HEAT FLOW AND HOT SPRING DATA-BASE IN CHINA AND COMPILATION OF GEOTHERMAL MAP-SET BY COMPUTER

Xiong Liang-ping, Liu Jie, He Li-juan, Hu Shen-biao and Wang Ji-yang

(Institute of Geology, Academia Sinica, Beijing 100029, China)

ABSTRACT

Heat flow and hot spring database have recently been set up in China, following rhe first geothermal resources database established in 1991. In the former, altogether 681 heat flow data so far obtained were stored. And in fhe latter, 2509 hot springs with temperature > 25°C were contained. Using ARC/INFO method. the Distribution Map of Average Heat Flow Value (20'*20') and the Map of Natural Heat Discharge of Hot Springs in China have been compiled. This is the first portion of color geothermal map- set compiled by computer and using the database in our country.

KEY WORDS Heat Flow, Hot Spring, Data Base, Map-Set. ARC/ INFO. Computer

INTRODUCTION

Terrestrial hear flow, and hot spring data are of significant importance for geothennal exploration and exploitation, In China, the exploited andior to he exploiting geothermal fields are located in the relatively high hcat tlow area andlor hot spring zone with strong hydrothermal activity. For instance, Tianjin and Beijing geothermal fields occur in relatively high geothermal background area with the basement uplift. Geothermal field such as Dengwu (Tengwu) in Guangdong, Fuzhou and Zhangzhou in Fujian and Huitang, Rucheng in Hunan Provinces are all situated in hot spring area. In many cases, the exploration wells for thermal water are drilled along the faults andlor fracture zones at which hot spring emerges. Therefore, setting up the heat flow and hot spring database along with the compilation of geothermal map-set by computer and using the database is urgently needed for prospecting for thermal water and for potential assessment of geothermal resources. Recently, heat flow and hot spring database have been set up following the first geothermal resources database established in China several years ago (Xiong et al., 1991: Xiong & Lin, 1993). Furthermore, the first portion of the color geothermal map-set, namely the Distribution Map of Average Heat Flow Value (20'*20') and the Map of Natural Heat Discharge of Hot Springs in China were accomplished by using the database.

'TERRESTRIAL HEAT FLOW AND HOT SPRING DATABASE

1. Terrestrial Heat Flow Database

Altogether 681 heat flow' data have been stored in this database among which nearly 1/2 heat flow data were measured by the Lab for Geothermics, Institute of Geology, Academia Sinica and 366 data were submitted to International Heat Flow Commission in 1990 for inclusion in the Global Heat Flow Data Compilation (Pollack et al., 1991: Wang & Huang, 1990). Heat flow database composed of 12 item: 1) Heat tlow measurement borehole ; 2) Geographical site of the borehole; 3) Longitude; 4) Latitude; 5) Elevation of the hole-head: 6) Borehole depth 7) Temperature logging interval: 8) Geothermal gradient; 9) Thermal conductivity; 10) Number of rock samples: 11) Calculated hcat flaw value; 12) Heat flow data quality. Owing to the measurement condition and different perturbation factors affecting the heat flow value, the data quality seems to he quite different. In this study, all the heat flow data were grouped into 4 quality categories 4, B, C, D as suggested in our previous study (Xiong et al., 1994: Wang & Huang, 1990). Data with highest quality were grouped into category A whereas data with high quality, category B. The data quality in C, D groups are rather low hut we still use these data for compilation to expand the data coverage area and to understand some particular phenomena such as ground water activity etc. (Wang & Xiong, 1991; Wang & Huang, 1990). In this study, A groupdataaccount for 47% of the wholedata-set: B, 29%:. C, 21% and D, 3%. The summary of heat flow data has been demonstrated in Table 1 and the histogram of all heat flow data (I) and quality grouped data (2) is given in Fig. 1

2. Hot Spring Database

Hot springs are widespread all over the country and China has a long history of utilizing liot spnng wafer for various purposes. Although investigations of hot spring in China have been staned in 1950's, intensive study on hot springs had only been initiated since early 1970's with the hope to solve energy-shortage problems in remonte areas of SW China especially in Tibet and Tengchong volcanic area of Yunnan Province (Chen et al., 1994: 1993 Tong et al., 1989; 1981) In addition, quite a few hot spring area nowadays became tourist area andlor areas for recreation. Therefore, hat springs are regarded as some sort of valuable resources for tourism. However, systematic analysis and compilation of hot spring data have not been coducted yet oationwide so far. For this reason, setting up the hot spring database are of great demand. The database contains 2509 hot spring data with temperature > 2 5 T and comprises 9 items including 1) Hot spring name: 2) Geographical site: 3) Longitute; 4) Latitude: 5) Temperature: hi Flow rate; 7) Water chemistry; 8) Geological settings and 9) Average ground temperature at 0.8 m depth of hor spring site The statistics of hot spring data in China were

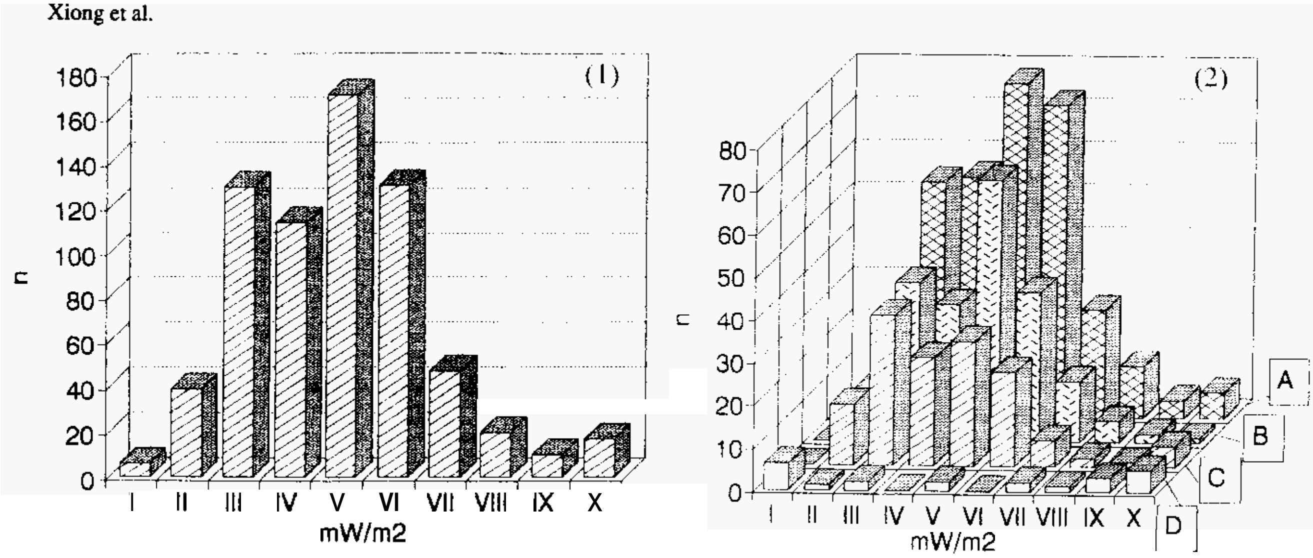

Fig. 1 Histogram of all heat flow data (1) and quality grouped data (2)

Table 1. Summary of heat **flow deta** in continental **area** of China

Province	I	II	III	IV	V	VI	VII	VIII	IX	X	A	B	C	D	Total
Anhui	0	0	3	4	I	5	I	0	0	1	6	2 6	1	1	5
Beijing	0	2	1	3	0	1	0	0	0	0	5	2	0	0	7
Fujian	0	0	5	3	3	11	2	I	2	3	11	10	4	5	30
Gansu	0	3	5	7	I2	6	6	0	0	0	21	12	5	1	39
Guangdong	0	0	0	0	11	1 0	3	3	0	0	6	14	5	2	21
Guangxi	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1
Hainan	0	0	0	0	1	1	0	0	0	0	I	0	1	0	2
Hem	0	11	25	13	9	9	2	I	0	I	31	25	14	1	71
Hebei	3	3	5	4	5	6	2	2	I	0	21	5	2	3	31
Heilongjiang	0	2	5	2	2	I	3	1	0	0	13	0	2	I	16
Hubei	0	I	10	3	0	0	0	0	0	0	I	X	5	0	14
Hunan	0	1	8	4	2	0	0	0	0	0	5	5	5	0	15
Jiangsu	0	0	0	5	8	10	5	0	0	0	I	I?	14	0	28
Jiangxi	0	0	0	3	8	9	I	1	0	0	12	10	0	0	22
Liaoning	I	I	18	13	27	16	5	2	2	0	71	Y	3	2	85
Inner-Mongolia	0	2	0	9	8	1	0	0	0	0	0	0	20	0	20
Ningxia	0	0	0	0	I	0	0	0	0	0	0	I	0	0	1
Qinghai	0	5	9	4	7	2	I	0	0	I	12	13	2	2	2Y
Shandong	0	0	4	3	7	4	2	0	0	0	11	7	2	0	20
Shanxi(Taiyuan)	0	0	2	11	6	4	0	0	0	I	10	2	I	0	13
Shanxi(Xian)	0	1	0	2	9	4	2	I	0	0	6	11	I	I	19
Sichuan	I	5	23	27	13	6	1	1	0	0	37	21	17	2	71
Tibet	0	0	0	0	2	0	3	2	2	9	11	4	3	0	18
Xinjiang	1	I	5	0	I	0	0	0	0	0	I	2	4	I	8
Yunnan	0	I	I	2	12	9	7	5		I	21	10	9	0	40
Zhejiang	0	0	0	0	13	15	I	0	0	0	6	10	13	0	2Y
Tianjin	0	0	0	I	2	0	0	0	I	0	I	2	I	0	4
total	6	39	129	113	170	130	47	20	1 0	17	321	199	139	22	681

I.q<30; II.30≤q<40; **III.40≤q<50**; IV.50≤q<60; V.60≤q<70; VI.70≤q<80; **VII.80≤q<90**; VIII.90≤q<100; **IX.100≤q<1In: X.q≥110.**

summerized in Table 2 and expressed in Fig. 2. It can be seen from Table 2 and Fig 2 that hot springs with temperature 40-60°C are widespread over most provinces and cities in China except for Shanghai and Tianjin cities where no hot springs were found so far and for Helongjiang and Ningxia Provinces where only exsist hot springs with temperature <25°C. Hot springs with temperature >85°C are rare and only amount to 5% of the total. Another feature of hot spring distribution in China is that **nearly** 70% of hot springs are concentrated in Fujian, Guangdong, Yunnan, Sichuan Provinces and Tibet. Furthermore, the high-temperature geothermal manifestations such as geysers, fumaroles. boiling **springs** and hydrothermal explosions occured in Tibet, W. Yunnan and W. Sichuan Provinces. With the rapid development of economy and the improvement of living standards, it is doubtless that these fantastic manifestations **will**

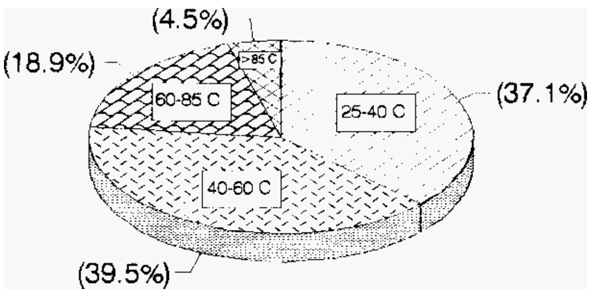

Fig. 2 Statistics of hot springs with different temperature range

attract more and more turists and also will become areas for geothermal development.

DISTRIBUTION MAP OF AVERAGE HEAT FLOW VALUE (20'*20') AND THE MAP OF NATURAL HEAT DISCHARGE OF HOT SPRINGS

Based on the heat flow and hot spring database and using the ARC/INFO method, the Distribution Map of Average Heat Flow Value (20'*20') and the Map of Natural Heat Discharge **of** Hot Springs were compiled recently (Figs. 3, 4). For heat flow map, the **grids** with different color represent the average value of quality-wreighted heat flow data For hut spring map. the grids exhibit the natural heat discharge of hot springs in each grid. Heat discharge is calculated as follows

$$Q=C_w \rho_w V(Ts-To) \qquad \text{---(1)}$$

Where. Q, Heat discharge of hot springs (J/s);

C_w, Specific heat of hot spring water (kJ/kg°C);

ρ_w, Density of hot spring water (kg/m3)

V. Flow rate of hot spring (m3/s);

Ts, Temperature of hot spring (°C) and

T_o, Ground temperature at 0.8m depth of hot spring site (°C).

From these two maps it is obviuos that:

1. Heat flow measurement sites are unevenly distributed. Most data are concentrated in the eastern pan especially in North China and SE coast. In W. China, heat tlow data are quite few. However, the data coverage in W. China is improved a lot in recent years with carrying out heat flow measurements in oil-gas fields in the West and other relavant projects:

2. Statistics indicates that hear flow value varies in a wide range (20-320 mW/m²) but most values are concentrated in the range of 40-100 mW/m². The average heat tlow value for the whole continental area ranges between 63- 69 mW/m² using different statistic methods (Wang & Huang, 1990; Huang & Wang. 1992), which is in good accordance with the global continental mean of 65+1.6 mW/m² reponed recently (Pollack et al., 1993). It means that the overal geothermal hackground of continental area of China appears to he "normal" compared to that of global continents:

3. The heat flow pattern is characterized by "High in the East & South" and "Lou in the West & North". The heat flow values from the East appear to he relatively high (60-70 mW/m2) whereas the values from the West, generally <50 mW/m2. High heat flow in continental area of China occurs in S. Tibet and Himalayan Geothermal Belt. For instance, heal flow from Yanghajing Geothermal Field is 108 mW/m2 (Shen et al., 1992) and the average heat flow in Tengchong volcanic area exhibits 85 mW/m2 (Wang et al., 1990). This kind of heat flow pattern in continental area of China may be considered to be the consequence of the strong influence of Pacific Plate from the East and the pushing process of Indian Plate from the South since Meso-Cenozoic era (Wang & Huang, 1995);

4. The total heat discharge of hot springs in China amonts to 2665×10^6 J/s. The heat discharge to the South of Yangrhi River is much more larger than that to the North of the River. The largest average heat discharge occurs in Tibet. W. Yunnan and W. Sichuan Provinces whereas the smallest one, in NE China. The heal discharge in Tibet and Yunnan Province amounts to nearly 50% of the total whereas that in vast NE China and Inner-Mongolia, only about 1% of the total (Table 2, Fig. 4);

5. It must he noted that the high heat discharge zone of Tibet, W. Yunnan and W. Sichuan Provinces coincide with the Himalayan Geothermal Belt which is the eastern extension of Mediterranean Geothermal Belt. In Tibet, thr high heat discharge area is located in S. Tibet along Yaluzangbu (Yarlung Tsangpo) sutue zone;

6. Although the total heat discharge in Taiwan ranks on the 7th (Table 2), the heat discharge per area appears to be the highest because of its Small area. It is well-known that Taiwan belongs to the

Table **2. Summary** of hot springs in China

Province	Number	Temperature(°C) ≥25~<40	≥40~<60	≥60~<85	≥85	Heat Discharge (10^3 J/s)
Yunnan	823	341	323	129	30	682507.00
Xizang (Tibet)	271	51	97	88	35	622928.90
Sichuan	240	89	118	27	6	335281.50
Guangdong	285	81	125	68	11	150645.72
Fujian	177	41	81	51	4	101609.01
Hunan	108	74	31	2	1	98700.26
Taiwan	78	7	27	31	13	93500.47
Shanxi(Xi'an)	14	8	6	0	0	80694.53
Hubei	52	30	15	7	0	68080.75
Qinghai	39	20	10	6	3	64725.62
Gansu	14	8	6	0	0	61851.92
Jiangxi	79	34	32	13	0	51159.79
Guizhou	58	40	18	0	0	37838.52
Jiangsu	7	3	3	1	0	33669.80
Xinjiang	56	23	23	6	4	28330.03
Henan	23	11	7	5	0	24817.53
Guangxi	36	19	12	5	0	21131.21
Anhui	17	8	7	2	0	20465.94
Hainan	34	7	14	12	1	18469.45
Jilin	5	2	1	2	0	17973.05
Hebei	27	6	12	8	1	17285.14
Liaoning	27	11	11	5	0	13596.11
Shandong	17	2	8	5	2	10751.39
Shanxi (Taiyuan)	5	3	1	1	0	3926.66
Inner-Mongolia	3	0	2	0	1	3746.00
Zhejiang	14	13	0	1	0	1180.10
Total	2509	932	990	475	112	2664866.40

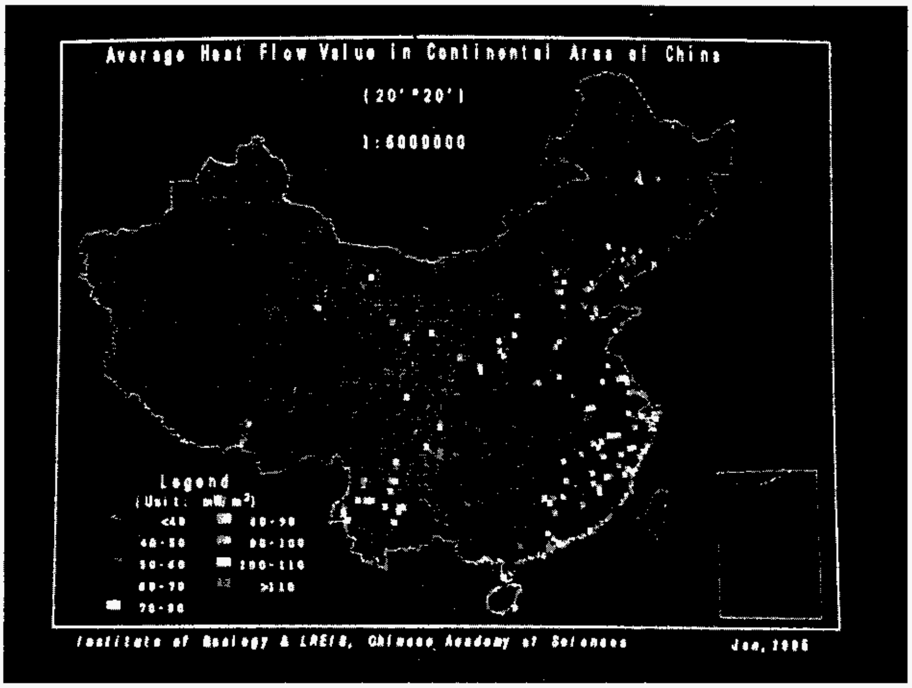

Fig. 3 Average heat flow value (20'×20') in continental area of China

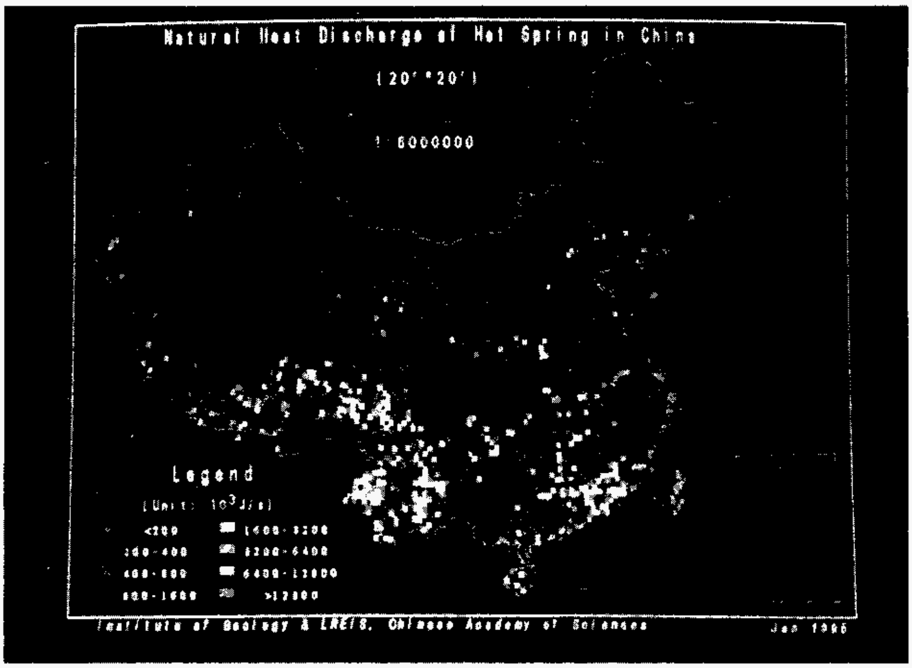

Fig. 4 Natural heat discharge of hot springs in China

"Corcum-Pacific Geothermal Belt" or "Circum Pacific Fire Ring". Therefore, many high-temperature geothermal manifestations in Taiwan are related to the volcanic activity of late-Cenozoic age (Chen, 1989) and the density of hot springs appears to be the highest in China;

7. Generally, there exists coincidence between heat flow and heat discharge of hot springs. For instance, heat flow in S.Tibet and Taiwan turns out to be very high and large heat discharge of hot springs has been observed there too (Figs. 3, 4). However, in Hunan and Shanxi (Taiyuan) Provinces, although the heat discharge appears to be very large, the heat flow is quite low. This is due mainly to the large flow rate of hot springs with relatively low temperature. For instance, the flow rate of some low-temperature hot springs in karst area may reach up to 1000 l/s.

ACKNOWLEGEMENTS

The authors are grateful to Dr. Gudmundur Palmason for encouragingsubmission of this paper. Our colleagues are highly thanked for useful discussion and providing necessary data.

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