https://doi.org/10.31705/ISERME.2024.28

Use of Integrated Geophysical Technology for Exploring Gem Gravel Beds in Rathnapura District, Sri Lanka

Wickramarathne[1] DVL, Yathushan[1] S, Gunarathna[1] RMCN, *Vijitha[1] AVP and Premasiri[1] HMR
[1]*Department of Earth Resources Engineering, Faculty of Engineering, University of Moratuwa, Sri Lanka*
*Corresponding author – Email: vijitha@uom.lk

Abstract

The pursuit of gemstones has captivated humanity for centuries, driven by their beauty and value. In Sri Lanka gem mining is carried out in a haphazard manner (blind digging) using conservative methods and without having an idea about the subsurface geology. The gem deposits in Sri Lanka are mainly secondary deposits which often occur in riverbeds, alluvial plains, and sedimentary environments. In this research, the aim is to enhance the exploration of gem gravel beds by leveraging integrated geophysical technology. Focusing on Sri Lanka's rich gemstone heritage, particularly in renowned areas like Rathnapura, this study utilized Ground Penetrating Radar (GPR) and resistivity surveying techniques to pinpoint gem-rich gravel layers with greater accuracy. By combining these advanced methods, the research aims to develop efficient and non-destructive approaches to delineate gem-bearing gravel beds, thereby minimizing environmental impact and maximizing resource recovery. Using the GPR instrument and GPRSoft software, could successfully interpret a profile which gives proportional results with the actual cross section of the gem pit and could utilize resistivity instruments to interpret a profile in low depth area of the mine site as well. Furthermore, through this research, empowerment of gem miners with precise data, contribution to the sustainability of Sri Lanka's gem industry, and advancement of scientific knowledge in geophysical exploration techniques are fulfilled.

Keywords: Secondary deposits; Gems; Sri Lanka; Ground Penetrating Radar; Resistivity

1. Introduction

Gemstones have captivated human interest for a long time, for their extraordinary beauty, rarity, and value. Sri Lanka, known for its rich gemstone heritage, stands among the top gem-bearing nations globally, offering a wide variety of high-quality precious and semi-precious stones. Such as Rubies, Star Rubies, Blue Sapphires, Yellow Sapphires, Pink Sapphires, Green Sapphires, Alexandrite, Cat's eyes etc [1], [4], [6]. At present Sri Lanka is reputed for its high-quality gemstones and quality cutting and finishing works meet highest standard of industrial requirement. Despite its wealth of resources, gem mining in Sri Lanka often employs traditional, labor-intensive methods that lack precision and can be environmentally harmful. Typically, gem deposits in Sri Lanka are secondary, found in riverbeds, alluvial plains, and sedimentary environments. This traditional approach to mining, characterized by "blind digging," lacks an understanding of the subsurface geology, leading to inefficient extraction and significant environmental disruption [3], [11].

This research to revolutionize the exploration of gem gravel beds in Sri Lanka by leveraging integrated geophysical technology. By utilizing advanced tools like Ground Penetrating Radar (GPR) and resistivity surveying techniques, the study aims to accurately locate gem-rich gravel layers. GPR is a non-invasive method that provides high-resolution images of subsurface structures, making it ideal for detecting changes in material composition, including potential gem deposits [16], [17].

Resistivity surveying complements this by measuring the electrical resistivity of subsurface materials, identifying different geological formations that may indicate the presence of gemstones [18],[21].

The integration of these technologies promises a more systematic and scientific approach to gem exploration. The primary goal is to develop efficient and non-destructive methods for identifying gem-bearing gravel beds. This approach not only aims to minimize environmental impact but also seeks to maximize resource recovery, thereby enhancing the economic viability of the gem industry in Sri Lanka. Accurate subsurface mapping and the ability to pinpoint gem deposits can significantly reduce unnecessary excavation and drilling, preserving the natural landscape. This research holds significant implications for the sustainability and profitability of the Sri Lankan gem industry. By providing miners with precise data on gem locations, the study empowers them to make informed decisions, optimizing their efforts and improving yield [24]. Furthermore, adopting these advanced techniques can contribute to the preservation of Sri Lanka's natural heritage, ensuring that mining activities do not irreversibly damage the environment. The use of GPR and resistivity surveys also advances scientific knowledge in geophysical exploration techniques, opening new avenues for their application in other areas of resource exploration [15].

In conclusion, the integration of geophysical technology in gem exploration represents a critical step towards modernizing the mining practices in Sri Lanka. This research aims to bridge the gap between traditional methods and cutting-edge technology, fostering a more sustainable and economically robust gem industry.

2. Methodology

2.1 Study Area

The study focuses on renowned gem-bearing areas, primarily centered around Rathnapura. Specifically, we have selected location in Rathnapura – Heraniyawaka area for our investigation. The choice of this land is also guided by their topography, as working with flat lands is more conducive than inclined terrains. This selection is essential for the ease of movement of the Ground Penetrating Radar (GPR) instrument, ensuring precise readings without distortions.

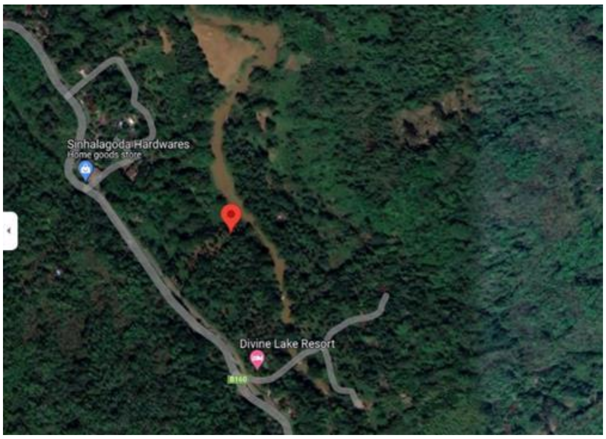

Figure 1 Study Area in Heraniyawaka

2.2 Data Collection Methods

Firstly, a field observation should be done to identify the location and its current status. Mainly two geophysical survey methods, GPR & Resistivity, are being used for our field observations. Ground Penetrating Radar (GPR): GPR will be employed to provide high-resolution images of subsurface structures. This technique is ideal for detecting changes in material composition, including gem-bearing gravel layers. Resistivity Surveying: Resistivity surveys will be conducted to measure the electrical resistivity of the subsurface. Variations in resistivity can help to identify different geological formations, including potential gem deposits. The GPR is equipped with antennas with frequencies of 100MHz, 300MHz and 900 MHz and then the equipment setup and calibration should be done. This phase includes setting up the GPR antenna, control unit and data acquisition system (field laptop), and equipment calibration to ensure accurate data collection. To collect the data, we should move the GPR instrument along the survey lines accordingly and then data would be stored automatically in the field laptop itself for further analysis [28].

Figure 2 GPR Profile phases

Measure electrical resistance between electrodes using a resistivity meter. Ensure good contact between electrodes and the ground (using water to moisture the contact points). Perform multiple measurements at each electrode spacing along the survey lines. Use resistivity inversion software to convert resistance measurements into resistivity profiles.

Figure 3 Resistivity survey points

2.3 Data Analysis

In the first stage data pre-processing should be done by removing distortions in the obtained data. In GPR it gives 2D representation by utilizing GPRSoft software. In the Resistivity method also, 2D representation can be obtained by using software like RES2DINV. Then the results can be compared of both 2D representations with the actual deposit of the gem pit.

Then the most prominent geophysical method for exploring gem gravel beds can be identified at the last [21].

3. Results and Discussion

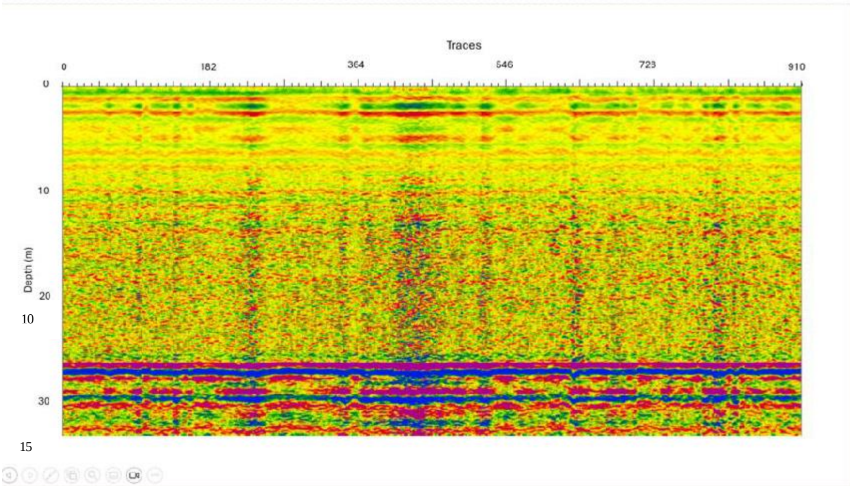

Figure 4 Profile obtained using 60MHz antenna in phase 2

In the work site, 1000MHz, 300MHz and 60MHz antennas were utilized to obtain GPR profiles in phase-1 and phase-2. Respectively the penetration depths were up to 1.5 m, up to 4 m and up to 30m for the above-mentioned frequencies. After analyzing all the profiles which were given by the above frequencies, in the profile, which was generated using 60MHz antenna, had some prominent anomalies with relative to the actual cross-sectional profile of the gem pit.

The depths and reflection patterns observed align with historical data (knowledge of the old miners) on gem-bearing gravel beds in the region, providing confidence in the GPR results. Previous mining areas also indicate that productive gem gravel beds in Rathnapura are often found at depths around 3-15 meters, corroborating the GPR findings. Furthermore, the cross section of the actual gem pit where the investigation was carried out, showed a gravel layer at a depth of 11.5m. After comparing the results of the GPR and actual cross section, the reliability of the data which we obtained, can be expressed.

High-amplitude reflections are interpreted as interfaces between the overlying clay or sandy layers and the denser, gem-bearing gravel layers. The continuity and strength of these reflections across multiple survey lines suggest extensive and potentially rich gravel beds. In the above profile, the purple color layer has a di electric constant around 5.5 and that correlates with the dielectric constant of gravel [17].

The resistivity method was also utilized using the Schlumberger array configuration in the phase-1 area which has a depth around 6 m. Due to the lower penetration depth and array, the resistivity profile, which was obtained, had not higher variation that helps to identify the subsurface geology.

The successful identification of potential gem gravel beds using integrated geophysical techniques has significant implications for gem exploration in the Rathnapura District. This non- invasive method allows for precise targeting of excavation sites, reducing environmental impact and increasing the efficiency of gem mining operations.

The depth and extent of the identified gravel beds suggest a substantial resource, warranting further exploration and sampling. Future work should include detailed geochemical analysis of the gravel to confirm gem content and quality. Additionally, expanding the geophysical survey grid could provide a more comprehensive understanding of the gravel bed distribution, aiding in resource estimation and mine planning.

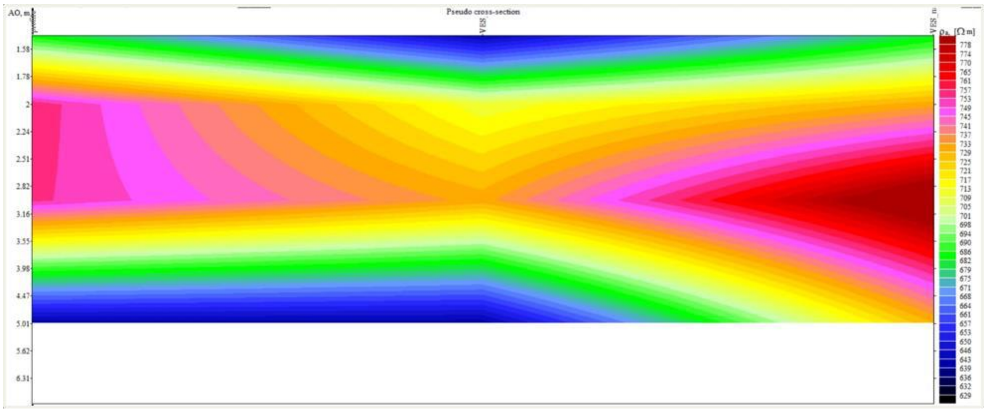

Figure 5 Resistivity profile

While the geophysical surveys have been successful, there are limitations to consider. The resolution of the resistivity and GPR data is influenced by soil moisture content and other environmental factors, which could affect the accuracy of depth estimates.

4. Conclusion

According to the results, the use of integrated geophysical technology has shown great promise for exploring gem gravel beds in the Rathnapura District. By combining resistivity imaging and GPR, a solid framework can be created for pinpointing and mapping out subsurface gravel layers. This makes gem mining more targeted and efficient. Not only does this approach help to make the most of our resources, but it also reduces environmental damage, supporting sustainable mining practices. In Sri Lanka most of the time secondary alluvial gem deposits are available and these results are related to gravel layers in that kind of deposit. Employing this method for secondary eluvial deposits and primary gem deposits would help to discuss the suitability of this geophysical method in broader way for that kind of gravel layers as well. As continuing to research and develop these technologies, even better results and broader applications in gem exploration can be expected in future.

Acknowledgement

We would like to express our deepest gratitude to Eng. A.V.P. Vijitha, our esteemed supervisor, for his invaluable guidance, continuous support and encouragement throughout the course of this research. His expertise and insights have been crucial to the successful completion of this project.

Our sincere thanks also go to Eng. Nuwan Samarasinghe, Assistant Director of the National Gem and Jewellery Authority (NGJA), for his significant assistance and support. His contributions have been instrumental in facilitating our research activities and providing us with essential data and resources. Special thanks go to the technical assistants for their help with the geophysical instruments and data analysis.

References

[1] "Industry Capability - Gem and Jewelry Industry in Sri Lanka," Sri Lanka Export Development Board. [Online].[Accessed: Nov. 28, 2024].

[2] "Gems of Sri Lanka," Wikipedia, May 6, 2021. [Online]. [Accessed: Nov. 28, 2024].

[3] "Sri Lanka: From Mine to Market, Part 1 | Research & News,"GIA.edu. [Online]. [Accessed: Nov. 28, 2024].
[4] "NGJA – National Gem and Jewellery Authority of Sri Lanka,"National Gem and Jewellery Authority. [Online]. [Accessed: Nov. 28, 2024].
[5] "Facets 2025 | Sri Lanka's Finest Gems and Jewellery: Visit Our Show,"Facets Sri Lanka, Jul. 9, 2024. [Online]. [Accessed: Nov. 28, 2024].
[6] "Sri Lanka Gems - EDB Sri Lanka,"Sri Lanka Export Development Board. [Online]. [Accessed: Nov. 28, 2024].
[7] "Gems from Sri Lanka - EDB Sri Lanka,"Sri Lanka Export Development Board, 2024. [Online]. [Accessed: Nov. 28, 2024].
[8] "Gem, Diamond and Jewellery Industry in Sri Lanka - SLEDB,"Sri Lanka Export Development Board. [Online]. [Accessed: Nov. 28, 2024].
[9] H. M. S. Priyanath, "Socio-economic and environmental impact of gem mining industry in Sri Lanka,"ResearchGate, 1999. [Online]. [Accessed: Nov. 28, 2024].
[10] "Sri Lanka: Expedition to the Island of Jewels | Gems & Gemology,"GIA.edu. [Online]. [Accessed: Nov. 28, 2024].
[11] "Why These Gorgeous Gemstones From Sri Lanka Are Worth Taking Home," Culture Trip, Nov. 30, 2017. [Online]. [Accessed: Nov. 28, 2024].
[12] "Welcome to Sri Gems – Dealers and Exporters of Quality Gems,"SriGems.lk, 2016. [Online]. [Accessed: Nov. 28, 2024].
[13] "Sri Lanka Tourism - The Official Website of Sri Lanka Tourism,"Sri Lanka Tourism, 2022. [Online]. [Accessed: Nov. 28, 2024].
[14] J. L. Davis and A. P. Annan, "Ground Penetrating Radar for High Resolution Mapping of Soil and Rock Stratigraphy,"Geophysical Prospecting, vol. 37, pp. 531–551, 1989.
[15] A. Ribolini, D. Bertoni, M. Bini, and G. Sarti, "Ground-Penetrating Radar Prospections to Image the Inner Structure of Coastal Dunes at Sites Characterized by Erosion and Accretion (Northern Tuscany, Italy),"Applied Sciences, vol. 11, no. 23, p. 11260, Nov. 2021, doi: https://doi.org/10.3390/app112311260.
[16] "RADAN | GPR Software by GSSI | Underground Mapping Software,"GSSI Geophysical Survey Systems, Inc. [Online]. [Accessed: Nov. 28, 2024].
[17] "Science for a Changing World | U.S. Geological Survey,"USGS.gov. [Online]. [Accessed: Nov. 28, 2024].
[18] "Guideline Geo | GPR | RES | TEM | SEIS | ABEM | MALÅ,"Guideline Geo. [Online]. [Accessed: Nov. 28, 2024].
[19] R. Antunes, A. Horn, and H. Joncew, "Use of GPR in pegmatite mining: example of a sheetlike body from northern Minas Gerais, Brazil, vol. 91, no. 1–2, pp. 7–12, Aug. 2018.
[20] L. Al-Qadi and S. Lahouar, "Measuring layer thicknesses with GPR – Theory to practice,"Construction and Building Materials, vol. 19, no. 10, pp. 763–772, Dec. 2005, doi: https://doi.org/10.1016/j.conbuildmat.2005.06.005.
[21] C. B. Dissanayake and M. S. Rupasinghe, "A Prospectors' Guide Map to the Gem Deposits of Sri Lanka,"Gems & Gemology, vol. 29, no. 3, pp. 173–181, Sep. 1993, doi: https://doi.org/10.5741/gems.29.3.173.
[22] "Handbook of Agricultural Geophysics," Google Books, 2017.
[23] F. A. Cook, "Applications of Geophysics in Gemstone Exploration," Gems & Gemology, vol. 33, no. 1, pp. 4–23, Apr. 1997, doi: https://doi.org/10.5741/gems.33.1.4.
[24] P. Chenrai, P. Charusiri, and W. Galong, "One Dimensional Resistivity Sounding for Resolving Gem-bearing Gravel Layer: A Comparison of Schlumberger with Wenner Techniques at Bo Rai, Eastern Thailand,"Bulletin of Earth Sciences of Thailand, vol. 3, no. 1, pp. 1–7, 2021.
[25] "The application of ground-penetrating radar to mineral specimen mining - ProQuest," ProQuest. [Online].