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Geothermal Study in Sonkim Area, Vietnam

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ABSTRACT

Sonkim geothermal area is situated in Huongson district of Ha Tinh province, northern central of Vietnam. In this area, geothermal research was carried out by geological, hydrogeological surveys, methods of geophysics and geochemistry. According to the results of investigations, the characteristics of fault system were defined as number, dimension, distribution of faults in the areas of geothermal temperature anomalies, chemistry of geothermal fluid and deep temperature of geothermal system. Sonkim is classified as low temperature geothermal system. Detailed geology, geophysics, geochemistry investigations and more exploratory drilling are needed to make a more accurate assessment of the geothermal potential of the area.

1. INTRODUCTION

The study area is a part of Sonkim Commune, Huongson District, Hatinh Province in the Northern Central region of Vietnam. It covers an area of about 300 km^2 and is situated about 100 km southeast of Ha Tinh Township.

In this study area, there are 7 hot springs (Sonkim, Quankhu4, Raomac, Ngamthep, Tram 5, Hatan and Khetre). Geological and geophysical surveys and hydrological sampling were conducted in area around these 7 springs. The most detailed exploration was undertaken covering about 20 km^2 around Sonkim spring.

This paper describes the results of these surveys and evaluates the geothermal potential of the hot spring systems.

2. GEOLOGICAL SETTING

Daigiang Formation (S_2-D_1dg)

The sedimentary rocks are composed of claystone inter-layered with sillstone. Each layer of sillstone and sandstone are 2-3cm thick. The stratigraphy from bottom to top in a south-north-northeast cross-section along Raoan stream shows a layer of sandstone of 2-4 cm thick with green grits weathered to purple, changing to grey and light green sillstone, and to claystone weathered to dark brown with a layer of organic vestiges. The Daigiang formation contains sandstone, sericit-clorit quartz slabs, biotite quartz, muscovite sericite, clay slabs and sericite-chlorite slabs. This formation is 550-600 m thick.

Quaternary (Q)

The Quaternary sedimentary rocks form narrow zones, mostly along with both sides of Raoan, Namchot, and Raomac streams. These are found on both sides of Raoan stream, the eastern side of Raomac stream and in some other places. The major compositions are pebbles of various sizes, pebble grits, sand, clay grits, and sandstone with clay layer in the top spreading which to form an inclining edge. Their thickness ranges from 3-2m to 6-7m.

Truongson granitoit complex (γC_1ts)

In the research area, Truong Son granitoid complex (γC_1ts) distributes in the north accounting for 60% of the total area. This complex is formed by medium to large blocks of biotite granite, which are bright grey or yellow pink to light green. Petrography analysis showed that the granite contains white feldspars, many of which have large grain size, notably in the lower section of Raoan and Namchot streams.

Geological structure

In the research area, there are three sets of faults trending in different directions, which divide the area into formation blocks of different sizes (Figure 3).

1- Raomac fault (Fl): this is found to the northwest-southeast of Raomac stream, trending in the west-southwest direction. This represents the largest tectonic faulting which produced large brecciate zones covered by the Quaternary sediments.

2- Namchot fault (F2): this is trending in the north-south direction. In the Namchot T-junction, a fault brecciate zone of 6m long and 0.6 m wide is found. In Ngamthep the fault brecciate zones cut through granite and have a similar width. They are trending in west-southwest direction.

3- Namchot river upper section fault (F3): this fault runs almost in the north-south direction, and created a brecciate zone of 0.5 m thick in the eastern side of Namchot.

4- In addition, there are also some smaller faults, mainly trending in the northeast-southwest direction.

The geological setting of Son Kim area suggests the existence of magmatic and young tectonics activities. This is a favorable condition for the development of geothermal systems.

3. GEOPHYSICAL CHARACTERISTICS

The geophysical surveys carried out in the research area include temperature and resistivity measurements. The results indicate two bands of anomaly in the Sonkim area.

Band No.1: This covers a large area from the Nuocchot Bridge running along the Raoan stream in the southern direction passing the Sonkim well. It is bound by 29°C isothermal lines (2 m depth).

Band No.2: it is situated in the Raomac stream area, south of national highway no. 8. It is also limited by 29°C isothermal1ine. This anomaly centers at Quankhu4 well.

These two bands of anomaly are associated with Schlumberge apparent resistivity values of 12 Ω-m to 36 Ω-m (AB/2 = 1000m).

The highest temperature in Sonkim well is 79.5^{o}C at the depth of 16 m. The maximum thermal gradient is 0.53^{o}C/m.

In Quankhu4 well the highest temperature is 44.5^{o}C at the depth of 40 m. The thermal gradient is 0.03^{o}C/m between 18 and 40 m.

4. GEOCHEMISTRY

The chemical compositions in a fluid are used as tracers and geo indicators (Giggenbach, 1991). A tracer is a conservative element such as CI, Band Li. These elements are essentially non-reactive and unaffected by charging temperature and water rock interaction. Geoindicators elements are chemically reactive, for example, Na, K, Ca, Mg and SiO_2. These element are influenced and controlled by fluid-mineral equilibrium and respond to charges in the environment. Therefore they are used for interpreting processes that affect the fluid rising to the surface (Giggenbach and Goguel, 1988).

The hot springs at Sonkim area are characteristic of bicarbonate water with pH = 7.4 to 8.1 and low mineral content of TDS about 114 to 381 mg/l.

The hot springs have a relatively high bicarbonate concentration of 74.6-309mg/l, a low chloride concentration of 3.5-14 mg/l and a sulphate concentration of 7.6-42mg/l.

The relative values of CI-SO_4-HCO_3 are presented in a triangular graph in Figure 1. It shows that all springs are bicarbonate water.

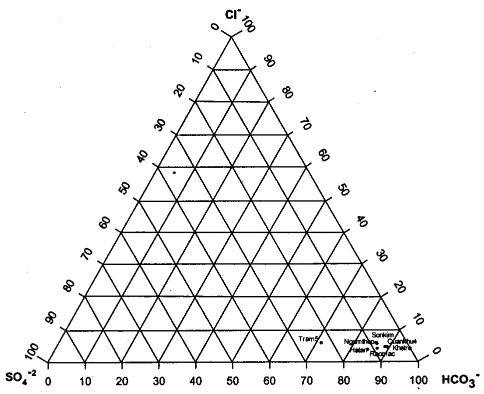

Figure 1: Triangular graph of Cl-SO_4-HCO_3 at Sonkim area

The isotopic composition of water from Sonkim spring is -8.7‰ δ^{18}O and -59‰ δD. It shows that the Sonkim spring lies on the meteoric water line. So the water origin of Sonkim thermal area is meteoric water.

5. GEOTHERMOMETRY

Geothermometers are based on the equilibrium concentration of all reactive species in a geothermal liquid that are affected by temperature. Solute geothermometers are based upon the mineral solubility of quartz and exchange reactions such as Na-K and K-Mg. The application of solute geothermometers based upon temperature dependent fluid mineral/rock equilibrium must fulfill five basic assumptions (White, 1970; Fournier, 1977 and Truesdell, 1976).

The results of the deep temperatures calculated for the spring at Sonkim are shown in the Table 1.

Table 1. Temperatures of the Deep Fluids at Sonkim Geothermal Area.

Name of spring	Surface Temp	Geothermometers (^{o}C)			
		Na-K (Fou.)	Na-K (Gigg.)	K-Mg	Quartz No steam loss
Son Kim	78	178	195	83	113
Ngamthep	35,5	176	194	80	110
Raomac	61	232	246	59	89
Quankhu4	44,5	206	222	80	115
Hatan	44,5	140	159	93	75
Khetre	44	201	217	81	97
Tram 5	30	212	228	64	107

Interpretation of these calculations requires consideration of the geological and hydrological setting, the physical and complete chemical analysis of the fluid.

Na-K Geothermometer

One advantage of the Na-K geothermometer is less affected by boiling, dilution and mixing, if the diluents waters have low concentration of Na, K and Ca.

The conditions mentioned above are not suitable for the spring at Sonkim. Because Sonkim is a low temperature geothermal system, and the equilibrium of this geothermometer is so high about 140-246°C. So these results may not be true.

Na-K-Mg Plot

This plot was proposed by Giggenbach (1998) (Figure 2) and is the combination of Na-K and K-Mg geothermometer. The relative contents of Na, K and Mg are plotted in a triangular diagram. One of the main advantages of this graph is that it can be used to assess the processes affecting spring water.

The Sonkim springs lie in the immature water field. If the K-Mg temperatures are reliable, the deep temperature of the system is about 100°C.

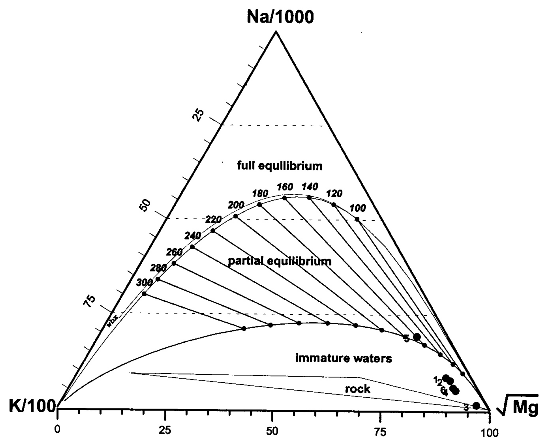

Figure 2: Relativfe concentration of Na-K-Mg

The use of silica geothermometry is based upon the solubility of silica species as a function of temperature. Quartz is the most stable and least soluble form of silica within the temperature and pressure range found in geothermal systems. The quartz equilibrium temperature of Sonkim springs ranges from 75 to l15°C.

At Sonkim thermal area, the deep fluid has a temperature of about 64-115^{o}C based upon the K-Mg, and Quartz without steam loss geothermometer.

6. ASSESSMENT OF HEAT POTENTIAL

The Sonkim thermal area is a low temperature geothermal system. Geothermometry suggests that the temperature of deep water is about 115°C.

Using a normal temperature gradient of 33°C/km and annual temperature of 24°C, we obtain:

Hence, the thermal water is likely to come from 2.75 km depth, assuming that there is no heat source other than the normal terrestrial heat flux.

Thermal potential of the Sonkim prospect

The minimum thermal potential of the prospect is equal to the total heat discharge by hot springs, which is 385 kW. It is not likely that these can be used to generate electricity.

Assuming that the shallow aquifer encountered by Sonkim well is widespread, we may estimate the thermal potential per square kilometers (km^2) of the area.

It is assumed that we can drill down to 60 m depth; hence the access able aquifer layer is 50 m thick. We may also assume that it has a porosity of 10% (0.1). The average temperature of water would be about 78°C in Son Kim well.

Hence, the heat that would be stored in 1 km^2 area is:

Heat stored in fluids: Q_f = 1.1E+12 kJ

Heat stored in rock matrix: Q_r = 6.6E+12 kJ

Assuming that we can take 100% of Q_f and 25% of Q_r, total potentially available heat is: Q = 2.7E+12 kJ

Assuming that we are going to use it for 25 year, the thermal potential of the prospect is: 3400KW/km^2

CONCLUSIONS

Sonkim thermal area extends about 300 km^2.It contains some low temperature geothermal systems. The geological setting of area suggests the existence of magmatic and young tectonic activities. This is favorable condition for the development of geothermal systems.

The hot springs have temperature ranging from 30 to 78°C and are characterized of bicarbonate water with pH = 7.4 to 8.1, low chloride concentration of 3.5-14mg/l and sulphate concentration of 7.6-42 mg/l.

The deep thermal fluids at Sonkim thermal area probably have a temperature of about 115°C, as estimated by K-Mg and Quartz (no steam loss) geothermormeter.

Minimum total heat discharge at Sonkim area is 385 KW. The thermal potential, of the Sonkim prospect is about 3400 kW/1km^2.

This study of the Sonkim thermal area is mainly based on surface investigations. The assessment of geothermal potential may contain large errors. Detailed geology, geophysics, geochemistry investigations and more exploratory drilling are needed to make a more accurate assessment of the geothermal potential of the area.

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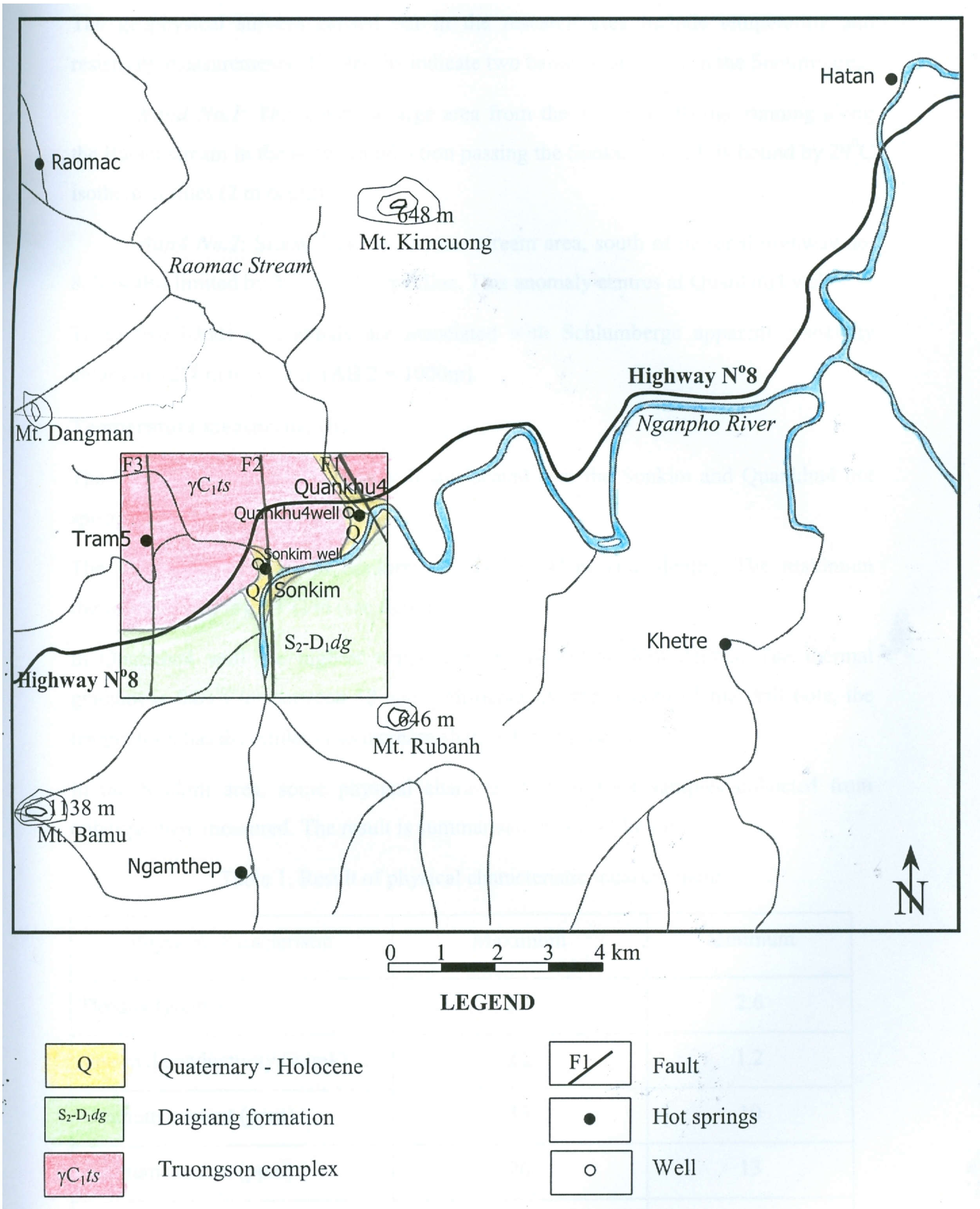

Figure 3: The geological map of Sonkim area