NEW ZEALAND'S COLOMBO PLAN PROJECTS TO DEVELOP INDONESIA'S GEOTHERMAL FIELDS IN 1971 AND 1975

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Keywords: *Geothermal exploration, productive fields, Java, Bali, Indonesia*

ABSTRACT

The aim of the New Zealand/Indonesian Geothermal Colombo Plan Project (1970) was to assess the geothermal potential of five selected geothermal fields on Java and Bali and to rank them for further development. The exploration of the five prospects were undertaken by several Indonesian/New Zealand field teams using geological, geophysical and geochemical surveys between 1971 and 1977. These were undertaken by Indonesian Volcanological Survey and New Zealand government experts from the DSIR. Four potentially productive fields were found: Kamojang, Darajat, Salak-Awibengkok, all located in Western Java, and Danau Bratan (Central Bali). The Cisolok-Cisukarame prospect was found not to be suitable for development.

The survey (and subsequent drilling) led to the discovery of three types of our geothermal systems: Type I: vapour-dominated (Kamojang and Darajat); Type II: liquid-dominated (Salak-Awibengkok and Danau Bratan); Type III: low temperature outflow system (Cisolok-Cisukarame). Halfway during the drilling project at Kamojang, the productivity of the first (small diameter; 6in./152mm) exploration wells at the end of 1974, led to the proposal seconded by New Zealand aid, to extend the Kamojang project. Pertamina came in to assist with the production drilling and contributed to the design of the power house starting in 1978 due to New Zealand's deteriorating financial aid in the late 1970s. The government of Indonesia, through Pertamina and PLN contributed some NZ$10 million towards civil works. The total project was estimated to be NZ$30 million.

Later developments of Darajat and Salak-Parabakti by US companies under licence by Pertamina, together with upgrading Kamojang, (110 MWe) produced a total electricity output of about 850 MWe. This paper is a recognition of the success of the 1970 Indonesian/New Zealand Aid project and its participants from both countries.

1. INTRODUCTION

During the Pelita (first 5-year development plan, 1969-1974), the Indonesian Geological Survey (IGS) and Volcanological Survey Indonesia (VSI) prepared an inventory of natural resources which included geothermal sites with significant manifestations. The catalogues were available from 1970. On behalf of the Indonesian Government VSI, IGS, Pertamina and PLN (State Electricity Company) became counterpart agencies in 1971 for the reconnaissance phase of the Colombo Plan Bilateral Geothermal Project.

A bilateral aid program (Colombo Plan) was proposed to ascertain the geothermal potential in selected parts of Indonesia. New Zealand Government Departments had acquired knowledge of developing geothermal fields for electric power production (Wairakei). A New Zealand Government group of scientists and engineers could assist geothermal aid projects. The aid funds were arranged through the New Zealand Ministry of Foreign Affairs. The program started with low intensity scientific surveys. GENZL Co. was formed as executing agency for New Zealand Government from 1973 onwards. The history of Indonesian/New Zealand Geothermal development programme has been divided into five phases: (1) the first phase, selection of geothermal prospects suitable for reconnaisance surveys (1971), (2) second phase, separate pre-feasibility (reconnaissance) field surveys of five selected fields from 1972 to 1976, (3) third phase, exploration drilling at Kamojang (1974-1975) and Darajat (1976-1977), (4) Fourth phase, production drilling (to 1.5 km depth) for 30 MW Kamojang plant (ten wells) from 1976 to 1979, (5) Fifth phase, design and construction of Kamojang I plant from 1979 to 1982/1983.

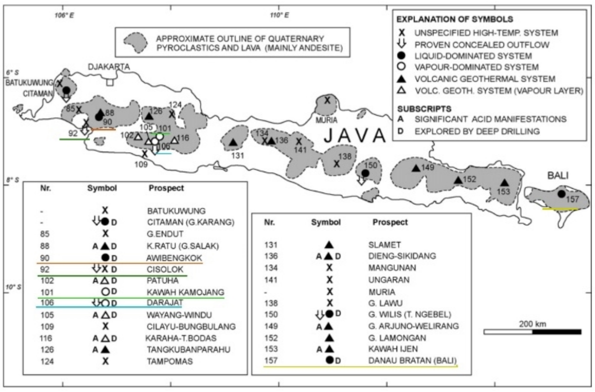

Figure 1: Location of high-temperature geothermal prospect on Java and Bali explored between 1970 and 2000 (Hochstein and Sudarman, 2008).

2. THE FIRST & SECOND PHASE

For the first phase, the reconnaissance survey was undertaken by the NZ Department of Scientific and Industrial Research (DSIR) and Indonesian VSI representative. The selection of suitable geothermal prospects was based on their geological setting, intensity and extent of active thermal manifestations, chemical fluid constituents, and ease of access. The second phase started when four prospects in Java had been selected by 1972. The four areas in Java that were selected were: Kamojang, Darajat, Salak-Awibengkok and Cisolok-Cisukarami; Danau Bratan in Bali was also selected.

2.1 Kamojang (1972 – 1975)

The exploration started with a heat loss survey at the end of 1972, including detailed mapping of thermal manifestations and steaming ground (approximately 100 MW_{th} natural discharge indicated) and detailed mapping of the manifestations. The resistivity structure, reflecting thermal alteration in the past, was mapped with DC-(Schlumberger) arrays and AB/2=500 m and 1000 m current spacings. Traverses together with DC soundings (up to AB/2=1000 m) in the area of interest (±14 km^2) of low resistivity whose thermal structure had to be checked by drilling. The survey was extended in part to the north and south of foothills. The near-surface T-structure was investigated by VSI, using up to 50 m holes, without finding a clear near-surface thermal pattern. The survey data were used to locate the first exploratory well in the phase 3 in the end of 1974.

During this period, there were ongoing negotiations about the scope of the geothermal program. New Zealand industry participants (Ceramco, McConnell-Dowell, Worleys, and Tonkin & Taylor) proposed a larger programme including a pilot geothermal plant development. The pilot plant proposal was approved by the New Zealand Prime Minister, N. Kirk, during a short visit to Indonesia in December to January 1973-1974.

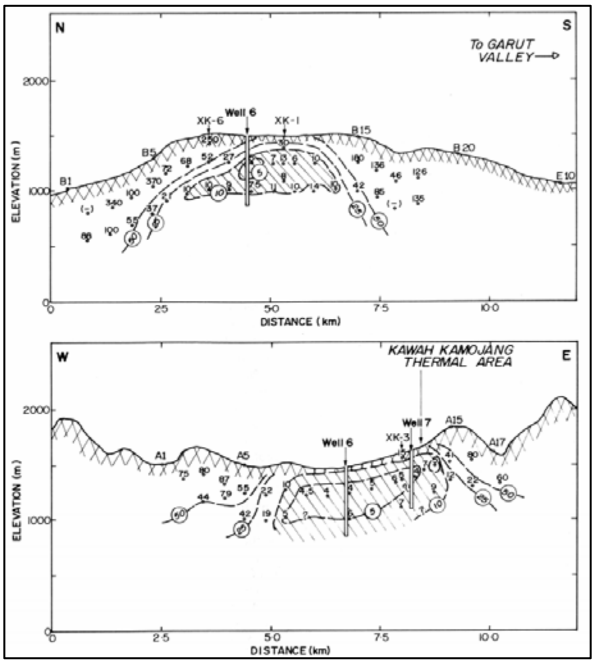

Figure 2: Section of apparent resistivity plotted versus depth (depth arbitrarily chosen as AB/4) along two profiles crossing the Kawah Kamojang Field in a north-south direction (top) and east-west direction (bottom) (Hochstein, 1975).

2.2 Darajat (1973 – 1976)

Exploration started with a heat loss survey, covering steaming ground, fumaroles, hot lakes and thermal springs, yielding a total anomalous heat discharge of 95 MW_{th}. This value is of similar magnitude to that at Kamojang. (Natural heat discharge outflows are indicated.) For the resistivity traversing survey, the same arrays as those used at Kamojang were used, for example DC-Schlumberger arrays with AB/2=500 m and 1000 m, and DC soundings with AB/2 max of 1000 m at approximately 20 sites. The survey outlined an area of approximately 15 km^2 with low resistivity rocks below 300 m depth with a centre beneath high standing terrain in the west while there is a indication in the resistivity contours for a concealed advective flow to the southeast. The survey data were sufficient to site two deep exploratory wells.

By Presidential Decree PD 16/1974, all geothermal exploration in Java and Bali became the responsibility of Pertamina. Similar exploration elsewhere in Indonesia was continued by VSI whose staff was retained at Kamojang until 1976-1977.

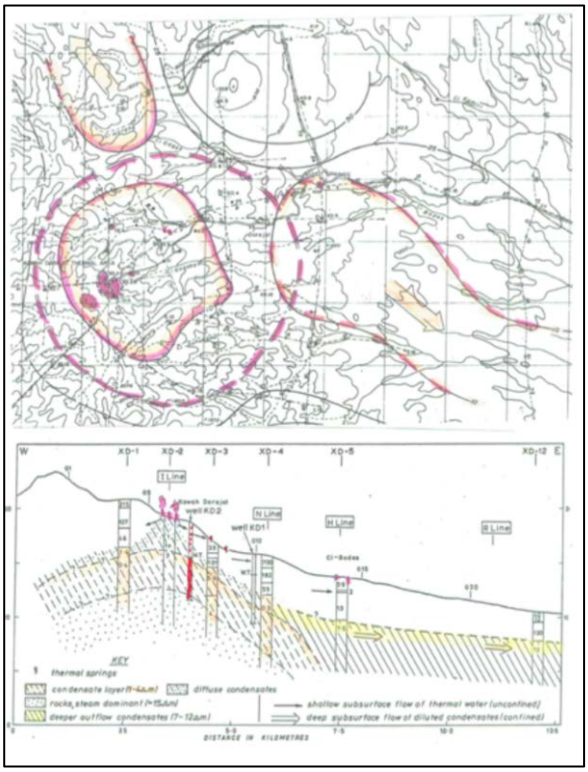

Figure 3: Resistivity cross-sections over inferred Darajat centre.

2.3 Awibengkok-Salak (1974 – 1975)

Reconnaissance studies of the Awibengkok-Salak prospects were the last surveys undertaken by GENZL and VSI staff as part of the New Zealand geothermal aid program between 1974 and 1975. Wide-spread surface manifestations of the prospect occur in rugged terrain over an approximately 100 km^2 large area in dense forest and bush setting. For the resistivity traverse program using AB/2=500 m and 1000 m arrays, a total of 75 km long profiles had been surveyed. The traverses led to the discovery of a large low-resistivity area (the Perbakti System) with a diameter of approximately 5 km in NE-SW section and the smaller Salak Sytem centred on Mount Salak.

Geochemical surveys showed that almost all thermal springs in both areas discharge bicarbonate water with the exception of one spring at the northern periphery of the Perbakti System (Saramaya Spring) where neutral-pH chloride water was discharged. Heat loss studies of fumaroles and steaming ground at Salak indicated losses of the order of 50 MW_{th}; incomplete surveys of the Perbakti manifestations indicated a similar subtotal value.

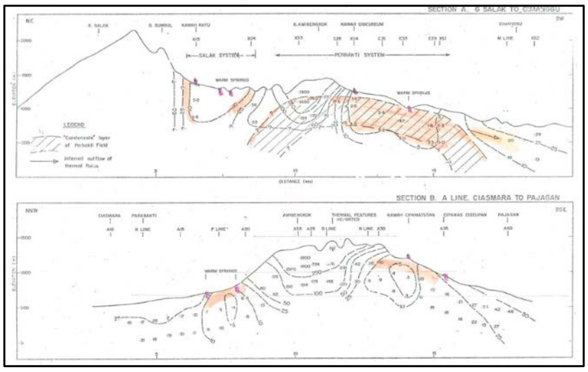

Figure 4: Resistivity sections of Awibengkok (Salak-Perbakti) surveys.

2.4 Cisolok-Sukarame (1972)

Early exploration of the Cisolok-Cisukarame prospects were started in 1972. The manifestations consisted of two large springs (close to boiling temperature) in the centre of the Cisolok River, about 9 km apart. The two groups discharged a total of about 65 MW_{th} using river gauging. The concealed subsurface flows enter the ocean, about 2.5 km downstream from Cisolok.

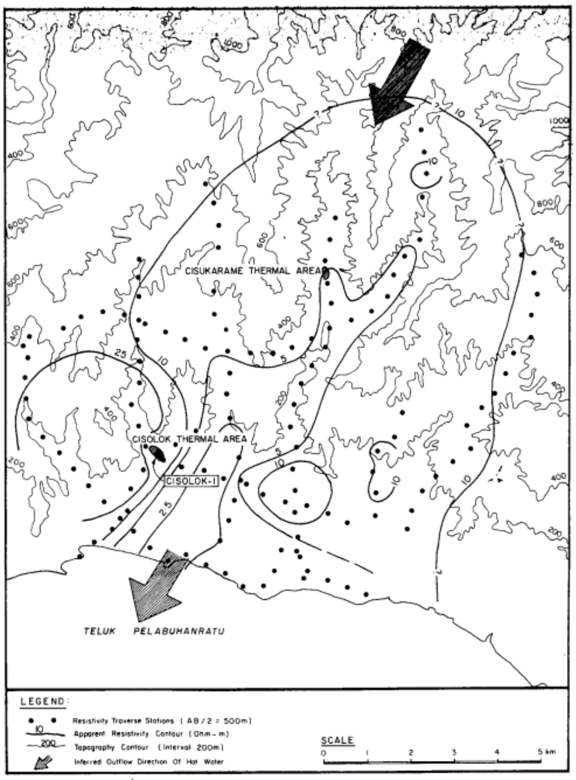

Figure 5: Apparent resistivity (AB/2=500 m) anomaly of the Cisolok-Sukarame outflow structure (West Java) (Hochstein, 1974).

The geochemistry points to the discharge of neutral-Ph NaCl type of thermal water, probably involving a coherent outflow from a high temperature system far upstream. The course of the underground out-flow could be outlined by DC resistivity profiles (AB/2 of 500 m) indicating thermal alteration effects.

The geochemistry of the the springs points to deep upstream T of <150^{0}C, suggesting it was unsuitable for power generation.. The predicted outflow was confirmed by the 1.2 km Cisolok-1 hole, drilled in late 1986 (close to the Cisolok hot springs), which encountered a 1000 m thick outflow of thermal water (bottom hole T was 120^{0}C).

2.5 Danau Bratan, Bali (1971)

Geothermal exploration of the Bali (Danau Bratan) prospect was started as a geological-geochemistry reconnaissance project in 1971 as part of the New Zealand bilateral aid project in co-operation with VSI (Hochstein, 2000). Geophysical (DC-Resistivity) surveys followed in 1973-1975 with results pointing to two elongated low resistivity structures beneath the caldera flanks. The southern flank outflow hosts a 10 km long set of small, aligned bicarbonate springs, about 1000 m below to the level of small acidic discharges near the center of the caldera (Teratai Bang Temple) and the Danau Bratan System. The exploration of the prospect was continued by Pertamina with a gravity survey in 1975. The Bali survey was now led by R. Mulyadi. A temperature-gradient survey in a few, up to 200 m deep T-gradient wells, were drilled as a Phase 3 survey by Pertamina in 1979 (inside and outside the caldera). Later surveys confirmed the earlier model of a large, deep-seated geothermal reservoir (Mulyadi and Hochstein, 1981; Soetantri and Prijanto, 1982).

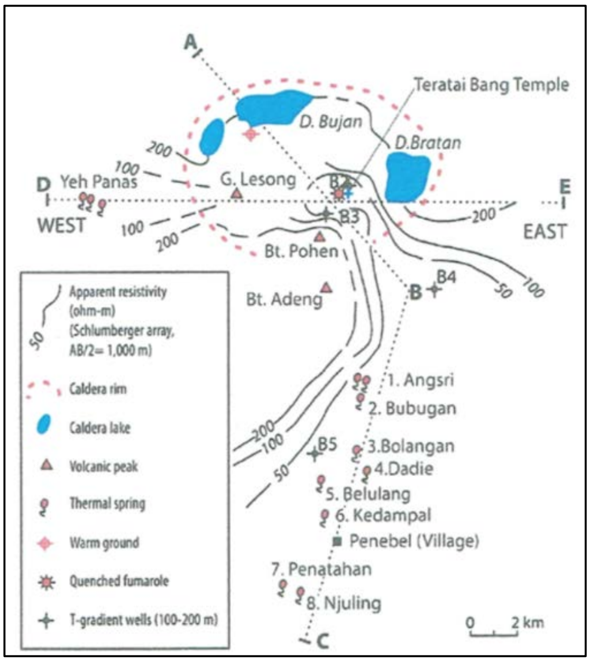

Figure 6: Apparent resistivity map of Bratan Caldera (Mulyadi and Hochstein, 1981)

3. THE THIRD PHASE

3.1 Kamojang Exploration Drilling

To assess the structure and (electric) power potential of the Kamojang prospect, some exploration drilling was undertaken. For this phase, a light, truck-mounted Failing DMX rig, together with ancillary equipment, was hired by the NZ Government from Brown Brothers (Hamilton) who also provided drillers of the project. The rig was capable of drilling to approximately 700 m depth. This well was of small diameter. Well-logging was undertaken by GENZL staff using mechanical Kuster tools, initially provided as long-term hire by the New Zealand Ministry of Works. Five sites were selected for the first exploration wells (KMJ-6 to KMJ-10) with KMJ-6 located in the center of field outlined by resistivity surveys with the other wells located close to the inferred field margin in cooperation with Pertamina, the first 140 mm diameter well (KMJ-6) was spudded in September 1974, with the last well KMJ-10 completed in August 1975. The first two wells were productive and vapour-dominated, and produced 6-8 ton/hour steam from 6-5/8 inch slotted liners (bottom hole at 0.61 km and 0.53 km respectively). Trained engineering staff had joined the GENZL group: N.D Dench, M.D. Allen, H.J. Head, and K.M Holyoake and picked up the new challenge.

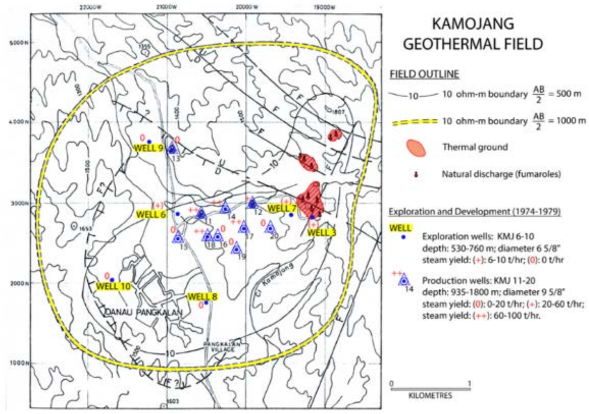

Figure 7: Sites of exploration drilling Kamojang

3.2 Darajat Exploration Drilling

Resistivity traversing maps and interpreted sections, together with results of geochemistry studies were used to propose sites for two exploratory well at Darajat. The Failing MX rig from the New Zealand aid programme budget was used to drill two small diameter wells. The models of the likely location of the reservoir were uncertain: a chemical fluid model postulated an upflow structure beneath the east slopes. There was a geophysical model with the center of the reservoir inferred to be near the center of a large low resistivity structure, near a large hot lake. The first well (DRJ-1) was drilled approximately 3 km down slope from the hot lake in August 1976 (Hochstein, 2000), it went down to 760 m encountering a bottom temperature of 146 °C. The second well (DRJ-2) was drilled near the hot lake in May 1977, found a bottom hole temperature of 239 °C and produced dry steam. The prospect was then taken over by Pertamina and exploration was continued by P Soetantri and S. Sudarman.

4. THE FOURTH PHASE

4.1 Early Production Drilling at Kamojang

During the exploration drilling phase, it was recognised that Kamojang could be developed for power production but that deeper wells were required. A large Mayhew 5000 rig was rented (Trenton Enterprise), refurbished in Singapore under GENZL (and McDow) supervision and transported to Kamojang (arriving one year after completion of the KMJ-10 well in August 1975). The new rig was used to drill ten deep wells (KMJ-11 to KMJ-20). The first eight wells were drilled by GENZL staff with Pertamina supplying crews. The last two wells were drilled by Pertamina using their National T 45 rig and their crews. All ten wells had been located within a narrow, 1.5 km wide east trending strip between the old productive wells KMJ-6 and KMJ-7. The 10 wells were drilled between September 1976 and October 1979 to depths between 930 and 1800 m (Hochstein, 2000). There was no correlation of productivity with depth or location of the wells (5 out of 10 wells were productive). At the end of the first production drilling period, a total of 350 ton/hour of steam supply was available at 5 well heads, approximately 1.5 times that required for a 30 MW_e plant (Hochstein, 2008). Interpretation of down-hole pressure data confirmed that Kamojang was a vapour-dominated geothermal system, a new rare type of system that had not previously been investigated by NZ scientist and engineers, although it was recognized at Larderello, Italy and The Geysers, U.S.A. The exploration data were sufficient to start with the design of the first power-house scheme.

4.2 Installation of the 250 kW_e (mini) plant at Kamojang

In 1978, a plan was promoted by GENZL to use the steam from the productive (slim-hole) exploration well KMJ-6 (near the center of the explore field) to produce electricity for camp buildings and the Pangkalan village. A 250 kW_e 'monoblock' units with free exhaust turbines (WW II vintage) were offered in the U.S. and a unit was purchased in 1978 by Pertamina (after inspection by GENZL staff) and shipped to Indonesia. The unit was installed near KMJ-6 well (Hochstein, 2000) and was tested with success (discharging its exhaust steam with significant noise through an upward tilted exhaust pipe). Towards the end of 1978, electricity from the mini-plant was used in the drilling camp and for lights in much of Pangkalan village.. The mini-plant operated until the 30 MW_e Kamojang plant was commissioned in 1983. It was a successful demonstration introducing geothermal electric power in Indonesia and justifies today a citation for a "40 year-anniversary of electric power use from a geothermal source."

5. THE FIFTH PHASE

The design started already in 1978. A Mitsubishi impulse, double flow condensing turbine with an output of 30 MW_e was ordered (inlet pressure 6.5 bar; steam temperature 162 °C.) The condenser vacuum was 0.13 bar abs. with 29 °C cooling water. The cooling system was designed to provide sufficient cooling water without using surface water. The system included a multicell mechanical-induced draught cooling tower. The generator was a single set, totally enclosed, self-ventilating air-cooled unit, furnished with stationary armature and its single rotor directly coupled to the steam turbine. The output was 30 MW_e, 3 phase and frequency of 50 Hz. Because of NZ's deteriorating financial (aid) in the late 1970's, the Government of Indonesia (through Pertamina) started to fund large parts of the civil construction of the power house. The total costs of the Kamojang project and the four reconnaissance surveys to New Zealand was some NZ$ 30 million, with Pertamina (and PLN) contributing some NZ$ 10 million towards civil works. The power station was commissioned in January 1983 and opened by former president Soeharto. During testing, the effect of fine dust particles in the 'dry' steam had been noticed which led to the late installation of cyclone filters at the entrance of the pilot plant (after January 1983).

6. CONCLUSION

The aim of the New Zealand / Indonesian geothermal Colombo Plan project (1970) was to assess the geothermal potential of 5 selected geothermal fields on Java and Bali and to rank them for further development. Exploration of the 5 prospects were undertaken by several Indonesian – New

Zealand field teams using geological, geophysical, and geochemical surveys between 1971 and 1977. Four potentially productive fields were found (Kamojang, Darajat, Salak-Awibengkok (all on Java) and Danau Bratan (Bali). The Cisolok-Cisukarame prospect was not suitable for development. Exploration and subsequent drilling led to the discovery of 3 types of geothermal systems: Type I: vapour-dominated (Kamojang and Darajat); Type II: liquid-dominated (Sala-Awibengkok and Danau Bratan); Type III: low temperature outflow system. Half-way along the project, the productivity of the first (small diameter) exploration wells at Kamojang (end of 1974) led to the proposal (supported by New Zealand aid) to extend the original project by including the construction of a 30 MW_e power station at Kamojang. This was followed by later developments of Kamojang, Darajat and Salak-Parabakti (together comprising 850 MW_e, half of present Indonesian geothermal power running capacity). This result is the best recognition of the success of the 1970 Indonesian/ New Zealand Aid project and its participants from both countries.

Figure 8: 1987 view of the finished scheme, Powerhouse Kamojang I

ACKNOWLEDGEMENTS

The authors acknowledge Tofan Sastranegara Mochamard and Sigit Suryanto for producting the first version of this manuscript.

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