INTRODUCTION TO THE GEOTHERMAL POTENTIAL OF THE NORTH-EASTERN VIETNAM

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ABSTRACT

Basing on the characteristics of geo-tectonical setting, the geologists assume that the geothermal potential of the North Eastern Vietnam territory is at the fourth position among six geothermal areas of Vietnam. There are 21 hot springs in the study area with the surface temperatures from 30.5^{o}C to 71^{o}C. The chemistry of thermal fluids shows that these 21 hot springs are mostly bicarbonate. The results of geothermometer calculation show the deep temperatures of the hot spring from 80^{o}C to 164^{o}C. The δD and δ^{18}O plot reveals that the origins of thermal fluids are meteoric. The results of U, Th, K radioactive elements are calculated and showing that the heat sources of these hot waters are not coming from radioactive decay.

Keyword: northeastern Vietnam, hot spring, geothermometer, radioactive

1. INTRODUCTION

The geologists have classified the territory of Vietnam into 6 structural-tectonic areas: Northwest, Northeast, North Red River Delta plain, Northern Central, Sothern Central and South Mekong River Delta plain. According to this classification, the initial evaluation of geothermal potential has been carried out basing on the existing manifestation of hot springs. The geothermal potential of Northeast area is at the fourth level among of 6 geothermal areas in Vietnam, lower than the geothermal potential of Northwestern, Northern Central, Sothern Central areas.

Basing on the hydrogeological investigation, 21 hot springs were found in area of 63,000 km^2 of the Northeastern Vietnam. Almost of the hot waters found are natural springs and some of them are from the shallow wells.

The geothermal study and investigation were implemented for the Northwestern, Northern Central, Sothern Central areas and North Red River Delta plain of Vietnam so far. Basing on the same methods those were applied for the said geothermal areas such as Geotectonic, geophysic, hydrogeologic, chemistry of thermal fluids, radioactive elements, the investigation of the geothermal potential of the Northeastern area has been completed early this year and this paper is presenting some of the investigated results.

2. GEOLOGICAL SETTING

2.1. Tectonic characteristics

The northeastern Vietnam corresponds to the major episodes of crustal formation in South China Plate (Dovjikov A. E., 1965) that is formed in early Neoproterozoi-Paleozoic with the characteristics of multi-periods (Tran Van Tri et al., 2009) and belongs to South-east of Eurasian plate. It is interacted by the Australian – Indian plates at the South-west and Pacific plate at the East. In the late Paleozoic-Kainozoic, the continental crust of the study area is in hinterland rift process. After Indosinian exacerbated orogeny phase at Norian (Fromaget J., 1941), the Northeastern Vietnam became the continent and the ocean was withdrawed completely. In early Kainozoic, in the Northeast Vietnam in particular and the Indochina area in general, the tectonic activities are quite stable, there were mainly erosive processes and denudation creating the surface gradation at Eocene (Tran Van Tri et al., 2009). The active Neotectonic period was started from Oligocene till now due to the collision between micro Indian continent and Eurasian plates (Nguyen Trong Yem, 1991 and Phung Van Phach et al., 1996).

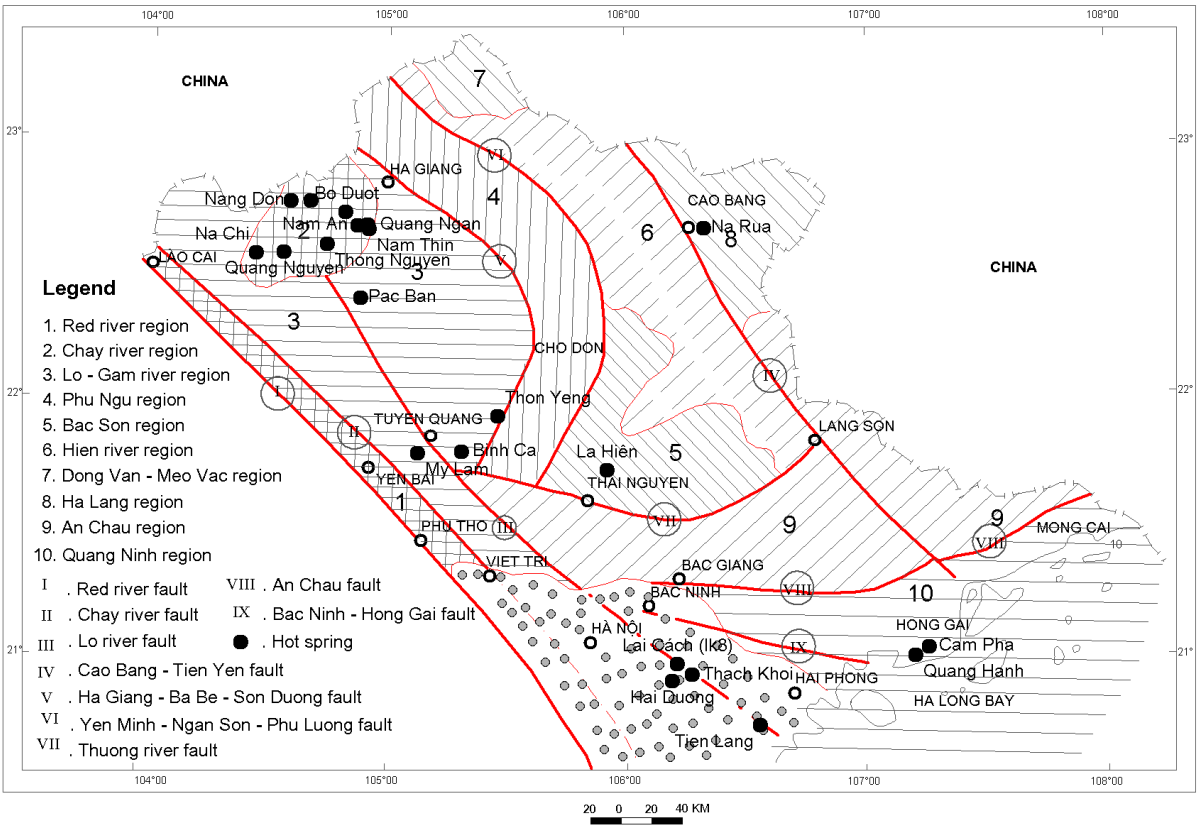


Figure 1. Tectonic – Structural Zonation Map of North-Eastern Vietnam

2.2. Tectonic subdivision

Based on present day knowledge of plate tectonics, distinctive morphotectonic features, structure and lithostratigraphy, the general geology of northeastern Vietnam, depicted in Fig. 1, shows ten geological entities: Red River region, Chay River region, Lo Gam region, Phu Ngu region, Bac Son region, Hien River region, Dong Van – Meo Vac region, Ha Lang region, An Chau region and Quang Ninh region. In general, these tectonic regions comprise various types of rocks with the ages from Proterozoic to Paleogene: granite, crystallization schist, terrigenous deposit, carbonaceous terrigenous deposit, effusive terrigenous deposit, carbonate, other magma from ultrmafic to acid.

2.3. Destructured faults

Fault system developes strongly in the study area with the deep and destructured faults oriented in Northwest-Souheast and West-east direction. The main deep and destructured faults can be listed: Red River fault, Chay River fault, Cao Bang – Tien Yen fault, Ha Giang – Ba Be – Son Duong fault, Yen Minh – Ngan Son – Phu Luong fault, Thuong River fault, An Chau fault and Bac Ninh – Hong Gai fault (Fig. 1).

The longest fault is Hong River with the length of 1,500 km and the shortest fault is Thuong River with the length of 80 km. The width of destructured zones are varied from 2-10 km. The depth of the faults is from 25-50 km and the displacement amplitude of the faults is from 1-3 km.

2.4. Magmatic formations

The magmatic formations consist of various types formed in the period from Proterozoic to Kainozoic in the different tectonic background such as: potassium rich granitoid, gabro, metagabroid, metabasalt, super mafic vocalnic rocks, alkaline granite (Tran Van Tri et al., 2009; Bui Minh Tam et al., 2010).

The granite formations in the study area are: Xom Giau potassium rich granitoid assemblage aged early Proterozoic. Song Chay granitoid assemblage aged early-middle Paleozoic (Dovjikov et al., 1965), isotopic age is in the range of 465 ± 34 m.a. (Ponomareva, 1977); 428 ± m.a. (Rogor, 2000); 424 ± 6 m.a.) Carter, 2001) in corresponding with Ordovic. The tectonic background of Song Chay granitoid assemblage is in relation with early Caledonian orogeny and folding process (Tran Van Tri et al., 1986). Nui Dieng granophyr granite aged early Trias. Phia Bioc aluminium rich granite assemblage aged late Permi – Trias and Pia Oac aluminium rich granite assemblage aged late Creta.

3. CHARACTERISTICS OF HOT SPRINGS

3.1. Manifestation of hot springs

The manifestation of hot springs in the study area is differentiated from the tectonic regions. The largest amount of hot spring numbers is in Song Chay region (with 6 hot spring) but there is not hot spring manifestation in Ha Lang, Dong Van – Meo Vac, Bac Son and Phu Ngu regions. There are 2 hot spring with highest surface temperatures of 62^{O}C and 71^{O}C in Song Chay region and close to the granitoid assemblage of Song Chay (Fig. 1).

The distribution and origin of hot springs are closely related to the fault activities in the Northeast area in Neotectonics and Recent tectonics, especially the role of deep fault zones those are mainly the ancient faults re-activated in Neotectonics.

3.2. Characteristics of thermal fluids

Chemical compositions of thermal fluids :

The thermal fluids occur on the surface of the study area in the form of the hot water with temperatures from 30^{O}C (Nang Don, and Nam Thin resources) to 71^{O}C (Bo Duot resource). Among 21 hot springs in the study area, there are mainly the hot springs of surface temperatures from 40^{O}C đến 60^{O}C. The pH of the hot springs are measured from 6.0 (Tien Lang resource) to 8.2 (Binh Ca resource) and mostly in between 6.6 to 7.2.

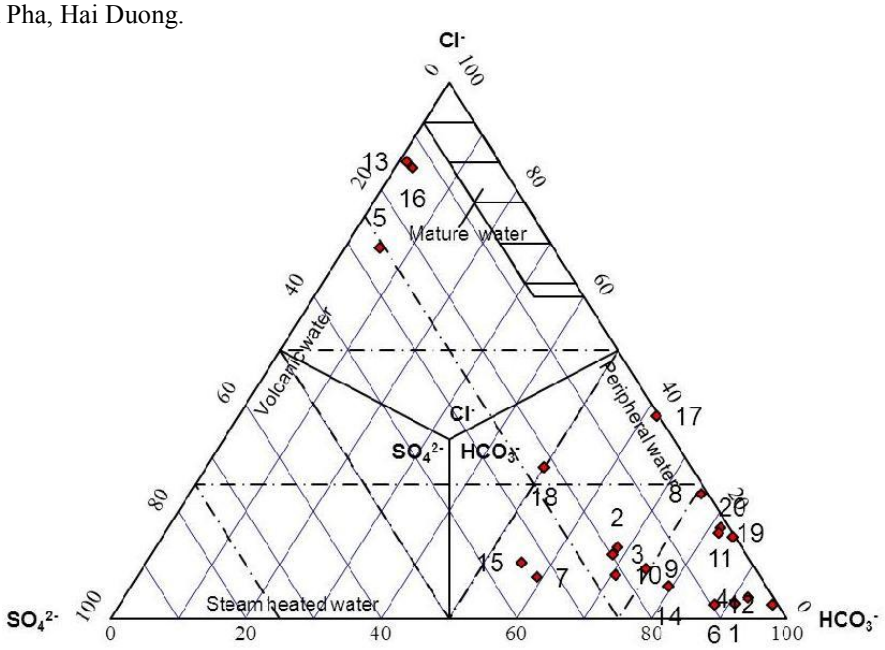
Most of the thermal fluids are bi-carbonate and chlorine. Total dissolved solids (TDS) of the bi-carbonate typed thermal fluids are quite low ranged from 0.12 g/l to 0.46 g/l. Total dissolved solids of the chlorine typed thermal fluids are mostly less than 1 g/l ranged from 0.7 g/l to 20.77 g/l. The hot springs with high TDS are located at the coastal zone, at the shallow wells, close to the sea such as Quang Hanh and Tam Hop resources. The chlorine of these hot springs are so high: from 6 g/l đến 11 g/l.

Origin of the thermal fluids:

The methods applied to define the origins of thermal fluids are Cl^- - SO_4^{2-} - HCO_3 Triangular Diagram and δD và $\delta^{18}O$ plot as following:

<u>Cl^- - SO_4^{2-} - HCO_3 Triangular diagram:</u>

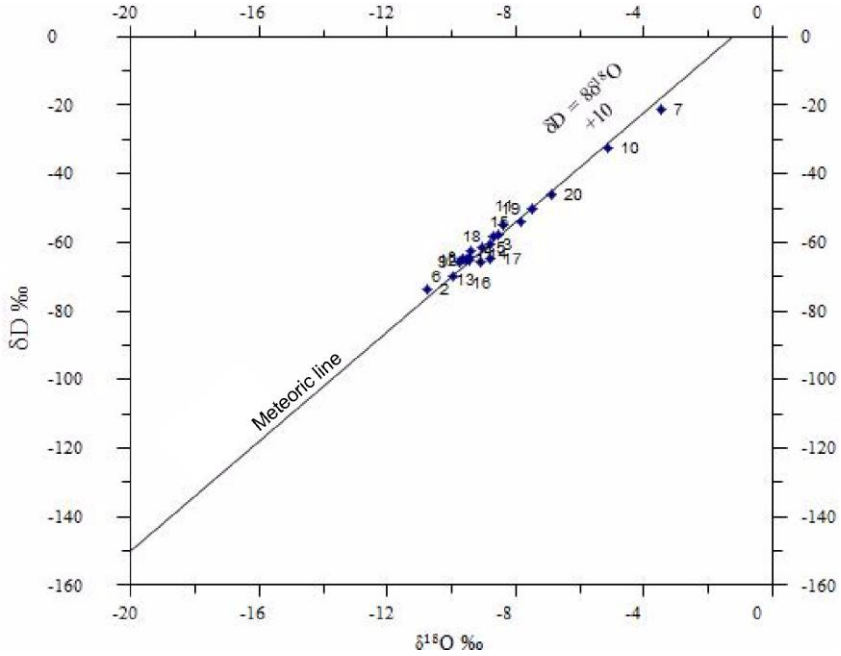
On the Cl^- - SO_4^{2-} - HCO_3^- Triangular diagram (Fig. 2), the positions of almost hot springs are converged at the HCO_3^- corner revealing the meteoric origin of the thermal water. These hot springs are: Bo Duot, Quang Ngan, Thong Nguyen, Quang Nguyen, Mo Muoi and My Lam . Some of the positions of hot springs scattered at Cl^- corner showing that the hot water can originated from magmatic water or mixing between sea water and meteoric water. These hot spring are: Quang Hanh, Cam Pha, Hai Duong.



1-Binh Ca	2-Bo Duot	3-Hoang Su Phi	4-La Hien	5-Lai Cach
6-My Lam	7-Na Chi	8-Na Rua	9-Nam Am	10-Nam Thin
11-Nang Đon	12-Pac Ban	13-Quang Hanh	14-Quang Ngan	15-Quang Nguyen
16-Tam Hop	17-Thach Khoi	18-Thon Yeng	19-Thong Nguyen	20-Tien Lang

Figure 2. Cl^- - SO_4^{2-} - HCO_3^- Triangular diagram

δD và $\delta^{18}O$ plot:



1- Ba Vi	6- Na Rua	11- Tam Hop	18- Bang
2- Bo Đuot	7- Nang Don	12- Thon Yeng	19- Sơn Kim
3- Hoang Su Phi	8- Quang Hanh	13- Thong Nguyen	20- Huyen Co
4- My Lam	9- Quang Ngan	16- Na Hai	
5- Na Chi	10- Quang Nguyen	17- Pom Lot	

Figure 3. δD và $\delta^{18}O$ Plot

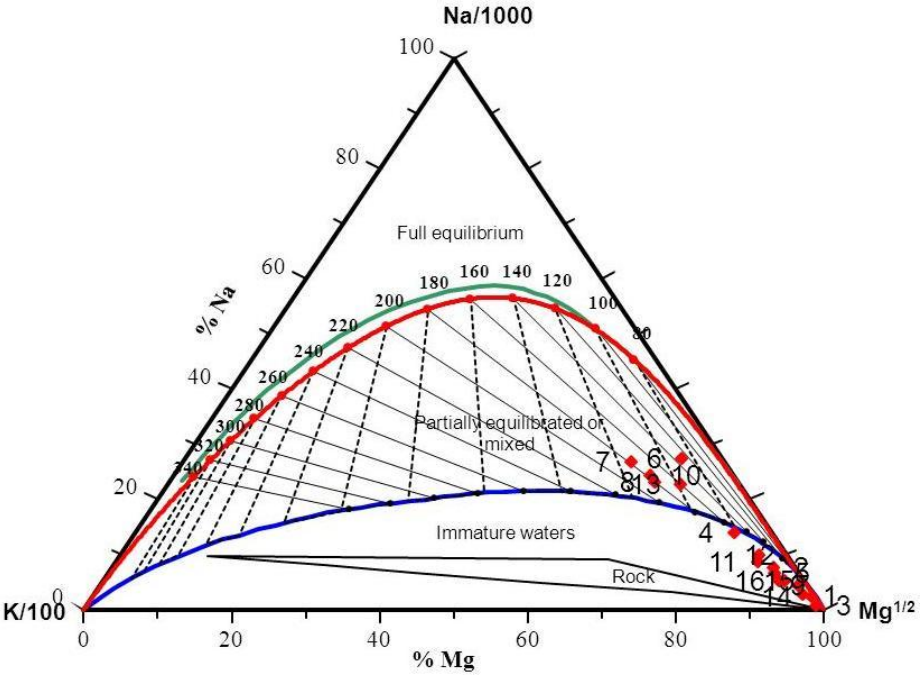
The positions of the hot spring are symbolized as tiny squares on the diagram and all of the positions are gathered along with the meteoric line (Fig. 3). This shows that the thermal water of these hot springs come from meteoric waters and similar to thermal waters in othe areas of Vietnam.

Deep temperatures of hot springs:
The deep temperatures of hot springs are determined by the methods of Na – K – Mg Triangular diagram as well as the geothermometers.

Na – K – Mg Triangular diagram:
The results of hot water analysis are used for constructing the Na – K – Mg Triangular diagram (Fig. 4). The triangular diagram consists of three corners of $Mg^{1/2}$, K/100 and Na/1000. It also consists of the lines to delineate the temperature positions of the thermal fluids and the degree of equilibrium of the chemical compositions with surrounding srock in ther reervoir of thermal water. Resulting from the diagram (Fig. 4), the temperatures of thermal springs are in between $80^{O}C$ and $190^{O}C$. The positions of the thermal water in the diagram show that most of the thermal water are immature. This can be explained that the thermal waters are not coming from their reservoirs and are mixed with local meteoric water on the way going to the surface of the earth.

Geothermometers:
Basing on the experiences of geothermal projects those have been implemented in Vietnam so far, the selecting geothermometers for calculating the deep temperatires of the hot springs are as follow::
- Na-K geothermometer, Arnórsson et al., 1983.
- Na-K geothermometer, Giggenbach 1983.
- SiO_2 geothermometer, Fournier and Potter 1982.

The results of geothermometer calculation are presented in the following table:



1-Bo Duot 2-Hoang Su Phi 3-La Hien 4-My Lam
5-Na Chi 6-Na Rua 7-Nam Am 8-Nam Thin
9-Nang Don 10-Quang Hanh 11-Quang Ngan 12-Quang Nguyen
13-Tam Hop 14-Thon Yeng 15-Thong Nguyen 16-Tien Lang

Figure 4. Na – K – Mg Triangular diagram

Table. Deep temperature of hot springs

No.	Hot spring	Geothermometer calculation		
		Quartz (20-330) ^{0}C	Na-K (25-250) ^{0}C	Na-K
		Fournier & Potter (1982b)	Arnórsson & et al., (1983)	Giggenbach et al. (1983)
1	Na Rua	85	81	129
2	Bo Duot	99	164	198
3	Hoang Su Phi	82	123	165
4	Na Chi	110	145	183
5	Nam Am	85	140	179
6	Nam Thin	-	143	181
7	Nang Don	-	108	152
8	Quang Ngan	98	151	188
9	Quang Nguyen	116	123	165
10	Thong Nguyen	107	173	205
11	Hai Duong	125	-	-
12	Thach Khoi	78	-	-
13	Tien Lang	83	149	186
14	Quang Hanh	-	139	178
15	Tam Hop	-	118	161
16	La Hien	78	-	-
17	My Lam	111	121	164
18	Thon Yeng	-	77	126

The results of geothermometer calculation listed in the above table show that the Quartz geothermometers caculated according to Fournier & Potter (1982b) fomula give the deep temperatures of the hot springs ranged 78^{O}C to 125^{O}C and are much lower than the temperatures calculated according to the K-Na geothermometers. The geothermometer calculation according to Arnórsson & et al., (1983) and Giggenbach et al. (1983) fomula give much higher temperatures but the results are also varried from Arnórsson's fomula to Giggenbach's fomula. The results of geothermometer calculated according to Arnorson are always lower than Giggenbach's geothermometer about 40^{O}C.

4. HEAT SOURCES OF THE GEOTHERMAL RESOURCES

One of the reason that causes the water become hot is the heat from the radioactive disintegrated reactions of the radioactive elements such as Uranium, Thoric and Potasium. In order to determine the major reason that directly heating the thermal waters in the Northeastern Vietnam i.e. to see if these radioactive elements generated the heat in the earth crust of the area or not? We calculated the heat-generating amount caused by radioreactions basing on the data of rock density, U, Th and K grades of the rock samples those are collected in the study area (Rybach, L., 1976).

$$Q_{sn\text{-}px} = \sigma\ (\alpha\, C_u + \beta\, C_{Th} + \gamma\, C_k)\ Kw/\ km^3$$

In which:

σ - density of the rock containing U, Th and K; unit in kg/ km^3.

C_u - Uranium grade of the rock sample; unit in ppm.

C_{Th} - Thoric grade of the rock sample; unit in ppm.

C_k – Potasium grade of the rock sample; unit in %.

When the radioactive elements of U, Th, K disintegrate, the energy is generated at a determined level that meets radioactive balance. In proportion to each of element, there is a certain heat-generating constant called "radioactive pyrogenic constant". Basing on the results of experiments, those constants are determined as following:

α - pyrogenic constant of U: 9,525 x 10^{-8} kw/kg.

β - pyrogenic constant of Th: 2,561 x 10^{-8} kw/kg.

γ - pyrogenic constant of K: 3,477 x 10^{-8} kw/kg.

Replacing the above values with the unit of rock density (σ) of g/cm^3, we have a following fomula:

$$Q_{sn\text{-}px} = 0{,}01.\sigma\ .\ (9{,}525.C_u + 2{,}561.C_{Th} + 3{,}477.C_k)\ Kw/km^3$$

The calculation has been applied for 60 samples collected in the study area revealing that the energy of all rocks those are generated by radioreactions is varried from 1.3Kw/km^3 to 3.1 Kw/km^3. These heat is smaller mean heat flux of earth crust (mean heat flux of earth crust is above 10Kw/km^3). So, the heat generated from radioreaction can not be able to cause the water hot but it is just supplementing the lost heat of the water. Therefore, the reason causing heat of the investigated hot springs is not directly come from radioreactions of the earth crust but due to geothermal gradient.

5. CONCLUSION

The twenty one hot springs are selected for geothermal potential investigation and evaluation in the study area. The investigation and evaluation show that the geothermal potential of the Northeastern Vietnam is quite low with the deep temperatures ranging from 80^OC to 164^OC. There are two hot springs with the highest deep temperatures located in Song Chay tectonic region, in Ha Giang province. They are Bo Duot hot spring with deep temperature of 164^OC and Quang Ngan hot spring with deep temperature of 151^OC.

All of the hot springs are meteoric waters. The hot springs those are close to the sea are mixed with sea water. The heat sources of the hot springs are geothermal gradient. Geothermal fluids are coming up the surface through the destructured faults in the area.

REFERENCES

Arnórsson, S., Gunnlaugsson, E., and Svavarsson, H., (1983b) The chemistry of geothermal waters in Iceland III. Chemical geothermometry in geothermal investigations. Geochim. Cosmochim. Acta, 47, 567-577.

Bui M. T. et al., (2010) Magmatic activities in Vietnam, Institute of Geoscience and Mineral Resources, Hanoi.

Cao D. G., et al., (2012) Evaluation of geothermal potential in the Northeastern Vietnam. Project Report, Institute of Geoscience and Mineral Resources, Hanoi.

Dovjikov, A. E. (ed.), Bui P. M., Vasilevskaia, E. D., Jamoida, A. I., Ivanov, G. V., Izokh, E. P., Le D. H., Mareitchev, A.I., Nguyen V. C., Nguyen T. T., Tran D. L., Pham V. Q. & Pham D. L., (1965) Geology of North Vietnam. Explanatory note of the Geological Map of North Vietnam at 1:500 000 scale. Geological Department of Vietnam, Hanoi, 584 pp.

Giggenbach, W.F., Gonfiantini, R., Jangi, B.L. and Truesdell, A.H. (1983) Isotopic and chemical composition of Parbati valley geothermal discharges, NW-Himalaya, India, Geothermics, 12: 199-222.

Fournier, R. O.; Potter, II, R. W (1982) An equation correlating the solubility of quartz in water from 25?? to 900??C at pressures up to 10,000 bars. Geochimica et Cosmochimica Acta, 46: 1969 – 1973.

Fromaget, J. (1941) L'Indochine française, sa structure géologique ses roches, ses mines et leurs relations possibles avec la tectonique. Bull. Serv. Géol. Indochine, vol. XXVI, fasc. 2.

Nguyen D. Xu. and Tran V. T., (2005) Tectonic geology and earthquake generated areas in Vietnam. Procedding of Vietnam Geological Conference, Hanoi.

Nguyen T. Y., (1991) Main features of recent geodynamics of Northern Vietnam. Geology - Resources, Ha Noi,Hanoi, pp.7-10.

Rybach, L., (1976) Radioactive heat production in rocks and its relation to other petrophysical parameters. Pure and Applied Geophysics, 114, 309–318.

Tran, V. T., (2006) Geology and Mineral resources of Vietnam, Natural science and Technology Publishing House, Hanoi, page 589.

Tran V. T. et al., (1986) Tectonics of Vietnam, Interpretation of Vietnam Tectonic Map scaled at 1:1.000.000, Institute of Geoscience and Mineral Resources, Hanoi.