THE GEOTHERMAL POTENTIAL OF BILIRAN ISLAND, PHILIPPINES

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SUMMARY - The Biliran Geothermal Field located on the northern tip of Leyte was the subject of geothermal investigation from 1979 to 1982 by the Philippines geothermal company PNOC-EDC and the KRTA of New Zealand. Results of the geoscientific studies lead to drilling three exploratory wells:

- BN-1
- BN -2
- BN -3

Wells BN-1 and BN-2 encountered neutral Cl fluids with T_{Si02} temperatures of 250^{o}C and 210^{o}C respectively. Both wells have a Cl/B ratio of 10, showing the homogeneity of the source fluid.

BN-3, which was drilled closer to the Vulcan Fault, discharged acid Cl-SO_4 waters having a weirbox pH of 3.0. The well reached a Clres of 2,000 mg/kg in its 15 days discharge. It has the very high SO_4, Mg and Fe concentrations typical of acid fluids. The discharge, which was accompanied by high excess enthalpy (360-1403 kj/kg), delivered enough steam to generate from 5-6 MWe. However, the corrosive nature of the discharge fluid destroyed the well head and forced the organization to shut down the well.

Two different conceptual models may be discerned from the interpretations of the Vulcan-Libtong system than have been set forth to date.

In the first model, the heat source is a deep magmatic body beneath the Libtong-Vulcan area. The source drives a convection cell with an up-flow channel located beneath the Vulcan thermal area. The fluid in the up-flow channel contains acid derived from gases and volatiles released by the magmatic body. The acid fluid reaches the surface at the Vulcan thermal area above the central up-flow zone through faults. Within the peripheral outflow zone, extensive interaction between the fluid and host rock neutralized the originally acid fluid. The central zone covers an area of about 9 km^{2}and has an acid and highly corrosive reservoir fluid at temperatures close to 300°C. The peripheral zone covers an area of about 15 km^2; its neutral exploitable reservoir fluid has temperatures of 200-250°C.

The second model is the same as the first with the following important exceptions: within the central up-flow zone acid fluids are limited to depths above 2000 $\pm$ 300 m. Above this depth limit, strongly acidic and gas-rich steam prevails in the reservoir, the gas having accumulated beneath the cap rock over a long period of time. Below this vapor-dominated zone, the reservoir fluid is neutral and similar to the fluid within the peripheral zone.

1. INTRODUCTION

The Biliran Geothermal Project is situated in the Island of Biliran at the northern tip of Leyte. Biliran, which is 1,115 km southeast of Manila, is connected by bridge to the mainland of Leyte where the Tongonan steam field is located. Biliran can be reached by a one-hour flight from Manila to Tacloban and 2.5 hours from Tacloban to Naval. Another option to reach Biliran is via Cebu, which has daily flights on domestic and international routes. From Cebu, it takes 2 hours by a fast ferry to Ormoc and 2 hours more by land to Naval.

The exploration for geothermal energy resources on Biliran Island began in 1979 with the inventory of surface hydrothermal features. Investigative work involving geology, geochemistry and a number of geophysical surveys was undertaken over a span of two years. As a result, three exploratory wells were drilled from 1982 to 1983 in the Vulcan area where the most impressive of the identified thermal areas is located.

Post-drilling evaluation (KRTA, 1986) concluded that neutral chloride fluids permeate the reservoir, but acidic components from a magmatic source introduced into the postulated up-flow region pose a major obstacle to development. Moreover, appropriately high temperatures at exploitable depths appear to be confined to a small area, i.e., less than 15 km^2. Even so, the resource was judged to have potential for a moderate-size development, strategies for which were recommended.

In July 10, 2008, the Philippine Department of Energy awarded a Geothermal Service Contract for Biliran island to the company Biliran Geothermal Incorporated (BGI). BGI is a company specifically established to undertake upstream development activities on island. The company is owned by Filtech Energy Drilling Corporation (Fedco) and Envent Holding Philippines (Envent).

Envent is a renewable energy business dedicated to the exploration of geothermal resources in the Philippines as well as to the development of geothermal power plants in the region. Envent's key shareholders are Reykjavik Energy Invest and Geysir Green Energy, both global leaders in the development of the renewable energy sector, with specific focus on geothermal energy. Both companies are based in Iceland, where almost 100% of the power capacity are derived from renewable sources (23% geothermal).

2. GEOTHERMAL MODELS

The geochemical, geological and geophysical data show the existence of several hydrothermal systems in Biliran (Figure 1).

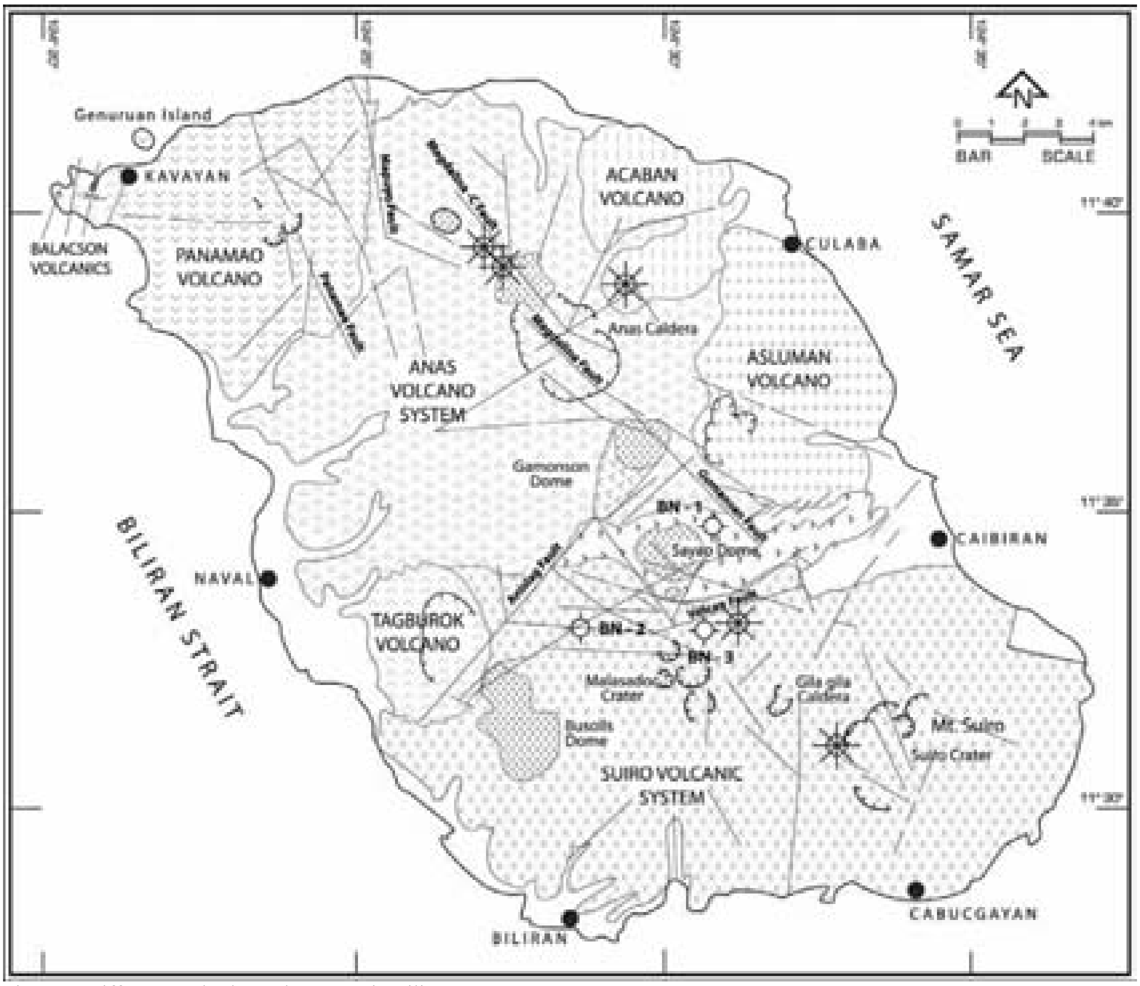

Figure 1: Different Hydrothermal Systems in Biliran

The Vulcan-Libtong thermal area is host to a volcano-magmatic geothermal system as shown in Figure 2. Ample evidence shows that the surface thermal activity in the Vulcan-Libtong area closely resembles the geochemical model proposed by Giggenbach et al. (1990) for the magmatic hydrothermal system in Nevado del Ruiz, Columbia. The chemical signatures of original magmatic vapor are largely retained in the fluid discharge chemistry data and isotope composition of the Vulcan and Tenego thermal discharges. These include:

1. The abundance of acid Cl-SO_4 waters at high elevations having excess Cl and/or SO_4, denoting the presence of free HCl and H_2S or SO_4 in the discharge;
2. Very high gas concentration and temperatures exceeding 300^oC;
3. Relative concentrations of unreactive gas species (He, N2, Ar) and high N2/Ar ratios (300-3,000), showing a definite magmatic contribution; and
4. Isotope composition of Vulcan and Tenego steam discharge, contributing 57-85% of the magmatic water.

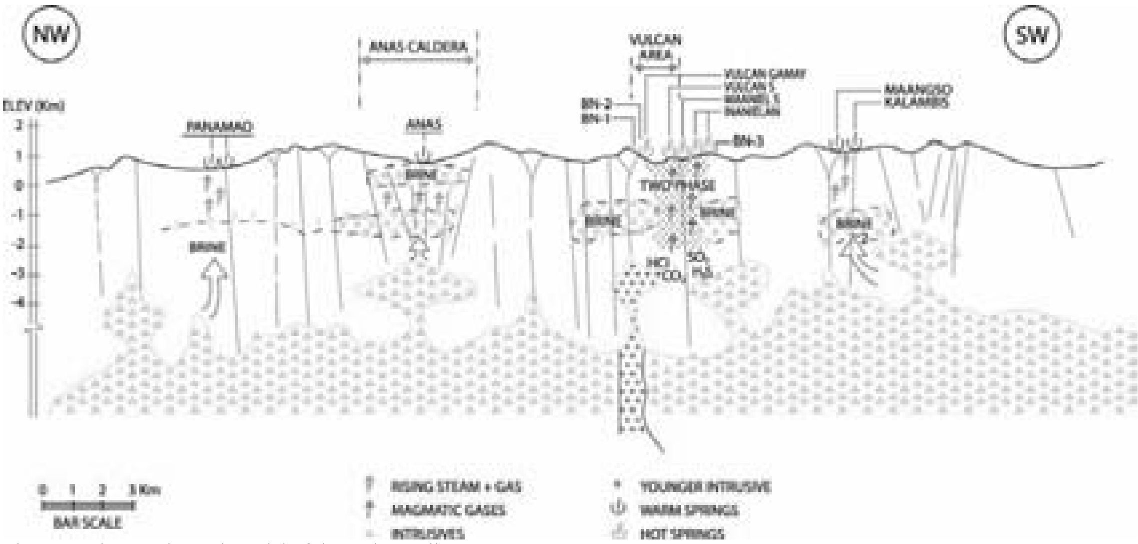

Figure 2: The Geothermal Model of the Vulcan-Libtong Area

The Vulcan Fault (Figure 3) is believed to be the main conduit for the passage of acid magmatic gases from a cooling magma beneath Vulcan to the surface. The heat source driving the system is the small magma body beneath Vulcan located at a depth of around 10 km or more, and which is interpreted to be partly molten.

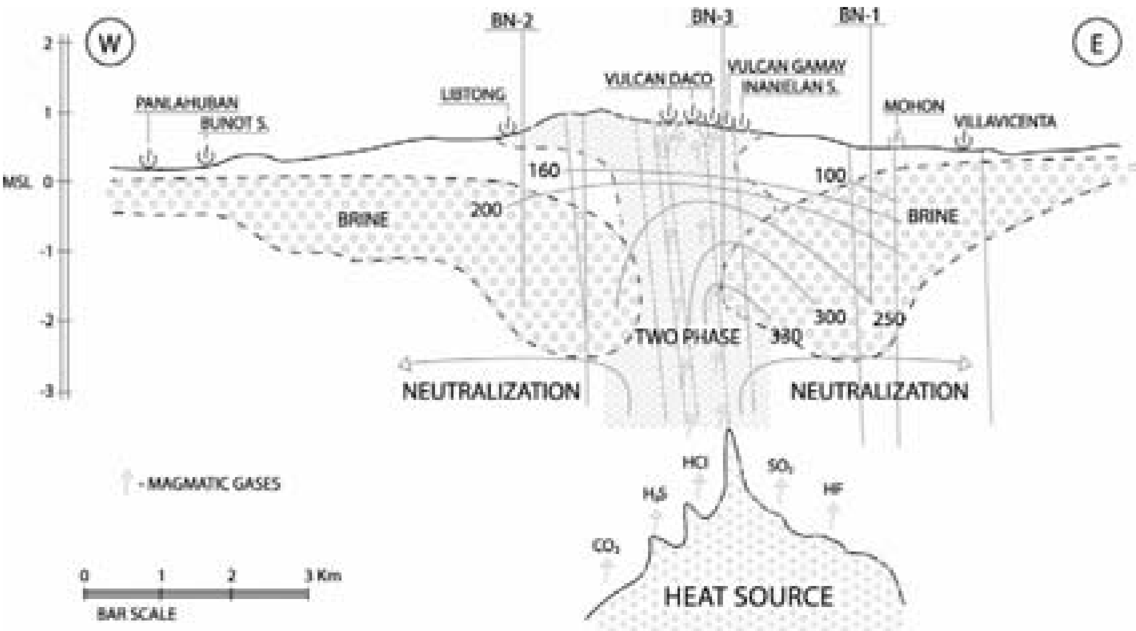

Figure 3: Simplified Geological Map of Biliran

Away from the Vulcan and Tenego thermal areas, a neutral Cl brine has evolved from a previously acidic fluid that was progressively neutralized by intensive water-rock interaction as the fluid migrated laterally. This was encountered at depth by wells BN-1 and BN-2. BN-3, which was drilled close to the Vulcan Fault but does not intersect it, also indicates the existence of neutral Cl fluids at much deeper levels. A shallow permeable zone of this well may have intersected a splay of the Vulcan Fault (Reyes, 1983b), which conducts magmatic gases giving rise to an acidic discharge at the weirbox. This is borne out by the confirmed presence of exotic minerals Lazurite-Scorzalite, which are strong indicators of magmatic contribution.

Wells BN-1 and BN-2 are already in the periphery of the viable geothermal resource as attested to by moderate fluid temperatures (210-240^oC). BN-3 is close to the high temperature resource with a source temperature of at least 300^oC.

The presence of cold acid SO_4 springs in Maangso and Kalambis southeast of Vulcan (Figure 1) may be due to the presence of another deep-seated, but older system related to Mt. Gila-gila with only the mobile gas phase reaching the surface. No subsurface temperature estimates are forwarded because current ionic water-based geothermometers are applicable only to neutral Cl and neutral Cl-HCO_3 waters and not to secondary waters.

Based on their greater geographical distance from Vulcan, the steam-heated acid SO_4 Panamao springs could belong to a separate geothermal system (Figure 1). Likely heat sources are the Mapuyo and Panamao domes (Figure 3). In fact, it is possible that the Panamao and Anas systems are related as discerned from their greater proximity. Also, the Mapuyo and Palayang Bayan Faults (Figure 3) could have merged the two convection system in the past (Pagado et al., 1993).

A shallow hydrothermal system may exist within the Anas caldera (Figure 1), with the caldera wall acting as a barrier to lateral fluid movement. The waters are immature and may have reservoir temperatures just slightly above their orifice temperatures (T_K = 66-68^oC). The likely heat source driving the system in Anas may be related to the sub-caldera intrusive and the relatively large magma body with a possible contribution from Mt. Naliwatan dome, which stands at the rim of the caldera (Pagado et al., 1993).

3. CONCLUSIONS

Biliran Island hosts several hydrothermal systems such as the Vulcan-Libtong, Kalambis, Panamao and Anas. The most impressive among these is the Vulcan-Libtong thermal area, which resembles the geothermal model of Nevado del Ruiz, Columbia. The Vulcan Fault is believed to be the main conduit for the passage of acid magmatic gases from the cooling magma beneath Vulcan to the surface. Away from the Vulcan area, a neutral Cl brine has evolved from a previously acid fluid that was progressively neutralized by intensive water-rock interaction. This was encountered at depth by wells BN-1 and BN-2. BN-3, which was drilled close to the Vulcan Fault, also indicates the presence of neutral Cl fluids at much deeper levels, although the discharge fluids are highly acidic due to mixing of shallow acid zone.

Many proven caldera-hosted geothermal systems are known (e.g. Alto Peak, Valles Caldera), but the Anas caldera has thermal features and chemical characteristics much similar to the unproductive Natib caldera. Discouraging features include inferred low permeability, low reservoir temperature, small resource size, and petrological evidence of a waning system.

Although some characteristics of known geothermal systems are found in Panamao and Kalambis (e.g. identified heat source, fault-related thermal manifestations), the reservoir beneath these areas is too small to sustain a viable geothermal field and may be in its waning stage.

4. REFERENCES

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