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Aquifer Characterization in Hard Rock Terrain of Brookshabad, Port Blair, South Andaman, India through 2-D Electrical Resistivity Imaging Technique

G Narshimulu[*1], Venkatesan Shiva Shankar[2], K Dharanirajan[2], PM Mohan[3], TR Satyakeerthy[4], Sunil Jacob[5]

[*1]Department of Geography, JNRM, Port Blair, Andaman and Nicobar Islands-744102, India, narshi.ani@gmail.com
[2]Department of Coastal Disaster Management, Pondicherry University, Brookashabad campus, Port Blair, Andaman and Nicobar Islands-744113, India., shivashankarvj@gmail.com
[2]Department of Coastal Disaster Management, Pondicherry University, Brookashabad campus, Port Blair, Andaman and Nicobar Islands-744113, India., dharanirajan@gmail.com
[3] Department of Ocean Studies and Marine Biology, Brookashabad Campus, Pondicherry University, Port Blair-744113, Andaman and Nicobar Islands, India., pmmnpu@redieffmail.com
[4]IGNOU Regional Centre, Port Blair, Andaman and Nicobar Islands, 744101 India., satyakeerthythonduparambil@gmail.com
[5]Department of Chemistry, Catholicate College, Mahatma Gandhi University, Pathanamthitta-689695, India., suniljacob07@gmail.com

Abstract: **Although tropical islands like the Andaman and Nicobar Islands (ANI's) receive ample rainfall but still face an acute shortage of freshwater. The present investigation aims at the characterization of the aquifer in the ophiolite suite (hard rock) of Brookshabad region in South Andaman using 2D electrical resistivity imaging techniques (Wenner-Schlumberger). Five profiles were laid, in each profile, thirty-two steel electrodes with 5 m intervals (32*5=160 m) have adhered. Out of the five profiles, the 2nd profile shows a promising freshwater lens at a depth of 21.5 to 31.5m.**

Index Terms: **Wenner-Schlumberger, Freshwater, Groundwater, 2-D Electrical Resistivity**

I. Introduction

The second most abundant and important freshwater source is the groundwater (Gyeltshen et al. 2019; Rajendran et al. 2020). Also, 26% of the freshwater is hidden beneath the Earth's surface in an unfrozen state (Arulbalaji et al. 2019). Globally the regions with undulating topography are devoid of perennial freshwater sources and some areas face acute shortage of water due to population explosion and urban sprawl (Gyeltshen et al. 2019). The Andaman and Nicobar Islands (ANI's) are located in the Bay of Bengal's tropical zone exhibit rolling topography. 70-90% of the rainfall is drained into the adjacent sea (Shiva Shankar et al. 2018). The majority of ANI's are underlined by a marine sedimentary group of rocks (70%), followed by 15% of volcanic rocks, and the rest a combination of igneous rocks and coralline formation. The ANI's are composed of two main rock formations viz., 1) Andaman flysch (turbidities), and 2) Ophiolite suite. The former rock type belongs to the Eocene-Oligocene age while the latter belongs to the Cretaceous age (Karunakaran et al. 1964; 1968). Over-exploitation of groundwater due to the growing population is considered a pertinent problem in recent decades (Mundalik et al. 2018). Thus, exploring and mapping the existing groundwater potential resources is the need of the hour to meet the demands of the growing population (Gyeltshen et al. 2019).

Geophysical exploration commonly called applied geophysical prospecting is conducted to locate economically significant accumulation of oil, natural gas, and other minerals including groundwater. The electrical resistivity survey is one such extensively applied geophysical exploration technique to understand the surface resistivity distribution (Loke 1999). Several vital geological parameters like the degree of water saturation in the rock, minerals, porosity, fluid content, etc, are correlated with the true resistivity measurements done by the electrical resistivity survey. Mineral exploration, mining, geotechnical and hydrological investigations were executed using electrical resistivity surveys for many decades (Pérez-Corona et al. 2015). Very recently, electrical resistivity surveys were deployed in environmental investigations. The two-dimensional (2D) Electrical resistivity technique is one of the best technology for identifying the groundwater potential in hard rock terrains (Daily et al. 2005; Mukhwathi and Fourie 2020) and has found an array of applications, including.

1. Aquifer characterization, hydraulic properties of aquifers, and mapping its potential (Gao et al. 2018; Gómez et al. 2019; Nasta et al. 2019; Tesfaldet and Puttiwongrak 2019; Thapa et al. 2019).
2. Appraisal of saltwater intrusion in the coastal aquifers (Aladejana et al. 2020; Hermans and Paepen 2020).
3. To find the depth of the groundwater table in order to determine the risk posed to archaeological sites and its infrastructure (Sharafeldin et al. 2019).
4. To map subsurface preferential pathways of groundwater conduits, discharge, seepage and contamination (Delgado-Rodríguez et al. 2018; Sreeparvathy et al. 2019; Hazreek et al. 2018; Paepen et al. 2020).
5. To study the interaction of groundwater/surface water (Steelman et al. 2017; Shakhane and Fourie 2019).

The objective of the present investigation was to recognize the groundwater potential in the hard rock terrain of the southern part of Brookshabad using the 2-D Electrical Resistivity Imaging method.

II. Study Area

The geographical extent of the focus area is bounded by 11°37'58.89" to 11°38'04.30" N latitude and 92°44'33.61"E to 92°44'40.71"E longitude with a total extent of 500 Sqm (Fig: 1). The study area entirely comprises of the ultramafic–mafic, plagiogranite, gabbro–plagiogranite–diorite–dolerite, boninite and tholeiitic basalt rocks (Karunakaran et al. 1964; 1968) (Fig: 2). Since the study are being a part of an active tectonic zone of the ANI's, the rocks are intensely fractured and sheared (Kar 2019). Also, the paucity of groundwater is ensured by the presence and distribution of poor unyielding aquifers in the area under investigation (Kar 2019). Further, owing to the plentiful precipitation (~3500mm), of which 60-70% of it empties into the adjacent seas as surface runoff (Shiva Shankar et al. 2018).

III. Materials and Methodology

The materials such as the PASI Electrical Imaging system, GPS, Brunton compass, and RES2DINV software (V. 3.57) were used to comprehend the objective of the present investigation.

Five resistivity traverses were perused through the Wenner-Schlumberger array with a maximum electrode separation ratio of 5m. The traverses were conducted in those areas where the underlying basement was expected to be shallow. Further,it will be easy to uncover fracture zones in the bedrock of this area. These fractured zones, associated with an equitable thickness of weathered overburden, could be considered suitable for location boreholes. 0.5m length of stainless steel, were planted to a depth of 0.5m for data collection with the Electrical Resistivity Imaging (ERI) system. 32 steel electrodes with 5 m intervals (32*5=160 m) were used. The length of one cable on one side is 80m and on the other side by the same length and the total length of the spread is 160 m. It was ensured that each electrode was in good contact with the ground survey lines. An effective maximum depth by Wenner–Schlumberger is approximately 31m.

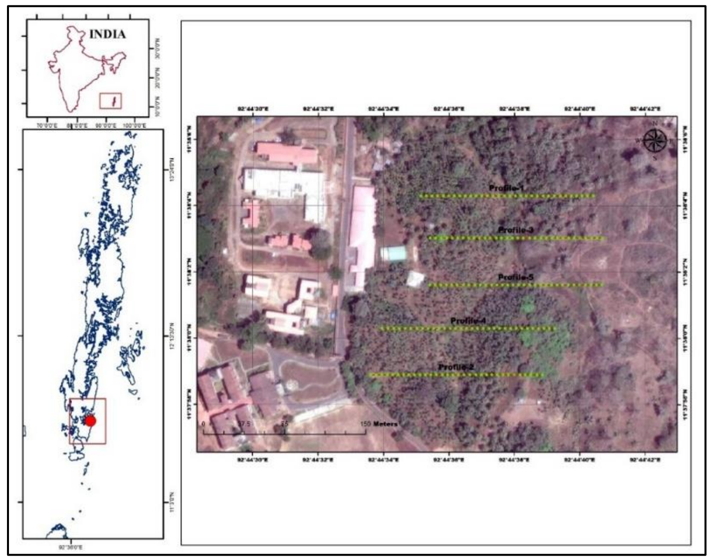

Fig 1: Study area Map

Fig 2: Hard rocks of the study area

IV. Results and Discussion

Wenner-Schlumberger's resistivity sounding method was comprehended to address the objective of the present study.

A. *Profile 1*

The pseudo-section along the profile 1 (Fig: 3) trending 80˚ and 280˚ to a length of 160m. The coordinates of the profile are from 11° 38' 4.298" N and 92° 44' 35.158" E to 11° 38' 4.302" N and 92° 44' 40.431" E. Five direct currents (DC) resistivity soundings were conducted with station spacing of

20m and the pseudo-section array maximum length of 160m. The resistivity section shows a weathered overburden with a resistivity value from 19849 to 45673 Ohm-m at a depth between 13.4 to 31.5m. The basement rock with a resistivity of around 45673 Ohm-m at the depth of 31.3m. The lowest resistivity value ranges from 5.91 to 106 ohm-m at a depth of 2.4 to 9.2m in this section indicating the freshwater. The intermediate overburden layers exhibit resistivity values that ranged from 1325 to 19849 Ohm-m at the depth of 10.4 to 15.6m. The resistivity value in hard rock ranges from 24298 to 45673 Ohm-m at the depth of 26.2 to 31.3m. High resistivity values suggest hard rocks like ultramafic–mafic, plagiogranite, gabbro–plagiogranite–diorite–dolerite, boninite and tholeiitic basalt.

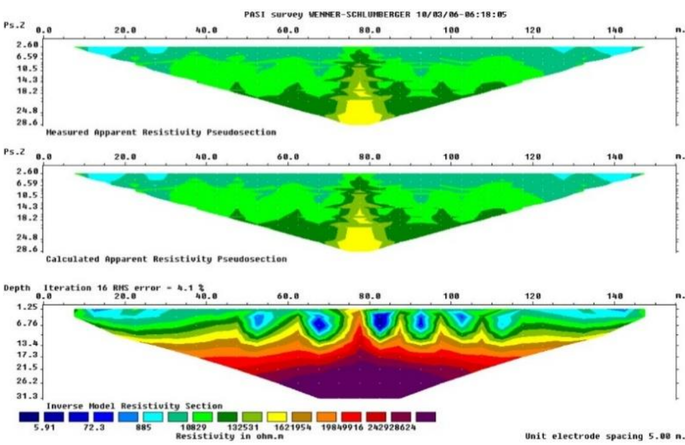

Fig 3: Wenner-Schulmberger pseudo section of profile 1

B. Profile 2

Profile 2 (Fig: 4) trends 75^0 and 285^0 to a length of 160m. The coordinates of the profile are from 11° 37' 58.897" N and 92° 44' 33.622" E to 11° 37' 58.902" N and 92° 44' 38.882" E. The model response Wenner-Schlumberger now clearly shows the resistivity range of 18.9 to 23839 Ohm-m at a depth from 1.25 to 17.3m. It was inferred as the hard rock and at depth a freshwater lens (blue colour) with sediment layers. The intermediate zone exhibited overburdened rocks and fractures as the values of resistivity ranged from 145 to 3100 ohm-m at the depth of 2.85 to 7.24m and it was identified as the hard and dry zone. The resistivity values were within the range from 18.9 to 98 Ohm-m at the depth between 21.5 to 31.3m was indicative of the presence of clay and freshwater bodies with alluvial sediment that were marked with low resistivity values.

C. Profile 3

The Profile 3 (Fig: 5) trends 60^0 and 300^0 to a length of 160m. The coordinates of the profile are from 11° 38' 3.030" N and 92° 44' 35.444" E to 11° 38' 3.034" N and 92° 44' 40.715" E. The pseudo-section image displayed an inversion resistivity value varying from 2.72 to 66977 Ohm-m. The resistivity values pseudo-section image shows the upper part of the area 2.72 to 8.30 ohm-m at a depth of 1.25 to 6.76m. The intermediate resistivity value for these beds ranges from 253 to 719 Ohm-m. at a depth of 7 .34 to15.6m, the resistivity values ranged from 2195 to 6697 Ohm-m at a depth of 14.6 to 31.5m suggests hard rocks like basalt and plagiogranite.

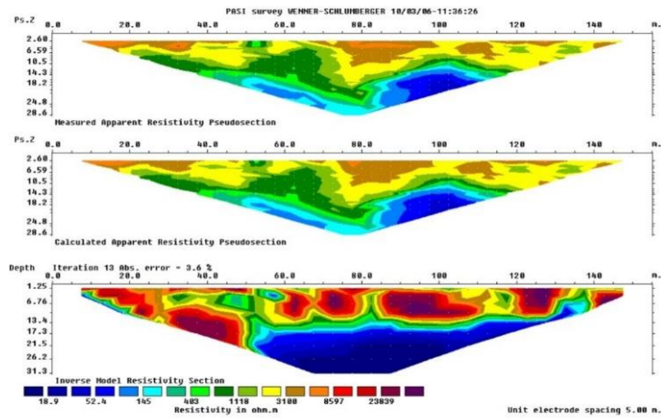

Fig 4: Wenner-Schulmberger pseudo section of profile 2

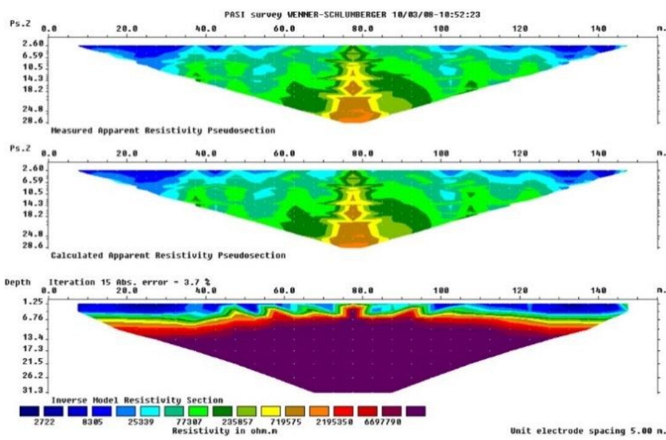

Fig 5: Wenner-Schulmberger pseudo section of profile 3

D. Profile 4

The pseudo-section along the profile 4 (Fig: 6) trending 50^0 and 310^0. The coordinates of the profile are from 11° 38' 0.295" N and 92° 44' 33.981" E to 11° 38' 0.300" N and 92° 44' 39.256" E. The resistivity section shows a top layer of low resistivity values ranging from 4.04 to 11.76 Ohm-m at a depth between 1.26 to 5.2m. This layer is dominated by small fractures and water bodies, hence the low resistivity was recorded. It was also inferred that this layer was composed of overburdened sediment layers for the sediment saturated freshwater. The intermediate layers were identified as the continuation of the top overburden and fracture zone at the thickness of 6 to 10m. The high resistivity value ranging from 2435 to 7076 Ohm-m encountered at the depth of 10.4 to 31.5m marked by dark violet colour is mostly composed of basaltic rocks.

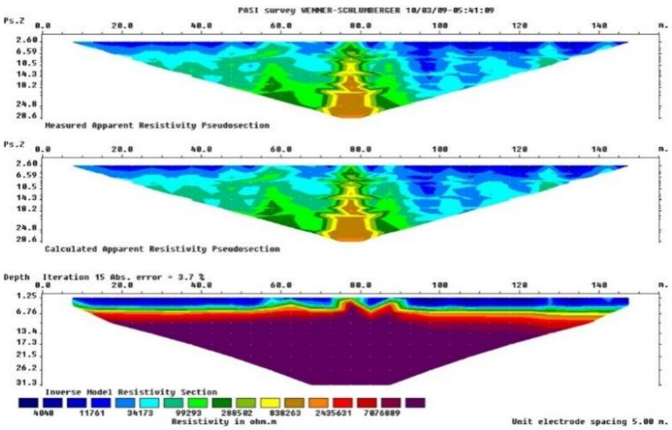

Fig 6: Wenner-Schulmberger pseudo section of profile 4

E. Profile 5

Profile 5 (Fig: 7) trends 80^0 and 280^0 to a length of 160m. The coordinates of the profile are from 11° 38' 1.608" N and 92° 44' 35.435" E to 11° 38' 1.613" N and 92° 44' 40.693" E. The field observation and the distribution pattern of resistivity values in the pseudo sections are used to classify the field condition and overburden layers and undulation of curve line and small fractures and water bodies at the surface layer and; in the lower part of the layer represent hard rock at the bottom.

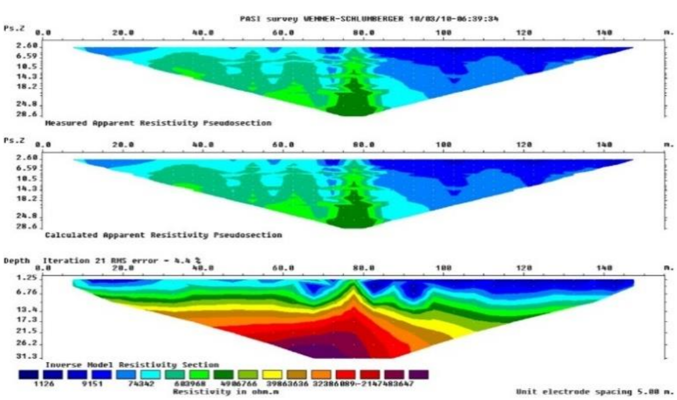

Fig 7: Wenner-Schulmberger pseudo section of profile 5

The resistivity values of the pseudo-section image show the upper part of the area 11.26 to 743.4 Ohm-m at a depth range of 1.25 to 5.34m indicating some surficial collection of freshwater. The intermediate layer's resistivity value for these beds ranges, from 603 to 32386 Ohm-m at the depth of 6.76 to 21.5m. The lowest part of the layer represents the highest resistivity values ranging from 32386 to 47483 Ohm-m in the depth of 26.2 to 31.5m.and the more undulations of curve lines dipping angle is northwestern ward side. The layer of the bottom is mostly plagiogtranite and basaltic rock which has more resistivity.

From the above results of the present investigation, it was understood that 2nd profile holds some promising freshwater lenses. On the other hand 3rd, 4th and 5th profile show signs of shallow water bodies with fractured zones of hard rock like plagiogtranite, and basalt. The weathered and fractured zones of hard rock terrain are promising sites to locate freshwater. Similar findings of freshwater in the Ophiolite suite were also reported from other parts of South Andaman (Maury and Balaji 2014; Maniruzzaman et al.2018).

Conclusion

To study the groundwater potential in hard rocks by using 2-D Electrical resistivity survey technique. The Wenner-Schlumberger array configuration was used in the southern part of Brookshabad in Port Blair. The study delineates both the horizontal and vertical pseudo-sections and depth-wise distribution of the resistivity values. The Wenner Schlumberger array of pseudo-section exhibited deep penetration to a depth of 31.5m. The overburden layer thickness is very less in the study area suggesting a less groundwater recharge rate. Also, it is understood from the present investigation that the draft level shall be very low and the water extracted from this source may not support a huge population. Landscaping with native flora, infiltration wells (Fig: 8) or ponds, and spillways will aid in groundwater recharge in hard rock terrain as in the study area.

Fig 8: Infiltration well in the study area

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