GPR mapping as a method for placer mineral exploration: A case study in Akurala, Sri Lanka

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Abstract

Placer mineral exploration includes mapping underlying strata extensively. There are numerous exploration techniques, including electric and gamma logging, shallow vertical drill holes, exploratory trenches, and pits. Due to limitations of these conventional methods, geophysical methods such as Ground Penetrating Radar (GPR), are widely being used. The purpose of this study is to map placer deposits using GPR as an exploratory approach. GPR is a modern, rapid, no-contact, high-resolution technique which transmit, reflect and receipt of high frequency electromagnetic (radar) wave. This study was carried out at Akurala, Galle, Southern Sri Lanka using 300MHz antenna. Based on the GPR data, sand layers were identified in clay beds, of an old riverbed, and the sand layer is deposited as a fluvial deposit, which are the sediments deposited by paleo river channel. Average thickness of the sand bed could be interpreted as 0.94m, extending perpendicular to shoreline, and situated at approximately 1.25m depth below surface level. GPR data profile indicate that the sand layer may enrich with valuable minerals and heavy minerals, and it was validated using thin sections prepared from test pit sampling.

Keywords: Alluvial placer, Geophysical Exploration, Heavy Mineral, Placer Deposits, Subsurface Exploration

1. Introduction

Mapping subsurface layers in the placer is important in placer mineral exploration. There are several exploration methods such as shallow vertical drill holes, exploratory trenches, and pits, seismic reflection methods, electric and gamma logs, etc. [1], [2]. Each exploration technique has different restrictions, and for example, conventional techniques like core drilling and exploratory trenching are time and money-consuming. On other hand, considering alternative faster methods such as Seismic reflection, are more suitable for continuous profiling of the subsurface but in poor vertical resolution (3m-4m) [3].

Ground Penetrating Radar (GPR) is a high-resolution, modern, no-contact method that transmits, reflects, and receives high-frequency electromagnetic (radar) waves [4],[5]. GPR gives results based on varying electrical properties of the sediments. Examples presented from the UK indicate that the technique can accurately delineate the stratigraphy and internal sedimentary structure of coastal barriers, spits, and strand plains, both above and below a fresh groundwater table [6]. Therefore, this GPR geophysical exploration method can be used for in-situ layer mapping and detection. Compared to traditional exploration methods, no other methods have facilities such as mobility, automation, and cost efficiency when assessing the shallow subsurface (between 0-32 m) [7],[8].

Placers created in river or stream sediments are known as alluvial placers. Stream placer is another term for alluvial placer [9], [10]. Heavy minerals that have been liberated from their parent rock, due to weathering, and concentrated as placer deposits. These heavy minerals are transported by water into streams, where they accumulate in gravel beds. Stream (alluvial) and beach placers are the two most significant categories of placers [11].

Heavy mineral deposits occupied the top position of Sri Lankan natural resources. Many exploitable heavy mineral deposits can find along the beach of Sri Lanka, as major deposits, at Pulmodai on the East coast and West coast of Beruwala, and small-scale deposits at Trincomalee, Kaikawala, Induruwa, Kelani river, Negombo North and Kudremalai, Ussangoda, Kirinda, and Hambantota areas. [12], [13].

Considering the placer mineral exploration of Sri Lanka, conventional exploration methods such as core drilling, and tail pits were commonly used [12]. But due to several reasons (time, high cost, and labor), mapping and exploration are limited to major deposits and a few more minor deposits. But a geophysical method such as GPR can utilize for small-scale or medium-scale explorations. In this study, our main objective is to map placer deposits using Ground Penetration Radar as an exploration method. Therefore, we focus on, developing an exploration technique with GPR for the subsurface of placer deposits for placer mineral exploration and mapping subsurface sand layers.

2. Methodology

2.1 Study Area

As the study area is situated at Akurala (at coordinates of 6.2017°N, 80.0705°E) of the Southern Province of Sri Lanka. The study area was selected as a GPR survey that needs to be performed in a safe, accessible, and likely to contain the placer deposit in a shallow depth, while also meeting any legal or regulatory requirements. The associated environment was a mainly coastal environment with marshland.

2.2 GPR exploration

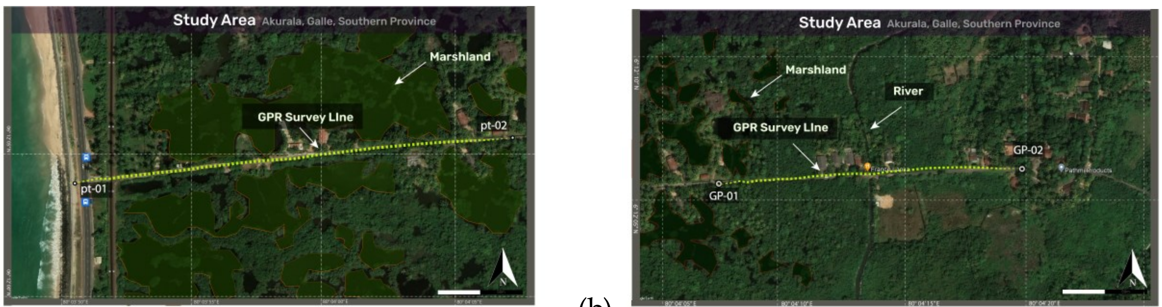
The exploration was done using two methods. First GPR survey and then shallow test pit exploration to validate the results obtained from the GPR survey. The GPR survey was conducted by following a road that was perpendicular to the shoreline. The profiles are recorded in two parts, Survey line 01 with 418.89m and survey line 02 with 590.24m (Figure 1). The basic parameters of the GPR system were, AKULA 900 C as a control unit and GEO-80 System. As an antenna, a GEKKO-80 unit with 300MHz frequency was used.

2.3 GPR data processing

The recorded GPR data set was then analyzed and processed using GPRSoft-Pro software. In the processing and analyzing stage, the following techniques were used.

2.3.1 Surface correction

Surface correction is for the elimination of airwaves and surface reflection. Using the build function of the GPRSoft-Pro software,



(a) (b)

Figure 1: Map of Study area, Akurala, Sothern Province (a) Survey line 01 (b) Survey line 02

each trace was automatically rectified using the data collected and the entered start or zero time to correct it in the time direction.

2.3.2 Frequency filtering

In this stage, the signal pauses are removed using the time-zero correction technique. De-wowing, which tries to remove noise. DC bias components, are the next procedure carried out after time zero correction is completed [14]. Filters are used for enhancing the quality of the radargrams. Simple filters are effective in filtering out high- and low-frequency noise.

2.3.3 Gain function

The attenuation in the ground can be highly varied, which is a significant issue with GPR data. Reachable depth can be up to, a few tens of meters in low attenuation, and in high attenuation, it may limit to only 1 to 2 meters of depth [15].

One approach to making the signal that has gone deeper visible or readable is to amplify it by a specified amplification factor which is referred to as data gain. [14]. Data is given a gain that grows over time following the transmit pulse. The gain functions increase is adapted to the signal amplitude versus time and the drop-off.

2.3.4 Velocity analysis

It is necessary to know the dielectric constant of the medium to compute both the overall depth of the medium and the depth of any anomaly or buried layer. The velocity in the media can be measured in three distinct ways,

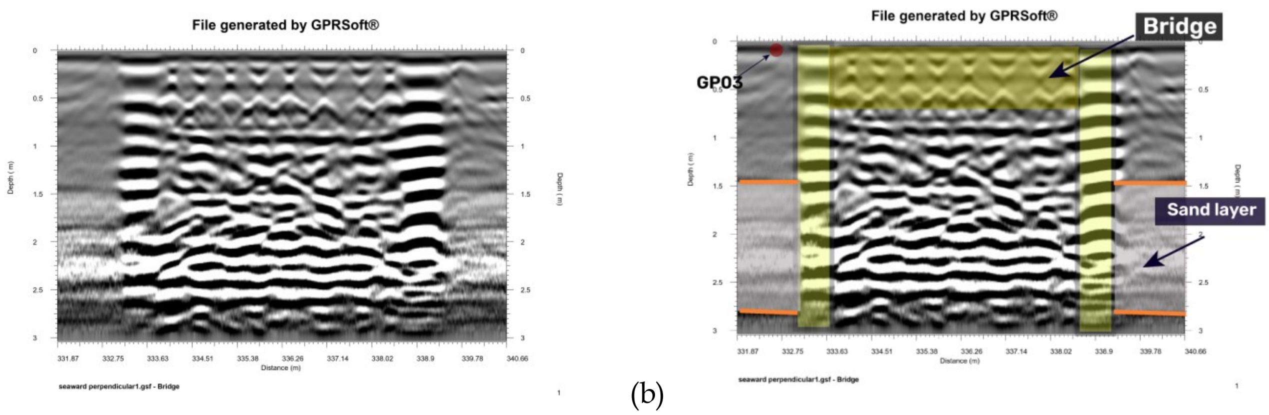
Hyperbola fitting - A signature of a point source; a hyperbole, was marked in the GPR profile using software, and using the hyperbole parameters, the velocity is estimated.

Slope fitting – Unshielded antennas can detect items above the ground, and if those objects are metallic or generally good reflectors, they can induce slopes in the data. Finding and distinguishing bogus layers from genuine ones can be accomplished with the help of the slope fitting tool.

Migration adaption – Iterative migration technique, try to obtain the proper migration velocity distribution as the migrated picture will be sharply focused everywhere. Diffractions will not collapse fully if migration velocities are too low, and diffraction tails will extend from the diffractor positions toward deeper levels. The diffraction tails will extend from the diffractor locations toward shallower depths when migration velocities are too great, causing diffractions to have traveled past their focus.

2.4 Validate the findings using test-pit sampling

To validate the findings, samples from several locations on the GPR survey line were collected (by digging shallow test pits with 1-1.5m depth), processed samples, and prepare thin sections for the visual identification of mineral grains using a



(a) (b)

Figure 2: (a) Processed GPR profile (b) Same GPR profile marked with identified features.

microscope.

The shallow test pits were dug in convenient locations near the GPR survey line and samples were obtained. 8 samples with 20g of each were taken in several depths up to 2m in these test pits.

The samples were properly labeled and stored. The sample was then washed to remove organic matter, shell pieces, and mud and subjected to drying. Then the sample was put into a glass thin section and the grain-mounted thin section was observed using a reflective microscope. Three photographs were taken from each thin section.

Table 1: Sand sample location details

Samples	Description
L01, L02	Test pit 1 (depth: 0.5m ,1.7m)
L03, L04	Test pit 1 (depth: 0.5m ,1.5m)
L05, L06	Overburden and surface soil
L07, L08	Beach sand

Table 2:Thin-sections

Thin-section label	Origin sample
S01	Washed L02
S02	Washed L04

Table 3:Sand Layer thickness measured Survey line 01 Radiogram

Chainage	Sand Layer thickness (m)
5m	0.93
232m	0.92
340m	0.94
440m	0.95
580m	0.93

3. Results and Discussion

3.1 GPR Profile Interpretation

The GPR survey was conducted by following a road that was perpendicular to the shoreline. The profiles are recorded in two parts, Survey line 02 and survey line 01. The associated environment was a mainly coastal environment with marshland.

Survey line 01 - The total length of the line is 418.89m. The survey was conducted toward the sea direction, starting from Pt-02 to Pt-01 (East to West).

Survey line 02 - The survey line has a total length of 590.24m. GPR survey was conducted from GP-02 to GP-01 East to West direction. A notable feature is a small river found at a chainage of 336.26m from the GP-02 (starting) point.

After the processing of the GPR profile, it was interpreted, and identifying features. As an aid, the identified features were marked with adobe illustrator.

The GPR profile between 331m to 340m can be interpreted as follows. The bridge upon the small river is clearly visible in the GPR profile. (two piles, cross beams, concrete structure, etc.) The length of the bridge is around 5m. At the river bank, it can clearly show layers with about 1.25 m (left) and 1.20 m (right) thickness. This sand layer is extended along the profile (Figure 8).

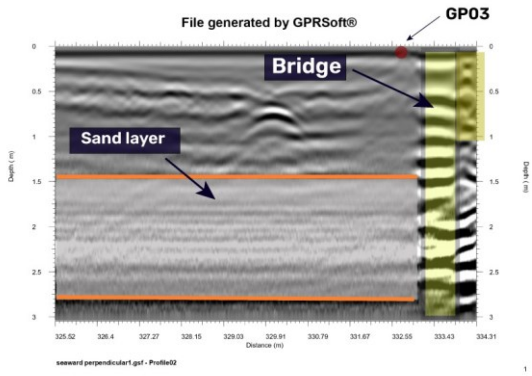


Figure 3: Sand layer near bridge

In this part of the profile, it can identify two (or three) objects which have a high possibility to be a pipeline. The sand layer can also clearly distinct from the layers.

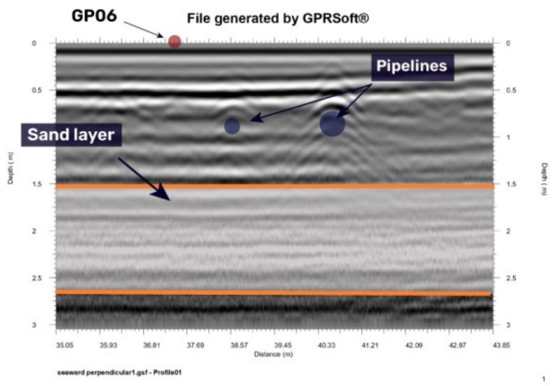


Figure 4: Identified pipelines in GPR profile

The presence of a sand layer around the river at an average depth of 1.5m can be directly identified using processed radiogram records. According to several publications [16],[17],[18], heavy minerals are given high concentrations of heavy minerals strong reflections when encountered, but a prominent constrain is that the high conductivity of mineral result in a rapidly attenuate signal and limit the penetration depth [16].

Additionally, as the dielectric properties of marshy clay deposits and fluvial sand bed differs, it could be clearly distinguished the layers from radargram.

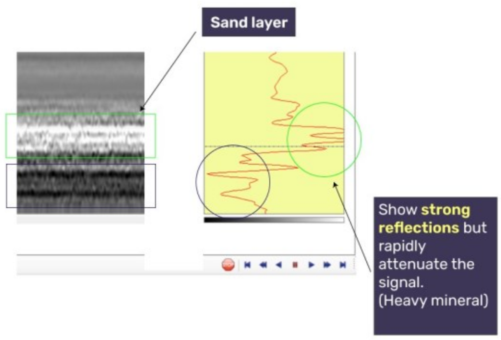


Figure 5: Sand layers distinguished by strong reflections

In the radiogram of survey line 02, it shows that the second layer is situated at about 1.5m depth showing a high reflection, and the below part show very poor reflection (at shadow) same phenomena can be observed. This is evidence that the presence of sand (heavy mineral sand) at that depth.

3.2 Result validation

The grain-mounted thin sections are clear enough to distinguish the mineralogy of the grain. *Figure 7* shows the identified minerals from the thin sections.

The mineral grains were counted and the results are listed in *Table 4*.

Figure 6: Labelled Thin section

Table 4:Mineral grain count

Mineral	S01	S02
Quartz	26	35
Ilmenite	38	10
Rutile	3	0
Zircon	4	0
Garnet	1	0
Total	72	45

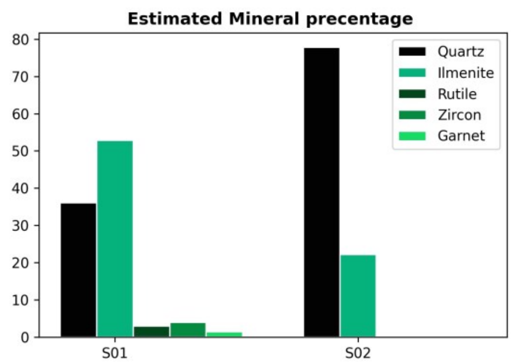


Figure 7: Estimated Percentage of Minerals in thin sections

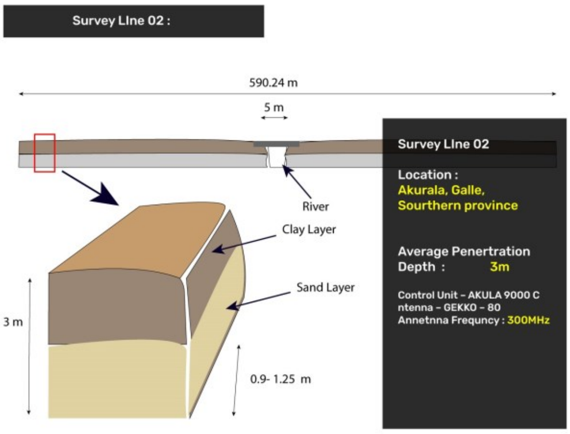


Figure 8: illustrated subsurface layers

4. Conclusion

According to the findings of the research, the following conclusions can be made. After processing data acquired from Ground Penetration Radar, it could identify and map placer deposits.

For 300MHz frequency, GPR could reach up to 3-4m depth as indicated in the radargrams. The processed radargrams can clearly distinguish the subsurface sand layer from clay. The identified sand bed is extending a considerable distance and can find almost all the length of both survey lines 01 and 02. The sand layers found in clay beds are of an old riverbed, and the sand layer is deposited as a fluvial deposit, which are the sediments deposited by the paleo river channel. The difference in dielectric properties of marshy clay and fluvial sand bed makes layers distinguishable in radargram. The average thickness of the sand bed could be interpreted as 0.94m.

Therefore, GPR profile shows a high likelihood of valuable placer minerals in these sand layers and the validation samples taken from test pits have confirmed that there is heavy sand located in the detected layer. From the results of thin section mineralogical analysis, S01 and S02 are showing 46% and 10% heavy mineral sand percentages respectively.

These sand layers may enrich with valuable minerals and heavy minerals. Therefore, the GPR exploration can use to mapping of placer minerals deposits. And also, further mapping and exploration can be recommended.

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