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Reconnaisance electrical survey for geothermal exploration in the Poring Hot Spring, Ranau, Sabah

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Abstract: Direct current electrical surveys were carried out in the vicinity of the Poring Hot Springs. These surveys have detected the presence of low resistivity layers due to the presence of hot water systems and a sheared zone. The results of electrical sounding and profilings suggest that the hot-water systems are in the form of channels. Electrical surveys carried out to the east and southeast of the hot springs did not detect any low resistivity layer.

INTRODUCTION

Although electrical methods have been applied to numerous geophysical studies, the major application has been in the exploration of geothermal resources, such as in New Zealand, Italy, USA and several other parts of the world (Zohdy *et al.*, 1973; Kumar *et al.*, 1982; Singh *et al.*, 1983). Electrical resistivity surveying is now regarded as one of the most valuable geophysical methods available for geothermal exploration. It was recognised in the early of distinguishing ground saturated with cold water from areas containing hot saline water of geothermal origin.

The bulk resistivities of rocks vary with such factors as temperature, rock type, presence of a steam/gas phase and porosity. According to White *et al.*, 1971, geothermal systems are of two types; hot-water systems and vapour-dominated systems. The electrical resistivity of a hot-water system is lower than the surrounding rocks (Gupta, 1980; Singh *et al.*, 1983). The hot groundwater has high dissolved salt (chlorides) content which lowered the electrical resistivity up to 100 times less than cold groundwater or most rock-forming minerals. The vapour-dominated geothermal systems, however, would give high resistivity and have high concentrations of sulfate anions and low concentration of chlorides (Zohdy *et al.*, 1973).

The Poring Hot Spring is located at an elevation of about 490 meters above sea level in the Ranau District, about 90 km from Kota Kinabalu, the Sabah state capital. The hot spring is under the management of the Sabah Park and is one of the tourist attraction centers in Sabah. Hot water from the main hot spring has a temperature of about 60°C and is used to fill hot water bathing pools. There are other hot springs found in the vicinity (Figure 1). Hot spring B is located at about 100 meters to the west of the main hot spring A, and has a limited flow of hot water with a temperature of about 60°C. The other hot springs are found on the bank of the Mamut river, about 300 meters to the south of the

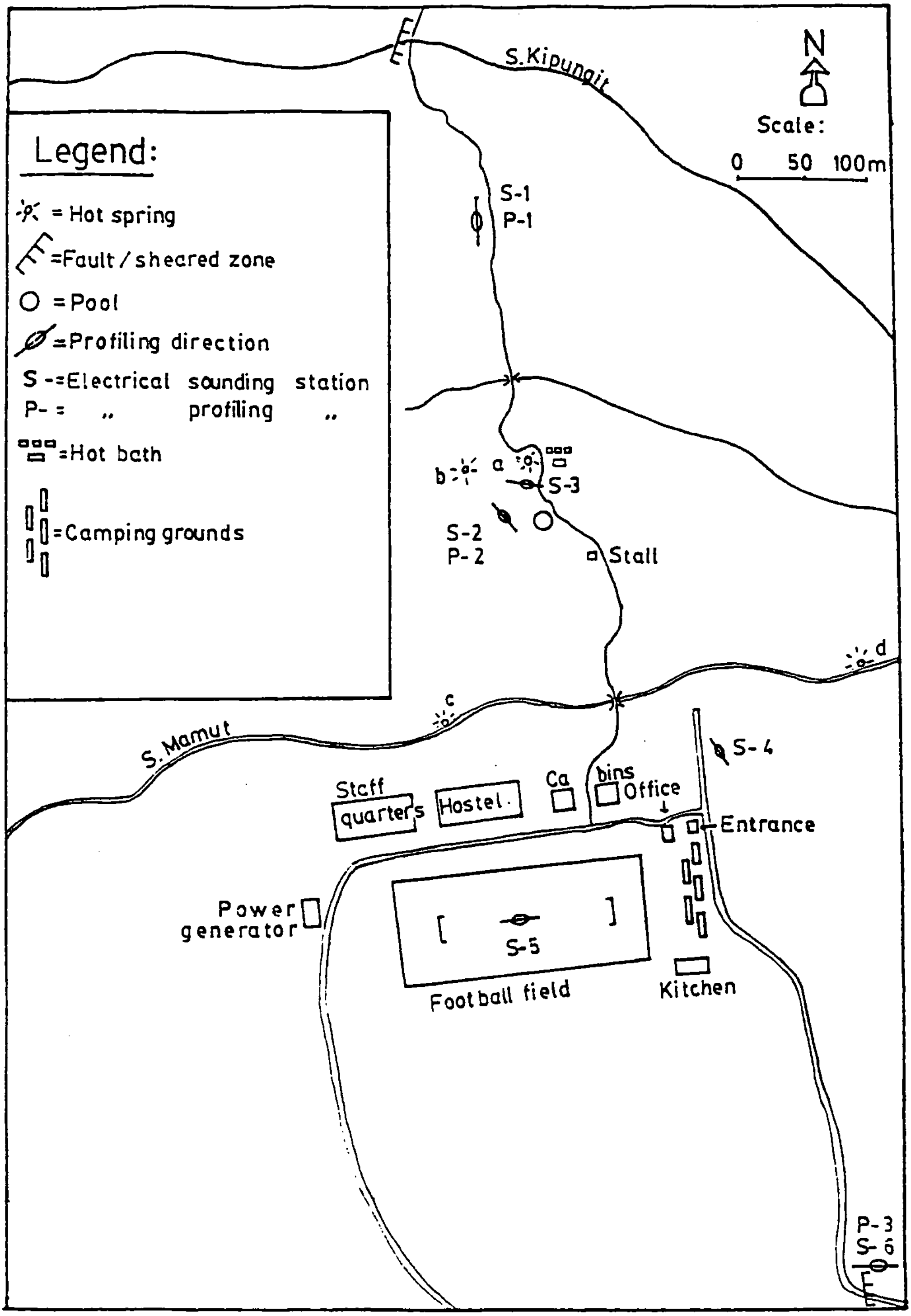

Figure 1: Location of electrical sounding and profiling stations at Poring Hot Spring.

main hot spring. They are about 350 meters apart (east-west) and have lower water temperatures of about 55°C.

Geological setting

The geology of Poring and its vicinity has been described by many authors including Collenette (1958), Haile (1969) and Jacobson (1970). The geology of Poring and its vicinity is shown in Figure 2. The main rock sequence consists of sedimentary rocks, igneous intrusions and Quaternary gravels.

The Trusmadi Formation is of Eocene to Miocene age, and it is made up of metamorphic rocks comprising interbedded metasandstone and argillite. It has undergone various periods of stresses that caused complex structures such as folds, faults and planes of unconformities. Rock exposures are found mostly on the river banks, where they were eroded by the river current, especially in the upper parts of the river.

Igneous intrusions of acid type occurred during the late Miocene-Pliocene, thus causing an uplift of few hundreds of meters above sea level. A later intrusion of adamellite caused the exposure of the older rocks at the surface. It is relatively young and it is believed that part of the magma has not solidified and acts as the heat source for the Poring geothermal system.

The Quaternary gravels are the Pinousok Gravels, tilloid deposits derived from granitic rocks of Mount Kinabalu. The gravels are poorly consolidated and can be found on the flanks of Mount Kinabalu (Jacobson, 1970). These gravels cover nearly the entire Poring area and can be easily seen on the roadsides between Poring and Ranau. Due to unconsolidated rocks, intensive grade of weathering, weaken the bonds between clasts and caused series of landslides along the road connecting Ranau and Kota Kinabalu.

Earlier geophysical exploration of the area

Aeromagnetic surveys have been conducted in the areas covering Mamut Mine and Poring (Akiyama, 1984). The surveys were meant for mineral exploration (copper) in the vicinity of the Mamut area. The principal objective was to locate areas with possible hidden acidic intrusions which might contain porphyry copper deposits like the one at Mamut. Although the survey failed to attain its objective, it revealed a number of previously unknown lithological and structural features. Acidic intrusions give positive magnetic anomalies as can be seen in Figure 3. The positive magnetic anomaly found at Poring Hot Springs is in agreement with what was reported by Younker *et al.* (1982), over the Salton Sea Geothermal Field, USA. The positive anomaly is due to the high susceptibility remanent magnetization of near-surface rock i.e. the acidic intrusion that provide heat for the Poring Geothermal System. There are two other positive magnetic anomalies down stream from Mamut and they might suggest the presence of geothermal systems in the two areas.

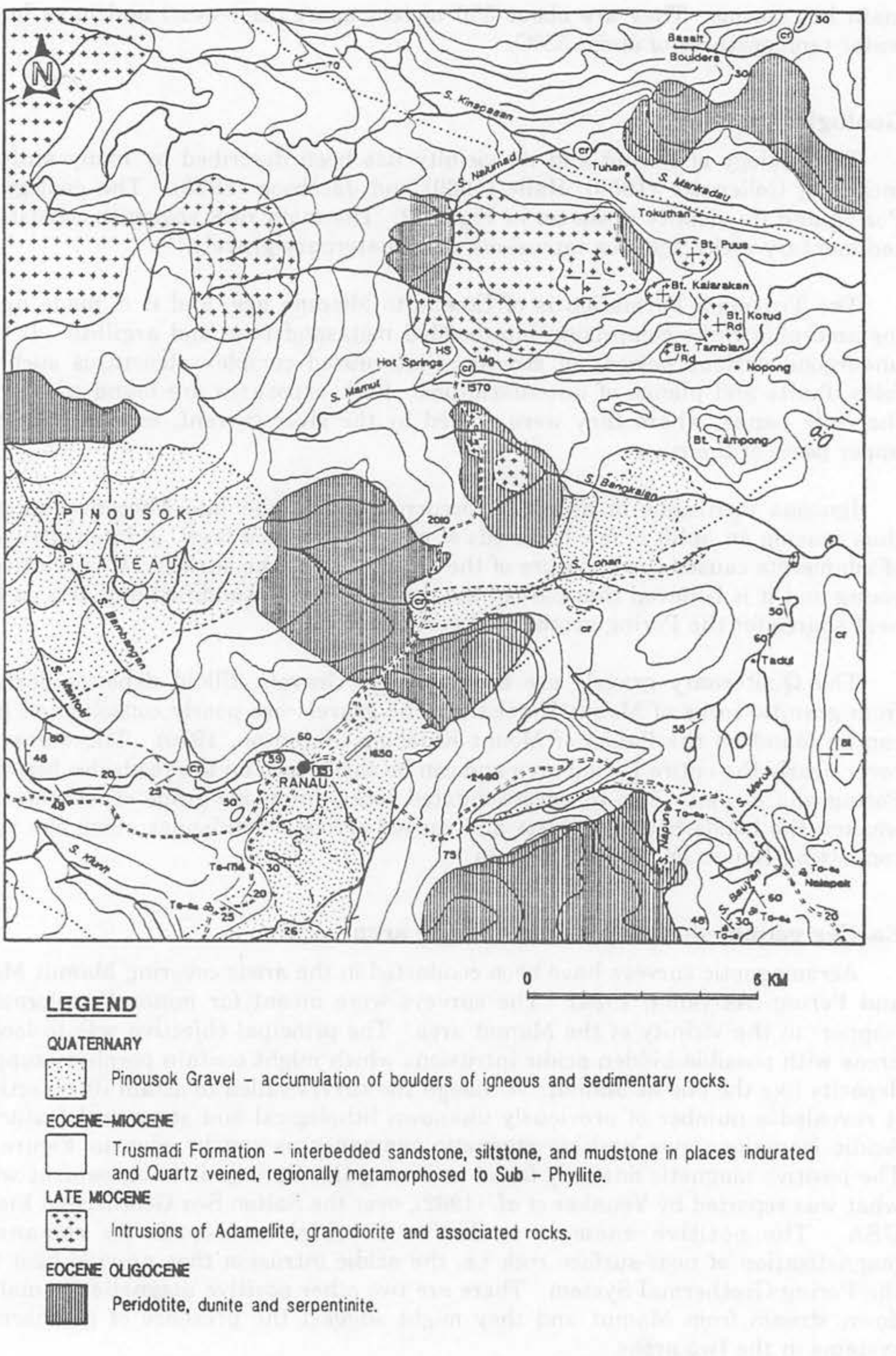

Figure 2: Geological map of Ranau area (After Jacobson, 1970).

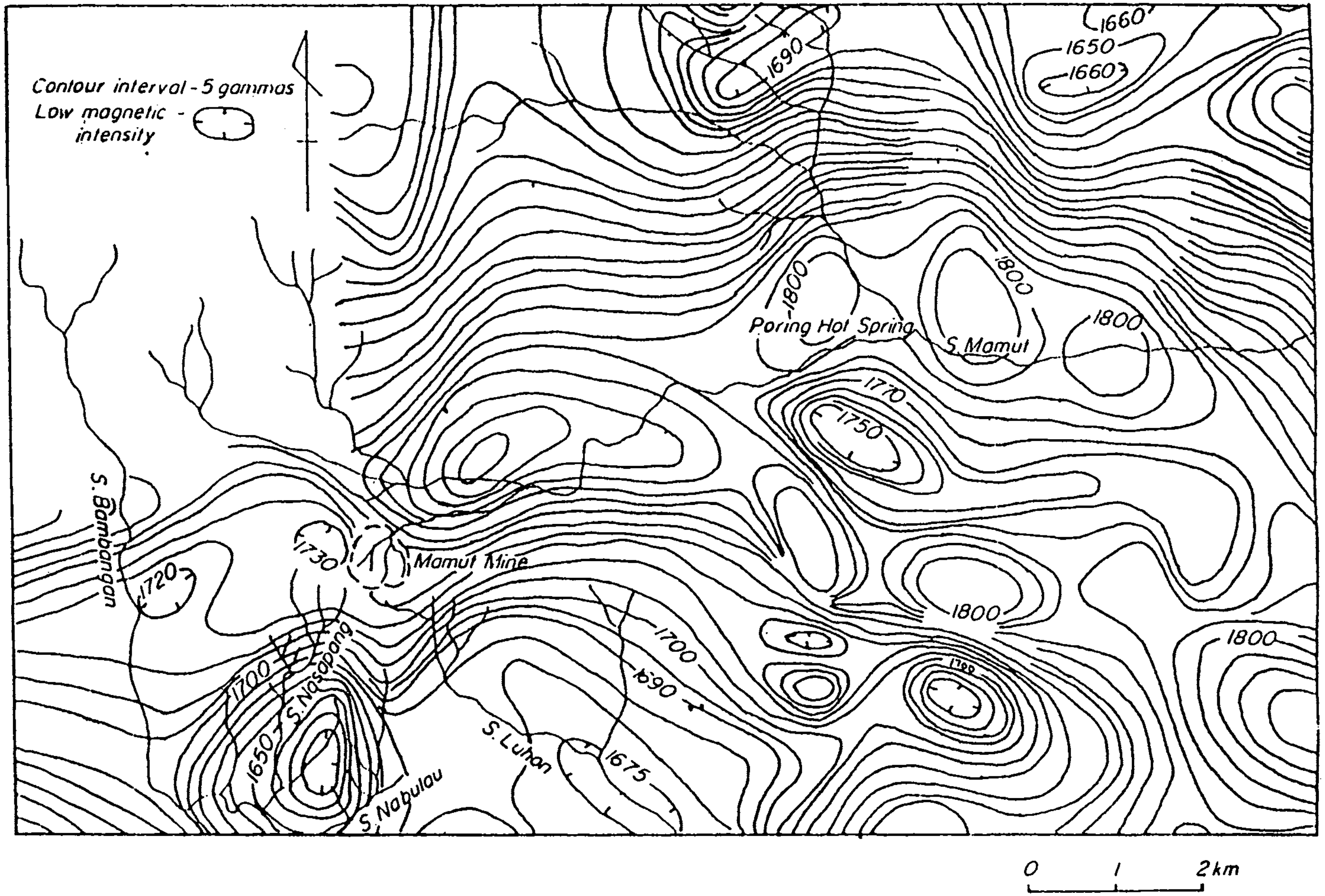

Figure 3: Aeromagnetic survey map (after Metallic Minerals Exploraion Agency of Japan, 1970).

Schlumberger array measurement

For the standard Schlumberger configuration, four collinear electrodes are used (Figure 4). Current from a 12 volt battery is injected into the ground through the outer electrodes (current electrodes A and B), and the amplitude ΔV of the resulting potential is recorded through the inner electrodes (potential electrodes M and N where MN << AB) using an ABEM AC Terrameter. The apparent resistivity (Kearey and Brooks, 1984) is given by:

$$pa = \frac{2\pi\Delta V}{I\left[\left(\frac{1}{AM} - \frac{1}{BM}\right) - \left(\frac{1}{AN} - \frac{1}{BN}\right)\right]}$$

where AM, BM, AN and BN are the distances between appropriate electrodes in Figure 4.

$$pa = 2\pi K \frac{\Delta V}{I}$$

where $K = \frac{a^2 - b^2}{8b}$; a and b are the distances shown in Figure 4.

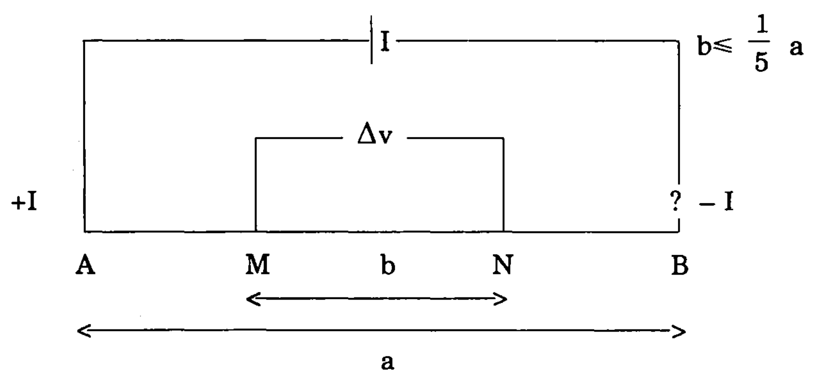

Figure 4: Schlumberger array used in the resistivity measurement.

Electrical soundings

The electrical sounding stations are shown in Figure 1. Electrical soundings are designed to investigate the variation of resistivity with depth. Standard four-electrode resistivity array (Schlumberger), was used for these soundings, with the spacing between the current electrodes incrementally expanded about a fixed centre. The theory of electrical sounding and its interpretation can be found in most geophysics text books such as Griffiths & King (1981), Dobrin (1981) and Telford *et al.* (1978). In Taiwan for example, Schlumberger soundings were used to map geothermal areas as reported by Cheng (1970).

Electrical profilings

Electrical profiling stations are shown in Figure 1. Electrical profilings are designed to determine the lateral variation of electrical properties. Due to the rugged topography, only measurements using distances of 200 meters between current electrodes (AB) were possible. The distance between potential electrodes (MN) was 5 meters. The center was moved along the line every 20 meter without changing the electrode spacing.

Interpretation of electrical sounding curves

Six electrical sounding were made using Schlumberger arrays with maximum electrode spacings (AB/2) ranging from 100 to 200 meters. Interpretation of the electrical sounding curves was made by curve-matching techniques (Ebert auxiliary point method) as described by Koefoed (1979). Exposures at the nearby Mamut river bank and geological information of the area were used in the interpretation process. The electrical sounding curves with their interpretation are shown in Figure 5. The sounding curve S-3 shows three-layer appearance whilst S-2 and S-6 show four-layer appearance and S-1, S-4 and S-5 show five-layer appearance.

The interpretation of sounding curve S-1 indicates the presence of a low resistivity layer (about 79 ohm-m) that extends from a depth of about 3 meters to a depth of about 5 meters. This low-resistivity layer is probably composed of saturated clay and gravels which might be partly affected by the hot water. The station which is about 10 meters higher than the other stations shows the presence of bedrock, weathered to fresh granite (about 1,250 ohm-m), at a depth about 30 meters.

The sounding curve S-2 shows saturated top soil and humus (75 ohm-m) with a thickness of about 2.5 meters. The second layer (750 ohm-m) is interpreted as clays and gravels. A low resistivity layer (150 ohm-m) found at a depth about 3 meters to 10 meters is interpreted as saturated alluvium, boulders and gravels. The bedrock (1,500 ohm-m) is found at a depth of about 10 meters. The sounding S-3 was taken in an east-west direction with the centre about 20 meters from the main hot spring. The top soil is about 5 meters thick (550 ohm-m). The second layer, that extends from a depth of 5 meters to a depth of 45 meters has a low resistivity (39 ohm-m). This layer is interpreted as clays and boulders of granite

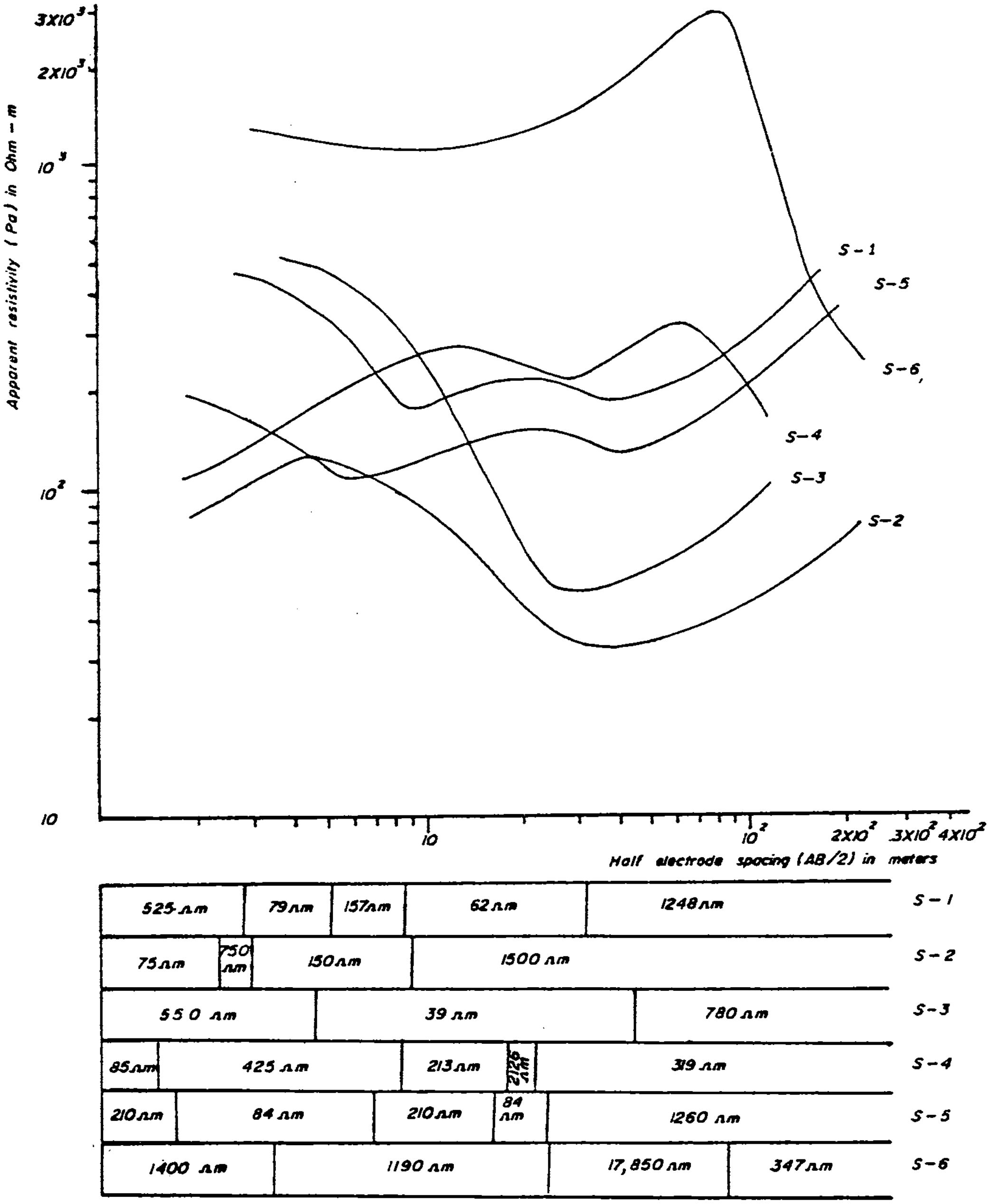

Figure 5: Schlumberger resistivity sounding curves with their interpretation.

probably saturated with hot water. The third layer is the bedrock (780 ohm-m).

The fourth sounding S-4 was taken about 350 meters south- east of the main hot spring. The top soil and humus is about 1.5 meters thick (85 ohm-m). The second and third layers, with resistivities of 425 and 213 ohm-m respectively, are interpreted as alluvium, compacted clays and gravels. The fourth and fifth layers, with resistivities of 2,125 and 319 ohm-m respectively are probably made up of igneous rocks. The low resistivity of the fifth layer might be due to the sheared zone detected by electrical profiling P-3 about 400 meters to the south.

The sounding station S-5 was located about 400 meters south of the main hot spring. The sound curve shows a five-layer type behaviour. The top soil (210 ohm-m) is made up of alluvium, sandy clay and humus having a thickness about 1.7 meters. The second layer (84 ohm-m) which is about 5 meters thick, is interpreted as saturated clayey alluvium. The third layer (210 ohm-m) is about 9 meters thick and is probably made up of sandy clays and gravels. The fourth layer (84 ohm-m) is probably made up of saturated rocks and is about 7 meters depth, is composed of moderately weathered granite.

The sounding station S-6 was taken about 800 meters south east of the main hot spring with the line along the road to Ranau in the east-west direction. The top layer has a high resistivity (1,400 ohm-m), is about 3.5 meters thick and made up of weathered metasediment. The second layer (1,190 ohm-m) is about 20 meters thick and is interpreted as saturated metasediment. The high resistivity third layer (17,850 ohm-m), which is about 61 meters thick, is probably made up of fresh metasediment or granite. The final layer, detected at a depth of about 85 meters (347 ohm-m), is interpreted as a sheared zone probably saturated with hot water is interpreted as a sheared zone probably saturated with hot water. The sheared zone can be seen on the roadside and is confirmed by resistivity profiling P-3 in the same location.

Interpretation of electrical profiling

Three electrical profilings (P-1, P-2 and P-3) were carried out using Schlumberger array as described earlier. The results of the electrical profilings are shown in Figures 6a, 6b and 6c. Profiling station P-1 was in the same line as S-1 to the south of the hot spring. The profile shows two low resistivity areas (180 and 220 ohm-m). These two low resistivity areas are related to the two hot springs (A & B). Profiling station P-2 also shows two relatively low resistivity areas ranging from 40 to 48 ohm-m. These two low-resistivity areas are due to hot springs A, B and C the later being located about 300 meters south of the main hot spring A. The other profiling, P-3 (same station as S-6) was carried out along the road to Ranau. The low resistivity area (71 to 200 ohm-m) is interpreted as a sheared zone as seen from the exposure on the roadside which comprises grey weathered mylonite. The other areas of the profile are made up of weathered metasediment (phylite quartzite).

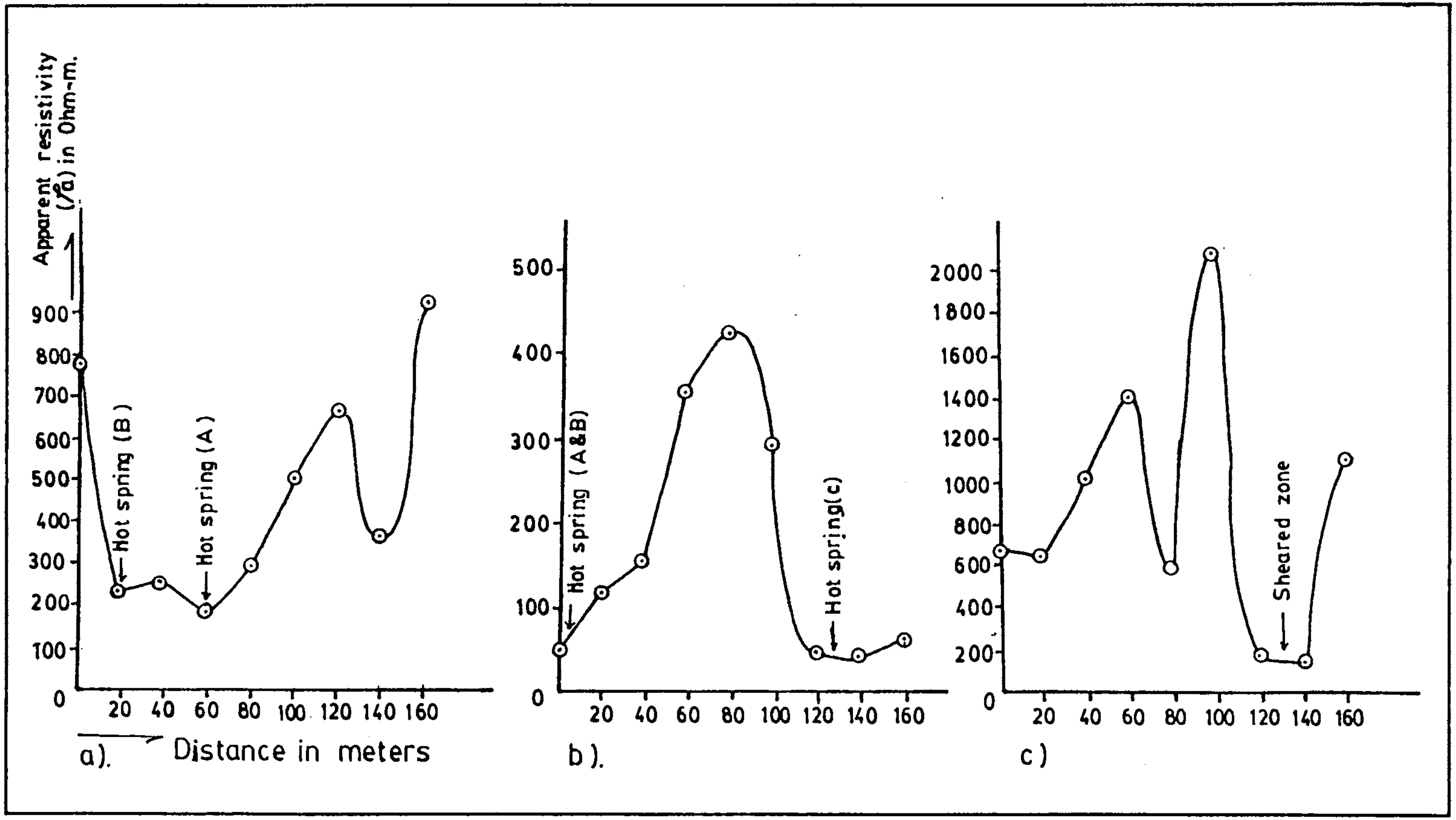

Figure 6: Resistivity profiling: a) P–1, b) P–2, and c) P–3.

CONCLUSION

In the absence of any borehole data, interpretation was made based on only regional and local geological information. Sounding data obtained near the hot springs revealed the effect of the hot geothermal water, which reduces the rocks electrical resistivities. This could be observed from sounding curves S-1, S-2 and S-3 in Figure 5. In general, the resistivity of alluvium, top soil and clayey overburden is in the range of 100-200 ohm-m, whereas the resistivity of colluvium (i.e. clayey top soil with gravels) is a little higher, about 200-500 ohm-m. For the above sounding station, layers with low resistivities (between 30 to 80 ohm-m) were presumably layers that have been affected by the flow of the small hot spring. This was proved by the survey of horizontal profiling near the hot spring, P-1 (Figure 6a) which gives resistivity of 10-30 ohm-m. At station S-3 (closest to the hot spring) the resistivity of the second layer from 5 to 45 meters depth, is 39 ohm-m. The resistivity of weathered granite ranged from 1,200-2,000 ohm-m. Stations S-4 and S-6 located far from the hot springs did not show any low resistivity zone and, thus these areas were concluded as not being affected by the presence of the hot spring.

The hot springs exposed scattered in the vicinity occur as channels or pipes originating from a parental hot body of intermediate to deep depth in the crust/mantle. The hot body appears to be associated with granitoid bodies in the surrounding areas.

The presence of positive magnetic anomalies in the two areas down the Mamut river might suggest the presence of geothermal systems. Future study should be carried out in these areas to search for any surface manifestation and an electrical survey should possibly be conducted.

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REFERENCES

AKIYAMA, Y., 1984. A case history - exploration, evaluation and development of Mamut prophyry copper deposit. *Geol. Soc. Malaysia Bulletin 17*, p. 237-255.

CHENG, W.T., 1970. Geophysical exploration in the Tatun volcanic region, Taiwan. *Geothermic Spec. Issue. 24.2, pt. 1*, p. 262-274.

COLLENETTE, P., 1958. The Geology and Mineral Resources of the Jesselton-Kinabalu Area, North Borneo. *Brit. Borneo Geol. Survey, Mem. 6*, p. 51-58.

DOBRIN, M.B., 1981. *Introduction to Geophysical Prospecting*. McGraw Hill International Book Co. 3rd Edition, 568-591 p.

GRIFFITHS, D.H. AND KING, R.F., 1981. *Applied Geophysics for Geologists and Engineers*. Pergamon Press, 99-111 p.

GUPTA, H.K., 1980. *Geothermal resources: an energy alternative*. Elsevier, Amsterdam, The Netherlands, 75 p.

HAILE, N.S., 1969. Geosynclinal theory and organization pattern of the North-West Borneo Geosyncline. *Journ. Geol. Soc. Lond. Vol. 124*, p. 171-194.

JACOBSON, G., 1970. Gunung Kinabalu Area, Sabah, Malaysia. *Geol. Survey Malaysia, Report 8*, p. 69-79.

KEAREY, P. AND BROOKS M., 1984. *An Introduction to Geophysical Exploration*. Blackwell Scientific Publication, 201 p.

KEOFFOED, O., 1979. *Geosounding Principles, 1 Resistivity Sounding Measurements*. Elsevier Scientific Publishing Co. 103-106 p.

KUMAR, R., SINGH, S.B., GUPTA, M.L. AND RAO, G.V., 1982. Geophysical surveys in Parvati Valley Geothermal Field, Kullu, India. *J. Volcanol. Geotherm. Res., 13*: p. 213-222.

METALLIC MINERALS EXPLORATION AGENCY OF JAPAN, 1970. *Aeromagnetic survey of Kinabalu-Tumbuyukan Areas, Sabah, Malaysia. Part one*, 1-28 (unpublished).

SINGH, S.B., DROLIA, R.K., SHARMA, S.R. AND GUPTA, M.L., 1983. Application of resistivity surveying to geothermal exploration in Puga Valley, India. *Geoexploration, 21*: p. 1-111.

STUDT, F.E., 1958. Geophysical Reconnaissance at Kawerau, New Zealand. *New Zealand Journal of Geology and Geophysics 1*: p. 219-246.

TELFORD, W.M., GELDART, L.P., SHERRIFF, R.E. AND KEYS, D.A., 1978. *Applied Geophysics*, Cambridge University Press. 632-693.

WHITE, D.E., MUFFLER, L.J.P. AND TRUESDELL, A.H., 1971. Vapor dominated hydrothermal systems compared with hot water systems. *Econ. Geol., 66*: p. 75-97.

YOUNKER, L.W., KASMEYER, P.W. AND TEWHEY, J.D., 1982. Geological, geophysical and thermal characteristics of the Salton Sea Geothermal Field, California. *J. Volcanol Geotherm. Res., 12*: p. 221-258.

ZOHDY, A.A.R., ANDERSON, L.A. AND MUFFLER, L.J.P., 1973. Resistivity, self potential and induced polarization surveys of a vapor-dominated geothermal system. *Geophysics, 38(6)*: p. 113-114.

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