Australian Journal of Basic and Applied Sciences, 6(9): 459-464, 2012
ISSN 1991-8178

Geophysical technique applied to gemexploration in Chanthaburi, Eastern Thailand

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Abstract: Chanthaburi Province, Eastern Thailand is one of the miningareas of the country, and gem has been exploited for more than 100 years. Khlung area in Chanthaburi was selected dueto the occurrence of many abandoned mines and the extensive alluvialdeposits. The gravel-bearing alluvial layer was reported to containan appreciable amount of gem and overlain by Cenozoicvolcanic rocks.In order to define the existence of gem-bearing layer, geophysical resistivity survey- Schlumberger technique –wasconducted in the Khlung area. We selected 12 survey-pointresponses in the alluvial deposit.Geoelectrical profiles of the study area show 5 distinct layers: (1) overburden, (2) fresh basalt, (3) weathered basalt, (4) un- to semi-consolidated gem-bearing layer, and (5) sandstone. Theresult reveals 9 significant anomalies with high-resistivityvalues at depth of 7-18 meters from the ground surface. These anomalies are interpreted to represent a layer of probablegem-bearing un- to semi-consolidated sediments with the thickness varying from 0.7 meters to 5.7 meters. The outstanding result points to the fact that there are more one basaltic layer and alluvial layer. Based on our synthesis, furtherdetailed exploration should be concentrated along theintermountain basin where gem-bearing layers are thought to belocated in the central part of the served area, particularly along the main stream.

Key words: Resistivity, Schlumberger, gem-bearing layer, Chanthaburi

INTRODUCTION

Gemstone deposits of the Eastern Thailand are important sources of raw jewelry gemstones for the SE Asian gemstone markets and mined from present alluvial (or gem-bearing gravel layer) and palaeoalluvial channel deposits as presented in Figure 1(Yui *et al*., 2006), that makes them similar to the well-known gemstone deposits of Vietnam, Laos and Australia. Therefore, the gem-bearing gravel layer is the most important source of gemstones in SE Asia. The most common generic 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).

Nowadays, applications of the geophysical technique can be used in gemstone explorations at many different scales of observation. Generally, geophysical techniques are used in a primary stage of exploration as a large scale delineated prospective region for focusing and aiding a detailed scale of exploration. Some applications have recently become popular such as ground-penetrating radar, magnetic and electrical surveys. However, electrical survey particularly resistivity method is considered to be economically benefit. In the case of resitivity, 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 dependent on the porosity, water content and conductivity of the fluid and the percentage of clay minerals (Telford *et al*, 1990). In addition, direct application in gem-bearing gravel layer is conducted and highly effective at Eastern Thailand (Chenrai *et al*, 2010).

The purpose of this study is to describe how resitivity method can be used in the gem exploration for gem-bearing gravel layer deposits. Some of the reason is technical; a large scale exploration is not required high resolution results, thus 1-dimension vertical sounding technique can be used and commonly available with many resitivity instruments. Also, some of the reason is economic; gemstone deposits are not sufficiently valuable to require an expensive geophysical technique.

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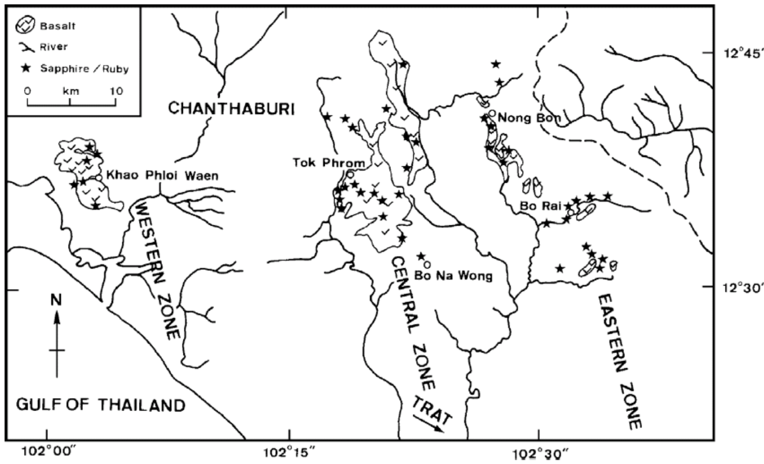

Fig. 1: Map of Eastern Thailand with distribution of gem deposits including study area (after Yui *et al*., 2006)

MATERIAL AND METHOD

Geologically, the main rocks in the study area comprise sedimentary and igneous rocks. The Triassic clastic sedimentary rocks are largely interbedded sandstone and mudstone strata and are characterized by massive sandstone beds interbedded with shale and conglomerate in the lower part. The Quaternary sediments include young unconsolidated sediments, such as alluvial and colluvial deposits, mostly comprising sand, silt and clay. Besides, some of these Quaternary sedimentary deposits contain appreciable amount of gems (Vichit, 1992). In the study area, the Cenozoic gem-bearing basalts are widely distributed and cross-cut the Quaternary sediments. Geochemically, these basalts are classified as “basanitoid” (Vichit *et al*., 1978). Additionally, Tritra-ngan (1990) and Vichit (1992) reported 2 layers of gem-bearing alluvial gravel deposits in the Chanthaburi-Trat area, one overlying the basalt layer and the other underlying it. The gravel layer is made up of fluvial gravels; the gravels comprise a sub-angular to sub-rounded pebble to cobble of basalts and sandstones and exhibits poor cementation, 10-15 cm thick and vary in some places to 2 m thick (Figure 2). We selected the areas in Khlung district, Chanthaburi province, where there are extensive mining activities and gems have been mined for many years. The spatial distribution of measuring location was selected, based on shallow natural exposuresandintegrated with the morphological map. The survey point locations are shown as in Figure 3.

The traditional resistivity surveys use a set of four in-line electrodes in an expanding-spread (sounding) or constant-spread (profiling) modifications. The quantitative interpretation of such data for a single sounding is usually limited to simple one-dimensional geometries (Beresnev *et al*, 2002). Commonly used data-collection techniques include the Wenner, Schlumberger, Dipole-Dipole and Pole-Pole array configurations. Each of these techniques 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). The resistivity sounding survey procedure involved introducing a direct-current field into the earth through two current electrodes, and the potential difference measurements are acquired from the potential electrode pair at incrementally increasing distances away from the current electrode positions.

Fig. 2: Gem-bearing gravel layer at Chantaburi-Trat region, Eastern Thailand.

In general, the main stream and alluvial deposits of the study area orients in the northwest-southeast direction, which enabled the designed traverse lines. Therefore the base survey line (line B in Figure 3) was assigned following the main stream and alluvial-deposit orientation. Theoretically, other survey lines should be perpendicular to the main line. So in this case, we selected the survey line C (Figure 3), approximately in the northeast-southwest direction from Ban TokPhrom to north of Ban Khao Thon. The other survey line (line A in Figure 3) was assigned obliquely to the main base line due to the difficulty in accessibility.

According to Chenrai (2010), on a comparison of the resistivity surveys using Wenner and Schlumberger techniques on field data in Eastern Thailand indicates that Schlumberger technique is most suited to the geology and in the Eastern Thailand. Therefore, the selection space of electrode combinations used for current and potential electrodes for survey is based on Chenrai (2010). The distance from the center of the Schlumberger to the moving current electrode were taken as 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.

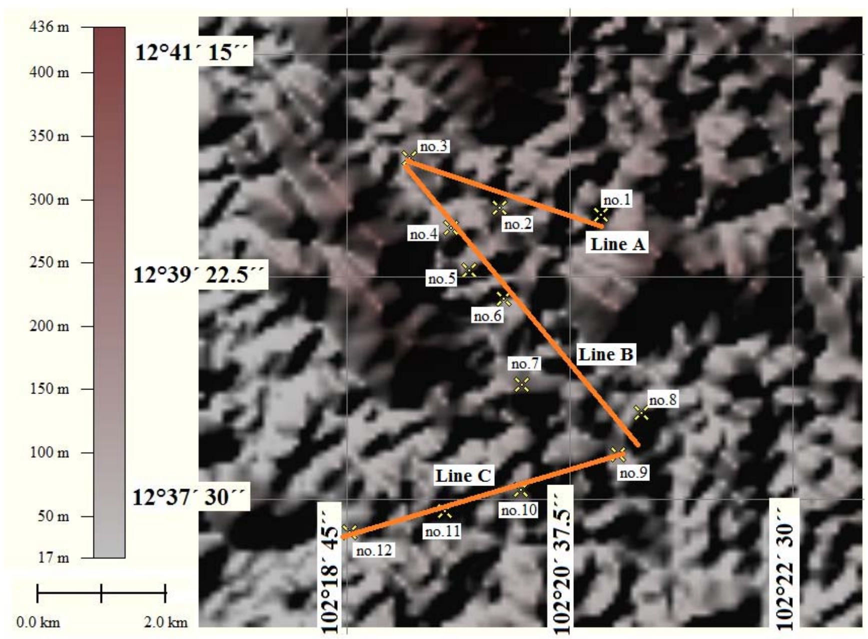

Fig. 3: Digital elevation model image showing locations of resistivity survey points at Khlung area, Chanthaburi.

Result:

The resistivity values of the twelve survey points at Khlungarea, Chanthaburi, were interpreted based on Chenrai (2010) and Telford *et al*., (1976) for the range of resistivity of some crustal rocks (Table.1). In the study area, five distinct geological layers are interpreted from the results of resistivity data. Resistivity values of the topmost layers range from 120-1,230 ohm-m are interpreted to be overburdens, with the approximate depth of 0-3 meters and thickness of about 1-3 meters. In the field they are top soils, lateritic soils, and laterites. The maximum range of resistivity values (900-1,810 ohm-m) is inferred to represent the un- to semi-consolidated layer or gravel layer (Table 1).

The depth and the thickness of this layer are 6-7 meters and 1-3 meters, respectively. The second maximum resistivity ranging from 510-900 ohm-m is considered as the weathered basalt whereas the third maximum of 280-490 ohm-m as the fresh basalt. The weathered basalts vary considerably in the depth from 0 to 14 meters and the thickness approximately from 1.5 to 5 meters. The fresh basalt also varies in the depth from 1 to 16 meters and thickness of about 2.5-5 meters. The next high value varies from 20 to 100 ohm-m with the depth of approximately 7-13 meters and thickness of about 3-23 meters. These high-resistivity layers are regarded as sandstone bedrocks. Base on the result obtained from this study, we were able to construct the schematic resistivity section following the survey lines A, B, and C. (see Figure 4).

Table 1: Comparison between the ranges of resistivity for some crustal rocks and those it the measured resistivity for previous study in Eastern Thailand (*1 after Telford and *2 after Chenrai (2010).

Material	Nominal resistivity*1 (ohm-m)	Measured resistivity*2 (ohm-m)	Interpreted material*2
Basalt	10-1.3 x 10^7	280-490	Fresh basalt
		510-900	Weathered basalt
Top soil	250-1,700	120-1,230	Overburden
Laterite	800-1,500		
Lateritic soil	120-1,500		
Sandstone	1-7.4 x 10^8	20-100	Sandstone
Conglomerates	2 x 10^3-10^4	900-1,800	Un- to semi-consolidated sediments
Gravel	100-1,400		

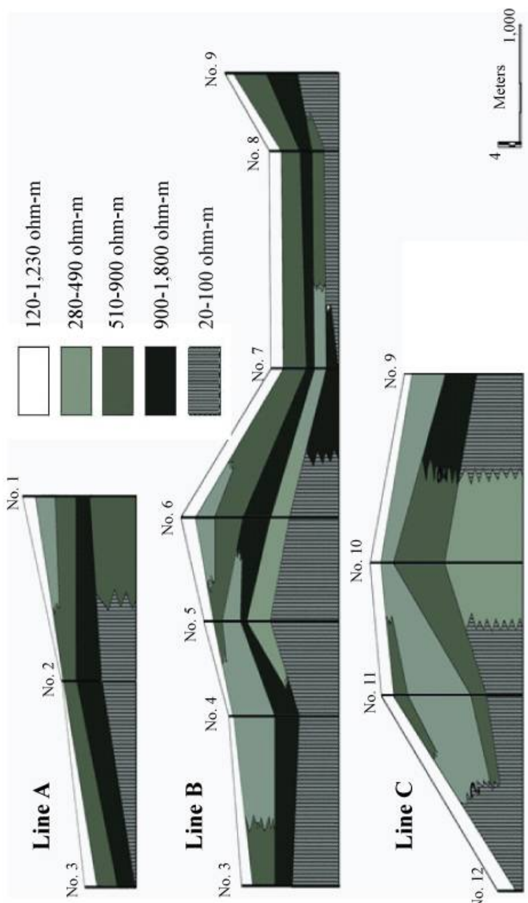

Fig. 4: Schematic resistivity cross section along lines A, B, and C based on the results of resistivity values at Khlungarea, Chanthaburi.

Discussion:

Upon establishing criteria for recognizing potential gem-bearing unconsolidated layers on the inverted resistivity section, we surveyed the twelve selected new-exploration sites. Based on the overall twelve resistivity readings, nine of them, where bulk resistivity exceeding 900 ohm-m, were considered representing coarse materials (un- to semi-consolidated layer).

Line A:

Three surveyed points were run at the line A, all of them showed the appearance of the significant accumulation of the 3 m-thick high resistivity at the depth between 4 and 7 meters from surface. This layer is clearly identified as the un- to semi-consolidated layer on this section and seem covered by the 2 to 4 m-thick lower resistivity layer. This lower resistivity layer is inferred as the weathered basalt layer. It is interesting that at the point no. 1 the un- to semi-consolidated layer is intervened in two basaltic layers.

Line B:

Along the survey line B, significant accumulations of high-resistivity deposits were also found at the depth of 6 to 11 m from surface, indicating the promising potential for un- to semi-cosolidated layer. The layout of seven points was conducted along the main stream. Local geology and geomorphic landforms indicate the present-day alluvial deposit. Resistivity cross-section along the line B clearly shows that this line exists the un- to semi-consolidated layer in all survey points, underlain by basalt. The thickness of unconsolidated layer varies from places to places varying from 1 to 5 m. The most interesting point is the survey point no. 4 displaying two anomaly at 6.2 and 9.8 meters, probably suggesting the un- to semi-consolidated layers intervened by a basaltic layer. Also, sandstone and basalt are overlain by unconsolidated layer. However, the bottom of the section in line B remained unclear. In survey point no.8 resistivity anomaly is about 900 ohm-m that may be either the semi- to un-consolidated layer or the strongly weathered basalt layer. But we consider it as to represent to the un- to semi-consolidated layer similar to these of the other points.

Line C:

A total of four points were conducted at the survey line C, roughly perpendicular to the base survey line B. One of the survey points (no. 9) also showed significant accumulation of the high resistivity layer. This layer is clearly identified on this section, probably occurs as a lens with a thickness of about 5 m. Therefore, these exists the unconsolidated layer at depth of about 7 m from surface. The resistivity cross-section along the survey line C clearly illustrates the well-defined correlatable stratigraphy with the overlying fresh and weathered basalts and underlying sequence.

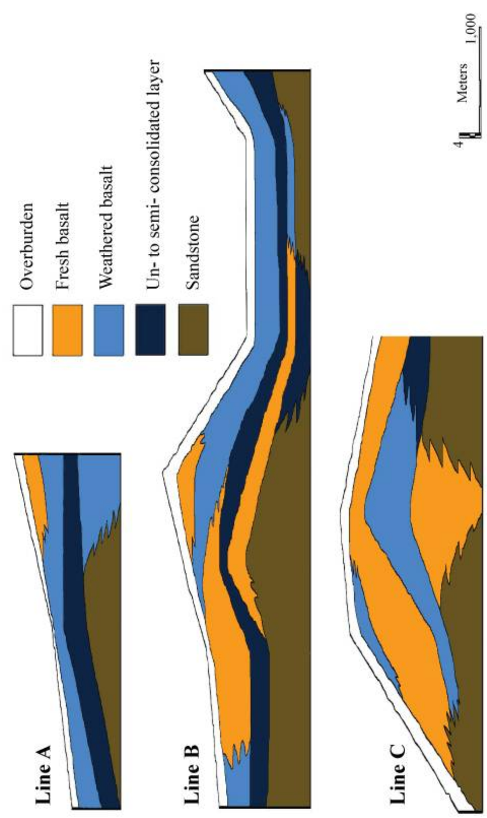

Fig. 5: Schematic geology cross-section along lines A, B, and C based on the results of resistivity values at Khlungarea, Chanthaburi.

Based upon our field evidence as show, revealed in Figure 2, it is considered that the gem-bearing layer underneath the basaltic layer is not a gravel bed. Its textural maturity is likely to be low. Therefore our conclusion is that the gem-bearing unit is volcanic breccia rather than the gravel bed as previously thought (e.g. Tritrangan, 1990). This interpretation conforms to that of the high resistivity value reported in this study.

In order for drilling and detailed exploration, high resistivity body is the main target to be concerned. Drilling method should be arranged at some points that yield high resistivity values with depth shallower than 10 meters. Detailed geophysical exploration should concentrate in area showing high resistivity layer underneath.

Conclusions:

The results of the surveys at Khlungarea, Chanthaburi indicate that the electrical-resistiviy configuration or imaging is a useful tool in rapid evaluation of the potential for the underneath gem-bearing layer.We also concluded that, for the investigated targets, Schlumberger configuration array provides the resolution at satisfaction level.

Geoelectrical profiles generally show 5 distinct layers: (1) overburden, (2) fresh basalt, (3) weathered basalt, (4) un- to semi-consolidated gem-bearing layer, and (5) sandstone. The outstanding result suggests that there are more one basaltic layer and alluvial layer in this region. Furtherdetailed exploration should be concentrated along theintermountain basin where gem-bearing layers are thought to belocated in the central part of the served area, particularly along the main stream.It is notably important to conclude here also that, although resistivity imaging is a good indicator of the presence of the underneath gem-bearing layer, the absolute quality and economic values of that material is difficult to ascertain without further exploration drilling.

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