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Evaluation of Geothermal Resources in the Dien Bien Region (The Northwestern Part of Vietnam)

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ABSTRACT

Geological, geochemical and geophysical surveys were performed in the Dien Bien to develop the hydrothermal model associated with the Dien Bien hot springs.

The geomorphology of the surveyed area is dominated by the Dien Bien Depression, which is a graben whose axis is oriented N-S. Four major geological structural features have been considered in the area: the Dien Bien deep-seated fault system, the Nam Rom deep seated fault, the NW-SE fault and NE-SW fault. All four faults cross the depression in which the Dien Bien deep seated fault system intersects the Dien Bien city centre.

The integrated interpretation of the geological, geochemical and geophysical data, suggests a meteoric origin for Dien Bien thermal waters, which infiltrate in the northwestern zone of Dien Bien Depression or further areas, percolate at great depth and ascend at the Dien Bien Depression, probably due to the intersection of the existing fault systems.

In fact, in these four zones, low resistivity values were measured, which are associated with the hydrothermal fluid circulation.

1. INTRODUCTION

The low temperature geothermal field of Dien Bien is an elemental part of a broad hydrothermal province situated in the Northwestern part of Vietnam, whose geothermal water chemistry is quite uniform. Many hot springs with temperature recorded from 60 to 74^{0}C occur on or related to two fault systems: WNW-ESE fault and NW-SE fault. Figure 1 shows the location of the main hot springs known in the Northwestern part of Vietnam. Figure 2 shows the schematic geological map of the Dien Bien geothermal area. All the geothermal waters are chemically similar. So the temperatures measured, suggest different pathways at depth. The Dien Bien geological structure, favoring the deep fluid circulation towards the regional, would play an important role to create the Dien Bien geothermal field. The activities of neotectonics, fault systems intersecting and existence of cataclastic zones in the depression, favoring for geothermal waters to ascend.

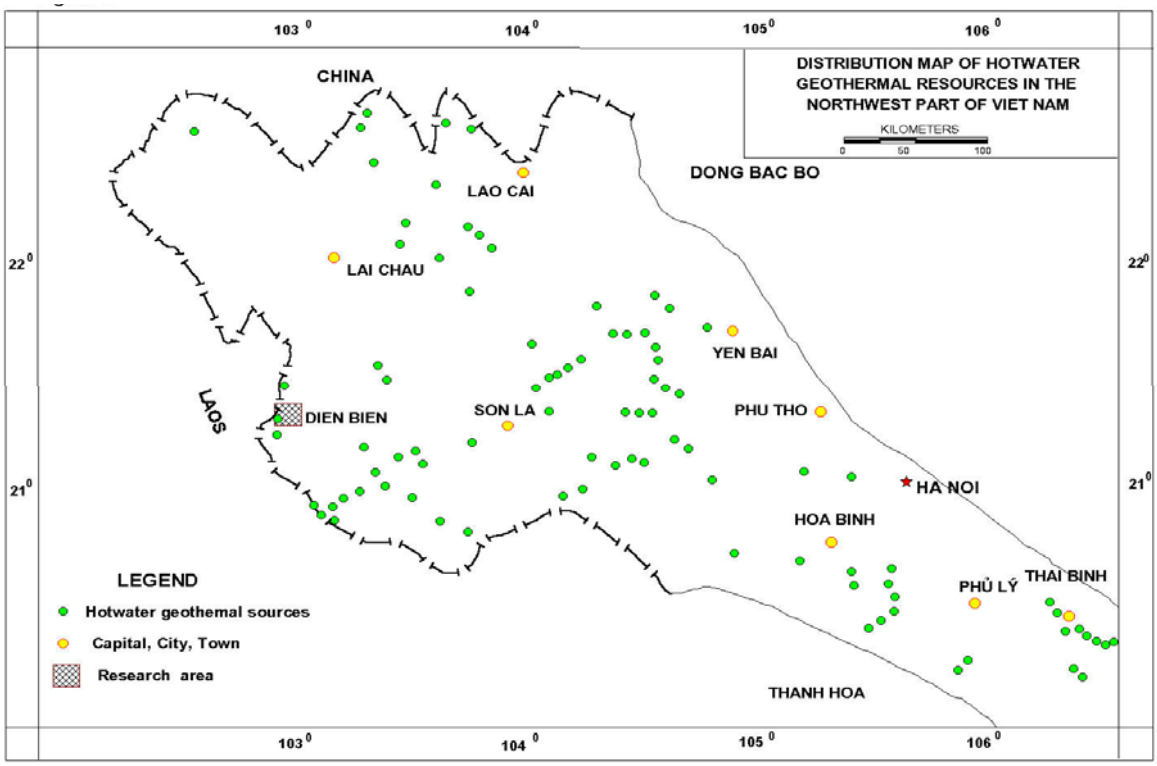

Figure 1: Distribution map of hotwater geothermal resources in the NW part of Vietnam.

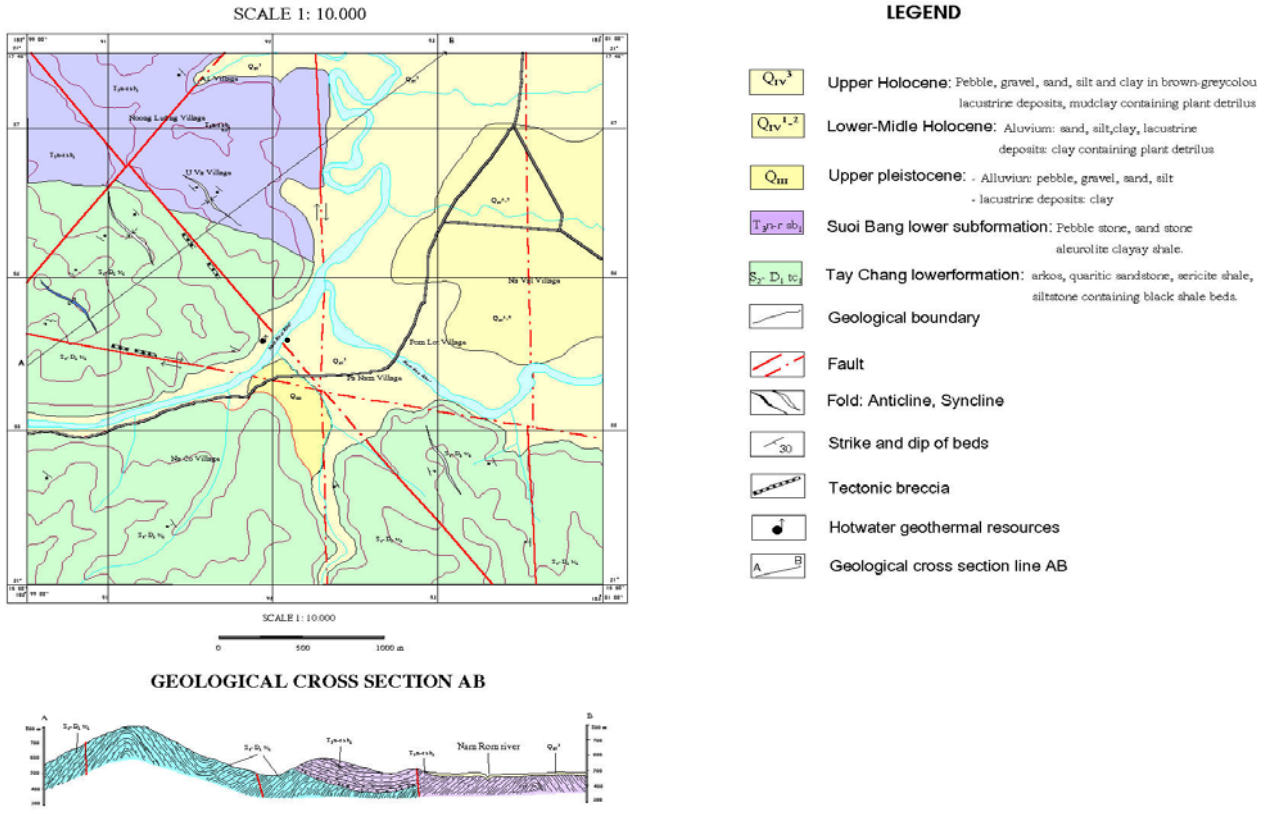

Figure 2: Geological map of Dien Bien region.

2. METHODS OF RESEARCH

The geological, hydrogeological mapping at 1:10.000 scale; rock, water and gas sampling; petrological analysis and compiled cleft rose diagram have been carried out in the Dien Bien region.

The geological mapping of Dien Bien region of 1:10.000 scale was established on the basis of a detailed study and a correlation of the obtained geological, geophysical results etc.

The Dien Bien region is characterized by four main faulted systems: The Dien Bien deep-seated faults, the Nam Rom deep-seated fault, NW-SE fault and NE-SW fault, crossing the Dien Bien basin.

On the geomorphology, the Dien Bien basin is dominated by the depression (15 km long and 4 km wide and elevation of about 450 m) which is a graben whose axis is oriented N-S. Along an axis perpendicular cross section of the Dien Bien graben, the escarpment reduces gradually from two sides to the centre (marking by stair fault series), ranging from 1.200m to 450m. Along the Dien Bien graben axis (outside the Dien Bien geological map), there were mapped Neogene and Triassic acid magmatic rock bodies. The central zone of the depression is marked by the development of the Nam Rom River alluvial plain.

The most recent Dien Bien formations are Holocene, Pleistocene sedimentary series. These formations vary significant'y in thickness from two sides to the centre of the graben. The oldest formations (Triassic, Silurian – Devonian) consist of weakly metamorphosed rocks: pebblestone, sandstone, siltstone; strongly metamorphosed rocks: quartzitic sandstone, arkosic sandstone, slate. At the Triassic time, pebblestone, sandstone, siltstone, slate were formed, then suffered the neotectonic activities, being metamorphosed slightly. In the Silurian and Devonian time, quartzitic sandstone, arkose, slate were formed, being metamorphosed during the late Mesozoic by the contact of some granitic intrusions. Later on, these rocks suffered from Indonesian folding and orogenesis. The activities of neotectonics, the crossing of fault systems and the existence of cataclasitic zones, favored the ascension of geothermal waters.

3. GEOPHYSICS

Geophysical methods that have been used in Dien Bien area include the magnetics, resistivity and radioactivity at the scale of 1:5000. Measured physical characteristics of collected rock samples such as the radioactive concentrations are U, Th, K.

3.1 Magnetics method

The measured magnetic results on the detailed study area show that the magnetic field varies from 10 to 30 nT which suggests that the detailed measurement area is composed mainly of pebblestone, sandstone, siltstone, quartzitic sandstone etc. From the Suoi Bang subformation and Tay Chang formation, we do not find any magnetic anomaly belt. According to the measured magnetic results on the study area, there are no magmatic activities and the hotwater geothermal resources do not relate to subsurface magma.

3.2 Results of polarization section method

Polarization section results of immediate gradient array with AB=500m, MN=60, at the 0.5 Hz frequency on four lines (T2, TOB, TO and TOA), are represented on the phase and resistivity value map at the 1:5000 scale (figure 3).

Section measured results show apparent resistivity values (ρK) ranging from 2 to 2100 ϛm, phase values ranging from 15 to 80 mrad. The results defined two anomaly belts in which apparent resistivity values are lower than 30 ϛm and phase values are lower than 40 mrad. The first anomaly belt is 1.5 km long, 200m wide that means there are NW-SE deep-seated fault systems and these faults are related directly to hot waters in the Dien Bien region. The second anomaly belt is 100m wide, it represents N-S fault but does not relate hot waters at Dien Bien.

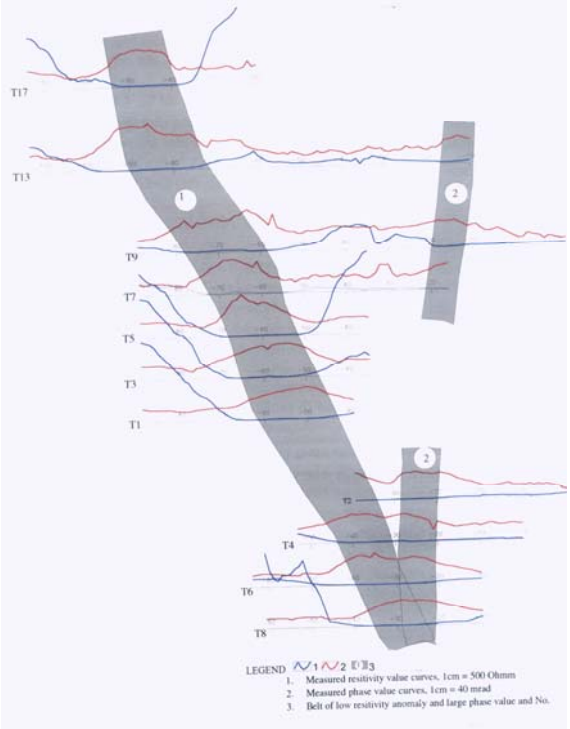

Figure 3: Phase and resistivity value map of Dien Bien region. Scale 1:5000.

3.3 Polarization sounding method

3.3.1 Polarization sounding results on TOP line

Inverse polarization sounding results on the Werner four symmetrical poles array with measured distance of 20m, on the TOP line from –69 pole to –32 pole, (hot water occurrence at –50 pole) were analyzed quantitatively by 2D (RES2DINV) program shown on figure 4. Polarization sounding results let us detect and define the resistivity anomaly zone lower than 35 ϛm and phase values are over 35 mrad. The depth is over 200m relating Dien Bien hot water reservoir, Figure 4.

3.3.2 Polarization sounding results on T6 line

Inverse polarization sounding results on the T6 line from –42 pole to –12 pole are analyzed quantitatively by 2D (RES2DINV) program. The polarization sounding results let us detect and define the 10 ϛm low resistivity anomaly zone and phase values are over 50 mrad. The depth is 200m representing the NW-SE fault zone, relating to hot water in Dien Bien. At the same time, we detect and define N-S fault, this is the small fault that does not relate to hot water at Dien Bien, Figure 5.

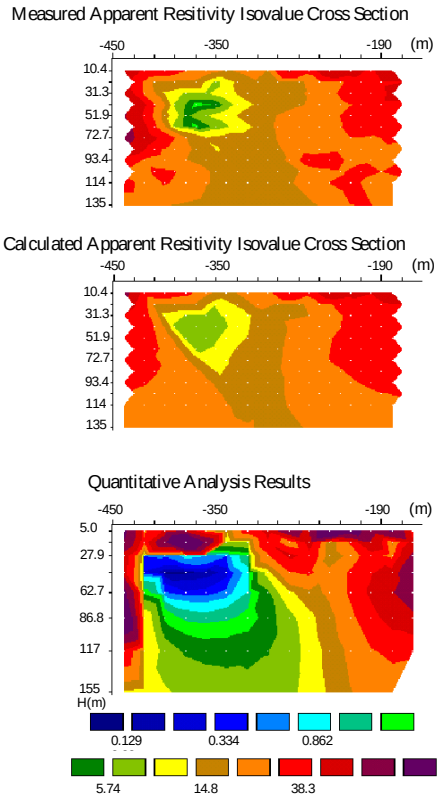

Figure 4: Polarization sounding of T6 line symmetrical array (resisitivity isovalue), Ponlot-Dienbien.

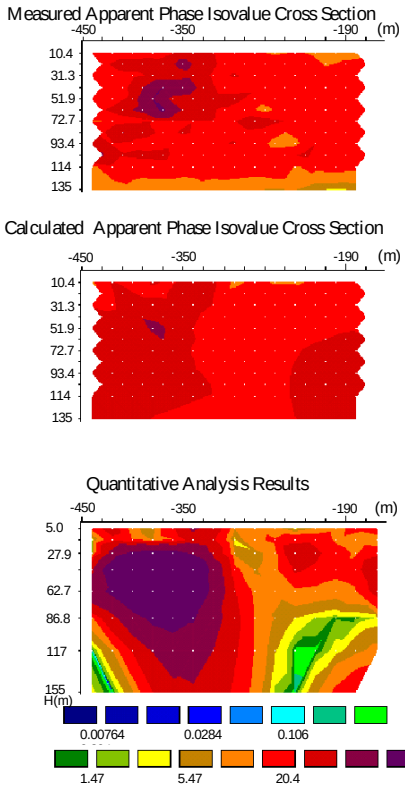

Figure 5: Polarization sounding of T6 line symmetrical array (phase isovalue)), Ponlot-Dienbien.

3.4 Radioactivity energy calculation results.

We have calculated radioactivity energy content based on measured results of density, U, Th content in collected rock samples in Dien Bien.

Based on the calculated results, the study area has radioactivity energy ranging from 1.3 to 3.8 kw/km^3. This energy is smaller than average energy of the Earth, and does not boil water, only contributes to the loss energy of the crust. So the cause of hot waters in Dien Bien does not relate to radioactivity.

4. GEOCHEMISTRY

4.1 Geothermal Geochemistry

Geothermal geochemical activities were carried out to define distribution of Ar and Hg elements in the research site. These elements reflect the distribution of geothermal bodies in the subsurface. The research results show general high Ar element content from 30 ppm to 200 ppm. We define four Ar content levels: <10 ppm; from 10 to 30 ppm; from 30 ppm to 100 ppm and > 100 ppm. Hg content varies commonly from <0,2 to 1,5 ppm. The research site is divided according to the distribution of Hg content: <0.2 ppm; from 0.2 to 0.5 ppm and > 0.5 ppm. The results show high Ar, Hg content-bearing site representing the geothermal body to account for 0.25 km^2 oriented to NW-SE fault.

4.2 Isotopic geochemistry.

Stable isotopic composition of Dien Bien thermal waters, characterized by $-64.8\delta^2$ H$^0/_{00}$ -8.8 δ^{18} O $^0/_{00}$ mean values, lie on or close to the world meoteroric water line. The oxygen and deuterium isotopic chart showing all thermal waters listed lies on close to the SMOW line. Dien Bien thermal waters are listed belonging to precipitation circulation thermal water.

4.3 Hot resource temperature.

Hot water temperatures of all the prospect studies in the North West part of Vietnam were below boiling (the temperatures of occurrence, Tmax = 75^{0}C).

Hot water geothermometry supports this view. A number of silica and cation geothermometer techniques were used in an attempt to estimate the deep fluid temperature. The deep temperature at Dien Bien was defined by using cation geothermometry indicating values from from 114^{0}C to 280^{0}C.

Temperature calculation of Dien Bien Hotwater resources according to the geothermometry

5. CONCLUSION

The geological and electrical regional models suggest an assumed flow path of the hydrothermal fluid strongly constrained by the NWN-ESE, NW-SE fault systems. Indeed, the low resistivity zones detected in Dien Bien region could be related to infiltrated meteoric waters. These fault systems, crossing the Dien Bien depression, would favor the assumed fluid circulation at depth, towards to the Dien Bien graben area. The existing strain field, favors the existence of decompression zones in the crossing areas of the fault systems, which coincide with very low resistivity zones. So, these low resistivity zones would be related to the existence of a geothermal reservoir fed by warmed meteoric waters through the existing fault system. This assumed model is supported by the geochemical surveys, which suggest an underground water flow system characterized by the infiltration of meteoric water flowing downward and mineralized water ascending. Meteoric waters infiltrate at the highest mountainous areas, where rainfall is very important around the Dien Bien depression, percolate at great depth and then emerge in a discharge area at lower altitude. Part of the meteoric waters, representative of precipitation which falls at low elevation, seems to flow into a shallow aquifer at Dien Bien plain.

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Table 1: Geothermometry of Dien Bien hot water

No.	Location	Sample No.	Cation content									Hotwater resources temperature according to geothermometry (C^0)		
			S_iO_2 mg/l	Na mg/l	K mg/l	Ca mg/l	Li mg/l	Mg mg/l	Cl mg/l	S_iO_4 mg/l	HCO_3 mg/l	Quartz	Na/k fournier	Na-k-Ca
1		2	3	4	5	6	7	8	9	10	11	12	13	14
1	Pomlot (Dien Bien)	401	66,77	119	119,32	8,5		7,2	27,56	37,9	518,5	114,7	153,8	241,5