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Yunnan-Tibet Geothermal Belt

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ABSTRACT

The distribution of thermal springs in China is concentrated in the southwest. According to statistics, Tibet has 907, western Sichuan has 342 and western Yunnan has 694 thermal springs. The region is called the Yunnan-Tibet Geothermal Belt. This paper is mainly restricted to the earth science of the Yunnan-Tibet Geothermal belt, including geological setting and resources assessment. The emergence of the Yunnan-Tibet Geothermal Belt is caused by collision of the fast-advancing Indian plate with the Eurasian plate. The main part of this paper deals with the geothermal resources of 1028 convective systems, which consist of 61 high temperature hydrothermal systems, 194 sub-high temperature systems, 112 middle temperature systems and 661 low temperature systems based on geochemical data. The tentative evaluation of geothermal energy of these convective systems is summarized in this paper.

1. HYDROTHERMAL SYSTEMS IN YUNNAN-TIBETAN GEOTHERMAL BELT

There are 1943 hydrothermal convection systems in the Yunnan-Tibetan geothermal belt (YTGB). The author has defined a thermal spring as one with a vent temperature that is 5℃ higher than the local annual air temperature. The thermal springs are divided still further into five categories, i.e., tepid springs (5℃ higher than the local annual air temperature≦ t ≦35℃), warm springs (36℃≦t≦45℃), hot springs (46℃≦t ≦boiling point of pure water at local altitude), boiling springs (vent temperature that is equal to or slightly higher than the boiling point at the local altitude) and fossil springs. The distribution of thermal springs in different provinces is shown in Table 1.

Based on reconnaissance through out the country, there are more than 3000 thermal springs in China. Thus, the total amount of thermal springs in YTGB accounts for half of the total number of thermal springs in the whole country. And YTGB is the sole region issuing boiling springs in the Chinese mainland (Tong Wei et al., 1981, 1989, 1991).

2. IDENTIFIED HYDROTHERMAL SYSTEMS

Based on water chemistry data, there are 1028 identified hydrothermal systems in YTGB, including 61 high-temperature systems with reservoir temperatures above 150℃, 194 sub-high temperature systems with reservoir temperatures above 150℃, 112 intermediate hydrothermal systems with reservoir temperature from 90 to 150℃ and 661 low temperature systems with reservoir temperature less than 90℃. The identification of high-temperature and sub-high temperature systems is by the average of silica, sodium-potassium, sodium-potassium-calcium and potassium-magnesium geothermometers, but the identification of intermediate-temperature and low-temperature systems is by average of chalcedony and potassium-magnesium geothermometers. The difference between high-temperature systems and sub-high temperature systems is that (1) the depth of reservoir of the former is less than 3000m and of the latter more than 3000m, and (2) the former discharges sodium—chloride water and the latter issue sodium-bicarbonate water. Thus, the reservoir of sub-high temperature hydrothermal systems belong to sub-economic type, which can be reasonably assumed to exist, but which are not producible for electricity with existing flashing technology and under present economic conditions. The high-temperature hydrothermal systems are mainly located along the Yarlong Zangbo suture in the Tibet Autonomous Region, where there are 57 systems scattered on both banks of Yarlung Zangbo river. There are three in western Yunnan and only one in western Sichuan. There are 194 sub-high temperature hydrothermal systems, of which Tibet has 72, western Sichuan 37 and western Yunnan 85. The amount of intermediate temperature systems is 112, of which Tibet has 31, western Sichuan 9, and western Yunnan 72. The amount of low temperature hydrothermal systems reaches 661, including 135 in Tibet, 166 in western Sichuan and 360 in western Yunnan (Table 2) (Liao Zhijie et al.,1999).

Table 1: Thermal springs in YTGB

Province	Amount	Boiling spring	Hot spring	Warm spring	Tepid spring	Fossil spring	No temp. data
Tibet	709	44	145	57	90	20	353
w. Yunnan	694	19	269	176	202	11	17
w. Sichuan	342	8	101	68	121	15	29
Total	1745	71	515	301	413	46	399
Per Cent	100	4	30	17	24	3	23

Table 2: Type of hydrothermal systems and its rates

Province	High-temp.system	Sub-high tem. S.	Inter. Tem. Sys.	Low-tem.system
Tibet 295	57 19%	72 24.4%	31 10.5%	135 46%
w. Sichuan 213	1 0.5%	37 17.4%	9 4%	166 80%
w.Yunnan 520	3 0.6%	85 16.3%	72 13.8%	360 69%
Total 1028	61 6%	194 18.9%	112 10.9%	661

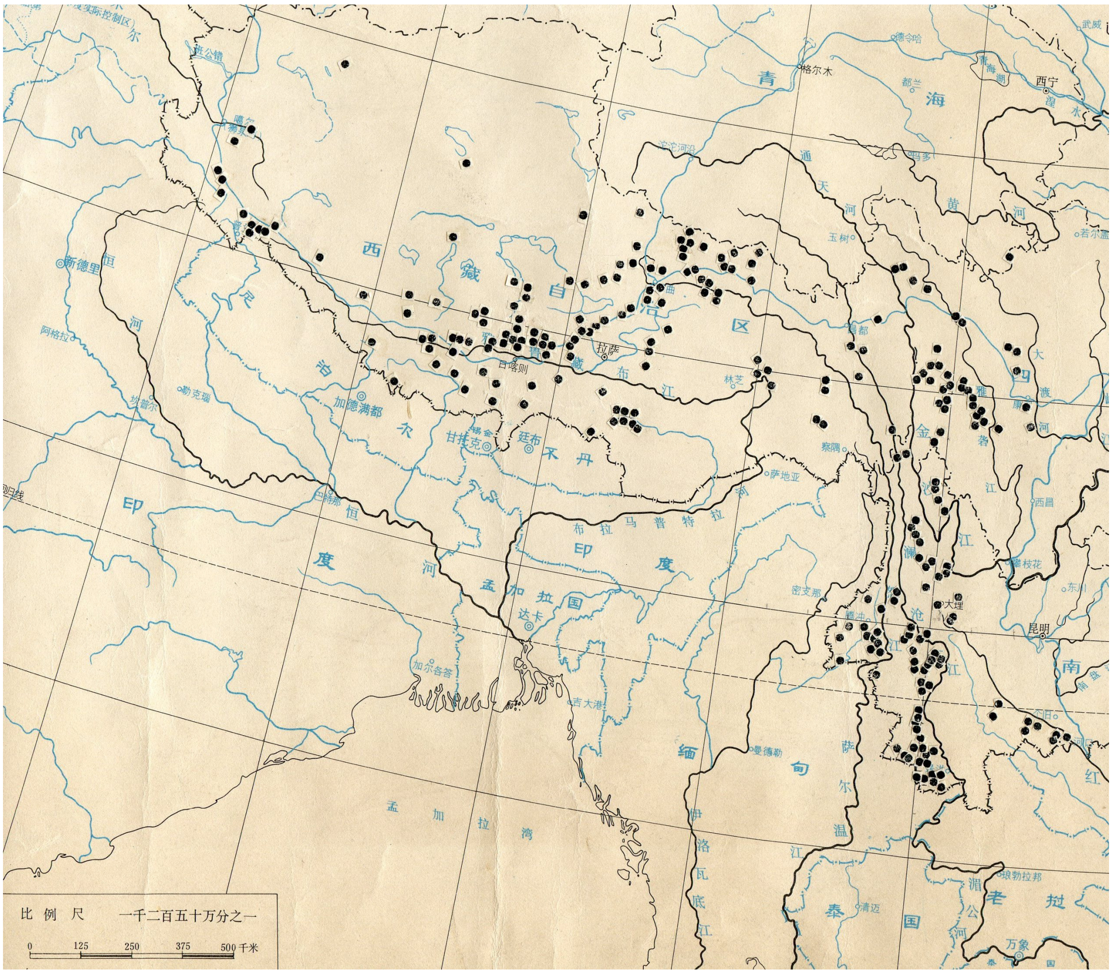

Fig.1: Distribution of High-Temperature Hydrothermal Systems in YTGB (Reservoir Temperature> 150℃).

3. IDENTIFIED HIGH-TEMPERATURE HYDRO-THERMAL SYSTEMS

The identification of high-temperature systems depends on reservoir temperatures that are more than 150℃ determined by average of silica, Na-K, Na-K-Ca and K-Mg geothermometers. There are 255 hydrothermal systems with reservoir temperature more than 150℃, which can be divided into two types by water chemistry: sodium-chloride and sodium-bicarbonate (Fig. 1). The sodium-chloride water is known as volcanic water by D E White (1875). A geothermal system discharging sodium-chloride-bicarbonate water could be related to shallow and young silica intrusions and generally has a shallow reservoir of less than 3 km, which can be produced under present economic conditions. The geothermal systems discharging sodium-bicarbonate water are the circulation systems in low porosity-fracture permeability environments in areas of high regional heat flow. High temperatures, from 150℃ to 200℃, can occur between 4 and 5 km depth, which cannot be economically mined at present. Thus, we would like to define systems discharging sodium-bicarbonate water as sub-high temperature hydrothermal systems.

The methodology used to estimate the thermal energy of hydrothermal convection systems in this paper is essentially similar to that used by Muffler (1978). The method of resources assessment involves the calculation of the thermal energy contained in a given volume of rock and water and then the estimation of how much of the energy might be recoverable. For high-temperature and sub-high temperature systems, the mean temperature of the reservoir is an average of silica, Na-K, Na-K-Ca and K-Mg geothermometers. The area of a geothermal field is taken to be at least 1.5 sq. km, the volume special heat of rock and water is taken as 2.7 J/g℃. A recovery factor of 25 per cent is used for all identified high-temperature and sub-high temperature systems. A quantity used frequently in thermodynamic calculations is available work, the maximum amount of work that can ideally be obtained from a given amount of thermal energy. In a real conversion cycle, the amount of electricity produced is always less than the available work and is related to available work by a utilization factor, which is a function of wellhead temperature and the particular conversion cycle chosen. In this paper, a utilization factor of 0.4 was used for all high-temperature systems. The result of assessment is listed in Table 3.

4. IDENTIFIED INTERMEDIATE- AND LOW-TEMPERATURE HYDROTHERMAL SYSTEMS

There are 112 identified intermediate-temperature and 661 identified low-temperature hydrothermal systems in YTGB. When we assess the thermal energy of intermediate-temperature systems, we should not overlook the thermal energy in the shallow reservoirs of 194 sub-high temperature hydrothermal systems, that could be correspond to that of an intermediate system. For intermediate- and low-temperature systems, the mean temperature of reservoir is an average of chalcedony and K-Mg geothermometers and the area of field is adopted as 1 sq. km. The volume special heat of rock and water is taken as 2.6 J/g℃. For these systems, this paper estimates beneficial heat as 24 per cent of the resource. Table 4 lists the result of assessment of geothermal resources of identified intermediate- and low-temperature hydrothermal systems in YTGB.

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Table 3: Geothermal resources of high- and sub-high temperature hydrothermal system

Type	Region	Amount	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Wellhead available work (EJ)	Electrical energy (MWe for 30 yr)
1, High	YTGB	61	120.27	30.06	6.582	2781.25
Temperature	Tibet	57	85.68	21.41	4.572	1930.11
Hydrother.	w. Sichuan	1	4.51	1.13	0.225	95.27
System	w. Yunnan	3	30.08	7.32	1.783	755.87
2, Sub-high	YTGBl	194	147.23	36.79	7.179	3036.4
Temperature	Tibet	72	53.91	13.49	2.623	1109.9
Hydrother.	w. Sichuan	37	29.65	7.38	1.471	622.23
System	w. Yunnan	85	63.67	15.92	3.085	1304.2
Total		255	267.50	66.85	13.762	5817.65

Table 4: Thermal energy of intermediate-and low-temperature hydrothermal systems

Type	Region	Amount	Reservoir thermal energy (EJ)	Wellhead thermal energy (EJ)	Beneficial heat (EJ)
1, Shallow	YTGB	194	85.43	14.543	5.155
Reservoir	Tibet	72	30.84	7.698	1.855
Of Sub-high	w. Sichuan	37	17.00	4.25	1.016
Temp. syst.	w.Yunnan	85	37.59	10.293	2.288
2, Intermed.	YTGB	112	38.76	9.536	2.297
Temperature	Tibet	31	11.93	2.84	0.681
systems	w. Sichuan	9	3.08	0.77	0.187
	w. Yunnan	72	23.75	5.926	1.429
Total (1+2)		306	124.19	24.079	7.452
3, Low-	YTGB	661	79.343	20.868	4.796
Temperature	Tibet	135	17.45	5.106	1.053
system	w. Sichuan	166	19.316	4.621	1.178
	w. Yunnan	360	42.577	19.84	2.565
Total(1 +2+3)		967	203.533	44.947	12.248