EXPLORATION FOR LOW TEMPERATURE GEOTHERMAL RESOURCES: A CASE HISTORY OF HAINAN ISLAND, CHINA

PANG ZHONG-HE, WANG Ji-YANG and ZHAO-PING

Laboratory for Geothermics, institute of Geology, Academia Sinica, China

SUMMARY - An exploration study of the geothermal resources in Hainan Island of China was carried out and results were interpreted for the potential of its development. The main types of geothermal resources are identified and the basic features of the hot spring types are discussed in detail. Improved geothermometry was applied and results indicate that the Island is rich in low temperature geothermal resources and should be suitable for direct utilization schemes.

1. INTRODUCTION

Hainan Island is located in the southern part of China and is the second largest island in the country (Figure 1). The island covers an area of *greater* than 33,000 km^2 and is the major part of Hainan Province or the Hainan Special Economic Zone (HSEZ). With the establishment of the HSEZ and the development of the local economy, energy shortage is becoming more and more severe and there is an urgent need to look for alternative energy sources.

Having made a trip to Hainan, sampled and gathered the available data, we studied the geological background, the distribution of geothermal manifestations and the basic characteristics of the quantity and quality of the natural geothermal discharges. The reservoir temperatures of the hot springs have been estimated by geochemical geothermometry.

2. GEOLOGY

The general geological background and the location of the main geothermal manifestations are schematically shown in Figure 1. Tectonically, Hainan Island is a part of the South China Fault-Fold System. The basement is of Paleozoic rocks consisting of intensively folded metamorphic rocks and migmatite. The prototype of the present-day tectonic framework was formed in the late Paleozoic period. Continental rifting activity possibly took place in the island during the Carboniferous period. The forms of tectonic movements in the Mesozoic era were mainly folding and faulting along the NE direction. Large amounts of intermediate to silicic magma erupted and many mechanically tensile "red basins" also formed during these periods. In the Cenozoic era, a large quantity of tholeite erupted on the northern coast of the island and many older faults reactivated.

There are two major fault systems in the island, i.e. the NE and E-W fault systems. The former can be derived according to the distribution of the sedimentary basins and the igneous rocks and the later is more obvious (see Figure 1). The tectonic framework was dominated by the two fault systems but the tectonic history of the area can be interpreted as the history of their activity. F_1 and F_2 are the north and south boundary faults respectively. To the south of F_2, there exists an old stable terrain different from that to the north. F_1 controls the occurrence of basaltic rocks and young basins in Cenozoic periods in the northern border areas of the Island.

3. TYPES OF GEOTHERMAL RESOURCES

Based on the data available and the geological background, the geothermal resources in the island can be divided into three types:

(1) Fissure water of deep circulation (convective) type, which occurs to the south of F_1;
(2) Sedimentary basin (conductive) type, which is *seated* beneath the thick sediments in the areas to the north of F_1;
(3) Geopressured geothermal resources, which have been found during oil-gas exploration in the Yinggehai Sea Basin, about 30 km southwest of the island.

This paper will focus only on the analyses and a preliminary interpretation of the first type.

4. HYDROGEOCHEMISTRY

Hot springs are found in many places on the island According to incomplete statistics, there are more than 50 hot springs (Table 1). Estimates of the natural flow-rate and chemical analyses of the thermal waters were made for 32 hot springs. There are two hot springs with temperatures higher than 80°C and the maximum discharge temperature is 84 °C. 19 of the hot springs are hotter than 50°C.

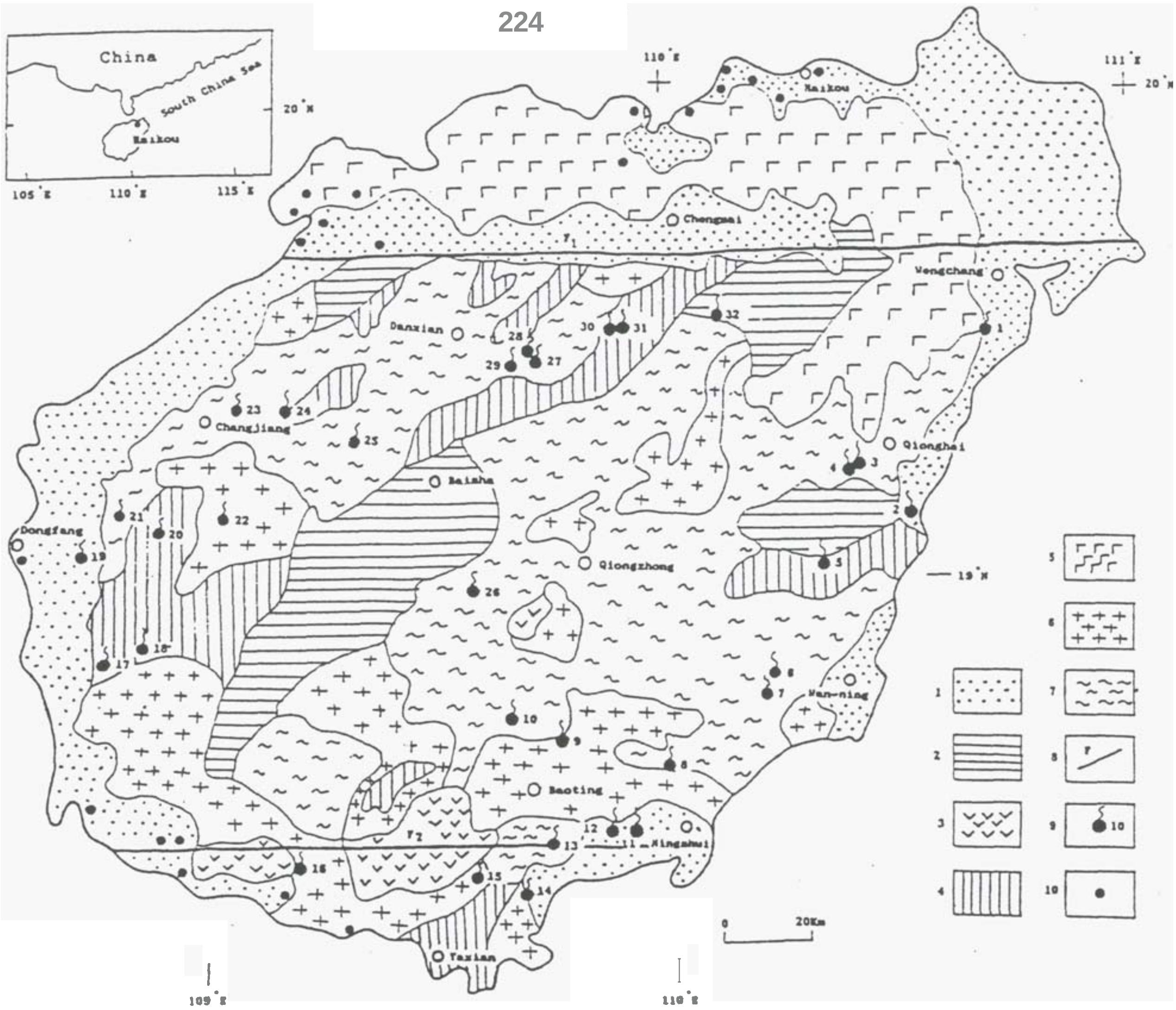

Figure 1. Map of **Hainan** Island showing the locations of the **major** geothermal manifestations and their geological settings. 1. Cenozoic sediments; **2.** Cretaceous **red** beds; 3. Jurassic volcanic rocks; **4.** Paleozoic metamorphic formations; **5.** Cenozoic basalt; **6.** Mesozoic granite and granodiorite; **7.** Paleozoic compound granite and migmatite; 8. Fault; 9. Hot spring and number; 10. Drillhole.

There **are** 18 hot springs with flow-rate higher **than 1 l/s; 2** have flow rates greater **than 5 l/s** and the maximum flow-rate is 14 **l/s.** Chemical types of the waters **are** $HCO_3(SO_4)$-Na(Ca) for **19** hot springs **and** Cl-Na(Ca) type for 9 springs. **Total** dissolved **solids are** less **than** 1 g/l for **23** hot springs, but *greater* **than** 1 **g/l** for **5** with a maximum of **7.5 g/l.** The Cl-Na type of hot springs with high salinity **are** commonly found along the *coastal* **areas** and their origin is believed to be influenced by the **sea** water. The pH of most of the thermal waters is from **7** to 9.

All these hot springs **are** found to the south of the major fault F_1. No hot springs have **been** recorded in the **area** to the north of the fault. The reservoir rocks of the hot springs **are** mostly granites **and** migmatite. The **occurrence** of the springs is controlled by **the NE** and **E-W** faults **and** most hot springs fall on the intersections of the two fault systems.

Isotope ($\delta D, \delta^{18}O$) composition (Figure 2) of the thermal water shows that it is meteoric. The water-rock exchange of isotopes is **not** intensive, which implies that the reservoir temperature **are not** very high **(Pang** & Wang, 1990).

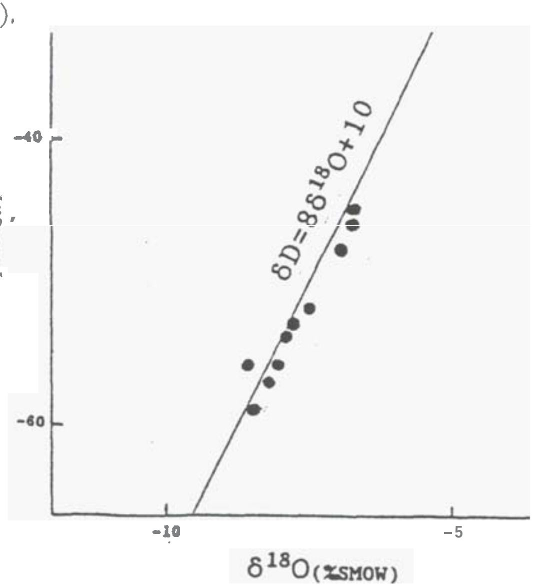

Figure **2.** 6D versus $\delta^{18}O$ plot for hot water and other **natural** waters in Hainan **Island**

5. GEOTHERMOMETRY

The reservoir temperatures of these hot springs are estimated by using a calibrated SiO_2 geothermometer (Pang, 1991). Results show that the most common reservoir temperature is 100-120°C and the maximum is about 140°C provided that there is no influence by mixing of thermal water with shallow ground waters (see Pang et al., 1990 for discussions on this). If the mixing effect is taken into consideration, the reservoir temperature could be slightly higher than this value.

6. DISCUSSION AND CONCLUSIONS

Isotope and geochemical methods have been very useful in the evaluation of the genesis and the energy potential of the geothermal resources in the area. The calibrated chemical geothermometry yields reasonable reservoir temperatures.

Based on the interpretation and analyses of all the data available, Hainan Island is found to be rich in low temperature geothermal resources. The thermal waters are mainly of meteoric origin but some are mixtures with sea water. The water is heated through the deep circulation of the meteoric water. The reservoir temperature is around 100-120°C with 140°C possibly the highest. Therefore, the thermal water is suitable for direct utilizations but is not economic far power generation.

This energy source is especially valuable for this island Province, suffering from a shortage of energy, and is suitable for direct uses. However, geothermal research and development on this island is still at a very low level. Data are so limited that no further evaluation could be made on its geothermal prospects.

For possible future geothermal studies in the area, the geopressured geothermal resources offshore is likely to become a promising energy s o m e and an investigation of this is strongly recommended.

7. ACKNOWLEDGEMENTS

The International Atomic Energy Agency (Contract 4850/R2/RB) and the National Natural Science Foundation of China (Project 49000034) and the Hawaii Natural Energy Institute are thanked for financial support for this study. The paper was kindly reviewed by Patrick Browne, Errol Anderson.. The authors are also grateful to Senior Engineer Feng Xunming for assistance in sampling for isotopes, and to Errol Anderson and Graeme Scott for help with the preparation of our paper.

8. REFERENCES

Pang, Z. and Wang, J., 1990, Oxygen and hydrogen isotope study on Zhangzhou Basin hydrothermal system, southeast of China, *GRC TRANSACTIONS,* Vol. 14, Part II, 945-951.

Pang Z., 1991, Calibration of chemical geothermometers based on fluid-mineral equilibrium calculations with application to the hot spring areas in the south of Fujian Province, China, *GRC TRANSACTIONS* (in press).

Pang, Z., Fan, Z. and Wang, J., 1990, Calculation of the reservoir temperature of Zhangzhou Geothermal Field using a SiO_2 mixing model, Chinese Science Bulletin (in English), 35(16), 1360-1363.

Table 1. Characterization of hot springs in Hainan Island, China

Location	Code	Geology	Q(l/s)	T_s(°C)	Chem.type	TDS(g/l)	T_c(°C)
Baisha	23	Granite	0.74	38	HCO_3-Na	0.3	93
Baisha	25	Schist	0.46	40	HCO_3-NaCa	0.3	81
Baoting	10	Quartzit	4.65	84	HCO_3-Na	0.3	122
Changjiang	22	Granite	1.82	47	HCO_3SO_4-Na	0.3	97
Chengmai	30	Granite	4.46	57	HCO_3-Na	0.3	101
Danxian	28	Granite	3.92	83	HCO_3-Na	0.3	107
Danxian	29	Granite	0.4	59	HCO_3-Na	0.3	81
Dongfang	17	Migmatite	0.3	38	HCO_3-Na	0.3	97
Dongfang	18	Shale	0.78	49	HCO_3-Na	0.3	101
Dongfang	19	Granite	7.73	78	Cl-Na	0.4	127
Dongfang	20	Migmatite	1.5	52	HCO_3-Na	0.5	110
Dongfang	21	Granite	2.0	51	HCO_3-Na	0.4	122
Ningshui	11	Granite	2.0	68	Cl-NaCa	1.3	110
Ningshui	12	Granite	4.65	72	Cl-Na	0.7	122
Qionghai	2	Schist	0.75	75	Cl-NaCa	7.5	119
Wanning	6	Granite	2.40	63	HCO_3-Na	0.4	116
Wenchang	1	Granite	3.69	74	Cl-Na	2.9	137
Yaxian	13	Granodio.	0.24	47	Cl-Na	1.0	107
Yaxian	15	Granite	4.65	78	HCO_3SO_4-Na	0.4	114
Yaxian	16	Granite	0.3	45	HCO_3SO_4-Na	0.04	90