PROCEEDINGS, Thirty-First Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 30-February 1, 2006
SGP-TR-179

FLUID-MINERAL EQUILIBRIA AND SUBSURFACE TEMPERATURE EVALUATION OF SELECTED HOT SPRINGS, JIANGXI PROVINCE, SE-CHINA

Zhanxue Sun, Zhanshi Zhang, Jinhui Liu and Bai Gao

East China Institute of Technology
56 Xuefu Road
Fuzhou, Jiangxi Province, 344000, China
e-mail: zhxsun@ecit.edu.cn

ABSTRACT

The fluid-mineral equilibrium and subsurface temperature of two selected hot spring areas in Jiangxi Province, SE-China, are analyzed on the basis of their hydrochemistry. The two geothermal fields include the Maanping Area and the Linchuan Area situated in the central part of the Province. Thermal waters of the Maanping Hot Spring Area are of the Na+K-HCO3 type, and those of the Linchuan Hot Spring Area are of Ca-HCO3 type. Solution-mineral equilibrium studies suggest that all the geothermal fluids from the two hot spring areas are departure from overall equilibrium but some minerals such as quartz, chalcedony, and calcite seem to approach equilibrium with the solution. Cation geothermometers are not applicable in such cases, while the chalcedony geothermometer is suggested as the most likely useful tool to estimate subsurface temperatures of such systems. The chalcedony geothermometer gives subsurface temperature between 70-80°C for the Maanping Area and 80-100°C for the Linchuan Area respectively. All the geothermal resources in the two areas are suitable for non-electric direct use.

GENERAL BACKGROUND

Jiangxi Province, SE-China, is one of the Provinces in which hot springs are most widely distributed in China. In this Province, 96 hot springs with temperatures ranging from 25 °C to 88 °C have been found. A systematic compilation of hot springs in the region was done by Li (1979), later by Sun (1988).

Two hot spring areas in the Province close to Fuzhou City in which the East China Institute of Technology is located, the Maanping Hot Spring Area and the Linchuan Hot Spring area, have been selected for this study. The locations are shown in Figure 1. In the Linchuan Hot Spring Area, one hot spring sanatarium has been in operation for more than 20 years, and it is famous all over the Province for its slightly radioactive bicarbonate water which is used as a treatment for rheumatism, arthritis, neurosis and various skin diseases such as psoriasis and scabies.

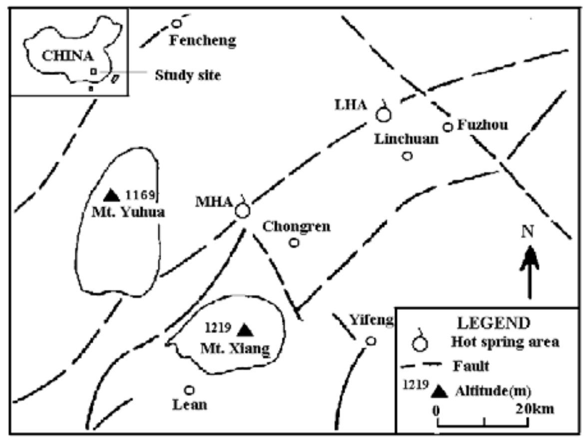

Figure 1. Locations of the Maanping Hotspring Area (MHA) and the Linchuan Hotspring Area (LHA).

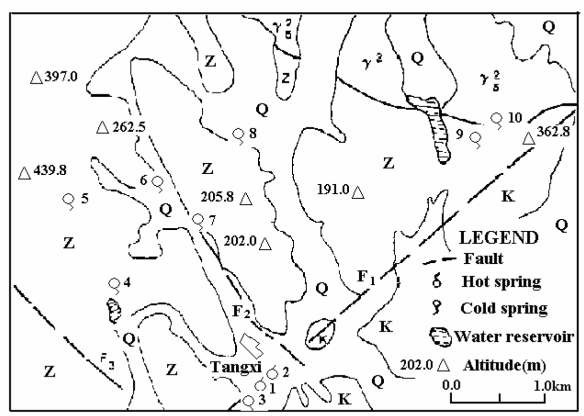

Figure 2. Geological map and sampling locations of the Maanping Hotspring Area (MHA).

Geologically, the two areas are quite similar to each other (Figures 2 and 3). Strata exposed in the two areas include the Sinian system (Z) composed of schists, the Cretaceous system (K) characterised by sandstone and conglomerate, and the Yanshanian

Table 1. Chemical and isotopic composition of spring water from Jiangxi Province, SE-China (conc. in ppm)

No.	T (°C)	pH/°C	SiO_2	T_{Fe}	Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_2	SO_4^{2-}	H_2S	Cl^-	F^-
1	42	6.13/42	60	0.56	218.3	24.2	109	4.88	1553.5	30	1.13	9.23	4.04
2	41	6.19/41	50	1.14	208.3	36.8	96.4	9.9	1453.5	30	1.36	8.88	3.13
3	20	5.97/20	25	nd	2	2.5	1.5	0.61	7.91	1.4	nd	0.25	nd
4	18	5.8/18	16	nd	0.2	0.3	4	2.1	16.95	0.15	nd	0.2	nd
5	18	5.9/18	10	nd	1.7	2.9	1.2	0.2	11.04	0.05	nd	0.5	nd
6	19	6.4/19	14	nd	0.4	0.6	8	4	33.04	0.1	nd	0.5	nd
7	22	6.1/22	14	nd	0.1	0.2	10.8	4.9	41.33	0.05	nd	0.6	nd
8	20	6.8/20	16	nd	2	4.3	3	0.4	18.03	0.5	nd	0.4	nd
9	19	5.6/19	12	nd	1.3	2.4	1.6	1.8	14.28	1.5	nd	0.6	nd
10	20	6.5/20	20	nd	2	3.1	2.3	1.8	19.9	1	nd	0.6	nd
L1	41	7.55/41	70	nd	4.3	3.4	33	3.12	97.9	17.04	nd	2.19	4
L2	39	7.4 /39	60	nd	2.9	3.9	48.1	4.87	87.3	33.62	nd	6.68	3.5
L3	59	8.27/59	80	nd	13.5	15.5	61.1	2.19	93.1	72	nd	2.49	6
L4	19	6.99/19	30	nd	1	1.9	1.6	0.62	6.69	2.98	nd	1.63	nd
L5	18	5.89/18	18	nd	2.2	2.5	1	0.25	8.88	1.25	nd	1.63	nd

Note: nd-not determined.

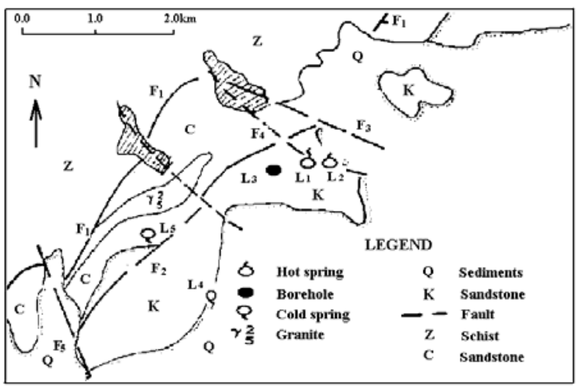

Figure 3. Geological map and sampling locations of the Linchuan Hotspring Area (LHA).

granite (γ_5^2) as well as Quaternary sediments (Q). In addition, carboniferous sandstone (C) is widely distributed in the Linchuan Hot Spring Area.

The hydrochemical compositions of natural waters in the two areas are presented in Table 1, and sampling locations are shown in Figures 2 and 3.

WATER CHEMISTRY

All the data are plotted in the triangular diagram (Figure 4) as relative concentrations. The waters in the two areas can be classified into three types: 1) Mg-HCO3 type: includes one cold water sample numbered 9; 2) Ca-HCO_3 type: includes cold water samples numbered 4, 6 and 7 and hot water samples numbered L1, L2, L3; 3) Na+K-HCO_3 type: the rest of the samples. Clearly, the difference in the chemical composition of hot springs in the two areas is quite significant.

All the data points are plotted in Giggenbach's (1988) Na-K-Mg triangular diagram (Figure 5). It

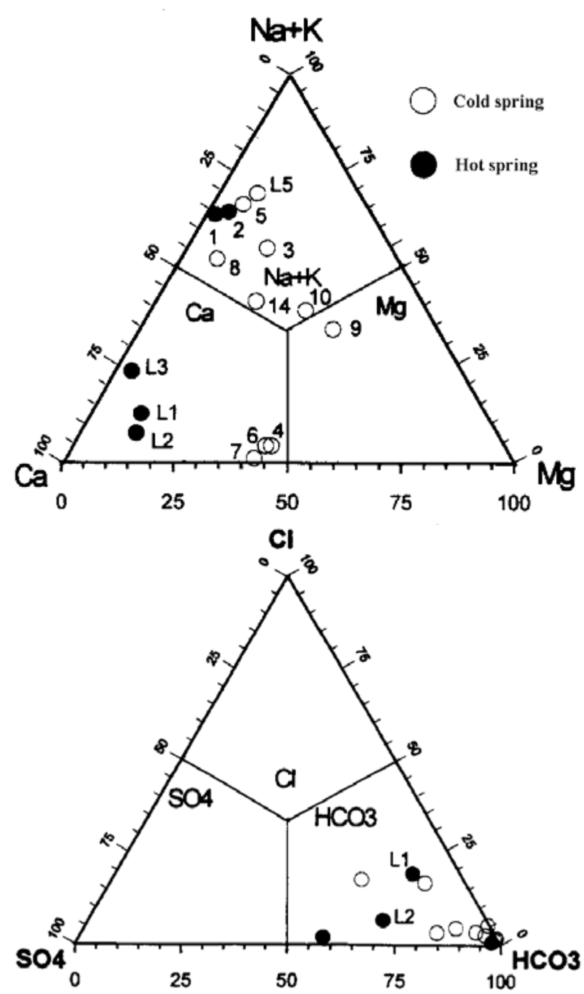

Figure 4. Triangular diagrams of relative component concentrations, in equivalents, for the Maanping and Linchuan waters.

shows that all the waters in the two areas are immature ones for which the application of cation geothermometers is not suitable.

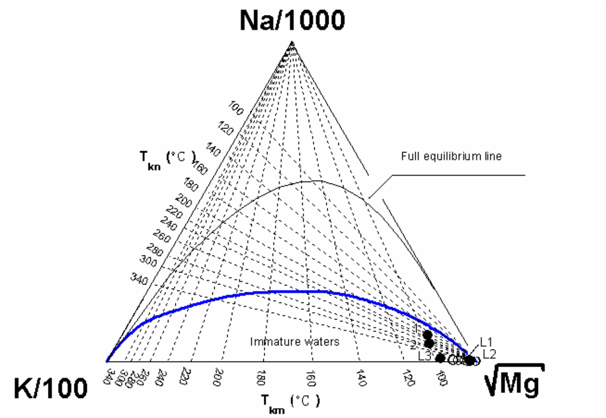

Figure 5. Na-K-Mg triangular diagram for the Maanping and the Linchuan waters.

SUBSURFACE TEMPERATURE ESTIMATION

Solute Geothermometry Result

As discussed above, all the thermal waters in the two areas are immature waters, so cation geothermometers such as Na-K and Na-K-Ca geothermometers are not applicable for these hot waters. The only option is to use silica geothermometers. The results are given in Table 2.

Clearly, the estimated subsurface temperatures range from 72 °C to 124 °C for the two hot spring areas. Results of drilling show that the temperatures of thermal waters from wells above 1000 m deep are not higher than 100 °C in the Province (Lin, 2004). So the chalcedony geothermometer temperatures, which are about 70-100°C, are probably closer to the reservoir temperature than the quartz ones.

Log (Q/K) Diagrams

The log (Q/K) values at varying temperatures are calculated using SOLVEQ (Reed and Spycher, 1984; Spycher and Reed, 1989). The log (Q/K) vs. temperature diagrams for the Mananping and Linchuan thermal waters are shown in Figure 6.

In Figure 6, the equilibrium temperatures for selected minerals range from approximately 40°C to 100°C for the Maanping thermal waters, and from 38°C to 120°C for the Linchuan thermal waters. For the Maanping hot springs, it can be seen that chalcedony, calcite, aragonite and dolomite cross the zero line of log(Q/K) within the range 60-80°C, which indicates that these minerals are close to equilibrium with the solution in the system. For the Linchuan hot springs, calcite, aragonite and dolomite seem to be in equilibrium with the solution at the discharge from a borehole, sample no.L3, shows that carbonate minerals are supersaturated and this suggests a degassing effect. No cluster can be found for any of the diagrams in Figure 6 probably due to mixing, and/or degassing, as well as incomplete chemical analyses that do not include Al and Fe concentrations and thus only relatively few minerals can be studied.

SUMMARIES

Thermal waters of the Linchuan hot spring area are of the Ca-HCO3 type, and those of the Maanping hot spring area are of the Na+K-HCO3 type. For the Maanping low-temperature system, the chalcedony geothermometer gives realistic subsurface temperatures of about 70-80°C which compare well with the equilibrium temperature of 60-80 °C for carbonate minerals from log (Q/K) diagrams. For the Linchuan hot spring area, the chalcedony geothermometer yields subsurface temperature of about 80-100 °C. In such a case, the log(Q/K) method can be used to identify equilibrium state of minerals with the solution although it is difficult to determine the subsurface temperatures by the method because of possible mixing, and/or degassing, as well as absence of Al and Fe analyses.

Table 2. Silica geothermometry results of the Maanping and Linchuan thermal waters

Sample No.	Measured temperature (°C)	Quartz temperature (Tqz) (°C)	Chalcedony temperature (Tch-1) (°C)	Chalcedony temperature Tch-2 (°C)
1	42	111	81	82
2	41	102	72	73
L1	41	118	90	90
L2	39	111	81	82
L3	59	124	97	97

Note: T_{qz}, $T_{ch\text{-}1}$ and $T_{ch\text{-}2}$ equations are from Fournier and Potter (1982), Fournier (1977) and Arnorsson, et al. (1983) respectively.

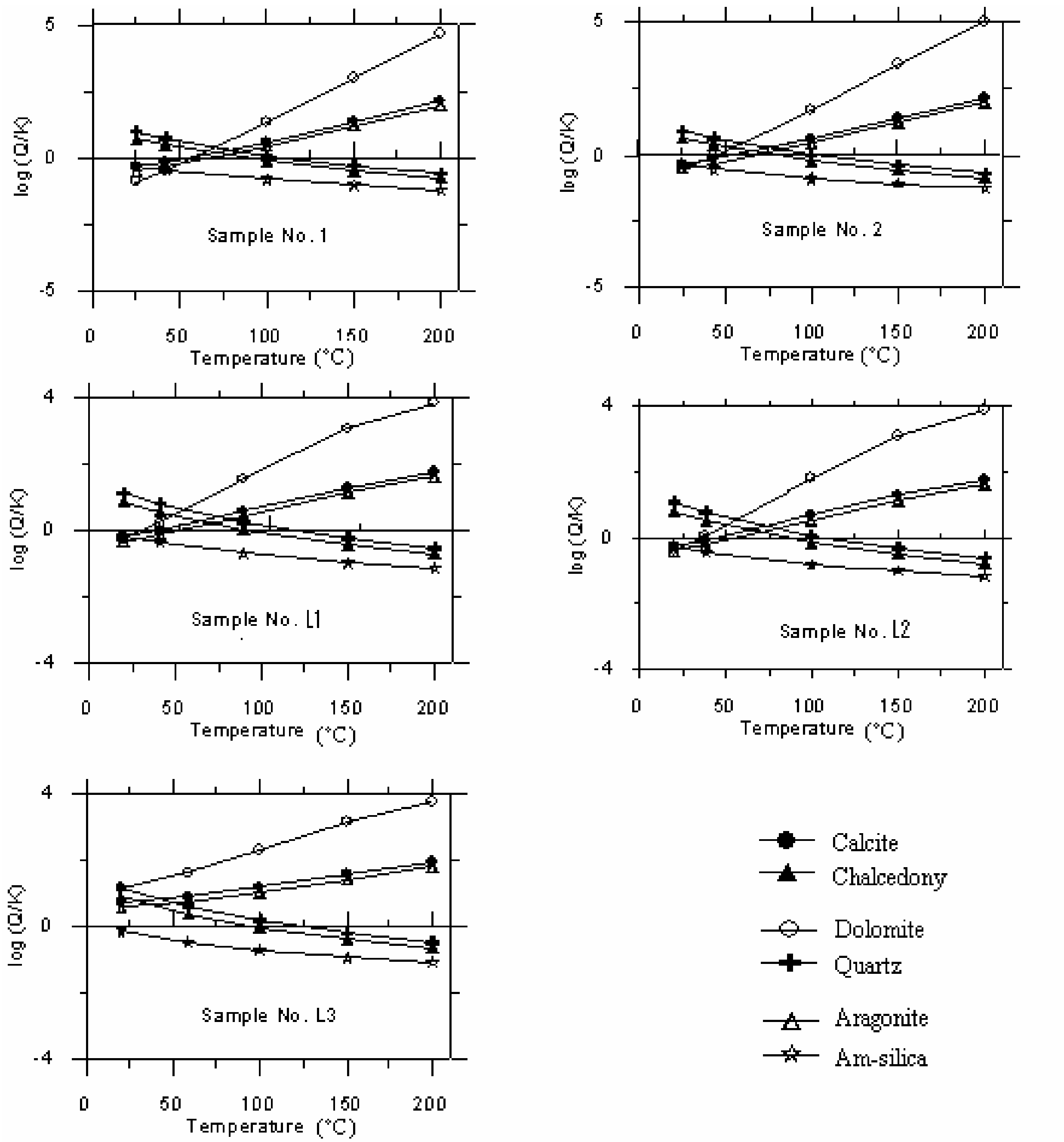

Figure 6. Log (Q/K) vs. temperature diagrams for the Maanping and Linchuan thermal waters

<u>ACKNOWLEDGEMENTS</u>

This study is supported by China National Foundation of Natural Sciences under the Project No. 40472147.

<u>REFERENCES</u>

Arnorsson, S., (1983), "Chemical equilibria in Icelandic geothermal systems. Implications for chemical geothermometry investigations," *Geothermics*, **12**, 119-128.

Fournier, R.O., (1977), "Chemical geothermometers and mixing model for geothermal systems," *Geothermics*, **5**, 41-50.

Fournier, R.O., and Potter, R.W. II, (1982), "A revised and expanded silica (quartz) geothermometer," *Geoth. Res. Council Bull.*, **11-10**, 3-12.

Giggenbach, W.F., (1988), “Geothermal solute equilibria. Derivation of Na-K-Mg-Ca geoindicators,” *Geochim. Cosmochim. Acta*, **52**, 2749-2765.

Li, X. L., (1979), “The relationship between distribution of thermal waters and uranium mineralization in Jiangxi,” *Journal of East China Geological institute,* **2**, 21-29.

Reed, M.H., and Spycher, N.F., (1984), Calculation of pH and mineral equilibria in hydrothermal water with application to geothermometry and studies of boiling and dilution. *Geochim. Cosmochim. Acta,* **48**, 1479-1490.

Spycher, N.F., and Reed, M.H., (1989), “User□s guide for SOLVEQ: A computer program for computing aqueous-minerals-gas equilibria (revised prelim.edition),” University of Oregon, Eugene, OR, 37 pp.

Lin, Q., (2004), “Temperatures in the boreholes of the geothermal fields, Jiangxi Province,” *Personal Communication.* Jiangxi Institute of Hydrogeology and Engineering Geology.

Sun, Z. X., (1988), “The formation conditions of hot springs in Jiangxi Province, SE-China,” *Master thesis of East China Geological Institute,* 50pp.