

GEOLOGIC AND GEOCHEMICAL CHARACTERISTICS OF HOI VAN GEOTHERMAL PROSPECT IN BINH DINH PROVINCE, CENTRAL VIETNAM

Chris Klein¹ and Tran Trong Thang²

¹GeothermEx, 3260 Blume Drive, Suite 220, Richmond, California 94806 USA

²Institute of Geoscience and Mineral Resources, Thanh Xuan, Hanoi, Vietnam

e-mail: ttthang@yahoo.com

ABSTRACT

One of the most potential geothermal resources that was found very early and extensively studied by the international geothermics and domestic geologists so far is Hoi Van hot spring in Central Vietnam. The recent studies have shown that the Hoi Van geothermal resource is not related to the volcanic or young magmatic activities in the region. A geologic and geochemical investigation on this geothermal prospect has been carried out in 2010. The result of thermal fluids study concludes that the deep temperatures of the thermal fluid of Hoi Van is about 140-145°C and is can be explored further for developing the electric generation.

Keywords: Hoi Van geothermal prospect, alluvial plain, fluids chemistry, deep temperatures.

1. INTRODUCTION

Hoi Van hot spring is one of 300 geothermal manifestations in Vietnam territory. It is situated in Phu Cat district, Binh Dinh province, is far from Qui Nhon city about 40 km to the North, from the highway No.1 2.5 km and from the sea line 21 km (Fig. 1). This hot spring has been known long time ago and is now utilised for balneological hospital, drying salt with a very small scale and for the people who want to see the hot water which comes from the earth.



Figure 1: Location of Hoi Van hot spring

Since Hoi Van hot spring is found up to now, there were several studies on it. Some of the most considerable researches are the following: a research for potential evaluation of mineral-hot water purpose was carried out by the Hydro-geological Division No.7 of Geological Survey of Vietnam in 1983 with three bore holes and electric resistivity; a geological and geochemical reconnaissance for energy potential evaluation of Hoi Van and some other geothermal resources in Central Vietnam was made by a geothermal and geological group of New Zealand and Vietnam in 1991; a project of investigation and evaluation of 70 geothermal potential resources in South Central Vietnam were carried out

by the Institute of Geoscience and Mineral Resources in 1995. Resulting from the said researches, Hoi Van is emerging as one of the most potential geothermal resources in South Central Vietnam and can be developed for electric generation.

In 2010, in the framework of supporting for LiOA-GP (a unique and newly established geothermal development company of Vietnam) to develop the Hoi Van geothermal potential for electric generation, a geologic and geochemical survey has been conducted by GeothermEx – Consultant company from USA. This paper is to present some of the investigation results of geologic and geochemical characteristics of Hoi Van geothermal prospect.

2. DESCRIPTION OF HOI VAN GEOTHERMAL AREA

Hoi Van is located along a shallow, small river on a large alluvial plain, at an elevation of about 20 m ASL or less (Fig. 2). The November 2010 field survey has been carried out along a 700 m section of the small river named “Hoi Van hot spring” where the geothermal manifestation occurs. The observation and sampling points have been illustrated on a satellite image as Fig. 2.

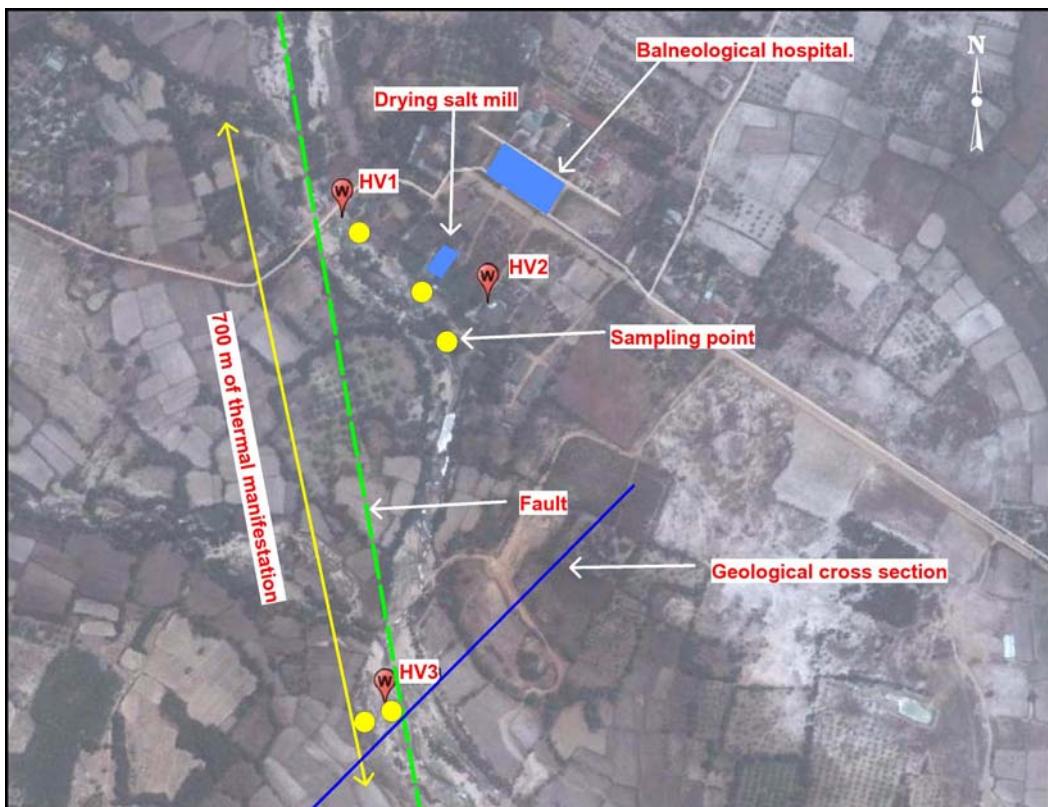


Figure 2: Description of Hoi Van geothermal area

The northern end of the thermal discharge zone is 80 m upstream of a bridge where the local access road crosses the river and two small, outdoor, bar-restaurants have been located. From the bridge moving downstream there are spring and seep discharges from bedrock and overlying sand that occur intermittently along about 700 m of the riverside. The discharges are variously in the river bed and on the left bank except at the far southern end of the zone, where there is a spring on the right bank adjacent to well HV3. In November 2010 the largest spring was flowing at about 40 lpm and the highest spring temperature measured was 79°C. The total spring discharge is uncertain, but seems unlikely to exceed 100 to 200 lpm. A small amount of gas can be seen in the river bed springs and in the flow of well HV3. There are no chemical precipitates at the springs or at the wells (Fig. 2).

Three wells were drilled in the early 1980s:

HV1: drilled to 126 m. KRTA (1993) reported a 300 lpm (5.5 lps) flow of 83°C water without a date. There is a graphical record of flow testing in October and November 1985 that shows a constant temperature of about 83°C and three steps in the flow rate that decrease from about 500 lpm (8.5 lps) to about 360 lpm (6 lps). A record of water sample collection on 3 November 1985 lists the temperature as 85°C and the flow as 500 lpm (8.26 lps). At present there is no access to the well flow at the wellhead itself, but instead a pipeline takes the water about 125 m to the S

where there is a sea-salt drying facility and the pipeline continues to a small balneological hospital. In November 2010 the discharge at the sea-salt-drying facility (into a cement basin) was about 80 lpm at 80°C and it was said that the flow to the hospital was shut-in.

HV2: drilled to 253 m. KRTA (1993) reports that this well found a maximum 71°C and was “less productive” than HV1. There is a graphical record of flow testing in December 1985 that shows a constant temperature of about 71°C and a constant rate of about 140 lpm (2.3 lps). A record of water sample collection on 2 November 1985 lists the temperature as 55°C and the flow rate as 140 lpm (2.28 lps). HV2 now sits idle, as a stub of casing about 1 m above ground level, covered by a board and a loose slab of concrete. It appears that it could be entered for logging.

HV3: drilled to 200 m. KRTA (1993) reports a 78°C flow at about 150 lpm (2.7 lps) without a date. There is a graphical record of flow testing in May 1986 that shows a constant temperature of 75°C (difficult to read) and three steps in the flow rate, decreasing from about 525 lpm (8.75 lps) to about 420 lpm (7 lps). A record of water sample collection on 14 May 1986 lists the temperature as 75°C and the flow rate as 525 lpm (8.75 lps). In November 2010, HV3 was flowing about 50 lpm at 80°C, with entrained gas bubbles, from the vertical casing stub about 1 m above ground level (there is no wellhead valve).

3. GEOLOGIC SETTING

The alluvial plain at Hoi Van lies between hills of granitic rock and related gneisses and schists that lie about 5 km to the W, N and S and locally to the E. Figure 3 shows the general setting of the area. The various intrusive rocks are all of Mesozoic age (>65 million years old) and the nearest younger volcanic rocks are more than 30 km to the NW. Therefore, the heat at Hoi Van cannot be expected to be of magmatic origin.

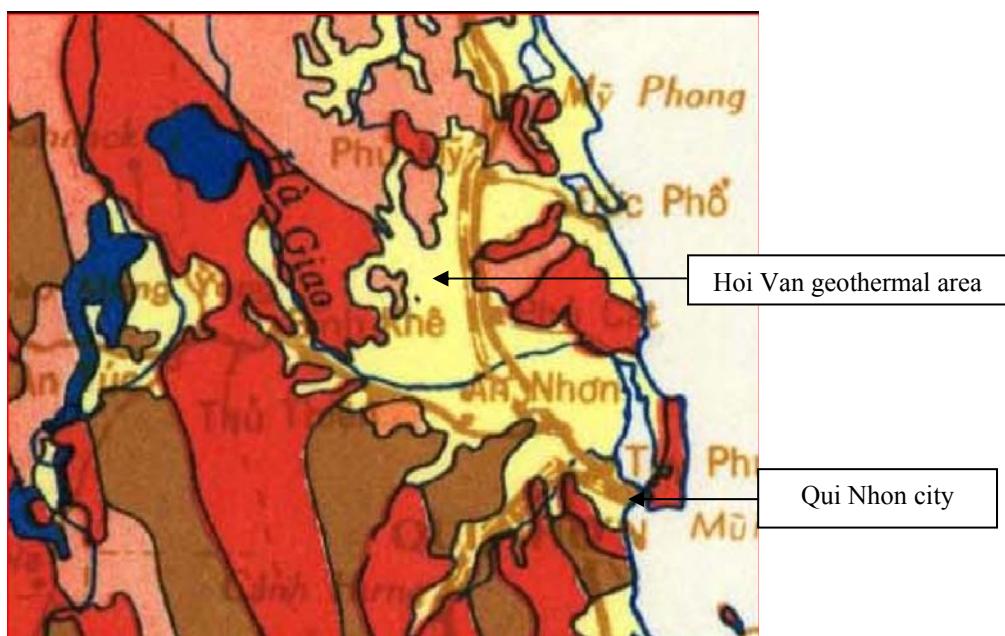


Figure 3: Geologic setting of the Hoi Van geothermal area - Regional view
(Images from: *Geological Map of Vietnam 1: 2.000.000, published in 1971*).

Legend of geological setting in Figure 3.

 Quaternary and recent lacustrine sediments and gravels

 Granite of all age (Trodden down huronian granite of P' ou-Tsi-Lung, song Ma etc..., anthracolitic granites of “Chaine Annamitique” P'ou Bia, South “Vietnam Central part”, Cambodia, etc..., secondary granites of West Cambodia).

 Dacites, rhyolites and micro-granites (form the effusions or intrusions in Upper-Anthracolitic and Lower and Middle Triassic (?): Lower Indosinias rocks).



Bassalts (flows of pliocene age, quaternary and recent, often transformed by alteration in red soil requested for rubber-tree and coffee shrub culture, etc...).



Not separated antehercynian granites, gneis, mica-schist, with or without younger granites.



Devonian rocks with or without Dinantian rocks (Schists, sandstones and limestones of North and East Vietnam, of Ta phin Plateau, of Van Yen sheet, of (Tran Ninh, of Pak Lay region of the “Chaine Annamitique” in lower Laos, of South Central Vietnam, etc..., red sandstone of East North Vietnam and Hue vicinities, sandstones and siliciuos rocks of the Gulf of Thailand, limestones of Cai river, Quang Nam).

The alluvial plain itself is mostly a sandy soil with few out crops of basement. There is a N-S-trending chain of granite and gneiss exposures that passes a short distance to the E of Hoi Van. There is a similar exposure of gneiss about 100 m N of well HV1, and there are exposures of the gneiss in the river bed just S of HV1. According to KRTA (1993), these local exposures (a “vein breccia” up to about 25 m wide) can be traced for about 2 km to the N.

KRTA (1993) further reports that the three wells were sited at the intersections of a N-S-trending fault with several minor N-W-trending ones inferred from field observations, with the location of the springs and with results obtained from geophysical surveys (resistivity, magneto-tellurics and a 1.5 m-deep soil temperature survey). The geophysical survey data and reports were not available for this review. The cross-section on Figure 4 shows a near-vertical fault passing through HV3, but in well-cuttings it also is very difficult to define faults with any certainty.

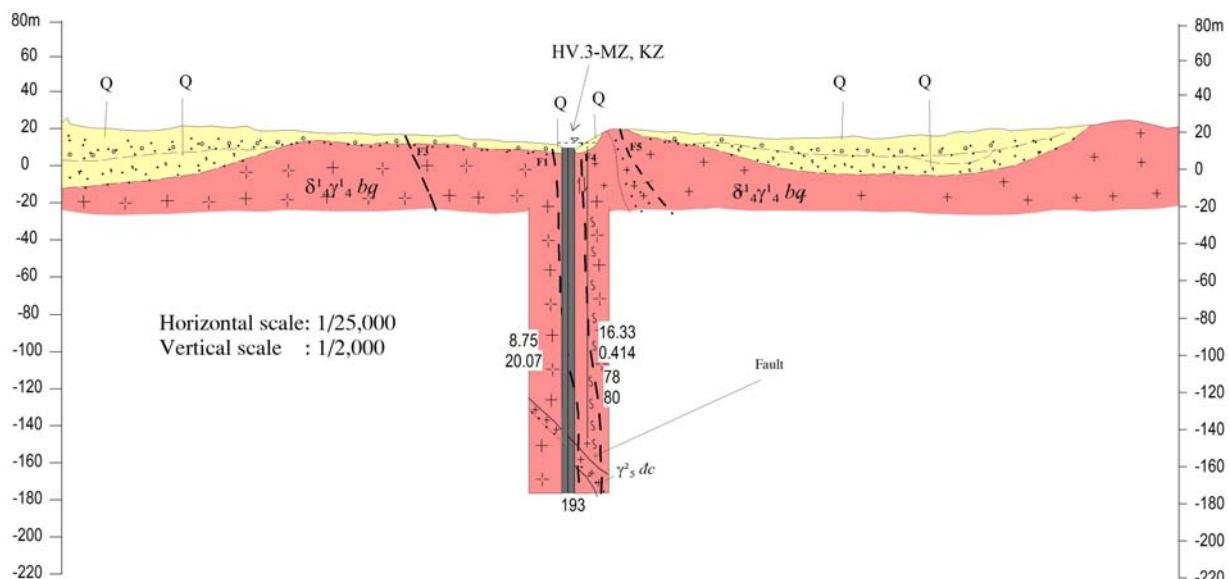


Figure 4: SW-NE geologic cross section through well HV3 (*image from hydrogeological map, scale of 1:25,000*)

All three wells were drilled into the granitic rocks. HV1 is reported to produce from fractures at 30.5 m, 43 m and 120 m. KRTA (1993) reports on petrographic analyses of surface vein samples from the area. The rocks show a high-temperature alteration history, but one that occurred in the distant past and is not related to current thermal conditions.

4. FLUIDS CHEMISTRY

Graphical representations of the Hoi Van fluids chemistry are presented on Figures 5 and 6. Not shown on these graphs are selected samples that were found to be anomalous with respect to other samples from the same sources and also to show a poor ion balance (all of the samples omitted from the graphs are pre-existing data).

The water is a dilute Na-(HCO₃≈Cl) type, with a small but distinct shift to increasing CO₃/Cl moving from N to S. Mixing between two components, one higher in Cl and the other higher in HCO₃ is implied. Normally in such situations it would be expected that: (a) the Cl-enriched component is of deeper and hotter origin and that the HCO₃-

enriched component is of shallower and cooler origin and; (b) other information would tend to confirm this. For example, the shallower, cooler component would be likely to show higher Mg and lower chemical temperatures.

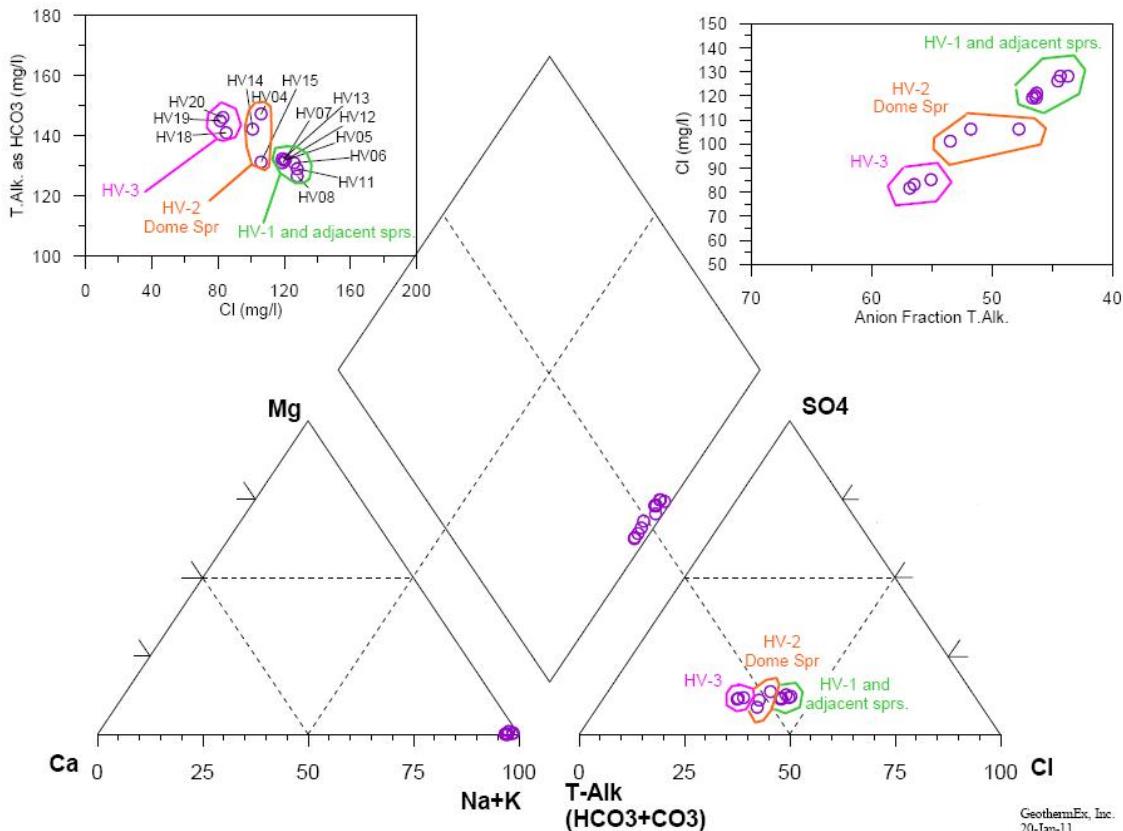


Figure 5: Piper diagram showing samples from Hoi Van

In this case, supporting evidence tends to imply that there is little-to-no temperature difference between the two components: the temperature-sensitive characteristics of HV1 and HV3 are (within normal ranges of uncertainty) effectively the same. This implies that neither component has a notably shallower and cooler origin relative to the other.

Chemical geothermometers of the Hoi Van waters can be summarized from Table 1 as follows, giving precedence to the well data of 1993 and 2010, since these are likely to be the most accurate and because the springs are subject to minor effects of cooling. The Fournier (F and Fg) versions of cation geothermometers are also favored over the Giggenbach (G) versions, because in this setting we consider them likely to be more accurate. Na-K-Ca-Mg and K-Mg temperatures are an automated result of Mg below detection, but values that correspond to the detection limit value are listed below.

All data are in °C:

Table 1: The calculated geothermometers in 1993 and 2010

Well	Na-K (F)	Na-K-Ca	Na-KCa-Mg	K-Mg(Fg)	SiO ₂ (chalcedony)	SiO ₂ (quartz)
1993 result – 2010 result						
HV1	142° – 146°	141° - 142°	141° - 142°	118° - ≥133°	105° - 107°	133° - 134°
HV3	141° – 149°	139° - 144°	139° - 144°	109° - ≥130°	109° - 114°	136° - 140°

The sulfate-water oxygen isotope temperatures under the heading $\delta^{18}\text{O}-\text{H}_2\text{O}$ - SO₄ are not included in the following summary because they are very low (52° - 62°C) and we believe that they are not valid. This geothermometer can successfully indicate the highest and deepest temperatures in a geothermal system because it equilibrates and adjusts to cooling very slowly. In this case, however, it appears probable that the time needed for equilibration has been much longer than the actual fluid residence time in the aquifer at depth.

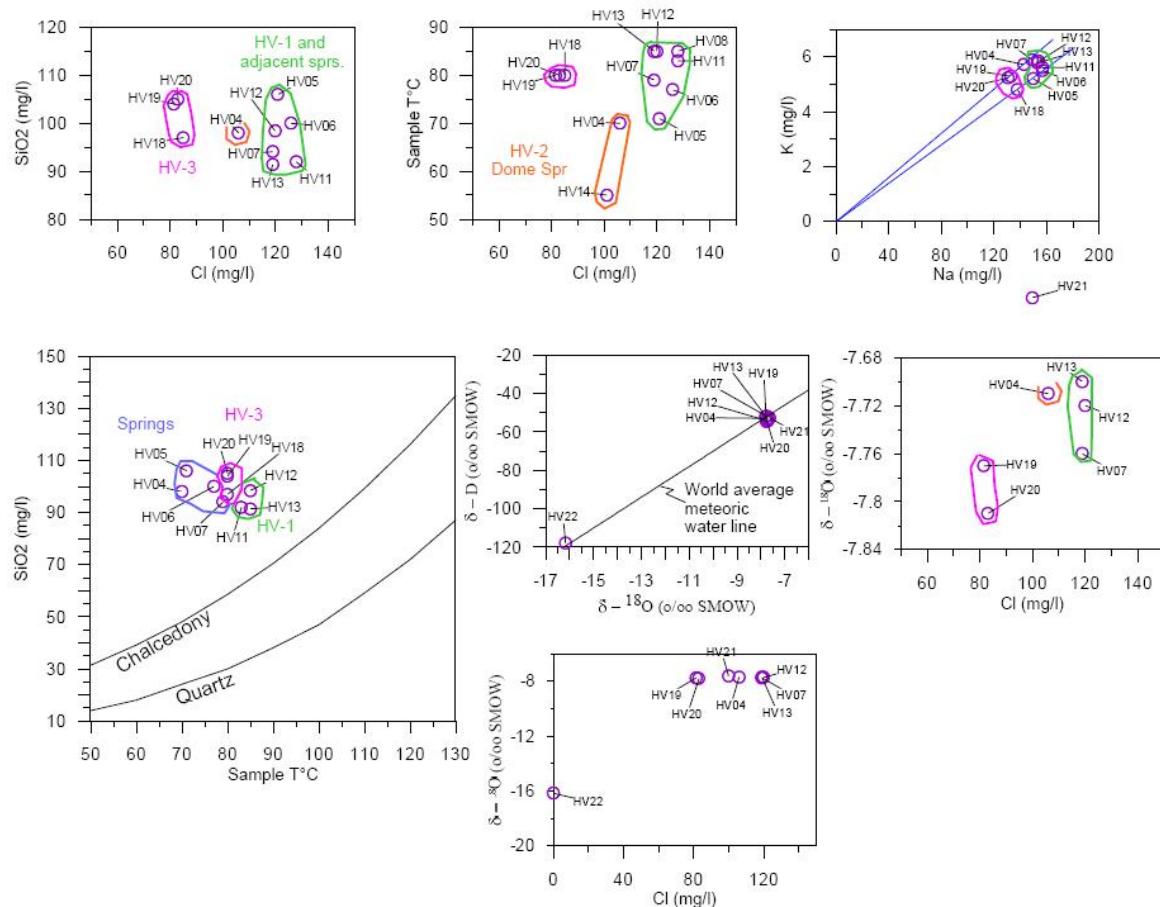


Figure 6: X-Y correlation diagrams showing samples from Hoi Van

The somewhat low K-Mg temperatures of 1993 are caused by higher Mg than detected in 2010, whereas the K-Mg temperatures for 2010 are expressed as minimum values because Mg was found to be below detection at 0.02 mg/l (the minimum values that are listed represent using the detection limit value for Mg). If Mg is instead 0.01 mg/l, then K-Mg for HV1 increases to 147°C and K-Mg for HV3 increases to 144°C. Discounting the 1993 K-Mg temperatures, there are three temperature clusters in the data: (a) 140° to 145°C (Na/K, Na-K-Ca, Na-K-Ca-Mg and perhaps K-Mg), (b) 130° to 135°C (quartz and perhaps K-Mg) and (c) about 110°C (chalcedony). These can be interpreted in light of several general rules:

- Different temperature results from different geothermometers can be the result of cooling in the geothermal system, which occurs as the thermal water ascends from its deepest level of circulation. The higher estimates reflect a failure to adjust to cooling, and the lower estimates represent solutes which have adjusted, completely or in part.
- The uncertainty of cation geothermometers is typically considered to be about 15°C, which is a precision of about one standard deviation when calculated temperatures are compared with real temperatures. Therefore, within one standard deviation, the 140° to 145°C range is actually about 125° to 160°C. Larger errors (to about $\pm 40^\circ\text{C}$) are possible but less likely.
- It is expected that the Mg-bearing cation geothermometers and silica (especially chalcedony) will adapt to cooling (in the aquifer) more rapidly than the Na/K and Na-K-Ca geothermometers.
- The silica geothermometers can be quite accurate, but at temperatures below about 150° to 210°C there is ambiguity concerning which form of silica is controlling SiO₂ solubility. Usually, at lower temperatures the chalcedony geothermometer is more likely to be accurate than the quartz geothermometer. At temperatures below about 100°C it is even possible that neither chalcedony nor quartz is controlling (or has controlled) the amount of SiO₂ in solution.

- It is always possible that the highest geothermometer temperatures represent conditions at depths which are too deep for drilling at an acceptable cost. At such depths it is also possible that formation permeability may be less than needed to support a commercial project.

5. CONCLUSION AND RECOMMENDATIONS

Considering the above, the greatest risk at Hoi Van is that the 110°C chalcedony geothermometer presents the highest temperature likely to be found by drilling to a commercially acceptable depth. Most-likely, however, the low chalcedony temperature is a result of silica equilibration at the depths of the existing Hoi Van wells, and deeper drilling is likely to find temperatures of about 140° to 145°C.

Based on the geologic and geochemical surveys, the geophysical survey is necessary to provide useful information regarding the distribution of rock units in the subsurface (through modelling of density variations) and the location and character of major structural features (reflected in gravimetric discontinuities) and the location and character of major structural features (reflected in gravimetric discontinuities). Although this seldom gives a direct indication of the presence and character of geothermal activity, it is valuable for refining the interpretation of the geologic environment and its relationship to the geothermal system.

It will be critical to define the location, extent and intensity of the thermal anomaly associated with the Hoi Van resource in order to assess the overall potential of the resource and to guide the selection of sites for deep drilling. For this purpose, the most cost-effective information will be obtained by drilling and logging a suite of shallow wells ("temperature gradient holes") designed specifically to measure downhole temperatures.

REFERENCES

Chris K. (2011) *Geologic and geochemical surveys of the Hoi Van and Tu Bong Geothermal prospects, Vietnam*. GeothermEx, California, USA.

Hydro-geological Division No.7 (1993). *An investigation and evaluation of the hot-mineral water of Hoi Van*. Report of the Geological Survey of Vietnam.

Gianelli, G., Piovesana F. and Quy H. H. (1997) *A reconnaissance geochemical study of thermal waters of south and central Vietnam*. Geothermics, Vol. 26, No.4, pp.519-533.

KRTA, 1993. *Geoscientific reconnaissance of selected geothermal areas, south central coastal region, Vietnam*. For: Ministry of External Relations and Trade and Geological Survey of Vietnam. P106100 July 1993. KRTA Limited, Newmarket, Auckland, New Zealand.

Quy H. H. et al. (1995) *Investigation and evaluation of the geothermal resources in the south central Vietnam*. Report of the Institute of Geosciences and Mineral Resources, Hanoi, Vietnam.