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One Dimensional Resistivity Sounding for Resolving Gem-bearing Gravel Layer: A Comparison of Schlumberger with Wenner Techniques at Bo Rai, Eastern Thailand

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Abstract

A direct detection of gem-bearing gravel is very difficult in areas covered by basaltic layer, especially in the eastern Thailand gem field, since the resistivity contrast between the gravel and basalt layers is usually much greater than the resistivity contrast within the bedrock itself. Electrical resistivity surveys are considered to be the most effective method for resolving gem-bearing gravel overlain by basalt environment. Schlumberger and Wenner electrode array configurations were applied to resistivity sounding in order to compare their effectiveness in the eastern Thailand gem field. When compared with a known lithological section in the Bo Rai area, Thailand, both survey arrays in this study were able to detect a high resistivity layer of gem bearing gravel layer, which is located under the basalt. However, the Schlumberger array is clearly more suitable for detecting zones of local gem-bearing gravel layers being more efficient, faster and more economical than the Wenner array. Thus the Wenner array is considered an option only in terrains where Schlumberger sounding cannot be conducted due to a lack of open space.

Keywords: sounding resistivity, gem-bearing gravel layer, Wenner, Schlumberger

1. Introduction

Gem deposits of the eastern Thailand have been important sources for the SE Asian gemstone markets. Gemstones have been mined from present alluvial (or gem-bearing gravel layer) and palaeo-alluvial channel deposits (Yui et al., 2006), that makes them similar to the well-known gem deposits of Vietnam, Laos and Australia. The most common genesis model described for this deposit is related to the alluvial deposits in which gemstones are eroded from their primary source by water and then accumulated within the gravel layer. Many of the deposits are underlain by Cenozoic basalts. These basalts were reported to carry good-quality gems (Vichit, 1992; Jungyusuk and Khositanont, 1992). At present, there is a rapid depletion of available gemstone reserves, creating a significant demand for finding new prospective sites. However, the near-surface gem deposits are now almost exhausted and so exploration should be launched for deposits in the deeper parts.

It is currently widely accepted that results from subsurface resistivity data collected in environmental, geological and archeological studies can be correlated to the degree of fluid saturation in the subsurface, lithology, porosity and the ionic strength of subsurface fluids (Paranis, 1997). Electrical-resistivity surveys have been used for locating and mapping buried gravel deposits since the 1950s (Jakosky, 1950; Welkie and Meyer, 1983). In general, the applicability of electrical methods to gravel exploration is based on the high resistivity of coarse-grained materials, in contrast to surrounding clay, silt or soil (Beresnev et al., 2002). Also, the electric resistivity parameter is highly dependant on the porosity, water content and conductivity of the fluid and the percentage of clay minerals (Telford et al., 1990).

The focus of this survey was primarily of a qualitative nature of the evaluation of the gem bearing gravel signature compared to the surrounding rock, whilst the objective was to compare the capability of two different array configurations, the Wenner and Schlumberger arrays, to see if resistivity could be used to map near surface gem bearing gravel in the Bo Rai gem mining area, Trat (eastern Thailand).

In the following section, two array configurations are discussed to demonstrate the potential resistivity sounding technique as a routine geophysical tool for the exploration of gem bearing gravel exploration especially in eastern Thailand and other subsurface study. The survey site is located in Bo Rai, Trat Province of eastern Thailand (Figure 1).

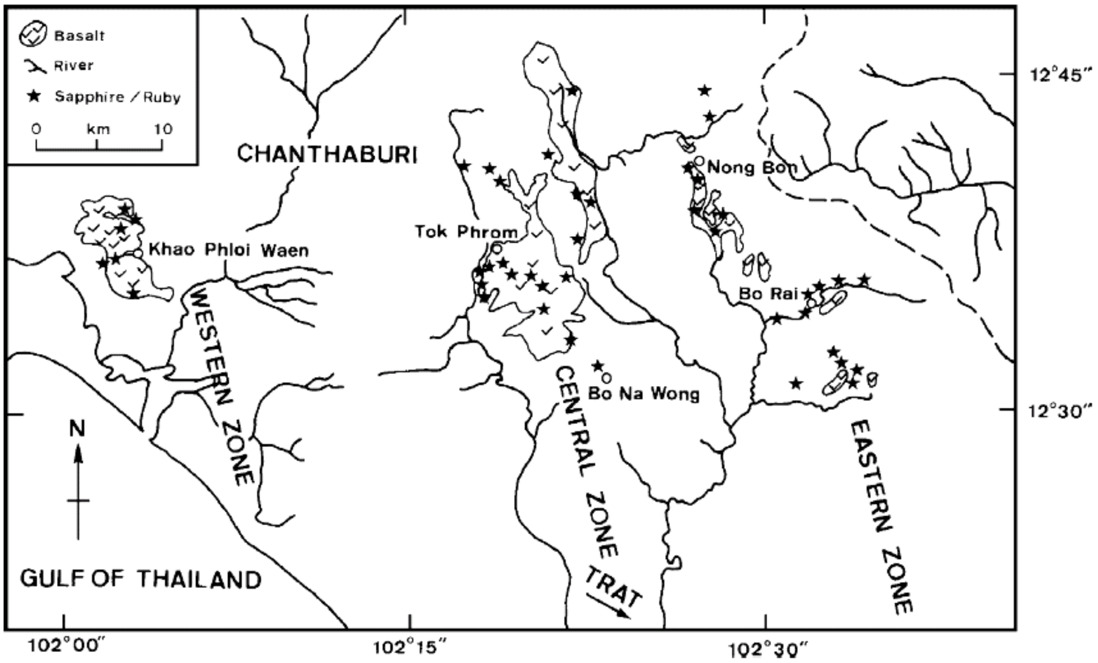

Figure 1. Map of Eastern Thailand showing the distribution of gem deposits, basalts and their age-dating data and the study area location at Bo Rai (modified after Yui et al., 2006).

2. Study area and methodology

The rocks in the Bo Rai area, Trat Province, Eastern Thailand, are of Carboniferous Permian age (Salyaphongse and Jungyusuk, 1980), and consist of siltstone, mudstone, tuffaceous sandstone, agglomerate and are locally interbedded by conglomerate lenses (Vichit, 1992). These rocks are overlain by basalt classified as nephalinite and olivine nephalinite (Bar and Macdonald, 1981; Sirinawin, 1981). Basalts in the Bo Rai area are generally found in low hills at approximate 40 - 60 m above mean sea level (Vichit, 1992). However, most of basalts have been weathered to lateritic soil.

The study site is a mine situated on a low hilly terrain. At this site, the lithology expression of a known gem bearing gravel is clearly seen from the top surface layer to the gravel bed (Figure 2). The subsurface consists of a shallow layer of weathered and then fresh basalt varying in thickness from 0 to 10 m, and then the gravel layer varying in thickness with typical ~5 m thick. The gravel layer is made up of fluvial gravels; the gravels comprise a sub-angular to sub-rounded pebble to cobble of basalt, which exhibit poor cementation. The bed rock which lies underneath the gravel is commonly tuffaceous sandstone.

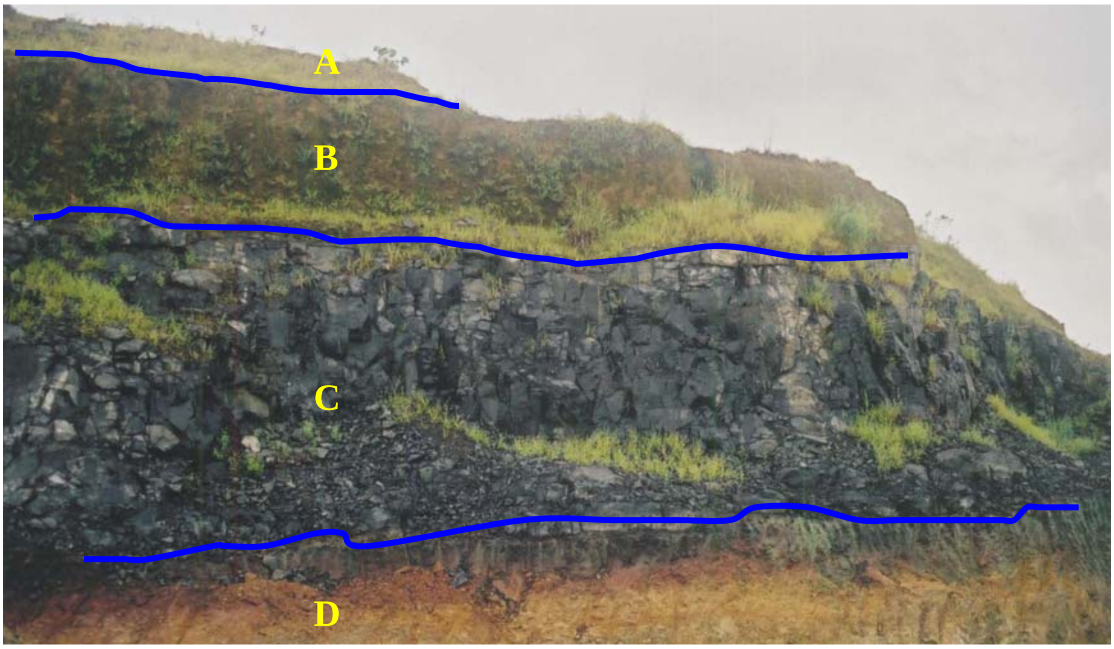

Figure 2. The exposed lithological section (mine quarry front) at the Si La Thong mine, Bo Rai study site, showing the stratigraphic sequences (major rock distribution) of basalt layer and underlying units. A = over burden, B = fresh basalt, C = weathered basalt and D = unconsolidated layer.

Commonly used data-collection techniques include the Wenner, Schlumberger, Dipole-Dipole and Pole-Pole array configurations. Each technique takes a series of voltage and current measurements from an array of electrodes placed on the ground surface, and each has a particular resolution, sensitivity to subsurface resistivity structure and telluric noise, and depth-penetrating capabilities (Dahlin and Loke, 1998).At the study site, a resistivity sounding was conducted using Schlumberger and Wenner electrode configurations. A conventional in-line survey was planned approximately though the center of the gem bearing gravel's layer expression.

The resistivity sounding survey procedure involved introducing a direct-current field into the earth through two current electrodes (A and B in the schematic Fig. 3), and the potential difference measurements are acquired from the potential electrode pair (M and N in the schematic Figure 3) at incrementally increasing distances away from the current electrode positions.

The distance from the center of the Schlumberger to the moving current electrode were taken at 1, 1.3, 1.6, 2, 2.5, 3.2, 3.2, 4, 5, 6.5, 8, 10, 10, 13, 16, 20, 25, 32, 32, 40, 50, 65, 80,100, 100, 130 m. The potential Schlumberger electrodes were fixed for a series of measurements. The 1 m was fixed for the current electrode positions of 1 to 3.2 m. Similarly, 3.2, 10, 32 and 100 m were fixed for 3.2 to 10 m, 10 to 32 m, 32 to 100 m and 100 to 130 m current electrode positions, respectively. The same sounding position was taken for the Wenner array, but the distance between the nearest electrodes of the current and potential electrode pairs was varied as a multiple na (n = 1, 2, 3, …, n) of the electrode spacing a in each pair.

Measurements were made at several discrete points as the potential electrode pair was moved incrementally away from the center to a maximum distance given by n = 40. Then, the current electrode pair was moved by one increment (a = 1) along the survey line. The process was repeated until the potential electrode pair had reached to 40 m apart. A total in-line survey length of approximately 120 m was surveyed for the Wenner array, whilst that for the Schlumberger array was approximately 260 m. Data were collected using a McOHM-2115 resistivity meter, manufactured by OYO.

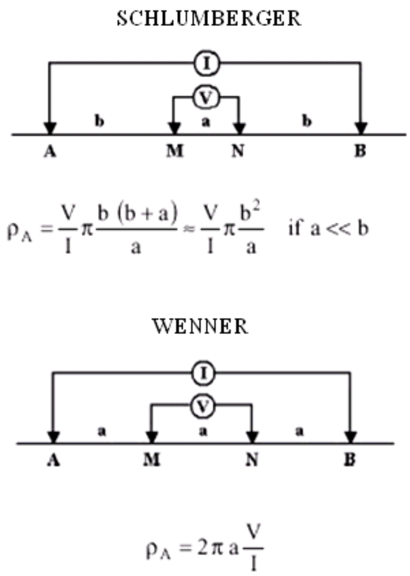

Figure 3. Schematic diagram of the current and potential electrode pair arrays used in the Schlumberger and Wenner arrays for sounding, and the appropriate formulae for the derivation of A.

3. Results

The layer model result parameters are listed in Table 1. Consideration of the layer model parameters for both arrays suggests that the presence of correlation between the resistivity model layer and the lithological section has a significantly similar variability in the layer structure. It clearly shows that the fourth layer of both array models have a very high values of resistivity compared with the adjacent layers. This layer correlates well with gravel layer known to be a gem bearing gravel layer. Note that the first layer may not only be a weathered basalt layer, but also probably a topsoil layer. The second and third layers, however, are represented as weathered and fresh basalt layers, respectively. Moreover, tuffaceous sandstone is expected to be a massive bed which has a low resistivity value at the bottom resistivity model. All the Schlumberger and Wenner resistivity model values are plotted in the same chart (Figure 4) for the comparison of sounding data taken with the corresponding point.

Table 1. Summary of the layer parameters on the interpretation of resistivity model layers for Schlumberger and Wenner array configurations.

Layer no.	Schlumberger			Wenner		
	Resistivity (Ohm-m)	Thickness (m)	Depth (m)	Resistivity (Ohm-m)	Thickness (m)	Depth (m)
1	949.7	2.4	2.4	1010.8	2.0	2.0
2	750.0	1.6	4.0	800.8	0.6	2.6
3	334.7	5.0	9.0	406.4	5.4	8.0
4	1602.7	3.0	12.0	1900.8	2.4	10.3
5	74.3	12.9	24.9	45.5	14.9	25.2

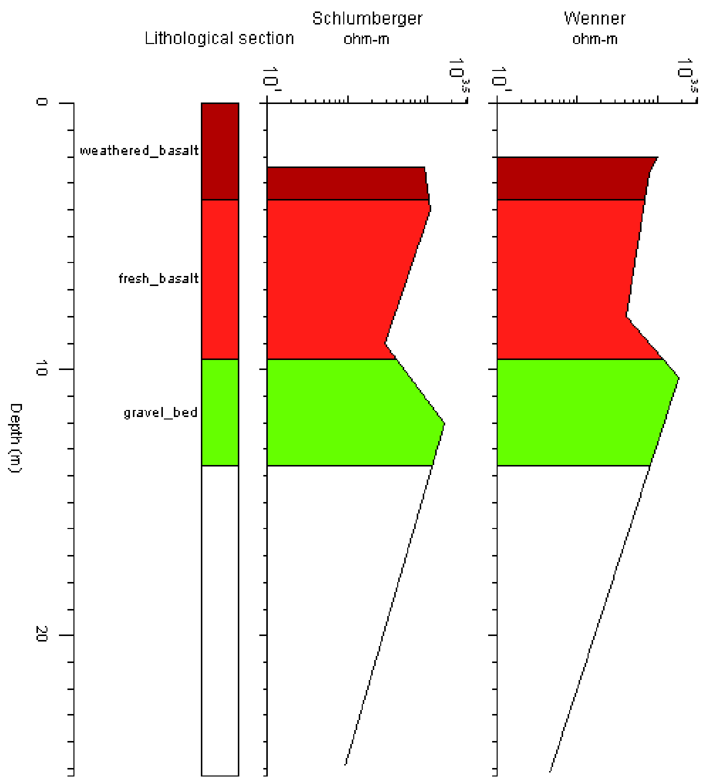

Figure 4. Comparison between the geological (lithological) section and the resistivity sections derived from the Schlumberger and Wenner array derived resistivity model layers of calibration site at Si La Thong mine, Bo Rai.

4. Comparison between the Schlumberger and Wenner arrays

The first step in the interpretation of resistivity survey is to classify the solution and accuracy of the geological section related to the geological section of each array. The Wenner array appears to have a high vertical resolution which is greater than that of the Schlumberger array because it provides the most detail at shallow depths in many studies. However, both survey arrays in this study were able to detect a high resistivity gem bearing gravel layer located under basalt (Table 1 & Fig. 4). The Schlumberger resistivity pattern is similar to the known lithological section and was more accurate than the Wenner array. During, field acquisition, the Schlumberger array configuration was found to have a nearly two-fold faster speed of coverage than using the Wenner technique. Also, the primary field data of the Wenner technique has more "noise" than that from the Schlumberger technique.

The Schlumberger array is clearly suitable for detecting zones of locally gem-bearing gravel layer. One exception to this is the use of Schlumberger array configuration to survey in locations that lack sufficient of open space for the required extensive survey line.

5. Conclusion

A comparison between the Schlumberger and Wenner array configurations in resistivity surveys revealed that both resistivity patterns were broadly similar to the known lithological section at the study site. Comparison of the two methods indicated that the Schlumberger technique is more efficient, faster and more economical than the Wenner technique, especially in gem bearing gravel exploration. The Wenner technique is suitable only for regions where Schlumberger sounding cannot be conducted due to the lack of open space.

Electrical resistivity provides reliable information for resolving the gem bearing gravel layer in the study area, in terms of a high resistivity value. It is possible that some of the high resistivity observed in the present study is due to the influence of hematite and magnetite from weathering and alteration process, but no clear evidence was recognized.

6. Acknowledgements

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7. References

Barr, S.M. and Macdonald, A.S., 1981. Geochemistry and geochronology of late Cenozoic basalts of Southeast Asia. *Geological Society of Malaysia* 10, 21-48.

Beresnev, I.A., Hruby, C.E. and Davis, C.A., 2002. The use of multi-electrode resistivity imaging in gravel prospecting. *Journal of Applied Geophysics* 49, 245-254.

Dahlin, T. and Loke, M.H., 1998. Resolution of 2D Wenner resistivity imaging as assessed by numerical modeling. *Journal of Applied Geophysics* 38, 237– 249.

Jakosky, J.J., 1950. *Exploration Geophysics*. 2nd edition, Trija Publishers, Los Angeles.

Jungyusuk, N. and Khositanont, S., 1992. Volcanic rocks and associated mineralization in Thailand, *In: Proceeding of a National Conference on Geologic Resources of Thailand, Potential for Future Development*, Bangkok, Thailand, 126-134.

Parasnis, D.S., 1997. *Principles of Applied Geophysics*. 5th edition. Chapman & Hall, London, New York.

Salyaphongse, S. and Jungyusuk, N., 1983. Geological map of Thailand 1:500,000; Central and Eastern Sheet: *Geological Survey Division, Department of Mineral Resources*, Bangkok, Thailand.

Sirinawin, T., 1981. Geochemistry and Genetic Significance of Gem-bearing Basalt in Chanthaburi-Trat Area. *Master Thesis (Unpublished), Department of Geological sciences, Chiang Mai*

University, Thailand (in Thai with English abstract).

Telford, W.M., Geldart, L.P. and Sheriff, R.E., 1990. *Applied Geophysics.* 2nd edition. Cambridge Univ. Press, New York.

Vichit, P., 1992. Gemstones in Thailand. *In the Proceeding of a National Conference on Geologic Resources of Thailand, Potential for Future Development*, Bangkok, Thailand. 126-134.

Welkie, C.J. and Meyer, R.P., 1983. Geophysical evidence that the Haeger Till member underlies southern western Lake Michigan. *Geoscience* 8, 45-48.

Yui, T.F., Wu, C.M., Limtrakun, P., Srichan, W. and Boonsoong, A., 2006. Oxygen isotope studies on placer sapphire and ruby in the Chanthaburi-Trat alkali basaltic gemfield, Thailand. *Lithos* 86. 197-211.

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