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Characteristics of Geothermal Fluids in North-West Area of North Plain, Vietnam

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ABSTRACT

With the specific structural and tectonic characteristics, the area appears to have a rich geothermal potential indicated by surface manifestations such as hot springs. Varied methods have been applied including the study of geothermal fluids. The project "Study and evaluation of geothermal potential in north-western of north plain of Vietnam and the geothermal prospects for economic development" has determined the characteristics of geothermal fluids, deep temperatures as well as the origin of geothermal fluids in the study area.

1. INTRODUCTION

The study area (Figure 1) is supposed to have the most potential in Vietnam basing on the geological structure of the area. There are 119 geothermal sources identified by surface hot springs and shallow bore holes. These geothermal sources have been discovered long time ago by the inhabitants and geologists. Our aim is to make clear the geothermal potential in north-west Vietnam. We have applied some of the geothermal methods of study such as geothermometers, triangular diagram, and stable isotopes.

Figure 1: Map of the study area.

2. GEOLOGICAL SETTINGS

2.1 Tectonic Position

The NW Bac Bo has the varied time and spatial characteristics during various tectonic cycles. On the Upper Paleozoic – Lower Mesozoic structural framework, it is the intersection of a lot of geomassifs (aged from Archean - Paleozoic) and interblock basins. Here the positive structures include the SW margins of the Hoa Nam landmass in the NW part of Ma River Landmass, and the west is the Lai Chau Landmass. The negative structures include the Da River and Sam Nua basins. During this time the NW Bac Bo is in the rifting dynamics and is a marginal sea with several narrow depositional depressions striking in NW – SE direction among the primitive landmasses. In Jurassic, most NW become mainland, existing only a few narrow troughs containing the coarse sediments and the latterly Cretaceous extrusive. In this stage the geomasses are attached into each other to form a plate and are connected to Eurasian plate (Le Nhu Lai, 1995).

2.2 Characteristics of Structural Blocks

The NW Bac Bo is small but it has a very complicated geostructure revealing the from Proterozoic to Kainozoic formations which are formed from many different tectonic cycles from Carelli to Hymalaya. It is divided into structural blocks (SB). A SB is seen as a tectonic unit that is based on the tectonic basic framework. During a same period, the SBs are close to each other and are subject to various tectonic regimes which are identified by analyses of structural complexes, geodynamics, metallogenies. The SBs do not remained forever. They are generated, grow up, and extinguish. It means that they, again, partially or entirely contribute to part of a new SB in a certain stage. The tectonic basic framework is the one that is built on a most distinctive, clear, strongest, tectonically developed stage of the Vietnamese NW. The NW Bac Bo SBs include: the Fanxipan SB, the Ma River SB, the Dien Bien SB, the Muong Te SB, the Tu Le SB, and the Ha Noi SB. These SBs are drawn on the geostructural and earthquake center scheme.

2.3 Shearing and Faulting

In the thermal conducting mechanism from depth upward, a role of the deep faults is very important. They are the channels to transport magmatic material or geothermic fluids into the earth surface. Acting history of the deep faults are normally long. Most of the ones that are faulting in Neotectonic in NW Bac Bo are inherited from the former ones and reactivated in the PreKainozoic multiple tectonic phases. The deep fault zones in NW Bac Bo are normally the boundaries between the SBs such as the Ma River fault zone, the Dien Bien – Lai Chau fault zone, the Son La fault zone, or lie on the concave of the basin like Da River fault zone. Recently the NW Bac Bo is inn uplift susceptive to denudation. Depending on breakages and lithological properties, geomorphologies and landforms could have various shapes such as linear or sinuous. The faults that have steep or vertical slides frequently result in fairly straight lineaments on the Lansat and SPOT images.

2.4 Earthquakes

Vietnam is geographically located close to two of the world's largest earthquake belts: the Pacific and Transasian Mediterranean belts so it is influenced by the two belts in term of seismics and tectonics. Vietnam has been experiencing thousands of tremors among which there are the dramatically destructive ones with magnitude of more than 6 degree on Richter scale.

On the Earthquake Center Scheme of Vietnam, the NW Bac Bo is the where the earthquakes are concentrated most. Some recorded events indicated that just in present, the NW Bac Bo is still strongly influenced by the tectonic activities.

According to the Nguyen Dinh Xuyen and Nguyen Can earthquake zoning (1992), the Ma River SB, part of Dien Bien and Son La SBs are possibly the areas that may generate the very strong earthquakes with magnitude up to 6.6 – 7.5 Richter degree. The Ha Noi SB can generate 5.5 – 6.5 Richter degree earthquakes. Within the remaining SBs the earthquakes can reach 5.0 – 5.5 degree.

So the earthquakes of the levels 8 – 9 could be generated in the regions of Lai Chau, Dien Bien, Ma River, Son La resulting the tremors of level 7 in the adjacencies. Earthquake of level 8 can occur in Hong River. We thus, can see that the state of earthquakes of the NW Bac Bo and the profuse geothermic potential is kept below the depth of NW Bac Bo.

2.5 Hidden Magma in NW Bac Bo

Rested on the differences of the specific parameters among the magmatic complexes and the surrounding rocks, geophysicists have predicted the hidden magmatic bodies in the NW Bac Bo that include the following intrusives: mafics and ultramafics, neutrals, acids, and alkaline acids. Their behaviours have an influence on the forming the shearing zones that create channels for hot water to migrate to the surface, and the question of whether the residual heat of the hidden magma could be able to heat water or not needs further studies.

3. THE CHARACTERISTICS OF GEOTHERMAL FLUIDS IN NORTH-WEST VIETNAM

The highest surface temperature of a hot spring is 78^{o}C and the lowest surface temperature is 30^{o}C in the study area. Almost of the hot spring have surface temperatures between 40 and 60^{o}C. The pH of hot springs are varied from 6.4 to 8.5. Most of the hot springs have pH of 7-7.5. Total Diluted Solution (TDS) is between 0.057 to 4.786 mg/l. Most of the hot springs are HCO_3 - SO_4 – Na – Ca – Mg. The chemical study of thermal fluids shows the content, properties, deep temperature as well as the origin of geothermal fluids, since then evaluate the geothermal potential to supply heat.

3.1 Triangular Diagram of HCO_3- CL - SO_4

The HCO_3- CL - SO_4 triangular (Figure 2) shows that most of the geothermal sources are positioned in the corners of HCO_3^- and SO_4^{2-}. These positions reveal that those fluids are of meteoric origin and are from unequilibrated acite fluids. Some of the geothermal fluids are positioned close to the Cl^- corner showing that they originated from magmatic equilibrated fluids or were influenced by sea-water. The geothermal sources with bicarbonate type fluids are Pe Luông, Pa Bát, Na Hai, Bản Mòng, Thôn Ngọc that are positioned at the HCO_3^- corners. Similarly, the geothermal fluids of SO_4^{2-} type are of magmatic origin or are influenced by sea-water such as Gia Hội, Sơn Thịnh, Ba Khe, Trạm Tấu. Geothermal fluids of Cl-type are of magmatic origin or are sea-water influenced types such as Phong Châu, Đông Cơ, Quang Bình. Although, some of the geothermal sources are positioned at magma corner but the their origin may not be of magmatic origin because of their other characters such as pH, TDS, which are not in support of a magmatic origin.

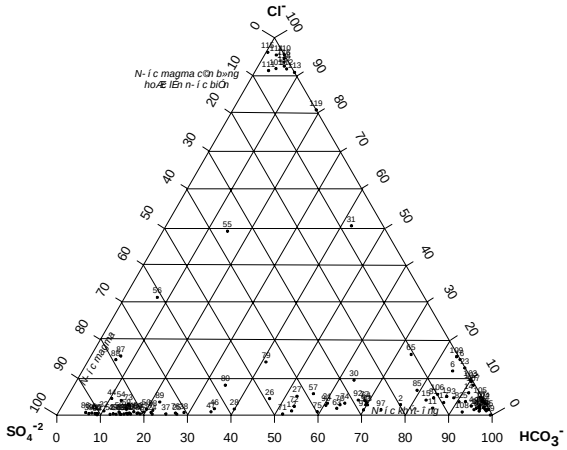

Figure 2: Triangular diagram of HCO_3- CL - SO_4.

3.2 Triangular Diagram of Na - K – √(Mg)

The results of geothermal fluids are used to form the triangular diagrams. The triangular diagram of Mg, K/100, Na/1000 (Figure 3) with partition lines to separate the temperature areas and the equilibrium of the elements in the geothermal fluids in contact with surrounding rocks of the reservoir. This means that the fluids are not from the center of reservoirs but are mixtures of fluids from reservoir and the meteoric waters; so a complete equilibrium status is not attained.

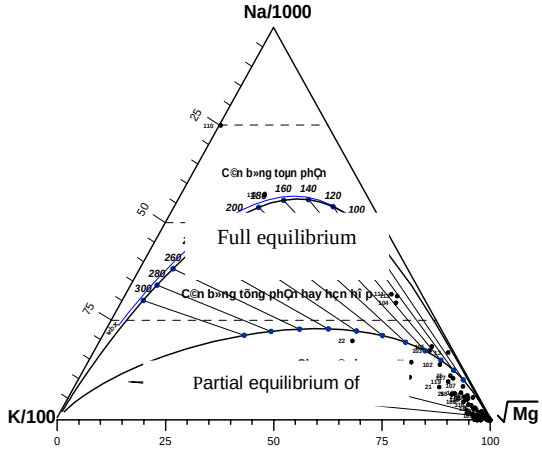

Figure 3: Triangular diagram of Na - K – √(Mg).

3.3 Geothermometers

The geothermometers are used to determine the reservoir temperatures are as following:

- K-Ca geothermometer by Tonani, 1980.
- Na-K-Ca geothermometer by Fourier and Truesdell, 1973.
- SiO_2 geothermometer Fourier and Potter, 1979.

Among of these geothermometers, the Na-K-Ca geothermometer is highest reliability. When the geothermal reservoirs in the study areas are strongly fractured by the neotectonic activities, the cold water from the above layers intruded into the reservoirs and diluted the thermal fluids in the reservoir. The different results of Na-K-Ca geothermometers is much smaller. On the other hand, the applied condition of this geothermometer is quite varied, so it maybe used for different geothermal models. Besides the

Na-K-Ca geothermometer, the SiO_2 geothermometer plays very important role in the determination of reservoir temperatures, however, the rock is fractured, the SiO_2 content is reduced in rainy season, resulting the result of calculated geothermometers are much lower than the reality. The K-Ca geothermometer result is used to be referenced. The results of geothermometers show that:

- According to Na-K-Ca geothermometer, the reservoir temperatures fluctuates in between 160-200^{o}C.
- The geothermal fluids contains mainly Cl in Hanoi structural block, the temperature are fluctuates between 110-228^{0}C.
- The geothermal sources in Muong Te, Điện Biên, Sông Đà, Sông Mã, Fansipan blocks have temperatures between 110-229^{0}C.
- According to the SiO_2 geothermometer, the reservoir temperatures fluctuates in between 70-96^{o}C in Tu Le structural block.
- The reservoir temperatures of the rest structural blocks are between 50-150^{o}C.
- According to K-Na geothermometer, the calculated results are normally higher than the other geothermometers, the temperatures of the reservoirs fluctuate between 120-250^{o}C.

So, the geothermal resources in the study area are low to moderate enthalpy.

3.4 Micro Elements in Geothermal Fluids

- The Li content in geothermal fluids of NW Vietnam is in the range from 0.01–0.1 mg/l. The content of Li in geothermal fluids of HCO_3^- type is usually higher than in the geothermal fluids of SO_4^-, about ten percent. The highest Li content is 0.336 mg/l (Pom Lot geothermal resource). The lowest Li content is 0.013 mg/l (Quynh Chau geothermal resource). The flour content of geothermal sources is usually smaller than 1.0 mg/l. Some of the geothermal sources with high flour contents are Pom Lot (1.3 mg/l), Na Hai (2.15 mg/l), Pac Ma (2.67 mg/l).
- The Boric content of most of the geothermal resources in NW of north plain of Vietnam is small ranging from 0.01 to 0.05 mg/l. The high Boric content geothermal resources are: Na Hai (0,72mg/l), Pác Ma (0,96mg/l), Pom Lót (1,37mg/l). They are almost in Dien Bien area.
- The Rb content is very small in the geothermal fluids in NW of north plain Vietnam. The content is ranging from 0.078 to 0.071 mg/l. The higher Rb content geothermal sources are Na Hai (0.078mg/l), Mường Pìa (0.071mg/l), Nậm Păm (0,1mg/l).
- The Br content fluctuates from 0.05 to 0.1 mg/l in geothermal fluids in NW north plain of Vietnam. Some of the geothermal fluids which have higher Br content are: Hủ Chim 2 (0.24mg/l), Nậm Păm (0.44mg/l), Mường Pìa (0.67mg/l).
- The As, Hg and Mn contents of NW north plain of Vietnam are small, mainly between 0.0001 - 0.01 mg/l Hg and smaller than 0.05mg/l As, and 0.1-0.01mg/l Mn. So, it is clear that the geothermal resources in NW of north plain Vietnam are not the high enthalpy classes.

3.5 Chemical Characteristics of Gases in Geothermal Fluids

The study of associate gases of thermal fluids of the geothermal resources can show the origins of gases, since then interpreter and determine the origin of thermal fluids those are magma, meteoric or mixing waters. In our project, we chose the methods of N_2-He-Ar triangular (Giggenbach) to determine the origin of gases of the geothermal resources in NW of north plain Vietnam (Figure 4).

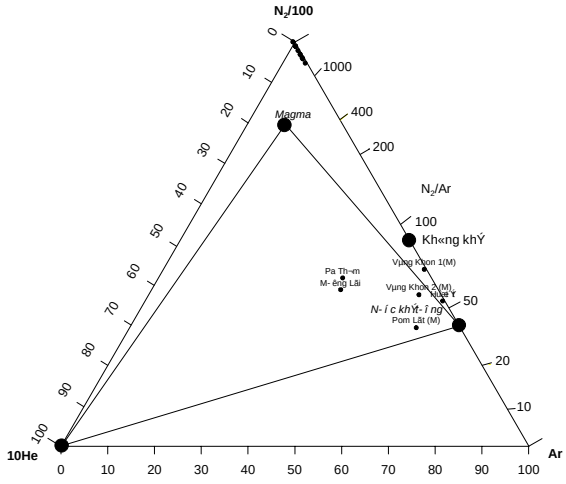

Figure 4: Triangular diagram of N_2 - He – Ar gas.

The result of study shows that most gas of geothermal fluids having N_2 content from 83.24 mol % to 97.7 mol %. Some of the geothermal sources have smaller N_2 content such as Nậm Păm (29.28 mol %), Pom Lót (26.7 mol %).

Almost of geothermal resources have lower Ar content ranging from 0.01 – 0.05 mol % such as Pac Ma, Vang Khon, Huoi It, Nam Pam and Ban Hoc. Some of the geothermal resources have higher such as Pom Lot – 1.38 mol % and Huoi It – 1.65 mol %.

The He content is just a trace and some time reaches to 0.05 mol %. The CO_2 and H_2S contents are very small in most geothermal sources in NW of north plain Vietnam. Their contents are normally less than 15 mol %. The CO^2 in Pom Lot and Nam Pam are 69.23 and 72.25 % mol that are quite high.

The Pa Thom, Muong Lot, Vang Khon and Huoi It positions are in the area of meteoric waters on the diagram. The samples were taken from these sources in rain season. The rest of geothermal resources are plotted at the conner of N/100 reflecting the possibility of magma originated gases.

3.6 Stable Isotope Diagram δD and $\delta^{18}O$

There are 24 samples collected for stable isotopes study of δD and $\delta^{18}O$ to determine the origin of thermal fluids. The geothermal sites those have been collected for δD and $\delta^{18}O$ analysis then plotted in the diagram (Figure 5), the meteoric water is a diagonal straight line following the equation of $\delta D = 8\delta^{18}O+10$. The positions of thermal fluids of geothermal sources are presented by the small circles sitting on or near the meteoric line showing that the origin of thermal fluids are meteoric. This means that the thermal fluids are come from surface waters infiltrated into the deeper layers then deep circulating.

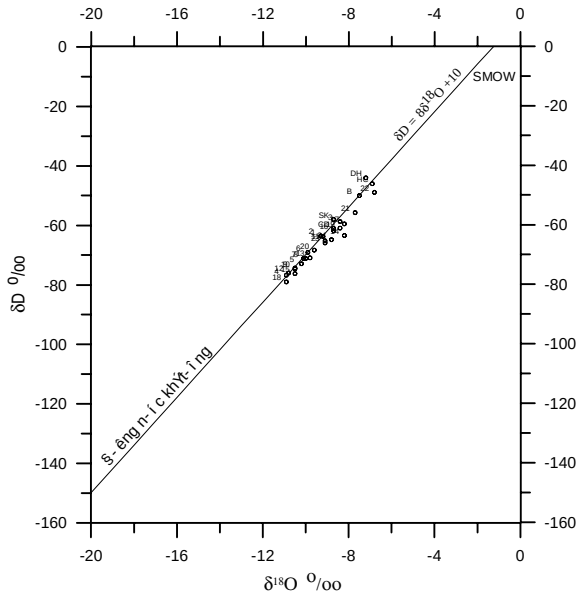

Figure 5: Stable isotope correlation diagram δD and $\delta^{18}O$.

4. CONCLUSION

Resulting from above research showing that almost all geothermal fluids in the NW North Plain of Vietnam originated from meteoric waters. Some of the fluids that are close to the sea originate from meteoric water mixing with sea water. The geothermal fluids are HCO_3 - SO_4 – Na – Ca hay Na – Mg types. Some geothermal sources near the sea are Cl-Na-Ca type. The temperatures in the reservoirs fluctuate from 160-200^oC, so they are classified into low – moderate enthalpy.

Due to the geological structure and tectonics of the study area, the authors believe that the deep reservoirs have a very large volume. However, deeper investigative methods should be carried out such as geophysic and deep drilling.

REFERENCES

Cao Duy Giang, 2004, Research and evaluation of geothermal potential in Nroth of central Vietnam and the utilization for social economy.

Cao Đinh Trieu and Pham Huy Long, 2002. Faults and tectonics in Vietnam territory. Science and Technique Publish.

Koenig J. May, 1981. Geothermal resources exploration in Vietnam. Geothermal council Bull.

Le Duy Bach, 1995. Tectonics and Metallogeny of NW Vietnam basing on new theory. Project No. KT01-03.

Nguyen Xuan Bao, 1981. Geological Mapping of Vietnam, scale of 1:500.000. Geological Archives, Hanoi.

Nguyen Kim Boi et al., 1994. Reference book of physical properties of rocks and some minerals in Vietnam. Geological Archives, Hà Nội.

Nguyen Đinh Xuyen and Nguyen Ngoc Thuy, 1996. Earthquake zonalization of Vietnam. Part 2, Report of State level project No. KH-ĐL 92-07, Hanoi.

Phan Cu Tien et al., 1984. Geological Mapping scale of 1:200.000, series of North West of North Plain Vietnam. Series of North West of North Plain Vietnam sheets. Geological Archives, Hanoi.

Vo Cong Nghiep et al., 1995. Mineral and hot water of Vietnam – One hundred years of research and utilization. Proceedings of 3rd Geological Conference, Vol. 2, Hanoi.