

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.

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 $\text{Cl-HCO}_3\text{-Na}$ type water or $\text{HCO}_3\text{-Cl-Na}$ 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 $\text{HCO}_3\text{--Ca}$ or $\text{HCO}_3\text{--Mg}$ 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 $\text{HCO}_3\text{--Na}$ type, except Yulinhe of Tardo County, which is $\text{Cl--HCO}_3\text{--Na}$ 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 slope 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 $>80^{\circ}\text{C}$, 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 ($>25^{\circ}\text{C}$) in Fujian Province emerge in 184 sites, eight of which are $>80^{\circ}\text{C}$, 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 trending. 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 Jiangnan 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, Autonom., Region	Num. springs	Area 10 ⁴ km ²	Num./ 10 ⁴ km ²	Num. Wells	City, Province, Autonom., 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)

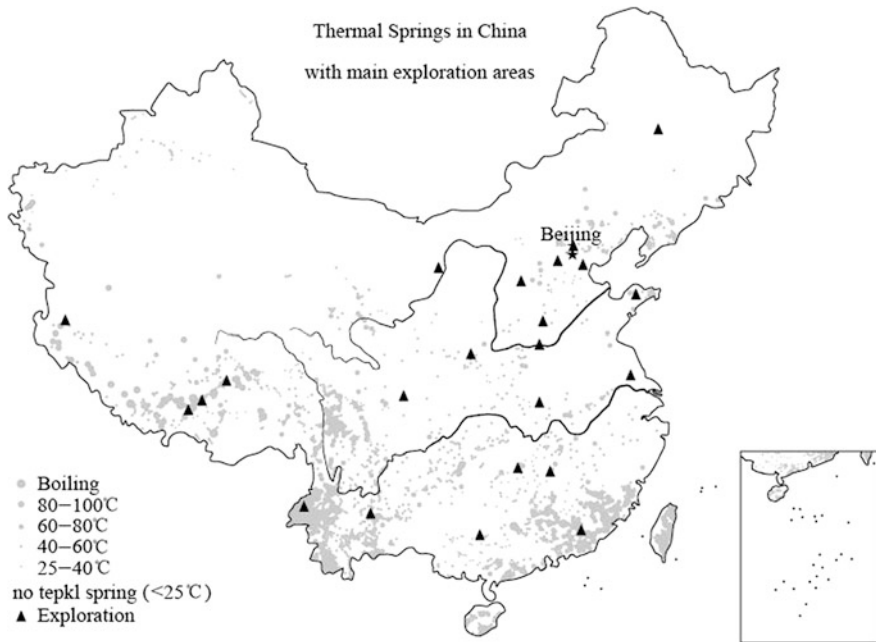


Fig. 2.1 The distribution of thermal springs in China (after Tian et al. 2006; with a bit of alteration)

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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