53.0, Ca 43.6, Mg 58.0, HCO_3 1930, SO_4 302, Cl 13.0, SiO_2 54.6, HBO_2 25.1. HCO_3–Na type water.

Th86, Zige Tangco or **Tanggogangnyi** hot spring is located on the southern bank of Zige Tangco in Amdo County. 90° 47′ 00″–53′ 00″E, 32° 02′ 15″N. Altitude: 4565–4575 m. There are 10 spring areas on the south bank of the lake, extending from west to east over 10 km. The hot springs is located on the north side in the middle sector of Dongqiao-Denqen ultrabasic rock zone, which invaded into the Devonian limestone and slate along Dongqiao-Denqen deep fracture belt. Top of Devonian and ultrabasic rock was covered by Jurassic limestone, sandstone, and Tertiary. This big fracture belt has not yet ceased and controls the formation of this hot springs belt. The temperature of 5 Spring areas exceeds 60 °C, and the maximum temperature of the hot springs is 68 °C. Two exceeds 55 °C. Three areas are tepid springs. The main chemical compositions of 68 °C spring are as follows: pH 7.2, TDS 1.092, Na 135, K 19, Ca 154, Mg 75.3, HCO_3 859, SO_4 210, Cl 19.1, SiO_2 44.2, HBO_2 3.50. HCO_3–Ca–Mg–Na type water.

Th87, Dazho Qucain hot spring is located to the north of Tumain Coal Mines of Amdo County. 91° 24′ 00″E, 32° 53′ 10″N. Altitude: 4940 m. There are many vents, and 8 of them more than 70 °C. The maximum temperature is 73 °C. Generally the spring water temperature is 65 °C or so. There are more than ten silica sinter cones. The main chemical compositions of 73 °C spring are as follows: pH 8.6, TDS 2.94, Na 890, K 93.5, Ca 5.55, Mg 5.05, CO_3 39.8, HCO_3 762.4, SO_4 1024.9, Cl 276.5, SiO_2 141.3, HBO_2 51.0. SO_4–HCO_3–Na type water.

Th88, Co Nag hot spring is located on the east side of Co Nag Lake in Amdo County. 91° 32′ 00″E, 32° 05′ 30″N. Altitude: 4590 m. The hot spring area is divided into two parts: one part of travertine precipitation away from the lakeshore area, and there are many tepid springs with temperature between 15 and 30 °C; the other part of the main spring area on unheated flood land, and most of which is inundated field The main vents is 71 °C. There is a pool at bank of the lake, and an 83 °C vent arises at foot of north wall of pool. The main chemical components of this 83 °C spring are following: pH_L 9.6, TDS 1.53, Na 445, K 51.5, Ca 12.0, Mg 15.6, Li 0.62, Rb 0.30, Cs nd, NH4 4.56, CO_3 243, HCO_3 648, SO_4 201, Cl 47.8, F 1.18, SiO_2 79.1, HBO_2 30.7. HCO_3–CO_3–Na type water.

Th89, Gyangngog or **Jibu** hot spring is located in Amdo County. 91° 29′ 00″E, 31° 48′ 00″N. Altitude: 4650 m. The temperature is 50.5 °C and flow rate is 15 L/s. The main chemical compositions are as follows: pH 7.1, TDS 1.28, Na 350, K 57, Ca 48, Mg 19.8, HCO_3 1120, SO_4 103, Cl 38.2, SiO_2 77.5, HBO_2 17.0. HCO_3–Na water.

Th90, Nagqu hot spring is located in Nagqu Town of Nagqu County. 92° 03′ 10″E, 31° 27′ 21″N. Altitude: 4500 m. The area of springs is about 900 m × 100 m, where there are many springs with temperature of 40–50 °C. The highest one is 59.6 °C. And discharges HCO_3–Na type water. The main chemical compositions of 48.5 °C spring are as follows: pH 7.5, TDS 2.88, Na 1000, K 51.5, Ca 20.6, Mg 5.20, HCO_3 2490, SO_4 206, Cl 225, SiO_2 79.1, HBO_2 30.7. The electric resources in Nagqu Prefecture are in very shortage. The government of Tibet Autonomous Region tries to exploit geothermal energy of Nagqu hot spring to ease the contradiction between the development of energy and supply. The geological exploration began in 1984 and ended in 1988. The total of drilling hole is 20, including four production wells. The wellhead temperatures is roughly 110–113 °C. Nagqu 1 MW geothermal power plant was completed in 1993, but due to serious scale of equipments, the pilot station had to stop.

Th91, Tuoma hot spring is located in Nagqu County. 91° 51′ 00″E, 31° 09′ 40″N. Altitude: 4680 m. The highest temperature. is 53.5 °C, and the flow rate is 15 L/s. Travertine developed. The main chemical compositions are as follows: pH 6.8, TDS 2.22, Na 570, K 72.5, Ca 117, Mg 18.7, HCO_3 1020, SO_4 798, Cl 38.2, SiO_2 78.9, HBO_2 15. HCO_3–SO_4–Na type.

Th92, Gongchaqulangma hot spring is located in Nagqu County. 92° 12′ 00″E, 31° 09′ 50″N. Altitude: 4560 m. The highest temperature is 55 °C. The flow rate is 2.5 L/s. The main chemical compositions are as follows: pH 6.5, TDS 1.35, Na 470, K 30.0, Ca 23.3, Mg 6.38, HCO_3 1250, SO_4 3.07, Cl 43.4, SiO_2 76.4, HBO_2 6.32. HCO_3–Na type water.

Th93, Yuze hot spring is located in Nyainrong County. 92° 05′ 42″E, 31° 45′ 40″N. Altitude: 4660 m. The highest temperature is 52 °C. The travertine looks most magnificent. The main chemical compositions are as follows: pH 6.5, TDS 1.99, Na 600, K 67.0, Ca 54.2, Mg 49.0, HCO_3 1730, SO_4 118, Cl 119, SiO_2 85.1, HBO_2 22.3, HCO_3–Na type water.

Th94, Chepocaka hot spring is located in Nyainrong County. 92° 50′ 30″E, 32° 34′ 50″N. Altitude: 4860 m. The area of springs is 2000 m in length and 300 m in width. There are many travertine cones, on the top of which hot water with temperature of 61 °C is discharged. Th main chemical compositions are as follows: pH 8.1, TDS 1.48, Na 450, K 60, Ca 29.7, Mg 13.2, CO_3 31.7, HCO_3 737.6, SO_4 384, Cl 30.9, SiO_2 77.2, HBO_2 14.9. HCO_3–SO_4–Na type water.

Th95, Dargarma hot spring is located in Nyainrong County. 92° 51′ 40″E, 32° 22′ 30″N. Altitude: 4720 m. The highest temperature is 52 °C. The total flux is very small only 0.2 L/s. The hot water flows out from the fracture in purplish sandstone. Th main chemical compositions are as follows: pH 9.1, TDS 2.09, Na 710, K 84, Ca 6.74, Mg 20.44, CO_3 187.5, HCO_3 1413.8, SO_4 153.9, Cl 70.7, SiO_2 85.7, HBO_2 40.5. HCO_3–Na type water.

Th96, Casangtang hot spring is located in Nyainrong County. 92° 43′ 35″E, 32° 09′ 00″N. Altitude: 4640 m. The spring area is 360 m × 100 m. The main vent is on top of a sinter cone discharging hot water of 54 °C. The main chemical compositions are as follows: pH 6.0, TDS 1.38, Na 205, K 26.5, Ca 121, Mg 72, HCO_3 1030.6, SO_4 298, Cl 14.5, SiO_2 81.9 HBO_2 42.1. HCO_3–SO_4–Ca–Na type water.

Th97, Dengerlong or **Dongar-Bana** hot spring is located in Nyainrong County. 92° 15′ 40″E, 32° 26′ 05″N. Altitude: 4510 m. The spring with highest temperature of 72 °C is situated on a stratified travertine in Dongar Village. The visible thickness of trivertine stratum is about 5 m. Country rock is grey quartzite. There are three spas with temperature of 60 °C flowing out from the base of the travertine. The total flux is only 1.5 L/s he flow. The main chemical compositions are as follows: pH 8.85, TDS 1.85, Na 587, K 78.5, Ca 1.19, Mg 44.24, CO_3 237.3, HCO_3 1081.8, SO_4 112.8, Cl 129, SiO_2 72.8, HBO_2 31.2. HCO_3–CO_3–Ca–Na type water.

Th98, Longcaka hot spring is located in Jiali County. 92° 25′ 10″E, 30° 25′ 00″N. Altitude: 4650 m. The spring water flows out from gravel beach. There are two vents with temperature of 52 and 45 °C. The flow rate is very small, only 0.2 L/s. The main chemical compositions are as follows: *t* 52 °C, pH 8.7, TDS 1.59, Na 510, K 60.0, Ca 6.34, Mg 8.18, CO_3 48.0, HCO_3 672.8, SO_4 71.6, Cl 374.9, SiO_2 79.3, HBO_2 80.3. HCO_3–Cl–Na type water.

Th99, Xagquka hot spring is located in Biru County. 92° 49′ 20″E, 31° 48′ 35″N. Altitude: 4280 m. There are many vents exposed along the river shore in about 50 m. When the July 2, 1976 visits coincided with the flood season, most of the vents have been submerged. The maximum temperature measured was 50 °C. It is said that the vent with highest temperature (65 °C) has been submerged underwater. The main chemical compositions are as follows: *t* 50 °C, pH 7.0, TDS 0.60, Na 66.8, K 11.6, Ca 14.0, Mg 111, HCO_3 578, SO_4 80.9, Cl 39.8, SiO_2 54.6. HCO_3–Mg type water.

Th100, Quese hot spring is located in Biru County. 92° 51′ 33″E, 31° 48′ 20″N. Altitude: 4340 m. Main vent (78.5 °C) is located above 2 m high sinter terrace. The flux is 1.2 L/s. The main chemical compositions are as follows: pH 7.68, TDS 1.04, Na 237, K 32.2, Ca 53.1, Mg 16.8, CO_3 8.25, HCO_3 461.1, SO_4 130.5, Cl 18.4, SiO_2 111.5, HBO_2 20.9. HCO_3–SO_4–Na type water.

Th101, Cayue hot spring is located in Biru County. 93° 00′ 40″E, 31° 50′ 30″N. Altitude: 4480 m. The area is 300 m × 5 m. The maximum temperature of the hot springs is 75 °C. The temperature of most of the springs are between 45 and 64 °C. The total flow rate is 3 L/s. Country rock is thick layer of limestone The main chemical compositions are as follows: pH 6.5, TDS 1.11, Na 195, K 33, Ca 6.57. Mg 98.7, HCO_3 800, SO_4 98.2, Cl 57.9, SiO_2 98.2, HBO_2 7.70. HCO_3–Na type water.

Th102, Qagze Calung or **Calungdo** hot spring is located in Biru County. 93° 10′ 35″E, 31° 42′ 14″N. Altitude: 4520 m. Springs area is large and can be divided into three plots. The distance between the first plot and the second plot is 200 m, a distance between the second plot and the third plot of 70 m. The area of first plot is 200 m × 25 m. The temperature of the spring water is between 49 and 69 °C. The flow rate is 31 L/s. The second plot is 30 m × 30 m at a temperature between 60 and 70 °C, and its flow rate is 2 L/s. The third plot is 30 m × 10 m. Its temperature is 67 °C, and its flow rate is 2.5 L/s. The main chemical compositions of 70 °C spring are as follows: pH 7.5, TDS 1.24, Na 306, K 38.5, Ca 2.47, Mg 62.6, HCO_3 800, SO_4 93.9, Cl 217, SiO_2 87.3, HBO_2 19.60. HCO_3_Cl–Na–Mg type water.

Th103, Gyaibri Pu hot spring is located in Biru County. 93° 13′ 30″E, 31° 31′ 00″N. Altitude: 4180–4250 m. This area can be divided into three plots. The first plot is located on travertine terrace, where there are a hot spring with a temperature of 62 °C and the flow rate is 1.3 L/s. In second plot there are two 42.5 °C springs discharging hot water at a flow rate is 6 L/s. The surrounding rock is carbide slate. The main vent in third plot is 41.5 °C and the flow rate is 4 L/s. The main chemical compositions of 62 °C spring are as follows: pH 6.5, TDS 1.34, Na 250, K 27, Ca 126, Mg 47.2, HCO_3 818, SO_4 256, Cl 113, SiO_2 49.1, HBO_2 45.4. HCO_3–Na–Mg type water.

Th104, Ragxi Caka hot spring is located in Biru County. 93° 16′ 15″E, 31° 31′ 42″N. Altitude: 4050 m. Many vents is distributed along a river inside 1.7 km in length, their temperature are all above 60 °C. The highest one is 69 °C. The main chemical compositions of 68.5 °C spring are as follows: pH 7.5, TDS 3.04, Na 920, K 78, Ca 37, Mg 41.2, CO_3 30.3 HCO_3 966, SO_4 236, Cl 1070, SiO_2 76.4, HBO_2 128. Cl- HCO_3–Na type water.

Th105, Yira Nang hot spring is located in Biru County. 93° 27′ 28″E, 31° 25′ 00″N. Altitude: 4220 m. Maximum temperature is 51 °C. The travertine was stratification reaching 3 m in thickness. The main chemical compositions are as follows: pH 7.0, TDS 2.01, Na 600, K 53, Ca 30.1, Mg 20.2, HCO_3 1310, SO_4 175, Cl 261, SiO_2 102, HBO_2 89.1. HCO_3–Na type water.

Th106, Ribug hot spring is located in Sog County. 94° 40′ 30″E, 31° 29′ 50″N. Altitude: 3820 m. The many springs are located in a open-air public baths. The maximum temperature is 65 °C. The main chemical compositions are as follows: pH 7.5, TDS 1.42, Na 500, K 13, Ca 17.9, Mg 8.77, HCO_3 1170, SO_4 111, Cl 60.0, SiO_2 87.3, HBO_2 25.1. HCO_3–Na type water.

Th107, Chani hot spring is located in Baqen County. 93° 55′ 45″E, 32° 22′ 00″N. Altitude: 4520 m. The spring area is 150 m ×30 m. There are 7 fountains in the top of trivetine cone of 3 m high. The temperature of main vent is 73 °C and flow rate is 15 L/s. The main chemical compositions are as follows: pH 8.32, TDS 3.08, Na 1120, K 89.8, Ca 13.5, Mg 17.8, CO_3 54.0 HCO_3 1077, SO_4 518.6, Cl 574.6, SiO_2 72.8, HBO_2 61.9. HCO_3–Cl–Na type water.

Th108, Baqen hot fountain is located in Baqen County. 93° 24′ 35″E, 32° 13′ 23″N. Altitude: 4240 m. It has been flooded during the time when our inspection was conducted on June 16, 1976. The temperature could be more than 60 °C.

Th109, Langposhan hot spring is located in Baqen County. 93° 52′ 40″E, 32° 20′ 35″N. Altitude: 4460 m. The maximum temperature is 67 °C. The flux is about 1.5 L/s. Water sample was lost.

Th110, Sogzhukug hot spring is located in Baqen County. 93° 33′ 30″E, 32° 05′ 30″N. Altitude: 4120 m. The area is 70 m × 5 m. The maximum temperature is 70 °C. The flow rate is 10 L/s. Country rock is carbonaceous slate with limestone. The main chemical compositions are as follows: pH 8.50, TDS 1.18, Na 335, K 25.4, Ca 36.9, Mg 19.0, CO_3 26.3, HCO_3 293, SO_4 411.6, Cl 86.0, SiO_2 68.5, HBO_2 16.9. SO_4–HCO_3–Na type water.

Th111, Lainnetang hot spring is located in Baqen County. 93° 34′ 35″E, 32° 05′ 10″N. Altitude: 4120 m. The spring area is 50 m × 40 m. There are two vents: one is 53 °C with a flow rate of 0.51 L/s; another is 55 °C with 0.2 L/s. The main chemical compositions are as follows: pH 7.50, TDS 0.51, Na 20.0, K 5.0, Ca 72.6, Mg 45.4, CO_3 18.2, HCO_3 389, SO_4 80.3, Cl 10.9, SiO_2 30.6, HBO_2 31.4. HCO_3–Mg–Ca type water.

Th112, Xuxubda or **Xixibda** hot spring is located in Baqen County. 93° 44′ 50″ E, 32° 03′ 22″N. Altitude: 4220 m. There are many trivertine cones on the terrace. The spring area can be divided into three parts. The north part is 150 m × 70 m. The maximum temperature is 56 °C and total flow rate is 5 L/s. The middle part is situated on a big sinter terrace, where three main vents discharge hot water of 71, 72 and 73 °C, respectively. Total flow rate is 1.2 L/s. In the south part, the temperature of main vent is 56 °C and flow rate is 1 L/s. The main chemical compositions of 72 °C spring are as follows: pH 7.5, TDS 2.45, Na 500, K 35, Ca 125, Mg 32.7, HCO_3 738, SO_4 1160, Cl 105, SiO_2 98.2, HBO_2 27.0. SO_4–HCO_3–Na type water.

Th113, Cadengka hot spring is located in Baqen County. 94° 00′ 20″E, 31° 58′ 05″N. Altitude: 4230 m. The temperature of main vent is 55 °C and the flow rate is 0.5 L/s. The main chemical compositions of 55 °C spring are as follows: pH 6.5, TDS 1.77, Na 440, K 45, Ca 84.8, Mg 47.6, HCO_3 1052, SO_4 309, Cl 246, SiO_2 56.7, HBO_2 26.7. HCO_3–Na type water.

Th114, Banglai hot spring is located in Baqen County. 94° 16′ 50″E, 31° 58′ 05″N. Altitude: 4230 m. The spring area is 200 m × 100 m, where there are many high and low scattered sinter cones. On the top of most sinter cone, spring waters flow out. The maximum temperature is 66 °C. The main chemical compositions of 66 °C spring are as follows: pH 6.5, TDS 2.29, Na 640, K 45, Ca 67.1, Mg 30.6, HCO_3 1220, SO_4 384, Cl 340, SiO_2 104, HBO_2 62.0. HCO_3–Na type water.

Th115, Zhuluo hot spring is located in Baqen County. 94° 29′ 30″E, 32° 26′ 00″N. Altitude: 4760 m. The area is about 5000 m^2. The temperature of spring is more than 50 °C. The main chemical compositions are as follows: pH 7.5, TDS 2.65, Na 250, K 30, Ca 333.6, Mg 71.7, HCO_3 773, SO_4 1070, Cl 72.3, SiO_2 38.1, HBO_2 11.9. SO_4–HCO_3–Ca–Na type water.

Th116, Yangando hot spring is located in Baqen County. 94° 26′ 00″E, 31° 50′ 18″N. Altitude: 4200 m. The area is 250 m × 10 m. There is a large trivertine hill. The temperature of main vent is 56 °C discharging 0.5 L/s. The main chemical compositions are as follows: pH 6.5, TDS 2.39, Na 510, K 45, Ca 217, Mg 23.1, HCO_3 814, SO_4 830, Cl 240, SiO_2 63.3, HBO_2 47.8. SO_4–HCO_3–Na–Ca type water.

6.1.5 Hot Springs in Shannan Prefecture

Th117, Ganzha Qucain hot spring is located in Nagarze County. 91° 10′ 10″E, 28° 47′ 25″N. Altitude: 4649 m. Vents beneath the villagers' residential houses, through culverts are leading to every household. The real position of vent in the villagers do not know. The highest temperature of water in ditch is 57.5 °C. The total flow rate 4 L/s. The main chemical compositions are as follows: pH 7.5, TDS

0.33, Na 52, K 11, Ca 22.4, Mg 5 23, HCO_3 214, SO_4 29.7, Cl 5.25, SiO_2 49.0, HBO_2 0.30. HCO_3–Na–Ca type water.

Th118, Lungdoi Qucain hot spring is located in Lhozhag County. 90° 40′ 45″E, 28° 08′ 35″N. Altitude: 4520 m. The spring area is surrounded by snow-capped mountains. It is located in the north of the Kingdom of Bhutan There are 108 vents with temperature of 60–70 °C and the flow rate is 5 L/s.

Th119, Gyangkar hot spring is located in Lhozhag County. 90° 50′ 08″E, 28° 12′ 00″N. Altitude: 3800 m. Maximum temperature was 55.5 °C and flow rate was 5–6 L/s in 1976.

Th120, **Damu** hot spring is located in Lhozhag County. 90° 50′ 40″E, 28° 12′ 30″N. Altitude: 3760 m. The area has a large vent and small vent, and the temperature was 69.5 and 55 °C, respectively. The total flow rate was about 10–15 L/s. In 1976. The main chemical compositions of large vent are as follows: pH 7.5, TDS 0.24, Na 72, K 2.6, Ca 17.2, Mg 4.18, HCO_3 139, SO_4 47.9, Cl 23.3, SiO_2 78.0, HBO_2 0.70. HCO_3–SO_4–Na type water.

Th121, Lhakang or **Teng Qucain** hot spring is located in Lhozhag County. 91° 06′ 00″E, 28° 07′ 00″N. Altitude: 3200 m. There is only one vent with temperature of 67 °C and the flow rate is 1 L/s. There are many travertine stratum 15 m thick. The main chemical compositions are as follows: pH 7.9, TDS 1.35, Na 408, K 26, Ca 57.9, Mg 3.55, HCO_3 675, SO_4 227, Cl 281, SiO_2 145, HBO_2 53.50. HCO_3–Cl–Na type water.

Th122, Jimei Qucain hot spring is located in Lhozhag County. 91° 11′ 40″E, 28° 10′ 40″N. Altitude: 3320 m. The vent already enclosed bathroom, to join the cold water for bathing. Estimated temperature is >50 °C.

Th123, Oiga hot spring is located in Sangri County. 92° 18′ 55″E, 29° 23′ 15″N. Altitude: 3920 m. There are four springs in the village Oiga nearby: The first one is in the north of the village with of 50.5 °C and a flow rate of 1 L/s, The outflow of water is from the fractured granite; The second (49.5 °C, flow 1 L/s) is in the north 0.35 km from the village. The third one (61.5 °C, flow 5.5 L/s) is located at north 0.5 km from the village. The fourth spring (69 °C) has 2 km away from the village Oiga. The main chemical compositions of sample taken on June 27 1989 are as follows: t 61.5 °C, pH 7.5, TDS 0.416, Na 114, K 4.15, Ca 2.45, Mg 0.60, HCO_3 80.6, SO_4 120, Cl 33.0, SiO_2 51.6, HBO_2 38.20. SO_4–HCO_3–Na type water.

Th124, Chabmaisa hot spring is located on the south bank of Yarlung Zangbo river in Qusum County. 92° 14′ 00″E, 29° 13′ 50″N. Altitude: 3520 m. There are four main vents. (1) A small fountain, 1 m higher than the river water surface, temperature of 75.5 °C, spray high 1 m; (2) An open-air bathing pond, the temperature 37 °C; (3) A hot springs to the southwest of the bathing pool, 63 °C; (4) A pulsating spring at 6 m of the east side of bathing pool, 75 °C. In addition, there is a spring in the river bed at the dry season, hard boiled eggs. The main chemical compositions of sample taken on June 27 1989 are as follows: pH 7.9, TDS 10.611, Na 2550, K 610, Ca 62.0, Mg 17, HCO_3 1035, SO_4 125, Cl 4212, SiO_2 245, HBO_2 2045. Cl–Na type water.

Th125, Sewu Quzhain hot spring is located in Qusum County. 92° 15′ 35″E, 28° 54′ 50″N. Altitude: 4400 m. The maximum temperature is 45.5 °C. The main chemical compositions are as follows: pH 7.8, TDS 0.775, Na 235, K 8.63, Ca 4.45, Mg 1.90, HCO_3 542, SO_4 6.75, Cl 92.1, SiO_2 53.0, HBO_2 96.1. HCO_3–Na type water.

Th126, Chigu hot spring is located on the northern bank of Chigu Co in Comai County. 91° 38′ 26″E, 28° 42′ 35″N. Altitude: 4600 m. There are two main vents, 200 m apart from each other. Away from the lake is relatively large spring, and its temperature is 51.2 °C. Another one verges on the lakeside with relatively high temperatures, up to 65.4 °C. The total flow rate is 3–4 L/s. The main chemical compositions are as follows: *t* 65.4 °C, pH 7.55, TDS 0.35, Na 310, K 16, Ca 25.9, Mg 1.88, HCO_3 957, SO_4 24, Cl 9.0, SiO_2 68.20, HBO_2 7.3. HCO_3–Na type water.

Th127, East Caka hot spring is located in Comai County. 92° 54′ 30″E, 28° 31′ 54″N. Altitude: 4480 m. It is one area of Gubdu geothermal system. The biggest feature of this area is that the west side of the springs area has a huge travertine ridge 80 m long and 15–20 m high. The base width is 25 m, and the ridge top width is 1–1.5 m. The main vent is located on northeast end of the travertine ridge. Its temperature was 64 °C in 1979 and went down to 60 °C in 1989. The main chemical compositions are as follows: *t* 64 °C, pH 8.1, TDS 2.083, Na 510, K 68, Ca 20.6, Mg 2.2, HCO_3 435, SO_4 148, Cl 549, SiO_2 198, HBO_2 330. Cl–HCO_3–Na type water.

Th128, Rongka Quchomo or **Cona City** hot spring is located in Cona County. 91° 56′ 00″E, 27° 59′ 20″N. Altitude: 4338 m. The average annual temperature in Cona County is 0 °C, and the average January temperature is −10 °C. However, in 1988 the winter minimum temperature reached −43 to −50 °C. And the winter lasts up to 2 months. Sometimes it snows in mid-June. Fortunately Cona City is full of hot water. Where the main vents are in? It is not known. The temperature of hot water is 61–63 °C. Drinking water's temperature is 20 °C. The main chemical components of hot water (at 63 °C) are as follows: pH 8.5, TDS 0.303, Na 74.5, K 3.80, Ca 0.75, Mg 0.60, CO_3 24.4, HCO_3 62.1, SO_4 80.5, Cl 10.4, SiO_2 68.2, HBO_2 4.24. SO_4–HCO_3–Na type water.

Th129, Gyaimoi Qucain or **Neizhong Co** hot spring is located in Lhunze County. 91° 55′ 35″E, 28° 25′ 05″N. Altitude: 5020 m. The maximum temperature is 47.5 °C and the flow rate is 0.5 L/s. The main chemical components are as follows: pH 6.5, TDS 0.6, Na + K 193.8, Ca 36.8, Mg 8.44, HCO_3 530, SO_4 105, Cl 1.74, SiO_2 32.5, HBO_2 18.9. HCO_3–Na type water.

Th130, Gyaimoi hot spring is located in Lhunze County. 91° 55′ 50″E, 28° 24′ 15″N. Altitude: 4950 m. The maximum temperature is 61 °C and the flow rate is 2.5 L/s. The main chemical components are as follows: pH 7.4, TDS 0.332, Na 56.5, K 5.2, Ca 40.5, Mg 9.50, HCO_3 273, SO_4 32.5, Cl 3.42, SiO_2 42.4, HBO_2 4.12. HCO_3–Ca–Na type water.

Th131, Molu hot spring is located in Lhunze County. 91° 56′ 30″–91° 57′ 40″E, 28° 23′ 22″N. Altitude: 4680–4760 m. The spring area extends from east to west along the river valley of about 3 km, from north to south 500 m. The spring's temperature on the north shore of the river is 39–65 °C, on the south 20–68 °C.

Travertine cone is very development. The main chemical components are as follows: *t* 65 °C, pH 8.0, TDS 1.937, Na 498, K 55.5, Ca 118, Mg 20.1, HCO_3 878, SO_4 158, Cl 339, SiO_2 60, HBO_2 217. HCO_3–Na type water.

Th132, Zhaxikang hot spring is located in Lhunze County. 92° 04′ 15″E, 28° 23′ 16″N. Altitude: 4300 m. The maximum temperature is 69.5 °C and the flow rate is 1 L/s. The main chemical components are as follows: *t* 69.5 °C, pH 8.1, TDS 0.924, Na 221, K 44.0, Ca 50.0, Mg 8.25, HCO_3 446, SO_4 192, Cl 79.9, SiO_2 54.1, HBO_2 40.5. HCO_3–SO_4–Na type water.

6.1.6 Hot Springs in Nyingchi Prefecture

Th133, Gamlungma or **141 highway maintenance squad** hot spring is located in Gongbo'gyamda County. 92° 21′ 42″E, 29° 54′ 40″N. Altitude: 4482 m. The maximum temperature is 67 °C and the flow rate is 0.2 L/s. The main chemical components of water samples collected on September 1974 are as follows: *t* 67 °C, pH 6.65, TDS 1.30, Na + K 375, Ca 20.4, Mg 1.21, HCO_3 518, SO_4 95.6, Cl 236, SiO_2 107, HBO_2 154.3. HCO_3–Cl–Na + K type water.

Th134, Nam hot spring is located on the eastern bank side of Yarlung Zangbo river in Mainling County. 94° 57′ 18″E, 29° 36′ 05″N. Altitude: 2550 m. The maximum temperature is 50.5 °C and the flow rate is 5 L/s. The main chemical components of water samples collected in 1975 are as follows: *t* 50.5 °C, pH 8.0, TDS 0.646, Na 83.5, K 4.5, Ca 88.46, Mg nd, HCO_3 59.92, SO_4 390.1, Cl 7.09, SiO_2 32.50, HBO_2 7.57. SO_4–Na–Ca type water.

Th135, Zaqu hot spring is located on the right bank side of Palong Zangbo river in Nyingchi County. 95° 07′ 45″E, 29° 53′ 07″N. Altitude: 1700 m. The maximum temperature is 85 °C and the flow rate is 10 L/s. The main chemical components of water samples collected on November 1973 are as follows: *t* 85 °C, pH 8.05, TDS 1.33, Na + K 226.83, Ca 106.69, Mg 72.56, HCO_3 317.41, SO_4 744.66, Cl 15.92. SO_4–HCO_4=Na–Mg–Ca type water.

Th136, Asdeng hot spring is located on the right bank side of Yarlung Zangbo river in Nyingchi County. 95° 12′ 30″E, 29° 52′ 18″N. Altitude: 1800 m. The maximum temperature is more than 60 °C. The main chemical components of water samples collected on November 1973 are as follows: pH 8.5, TDS 0.35, Na + K 104.12, Ca 32.71, Mg 0.84, CO_3 16.98, HCO_3 168.59, SO_4 112.10, Cl 20.24. SO_4–HCO_4=Na–Ca type water.

Th137, Demulungba or **Guodeng** hot fountain is located on the right bank side of Demulungba river in Medog County. 95° 17′ 23″E, 29° 45′ 20″N. Altitude: 1275 m. The maximum temperature is 68 °C and the flow rate is 5 L/s. The main chemical components of water samples collected on October 1973 are as follows: pH 8.5, TDS 0.35, Na + K 104.12, Ca 32.71, Mg 0.84, CO_3 16.98, HCO_3 168.59, SO_4 112.10, Cl 20.24. SO_4–HCO_4=Na–Ca type water.

Th138, Laka hot spring is located in Bome County. 94° 55′ 30″E, 30° 13′ 46″N. Altitude: 2300 m. The maximum temperature is 51 °C and the flow rate is 2 L/s. The main chemical components are as follows: pH 7.25, TDS 0.668, Na + K 82.8, Ca 61.6, Mg 59.8, HCO_3 566, SO_4 44.2, Cl 44.5, SiO_2 80, HBO_2 9.94. HCO_4–Mg–Na–Ca type water.

Th139, Qoizong Lungba hot spring is located in Bome County. 95° 12′ 00″E, 30° 01′ 30″N. Altitude: 2600 m. The maximum temperature is 56.3 °C and the flow rate is 4 L/s. The main chemical components of water samples collected in June 30 1976 are as follows: pH 8.3, TDS 0.961, Na 190, K 19.8, Ca 102.3, Mg 4.81, CO_3 7.50, HCO_3 102, SO_4 403.4, Cl 92.2, SiO_2 81.4, HBO_2 5.62. SO_4–Na–Ca type water.

Th140, Bakong Quzi hot spring is located in Zayu County. 96° 17′ 30″E, 29° 12′ 30″N. Altitude: 3000 m. Local government told us that there was a very high temperature hot springs, like boil as upward spray. No field inspection was conducted. Its temperature and the flow rate are unknown.

Th141, Puzang hot spring is located in Zayu County. 96° 32′ 30″E, 29° 35′ 35″N. Altitude: 2250 m. There are three main vents with temperature of 57–73 °C and the flow rate is 2.5 L/s. Spring water flows out from fractures of granite. The main chemical components of water samples collected in June 6 1976 are as follows: pH 6.5, TDS 1.26, Na 330, K 18, Ca 52.9, Mg 4.59, CO_3 nd, HCO_3 203, SO_4 330.4, Cl 282, SiO_2 126.4, HBO_2 11.3. Cl–SO_4–Na type water.

Th142, Be hot spring is located in Zayu County. 96° 35′ 55″E, 29° 02′ 10″N. Altitude: 2200 m. There is only one main vents with temperature of 61 °C and the flow rate is 2 L/s. The spring water flows out from slope sediments of granite. The main chemical components are as follows: pH 8.05, TDS 0.686, Na 295, K 23.3, Ca 16.3, Mg nd, CO_3 18.8, HCO_3 236.7, SO_4 95.5, Cl 227.4 SiO_2 128.6, 4 HBO_2 16.9. Cl–SO_4–Na type water.

Th143, Bangdoi Quzi hot spring is located in Zayu County. 96° 37′ 45″E, 28° 58′ 05″N. Altitude: 2050 m. There are two main vents with temperature of 45–63 °C and the flow rate of 3.5 L/s. The spring water flows out from the granite. The main chemical components are as follows: t 63 °C, pH 6.5, TDS 0.75, Na 205, K 9.0, Ca 19.7, Mg 0.997, CO_3 nd, HCO_3 295, SO_4 90.9, Cl 134, SiO_2 126.4, HBO_2 5.06. HCO_3–Cl–Na type water.

Th144, Baixoi hot spring is located in Zayu County. 96° 08′ 30″E, 29° 25′ 55″N. Altitude: 2250 m. The local government said that the temperature was so high that eggs can be cooked in the spring water.

Th145, Goqen hot spring is located in Zayu County. 97° 11′ 40″E, 29° 11′ 40″N. Altitude: 3200 m. There are three main vents with temperature of 59.5–64.8 °C and the flow rate of 3.5 L/s. The spring water flows out from alluvial. The main chemical components of water samples collected in June 12 1976 are as follows: pH 6.8, TDS 1.11, Na 3305, K 10, Ca 32.5, Mg 9.77, CO_3 nd, HCO_3 923, SO_4 45.5, Cl 68.7, SiO_2 126, HBO_2 12.1. HCO_3–Na type water.

Th146, Luoba hot spring is located in Zayu County. 97° 58′ 15″E, 28° 53′ 25″N. Altitude: 3250 m. The local government said that the temperature is so high that eggs can be cooked in the spring water.

Th147, Jiangtuo hot spring is located in Zayu County. 97° 14′ 30″E, 29° 52′ 30″N. Altitude: 3800 m. The local government said that the temperature is about 57 °C, and the wild ox often patronizes to lap up the salt in the spring area.

Th148, Zigba hot spring is located in Zayu County. 97° 57′ 00″E, 29° 05′ 18″N. Altitude: 2700 m. The local government said that there are four springs including one fountains.

Th149, **Gyigang** hot spring is located in Zayu County. 97° 27′ 40″E, 28° 39′ 20″N. Altitude: 2300 m. There are three main vents with the maximum temperature of 57.4 °C and the flow rate of 5.5 L/s. The spring flows out from granite. The main chemical components of water samples collected in May 30 1976 are as follows: pH 6.5, TDS 0.532, Na 158, K 8.4, Ca 11.9, Mg nd, CO_3 nd, HCO_3 77.8, SO_4 187.3, Cl 55.3, SiO_2 57.8, HBO_2 7.22. SO_4–Na type water.

Th150, **Mori** hot spring is located in Zayu County. 97° 55′E, 28° 37′N. Altitude: 4000 m. Local government staff informed us that the temperature of this spring was very high and one needed to mix it with cold water for bathing. The flow rate is fairly large.

Th151, **Zuopu** hot spring is located in Zayu County. 98° 17.5′E, 28° 37.5′N. Altitude: 2000 m. The local government staff informed us that the temperature of this spring was very high and one needed to mix it with cold water for bathing.

Th152, **Luxu** hot spring is located in Zayu County. 98° 18′ 20″E, 28° 50′ 00″N. Altitude: 2000 m. The local government staff informed us that the temperature of this spring is very high and one needed to mix it with cold water for bathing.

6.1.7 Hot Springs in Qamdo Prefecture

Th153, Wameka hot spring is located in Qamdo County. 97° 03′ 40″E, 30° 59′ 50″ N. Altitude: 4100 m. The temperature of spring is 55 °C and the flow rate is 2.5 L/s. The main chemical components are as follows: pH 7.9, TDS 2.05, Na 130, K 10, Ca 456.6, Mg 48.8, CO_3 11.3, HCO_3 153, SO_4 1181.3, Cl 79.9. SiO_2 40.7, HBO_2 2.0. SO_4–Ca type water.

Th154, Ren Co hot spring is located in Baxoi County. 96° 40′ 50″E, 30° 43′ 30″N. Altitude: 4450 m. The temperature of this spring is 65.6 °C and the flow rate is 15 L/s. The spring water comes out from the fissures of granodiorite. The main chemical components are as follows: pH 6.5, TDS 0.656, Na 205, K 5.0, Ca 8.55, Mg 4.98, CO_3 nd, HCO_3 437, SO_4 59.6, Cl 28.2, SiO_2 104, HBO_2 6.48. HCO_3–Na type water.

Th155, Nalung hot spring is located in Baxoi County. 96° 46′ 10″E, 30° 18′ 30″N. Altitude: 4200 m. There are three main vents. The highest temperature of spring is 46.5 °C and the total flow rate is 3.5 L/s. The spring water comes out from the contact zone between granite and metamorphic rocks. The main chemical components are as follows: pH 6.5, TDS 0.833, Na 275, K 5.0, Ca 28.3, Mg 7.97, CO_3 nd, HCO_3 587, SO_4 156, Cl 45.6, SiO_2 9.8, HBO_2 5.02. HCO_3–SO_4–Na type water.

Th156, **Badong-Buyu** hot spring is located in Baxoi County. 96° 51′ 10″E, 30° 03′ 00″N. Altitude: 3450 m. The Badong spring is situated on right bank of river and Buyu on left bank. The temperature of main vent in Badong is 75 °C and the temperature of Buyu is 73.6 °C. The main chemical components of Buyu spring are as follows: *t* 73.5 °C, pH 8.5, TDS 1.04, Na 275, K 23.2, Ca 849.6, Mg 16.1, CO_3 28.5, HCO_3 456.9, SO_4 228.9, Cl 101.4, SiO_2 57.8, HBO_2 19.7. HCO_3–SO_4–Na type water.

Th157, **Capu** hot spring is located in Baxoi County. 96° 38′ 40″E, 29° 47′ 10″N. Altitude: 4150 m. The spring water gushes out from the gravel layer of the banks of rivulet. In the range of 150 m, there are dozens of vents, and seven of them are large. The temperatures are above 70 °C, up to 78.5 °C and a flow rate is up to 24 L/s. The main chemical components are as follows: pH 8.5, TDS 0.739, Na 200, K 18, Ca 15.5, Mg 3.61, CO_3 38.3, HCO_3 333, SO_4 37.9, Cl 36.9, SiO_2 102, HBO_2 8.43. HCO_3–Na type water.

Th158, **Gyangzhong** hot spring is located in Baxoi County. 96° 40′ 00″E, 29° 46′ 30″N. Altitude: 4100 m. There are three main vents. The maximum temperature is 62.3 °C, and the flow rate is 2.0 L/s. The main chemical components are as follows: pH 6.5, TDS 1.23, Na 305, K 30, Ca 63.8, Mg 15.0, CO_3 nd, HCO_3 926, SO_4 58.4, Cl 114, SiO_2 nd, HBO_2 12.8. HCO_3–Na type water.

Th159, Chongsar hot spring is located in Baxoi County. 96° 41′ 00″E, 29° 46′ 20″N. Altitude: 4100 m. The spring water gushes out from the gravel layer of the banks. In the range of 500 m, there are dozens of vents, and ten of them are large vents. The temperatures are above 51 °C, up to 56.2 °C and the flow rate is up to 40 L/s.

Th160, **NuJiang Bridge** hot spring is located in Baxoi County and is located next to the Sichuan-Tibet Highway No. 68 Highway maintenance squad room. 98° 12′ 30″E, 30° 06′ 00″N. Altitude: 2740 m. The workers of maintenance squad told us that the temperature of this spring is very high, (maybe more than 70 °C), you need to add cold water before bathing. When we visited this area on July 3, 1976. It was flooded by Nujiang river.

Th161, Yuxi hot spring is located Chagyab County. 97° 17′ 30″E, 30° 41′ 35″N. Altitude: 3700 m. It is located next to the Sichuan-Tibet Highway No. 53 Highway maintenance squad room. There are seven bigger vents. A fountain of 67.5 °C is situated in a corner of the hospital. A 68 °C hot spring is situated at top of a trivertine cone. A bigger fountain of 69.4 °C lies in riverbed of rivulet. The total flow rate is estimated to be 10–15 L/s. The main chemical components are as follows: pH 6.5, TDS 1.79, Na 580, K 71, Ca 11.9, Mg 18.3, CO_3 76.5, HCO_3 730.7, SO_4 61.47, Cl 473.2, SiO_2 68.6, HBO_2 49.8. Cl–HCO_3–Na type water.

Th162, Gyitang hot spring is located Chagyab County. 97° 21′ 10″E, 30° 42′ 10″N. Altitude: 3100 m. The area stretches for 150 m in south-north direction. There are four main springs, which come out from travertine. The maximum temperature is 61.2 °C discharging 15 L/s. The main chemical components are as follows: pH 6.5, TDS 4.105, Na 1420, K 100, Ca 79.2, Mg 19.1, CO_3 nd, HCO_3 834, SO_4 89.8, Cl 1850, SiO_2 98.2, HBO_2 24.1. Cl–HCO_3–Na type water.

Th163, **Qusib** hot spring is located Chagyab County. 97° 30′ 40″E, 30° 43′ 30″N. Altitude: 3350 m. The area is located on the halfway up a hill. There are two main springs, which come out from red sandstone. The maximum temperature is 67 °C and total flow rate of 10 L/s. The main chemical components are as follows: pH 8.15, TDS 1.55, Na 555, K 14.5, Ca 6.34, Mg 2.40, CO_3 75.6, HCO_3 1184.6, SO_4 79.0, Cl 92.2, SiO_2 85.7, HBO_2 11.6. HCO_3–Na type water.

Th164, **Daba** or **Gyilebwa** hot spring is located Chagyab County. 98° 03′ 30″E, 30° 30′ 40″N. Altitude: 3400 m. There are four main vents, which come out from a huge travertine hill. The maximum temperature is 52 °C and the total flow rate is 8 L/s. The main chemical components are as follows: pH 6.5, TDS 3.26, Na 1110, K 31.5, Ca 7.93, Mg 13.2, CO_3 71.3, HCO_3 1865.7, SO_4 633.8, Cl 242.7, SiO_2 81.4, HBO_2 94.3. HCO_3–SO_4–Na type water.

Th165, **Ango** hot spring is located in Zogang County. 97° 26′ 30″E, 30° 13″ 00″N. Altitude: 4150 m. There are many vents at the foot of a hill. The highest temperature is 54.5 °C and the flow rate is 13 L/s. No water sample.

Th166, **Qingkaburlo** hot spring is located in Zogang County. 97° 26′ 40″E, 30° 10′ 15″N. Altitude: 4160 m. The center of area is a travertine hill of 20 m in height, on the top of which there is hot water pool with diameter of 30 m. The temperature of water surface is 20 °C, and the temperature at 2 m depth is 65.6 °C. There are many small vents along the foot of travertine hill. Their temperatures are 30–40 °C and the total flow rate is 10 L/s. The main chemical components are as follows: t 65.6 °C, pH 6.5, TDS 1.494, Na 325, K 35.9, Ca 145.5, Mg 17.1, CO_3 30.8, HCO_3 218.1, SO_4 654.4, Cl 64.5, SiO_2 68.6, HBO_2 30.9. SO_4–Na–Ca type water.

Th167, **Kyanggarda** hot spring is located in Zogang County. 97° 25′ 00″E, 30° 10′ 20″N. Altitude: 412 0 m. Many springs concentrated in three-piece region. In the east piece there is no big spring, but there are many small bubbling strong seepages with temperature 36–40 °C. The spring water is tart flavor. The second piece is 200 m west to the first piece. The main vents over there is a circular pool, and hot water is rolling, like boiling prance. The spring water also has a sour taste. Its temperature is 56 °C. The third piece is a hot spring, bubbling strongly, its highest temperature is 60 °C. The total flux of three areas is 5–8 L/s. The main chemical components are as follows: t 60 °C, pH 6.0, TDS 1.852, Na 560, K 27, Ca 32.5, Mg 42.5, CO_3 nd, HCO_3 1120, SO_4 459, Cl 79.6, SiO_2 76.4, HBO_2 5.43. HCO_3–SO_4–Na type water.

Th168, **Kayu** hot spring is located in Zogang County. 97° 57′ 10″E, 30° 06′ 10″N. Altitude: 3900 m. The local government staff informed us that the temperature of this spring is very high and that one needed to add cold water into it before bathing. The estimated temperature is between 45 and 50 °C.

Th169, **Shalungniuchang** or **Quzika** hot spring is located in Zogang County. 97° 55′ 10″E, 29° 50′ 00″N. Altitude: 4300 m. The local government officials claim that the spring has a high temperature and big flow rate. There are four to five large vents. The spring area produced sulfur, which the local villagers collect to make gunpowder. Not fieldwork is done.

Th170, Taglung hot spring is located in Zogang County. 97° 43′ 18″E, 29° 52′ 30″N. Altitude: 4100 m. There are seven main vents with temperature from 39 to 58 °C. The total flow rate is 8 L/s. Country rock is limestone. The main chemical components are as follows: *t* 58 °C, pH 7.0, TDS 0.792, Na 200, K 9, Ca 24.7, Mg 70.3, CO_3 10.9, HCO_3 530, SO_4 80.7, Cl 20.3, SiO_2 98.2, HBO_2 10.7. HCO_3–Na–Mg type water.

Th171, **Mogkog** or **Mogkug** hot spring is located in Zogang County. 97° 43′ 10″E, 29° 46′ 30″N. Altitude: 3900 m. There are many seepages in the alluvium. There are two main vents, the temperature of one is 50 °C, and of another is 43.5 °C. Total flow rate is 3 L/s. No water samples.

Th172, **Wuri** hot spring is located in Zogang County. 97° 29′ 40″E, 29° 24′ 35″N. Altitude: 3800 m. The local government staff claimed that the temperature of this spring is very high, and one needs to add cold water into it for bathing.

Th173, **Gyorxung** hot spring is located in Jomda County. 97° 50′ 00″E, 31° 23′ 18″N. Altitude: 4100 m. The area is located at south side of the Sichuan- Tibetan highway. There are five vents with temperature from 33 to 58.3 °C. And the flow rate is 10–12 L/s. The spring water has a sour taste. The vent sends up bubbles. The main chemical components are as follows: *t* 58.3 °C, pH 6.5, TDS 1.66, Na 510, K 40.8, Ca 56.3, Mg 15.4, CO_3 16.5, HCO_3 699.6, SO_4 284.4, Cl 288.8, SiO_2 75, HBO_2 16.0. HCO_3–Cl–SO_4–Na type water.

Th174, Quzeka hot spring is located in Markam County. 98° 44′ 30″E, 29° 48′ 35″N. Altitude: 3400 m. The area stretches for 200 m in S–N direction and with 50 m in wide. There are three main vents with temperature of 46.3–47 °C and the flow rate is 15 L/s. The spring waters gushed out from the gravels of granodiorite. Travertine is very developed. There are travertine fan, sinter cone, and sinter mound. The main chemical components are as follows: *t* 47 °C, pH 6.5, TDS 0.35, Na 44.0, K 2.3, Ca 60.8, Mg 17.0, CO_3 nd, HCO_3 330, SO_4 9.41, Cl 7.23, SiO_2 38.2, HBO_2 4.38. HCO_3–Ca–Na type water. The local residents give the spring water to drink and for irrigation.

Th175, Rirong hot spring is located in Markam County. 98° 56′ 00″E, 29° 45′ 30″N. Altitude: 2450 m. There is big travertine body, to the east of which is a vent. The maximum temperature is 57.2 °C and the flow rate is 4 L/s. The main chemical components are as follows: *t* 57.2 °C, pH 7.0, TDS 0.639, Na 200, K 5.0, Ca 22.4, Mg 5.98, CO_3 nd, HCO_3 558, SO_4 26.3, Cl 14.5, SiO_2 70.9, HBO_2 10.5. HCO_3–Na type water.

Th176, Duba or **Donglagong** hot spring is located in Markam County. 98° 24′ 00″ E, 29° 37′ 30″N. Altitude: 3050 m. There are six main vents with temperature of 30.5–50.5 °C and the flow rate is 6.5 L/s. The main chemical components are as follows: *t* 50.5 °C, pH 6.5, TDS 1.37, Na 440, K 4.0, Ca 46.0, Mg 7.97, CO_3 nd, HCO_3 671.6, SO_4 292, Cl 243, SiO_2 87.3, HBO_2 8-75. HCO_3–Cl–SO_4–Na type water.

Th177, Qucainka or **Daxoi** hot spring is located in Markam County. 98° 44′ 30″E, 29° 48′ 35″N. Altitude: 3400 m. The area is 80 m long and 50 m wide. There are six bigger vents with temperature of 49.2–72.5 °C and the total flow rate is 20 L/s. A lot of small vents with lower temperature emerge in this area. The main chemical components are as follows: *t* 72.5 °C, pH 6.5, TDS 0.393, Na 94.0, K

4.95, Ca 10.2, Mg 15.5, CO_3 8.47, HCO_3 196, SO_4 37.1, Cl 23.1, SiO_2 85.1. HCO_3–Na type water. The coldish spring water irrigates nearby farmland in getting bumper crops.

Th178, Lagyabxoi hot spring is located in Markam County. 98° 38′ 00″E, 29° 07′ 40″N. Altitude: 2400 m. The area is located at left bank of Lancang river. The local government officials claimed that: the spring temperatures is very high, and that it is often inundated by Lancang river.

Th179, Adong hot spring is located in Markam County. 98° 37′ 20″E, 28° 46′ 25″N. Altitude: 3400 m. The area is located in a tributary of west bank of Lancang river. The local government staff claimed that the temperature of this spring is very high, and that one needed to add cold water into it for bathing.

6.2 Hot Springs in Western Sichuan Provence

According to the data *Thermal Springs in Hengduan (Traverse) Mountain* there are 105 hot springs in the western part of Sichuan Province (the eastern part of the Qingzang Plateau) (Tong and Zhang 1994).

6.2.1 Hot Springs in Garze Zang Autonomous Prefecture

Sh01, Seryichayima hot spring is located in Serxu County of Garze Zang Autonomous Prefecture. 97° 39′ 00″E, 33° 34′ 30″N. Altitude: 4500 m. The temperature of the spring is 68 °C. The flow rate is 0.6 L/s. The main chemical compositions are as follows: *t* 68 °C, pH 7.6, TDS 1.960, Na **82.97,** K 46, HCO_3 898, F 2.6, Mn 1.12, Metasilicicic acid 227.14. The chemical type is HCO_3–Na water.

Sh02, Baro Si hot spring-1 is located in Serxu County of Garze Zang Autonomous Prefecture. 97° 45′ 30″E, 33° 31′ 40″N. Altitude: 4197 m. The temperature of the spring is 48.9 °C. The flow rate is 0.085 L/s. There is no water chemical data.

Sh03, Baro Si hot spring-2 is located in Serxu County of Garze Zang Autonomous Prefecture. 97° 45′ 30″E, 33° 31′ 10″N. Altitude: 4192 m. The temperature of the spring is 60.5 °C and the flow rate is 7.279 L/s.

Sh04, Quroin hot pool is located in Dega County of Garze Zang Autonomous Prefecture. 98° 17′ 15″E, 32° 21′ 40″N. Altitude: 3730 m. The manifestation areas can be divided into three parts along the east–west direction. There are three main vents in east part. The temperatures are 47–61.5 °C and the flow rate is 2.8 L/s. The temperatures of the springs in the middle part are 63–67 °C, the flow rate is 1.5 L/s. The temperatures of two vents at west part are 54 and 59 °C, respectively. Travertine is widely developed. The main chemical compositions are as follows: *t* 67 °C, pH 8.34, TDS 0.819, Na 265, K 21.9, Ca 11.7, Mg 8.91, HCO_3 783, SO_4 11.6, Cl 7.02, SiO_2 92.6. HCO_3–Na type.

Sh05, Qunggolung hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 98° 17′ 50″E, 32° 21′ 40″N. Altitude: 3760 m. The highest temperature is 49.5 °C. The flow rate is 5 L/s. The main chemical compositions are as follows: pH 8.38, TDS 0.624, Na 181, K 18.5, Ca 21.8, Mg 13.5, HCO_3 795, SO_4 11.7, Cl 7.02, SiO_2 50.0. HCO_3–Na type.

Sh06, Legrongkog hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 98° 38′ 30″E, 32° 09′ 20″N. Altitude: 3900 m. The area is 1 km long. The temperature is 49 °C and the flow rate is 2.16 L/s. The main chemical compositions are as follows: pH 6.6, TDS 1.677, Na 339, K 39.6, Ca 224.69, Mg 47.29, HCO_3 1914.77, SO_4 1.00, Cl 14.61, SiO_2 50.0. HCO_3–Na–Ca type.

Sh07, Lungdong hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 98° 50′ 15″E, 32° 11′ 00″N. Altitude: 3860 m. The temperature is 56 °C and the flow rate is 1.5 L/s. The main chemical compositions are as follows: pH 8.5, TDS 0.849, Na 290, K 18.5, Ca 11.5, Mg 5.61, CO_3 33.6, HCO_3 808, SO_4 11.60, Cl 7.02, SiO_2 60.6. HCO_3–Na type.

Sh08, Pangomaqoi hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 98° 51′ 35″E, 31° 57′ 25″N. Altitutde: 4100 m. There are three vents. The highest temperature is 50 °C. The thickness of travertine is 1.5 m at the area of 50 m × 50 m. The main chemical compositions are as follows: pH 7.3, TDS 1.638, Na 518, K 52.0, Ca 71.32, Mg 30.18, HCO_3 1793.78, SO_4 nd, Cl 11.52, SiO_2 9.35. HCO_3–Na type.

Sh09, West of Chola Shan Pass hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 98° 53′ 50″E, 31° 57′ 20″N. Altitude: 4450 m. The spas are distributed in an area of 300 m long in the east-west direction along the fractures in Granite. The temperatures are 67 °C in west part, 68 °C in middle and 63 °C in east part. The total flow rate is 8.32 L/s. The main chemical compositions are as follows: *t* 67 °C, pH 7.3, TDS 0.753, Na 242.5, K 17.35, Ca 39.80, Mg 1.51, HCO_3 803, SO_4 nd, Cl 17.90, SiO_2 23.69. HCO_3–Na type.

Sh10, Gyabrong Caquka hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 99° 21′ 20″E, 32° 04′ 05″N. Altitude: 4320 m. The area is 40 m × 10 m. There are three vents of temperature of 58–59 °C. The flow rate is 1.519, 0.544 and 3.148 L/s. The main chemical compositions are as follows: *t* 59 °C, pH 6.9, TDS 0.834, Na 232.5, K 29.3, Ca 38.28, Mg 16.33, HCO_3 873.52, SO_4 9.0, Cl 4.53, SiO_2 60.00. HCO_3–Na type.

Sh11, Chotangkog hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 99° 23′ 50″E, 31° 47′ 40″N. Altitude: 3720 m. The temperature is 47 °C and the flow rate is 1.461 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 6.7, TDS 0.826, Na 216.5, K 9.25, Ca 77.11, Mg 8.05, HCO_3 652.52, SO_4 118.95, Cl 50.13, SiO_2 14.96. HCO_3–Na type.

Sh12, Rongcaka hot spring is located in Dega County of Garze Zang Autonomous Prefecture. 99° 29′ 30″E, 31° 48′ 50″N. Altitude: 3580 m. The area is about 110 m^2. Main vent's temperature is 71.5 °C. The flow rate is 1.931 L/s. The thickness of travertine is 4–5 m. The main chemical compositions are as follows: *t* 71.5 °C, pH 8.0, TDS 1.215, Na 430, K 36.4, Ca 19.84, Mg 19.35, HCO_3 1327.42, SO_4 4.0, Cl 4.54, SiO_2 35.00. HCO_3–Na type.

Sh13, Tinggo hot spring is located in Baiyu County of Garze Zang Autonomous Prefecture. 99° 07′ 55″E, 31° 34′ 35″N. Altitude: 3760 m. The spa temperature is 48 °C. The flow rate is 0.24 L/s. There is lack of water sample.

Sh14, Targyilung hot spring is located in Baiyu County of Garze Zang Autonomous Prefecture. 99° 00′ 00″E, 30° 47′ 50″N. Altitude: 3000 m. The spa temperature is 58 °C and the flow rate is 0.039 L/s. The main chemical compositions are as follows: pH 6.9, TDS 1.342, Na 316, K 50, Ca 118.02, Mg 19.72, HCO3 1325, SO4 90, Cl 23.54, SiO_2 36.0. HCO_3–Na type.

Sh15, Toinzhubdo hot spring is located in Baiyu County of Garze Zang Autonomous Prefecture. 99° 10′ 40″E, 30° 37′ 22″N. Altitude: 3400 m. The highest temperature of the vent is 48 °C and the flow rate is 1.801 L/s. The main chemical compositions are as follows: pH 6.9, TDS 0.825, Na 156, K 22.3, Ca 106.19, Mg 19.32, HCO_3 719.57, SO_4 120.89, Cl 9.96, SiO_2 28.0. HCO_3–Na–Ca type.

Sh16, Qiqu hot spring is located in Baiyu County of Garze Zang Autonomous Prefecture. 99° 34′ 10″E, 30° 56′ 30″N. Altitude: 3950 m. The area is 200 m long and 20 m wide. The temperature is 42–54 °C and the flow rate is 1 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 8.75, TDS 0.751, Na 240, K 14.2, Ca 25.5, Mg 20.5, CO_3 18.7, HCO_3 723, SO_4 6.21, Cl 6.98, SiO_2 50.3. HCO_3–Na type.

Sh17, Qungkoicatog hot spring is located in Baiyu County of Garze Zang Autonomous Prefecture. 99° 44′ 10″E, 31° 03′ 25″N. Altitude: 4320 m. The main vent is located at a travertine terrace near the No. 7 highway maintenance squad of Garze to Baiyu. The spa's temperature is 68 °C, The flow rate is 1 L/s. The main chemical compositions are as follows: *t* 68, pH 8.90, TDS 0.937, Na 273, K 30.2, Ca 42.6, Mg 14.1, CO_3 31.2, HCO_3 694, SO_4 40.1, Cl 34.9 SiO_2 62.8. HCO_3–Na type.

Sh18, Meyulung hot spring is located in Garze County of Garze Zang Autonomous Prefecture. 99° 42′ 00″E, 31° 40′ 30. Altitude: 3100 m. The temperature of the spring is 48 °C. The main chemical compositions are as follows: *t* 48 °C, pH 9.3, TDS 0.980, Na 315, K 14.0, Ca 53.17, Mg 6.45, CO_3 nd, HCO_3 993.97, SO_4 20.0, Cl 7.55, SiO_2 60.8, HCO_3–Na type.

Sh19, Shibngo hot spring is located in Garze County of Garze Zang Autonomous Prefecture. 100° 00′ 30″E, 31° 36′ 18″N. Altitude: 3355 m. The vent is located on the back of low alluvial flat, and for this reason it appears during the dry season and disappears during the rainy season. The temperature of the vent is 51 °C. The chemical compositions are as follows: TDS 0.646, Na 198.50, K 17.35, Ca 41.92, Mg 7.68, HCO_3 690, SO_4 25.0, Cl 9.47. HCO_3–Na type.

Sh20, Capug hot spring is located in Nyagrong County of Garze Zang Autonomous Prefecture. 100° 03′ 10″E, 31° 06′ 30″N. Altitude 4340 m. The temperature is 71 °C and the flow rate is 18.94 L/s. Travertine appears. The main chemical compositions are as follows: *t* 71 °C, pH 6.9, TDS 0.886, Na 268, K 37.50, Ca 68.78, Mg 7.12, CO_3 nd, HCO_3 881.51, SO_4 nd, Cl 55.24, SiO_2 na. HCO_3–Na type.

Sh21, Surqenxi hot spring is located in Nyagrong County of Garze Zang Autonomous Prefecture. 100° 02′ 10″E, 30° 58′ 35″N. Altitude: 4010 m. The temperature is 55 °C and the flow rate is 12.2 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 7.3, TDS 0.353, Na 116, K 4.30, Ca 8.00, Mg 2.75, CO_3 nd, HCO_3 303, SO_4 8.00, Cl 23.36, SiO_2 36.00. HCO_3–Na type.

Sh22, Nyidaca hot spring is located in Nyagrong County of Garze Zang Autonomous Prefecture. 100° 03′ 15″E, 30° 54′ 40″N. Altitude: 3700 m. There are four vents. The temperatures are 45, 52, 57 and 59 °C. The total flow rate is 27.9 L/s. The main chemical compositions are as follows: *t* 59 °C, pH 7.0, TDS 1.246, Na 360, K 50.0, Ca 98.34, Mg 12.14, CO_3 nd, HCO_3 1241, SO_4 nd, Cl 66.01, SiO_2 36.00. HCO_3–Na type.

Sh23, Xingnag Caqu hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 06′ 30″E, 31° 03′ 30″N. Altitude: 3280 m. The temperatures are 38.5–52 °C. The main chemical compositions are as follows: *t* 46 °C, pH9.20, TDS 1.283, Na 485, K 18.8, Ca 8.5, Mg 19.0, CO_3 171, HCO_3 1030, SO_4 23.8, Cl 5.26, SiO_2 54.0. HCO_3–Na type of water.

Sh24, Poi Caqu hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 10′ 35″E, 31° 10′ 00″N. Altitude: 3920 m. The highest temperature is 53 °C. The temperature of the spa with maximum flow rate is 52 °C, which is located at travertine terrace. The main chemical compositions are as follows: *t* 52 °C, pH 8.26, TDS 0.673, Na 177, K 12.8, Ca 67.89, Mg 18.0, CO_3 nd, HCO_3 628, SO_4 4.60, Cl 10.5, SiO_2 76.6. HCO_3–Na type of water.

Sh25, Qumarkog Caqu hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 11′ 05″E, 31° 07′ 40″N. Altitude: 3960 m. The area is 1 km long along a river. A spa of 37 °C is located at the north part. The middle part was buried beneath the alluvial apron. The temperatures of spas at travertine terrace in south part are 49–58 °C. The main chemical compositions are as follows: *t* 58 °C, pH 8.34, TDS 0.584, Na 128, K 13.4, Ca 48.4, Mg 14.5, CO_3 nd, HCO_3 516, SO_4 6.40, Cl 10.5, SiO_2 84.6, HCO_3–Na type of water.

Sh26, Lungpug Caqu hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 14′ 35″E, 30° 57′ 20″N. Altitude: 3400 m. There are 7 vents at diluvium 300 m long. The temperatures are 36.5–49 °C. The total flow rates are 3 L/s. The main chemical compositions are as follows: *t* 49 °C, pH 7.98, TDS 0.790, Na 250, K 13.4, Ca 11.7, Mg 15.0, CO_3 nd, HCO_3 808, SO_4 1.12, Cl 17.5, SiO_2 54.0. HCO_3–Na type of water.

Sh27, Lhamnang Caqu or **Kugqag** hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 17′ 30″E, 30° 52′ 05″N. Altitude: 3560 m. The area is a ladder-like travertine terrace. There are springs at every terraces. From top to base, the temperatures of the springs are 37, 45 and 43.5 °C. The main chemical compositions are as follows: *t* 43.5 °C, pH 7.91, TDS 0.623, Na 116, K 17.2, Ca 58.0, Mg 38.5, CO_3 nd, HCO_3 653, SO_4 11.6, Cl 4.21, SiO_2 47.40. HCO_3–Na–Mg–Ca type of water.

Sh28, Kainba-Yuma Caqu or **Caqu Lungba** hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 37′ 20″E, 30° 32′ 27″N. Altitude: 3660 m. The springs are distributed along the Caqu Lungba rivulet with the S–N trend about 500 m. One spa of 54.5 °C is located on the west bank of rivulet. There are 4 springs at east bank of rivulet, their temperatures are 45, 44, 66, and 72 °C from south to north. Country rock is Granite. The main chemical compositions are as follows: *t* 72 °C, pH 7.0, TDS 0.842, Na 150, K 23.0, Ca 3.51, Mg 3.45, CO_3 30.6, HCO_3 1020, SO_4 2.80, Cl 38.6, SiO_2 139. HCO_3–Na type of water.

Sh29, **Yala Caqu** hot spring is located in Dawu County of Garze Zang Autonomous Prefecture. 101° 40′ 45″E, 30° 22′ 40″N. Altitude: 4100 m. There are 6 vents, and the temperatures are 49–61 °C. The flow rate is 2.428 L/s. The main chemical compositions are as follows: *t* 49 °C, pH 7.2, TDS 0.443 Na 142, K 6.0, Ca 8.48, Mg 0.0 5, CO_3 nd, HCO_3 345.97, SO_4 12.0, Cl 16.45, SiO_2 74.8. HCO_3–Na type of water.

Sh30, Dangling hot springs are located in Rongchag County of Garze Zang Autonomous Prefecture. 101° 24′ 20″–40″E, 31° 02′ 30″–40″N. Altitude: 3620–3700 m. There are two hot springs. One is called **Bangkacaqu,** and its temperature is 70 °C and the flow rate is 0.395 L/s. Another is called Mogricaqu with temperature of 75 °C and flow rate of 1.24 L/s. The main chemical compositions of the latter are as follows: *t* 75 °C, pH na, TDS 0.829, Na 200, K 12.5, Ca 377.66, Mg 18.33, CO_3 nd, HCO_3 861.80, SO_4 3.00, Cl 25.03, SiO_2 51.39. HCO_3–Na type of water.

Sh31, Caxoi hot springs are located in Batang County of Garze Zang Autonomous Prefecture. 99° 04′ 35″–05′ 20″E, 29° 57′ 35″–58′ 55″N. Altitude: 2600 m. The hydrothermal area is intermittently stretched about 3 km along the river. There are four main vents. Their temperatures are 76, 74, 72 and 75.5 °C. No water sample.

Sh32, Lingdo hot spring are located in Batang County of Garze Zang Autonomous Prefecture. 99° 05′ 27″E, 29° 52′ 25″N. Altitude: 3220 m. The temperature of main vent is 63 °C and the flow rate is 4.026 L/s. The main chemical compositions are as follows: *t* 63 °C, pH 8.5, TDS 0.254, Na 75.0, K 1.50, Ca 5.33, Mg nd, CO_3 46.27, HCO_3 60.22, SO_4 32.0, Cl 15.92, SiO_2 36.00. HCO_3–Na type of water.

Sh33, Xagoxi or **Baqungxi** hot spring is located in Batang County of Garze Zang Autonomous Prefecture. 99° 10′ 52″E, 29° 58′ 10″N. Altitude: 3080 m. The temperature is 47 °C and the flow rate is 0.325 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.1, TDS 1.196, Na 225.0, K 30.00, Ca 164.11, Mg 47.74, CO_3 nd, HCO_3 1286.73, SO_4 40.0, Cl 33.86, SiO_2 10.00. HCO_3–Na–Ca type of water.

Sh34, 336 Highway maintenance squad hot spring is located in Batang County of Garze Zang Autonomous Prefecture. 99° 19′ 35″E, 30° 13′ 28″N. Altitude: 3160 m. There are two vents. The highest temperature is 62 °C. The flow rate is 7 L/s. No water sample.

Sh35, West of Chong Co hot spring is located in Batang County of Garze Zang Autonomous Prefecture. 99° 20′ 30″E, 30° 16′ 50″N. Altitude: 3360 m. The main manifestation is a travertine terrace of 150 m long, on which there are many vents. There are two main vents. Their temperatures and flow rates are 66 °C discharging of 0.2 L/s and 64 °C discharging of 0.3 L/s. The main chemical compositions are as follows: *t* 66 °C, pH7.0, TDS 0.938 Na 285.0, K 23.10, Ca 8.5, Mg 12.6, CO_3 18.4, HCO_3 733, SO_4 87.0, Cl 17.5, SiO_2 108. HCO_3–Na type of water.

Sh36, 305 Highway maintenance squad hot spring is located in Batang County of Garze Zang Autonomous Prefecture. 99° 27′ 13″E, 30° 15′ 59″N. Altitude: 3940 m. The thermal manifestation area is stretched about 1.5 km along the river. The hot springs are located in the middle section. The temperatures range from 65.5 to 70 °C and the total flow rate is 5.599 L/s. The main chemical compositions are as follows: *t* 70 °C, pH 7.4, TDS 0.739 Na 245.0, K 23.00, Ca 26.01, Mg 3.23, CO_3 nd, HCO_3 746.85, SO_4 8.0, Cl 18.93, SiO_2 40. HCO_3–Na type of water.

Sh37, Chagrug or **Yarrigang** hot spring is located in Batang County of Garze Zang Autonomous Prefecture. 99° 22′ 15″E, 30° 28′ 45″N. Altitude: 3360 m. The temperature of vent is 48 °C and the flow rate is 0.281 L/s. The travertine body has 200 m long and 5 m thick. The main chemical compositions are as follows: *t* 48 °C, pH 7.0, TDS 1.361 Na 240, K 55.0, Ca 234.17, Mg 23.63, CO_3 nd, HCO_3 1471, SO_4 nd, Cl 29.57, SiO_2 36. HCO_3–Na type of water.

Sh38, Rabqu or **Zaingo** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 53′ 00″E, 30° 22′ 30″N. Altitude: 4240 m. The area is 400 m × 400 m. There are five vents. The highest temperature is 63 °C and the total flow rate is 1.405 L/s. The main chemical compositions are as follows: *t* 63 °C, pH 7.1, TDS 1.329, Na 460, K 28.0, Ca 26.55, Mg 10.46, CO_3 nd, HCO_3 1329, SO_4 10, Cl 40.81, SiO_2 70. HCO_3–Na type of water.

Sh39, Qowo hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 05′ 45″E, 30° 27′ 40″N. Altitude: 3330 m. There are hot springs, hot ground 80 m × 70 m, imposing and magnificent travertine forest in this area. The highest pillar travertine is 12 m. The vent is located at the bottom of pillar. The highest temperature is 76 °C and the sum total of flow rate is 3.415 L/s. The main chemical compositions are as follows: *t* 76 °C, pH 8.1, TDS 1.451, Na 510, K 45.20, Ca 21.26, Mg 22.79, CO_3 nd, HCO_3 1356, SO_4 100.0, Cl 44.32, SiO_2 26. HCO_3–Na type of water.

Sh40, North Joxi hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 08′ 15″E, 30° 28′ 15″N. Altitude: 3420 m. The main vent is located at a travertine terrace. Its temperature is 53 °C and the flow rate is 2.694 L/s. The main chemical compositions are as follows: *t* 53 °C, pH 7.0, TDS 0.748, Na 226, K 16.0, Ca 48.94, Mg 8.35, CO_3 nd, HCO_3 771.29, SO_4 18.0, Cl 4.04, SiO_2 40. HCO_3–Na type of water.

Sh41, South Joxi hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 09′ 28″E, 30° 23′ 53″N. Altitude: 4560 m. The two main vents are 300 m apart on a travertine terrace. Their temperatures are 47 and 37 °C, respectively. The total flow rate is 1.825 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.2, TDS 0.866, Na 278, K 17.40, Ca 48.94, Mg 8.81, CO_3 nd, HCO_3 912.55, SO_4 12.0, Cl 2.52, SiO_2 40. HCO_3–Na type of water.

Sh42, Caqubug hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 31′ 00″E, 30° 23′ 52″N. Altitude: 4280 m. Several springs with temperatures up to 61 °C are located in an area 45 m× 30 m travertine high terrace. The total flow rate is 1.884 L/s. The main chemical compositions are as follows: *t* 61 °C, pH 7.3, TDS 1.612, Na 540, K 50.0, Ca 45.83, Mg 4.13, CO_3 nd, HCO_3 1649.29, SO_4 8.0, Cl 30.06, SiO_2 40. HCO_3–Na type of water.

Sh43, Qacha hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 40′ 00″E, 29° 50′ 00″N. Altitude: 4400 m. The two spas with temperature up to 51 °C are 11 m apart. The flow rate is 1.638 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 6.0, TDS 0.921, Na + K 283.13, Ca 52.3, Mg 36.35, CO_3 nd, HCO_3 1047.05, SO_4 nd, Cl 26.59, SiO_2 na. HCO_3–Na type of water.

Sh44, Kezi or **Zaitang** or **Zailung** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 46′ 30″E, 29° 50′ 25″N. Altitude: 3790 m. Several vents appear in the high flood land. The highest temperature is 48 °C discharging 0.30 L/s. Travertine is deposited. The travertine cone is 5.5 m high. The main chemical compositions are as follows: *t* 48 °C, pH 7.1, TDS 1.071, Na 284, K 40.04, Ca 76.39, Mg 23.86, CO_3 nd, HCO_3 1108.19 SO_4 0.50 Cl 43.04, SiO_2 40. HCO_3–Na type of water.

Sh45, Dongyu hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 52′ 05″E, 30° 13′ 57″N. Altitude: 4228 m. Main manifestation area appeared at the slope about 30 m in length. The vent at west end is 46 °C discharging 0.5 L/s. The spring puffs as if the water was boiling. The vent at east end is 47 °C also discharging 0.5 L/s. The spring releases a large number of gasses. The main chemical compositions are as follows: *t* 47 °C, pH 7.0, TDS 1.495, Na 462, K 61.6, Ca 14.0, Mg 34.5, CO_3 nd, HCO_3 1450, SO_4 13.4, Cl 63.2, SiO_2 67.4. HCO_3–Na type of water.

Sh46, Ozhi hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 52′ 25″E, 29° 39′ 48″N. Altitude: 3540 m. The vent is located on a high flood bed to 67 °C discharging 0.481 L/s. The main chemical compositions are as follows: *t* 67 °C, pH 7.4, TDS 0.675, Na 197, K 15.0, Ca 34.79, Mg 2.75, CO_3 nd, HCO_3 571.97, SO_4 4.0, Cl 61.09, SiO_2 60. HCO_3–Na type of water.

Sh47, Garoog hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 49′ 0527″E, 29° 34′ 00″N. Altitude: 3400 m. The main vent was inundated. The vent sampled is close rip to 72 °C discharging 0.714 L/s. The main chemical compositions are as follows: *t* 72 °C, pH 7.1, TDS 0.806, Na 244, K 40.0, Ca 31.36, Mg 9.14, CO_3 nd, HCO_3 734.30, SO_4 30.0, Cl 39.03, SiO_2 40. HCO_3–Na type of water.

Sh48, Dingbo hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 99° 58′ 45″E, 29° 29′ 07″N. Altitude: 3580 m. There are four vents in this area. The highest temperature is 51 °C discharging 0.483 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 7.7, TDS 1.243, Na 436, K 38.0, Ca 38.70, Mg 12.14, CO_3 nd, HCO_3 1260.37, SO_4 4.0, Cl 53.75, SiO_2 18. HCO_3–Na type of water.

Sh49, Horanyingba hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 08′ 28″E, 30° 02′ 18″N. Altitude: 3974 m. The area is 200 m long along the river. The hot water flows out from the fractures of quartz porphyry at forward position of second bottom. The temperature of west vent is the highest to 58 °C discharging 0.304 L/s. There are two east vents to 50 and 52 °C. The main chemical compositions are as follows: *t* 58 °C, pH 7.0, TDS 1.201, Na 391, K 23.9, Ca 10.3, Mg 19.5, CO_3 nd, HCO_3 1190, SO_4 2.80, Cl 42.1, SiO_2 58.1. HCO_3–Na type of water.

Sh50, Yucalungba hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 09′ 12″E, 30° 01′ 10″N. Altitude: 3984 m. The main vent is close the river bank to 46.5 °C discharging 0.5 L/s. The main chemical compositions are as follows: *t* 46.5 °C, pH 7.0, TDS 1.885, Na 632, K 51.0, Ca 6.04, Mg 21.2, CO_3 nd, HCO_3 1890.0, SO_4 1.12, Cl 56.2, SiO_2 108. HCO_3–Na type of water.

Sh51, Maoya or **Maoya-caka** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 12′ 50″E, 29° 59′ 32″N. Altitude: 3964 m. The most outstanding characteristic of Maoya-caka is broad scale of travertine, which is formed in both modern and ancient times. The scope of ancient travertine is greater than modern one. The temperatures of spas are 30–60 °C. The total flow rate is 1.61 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 8.28, TDS 1.933, Na 674, K 31.40, Ca 8.01, Mg 20.5, CO_3 nd, HCO_3 2050.0, SO_4 6.4, Cl 35.1, SiO_2 74.2. HCO_3–Na type of water.

Sh52, Qoiyigkog hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 11′ 30″E, 29° 42′ 36″N. Altitude: 4120 m. The temperature is 72 °C discharging 4.933 L/s. The main chemical compositions are as follows: *t* 72 °C, pH 7.1, TDS 0.543, Na 176, K 18.75, Ca 27.23, Mg 5.04, CO_3 nd, HCO_3 551.47, SO_4 9.0, Cl 21.02, SiO_2 4.0. HCO_3–Na type of water.

Sh53, Carongxi or **Qawa** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 24′ 48″E, 29° 47′ 10″N. Altitude: 3760 m. The area is 1 km × 200 m along the ravine. The main vent of 55 °C is located at the south end of a big travertine body discharging 1 L/s. There are four vents on the north end of travertine sinter. Their temperatures are 42–45.5 °C discharging 1.5 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 7.0, TDS 1.215, Na 421, K 21, Ca 11.5, Mg 24.5, CO_3 nd, HCO_3 1310, SO_4 2.80, Cl 12.3, SiO_2 50.0. HCO_3–Na type of water.

Sh54, Cango or **Xonlungca** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 28′ 00″E, 29° 44′ 52″N. Altitude: 3580 m. The highest temperature of the spas is 54 °C, the others are from 53 to 47 °C. A mushroom-shaped travertine mass appears on the south end of the area, on the top of which there is a spring to 40 °C discharging 0.01 L/s. and at the bottom of which there two springs of 44 °C discharging 0.5 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 7.0, TDS 1.285, Na 442, K 47.7, Ca 4.01, Mg 10.5, CO_3 nd, HCO_3 1350, SO_4 4.60, Cl 11.6, SiO_2 71.02. HCO_3–Na type of water.

Sh55, Nagxuqu or **Kemo** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 27′ 05″E, 29° 21′ 42″N. Altitude: 4000 m. The highest temperature is 46 °C discharging 3.858 L/s. The area of travertine mass is 80 m × 100 m, and the thickness is 3 m. The main chemical compositions are as follows: *t* 46 °C, pH 6.2, TDS 1.063, Na 271, K 62.5, Ca 88.52, Mg 17.89, CO_3 nd, HCO_3 1115.39, SO_4 14.0, Cl 46.05, SiO_2 8.0. HCO_3–Na type of water.

Sh56, Tewang hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 35′ 37″E, 29° 27′ 30″N. Altitude: 3580 m. The main vent is a shallow pond with diameter of 2 m located in a highland barley field of the east bank of a river. Its temperature is 72 °C and its flow rate is 1 L/s. The travertine is developed in the west bank, the subjacent river bed is well-cemented sandy gravel and the overlying bed is massive well-crystallized travertine. The main chemical compositions are as follows: *t* 72 °C, pH 8.0, TDS 1.422, Na 479, K 46.8, Ca 3.01, Mg 11.00, CO_3 49.0, HCO_3 1340, SO_4 4.60, Cl 17.50, SiO_2 117. HCO_3–Na type of water.

Sh57, Naisang or **Naisang-ca** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 37′ 50″E, 29° 37′ 08″N. Altitude: 3600 m. The area is stretched for about 60 m along the river. At both ends, there appears mushroom-shaped travertine mass. The main vent is placed in the middle of the area. Its temperature is 47 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.0, TDS 1.118, Na 333, K 48.1, Ca 11.3, Mg 31.0, CO_3 nd, HCO_3 1220, SO_4 1.12, Cl 10.5, SiO_2 62.1. HCO_3–Na type of water.

Sh58, Dongbo-caka or **Molamai-caka** hot spring is located in Litang County of Garze Zang Autonomous Prefecture. 100° 39′ 30″E, 29° 35′ 30″N. Altitude: 3420 m. The main vent is a seep with diameter slightly less than 1 m. The temperature of hot water is 48 °C and the flow rate is 0.5 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 7.8, TDS 1.243, Na 415, K 48.5, Ca 5.31, Mg 24.3, CO_3 nd, HCO_3 1532, SO_4 0.10, Cl 12.3, SiO_2 47.4. HCO_3–Na type of water.

Sh59, Dequ hot spring is located in Qazheng County of Garze Zang Autonomous Prefecture. 99° 29′ 30″E, 29° 26′ 22″N, Altitude: 3200 m. The spa temperature is 53 °C and the flow rate is 0.544 L/s. The main chemical compositions are as follows: *t* 53 °C, pH 6.8, TDS 1.358, Na 416, K 46, Ca 65.37, Mg 24.68, CO_3 nd, HCO_3 1371.36, SO_4 30.0, Cl 53.57, SiO_2 32. HCO_3–Na type of water.

Sh60, Degoin Caqu hot spring is located in Qazheng County of Garze Zang Autonomous Prefecture. 99° 54′ 18″E, 29° 08′ 37″N, Altitude: 3040 m. There are three vents in this area. The south vent was inundated when we visited in 1981. The north vent is located at sheer precipice too high to reach. The middle one is a circular pool on the flood land. Its temperature is 46.5 °C discharging 0.3 L/s. The main chemical compositions are as follows: *t* 46.5 °C, pH 7.0, TDS 0.751, Na 191, K 27.9, Ca 21.0, Mg 33.1, CO_3 12.2 HCO_3 777, SO_4 1.12, Cl 19.3, SiO_2 46. HCO_3–Na type of water.

Sh61, Cakacaqu hot spring is located in Qazheng County of Garze Zang Autonomous Prefecture. 99° 53′ 45″E, 29° 05′ 16″N, Altitude: 2960 m. There are three spas in 100 m^2 area. Two vents were inundated when we visited in 1981. The south springs appear on the bank of the river. The temperature of surface water is 45 °C discharging 0.7–1 L/s. The main chemical compositions are as follows: *t* 45 °C, pH 5.5, TDS 0.946, Na 289, K 21.5, Ca 10.7, Mg 20.4, CO_3 nd, HCO_3 951, SO_4 1.04, Cl 42.1, SiO_2 59.4. HCO_3–Na type of water.

Sh62, Zadoi or **Ragwa** hot spring is located in Qazheng County of Garze Zang Autonomous Prefecture. 99° 35′ 45″E, 28° 43′ 07″N, Altitude: 2800 m. The springs are in a zonal distribution about 500 m at the second terrace along the river. There are 18 vents, and their temperatures range from 30 to 52 °C and the total of flow rate is only 0.7 L/s. The main chemical compositions are as follows: *t* 52 °C, pH 7.96, TDS 1.405, Na 453, K 55, Ca 10.5, Mg 16.5, CO_3 nd, HCO_3 1280, SO_4 1.12, Cl 84.2, SiO_2 119. HCO_3–Na type of water.

Sh63, Rogbocaka or **Caxor** hot spring is located in Dabba County of Garze Zang Autonomous Prefecture. 100° 19′ 26″E, 29° 01′ 27″N, Altitude: 3736 m. The areal extent of the spring is only 5 m^2, where there are four vents of 66, 65.8, 65.8 and 66.2 °C. The total flow rate is 25–30 L/s. The main chemical compositions are as follows: *t* 66.2 °C, pH 9.66, TDS 0.177, Na 32.1, K 0.8, Ca 3.70, Mg 3.20, CO_3 42.8, HCO_3 12.4, SO_4 1.12, Cl 4.56, SiO_2 79.4. CO_3–Na type of water.

Sh64, Rimadab hot spring is located in Nyqu County of Garze Zang Autonomous Prefecture. 100° 49′ 03″E, 29° 36′ 47″N, Altitude: 3520 m. The spa temperature is 69 °C discharging 3.401 L/s. The main chemical compositions are as follows: *t* 69 °C, pH 7.1, TDS 0.319, Na 105, K 5.0, Ca 3.49, Mg 0.92, CO_3 nd, HCO_3 171.58, SO_4 80.0, Cl 18.05, SiO_2 8.0. HCO_3–SO_4–Na type of water.

Sh65, Horqu hot spring is located in Nyqu County of Garze Zang Autonomous Prefecture. 100° 56′ 38″E, 29° 39′ 17″N, Altitude: 3320 m. The temperature of main vent is 47 °C and the flow rate is 0.738 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.0, TDS 1.340, Na 276, K 62.5, Ca 165.67, Mg na, CO_3 nd, HCO_3 1603.64, SO_4 2.0, Cl 20.03, SiO_2 8.0. HCO_3–Na–Ca type of water.

Sh66, Jigdag hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 11′ 18″E, 29° 23′ 12″N, Altitude: 3080 m. The spa temperature is 56 °C discharging 2.333 L/s. The travertine has 200 m long, 50 m wide and 10 m thick. The main chemical compositions are as follows: *t* 56 °C, pH 6.7, TDS 0.912, Na 194, K 44.8, Ca 92.06, Mg 15.89, CO_3 nd, HCO_3 870.83, SO_4 5.0, Cl 64.31, SiO_2 57.65. HCO_3–Na–Ca type of water.

Sh67, Kuyirong or **Koixi Lungba** or **Jigden** hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 20′ 24″E, 29° 16′ 36″N, Altitude: 4000 m. The temperature of vent is 67 °C and the flow rate is 5.055 L/s. No water chemistry data.

Sh68, Dagai hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 52′ 00″E, 230° 16′ 12″N, Altitude: 3110 m. The highest temperature of main vent is 58 °C discharging 0.61 L/s. The content of SiO_2 is 54.54 mg/L.

Sh69, Chonggo hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 52′ 12″E, 30° 15′ 48″N, Altitude: 3100 m. The highest temperature is 66 °C discharging 1.965 L/s. There is minor travertine. The content of SiO_2 is 13.09 mg/L.

Sh70, Yagra hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 53′ 12″E, 30° 14′ 36″N, Altitude: 3030 m. There are more than eight vents. The highest temperature is 55 °C. The area of travertine deposition is more than 1000 m^2. The content of SiO_2 is 13.09 mg/L.

Sh71, Diaohaiz hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 52′ 12″E, 30° 10′ 42″N, Altitude: 3400 m. The temperature of spring water is 48 °C, and the flow rate is 2.0 L/s. The content of SiO_2 is 56.09 mg/L.

Sh72, Jetog hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 53′ 36″E, 29° 59′ 42″N, Altitude: 3250 m. The spring site is a pool of 7 m × 5 m. The temperature is 54 °C discharging 1.5 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 6.7, TDS 0.523, Na 205, K 3.51, Ca 3.10, Mg 1.25, CO_3 12.2, HCO_3 404, SO_4 6.40, Cl 14.0, SiO_2 47.4, HCO_3–Na type of water.

Sh73, Nyalunggo Qu (Xiaoreshui) geothermal field is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 57′ 18″–57′ 48″E, 29° 57′ 00″–59′ 18″N, Altitude: 2900 ~ 304 m. The spring area is stretched along the Xianshuihe fracture belt with the NNW trending for about 2 km. There are 10 or 12 springs (Fig. 6.1). The western plate is granite, and eastern plate is marble of the Proterozoic Era. The types of geothermal manifestation include hot springs, travertine cones, and hydrothermal alteration. There is small sulfur crystal. The highest temperature of hot spring is 85 °C in Guangling (Fig. 6.2). This area discharges HCO_3–Cl–Na type water, which is sole spring water of chloride contend reached 25% in western Sichuan. The main chemical compositions are as follows: *t* 85 °C, pH 8.14, TDS 1.366, Na 387, K 48.9, Ca 29.5, Mg 18.5, CO_3 nd, HCO_3 709, SO_4 52.0, Cl 286, SiO_2 162. HCO_3–Cl–Na type of water. Since 2006, Kangsun Geothermal Company decided to exploit geothermal energy, more than 10 wells have been drilled. Deepest well drilled to over 600 m, maximum well temperature 180 °C at well top (Xu et al. 2012). Up till the present moment, the geothermal water only use for space heating and balneological purpose.

Sh74, Gyaghor hot spring is located in Tardo County of Garze Zang Autonomous Prefecture. 101° 06′ 36″E, 29° 19′ 24″N. Altitude: 3400 m. The temperature of vent is 54 °C and the flow rate is 16.96 L/s.

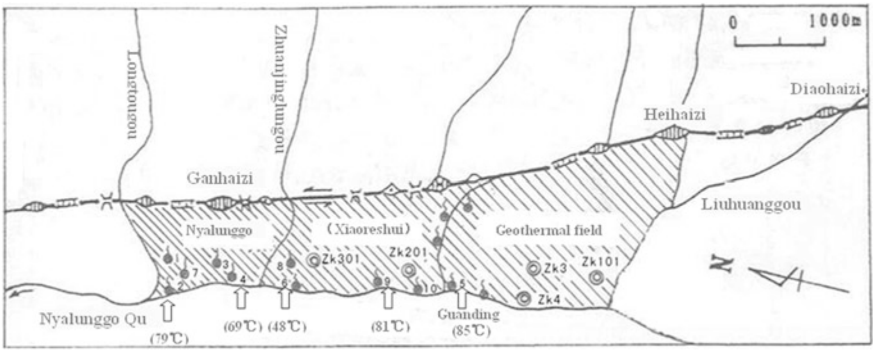

Fig. 6.1 Nyalunggo (Xiaoreshui) Geothermal field (after Xu et al. 2012)

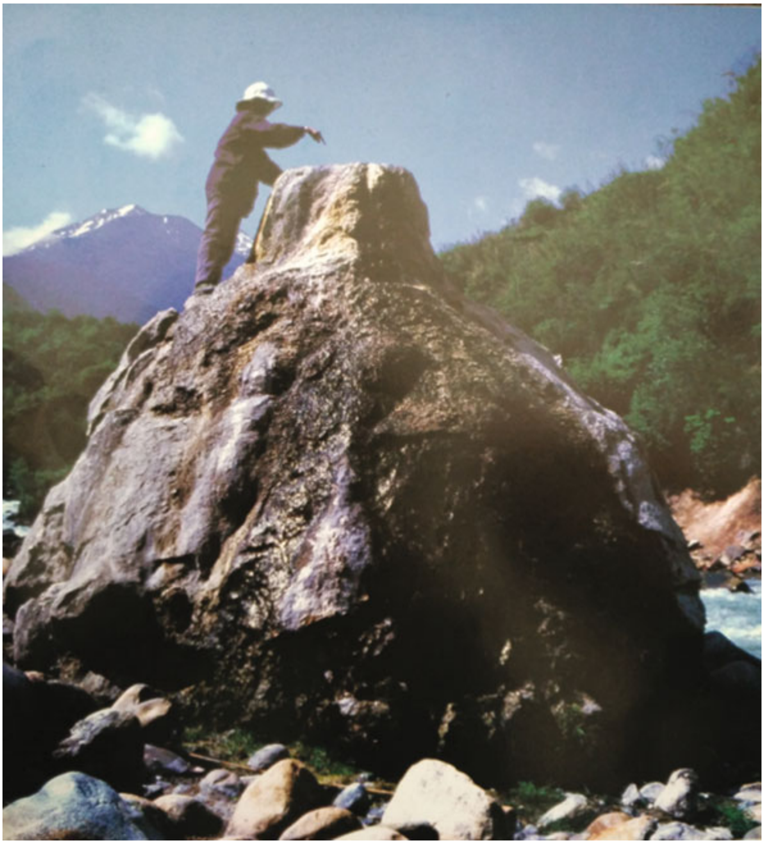

Fig. 6.2 Travertine cone in Guangling

Sh75, Moxi Reshuigou or **Hailuo Reshuigou** hot spring is located in Luding County of Garze Zang Autonomous Prefecture. 102° 01′ 30″E, 29° 35′ 00″N. Altitude: 2580 m. The maximum temperature is 72 °C and the flow rate is 48.77 L/s. The main chemical compositions are as follows: *t* 72 °C, pH na, TDS 0.288, Na 3.20, K 1.80, Ca 31.1, Mg 34.84, CO_3 nd, HCO_3 265.91, SO_4 15.0, Cl 2.87, SiO_2 64.38. HCO_3–Mg–Ca type of water.

Sh76, Shanshuping or **Baiyangping** hot spring is located in Luding County of Garze Zang Autonomous Prefecture. 102° 06′ 12″E, 29° 57′ 00″N. Altitude: 1600 m. The highest temperature is 59 °C discharging 1.335 L/s. The main chemical compositions are as follows: *t* 59 °C, pH na, TDS 0.566, Na 113, K 14.5, Ca 57.78, Mg 15.63, CO_3 nd, HCO_3 456.77, SO_4 50.0, Cl 22.87, SiO_2 62.20. HCO_3–Na type of water.

Sh77, Yinchanggou hot spring is located in Luding County of Garze Zang Autonomous Prefecture. 102° 02′E, 29° 30′N. Altitude: 2800 m. The temperature is 53 °C and the flow rate is 1.965 L/s. No water sample.

Sh78, Bindong hot spring is located in Gyaisi County of Garze Zang Autonomous Prefecture. 102° 06′ 50″E, 29° 14′ 47″N. Altitude: 2450 m. The temperature is 61 °C and the flow rate is 2 L/s. The main chemical compositions are as follows: *t* 61 °C, pH 7.1, TDS 1.795, Na 624, K 33, Ca 59.52, Mg 25.51, CO_3 nd, HCO_3 1653.56, SO_4 20.0, Cl 153.58, SiO_2 52.36. HCO_3–Na type of water.

6.2.2 *Hot Springs in Aba Zang and Qiang Nationalities Autonomous Prefecture*

Sh79, Baoyan Reshuitang is located in Barkam County of Aba Zang and Qiang Nationalities Autonomous Prefecture. 101° 43′ 30″E, 32° 13′ 36″N. Altitude: 3360 m. The temperature is 48 °C and the flow rate is 8.69 L/s. It is very famous for skin disease and arthritis treatment in Barkam County. The main chemical compositions are as follows: *t* 48 °C, pH 7.2, TDS 0.454, Na 184.25, K 10.09, Ca 11.87, Mg 0.26, CO_3 nd, HCO_3 466.65, SO_4 9.98, Cl 5.0. HCO_3–Na type of water.

Sh80, Jiangzha Reshuitang is located in Zoige County of Aba Zang and Qiang Nationalities Autonomous Prefecture. 102° 42′ 48″E, 34° 12′ 18″N, Altitude: 3260 m. It can divide into eight areas. The temperatures range from 49 to 23 °C. The total flow rate is 5 L/s. The main chemical compositions are as follows: *t* 42 °C, pH 8.04, TDS 0.664, Na 48.6, K 8.72, Ca 120, Mg 33.0, CO_3 nd, HCO_3 345, $SO_4$224, Cl 6.98, SiO_2 43.0. HCO_3–SO_4–Na type of water. Jiangzha Reshuitang is a famous thermal spring and a scenic place on border of Sichuan, Gansu and Qinghai three Provinces. The spa's water has a special curative effect for skin disease and arthritis.

Sh81, Guergou Reshuitang or **Muchenggou Reshuitang** is located in Lixian County of Aba Zang and Qiang Nationalities Autonomous Prefecture. 102° 59′ 12″ E, 31° 31′ 12″N, Altitude: 2578 m. There are three vents. Their temperatures are 60, 57, and 42 °C. The corresponding flow rate is 0.5, 0.01 and 0.01 L/s, respectively. The main chemical compositions are as follows: *t* 60 °C, pH 7.0, TDS 0.191, Na 34.2, K 1.57, Ca 9.70, Mg 1.02, CO_3 nd, HCO_3 88.9., SO_4 20.0, Cl 6.98, SiO_2 69.2. HCO_3–Na type of water.

6.2.3 *Hot Springs in Liangshan Yi Nationality Autonomous Prefecture*

Sh82, **Mairi Reshuitang is** located in Muli Zang Autonomous County of Liangshan Yi Nationality Autonomous Prefecture. 100° 34′ 40″E, 28° 42′ 15″N. Altitude: 2578 m. The highest temperature of spa could be 60 °C. The temperatures of most springs in this area are 38 or 39 °C. No water sample.

Sh83, Limin Reshuitang is located in Muli Zang Autonomous County of Liangshan Yi Nationality Autonomous Prefecture. 100° 38′E, 28° 26′N. Altitude: 2080 m. The highest temperature of the spa could be 60 °C. The bulk was inundated very easy.

Sh84, Guanji Reshuitang is located in Muli Zang Autonomous County of Liangshan Yi Nationality Autonomous Prefecture. 101° 10′ 10″E, 28° 50′ 30″N. Altitude: 2120 m. The temperature of main vent is about 60 °C.

Sh 85, Aidai hot spring **i**s located in Ganluo County of Liangshan Yi Nationality Autonomous Prefecture. 102° 47′ 48″E, 29° 01′ 00″N, Altitude: 1000 m. Country rock is dolomite of Late Proterozoic Era. The temperature is 51 °C discharging 0.5 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 8.22, TDS 0.387, Na 33.5, K 11.4, Ca 47.3, Mg 26.5, CO_3 nd, HCO_3 242., SO_4 68.1, Cl 24.4, SiO_2 19.7. HCO_3–Ca–Mg type of water.

Sh86, Xide or **Guluqiao** hot spring **i**s located in Xide County of Liangshan Yi Nationality Autonomous Prefecture. 102° 22′ 36″E, 28° 19′ 30″N. Altitude: 1787 m. The temperatures of springs are between 35 to 52 °C discharging 30 L/s. Country rock is Late Proterozoic era dolomite. The main chemical compositions are as follows: *t* 52 °C, pH 7.95, TDS 0.774, Na 67.6, K 37.1, Ca 102, Mg 52.8, CO_3 nd, HCO_3 503, SO_4 196, Cl 24.4, SiO_2 314. HCO_3–SO_4–Ca–Mg type of water.

Sh87, Huilong Reshuitang, or **Hongmo Reshuitang** or **Taoyuan Reshuihe i**s located in Xide County of Liangshan Yi Nationality Autonomous Prefecture. 102° 15′ 00″E, 28° 05′ 24″N. Altitude: 1840 m. The highest temperature of springs is 52 °C discharging 5.6 L/s. The hot water converges to form a hot water river (Reshuihe).

Sh88, Zhuhe hot spring **i**s located in Zhaojue County of Liangshan Yi Nationality Autonomous Prefecture. 102° 55′ 30″E, 28° 04′ 30″N, Altitude: 1905 m. The temperature is 50–53 °C discharging 20 L/s. In this area there is a regular swimming pool. The main chemical compositions are as follows: *t* 50 °C, pH 8.48, TDS 0.224, Na 42.5, K 4.98, Ca 15.8, Mg 4.70, CO_3 nd, HCO_3 179, SO_4 12.1, Cl 5.23, SiO_2 43.0. HCO_3–Na type of water.

Sh89, Dacaohe or **Luojishan** hot spring **i**s located in Puge County of Liangshan Yi Nationality Autonomous Prefecture. 102° 25′ 18″E, 27° 28′ 48″N. Altitude: 1800 m. The vent is located on the precipice of dolomite of Late Proterozoic era, The temperature could be more than 50 °C discharging 100 L/s. The spring water converges into river to form a fall of 5 m high. The temperature of mixed water is 31.5 °C. The main chemical compositions are as follows: *t* 31.5–50 °C, pH 8.40, TDS 0.265, Na 6.30, K 1.74, Ca 40.9, Mg 27.4, CO_3 nd, HCO_3 219, SO_4 40.0, Cl 4.53, SiO_2 22.6. HCO_3–Mg–Ca type of water.

Sh90, Lutie Reshuitang hot spring **i**s located in Ningnan County of Liangshan Yi Nationality Autonomous Prefecture. 102° 38′ 12″E, 27° 15′ 30″N. Altitude: 1300 m. The temperatures of the vents are between 53 and 60 °C discharging 80 L/s. The main chemical compositions are as follows: *t* 60 °C, pH 7.78, TDS 1.921, Na 168, K 27.7, Ca313, Mg 64.2, CO_3 nd, HCO_3 254, SO_4 1090, Cl 55.4, SiO_2 57.5. SO_4–HCO_3–Ca–Na type of water.

Sh91, Bijihe hot spring **i**s located in Ningnan County of Liangshan Yi Nationality Autonomous Prefecture. 102° 45′E, 26° 55′ 48‴N, Altitude: 900 m. The springs appear in the Biji river valley. There are 4 vents. Their temperatures are 49.8, 49.5, 51.3 and 49 °C. The total flow rate is 5 L/s. The main chemical compositions are as follows: *t* 51.3 °C, pH 8.02, TDS 1.131, Na 175, K 37.1, Ca 87.0, Mg 47.6, CO_3 nd, HCO_3 305, SO_4 560, Cl 20.0, SiO_2 48.8. SO_4–HCO_3–Na–Ca type of water.

Sh92, Hulukou hot spring **i**s located in Ningnan County of Liangshan Yi Nationality Autonomous Prefecture. 102° 53′ 00″E, 26° 58′ 24″N. Altitude: 600 m. The springs are located in a river valley. There are seven vents. Three vents were inundated. Their temperatures are 70–75 °C. The flow rate is difficult to measure. The main chemical compositions are as follows: *t* 75 °C, pH 7.74, TDS 2.079, Na 268, K 39.4, Ca 261.0, Mg 92.3, CO_3 nd, HCO_3 395, SO_4 852, Cl 302, SiO_2 53.7. SO_4–Cl–Na–Ca type of water.

Sh93, Yuzha hot spring **i**s located in Huili County of Liangshan Yi Nationality Autonomous Prefecture. 101° 56′ 00″E, 26° 20′ 30″N. Altitude: 960 m. The area is stretched along the left bank of Jinshajiang river for about 80 m. The temperatures are 52–65 °C. The main chemical compositions are as follows: *t* 52 °C, pH 7.89, TDS 0.627, Na 63.5, K 10.2, Ca 89.5, Mg 31.9, CO_3 nd, HCO_3 256, SO_4 204, Cl 34.8, SiO_2 60.4. SO_4–HCO_3–Ca–Na–Mg type of water.

Sh94, Jianbaoshan hot spring **i**s located in Huidomg County of Liangshan Yi Nationality Autonomous Prefecture. 102° 34′ 00″E, 26° 22′ 00″N. Altitude: 840 m. It is located on the sandy beach of left bank of Jinshajiang River. It emerges only in the dry season. The temperature is 48 °C discharging about 3 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 6.8, TDS 1.178, Na 84, K 55.6, Ca 231.5, Mg 76.1, CO_3 nd, HCO_3 1052.67, SO_4 32.1, Cl 149.8, SiO_2 22.37. HCO_3–Ca–Mg type of water.

Sh95, Luji Reshuitang is located in Huidong County of Liangshan Yi Nationality Autonomous Prefecture. 102° 58′ 40″E, 26° 48′ 30″N. Altitude: 680 m. The area is close to the riverbed and was usually submerged. The main vent forms a pool with diameter of 5 m. Its temperature is 50 °C discharging 2.5 L/s. The main chemical compositions are as follows: *t* 50 °C, pH 7.0, TDS 0.457, Na 41.8, K 14.9, Ca 60.9, Mg 32.5, CO_3 nd, HCO_3 297, SO_4 80.0, Cl 36.3, SiO_2 40.1. HCO_3–Ca–Mg type of water.

Sh96, Xisujiao or **Majingzi** hot spring **i**s located in Leibo County of Liangshan Yi Nationality Autonomous Prefecture. 103° 26′ 12″E, 28° 13′ 48″N. Altitude: 720 m. There are two vents. One is 43.5 °C from the talus fan, and another one is 46 °C at riverside and is used as a open-air bathing pool. The main chemical compositions are as follows: pH 7.74, TDS 1.782, Na 92.3, K 20.2, Ca 400, Mg 15.3, CO_3 nd, HCO_3 289, SO_4 1032, Cl 31.4, SiO_2 34.2. SO_4Ca-type of water.

Sh97, Huashengdi or **Qianwanguan** hot spring **i**s located in Leibo County of Liangshan Yi Nationality Autonomous Prefecture. 103° 27′ 30″E, 28° 07′ 24″N. Altitude: 500 m. The vent is close water level line of Jinshajiang River. The 58 °C hot water come out from the Cambrian limestone. The main chemical compositions are as follows: *t* 57 °C, pH 7.82, TDS 1.629, Na 231, K 33.8, Ca 250, Mg 18.3, CO_3 nd, HCO_3 308, SO_4 750, Cl 125, SiO_2 50.2. SO_4–Ca–Na type of water

Sh98, Jinjiang Reshuihe is located in Leibo County of Liangshan Yi Nationality Autonomous Prefecture. 103° 29′ 00″E, 27° 50′ 30″N. Altitude: 680 m. The temperature is 50 °C.

Sh99, Cangfang hot spring **i**s located in Leibo County of Liangshan Yi Nationality Autonomous Prefecture. 103° 13′ 30″E, 27° 37′ 00″N. Altitude: 700 m. There are many vents. The highest temperature is 46 °C. The main chemical compositions are as follows: *t* 46 °C, pH 7.59, TDS 2.430, Na 87.4, K 11.6, Ca 515, Mg 153, CO_3 nd, HCO_3 481, SO_4 1380, Cl 6.89, SiO_2 28.4. SO_4–Ca–Mg type of water.

6.2.4 Hot Springs in Panzhihua City and Some Adjacent Counties

Sh100, Yanbian hot spring is located in Yanbian County of Panzhihua City. 101° 15′ 45″E, 27° 00′ 45″N. Altitude: 1760 m. The area is 500 m long along a river, where there are 15 vents. The highest temperature is 49 °C discharging 2 L/s. The total of flow rate is 25 L/s. The main chemical compositions are as follows: *t* 49 °C, pH 7.74, TDS 2.105, Na 439, K 29.3, Ca 145, Mg 62.5, CO_3 nd, HCO_3 340., SO_4 620, Cl 581, SiO_2 43.0. Cl–SO_4–Na type of water.

Sh101, Qingmenkou hot spring is located in Panzhihua City. 101° 58′ 00″E, 26° 31′ 50″N. Altitude: 1330 m. The hot water in 46.5 °C flows out from a steel tube inserted a cement table. The flow rate is about 2.5 L/s. The main chemical compositions are as follows: *t* 46.5 °C, pH 7.2, TDS 0.760, Na 220, K 18.0, Ca 11.3, Mg 6.32, CO_3 nd, HCO_3 148, SO_4 156, Cl 160, SiO_2 67.7. Cl–SO_4–Na type of water.

Sh102, Caoke Da Reshui hot spring is located in Shimian County of Yaan Prefecture. 102° 06′ 12″E, 29° 23′ 18″N. Altitude: 1340 m. The temperature is 47 °C discharging 20 L/s. The main chemical compositions are as follows: *t* 47 °C, pH ?, TDS 0.474, Na 47, K 5.70, Ca 95.99, Mg 4.31, CO_3 nd, HCO_3 249.32, SO_4 152.20, Cl 8.28, SiO_2 34.28. HCO_3–SO_4–Ca–Na type of water.

Sh103, Tianwan Reshuitang hot spring is located in Shimian County of Yaan Prefecture. 102° 07′ 30″E, 29° 28′ 00″N. Altitude: 1690 m. The temperature is 65 °C discharging 50 L/s.

Sh104, Gongyi hot spring is located in Shimian County of Yaan Prefecture. 102° 23′ 30″E, 29° 01′ 30″N. Altitude: 2150 m. The hot water comes from the granite. The temperatures are between 58 and 40 °C. The main chemical compositions are as follows: *t* 58 °C, pH 7.5, TDS 0.409, Na 108, K 6.89, Ca 10.3, Mg 6.81, CO_3 46.5, HCO_3 35.4, SO_4 40.0, Cl 51.6, SiO_2 96.8. Cl–Na type of water.

Sh105, Jinyan or **Jiawa** hot spring is located in Ebian County of Leshan Prefecture. 103° 09′E, 29° 03′N. Altitude: 900 m. The two vents are 500 m apart. The north one is 43 °C and is located in the riverbed. The south one 59 °C and gushes out from fracture of dolomite of Late Proterozoic era. The main chemical compositions are as follows: *t* 59 °C, pH 8.12, TDS 0.827, Na 94.9, K 20.9, Ca 102, Mg 38.8, CO_3 nd, HCO_3 175, SO_4 401, Cl 31.4, SiO_2 40.1. SO_4–Ca–Na type of water.

6.3 Hot Springs in Southwestern Yunnan Province

According to the data of books *Geothermics in Tengchong* (Tong and Zhang 1989) and *Thermal Springs in Hengduan (Traverse) Mountains* (Tong and Zhang 1989), there are 265 hot springs in southwestern Yunnan Province.

6.3.1 Hot Springs in Deqen Zang Nationality Autonomous Prefecture

Yh01, Sainang hot spring is located in Deqen County of Deqen Zang Nationality Autonomous Prefecture. 98° 47′ 40″E, 28° 31′ 30″N. Altitude: 2120 m. The area is 100 m × 20 m. Many vents are dispersed over this area. The highest temperature is 70 °C. The main chemical compositions are as follows: *t* 70 °C, pH 7.5, TDS 1.354, Na 430, K 22.3, Ca 9.8, Mg 18.1, CO_3 nd, HCO_3 500, SO_4 412, Cl 92.3, SiO_2 108. HCO_3–SO_4–Na type of water.

Yh02, Xiaadong or **Quzika** hot spring is located in Deqen County of Deqen Zang Nationality Autonomous Prefecture. 98° 51′ 20″E, 28° 33′ 50″N. Altitude: 2780 m. The area is 500 m × 100 m. The main vent is 64 °C and appears at ridge of a travertine hill. The disparity of height of emerging place of hot springs reached 250 m. The main chemical compositions are as follows: *t* 64 °C, pH .7, TDS 2.893, Na 684, K 38.7, Ca 190, Mg 38.3, CO_3 nd, HCO_3 475, SO_4 1502, Cl 38.3, SiO_2 131. SO_4–Na type of water.

Yh03, Goza or **Quzideng** hot spring is located in Deqen County of Deqen Zang Nationality Autonomous Prefecture. 98° 53′ 00″E, 28° 07′ 50″N. Altitude: 2080 m. The temperature of the spring is 56 °C, and the flow rate is 2 L/s. The main chemical compositions are as follows: *t* 56 °C, pH 8.4, TDS 0.509, Na 137, K 8.08, Ca 4.52, Mg 1.01, CO_3 nd, HCO_3 303.0, SO_4 59.2, Cl 31.3, SiO_2 107. HCO_3–Na type of water.

Yh04, Bumpulung hot spring is located in Deqen County of Deqen Zang Nationality Autonomous Prefecture. 99° 03′ 40″E, 28° 40′ 00″N. Altitude: 3270 m. The area is 120 m × 100 m. The main vent can boil eggs. Its temperature could be more than 70 °C. The flow rate could be 4 L/s. Water temperature is not measured. The main chemical compositions are as follows: pH 8.20, TDS 0.841, Na 275, K 19.3, Ca 1.01, Mg 0.75, CO_3 nd, HCO_3 600.0, SO_4 59.7, Cl 31.3, SiO_2 123. HCO_3–Na type of water.

Yh05, Xilu hot spring is located in Deqen County of Deqen Zang Nationality Autonomous Prefecture. 99° 39′ 30″E, 28° 55′ 45″N. Altitude: 2280 m. The main vents were inundated. The temperature could be 50 °C.

Yh06, Liduguang hot spring is located in Deqen County of Deqen Zang Nationality Autonomous Prefecture. 99° 11′ 10″E, 27° 46′ 00″N. Altitude: 2360 m. The main vent can boil the eggs. The temperature could be more than 65 °C.

Yh07, Longdu hot spring is located in Weixi County of Deqen Zang Nationality Autonomous Prefecture. 98° 59′ 00″E, 27° 53′ 20″N. Altitude: 2360 m. The temperature of vent is 55 °C in the rainy season. But it can boil the eggs in the dry season.

Yh08, Jiangheqiao or **Baijixun** hot spring is located in Weixi County of Deqen Zang Nationality Autonomous Prefecture. 99° 06′ 10″E, 27° 21′ 10″N. Altitude: 1800 m. The temperature of main vent is 47.4 °C discharging 0.5 L/s. The main chemical compositions are as follows: *t* 47.4 °C, pH 7.75, TDS 1.794, Na 475, K 30.2, Ca 84.4, Mg 44.1, CO_3 nd, HCO_3 544.0, SO_4 501, Cl 334, SiO_2 44.1. SO_4–Cl–HCO_3–Na type of water.

Yh09, Beidian hot spring is located in Weixi County of Deqen Zang Nationality Autonomous Prefecture. 99° 15′ 12″E, 27° 50′ 50″N. Altitude: 1750 m. The main spring appears on second bottom to 55 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 7.70, TDS 2.801, Na 801, K 45.7, Ca 45.1, CO_3 nd, HCO_3 506, SO_4 658, Cl 818, SiO_2 36.1. Cl–SO_4–Na type of water.

Yh10, Tianshenqiao hot spring is located in Shangri-la County of Deqen Zang Nationality Autonomous Prefecture. 99° 49′ 00″E, 27° 50′ 00″N. Altitude: 3440 m. The main vent of 56 °C is located at slope over 30 m of surface of river water. Many vents appear on the riverside. Their temperatures are 49 °C. The total of flow rate is 5 L/s. The travertine is very magnificent sight to form a spine. The main chemical compositions are as follows: *t* 56 °C, pH 8.15, TDS 0.732, Na 172, K 13.2, Ca 1.44, Mg 3.40, CO_3 nd, HCO_3 662.0, SO_4 29.3, Cl 22.6, SiO_2 40.1. HCO_3–Na type of water.

Yh11, Gaica-caquka hot spring is located in Shangri-la County of Deqen Zang Nationality Autonomous Prefecture. 99° 50′ 00″E, 27° 58′ 30″N. Altitude: 3650 m. The area is 50 m × 10 m., where two vents are 10 m apart. Their temperatures are 60 and 59 °C. The total of flow rate is 1.3 L/s. Travertine develops. The main chemical compositions are as follows: *t* 60 °C, pH 8.20, TDS 1.007, Na 310, K 26.5, Ca 32.5, Mg 12.5, CO_3 nd, HCO_3 681, SO_4 130, Cl 57.4, SiO_2 83.0. HCO_3–Na type of water.

Yh12, Chaggar Caka or **Lamdeng** hot spring is located in Shangri-la County of Deqen Zang Nationality Autonomous Prefecture. 99° 51′ 20″E, 27° 47′ 00″N. Altitude: 3480 m. The area is 600 m × 200 m. There is a travertine hill on northwestern end of this area, where there are no any hydrothermal activities. The spas appear in the low-lying land of the bottom of travertine mass. The temperatures of the greater part of springs are 60 °C, and the highest one is 67 °C. The total flux is 10 L/s. The main chemical compositions are as follows: *t* 67 °C, pH 8.25, TDS 0.804, Na 243, K 20.9, Ca 24.3, Mg 9.01, CO_3 nd, HCO_3 640, SO_4 30.4, Cl 29.6, SiO_2 103.0. HCO_3–Na type of water.

Yh13, Zhuenreka hot spring is located in Shangri-la County of Deqen Zang Nationality Autonomous Prefecture. 100° 11′ 00″E, 27° 29′ 40″N. Altitude: 1600 m. This spring is inundated from June to October. The temperature could be more than 45 °C on the dry season.

6.3.2 *Hot Spring in Nujiang Lisu Nationality Autonomous Prefecture*

Yh14, Luodi hot spring is located in Bijiang County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 58′ 08″E, 26° 14′ 20″N. Altitude: 1960 m. The area is about 0.6 km^2. The temperature of the vent is 47.2 °C and the flow rate is 0.95–2 L/s. The main chemical compositions are as follows: *t* 47.2 °C, pH 7.95, TDS 0.627, Na 121, K 14.6, Ca 106, Mg 15.1, CO_3 nd, HCO_3 596, SO_4 11.2, Cl 10.5, SiO_2 37.4.0. HCO_3–Na–Ca type of water.

Yh15, Bailong Reshuitang is located in Lanping County of Nujiang Lisu Nationality Autonomous Prefecture. 99° 15′ 10″E, 27° 00′ 45″N. Altitude: 1750 m. It only is a big spring pool. The temperature of pool water is 57 °C. The main chemical compositions are as follows: *t* 57 °C, pH 7.85, TDS 1.298, Na 375, K 29.2, Ca 4.75, Mg 14.5, CO_3 nd, HCO_3 437, SO_4 434, Cl 134, SiO_2 77.6. SO_4–HCO_3–Na type of water.

Yh16, Chongmei hot spring is located in Lamping County of Nujiang Lisu Nationality Autonomous Prefecture. 99° 18′ 55″E, 26° 59′ 18″N. Altitude: 1900 m. The temperature of the spring is 47 °C. The main chemical compositions are as follows: *t* 47 °C, pH 7.80, TDS 1.057, Na 301, K 26.8, Ca 8.55, Mg 20.1, CO_3 nd, HCO_3 387, SO_4 305, Cl 141, SiO_2 53.5. SO_4–HCO_3–Na type of water.

Yh17, Gutanhe hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 45′ 35″E, 26° 56′ 03″N. Altitude: 1650 m. The main geothermal manifestation is a nozzle, which was built by laying stones to become a pool. The temperature of the vent is 51.5 °C discharging 0.5 L/s. The main chemical compositions are as follows: *t* 51.5 °C, pH 7.0, TDS 0.175, Na 29.6, K 1.25, Ca 1.45, Mg 0.32, CO_3 31.3, HCO_3 25.4, SO_4 12.5, Cl 2.79, SiO_2 66.9. CO_3–Na type of water.

Yh18, Dishuidong or **Dishuihe** hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 46′ 30″E, 25° 55′ 10″N. Altitude: 1380 m. The areas appear at a slope. The distance between the slope and the river is more than 10 m. There are three springs in this area along the river. The west end is a shallow spring-fed pool 5 m × 1 m. The temperature is 60–64.3 °C with minimum flow rate. The middle and east end both are 4 m square common bathing pool. Their temperatures are 52 and 54 °C. The main chemical compositions are as follows: *t* 64.3 °C, pH 7.8, TDS 0.176, Na 31.0, K 2.01, Ca 1.40, Mg 0.31, CO_3 nd, HCO_3 85.7, $SO_4$9.87, Cl 2.45, SiO_2 83.0. HCO_3–Na type of water.

Yh19, Denggeng hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 50′ 05″E, 25° 56′ 48″N. Altitude: 980 m. The area appears along the west bank of Nujiang River. There are six springs at travertine mass. Their temperatures from north to south are 49.5, 52.5, ?, 46, 34.5 and 48.5 °C. The No. 3 comes out from a cliff of travertine and is too high to measure. The main chemical compositions are as follows: *t* 52.5 °C, pH 7.0, TDS 0.446, Na 18.9, K 7.38, Ca 95.8, Mg 30.5, CO_3 nd, HCO_3 444, SO_4 25.8, Cl 3.15, SiO_2 41.4. HCO_3–Ca–Mg type of water.

Yh20, Mabu hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 50′ 15″E, 25° 53′ 10″N. Altitude: 800 m. The area is 400 m long along the Nujiang River and 100 m wide. Two springs are 200 m apart. The temperatures of north springs are from 47 to 54 °C discharging 6 L/s. The temperatures of south springs are between 55.5 and 55.8 °C discharging 7 L/s. The main chemical compositions are as follows: *t* 55.8 °C, pH 7.80, TDS 0.623, Na 98.2, K 25.2, Ca 71.0, Mg 28.0, CO_3 nd, HCO_3 457, SO_4 105, Cl 6.99, SiO_2 54.9. HCO_3–Na–Ca type of water.

Yh21, Mankouhe hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 50′ 30″E, 25° 36′ 15″N. Altitude: 1100 m. There are four vents. The highest temperature is about 65 °C.

Yh22, Baishuihe or **Duanjiazhai** or **Lubia**o hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 98° 56′ 20″E, 25° 50′ 25″N. Altitude: 1020 m. The detritus streams are of frequence occurrence in this area. This spring was buried beneath the debris flow in 1976 and was buried beneath 30 m by three times mud flows in 1981. The temperature of spring was 50 °C.

Yh23, Zhongyuan hot spring is located in Lushui County of Nujiang Lisu Nationality Autonomous Prefecture. 99° 05′ 00″E, 25° 52′ 10″N. Altitude: 2020 m. There are two bathing pools (one bigger and one small) in this area. The big one is 6 m × 3.5 m and depth 1.8 m, the water's depth is only 0.3 m and the temperature is 46.5 °C discharging 0.5 L/s. The small one is 2 m × 3 m and water's depth 0.2 m. Its temperature is 39 °C discharging 0.8 L/s. The main chemical compositions are as follows: *t* 46.5 °C, pH 8.10, TDS 0.760, Na 259, K 17.7, Ca 15.1, Mg 2.25, CO_3 nd, HCO_3 635, SO_4 41.2, Cl 10.5, SiO_2 88.4. HCO_3–Na type of water.

6.3.3 Hot Springs in Dehong Dai and Jingpo Nationality Autonomous Prefecture

Yh24, Tenglagong hot spring is located in Yingjiang County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 46′ 48″E, 25° 00′ 00″N. Altitude: 1210 m. The spring water comes out from the alluvium in riverbed. The area is 300 m^2. The temperature is 62 °C discharging 1.5 L/s. The main chemical compositions are as follows: *t* 62 °C, pH 7.5, TDS 1.147, Na 394, K 23.8, Ca 33.9, Mg 6.03, CO_3 nd, HCO_3 908, SO_4 130, Cl 30.6, SiO_2 67.4. HCO_3–Na type of water.

Yh25, Taiping hot spring is located in Yingjiang County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 50′ 30″E, 24° 39′ 50″N. Altitude: 810 m. The area is 400 m^2. The highest temperature of spa is 58 °C. There are the hot marsh in wide area. Total flux is 30 L/s. The main chemical compositions are as follows: *t* 58 °C, pH 9.6, TDS 0.224, Na 67, K 1.3, Ca 1.72, Mg 0.09, CO_3 27, HCO_3 62, SO_4 13.2, Cl 1.74, SiO_2 74.7. HCO_3–Na type of water.

Yh26, Nanhuan hot spring is located in Yingjiang County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 55′ 00″E, 24° 37′ 12″N. Altitude: 835 m. It appears on an alluvial talus, where there are many hot springs and warm springs. The highest temperature is 49.5 °C discharging 10 L/s. The main chemical compositions are as follows: *t* 49.5 °C, pH 7.0, TDS 0.195, Na 36.5, K 1.6, Ca 4.57, Mg 0.86, CO_3 nd, HCO_3 93, SO_4 24.7, Cl 10.4, SiO_2 63.0. HCO_3–Na type of water.

Yh27, Luositang hot spring is located in Yingjiang County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 08′ 00″E, 25° 13′ 30″N. Altitude: 1320 m. The hot water rushed out from slope materials. The temperature is 56 °C and the flow rate is 4 L/s. The main chemical compositions are as follows: *t* 56 °C, pH 7.5, TDS 0.836, Na 127, K 21.5, Ca 161, Mg 12.4, CO_3 nd, HCO_3 753, SO_4 59.9, Cl 31.3, SiO_2 42.1. HCO_3–Ca–Na type of water.

Yh28, Langwaihe hot spring is located in Yingjiang County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 09′ 30″E, 24° 54′ 30″N. Altitude: 1050 m. The fountain rushed out from deluvial materials. The temperature is 79.5 °C discharging 2.3 L/s. The main chemical compositions are as follows: *t* 79.5 °C, pH 7.5, TDS 0.334, Na 97, K 4.2, Ca 2.14, Mg 0.15, CO_3 nd, HCO_3 161, SO_4 32.3, Cl 2.78, SiO_2 97.2. HCO_3–Na type of water.

Yh29, Mangke hot spring is located in Yingjiang County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 09′ 30″E, 24° 54′ 30″N. Altitude: 1050 m. The hot water was pouring out from slope and deluvial materials. The area is about 50 m^2. The highest temperature is 82 °C discharging 8 L/s. The main chemical compositions are as follows: *t* 82 °C, pH 8.1, TDS 0.398, Na 123, K 5.0, Ca 6.25, Mg 0.41, CO_3 nd, HCO_3 191, SO_4 24.7, Cl 12.2, SiO_2 113. HCO_3–Na type of water.

Yh30, Longxian Manbeng hot spring is located in Longchuan County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 43′ 48″E, 24° 20′ 12″N. Altitude: 1420 m. The area is 60 m^2. The maximum temperature is 64.5 °C. Total flux is 1.5 L/s. The main chemical compositions are as follows: *t* 64.5 °C, pH 9.7, TDS 0.288, Na 70, K 2.0, Ca 2.68, Mg 0.07, CO_3 42, HCO_3 22, SO_4 22.3, Cl 10.4, SiO_2 66.9. CO_3–Na type of water.

Yh31, Xima hot spring is located in Longchuan County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 43′ 48″E, 24° 20′ 12″N. Altitude: 1420 m. The hot water flows out from slope deposits. The temperature is 49 °C discharging 4 L/s. The main chemical compositions are as follows: *t* 49 °C, pH 9.7, TDS 0.219, Na 54, K 0.9, Ca 1.14, Mg 0.07, CO_3 12, HCO_3 22, SO_4 22.3, Cl 10.4, SiO_2 66.9. CO_3–Na type of water.

Yh32, Guangling hot spring is located in Longchuan County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 59′ 36″E, 24° 26′ 42″N. Altitude: 980 m. The hot water rushes out from granitic slope materials. The maximum temperature is 70.5 °C. Total flux is 70 L/s. The main chemical compositions are as follows: *t* 70.5 °C, pH 8.0, TDS 0.247, Na 64.6, K 2.4, Ca 2.43, Mg 0.06, CO_3 nd, HCO_3 124, SO_4 17.2, Cl 0.695, SiO_2 87.5. HCO_3–Na type of water.

Yh33, Sading hot spring is located in Longchuan County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 58′ 48″E, 24° 19′ 30″N. Altitude: 980 m. The hot water came out from Neogene system. The highest temperature is 45.8 °C discharging 0.2 L/s. The main chemical compositions are as follows: *t* 45.8 °C, pH 7.4, TDS 0.334, Na 97, K 2.5, Ca 4.57, Mg 0.20, CO_3 nd, HCO_3 68, SO_4 119, Cl 7.68, SiO_2 64.3. SO_4–HCO_3–Na type of water.

Yh34, **Bengnie** hot spring is located in Longchuan County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 97° 59′ 30″E, 24° 18′ 54″N. Altitude: 1040 m. The hot water came out from Neogene system. The temperature is 55.5 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 55.5 °C, pH 9.4, TDS 0.287, Na 82.6, K 2.0, Ca 3.14, Mg 0.11, CO_3 18, HCO_3 37, SO_4 85.5, Cl 5.56, SiO_2 68.2. SO_4–Na type of water.

Yh35, Pendu hot spring is located in Longchuan County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 15′ 56″E, 24° 29′ 30″N. Altitude: 1040 m. The main spring is located in artificial pool 8 m × 3 m. The hot water came out from gneissic granite. The temperature is 47 °C discharging 5 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 9.3, TDS 0.154, Na 41, K 0.7, Ca 1.90, Mg 0.16, CO_3 18, HCO_3 62, SO_4 7.80, Cl 0.75, SiO_2 51.3. HCO_3–CO_3–Na type of water.

Yh36, Baweijie hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 09′ 05″E, 24° 35′ 40″N. Altitude: 1010 m. This spring appears in riverbed in the dry season and disappeared in the rainy season. Taking a bath needs in the spring, people need to add cold water. The temperature is estimated to be 60 °C.

Yh37, Gailing hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 12′ 31″E, 24° 31′ 40″N. Altitude: 920 m. There are two vents. The temperature is 47 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 9.3, TDS 0.226, Na 67, K 0.9, Ca 3.04, Mg 0.36, CO_3 15, HCO_3 102, SO_4 13.3, Cl 13.9, SiO_2 56.5. HCO_3–Na type of water.

Yh38, Nameng hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 15′ 30″E, 24° 40′ 20″N. Altitude: 1035 m. The spring appears in the flood land. The temperature is 50.5 °C discharging 2–3 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.7, TDS 0.182, Na 51.4, K 0.5, Ca 1.54, Mg 0.07, CO_3 33, HCO_3 43. SO_4 5.72, Cl 5.61, SiO_2 56.5. HCO_3–CO_3–Na type of water.

Yh39, Manlong hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 18′ 00″E, 24° 49′ 40″N. Altitude: 1040 m. The hot water comes out from the sandy gravel. The highest temperature is 48 °C. The main chemical compositions are as follows: *t* 48 °C, pH 7.7, TDS 0.835, Na 265, K 17.2, Ca 21.4, Mg 4.76, CO_3 nd, HCO_3 633, SO_4 101, Cl 27.1, SiO_2 73.4. HCO_3–Na type of water.

Yh40, Mengyang Xiaotang hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 17′ 25″E, 24° 35′ 35″N. Altitude: 900 m. There are two springs. One is a hot marsh 20 m ×30 m. The temperature of spa in the center of this area is 53 °C. Another is a pool. The temperature is 52.5 °C discharging 2 L/s. In the dry season, The salt effloresce is all over the area, Thus this place gave a name to Xiaotang (salina). The livestock like to come here to tick the salt. The main chemical compositions are as follows: *t* 53 °C, pH 7.8, TDS 0.206, Na 46.5, K 1.1, Ca 3.46, Mg 0.80, CO_3 nd, HCO_3 151, $SO_4$16.7, Cl 1.04, SiO_2 53.9. HCO_3–Na type of water.

Yh41, Diyang hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 18′ 30″E, 24° 35′ 30″N. Altitude: 880 m. There are two pools 700 m apart. The bigger one is located on the granite mass 10 m ×20 m. Many spas flow out from the fracture. The temperature are between 67 and 71 °C discharging 6 L/s. The smaller pool also has many spas. The highest temperature is 67.5 °C discharging 2–3 L/s. The main chemical compositions are as follows: *t* 71 °C, pH 8, TDS 0.256, Na 67.0, K 1.3, Ca 1.67, Mg 0.18, CO_3 30, HCO_3 68, SO_4 32.3, Cl 1.04, SiO_2 77.7. HCO_3–CO_3–Na type of water.

Yh42, Longlinba hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 18′ 35″E, 24° 35′ 25″N. Altitude: 880 m. The hot water gushed out from the fracture in granite. Its temperature is 47 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.5, TDS 0.160, Na 42.7, K 0.7, Ca 2.14, Mg 0.19, CO_3 nd, HCO_3 108, SO_4 11.4, Cl 1.52, SiO_2 43.4. HCO_3–Na type of water.

Yh43, **Bingcai** hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationality Autonomous Prefecture. 98° 19′ 40″E, 24° 51′ 50″N. Altitude: 930 m. There are three hot pools in an area of 500 m × 80 m. The two pools are of circular shape with diameter to be 1 m and 1.5 m. another one is in the rectangular shape of 1 m × 2 m. The highest temperature is 89 °C. The main chemical compositions are as follows: *t* 89 °C, pH 7.9, TDS 0.886, Na 305, K 17.8, Ca 13.8, Mg 3.56, CO_3 nd, HCO_3 673, SO_4 77, Cl 34.7, SiO_2 87.5. HCO_3–Na type of water.

Yh44, Mengban Xianrenzaotang hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 31′ 35″E, 24° 50′ 40″N. Altitude: 1440 m. The hot water is gushed out from the fracture of gneissic granite. The temperature is 48 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 9.6, TDS 0.247, Na 62, K.1.0, Ca 1.67, Mg 0.10, CO_3 36, HCO_3 56, SO_4 9.52, Cl 1.74, SiO_2 96.8. CO_3–HCO_3–Na type of water.

Yh45, Dapingshan hot spring is located in Lianghe County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 31′ 35″E, 24° 50′ 15″N. Altitude: 1500 m. The hot water is gushed out from the joints in gneissic granite. There are three main vents in 1 m × 5.5 m area.. Their temperatures are 53, 51 and 45 °C. Total flux is 1.2 L/s. The main chemical compositions are as follows: *t* 53 °C, pH 7.5, TDS 0.204, Na 54, K 0.8, Ca 1.78, Mg 0.12, CO_3 24, HCO_3 65., SO_4 13.3, Cl 1.04, SiO_2 68.2. HCO_3–CO_3–Na type of water.

Yh46, Pailu Hot lake is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 09′ 25″E, 24° 10′ 50″N. Altitude: 784 m. It is a lunate lake 100 m in length. Both the northeast and the northwest ends of hot lake appear hot marsh, where is overgrown with reeds, but numerous spring eyes send up bubbles and the sands rolled. The highest temperature of vent is 54 °C.

Averagely 50 °C. Total flux is 10 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 7.6, TDS 0.297, Na 3.5, K 1.4, Ca 64.3, Mg 25.6, CO_3 nd, HCO_3 309, SO_4 11.4, Cl 1.04, SiO_2 31.7. HCO_3–Ca–Mg type of water.

Yh47, Hemeng hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 16′ 35″E, 24° 16′ 10″N. Altitude: 800 m. The area is 3 km long in south-north direction and 0.5 km wide in east-west direction, where was a large number hot marsh, hot lake and springs before 1961. The local peasants excavated ditch to drain off water and remained more than 20 hot lakes in 1961. The temperatures are from 50 to 70 °C. The highest one is 77 °C. Total flux is 50–70 L/s. The main chemical compositions are as follows: *t* 77 °C, pH 7.5, TDS 0.438, Na 28.2, K.9.7, Ca 84, Mg 20.4, CO_3 nd, HCO_3 426, SO_4 22.8, Cl 1.74, SiO_2 54.9. HCO_3–Ca type of water.

Yh48, Batuo hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 17′ 35″E, 24° 17′ 50″N. Altitude: 810 m. The main vent appears at west end of oval shaped hot pool 7 m × 6 m. A great quality of bubble with hot water gushed out. The temperature of water is 55 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 7.1, TDS 0.850, Na 97.5, K 21.0, Ca 82.2, Mg 30.9, CO_3 nd, HCO_3 667, SO_4 23.8, Cl 6.95, SiO_2 47.4. HCO_3–Na–Ca type of water.

Yh49, Langa hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 19′ 30″E, 24° 31′ 20″N. Altitude: 1060 m. The area is located in an incised valley 1000 m long. The temperature of hot water is 48.5 °C discharging 2–4 L/s. The main chemical compositions are as follows: *t* 48.5 °C, pH 7.9, TDS 0.163, Na 44.5, K 0.6, Ca 3.04, Mg 0.24, CO_3 nd, HCO_3 102, SO_4 13.3, Cl 1.74, SiO_2 43.4. HCO_3–Na type of water.

Yh50, Hongfa hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 22′ 05″E, 24° 26′ 30″N. Altitude: 960 m. The area is located on the stream terrace, where there are two open baths 700 m apart. Their temperature is 50 and 48.5 °C. The main chemical compositions are as follows: *t* 50 °C, pH 7.5, TDS 0.179, Na 49.5, K 0.6, Ca 2.26, Mg 0.13, CO_3 12, HCO_3 90, SO_4 7.62, Cl 1.39, SiO_2 56.5. HCO_3–Na type of water.

Yh51, Liuhuangchang hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 26′ 30″E, 24° 27′ 10″N. Altitude: 920 m. The area was a rabbet mining sulfur 200 m × 400 m. The temperature of spring water is 52 °C discharging 40 L/s. The main chemical compositions are as follows: *t* 52 °C, pH 7.8, TDS 1.216, Na 338, K 65, Ca 54.1, Mg 20.4, CO_3 nd, HCO_3 1034, SO_4 105.6, Cl 31.3, SiO_2 63.1. HCO_3–Na type of water.

Yh52, Manniu hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 32′ 00″E, 21′ 40″N. Altitude: 880 m. The area is 30 m × 30 m, where there are two common bathing pools showing calabash in shape. The temperatures are 57 and 58 °C. The total flux is 4 L/s. The main chemical compositions are as follows: *t* 58 °C, pH 7.7, TDS 0.292, Na 10.2, K 5.2, Ca 69.7, Mg 11.9, CO_3 nd, HCO_3 256, SO_4 15.2, Cl 1.39, SiO_2 46. HCO_3–Na type of water.

Yh53, Fapamanbang hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 33′ 25″E, 24° 22′ 30″N. Altitude: 890 m. The area is 200 m × 500 m. There is a common bathing pool. The temperature of the vent is 48.5 °C discharging 20 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 7.6, TDS 0.302, Na 2.2, K 1.7, Ca 66.1, Mg 28.7, CO_3 nd, HCO_3 321, SO_4 22.8, Cl 1.74, SiO_2 16.8. HCO_3–Ca–Mg type of water.

Yh54, Longjing hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 33′ 15″E, 24° 18′ 10″N. Altitude: 1095 m. The area is 100 m × 20 m. There are three contiguous common bathing pools. The temperature is from 40 to 48.5 °C. The total flux is 8 L/s. The main chemical compositions are as follows: *t* 48.5 °C, pH 7.8, TDS 0.223, Na 0.8, K 0.6, Ca 44.7, Mg 24.9, CO_3 nd, HCO_3 238, SO_4 20, Cl 0.45, SiO_2 11.0. HCO_3–Ca–Mg type of water..

Yh55, Mangshi Xiaowa hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 41′ 05″E, 24° 31′ 10″N. Altitude: 1120 m. There are three areas within the limits of 1.5 km along a rivulet. Their temperatures from east to west are 67, 33 and 49 °C. The total flux is 5 L/s. The main chemical compositions are as follows: *t* 67 °C, pH 7.5, TDS 0.276, Na 81, K 2.9, Ca 2.77, Mg 0.10, CO_3 18, HCO_3 68, SO_4 24.3, Cl 5.56, SiO_2 87.7. HCO_3–Na type of water.

Yh56, Yunmem hot spring is located in Luxi County of Dehong Dai and Jingpo Nationalities Autonomous Prefecture. 98° 27′ 35″E, 24° 23′ 35″N. Altitude: 960 m. The spa was inundated when we visited. The temperature is estimated to be 50 °C.

6.3.4 Hot Springs in Baoshan City

Yh57, Heinitang hot spring is located in Tengchong County of Baoshan City. 98° 08′ 10″E, 25° 21′ 00″N. Altitude: 1790 m. Then geothermal manifestations include hot springs, hot marsh and travertine cones in the area of 150 m× 70 m. There are more than 10 vents forming 3 groups. The temperatures all are more than 60 °C, The highest one is 66 °C. The total flux is 10 L/s. There are 10 travertine cones on the terrace. The main chemical compositions are as follows: *t* 65.5 °C, pH 7.0, TDS 0.886, Na 190, K 24, Ca 122, Mg 8.03, CO_3 0, HCO_3 744, SO_4 1, Cl 64, SiO_2 90. HCO_3–Na–Ca type of water.

Yh58, Danza hot spring is located in Tengchong County of Baoshan City. 98° 15′ 30″E, 25° 28′ 00″N. Altitude: 1880 m. There are six springs. Their temperatures are 53.2, 52.5, 49, 47.5, 42 and 32 °C. The total flux is 16.88 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 7.5, TDS 0.282, Na 63, K 2.0, Ca 2.43, Mg 0.01, CO_3 28, HCO_3 72, SO_4 4.0, Cl 2.0, SiO_2 83. HCO_3–Na type of water.

Yh59, Shihuadong hot spring is located in Tengchong County of Baoshan City. 98° 16′ 00″E, 25° 25′ 00″N. Altitude: 1900 m. The main manifestations are four hot springs, magnificent travertine terrace 8 m high. The vents appear at base of terrace.

Their temperatures are 69.5, 69, 67 and 66.5 °C. The main chemical compositions are as follows: *t* 65 °C, pH 7.7, TDS 0.330, Na 85, K 4.0, Ca 12.9, Mg 0.03, CO_3 0, HCO_3 194, SO_4 10, Cl 7.0, SiO_2 95. HCO_3–Na type of water.

Yh60, Mengbang hot spring is located in Tengchong County of Baoshan City. 98° 18′ 20″E, 25° 59′ 50″N. Altitude: 1620 m. The main vent is a hot pool with enclosing wall. The diameter of pool is about 7 m. The highest temperature is 66 °C discharging 1.2 L/s. The main chemical compositions are as follows: *t* 63 °C, pH 7.9, TDS 0.406, Na 123, K 5.5, Ca 12.5, Mg 0.53, CO_3 0, HCO_3 173, SO_4 62.3, Cl 5.61, SiO_2 91.6. HCO_3–Na type of water.

Yh61, Qianmaqin hot spring is located in Tengchong County of Baoshan City. 98° 21′ 00″E, 25° 08′ 10″N. Altitude: 1540 m. There are two springs. One area is 25 m × 25 m and encloses more than 10 spas. The highest temperature is 79 °C discharging 1 L/s. Another area is 30 m × 20 m and the temperature of main vent is 76 °C discharging 15 L/s. The main chemical compositions are as follows: *t* 76 °C, pH 6.5, TDS 0.288, Na 75, K 2.0, Ca 2.14, Mg 0.01, CO_3 31, HCO_3 91, SO_4 41.0, Cl 5.0, SiO_2 93. HCO_3–Na type of water.

Yh62, Qimucun hot spring is located in Tengchong County of Baoshan City. 98° 20′ 00″E, 24° 57′ 00″N. Altitude: 1300 m. The area in paddy field is 250 m × 100 m. The temperature is 67 °C discharging 3.5 L/s. The water give off stinking smell. The main chemical compositions are as follows: *t* 67 °C, pH 7.5, TDS 0.575, Na 161, K 7.6, Ca 25, Mg 0.30, CO_3 0, HCO_3 265, SO_4 118.0, Cl 11.1, SiO_2 107. HCO_3–SO_4–Na type of water.

Yh63, Xiaodian hot spring is located in Tengchong County of Baoshan City. 98° 23′ 50″E, 25° 21′ 20″N. Altitude: 1880 m. The spring water comes out from the fracture of the granite. There are two vents, their temperatures are 46 and 42.5 °C. The flow rate is 1 L/s. Three cold spas 11.5 °C emerged nearby. The main chemical compositions are as follows: *t* 46 °C, pH 8.3, TDS 0.158, Na 42, K 1.0, Ca 3.43, Mg 0.06, CO_3 0, HCO_3 78, SO_4 8.0, Cl 2.0, SiO_2 50. HCO_3–Na type of water.

Yh64, Shanghoudian hot spring is located in Tengchong County of Baoshan City. 98° 24′ 00″E, 25° 24′ 00″N. Altitude: 1880 m. There are two springs emerging on the right bank of a brooklet. The temperatures of main vents are 56 °C and 41.5 °C. The total flux is 1.7 Ls. The main chemical compositions are as follows: *t* 56 °C, pH 9.0, TDS 0.227, Na 51.2, K 1.3, Ca 3.29, Mg 0.11, CO_3 10, HCO_3 82, SO_4 21.8, Cl 3.47, SiO_2 79.9. HCO_3–Na type of water.

Yh65, Beidong hot spring is located in Tengchong County of Baoshan City. 98° 24′ 20″E, 25° 07′ 00″N. Altitude: 1740 m. There are two springs on the mountain slope, Their difference of elevation is about 30 m apart. The temperatures are 59–61 °C discharging 0.7 L/s. The main chemical compositions are as follows: *t* 61 °C, pH 8.0, TDS 0.324, Na 100, K 2.0, Ca 7.86, Mg 0.21, CO_3 0, HCO_3 209, SO_4 11.0, Cl 7.0, SiO_2 75.0. HCO_3–Na type of water..

Yh66, Ruidian Geothermal Field is located in Tengchong County of Baoshan City. 98° 27′ 30″E, 25° 26′ 30″N. Altitude: 1700 m. The field stretches for 1.3 km from NNW to SSE trend. There are following six areas: Men's Bath (78 °C, 3.5 L/s); Women's bath (87 °C, 4.63 L/s); 105 Bath (90.2 °C, 2 L/s); 23 Highway maintenance squad (56 °C, 0.3 L/s); Dazhuyuan (78.2 °C, 1.5 L/s); and Shapojiao

(81 °C, 3.12 L/s). The main chemical compositions of 105 Bath are as follows: *t* 86.5 °C, pH 7.7, TDS 1.273, Na 400, K 42, Ca 23.6, Mg 3.57, CO_3 0, HCO_3 912, SO_4 16, Cl 157, SiO_2 148. HCO_3–Na type of water.

Yh67, Suqing hot spring is located in Tengchong County of Baoshan City. 98° 28′ 00″E, 24° 40′ 40″N. Altitude: 960 m. The area is 25 m × 10 m. The spring water wells up from the fractures of gneiss. Its temperature is 49.5 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 47.5 °C, pH 7.5, TDS 0.829, Na 300, K 17.2, Ca 20.5, Mg 3.39, CO_3 0, HCO_3 750, SO_4 4.32, Cl 31.6, SiO_2 64.3. HCO_3–Na type of water..

Yh68, Heishihe hot spring is located in Tengchong County of Baoshan City. 98° 29′ 00″E, 24° 42′ 00″N. Altitude: 1060 m. The area is 30 m × 25 m. The spring water wells up from the hole of gneiss. Its temperature is 77.5 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 77.5 °C, pH 7.1, TDS 0.911, Na 290, K 21, Ca 19.9, Mg 3.04, CO_3 0, HCO_3 719, SO_4 21, Cl 59, SiO_2 115. HCO_3–Na type of water.

Yh69, Bazhu hot spring is located in Tengchong County of Baoshan City. 98° 31′ 40″E, 24° 42′ 00″N. Altitude: 1240 m. There are two vents from the fracture of diorite. They are 200 m apart. One is 50 °C discharging 0.1 L/s and another is 48 °C discharging 0.4 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 7.2, TDS 0.201, Na 47, K 1.0, Ca 6.0, Mg 0.66, CO_3 0, HCO_3 112, SO_4 10, Cl 5.0, SiO_2 70.0. HCO_3–Na type of water.

Yh70, Shangbangnai hot spring is located in Tengchong County of Baoshan City. 98° 33′ 20″E, 24° 43′ 50″N. Altitude: 1400 m. There are two vents. The north vent is 49.5 °C discharging 1.4 L/s; and the south vent is 42 °C discharging 1 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 49.5 °C, pH 7.5, TDS 0.182, Na 44, K 1.0, Ca 1.72, Mg <0.01, CO_3 37, HCO_3 63, SO_4 13, Cl 4.0, SiO_2 46.0. HCO_3–Na type of water.

Yh71, Hubang hot spring is located in Tengchong County of Baoshan City. 98° 35′ 20″E, 24° 44′ 00″N. Altitude: 1350 m. The area is located in farmland. There are four vents. The temperatures are 51–53 °C discharging 2.6 L/s. The main chemical compositions are as follows: *t* 53 °C, pH 7.5, TDS 0.262, Na 62, K 1.0, Ca 1.14, Mg 0.09, CO_3 55, HCO_3 75, SO_4 10, Cl 4.0, SiO_2 83.0. CO_3–HCO_3–Na type of water.

Yh72, Datang hot spring is located in Tengchong County of Baoshan City. 98° 40′ 00″E, 25° 38′ 00″N. Altitude: 1740 m. There are three areas: Dongjiazhai is 54 °C discharging 1.5 L/s. Zhongzhai is 75 °C discharging 6.75 L/s and Zhuanshan bath is 46 °C discharging 2.18 L/s. The main chemical compositions are as follows: *t* 75 °C, pH 7.4, TDS 0.763, Na 42, K 6.0, Ca 55.6, Mg 10.6, CO_3 0, HCO_3 331, SO_4 45, Cl 4.0, SiO_2 32.0. HCO_3–Ca–Na type of water.

Yh73, Shiqiang hot spring is located in Tengchong County of Baoshan City. 98° 38′ 00″E, 25° 21′ 40″N. Altitude: 1510 m. The area is 1.5 km × 0.6 km. There are numerous spring mouths. The highest temperature of main vent is 68 °C. The total flux is 8 L/s. Country rock is limestone. The mushroom-shaped travertine mass very developed. The main chemical compositions are as follows: *t* 68 °C, pH 7.3, TDS 1.495, Na 470, K 65.0, Ca 40.4, Mg 10.9, CO_3 0, HCO_3 1543, SO_4 10.9, Cl 40.4, SiO_2 52.0. HCO_3–Na type of water.

Yh74, Yongan hot spring is located in Tengchong County of Baoshan City. 98° 37′ 30″E, 25° 18′ 50″N. Altitude: 1490 m. The area is 100 m × 50 m, where there are two vents. One is 52 °C and another is 42 °C. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 52 °C, pH 7.1, TDS 1.438, Na 500, K 42, Ca 13.6, Mg 16.6, CO_3 0, HCO_3 1518, SO_4 < 1, Cl 36, SiO_2 50.0. HCO_3–Na type of water.

Yh75, Mayuwo hot spring is located in Tengchong County of Baoshan City. 98° 34′ 30″E, 25° 04′ 30″N. Altitude: 1685 m. The south bath and the north bath are 50 m apart. The temperature is 55 °C and the flow rate is 2 L/s. A wide expanse of hot marsh closed north bath. The main chemical compositions are as follows: *t* 55 °C, pH 6.5, TDS 0.183, Na 42, K < 1.0, Ca 1.72, Mg 0.03, CO_3 37, HCO_3 69, SO_4 10, Cl 2.0, SiO_2 50.0. CO_3–HCO_3–Na type of water.

Yh76, **Cuanlong** hot spring is located in Tengchong County of Baoshan City. 98° 43′ 50″E, 25° 01′ 40″N. Altitude: 1820 m. There are four main vents, three of which were enclosed as common bathing pools. The temperatures are 47–50 °C and the flow rates are 2.7 L/s. Country rock is gneiss. The main chemical compositions are as follows: *t* 49 °C, pH 7.0, TDS 0.193, Na 45.3, K 0.9, Ca 2.0, Mg 0.12, CO_3 12, HCO_3 80, SO_4 21.2, Cl 1.39, SiO_2 63.0. HCO_3–Na type of water.

Yh77, Banghong hot spring is located in Longling County of Baoshan City. 98° 35′ 00″E, 24° 37′ 00″N. Altitude: 1080 m. The temperature is 50 °C and the flow rate is 3 L/s. Country rock is migmatite. It emerges in the dry season. The main chemical compositions are as follows: *t* 50 °C, pH 7.0, TDS 0.354, Na 100, K 4.9, Ca 14.5, Mg 1.33, CO_3 nd, HCO_3 216, SO_4 30, Cl 5.61, SiO_2 73.4. HCO_3–Na type of water.

Yh78, Bachawa hot spring is located in Longling County of Baoshan City. 98° 36′ 00″E, 24° 37′ 00″N. Altitude: 1040 m. The temperature is 65 °C and the flow rate is 0.2 L/s. Country rock is migmatite. The main chemical compositions are as follows: *t* 65 °C, pH 7.6, TDS 0.686, Na 204, K 14.3, Ca 15.9, Mg 1.69, CO_3 nd, HCO_3 531, SO_4 52.1, Cl 12.6, SiO_2 92.9. HCO_3–Na type of water.

Yh79, Bangbie hot spring is located in Longling County of Baoshan City. 98° 40′ 40″E, 24° 43′ 00″N. Altitude: 1280 m. The main vent is a pool of 4 m × 3 m and 0.3 m depth. The temperature is 48.5 °C and the flow rate is 0.2 L/s. The main chemical compositions are as follows: *t* 48.5 °C, pH 7.0, TDS 0.757, Na 198, K 17.8, Ca 8.23, Mg 14.7, CO_3 12, HCO_3 574, SO_4 39.5, Cl 3.47, SiO_2 107. HCO_3–Na type of water.

Yh80, Sanguan or **Wazidi** hot spring is located in Longling County of Baoshan City. 98° 42′ 00″E, 24° 32′ 00″N. Altitude: 1320 m. The area is 22 m long with NE trend, where there are four vents. The temperature is 62 °C and the total flux is 4.5 L/s. The main chemical compositions are as follows: *t* 62 °C, pH 7.0, TDS 0.238, Na 58, K 14.3, Ca 3.18, Mg 0.22, CO_3 24, HCO_3 52, SO_4 36.1, Cl 5.16, SiO_2 76.1. HCO_3–Na type of water.

Yh81, Zhanshuihe or **Laohubang** hot spring is located in Longling County of Baoshan City. 98° 43′ 10″E, 24° 39′ 35″N. Altitude: 1480 m. The area is 40 m × 30 m. The temperature is 59 °C and the flow rate is 2.5 L/s. Country rock is the Cambrian migmatite. The main chemical compositions are as follows: *t* 58 °C, pH 7.5, TDS 0.548, Na 97.5, K 8.5, Ca 65.2, Mg 10.7, CO_3 nd, HCO_3 380, SO_4 91.3, Cl 6.95, SiO_2 63.1. HCO_3–Na–Ca type of water.

Yh82, Xiaolantian or **Baijiazhai** hot spring is located in Longling County of Baoshan City. 98° 44′ 20″E, 24° 39′ 35″N. Altitude: 1580 m. The area is close to the north bank of a rivulet. The greater part of area was inundated. The temperature is 66.5 °C and the flow rate is 2 L/s. Before Longling earthquake in 1976, this spring was only 30 °C, but the temperature of the spring was going up to 70 °C after 1976 shock. The main chemical compositions are as follows: *t* 66.5 °C, pH 7.5, TDS 0.337, Na 90, K 2.7, Ca 3.73, Mg 0.07, CO_3 nd, HCO_3 179, SO_4 49.5, Cl 8.68, SiO_2 82.6. HCO_3–Na type of water.

Yh83, Dazhulin or **Gaotouzhai** hot spring is located in Longling County of Baoshan City. 98° 45′ 00″E, 24° 39′ 35″N. Altitude: 1640 m. The highest temperature is 62 °C. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 62 °C, pH 7.5, TDS 0.290, Na 70, K 1.9, Ca 3.46, Mg 0.29, CO_3 nd, HCO_3 139, SO_4 55.2, Cl 1.74, SiO_2 76.1. HCO_3–SO_4–Na type of water.

Yh84, Xiangda hot spring is located in Longling County of Baoshan City. 98° 43′ 20″E, 24° 26′ 40″N. Altitude: 1660 m. The area is 20 m × 15 m. The main vent has built a pool of 6 m × 3 m with flag. The temperature of water at the surface is 71 °C, but the temperature at the bottom is 76 °C. The flow rate is 3 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 76 °C, pH 7.0, TDS 0.356, Na 90, K 3.8, Ca 3.46, Mg 0.05, CO_3 12, HCO_3 74, SO_4 71.3, Cl 5.85, SiO_2 112. HCO_3–SO_4–Na type of water.

Yh85, Huangcaoba hot spring is located in Longling County of Baoshan City. 98° 46′ 30″E, 24° 38′ 40″N. Altitude: 1750 m. The spring emerges at Longling—Ruili fracture belt between granite and migmatite. The area is 80 m × 20 m with NE trend. The highest temperature is 62 °C and total flux is 13 L/s. The main chemical compositions are as follows: *t* 62 °C, pH 7.5, TDS 0.246, Na 67.5, K 1.2, Ca 3.6, Mg 1.45, CO_3 9, HCO_3 120, SO_4 15, Cl 1.74, SiO_2 76.1. HCO_3–Na type of water.

Yh86, Bangmiao or **Longquan** hot spring is located in Longling County of Baoshan City. 98° 47′ 40″E, 24° 32′ 30″N. Altitude: 1790 m. The area is 50 m × 20 m. Country rock is granite. The main vent has closed a pool of 3 m × 3 m. The temperature of water at the surface is 73 °C, but is 81 °C at the bottom, discharging 1.2 L/s. The main chemical compositions are as follows: *t* 81 °C, pH 7.5, TDS 0.367, Na 106, K 3.7, Ca 4.15, Mg 0.29, CO_3 nd, HCO_3 213, SO_4 34.2, Cl 1.7, SiO_2 94.0. HCO_3–Na type of water.

Yh87, Yangmeipo or **Xinzhai** hot spring is located in Longling County of Baoshan City. 98° 29′ 00″E, 24° 29′ 00″N. Altitude: 1650 m. The temperature is 63 °C discharging 3 L/s. The main chemical compositions are as follows: *t* 63 °C, pH 7.7, TDS 0.244, Na 55, K 1.9, Ca 3.18, Mg 0.06, CO_3 nd, HCO_3 133, SO_4 20.2, Cl 2.43, SiO_2 79.4. HCO_3–Na type of water.

Yh88, Nansa Xiaotangba hot spring is located in Longling County of Baoshan City. 98° 48′ 00″E, 24° 26′ 00″N. Altitude: 1600 m. The area is 20 m × 5 m. The main vent has closed a pool of 5 m × 5 m. The temperature of water surface is 43 °C and bottom is 51 °C. The flow rate is 0.4 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 7.2, TDS 0.645, Na 198, K 11, Ca 9.53, Mg 0.97, CO_3 nd, HCO_3 488, SO_4 40.9, Cl 22.4, SiO_2 73.4. HCO_3–Na type of water.

Yh89, Yinjiatian or **Bianlian** hot spring is located in Longling County of Baoshan City. 98° 47′ 00″E, 24° 25′ 50″N. Altitude: 1580 m. The temperature is 76 °C discharging 2.5 L/s. The main chemical compositions are as follows: *t* 76 °C, pH 7.5, TDS 0.668, Na 184, K 10.8, Ca 8.93, Mg 0.46, CO_3 nd, HCO_3 525, SO_4 31.4, Cl 20.6, SiO_2 114.0. HCO_3–Na type of water.

Yh90, Maocaozhai hot spring is located in Longling County of Baoshan City. 98° 47′ 50″E, 24° 26′ 00″N. Altitude: 1490 m. The area is 35 m × 20 m. The main vent is 76 °C discharging 17 L/s. It was build into a square pool, which were encircled by hot marsh of 20 m × 20 m. The main chemical compositions are as follows: *t* 76 °C, pH 7.5, TDS 0.461, Na 118, K 9.8, Ca 11.6, Mg 1.06, CO_3 nd, HCO_3 330, SO_4 39, Cl 6.88, SiO_2 89.1. HCO_3–Na type of water.

Yh91, Daxiao hot spring is located in Longling County of Baoshan City. 98° 48′ 40″E, 24° 30′ 00″N. Altitude: 1720 m. The area is 40 m × 25 m with N-S direction along the Supa river. In 1980s, the main vent is located in a small pond 4 m × 2.6 m. The temperature is 74 °C. The flow rate could be 15 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 74 °C, pH 7.5, TDS 0.443, Na 108, K 11.2, Ca 25, Mg 1.06, CO_3 nd, HCO_3 287, SO_4 45.7, Cl 5.61, SiO_2 91. HCO_3–Na type of water.. Daxiao hot spring was located in the gorge of Supa river The slope is steep and the path narrow. It is very difficult to reach by walking. But now a hydropower station has been established in the spring area and the dam stands erected on the north side. The spring becomes shower room of staff and workers of power station.

Yh92, Manggao hot spring is located in Longling County of Baoshan City. 98° 49′ 45″E, 24° 44′ 10″N. Altitude: 1500 m. The main vent emerges on the precipitous cliff under the fall. The temperature is 76 °C discharging 4 L/s. There are still two vents on the slope. The total flux estimates 10 L/s. The main chemical compositions are as follows: *t* 76 °C, pH 7.5, TDS 0.342, Na 92.5, K 3.6, Ca 4.15, Mg 0.22, CO_3 nd, HCO_3 188, SO_4 20.9, Cl 1.74, SiO_2 107. HCO_3–Na type of water.

Yh93, Sileng hot spring is located in Longling County of Baoshan City. 98° 49′ 10″E, 24° 08′ 10″N. Altitude: 680 m. The main vent appears on the steep slope 20 m high of northern bank of Nujiang river. The spa temperature is 57.5 °C discharging 5 L/s. to form a hot water fall. This is an untraveled region and monkeys bustling paradises. The travertine mass 40 m in length is well preserved. The main chemical compositions are as follows: *t* 57.5 °C, pH 7.5, TDS 0.653, Na 190, K 11.3, Ca 27.7, Mg 11.8, CO_3 nd, HCO_3 580, SO_4 46.6, Cl 1.74, SiO_2 66.3. HCO_3–Na type of water.

Yh94, Jueyepohe or **Longtang** hot spring is located in Longling County of Baoshan City. 98° 53′ 00″E, 24° 24′ 00″N. Altitude: 1400 m. The area is 30 m × 5 m. There are many vents in the granite. The temperature is 47.5 °C discharging

6.5 L/s. The main chemical compositions are as follows: *t* 47.5 °C, pH 7.5, TDS 0.653, Na 50.5, K 1.1, Ca 1.76, Mg 0.12, CO_3 15, HCO_3 83, SO_4 24, Cl 4.17, SiO_2 60.4. HCO_3–Na type of water.

Yh95, Laohuqing or **Ganzhedi** hot spring is located in Longling County of Baoshan City. 98° 54′ 50″E, 24° 25′ 30″N. Altitude: 1020 m. The temperature is 55.5 °C and the flow rate is 1.5 L/s. The main chemical compositions are as follows: *t* 55.5 °C, pH 8.9, TDS 0.259, Na 50.5, K 2.2, Ca 2.9, Mg 0.1, CO_3 12, HCO_3 80, SO_4 39, Cl 2.1, SiO_2 105. HCO_3–Na type of water.

Yh96, Shalamen hot spring is located in Longling County of Baoshan City. 99° 02′ 00″E, 24° 32′ 00″N. Altitude: 640 m. The hot springs spread all over the sandy beach 1500 m long and 15 m wide of right bank of Nujiang river. The highest temperature is 51.5 °C discharging 3 L/s. The main chemical compositions are as follows: *t* 51.5 °C, pH 7.3, TDS 0.549, Na 13.5, K 8.9, Ca 67, Mg 48.3, CO_3 nd, HCO_3 519, SO_4 15.2, Cl 1.72, SiO_2 44.7. HCO_3–Ca–Mg type of water.

Yh97, Daheidu hot spring is located in Longling County of Baoshan City. 99° 01′ 35″E, 24° 18′ 50″N. Altitude: 650 m. It is located on the right bank of Nujiang river. The temperature is 54.5 °C. The most part of the area was inundated by river. The main chemical compositions are as follows: *t* 54.5 °C, pH 7.3, TDS 0.346, Na 2.2, K 2.1, Ca 67, Mg 33.2, CO_3 nd, HCO_3 358, SO_4 15.2, Cl 0.41, SiO_2 43.6. HCO_3–Ca–Mg type of water.

Yh98, Dashanjiao hot spring is located in Longling County of Baoshan City. 99° 06′ 05″E, 24° 18′ 50″N. Altitude: 800 m. The temperature is 57 °C. The main chemical compositions are as follows: *t* 57 °C, pH 7.4, TDS 0.884, Na 290, K 12.8, Ca 33.5, Mg 7.39, CO_3 nd, HCO_3 883, SO_4 12.1, Cl2.78, SiO_2 56.6. HCO_3–Na type of water.

Yh99, Hanlong Reshuitang is located in Longyang District of Baoshan City. 98° 46′ 00″E, 25° 19′ 00″N. Altitude: 2280 m. The spring emerges at east slope of Mt. Gaoligong. It is a region with no sigh of human habitation. People know nothing about it for long times. Only lumberman come to here for bathing. The area is 50 m × 10 m. The temperatures are 51–57 °C discharging 15 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 7.0, TDS 0.178, Na 38.5, K 1.3, Ca 2.72, Mg 0.09, CO_3 9, HCO_3 74, SO_4 15.2, Cl 0.85, SiO_2 69.5. HCO_3–Na type of water.

Yh100, Hanlong Xizhahe is located in Longyang District of Baoshan City. 98° 47′ 50″E, 25° 18′ 45″N. Altitude: 1480 m. There is a elliptic pool 15 m × 10 m in this area. The waves rolled and foamed in the pool. The temperature of bottom of pool is 59 °C discharging 5 L/s. There are many hot springs at the southwest of pool. Their temperatures are 55–61 °C. The main chemical compositions are as follows: *t* 61 °C, pH 7.5, TDS 0.882, Na 225, K 31.6, Ca 53.6, Mg 13.2, CO_3 nd, HCO_3 858, SO_4 6.25, Cl 10.4, SiO_2 104. HCO_3–Na type of water.

Yh101, Bailuotang hot spring is located in Longyang District of Baoshan City. 98° 46′ 20″E, 25° 09′ 30″N. Altitude: 1930 m. The area is a low-lying land 60 m × 40 m at eastern foot of Mt. Gaoligong. The temperature of main vent is 86 °C. The spa’s water gushes out from the fracture of gneiss. The center of the area is a sinter lined mound of 30 m in length, 10 m in wide and 1 m in high with NE–SW trend over the gneiss, on which there are two bathing pools 53 °C. No people use it for long times. The water in men's pool is so clear and water in women's pool is turbid cream color. The main chemical compositions are as follows: *t* 82 °C, pH 7.9, TDS 0.635, Na 134, K 16.2, Ca 50, Mg 16.2, CO_3 nd, HCO_3 259, SO_4 163, Cl 6.95, SiO_2 120. HCO_3–SO_4–Na–Ca type of water.

Yh102, Dongde hot spring is located in Longyang District of Baoshan City. 98° 52′ 20″E, 25° 22′ 00″N. Altitude: 740 m. The area is 500 m in length and 20 m in wide on the sandy beach of east bank of Nujiang river. There is no surface runoff, but has groundwater runoff in this area. The hot water of 50 °C flew out when we dug a hole of 10 cm on the sandy beach. When a hole went down to 20 cm, the temperature of water rose up to 61 °C. Local resident excavates a pit on the sandy beach for sitting bathing. The main chemical compositions are as follows: *t* 61 °C, pH 7.5, TDS 0.611, Na 29.5, K 9.8, Ca 164, Mg 27.9, CO_3 nd, HCO_3 553, SO_4 35, Cl 3.47, SiO_2 59.8. HCO_3–Ca type of water.

Yh103, **Damenkan** hot spring is located in Longyang District of Baoshan City. 98° 54′ 30″E, 25° 23′ 20″N. Altitude: 780 m. The area is 20 m × 5 m at two sides of a rivulet. The vent of south bank emerges on the flood land. The highest temperature is 47 °C discharging 2 L/s. The spa's water on the north bank gushes out from the fracture in rocks. In the dry season, a large of hot springs emerge on the flood land. The main chemical compositions are as follows: *t* 47 °C, pH 7.4, TDS 0.354, Na 2.3, K 1.1, Ca 75.0, Mg 43.0, CO_3 nd, HCO_3 414, SO_4 9.32, Cl 0.48, SiO_2 12.2. HCO_3–Ca–Mg type of water.

Yh104, Maanshan hot spring is located in Longyang District of Baoshan City. 98° 51′ 05″E, 25° 10′ 00″N. Altitude: 700 m. The area is estimated to be about 20 m × 3 m. Its large part was inundated by Nujiang River in summer 1981. A few springs emerge on the shore 20 m high. Its temperature is 59 °C discharging 0.7 L/s. The main chemical compositions are as follows: *t* 61 °C, pH 7.5, TDS 0.342, Na 13.5, K 3.5, Ca 64.3, Mg 19.6, CO_3 nd, HCO_3 269, SO_4 57.2, Cl 1.0, SiO_2 46.8. HCO_3–Ca–Mg type of water.

Yh105, Manghai hot spring is located in Longyang District of Baoshan City. 98° 54′ 35″E, 24° 52′ 25″N. Altitude: 670 m. The highest temperature is 51 °C discharging 0.2 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 7.4, TDS 0.454, Na 14, K 7.8, Ca 98.3, Mg 25.3, CO_3 nd, HCO_3 371, SO_4 69.4, Cl 1.04, SiO_2 50.0. HCO_3–Ca–Mg type of water.

Yh106, Wangtian or **Xinzhaizi** hot spring is located in Longyang District of Baoshan City. 98° 54′ 00″E, 24° 50′ 30″N. Altitude: 700 m. The spring emerges in muddy pool. The temperature is 60.5 °C. A large number of bubble turn up the black mud in the pool like boiling mud pot. The main chemical compositions are as follows: *t* 55 °C, pH 7.6, TDS 0.730, Na 15, K 10, Ca 232, Mg 40.7, CO_3 nd, HCO_3 395, SO_4 166, Cl 1.04, SiO_2 64.3. HCO_3–SO_4–Ca type of water.

Yh107, Xiawuqi hot spring is located in Longyang District of Baoshan City. 98° 56′ 40″E, 25° 06′ 00″N. Altitude: 980 m. There are six vents. The highest temperature is 46 °C. The total flux is 22.7 L/s. The main chemical compositions are as follows: *t* 37 °C, pH 7.2, TDS 0.570, Na 47.5, K 5.0, Ca 157, Mg 16.8, CO_3 nd, HCO_3 593, SO_4 10.5, Cl 3.47, SiO_2 26.5. HCO_3–Ca type of water.

Yh108, Huiliu hot spring is located in Longyang District of Baoshan City. 98° 54′ 50″E, 24° 55′ 50″N. Altitude: 680 m. There is a large hot water ditch 60 m in length. Then total flux is 17 L/s. The highest temperature is 52 °C. The main chemical compositions are as follows: *t* 50.5 °C, pH 7.4, TDS 0.382, Na 7.3, K 2.6, Ca 85.8, Mg 30.5, CO_3 nd, HCO_3 377, SO_4 34.3, Cl 2.43, SiO_2 27.8. HCO_3–Ca–Mg type of water.

Yh109, Paoshitou hot spring is located in Longyang District of Baoshan City. 98° 54′ 15″E, 24° 55′ 50″N. Altitude: 660 m. It emerges at east bank of Nujiang. The area is 300 m × 25 m. The north bath is 43 °C and the south one is 47 °C The total flux is 11 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 7.9, TDS 0.332, Na 7.3, K 2.0, Ca 48.2, Mg 24.1, CO_3 nd, HCO_3 337, SO_4 47.2, Cl 2.08, SiO_2 29.1. HCO_3–Ca–Mg type of water.

Yh110, Pupiao hot spring is located in of Baoshan City. 99° 00′ 40″E, 25° 01′ 35″N. Altitude: 1360 m. The area is 400 m in length and 20 m in wide with S–N trend. There are six main vents. There are two bathing pools. The highest temperature is 51.5 °C. The flow rate of two pools is 11 L/s. The main chemical compositions are as follows: *t* 51.5 °C, pH 7.2, TDS 0.823, Na 178, K 9.7, Ca 94.7, Mg 17.7, CO_3 nd, HCO_3 818, SO_4 46.1, Cl 12.2, SiO_2 46.1. HCO_3–Na–Ca type of water.

Yh111, Dawozi hot spring is located in Shidian County of Baoshan City. 99° 00′ 30″E, 24° 44′ 38″N. Altitude: 1100 m. The area stretches about 150 m along a river. The temperatures are 38–52 °C. The total flux is 20 L/s. Travertine is developed broadly in scale. The main chemical compositions are as follows: *t* 50 °C, pH 7.4, TDS 0.284, Na 3.1, K 1.3, Ca 56.1, Mg 25.3, CO_3 nd, HCO_3, 309, SO_4 24, Cl 1.04, SiO_2 24.0. HCO_3–Ca–Mg type of water.

Yh112, **Dapuzhai** hot spring is located in Shidian County of Baoshan City. 99° 04′ 28″E, 24° 43′ 16″N. Altitude: 700–760 m. The area stretches 500 m along a rivulet. The spas mainly emerge on the north bank, the temperatures of main vents are 51, 40, 51 °C (men's bath), 55 °C (women's bath), and 59.5 °C from east to west. There are two springs on the south bank. Their temperatures are 59.5 and 49.8 °C. Travertine is developed near men's bath. The main chemical compositions are as follows: *t* 59.5 °C, pH 7.5, TDS 0.976, Na 133, K.31.6, Ca 139, Mg 35.4, CO_3 nd, HCO_3 905, SO_4 67.2, Cl 16.0, SiO_2 53.3. HCO_3–Ca–Na type of water.

Yh113, Guojiazhai hot spring is located in Shidian County of Baoshan City. 99° 05′ 00″E, 24° 23′ 36″N. Altitude: 860 m. The area is 120 m × 15 m along both sides of a rivulet. The dense vents are dispersed on the right bank of rivulet. The temperatures are 68–77 °C discharging 8.5 L/s. There is only one spa on the south bank of rivulet. Its temperature is 77.5 °C discharging 0.7 L/s. The main chemical compositions are as follows: *t* 77 °C, pH 7.4, TDS 0.894, Na 308, K 9.2, Ca 114, Mg 3.54, CO_3 nd, HCO_3 778, SO_4 58.6, Cl 1.75, SiO_2 101. HCO_3–Na type of water.

Yh114, Qitianhekou hot spring is located in Shidian County of Baoshan City. 99° 05′ 10″E, 24° 20′ 25″N. Altitude: 620 m. The area stretches 25 m long along the rivulet. The main vent appears on the right side of rivulet mouth. Its temperature is 59 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 59 °C, pH 7.1, TDS 0.698, Na 194, K 13.5, Ca 25.9, Mg 14.9, CO_3 nd, HCO_3 685, SO_4 88.4, Cl 3.47, SiO_2 53.3. HCO_3–Na type of water.

Yh115, Hulukou hot spring is located in Shidian County of Baoshan City. 99° 16′ 35″E, 24° 26′ 55″N. Altitude: 720 m. Numerous spas emerge at water level line of river. The stretching distance is about 250 m. The temperature of main vent is 62.5 °C. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 62.5 °C, pH 7.4, TDS 0.348, Na 9.0, K 1.7, Ca 71.5, Mg 23.4, CO_3 nd, HCO_3 315, SO_4 36.5, Cl 0.5, SiO_2 43.5. HCO_3–Ca–Mg type of water.

Yh116, Ermulai hot spring is located in Changning County of Baoshan City. 99° 20′ 12″E, 24° 40′ 12″N. Altitude: 890 m. The spa's temperature is 60 °C discharging 3 L/s. No water sample.

Yh117, Xiaojiezi hot spring is located in Changning County of Baoshan City. 99° 21′ 42″E, 24° 33′ 00″N. Altitude: 720 m. The temperature of spring is 55 °C and the flow rate is 2.5 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 7.0, TDS 0.964, Na 223, K 20.3, Ca 100, Mg 19.6, CO_3 nd, HCO_3 463, SO_4 64.4, Cl 7.64, SiO_2 63.0. HCO_3–Ca–Mg type of water.

Yh118, Datianba hot spring is located in Changning County of Baoshan City. 99° 21′ 42″E, 24° 21′ 12″N. Altitude: 780 m. The spring emerges from a fault with S–N trend The temperature of the spring is 64 °C and the flow rate is 5 L/s. The main chemical compositions are as follows: *t* 64 °C, pH 7.5, TDS 0.557, Na 109, K 6.6, Ca 56.3, Mg 7.54, CO_3 nd, HCO_3 463, SO_4 57.6, Cl 3.47, SiO_2 72.8. HCO_3–Na–Ca type of water.

Yh119, Nanjietianshan hot spring is located in Changning County of Baoshan City. 99° 22′ 18″E, 24° 14′ 42″N. Altitude: 800 m. The area is located on an intersection of both faults. The temperature of the spring is 50 °C discharging 0.48 L/s. Country rock is the limestone of Early Permian system. No water sample.

Yh120, Damanghui hot spring is located in Changning County of Baoshan City. 99° 23′ 30″E, 24° 27′ 00″N. Altitude: 920 m. The temperature is 47 °C and the flow rate is 2.24 L/s. No water sample.

Yh121, Hulukou hot spring is located in Changning County of Baoshan City. 99° 23′ 30″E, 24° 46′ 30″N. Altitude: 950 m. The temperatures of the springs are from 48 °C to 71 °C. The total flux is 2 L/s. The main chemical compositions are as follows: *t* 48 °C, pH 7.2, TDS 0.969, Na 218, K 75, Ca 66.1, Mg 26.8, CO_3 nd, HCO_3 926, SO_4 42.3, Cl 10.4, SiO_2 45.9. HCO_3–Na type of water.

Yh122, Ganlanhe hot spring is located in Changning County of Baoshan City. 99° 28′ 12″E, 24° 54′ 30″N. Altitude: 1200 m. The area is 1200 m^2. The temperature of the spring is 74 °C and the flow rate is 70 L/s. The hot water comes out from the juncture of slate and porphyritic granite. The main chemical compositions are as follows: *t* 74 °C, pH 7.5, TDS 0.262, Na 81, K 1.8, Ca 1.72, Mg 0.11, CO_3 24, HCO_3 86, SO_4 10.0, Cl 2.43, SiO_2 75.5. HCO_3–Na type of water.

Yh123, Jifei Bath hot spring is located in Changning County of Baoshan City. 99° 28′ 18″E, 24° 44′ 18″N. Altitude: 1050 m. Jifei bath is famous the western Yunnan over. The area is a large travertine mass 170 m in length and 50 m in wide. There are more than 20 travertine cones. The highest one is 7 m high. Out of the travertine mass, the spring's waters inexhaustibly dispersed quickly. The highest temperature is 81 °C and the lowest is 36 °C. The total flux is 152 L/s. The main chemical compositions are as follows: *t* 81 °C, pH 7.5, TDS 0.769, Na 182, K 22.8, Ca 57.2, Mg 14.0, CO_3 nd, HCO_3 710, SO_4 25.0, Cl 1.74, SiO_2 82.0. HCO_3–Na type of water.

Yh124, Yudili hot spring is located in Changning County of Baoshan City. 99° 29′ 42″E, 24° 52′ 42″N. Altitude: 1350 m. The area is a slope. The highest temperature of vent is 72 °C. The total flux is 26 L/s. The sulfur crystal appear on the surface. The main chemical compositions are as follows: *t* 72 °C, pH 7.9, TDS 0.479, Na 113, K 9.4, Ca 12.5, Mg 1.88, CO_3 nd, HCO_3 247, SO_4 47.2, Cl 4.52, SiO_2 142. HCO_3–Na type of water.

Yh125, Xiaoshiqiao hot spring is located in Changning County of Baoshan City. 99° 41′ 48″E, 24° 41′ 54″N. Altitude: 1570 m. The area is located at the foothill belt. The springs emerge out from limestone and marble. There are three vents. The main vent has been covered by flagstone as a water place of a bathroom. The highest temperature is 55 °C. The total flux is 15 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 7.0, TDS 0.157, Na 35.6, K 1.0, Ca 5.0, Mg 0.22, CO_3 nd, HCO_3 98, SO_4 16.1, Cl 1.74, SiO_2 42.5. HCO_3–Na type of water.

6.3.5 Hot Springs in Lijiang City

Yh126, Lunan hot spring is located in Gucheng District of Lijiang City. 100° 03′ 40″E, 27° 09′ 38″N. Altitude: 1730 m. The area closely links up with Jinshajiang river. There are three vents. The highest temperature is 55–60 °C in the dry season. It was inundated in the rainy season.

Yh127, **Dadong** hot spring is located in Gucheng District of Lijiang City. 100° 25′ 40″E, 27° 10′ 05″N. Altitude: 1650 m. The area is about 2 km^2. The travertine is broad in scope. There are many vents. The highest temperature is 52 °C and total flux is 5 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 7.0, TDS 0.499, Na 28.7, K 7.76, Ca 29.2, CO_3 nd, HCO_3 247, SO_4 156, Cl 5.22, SiO_2 68.3. HCO_3–SO_4–Ca–Mg type of water.

Yh128, **Dongjiang** or **Yuhe** hot spring is located in Gucheng District of Lijiang City. 100° 27′ 10″E, 26° 57′ 10″N. Altitude: 1450 m. The area is 150 m away from the Jinshajiang river. Travertine is broad in scope, on which there is a vent 46.5–47 °C. The spring with highest temperature 56 °C emerge in a banana ground. The main chemical compositions are as follows: *t* 56 °C, pH 7.0, TDS 0.540, Na 88.0, K 19.8, Ca 70.0, Mg 22.1, CO_3 nd, HCO_3 456, SO_4 17.4, Cl 6.96, SiO_2 80.3. HCO_3–Ca–Na type of water.

Yh129, Ganzhuan hot spring is located in Yongsheng County of Lijiang City. 100° 23′ 55″E, 26° 18′ 35″N. Altitude: 1180 m. This spring emerges at east bank of Jinshajiang River. It is inundated in rainy season (from May to September) every year and appears in the dry season. The spring's temperature is high enough to boil eggs, and so it could be at least 70 °C.

Yh130, Rehe hot spring is located in Yongsheng County of Lijiang City. 100° 33′ 42″E, 26° 05′ 50″N. Altitude: 1080 m. The area stretches in S–N direction along a rivulet. There are three vents in east bank of rivulet. The highest temperature is 46 °C. The flow rate is very small. The temperatures of the springs in west bank are only 30–34 °C. In 1979, a bore hole drilled in south of spas. The hole depth is 30 m and borehole yield is 2.5 L/s. The temperature at mouth of well is 51.5 °C. The main chemical compositions are as follows: *t* 51.5 °C, pH 8.0, TDS 0.317, Na 81.2, K.1 42, Ca 1.25, Mg 1.50, CO_3 58.4, HCO_3 nd, SO_4 27.6, Cl 11.1, SiO_2 126. CO_3–Na type of water.

Yh131, Bujia or Yongxingzhuan hot spring is located in Yongsheng County of Lijiang City. 100° 33′ 22″E, 26° 02′ 00″N. Altitude: 1250 m. The main vent emerged near a ridge between fields and enclosed with stone to become a hot pool 7 m × 4 m. The temperature of water in the pool is 51.5 °C. The temperatures of other spas are 46 °C or 50 °C. The main chemical compositions are as follows: *t* 51.5 °C, pH 8.0, TDS 0.407, Na 109, K 2.13, Ca 4.20, Mg 1.41, CO_3 52.2, HCO_3 50.0, SO_4 80.3, Cl 41.8, SiO_2 80.3. HCO_3–Ca–Na type of water.

6.3.6 Hot Springs in Dali Bai Nationality Autonomous Prefecture

Yh132, Caojian Xiazaotang hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 03′ 45″E, 25° 40′ 35″N. Altitude: 1750 m. The hot water poured out from fractures of granite-gneiss at foothill. Spring eyes are too many to count. The hot waters converge into a river. Local people call it as a “bathing ditch.” The temperatures of the springs are 38–68.2 °C. The area is 0.25 km^2. The total flux is 45 L/s. The main chemical compositions are as follows: *t* 68.2 °C, pH 8.82, TDS 0.233, Na 55, K 2.29, Ca 0.9, Mg 0.3, CO_3 18.8, HCO_3 82.5, SO_4 20.5, Cl 1.75, SiO_2 83. HCO_3–CO_3–Na type of water.

Yh133, Caojian Shangzaotang hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 09′ 35″E, 25° 40′ 30″N. Altitude: 2480 m. The area is 20 m × 10 m on both banks of rivulet. There is a hot pool 6 m × 3 m on the left bank of rivulet. The surface temperature of hot water is 40 °C and the bottom temperature of pool is 61 °C. There is a travertine terrace on the right bank of rivulet, where there are many spring eyes. The highest temperature is 59 °C. The total flux is 0.6 L/s. The main chemical compositions are as follows: *t* 61 °C, pH 7.98, TDS 0.972, Na 272, K 31.8, Ca 16.1, Mg 8.42, CO_3 nd, HCO_3 723, SO_4 99.0, Cl 27.9, SiO_2 144. HCO_3–Na type of water.

Yh134, Biaocun Shangchanghe hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 06′ 00″E, 26° 05′ 50″N. Altitude: 1650 m. It is located in west bank of Lancangjiang river and north bank of Shangchanghe river. The temperature of main vent is 64 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 64 °C, pH 8.12, TDS 1.051, Na 344, K 14.3, Ca 21.5, Mg 12, CO_3 nd, HCO_3 837, SO_4 92.4, Cl 17.7, SiO_2 100. HCO_3–Na type of water.

Yh135, Xinshan or **Gujiqiao** hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 22′ 35″E, 25° 43′ 45″N. Altitude: 1200 m. The spring appears in the flood bed. There are many spring eyes with small flow rate. The temperatures of spas are 23–52 °C. The total flux is only 1.5 L/s. The main chemical compositions are as follows: *t* 52 °C, pH 7.60, TDS 3.011, Na 1010, K 42.1, Ca 64.5, Mg 20.5, CO_3 nd, HCO_3 666, SO_4 480, Cl 979, SiO_2 62.9. Cl–Na type of water.

Yh136, Wenxing or **Madichang** hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 16′ 45″E, 26° 07′ 20″N. Altitude: 2060 m. The hot water flows out from deluvial materials. The highest temperature is 52 °C discharging 3.5 L/s. The main chemical compositions are as follows: *t* 52 °C, pH 7.9, TDS 2.234, Na 509, K 14.9, Ca 198, Mg 27.0, CO_3 nd, HCO_3 362, SO_4 981, Cl 273, SiO_2 46.8. SO_4–Na–Ca type of water.

Yh137, Fenglianchang hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 22′ 35″E, 26° 02′ 30″N. Altitude: 1820 m. There are two vents. The highest temperature is 54 °C. The total flux is 2 L/s. The main chemical compositions are as follows: *t* 53.2 °C, pH 7.85, TDS 1.419, Na 410, K 16.2, Ca 68.2, Mg 21.0, CO_3 nd, HCO_3 390, SO_4 294, Cl 360, SiO_2 50.8. Cl–HCO_3–SO_4–Na type of water.

Yh138, Shicheng hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 22′ 05″E, 25° 50′ 15″N. Altitude: 1600 m. The area stretches 200 m along a rivulet. There are two vents. The vent on upper reaches is 53 °C discharging 0.7 L/s. The taste of water is very salty. It is typical salt solution from saline formation. The main chemical compositions are as follows: *t* 53 °C, pH 7.7, TDS 8.285, Na 3000, K 133, Ca 113, Mg 34.1, CO_3 nd, HCO_3 723, SO_4 860, Cl 3705, SiO_2 57.5. Cl–Na type of water.

Yh139, Dalishu or **Haikou** hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 24′ 00″E, 25° 41′ 00″N. Altitude: 1500 m. This area is a hot pool 4.5 m long and 2.5 m wide, which is located on a travertine mass 15 m × 15 m. There are two vents in hot pool to supply the hot water. The south vent is 57 °C discharging 0.4 L/s and the north vent is 56 °C discharging 0.3 L/s. The main chemical compositions are as follows: *t* 57 °C, pH 8.1, TDS 1.470, Na 489, K 9.53, Ca 8.05, Mg 4.52, CO_3 nd, HCO_3 654, SO_4 518, Cl 43.7, SiO_2 61.6. SO_4–HCO_3–Na type of water.

Yh140, Dada hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 28′ 15″E, 25° 05′ 05″N. Altitude: 2040 m. The area is 200 m × 30 m. There are two bath pools. One is located on the south bank of Dada rivulet. The temperature is 48.5 °C. Another is located on north bank of Dada rivulet. The temperature is 39.5 °C. The two bath pools are 150 m apart. The total flux is 5 L/s. Travertine mass is developed in this area. The main chemical compositions are as follows: *t* 48.5 °C, pH 7.9, TDS 2.068, Na 751, K 77.1, Ca 3.72, Mg 26.4, CO_3 nd, HCO_3 1294, SO_4 86.1, Cl 402, SiO_2 42.8. HCO_3–Cl–Na type of water.

Yh141, Lianchangping or **Shierguan** hot spring is located in Yunlong County of Dali Bai Nationality Autonomous Prefecture. 99° 28′ 30″E, 26° 01′ 45″N. Altitude: 2000 m. This area is a huge travertine fan 1000 m × 500 m, which consists of fourth terraces. There are ten odd vents on first terrace. The temperature of biggest one is 51 °C and the highest temperature is 53.2 °C in a pool. The most vents appear on second and third terraces, but the temperature is 50 °C. Two villages are situated on fourth terrace, which is 120 m higher than river level. The total flux is 25 L/s. The main chemical compositions are as follows: *t* 53.2 °C, pH 7.45, TDS 3.105, Na 404, K 46.7, Ca 385.0, Mg 112, CO_3 nd, HCO_3 539, SO_4 1510, Cl 320, SiO_2 36.0. SO_4–Ca–Na type of water.

Yh142, Zhaizipo hot spring is located in Heqing County of Dali Bai Nationality Autonomous Prefecture. 100° 21′ 20″E, 26° 17′ 47″N. Altitude: 1360 m. The area is 30 m × 10 m on a valley mouth. There are three springs, two of which are located on north side of valley and one on south side. The highest temperature of vent is 50.3 °C on the north side. The main chemical compositions are as follows: *t* 50.3 °C, pH 8.0, TDS 0.595, Na 180, K 6.44, Ca 0.25, Mg nd, CO_3 104, HCO_3 74.9, SO_4 96.1, Cl 12.2, SiO_2 20.0. CO_3–SO_4–Na type of water.

Yh143, Jiangying Farm or **Tongyuansi** hot spring is located in Heqing County of Dali Bai Nationality Autonomous Prefecture. 100° 14′ 55″E, 26° 06′ 55″N. Altitude: 1620 m. There are two pools. Their temperatures are 61 °C and 61.6 °C. The total flux is 4 L/s. The main chemical compositions are as follows: *t* 61.6 °C, pH 8.4, TDS 0.856, Na 291, K 16.9, Ca 6.30, Mg 3.25, CO_3 nd, HCO_3 587, SO_4 98.9, Cl 30.9, SiO_2 73.6. HCO_3–Na type of water.

Yh144, Xinzhuan hot spring is located in Heqing County of Dali Bai Nationality Autonomous Prefecture. 100° 14′ 20″E, 26° 05′ 40″N. Altitude: 1400 m. There is a small pool 1 m^2 near a hill. The temperature of pool spring is 53.3 °C, which flows downward into a large pool 3 m^2. There are some vents in large pool, its highest temperature is 58 °C. The total flux is only 0.2 L/s. The main chemical compositions are as follows: *t* 53.3 °C, pH 8.5, TDS 0.716, Na 243, K 14.4, Ca 4.28, Mg 2.12, CO_3 nd, HCO_3 519, SO_4 44.8, Cl 24.4, SiO_2 87.0. HCO_3–Na type of water.

Yh145, Xiamiandian hot spring is located in Heqing County of Dali Bai Nationality Autonomous Prefecture. 100° 14′ 35″E, 26° 02′ 55″N. Altitude: 1560 m. The hot water comes out from the fractures in basalt. The temperatures are from 34 °C to 71.4 °C. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 71.4 °C, pH 8.4, TDS 0.616, Na 167, K 15.4, Ca 4.25, Mg 4.34, CO_3 nd, HCO_3 478, SO_4 10.4, Cl 6.96, SiO_2 151. HCO_3–Na type of water.

Yh146, Hanzhuan or **Malipo** hot spring is located in Eryuan County of Dali Bai Nationality Autonomous Prefecture. 99° 46′ 12″E, 26° 02′ 55″N. Altitude: 1810 m. The area is 10 m × 80 m along a river, where hot water spill over at all places. Two hot pools are chief geothermal manifestation, The big pool is 5.5 m × 1.5 m with temperature to 46.4 °C discharging 0.5 L/s and the small one is 2 m × 2 m with temperature to 43 °C discharging 0.15 L/s. The main chemical compositions are as follows: *t* 46.4 °C, pH 7.9, TDS 1.249, Na 381, K 40.2, Ca 62.2, Mg 14.8, CO_3 nd, HCO_3 537, SO_4 98.0, Cl 268, SiO_2 66.9. HCO_3–Cl–Na type of water.

Yh147, Yuhuzhen or **Reshuicheng** hot spring is located in Eryuan County of Dali Bai Nationality Autonomous Prefecture. 99° 57′ 00″E, 26° 07′ 20″N. Altitude: 2000 m. At the west end of Yuhuzhen there is a Kong Temple at ancient travertine mass. The east part of temple is a bathing room The temperature in its storage well is 69.6 °C discharging 1.5 L/s. At the east end of bathing room has a swimming pool, where was a hot lake 600 m^2 before. The main chemical compositions are as follows: *t* 68.8 °C, pH 8.6, TDS 1.817, Na 637, K.43.4, Ca 2.01, Mg 3.12, CO_3 18.4, HCO_3 1125., SO_4 400, Cl 34.8, SiO_2 102. HCO_3–Na type of water.

Yh148, Jiuqitai hot spring is located in Eryuan County of Dali Bai Nationality Autonomous Prefecture. 99° 57′ 03″E, 26° 07′ 20″N. Altitude: 1995 m. It is located outer east entrance of Yuhuzhen. The two areas are 600 m apart. Jiuqitai in fact is a big travertine mound, on which built a temple in Ming Dynasty. The springs emerge around travertine mass with temperature up to 76 °C. The spring water flowed sluggishly in ditch. When ditch is covered with bricks, the base of brick will produce many sulfur crystals after a few days. Annual output is several hundred kilograms. The main chemical compositions are as follows: *t* 75.5 °C, pH 7.8, TDS 0.733, Na 121, K.11.6, Ca 74.4, Mg 24.0, CO_3 nd, HCO_3 262., SO_4 295, Cl 6.96, SiO_2 61.6. SO_4–HCO_3–Na–Ca type of water.

Yh149, Xiashankou hot spring is located in Eryuan County of Dali Bai Nationality Autonomous Prefecture. 100° 01′ 37″E, 26° 04′ 50″N. Altitude: 2000 m. The area is 1 km^2. The main vent was sunken a pool 2 m × 1.5 m and 0.5 m in depth. The temperature of water surface is 81 °C and of nozzle at the pool bed is 84 °C. The main chemical compositions are as follows: *t* 84 °C, pH 8.23, TDS 0.679, Na 152, K.20.4, Ca 17.7, Mg 7.21, CO_3 nd, HCO_3 259., SO_4 200, Cl 16.0, SiO_2 123. HCO_3–SO_4–Na type of water.

Yh150, Yousuo or **Dengchuan** hot spring is located in Eryuan County of Dali Bai Nationality Autonomous Prefecture. 100° 01′ 50″E, 26° 01′ 20″N. Altitude: 2000 m. The temperature of vent is 54 °C and the flow rate is 4 L/s. A well has been drilled in Feb. 1981 nearby. The reported temperature was 64 °C at 33.6 m. The natural spring has cut out after pumping for one day in this well. The main chemical compositions are as follows: *t* 54 °C, pH 7.90, TDS 0.571, Na 112, K.13.7, Ca 47.9, Mg 16.8, CO_3 nd, HCO_3 369., SO_4 90.5, Cl 13.9, SiO_2 84.4. HCO_3–Na–Ca type of water.

Yh151, Niujie-Sanying Geothermal field is located in Eryuan County of Dali Bai Nationality Autonomous Prefecture. 99° 59′ 20″E, 26° 14′ 22″–15′ 20″N. Altitude: 2080 m. The area is 3 km long in the SN direction and 1 km wide. There are seven springs. Their temperature are 81.5, 81.2, 81, 78, 74.3, 69.2 and 47 °C. The total flux is about 12 L/s. The distribution of the springs is controlled by fault in SN trend. The reservoir could be limestone and calcibreccia. The main chemical compositions are as follows: *t* 81.5 °C, pH 8.30, TDS 1.061, Na 295, K.44.0, Ca 14.5, Mg 22.2, CO_3 nd, HCO_3 687., SO_4 159, Cl 24.1, SiO_2 134. HCO_3–Na type of water.

Yh152, Shaba or **Maidi** or **Daicun** hot spring is located in Yangbi County of Dali Bai Nationality Autonomous Prefecture. 99° 55′ 35″E, 25° 48′ 10″N. Altitude: 1550 m. The area (500 m × 300 m) emerges at both banks of a river and the inundation is a common occurrence. The water can boil eggs in dry season. Its temperature could be 70 °C.

Yh153, Bajiaoqing hot spring is located in Yangbi County of Dali Bai Nationality Autonomous Prefecture. 99° 58′ 15″E, 25° 48′ 05″N. Altitude: 2000 m. It is a small pit for one person sitting bath. The temperature is estimated at 50 °C.

Yh154, Xincun or **Huanglian** hot spring is located in Yongping County of Dali Bai Nationality Autonomous Prefecture. 99° 46′ 40″E, 25° 28′ 55″N. Altitude: 1380 m. There are seven vents. Their temperatures are from 56 to 57 °C discharging 3 L/s. Country rock is limestone. The main chemical compositions are as follows: *t* 57 °C, pH 7.70, TDS 1.603, Na 80.4, K.8.73, Ca 350, Mg 36.2, CO_3 nd, HCO_3 419., SO_4 860, Cl 12.2, SiO_2 40. SO_4–Ca type of water.

Yh155, Xierhe hot springs are located in Dali City of Dali Bai Nationality Autonomous Prefecture. There are two springs. One is **Jiangxiqiao** (100° 08′ 25″E, 25° 34′ 00″N, Altitude: 1750 m). There are three springs in this area. Their temperatures from east to west are 64, 55, and 58 °C. The total flux is 2.5 L/s. Another is called **Daba** springs (100° 08′ 40″E, 25° 34′ 17″N, Altitude: 1800 m). There are two vent to 64.2 and 57 °C discharging 2–3 L/s and 3–4 L/s, respectively. The main chemical compositions of Jiangxiqiao's water sample are as follows: *t* 64 °C, pH 9.20, TDS 0.239 Na 54.3, K.2.42, Ca 0.60, Mg nd, CO_3 25, HCO_3 31.7, SO_4 43.2, Cl 2.1, SiO_2 89.7. SO_4–CO_3–Na type of water.

Yh156, Xiaguan or **Tangzipu** hot spring is located in Dali City of Dali Bai Nationality Autonomous Prefecture. 100° 11′ 00″E, 25° 34′ 10″N. Altitude: 1950 m. It is located in a tributary of south bank of Xierhe river. There are 13 vents. The temperatures are from 25 to 76 °C discharging 3.55 L/s. The main chemical compositions are as follows: *t* 76 °C, pH 8.20, TDS 0.939, Na 280, K.22.5, Ca 27.2, Mg 8.10, CO_3 nd, HCO_3 447, SO_4 270, Cl 15.7, SiO_2 73.6. HCO_3–SO_4–Na type of water.

Yh157, Axudi hot spring is located in Weishan County of Dali Bai Nationality Autonomous Prefecture. 100° 06′ 15″E, 24° 59′ 40″N. Altitude: 1150 m. The area is located on the north bank of a river and is usually inundate in rainy season. The temperature is about 50 °C discharging 0.01 m^3/s.

Yh158, Wengbi hot spring is located in Weishan County of Dali Bai Nationality Autonomous Prefecture. 100° 19′ 20″E, 25° 10′ 00″N. Altitude: 1800 m. There are 5–6 vents to 50 °C discharging 1.0 L/s. The spring's water can produce natron. The main chemical compositions are as follows: *t* 50 °C, pH 8.40, TDS 2.441, Na 842, K.24.3, Ca 1.50, Mg 9.65, CO_3 nd, HCO_3 1724., SO_4 510, Cl 62.7, SiO_2 50.8. HCO_3–SO_4–Na type of water.

Yh159, Gaoqing or **Gaomengying** hot spring is located in Midu County of Dali Bai Nationality Autonomous Prefecture. 100° 28′ 50″E, 25° 18′ 25″N. Altitude: 1750 m. The area is 100 m × 30 m, where there are three ravines thick with hot springs. The maximum temperature is 69.8 °C in the middle ravine. The temperature of the spring in east ravine is 66.3 °C. The south end of west ravine has a pool

59 °C. The total flux is 7.7 L/s. The main chemical compositions are as follows: *t* 69.8 °C, pH 8.60, TDS 0.587, Na 163, K.16.7, Ca 12.1, Mg 11.0, CO_3 nd, HCO_3 400., SO_4 101, Cl 6.96, SiO_2 68.3. HCO_3–Na type of water.

Yh160, Baizongqi hot spring is located in Midu County of Dali Bai Nationality Autonomous Prefecture. 100° 30′ 35″E, 25° 20′ 30″N. Altitude: 1750 m. The area is a big pool 20 m (in SN trend)×15 m (in EW trend). The vents mainly distributed in the north part of pool. The temperature at subaqueous 2.5 m depth is 55.6 °C. The temperature of waterspout of pool is 48 °C. The main chemical compositions are as follows: *t* 48 °C, pH 8.25, TDS 0.430, Na 96.9, K.16.5, Ca 27.3, Mg 17.2, CO_3 nd, HCO_3 294., SO_4 31.2, Cl 45.3, SiO_2 44.2. HCO_3–Na type of water.

Yh161, Jiashidong or **Xianguying** hot spring is located in Midu County of Dali Bai Nationality Autonomous Prefecture. 100° 30′ 40″E, 25° 19′ 55″N. Altitude: 1750 m. The area is 150 m (in EW trend) × 50 m. (in SN trend). The center of the area is a big pool 46 °C. There are two post holes at south end and north end of the area. North short hole was 50 °C but fell to 45.7 °C in 1981. South short hole was 55 °C but dropped to 50 °C. The main chemical compositions are as follows: *t* 50 °C, pH 8.00, TDS 0.554, Na 153, K.18.4, Ca 25.5, Mg 13.5, CO_3 nd, HCO_3 319., SO_4 40.4, Cl 90.5, SiO_2 46.8. HCO_3–Na type of water.

Yh162, Midu or **Shizui** hot spring is located in Midu County of Dali Bai Nationality Autonomous Prefecture. 100° 30′ 35″E, 25° 19′ 15″N. Altitude: 1700 m. The area is 50 m × 20 m. The main vent emerged at a slope and inundated by slope materials. The temperature is 45.5 °C discharging 0.25 L/s into a pool for bathing. There were two hole 40 m inside and outside the pool, respectively. The temperature of drill hole is 50 °C discharging 0.7 L/s. The main chemical compositions are as follows: *t* 49.5 °C, pH 8.5, TDS 0.707, Na 207, K.22.5, Ca 42.8, Mg 13.0, CO_3 nd, HCO_3 419., SO_4 40.1, Cl 129, SiO_2 60.2. HCO_3–Cl–Na type of water.

Yh163, Tianma or **Tianmashan** or **Majie** hot spring is located in Xiangyun County of Dali Bai Nationality Autonomous Prefecture. 100° 40′ 10″E, 25° 23′ 45″N. Altitude: 1980 m. The bathing room is closed a temple. The vent is a small karst cave inside of this temple. In order to seek cold water for irrigation of paddy field, local farmer have done explosion once at foot of Mt. Tianmashan nearby. The result of explosion emerged in large number of hot water 47.9 °C. The main chemical compositions are as follows: *t* 47.5 °C, pH 7.8, TDS 1.664, Na 15.9, K.5.08, Ca 298, Mg 118, CO_3 nd, HCO_3 156., SO_4 1100, Cl 5.22, SiO_2 40.0. SO_4–Ca–Mg type of water.

Yh164, Hedian hot spring is located in Xiangyun County of Dali Bai Nationality Autonomous Prefecture. 100° 42′ 15″E, 25° 38′ 28″N. Altitude: 1900 m. There are two bath pools and one travertine cave. The temperature of small pool is 53.5 °C discharging 0.1 L/s. The bigger one is 49.4 °C discharging 0.5 L/s. The two bath pools are 10 m apart on the east end of travertine terrace. The travertine cave appears inside terrace 5 m in thickness. A village is located on the travertine terrace. The west end of travertine terrace has a pool 49.5 °C discharging

0.3 L/s. The main chemical compositions are as follows: *t* 49.5 °C, pH 8.20, TDS 1.258, Na 451, K.23.4, Ca 5.01, Mg 14.2, CO_3 nd, HCO_3 831., SO_4 136, Cl 118, SiO_2 77.7. HCO_3–Na type of water.

6.3.7 Hot Springs in Lincang City

Yh165, Xiangshui longdong hot spring is located in Zhenkang County of Lincang City. 98° 59′ 30″E, 24° 06′ 30″N. Altitude: 1140 m. There are two vents. Two streams of spring water flow into two bathing pools (3 m × 3 m) build by stone, respectively. The temperature of east vent is 47 °C discharging 6.44 L/s and of west vent is 41 °C discharging 4.89 L/s. The main chemical compositions are as follows: *t* 47 °C, pH 8.30, TDS 0.186, Na 3.21, K 0.59, Ca 45, Mg 16.3, CO_3 nd, HCO_3 203, SO_4 6.35, Cl 1.75, SiO_2 10.6. HCO_3–Ca–Mg type of water.

Yh166, Mengbang hot spring is located in Zhenkang County of Lincang City. 98° 53′ 45″E, 23° 59′ 30″N. Altitude: 980 m. The area has many hot springs in the hot marsh 150 m × 100 m. The main vent 71 °C is located at southwestern corner. The temperatures of springs in marsh are from 30 to 60 °C. The total flux is 26.4 L/s. Country rock is limestone. The main chemical compositions are as follows: *t* 71 °C, pH 7.95, TDS 0.728, Na 242, K.15.9, Ca 24.0, Mg 6.52, CO_3 nd, HCO_3 717., SO_4 6.42, Cl 2.79, SiO_2 65.6. HCO_3–Na type of water.

Yh167, Junlong Reshuihe is located in Zhenkang County of Lincang City. 98° 58′ 48″E, 23° 45′ 30″N. Altitude: 580 m. The hot spring is located in a karst cave about 15–20 m depth. There are three vents. The maximum temperature is 62.5 °C discharging 3 L/s. The main chemical compositions of Jiangxiqiao’s water sample are as follows: *t* 62.5 °C, pH 8.20, TDS 0.510, Na 13.5, K 2.65, Ca 88.6, Mg 25.6, CO_3 nd, HCO_3 165, SO_4 215, Cl 1.75, SiO_2 77.6. SO_4–HCO_3–Ca–Mg type of water.

Yh168, Banlong hot spring is located in Youngde County of Lincang City. 99° 18′ 00″E, 24° 04′ 47″N. Altitude: 1420 m. The temperature of main vent is 52.5 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 52.5 °C, pH 8.20, TDS 0.273, Na 12.1, K 1.33, Ca 44.3, Mg 21.8, CO_3 nd, HCO_3 267, SO_4 24.0, Cl 2.10, SiO_2 33.4. HCO_3–Ca–Mg type of water.

Yh169, Dachushui or **Tianbazhai** hot spring is located in Youngde County of Lincang City. 99° 18′ 00″E, 24° 04′ 47″N. Altitude: 1420 m. The area is a V-shaped pool. There are two vents at north side and east side, respectively. The temperature of north vent is 56 °C and of east spring is 54 °C. The total flux is 20–30 L/s. The main chemical compositions are as follows: *t* 56 °C, pH 8.34, TDS 0.359, Na 33.1, K 3.67, Ca 50, Mg 14.4, CO_3 nd, HCO_3 184, SO_4 101, Cl 3.49, SiO_2 60.2. HCO_3–SO_4–Ca–Na type of water.

Yh170, Yuhua hot spring is located in Youngde County of Lincang City. 99° 19′ 30″E, 23° 56′ 10″N Altitude: 1750 m. The area stretches 150 m along a valley in east-west trend. There are five springs. The temperature of vent at most east end is 70.5 °C discharging 0.2 L/s. The second at SW 20 m is 62.5 °C discharging 0.5 L/s. The third one 10 m apart is 51.5 °C discharging 1 L/s. The forth one 15 m apart is 66.5 °C discharging 20 L/s and the most western one is 49.5 °C discharging 16.8 L/s. Country rock is limestone. The main chemical compositions are as follows: *t* 66.5 °C, pH 8.35, TDS 0.326, Na 23.7, K 3.13, Ca 47.7, Mg 12.1, CO_3 nd, HCO_3 178, SO_4 84.6, Cl 2.10, SiO_2 61.6. HCO_3–SO_4–Ca type of water.

Yh171, Duanleng hot spring is located in Youngde County of Lincang City. 99° 22′ 56″E, 24° 04′ 20″N. Altitude: 900 m. There are three pits within 120 m in NE—SW trend. No. 1 pit is 60 °C discharging 6 L/s. No. 2 is 56 °C discharging 1 L/s and No. 3 is 47 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 60 °C, pH 8.4, TDS 0.329, Na 10.9, K 2.67, Ca 59.1, Mg 10.5, CO_3 nd, HCO_3 216, SO_4 65.1, Cl 3.49, SiO_2 53.5. HCO_3–SO_4–Ca–Mg type of water.

Yh172, Nanqiaohe or **Mangshizhai** hot spring is located in Youngde County of Lincang City. 99° 24′ 30″E, 24° 06′ 47″N. Altitude: 84 m. The area is 200 m × 10 m in the rear word of flood bed. The spa's temperatures are from 39 to 58 °C. The total flux is 2–3 L/s. The main chemical compositions are as follows: *t* 58 °C, pH 8.30, TDS 0.361, Na 16.7, K 4.04, Ca 59.0, Mg 25.1, CO_3 nd, HCO_3 301, SO_4 47.2, Cl 2.79, SiO_2 53.5. HCO_3–Ca–Mg type of water.

Yh173, Malizhai hot spring is located in Youngde County of Lincang City. 99° 23′ 18″E, 23° 58′ 32″N. Altitude: 1420 m. It is a solitary spring to 55 °C discharging 5 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 8.30, TDS 0.383, Na 14.7, K 2.45, Ca 78.1, Mg 26.1, CO_3 nd, HCO_3 311, SO_4 58.4, Cl 3.49, SiO_2 42.8. HCO_3–Ca–Mg type of water.

Yh174, Huluzui hot spring is located in Youngde County of Lincang City. 99° 26′ 23″E, 24° 13′ 47″N. Altitude: 880 m. More than 10 vents emerge in 200 m steam segments. The temperatures are from 27 to 46 °C. The main chemical compositions are as follows: *t* 46 °C, pH 8.30, TDS 0.295, Na 8.56, K 1.72, Ca 57.0, Mg 24.1, CO_3 nd, HCO_3 362, SO_4 12.1, Cl 1.75, SiO_2 20.0. HCO_3–Ca–Mg type of water.

Yh175, Laoyawo hot spring is located in Youngde County of Lincang City. 99° 45′ 00″E, 24° 04′ 10″N. Altitude: 1040 m. The area is 30 m × 70 m, where there are two clusters of spring. The east cluster has three springs. Their temperatures are from 30 to 54 °C discharging less than 10 L/s. There are seven springs in the west cluster. Their temperatures are from 46 to 57.5 °C and the total flux is 10 L/s. The main chemical compositions are as follows: *t* 57.5 °C, pH 8.30, TDS 0.488, Na 152, K12.2, Ca 12.5, Mg 0.85, CO_3 nd, HCO_3 425, SO_4 66.9, Cl 5.24, SiO_2 66.9. HCO_3–Na type of water.

Yh176, Nanli hot spring is located in Gengma County of Lincang City. 99° 10′ 45″E, 23° 30′ 18″N. Altitude: 520 m. The spring emerges at hanging wall of Nandinghe fault. The temperature estimates 70 °C.

Yh177, Sifangjing hot spring is located in Gengma County of Lincang City. 99° 11′ 48″E, 23° 38′ 00″N. Altitude: 520 m. The area is 500 m × 100 m along the Nandinghe fault. There are two main vents. Their temperatures are 61 and 64 °C. The total flux is 35 L/s. Country rock is Permian limestone. The main chemical compositions are as follows: *t* 64 °C, pH 8.00, TDS 0.309, Na 12.8, K 2.28, Ca 54.5, Mg 25.2, CO_3 nd, HCO_3 305, SO_4 10.5, Cl 2.45, SiO_2 48.2. HCO_3–Ca–Mg type of water.

Yh178, Payaba or **Xiaojunsai** hot spring is located in Gengma County of Lincang City. 99° 16′ 30″E, 23° 41′ 12″N. Altitude: 520 m. The area stretches 2 km along the Nandinghe fault. Altogether four vents put in order of NE direction. The general parameters of four vents from SW to NE are 40.5 °C, 10 L/s; 44 °C, 3 L/s; 45.8 °C, 20 L/s and 52 °C, 3 L/s. Country rock is Permian limestone. The main chemical compositions are as follows: *t* 52 °C, pH 7.8, TDS 0.299, Na 8.45, K 1.44, Ca 65.4, Mg 25.0, CO_3 nd, HCO_3 317, SO_4 11.0, Cl 2.10, SiO_2 26.7. HCO_3–Ca–Mg type of water.

Yh179, Yongrang hot spring is located in Cangyuan County of Lincang City. 99° 25′ 12″E, 23° 15′ 48″N. Altitude: 1220 m. The hot spring emerges at rivulet side. The springs in south bank are 48–52 °C discharging 5 L/s. Only one vent in north bank is 62 °C discharging 1 L/s. The area has a heavy hydrogen sulfide odor. The main chemical compositions are as follows: *t* 62 °C, pH 8. 0, TDS 0.565, Na 176, K 21.1, Ca 16.5, Mg 5.50, CO_3 nd, HCO_3 527, SO_4 8.90, Cl 5.24, SiO_2 60.2. HCO_3–Na type of water.

Yh180, Wangjiazhai hot spring is located in Fengqing County of Lincang City. 99° 41′ 24″E, 24° 26′ 00″N. Altitude: 1240 m. There are 5 streams of spring water in 1000 m^2 area. The maximum temperature is 46 °C and the total flux is 12 L/s. Country rock is granite and quartzite. The main chemical compositions are as follows: *t* 46 °C, pH 7.85, TDS 0.636, Na 166, K 16.5, Ca 48.0, Mg 11.0, CO_3 nd, HCO_3 536, SO_4 40.5, Cl 15.4, SiO_2 44.1. HCO_3–Na type of water.

Yh181, Xiqian hot spring is located in Fengqing County of Lincang City. 99° 43′ 42″E, 24° 36′ 54″N. Altitude: 1480 m. There are 7 pits along a left bank of a river in 300 m long. The temperatures are from 42 to 56 °C and the flow rates are 2–3 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 7.50, TDS 0.448, Na 121, K 15.8, Ca 16.0, Mg 2.10, CO_3 nd, HCO_3 390, SO_4 9.10, Cl 5.24, SiO_2 75.0. HCO_3–Na type of water.

Yh182, Xiabangbing hot spring is located in Fengqing County of Lincang City. 99° 46′ 00″E, 24° 25′ 30″N. Altitude: 148 m. The main vent emerges from slope material of valley wall. The temperature is 61 °C discharging 5 L/s. The travertine is developed. The main chemical compositions are as follows: *t* 61 °C, pH 7.90, TDS 0.449, Na 135, K 13.8, Ca 10.1, Mg 3.45, CO_3 nd, HCO_3 387, SO_4 5.43, Cl 3.49, SiO_2 65.6. HCO_3–Na type of water.

Yh183, Dazhai hot spring is located in Fengqing County of Lincang City. 99° 51′ 30″E, 24° 46′ 12″N. Altitude: 1120 m. There are three streams of spring water. The maximum temperature is 59 °C and the flux is 5.62 L/s.

Yh184, Luoguozhai hot spring is located in Fengqing County of Lincang City. 99° 51′ 48″E, 24° 45′ 54″N. Altitude: 1140 m. The maximum temperature of the spring is 70 °C and the total flux is 7.14 L/s. The main chemical compositions are as follows: *t* 70 °C, pH 8.54, TDS 0.252, Na 52.3, K 2.27, Ca 3.05, Mg 0.81, CO_3 9.39, HCO_3 98.4, SO_4 15.8, Cl 6.99, SiO_2 102. HCO_3–Na type of water.

Yh185, Daxing hot spring is located in Fengqing County of Lincang City. 100° 05′ 24″E, 24° 29′ 18″N. Altitude: 1180 m. The temperatures are from 60 to 68 °C discharging 1 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 68 °C, pH 7.80, TDS 1.429, Na 442, K 76.8, Ca 50.0, Mg 19.0, CO_3 nd, HCO_3 1332, SO_4 21.3, Cl 48.9, SiO_2 84.4. HCO_3–Na type of water.

Yh186, Maolan or **Mengdi** hot spring is located in Yunxian County of Lincang City. 100° 14′ 30″E, 24° 34′ 00″N. Altitude: 1220 m. The hot water gushes from fracture in NNW trend in two-mica granite. The maximum temperature is 68 °C and the total flux is 8 L/s. The main chemical compositions are as follows: *t* 68 °C, pH 8.90, TDS 0.280, Na 60.2, K 3.68, Ca 0.51, Mg.0.12, CO_3 21.9, HCO_3 57.1, SO_4 36.8, Cl 14.5, SiO_2 104. HCO_3–SO_4–CO_3–Na type of water.

Yh187, Xiaomaolan hot spring is located in Yunxian County of Lincang City. 100° 14′ 24″E, 24° 33′ 00″N. Altitude: 1160 m. There is a pool about 3 m × 3 m in rice field. The temperature is 50 °C and the flow rate is 0.8 L/s. The main chemical compositions are as follows: *t* 50 °C, pH 8.40, TDS 0.275, Na 68.2, K 2.25, Ca 0.24, Mg 0.15, CO_3 nd, HCO_3 114, SO_4 44.5, Cl 8.74, SiO_2 87.0. HCO_3–SO_4–Na type of water.

Yh188, **Yongbao** hot spring is located in Yunxian County of Lincang City. 100° 18′ 36″E, 24° 16′ 30″N. Altitude: 1880 m. The area is located on the south side of hillock of granite. There are seven springs with straight distribution along a fracture in EW trend. The temperatures are from 45 to 50 °C and the total flux is 4 L/s. The main chemical compositions are as follows: *t* 50 °C, pH 8.62, TDS 0.206, Na 47.4, K 1.36, Ca 0.60, Mg 0.31, CO_3 9.39, HCO_3 88.8, SO_4 23.1, Cl 4.54, SiO_2 69.6. HCO_3–Na type of water.

Yh189, Xinlian or **Xinping** hot spring is located in Yunxian County of Lincang City. 100° 19′ 00″E, 24° 29′ 00″N. Altitude: 1100 m. There are many spas within 50 m along a ravine. The maximum temperature is 56 °C and the lowest is 43 °C. The total flux is 1 L/s. Country rock is the Triassic volcanic rock. The main chemical compositions are as follows: *t* 56 °C, pH 8.00, TDS 0.526, Na 148, K 12.4, Ca 3.0, Mg 0.24, CO_3 nd, HCO_3 270., SO_4 64.1, Cl 16.4, SiO_2 128. HCO_3–Na type of water.

Yh190, Hetaolin hot spring is located in Yunxian County of Lincang City. 100° 21′ 00″E, 24° 37′ 30″N. Altitude: 1800 m. Five vents flow out from the fracture in granite. The highest temperature is 48.5 °C. The total flux is 0.97 L/s. The main chemical compositions of 39 °C spring are as follows: pH 8.85, TDS 0.187, Na 34.7, K 1.52, Ca 0.46, Mg 0.31, CO_3 18.8, HCO_3 50.8, SO_4 24.0, Cl 3.49, SiO_2 75.0. HCO_3–CO_3–Na type.

Yh191, Zhafang hot spring is located in Linxiang District of Lincang City. 99° 58′ 54″E, 23° 55′ 54″N. Altitude: 1800 m. The area is located a flood bed of a ravine to form a hot marsh. The main vent emerges out from a ridge between fields. The temperature is 64 °C and the flow rate is 2 L/s. The main chemical compositions are as follows: *t* 64 °C, pH 8.0, TDS 0.456, Na 139, K 9.22, Ca 5.50, Mg 1.25, CO_3 nd, HCO_3 330, SO_4 22.0, Cl 8.74, SiO_2 85.7. HCO_3–Na type of water.

Yh192, Lincang hot spring is located in Linxiang District of Lincang City. 100° 04′ 00″E, 23° 50′ 36″N. Altitude: 1600 m. The area is a hot pool build by stones of 13 m × 10 m. The temperature is 64 °C and the flow rate is 4.9 L/s. The main chemical compositions are as follows: *t* 64 °C, pH 8.05, TDS 0.754, Na 247, K 22.7, Ca 7.51, Mg 0.85, CO_3 nd, HCO_3 600, SO_4 25.6, Cl 17.5, SiO_2 96.4. HCO_3–Na type of water.

Yh193, Bangbie hot spring is located in Linxiang District of Lincang City. 100° 12′ 12″E, 23° 42′ 12″N. Altitude: 1360 m. The temperature is 63 °C and the flow rate is 0.5 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 63 °C, pH 8.24, TDS 0.388, Na 100, K 6.37, Ca 0.61, Mg nd, CO_3 nd, HCO_3 171, SO_4 60.2, Cl 11.5, SiO_2 107. HCO_3–Na type of water.

Yh194, Donglai hot spring is located in Shuangjiang County of Lincang City. 99° 56′ 18″E, 23° 36′ 24″N. Altitude: 1360 m. There are four spas in EW direction. The highest temperature is 58 °C and the lowest is 45 °C. The total flux is 2.5 L/s. It is a contact strip between granite and granite-gneiss. The main chemical compositions are as follows: *t* 58 °C, pH 8.70, TDS 0.254, Na 70.4, K 2.19, Ca 0.36, Mg nd, CO_3 18.8, HCO_3 95.2, SO_4 24.8, Cl 1.74, SiO_2 72.3. HCO_3–Na type of water.

Yh195, Hongtuzhai or **Bangkongtian** hot spring is located in Shuangjiang County of Lincang City. 99° 56′ 12″E, 23° 31′ 30″N. Altitude: 1540 m. The area stretches for 800 m in NW trend. There are five vents. The highest temperature is 53 °C and the total flux is 2 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 53 °C, pH 8.10, TDS 0.309, Na 71.3, K 4.56, Ca 1.01, Mg 0.41, CO_3 nd, HCO_3 159, SO_4 25.0, Cl 6.64, SiO_2 103. HCO_3–Na type of water.

6.3.8 Hot Springs in Puer City

Yh196, Manglang hot spring is located in Menglian County of Puer City. 99° 22′ 00″E, 22° 15′ 00″N. Altitude: 950 m. The area is 120 m × 100 m. The main vent is two hot water pool with 1 m diameter. Their temperature are 54 °C discharging 1 L/s. The main chemical compositions are as follows: *t* 54 °C, pH 8.05, TDS 1.834, Na 21.4, K 5.95, Ca 415, Mg 47.5, CO_3 nd, HCO_3 178, SO_4 1210, Cl 4.19, SiO_2 40.2. SO_4–Ca type of water.

Yh197, Mangyang hot spring is located in Menglian County of Puer City. 99° 34′ 30″E, 22° 19′ 00″N. Altitude: 960 m. The area composed of three hot water pools is located in rice field. The temperature of hot water are 56.5, 46 and 28.5 °C, respectively. The main chemical compositions are as follows: *t* 56.5 °C, pH 8.10, TDS 0.541, Na 158, K 12.1, Ca 6.15, Mg 1.21, CO_3 nd, HCO_3 317, SO_4 70.4, Cl 10.5, SiO_2 107. HCO_3–Na type of water.

Yh198, Bangbing hot spring is located in Menglian County of Puer City. 99° 38′ 00″E, 22° 14′ 00″N. Altitude: 108 m. The highest temperature of the spring is 61.5 °C and the lowest is 45 °C.

The main chemical compositions are as follows: *t* 61.5 °C, pH 8.10, TDS 1.145, Na 423, K 37.9, Ca 19.0, Mg 6.50, CO_3 nd, HCO_3 1142, SO_4 3.45, Cl 13.6, SiO_2 50.8. HCO_3–Na type of water.

Yh199, Nanlei hot spring is located in Menglian County of Puer City. 99° 38′ 48″E, 22° 11′ 42″N. Altitude: 1100 m. The main vent is a big hot water pool up to 57 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 57 °C, pH 7.8, TDS 0.299, Na 75.8, K 10.9, Ca 9.05, Mg 3.12, CO_3 nd, HCO_3 254, SO_4 4.12, Cl 2.45, SiO_2 61.6. HCO_3–Na type of water.

Yh200, Wanda hot spring is located in Menglian County of Puer City. 99° 38′ 48″E, 22° 10′ 00″N. Altitude: 950 m. The two vents at riverside are 100 m apart. Their temperatures (in river water) are 44 and 46 °C. The main chemical compositions are as follows: *t* 44.5 °C, pH 7.82, TDS 0.446, Na 138, K 13.9, Ca 14.0, Mg 6.01, CO_3 nd, HCO_3 425, SO_4 4.30, Cl 7.25, SiO_2 41.5. HCO_3–Na type of water.

Yh201, Tuanshan Xinzhai hot spring is located in Lancang County of Puer City. 99° 33′ 05″E, 22° 29′ 00″N. Altitude: 1300 m. The area is 30 m × 10 m. There are two vents. The highest temperature of the spring is 50 °C and is belching bubble just like boiling. The total flux is 5 L/s.

Yh202, Nanbo hot spring is located in Lancang County of Puer City. 99° 40′ 10″E, 22° 59′ 45″N. Altitude: 1360 m. The area is 50 m × 40 m. There are four vents with bigger flow rate. Their temperatures are from 48.5 to 52.5 °C. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 52.5 °C, pH 8.46, TDS 0.322, Na 87.0, K 9.41, Ca 14.5, Mg 3.80, CO_3 12.5, HCO_3 247, SO_4 12.0, Cl 4.41, SiO_2 44.6. HCO_3–Na type of water.

Yh203, Dabalao hot spring is located in Lancang County of Puer City. 99° 51′ 00″E, 22° 58′ 25″N. Altitude: 1220 m. The area is 20 m × 10 m. The main vent is 56 °C discharging 4.5 L/s. The other springs are from 50 to 54 °C. The main chemical compositions are as follows: *t* 56 °C, pH 8.48, TDS 0.491, Na 128.0, K 12.0, Ca 10.5, Mg 3.20, CO_3 12.5, HCO_3 273, SO_4 55.8, Cl 13.2, SiO_2 96.5. HCO_3–Na type of water.

Yh204, Xinmanbang hot spring is located in Lancang County of Puer City. 99° 53′ 00″E, 22° 59′ 40″N. Altitude: 1200 m. The area is 150 m × 10 m along the rivulet in NE–SW trend. The temperature of the main vent is 80 °C and gives off strong H_2S smell. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 80 °C, pH 8.49, TDS 0.525, Na 134, K 14.2, Ca 7.01, Mg 4.01, CO_3 21.8, HCO_3 219, SO_4 48.1, Cl 20.1, SiO_2 144. HCO_3–Na type of water.

Yh205, Laobandeng hot spring is located in Lancang County of Puer City. 99° 53′ 40″E, 22° 02′ 25″N. Altitude: 1200 m. The main vent emerges out from bank of gravel. The temperature is 51.5 °C and the flow rate is 0.5 L/s. The main chemical compositions are as follows: *t* 51.5 °C, pH 8.43, TDS 0.543, Na 157.0, K 16.8, Ca 11.4, Mg 3.31, CO_3 18.7, HCO_3 362, SO_4 40.0, Cl 12.8, SiO_2 85.5. HCO_3–Na type of water.

Yh206, Xiaotanghe hot spring is located in Lancang County of Puer City. 99° 56′ 25″E, 22° 14′ 30″N. Altitude: 880 m. This area has only one spa. Its temperature is 65 °C discharging 2 L/s. There is strong H_2S smell in the area. The main chemical compositions are as follows: *t* 65 °C, pH 8.94, TDS 0.846, Na 229.0, K 46.6, Ca 19.5, Mg 17.5, CO_3 43.7, HCO_3 654, SO_4 15.8, Cl 9.03, SiO_2 115. HCO_3–Na type of water.

Yh207, Dagoujiao hot spring is located in Lancang County of Puer City. 99° 56′ 50″E, 23° 05′ 35″N. Altitude: 1510 m. The area is 120 m × 50 m along a rivulet. The highest temperature of spa is 55 °C discharging 6.5 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 55 °C, pH 8.26, TDS 0.295, Na 65.8, K 4.91, Ca 4.24, Mg 3.71, CO_3 nd, HCO_3 146, SO_4 24.1, Cl 8.3, SiO_2 89.3. HCO_3–Na type of water.

Yh208, Pojiao hot spring is located in Lancang County of Puer City. 99° 54′ 38″E, 22° 46′ 15″N. Altitude: 1370 m. The hot water emerges out from granite waste. The maximum temperature is 60 °C and the total flux is 2.5 L/s. The main chemical compositions are as follows: *t* 60 °C, pH 8.28, TDS 0.336, Na 88.0, K 4.22, Ca 4.80, Mg 1.71, CO_3 nd, HCO_3 152, SO_4 49.2, Cl 3.20, SiO_2 89.3. HCO_3–SO_4–Na type of water.

Yh209, Menglang or **Daqiaotou** hot spring is located in Lancang County of Puer City. 99° 55′ 15″E, 22° 32′ 50″N. Altitude: 1060 m. The temperature of the spring is 63 °C and the flow rate is 5 L/s. The main chemical compositions are as follows: *t* 63 °C, pH 8.85, TDS 0.519, Na 155, K 20.5, Ca 12.6, Mg 7.31, CO_3 43.7, HCO_3 388, SO_4 6.72, Cl 3.2, SiO_2 69.2. HCO_3–Na type of water.

Yh210, Donglang hot spring is located in Lancang County of Puer City. 99° 56′ 00″E, 22° 32′ 50″N. Altitude: 1080 m. There are two main vents at riverside. The maximum temperature is 58 °C discharging 2 L/s. Another one is 54.5 °C discharging 3 L/s. Many hot springs can emerge out at riverbed in dry season. The temperatures are about 40 °C discharging 30 L/s. The main chemical compositions are as follows: *t* 58 °C, pH 8.38, TDS 0.466, Na 128, K 23.4, Ca 12.5, Mg 6.91, CO_3 nd, HCO_3 393, SO_4 8.05, Cl 14.0, SiO_2 57.5. HCO_3–Na type of water.

Yh211, Menggen hot spring is located in Lancang County of Puer City. 99° 58′ 30″E, 22° 20′ 25″N. Altitude: 920 m. The temperature of main vent is 64 °C and the flow rate is 10 L/s. The main chemical compositions are as follows: *t* 64 °C, pH 8.34, TDS 0.382, Na 89.1, K 16.4, Ca 22.8, Mg 9.20, CO_3 12.5, HCO_3 299, SO_4 21.2, Cl 7.61, SiO_2 46.5. HCO_3–Na type of water.

Yh212, Xiatianfang hot spring is located in Lancang County of Puer City. 100° 05′ 30″E, 23° 02′ 35″N. Altitude: 1200 m. The water temperature is 50 °C and the flow rate is 0.5 L/s.

Yh213, Mangpian hot spring is located in Lancang County of Puer City. 100° 08′ 15″E, 23° 33′ 10″N. Altitude: 980 m. The area is 10 m × 5 m. There are three slope springs. Their temperatures are 45–47.5 °C discharging 3 L/s. The main chemical compositions are as follows: *t* 47.5 °C, pH 8.30, TDS 0.475, Na 147, K. 9.82, Ca 7.53, Mg 3.00, CO_3 nd, HCO_3 349, SO_4 28.8, Cl 11.6, SiO_2 64.8. HCO_3–Na type of water.

Yh214, Xiabangdao hot spring is located in Lancang County of Puer City. 100° 07′ 25″E, 22° 32′ 00″N. Altitude: 1040 m. The area is 40 m × 30 m and can be divided into two parts. The two parts are 1 km apart. One part appears at the bend of river. The temperature is 70 °C and the flow rate is more than 3 L/s. Another one is located at upper reaches of river but was inundated when we visited. The main chemical compositions are as follows: *t* 70 °C, pH 8.54, TDS 0.554, Na 153, K 12.0, Ca 6.32, Mg 3.05, CO_3 18.7, HCO_3 266, SO_4 54.0, Cl 15.8, SiO_2 126. HCO_3–Na type of water.

Yh215, Fula hot spring is located in Lancang County of Puer City. 100° 11′ 25″ E, 22° 15′ 35″N. Altitude: 1320–1400 m. The area is 350 m × 20 m along a rivulet in NW-SE trend. It can be divided into three parts. One part is the SE end, where the temperatures of many springs are more than 80 °C and the maximum is 85 °C. The total flux is 7 L/s. The second part is hot water pool with diameter of 20 m and depth of 2 m. Many vents appear in the pool bed. Then temperatures are from 75 to 80 °C and the flow rate is 15 L/s. The third part is a hot marsh in 35 m × 25 m. The highest temperature is 75 °C and the flow rate is 3.5 L/s. Country rock is the sericitized schist. The main chemical compositions are as follows: *t* 85 °C, pH 8.54, TDS 0.492, Na 125, K 12.7, Ca 7.10, Mg 3.22, CO_3 12.5, HCO_3 228, SO_4 45.6, Cl 22.0, SiO_2 126. HCO_3–Na type of water.

Yh216, Laozhai hot spring is located in Lancang County of Puer City. 100° 14′ 45″E, 22° 38′ 05″N. Altitude: 720 m. The area is 15 m × 10 m. The temperature of hot water is 80 °C and the flow rate is 5.6 L/s.

Yh217, Hutiaoshi hot spring is located in Lancang County of Puer City. 100° 22′ 00″E, 22° 40′ 30″N. Altitude: 640 m. The temperature of hot water is 60 °C and the flow rate is 5 L/s.

Yh218, Heishan or **Mahuangba** or **Mangwoshan** hot spring is located in Lancang County of Puer City. 100° 20′ 40″E, 22° 18′ 15″N. Altitude: 1060 m. The area stretches 100 m along a river in EW direction. The temperature of hot water is 89 °C and the flow rate is 3 L/s. This area is remote and uninhabited. The main chemical compositions are as follows: *t* 89 °C, pH 8.48, TDS 0.376, Na 96.0, K 7.90, Ca nd, Mg nd, CO_3 12.5, HCO_3 165, SO_4 28.4, Cl 11.6, SiO_2 114. HCO_3–Na type of water.

Yh219, Nanjiaohe hot spring is located in Lancang County of Puer City. 100° 51′ 40″E, 22° 18′ 40″N. Altitude: 1060 m. The area is 150 m × 150 m. The hot water emerges from the fractures of granite. The temperature is 63.5 °C and the flow rate is 6 L/s. The main chemical compositions are as follows: *t* 63.5 °C, pH 8.62, TDS 0.324, Na 97.1, K 4.62, Ca 2.12, Mg 0.52, CO_3 12.5, HCO_3 174, SO_4 18.8, Cl 10.8, SiO_2 71.9. HCO_3–Na type of water.

Yh220, Xiejiatian Dareshui is located in Zhenyuan County of Puer City. 100° 27′ 35″E, 23° 55′ 10″N. Altitude: 960 m. The area is 40 m × 30 m. The temperature of main vent is 51.5 °C. The total flux is 3 L/s. Country rock is the Jurassic sandstone. The main chemical compositions are as follows: *t* 51.5 °C, pH 8.35, TDS 1.399, Na 440, K 18.1, Ca 55.5, Mg 8.90, CO_3 12.5, HCO_3 311, SO_4 281, Cl 347, SiO_2 66.5. Cl–SO_4–Na type of water.

Yh221, Mange hot spring is located in Jinggu County of Puer City. 100° 08′ 45″E, 23° 27′ 05″N. Altitude: 800 m. The area is 20 m × 10 m. The highest temperature is 56.5 °C and the total flux is 6 L/s. Country rock is a contact strip between granite and gneiss. The main chemical compositions are as follows: *t* 56.5 °C, pH 8.45, TDS

0.556, Na 160, K 15.8, Ca 11.0, Mg 5.31, CO_3 18.7, HCO_3 219, SO_4 56.0, Cl 92.2, SiO_2 71.9. HCO_3–Cl–Na type of water.

Yh222, Huanle hot spring is located in Jinggu County of Puer City. 100° 42′ 00″ E, 23° 25′ 20″N. Altitude: 1020 m. The area is 300 m × 50 m. The maximum temperature of main vent is 49.5 °C and the flow rate is 10 L/s. Country rock is the Jurassic purple sandstone. The main chemical compositions are as follows: *t* 49.5 °C, pH 7.9, TDS 6.076, Na 1995, K 34.1, Ca 195, Mg 37.3, CO_3 nd, HCO_3 260, SO_4 620, Cl 3013, SiO_2 44.6. HCO_3–Na type of water.

Yh223, Yanshuihe or **Mangka** hot spring is located in Jinggu County of Puer City. 100° 44′ 30″E, 23° 35′ 50″N. Altitude: 1040 m. The area is 150 m × 50 m along a rivulet. The main spring emerges on the left bank of rivulet. Its temperature is 56.5 °C discharging 20 L/s. Some springs appear on the right bank, but the temperatures are less than 50 °C. The travertine is developed. Country rock is the Jurassic purple sandstone. The main chemical compositions are as follows: *t* 56.5 °C, pH 7.68, TDS 10.444, Na 3590, K 56.1, Ca 375, Mg 44.1, CO_3 nd, HCO_3 165, SO_4 1000, Cl 5246, SiO_2 39.2. HCO_3–Na type of water.

Yh224, Xisa Xiaoreshui hot spring is located in Ninger County of Puer City. 100° 00′ 00″E, 23° 12′ 55″N. Altitude: 1060 m. Many vents are densely covered in brooklet. The main vent is 48.5 °C. The flux is 3 L/s. Country rock is argillutite. The main chemical compositions are as follows: *t* 48.6 °C, pH 7.6, TDS 0.407, Na 56.7, K 2.55, Ca 72.3, Mg 11.0, CO_3 nd, HCO_3 292, SO_4 27.0, Cl 55.9, SiO_2 33.4. HCO_3–Ca–Na type of water.

Yh225, Manzhongtian hot spring is located in Simao District of Puer City. 101° 20′ 25″E, 22° 40′ 30″N. Altitude: 880 m. The main vent is a hot mud pool of 7 m diameter. The temperature of water surface is 50.5 °C and the flow rate is 10 L/s. Country rock is silt rock. The main chemical compositions are as follows: *t* 50.5 °C, pH 8.0, TDS 2.522, Na 900, K 17.7, Ca 60.2, Mg 19.5, CO_3 nd, HCO_3 515, SO_4 254, Cl 957, SiO_2 50.3. Cl–Na type of water.

Yh226, Mangling hot spring is located in Mojiang County of Puer City. 101° 20′ 30″E, 23° 00′ 00″N. Altitude: 790 m. The spring emerges from a NE trending fault. Country rock is the Cretaceous sandstone. The temperature is 55.5 °C and the flow rate is o.2 L/s. The main chemical compositions are as follows: *t* 42 °C, pH 8.05, TDS 0.974, Na 273, K 18.3, Ca 53.2, Mg 25.2, CO_3 nd, HCO_3 657, SO_4 152, Cl 69.8, SiO_2 48.8. HCO_3–Na type of water.

Yh227, Eli or **Tufang** hot spring is located in Mojiang County of Puer City. 101° 25′ 00″E, 23° 25′ 25″N. Altitude: 1150 m. The area is 60 m × 15 m along a rivulet. The temperature of the spring water is 55 °C discharging 5 L/s. Country rock is purple sandstone. The main chemical compositions are as follows: *t* 55 °C, pH 7.92, TDS 0.436, Na 80.0, K 14.3, Ca 50.2, Mg 11.8, CO_3 nd, HCO_3 392, SO_4 12.5, Cl 17.4, SiO_2 45.9. HCO_3–Na type of water.

Yh228, Qingping hot spring is located in Mojiang County of Puer City. 101° 26′ 00″E, 23° 19′ 15″N, Altitude: 1180 m. The area is 0.2 km^2, where there are three springs. Their temperatures are 62.5, 61 and 40 °C. The travertine is developed. Country rock is the Cretaceous quartziferous sandstone. The main chemical compositions are as follows: *t* 62.5 °C, pH 8.14, TDS 0.952, Na 282.0, K 24.9, Ca 16.6, Mg 23.5, CO_3 nd, HCO_3 595, SO_4 70.0, Cl 169, SiO_2 56.1. HCO_3–Cl–Na type of water.

Yh229, Xiaxinzhai hot spring is located in Mojiang County of Puer City. 101° 36′ 05″E, 23° 02′ 10″N. Altitude: 820 m. The area is 15 m × 5 m. The temperature of the spring is 46 °C discharging 0.3 L/s. Country rock is the Cretaceous quartziferous sandstone. The main chemical compositions are as follows: *t* 46 °C, pH 8.06, TDS 1.527, Na 505, K 19.1, Ca 60.2, Mg 15.5, CO_3 nd, HCO_3 436, SO_4 160.0, Cl 494, SiO_2 50.2. Cl–HCO_3–Na type of water.

Yh230, Dashujiao hot spring is located in Jiangcheng County of Puer City. 101° 16′ 30″E, 22° 48′ 25″N. Altitude: 1090 m. The area is 300 m × 20 m along the bed of rivulet. The temperature of main vent is 53.5 °C discharging 6 L/s. There are travertine around the springs. The main chemical compositions are as follows: *t* 53.5 °C, pH 7.82, TDS 1.977, Na 445.0, K 23.7, Ca 135, Mg 46.2, CO_3 nd, HCO_3 437, SO_4 945.0, Cl 107, SiO_2 5.3. SO_4–HCO_3–Na type of water.

6.3.9 Hot Springs in Xishuangbanna Dai Nationality Autonomous Prefecture

Yh231, Pazuo hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 99° 58′ 20″E, 21° 45′ 30″N. Altitude: 650 m. The area is 250 m × 20 m along a rivulet. The highest temperature of vent is 58.5 °C. The total flux is 1 L/s. Country rock is sericitic quartz schist. The main chemical compositions are as follows: *t* 58.5 °C, pH 8.06, TDS 0.459, Na 125, K 13.3, Ca 6.52, Mg 3.60, CO_3 nd, HCO_3 254, SO_4 62.0, Cl 6.98, SiO_2 89.5. HCO_3–Na type of water.

Yh232, Manbang hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 99° 59′ 50″E, 21° 85′ 50″N. Altitude: 770 m. The area is 120 m × 20 m along the bed of rivulet in NW trending. The highest temperature of the spring is 74 °C and the total flux is 7 L/s. The main chemical compositions are as follows: *t* 74 °C, pH 8.68, TDS 0.527, Na 156, K 12.5, Ca 11.7, Mg 4.82, CO_3 21.8, HCO_3 365, SO_4 39.2, Cl 8.72, SiO_2 79.2. HCO_3–Na type of water.

Yh233, Xiding Manbang hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 01′ 00″E, 22° 02′ 00″N. Altitude: 1050 m. The area is 45 m × 15 m along the left bank of riverlet. The hot water emerges from the congromerate. The highest temperature is 75.5 °C. The total flux is 15 L/s. There is very strong H_2S smell. The main chemical compositions are as follows: *t* 70 °C, pH 8.5, TDS 0.579, Na 139, K 18.4, Ca 18.0, Mg 4.04, CO_3 18.7, HCO_3 286., SO_4 96.4, Cl 23.2, SiO_2 96.5. HCO_3–Na type of water.

Yh234, Manle-Manxi hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 00′ 15″E, 21° 46′ 40″N. Altitude: 880 m. The spring area can be divided into two parts. The west part is called Manle and east part is called Manxi which are 2 km apart. The Manle's spa is 55.5 °C discharging 2.5 L/s and the Manxi 70 °C discharging 1.2 L/s. The main chemical compositions are as follows: *t* 70 °C, pH 8.72, TDS 0.433, Na 108, K 6.90, Ca 10.2, Mg 5.92, CO_3 15.6, HCO_3 245, SO_4 35.2, Cl 3.48, SiO_2 99.2. HCO_3–Na type of water.

Yh235, Manka hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 08′ 10″E, 21° 41′ 45″N. Altitude: 620 m. The hot springs spread all over the riffle area. The highest temperature is 73.7 °C and the total flux is 5 L/s. The main chemical compositions are as follows: *t* 50 °C, pH 8.93, TDS 0.644, Na 205, K 20.7, Ca 7.30, Mg 3.12, CO_3 24.9, HCO_3 489, SO_4 12.0, Cl 10.4, SiO_2 89.6. HCO_3–Na type of water.

Yh236, Mannan hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 16′ 40″E, 21° 38′ 00″N. Altitude: 800 m. The temperature of the main vent is 55 °C discharging 2 L/s. The main chemical compositions are as follows: *t* 55 °C, pH 8.25, TDS 0.411, Na 117, K 13.3, Ca 12.4, Mg 5.03, CO_3 nd, HCO_3 334, SO_4 18.5, Cl 6.95, SiO_2 56.1. HCO_3–Na type of water.

Yh237, Bangdeng hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 17′ 05″E, 21° 40′ 00″N. Altitude: 900 m. The temperature is about 50 °C.

Yh238, Zhangjia Bangtang hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 19′ 30″E, 21° 30′ 25″ N. Altitude: 780 m. The area is 20 m × 10 m. The temperature of main vent is 57.5 °C. The temperatures of some seepages in marsh basin are 50 °C The total flux is 2 L/s. The main chemical compositions are as follows: *t* 57.5 °C, pH 8.48, TDS 0.391, Na 107, K 10.7, Ca 10.9, Mg 4.13, CO_3 11.2, HCO_3 268, SO_4 20.8, Cl 6.95, SiO_2 56.1. HCO_3–Na type of water.

Yh239, Mengajie hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 19′ 10″E, 22° 11′ 20″N. Altitude: 1060 m. The area is 500 m × 200 m and can be divided into four parts. The first part is about 50 m^2, where has a hot pond of 1.5 m^2 and 0.3 m depth. The temperature of surface of water is 67 °C and the temperature of mouth of the spring at bottom of pond is 77.5 °C. The temperature of the second part is highest reaching 82.2 °C in 5 cm depth. The temperature in third and fourth parts are not quite high, only 60–67 °C. The total flux is 10 L/s. The main chemical compositions are as follows: *t* 77.5 °C, pH 8.5, TDS 0.332, Na 89.1, K 4.60, Ca 1.03, Mg 0.52, CO_3 12.5, HCO_3 155, SO_4 25.6, Cl 9.61, SiO_2 92.9. HCO_3–Na type of water.

Yh240, Nanlu hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 18′ 40″E, 22° 05′ 45″N. Altitude: 1140 m. The water temperature is 45.5 °C and the flow rate is 2 L/s. The main chemical compositions are as follows: *t* 45.5 °C, pH 8.38, TDS 0.370, Na 120, K 2.70, Ca 1.62, Mg 0.90, CO_3 12.5, HCO_3 190, SO_4 59.2, Cl 6.30, SiO_2 44.4. HCO_3–Na type of water.

Yh241, Sunhuan Bangtang hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 22′ 410″E, 22° 14′ 20″N. Altitude: 1040 m. The spa is located in river bed. The maximum temperature is 78 °C. The flow rate could be 2 L/s. The main chemical compositions are as follows: *t* 78 °C, pH 8.48, TDS 0.215, Na 59.6, K 1.73, Ca 6.3, Mg 1.50, CO_3 12.5, HCO_3 127, SO_4 12.1, Cl 6.02, SiO_2 44.0. HCO_3–Na type of water.

Yh242, Nanjinghe Bangtang hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 23′ 40″E, 22° 06′ 30″ N. Altitude: 1110 m. The area is located in a beach of rivulet bed about 300 m in length and 50 m in wide. In the rainy season all hot springs were inundated. But in the dry season if you excavate the sand 30 cm deep, you can find hot water of 37–50 °C. If the depth reached 1 m, the temperature of hot water will exceed 50 °C. The main chemical compositions are as follows: *t* 45.5 °C, pH 7.96, TDS 0.207, Na 58.1, K 1.92, Ca 1.72, Mg 0.31, CO_3 nd, HCO_3 143, SO_4 17.2, Cl 1.75, SiO_2 44.4. HCO_3–Na type of water.

Yh243, Manhei hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 24′ 00″E, 22° 00′ 20″N. Altitude: 1180 m. The area is 20 m × 20 m. The main vent is a hot pond with 5 m in diameter and 0.6 m in depth. The temperature of surface of water is 36.5 °C. The temperature of bottom of pond is more than 45 °C. The main chemical compositions are as follows: *t* 70 °C, pH 8.35, TDS 0.299, Na 91.2, K 5.0, Ca 0.80, Mg 0.32, CO_3 nd, HCO_3 184, SO_4 27.2, Cl 7.03, SiO_2 57.4. HCO_3–Na type of water.

Yh244, Manlie hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 26′ 30″E, 22° 23′ 15″N. Altitude: 860–940 m. This area can be divided into five parts. No. 1: 60 °C and 1 L/s; No. 2: 60 °C and 1.5 L/s. No. 3: 46.5 °C and 1 L/s; No. 4: 63 °C and 1.5 L/s, No. 5: 44–62.5 °C hot marsh. The main chemical compositions are as follows: *t* 63 °C, pH 8.48, TDS 0.494, Na 140, K 9.40, Ca 1.65, Mg 1.01, CO_3 15.6, HCO_3 219, SO_4 77.6, Cl 16.0, SiO_2 95.6. HCO_3–Na type of water.

Yh245, Manyanghan hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 28′ 20″E, 21° 59′ 40″N. Altitude: 1164 m. The main vent is a hot spring bowl of 16 m in length, 7 m in wide, and 0. 4 m in depth. The temperature of water surface is 47 °C and bottom of pond 52.5 °C. The flow rate is 2 L/s. The main chemical compositions are as follows: *t* 52.5 °C, pH 7.55, TDS 0.307, Na 89.1, K 4.62, Ca 0.82, Mg 0.40, CO_3 nd, HCO_3 151, SO_4 32.0, Cl 23.5, SiO_2 62.8. HCO_3–Na type of water.

Yh246, Manwei Bangtang hot spring is located in Menghai Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 29′ 35″E, 21° 59′ 40″N. Altitude: 1160 m. The main vent is a small bathing pond of 4.5 and 0.4 m depth. The temperature of water surface is 38 °C and silt on bottom of pond is 50 °C. The main chemical compositions are as follows: *t* 50 °C, pH 7.38, TDS 0.299, Na 83.2, K 5.7, Ca 0.73, Mg 0.41, CO_3 nd, HCO_3 133, SO_4 32.8, Cl 17.9, SiO_2 62.8. HCO_3–Na type of water.

Yh247, Manbo hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 33′ 10″E, 21° 31′ 50″N. Altitude: 780 m. There are seven springs in this area. The main vent is a circular hole of 10 cm diameter. The temperature of mouth is 76.2 °C discharging 3 L/s. The others are 42.5–72 °C. There is travertine. Country rock is quartzite. The main chemical compositions are as follows: *t* 76.2 °C, pH 8.60, TDS 0.257, Na 55.7, K 3.04, Ca 0.74, Mg 0.21, CO_3 15.6, HCO_3 105, SO_4 12.8, Cl 2.45, SiO_2 96.4. HCO_3–Na type of water.

Yh248, No. 9 Fraction of Dongfeng Farm hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 38′ 15″E, 21° 40′ 55″N. Altitude: 760 m. There were two hot spring with 70 °C. But their temperatures have changed after two bathing ponds constricted. The temperature of men's bating pool is only 46 °C discharging 0.2 L/s and women's bathing pool is 50 °C discharging 1 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 50 °C, pH 7.95, TDS 0.250, Na 66.1, K 2.33, Ca 1.81, Mg 1.52, CO_3 nd, HCO_3 130, SO_4 21.2, Cl 5.24, SiO_2 69.6. HCO_3–Na type of water.

Yh249, Bangleng hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 41′ 40″E, 21° 43′ 05″N. Altitude: 660 m. The area is 250 m × 80 m. The highest temperature is 81.3 °C. It was a fountain before 1978 and the spurted altitude attained 50 cm. There is a bathhouse and swimming pool over there. The main chemical compositions are as follows: *t* 79 °C, pH 8.15, TDS 0.359, Na 87.5, K 6.44, Ca 1.75, Mg 0.43, HCO_3 155, SO_4 23.5, Cl 10.5, SiO_2 131. HCO_3–Na Type.

Yh250, Ximanmoxie hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 41′ 30″E, 21° 56′ 20″N. Altitude: 620 m. This area has two bathing pool. of 3 m diameter and 1 m depth. The men's pool has 45.7–49 °C and women's 45 °C. The total flux is 0.5 L/s. The main chemical compositions are as follows: *t* 46 °C, pH 7.70, TDS 0.240, Na 70.8, K 1.49, Ca 0.86, Mg 0.20, CO_3 nd, HCO_3 159, SO_4 10.9, Cl 6.99, SiO_2 52.2. HCO_3–Na type of water.

Yh251, Shayao hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 41′ 15″E, 21° 55′ 40″N. Altitude: 640 m. There are two springs in Shayao Hani Nationality Village. One is located on north of Shayao. The temperatures are 61.8–66.6 °C discharging 0.5 L/s. The another is located on northeast of Shayao. Its temperatures are 44.2–57.2 °C discharging 0.1 L/s. Country rock is granite. The main chemical compositions are as follows: *t* 66.6 °C, pH 8.10, TDS 0.253, Na 66.2, K 1.93, Ca 1.72, Mg 0.10, CO_3 nd, HCO_3 136, SO_4 19.8, Cl 6.99, SiO_2 69.6. HCO_3–Na type of water.

Yh252, Manda hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 43′ 50″E, 21° 56′ 15″N. Altitude: 565 m. There are three dimple springs. The biggest one covers a space of 4 × 2.5 m^2 and 0.25 m in depth. Its temperature is 41.5 °C discharging 0.5 L/s. The highest temperature of dimple spring is 53 °C discharging 0.05 L/s. Country rock is biotite granite. The main chemical compositions are as follows: *t* 53 °C, pH 7.89, TDS 0.302, Na 74.1, K 2.45, Ca 0.82, Mg 0.21, CO_3 nd, HCO_3 121, SO_4 50.9, Cl 8.74, SiO_2 88.6. HCO_3–SO_4–Na type of water.

Yh253, Mansa hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 45′ 10″E, 21° 57′ 20″N. Altitude: 550 m. There are five dimple springs in area of 50 m ×30 m. The temperature of spring is from 34.5 to 51 °C and the total flux is 2 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 7.35, TDS 0.313, Na 91.2, K 3.07, Ca 2.52, Mg 0.82, CO_3 nd, HCO_3 127, SO_4 33.5, Cl 12.2, SiO_2 81.6. HCO_3–Na type of water.

Yh254, Maopu hot spring is located in Jinghong Country of Xishuangbanna Dai Nationality Autonomous Prefecture. 100° 38′ 45″E, 22° 20′ 25″N. Altitude: 570 m. It is a preserve area, which is the haunt of wild elephant. The temperature is estimated to be about 70 °C.

6.3.10 Hot Springs in South Bank of Hong River

Yh255, Abohei or **Baihecun** hot spring is located in Xinping County of Yuxi City. 101° 35′ 40″E, 23° 54′ 50″N. Altitude: 2200 m. The temperature is 48.5 °C discharging 0.2 L/s. The intense smell of the H_2S gas is unbearable there.

Yh256 Wana hot spring is located in Yuanjiang County of Yuxi City. 101° 54′ 05″E, 23° 31′ 30″N. Altitude: 890 m. The area is 30 m × 20 m along a rivulet in Mt. Ailao. The springs are gathering on the riffle area. The highest temperature of the main vent is 87.5 °C at river bank. The total flux is 4.2 L/s. The main chemical compositions are as follows: *t* 87.5 °C, pH 8.82, TDS 0.480, Na 153, K 6.85, Ca 1.92, Mg 1.82, CO_3 18.7, HCO_3 285, SO_4 16.5, Cl 24.4, SiO_2 89.3. HCO_3–Na type.

Yh257, Xilahe hot spring is located in Yuanjiang County of Yuxi City. 101° 55′ 22″E, 23° 43′ 37″N. Altitude: 620 m. The temperatures are from 55 to 60 °C.

Yh258, Nanlin hot spring is located in Yuanyang County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 102° 38′ 30″E, 22° 55′ 45″N. Altitude: 700 m. The area is 25 m × 15 m on terraced field nearby. The springs was encircled by stone to become a pond. The diameter of pond is 2 m and the depth is 0.3 m. The main vent is located in the northeast corner. Its temperature is 59 °C. The total flux is 1 L/s. The main chemical compositions are as follows: *t* 59 °C, pH 8.62, TDS 0.856, Na 272, K 24.7, Ca 8.80, Mg 2.62, CO_3 18.7, HCO_3 553, SO_4 80.0, Cl 45.3, SiO_2 99.7. HCO_3–Na type.

Yh259, Xinjie hot spring is located in Yuanyang County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 102° 41′ 20″E, 23° 10′ 30″N. Altitude: 1220 m. The area is 300 m × 15 m along a rivulet elongation. The temperature of main vent is 78.5 °C and the others are about 60 °C. The total flux is 3 L/s. The main chemical compositions are as follows: *t* 78.5 °C, pH 8.48, TDS 0.350, Na 82.9, K 4.01, Ca 1.02, Mg 0.81, CO_3 6.24, HCO_3 131, SO_4 78.0, Cl 8.72, SiO_2 92.5. HCO_3–SO_4–Na type.

Yh260, Feixiangcun hot spring is located in Yuanyang County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 102° 42′ 00″E, 23° 09′ 20″N. Altitude: 960 m. The area stretches in south- north direction. The main vent is located the north end of the area. Its temperature is 52 °C, and the spa is used as men's bathing pond. A spring of 46 °C lie south of the main vent. The women's bathing pond (44 °C) is to the south of 46 °C spring. The total flux is 5 L/s. Country rock is gneiss. The main chemical compositions are as follows: *t* 52 °C, pH 8.52, TDS 0.387, Na 107, K 4.67, Ca 1.90, Mg 1.42, CO_3 9.36, HCO_3 130., SO_4 78.4, Cl 6.97, SiO_2 94.0. HCO_3–SO_4–Na type.

Yh261, Taoyuan hot spring is located in Yuanyang County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 102° 43′ 52″E, 23° 15′ 05″N. Altitude: 520 m. The hot water (51.5 °C) of main vent emerges out from the fracture of marble. The total flux is 1.4 L/s. The main chemical compositions are as follows: *t* 51.5 °C, pH 7.96, TDS 1.557, Na 254, K 22.3, Ca 166, Mg 30.5, CO_3 nd, HCO_3 228, SO_4 840, Cl 38.4, SiO_2 86.6. SO_4–Na–Ca type.

Yh262, Nanxing hot spring is located in Jinping County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 103° 01′ 35″E, 22° 32′ 00″N. Altitude: 480 m. The area is 20 m^2. The temperature of water is 50 °C and the flow rate is 3 L/s. Country rock is slate and sandstone carring limestone.

Yh263, Puer hot spring is located in Jinping County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 103° 02′ 30″E, 22° 39′ 10″N. Altitude: 440 m. The temperature of the main vent is 59 °C emerging in a rubber plantation. Country rock is granite. The total flux is 10 L/s. The main chemical compositions are as follows: *t* 59 °C, pH 8.62, TDS 0.423, Na 122, K 13.2, Ca 2.10, Mg 1.70, CO_3 12.5, HCO_3 260, SO_4 19.2, Cl 12.2, SiO_2 95.4. HCO_3–Na type.

Yh264, Shilicun hot spring is located in Jinping County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 103° 17′ 15″E, 22° 42′ 40″N. Altitude: 680 m. The hot spring is located in farmland. It is a closest discharge point inside 50 m^2. The temperature of hot water is about 70 °C discharging 1.5 L/s. The main chemical compositions are as follows: *t* 70 °C, pH na, TDS 0.541, Na 150, K 8.72, Ca 4.34, Mg 0.48, CO_3 nd, HCO_3 81.2, SO_4 212, Cl 8.02, SiO_2 108. SO_4–Na type.

Yh265, Dadipeng or **Xiaomadian** hot spring is located in Jinping County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 103° 21′ 40″E, 22° 59′ 20″N. Altitude: 380 m. The area is 200 m × 20 m along a highway. The temperature of hot water is 51 °C and the flow rate is 4 L/s. The main chemical compositions are as follows: *t* 51 °C, pH 8.34, TDS 1.074, Na 152, K 13.1, Ca 127, Mg 8.60, CO_3 nd, HCO_3 114, SO_4 580, Cl 12.2, SiO_2 116. SO_4–Na–Ca type.

Yh266, Malizhai or **Asizhai** hot spring is located in Jinping County of Honghe Hani and Yi Nationalities Autonomous Prefecture. 103° 25′ 35″E, 22° 55′ 50″N. Altitude: 280 m. It is located in riverside. The temperature of water is 60 °C discharging 4.6 L/s.

6.4 Hot Springs in Qinghai Province

There are more than 12 hot springs in Qinghai Province (Huang 1993).

Qh01 103 Highway maintenance squad, (91° 56′E/ 33° 26′N) 70 °C, 0.04 L/s, TDS 1.94 g/L, SO_4–Ca–Na type (at the North foot of Mt. Damgla)

Qh02 104 Highway maintenance squad, (Qinghai–Tibet Highway) (91° 56′E/ 33° 00′N) 65 °C, 5.0 L/s, TDS 2.51 g/L, HCO_3–SO_4–Ca–Mg type (at the North foot of Mt. Damgla)

Qh03 Nalonggou in Yequ of Batang District of Yushu County, (97° 17′ E/32331′N), 66 °C.

Qh04 Daqaidan, in Qaidam Basin, Golmud City, (95° 25′E/37° 55′N), There are 87–109 vents, 73.5 °C, 13.1 L/s, TDS 1.26 g/L. Cl–SO_4–Na (Zhang et al. 2005).

Qh05 Reshui, Dulan County, at southwest Qinghai Lake, (98° 45′E/36° 01′N), 82 °C, granite

Qh06 Wulongtuo, Dulan County, at southwest Qinghai Lake, (98° 48′E/36° 24′N), 69 °C. Granite.

Qh07 Zacansi, Guide County at southeast of Qinghai Lake, (101° 30′E/35° 58′N), altitude: 2497 m, 14 vents, 78–93 °C, 15.20 L/s, TDS 1.13 g/L. Cl–SO_4–Na. SiO2 93.39, the Mesozoic Granite and the Triassic sandstone and limestone (Zhao et al. 2005).

Qh08 Qunaihai, Guide County at southeast of Qinghai Lake, 30vents, (101° 14′E/36° 05′N), 88.5 °C, 5 L/s, TDS 1.97 g/L, Cl-Na, Travertine.

Qh09 Qulanggou of Xinghai County, in south of Qinghai Lake, (99° 30′ E/35° 24′N), 57 °C, 22.579 L/s, TDS 1.0 g/L. SO_4–Cl–Na.

Qh10 Lancaihe, Tongren County, in south bank of Yellow River, (101° 48′ E/35° 35′N), 69 °C granite.

Qh11 Ganzihe, Haiyan County at northeast of Qinghai Lake, (101° 45′E/37° 15′N), 8 vents, 57 °C, 11 L/s, 0.72 g/L, HCO_3–Na.

Qh12 Baohutu,, Haiyan County at northeast of Qinghai Lake, (100° 55′ E/37° 18′N), 55 °C.

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Chapter 7
Warm Springs and Tepid Springs in the Southwest China

Abstract This chapter will briefly introduce warm springs and tepid springs in research area by making use of tabulation. The items in table will show serial number, spa's name, county, longitude and latitude, altitude, spa's temperature, the SiO_2 content and TDS values of spa's water, and type of water. The table is marked "SiO_2 concentration" that can distinguish type of hydrothermal convective system. The chemical content of some low-temperature springs is similar to that of high-temperature system. The analysis results of its water sample will be fully revealed.

Keywords Serial number · Spa's temperature · SiO_2 concentration · TDS value

This chapter will be different from the fifth and sixth chapters of boiling springs and hot springs and will do great detail in the introduction of warm springs and tepid spring in southwest China. Because of the relatively low temperatures of warm springs and tepid springs, their energy value may be relatively low, and their chemical composition are also significantly different from the boiling springs and hot springs, so their process of formation, storage, and migration under ground also differs from boiling and hot springs. Of course, some tepid springs or warm springs are exceptions. Their chemical compositions are very special, they merits particular interest.

7.1 Warm Springs and Tepid Springs in Tibet Autonomous Region

In book "Thermal Springs in Tibet" (Tong et al. 2000), the number of warm springs (36–45 °C) in the Tibet Autonomous Region is 295. But in fact only 290. The reason is that three warm springs in Zhongba County are actually boiling springs, a warm spring in Bangoin County is actually a hot springs, and a warm spring in Qamdo County should be a tepid spring.

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The number of tepid springs (35–5 °C) in Tibet Autonomous Region is 126, including 73 microthermal spring (35–21 °C) and 35 tepid springs (20–5 °C).

Quite frankly, the accuracy in the number of low-temperature thermal springs in this book is not very high, because of the lack of on-the-spot investigation. Many warm springs are short of most fundamental temperature data and are only in the light of comments of local herdsman or officials, or the mark of "warm" on topographic map.

In terms of the number of warm and tepid springs in different prefecture: In the first place is the Nagqu Prefecture with warm 98 springs and 36 Tepid springs, and the sum is 134; in the second place is the Qamdo Prefecture with 64 warm springs, and 35 tepid-springs, and the sum is 99; in the third is the Xigaze Prefecture with the sum of 62, and the fourth Ngari Prefecture with the sum of 59. Such a distribution pattern depends on a number of geology–geography factors. The first two prefectures are located in northern Tibet and Tibetan east, away from the Yarlung Zangbo suture, mainly low-temperature warm springs and tepid springs, basically no boiling springs (Nagqu's two boiling springs are located on the most southern part). The latter two prefectures have the vast in territory, Yarlung Zangbo suture pass through these regions. Both the high-temperature and low-temperature thermal springs coexist.

In terms of the number of warm springs, in the first place is Gerze County of Ngari Prefecture, which has 17. Amdo County of the Nagqu Prefecture has 16 and is in the second place. The following counties have number of warm spring reaching 10: Zhongba County of Xigaze Prefecture (10). Nagqu County of Nagqu Prefecture (14), Shuanghu Special District of Nagqu Prefecture (11), Cona County of Shannan Prefecture (10), Bome County of Nyingchi Prefecture (11), and Mangkam County (13) and Baxoi County (10) of Qamdo Prefecture.

From Table 4.1, we can see that the whole territory of the Tibet Autonomous Region has 645 thermal springs, including 48 boiling springs and 179 hot springs, 291 warm springs, and 127 tepid springs. In other words: there are 227 over 46 °C hot and boiling springs, accounting for 35% of the total thermal spring; while the total number of warm and tepid springs below 45 °C are 417, accounting for 65% of the total number of thermal springs. The water chemistry data of thermal springs is from the book "Thermal Springs in Tibet", which offered a set of 310 water chemistry data for 310 thermal springs. In these data, 227 hot and boiling springs have 180 parts. In other words, for more than 80% of the boiling and hot springs we have ever been to the field for inspection and water sampling and managed to do a chemical analysis of the water samples. Nevertheless, 20% springs have not been visited, or due to some special circumstantial reasons no temperature measurements and sampling were done, or but the water samples were damaged or lost in transit.

That is, in these 310 sets of water samples, only 83 sets are extracted from 417 warm and tepid springs. Therefore, we can certainly say that the geothermal inspection process, only 31% of the low temperature of thermal springs got too patronizing. Because there is too vast area, too difficult road, too tight time, to go to every spas, only to have a choice. From the statistical data, there are 48 boiling springs, and only eight have no water samples (two of them are actually lost during transit); there are 179 hot springs, 37 of which have no water samples; 290 warm springs, 243 no water samples; 127 tepid springs, 51 no water samples. Percentage of lack of water samples are 16 and 20%. 84 and 40% for boiling, hot, warm and tepid springs, respectively.

In Nagqu Prefecture, for example, there are 97 hot springs, only 13 water samples. 84 hot springs without water samples. Specifically, Nyima County 19 warm springs, only four investigated, none of the eight warm springs in Bangoin County have been visited, none of 15 warm springs in Amdo County have been visited; Only one in 14 warm springs. of Nagqu County have been visited. The Gêrzê County of Ngari Prefecture is located in the core area of northern Tibet Plateau, that has 17 warm springs, and only one has ever been visited. These areas are the depopulated zone too high altitude, severely lack oxygen. Qamdo Prefecture is another situation. It is located in three rivers (Nu river, Lancang river, and Jinsha river) valleys and the Hengduan Mountains, with complex topography and roads difficult, and pressing time to force many low-temperature springs to give up.

In the book "The Thermal Springs in Tibet", there are chemical analysis data of 130 sets for warm springs and tepid springs (Tong et al. 2000), in which there are 50 sets for warm springs and 80 sets for tepid springs (Tables 7.1 and 7.2).

Chemical composition of low-temperature thermal spring water is significantly different from the hot and boiling springs, mainly in reducing chloride ion contents and increased calcium and magnesium ions contents. The most chemical type of warm springs water is HCO_3–Na type (12 sets), followed by HCO_3–SO_4 type or SO_4–HCO_3 type (12 sets), HCO_3–Na–Ca type or HCO_3–Ca–Na type (7 sets), as well as HCO_3–Cl–Na or Cl–HCO_3–Na type (6 sets). In addition, a few springs are of Cl–Na type, Cl–HCO_3–SO_4–Na type, and HCO_3–Mg–Ca type. For example, the chemical compositions of Langdoi or Lopu warm spring of Xainza County (Tw 38 in Table 7.1) are as follows: t 35.5 °C, pH 6.5, TDS 3.28, Na 980, K 98.0, Ca 33.2, Mg 658, HCO_3 1870, SO_4 441, Cl 532, SiO_2 186, HBO_2 53.10, As 1.64. HCO_3–Cl–Na type of water. The water chemistry type of this warm spring is not different from those of many boiling springs. The calculated temperature value calculated by silica geothermometer 175 °C, and it should belong to the high-temperature geothermal systems.

The chemical type of tepid springs are mainly HCO_3–Ca and HCO3–Ca–Mg (each 13 sets). HCO_3–Na type has nine sets, and the temperatures of most of them are around 30 °C.

Only one Cl–HCO_3–Na type appears in Kabusang Xiushui, (smelly water) of Nedong County of Shannan Prefecture (Tt80 in Table 7.2). The water is coming out from the metamorphic sandstone. The temperature of water is only 14 °C and the flow rate is only 0.01 L/s, but water stinks so much that you can smell it when you are only passing by. It is well-known throughout the Nedong County and even Lhunze County nearby. Its water chemistry type is similar to those in

Table 7.1 The schedule of expeditionary warm springs (36–45 °C) in Tibet

No. Tw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
01	Quzhain Regong	Rutog	80° 33′ 45″	34° 33′ 40″	5200	42	32.7	0.84	HCO_3·Cl–Na–Ca
02	Xang Qu	Ge'gyai	81° 53′ 48″	32° 05′ 12″	4580	37.3	60	1.53	HCO_3–Na
03	Zameirua	Gerze	84° 44′ 00″	33° 03′ 24″	4800	40			
04	Qiusongmadango	Gerze	84° 51′ 30″	33° 12′ 30″	4780	40			
05	Dongco	Gerze	84° 52′ 00″	32° 15′ 00″	4600	40			
06	Xagang-jam	Gerze	85° 00′ 45″	31° 46′ 00″	4500	40	58.9	0.81	HCO_3–Na·Ca
07	Xungba	Ngamring	87° 04′ 40″	29° 47′ 40″	4880	43	60.	0.62	Cl–HCO_3–Na
08	Seluo	Ngamring	87° 09′ 15″	29° 06′ 45″	4150	40	32.2	1.38	HCO_3–Ca–Na
09	Ca	Ngamring	87° 11′ 33″	29° 07′ 06″	4100	44.5	57.8	1.56	HCO_3–Na–Ca
10	Camda	Tingri	86° 29′ 00″	28° 36′ 00″	4400	45	75.2	1.46	HCO_3–Na–Ca
11	Qoilung	Lhaze	87° 51′ 52″	29° 29′ 08″	4270	40			
12	Daqen	Xaitongmoin	87° 48′ 14″	29° 41′ 40″	4960	40			
13	Bazando	Xaitongmoin	88° 39′ 30″	30° 04′ 44″	5020	39.3	70.8	0.83	HCO_3–Na
14	Laga	Xaitongmoin	88° 37′ 30″	29° 40′ 00″	4160	43	51.8	0.63	CO_3–Na
15	Qucaingang	Sa'gya	88° 23′ 25″	28° 55′ 30″	4066	37	81.5	3.28	Cl–HCO_3–Na
16	Zexong	Namling	88° 02′ 20″	29° 51′ 08″	4400	40	28.0	2.84	Cl–HCO_3–Na
17	Salagang	Gyangze	89° 54′ 00″	28° 48′ 00″	4400	40	70.0	0.71	HCO_3–Na
18	Cierdai	Kangmar	89° 14′ 13″	28° 27′ 49″	4750	42.5	33.8	2.77	HCO_3–Cl–Na
19	Chechexiama	Damxung	90° 40′ 40″	30° 35′ 05″	4550	45	63.0	1.16	HCO_3–SO_4–Na
20	Sambasar	Damxung	90° 32′ 00″	30° 07′ 20″	4330	39	56.3	1.54	HCO_3–Cl–Na
21	Wujian	Nyemo	90° 15′ 25″	29° 29′ 35″	4000	43	49.3	0.58	Cl–HCO_3–SO_4–Na
22	Qiabunie	Nyemo	90° 10′ 40″	29° 23′ 55″	3700	42	32.0	0.40	SO_4–Cl–Na

(continued)

Table 7.1 (continued)

No. Tw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
23	Qubsang	Doilungdeqen	90° 45′ 30″	30° 10′ 30″	4290	43	80.1	0.93	HCO_3–Cl–Na–Ca
24	Dujiu	Maizhokunggar	92° 15′ 40″	29° 41′ 10″	4380	36	29.6	1.80	HCO_3–Cl–Na
25	Darngo Congoin	Nyima	88° 42′ 40″	33° 39′ 32″	5070	40	na	3.43	Cl–Na
26	Darngoco	Nyima	88° 45′ 40″	33° 37′ 25″	5000	40			
27	Normaco	Nyima	87° 59′ 15″	32° 19′ 05″	4698	45	na	2.65	HCO_3–Na
28	Marpuqusa	Nyima	88° 36′ 45″	32° 31′ 55″	4752	40			
29	Dogco-3	Shuanghu	89° 01′ 05″	34° 18′ 40″	4880	39			
30	Dogco-4	Shuanghu	89° 03′ 25″	34° 18′ 30″	4940	39			
31	Yuanquan	Shuanghu	89° 03′ 15″	34° 14′ 05″	4950	39.5	18.0	3.60	Cl–Na
32	E. Dogco	Shuanghu	89° 15′ 00″	34° 13′ 30″	5020	39			
33	EE. Dogc	Shuanghu	89° 17′ 30″	34° 12′ 30″	5080	39			
34	Luzong Lhai	Shuanghu	89° 12′ 42″	32° 38′ 10″	4880	40			
35	Goigoin	Shuanghu	89° 09′ 05″	32° 23′ 10″	4675	40?			
36	Caqubarg	Shuanghu	89° 47′ 25″	32° 26′ 25″	4700	35.5	32.7	1.17	HCO_3–Na
37	Qixianco	Shuanghu	89° 56′ 00″	32° 23′ 36″	4660	40			
38	Cholo	Xainza	88° 12′ 50″	30° 49′ 15″	4755	37	60	1.33	HCO_3–Na
39	Xiru	Xainza	88° 47′ 43″	30° 47′ 04″	4695	43	186	3.28	HCO_3–Cl–Na
40	Musihl	Xainza	88° 37′ 17″	30° 32′ 08″	4840	40?			
41	Lhoma	Nagqu	91° 52′ 15″	31° 17′ 55″	4480	42	52.9	1.65	HCO_3–Na
42	Xeqen	Nyainrong	92° 47′ 45″	32° 14′ 40″	4730	42	60	2.32	HCO_3–Na
43	Caquka	Jiali	93° 33′ 00″	30° 50′ 00″	?	42			
44	Caqugolo	Biru	93° 23′ 45″	31° 32′ 00″	4050	40			

(continued)

Table 7.1 (continued)

No. Tw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
45	Garlong	Biru	93° 30′ 33″	31° 29′ 00″	4035	43	104	1.99	HCO_3–Na
46	Ngolung	Sog Xian	93° 46′ 46″	31° 49′ 50″	3970	37	41.5	1.34	HCO_3–SO_4–Na–Ca
47	Quren	Baqen	93° 42′ 10″	32° 29′ 06″	4710	42			
48	Regqen	Baqen	93° 38′ 00″	32° 12′ 40″	4280	45			
49	Doponggai	Baqen	93° 36′ 20″	32° 09′ 10″	4180	38	49.1	3.17	SO_4–HCO_3–Ca–Na
50	Xieduo	Baqen	94° 37′ 30″	32° 30′ 00″	4660	40	54.6	5.01	Cl–HCO_3–Na–Mg
51	Lincun	Nagarze	90° 33′ 20″	28° 43′ 20″	4620	40			
52	Kadong Quzhou	Cona	91° 56′ 36″	28° 00′ 56″	4340	39	40.6	0.49	SO_4–HCO_3–Na
53	Legbu	Cona	91° 46′ 40″	27° 51′ 45″	2300	42			
54	Lai	Cona	91° 45′ 10″	27° 51′ 45″	2100	42			
55	Kada	Cona	92° 22′ 00″	28° 01′ 30″	4700	40			
56	Sumdo	Gongbo'gyamda	92° 29′ 17″	29° 53′ 45″	4200	43	35	0.59	HCO_3–Na
57	Qepab	Gongbo'gyamda	93° 20′ 40″	29° 44′ 03″	3660	43			
58	Godeng 2	Medog	95° 16′ 50″	29° 45′ 12″	1600	37	na	1.06	SO_4–HCO_3–Ca–Mg
59	Badengze	Medog	95° 10′ 16″	29° 17′ 16″	2600	>42			
60	Papa	Bome	95° 03′ 00″	30° 10′ 30″	2200	41.6	120	1.66	HCO_3–SO_4–Mg–Na
61	Qoizong Lungba-2	Bome	95° 12′ 00″	30° 02′ 00″	2550	40			
62	Na'oi Lungbadi	Bome	96° 12′ 10″	29° 50′ 30″	3900	41.8	nd	0.55	HCO_3–SO_4–Ca–Mg
63	Midoi	Bome	96° 31′ 10″	29° 33′ 30″	3900	39.5	nd	0.32	SO_4–HCO_3–Na
64	Gadag	Zayu	97° 46′ 00″	28° 34′ 00″	3700	>40			
65	Quzhu	Zayu	98° 14′ 30″	28° 25′ 00″	1750	45			
66	Lungring	Zayu	97° 44′ 30″	29° 05′ 15″	4200	>40			

(continued)

Table 7.1 (continued)

No. Tw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
67	Samxig	Dengqen	95° 03′ 40″	31° 39′ 20″	3770	37	21.5	0.80	HCO_3–Na–Mg
68	Mangdak	Dengqen	95° 03′ 40″	31° 38′ 20″	3760	37.1			
69	Chalaen	Dengqen	95° 35′ 10″	31° 31′ 40″	4100	44.3	nd	0.68	HCO_3–Ca
70	Ebolung	Dengqen	95° 37′ 00″	31° 29′ 20″	4100	41.2			
71	Qunkaka	Dengqen	95° 38′ 30″	31° 29′ 10″	4050	42.6	23.6	0.33	HCO_3–SO_4·Mg–Ca
72	Xongzong	Lhorong	96° 21′ 30″	30° 52′ 00″	4100	45			
73	Qukoido	Riwoqe	96° 34′ 00″	31° 34′ 50″	3900	41.6	32.2	2.32	HCO_3–MgCa
74	Guro	Qamdo	96° 46′ 30″	31° 58′ 00″	3700	45			
75	La'og	Qamdo	96° 53′ 10″	31° 58′ 30″	3650	45			
76	Jongne	Baxoi	96° 51′ 10″	30° 42′ 20″	4380	45			
77	Medog	Baxoi	96° 31′ 10″	30° 31′ 00″	3800	42			
78	Nyige	Baxoi	97° 05′ 30″	30° 34′ 40″	4300	37.5			
79	Wape	Baxoi	96° 47′ 50″	30° 02′ 15″	3500	42.5	62.2	1.85	HCO_3–Na
80	Xaiba	Chagyab	97° 21′ 50″	30° 37′ 30″	4200	40			
81	Moba	Chagyab	97° 43′ 30″	30° 34′ 40″	3400	40	70.9	1.74	HCO_3–Na
82	Sala	Zogang	97° 27′ 00″	29° 51′ 30″	3400	37.5	32.7	0.33	HCO_3–MgCa
83	Chagdun	Zogang	98° 02′ 00″	29° 19′ 00″	3600	36.2	38.1	0.33	HCO_3–Na–Ca
84	Canyaiqu	Jomda	98° 10′ 20″	31° 31′ 20″	4000	42	38.6	1.56	SO_4–Ca
85	Zhiba	Markam	98° 35′ 00″	30° 16′ 35″	3900	45			
86	Qunta	Markam	98° 35′ 00″	30° 03′ 00″	4000	45			
87	Xoi qu	Markam	98° 58′ 00″	29° 45′ 20″	2400	40.6	100	1.99	HCO_3–Na
88	3-H	Markam	98° 52′ 00″	29° 42′ 30″	2880	42			

(continued)

Table 7.1 (continued)

No. Tw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
89	Buko	Markam	98° 06′ 00″	29° 24′ 30″	3450	42			
90	Lebbegang	Markam	98° 39′ 30″	29° 12′ 45″	3450	37	32.7	0.85	HCO_3–SO_4–Ca–Na
91	Yanjing	Markam	98° 35′ 30″	29° 03′ 00″	2300	41.4	51.4	30.7	Cl–Na
92	Ringda	Markam	98° 39′ 00″	28° 53′ 00″	2100	42	54.6	2.71	SO_4–Cl–Ca–Na

Table 7.2 The schedule of expeditionary tepid springs (5–35 °C) in Tibet

No. Tt	Name of tepid springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
01	Qumig Co	Rutog	80° 08′ 58″	34° 44′ 50″	5130	3	4.50	0.26	HCO_3–SO_4–Mg–Ca
02	Lum Co	Rutog	80° 20′ 20″	34° 35′ 55″	4880	8	na	0.60	Cl·HCO_3·SO_4–Mg–Na–Ca
03	Ringsug Ri	Rutog	80° 18′ 45″	33° 45′ 48″	4425	7			
04	Qiugajiang	Rutog	80° 27′ 20″	33° 40′ 45″	4450	21.5	32.7	0.313	HCO_3–Ca–Mg
05	Risum Qiao	Rutog	79° 50′ 00″	33° 10′ 00″	4330	8	17.12	0.26	HCO_3–Ca–Mg
06	W. Kun-Lun V.	Rutog	80° 53′ 20″	35° 08′ 11″	5500	25			
07	Gozha Co	Rutog	81° 22′ 00″	35° 04′ 00″	5190	4	na	1.93	Cl–Na
08	Zapug	Rutog	80° 48′ 36″	33° 18′ 24″	4334	18	16.4	0.39	HCO_3–Ca–Mg
09	Langma	Gar	79° 50′ 00″	32° 28′ 00″	4260	19			
10	Qiu	Gar	79° 53′ 00″	32° 14′ 48″	4700	35	43.7	0.264	HCO_3–SO_4–Na–Ca
11	Yarqen Qu	Gar	80° 56′ 00″	31° 11′ 00″	4900	13			
12	Lagar	Zanda	79° 32′ 00″	31° 44′ 00″	4100	7	76.4	4.79	HCO_3–Cl–Na
13	Jinzhu	Zanda	80° 08′ 24″	31° 06′ 46″	4000	30	32.7	0.443	HCO_3–Na
14	Zeerjun-naha	Zanda	80° 31′ 00″	31° 02′ 48″	4200	30	19.6	0.97	HCO_3–Ca–Na–Mg
15	E.Kyunglung	Zanda	80° 34′ 05″	31° 03′ 30″	4317	18	16.4	0.662	HCO_3–Mg–Ca–Na
16	Zhale	Ge'gyai	81° 22′ 30″	32° 05′ 12″	5156	20	43.7	0.455	SO_4–Cl–HCO_3–Na
17	Chagcam	Ge'gyai	82° 31′ 00″	32° 33′ 00″	4400	15	8.6	0.224	HCO_3–SO_4–Ca–Mg–Na
18	Yazihu	Gerze	82° 31′ 00″	34° 43′ 00″	5260	13	10	0.878	HCO_3–Na
19	Chabug	Gerze	83° 18′ 20″	32° 07′ 00″	4548	21	15.45	0.505	HCO_3–CaMg
20	Marme	Gerze	83° 40′ 12″	32° 05′ 00″	4390	25	24	0.754	HCO_3–SO_4–Ca
21	Kangtog	Gerze	84° 13′ 24″	33° 35′ 30″	4690	8	14.2	0.544	HCO_3–Ca
22	Yubzha	Gerze	84° 26′ 48″	32° 38′ 18″	4740	11	16.4	0.526	HCO_3–CaNa

(continued)

Table 7.2 (continued)

No. Tt	Name of tepid springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
23	Chabyer Caka	Zhongba	83° 02′ 10″	31° 22′ 00″	4800	16	na	1.99	HCO_3–Na–Ca
24	Chogmar	Gyirong	85° 19′ 54″	28° 54′ 40″	4340	33	37.8	3.04	HCO_3–SO_4–Na–Ca
25	Adan	Nyalam	86° 06′ 33″	28° 22′ 55″	4360	11	5.5	0.32	HCO_3–CaMg
26	Numigang	Ngamring	86° 36′ 40″	29° 10′ 05″	4400	23			
27	Ganggar	Tingri	86° 38′ 00″	28° 34′ 00″	4200	8.2			
28	Zilung	Lhaze	88° 10′ 30″	29° 11′ 45″	4000	20.2			
29	Yangxung	Namling	89° 06′ 20″	29° 58′ 25″	4800	35	74.7	1.09	HCO_3–Cl–Na–Ca
30	Lhabu	Namling	89° 21′ 30″	29° 43′ 07″	4250	11	9.2	0.18	HCO_3–Ca
31	Chagar	Namling	89° 37′ 00″	29° 32′ 43″	4300	26	60.2	2.07	HCO_3–Na
32	Chadang	Kangmar	89° 37′ 44″	28° 42′ 00″	4300	18.5	23.5	0.70	HCO_3–CaNa
33	Zebuduoduo	Kangmar	89° 40′ 12″	28° 42′ 00″	4300	34.5	45	1.77	HCO_3–Cl–Na–Ca
34	Doqen	Yadong	89° 18′ 33″	28° 06′ 00″	4400	13.7	27.7	1.69	HCO_3–Na–Mg–Ca
35	Quni	Yadong	88° 55′ 45″	27° 25′ 38″	2600	13.5			
36	Qumado	Damxung	91° 11′ 30″	30° 35′ 05″	4550	24			
37	Xungba-laqu	Doilungdoqen	90° 56′ 10″	29° 38′ 45″	3680	16.5	20.1	0.137	HCO_3–Ca
38	Donggar-Sangmo	Doilungdoqen	91° 01′ 50″	29° 39′ 10″	3760	12.6	28.5	0.193	HCO_3–Ca
39	Sanyipu	Lhasa	91° 11′ 30″	29° 43′ 00″	4080	22.5	14.5	0.116	HCO_3–Ca
40	Tayu	Lhunzhub	91° 08′ 30″	30° 00′ 24″	3945	21.5	14.8	0.15	HCO_3–Ca
41	Chana	Lhunzhub	91° 22′ 30″	29° 58′ 50″	4100	19.5	15.3	0.27	HCO_3–Ca
42	Quguogan	Maizhokunggar	91° 45′ 35″	29° 51′ 50″	3825	24	12.5	0.493	HCO_3–Ca
43	Muztag	Nyima	87° 09′ 20″	36° 16′ 22″	5250	8			
44	Mani	Nyima	87° 07′ 15″	34° 45′ 24″	4940	0			

(continued)

Table 7.2 (continued)

No. Tt	Name of tepid springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
45	Co Nyi	Nyima	87° 18′ 00″	34° 34′ 00″	4920	17.8	7.64	0.785	HCO_3–Na
46	Jagroi	Nyima	87° 01′ 00″	33° 37′ 00″	4940	7.7	14.2	1.90	Cl–SO_4–Na–Mg
47	Naroyi	Nyima	87° 19′ 34″	33° 43′ 38″	5130	15.2	8.7	1.20	SO_4–Ca–Mg
48	Amu Co	Nyima	83° 43′ 42″	33° 25′ 05″	5000	15	27.3	2.63	SO_4–Mg–Na
49	Xo Caka	Nyima	87° 47′ 17″	33° 02′ 15″	4800	18	0.5		
50	Boidoi Co	Nyima	87° 52′ 00″	32° 52′ 00″	4820	26	na	0.307	HCO_3–Na–Ca
51	AndarCo	Shuanghu	89° 34′ 20″	32° 57′ 40″	4990	30	na	1.076	Cl–HCO_3–Na
52	Sewa	Shuanghu	89° 51′ 30″	32° 26′ 50″	4650	27	38.2	4.05	HCO_3–Na
53	Sokalem	Shuanghu	88° 55′ 26″	33° 05′ 27″	4900	2			
54	Jianmaluqi	Shuanghu	89° 03′ 16″	33° 07′ 05″	4900	2.75			
55	Doiding	Shuanghu				35			
56	Xainza	Xainza	88° 42′ 15″	30° 56′ 08″	4650	8.5	4.28	0.18	HCO_3–CaMg
57	Lunglin	Amdo	91° 10′ 00″	31° 48′ 35″	4570	32	64.3	1.627	HCO_3–Na
58	Konmaqiequ	Amdo	91° 35′ 00″	32° 57′ 00″	5050	10			
59	Chaqu	Amdo	91° 32′ 00″	31° 45′ 30″	4960	28			
60	4 daoban	Amdo	91° 28′ 55″	32° 37′ 25″	4850	30			
61	115 DB	Amdo	91° 44′ 40″	32° 24′ 00″	4790	11	13.8	1.23	HCO_3–Ca
62	125DB	Amdo	91° 51′ 25″	31° 41′ 25″	4610	31	50.9	2.08	HCO_3–NaCa
63	Mainqukug	Nagqu	91° 37′ 00″	31° 03′ 35″	4730	30.8	31.1	0.67	HCO_3–SO_4–Na
64	Nyainrong	Nyainrong	92° 17′ 40″	32° 07′ 00″	4600	12	32.7	0.29	HCO_3–NaCa
65	Yangbing	Nyainrong	92° 39′ 30″	32° 17′ 30″	4640	31.5	60	3.80	HCO_3–Na
66	Tang Ri	Nyainrong	92° 53′ 35″	32° 22′ 55″	4700	25	30.6	1.53	HCO_3–SO_4–Mg–Ca

(continued)

Table 7.2 (continued)

No. Tt	Name of tepid springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
67	Chalung	Nyainrong	92° 45′ 00″	32° 14′ 00″	4560	15	30.6	0.45	HCO_3–Ca
68	Chugyog	Jiali	92° 25′ 20″	30° 27′ 00″	4580	9			
69	Abqung	Jiali	92° 16′ 10″	30° 46′ 30″	4500	33	32.7	2.16	SO_4–HCO_3–Ca
70	Cegang	Baqen	94° 15′ 12″	32° 09′ 28″	4480	22	9.8	0.47	HCO_3–Ca–Mg
71	Jangmai	Baqen	94° 11′ 35″	32° 04′ 20″	4410	9.5			
72	Waqen Lung	Baqen	94° 11′ 30″	31° 54′ 20″	4400	34			
73	Darrutang	Baqen	94° 16′ 50″	31° 54′ 40″	4450	32			
74	Kungmo-cang Lung	Baqen	94° 26′ 05″	31° 56′ 30″	4320	34	16.4	1.07	SO_4–HCO_3–Ca–Mg–Na
75	Kyung-cangna	Baqen	94° 29′ 35″	31° 50′ 45″	4280	21.5	19.6	0.22	HCO_3–Ca
76	Zinba	Nagarze	90° 31′ 00″	28° 55′ 00″	4470	30			
77	Sana	Konggar	90° 49′ 06″	29° 16′ 50″	3600	16	16.0	0.12	CO_3–SO_4–Ca
78	Kabusang Xiushui	Nedong	91° 57′ 00″	28° 53′ 25″	4280	14	150	3.118	Cl–HCO_3–Na
79	Woka	Sangri	92° 12′ 40″	29° 14′ 50″	3522	13.3	38.0	0.171	HCO_3–Ca–Mg
80	Dengba	Comai	91° 12′ 00″	28° 14′ 10″	3480	25			
81	Comai	Comai	91° 25′ 45″	28° 28′ 40″	4400	14	29.5	3.67	HCO_3–Cl–Na
82	Nam	Mainling	94° 58′ 30″	29° 35′ 18″	2950	35	32.5		
83	Kogdem-3	Medog	95° 16′ 35″	29° 45′ 18″	1900	18	na	0.35	HCO_3–SO_4–Ca–Mg
84	Bengxing	Medog	95° 23′ 20″	29° 38′ 35″	1050	35	na	0.20	SO_4–HCO_3–Ca
85	Yiong	Bome	94° 47′ 00″	30° 16′ 00″	2300	29.5	36.0	0.561	HCO_3–SO_4–Ca–Mg
86	Bai	Bome	94° 53′ 10″	30° 12′ 50″	2200	31			

(continued)

Table 7.2 (continued)

No. Tt	Name of tepid springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
87	Gyazong	Bome	94° 58′ 50″	30° 10′ 10″	2150	18.5	76.4	0.548	HCO_3–Ca
88	Benjue	Dengqen	95° 21′ 40″	31° 28′ 30″	4450	34.6	nd	0.358	HCO_3–Ca–Mg
89	Dotongka	Dengqen	95° 47′ 00″	31° 25′ 30″	4100	25	19.6	0.363	HCO_3–Ca–Mg
90	Rakyan-Wakog	Dengqen	95° 44′ 00″	31° 19′ 30″	3700	17	2.15	0.695	Cl–HCO_3–Mg–Ca
91	Kadoi	Dengqen	95° 56′ 00″	31° 16′ 00″	3950	28.1	27.3	0.507	HCO_3–Mg–Ca
92	Garruka-lung	Dengqen	95° 57′ 50″	31° 15′ 30″	3950	33	32.7	0.798	HCO_3–Mg–Ca
93	Romtang	Dengqen	96° 00′ 58″	31° 12′ 58″	3750	19	24.0	1.13	HCO_3–Mg–Ca
94	Gurgyugtang	Lhorong	96° 08′ 30″	30° 46′ 50″	3900	21	49.1	0.82	HCO_3–Ca–Mg
95	Buxoi	Lhorong	96° 28′ 00″	30° 54′ 00″	4000	16.5			
96	Lanyibar	Riwoqe	96° 22′ 00″	31° 05′ 40″	4200	18.5	27.3	1.03	HCO_3–Ca–Mg
97	Quniger	Riwoqe	96° 28′ 00″	31° 12′ 20″	4100	20	30.6	0.90	HCO_3–Mg–Ca
98	Naiza	Riwoqe	96° 33′ 20″	31° 23′ 40″	4200	23.2	19.7	2.28	SO_4–Ca–Mg
99	Penda	Riwoqe	96° 46′ 20″	31° 07′ 40″	3400	17	60	0.79	Cl–SO_4–Ca–Na–Mg
100	Zerenka	Qamdo	97° 06′ 18″	31° 48′ 45″	4000	19	19.6	0.197	HCO_3–Ca–Mg
101	Yorda	Qamdo	97° 00′ 30″	31° 44′ 30″	3700	26.5	27.3	0.288	HCO_3–SO_4–Ca
102	Coinzha-ma	Qamdo	97° 06′ 20″	31° 24′ 00″	4300	27	27.3	0.756	SO_4–HCO_3–Ca–Mg
103	Danlung	Qamdo	97° 09′ 15″	31° 20′ 45″	3900	27.5			
104	Qamdo Mucang	Qamdo	97° 35′ 00″	31° 25′ 10″	4000	16	18.6	0.205	HCO_3–Ca–Mg
105	Wulung	Qamdo	97° 32′ 00″	31° 21′ 00″	3850	20	8.57	0.972	SO_4–HCO_3–Ca
106	Chexoinang	Qamdo	97° 11′ 40″	31° 04′ 00″	3400	26	30.6	3.16	SO_4–Ca–Mg
107	Jigang	Qamdo	97° 11′ 50″	31° 02′ 30″	3500	18.2			
108	Gizhong	Baxoi	97° 13′ 00″	30° 21′ 00″	4260	25			

(continued)

Table 7.2 (continued)

No. Tt	Name of tepid springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
109	Zekug	Baxoi	97° 11′ 00″	30° 18′ 30″	4200	31			
110	Xudoi	Chagyab	97° 15′ 00″	30° 38′ 20″	4200	29.5			
111	Quchoi-wa	Chagyab	97° 40′ 30″	30° 46′ 45″	3650	31	32.7	2.15	SO_4–Ca–Mg
112	Soben	Chagyab	97° 41′ 10″	30° 41′ 25″	3400	12			
113	Shang Bangzo	Zogang	97° 27′ 05″	29° 51′ 30″	3250	33.5			
114	Xia Bangzo	Zogang	97° 27′ 10″	29° 51′ 32″	3100	33			
115	Qacha-gang	Markam	98° 36′ 20″	29° 39′ 20″	3850	19	60	0.981	HCO_3–Na–Ca

high-temperature geothermal fields. And the analysis results are as follows. pH 6.5, TDS 3.118, Na 715, K 141, Ca 125, Mg 26, Li 19.3, Rb 3.12, Cs 17.8, CO_3 nd, HCO_3 1153, SO_4 60.8, Cl 886, F 2.08, SiO_2 150, HBO_2 385, As 0.045, H_2S 0.52. Cl–HCO_3–Na type of water.

Another special spa is Laga tepid spring of Zanda County of Ngari Prefecture, which is located in dry riverbed. 79° 32′E, 31° 44′N, Altitude: 4100 m. The temperature is only 7 °C and flow rate is 2 L/s. There is brown precipitate. I have ever been there on August 9 1976. The analysis results of water sample are as follows: pH 6.5, TDS 4.79, Na 1300, K 56, Ca 57.9, Mg 144.3, Li 5.9, Rb 0.1, Cs 0.1, CO_3 nd, HCO_3 2060, SO_4 nd, Cl 1120, F 0.12, SiO_2 76.4, HBO_2 789, As nd. HCO_3–Cl Na type of water. This is a rare spring by its chemical compositions.

Based on the above-mentioned examples of three low-temperature thermal springs, we think that silica concentration in thermal water is very important. In general, silica concentration is determined by the equilibrium solubility of quartz and so is function of the temperature of the geothermal brine in the reservoir. Mahon (1966) showed that the silica concentrations in waters from geothermal wells in New Zealand are controlled by the solubility of quartz. Fournier (1981) pointed out that the equations commonly used to describe the solubility of quartz at the vapor pressure of the solution are good to about ±2 °C over the temperature range 0° to 250 °C. If we make full use of silica geothermometers (quartz-no steam less) to calculate the subsurface temperature of thermal springs in research region, we can roughly understand the general situation of energy of hydrothermal convection system over there. When we use above-mentioned quartz geothermometer to find that SiO_2 value is 38.5 mg/L, the reservoir temperature could be 90 °C, and the SiO_2 value is 125 mg/L, the reservoir temperature could be 150 °C. Thus we can decide the nature of thermal springs. Therefore, I shall reveal the silica values of both warm and tepid springs of Tibet, west Sichuan, and southwest Yunnan in following six tables.

Table 7.1 only includes the expeditionary warm springs and Table 7.2 is the expeditionary tepid springs in Tibet, respectively.

This table is not including 198 warm springs lack of data of temperature and water chemistry.

This table is not including 12 tepid springs lack of data of temperature and water chemistry.

From silica concentrations of warm springs water shown in Table 7.1 and of tepid springs in Table 7.2, it is evident that the silica concentration of only one warm spring (Tw 39) and one tepid spring (Tt 78) exceed 125 mg/L to belong to high-temperature hydrothermal system, and that the silica concentrations of 28 warm springs and 13 tepid springs are between 38.5 and 125 mg/L (i.e., 90–150 °C) to be intermediate-temperature hydrothermal systems.

7.2 Warm Springs and Tepid Springs in Western Sichuan

There are reliable 66 warm springs (36–45 °C) in the western Sichuan (Table 7.3), in which 41 warm springs have sampled and have analyzed to get necessary data (making up 62%) and 25 springs did not sample but only have their temperature information (making up 38%). The main chemical type of warm springs is HCO_3–Na, that is 21 accounting for 50% (Tong and Zhang 1994).

The highest silica concentration of warm springs in west Sichuan is 80.8 mg/L (Sw52 in Table 7.3) and its reservoir temperature could be 126 °C. Therefore, it will not discover high-temperature systems in warm spring area. But the silica concentrations of 17 warm springs lie between 38.5 and 125 mg/L and their reservoir temperature could be between 90 and 150 °C to be intermediate temperature system. The rest of 24 warm springs are merely the low temperature less than 90 °C.

Table 7.4 shows the tepid springs in western Sichuan, the highest temperature of tepid spring is 35.9 °C. The lowest temperature depends on local elevation. The differences of mean annual temperature between different counties is very large: Serxu is—1.6 °C, Dege 0–6.5 °C, Garze 5.6 °C, Litang 3.1 °C, Dawu 7.8 °C, Tardo 2–16 °C, Aba 3.3 °C, Zoigei 0.3 °C, Liangshan region ~16 °C. Dukou 20 °C. Thus, the lowest temperature of tepid spring is different to local conditions.

There are 123 tepid springs in west Sichuan Province, among which 73 spas, accounting for 59%, have been sampled and analyzed for chemical examination, and 50 springs, making up 41%, are barely of temperature data. Judged by result of chemical analysis: the maximum is HCO_3–Ca–Mg type of water, there are 17, accounting for 23%; the second is HCO_3–Na type, there are 15, accounting for 21%. The tertiary is 13 HCO_3–Ca–Na type, accounting for 18% and once more is 12 HCO_3–Ca type, accounting for 16%. The total of four items amounts to 78%.

There are 59 silica concentration values for the tepid springs of western Sichuan Province. The highest value is 85.19 mg/L and its subsurface temperature is 128 °C to be intermediate temperature system. There are only 13 tepid springs to be intermediate temperature system in west Sichuan.

7.3 Warm Springs and Tepid Springs in Southwestern Yunnan Province

The amount of thermal springs in Yunnan province gets a first throughout the country about 862 in all. The eastern Yunnan to the east of Jinshajiang—Red River strike—slip fault zone is outside the range of this book. The Eastern Yunnan is the most west end of Yangtze Plate. The west and south Yunnan is the stretch of

Table 7.3 The schedule of warm springs (36–45 °C) in western Sichuan

No. Sw	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
01	Nyainrong Caquka	Dege	98° 24′ 20″	32° 13′ 10″	3900	41	25.0	0.922	HCO_3–Na
02	Tanggo	Dege	99° 21′ 20″	32° 09′ 40″	3580	44	80.0	1.316	HCO_3–Na
03	Xukur	Dege	99° 14′ 10″	31° 11′ 50″	3980	45	28.0	1.387	HCO_3–Na
04	Ngamongkor	Dege	99° 11′ 00″	31° 41′ 00″	4120	42			
05	Martarkog	Dege	99° 26′ 30″	31° 49′ 25″	3840	38			
06	Boinxucatog	Baiyu	99° 35′ 30″	30° 37′ 55″	4220	40	56.0	0.895	HCO_3–NaCa
07	Dakog	Garze	99° 41′ 24″	31° 37′ 00″	3640	38			
08	Zangdaqu	Garze	99° 58′ 48″	31° 27′ 30″	4250	36	9.05	0.171	HCO_3–Ca
09	Qigriling	Garze	99° 59′ 48″	31° 36′ 54″	3371	43		0.42	HCO_3–Na–Ca–Mg
10	Nawakog	Nyagrong	99° 52′ 10″	30° 50′ 15″	4260	42	24.0	0.151	HCO_3–Na
11	A’serkog	Nyagrong	100° 06′ 50″	31° 17′ 40″	3570	41	20.0	1.068	HCO_3–Na
12	Baxoi	Nyagrong	100° 18′ 40″	30° 34′ 20″	2900	36.5	40	1.125	HCO_3–Na
13	Qukodenm	Sertar	99° 01′ 00″	33° 10′ 00″	4380	40			
14	Koyu	Chaggo	100° 47′ 55″	31° 16′ 50″	3120	43	4.0	0.906	HCO_3–Na–Ca
15	Nyilhagcatog	Chaggo	100° 54′ 20″	31° 19′ 55″	3420	44	8.0	1.197	HCO_3–Na
16	Yukog	Dawu	101° 10′ 35″	31° 17′ 00″	3720	40		0.766	HCO_3–NaCa
17	Dando	Rongchag	101° 30′ 00″	31° 15′ 20″	3400	42	78.96	1.451	HCO_3–Na
18	Nyewa	Batang	99° 11′ 35″	30° 09′ 20″	2730	42	67.4	0.895	HCO3–Na–Mg
19	Bogorxi	Batang	99° 19′ 25″	30° 13′ 00″	3390	40	48.6	0.957	HCO3–Na–Ca–Mg
20	Sarkyi	Batang	99° 21′ 17″	30° 20′ 07″	3480	38			
21	Conagkog	Batang	99° 28′ 39″	30° 11′ 26″	4100	38			

(continued)

Table 7.3 (continued)

No. Sw	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
22	Xaruca	Litang	99° 40′ 35″	30° 04′ 45″	4256	44	60.0	1.304	HCO_3–Na
23	Yida	Litang	99° 49′ 13″	29° 49′ 58″	3700	38.5	40.0	0.837	HCO_3–Na
24	Oasarkog	Litang	99° 46′ 30″	30° 02′ 40″	4540	38	19.9	0.264	HCO_3–CaNa
25	249 DB	Litang	99° 55′ 45″	30° 09′ 40″	4120	37	nd	1.171	HCO_3–Mg
26	229 DB	Litang	100° 04′ 37″	30° 06′ 17″	3900	42	37.0	0.146	HCO_3–Na
27	Qoibokog	Litang	100° 13′ 30″	29° 46′ 40″	4040	39			
28	Kamca-caka	Litang	100° 23′ 58″	29° 41′ 25″	3650	42.5	8.0	1.747	HCO_3–Na
29	Zhongrong	Derong	99° 08′ 13″	28° 43′ 40″	2440	40			
30	Cakacaqu	Qazheng	99° 53′ 45″	29° 05′ 16″	2960	45	59.4	0.946	HCO_3–Na
31	Zhamwalung	Qazheng	99° 53′ 25″	29° 04′ 23″	2920	43			
32	Racaka Bathing	Qazheng	99° 50′ 40″	28° 53′ 00″	3020	36.2	32.6	1.015	HCO_3–Na
33	Xinrang	Qazheng	99° 51′ 53″	28° 53′ 32″	3440	39.5	47.4	0.245	HCO_3–Na
34	Buygang-bugze	Qazheng	99° 52′ 23″	28° 53′ 32″	3500	40			
35	Quzham	Qazheng	99° 54′ 18″	28° 47′ 39″	3420	40			
36	Nyayuxab-Caqu	Nyqu	101° 02′ 35″	29° 16′ 42″	2360	39.4			
37	Geba	Tardo	101° 07′ 42″	29° 09′ 36″	3120	38			
38	Chenyinga	Tardo	101° 10′ 42″	29° 14′ 36″	4040	44			
39	Erdaoqiao	Tardo	101° 56′ 42″	30° 05′ 18″	2600	42	56.7	0.939	HCO_3–NaCa
40	Guanmulin	Luding	102° 03′ 30″	29° 45′ 12″	2240	43	7.48	0.998	HCO_3–Na
41	Wangdong	Luding	102° 08′ 36″	29° 31′ 30″	1340	44	14.56	1.245	HCO_3–NaCa
42	Zilam	Gyaisi	101° 14′ 15″	29° 05′ 15″	3620	45			
43	Bawolung	Gyaisi	101° 11′ 30″	29° 52′ 30″	2160	43	46.63	1.30	HCO_3–Na
44	Jiashikou	Lixian	103° 04′ 48″	31° 20′ 42″	2840	44			

(continued)

Table 7.3 (continued)

No. Sw	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
45	Wolong	Wenchuan	103° 00′ 36″	31° 04′ 18″	3420	42			
46	Mairi	Muli	100° 34′ 40″	28° 42′ 15″	2600	39			
47	Nyatolang	Muli	100° 32′ 00″	28° 39′ 20″	2580	40			
48	Ogongbao	Muli	100° 52′ 15″	28° 23′ 00″	2280	37	21.5	0.447	HCO_3–Ca–Na–Mg
49	Kubadian	Muli	100° 00′ 30″	28° 05′ 40″	2640	36			
50	Danbo	Muli	101° 12′ 00″	28° 39′ 30″	2300	40			
51	Masa	Muli	101° 14′ 35″	28° 27′ 10″	2120	42.5			
52	Ganjian	Muli	101° 20′ 20″	28° 21′ 35″	2100	45	80.8	1.044	HCO_3–Na
53	Jinhe	Yanyuan	101° 57′ 05″	27° 43′ 00″	1360	37	24.4	0.254	HCO_3–Na
54	Hexi	Xichang	102° 09′ 00″	27° 45′ 20″	1520	39	45.9	0.177	HCO_3–CO_3–Na
55	Aga	Ganluo	102° 51′ 36″	28° 44′ 24″	1700	40	29.9	0.419	SO_4–HCO_3–Ca–Mg
56	Kudangou	Yuexi	102° 33′ 36″	28° 42′ 42″	1625	43		0.892	HCO_3–SO_4–Mg–Ca–Na
57	Qukedi	Yuexi	102° 39′ 48″	28° 33′ 18″	1920	41	32.8	0.179	HCO_3–Ca–Mg–Na
58	Lire	Zhaojue	102° 55′ 24″	28° 04′ 36″	1950	44	44.4	0.220	HCO_3–Na
59	Puge Reshuitang	Puge	102° 32′ 30″	27° 24′ 00″	1283	44	35.7	0.619	HCO_3–SO_4–Ca
60	Kuaniwang	Ningnan	102° 46′ 12″	27° 00′ 30″	800	44	43.0	0.834	HCO_3–Ca–Na
61	Lugao	Jinyang	103° 14′ 30″	27° 34′ 30″	600	41			
62	Taoping	Jinyang	103° 16′ 24″	27° 37′ 48″	560	37	22.6	1.632	SO_4–HCO_3–Ca–Na
63	Tianba	Miyi	102° 09′ 30″	27° 00′ 30″	1200	38			
64	Zhongliangzi	Miyi	102° 09′ 30″	26° 52′ 50″	1470	36.5	72.1	0.239	CO_3–Na
65	Longtang	Miyi	102° 12′ 00″	27° 00′ 00″	1480	38			
66	Caoke Xiaoreshui	Shimian	102° 05′ 30″	29° 23′ 12″	1550	41	4.99	0.268	HCO_3–SO_4–Ca

Table 7.4 The schedule of tepid springs (<36 to >5 °CMAT) in west Sichuan

No. St	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/s)	TDS (g/L)	Type of water
01	Canyoug	Serxu	97° 39′ 24″	33° 34′ 16″	4400	30.5			
02	Barotawa	Serxu	97° 38′ 40″	33° 28′ 20″	5000	30.5			
03	Goinqen	Dege	98° 34′ 55″	31° 49′ 00″	3400	16.5			
04	Xega	Dege	98° 39′ 20″	31° 41′ 2″	3350	19			
05	Goinpu	Dege	98° 51′ 55″	32° 05′ 35″	3980	25.5	6.0	0.353	HCO_3–Na
06	Dopulung	Dege	98° 57′ 50″	31° 46′ 35″	4250	31			
07	Yueba	Dege	99° 01′ 30″	31° 35′ 20″	3440	34	28.0	0.594	HCO_3–CaNa
08	Manyikaingo	Dege	99° 10′ 35″	31° 56′ 25″	3960	18			
09	Choqu	Dege	99° 10′ 20″	31° 55′ 15″	4030	20			
10	Gyidong	Baiyu	98° 49′ 30″	31° 10′ 55″	3250	17	8.0	0.188	HCO_3–Ca
11	Zheda	Baiyu	99° 19′ 00″	31° 36′ 00″	3880	30	16.0	0.158	HCO_3–Na
12	Shang Caka	Baiyu	99° 09′ 05″	31° 08′ 20″	3920	21.5			
13	Mamain	Baiyu	99° 14′ 45″	30° 58′ 25″	3600	23	nd	0.808	HCO_3–NaCa
14	Cakakog	Baiyu	99° 08′ 55″	30° 51′ 30″	3950	28.5	4.0	0.71	HCO_3–NaCa
15	Gaje	Baiyu	99° 02′ 00″	30° 46′ 40″	3000	24	6.0	0.323	HCO_3–Ca–Mg
16	Qangqumdor	Baiyu	99° 26′ 40″	31° 13′ 50″	4155	17			
17	Qukog	Baiyu	99° 31′ 00″	30° 52′ 55″	4160	21	8.0	0.323	HCO_3–Ca
18	Chobgoi Si	Baiyu	99° 40′ 05″	30° 59′ 25″	4080	25	19.3	0.242	HCO_3–CaNa
19	Odarkog	Garze	99° 32′ 12″	31° 54′ 48″	4080	31.5	9.0	0.148	HCO_3–Ca–Mg
20	N. Zakog	Garze	99° 38′ 00″	31° 57′ 12″	4520	17			
21	Zakog	Garze	99° 38′ 30″	31° 54′ 12″	3440	23	30.0	1.234	HCO_3–Na
22	Jagporca	Garze	99° 43′ 42″	31° 40′ 30″	3100	34	12.1	0.149	HCO_3–Ca

(continued)

Table 7.4 (continued)

No. St	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/s)	TDS (g/L)	Type of water
23	Zangdokog	Garze	99° 44′ 18″	31° 05′ 24″	4000	25	52.5	1.202	HCO_3–Na
24	Bailo	Nyagrong	100° 06′ 30″	31° 29′ 30″	3480	19			
25	Gyaxoi	Nyagrong	100° 14′ 00″	31° 20′ 30″	3570	18			
26	Wonyalungba	Nyagrong	100° 01′ 45″	30° 54′ 40″	3880	32	28.0	0.172	HCO_3–Na
27	Gunglung	Nyagrong	100° 07′ 20″	30° 52′ 40″	4160	21			
28	Chaggo	Nyagrong	100° 08′ 55″	30° 50′ 00″	2990	16.0	14.0	0.428	HCO_3–Mg–Ca
29	Zaindadag	Nyagrong	100° 19′ 35″	30° 32′ 30″	2880	22	nd	2.048	HCO_3–Na
30	Targar-lungdo	Nyagrong	100° 35′ 20″	30° 47′ 50″	4080	17			
31	Luosonglong	Chaggo	100° 17′ 00″	31° 41′ 40″	3700	17			
32	Gugdeng Lungba	Chaggo	100° 25′ 55″	31° 35′ 15″	3460	27	na	0.304	HCO_3–Ca–Mg
33	Domkar	Chaggo	100° 28′ 15″	31° 33′ 00″	3320	15	4.0	0.239	HCO_3–Ca–Mg
34	Yadecaka	Chaggo	100° 34′ 40″	31° 27′ 35″	3240	28	10.0	0.817	HCO_3–Ca
35	Zongbanang	Chaggo	100° 50′ 00″	31° 14′ 50″	3160	19			
36	Ridu	Chaggo	100° 43′ 15″	31° 34′ 50″	3340	23	11.22	1.776	HCO_3–Na
37	Gyayukog	Chaggo	100° 46′ 00″	31° 36′ 30″	3560	18			
38	Asecatog	Chaggo	100° 55′ 30″	31° 28′ 50″	3640	17	nd	2.031	HCO_3–NaCa
39	Huoge	Dawu	100° 57′ 35″	31° 07′ 30″	3160	20	14.4	0.276	HCO_3–Ca–Mg
40	Xianshui	Dawu	101° 06′ 50″	30° 59′ 25″	2980	20	17.14	3.999	HCO_3–Na
41	Gunpu	Dawu	101° 06′ 20″	30° 59′ 00″	2960	20	12.47	1.241	HCO_3–Ca–Mg
42	Raea	Dawu	101° 07′ 20″	30° 55′ 00″	2950	16			
43	Melen	Dawu	101° 02′ 05″	30° 29′ 30″	2750	16			
44	Yunga	Dawu	101° 00′ 35″	30° 26′ 40″	2800	17			

(continued)

Table 7.4 (continued)

No. St	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/s)	TDS (g/L)	Type of water
45	Caring	Dawu	101° 12′ 20″	31° 07′ 20″	4060	30			
46	Nangpu Lungba	Dawu	101° 14′ 05″	30° 56′ 20″	3360	19			
47	Sishuitang	Dawu	101° 26′ 50″	30° 26′ 05″	3880	16			
48	Karmar	Dawu	101° 32′ 00″	30° 29′ 05″	3640	28			
49	Bairi	Rongchag	101° 34′ 15″	31° 03′ 25″	2760	17	85.19	2.736	HCO_3–Na
50	Buyizhai	Rongchag	101° 49′ 50″	31° 02′ 00″	2640	23	23.96	1.775	HCO_3–SO_4–Ca–Mg
51	Surwo	Rongchag	101° 53′ 12″	30° 54′ 33″	2000	19	9.04	0.908	SO_4–Ca
52	Baingoin	Rongchag	101° 55′ 55″	30° 55′ 00″	2200	21			
53	Sogbo	Rongchag	101° 56′ 00″	30° 51′ 23″	2080	16	nd	2.945	SO_4–Ca
54	Samdoi	Rongchag	101° 56′ 13″	30° 50′ 16″	1920	17			
55	Pudo	Batang	99° 19′ 52″	30° 14′ 25″	3200	19	16.0	0.349	HCO_3–SO_4–Ca–Na
56	Nalungama	Batang	99° 36′ 30″	30° 27′ 40″	4180	16	nd	1.713	HCO_3–CaNa
57	Lhalunggung-ma	Litang	99° 38′ 50″	30° 26′ 20″	4300	20			
58	Sicarkama	Litang	99° 43′ 00″	30° 32′ 10″	4440	17	10.0	0.361	HCO_3–Ca
59	Yourolungba	Litang	99° 55′ 35″	30° 39′ 59″	4240	17			
60	Chacangxi	Litang	99° 38′ 40″	29° 44′ 40″	3920	19			
61	Chamna	Litang	99° 47′ 58″	29° 45′ 27″	3640	22	nd	0.255	HCO_3–Ca
62	Laxoiconyi	Litang	99° 57′ 27″	29° 48′ 27″	4200	22			
63	Qugyaitang	Qazheng	99° 41′ 30″	29° 33′ 05″	4150	28	7.0	0.116	HCO_3–Ca
64	Dongchong	Qazheng	99° 43′ 00″	29° 22′ 40″	3880	34	na	0.123	HCO_3–Ca
65	Nyedeng	Qazheng	99° 39′ 53″	29° 05′ 16″	3400	20.8	7.05	0.155	HCO_3–Ca
66	Ganyoun	Qazheng	99° 46′ 49″	28° 57′ 32″	2840	16.3		0.751	HCO_3–Na–Mg
67	Racaka	Qazheng	99° 50′ 18″	28° 53′ 02″	2870	28	42.1	2.666	HCO_3–NaCa

(continued)

Table 7.4 (continued)

No. St	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/s)	TDS (g/L)	Type of water
68	Nyqu Fe Sp.	Nyqu	101° 01′ 25″	30° 02′ 18″	2600	16.5	24.93	1.097	HCO_3–Na–Mg–Ca
69	Ridug	Nyqu	101° 02′ 00″	30° 01′ 57″	2960	19			
70	Zerong	Nyqu	101° 16′ 08″	30° 09′ 07″	3760	16			
71	Caqu Lungba	Tardo	101° 26′ 18″	30° 05′ 06″	3600	20	nd	0.892	HCO_3–Ca
72	Berme	Tardo	101° 35′ 30″	29° 26′ 00″	3600	26			
73	Terma	Tardo	101° 28′ 54″	30° 23′ 36″	3880	18			
74	Erdaoqiao Choushui	Tardo	101° 56′ 42″	30° 05′ 42″	2700	23	25.7	0.661	HCO_3–Ca–\Na
75	Xingfuqiao	Tardo	101° 57′ 24″	30° 04′ 05″	2520	35	42.	0.606	HCO_3–CaNa
76	Tardo City	Tardo	101° 57′ 35″	30° 03′ 12″	2600	30	46.5	0.642	HCO_3–Na–Mg
77	Simaqiao	Tardo	101° 57′ 12″	29° 59′ 42″	2800	31			
78	Dahuodi	Tardo	102° 14′ 54″	30° 19′ 06″	1830	11			
79	Pawang	Luding	102° 15′ 00″	29° 48′ 00″	1640	20			
80	Yangshan	Luding	102° 15′ 00″	29° 46′ 00″	1740	20			
81	Nanmuda	Zamtang	101° 04′ 00″	32° 24′ 30″	3570	11.5	nd	1.698	HCO_3–Na–Ca
82	Jiamuduo	Zamtang	101° 21′ 00″	31° 56′ 36″	3920	34	na	0.125	CO_3–HCO_3–Na
83	Yingu	Barkam	101° 31′ 30″	32° 11′ 00″	2880	10	na	0.502	HCO_3–Na–Mg
84	Jiaerda	Barkam	101° 38′ 00″	31° 54′ 00″	3140	11	na	0.424	HCO_3–Ca
85	Taiyanghe	Jin-chuan	101° 43′ 00″	31° 44′ 48″	2600	12	na	0.401	HCO_3–Ca–Na
86	Tawa	Zoige	102° 44′ 00″	34° 05′ 48″	3500	29.5		0.208	HCO_3–Ca–Mg
87	Lenensancuo	Jiu Zhai Gou	103° 41′ 00″	33° 24′ 00″	3010	20			
88	Kakagou	Songpan	103° 40′ 00″	32° 58′ 24″	3400	25	16.8	0.278	HCO_3–Ca

(continued)

Table 7.4 (continued)

No. St	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/s)	TDS (g/L)	Type of water
89	Yuanshanzi	Songpan	103° 38′ 18″	32° 52′ 12″	3080	10	17.9	0.884	HCO_3–Mg
90	Mounigou	Songpan	103° 32′ 18″	32° 34′ 24″	3000	25			
91	Huanglong	Songpan	103° 54′ 30″	32° 47′ 30″	3578	11	11.3	0.193	HCO_3–Ca–Mg
92	Xiadagai	Heishui	103° 01′ 00″	32° 22′ 12″	3540	35	38.57	0.22	HCO_3–Ca–Mg
93	Weiguan	Lixian	103° 10′ 48″	31° 28′ 00″	1988	30	56.1	0.705	HCO_3–SO_4–Na
94	Jiyugou	Mao Xian	103° 45′ 54″	31° 37′ 24″	1600	32.5	51.7	1.729	SO_4–Ca–Mg
95	Guanyinmiao	Wenchuan	103° 22′ 06″	31° 12′ 48″	1900	31	45.56	2.749	HCO_3–Na+K
96	Yinshan	Muli	101° 01′ 25″	28° 02′ 35″	2320	33.5	19.7	0.557	HCO_3–Mg–Ca
97	Jiyi	Muli	101° 10′ 00″	28° 29′ 00″	3100	20			
98	Zangwen	Muli	101° 10′ 20″	28° 25′ 30″	3040	24	37.4	1.314	HCO_3–Na
99	Ganhaizi	Muli	101° 38′ 45″	28° 17′ 45″	1680	20			
100	Libeichenye	Mianning	102° 14′ 36″	28° 43′ 00″	2100	25	17.9	3.594	Cl–Na
101	Daluo	Xichang	101° 55′ 00″	27° 49′ 40″	1600	29	7.45	0.164	HCO_3–Ca–Mg
102	Tajiaogu	Ganluo	102° 38′ 30″	28° 52′ 30″	1230	32			
103	Aidai-chezhan	Ganluo	102° 47′ 42″	29° 01′ 06″	1025	31	19.7	0.189	HCO_3–Mg–Ca
104	Dabujue	Yuexi	102° 48′ 30″	28° 26′ 00″	2600	27			
105	Sikai	Zhaojue	102° 44′ 00″	27° 56′ 00″	2200	29	47.7	0.155	CO_3–HCO_3–Na
106	Zhulilada	Zhaojue	102° 46′ 36″	27° 57′ 30″	2150	32	40.1	0.300	HCO_3–Na
107	Wajing	Zhaojue	102° 51′ 24″	28° 04′ 42″	2100	25.5	50.6	0.151	CO_3–Na
108	Weiziluo	Butuo	102° 58′ 00″	27° 51′ 30″	1950	22			
109	Guadagou	Ningnan	102° 31′ 12″	27° 12′ 18″	1600	29			
110	Guoyuan	Huili	102° 12′ 30″	26° 37′ 30″	1820	24			

(continued)

Table 7.4 (continued)

No. St	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/s)	TDS (g/L)	Type of water
111	Xiaochahe	Huidong	102° 36′ 15″	26° 36′ 00″	1750	34.5	21.2	0.478	HCO_3–Ca–Mg
112	Shangdalong	Huidong	102° 46′ 00″	26° 45′ 00″	1960	29.3	17.9	0.255	HCO_3–SO_4–Mg–Ca
113	Xiaoluotian	Huidong	102° 56′ 20″	26° 20′ 40″	820	23	14.91	0.514	SO_4–HCO_3–Ca–Mg
114	Xintian	Huidong	102° 57′ 00″	26° 20′ 45″	720	24	2.26	7.098	Cl–Na
115	Deguguo	Jinyang	103° 13′ 54″	27° 40′ 42″	1100	33	21.2	0.874	HCO_3–Ca–Mg
116	Guanyinyan	Yanbian	101° 11′ 10″	27° 02′ 10″	2440	25	19.5	0.426	HCO_3–SO_4–Na–Ca
117	Chanputian	Yanbian	101° 20′ 30″	26° 59′ 00″	1380	30.5	28.4	1.163	Cl–Na
118	Zhemulong	Yanbian	101° 38′ 00″	27° 13′ 00″	1760	31	11.79	0.884	SO_4–HCO_3–Ca–Mg
119	Longpingzi	Dukou	101° 33′ 00″	26° 36′ 25″	1240	27	6.43	0.387	HCO_3–Ca–Mg
120	Xigeda	Dukou	101° 36′ 40″	25° 33′ 55″	1260	26	28.8	0.379	HCO_3–Ca–Mg
121	Nanyahe	Shimian	102° 22′ 30″	29° 01′ 30″	900	30			
122	Shaqian	Mabian	103° 23′ 48″	28° 46′ 42″	960	26.5	12.4	0.499	HCO_3–Ca–Mg
123	Wenshuidan	Mabian	103° 25′ 30″	28° 54′ 00″	960	24.4	12.4	0.292	HCO_3–Ca

Tibetan tectonic line to the east. Thus the southwest Yunnan had occurred stronger tectonic deformation and followed rich and varied geothermal activities, including volcanoes and thermal springs since the Neogene. The quantity of thermal springs in southwest Yunnan reaches 663, account for 77% of whole Province, which includes 20 boiling springs, 266 hot springs, 178 warm springs, and 199 tepid springs (Table 4.3). Tables 7.5 and 7.6 will show the warm springs and tepid springs, respectively (Tong and Zhang 1989, 1994).

There are reliable 178 warm springs (36–45 °C) in the southwestern Yunnan (Table 7.5). 119 of these warm springs (67%) have been sampled and analyzed, whereas 59 springs (33%) were not sampled but we have their temperature information. The majority chemical type of 119 sampled warm springs is HCO_3–Na or HCO_3–CO_3–Na water, that is 58 accounting for 49%. The reservoir of HCO_3–Na type water is granite. The second majority type is of Ca and Mg cations, and these account for 30% and appear in the sedimentary formation, particularly in limestone region.

In southwest Yunnan, 119 suits of water chemical data all have silica concentrations, in 72 of which the concentrations are in the range of 38.5–125 ppm, and so their reservoir temperature would be between 90 and 150 °C. They are entirely possible to be intermediate temperature systems. We cannot find high temperature system, but we can confirm that there are 47 low-temperature systems from warm springs in southwest Yunnan.

Table 7.6 lists 198 tepid springs in southwest Yunnan.

There are in total 199 tepid springs in southwest Yunnan Province, in which two-thirds spas (131) are provided with hydrochemical data and the rest (68 spas) only have temperature data. Among the 131 springs with the hydrochemical data, 41 are of HCO_3–Ca–Mg type, accounting for 31%, 32 HCO_3–Na type, 24.4%, 19 HCO3–Ca type, 14.5% and 10 HCO3–Na–Ca type 8%. The sum of four types is 102, making up 80% of the total.

There are silica concentrations in all 131 suits of hydrochemical data of tepid springs. The silica-bearing tepid spring here fall roughly into three categories: The silica concentrations of six spas are more than 125 ppm, thus, their reservoir temperatures could be higher than 150 °C They are all low-temperature carbonated spring in Tengchong volcanic region. The second category has silica concentration in the range of 38.5–125 ppm in 39 tepid springs, which ought to be intermediate temperature systems. The rest 88 spas plus 68 spas are lake of hydrochemical data, which should be low-temperature hydrothermal systems, accounting for 78% of the total.

Table 7.5 The schedule of warm springs (36–45 °C) in southwest Yunnan

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
01	Cogba	Deqen	98° 40′ 00″	28° 50′ 40″	2260	40			
02	Gangzhong	Deqen	98° 42′ 20″	28° 49′ 55″	2940	36			
03	Nyiringnang	Deqen	98° 42′ 00″	28° 56′ 00″	3300	39	57.5	0.682	HCO_3–Na
04	Xardang	Deqen	98° 49′ 00″	28° 25′ 35″	2640	36			
05	Langzhe	Deqen	98° 49′ 20″	28° 12′ 00″	2160	38			
06	Joida	Deqen	98° 51′ 00″	28° 24′ 20″	2000	43			
07	Quzixoi	Deqen	98° 51′ 00″	28° 16′ 30″	2280	40	53.5	1.227	SO_4–Ca–Mg
08	Bumdaxoi	Deqen	99° 06′ 50″	28° 42′ 40″	2450	40			
09	Tangshang	Weixi	99° 19′ 22″	27° 08′ 40″	2250	35–40	88.4	0.968	HCO_3–Na
10	Heping Caqugo	Shangrila	99° 50′ 30″	27° 31′ 00″	3250	38.7	29.4	0.176	HCO_3–Ca–Mg
11	Lazagu	Shangrila	100° 03′ 40″	27° 09′ 50″	1860	38			
12	Dimaluo	Gongshan	98° 43′ 20″	28° 01′ 00″	2600	37–38			
13	Zileng	Bijiang	98° 54′ 40″	28° 36′ 25″	1200	38.3	29.5	0.173	HCO_3–Ca–Na
14	Nonggajiu	Bijiang	98° 54′ 46″	26° 34′ 18″	1200	37	23.4	0.175	HCO_3–Ca
15	Hongtujian	Lanping	99° 14′ 00″	26° 30′ 50″	1950	45	49.5	3.105	SO_4–Na
16	Hexi	Lanping	99° 23′ 45″	26° 52′ 00″	2050	45	42.8	4.429	SO_4–Cl–HCO_3–Na
17	Qiaotuo	Lanping	99° 24′ 20″	26° 51′ 05″	2050	39	52.2	2.225	SO_4–Na–Ca
18	Zhongshan	Yingjiang	97° 43′ 10″	24° 32′ 00″	1300	40			
19	Hushan	Yingjiang	97° 43′ 48″	24° 31′ 12″	800	37.5	36.9	0.188	HCO_3–Na
20	Mangyun	Yingjiang	97° 44′ 48″	24° 32′ 00″	800	37			
21	Yangsanhe	Yingjiang	97° 40′ 30″	24° 34′ 42″	1290	36	44.7	0.184	HCO_3–Na
22	Longfei	Yingjiang	97° 54′ 30″	24° 35′ 48″	900	38	62.2	0.191	HCO_3–Na

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
23	Longmu	Yingjiang	97° 44′ 00″	24° 30′ 48″	1160	40.5	57.8	0.173	HCO_3–Na
24	Lushan	Yingjiang	98° 02′ 00″	25° 13′ 00″	1680	43.3	47.4	0.144	HCO_3–Na
25	Jingxing	Yingjiang	98° 09′ 00″	25° 01′ 30″	1120	42			
26	Mangya	Yingjiang	98° 06′ 30″	25° 00′ 18″	990	42.5	79.9	0.671	HCO_3–Na
27	Xiaka	Yingjiang	98° 08′ 00″	24° 50′ 30″	1040	45	60.4	0.177	HCO_3–Na
28	Shoufenzhai	Yingjiang	98° 06′ 30″	24° 48′ 30″	880	36	42.1	0.198	HCO_3–Na
29	Kangma	Longchuan	97° 43′ 48″	24° 19′ 00″	1160	37	64.3	0.200	HCO_3–Na
30	Lulian	Longchuan	97° 56′ 30″	24° 23′ 42″	1020	36	52.6	0.158	HCO_3–Na–Ca
31	Nantian	Longchuan	97° 55′ 30″	24° 22′ 00″	980	39	52.6	0.188	HCO_3–Na–Ca
32	Dengga	Ruili	97° 37′ 10″	23° 53′ 40″	760	40			
33	Leimen	Ruili	97° 51′ 00″	24° 10′ 24″	1040	41	60.4	0.199	HCO_3–Na
34	Zhaduo	Ruili	97° 59′ 05″	24° 06′ 30″	960	38	18.7	0.244	HCO_3–Ca–Mg
35	Bangwai	Lianghe	98° 10′ 25″	24° 32′ 00″	930	38	78.6	0.240	HCO_3–Na
36	Bangbei	Lianghe	98° 12′ 25″	24° 38′ 30″	1045	45	73.4	0.229	CO_3–HCO_3–Na
37	Xiao Manglong	Lianghe	98° 16′ 40″	24° 35′ 00″	900	39	46.1	0.181	HCO_3–Na
38	Jiazhong manbang	Luxi	98° 08′ 10″	24° 09′ 50″	790	45	20.0	0.316	HCO_3–Ca–Mg
39	Jiangweiba	Luxi	98° 17′ 00″	24° 31′ 25″	900	43	35.6	0.169	HCO_3–Na
40	Manbang reshuihe	Luxi	98° 19′ 25″	24° 14′ 10″	890	44	14.8	0.298	HCO_3–Ca–Mg
41	Bali	Tengchong	98° 14′ 10″	25° 21′ 30″	1700	42	50.0	0.417	HCO_3–Na
42	Yangjiatian	Tengchong	98° 15′ 40″	25° 20′ 40″	1710	44	83	0.308	HCO_3–Na
43	Sujiang	Tengchong	98° 17′ 00″	25° 21′ 00″	1750	40	45	1.180	HCO_3–Na
44	Qingkou Malishan	Tengchong	98° 18′ 20″	25° 14′ 00″	1770	43	70	0.254	HCO_3–Na

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
45	Dacun	Tengchong	98° 22′ 30″	25° 03′ 20″	1390	42	58	0.279	HCO_3–SO_4–Na
46	Shuanjiatang	Tengchong	98° 23′ 40″	25° 24′ 10″	1860	44	64.3	0.180	HCO_3–Na
47	Shizhuba	Tengchong	98° 24′ 00″	25° 16′ 10″	1880	45	55.0	0.146	HCO_3–Na
48	Lengxiaotang	Tengchong	98° 24′ 20″	25° 21′ 00″	1840	36	51.3	0.209	HCO_3–Na
49	Yongle	Tengchong	98° 32′ 00″	24° 57′ 30″	1690	38.5	55.0	0.195	CO_3–HCO_3–Na
50	Huangpo	Tengchong	98° 32′ 30″	24° 58′ 40″	1720	41	43.0	0.139	HCO_3–CO_3–Na
51	Shaba Xiaotang	Tengchong	98° 40′ 42″	25° 40′ 20″	1820	45	14.8	0.143	HCO_3–Ca–Mg
52	Zhoujiawa	Tengchong	98° 40′ 00″	25° 32′ 00″	1600	44	36.9	1.227	HCO_3–Na
53	Menglian	Tengchong	98° 35′ 30″	24° 54′ 00″	1680	42	58.0	0.174	HCO_3–Na
54	Banshan	Tengchong	98° 37′ 00″	24° 57′ 30″	1830	45	46.1	0.119	CO_3–HCO_3–Na
55	Puqing	Tengchong	98° 39′ 20″	25° 06′ 40″	1550	45	40.8	0.124	HCO_3–CO_3–Na
56	Xinzhai	Tengchong	98° 40′ 10″	25° 01′ 30″	1450	30.5	33.0	1.226	HCO_3–Na
57	Hehua	Longling	98° 40′ 30″	24° 42′ 40″	1260	39	104	0.833	HCO_3–Na
58	Diandi	Longling	98° 43′ 30″	24° 49′ 40″	1600	37	95.5	0.641	HCO_3–Na
59	Xiyugou	Longling	98° 44′ 40″	24° 33′ 00″	1550	40	35.6	0.155	HCO_3–SO_4–Na
60	Bajiaolin	Longling	98° 53′ 05″	24° 14′ 05″	1380	42.5	79.9	0.303	HCO_3–Na
61	Songjia Zaotang	Longling	98° 56′ 30″	24° 32′ 00″	1740	42.5	40.8	0.251	HCO_3–Na
62	Hekou	Longling	98° 58′ 20″	24° 44′ 05″	670	40	33.0	0.375	HCO_3–Mg–Ca
63	Qiuchang	Longling	98° 52′ 40″	24° 32′ 40″	1900	37			
64	Xiaoxinzhai	Baoshan, Longyang	98° 49′ 50″	25° 13′ 00″	840	38	25.2	0.266	HCO_3–Ca
65	Houziya	Baoshan	98° 50′ 20″	25° 05′ 45″	700	45	30.4	0.769	HCO_3–Ca–Mg

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
66	Xincheng	Baoshan	98° 52′ 15″	24° 52′ 40″	800	41	34.3	0.489	HCO_3–Ca
67	Hengshan	Baoshan	98° 56′ 10″	25° 06′ 40″	1020	36			
68	Daojie	Baoshan	98° 54′ 55″	24° 58′ 50″	760	44	21.3	0.336	HCO_3–Ca–Mg
69	Fanrong	Baoshan	99° 17′ 40″	25° 26′ 45″	1380	36.5	27.4	0.890	SO_4–Ca
70	Huzhang	Baoshan	99° 11′ 50″	25° 11′ 30″	1720	37			
71	Jinji	Baoshan	99° 15′ 40″	25° 08′ 50″	1680	39.5	27.3	0.669	HCO_3–Ca
72	Daheidu	Shidian	99° 01′ 30″	24° 24′ 17″	600	44	30.5	0.457	HCO_3–Ca–Mg
73	HemuSuanshuitang	Changning	99° 25′ 00″	42° 52′ 00″	970	37	33.0	1.188	HCO_3–Ca
74	Songlin	Changning	99° 25′ 48″	24° 52′ 48″	1000	44	29.2	0.641	HCO_3–Ca–Na
75	Abeizhai	Changning	99° 43′ 42″	24° 51′ 48″	1510	42	46.5	0.197	HCO_3–Na
76	Sujia	Changning	99° 44′ 48″	24° 52′ 12″	1300	40	45.9	0.179	HCO_3–Na
77	Laochangjie	Changning	99° 47′ 00″	24° 49′ 18″	1600	42			
78	Wenqing	Changning	99° 59′ 18″	25° 04′ 00″	1180	45			
79	Daju	Lijiang	100° 13′ 00″	26° 53′ 40″	2100	44			
80	Yongning	Ninglang	100° 42′ 10″	27° 49′ 20″	2670	38.2	41.5	0.712	HCO_3–Cl–Na–Ca
81	Wagaiwa	Ninglang	100° 42′ 00″	27° 48′ 40″	2680	36.5			
82	Shanglu	Yongsheng	100° 26′ 25″	26° 09′ 28″	1280	41.3	97.8	0.311	CO_3–Na
83	Yangtizi	Yunlong	99° 09′ 05″	25° 39′ 20″	2460	40.5	80.3	0.526	HCO_3–Na–Ca
84	Biaocun	Yunlong	99° 06′ 00″	26° 04′ 55″	1700	40			
85	SongpingXiachang	Yunlong	99° 05′ 00″	26° 03′ 50″	1900	43	50.8	0.632	HCO_3–Na–Ca
86	Dalang	Yunlong	99° 27′ 22″	26° 10′ 55″	1980	43	40.0	1.963	HCO_3–Cl–Na
87	Yangchimi	Yunlong	99° 41′ 00″	25° 44′ 35″	2060	36	20.0	0.759	HCO_3–SO_4–Ca
88	Xinhe	Jianchuan	99° 36′ 55″	26° 35′ 05″	2600	42	68.3	0.386	HCO_3–Na

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
89	Hodian	Yunlong	99° 37′ 30″	26° 26′ 10″	2300	42	72.3	2.839	SO_4–Cl–Na
90	Longmen	Yunlong	99° 53′ 20″	26° 30′ 17″	2000	40.5	48.2	0.406	HCO_3–Ca–Na
91	Shangjiangzui	Eryuan	99° 46′ 45″	26° 01′ 38″	1800	40	83.0	2.07	HCO_3–Cl–Na
92	Shanyangping	Eryuan	99° 53′ 00″	25° 50′ 56″	1680	41.2	48.2	0.631	HCO_3–Na–Ca
93	Liancheng	Eryuan	99° 59′ 00″	26° 06′ 00″	2000	41	75.0	1.103	HCO_3–SO_4–Na
94	Xili	Yangbi	99° 41′ 05″	25° 34′ 40″	1800	36.5	21.4	0.970	SO_4–HCO_3–Ca–Mg
95	Jiangqiao	Yangbi	99° 55′ 35″	25° 47′ 28″	1600	44.2	57.6	0.872	HCO_3–Na
96	Jiyipu	Yangbi	100° 02′ 35″	25° 36′ 30″	1500	43	57.6	0.211	SO_4–Na
97	Qudong	Yongping	99° 31′ 45″	25° 25′ 50″	1570	37	41.5	0.539	HCO3–Ca–Mg
98	Alin	Yongping	99° 40′ 55″	25° 11′ 00″	1500	39.5	49.5	3.253	SO_4–$HCO_\#$–Na–Ca
99	Yongcui	Nanjian	100° 25′ 25″	24° 56′ 20″	1900	37.5	62.9	2.272	SO_4–Ca–Mg
100	Jianba	Nanjian	100° 32′ 25″	25° 03′ 05″	1450	40	38.8	2.157	HCO_3–SO_4–Na
101	Guodishan	Midu	100° 25′ 45″	25° 28′ 30″	1950	37.6			
102	Xikelang	Midu	100° 33′ 28″	25° 06′ 43″	1600	36	26.7	0.256	HCO_3–Mg–Ca
103	Tangzi	Midu	100° 42′ 17″	25° 07′ 32″	1400	36.8	33.4	1.705	SO_4–Ca–Mg
104	Malishu	Yongde	99° 14′ 50″	24° 13′ 40″	1660	37	29.4	0.245	HCO_3–Ca=Mg
105	Menggong	Yongde	99° 14′ 05″	23° 57′ 50″	1450	43	28.0	0.248	HCO_3–Ca=Mg
106	Minglang	Yongde	99° 13′ 00″	23° 52′ 45″	1800	39	28.0	0.190	HCO_3–Ca=Mg
107	Songgui	Yongde	99° 21′ 25″	24° 03′ 20″	850	38	24.0	0.347	HCO_3–Ca
108	Menghei	Yongde	99° 25′ 23″	24° 13′ 27″	820	37	20.0	0.327	HCO_3–Ca=Mg
109	Xiajunle	Gengma	99° 28′ 30″	23° 48′ 06″	570	43	38.8	0.438	HCO_3–Ca–Mg

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
110	Baihe-Tiechang	Fengqing	99° 42′ 36″	24° 30′ 12″	1380	36	20.0	0.219	HCO_3–Ca
111	Lipu	Fengqing	99° 43′ 00″	24° 30′ 12″	1300	40			
112	Nanpan	Lancang	99° 34′ 00″	22° 58′ 40″	1500	44.5	27.0	1.655	SO_4–Ca
113	Hewei	Lancang	99° 49′ 15″	23° 08′ 10″	870	45	29.9	0.398	HCO_3–Na
114	Laomanbang	Lancang	99° 53′ 10″	23° 00′ 40″	1200	40			
115	Mengbin	Lancang	99° 53′ 55″	22° 31′ 20″	1040	40.5	34.3	0.357	HCO_3–Na
116	Xiaohuizhang	Lancang	100° 00′ 55″	22° 39′ 35″	900	40			
117	Mangfu	Lancang	100° 02′ 30″	22° 61′ 0″	1200	42			
118	Malashan	Lancang	100° 11′ 20″	22° 15′ 35″	1520	40			
119	Manggen	Lancang	100° 04′ 30″	22° 12′ 20″	870	42	48.8	0.561	HCO_3–Na
120	Lasa	Lancang	100° 19′ 20″	22° 51′ 30″	620	40			
121	Siqi	Lancang	100° 22′ 20″	22° 43′ 00″	650	40			
122	Yakou	Lancang	100° 06′ 00″	22° 40′ 20″	1040	40			
123	Yingpan Xincun.	Lancang	99° 38′ 06″	22° 30′ 45″	1060	39	21.2	0.220	HCO_3–Ca–Mg
124	Zhongcang	Jingdong	100° 36′ 25″	24° 41′ 00″	1520	43.5	38.6	1.344	HCO_3–SO_4–Na
125	Tiankoucun	Zhenyuan	100° 28′ 00″	23° 54′ 25″	1040	40	37.2	0.546	SO_4–HCO_3–Ca
126	Mangfei	Jinggu	100° 39′ 00″	23° 25′ 30″	960	40			
127	Mengnai	Jinggu	100° 56′ 50″	23° 24′ 15″	1000	43	28.4	0.696	Cl–HCO_3–Na–Ca
128	Yangcaotang	Ninger	101° 05′ 15″	22° 57′ 28″	1240	35.8	20.0	0.434	HCO_3–Ca
129	Wanengneng	Mojiang	101° 25′ 00″	23° 25′ 25″	1150	44.5	44.4	0.572	HCO_3–Na
130	Waye	Mojiang	101° 33′ 00″	23° 16′ 20″	760	38			
131	Panjiatian	Mojiang	101° 32′ 25″	23° 02′ 10″	1360	38			

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
132	Landuifang	Jiangcheng	101° 18′ 00″	22° 47′ 40″	980	40.5	35.7	1.334	HCO_3–Na
133	Dahebian	Jiangcheng	101° 30′ 10″	22° 32′ 05″	960	40			
134	Zhengdong Bangtang	Jiangcheng	101° 32′ 00″	22° 30′ 30″	880	41	38.6	1.621	Cl–SO_4–Na–Ca
135	Pabai	Jinghong	100° 33′ 45″	21° 31′ 10″	760	43.3	85.7	0.241	HCO_3–Na
136	Nanpen	Jinghong	100° 28′ 20″	21° 47′ 00″	1580	45			
137	No 7-10 F. Dongfeng .	Jinghong	100° 40′ 00″	21° 42′ 40″	880	41			
138	Manzahanbing	Jinghong	100° 40′ 15″	21° 43′ 20″	680	45.3	66.9	0.335	HCO_3–Cl–Na
139	No 7-5 F. Dongfeng	Jinghong	100° 42′ 00″	21° 42′ 45″	700	45			
140	Mangebo	Jinghong	100° 40′ 30″	22° 00′ 20″	820	39	56.2	0.237	HCO_3–Na
141	No 5-6 F. Dongfeng	Jinghong	100° 40′ 50″	21° 55′ 10″	860	45			
142	Liushahe	Jinghong	100° 13′ 10″	22° 00′ 50″	580	40	73.6	0.297	HCO_3–Na
143	Manmai	Jinghong	100° 44′ 55″	21° 59′ 40″	550	40			
144	Gasananbang	Jinghong	100° 46′ 00″	21° 56′ 40″	550	39.8			
145	Sangle	Menghai	100° 11′ 25″	21° 32′ 30″	680	40			
146	Mansang	Menghai	100° 12′ 15″	21° 33′ 40″	680	40			
147	Manna	Menghai	100° 13′ 45″	21° 55′ 00″	760	40			
148	Mengwanghe	Menghai	100° 29′ 00″	22° 13′ 45″	810	44.5	67.7	0.239	HCO_3–CO_3–Na
149	Balananbang	Menghai	100° 32′ 45″	21° 58′ 30″	1180	36.5	51.7	0.234	HCO_3–Na
150	Bangganlahu	Menghai	100° 34′ 40″	22° 09′ 50″	1500	42	64.8	0.183	HCO_3–Na
151	Manxingmian	Menghai	100° 37′ 10″	22° 08′ 15″	1240	36	45.9	0.185	HCO_3–CO_3–Na

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
152	Danuoyou	Menghai	100° 38′ 25″	22° 12′ 00″	800	43.5	47.4	0.189	HCO_3–Na
153	Popai	Menghai	100° 21′ 35″	22° 06′ 15″	1070	40	60.4	0.325	HCO_3–Na
154	Nanni	Mengla	101° 23′ 25″	21° 32′ 50″	650	37.6	19.7	0.935	Cl–Na–Ca
155	Yingzhai	Xingping	101° 35′ 40″	24° 04′ 40″	500	42.5	43.0	5.394	Cl–Na
156	Yangwu	Xingping	102° 09′ 00″	23° 56′ 00″	1380	40			
157	Manlin	Yuanjiang	101° 59′ 05″	23° 37′ 40″	420	41	28.4	0.468	HCO_3–Na–Ca–Mg
158	Mansatian	Yuanjiang	101° 54′ 58″	23° 33′ 40″	640	44			
159	Erpu	Luchun	102° 22′ 40″	22° 36′ 50″	540	39	56.1	0.414	HCO_3–Na
160	Luosha-Kucong	Luchun	102° 22′ 15″	22° 38′ 50″	480	40			
161	Pingkun	Luchun	102° 27′ 45″	22° 51′ 20″	780	43.5	67.7	0.928	HCO_3–Na
162	Zongzhai	Yuanyang	102° 39′ 59″	23° 14′ 00″	780	42			
163	Paisha	Yuanyang	102° 47′ 00″	23° 13′ 50″	320	41	53.2	0.430	HCO_3–SO_4–Ca–Na
164	Shitouzhai	Yuanyang	102° 47′ 45″	23° 10′ 20″	840	38			
165	Fengchun-ling	Yuanyang	103° 07′ 25″	23° 00′ 15″	940	40			
166	Baha	Jinping	102° 37′ 35″	22° 47′ 50″	720	45			
167	Gudixinzhai	Jinping	102° 56′ 15″	22° 49′ 30″	460	41			
168	Qiaocaiping	Jinping	102° 59′ 20″	22° 41′ 00″	460	40			
169	Nafa	Jinping	103° 10′ 00″	22° 37′ 00″	320	40			
170	Shidong	Jinping	103° 24′ 00″	22° 28′ 30″	280	38			
171	Mapiyi	Jinping	103° 27′ 30″	22° 54′ 00″	360	40			
172	Hujie	Honghe	102° 28′ 53″	23° 19′ 22″	400	36	50.3	0.432	HCO_3–Ca–Na
173	Manfang	Honghe	102° 32′ 40″	23° 18′ 35″	390	36	50.2	0.461	HCO_3–Ca

(continued)

Table 7.5 (continued)

No. Yw	Name of warm springs	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO (mg/L)	TDS (g/L)	Type of water
174	Lamenga	Lushui	98° 51′ 45″	26° 09′ 50″	950	38			
175	Danjialuoga	Lushui	98° 51′ 36″	26° 06′ 48″	950	38			
176	Shangbangwa	Luxi	98° 23′ 35″	24° 27′ 40″	1050	42	43.4	0.168	HCO_3–Na
177	Xianrendong	Luxi	98° 25′ 30″	24° 33′ 55″	1100	40	38.2	0.140	HCO_3–Na
178	Bangxian	Luxi	98° 32′ 35″	24° 28′ 00″	920	40	31.7	0.269	HCO_3–Ca–Mg–Na

Table 7.6 The schedule of tepid springs (10–35 °C) in southwest Yunnan

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
01	Yangza	Deqen	98° 52′ 00″	28° 15′ 20″	2400	33	26.7	1.018	SO_4–Mg–Ca
02	Luoyi	Weixi	98° 58′ 50″	27° 54′ 16″	2380	20			
03	Zhonglu	Weixi	99° 09′ 00″	27° 11′ 00″	1750	20			
04	Ludu	Weixi	99° 17′ 00″	27° 13′ 40″	2200	24			
05	Shangqiaotou	Shangri-la	99° 23′ 50″	28° 10′ 15″	3380	34.5	26.7	0.238	HCO_3–Ca–Mg
06	Longtan	Shangri-la	98° 43′ 10″	27° 49′ 30″	3380	13	10.0	0.130	HCO_3–Ca
07	Niyongka	Shangri	99° 49′ 40″	27° 58′ 00″	3400	31	87.0	0.891	HCO_3–Na
08	Surkar	Shangri	99° 51′ 06″	27° 30′ 10″	3250	32	29.4	0.195	HCO_3–Ca–Mg
09	Caqudeng	Shangri	99° 52′ 00″	27° 48′ 00″	3400	20			
10	Majiacun	Shangri	100° 01′ 00″	27° 25′ 30″	3220	21	19.4	0.217	HCO_3–Mg–Ca
11	Xundong	Shangri	100° 02′ 00″	27° 26′ 30″	2660	29.5	107	1.348	HCO_3–Mg–Na
12	Lamazuzha	Shangri	100° 12′ 20″	27° 24′ 00″	1600	30			
13	Qiukedang	Gongshan	98° 36′ 40″	28° 01′ 30″	2050	25			
14	Galaboyi	Gongshan	98° 42′ 55″	27° 42′ 30″	1520	30			
15	Dasuo	Gongshan	98° 42′ 25″	27° 40′ 50″	1480	19	16.1	0.158	HCO_3–Ca
16	Dangzhu	Gongshan	98° 43′ 05″	27° 40′ 00″	1460	20	14.7	0.155	HCO_3–Ca
17	Lishadi	Fugong	98° 53′ 20″	27° 13′ 40″	1240	28			
18	Lumadeng	Fugong	98° 51′ 50″	27° 01′ 40″	1190	28	83.7	0.599	HCO_3–Ca–Mg
19	Gade	Bijiang	98° 53′ 00″	26° 46′ 55″	1260	34.5	58.9	0.424	HCO_3–Ca
20	Pixie	Bijiang	98° 54′ 00″	26° 34′ 55″	1100	35.2	36.2	0.264	HCO_3–Ca
21	3rd M. Schl.	Bijiang	98° 54′ 15″	26° 30′ 56″	1200	20.5	22.5	0.268	HCO_3–Ca
22	Wenxuju	Bijiang	98° 53′ 30″	26° 28′ 10″	1050	25	34.8	0.270	HCO_3–Ca–Mg

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
23	Laipa	Bijiang	98° 54′ 55″	26° 27′ 47″	1650	25			
24	Makuangdi	Bijiang	98° 54′ 28″	26° 23′ 35″	1500	20.3	16.3	0.256	HCO_3–Ca–Mg
25	Sideng	Lanping	99° 09′ 18″	26° 44′ 00″	2000	20			
26	Shuimofang	Lanping	99° 23′ 40″	26° 49′ 35″	2100	28	21.4	2.219	SO_4–Ca–Mg
27	Xinshengqiao	Lanping	99° 21′ 20″	26° 28′ 40″	2440	22.2	16.7	0.124	HCO_3–Ca–Na
28	Yaba	Lushui	98° 48′ 15″	26° 02′ 20″	1800	30			
29	Xianyangqiao	Lushui	98° 51′ 18″	25° 50′ 50″	820	29.3	28.1	0.352	HCO_3–Ca–Mg
30	Zhong Longtan	Lushui	98° 52′ 00″	25° 37′ 45″	860	20.8	15.8	0.302	HCO_3–Ca–Mg
31	Laowo	Lushui	99° 02′ 00″	25° 51′ 45″	1450	33.7	13.4	0.179	HCO_3–Ca–Mg
32	Yangsanheba	Yingjiang	97° 40′ 30″	24° 34′ 42″	1290	35.5	44.7	0.184	HCO_3–Na
33	Manhai	Longchuan	97° 54′ 54″	24° 27′ 12″	1500	20.5	46.1	0.143	HCO_3–Ca–Na
34	Shuicaoba	Longchuan	98° 13′ 30″	24° 31′ 35″	900	29	42.1	0.121	HCO_3–Na
35	Guanghan	Ruili	97° 37′ 05″	23° 53′ 30″	760	28	62.2	0.414	HCO_3–Na–Ca
36	Manghai	Ruili	97° 38′ 25″	23° 57′ 50″	810	31	44.7	0.196	HCO_3–Na
37	Mangbang	Wanding	98° 05′ 25″	24° 06′ 00″	860	31.5	18.7	0.332	HCO_3–Ca–Mg
38	Qiaotou	Lianghe	98° 15′ 55″	24° 48′ 05″	1015	30	83.8	0.440	HCO_3–Na
39	Bangjia	Luxi	98° 18′ 00″	24° 13′ 40″	880	33	21.3	0.285	HCO_3–Ca–Mg
40	Dangliang	Luxi	98° 34′ 15″	24° 19′ 00″	1010	33	14.8	0.288	HCO_3–Ca–Mg
41	Tongchangjiao	Tengchong	98° 25′ 50″	25° 30′ 40″	1760	19.5	77.3	1.721	HCO_3–Na
42	Bapai	Tengchong	98° 24′ 00″	25° 27′ 00″	1180	21	55.0	0.126	HCO_3–Na–Ca–Mg
43	Hetou	Tengchong	98° 29′ 30″	25° 20′ 50″	1770	26	33.0	0.182	HCO_3–Na

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
44	Heshun Suanshuigou	Tengchong	98° 28′ 00″	25° 00′ 40″	1580	24.5	85.0	0.236	HCO_3–Mg–Ca
45	Longguangtai	Tengchong	98° 28′ 40″	25° 02′ 00″	1590	23			
46	Dieshuihe	Tengchong	98° 29′ 00″	25° 02′ 00″	1640	23	125	1.610	HCO_3–Mg–Ca–Na
47	Guanyintang	Tengchong	98° 29′ 30″	25° 02′ 40″	1620	19.7	63.0	0.124	HCO_3–Mg–Ca
48	Yuanjiatang	Tengchong	98° 31′ 00″	25° 01′ 40″	1640	21.2	88.0	0.244	HCO_3–Mg–Ca
49	Wubanqiao	Tengchong	98° 31′ 40″	24° 58′ 00″	1670	35	37.0	0.134	HCO_3–Na
50	Xiabiaoyuan	Tengchong	98° 34′ 20″	25° 13′ 00″	1520	26.2	138	1.348	HCO_3–Mg
51	Ludiantian	Tengchong	98° 34′ 40″	25° 12′ 40″	1500	25	125	0.783	HCO_3–Mg–Na
52	Qushi Xiaotangba	Tengchong	98° 35′ 40″	25° 12′ 50″	1480	28	135	1.932	HCO_3–Mg–Na
53	Chequetang	Tengchong	98° 37′ 50″	25° 13′ 50″	1440	25.5	115	1.648	HCO_3–Mg–Na
54	Dong-Yujiazhai	Tengchong	98° 42′ 00″	25° 22′ 50″	1830	27.5	43.4	0.303	HCO_3–Ca–Na
55	Xinzhai	Tengchong	98° 40′ 10″	25° 01′ 30″	1450	30.5	33.0	1.226	HCO_3–Na
56	Longanqiao	Tengchong	98° 40′ 50″	24° 51′ 50″	1190	29	123	0.866	HCO_3–Na
57	Gaojiancao	Tengchong	98° 42′ 00″	25° 07′ 30″	1760	34	31.7	0.132	HCO_3–Na
58	Zongfu	Tengchong	98° 43′ 20″	25° 04′ 50″	2320	35	47.4	0.152	HCO_3–Na
59	Yangxiba	Longling	98° 39′ 10″	24° 26′ 15″	1160	34	23.9	0.927	HCO_3–Na
60	Qingtang	Longling	98° 40′ 45″	24° 45′ 20″	1630	21	42.1	0.160	HCO_3–Ca–Mg
61	Longjing	Longling	98° 41′ 25″	24° 45′ 25″	1580	20	46.1	0.112	HCO_3–Mg–Ca
62	Fulongsi	Longling	98° 40′ 00″	24° 35′ 00″	1530	25	16.1	0.171	CO_3–Ca
63	Huangcaoshan	Longling	98° 44′ 00″	24° 49′ 30″	1680	33	127	0.773	HCO_3–Na
64	Sidaohe	Longling	98° 44′ 35″	24° 49′ 45″	1740	30	44.7	0.112	HCO_3–Na–Ca

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
65	Longjiang Xiaotang	Longling	98° 44′ 00″	24° 45′ 10″	1920	20	42.1	0.08	HCO_3–SO_4–Na–Ca
66	Luojiazhai	Longling	98° 52′ 55″	24° 18′ 05″	1980	21	30.4	0.106	HCO_3–Ca–Na
67	Potou	Longling	98° 54′ 00″	24° 26′ 20″	1550	33	81.2	0.257	HCO_3–SO_4–Na
68	Taozizhai	Longling	98° 56′ 30″	24° 26′ 00″	1330	28	61.3	0.209	HCO_3–SO_4–Na
69	Pilizhai	Longling	98° 56′ 20″	24° 18′ 00″	1510	34	40.8	0.187	HCO_3–Na
70	Bizhai	Longling	99° 02′ 20″	24° 34′ 30″	710	32.5	25.2	0.413	HCO_3–Ca–Mg
71	Mamushu	Baoshan	98° 57′ 00″	24° 58′ 25″	1350	24			
72	Tuanshantou	Baoshan	98° 57′ 45″	24° 58′ 40″	1250	32	14.8	0.341	HCO_3–Ca–Mg
73	Wandoudi	Baoshan	99° 02′ 00″	25° 03′ 30″	1400	23			
74	Longjing	Baoshan	99° 03′ 00″	25° 02′ 00″	1820	24			
75	Daxinzhai	Baoshan	99° 02′ 15″	25° 00′ 10″	1400	23			
76	Daguanmiao	Baoshan	99° 15′ 00″	25° 07′ 00″	1660	25	17.5	0.284	HCO_3–Ca–Mg
77	Xiuling	Baoshan	99° 20′ 40″	25° 01′ 30″	1620	32	24.0	0.995	HCO_3–Ca–Mg
78	Renhe RST	Shidian	99° 11′ 00″	24° 46′ 28″	1460	30			
79	Wuyi Xiaoreshuitang	Shidian	99° 10′ 40″	24° 41′ 45″	1650	29.5	24.0	0.266	HCO_3–Ca–Mg
80	Wangdian	Changning	99° 21′ 00″	24° 31′ 30″	680	31	20.8	0.319	HCO_3–Ca–Mg
81	Bawei	Changning	99° 43′ 12″	24° 53′ 48″	1680	35	42.5	0.157	HCO_3–Na
82	Gojie	Changning	99° 48′ 00″	25° 02′ 12″	1560	30			
83	Lamasi	Lijiang	99° 28′ 20″	27° 12′ 10″	2580	19	48.2	0.600	HCO_3–Mg–Ca–Na
84	Longba	Lijiang	99° 30′ 30″	27° 25′ 30″	2300	19.	46.9	0.944	HCO_3–Na–Ca
85	Xiugesan	Lijiang	99° 30′ 30″	27° 24′ 35″	3250	19			

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
86	Tacheng	Lijiang	99° 31′ 55″	27° 28′ 45″	2100	19			
87	Luxi	Lijiang	99° 34′ 08″	27° 15′ 20″	2100	15.4	52.0	1.42	HCO_3–Na
88	Deliang	Lijiang	99° 35′ 30″	27° 23′ 55″	2000	19	44.2	1.11	HCO_3–Na
89	Lanxiang	Lijiang	99° 49′ 25″	26° 44′ 17″	2100	29	30.1	1.708	HCO_3–Na
90	Datong	Lijiang	99° 57′ 13″	26° 52′ 35″	1760	27.2			
91	Zhongxin	Lijiang	100° 10′ 56″	26° 53′ 40″	2380	18.5	19.4	0.230	HCO_3–Ca–Mg–Na
92	Changguo	Lijiang	100° 20′ 43″	26° 37′ 35″	1750	31	34.8	0.248	HCO_3–Ca
93	Meihe	Lijiang	100° 26′ 00″	26° 51′ 05″	1650	20			
94	Ladigu	Ninglang	100° 38′ 10″	27° 44′ 20″	2620	20.5	10.0	0.167	HCO_3–Ca–Mg
95	Cuiyu	Ninglang	100° 41′ 00″	27° 28′ 40″	2380	25			
96	Erdaoping	Ninglang	100° 48′ 30″	26° 49′ 00″	2580	25	21.4	0.217	HCO_3–Ca
97	Xiaoshuiping	Ninglang	100° 53′ 00″	27° 23′ 30″	2170	21.5	48.9	2.200	HCO_3–Cl–Na–Mg
98	Shulaohe Cave	Ninglang	100° 52′ 30″	27° 16′ 45″	2280	22	13.4	0.286	HCO_3–Ca–Mg
99	Longquansi	Yongsheng	100° 39′ 20″	26° 24′ 18″	1560	28	23.4	0.227	HCO_3–Ca–Mg
100	Yangping	Yongsheng	100° 48′ 40″	26° 40′ 56″	2750	30	34.7	0.374	HCO_3–Ca
101	Hedong Shiziyan	Huaping	100° 17′ 10″	26° 36′ 10″	1190	25	24.1	0.485	HCO_3–SO_4–Ca–Mg
102	Yazizhuang	Huaping	101° 17′ 25″	26° 24′ 30″	1240	35	33.4	0.543	HCO_3–SO_4–Mg–Ca
103	Rongjiang	Huaping	101° 20′ 40″	26° 31′ 30″	1165	28	21.4	0.441	HCO_3–Cl–Mg–CA–Na
104	Yangdanshan	Yunlong	99° 03′ 50″	25° 40′ 02″	1700	33.2	42.2	0.144	HCO_3–Na
105	Caojian Xiaoshui	Yunlong	99° 07′ 45″	25° 38′ 50″	2040	26	126	2.513	HCO_3–Na
106	Shanxi	Yunlong	99° 14′ 20″	25° 46′ 25″	1660	17.5	12.8	0.132	HCO_3–Ca

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
107	Jinhe	Yunlong	99° 13′ 40″	25° 37′ 30″	1950	21	28.1	0.583	SO_4–Ca
108	Yongan	Yunlong	99° 19′ 30″	25° 58′ 59″	1780	23	24.1	4.433	Cl–Na
109	Dalishu	Yunlong	99° 20′ 50″	26° 36′ 45″	1300	33.6	21.4	0.464	HCO_3–Ca–Mg
110	Wenshui Longtan	Heqing	100° 10′ 20″	26° 30′ 08″	2200	30.6	20.0	0.182	HCO_3–Ca–Mg
111	Baoziguo	Eryuan	99° 47′ 30″	25° 57′ 40″	1700	35			
112	Liyuan	Eryuan	99° 56′ 30″	26° 11′ 08″	2040	32.2			
113	Guanyuan	Eryuan	99° 55′ 45″	26° 09′ 40″	2040	26.5	30.7	0.423	HCO_3–Ca–Mg
114	Yunhengcun	Eryuan	99° 57′ 28″	26° 08′ 20″	2050	25.6			
115	Dabao	Eryuan	99° 55′ 30″	26° 00′ 52″	2260	19.8			
116	Qiongshuidong	Yangbi	99° 57′ 40″	25° 46′ 10″	2000	24.3	24.1	0.111	HCO_3–Na–Ca
117	Shangbatian	Yangbi	100° 03′ 20″	25° 35′ 50″	1700	33.2	34.8	0.142	HCO_3–SO_4Na–Ca
118	Mianhuadi	Yongping	99° 20′ 50″	25° 17′ 25″	1180	30.2	15.4	0.259	HCO_3–Ca–Mg
119	Shangcaotan	Yongping	99° 24′ 30″	25° 18′ 45″	1500	30			
120	Chalu	Yongping	99° 31′ 40″	25° 20′ 45″	1500	23.5	18.7	0.199	HCO_3–Ca–Mg
121	Henan	Weishan	100° 02′ 20″	25° 16′ 08″	1250	32	20.0	0.380	HCO_3–SO_4–Ca–Mg
122	Sanhe	Weishan	100° 06′ 50″	25° 18′ 00″	1800	32	33.4	0.520	HCO_3–Na
123	Lamaju	Nanjian	100° 16′ 55″	24° 58′ 20″	1800	27	18.7	0.474	HCO_3–SO_4 Na–Ca
124	Akedi	Nanjian	100° 21′ 40″	25° 02′ 10″	1700	25			
125	Dongsheng	Nanjian	100° 23′ 10″	25° 02′ 10″	1750	25			
126	Shidongsi	Nanjian	100° 31′ 00″	24° 50′ 20″	1750	33	42.8	2.543	SO_4–Ca–Mg
127	Bachong Longtan	Midu	100° 26′ 10″	25° 27′ 10″	1800	19.3	16.7	0.238	HCO_3–Ca–Mg

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
128	Shixia	Midu	100° 27′ 20″	25° 25′ 18″	1850	27.2	25.4	0.126	HCO_3–Ca–Mg
129	Duoyushan	Midu	100° 31′ 40″	25° 22′ 15″	1800	29			
130	Juli Wen shuitang	Midu	100° 34′ 56″	25° 10′ 57″	1480	21.5	28.1	0.294	HCO_3–Mg–Ca
131	Zulai	Midu	100° 43′ 18″	25° 07′ 55″	1400	31	26.7	1.447	SO_4–Mg–Ca
132	Shuizhai	Binchuan	10° 31′ 50″	25° 58′ 45″	1380	35	64.3	0.290	HCO_3–Na
133	Gongdezhuang	Binchuan	100° 31′ 20″	25° 57′ 30″	1500	26			
134	Jingtouying	Binchuan	100° 31′ 00″	25° 50′ 45″	1480	23	18.7	0.316	HCO_3–Mg–Ca
135	Shuangdun	Binchuan	100° 31′ 40″	25° 42′ 50″	1540	31	56.2	0.323	HCO_3–Mg–Ca
136	Heishu	Binchuan	100° 31′ 40″	25° 42′ 10″	1520	23.5	17.4	0.242	HCO_3–Ca
137	Dongzhuan	Binchuan	100° 34′ 00″	25° 39′ 30″	1660	28			
138	Taihe	Binchuan	100° 37′ 00″	25° 49′ 30″	1490	28	28.1	0.326	HCO_3–Ca–Na
139	Linjiatian	Binchuan	100° 45′ 45″	26° 10′ 30″	1160	28.5	22.7	0.234	HCO_3–Ca–Mg
140	Dabatian	Binchuan	100° 46′ 20″	26° 09′ 40″	1520	26.5	21.3	0.213	HCO_3–Ca–Mg
141	Zongfuzhuang	Xiangyun	100° 32′ 30″	25° 24′ 18″	1900	22			
142	Dabona	Xiangyun	100° 45′ 10″	25° 30′ 20″	1880	21			
143	Baishapo	Xiangyun	100° 47′ 05″	25° 42′ 20″	1980	20.5			
144	Wangjiazhuang	Xiangyun	100° 46′ 45″	25° 27′ 52″	1965	35	46.8	1.055	HCO_3–Na
145	Maai	Zhenkang	99° 05′ 00″	23° 56′ 03″	1360	30			
146	Maiba	Yongde	99° 13′ 28″	24° 14′ 42″	1040	30			
147	Longwangmiao	Gengma	99° 45′ 24″	23° 56′ 36″	1160	22	8.05	0.243	HCO_3–Ca
148	Taiping	Fengqing	99° 52′ 48″	24° 45′ 48″	1100	24	16.7	0.252	HCO_3–Ca
149	Anping	Fengqing	99° 43′ 48″	24° 25′ 30″	1360	28	12.0	0.234	HCO_3–Ca

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
150	Yangjiawo	Fengqing	100° 03′ 00″	24° 39′ 12″	1720	32			
151	Bangcun	Yunxian	100° 14′ 24″	24° 28′ 12″	1160	25			
152	Dazhai	Yunxian	100° 14′ 24″	24° 10′ 12″	1740	29			
153	Shangmang-jiao	Linxiang	100° 04′ 00″	23° 52′ 54″	1560	33	42.8	0.224	HCO_3–Na
154	Bangce	Lancang	99° 41′ 15″	22° 31′ 55″	1100	23	10.6	0.202	HCO_3–Ca–Mg
155	Babie	Lancang	100° 42′ 15″	22° 53′ 40″	800	30			
156	Zapu	Lancang	99° 45′ 00″	22° 53′ 00″	1480	26			
157	Baishuijing	Lancang	99° 46′ 50″	22° 51′ 40″	1340	28			
158	Kabike	Lancang	99° 46′ 50″	22° 49′ 50″	1330	25			
159	Yubaozhai	Lancang	99° 48′ 20″	22° 48′ 20″	1020	27			
160	Wagu	Lancang	99° 47′ 45″	22° 45′ 20″	970	34			
161	Menggen-Xiaozhai	Lancang	99° 56′ 10″	22° 19′ 40″	920	35			
162	Xinyingpan	Lancang	100° 01′ 50″	22° 42′ 20″	1170	25	35.7	0.203	HCO_3–Na
163	Mengkan	Lancang	100° 02′ 55″	22° 42′ 30″	1360	35			
164	Gaixin Xinzhai	Lancang	100° 09′ 55″	22° 21′ 30″	1400	32.5	47.4	0.250	HCO_3–Na
165	Datianqing	Lancang	100° 13′ 20″	22° 28′ 00″	1340	31			
166	Xiabangtang	Lancang	100° 16′ 30″	22° 26′ 00″	1590	30			
167	Mengsa	Lancang	100° 18′ 00″	22° 54′ 00″	640	35			
168	Malutian	Jingdong	100° 25′ 20″	24° 40′ 25″	970	35			
169	Yanzijiao	Zhenyuan	100° 45′ 00″	24° 01′ 35″	1260	21.8	14.2	0.501	SO_4–HCO_3–Na
170	Dajueka	Zhenyuan	100° 53′ 30″	24° 03′ 00″	1860	25			
171	Enkengjing	Zhenyuan	100° 57′ 00″	23° 42′ 30″	1500	28			

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
172	Donggui	Zhenyuan	101° 30′ 20″	24° 03′ 40″	1150	26			
173	Liuanqian	Jinggu	100° 04′ 30″	23° 19′ 25″	680	35			
174	Pazhuang	Jinggu	100° 58′ 10″	23° 23′ 10″	980	30			
175	Manfei	Ninger	101° 00′ 30″	23° 11′ 00″	1070	24.3			
176	Ximen Longtan	Ninger	101° 02′ 20″	23° 04′ 15″	1320	29.5	30.8	0.254	HCO_3–Ca–Mg
177	Hualiang	Ninger	101° 00′ 05″	23° 02′ 55″	1400	32.8	23.4	0.278	HCO_3–Ca
178	Laoyaozhai	Ninger	101° 05′ 40″	23° 02′ 30″	1320	28	16.9	0.260	HCO_3–Ca
119	Sanjiacun	Simao	100° 44′ 45″	22° 45′ 15″	960	30	16.8	0.237	HCO_3–Ca
180	Huimahe	Simao	101° 06′ 40″	22° 51′ 40″	1320	34.2	28.4	0.338	HCO_3–Ca–Mg
181	Daheiqing	Simao	101° 09′ 00″	22° 50′ 10″	1140	27	20.1	0.311	HCO_3–Na
182	Lasi	Simao	101° 10′ 25″	25° 50′ 10″	1160	27			
183	Zakamo	Mojiang	101° 23′ 30″	23° 28′ 35″	1240	26	0.10	0.25	HCO_3–Ca
184	Nanpanhe	Menghai	100° 22′ 30″	22° 13′ 15″	1060	28	44.0	0.215	HCO_3–Na
185	Najing	Menghai	100° 25′ 05″	22° 11′ 20″	1150	25			
186	Bangnan	Menghai	100° 29′ 20″	22° 06′ 15″	1420	26	34.6	0.147	HCO_3–Na–Ca
187	Banglong	Menghai	100° 29′ 50″	22° 06′ 50″	1500	31	37.5	0.179	HCO_3–Na
188	Sanmai Zhongzhai	Menghai	100° 39′ 00″	22° 00′ 30″	820	30	47.4	0.222	HCO_3–Na
189	Manyan Manbang	Mengla	101° 42′ 00″	21° 49′ 15″	790	29.2	41.9	2.731	Cl–SO_4–Na
190	Leida	Xingping	101° 53′ 00″	23° 51′ 00″	780	34	21.8	0.414	HCO_3–Ca
191	Zhaomike	Xingping	102° 08′ 00″	23° 56′ 00″	1390	30			
192	Menglong	Honghe	102° 24′ 40″	23° 19′ 40″	520	30	57.5	0.348	HCO_3–Ca
193	Quzui	Luchun	102° 25′ 30″	22° 51′ 20″	1150	30	30.2	0.523	HCO_3–Na

(continued)

Table 7.6 (continued)

No. Yt	Name	County	Longitude (E)	Latitude (N)	Altitude (m)	Temperature (°C)	SiO_2 (mg/L)	TDS (g/L)	Type of water
194	Kunche	Yuanyang	102° 35′ 00″	23° 17′ 25″	490	27			
195	Yangxi	Jinping	102° 45′ 00″	22° 46′ 00″	600	30			
196	Citongba	Jinping	102° 48′ 00″	22° 44′ 20″	480	25			
197	Mahuangtang	Jinping	102° 55′ 00″	22° 42′ 50″	790	35			
198	Longguhe	Jinping	103° 11′ 30″	22° 39′ 00″	350	35			
199	Xiaoshuiba	Tengchong	98° 17′ 30″	25° 18′ 00″	1730	33	85.0	0.978	HCO_3–Na

7.4 Warm Springs and Tepid Springs in Qinghai Province

The warm and tepid springs in Qinghai Province are about 24, accounting for 55% of the total. Their distribution regions are located in south foot of Mt. Qilian and Yushu Prefecture between Mt. Bayan Har and Mt. Dangl (Huang 1993).

In the region between Mt. Qilian and Qinghai Lake, the warm springs are Muli coal mine of Tianjun County (43 °C) (Qw01), Reshui coal mine of Gangca County (37–40 °C) (Qw02), Wangjiazhuang of Ledu County (27 °C) (Qt01), Yaoshuitang of Huangzhong County (24 °C) (Qt02), Reshuigou of Qilian County (31–35 °C) (Qt03).

In Yushu Prefecture, the warm and tepid springs are: Reshuigou of Yushu County (36 °C) (Qw03), Qingshuihe of Chunduo County (39.5 °C) (QW04), Juelayinqugou of Nangqen County (35 °C) (Qw 05).

In south bank of Qinghai Lake, The warm spring are Ayihai of Gonghe County (32 °C) (Qt04), Bayingeli of Ulan County (42.5 °C) (Qw06) and Lagan of Guinan County (38 °C) (Qw07).

At northern foot of Dangla Mountain: the warm spring is Tingquyuan (43 °C) (Qw 08); the tepid springs are Dangqu (30 °C) (Qt 05) and Tuotuohenan (19 °C) (Qt 06).

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Chapter 8
Hydrothermal Convection Systems and Geothermal Energy in the Southwest China

Abstract This chapter is the assessment of geothermal resources (high and intermediate temperature) of the Qingzang Plateau and its surroundings. Based on the average of SiO_2, Na–K, Na–K–Ca and K–Mg geothermometers, 107 high-temperature hydrothermal convective systems have been determined and then their installed capacity has been estimated. The definition of 559 intermediate temperature systems relies upon SiO_2 geothermometer for help. The geothermoelectric potential of high-temperature system is 3410 MW_{30yr} and the beneficial heat is 11.78 EJ in research area.

Keywords Assessment of geothermal resources · Geothermometers · Geothermoelectric potential

8.1 The Hydrothermal Convection System in China

In 1976, Muffler put forward a suggestion of classification of geothermal system in the second U.N. Symposium on the Development and Use of Geothermal resources in San Francisco. According to the geological setting and heat transfer regimes of geothermal system, geothermal systems can be subdivided into two categories: convective geothermal system and conductive geothermal system.

The convective geothermal system is also called as hydrothermal convective system. It is characterized by natural circulation of the working fluid, thus most of the heat is transferred by convection of circulating fluids rather than by conduction. Convection of circulating fluids tends to increase the temperature in the upper part of convection cells, while decreasing the temperature in the lower part.

Hydrothermal convective system can be divided into two categories. One type has young intrusions as heat sources of system. They form the high-temperature hydrothermal system at depths shallow enough (<3 km) to be tapped by drillholes. The other type is deep circulation system along the fault or fracture zones with sufficient permeability for water circulation.

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Conductive geothermal systems also can be divided into two types: one is deep sedimentary basin (including geopressured zones) and the other is Hot Dry Rock system.

With the furnished information in Chaps. 2 and 3, we understand the nature, occurrence, and distribution of geothermal resources in China Fig. 8.1 drawn up by Prof. Wang et al. (1996) shows the distribution and types of geothermal system in China. The high-temperature geothermal belt shown in Fig. 8.1 is the sole region in Chinese mainland. We all call it Himalayan Geothermal Belt (HGB) (Tong et al. 1978) or Yunnan–Tibet Geothermal Belt (Liao and Zhao 1999). Himalayan Geothermal Belt stretches right to Pamir via Kashmir along Indus suture. Twenty-nine thermal springs discharge in Kashmir region, including famous Puga (93 °C), Panamic (80 °C), Khorkun (85 °C), Chummathang (86 °C) and Murtazabad (91 °C). There are many warm and hot springs at south slope of main ridge of Himalayas, including Bhutan, Nepal, Himachal Pradesh and northwest part of Uttar Pradesh of India except for Manikarn boiling springs (94.4 °C) in Himachal Pradesh and Jumnotri boiling spring (90 °C) at source of Jumna River in Uttar Pradesh (Waring 1965; Bakht 2000).

The identified 1419 hydrothermal convective systems in Chaps. 5, 6, and 7 can motivate us to assess the potential of hydrothermal resources. Based on the temperature of fluid in geothermal reservoir, the hydrothermal system may be divided into the following three categories: high-temperature (≥ 150 °C), intermediate-temperature (90–149 °C) and low-temperature (<90 °C). They serve different purposes: the exploitation of high-temperature hydrothermal system is mainly to

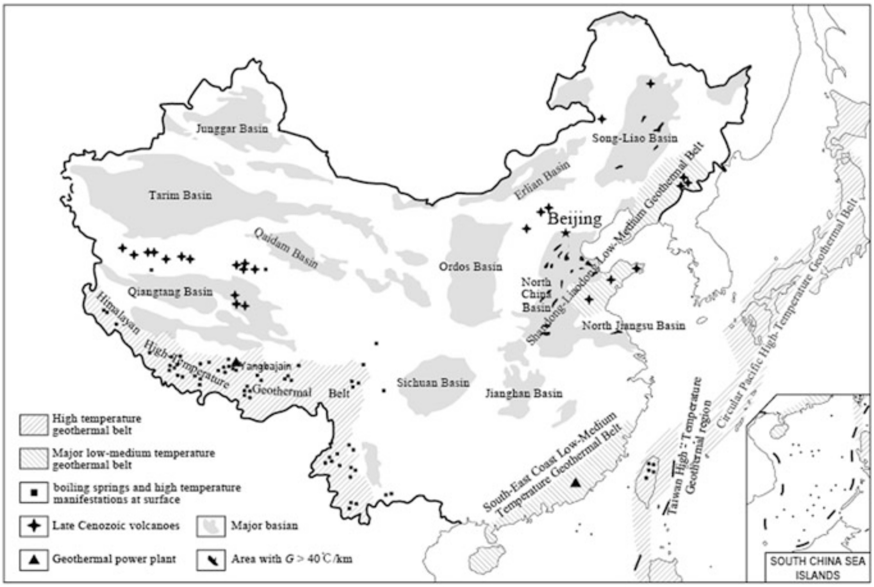

Fig. 8.1 Geothermal systems in China (After Wang et al. 1996, with a bit of alteration)

use geothermal power to produce secondary energy for agricultural and industrial development of a country, whereas development of intermediate-temperature systems is often directly use for industrial and agricultural production.

8.2 The Types of High-Temperature Hydrothermal Convection Systems

The total heat contained in a geothermal reservoir may be computed if the volume of the reservoir is known and the fluid and rock properties and characteristics can be estimated. The temperature of the fluid and the associated rock together with the reservoir volume are the primary factor in the heat content estimation. The temperature alone is the dominant factor in the quality estimation—the higher the temperature the higher the quality of the heat. Thus the high-temperature hydrothermal convective system will certainly be of more interest.

A necessary condition for the formation of high-temperature geothermal systems in shallow crust is magmatic heat, or deep faults near the earth's crust. Geological structures appear to control high-temperature geothermal systems and their distribution, which are mainly distributed in the convergent boundaries between the plates, or divergent boundaries, or transform boundaries, or plates inside the hot spots. In Table 8.1 are their classifications listed.

Table 8.1 is the classification of cause of formation of high-temperature hydrothermal systems according to their heat source. No. 1, No. 2, and No. 3 in Table 8.1 was put forward by Heiken in (1982). There are other two types in the classification of cause of formation of geothermal systems of Heiken: sedimentary basin and common fault zones, which are eliminated from Table 8.1 due to their lower reservoir temperature.

The No. 4 type in Table 8.1 is unique to China. Before two deep holes (ZK4001 and 4002) in the Yangbajain geothermal field in Tibet were drilled, many of the world geothermal experts doubt whether there is magma source over there. Heat source of geothermal systems and magnitude of terrestrial heat flow within the Himalayan Geothermal Belt (HGB) are of paramount scientific interest. Hochstein pointed out (Hochstein and Yang 1995): "The absence of volcanism and absence of a ^{3}He component in thermal fluids strongly suggest that any anomalous heat beneath the HGB is of crustal origin and is not associated with cooling intrusion in the brittle upper crust.—Natural ^{2}H and ^{18}O isotopes of geothermal fluids indicate that heat is swept from the deeper brittle crust into permeable fractures by deeply infiltrating surface waters; at an upper level, fracture zones and concealed outflows constitute the reservoir of thermal prospects. Deep fluid temperatures would then be controlled by sweep depths in the absence of crustal intrusions." He thought that the temperature of least diluted hot fluids is 175 °C at his geological section and conceptual fluid flow of upper reservoir of Yangbajain field. At same times, ZK305 reached 202 °C at a depth of 905 m in 1987 and ZK4002 reached 329.8 °C at a

Table 8.1 The classification of high-temperature hydrothermal system

Heat source	1. Large silica-rich magma	2. Neutral magma	3. Basalt magma	4. Remelting magma	5. Radiogenic heat
Description of heat source	Large magma body (batholith 1000 km × 500 km), there is a small bell rock rises to the surface, thin (<10 km), penetrated to the surface within 5 km. Long cooling time (>1 Ma)	Composite volcanoes. Fire tongue inside center vents smaller (<1 km^3). A big magma chamber beneath the volcano at 10–15 km. Cooling time ranging from a few days to 1 Ma	Dikes, sills, and rock cap composed of network structure. prolate dyke system. Unless the invasion rate is high, otherwise the magma cooled quickly	Reflection highlights at 15 km (crustal remelting magma source); Bubble-like high conductor, above 10 km. (late tectonic emplacement molten or semi-molten magma chambers)	Maybe no magma heat source. High heat flow area
Surface manifestation	Caldera and ring dykes, a lot of rhyolite, ignimbrite. A large area of boiling springs and geysers	Composite volcano, Cinder cone volcano, Andesite, hot springs, fountains, fumaroles	Fissures, shield volcano, volcanic cinder cones. Basalts, Fumaroles, hot springs activity	Boiling spring, geysers, fumaroles, hydrothermal alteration	Boiling springs
Chemical type of water	Cl–Na type volcanic water	Cl–Na type volcanic water	Cl–Na type volcanic water	Cl–Na type volcanic water	HCO_3–Na type of water
Tectonic settings	Subduction zone, hot spot	Subduction zone, hot spot	Mid-ocean ridge, Continental rift, hot spot	Continental/continental Collision belt	Deep fracture belt
Cases	Yellowstone, Taupo (NZ) Volcanic zone	Fuji of Japan, Taibei and Tengchong	Iceland, East African rift	Southern Tibet	Ruili and Yun County of Yunnan

depth of 2006.8 m in March 1994 in the north part of Yangbajain field. Italian experts went to Yangbajain to do thermologging in 1995, The thermometric result of Tibet Geothermal Team was approved by Italian experts, who put forward a hypothesis of metamorphic complex. The deep fluid of Yangbajain is also NaCl type volcanic water suggested by White (1975).

The No. 5 is very common in Yunnan Province, mainly along the deep fault or uplift structures, the main geothermal manifestation is boiling spring in relatively small area. They have been called as "Quasi-temperature geothermal systems" (Liao and Zhao 1999). This kind of hydrothermal convective system is mostly characterized by hot spring or warm spring discharges in fault/fracture zones (i.e., intermediate or low-temperature system), especially where these encounter topographic lows. Recharge of such systems occurs preferentially along faults zones as well. This kind of hydrothermal systems is lack of magmatic activity. The discharging fluid is HCO_3–Na type meteoric water. The disparity between high and intermediate-low temperature depends on the circulatory depth of meteoric water.

8.3 Recent Geothermal Resource Assessment of Hydrothermal Convection Systems

Geothermal resources consist primarily of thermal energy, and thus geothermal resources assessment is the estimation of the thermal energy in the ground with reference to the mean annual temperature, coupled with an estimation of the amount of the energy that might be extracted economically and legally at some reasonable future time.

Many countries have seen a great increase in attention paid to systematic geothermal resources assessment since 1975. The effort began with an estimation of the geothermal potential of the pre-Apennine belt of central-southern Italy (Barelli et al. 1975) and with the first comprehensive geothermal resource assessment of the United States (White and Williams 1975). Subsequently, Japan and New Zealand also paid great attention to this work. But we follow with interest the follow-up assessments of Muffler (1979).

Methodologies used for geothermal resource assessment were divided into four main categories: (1) surface flux, (2) volume, (3) planar fracture, and (4), magmatic heat budget. The volume method was used by Muffler for assessment of geothermal resources in the United States in 1978 (1979). His book is a dealing with hydrothermal convective systems in the United States with mean reservoir temperature greater than or equal to 90 °C and depths less than 3 km. Their method is to determine (1) the accessible resource base, (2) the resource at wellhead, and (3) the amount of electricity or beneficial heat that might be produced from high-temperature or intermediate-temperature system. In the assessment of geothermal resources, the concept between Muffler's accessible resource base and White's resource base is distinct in depth limit. Muffler thought that the depth limit of economic production drilling for geothermal resources varies with drilling costs and economics and currently is about 3 km White and Williams (1975) thought that the anomalous heat of the hydrothermal convection and the igneous-relayed systems are superimposed on the regional conduction-dominated environments, with the total thus representing the "resource base" (to 10 km).

Muffler and Cataldi (1977, 1978) attempted to develop a logical resource terminology specifically for geothermal energy building on the general background. Geothermal resource base is defined as "all the heat in the Earth's crust beneath a specific area, measured from local mean annual temperature." The accessible resource base is the thermal energy at depths shallow enough to be tapped by drilling in the foreseeable future, whereas that fraction of the accessible resource base that might be extracted economically and legally at some reasonable future time is the geothermal resource. The geothermal reserve is identified geothermal energy that can be extract legally today at a cost competitive with other energy sources.

8.3.1 Determination of Accessible Resource Base

The volume method used to estimate the thermal energy of hydrothermal convection system in Circular 790 in 1978 is essentially similar to that used in Circular 726 in 1975 of U.S. Geological Survey. In order to calculate the reservoir thermal energy for each hydrothermal convection system, the indispensable parameters include the temperature in reservoir, the subsurface area of geothermal field, and the thickness of reservoir, which all are variable for each field. The constant parameter is the volumetric specific heat of rock plus water. The reservoir thermal energy may be derived from following equations with these parameters:

$$q_{\mathrm{R}} = \rho c \times a \times d \times (t - t_{\mathrm{ref}})$$

where

q_{R} reservoir thermal energy in Joules (J)
ρc volumetric specific heat of rock plus water (2.7 J/cm^3/ °C)
a reservoir area
d reservoir thickness
t reservoir temperature
t_{ref} reference temperature (5 °C for Tibet and the Plateau of west Sichuan; 15 °C for Yunnan)

Thermal energy in reservoir of identified hydrothermal convection systems of the United States was calculated by Renner et al. (1975) using the volume method. Reservoir tops was either estimated from drillhole data or assumed (at 1.5 km) and reservoir bottom were assumed to be at a depth of 3 km. Areas were estimated from geological, geophysical, and available drilling data, and reservoir temperatures were estimated from drillhole measurements and chemical geothermometers (quartz and Na–K–Ca). The thermal energies were tabulated separately for high-temperature system (>150 °C) and intermediate temperature systems (90–150 °C).

The methodology used to estimate the thermal energy of hydrothermal convection systems of the United States in 1978 is essentially similar to that used in 1975, with the addition of statistical methodology of the Monte Carlo methods.

I'd like to use the handy method in Circular 726.

8.3.2 Temperature Estimates of Reservoir

The geothermal resource assessment methodology is to first assess whether a geothermal area is a high-temperature hydrothermal system or is an intermediate temperature system or a low-temperature system. Of course, the reliable way is to drill and measure the temperature in the hole. However, this is impossible to assess the potential of a region. For most geothermal areas, there are no detailed geological prospecting and geophysical explorations. We can only use collected water samples and results of chemistry analysis in most geothermal areas, based on the analysis results, the application of various geochemical geothermometer to calculate temperature of geothermal fluid in reservoir.

Among all geochemical thermometers, silica thermometer is the most important, The concentration of silica in a thermal water depends principally on the temperature-dependent solubility of quartz, chalcedony, alpha cristobalite, or amorphous silica. Fournier (1973) made the following generalizations: (1) the solubility of quartz controls silica concentrations in all high-temperature reservoirs (>180 °C), and quartz may be the controlling mineral in granitic rocks down to temperature as low as 90 °C; (2) chalcedony commonly controls silica concentration in lower temperature reservoirs and may be the limiting mineral in basaltic rocks up to 180 °C; (3) in some low-temperature environments the rapid decomposition of silicates, such as plagioclase and serpentine, allows solutions to become supersaturated with respect to quartz and chalcedony.

The quartz geothermometer works best for well waters where subsurface temperatures are above about 150 °C. It has been shown to work well for some hot spring waters (Fournier and Truesdell 1970).

The temperature of geothermal reservoir fluid in a high-temperature hydrothermal system first requires that quartz thermometer temperature should exceed 150 °C. Namely the content of silica in high-temperature hydrothermal system needs to achieve at least 125 mg/L. However, there are serious questions in our analytic data. Let us check the analytic data of silica of 1975 against 1989. The 1975 data are outside the brackets; whereas the 1989 data inside the brackets: Setang: 6.2 (150), Qucain: 13.5 (203), Yangyi: 13 (258), Daggyai: 22.7 (120.03), Kuma: 17, Targyai: 7, Kogco: 15, Rugyog: 12.5, Dagze: 33.4. The difference between two corresponding results of the analysis data can be as high as 5–24 times. I remember that some water samples of important spas in 1975 were analyzed by hydrogeological research units. Obviously, the silica data of boiling spring in Tibet in 1975 are inconceivable and incorrect. The possible reasons are that (1) the analyst, who did not understand that the silica method is of no use for cold groundwater, used it to analyze cold groundwater as opposed to the thermal spring water, and therefore the analysis results did not make a distinction between Na cation and K cation are in 1973–1974 and a part of 1975. (2) possible polymerization of silica occurred after sample collection due to improper preservation of the sample. It seems that Chinese research workers generally did not understand the importance of silica in thermal spring, especially its characteristic and the analysis method before 1975. As a result, lake of silica data is common for collected samples in 1973 and 1974, for example: Tb47, Th135, Th136, Th137, Tw58, Tt83, Tt84, etc.

How do you define the nature of a geothermal system by use of geothermometer?

To the high-temperature hydrothermal convection dystem:

1. It must be a boiling springs. When the pH value of the boiling spring is neutral to slightly acid, the silica geothermometer can give accurate results. If its silica value of one boiling spring is less than 125 ppm, we may suppose there is problem in the course of analysis;
2. The silica value for hot spring, warm spring or tepid spring must be equal to or more than 125 ppm.
3. If the concentration of silica exceeds 125 ppm, the Na/K geothermometer and the Na–K–Ca geothermometercan be used to calculate reservoir temperature. Where waters are known to come from high-temperature environments (>150 °C), the Na/K method and the Na–K–Ca method generally give excellent results.
4. Giggenbach's K/Mg geothermometer (1986) can be used to examine the mixing level of shallow cold blended groundwater. If K–Mg thermometer temperature is relatively low, then reduce the temperature of the quartz thermometer requirements.
5. if the area of high-temperature hot springs area or boiling springs area is huge, intense hydrothermal alteration and a large thermal manifestation area, a large number of sulfur crystals, but the lack of water chemistry data should also be taken into account. Geothermal reservoir temperature was to set up 160–170 °C.

In brief, the reservoir temperature for high-temperature hydrothermal convection system is decided by average value of $TSiO_2$, TNa/K, TNa–K–Ca, and TK/Mg, when TK/Mg value is more than 100 °C. The temperature value of TK/Mg geothermometer is too low to use, due to mixing of a large of cold water.

To intermediate- or low-temperature hydrothermal systems:

1. It only calculates the quartz geothermometer in magmatic rock area, or the chalcedony geothermometer in sedimentary rock area, specially limestone district. For an intermediate-temperature system, the concentration value of silica should be in the range 38.5–125 ppm, when use of the quartz geothermometer, but 70–180 ppm for chalcedony geothermometer.

2. The Na/K geothermometer and the Na–K–Ca geothermometer fail to give reliable results for waters from environments with temperatures below 100 °C.
3. The K/Mg geothermometer can use to judge the mixing degree of cold waters.

8.3.3 Volume Estimates

The largest difficulty in assessment of thermal resource is the area of reservoir The approximate area of a geothermal field can be determined only by drilling or suitable geophysical exploration. However, the thermal springs through drillhole exploration or geophysical exploration are less than six in the Qingzang Plateau and its surroundings.

In Qingzang Plateau, the boiling springs plus some hot springs with more than 80 °C usually appear to have the most intense thermal activity, including rich in boiling springs and steaming grounds, abundant natural heat output, and large-scale hydrothermal alteration region, for localities where data on subsurface conditions are too few or absent, a standard reservoir area of 5–10 km^2 was assigned.

For the low-temperature hot springs, warm springs and tepid springs, a rational reservoir area of 0.5–1.5 km^2 was assigned.

The thickness of the heat storage became even more an unknown number, the general admissible number is 1 km. The volume of the geothermal reservoir is 5–10 km^3 for high-temperature hydrothermal convection system and 0.5–1.5 km^3 for intermediate- or low-temperature systems.

In geothermal resources assessment, the temperature of reservoir fluid and the volume of reservoir are two variable parameters; they get different values for different geothermal systems. There are other two fixed parameters: volume specific heat of rock and water in reservoir (2.7 J/g °C) and local annual average temperature.

Using these four parameters, the resources assessment of a geothermal resources area can be done. Specifically, it can be divided into following four steps: The first step is to calculate the thermal energy of the reservoir. The second step is to calculate the heat energy at wellhead, the third step is to calculate the wellhead useful work, the fourth step is to calculate the power potential of 30 years. Specific methods are in accordance with US geothermal resource assessment methods used by White in (1975) and by Muffler in 1978 and with the regulations of our country. This is not described in detail.

8.3.4 The Wellhead Thermal Energy

Assessing hot-water geothermal resources involves defining a geothermal recovery factor, R_g, such that R_g is the ratio geothermal energy recovered at wellhead, Q_{wh}, to the geothermal energy originally in the reservoir, Q_R:

$$R_g = Q_{wh}/Q_R$$

R_g reflects the physical and technological constraints. In assessment of geothermal resources of the United States-1978, Rg equals 25% for all hot-water reservoirs (Muffler 1979). We shall use these values for assessment of geothermal resources in Qingzang Plateau and its surroundings.

8.3.5 Available Work

Electricity is produced from geothermal resources by converting part of the thermal energy into mechanical work and then using this work to generate electrical energy. In the conversion of thermal energy to mechanical work, some heat is always rejected to the surroundings as waste heat. There is a maximum amount of work that can be obtained from a given amount of thermal energy. It is called available work (W_a), which is given by:

$$W_a = \Delta H - T\Delta S$$

where

ΔH (enthalpy change)	is the amount of energy liberated or absorbed when a fluid changes from some initial state to some final state.
ΔS	is the entropy change of a fluid.
$T\Delta S$	can be considered a measure of the waste heat which cannot convert into work.

The calculation of available work will make use of method of assessment of geothermal resources of the United States in Geological Survey Circular 790 (Muffler 1979). When we know the temperature of reservoir and use submitted graph in Circular 790, it is easy to evaluate W_a value.

8.3.6 Electricity and Beneficial Heat

For high-temperature convection system, the electrical energy E obtainable from a geothermal reservoir is given by the equation:

$$E = W_a \times \eta_u$$

η_u is a utilization factor less than one to account for mechanical and other losses that occur in a real power cycle. For hot-water systems a representative value of 0.4 is usually chosen.

For intermediate-temperature system, the amount of the resource that could be directly applied to no electric uses is called beneficial heat and is calculated from:

$$\text{Beneficial heat} = Q_{wh} \times U_b$$

where U_b is defined as beneficial heat utilization factor. According to Circular 790, the value of U_b is the fraction of thermal energy obtained when 150 °C water undergoes a 32 °C drops or 100 °C water undergoes a 20 °C drop and is equal to 0.24.

8.4 The Evaluation of Geothermal Resource Potential of High-Temperature Hydrothermal Convection System in Tibet Autonomous Region

According to the information provided by the "Geothermas beneath Xizang (Tibetan) Plateau" (Tong et al. 1981) and "Thermal Springs in Tibet" (Tong et al. 2000), by calculating and screening, the total number of high-temperature hydrothermal system within the Tibet Autonomous Region is about 62. The results are shown in Table 8.2.

Several things are worth noting in Table 8.2: First, in the territory of Tibet, initially there are 62 initially identified high-temperature hydrothermal system, of which 40 boiling springs, 19 hot springs, 1 warm spring, 1 tepid spring, and 1 unknown situation; second, in Sect. 5.1, there are in total 48 known boiling springs in Tibet, and so 8 boiling springs are not included in the high-temperature hydrothermal systems here, the reason is that four boiling springs are lack of water chemistry data and their rugged terrain too difficult to develop, and for the other four boiling springs, though there are water chemistry data, the results by geothermometers are very low, they need further investigations and reevaluations.

Some problems exist in the measurement methods and in the results of chemical analysis of water of boiling springs. There is no separately for the Na and K ions using conventional analytic methods of cold groundwater, Moreover, analyst in 1975 did not know the analytic methods of SiO_2, I do not have much belief in analytic results with such low SiO_2 values.

Revisits were made for some springs in 1979 and 1989, very different SiO_2 values were found, though other components remained the same. For instance, Samig's analysis results are 6.27 mg/L in 1975, but is 150 mg/L in 1989, a difference of 23.9 times. Qucai 13.5 mg/L in 1975, but 203 mg/L in 1989, a difference

Table 8.2 High-temperature hydrothermal systems in Tibet autonomous region

No	Geothermal areas	County	Spa's temp. (°C)	Chemical type of water	$TSiO_2$	TNa/K	TNa K–Ca	TK–Mg	T. of reservoir
1	Sogdoi	Gar	86	Cl–Na	148	228	232	169	194
2	Langiu	Gar	78	$Cl–HCO_3–SO_4–Na$	156	206	191	111	160
3	Bar	Gar	93	No sample					160
4	Qangba	Ge'gyai	51	$HCO_3–Cl–Na$	142	184	180	118	156
5	Qiugoinba	Burang	81	$Cl–HCO_3–Na$	162	236	245	151	199
6	Abug	Burang	85	$HCO_3–Na$	130	216	210	105	165
7	Qucain Lungba	Burang	95	$HCO_3–Cl–Na$	141	223	248		189
8	Yamenza	Burang	79	$HCO_3–Na$	153	264	225	133	194
9	Targokyimsa	Burang	86	$HCO_3–Na$	148	218	207	118	173
10	Tuoheping Co	Gerze	94	$HCO_3–Na$	160	207	234	152	188
11	Charu Qucain	Coqen	83	$HCO_3–Na$		199	183	104	162
12	Janggu Malung	Zhongba	99	No sample					160
13	Zuolong	Zhongba	82	No sample					150
14	Yulung Lungba	Zhongba	82	No sample					150
15	Rugyog	Saga	85	$HCO_3–Cl–Na$	84?				180
16	Kangleg	Saga	88	$HCO_3–Cl–Na–Ca$	144	257	187	93	169
17	Daggyai	Ngamring	85	$HCO_3–Cl–Na$	148	227	212	128	179
18	Nandumu	Ngamring	86	$HCO_3–Na$	159	214	202	118	173
19	Labulang	Ngamring	85	$Cl–CO_3–Na$	160	236			198
20	Samig	Ngamring	86	$Cl–CO_3–Na$	146	253	254	145	200
21	Buloba	Ngamring	80	Cl–Na	163	207	209	139	180
22	Chala	Ngamring	53	$Cl–HCO_3–Na$	142	200	190	128	165
23	Lolo Qucain	Tingri	86	$HCO_3–Cl–Na$	150	239	195	139	176
24	Capu	Xaitongmoin	86	$Cl–HCO_3–Na$	206	259	283	163	228

(continued)

Table 8.2 (continued)

No	Geothermal areas	County	Spa's temp. (°C)	Chemical type of water	$TSiO_2$	TNa/K	TNa K–Ca	TK–Mg	T. of reservoir
25	Lhawangze	Xaitongmoin	63	Cl–HCO_3–Na	152	226	191	118	172
26	Qangbugqabka	Xaitongmoin	81	Cl–HCO_3–Na	167	194	181	89	158
27	Kungqu	Xaitongmoin	84	HCO_3–Na	33?				160
28	Cakakambug	Xaitongmoin	64	HCO_3–Na	142	226	198	123	172
29	KawuQucain	Sa'gya	86	Cl–Na	182	253	288	208	233
30	Kurme	Kamba	86	Cl–Na	57?				165
31	Kogco	Kamba	85	HCO_3–Na	53?				165
32	Bibilung	Namling	87	HCO_3–Na	137				165
33	Sertangcaka	Namling	82	HCO_3–Cl–Na	161	234	228	139	181
34	Gyinkar (?)	Gyangze	57	Cl–HCO_3–Na	124	269	217	127	184
35	Chagbaqucain	Rinbung	70	Ci–HCO_3–Na	145	212	200	131	172
36	Xumai (Molung)	Nyemo	87	SO_4–Cl–Na	128	166	149	60	165
37	Yangyi	Damxung	87	CO_3–HCO_3–Na	206	180	199	165	188
38	Guringqu	Damxung	85	HCO_3–Na	159	169	162	109	150
39	Yangbajain	Damxung	93	Cl–HCO_3–Na	169	228	207	119	181
40	Qucain	Damxung	91	Ci–HCO_3–Na	181	270	270	156	219
41	Caquwo	Maizhokunggar	83	HCO_3–Cl–Na	166	245	238	148	199
42	Xiru warm spa	Xainza	35	HCO_3–Cl–Na	175	217	235	156	191
43	Xezhag	Bangoin	63	HCO_3–Na	158	180	158		165
44	Dazho	Amdo	73	SO4–HCO_3–Na	158	221	230	139	185
45	Gulu	Nagqu	85	Cl–HCO_3–Na	149	226	227	109	178
46	Sangle	Nagqu	85	No sample					150
47	Lhakang	Lhozhag	67	HCO_3–Cl–Na	159	181	163	105	152
48	Kabusang	Nedong	14	Cl–HCO_3–Na	161	274	195	125	189

(continued)

Table 8.2 (continued)

No	Geothermal areas	County	Spa's temp. (°C)	Chemical type of water	$TSiO_2$	TNa/K	TNa K–Ca	TK–Mg	T. of reservoir
49	Chabmaisa	Qusum	75	Cl–Na	195	305	287	186	243
50	Riro	Comai	84	$Cl–HCO_3–Na$	152	20	202	110	174
51	Buxionglangu	Comai	85	$Cl–HCO_3–Na$	238	256	295	189	245
52	Caka	Comai	83	$Cl–HCO_3–Na$	171	248	214	124	189
53	Sagarnamka	Comai	86	Cl–Na	187	263	234	136	205
54	Babudimi	Comai	87	Ci–Na	162	254	235	154	201
55	Quzhomo	Cona	83	$Cl–SO_4–Na$	126	261	203	99	172
56	Zhangtang	Lhunze	88	$HCO_3–Cl–Na$	161	133	320	100	179
57	Tangmai	Bome	94	$CO_3–SO_4–Na$	171				171
58	Dilungqucain	Meodog	?	$Cl–CO_3–Na$	266	159	189	132	187
59	Puzang	Zayu	73	$Cl–SO_4–Na$	151	170	153	(91)	158
60	Bu	Zaru	61	$Cl–HCO_3–Na$	151	198	180		166
61	Bangdoi	Zaru	63	$HCO_3–Cl–Na$	151	155	145	(93)	150
62	Goqen	Zayu	65	$HCO_3–Na$	151				151

of 15 times. Yangyi is 13 mg/L in 1975, but 258 mg/L in 1979, a difference of 19.8 times. There are many similar results, but not enumerated here, and I am sure that the analysis data of SiO_2 for some boiling springs with such low values are wrong.

Finally, we shall discuss the four hot springs in Zayu County, which are located in interchanges between Yarlung Tsangbo Suture and ophiolite belt of Naga in the eastern foot of Myanmar arc in the geological structure, which is likely a region of high-temperature hydrothermal system in eastern Tibet. For No. 59, 60, 61 and 62 four hot springs, its quartz geothermometer's temperature reach 151 °C, but they are so close to the local tropical rainforest zones with abundant rainfall, that they may suffer from surface water infiltration, and so K/Mg thermometer temperatures are relatively low, and Na, K, Ca temperatures also are relatively low. They might be high-temperature hydrothermal system, which, however, requires drilling to confirm.

Table 8.3 shows the result of assessment of geothermal resources of high temperature hydrothermal convection systems in Tibet.

The total electrical potential of high temperature hydrothermal convection systems in Tibet Autonomous Region is about 1991.69 MW_{30a}.

8.5 Evaluation of Geothermal Resource Potential of High-Temperature Hydrothermal Convection System in Western Sichuan Province

According to the information provided by the "Thermal Springs in Hengduan (Traverse) Mountains" (Tong and Zhang 1994), there are 327 thermal springs in western Sichaan Province, including 8 boiling springs. In fact, There are 10 high-temperature hydrothermal convection systems, including 8 boiling springs and 2 hot springs, based on the calculation of geothermometer and temperature measurement in drillholes (Table 8.4).

Table 8.5 shows the results of assessment of high-temperature geothermal resources in western Sichuan.

The total electrical potential of 10 high-temperature hydrothermal convection systems in western Sishuan is 407.76 MW_{30a}, 30% of which is from Nyalunggo Qu in Tardo County.

Among the 10 high-temperature hydrothermal convection systems in west Sichuan, only one field (Nyalunggo Qu of Tardo Count) discharge HCO_3–Cl–Na type of water, and the rest discharge HCO_3–Na water. The Nyalunggo Qu (Xiaoreshui) is the third drilled geothermal field in Qingzang Plateau, and its temperature is of 207 °C at 267 m depth and wellhead temperature of 174 °C in ZK201 (Xu and Liang 2013).

Table 8.3 Results of the assessment of thermal resources of high-temperature convection system in Tibet

No	Geothermal areas	County	Reservoir's temp. (°C)	Reservoir's volume (km^3)	Reservoir's thermal energy (EJ)	Thermal energy at well hole (EJ)	Available work at well hole (EJ)	Electric potential (MW_{30a})
1	Sogdoi	Gar	194	5	2.55	0.64	0.13	50.07
2	Langiu	Gar	166?	5	2.17	0.54	0.10	42.73
3	Bar	Gar	169	3	1.34	0.33	0.064	27.11
4	Qangba	Ge'gyai	156	2	0.82	0.20	0.04	15.51
5	Qiugoinba	Burang	199	2	1.05	0.26	0.058	24.35
6	Abug	Burang	165	1.5	0.65	0.16	0.030	12.87
7	Qucain Lungba	Burang	189	5	2.48	0.52	0.13	54.59
8	Yamenza	Burang	194	1.5	0.77	0.19	0.042	17.79
9	Targokyimsa	Burang	173	3	1.36	0.34	0.067	28.18
10	Tuoheping Co	Gerze	188	5	2.47	0.62	0.131	55.34
11	Charu Qucain	Coqen	162	1.5	0.656	0.164	0.03	12.87
12	Janggu Malung	Zhongba	160	3	1.34	0.33	0.064	27.11
13	Zuolong	Zhongba	150	3	1.25	0.31	0.014	6.02
14	Yulung Lungba	Zhongba	150	10	4.05	1.01	0.046	19.26
15	Rugyog	Saga	180	5	2.36	0.59	0.123	51.92
16	Kangleg	Saga	169	5	2.21	0.55	0.11	44.91
17	Daggyai	Ngamring	179	10	5.00	1.25	0.27	113.99
18	Nandumu	Ngamring	173	3	1.36	0.34	0.067	28.18
19	Labulang	Ngamring	243	2	1.29	0.32	0.084	35.30
20	Samig	Ngamring	200	2	1.05	0.26	0.059	24.92
21	Buloba	Ngamring	180	2	0.95	0.24	0.049	20.77
22	Chala	Ngamring	165	1.5	0.65	0.16	0.03	12.87
23	Lolo Qucain	Tingri	176	5	2.31	0.58	0.115	48.78
24	Capu	Xaitongmoin	228	10	6.02	1.51	0.367	155.22
25	Lhawangze	Xaitongmoin	172	1.5	0.68	0.17	0.033	14.01

(continued)

Table 8.3 (continued)

No	Geothermal areas	County	Reservoir's temp. (°C)	Reservoir's volume (km^3)	Reservoir's thermal energy (EJ)	Thermal energy at well hole (EJ)	Available work at well hole (EJ)	Electric potential (MW_{30a})
26	Qangbugqabka	Xaitongmoin	158	1.5	0.62	0.15	0.029	12.05
27	Kungqu	Xaitongmoin	160	1.5	0.648	0.16	0.031	13.00
28	Cakakambug	Xaitongmoin	172	1.5	0.68	0.17	0.032	13.72
29	KawuQucain	Sa'gya	233	5	3.08	0.77	0.191	80.65
30	Kurme	Kamba	165	5	2.16	0.54	0.102	42.90
31	Kogco	Kamba	185	2	0.97	0.24	0.052	21.77
32	Bibilung	Namling	165	1.5	0.65	0.16	0.030	12.87
33	Sertangcaka	Namling	181	2	0.95	0.24	0.048	20.89
34	Gyinkar (?)	Gyangze	184	1.5	0.72	0.18	0.038	16.24
35	Chagbaqucain	Rinbung	172	2	0.90	0.23	0.044	18.67
36	Xumai (Molung)	Nyemo	165	2.4	1.03	0.258	0.053	22.35
37	Yangyi	Damxung	188	1.6	0.81	0.20	0.065	23.67
38	Guringqu	Damxung	150	1.5	0.608	0.15	0.029	12.05
39	Yangbajain	Damxung	181	10	4.75	1.19	0.247	104.43
40	Qucain	Damxung	219	2	1.16	0.29	0.069	29.3
41	Caquwo	Maizhokunggar	199	1.5	0.65	0.16	0.031	12.96
42	Xiru warm spa	Xainza	191	1.5	0.78	0.20	0.065	23.67
43	Xezhag	Bangoin	165	2	0.96	0.24	0.050	21.12
44	Dazho	Amdo	187	2	0.98	0.25	0.052	22.01
45	Gulu	Nagqu	178	5	2.35	0.58	0.121	51.32
46	Sangle	Nagqu	150	1.5	0.608	0.15	0.053	12.05
47	Lhakang	Lhozhag	152	1.5	0.60	0.15	0.026	11.07
48	Kabusang	Nedong	189	1.5	0.73	0.18	0.039	16.51
49	Chabmaisa	Qusum	243	5	3.21	0.80	0.208	88.26
50	Riro	Comai	163	1.5	0.64	0.16	0.030	12.71

(continued)

Table 8.3 (continued)

No	Geothermal areas	County	Reservoir's temp. (°C)	Reservoir's volume (km^3)	Reservoir's thermal energy (EJ)	Thermal energy at well hole (EJ)	Available work at well hole (EJ)	Electric potential (MW_{30a})
51	Buxionglangu	Comai	245	5	3.24	0.81	9.211	89.00
52	Caka	Comai	189	5	2.48	0.62	0.134	56.69
53	Sagarnamka	Comai	205	5	2.51	0.63	0.136	57.30
54	Babudimi	Comai	201	5	2.65	0.66	0.148	62.62
55	Quzhomo	Cona	172	1.5	0.57	0.17	0.032	13.72
56	Zhangtang	Lhunze	179	1.5	0.71	0.18	0.039	16.51
57	Tangmai	Bome	171	3	1.30	0.33	0.063	26.45
58	Dilungqucain	Meodog	187	1.5	0.74	0.18	0.039	16.51
59	Puzang	Zayu	158	1.5	0.595	0.15	0.027	11.32
60	Bu	Zaru	166	3	1.26	0.32	0.059	25.10
61	Bangdoi	Zaru	150	1.5	0.56	0.14	0.024	10.23
62	Goqen	Zayu	151	1.5	0.567	0.14	0.024	10.24
	Total				95.262	23.712	4.924	1991.69

Table 8.4 The high-temperature hydrothermal convective systems in western Sichuan

No	Geothermal area	County	Spa's temp. (°C)	Type of water	$TSiO_2$ (°C)	TNa/K (°C)	TNa–K–Ca	T K–Mg (°C)	T of Res. (°C)
1	Garyungo	Garze	92	HCO_3–Na	186	211	263	119	195
2	Kangrilung	Batang	97	HCO_3–Na	148	166	207	(73)	174
3	Caluparseng Qumig	Batang	88.5	HCO_3–Na	217	208	209	126	190
4	Zamkug	Batang	90	HCO_3–Na	148	206	211		188
5	Qukoilungba	Litang	86.5	HCO_3–Na	146	224	221	114	176
6	Yemucha	Litang	83	HCO_3–Na	137	165	154	(69)	152
7	Garbokoi	Litang	83	HCO_3–Na	(20)?	195	159	(79)	177
8	KainbaYuma Caqu	Dawu	72	HCO_3–Na	157	205	197	102	165
9	Nyalunggo Qu	Tardo	85	HCO_3–Cl–Na	166	205	238	(99)	204
10	Lungkequker	Aba	85	HCO_3–Na	134	176	163	(91)	158

Table 8.5 The assessment of high-temperature geothermal resources in western Sichuan

No	Geothermal areas	County	Reservoir's temp. (°C)	Reservoir's volume (km^3)	Reservoir's thermal energy (EJ)	Thermal energy at well hole (EJ)	Available work at well hole (EJ)	Electric Potential (MW_{30a})
1	Garyungo	Garze	195	5	2.57	0.64	0.141	59.76
2	Kangrilung	Batang	174	2	0.913	0.228	0.046	19.29
3	Caluparseng Qumig	Batang	190	5	2.50	0.62	0.133	56.02
4	Zamkug	Batang	188	3	1.48	0.37	0.075	31.91
5	Qukoilungba	Litang	176	5	2.31	0.58	0.113	47.86
6	Yemucha	Litang	152	2	0.79	0.198	0.034	14.36
7	Garbokoi	Litang	177	3	1.39	0.35	0.0695	29.38
8	KainbaYuma Caqu	Dawu	165	1.5	0.65	0.16	0.0299	12.64
9	Nyalunggo Qu	Tardo	204	10	5.10	1.28	0.286	120.75
10	Lungkequker	Aba	158	2	0.83	0.21	0.037	15.79
	Total				18.533	4.636	0.9644	407.76

The mean annual temperature is 5 °C in plateau of western Sichuan and is 15 °C in Daduhe Valley of Tardo County

8.6 The High Temperature Hydrothermal Convection System in the Southwest Yunnan

According to the information provided by the "Geothermics in Tengchong" (Tong and Zhang 1989) and the "Thermal Springs in Hengduan (Traverse) Mountains" (Tong and Zhang 1994), there are 641 thermal springs in western Yunnan Province, of which 20 boiling springs, 10 hot springs and 5 tepid springs should be the high-temperature hydrothermal convection systems with silica content over 125 mg/L. There are altogether 35 high-temperature hydrothermal convection systems in southwestern Yunnan (Table 8.6).

Table 8.7 shows the result of resource assessment of the high temperature hydrothermal convection systems in southwestern Yunnan Province (Liao et al. 1986).

The total geothermal electrical capacity of high-temperature convection system in the southwestern Yunnan is about 1000 MW_{30a}, in which one fourth is from the Rehai geothermal field of Tengchong County occupied. In all thirty five high-temperature hydrothermal convection systems in Yunnan Province, only the Rehai geothermal field and neighboring Langpu Reshuitang discharge Cl–Na type of volcanic waters, and the rest discharge deep-circulation HCO_3–Na type of meteoric water along the deep fracture zones.

The geothermal electric potentials of 107 high-temperature hydrothermal convection systems in Tibet, western Sichuan and southwestern Yunnan are about 3410 MW_{30a}, in which Tibet is 1991.69 MW_{30a} accounting for 58.59%, western Sichuan 407.76 MW_{30a} accounting for 12.0% and southwestern Yunnan 1009.76 MW_{30a} accounting for 29.4%.

There are five geothermal fields with geothermoelectric potentials over 100 MW_{30a}. They are: Rehai (233.8),Capu (155.22), Nyolunggo Qu (120.75), Daggyai (113.99), and Yangbajain (104.43). The calculated parameters for Yangbajain field are 181 °C for reservoir temperature and 10 km^3 for volume, this result is on the low side because the temperature at about 2000 m is about 330 °C.

8.7 The Intermediate-Temperature Geothermal Resources of Hydrothermal Convection System

Hydrothermal convection systems with reservoir temperature between 90 and 150 °C are called intermediate geothermal systems, which could be directly applied to nonelectric uses. Determination of an intermediate-temperature system depends on the silica content of spa's water. When the silica content of thermal water is between 38.5 and 125 mg/L. The temperature of the reservoir temperature will be between 90 and 150 °C by the quartz geothermometer.

Fourier pointed out (1981) that where waters are known to be from a high-temperature environment (>180 to 200 °C), the Na/K method generally gives

Table 8.6 The high temperature hydrothermal convection system in the southwestern Yunnan

No	Geothermal area	County	Spa's temp. (°C)	Type of water	$TSiO_2$ (°C)	TNa/K (°C)	TNa–K–Ca	TK–Mg (°C)	T of Res. (°C)
1	Rehai (Hot Sea)	Tengchong	96	$Cl–HCO_3–Na$	173	250	310	182	229
2	Langpu Reshuitang	Tengchong	96	$HCO_3–Cl–Na$	161	197	221	149	182
3	Panzhihua Xiaotang	Tengchong	96	$HCO_3–Na$	164	190	186	125	157
4	Bannazhang	Longling	97	$HCO_3–Na$	208	209	219	141	192
5	Longwozhai	Lianghe	96.5	$HCO_3–Na$	138	169	180	(83)	162
6	Humeng	Yingjiang	94	$HCO_3–Na$	162	197	173	112	161
7	Lanniba	Yingjiang	93	$HCO_3–Na$	158	171	220	(72)	183
8	Peacock Spa	Ruili	95	$HCO_3–Na$	164	200	202	136	176
9	Yandengshan	Yunlong	94.5	$HCO_3–Na$	174	211	180	105	168
10	Juanqiaohe	Fengqing	97	$HCO_3–Na$	163	203	181	(82)	182
11	Yongxin	Fengqing	97	$HCO_3–CO_3–Na$	159	166	154	(72)	160
12	Bingling	Yunxian	94	$HCO_3–Na$	165	216	205	126	178
13	Xinlian	Yunxian	56	$HCO_3–Na$	152	202	193	123	167
14	Dakongbeng	Yunxian	96	$HCO_3–Na$	180	242	253	157	208
15	Xingfu	Yunxian	96	$HCO_3–Na$	194	222	223	139	195
16	Malutianba	Yunxian	96	$HCO_3–Na$	173	218	197	138	182
17	Yunnancheng	Lancang	99	$HCO_3–Na$	155	228	188	(88)	190
18	Mengman	Menghai	99	$HCO_3–Na$	188	230	228	148	199
19	Manzhao	Menghai	97	$HCO_3–Na$	181	214	203	109	172
20	Xiaojie Manbang	Jinghong	101	$HCO_3–Na$	163	191	190	121	166
21	Bangleng	Jinghong	79	$HCO_3–Na$	153	192	174	(95)	173
22	Mengping	Jinping	102	$SO_4–HCO_3–Na$	177	216	196	111	175
23	Rudian	Tengchong	92	$HCO_3–Na$	160	213	194	119	172
24	Yudili	Changning	72	$HCO_3–Na$	158	202	168	(86)	176
25	Caojia (Shang Zaotang)	Yunlong	61	$HCO_3–Na$	159	205	208	(72)	161
26	Xiamiandian	Heqing	71.4	$HCO_3–Na$	162	210	190	(88)	163

(continued)

Table 8.6 (continued)

No	Geothermal area	County	Spa's temp. (°C)	Type of water	$TSiO_2$ (°C)	TNa/K (°C)	TNa–K–Ca	TK–Mg (°C)	T of Res. (°C)
27	Niujie–Sanying	Eryuan	81	HCO_3–Na	154	235	218	(94)	173
28	Xinmanbang	Lancang	80	HCO_3–Na	159	194	182	(87)	155
29	Xiabangdao	Lancang	70	HCO_3–Na	151	197	176	(86)	153
30	Fula	Lancang	85	HCO_3–Na	151	218	185	(87)	160
31	Huangcao–shan	Longling	33	HCO_3–Na	151	203	173	108	159
32	Xiabiaoyuan	Tengchong	28	HCO_3–Mg	156	239	185	(42)	155
33	Ludiantian	Tengchong	25	HCO_3–Mg–Na	150	260	197	(54)	165
34	Qushi Xiaotangba	Tengchong	28	HCO_3–Mg–Na	154	203	197	(58)	153
35	Dieshuihe	Tengchong	23	HCO_3–Mg–Ca–Na	150	25	177	(53)	151

Table 8.7 The assessment of high-temperature hydrothermal convection systems in southwestern Yunnan

No	Geothermal area	County	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Thermal energy at wellhead (EJ)	Available work (EJ)	Electricity (MW_{30a})
1	Rehai (Hot Sea)	Tengchong	229	8.5 × 1.5	9.21	2.30	0.553	233.8
2	Langpu Reshuitang	Tengchong	182	4.5 × 1.5	4.05	1.01	0.222	93.86
3	Panzhihua Xiaotang	Tengchong	157	3	1.15	0.29	0.052	22.07
4	Bannazhang	Longling	192	5	2.39	0.60	0.130	54.93
5	Longwozhai	Lianghe	162	2	0.79	0.198	0.033	13.95
6	Humeng	Yingjiang	161	1.5	0.59	0.15	0.027	11.49
7	Lanniba	Yingjiang	183	2	0.75	0.19	0.034	14.38
8	Peacock Spa	Ruili	176	10	4.35	1.09	0.217	91.85
9	Yandengshan	Yunlong	168	1.5	0.62	0.15	0.029	12.47
10	Juanqiaohe	Fengqing	182	1.5	0.55	0.14	0.024	10.12
11	Yongxin	Fengqing	160	1.5	0.61	0.15	0.029	12.07
12	Bingling	Yunxian	178	1.5	0.66	0.17	0.034	14.28
13	Xinlian	Yunxian	167	1.5	0.62	0.15	0.029	12.23
14	Dakongbeng	Yunxian	208	3	1.56	0.39	0.090	38.19
15	Xingfu	Yunxian	195	3	1.46	0.36	0.080	33.89
16	Malutianba	Yunxian	182	3	1.35	0.34	0.071	29.84
17	Yunnancheg	Lancang	190	2	0.81	0.20	0.039	16.77
18	Mengman	Menghai	199	3	1.49	0.37	0.084	35.27
19	Manzhao	Menghai	172	3	1.27	0.32	0.062	26.07
20	Xiaojie Manbang	Jinghong	166	2	0.82	0.20	0.038	16.20
21	Bangleng	Jinghong	173	1.5	0.64	0.16	0.031	12.99
22	Mengping	Jinping	175	3	1.30	0.32	0.065	27.39
23	Rudian	Tengchong	172	3	1.27	0.32	0.062	26.23
24	Yudili	Changning	154	1.5	0.56	0.14	0.025	10.71
25	Caojia(Shang Zaotang)	Yunlong	172	1.5	0.64	0.16	0.031	13.01

(continued)

Table 8.7 (continued)

No	Geothermal area	County	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Thermal energy at wellhead (EJ)	Available work (EJ)	Electricity (MW_{30a})
26	Xiamiandian	Heqing	163	1.5	0.60	0.15	0.028	11.80
27	Niujie-Sanying	Eryuan	173	3	1.28	3.20	0.063	26.51
28	Xinmanbang	Lancang	164	1.5	0.60	0.15	0.028	11.94
29	Xiabangdao	Lancang	153	1.5	0.56	0.14	0.025	10.51
30	Fula	Lancang	160	1.5	0.59	0.15	0.027	11.42
31	Huangcao-shan	Longling	159	1.5	0.58	0.15	0.027	11.34
32	Xiabiaoyuan	Tengchong	155	1.5	0.57	0.14	0.024	10.06
33	Ludiantian	Tengchong	165	1.5	0.61	0.15	0.029	12.12
34	Qushi Xiaotangba	Tengchong	153	1.5	0.56	0.14	0.0235	9.92
35	Dieshuihe	Tengchong	151	1.5	0.55	0.14	0.0235	9.91
	Total				46.01	14.378	2.389	1009.76

excellent results, but it fails to give reliable results for waters from environments with temperature below 100 °C. In particular, low-temperature waters rich in calcium give anomalous results by the Na/K method. For this reason, The Na/K and Na–K–Ca methods are not suitable for using in the intermediate-temperature hydrothermal systems.

Hydrothermal convection systems with reservoir temperature between 90 and 150 °C are called intermediate geothermal systems, which could be directly applied to nonelectric uses. Determination of an intermediate-temperature system depends on the silica content of spa's water. Fournier pointed out (1981) that in most natural waters at temperature above 159 °C, and in some waters below that temperature, quartz appears to control the dissolved silica concentration. However, under special conditions for short periods of time any of the other silica species may control aqueous silica. In some granite terrains, aqueous silica is controlled by quartz at temperature above 90 °C, and by chalcedony at lower temperatures. Most groundwaters which have not attained temperature greater than 80–90 °C have silica concentrations greater than those predicted by the solubility of quartz. Some of these low-temperature waters have equilibrated with chalcedony. Thus, when the silica content of thermal water is controlled by quartz, by quartz geothermometer, the concentration of silica for the intermediate-temperature reservoir between 90 and 150 °C should be 38.5–125 mg/L; but by chalcedony, the concentration of silica could be 70–178 mg/L.

The assessment of geothermal resources for intermediate-temperature system differs from that of high-temperature geothermal systems. The amount of thermal energy is called beneficial heat and is calculated from:

$$\text{Beneficial heat} = Q_{\text{WH}} \times U_{\text{b}}$$

where Q_{WH} is mean reservoir thermal energy in 10^{18} J; U_{b} is defined as the beneficial heat utilization factor. The value of U_{b} is the fraction of thermal energy obtained when 150 °C water undergoes a 32 °C drop or 110 °C water undergoes 20 °C drop and it is equal to 0.24.

Tables 8.8, 8.9 and 8.10 are the intermediate-temperature hydrothermal systems of Tibet, western Sichuan and southwest Yunnan, respectively.

There are 559 intermediate-temperature hydrothermal convection systems in southwestern China, including 144 in Tibet, 85 in western Sichuan and 330 in southwestern Yunnan, by quartz geothermometer. The beneficial heat is calculated as 24% of the recoverable thermal energy from intermediate-temperature systems. The total of beneficial heat is about 11.78 EJ, of which 3.624 EJ is for Tibet, accounting for 30.8%, 1.856 EJ for western Sichuan, accounting for 15.8%, and 6.30 EJ for southwestern Yunnan, making up for 53.5%.

Those numerical values may not be right. If we calculate reservoir temperature by using of chalcedony geothermometer, the silica concentrations of groundwaters must be greater than 70 mg/L, the reservoir fluid has attained temperature greater than 90 °C. Because some of those low-temperature waters with high silica concentration have equilibrated with chalcedony. Now we review Tables 8.8, 8.9 and 8.10, and discover that the springs with silica concentration over 70 mg/L are 81 in

Table 8.8 The intermediate-temperature hydrothermal convection systems in Tibei

No	Th Tw Tt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
1	Th01	Musi Qucain	60.5	76.4	123	1.5	0.478	0.119	0.029
2	04	Moincer	71.4	43.7	96	1.5	0.389	0.097	0.023
3	10	Qangba	51	109	142	1.5	0.575	0.144	0.035
4	11	Quduowa	58	94.2	134	1.5	0.542	0.136	0.033
5	14	Kunggyu	71.5	76.4	123	1.5	0.497	0.124	0.030
6	18	Qucainmenbo	75.3	90	131	1.5	0.532	0.133	0.032
7	19	Lug La	56	90	131	1.5	0.532	0.133	0.032
8	20	Quxam Qucain	57.5	115	145	1.5	0.588	0.147	0.035
9	24	Chala	52.5	109	142	1.5	0.575	0.144	0.035
10	25	LOngba	85.2	78.8	124	1.5	0.50	0.126	0.030
11	26	Salu	76	74.7	122	1.5	0.494	0.124	0.030
12	27	Vendum Qucain	67	57.9	109	1.5	0.441	0.110	0.026
13	28	Jiggyob Qucain	77.5	102	138	1.5	0.560	0.140	0.034
14	29	Nyxia	47	76.3	123	1.5	0.497	0.124	0.030
15	30	Mangpu	47	57.8	109	1.5	0.440	0.110	0.026
16	31	Xiqen Qucain	54	48.4	101	1.5	0.408	0.102	0.024
17	32	Langna	57	102	138	1.5	0.560	0.140	0.034
18	33	Qungtag	50	67.8	117	1.5	0.472	0.118	0.028
19	34	Langmado	50	69.3	118	1.5	0.477	0.119	0.029
20	35	Chagla	72	73	120	1.5	0.486	0.122	0.029
21	36	Qabka	60	74.02	121	1.5	0.490	0.123	0.029
22	39	Dergyu	59	88.7	130	1.5	0.528	0.132	0.032
23	40	Cakakambug	64.2	109	142	1.5	0.575	0.144	0.035
24	41	Chaga	51	70.6	119	1.5	0.480	0.120	0.029

(continued)

Table 8.8 (continued)

No	Th Tw Tt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
25	42	Dongla	48	91.8	132	1.5	0.537	0.134	0.032
26	44	Pundam	62	105.4	140	1.5	0.568	0.142	0.034
27	46	Beiqiagarba	70	84.4	128	1.5	0.518	0.129	0.031
28	47	Nanqiagarba	77.5	64.3	114	1.5	0.461	0.115	0.028
29	49	Gyinkar Qucain	60	78	124	1.5	0.501	0.125	0.030
30	51	Kambu Qucain	49	65	114	1.5	0.464	0.116	0.028
31	53	Chagba Qucain	70	114	145	1.5	0.586	0.146	0.035
32	55	Yoirai Qu	67	70	118	1.5	0.479	0.120	0.029
33	57	Latogka	46.5	80	125	1.5	0.486	0.122	0.029
34	58	Gariqiong	78	88	130	1.5	0.506	0.127	0.030
35	59	Gyaidadargar	65	98	136	1.5	0.531	0.133	0.032
36	62	Bugba	69	115	145	1.5	0.568	0.142	0.034
37	64	Derzhom	46	90	131	1.5	0.510	0.128	0.031
38	65	Rutog	81.5	94.5	134	1.5	0.522	0.131	0.031
39	66	Rongma	72	68.6	117	1.5	0.454	0.114	0.027
40	71	Maerzhou	50	92.2	133	1.5	0.517	0.129	0.031
41	73	Quse	75	83.5	127	1.5	0.459	0.115	0.028
42	75	Dagiungba Qucain	56	76	122	1.5	0.476	0.119	0.029
43	76	Xinggun	51.5	54.6	106	1.5	0.409	0.102	0.025
44	77	Mudig	53	60	111	1.5	0.429	0.107	0.026
45	78	Bangoin Co No. 1	57	54.8	106	1.5	0.409	0.102	0.025
46	80	Qucain Xong	56	61.06	111	1.5	0.431	0.108	0.026
47	81	Samogoninba	79	93.0	133	1.5	0.519	0.130	0.031
48	83	Duobu	50	49.1	101	1.5	0.386	0.097	0.023

(continued)

Table 8.8 (continued)

No	Th Tw Tt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
49	85	Turui	58	54.6	106	1.5	0.410	0.102	0.025
50	86	Zige Tangco	68	44.2	96	1.5	0.369	0.092	0.022
51	88	Co Nag	71	79.1	125	1.5	0.484	0.121	0.029
52	89	Gyangngog	50.5	77.5	123	1.5	0.480	0.120	0.029
53	90	Nagqu	59.6	79.1	125	1.5	0.484	0.121	0.029
54	91	Tuoma	53.5	78.9	124	1.5	0.483	0.121	0.029
55	92	Gongchaqulangma	55	76.4	123	1.5	0.477	0.119	0.029
56	93	Yuze	52	85.1	128	1.5	0.498	0.125	0.030
57	94	Chepocaka	61	77.2	123	1.5	0.479	0.120	0.029
58	95	Dargarma	52	85.7	129	1.5	0.501	0.125	0.030
59	96	Gasangtang	54	81.9	126	1.5	0.491	0.123	0.029
60	97	Dengerlong	72	72.8	120	1.5	0.467	0.117	0.028
61	98	Longcaka	52	79.3	125	1.5	0.485	0.121	0.029
62	99	Xagquka	50	80.6	125	1.5	0.488	0.122	0.029
63	100	Quese	78.5	111.5	143	1.5	0.560	0.140	0.034
64	101	Cayue	75	98.2	136	1.5	0.531	0.133	0.032
65	102	Qagze Calung	70	87.3	130	1.5	0.505	0.126	0.030
66	103	Gyaibri	62	49.1	101	1.5	0.389	0.097	0.023
67	104	Ragxi Caka	69	76.4	123	1.5	0.477	0.119	0.029
68	105	Yira Nang	51	102	136	1.5	0.540	0.135	0.032
69	106	Ribug	65	87.3	130	1.5	0.505	0.126	0.030
70	107	Chani	73	72.8	120	1.5	0.467	0.117	0.028
71	110	Sogzhukug	70	68.5	117	1.5	0.454	0.113	0.027
72	112	Xuxubda	56	98.2	136	1.5	0.531	0.133	0.032

(continued)

Table 8.8 (continued)

No	Th Tw Tt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
73	113	Cadengka	55	56.7	108	1.5	0.416	0.104	0.025
74	114	Banglai	66	104	139	1.5	0.544	0.136	0.033
75	116	Yangando	56	63.3	113	1.5	0.438	0.109	0.026
76	117	Ganzha Qucain	57.5	49	101	1.5	0.388	0.097	0.023
77	120	Damu	55	78	124	1.5	0.481	0.120	0.029
78	123	Oiga	50.5	51.6	103	1.5	0.398	0.100	0.024
79	125	Sewu Quzhain	45.5	53	105	1.5	0.403	0.101	0.024
80	126	Chigu	51.2	68.2	117	1.5	0.453	0.113	0.027
81	128	Rongka Quchomo	63	68.2	117	1.5	0.453	0.113	0.027
82	130	GYaimoi	61	42.4	94	1.5	0.361	0.090	0.022
83	131	Molu	65	60	111	1.5	0.428	0.107	0.026
84	132	Zhaxikang	69.5	54.1	106	1.5	0.407	0.102	0.024
85	133	Gamlungma	67	107	141	1.5	0.551	0.135	0.033
86	138	Laka	51	80	125	1.5	0.486	0.122	0.029
87	139	Qoizong Lungba	56.3	81.4	126	1.5	0.490	0.123	0.029
88	149	Gyigang	57.4	57.8	109	1.5	0.421	0.105	0.025
89	153	Wameka	55	40.7	92	1.5	0.354	0.089	0.021
90	154	Ren Qu	65.6	104	139	1.5	0.544	0.136	0.033
91	156	Badong-Buyu	75	57.8	109	1.5	0.421	0.105	0.025
92	157	Capu	78.5	102	138	1.5	0.540	0.135	0.032
93	161	Yuxi	69.4	68.6	117	1.5	0.454	0.114	0.027
94	162	Gyitang	61.2	98.2	136	1.5	0.531	0.133	0.032
95	163	Qusib	67	85.7	129	1.5	0.501	0.125	0.030
96	164	Daba	52	81.4	126	1.5	0.490	0.123	0.029

(continued)

Table 8.8 (continued)

No	Th Tw Tt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
97	166	Qingkaburlo	65.6	68.6	117	1.5	0.454	0.114	0.027
98	167	Kyanggarda	60	76.4	123	1.5	0.477	0.119	0.029
99	170	Taglung	58	98.2	136	1.5	0.531	0.133	0.032
100	173	Gyorxung	58.3	75	122	1.5	0.473	0.118	0.028
101	175	Rirong	57.2	70.9	119	1.5	0.461	0.115	0.028
102	176	Duba	50.5	87.3	130	1.5	0.505	0.126	0.030
103	177	Qucainka	72.5	85.1	128	1.5	0.500	0.125	0.030
104	Tw02	Xang Qu	37.3	60	111	1.0	0.286	0.072	0.017
105	06	Xagang	40	58.9	110	1.0	0.282	0.071	0.017
106	07	Xungba	43	60	111	1.0	0.285	0.071	0.017
107	09	Ca	44.5	57.8	109	1.0	0.280	0.070	0.017
108	10	Camda	45	75.2	122	1.0	0.316	0.079	0.019
109	13	Bazando	39.3	70.8	119	1.0	0.307	0.077	0.018
110	14	Laga	43	51.8	103	1.0	0.266	0.066	0.016
111	15	Qucaingang	37	81.5	126	1.0	0.327	0.082	0.020
112	17	Salagang	40	70	118	1.0	0.305	0.076	0.018
113	19	Chechexiama	45	63	113	1.0	0.291	0.073	0.017
114	20	Sambasar	39	56.3	107	1.0	0.277	0.069	0.017
115	21	Wujian	43	49.3	101	1.0	0.260	0.065	0.016
116	23	Qubsang	43	80.1	125	1.0	0.324	0.081	0.019
117	37	Cholo	37	60	111	1.0	0.285	0.071	0.017
118	40	Lhoma	42	52.9	105	1.0	0.269	0.067	0.016
119	41	Xeqen	42	60	111	1.0	0.285	0.071	0.017
120	43	Garlong	43	104	139	1.0	0.363	0.097	0.022

(continued)

Table 8.8 (continued)

No	Th Tw Tt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir volume (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
121	44	Ngolung	37	41.5	93	1.0	0.238	0.060	0.014
122	47	Doponggai	38	49.1	101	1.0	0.259	0.065	0.016
123	48	Xiedue	40	54.6	106	1.0	0.273	0.068	0.016
124	50	Kadong Quzhai	39	40.6	92	1.0	0.236	0.060	0.014
125	51	Papa	41.6	120	148	1.0	0.385	0.096	0.023
126	75	Wape	42.5	62.2	112	1.0	0.290	0.072	0.017
127	77	Moba	40	70.9	119	1.0	0.307	0.077	0.018
128	80	Canyaiqu	42	38.6	90	1.0	0.230	0.057	0.014
129	83	Xoiqu	40.6	100	137	1.0	0.357	0.089	0.021
130	87	Yanjing	41.4	51.4	103	1.0	0.265	0.066	0.016
131	88	Ringda	42	54.6	106	1.0	0.273	0.068	0.016
132	Tt 10	Qiu	35	43.7	96	1.0	0.245	0.061	0.015
133	12	Lagar	7	76.4	123	1.0	0.318	0.079	0.019
134	16	Zhale	20	43.7	96	1.0	0.245	0.061	0.015
135	29	Yangxung	35	71.7	119	1.0	0.308	0.077	0.018
136	31	Chagar	26	60.2	111	1.0	0.285	0.071	0.017
137	33	Zebaduodue	34.5	45	97	1.0	0.248	0.062	0.015
138	57	Lunglin	32	64.3	114	1.0	0.294	0.074	0.018
139	62	125 Daoban	31	50.9	103	1.0	0.264	0.066	0.016
140	65	Yangbing	31.5	60	111	1.0	0.285	0.071	0.017
141	89	Gyazong	18.5	76.1	122	1.0	0.317	0.079	0.019
142	96	Gurgyugtang	21	49.1	101	1.0	0.259	0.065	0.016
143	101	Penda	17	60	111	1.0	0.285	0.071	0.017
144	114	Quchagang	19	60	111	1.0	0.285	0.071	0.017

Table 8.9 The intermediate-temperature hydrothermal convection systems in western Sichuan

No	Sh Sw St	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
1	Sh04	Quroin	67	92.6	133	1.5	0.511	0.128	0.031
2	05	Qunggolung	49.5	50	102	1.5	0.392	0.098	0.024
3	06	Legrongkog	49	50	102	1.5	0.392	0.098	0.024
4	07	Lungsong	56	60.6	111	1.5	0.429	0.107	0.026
5	10	Gyabrong	59	60	111	1.5	0.427	0.107	0.026
6	16	Qiqu	54	50.3	102	1.5	0.393	0.098	0.024
7	17	Qungkoicatog	68	62.8	113	1.5	0.436	0.109	0.026
8	18	Meyulung	48	60.8	111	1.5	0.427	0.107	0.026
9	23	Xingnag	46	54	105	1.5	0.407	0.102	0.024
10	24	Poi Caqu	52	76.6	123	1.5	0.477	0.119	0.029
11	25	Qumarkog	58	84.6	128	1.3	0.498	0.125	0.030
12	26	Lungpug	49	54	105	1.5	0.407	0.102	0.024
13	27	LhamnangCaqu	43.5	47.4	99	1.5	0.382	0.096	0.023
14	29	Yala Caqu	62	74.8	122	1.5	0.472	0.118	0.028
15	30	Dangling	75	51.4	103	1.5	0.397	0.099	0.024
16	35	W. Chong Co	66	108	142	1.5	0.553	0.138	0.033
17	36	305 Daoban	70	40	92	1.5	0.352	0.088	0.021
18	38	Rabqu	63	70	118	1.5	0.458	0.114	0.027
19	40	North Joxi	53	40	92	1.5	0.351	0.088	0.021
20	41	South Joxi	47	40	92	1.5	0.351	0.088	0.021
21	42	Caqubug	61	40	92	1.5	0.351	0.088	0.021
22	44	Kezi	48	40	92	1.5	0.351	0.088	0.021
23	45	Dongyu	47	67.4	116	1.5	0.451	0.113	0.027
24	46	Ozhi	67	60	111	1.5	0.427	0.107	0.026

(continued)

Table 8.9 (continued)

No	Sh Sw St	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
25	47	Garoog	72	40	92	1.5	0.351	0.088	0.027
26	49	Haoranyingba	58	58.1	109	1.5	0.421	0.105	0.025
27	50	Yucalungba	46.5	108	142	1.5	0.553	0.138	0.033
28	51	Maoya	60	74.2	121	1.5	0.471	0.118	0.028
29	53	Carongxi	55	50	102	1.5	0.392	0.098	0.024
30	54	Cango	54	71.02	119	1.5	0.461	0.115	0.028
31	56	Tewang	72	117	146	1.5	0.591	0.148	0.035
32	57	Naisang	47	62.1	112	1.5	0.434	0.109	0.026
33	58	Dongbo-caka	48	47.4	99	1.5	0.382	0.096	0.023
34	60	Degoin Caqu	46.5	46	98	1.5	0.376	0.094	0.023
35	61	Cakacaqu	45	59.4	110	1.5	0.425	0.106	0.026
36	62	Zadoi	52	119	147	1.5	0.576	0.144	0.035
37	63	Rogbocaka	66.2	79.4	125	1.5	0.488	0.121	0.029
38	66	Jigdag	56	57.65	109	1.5	0.419	0.105	0.025
39	68	Dagai	58	54.54	106	1.5	0.409	0.102	0.025
40	71	Diaohaiz	48	56.09	107	1.5	0.413	0.103	0.025
41	72	Jetog	54	47.4	99	1.2	0.382	0.096	0.023
42	75	Moxi	72	64.38	114	1.5	0.400	0.100	0.024
43	76	Shanshuiping	59	62.2	112	1.5	0.394	0.098	0.024
44	78	Bindong	61	52.36	104	1.5	0.385	0.096	0.023
45	80	Jiangzha	49	43	95	1.5	0.384	0.096	0.023
46	81	Guergou	60	69.2	118	1.5	0.436	0.109	0.026
47	88	Zhuhe	53	43	95	1.5	0.405	0.086	0.021
48	90	Lutie	60	57.5	108	1.5	0.378	0.095	0.023

(continued)

Table 8.9 (continued)

No	Sh Sw St	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
49	91	Bijihe	51.3	48.8	101	1.5	0.347	0.087	0.021
50	92	Hulukou	75	53.7	105	1.5	0.365	0.091	0.02
51	93	Yuzha	52	60.4	111	1.5	0.388	0.097	0.023
52	95	Luji	50	40.1	92	1.5	0.311	0.078	0.019
53	97	Huashengdi	58	50.2	102	1.5	0.352	0.088	0.021
54	100	Yanbinan	49	43	95	1.5	0.324	0.081	0.019
55	101	Qingmenkou	46.5	67.7	117	1.5	0.411	0.103	0.025
56	104	Gongyi	58	96.8	135	1.5	0.488	0.122	0.029
57	105	Jinyan	59	40.1	92	1.5	0.312	0.078	0.019
58	Sw02	Tangge	44	80	125	1.0	0.338	0.084	0.020
59	06	Boinxucatog	40	56	107	1.0	0.276	0.069	0.017
60	12	Baxoi	36.5	40	92	1.0	0.235	0.059	0.014
61	17	Dando	42	78.96	124	1.0	0.322	0.081	0.019
62	18	Nyewa	40	48.6	100	1.0	0.270	0.068	0.016
63	22	Xaruca	44	60	111	1.0	0.300	0.075	0.018
64	23	Yida	38.5	40	92	1.0	0.248	0.062	0.015
65	30	Cakacaqu	45	59.4	110	1.0	0.405	0.101	0.024
66	33	Xinrang	39.5	47.4	99	1.0	0.241	0.060	0.014
67	39	Erdaoqiao	42	56.7	108	1.0	0.277	0.069	0.017
68	43	Bawolung	43	46.63	99	1.0	0.253	0.063	0.015
69	52	Ganjian	45	80.8	126	1.0	0.312	0.078	0.019
70	54	Hexi	39	45.9	98	1.0	0.223	0.056	0.013
71	58	Lire	44	44.4	96	1.0	0.233	0.058	0.014
72	60	Kuaniwang	44	43	95	1.0	0.216	0.054	0.013

(continued)

Table 8.9 (continued)

No	Sh Sw St	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
73	64	Zhongliangzi	36.1	72.1	120	1.0	0.283	0.071	0.017
74	St23	Zangdokog	25	52.5	104	1.0	0.267	0.067	0.016
75	49	Bairi	17	85.2	128	1.0	0.333	0.083	0.020
76	67	Racaka	28	42.1	94	1.0	0.240	0.060	0.014
77	75	Xingfuqiao	35	42	94	1.0	0.226	0.057	0.014
78	76	Tardo City	30	46.5	98	1.0	0.251	0.063	0.015
79	92	Xiadagai	35	38.57	90	1.0	0.230	0.057	0.014
80	93	Weiguan	30	56.1	107	1.0	0.263	0.066	0.016
81	94	Jiyugou	32.5	51.7	103	1.0	0.252	0.063	0.015
82	95	Guanyiamiao	31	45.56	98	1.0	0.250	0.062	0.015
83	105	Sikai	29	47.7	100	1.0	0.242	0.060	0.015
84	106	Zhulilada	32	40.1	92	1.0	0.221	0.055	0.013
85	107	Wajing	25.5	50.6	102	1.0	0.249	0.062	0.015

Table 8.10 The intermediate-temperature hydrothermal convection systems in SW Yunnan

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
1	Yh01	Sainang	70	108	142	1.5	0.553	0.138	0.033
2	03	Goza	56	107	141	1.5	0.551	0.138	0.033
3	04	Bumpulung	70	123	149	1.5	0.584	0.146	0.035
4	02	Xiaadong	64	131	153	1.5	0.599	0.15	0.036
5	08	Jiangheqiao	47.4	44.1	96	1.5	0.348	0.087	0.021
6	10	Tianshengqiao	49	40.1	92	1.5	0.351	0.088	0.021
7	11	Gaica-caquka	60	83	127	1.5	0.494	0.124	0.030
8	12	Chaggar	67	103	139	1.5	0.542	0.136	0.033
9	15	Bailong	57	77.6	124	1.5	0.462	0.115	0.028
10	16	Chongmei	47	53.5	105	1.5	0.385	0.096	0.023
11	17	Gutanhe	51.5	66.9	116	1.5	0.409	0.102	0.025
12	18	Dishuidong	84	83	127	1.5	0.454	0.113	0.027
13	19	Denggeng	52.5	41.4	93	1.5	0.317	0.079	0.019
14	20	Mabu	55.8	54.9	106	1.5	0.369	0.092	0.022
15	23	Zhongyuan	46.5	88.4	130	1.5	0.467	0.117	0.028
16	24	Tenglagong	62	67.4	116	1.5	0.394	0.098	0.024
17	25	Taiping	58	74.7	122	1.5	0.415	0.104	0.025
18	26	Nanhuan	49.5	63	113	1.50	0.380	0.095	0.023
19	27	Luositang	56	42.1	94	1.5	0.304	0.076	0.018
20	28	Langwaihe	79.5	97.2	136	1.5	0.472	0.118	0.028
21	29	Mangke	82	113	144	1.5	0.507	0.0127	0.030
22	30	Longxian Manbeng	64.5	66.9	116	1.5	0.392	0.098	0.024
23	31	Xima	49	66.9	116	1.5	0.392	0.098	0.024

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
24	32	Guangling	82	87.5	130	1.5	0.449	0.112	0.027
25	33	Sading	45.8	64.3	114	1.5	0.384	0.096	0.023
26	34	Bengnie	55.5	68.2	117	1.5	0.396	0.099	0.024
27	35	Pendu	47	51.3	103	1.5	0.340	0.085	0.020
28	38	Nameng	47	56.5	108	1.5	0.363	0.091	0.022
29	39	Manlong	48	73.4	121	1.5	0.417	0.104	0.025
30	40	Mengyang	52.5	53.9	105	1.5	0.535	0.088	0.021
31	41	Diyang	71	77.7	124	1.5	0.428	0.107	0.026
32	42	Longlinba	47	43.4	95	1.5	0.313	0.078	0.019
33	43	Bingcai	89	87.5	130	1.5	0.453	0.113	0.027
34	44	Mengban	48	96.8	135	1.5	0.475	0.119	0.029
35	45	Dapingshan	53	68.2	117	1.5	0.400	0.100	0.024
36	47	Hemeng	77	54.9	106	1.5	0.353	0.088	0.021
37	48	Batuo	55	47.4	99	1.5	0.324	0.081	0.019
38	49	Langa	48.5	43.4	95	1.5	0.309	0.077	0.019
39	50	Hongfa	50	56.5	106	1.5	0.359	0.090	0.022
40	51	Liuhuangchan	52	63.1	113	1.5	0.381	0.095	0.023
41	52	Manniu	58	46	98	1.5	0.320	0.080	0.019
42	55	Mangshi Xiaowa	67	87.7	130	1.5	0.450	0.12	0.027
43	57	Heinitang	66	90	131	1.5	0.471	0.118	0.028
44	58	Danza	51	83	127	1.5	0.454	0.113	0.027
45	59	Shihuadong	65	95	134	1.5	0.483	0.121	0.029
46	60	Mengbang	66	91.6	12	1.5	0.457	0.119	0.029
47	61	Qianmaqin	76	93	133	1.5	0.479	0.120	0.029

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
48	62	Qimucun	67	107	141	1.5	0.510	0.128	0.031
49	63	Xiaodian	46	50	103	1.5	0.352	0.088	0.021
50	64	Shanghoudian	56	79.9	125	1.5	0.446	0.111	0.027
51	65	Beidong	61	75	122	1.5	0.432	0.011	0.026
52	67	Suqing	47.5	64.3	114	1.5	0.401	0.100	0.024
53	68	Heishihe	77.5	115	145	1.5	0.527	0.132	0.032
54	69	Bazhu	48	70	118	1.5	0.417	0.104	0.025
55	70	Shangbangnai	49.5	46	98	1.5	0.336	0.084	0.020
56	71	Hubang	53	83	127	1.5	0.454	0.113	0.027
57	73	Shiqiang	68	52	104	1.5	0.359	0.090	0.022
58	74	Yongan	52	50	103	1.5	0.352	0.088	0.021
59	75	Mayuwo	55	50	103	1.5	0.352	0.088	0.021
60	76	Cuanlong	49	63	113	1.5	0.397	0.099	0.024
61	77	Banghong	50	73.4	121	1.5	0.428	0.107	0.026
62	78	Bachawa	65	92.9	133	1.5	0.478	0.120	0.029
63	79	Bangbei	48.5	107	141	1.5	0.510	0.128	0.031
64	80	Sanguan	62	76.1	122	1.5	0.433	0.108	0.026
65	81	Zhanshuihe	58	63.1	113	1.5	0.397	0.099	0.024
66	82	Xiaolantian	66.5	82.6	127	1.5	0.454	0.113	0.027
67	83	Dazhulin	62	76.1	122	1.5	0.435	0.109	0.026
68	84	Xiangda	76	112	144	1.5	0.521	0.130	0.031
69	85	Huangcaoba	62	76.1	122	1.5	0.435	0.109	0.026
70	86	Bangmiao	81	94	134	1.5	0.481	0.120	0.029
71	87	Yangmeipo	63	79.4	125	1.5	0.444	0.111	0.027

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
72	88	Nansa	51	73.4	121	1.5	0.428	0.107	0.026
73	89	Yinjiatian	75	114	145	1.5	0.525	0.131	0.032
74	90	Maocaozhai	76	89.1	131	1.5	0.469	0.117	0.028
75	91	Daxiao	74	91	132	1.5	0.474	0.118	0.028
76	92	Manggao	76	107	141	1.5	0.510	0.128	0.031
77	93	Sileng	57.5	66.3	115	1.5	0.407	0.102	0.024
78	94	Jueyepohe	47.5	60.4	111	1.5	0.388	0.097	0.023
79	95	Laohuqing	55.5	105	140	1.5	0.506	0.127	0.030
80	96	Shalamen	51.5	44.7	97	1.5	0.332	0.083	0.020
81	97	Daheidu	54.5	43.6	96	1.5	0.326	0.082	0.020
82	98	Dashanjiao	57	56.6	108	1.5	0.377	0.094	0.022
83	99	Hanlong	55	69.5	118	1.5	0.416	0.104	0.025
84	100	H.L. Xizhahe	61	104	139	1.5	0.504	0.126	0.030
85	101	Bailuotang	86	120	148	1.5	0.537	0.134	0.032
86	102	Dongde	61	59.8	110	1.2	0.386	0.097	0.023
87	104	Maanshan	62	46.8	99	1.5	0.339	0.085	0.020
88	105	Manghai	51	50	102	1.5	0.352	0.0	0.021
89	106	Wangtian	55	64.3	114	1.5	0.401	0.10	0.024
90	110	Pupiao	51.5	46.1	98	1.5	0.336	0.084	0.020
91	112	Dapuzhai	59.5	53.3	105	1.5	0.356	0.089	0.021
92	113	Guojiazhai	77	101	138	1.5	0.489	0.122	0.029
93	114	Qitianhekou	59	53.3	105	1.5	0.356	0.089	0.021
94	115	Hulukou	62.5	43.5	96	1.5	0.320	0.080	0.019
95	117	Xiaojiezi	48	63	113	1.5	0.397	0.099	0.024

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
96	118	Datianba	64	72.8	120	1.5	0.426	0.107	6.026
97	121	Hulukou	48	45.9	98	1.5	0.336	0.084	0.020
98	122	Ganlanhe	74	75.5	122	1.5	0.434	0.108	0.026
99	123	Jifei Bath	81	82	126	1.5	0.451	0.113	0.027
100	125	Xiaoshiqiao	55	42.5	94	1.5	0.320	0.080	0.019
101	127	Dadong	52	68.3	117	1.5	0.425	0.106	0.026
102	128	Dongjiang	56	80.3	125	1.5	0.458	0.114	0.027
103	131	Bujia	51.5	80.3	125	1.5	0.454	0.113	0.027
104	132	Caojian	68.2	83	127	1.5	0.462	0.115	0.028
105	134	Biaocun Shangchenghe	64	100	137	1.5	0.502	0.16	0.030
106	135	Xinshan	52	62.9	113	1.5	0.404	0.101	0.024
107	136	Wenxing	52	46.8	99	1.5	0.347	0.087	0.021
108	137	Fengliancheng	54	50.8	103	1.5	0.363	0.091	0.022
109	138	Shicheng	53	57.5	108	1.5	0.387	0.097	0.023
110	139	Dalishu	57	61.6	112	1.5	0.400	0.100	0.024
111	140	Dada	48.5	42.8	95	1.5	0.331	0.083	0.020
112	143	Jiangying farm	61.6	73.6	121	1.5	0.436	0.109	0.026
113	144	Xinzhuan	53.3	87	130	1.5	0.472	0.118	0.028
114	146	Hanzhuan	46.4	66.9	116	1.5	0.413	0.103	0.025
115	147	Yuhuzhen	68.8	102	138	1.5	0.503	0.126	0.030
116	148	Jiuqitai	76	61.6	112	1.5	0.396	0.099	0.024
117	149	Xiashankou	84	123	149	1.5	0.547	0.137	0.033
118	150	Dengchuan	54	84.4	128	1.5	0.461	0.115	0.028

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
119	154	Xincun	57	40	92	1.5	0.307	0.077	0.018
120	155	Xierhe	64	89.7	131	1.5	0.471	0.118	0.028
121	156	Xiaguan	76	73.6	121	1.5	0.428	0.107	0.026
122	158	Wengbi	50	50.8	103	1.5	0.355	0.089	0.021
123	159	Gaoqing	69.8	68.3	117	1.5	0.409	0.1020	0.025
124	160	Baizongqi	48	44.2	96	1.5	0.325	0.081	0.019
125	161	Jiashidong	50	46.8	99	1.5	0.335	0.084	0.020
126	162	Midu	45.5	60.2	111	1.5	0.383	0.096	0.023
127	163	Tianma	47.5	40	92	1.5	0.307	0.077	0.018
128	164	Hedian	49.5	77.7	124	1.5	0.436	0.109	0.026
129	166	Mengbang	71	65.6	115	1.5	0.388	0.097	0.023
130	167	Junlong	62.5	77.6	124	1.5	0.423	0.106	0.025
131	169	Dachushui	56	60.2	111	1.5	0.379	0.095	0.02
132	170	Yuhua	66.5	61.6	112.	1.5	0.384	0.096	0.023
133	171	Duanleng	60	53.5	105	1.5	0.356	0.089	0.021
134	172	Nanqiaohe	58	53.5	105	1.5	0.356	0.089	0.021
135	173	Malizhai	55	42.8	95	1.5	0.315	0.079	0.019
136	175	Laoyawo	57.5	66.9	116	1.5	0.401	0.100	0.024
137	177	Sifangjing	64	48.2	100	1.5	0.329	0.082	0.020
138	179	Yongrang	62	60.2	111	1.5	0.381	0.095	0.023
139	180	Wangjiazhai	46	44.1	96	1.5	0.322	0.080	0.019
140	181	Xiqian	54	75	122	1.5	0.426	0.107	0.026
141	182	Xiabangbing	61	65.6	115	1.5	0.399	0.100	0.024
142	184	Luoguozhai	70	102	138	1.5	0.492	0.123	0.030

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
143	185	Daxing	68	84.4	128	1.5	0.451	0.113	0.027
144	186	Maolan	68	104	139	1.5	0.488	0.122	0.029
145	187	Xiaomaolan	50	87	130	1.5	0.448	0.112	0.027
146	188	Yongbao	50	69.6	118	1.5	0.401	0.100	0.024
147	190	Hetaolin	48.5	75	122	1.5	0.416	0.104	0.025
148	191	Zhafang	64	85.7	129	1.5	0.453	0.113	0.027
149	192	Lincang	64	96.4	135	1.5	0.478	0.119	0.029
150	193	Bangbie	63	107	141	1.5	0.502	0.126	0.030
151	194	Donglai	58	72.3	120	1.5	0.406	0.102	0.024
152	195	Hongtuzhai	53	103	139	1.5	0.483	0.121	0.029
153	196	Manglian	54	40.2	92	1.5	0.295	0.074	0.018
154	197	Mangyang	56.5	107	141	1.5	0.494	0.124	0.030
155	198	Bangbing	61.5	50.8	103	1.5	0.338	0.085	0.020
156	199	Nanlei	57	61.6	112	1.5	0.376	0.094	0.023
157	200	Wanda	44.5	41.5	93	1.5	0.301	0.075	0.018
158	202	Nanbo	52.5	44.6	97	1.5	0.314	0.079	0.019
159	203	Dabalao	56	96.5	135	1.5	0.471	0.118	0.028
160	205	Laobandeng	51.5	85.5	129	1.5	0.444	0.111	0.027
161	206	Xiaotanghe	65	115	145	1.5	0.511	0.128	0.031
162	207	Dagoujiao	55	89.3	131	1.5	0.453	0.113	0.027
163	208	Pojiao	60	89.3	131	1.5	0.453	0.115	0.022
164	209	Menglang	63	69.2	118	1.5	0.399	0.100	0.024
165	210	Donglang	58	57.5	108	1.5	0.362	0.091	0.022
166	211	Menggen	64	46.5	98	1.5	0.322	0.080	0.019

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
167	213	Mangpian	47.5	54.8	106	1.5	0.353	0.088	0.021
168	218	Heishan	89	114	145	1.5	0.509	0.127	0.031
169	219	Nanjiaohe	63.5	71.9	120	1.5	0.407	0.102	0.024
170	220	Xiejiatian	51.5	66.5	116	1.5	0.393	0.098	0.024
171	221	Mange	56.5	71.9	120	1.5	0.403	0.101	0.024
172	222	Huanie	49.5	44.6	97	1.5	0.310	0.078	0.019
173	223	Yanshuihe	56.5	39.2	91	1.5	0.287	0.072	0.017
174	225	Manzhongtian	50.5	50.3	102	1.5	0.341	0.085	0.020
175	226	Mangling	42	48.8	101	1.5	0.336	0.084	0.020
176	227	Tufang	55	45.9	98	1.5	0.325	0.081	0.020
177	228	Qingping	62.5	56.1	107	1.5	0.363	0.091	0.022
178	229	Xiaxinzhai	46	50.2	102	1.5	0.342	0.085	0.021
179	230	Dashujiao	53.5	50.3	102	1.5	0.31	0.085	0.020
180	231	Pazuo	58.5	89.5	131	1.5	0.450	0.112	0.027
181	232	Manbang	74	79.2	125	1.5	0.424	0.106	0.025
182	233	Xiding MB	70	96.5	135	1.5	0.467	0.167	0.028
183	234	Manle-Manxi	70	99.2	137	1.5	0.474	0.118	0.028
184	235	Manka	73.7	89.6	131	1.5	0.450	0.112	0.027
185	236	Mannan	55	56.1	107	1.5	0.353	0.088	0.021
186	238	Zhangjia	57.5	56.1	107	1.5	0.353	0.088	0.021
187	239	Mengajie	77.5	92.9	133	1.5	0.458	0.115	0.027
188	240.	Nanlu	45.5	44.4	96	1.50	0.309	0.077	0.019
189	241	Sunhuan	78	44	96	1.5	0.308	0.077	0.018
190	242	Nanjianghe	45.5	44.4	96	1.5	0.309	0.077	0.019

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
191	243	Manhei	70	57.4	108	1.5	0.358	0.089	0.021
192	244	Mamlie	63	95.6	135	1.5	0.465	0.116	0.028
193	245	Manyanghan	52.5	62.8	113	1.5	0.376	0.094	0.023
194	246	Manwei	50	62.8	13	1.5	0.376	0.094	0.023
195	247	Manbo	76.2	96.4	13	1.5	0.539	0.135	0.032
196	248	No. 9 Dongfeng	50	69.6	118	1.5	0.396	0.099	0.024
197	250	Ximanmoxie	49	52.2	104	1.5	0.340	0.085	0.020
198	251	Shayao	66.6	69.6	118	1.5	0.396	0.099	0.024
199	252	Manda	53	88.6	131	1.5	0.448	0.112	0.027
200	253	Mansa	51	81.6	126	1.5	0.430	0.107	0.026
201	256	Wana	87.5	89.3	131	1.5	0.433	0.108	0.026
202	258	Nanlin	59	80	125	1.5	0.433	0.108	0.026
203	259	Xinjie	78.5	92.5	133	1.5	0.465	0.116	0.028
204	260	Feixiangcun	52	94	134	1.5	0.469	0.117	0.028
205	261	Taoyuan	51.5	86.6	129	1.5	0.441	0.110	0.026
206	263	Puer	59	95.4	135	1.5	0.464	0.116	0.028
207	264	Shilicun	70	108	142	1.5	0.492	0.123	0.030
208	265	Dadiping	51	116	147	1.5	0.509	0.127	0.031
209	Yw03	Nyiringnang	39	57.5	108	1.0	0.278	0.069	0.017
210	07	Quzixoi	40	53.5	105	1.0	0.270	0.067	0.016
211	09	Tangshang	40	88.4	130	1.0	0.325	0.081	0.020
212	15	Hongtujian	45	49.5	101	1.0	0.247	0.062	0.015
213	16	Hexi	45	42.8	65	1.0	0.229	0.057	0.014
214	17	Qiaotuo	39	52.2	104	1.0	0.253	0.063	0.016

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
215	22	Longfei	38	62.2	112	1.0	0.252	0.063	0.015
216	23	Longmu	40.5	57.8	109	1.0	0.244	0.061	0.015
217	24	Lushan	43.3	47.4	99	1.0	0.216	0.054	0.013
218	26	Mangya	42.5	79.9	125	1.0	0.286	0.072	0.017
219	27	Xiaka	45	60.4	111	1.0	0.248	0.062	0.015
220	28	Shoufanzhai	36	42.1	94	1.0	0.203	0.051	0.012
221	29	Kangma	37	64.3	114	1.0	0.256	0.064	0.015
222	30	Lulian	36	52.6	104	1.0	0.230	0.058	0.014
223	31	Nantian	39	52.6	104	1.0	0.230	0.058	0.014
224	33	Leimen	41	60.4	111	1.0	0.248	0.062	0.015
225	35	Bangwai	38	78.4	124	1.0	0.286	0.072	0.017
226	36	Bangbei	43	73.4	121	1.0	0.277	0.069	0.017
227	37	Xiaomanlong	39	46.1	98	1.0	0.216	0.054	0.013
228	41	Bali	42	50	102	1.0	0.234	0.059	0.014
229	42	Yangjiatian	44	83	127	1.0	0.303	0.076	0.018
230	43	Shujiang	40	45	97	1.0	0.221	0.055	0.013
231	44	Malishan	43	70	118	1.0	0.279	0.070	0.017
232	45	Dacun	42	58	109	1.0	0.253	0.063	0.015
233	46	Shuanjiaotang	44	64.3	114	1.0	0.267	0.067	0.016
234	47	Shizhuba	45	55	106	1.0	0.246	0.061	0.015
235	48	Lengxiaotang	36	51.3	103	1.0	0.238	0.059	0.014
236	49	Yongle	38.5	55	106	1.0	0.246	0.061	0.015
237	50	Huangpo	41	43	95	1.0	0.216	0.054	0.013
238	53	Menglian	42	58	109	1.0	0.253	0.063	0.015

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
239	54	Banshan	45	46.1	98	1.0	0.224	0.056	0.013
240	55	Puqing	45	40.8	93	1.0	0.209	0.052	0.013
241	57	Hehua	39	104	139	1.0	0.336	0.084	0.020
242	58	Diandi	37	95.5	135	1.0	0.032	0.081	0.019
243	60	Bajiaolin	42.5	79.9	125	1.0	0.030	0.074	0.018
244	61	Songjia Zatang	42.5	40.8	93	1.0	0.211	0.053	0.013
245	75	Abeizhai	42	46.5	98	1.0	0.225	0.056	0.014
246	76	Sujia	40	45.9	98	1.0	0.224	0.056	0.013
247	80	Yongning	38.2	41.5	93	1.0	0.218	0.054	0.013
248	82	Shanglu	41.3	97.8	136	1.0	0.330	0.083	0.020
249	83	Yangtizi	40.1	80.3	125	1.0	0.302	0.075	0.018
250	85	Xiachanghe	43	50.8	103	1.0	0.240	0.080	0.014
251	86	Dalang	43	40	92	1.0	0.209	0.052	0.013
252	88	Xinhe	42	68.3	117	1.0	0.283	0.071	0.017
253	89	Houdian	42	72.3	120	1.0	0.291	0.073	0.017
254	90	Longmen	40.5	48.2	100	1.0	0.240	0.059	0.014
255	91	Shangjiangzui	40	83	127	1.0	0.305	0.076	0.018
256	92	Shangyangping	41.2	48.2	100	1.0	0.240	0.059	0.014
257	93	Liancheng	41	75	137	1.0	0.333	0.083	0.020
258	95	Jiangqiao	44.2	57.6	109	1.0	0.250	0.062	0.015
259	96	Jiyipu	43	57.6	109	1.0	0.250	0.062	0.015
260	97	Qudong	37	41.5	93	1.0	0.206	0.052	0.012
261	98	Alin	39.5	49.5	101	1.0	0.228	0.057	0.014
262	99	Yongcui	37.5	62.9	113	1.0	0.261	0.065	0.016

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
263	100	Jianba	40	38.8	90	1.0	0.201	0.050	0.012
264	109	Xiajunle	43	38.8	90	1.0	0.194	0.049	0.012
265	119	Mangen	43	48.8	101	1.0	0.221	0.055	0.013
266	124	Zhongcang	43	38.6	90	1.0	0.195	0.490	0.012
267	129	Wanengneng	44.5	44.4	96	1.0	0.213	0.053	0.013
268	134	Zhengdong	41	38.6	90	1.0	0.194	0.049	0.012
269	135	Pabai	43.3	85.7	129	1.0	0.294	0.073	0.018
270	138	Manzahanbin	45.3	66.9	116	1.0	0.259	0.065	0.016
271	140	Manguopo	39	56.2	107	1.0	0.236	0.059	0.014
272	142	Liushahe	40	73.6	121	1.0	0.272	0.068	0.016
273	148	Mengwaba	44.5	67.7	117	1.0	0.261	0.065	0.016
274	149	Balananbang	36.5	51.7	103	1.0	0.225	0.056	0.014
275	150	Bangganlahu	42	64.8	114	1.0	0.254	0.063	0.015
276	151	Manxindai	36	45.9	98	1.0	0.210	0.053	0.013
277	152	Dalaoyou	43.5	47.4	99	1.0	0.214	0.054	0.013
278	153	Popai	40	60.4	111	1.0	0.245	0.061	0.015
279	155	Yingzhai	42.5	43	95	1.0	0.210	0.053	0.013
280	159	Ernan	39	56.1	107	1.0	0.245	0.061	0.015
281	161	Pingkun	43.5	67.7	117	1.0	0.270	0.068	0.016
282	163	Paisha	41	53.2	105	1.0	0.229	0.057	0.014
283	172	Hujie	36	50.3	102	1.0	0.222	0.055	0.013
284	173	Manfang	36	50.2	102	1.0	0.221	0.055	0.013
285	176	Shangbanwa	42	43.4	95	1.0	0.203	0.051	0.012
286	177	Xianrendong	40	38.2	90	1.0	0.188	0.047	0.011

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
287	Yt07	Niyongka	31	87	130	1.0	0.335	0.084	0.020
288	11	Xundong	29.5	107	141	1.0	0.367	0.092	0.022
289	18	Lumadong	28	83.7	127	1.0	0.297	0.074	0.018
290	19	Gade	34	58.9	110	1.0	0.259	0.065	0.016
291	32	Yangsanheba	35.5	44.7	97	1.0	0.210	0.052	0.013
292	33	Manhai	20.5	46.1	98	1.0	0.213	0.053	0.013
293	34	Shuicaoba	29	42.1	94	1.0	0.202	0.051	0.012
294	35	Guanghan	28	62.2	112	1.0	0.249	0.062	0.015
295	36	Manbai	31	44.7	97	1.0	0.207	0.052	0.012
296	38	Qiaotou	30	83.8	28	1.0	0.296	0.074	0.018
297	41	Tongchangjiao	19.5	77.3	123	1.0	0.292	0.073	0.018
298	42	Bapai	21	55	116	1.0	0.246	0.062	0.015
299	44	Suanshuigou	24	85	128	1.0	0.306	0.076	0.018
300	47	Guanyintang	19.7	63	113	1.0	0.264	0.066	0.016
301	48	Yuanjiatang	21.2	88	130	1.0	0.311	0.078	0.019
302	53	Chequetang	21.5	115	145	1.0	0.351	0.088	0.021
30.	54	Dongjiazhai	27.5	43.4	95	1.0	0.217	0.054	0.013
304	55	Longanqiao	29	123	149	1.0	0.362	0.091	0.02
305	58	Zongfu	35	47.4	99	1.0	0.227	0.057	0.014
306	60	Qingtang	21	42.1	94	1.0	0.213	0.053	0.013
307	61	Longjiang	20	46.1	98	1.0	0.224	0.056	0.013
308	64	Sidaohe	30	44.7	97	1.0	0.220	0.055	0.013
309	65	Longjiang	20	42.1	94	1.0	0.213	0.053	0.013
310	67	Potou	33	81.2	126	1.0	0.299	0.075	0.018

(continued)

Table 8.10 (continued)

No	Yh Yw Yt	Name of area	Spa's temp. (°C)	Silica content (mg/L)	Reservoir temp. (°C)	Reservoir Vol. (km^3)	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
311	68	Taozjzhai	28	61.3	112	1.0	0.261	0.065	0.016
312	69	Pilizhai	34	40.8	93	1.0	0.209	0.052	0.013
313	81	Bawai	35	42.5	94	1.0	0.214	0.054	0.013
314	83	Lamasi	19	48.2	100	1.0	0.236	0.059	0.014
315	84	Longba	19	46.9	99	1.0	0.233	0.058	0.014
316	87	Luxi	15.4	52	104	1.0	0.246	0.061	0.015
317	88	Deliang	19	44.2	96	1.0	0.226	0.056	0.014
318	97	Xiaoshuiping	21.5	48.9	101	1.0	0.238	0.059	0.014
319	104	Yandanshan	33.2	42.2	94	1.0	0.218	0.054	0.013
320	126	Shidongsi	33	42.8	95	1.0	0.212	0.053	0.013
321	132	Shuizhai	35	64.3	114	1.0	0.260	0.065	0.016
322	135	Shuandun	31	56.2	107	1.0	0.242	0.060	0.015
323	144	Wangjiazhuan	35	46.8	99	1.0	0.227	0.057	0.014
324	153	Shangmanjiao	33	42.8	95	1.0	0.10	0.052	0.013
325	164	Gaixin	32.5	47.4	99	1.0	0.217	0.054	0.013
326	184	Nanpanhe	28	44	96	1.0	0.205	0.051	0.012
327	188	Sammai	30	47.4	99	1.0	0.214	0.054	0.013
328	189	Manyan	29.2	41.9	94	1.0	0.199	0.50	0.012
329	192	Menglong	30	57.5	108	1.0	0.239	0.060	0.014
330	199	Xiaoshuiba	33	85	128	1.0	0.306	0.076	0.018

Tibet, only 18 in west Sichuan and 129 in southwest Yunnan and a total of 228. That is: the numerical values of intermediate-temperature geothermal system are 559 by quartz thermometer or 228 by chalcedony thermometer. There is no comparison between the two of them. The latter is only 40% of the former. Thus the total of beneficial heat of 228 intermediate-temperature systems by chalcedony thermometer could be about 4.7 EJ.

We should pay attention to the number of this report, that there are about 1317 thermal springs with thermometric data and hydrochemical analysis data This amount includes identified 107 high-temperature hydrothermal convection systems and identified 559 intermediate-temperature hydrothermal convection systems. The rest could be the low-temperature geothermal resources less than 90 °C.

Muffler pointed out (1981) that in the 1978 assessment of geothermal resources of the United States, no quantitative estimate was made of the thermal energy of geothermal waters at temperature less than 90 °C. This deliberate omission reflected the lack of sufficient reliable data upon which an estimate could be based. Furthermore, estimating reservoir temperature in these low-temperature mixed water systems by geochemical methods was deemed to be especially unreliable. The net evaluation of these factors in 1978 was that numerical estimates of thermal energy in geothermal waters at temperatures less than 90 °C would have been wholly unreliable and meaningless and would have done more harm than good. These surpassing words impel me to put off the assessment of low-temperature geothermal resources in southwestern China, despite there is a precedent for assessment of low-temperature geothermal resources of the United States—1982 (Reed 1983). Sorey et al. (1983) advanced categories of low-temperature geothermal resources in Geological Survey Circular 892, actually these categories are not confined to low-temperature systems, and they are also suited to intermediate-temperature systems in Yunnan and Tibet.

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Chapter 9
Hot Dry Rock Geothermal Resources in Southwestern China

Abstract This chapter discusses Hot Dry Rock geothermal resources in southwest China and establishment of EGS system. Chinese terrestrial heat flow data amounts to 921 in 2001, which is the foundation assessing HDR geothermal resource. The highest heat flow values widely appeared in the Tibetan Plateau. The deep temperature patterns calculated by heat flow values in the continental area of China show that the temperature of most part of Tibet at the depth 3.5–8.5 km has reached 200–400 °C. The southern part of Qinghai-Tibetan Plateau is provided with rich in HDR geothermal resources, accounting for 20.5% of total resource base.

Keywords HDR geothermal resources · EGS system · Heat flow data · Total resource base

9.1 HDR and EGS

Our fieldwork of geothermal resources only deals with the research of hydrothermal convection systems with a reservoir depth of 3 km below the surface. In most 'normal' continental areas geothermal heat is present in great quantities at depths of 3–10 km which are accessible with today's drilling technology. Since working fluids are absent due to the low natural permeability of the deep strata. The heat in a high temperature and low permeability environment is called Hot Dry Rock (HDR). Ewing (1973) thought only naturally occurring geothermal systems lying at depth of less than 3 km and assuming that 1% of the heat energy in such systems is recoverable by present technology near present-day energy generation costs, White estimates that 2 × 10 calories are available, an amount roughly equivalent to the U. S. energy consumption for 1972. And at depths up to 10 km, the total energy available in such systems is estimated by White to be about 500 times greater, though its exploration would require improvements in the drilling and stimulating technology. Much more energy would become accessible if methods were developed for the recovery of energy from HDR. Estimates put the energy recoverable from this source at 100–1000 times that available in hydrothermal systems or

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1024–1025 calories. Systems exploiting HDR are thus potentially capable of supplying U.S. energy needs for 50,000–500,000 years at the present rate of consumption. This heat can be extracted from such HDR resources only by establishing artificial fluid circulation. The full EGS is when both permeability and reservoir are artificially created. The first pilot was at Fenton Hill in New Mexico State in 1972. A summary of past EGS experiments is provided by Tester et al. of MIT (2006). The principle is that production and injection wells are drilled and fractures are created in the rock around them, providing a path between injection and production wells. The fracture system is intended to pervade a sufficient volume that a reservoir is created, not just a path between the two wells. Water is circulated down the injection well through the rock and back up the production well.

EGS prototype systems have been built and circulated in U.S., UK, France, German, Japan, and Australia to date. The pilot plan is running well at Soultz of France in Rhine Graben. Both Fenton Hill and Hijiori in younger caldera had high reservoir temperature, but all were deferred due to high reservoir impedance or large lose of waters (Evans 2010).

For electrical power production, the main condition for the HDR resource are: (a) production capacity to 50–100 kg/s; (b) Temperature of fluid at wellhead to 150–200 °C; (c) useful heat transfer surface area $>2 \times 10^6$ m^2; (d) reservoir volume $>2 \times 10^8$ m^3; (e) reservoir impedance ≤ 0.1 MPa kg^{-1}; (f) water loss $\leq 10\%$ (Rybach 2010). There is some trouble to satisfy these six conditions. Thus, a HDR reservoir can mainly be characterized by its natural permeability and heat content. The natural permeability at depth (i.e., degree of fracturing) is rather difficult to be determined at the surface. Some possibility to obtain information on the variation of fracture permeability with depth is studying by the reservoir engineers. The temperature in reservoir of HDR can be evaluated from the result of terrestrial heat flow measurements.

9.2 Terrestrial Heat Flow Measurement in China

The systematical research of terrestrial heat flow in China began in the early 1970s. The first portion of reliable 25 heat flow data were published by the Geothermal Research Group of Institute of Geology of Academia Sinica in 1979. After more than 20 years' effort, altogether 681 continental heat flow data have been accumulated (Wang and Huang 1988, 1990). Fifteen years ago, the Chinese terrestrial heat flow data amounts to 921 (Hu et al. 2001), which is the foundation for assessing HDR geothermal resources. Figure 9.1 is updated map of heat flow in the continental area of China (Wang et al. 2012), on which the highest heat flow values widely appeared in the Tibetan Plateau.

The heat flow measurement of the Tibetan Plateau have been carried out in four stages: (1) Sino-French bottom lake heat flow measurements in 1982; (2) heat flow observation in Yangbajain geothermal field in 1983–1985; (3) drillhole heat flow measurement in northern Tibet as a NNSFC-supported project in 1986–1987;

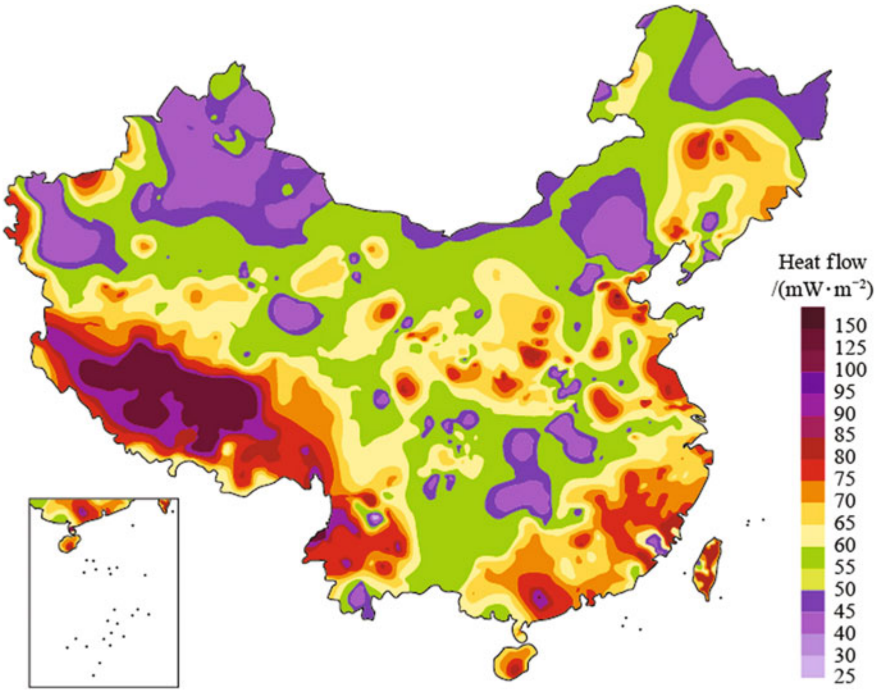

Fig. 9.1 Updated map of heat flow in the continental area of China (after Wang et al. 2012)

(4) S-N heat flow profile study as a subprojected of the Yadong–Golmud GGT project in 1987–1989 (Shen et al. 1995).

Figure 9.2 is a schematic cross section of Tibetan Plateau with projected observed surface heat flow on the top and schematic crustal thermal structure picture underneath. It shows:

(1) An abrupt variation of observed heat flow near the Bangong-Nujiang suture zone (BNSZ), by which the Tibet Plateau can be divided into the cold northern part of old stable massif and the warm southern part of young mobile massif.
(2) The northern cold massif has a low heat flow, ranging from 47 to 40 mW/m^2.
(3) The southern massif can be divided into two zones: Himalayan zone (HM) and Lhasa-Gangdise zone (LG), with scattering heat flow, from 66 to 64 mW/m^2. Three heat flow values are over 300 mW/m^2 due to true in drillholes in geothermal fields.
(4) The Yarlung-Zangbo suture zone (YZSZ) has an observed heat flow of only 60 mW/m^2 due to low temperature gradient, high thermal conductance, and low heat production. It is obvious that it is a thermal boundary between Himalayan and Lhasa-Gangdise zones.
(5) The Lhasa-Gangdise zone with distinct anomalous thermality is a natural reflection of the complex thermal status, where has four levels in the crust controlling the orders of magnitude of surface heat flow: superficial

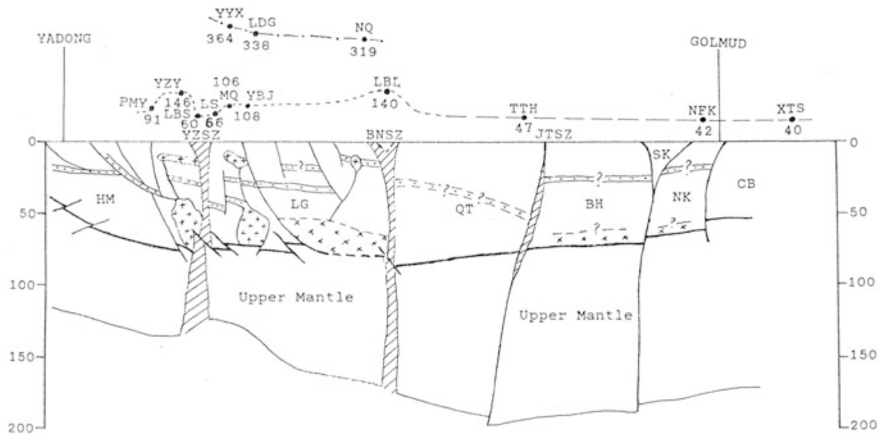

Fig. 9.2 Schematic cross section of observed heat flow and crust–mantle thermal structure along Yadong-Golmud Geoscience Transect (after Shen et al. 1995). *Terranes* HM-himalaya Terrane; *LG* Lhasa-Gangdise Terrane; *QT* Qiangtang Terrane; *BH* Bayan Har Terrane; *SK* South Kunlun Terrane; *NK* Kunlun Terrane; *CB* Caidam Basin. *Suture Zone* YZSZ-Yarlung-Zangbo Suture Zone; *BNSZ* Bangong-Nujing Zone; *JTSZ* Jinsha-Tongtian suture Zone. Heat flow sites: *PMY* Pumuyung Lake; *YZY* Yangzhuoyung Lake; *LBS* Luobusha; *LS* North suburb of Lhasa; *MQ* Maqu; *YBJ* Yangbajing; *YYX* Yangyingxiang; *LDG* laduogong; *NQ* Naqu; *LBL* Lumbula Basin; *TTH* Tuotuohe; *XTS* Xitieshan; *NFK* Northern Foothill of Kunlun Mts. Figures-observed heat flow in mW/m^2; hatched area-ophiolite belt; *dotted area* partially melting layer; *crossed area* magmatic source regions; *x-noted region* possible crust–mantle mixing; *broken line on top of a figure* a general trend of conductive heat flow variation; *dot-dash* line links the conductive-convective heat flow together

hydrothermal circulation zone, upper crustal heat source region, mid-crustal partially melting layer, and Moho boundary from top to bottom.

The heat flow profile is quite consistent with the heterogeneity in velocity, density, and electric Resistance of the strata on the Plateau (Molnar 1988).

Shen et al. (1984) settled a reservoir model for the Yangbajain geothermal field (Fig. 9.3). I disagree with them about this model. I think that the heat source of the Yangbajain field is located beneath the Sulfur Mine, where there is an ascending zone of heat fluids. Then it forms horizontal flows in the basin flowing from the Sulfur Mine to the Zangboqu river. The recharging water is coming from Mt. Nyainqentanglha.

9.3 Deep Temperature Patterns

Figure 9.4 is the deep temperature patterns calculated by heat flow values in the continental area of China. At the depth 3.5 km, the temperature of southern Tibet has reached 100–200 °C and the rest are below 100 °C. At the depth 5.5 km, the

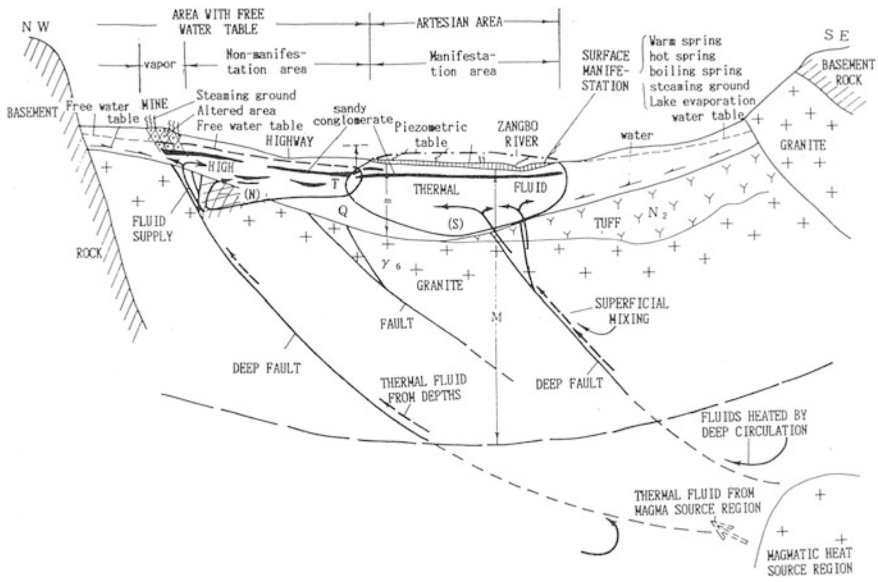

Fig. 9.3 Planar dynamic reservoir model with separate N-S supply of cognate hydrothermal fluid by diverse paths for the Yangbajain Geothermal field, Tibet Autonomous Region (after, Shen and Wang 1984). *N* northern subregion; *S* southern subregion; *M* circulation depth; *m* reservoir thickness; *T* Temperature; *Q* Quatermary; N_2 Neogene; γ_6 granite of Yanshanian stage

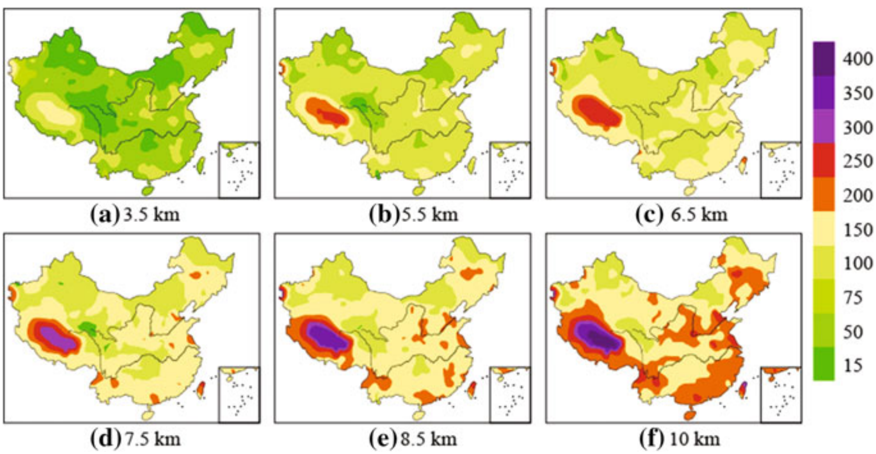

Fig. 9.4 Deep temperature patterns in the continental area of China (after Wang et al. 2012)

temperature of the southern part of Tibet exceeds 200 °C. At the depth 6.5 km, the temperature of greater part of southern Tibet has reached 250–300 °C; and the temperature of Yunnan-Guizhou Plateau, etc., has reached 150–200 °C. At the

Table 9.1 Estimative recoverable fraction of energy and resource base from HDR in the continent area of China (after Wang et al. 2012)

Type of geothermal resources	Total resource base (100%)		Upper limit of recoverable resource (40%)		Median of recoverable resource (20%)		Lower limit of recoverable resource (2%)	
	HE/10^6 EJ	SCE/10^{12} t	HE/10^6 EJ	SCE/10^{12} t	HE/10^6 EJ	SCE/10^{12} t	HE/10^6 EJ	SCE/10^{12} t
HDR	21.0	714.9	8.4	286.0	4.2	143.0	0.42	14.3
HCS							0.025	0.852

1 EJ = 10^{18} J = 2.930760 t standard coal
HE heat energy, *SCE* Standard coal equivalent
HDR Hot dry rock; *HCS* Hydrothermal convection system

Table 9.2 Estimated total geothermal resource base and recoverable resource in the major geothermal areas of China (Wang et al. 2012)

Main HDR geothermal areas	Total resource base		Upper limit of recov. resource (40%)		Median of recov. resource (20%)		Lower limit of recov. resource (2%)		Percentage of total resources (%)
	GHE/10^6 EJ	SCE/10^{12} t	GHE/10^6 EJ	SCE/10^{12} t	GHE/10^6 EJ	SCE/10^{12} t	GHE/10^6 EJ	SCE/10^{12} t	
Tibet	4.30	146.8	1.72	58.7	0.86	29.4	0.09	2.94	20.5
N. China	1.81	61.7	0.72	24.7	0.36	12.3	0.04	1.23	8.6
Southeast	1.73	58.9	0.69	23.6	0.35	11.8	0.03	1.18	8.2
Northeast	1.08	37.0	0.43	14.8	0.22	7.4	0.02	0.74	5.2
Tengchong of Yunnan	0.82	28.1	0.33	11.2	0.16	5.6	0.02	0.56	3.9

GHE Geothermal energy, *SCE* Standard coal equivalent depth 8.5 km, the temperature of the most part of Tibet has exceeded 200 °C, and of the center of high temperature reached 400 °C.

9.4 The Geothermal Resources of Hot Dry Rock

Wang et al. (2012) have calculated the resources of HDR at depth from 3 to 10 km based on the deep temperature of the continental area of China. The estimated total HDR resource base is 20.9×10^6 EJ, which convert into SCE of 714.9×10^{12} t and which is higher than that (14×10^6 EJ) of metropolitan territory of the United States (except Yellowstone Park). If the active resource calculation is 2%, it would be 4400 times of total consumption of energy resources of continental area of China in 2010 (32.5×10^8 t SCE) (Tables 9.1 and 9.2).

Wang et al. (2012) think that the southern part of the Qinghai-Tibetan Plateau is provided with rich in HDR geothermal resources, accounting for 20.5% of total resource base (Table 9.2). Then the sedimentary basin of northern China and the Mesozoic magma rock areas in Zhejiang, Fujian, and Guangdong make up 8.6 and 8.2%, respectively. Furthermore, the Song-Liao basin in the northeastern China is fourth, accounting for 5.2%. In the Tengchong massif of western Yunnan Province, where the temperature is very high, but the area is smaller, its heat resource is only making up 3.9%.

Wang et al. are still thinking that the depth between 3 and 10 km, the HDR resource with <75 °C is only 0.4×10^6 EJ, accounting for 2% of total resources; The HDR resources of 75–150 °C is 8.9×10^6 EJ, accounting for 43%; the HDR resource more than 150 °C is 11.7×10^6 EJ, accounting for 55%. The purpose exploiting HDR is geothermal electricity production, the depth of exploited well with 4–7 km is a fairly better.

The development of HDR has been focus of the Ministry of Land and Resources and China Geological Survey. "2016 International symposium on HDR & EGS" held in October 11–12, 2016 in Jilin University. In the same year on December 16–17 "Geothermal Resources Exploration and geothermal Energy Utilization Workshop" held in Tianjin. The home and abroad experts at these meetings mentioned that we should steadily promote China's HDR development, and that the main target of HDR should be mainly in the economically developed eastern China.

Since 2016, China's HDR research projects mainly choose Fujian's Zhangzhou, Bohai Bay Basin, Shandong, Henan's Zhengzhou and Qinghai's Gonghe Basin.

Many of the boreholes in eastern China are still drilling. Four holes in Gonghe Basin (100° 35′E, 36° 15′N) of Qinghai province have been exposed to HDR. Hale depth is of 3000–4000 m, respectively. The upper port of basin is a Tertiary sediments with a thickness of 920 to 1350 m. The underlying bedrock is granite. The bottom-hole temperature in granite is 183–195 °C.

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Chapter 10
The Future of Geothermal Energy in Qingzang Plateau

Abstract This chapter discusses the future of geothermal energy in Qingzang Plateau. The current situation of geothermal exploitation is that direct use ranks first in the world and geothermal power generation ranks eighteenth in 24 countries. The direct use in China mainly presented in bigger cities of eastern part of country to use intermediate-low temperature hot water from sedimentary basin. But the remote west region abounds in high-temperature geothermal resources and hydroelectric potentials. Thus, the geothermal electricity could only be an important supplement to hydropower stations.

Keywords Geothermal direct use · Geothermal electricity · Hydroelectric potentials

10.1 Accessible Resources Base in Qingzang Plateau

For 107 systems of reservoir temperature greater than 150 °C, the author of this book calculated available work and their electrical energy (in MW for 30 years). The total of geothermal electrical potential is about 3400 MW_{30a}.

For 559 systems having reservoir temperature of 90–150 °C, the author of this book estimated that the beneficial heat is 24% of the resource. The total is about 11.78 EJ.

The author of this book presents a detailed inventory of thermal energy to a depth of 3 km in identified hydrothermal convective system with reservoir temperature of 90 °C or more. In addition to the accessible resource base calculated for identified systems. A substantial undiscovered component of the accessible resource base undoubtedly exist. White et al. (1975) estimated that for the whole the United States, the undiscovered component of hot water convection systems having reservoir temperature greater than 150 °C was five times the identified component. The undiscovered component at 90–150 °C was estimated as three times the identified. This undiscovered part consists of (1) additional thermal energy due to upward revisions of the volume of the identified systems (2) additional thermal

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Table 10.1 Summary of the identified and undiscovered accessible resource base for Tibet, western Sichuan and southwestern Yunnan

Province	Hydrothermal convection system	Identified accessible resources base (EJ)	Undiscovered accessible resources base (EJ)
Tibet	High-temperature	95	475
W. Sichuan	High-temperature	19	95
SW. Yunnan	High-temperature	46	230
Total	(>150 °C)	160	800
Tibet	Intermediate temperature	0.285	0.855
W. Sichuan	Intermediate temperature	0.249	0.747
SW. Yunnan	Intermediate temperature	0.306	0.918
Total	(90–150 °C)	0.840	2.520

1 EJ = 10^{18} J

energy due to upward revisions of temperature estimates, and (3) thermal energy in systems that have not yet been identified (White et al. 1975). Of course, both the identified and undiscovered components of the accessible resource base in this assessment are restricted to depth less than 3 km.

The identified and undiscovered components of the accessible resource base for Qingzang Plateau and its surrounding areas are given in Table 10.1.

The total of identified accessible base is 160 EJ for the high-temperature hydrothermal systems (except Qinghai Province). Most high-temperature hydrothermal convection systems in Tibet are located at north side and south side along Yarlung Zangbo suture. Their identified accessible resources bases are 95 EJ accounting for 59.3% of total. The high-temperature hydrothermal systems in Yunnan are located at Tengchong Massif and west side of Lancang Jiang Fault, with the identified assessable resources base of 46 EJ, account for 28.8% of total. The identified accessible resource base of the Rehai (Hot Sea) geothermal field is 9.21 EJ, being 20% of Yunnan. The high-temperature hydrothermal convection systems of western Sichuan are located at the most east part of the Qingzang Plateau. Their distribution is controlled by fracture zone with NW trend. The identified accessible resource base is only 19 EJ, accounting for 11.8% of total.

10.2 The Status Quo of Geothermal Exploitation in China

Based on the data from World Geothermal Conferences in Bali (2010) and in Melbourne (2015), Zheng et al. (2015), the installed capacity of geothermal electricity in China ranks eighteenth in 24 countries with about 25 MWe since 1980s (Bertani 2010, 2015). In terms of geothermal direct use, China ranks the first in 82 countries of the world with the installed capacity of 17,416 MWt and annual energy use 174,352 TW/year. The United States occupies second with the installed capacity 17,416 MWt and utilization of 75,862 TW/year. The third is Sweden with installed capacity of 5600 MWt and utilization of 91,920 TW/year only for geothermal heat pump. Table 10.2 shows the direct use of geothermal energy of both China and the United States (Lund et al. 2015).

Both China and the United States are well matched in the installed capacity of direct use but the projects are widely divergent. The main project in the United States is geothermal heat pump, with the installed capacity accounting for 96% of direct use. But in China the project of geothermal heat pump only occupies 66%.

It must be pointed out that the main projects of direct use, including district heating and geothermal heat pump, in China all are distributed into the eastern China outside the Qingzang plateau. The geothermal space heating in China provides heat for 60.32 million m^2, with 19 million m^2 in Tianjin and 13.8 million m^2 in Hebei Province. The geothermal heat pump has increased from heating area of 7.67 million m^2 in 2004, to 100.7 million m^2 in 2009, to 300 million m^2 in 2014. The largest concentration is in Shengyang, where 22.48% of the China's capacity has been installed, following by Beijing with 15.8%, then Henan with 10.4%, Shanxi with 8.7%, Jiangsu with 7.3%, Tianjin with 4.6% and Hebei with 4.4%.

China's development of geothermal energy began during the 1970s global oil crisis. A geothermal survey and exploration were conducted throughout the country. Nine small geothermal pilot plants of 50–300 kW capacity were installed, and direct use has sprung up like mushrooms. Geothermal energy offers huge potential for China, with the country ranked first in the world in the direct use of geothermal resources, but only eighteenth in geothermal electricity generation (24.2 MW). Seven plants of nine small pilot units in eastern China have closed due to low temperature and inefficiencies.

Table 10.2 The direct use of geothermal energy of both the United States and China in 2015

Kind of utilization	The United States		China	
	MWt	TW/year	MWt	TW/year
Traditional geothermal use	615.91	9191.6	6089	74,041
Individual space heating	139.89	1360.6		
District heating	81.55	839.6	2946	33,710
Air conditioning	2.31	47.6		
Greenhouse heating	96.91	799.8	154	1797
Fish farming	141.95	3074	217	2395
Agricultural drying	22.41	292.0	95	1198
Industrial process heating	15.43	201.1	169	3304
Snow melting	2.53	20.0		
Bathing and swimming	112.93	2557.5	2508	31,637
Geothermal heat pump	16,800	66,670.61	11,781	100,311
Total	17,415.91	75,862.21	17,870	174,352

10.3 China in World's Geothermal Power Generation

The advanced world level of geothermal development for one country depends to a large extent on the total installed capacity of geothermal power generation, which is a reflection of country's geothermal potential and standard of industrialization and which can produce quadric energy to bring about a great advance in national economic and country's GDP. The data of Table 10.3 are all the countries currently generating geothermal electricity in the world, which are presented by Bertani (2015).

Table 10.3 Installed capacity and produce energy for 2010, 2015 and forecasting for 2020

Country	2010		2015		2020	Percentage (%) of some national production, 2015
	MWe	GWh	MWe	GWh	MWe	
The United States	3086	16,603	3450	16,600	5600	0.3
Philippines	1904	10,311	1870	9646	2500	27.0
Indonesia	1197	9600	1340	9600	3500	3.7
Mexico	958	7047	1017	6071	1400	3.0
New Zealand	762	4055	1005	7000	1350	4.5
Italy	843	5520	916	5660	1000	1.5
Iceland	575	4597	665	5245	1300	30.0
Kenya	202	1430	594	2848	1500	51.0
Japan	536	3064	519	2687	570	0.1
Turkey	82	490	397	3127	600	0.3
Costa Rica	166	1131	207	1511	260	14.0
El Salvador	204	1422	204	1442	300	25.0
Nicaragua	88	310	159	492	200	10.0
Russia	82	441	82	441	190	
Papua New Guinea	56	450	50	432	70	
Guatemala	52	289	52	237	140	
Portugal	29	175	29	196	60	
China	24	150	27	150	100	
Germany	6.6	50	27	35	60	
France	16	95	16	115	40	
Ethiopia	7.3	10	7.3	10	50	
Austria	1.4	3.8	1.2	2.2	6	
Australia	1.1	0.5	1.1	0.5	20	
Thailand	0.3	2.0	0.3	1.2	1	
Total	10,897	67,246	12,635	73,549	20,757	

The data are taken from Bertani (2015) and Wikipedia (online)

Based on Bertani's data (2015), 27 countries or regions will join the ranks of geothermal power generation in 2020. The installed capacity will increase to 21,443 MWe at that time. The increased quantity is 686 MWe, in which the first place is Chile with 150 MWe and the second is Djibouti with 50 MWe. There are five counties, including Bolivia, Ecuador, Greece, Peru, and Spain, with 40 MWe for each. Both Honduras and Nevis, each has 35 MWe.

Accordingly, we can reach following views:

1. The geological setting of most countries is situated at boundary of different plates:

   At Pacific Ring of Fire: The United States, Mexico, Guatemala, El Salvador, Nicaragua, Costa Rica, Kamchatka of Russia, Japan, Taiwan Province of China, Philippines, Indonesia, Papua New Guinea, New Zealand;
   At Mid-Atlantic Ridge: Iceland, Azores Island of Portugal;
   At Lesser Antilles arc: Guadeloupe of France;
   At boundary between Eurasian and African Plates: Italy and Turkey;
   At Continent crust–Continent crust Collision Belt: Southwestern China and Kashmir;
   At East African Rift: Kenya and Ethiopia.

2. Most countries in Table 10.3 have rich high-temperature geothermal resources, which are mainly convective hydrothermal systems. There are two basic classes of these convective systems depending on the source of the thermal energy: volcanic and non- volcanic. A volcanic convective system drives its thermal energy from a cooling magma body, while a non-volcanic convective system drives its thermal energy by meteoric water which has heated up by deep circulation in high heat flow area of the crust. There is no magma body associated with such a system. The system hotter than 200 °C are generally volcanic, whereas those cooler than 200 °C are non-volcanic. The later systems are more in number than the former (Sanyal 2010). Table 10.4 shows the number of active volcanoes and estimated geothermal potential for electrical generation in some countries and regions.

The younger volcanoes are scattered all over the Mt. Kunlun of northern margin of Qingzang Plateau. At both southern and northern sides of Yarlun Zangbo suture, there are many deep reflection highlights in the depth of 15 km and shallow high-conductor in the depth about 10 km, which could be molten or semi-molten state magma chamber of later.

3. The enumerated countries in Table 10.3 can be divided into four categories:

The first types are countries lack of conventional energy resources (coal, oil or natural gas), for example: Italy, New Zealand, Philippines, Iceland, Kenya, Japan, Papua New Guinea, and so on.

Italy has few energy resources and most of supplies are imported. But it is rich in geothermal resources. In the early days of the twentieth century, a great demand for

Table 10.4 Number of active volcanoes and identified potential

<table>
<tr><th colspan="2">Country or Region</th><th>Number of active volcanoes</th><th>Electrical energy (MWe for 30 year)</th><th>References</th></tr>
<tr><td colspan="2">The United States</td><td>133</td><td>23,000</td><td>Muffler (1979)</td></tr>
<tr><td colspan="2">Japan</td><td>100</td><td>20,000</td><td>Takasima (1980)</td></tr>
<tr><td colspan="2">Indonesia</td><td>126</td><td>16,000</td><td>WEC (1998)</td></tr>
<tr><td colspan="2">Philippines</td><td>53</td><td>6000</td><td>Wright (1999)</td></tr>
<tr><td colspan="2">Mexico</td><td>35</td><td>6000</td><td>Mulas de Pezo et al. (1985)</td></tr>
<tr><td colspan="2">Iceland</td><td>33</td><td>5800</td><td>Polmason et al. (1985)</td></tr>
<tr><td colspan="2">New Zealand</td><td>19</td><td>3650</td><td>Lawless (2002)</td></tr>
<tr><td colspan="2">Tuscany of Italy</td><td>3</td><td>700</td><td>Muffler et al. (1978)</td></tr>
<tr><td colspan="2">Turkey</td><td></td><td>4500</td><td>Mertoglu (2015)</td></tr>
<tr><td colspan="2">Kenya</td><td>17–30</td><td>7000</td><td>Simiyu (2010)</td></tr>
<tr><td colspan="2">Costa Rica</td><td>3</td><td>1400</td><td>Kim (2001)</td></tr>
<tr><td colspan="2">El Salvador</td><td>2</td><td>1055</td><td>Kim (2001)</td></tr>
<tr><td colspan="2">Guatemala</td><td>29?</td><td>1655</td><td>Kim (2001)</td></tr>
<tr><td colspan="2">Nicaragua</td><td>18?</td><td>1675</td><td>Kim (2001)</td></tr>
<tr><td colspan="2">Papua New Guinea</td><td>17</td><td>21.9 TW/h</td><td>Kuna et al. (2015)</td></tr>
<tr><td rowspan="3">China</td><td>Tibet, Sichuan</td><td>Reflection highlight</td><td>1992 MWe, 408 MW</td><td>This book</td></tr>
<tr><td>Yunnan</td><td>3</td><td>1010 MWe</td><td>This book</td></tr>
<tr><td>Taiwan</td><td>5</td><td>80–200 MW</td><td>C H Chen (1970)</td></tr>
</table>

electricity led to the consideration of geothermal power as a generating source. Prince Piero Ginori Conti tested the first geothermal power generator on July 4, 1904 in the Larderello. It successfully lit four light bulbs. Later, the world's first commercial geothermal power plant with 250 kW was built there. Experimental generators were built in the United States and Japan before the Second World War, but Italy was the world's only industrial producer of geothermal electricity until New Zealand built a power plant in 1958 (Wikipedia 2015a, b).

Japan lacks significant domestic resources of fossil fuel and must import substantial amounts of crude oil, natural gas, and uranium. Japan relied on oil imports to meet about 42% of its energy needs in 2010. Japan was also the first coal importer in 2010, with 187 MT (about 20% of total world coal import), and the first natural gas importer with 99 bcm (12.1% of world total gas import). Japan had relied on nuclear power to meet about one-fourth of its electricity needs. Japan is located in Pacific Ring of Fire rich in geothermal potential estimating about 20 GWe. Its first geothermal pilot plant was opened in 1925 in Beppu. However, research in geothermal energy was slowed down by the Second World War. The present total capacity of 18 geothermal power plants is still around 500 MWe, almost unchanged for more than decade. These plants are mostly situated in the national park. After the nuclear accident in March 2011, the government restarted an incentive scheme for geothermal exploitation and mitigation of constraints in national parks, encouraging new geothermal exploration by private sectors as well as quick installation of small binary systems, Japan is the world's third economy, and has developed industry, hence power consumption is huge, however geothermal power generation accounts for only 1/1000 of the country's electricity generation (Wikipedia 2015a, b).

Philippines has a little of coal, deep-water oil and offshore natural gas resources, but these still do not meet the country's demands without imports. It is also located in Pacific Ring of Fire with geothermal potential of 6000 MWe. Philippines began to exploit geothermal energy due to world's energy crisis in 1970s. The current installed capacity of 1870 MWe geothermal contributes to 14% of the total electricity requirements from seven plants. Currently the Philippines is the second highest producer of geothermal energy. The government has set a goal to surpass the United States as the highest producer in the world.

Kenya is a country poor in conventional energy resources. Both natural gas and oil reserves have nothing in reserves. And coal reserves are unavailable. Kenya is situated in East Africa Rift rich in active volcanoes and hydrothermal activities. The geothermal power generation of Kenya accounts for 51% of the country's electricity generation.

Also lack of fossil fuels is Nicaragua and Costa Rica in Latin America, but the geothermal power generation accounts for 10 and 25% of their country's electricity generation, respectively.

The second types of countries are rich in fossil fuels and geothermal resources, such as the United States, Mexico, and Indonesia.

As everyone knows that the United States is the world's first economy with world-famous gross output value of industry and agriculture, rich in energy resources. According to a recent report, an updated version of a 2009 paper, the United States' resources are larger than Saudi Arabia, China, and Canada, combined. The report estimated that the United States has 163 billion barrels of recoverable oil and enough natural gas to meet the country's demands for 90 years (Carvey 2013). In the United States, the output of petroleum is 37 billion barrels in 2014, of natural gas is 25,728 billion ft^3 in 2014 and of coal is 1016,458 thousand short tons in 2012 (eia 2015a). In 2013 the total installed electricity generation summer capacity in the United States was 1000 GWe. The main energy sources for electrical production include: Thermal fossil fuel 772 GWe, Nuclear 99 GWe, Hydropower 79 GWe, Wind 60 GWe, and so on. Major energy sources and percent share of total electricity generation are as follows: Fossil fuels 2746 TWh accounting for 67%, Nuclear 789 TWh accounting for 19%, Hydropower 269 TWh accounting for 6.5%, wind 167.84 TWh 4.1%, Biomass 60.83 TWh accounting 1.5%, geothermal 15.78 TWh accounting for 0.38% and Solar 9.04 TWh accounting for 0.22% (eia 2015b, c). In 2015, both the installed capacity and annual generation of geothermal electricity in the United States are the world's first with of 3450 MWe and 16,600 GWh, respectively (Bertani 2015). The accessible resource base to 3 km of reservoir of hydrothermal convection systems more than 150 °C is

950 EJ (do not include 1289 EJ in Yellowstone) and the electricity is 23,000 MW_{30year} (Muffler 1979). In 2015, the total installed capacity of all the countries currently generating geothermal electricity was about 12,636 MWe for 30 years (Bertani 2015), in which the United States accounted for 27% Despite it is the first in geothermal power, but produced geothermal electricity only accounts for 0.38% of the total energy production in the United States.

Mexico is the world's fourth in geothermal power generation with the installed capacity of 1017 MWe and produced electricity of 6071 GWh in 2015, distributed into four fields in operation. The production of fossil fuel includes: oil of 10 billion barrels, natural gas of 1603 billion ft^3 in 2014, and coal of 16,743 thousand short tons in 2012. Mexico was described energy and electricity production, consumption, import, and export. Total electrical installed capacity in Mexico is 31,884 MWe by August, 1994, of which 21,565 MWe based upon fossil fuels accounting for 67.6%, 8891 MWe were hydroelectric accounting for 28%, 675 MWe were nuclear electricity accounting for 2% and 753 MWe were installed geothermal electrical capacity accounting for 2.3%. The total electrical capacity projected in Mexico by 2000 was estimated in 38,352 MWe, of which thermal electricity was 23,924 MWe, making up 62%, hydroelectric power 12,018 MWe making up 31%, nuclear electricity 1350 MWe making for 3.5% and geothermal power 1144 MWe making up 3.0% (Quijano-Leon and Negrin 1995). In fact, the geothermal power in Mexico was only 958 MWe in 2010 (Bertani 2015), which was less than the projection by 2000.

Indonesia is a country rich in both geothermal resource and fossil fuel. Indonesia has exploited geothermal energy since 1970s as a response to the energy crisis. Indonesia had an estimated 51 GW of installed capacity and generated 220 billion kWh in 2013, about 88% of the power generation came from fossil sources; with the rest coming from hydro (8%) and geothermal (5%).

Indonesia produced 911,000 barrels per day of petroleum in 2014, ranking as the 22nd largest oil producer in the world in 2014 and accounting for 1% of world production. In 2014, Indonesia imported more than 441,000 b/d of crude oil from seven countries—Saudi Arabia, etc. At same year, Indonesian crude oil experts were roughly 381,000 b/d, primary to regional buyers: Japan accounting for 26%, Australia for 13%, Thailand for 12%, China for 10%, Singapore for 9%, South Korea for 8%, Malaysia for 8%, the Unites States for 8% and other for 8%. Indonesian natural gas reserves are the thirteenth largest in the world. It possessed 103.4 trillion cubic feet (bcf) in 2015. In 2014, it exported 762 (bcf) natural gas, to Japan (36%), South Korea (33%), China (29%), including Taiwan (14%), Mexico (2%). Indonesia played an important role in world coal market in 2014. Indonesia was the world's largest exporter of coal. Its coal production was 538 million short tons in 2013, but consumption was only 79 million short tons. In 2014, Indonesia exported about 480 million short tons coal to India (33%), China (including Hong Kong) (27%), Japan, South Korea, etc.

Indonesia expected geothermal potential of about 28 GWe composed of 312 geothermal regions. The current geothermal fields are operated in 10 locations. The installed capacity consists of 1340 MWe and produced geothermal electricity of 9600 GWh (eia, Beta 2015b, c).

The third type is the countries that lack of high-temperature geothermal resources, for example, France, Portugal, Austria, and Germany in Europe and Thailand in Asia and Australia.

In terms of geological setting, Europe belongs to stable new platform lacking of high enthalpy geothermal water for electricity production. The geothermal power generation in France and Portugal are not emerging on their mainland, but limited to the overseas territories.

The high enthalpy utilization for electricity production in France is only at Bonillante field on Guadeloupe island of Lesser Antilles arc in Caribbean Sea. There are many active volcanoes due to Caribbean micro plate overthrowing on the Atlantic plate. Its exploitation stared in 1984, A second unit has been commissioned in 2004. The reserve temperature is 250 °C at shallow depth. The total capacity of 15 MW produces 95 GWh, corresponding to 8% of the local consumption. The activity for their unit of 20 MW is ongoing. The final target will reach 20% of geothermal contribution to the electrical needs.

In France mainland, the EGS project at Soult-sous-Forets is now operating a scientific pilot plant of 1.5 MW. The EGS exploited with a three-well system in the granite at depth 5000 m inside Rhein graben. It is fully operative (Bertani 2010, 2015).

In the Portugal mainland, thermal waters are related with active faulting in crystalline rocks. Twenty-seven springs have discharging temperature 25 and 75 °C, and are used in balneotherapy. In capital Lisbon area's sedimentary basin, Low Cretaceous reservoir with temperature is up to 50 °C. The exploitation of high enthalpy geothermal resources of Portugal is located in the Azores archipelago, where there is an active volcanic region emerging from a tectonic triple junction point of the North American, Eurasian, and African plates. Over 30 volcanic eruption were registered, the last occurring in 1998–2000. The high-temperature geothermal field is exploited for power generation since 1980. Five geothermal plants exist on Sao Miguel Island, one near Pico Vermelho and four binary cycle power plants in Ribeira Grande (250 °C), which have together an installed capacity of 16 MWe. Another one exists on Terceira (300 °C) has 12 MWe (Carvallo et al. 2005).

Germany is situated in hinterland lack of high temperature hydrothermal convective system. Three types of reservoirs were considered hot water aquifers, fault and crystal rocks with temperature above 100 °C and at depths down to 7000 m. The electrical energy was estimated to 10 EJ for hot water aquifers, to 45 EJ for fracture zones and to 1100 EJ for crystal rock areas. Organic Rankino and Kalina cycle techniques allow efficient electricity production at temperature down to 100 °C and make geothermal power production feasible even for countries lacking high enthalpy resources at shallow depth (Schellschmidt et al. 2010). The first Germany geothermal power plant with ORC technology at low temperature was built in 2003 in Naustadt Glewe located in North Germany. At the beginning of 2014, seven plants with facilities for geothermal power production were in operation. There are two 5.5 MWe ORC plants (in Kirch and Durmhaar), two 5 MWe ORC plants (in Sauerlach and Upper Rhine graben), one 3 MWe ORC plant (in Landaw) and 2 Kalina cycle plants (one with 3.3 MWe in Unterhaching and one with 0.55 MWe in Bruchsal). In 2015, Germany has been commissioned resulting in a total installed capacity of 27.1 MWe and the electricity produced amounted to 35.5 GWh (Weber et al. 2015). Germany uses low temperature geothermal fluids to erect 5.5 MWe ORC plant and that is a miracle. There is much in their method that we can make use of.

The fourth type is China rich in geothermal resources and direct utilization but short of geothermal power generation.

The most east part, Taiwan, is situated at Pacific Ring of Fire. The Datun volcanoes emerged in northern end of Taiwan Island. The estimated electrical energy is 80–200 MW (Chen 1970). In 2015, Estimated power generation capacity of geothermal reserves with geothermal temperature to excess of 175 °C in the four geothermal areas of Taiwan are shown in Table 10.5 (Yang et al. 2015).

In 2015, Yang and Geothermal Research Teams of Taiwan published the result of assessment of geothermal resources of Taiwan (Table 10.5) (Yang et al. 2015), but not presented the methodology used in determining the power generation capacity for each geothermal areas. In my opinion, their results seem a bit too high. It is a common knowledge that the identified electricity of reservoirs of hydrothermal convection systems of the United States (not including Yellowstone) is only 23,000 MWe (Muffler 1979) And then we are checking C-area, Hualian–Taidung geothermal area, which is the boundary between Eurasian and Philippines plates being a sinistral strike-slip fault 250 km long. It not is a rift but with power capacity of 100,431 MWe. However, the Kenya's section of East African rift is 700 km long with about 30 volcanoes with electricity of 7000 MWe (Simiyu 2010). Beside, the geothermal energy of Pacific Border of the United States along the San Andreas Fault is 1670 ± 700 MWe (Muffler 1979). The estimated result of Taiwan includes the geothermal resources of HDR, which could be power generating capacity of more than 2 km geothermal reserves with 15,900 MWe. If 15,900 from 100,431 MWe is 84,531 MWe, which far exceed 7000 MWe of Kenya or 1670 MWe of California of The United States.

Taiwan has two mini geothermal power stations in Lilan Country. The bigger one is situated in Qingshui with 3 MW dual flash unit since 1979 and another one in Tuchang with 300 kW single flash unit since 1986. They are discharging bicarbonate sodium water with serious scales.

Fujian and Guangdong Provinces in China's mainland emerged many thermal springs, but the high-temperature hydrothermal convective systems have not been discovered yet since 1970s. In those years many pilot plants using single flash or binary cycle techniques were built in Guangdong, Hebei, Jiangxi, Hunan, Guangxi, Liaoning, and Shandong using the temperature of thermal springs between 66 and 92 °C. The running of most of these pilot plants stopped in the middle of 1970s due to low economical benefits.

Table 10.5 Geothermal power generation capacity of Taiwan, China (Yang et al. 2015)

Area	Covered total area (km^2)	Power generation capacity (MWe)	Ratio (%)	Power generating capacity of geothermal reserves of different depths				
				>2 km	1.5–2.0 km	1.0–1.5 km	0.5–1.0 km	<500 m
A	532	36, 923	23.13	30,215	13	456	2100	4135
B	88	2886	1.81	0	0	0	716	2170
C	5403	100,431	69.92	15,900	43,334	15,443	12,880	12,874
D	954	19,366	12.13	10,143	5194	3;859	170	0
Total	6977	159,606		56,262 (35.3%)	48,541 (30.4%)	19,758 (12.4%)	15,866 (19.1%)	19,179 (12.0%)

Area: *A* Ilan Plain; *B* Datun Volcanic Group; *C* Hualian–Taidung geothermal area; *D* Lushan geothermal area

In 1973, Qingzang Plateau Comprehensive Scientific Expedition of CAS (Tong et al. 1981) and the geothermal inspect of Tengchong volcanic region of geothermal research section of Peking University (Tong and Zhang 1989, 1994) discovered many high-temperature geothermal areas to raise the curtain of development of high-temperature geothermal resources in Tibet and Yunnan.

10.4 The Prospect for High-Temperature Geothermal Energy in Qingzang Plateau and Its Surrondings

In 1974, Geophysical Exploration Team of Tibetan Geologo-Mineral Bureau completed the direct current resistivity soundings using the Schlumberger electrode configuration in Yangbajain basin. The obtained resistivity section and plane figure revealed that there could be a big geothermal field under the Yangbajain basin.

In 1975, the government of Tibet Autonomous Region decided to exploit the Yangbajain geothermal field and many departments concerned, including the Ministry of Water and Electricity, Tibetan industrial and geological departments and the Scientific Expedition of CAS, who have participated the exploration of geothermal field. I was honored to be part of the exploration.

A pilot unit with 1 MW single flash was installed and began in motion in October 12, 1977. The amount of electric power produced by pilot plant was from 83.15×10^4 kWh in 1978 to 341.52×10^4 kWh during 1980. Geothermal development in Yangbajain has been started with success in 25 MW and has been in active operation of first 3 MW formal plants since December 23, 1981. There were eight 3 MW units after 1991. Since 1982, Yangbajain geothermal power station has begun to transmit electricity with 110 kV transmission line to Lhasa. The amount of electric power produced by Yangbajain geothermal station in 1990 was 6059.58×10^4 kWh, Power plant of Lhasa mainly is hydroelectricity and a little oil electricity and produced amount of electric power during the same period was 8783.19×10^4 kWh and 323.50×10^4 kWh, respectively. This means that the geothermal contribution of 6060×10^4 kWh accounted for 39.69% of Lhasa electrified wire netting, and hydropower for 57.53% and oil electricity only for 2.78% (Tong et al. 2000).

The Yangbajain geothermal station was running well in 1981 that was the most heartening news to Tibetan people and governments at different levels, especially to the governments of Ngari and Nagqu Prefectures. The capitals of both prefectures are gravely short of electricity, but there are hot springs near here. They look forward to replace previous diesel power by geothermal exploitation.

In 1984, the government of Ngari Prefecture decided to exploit Langju hot spring of 78 °C. The distance between the capital of Ngari and Langju is 30 km. There were not careful geological and geophysical explorations to drill 13 wells in the same funnel with 300 m × 150 m and a plat with 2 × 1 MW single flash units built. The depth of wells is about 100 m. The working temperature at wellhead was between 91 and 105 °C and the flux was between 22.6 t/h and 178.38 t/h. The result was that the generated electricity energy was only 600–700 kW only to meet plant itself.

The energy shortage in Nagqu Prefecture is very serious. The capital, Nagqu town, only had a 2 MW diesel power plant. There were two larger hydropower stations in Jiali County (0.32 MW) and Baqen County (0.32 MW). There were yet five mini hydropowers with total capacity only 0.12 MW. The energy consumption of vast pastoral area is cow dung with 7.5 kg for one person in one day. The energy consumption in Nagqu Prefecture is cow dung accounting for 97.77%, electricity for 0.7% and oil for 1.53%. Nagqu hot spring is located to the south of Nagqu town about 1 km with an area of 900 m × 100 m along a ditch nearby Qinghai–Tibet Highway. There are many hot springs and warm springs with temperature about 40–50 °C. The highest one is 59.6 °C. There are many travertines on the surface. The Government of Tibet Autonomous Region decided to exploit Nagqu geothermal field to solve energy grave of Nagqu. Since 1984, Tibetan Geothermo-Geological Team and Tibetan Geophysical Exploration Team began exploration of Nagqu geothermal field. Thirty-eight exploratory wells, including 20 wells for logging, 12 exploratory well, and 6 production wells, were drilled from 1984 to 1990. The total flux of 4 production wells were 1051 t/h with temperature of 113–116 °C at wellhead. Since 1988, the project subsidized by UNDP and the project's number was CRP/88/007 to construct 1 MW binary cycle plant. The executive body was Italian AQUATER SpA. The experts of AQUATER SpA discovered that the most outstanding characteristics discharging from wells precipitate enormous $CaCO_3$ in September 1989 and the diameter of production wells and pipelines on the surface gradually reduce day by day. Eventually, the pumps inside wells also have been blocked up by $CaCO_3$ sediments on December 29, 1993.

Yangyi geothermal field was third region submitted regular geological exploration report in Tibet in 1990. Its installed capacity was estimated to be 30 MWe and the prospective reserves of 50 MWe. But it was an idle geothermal field for 20 years due to construction of the Yamzho Yum Co hydropower station in the meantime. It is completely understandable that Tibetan government authorities puts great importance to hydropower. Because hydropower is the most important energy source in Tibet, Sichuan, and Yunnan.

Tibet is poor in coal, oil, and natural gas, but rich in hydro, geothermal, solar, and wind energy. Tibet especially values hydroelectric energy resources, producing approximately 200 GW of natural hydro-energy annually, or about 30% of China productivity. About 70% of Tibet's hydro-energy resources are concentrated in southeastern Tibet. The Yarlung Zangbo River promises 80 GW in exploitable energy capacity. This value plus the hydroelectrical capacity in its five tributaries, including Doxunmg Zangbo, Nyang Qu, Lhasa river, Ny'ang, and Parlung Zhangbo, adds about 90 GW to the reserves. At area between Nyingzhi County and Medog County is a big turn of Yarlurn Zangbo river, which cuts across Mt. Himalayas. A long canal of 36 km from Posiqu in Nyingzhi to Lidongqiao in

Medog will cut through the Mt. Himalayas. A fall produced of 2190 m could be exploited to build a greatest hydropower station with a installed capacity of 40 GW.

In 2006, Guotian Cai et al. (2006) introduced Tibet's energy sources in a paper. They include: hydro, geothermal, solar, wind, biomass, oil, and coal. Hydropower is the most important energy resource, accounting for 90% with installed capacity of about 200 GW, of which the installed capacity of Yarlung Zangbo River is 48.5 GW. Cai et al., suggests that it is necessary for Tibet to change its energy consumption structure, in order to make full use of renewable energy such as solar energy, wind energy, hydro-energy instead of native vegetation and animal's droppings.

The energy resource structure of Sichuan Province is as follows: hydro-energy accounting for 79.7%, coal for 19%, natural gas for 1.2%, and oil for 0.1%. The installed capacity of hydro-energy in Sichuan is $14,268.96 \times 10^4$ kW, accounting for 21.11% of whole province (Jia et al. 2004). At the west Sichuan (the eastern end of Qingzang Plateau), installed capacity of three rivers (Jinsha, Yalong, and Dadu) is 9166×10^4 kW, accounting for 63% of whole province.

The energy resource structure in 2011 of Yunnan Province is as follows: hydropower 307.1×10^8 kWh accounting for 53%, thermal power 271.9×10^8 kWh accounting for 46%, wind energy 5.7×10^8 kWh and solar energy 1436×10^4 kWh (The west exploitation office of The State Council 2015).

The Qingzang Plateau has vast in territory and a sparse population. The area of Tibet is about 1.2 million km^2 and the population is 2 million. The east end of Qingzang Plateau (the west Sichuan) is about 0.3 million km^2 and has 7.7 million people. The Qingzang Plateau is extremely rich in hydropower resource and short of fossil fuel. Thus the construction of hydroelectric station is of primary importance. The Qingzang Plateau is also rich in geothermal resources, but its exploitation will involve quite trouble geothermal exploration. Tibet Autonomous Region is also rich in both solar and wind energies, but their installed capacity is too small and too expense. So hydropower is the main construction and basic load in Tibet Plateau. But the weather of Plateau is cold and the ground is frozen. In some small hydropower stations people have to constantly break ice in winter and dredge up sand in the summer. The geothermal power station has high load factor and the development of the geothermal can become necessary supplement of hydropower.

The high-temperature hydrothermal convection systems in the Southwestern Yunnan are mainly distributed in two regions: Tengchong massif and Lincang granite body of the west bank of Lancangjiang river. The Rehai (Hot Sea) of Tengchong County is a high-temperature hydrothermal convection system with magma heat source and is also most famous park for balneology. Local government did not like to tap geothermal fluid for development of electricity, because the step-development of Longchuan River can satisfy the electricity needs of Tengchong County. The probability to develop more than ten high-temperature hydrothermal convection systems along the west bank of the Lancang river is very low, because the installed capacity of three reservoirs and 15 step hydropower stations along the Lancang River will amount to 25.5 GWe and 8 hydropower stations in the middle reaches with installed capacity of 15.9 GW are constantly constructing. Moreover, the installed capacity of hydropower for Jinshajiang (1 reservoir and 8 steps) would be 20.58 GW and for Nujiang (2 reservoirs and 13 steps) 21.32 GW (Chinadmd 2015). Such being the case, the development of geothermal power will be very difficult in Yunnan but balneology has been well received by the masses. In Yunnan, if the energy is not confined to the development of hydropower, and geothermal resources in Yunnan are far superior to Germany, if methods of geothermal power generation of Germany can learn by Yunnan, where many emissions HCO3-NA water boiling spring, as long as the drill depth of 1000 m on can achieve more than 100 °C temperature, it can build one 3–5 MW geothermal power plant.

In a word, China's high-temperature geothermal resources mainly exist in the remote regions of Tibet, west Sichuan, and southwest Yunnan, except Taiwan, which holds the greatest for geothermal power generation But these areas are abundant in hydroelectric resources and therefore China's convection geothermal resource has not received the same attention or development as other renewable source, such as hydro and wind. Geothermal electricity is unlikely to play a more important role in China's nationwide electricity supply in the near future. It could be an important supplement to hydroelectric resource in remote southwest regions. As for the development of HDR in China, particular in Qingzang Plateau rich in HDR resources, that is not realizable within the foreseeable future.

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Erratum to: Thermal Springs and Geothermal Energy in the Qinghai-Tibetan Plateau and the Surroundings

Zhijie Liao

Erratum to:
Z. Liao, *Thermal Springs and Geothermal Energy in the Qinghai-Tibetan Plateau and the Surroundings*, Springer Hydrogeology, https://doi.org/10.1007/978-981-10-3485-5

In the original version of the book, the following corrections have to be incorporated:

In Chap. 5, the sentence "The beginning of this century, Jiangxi Huadian Group built a pilot plant to use self-produced screw expander and original drillholes and achieved geothermal full flow power generation in Yangyi Field" has to be newly included at the end of paragraph in the citation of Fig. 5.5, which is a belated correction.

In Backmatter, "References" page has to be deleted and the references have to be added in "Appendix" page.

The erratum book has been updated with the changes.

The updated online version of this book can be found at https://doi.org/10.1007/978-981-10-3485-5

Z. Liao, *Thermal Springs and Geothermal Energy in the Qinghai-Tibetan Plateau and the Surroundings*, Springer Hydrogeology,
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Appendix

All sorts of useful geothermometers in this book:

(Equations expressing the temperature dependence of selected geothermometers. *C* is the concentration of dissolved silica. All concentrations are in mg/kg)

Geothermometer	Equation	Restriction
(a) Quartz-no steam loss	$T° = [1309/(5.19 - \text{Log}C)] - 273.15$	$T = 0 – 250$ °C
(b) Quartz-max. steam loss	$T° = [1522/(5.75 - \text{Log}C)] - 273.15$	$T = 0 – 250$ °C
(c) Chalcedony	$T° = [1032/(4.69 - \text{Log}C)] - 273.15$	$T = 0 – 250$ °C
(d) Na/K (Fournier)	$T° = \{1217/[\log(\text{Na/K}) + 1.483]\} - 273.15$	$T > 150$ °C
(e) Na/K (Truesdell)	$T° = \{855.6/[\log(\text{Na/K}) + 0.8573]\} - 273.15$	$T > 150$ °C
(f) K/Mg (Giggenbach)	$T° = \{4410/[13.95 - \log(\text{K}^2/\text{Mg})]\} - 273.15$	$T = 50 – 300$ °C
(g) Na–K–Ca	$T° = \{1647/\{\log(\text{na/K}) + \beta[\log(\sqrt{\text{C}}\text{a/Na}) + 2.06] + 2.47\} - 273.15$	$T < 100$ °C, $\beta = 4/3$ $T > 100$ °C, $\beta = 1/3$

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Index to Thermal Springs[1]

A

B

[1]Tb: Tibetan boiling spring; Th: Tibetan hot spring; Tw: Tibet warm spring; Tt: Tibetan Tepid spring.
Sb: Sichuan's boiling spring; Sh: Sichuan's hot springs; Sw: Sichuan's warm spring; St: Sichuan's tepid spring.
Yb: Southwestern Yunnan's Boiling spring; Yh: Southwestern Yunnan's hot spring; Yw: Southwestern Yunnan's warm spring; Yt: Southwestern Yunnan's tepid spring.
Qb: Qinghai' s boiling spring; Qh: Qinghai's hot spring; Qw: Qinghai's warm spring; Qt: Qinghai's tepid spring.

Z. Liao, *Thermal Springs and Geothermal Energy in the Qinghai-Tibetan Plateau and the Surroundings*, Springer Hydrogeology,
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