GEOTHERMAL PROSPECTS OF SUMATRA (OVERVIEW)

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SUMMARY - There are at least 30 high temperature geothermal systems (inferred *reservoir* temperature >200°C) in Sumatra which transfer heat from crustal intrusions to the surface along the active Sumatra volcanic arc. Their position is controlled by the Sumatra Fault Zone, an active mega-shear zone which follows the median axis of the arc. Large, low temperature resources exist in the Tertiary sedimentary basins of East Sumatra where anomalously high thermal gradients (up to 8°C/100 m) have been observed.

1. INTRODUCTION

The western half of Sumatra is part of an active volcanic arc where, over a length of about 1700 km, a total of 11 active volcanoes can be found. The arc is bisected by the Sumatra Fault Zone (Barisian Fault Zone). All the volcanoes and geothermal systems lie close to or within this fault zone (see Fig. 1). Little has been published about the high temperature systems in Sumatra; the active volcanoes and most solfatara fields have been described by Neumann van Padang (1951); the USGS inventory of Waring (1965) lists 23 localities of hot springs, using in part an old reconnaissance survey (Junghuhn, 1854).

A more recent inventory by Radja (1985) lists 18 geothermal prospects (without classification). Another inventory by GENZL and DESIR (1986) lists 37 warm and hot spring prospects of which 17 are high temperature prospects according to their fluid characteristics.

Geothermal reconnaissance studies have been undertaken over the past 20 years by Indonesian organizations (VSI, PERTAMINA, aid projects and private organizations). Recently I visited most of the geothermal prospects in Sumatra along a 1000 km long section of the Sumatra Fault Zone; interviews and inspections of internal reports provided the background for the assessment of other prospects.

2. HIGH TEMPERATURE SYSTEMS

The visit showed that at least 30 high temperature systems occur in Sumatra, their locality is shown in Fig. 1. For 25 prospects, geological and geochemical reconnaissance data are now available, a total of 10 prospects have been explored by geophysical methods of variable standard. Likely minimum reservoir temperatures can be inferred for almost half of the prospects, gas analyses and isotopic data (D/18O) are available for one-fifth of all prospects. Only one prospect, the G. Kunjit (Lempur) field, has been explored by deep drilling (Hasri, 1984). The majority (at least 18) of the prospects are associated with Quaternary (andesitic) stratovolcanoes and are characterised by concealed outflows of condensates and/or deeper thermal fluids. There are at least 7 prospects which are only known from outflows (3rd group in Fig. 1). The natural heat loss of the high temperature prospects lies within the range of 50 to 300 MW, with a median value of about 100 MW. All prospects appear to be liquid-dominated systems.

There is a high Occurrence of volcanic-geothermal systems where magmatic gases enter the liquid-dominated reservoir and become quenched. High Cl and SO4 values in the acid condensates on top of these reservoirs indicate that they originate from condensation of magmatic gases which can often be found as traces in fumaroles and solfataras located above the upflow zone. There are at least 7 volcanic geothermal systems in Sumatra, each associated with a Quaternary stratovolcano, and five (Sibayak, Sinabun, Pendan, Marga Bajur and Sekincau) can probably be classified as degassing volcanoes.'

Little is known about the structure of volcanic' geothermal systems. The team was introduced in 1980 to describe an unusual geothermal system on Vanua Lava in Vanuatu (Hochstein, 1980; Heming et al., 1982). At least two other volcanic geothermal systems have been explored by deep drilling, namely, Tatun on Taiwan (referred to in Heming et al., 1982) and Biliran in the Philippines (Lawless and Gonzales, 1982). Although the outer part of the Biliran reservoir is saturated with non-corrosive, neutral pH NaCl fluids, the core contains highly corrosive acid fluids. The circumstance that neither the Tatun nor the Biliran prospect has been developed yet indicates the technological difficulties associated with the development of volcanic geothermal reservoirs. Recently another volcanic system has been described in Columbia by Giggenbach et al. (1990). It appears therefore that volcanic systems on the whole are rare elsewhere, but for yet unknown reasons they are widespread in Sumatra. Because of inferred technological problems associated with their development, I believe that all volcanic geothermal systems on Sumatra should be given a low ranking for future development; all volcanic geothermal systems are also associated with a high volcanic risk.

There are 8 liquid-dominated systems for which the source (reservoir) area is known. All 8 prospects in this group (2nd group in Fig. 1) discharge deeper, neutral pH sodium chloride waters in at least one boiling spring (or boiling
Fig. 1. Location of presently known high, intermediate and low temperature systems of Sumatra. Small white arrows indicate volcanic geothermal systems with concealed outflow; black arrow points to the locality of liquid-dominated systems known only from outflows (the first digit identifies the province: 1 for Aceh Province, 2 for Sumatra Utara, 3 for Sumatra Barat, 4 for Jambi, 5 for Bengkulu Province, 6 for Sumatra Selatan, and 7 for Lampur Province). The location of the Tertiary basins was taken from Klemme (1975) and da Silva-C et al. (1980). The position of the Sumatra Fault Zone is that shown by Hamilton (1979).
pool). The only exception is the G. Kunjit (Lempur) field which discharges acid condensates at higher levels. Cation geothermometers (Giggenbach, 1986) indicate reservoir temperatures greater than 220°C for all prospects in this group. These prospects are probably the most attractive ones for future geothermal developments.

Seven liquid-dominated systems are only known from discharges at the top of concealed outflows which discharge neutral pH sodium chloride waters; cation geothermometers indicate reservoir temperatures greater than 200°C. The likely direction of the outflows can often be inferred from the hydrological and tectonic setting (see Fig. 1).

Another group of prospects is characterised by extensive fumarole fields. All six prospects (group with unknown deep fluids but an identified source in Fig. 1) are associated with partly eroded Quaternary stratovolcanoes but only discharge acid and neutralised condensates at higher and lower levels respectively. In two prospects (Sabang and Rajabasa) boiling water is discharged along the seashore but the fluids are contaminated by seawater. In terms of their development potential, these prospects are almost as attractive as those in group 2.

There is also a small group of prospects which cannot yet be classified since they are only known from discharges of mixed condensates (mainly sodium bicarbonate-sulphate waters) which exhibit high temperatures (>65°C) at discharge point or are associated with large travertine deposits (Sipoholon prospect, for example); their source area is also unknown.

So far, only one of the 30 high temperature prospects has been explored by deep drilling - the Gunung Kunjit (Lempur) prospect. This was explored by two 1 km deep holes by a JICA-VSI bilateral aid project in 1984. Well testing showed that both wells bottomed in a liquid-dominated reservoir saturated with neutral pH NaCl water; the bottom temperature is about 200°C (Hasri, 1984). One of the wells was still on bleeding discharge in January 1991. Wellhead pressure was low (of the order of a few bars). The cores of these wells are not thermally altered and indicate rather tight reservoir rocks.

3. INTERMEDIATE AND LOW TEMPERATURE SYSTEMS

Apart from the 30 identified high temperature systems, there are also at least three of intermediate temperature where cation equilibrium temperatures are less than 160°C. Two are associated with the Sumatra Fault Zone, namely Panti and northern Muaralabuh (see Fig. 1). Their high surface discharge temperature (>90°C) has been used in the past to classify them as high-temperature prospects. The fluid chemistry, however, shows that these neutral sodium sulphate waters have affinity with those of intermediate temperature systems standing in granitic host rocks (i.e. no volcanic heat source).

The large Tertiary sedimentary basins of East Sumatra constitute a large geothermal resource. A summary of the temperature structure of the basins has been given by Klemme (1975) and da Silva-C et al. (1980); pooled data from both sources were used to define the areas with anomalous temperatures shown in Fig. 1. Reference to high bottom hole temperatures in these basins has also been made by Hamilton (1979). In the Central Sumatra Basin gradients as high as 8°C/100 m have been observed (da Silva et al., 1980). High gradients have also been observed in wells at the western margins of these basins. It is possible that concealed outflows of diluted thermal waters from the arc transfer heat towards the basins. Such concealed outflows, however, are not the only heat source; other possible sources are deep crustal intrusions (back arc diapirs?) and radioactive heat from the granitic basement. These resources may become important when exploitation of the hydrocarbon resources declines and demand for low grade heat increases.

Only a few warm springs are known in East Sumatra. There are some springs associated with fracture zones in the NE Sumatra Basin, another group of warm springs occurs in granitic rocks on Banka Island. It is likely that warm springs are more abundant in East Sumatra than shown in Fig. 10.

4. COMPARISON WITH GEOTHERMAL RESOURCES ON JAVA

Although all the high temperature systems in Sumatra have not been mapped yet, it appears that the density of high temperature prospects (about two per 100 km2) is somewhat less but of the same order as that of similar prospects on Java and Bali (about 3 prospects per 100 km2). Whereas 7 of the 30 high temperature prospects on Java and Bali have been explored by deep drilling (Dieng, Komojang, Darajat, Salak, Banten, Cisolok and, recently, Wayang-Windu), only one of the 30 known high temperature prospects in Sumatra has been explored by drilling (G. Kunjit prospect). It is likely that geothermal exploration of Sumatran prospects will increase in the near future.

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REFERENCES


