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Azimuthal Square Array Configuration and Groundwater Prospecting in Quartzite Terrian at Edaikkal, Ambasamudram, Tirunelveli

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Abstract: The Azimuthal square array electrical resistivity (DC) surveys were conducted in the Edaikkal, Ambasamudram, Tirunelveli District. The water is an essential part of industrial complex in the sugar cane agriculture development. The study area is 3 square kilometers under thick cover of red soil, gravel, quartzite ridge and hard rock of charnockite in study area. The surveys were carried out using the help of the equipments CRM-500 Aquameter, electrodes and wire spools with accessories. The array is expanded symmetrically about the centre point, in increments of A (2) ½, so that the sounding can be interpreted as a function of depth. The azimuthal polar plots, litho stratigraphical graphical representation were used to distinguish the depth wise variation of the resistivity change in the study area. From the electrical resistivity study the water bearing zone occurs at a depth of 25,75m that range of apparent resistivity from 100-120 Ohm.m in quartzite ridge. The compact hard rock of charnockite occurs from the depth of 100m and 125m that range of apparent resistivity 1500 Ohm.m in the study area. The azimuthal square array methods have delineated geological structures of the quartzite ridge. The azimuthally square array resistivity variation is used to identify the aquifer thickness of the study area.

Key words: Azimuthal Square array, Resistivity, Groundwater, Quartzite ridge, Edaikal

INTRODUCTION

In the present study, the main aim of the investigation through Electrical Resistivity, Square Array method is used to measure the apparent resistivity of the selected locations, for subsurface condition.

The study area chosen was in between in and around area of Edaikal village, Ambasamudaram, Tirunelveli District, Tamilnadu. The in-between place was covered by Quartzite rocks with a capping of red soil at some exposures of granitic rock. The district is located between 770 28' 22'' and 8045'54''N Latitudes and 77028'54'' and 8045'57.5" E Longitudes. The northern border of the district is bounded by Virudhunagar district and the Western, Southern and Southwestern parts are covered by Tirunelveli district. The Eastern part of the district is bordered by Gulf of Mannar (Fig.1). The district enjoys a su-tropical climate. The period from May to June is generally hot and dry. The weather is pleasant during the period from December to January. The mean minimum temperature is 22.9°C and means maximum daily temperature is 33.5°C respectively. Rainfall data from IMD stations over the period 1901-2000 were utilized and a perusal of the data shows that the normal annual rainfall over the district is 879 mm.

Geomorphology: The study area Tirunelveli district is bordered by Western Ghats (Ridge and valley complex) in the West. A major part of the district constitutes a plain terrain with a gentle slope toward East and Southeast, except for the hilly terrain in the west. The general elevation of the area varies from less than 10 to 1408 m amsl (Tulukkaparai hill range). The prominent geomorphic units identified in the district through interpretation of Satellite imagery are Structural Hill, Bazada Zone, Valley Fill, Flood Plain, Pediment, Shallow buried pediment, Deep buried pediment and Coastal Plain.

Soils in the area have been classified into i) Deep Red soil ii) Red Sandy Soil. iii) Block Cotton Soil iv) Saline Coastal Alluvium and v) River Alluvium. The study area is formed in the structural and tectonic history of the district in Western crystalline terrain.

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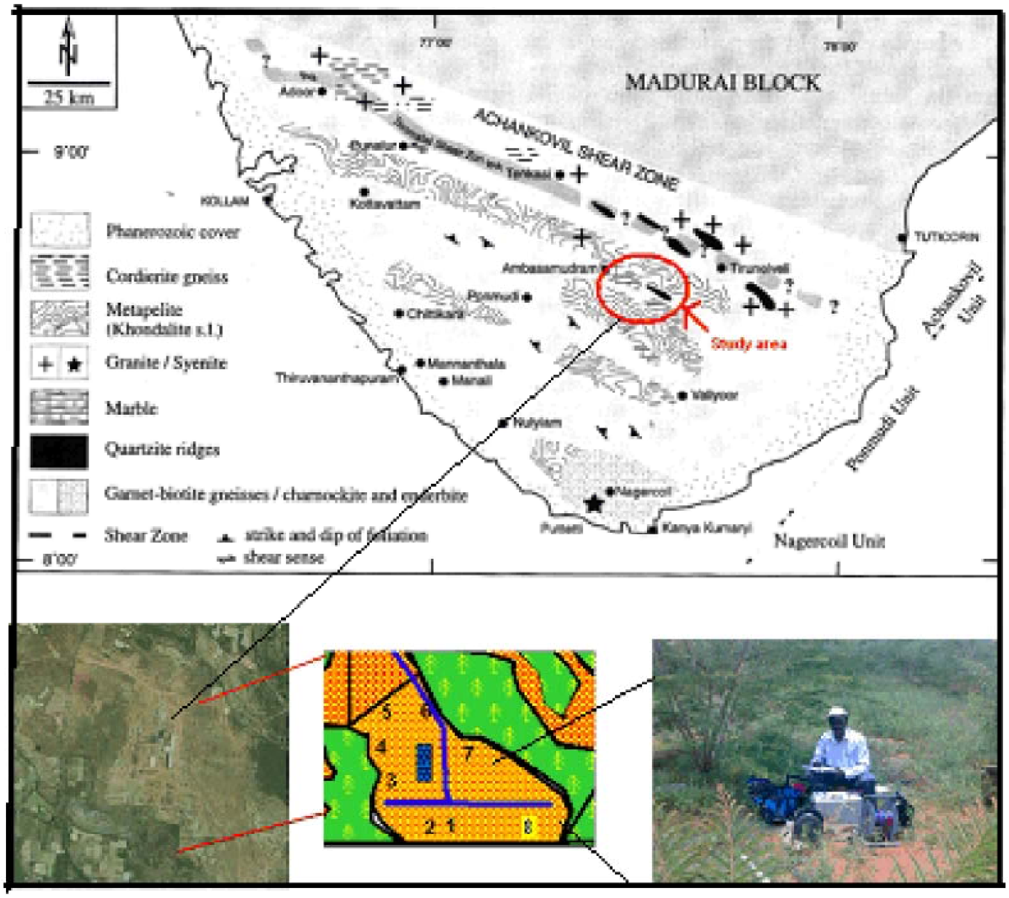

Fig. 1: Shows the data collection profiles location in the study area.

The study area is underlain by both porous and fissured formations. The important aquifer systems in the district are constituted by weathered and fractured hard rock formations of Archaean age. Geophysical electrical resistivity study is used for the groundwater exploration in the coastal and terrain environments [1-6].

Azimuthal Square Array Method: Azimuthal square array (dc) resistivity is a modified resistivity method, where in the magnitude and directions of the electrical anisotropy are determined. An electrode array is rotated about its center so that the apparent resistivity is observed for several directions. The side length of the square is defined as spacing and is equal to the depth of penetration. The array is expanded symmetrically about the centre point with an increment in 'a' spacing of each diagonal [7-11].

Field Measurements: For each square, three measurements are made, in which two perpendicular measurements namely Alpha (α) and Beta (β) Gamma (γ). The same will repeat after rotation of certain angle, such as 150, 450 and they are denoted by the letter α', β', '. The α and β measurements provide information on the directional variation of the sub-surface apparent resistivity (ρa). The "γ" measurement serves as a check on the accuracy of the α and β measurements (Fig. 2).

Apparent resistivity

$$\rho_a = \frac{K?\,V}{I} \qquad (1)$$

Where
ρ_a = apparent resistivity;
K = geometric factor for the array;
V = potential difference, in volts; and
I = current magnitude, in amperes.

The geometrical factor (K) for square array is calculated by using the formula

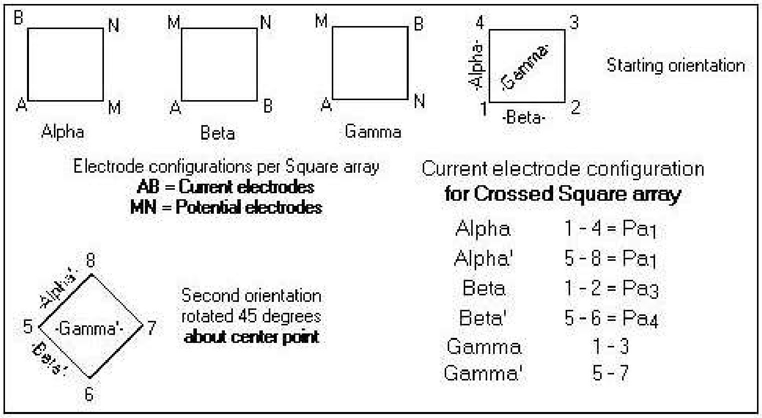

Fig. 2: Shows square array electrode arrangements.

$$K = \frac{2\pi A}{2-(2)^{1/2}} \quad (2)$$

Where A = square-array side length, in meters Habberjam & Watkins [9]. The data generated for bed rock anisotropy (N) and apparent anisotropy (λa) by using the equation number, are utilized to construct the diagram to characterize the anisotropism of bedrocks in the study areas. The square array is more sensitive to anisotropy than Schlumberger or Wenner array Habberjam [12].

Azimuthal Square Array Resistivity Surveys and Data Collection: Azimuthal square array (dc) resistivity is a modified resistivity method, wherein the magnitude and directions of the electrical anisotropy are determined. An electrode array is rotated about its center so that the apparent resistivity is observed for several directions. The side length of the square is defined as spacing 'a' and is equal to the depth of penetration [9]. The array is expanded symmetrically about the centre point with an increment in 'a' spacing by (2)" The square array sounding technique requires 65% less surface technique is about twice as sensitive to anisotropy as linear array. This azimuthal square array study was carried out at three experimental sites at Edaikkal Village with CRM 500 Resistivity meter, steel electrodes and connecting cables. Data Acquisition of Apparent Resistivity from Square Array Resistivity Method: The starting orientation of square array is aligned in N-S direction. The apparent resistivity is measured from perpendicular sides (alpha and beta) and diagonal (gamma) of each square. In each of the eight experimental sites, azimuthal square array soundings were carried out for alpha, beta and gamma array orientations. Depth wise apparent resistivity was obtained by varying spacing between 25-125m, at an interval of 25m, which resulted in nine azimuthal squares with each of the orientations. The same procedure is repeated for alpha', beta' and gamma' configurations also (Fig. 2).

RESULTS AND DISCUSSION

The apparent resistivity is calculated by multiplying apparent resistance measured in azimuthal square array survey with the configuration factor. The calcualted values of three types of graph were plotted. The three types of graphs are Azimuthal polar plots and depth sounding graphs.

Azimuthal Polar Plots: The apparent resistivity values calculated for the three locations are plotted as Azimuthal graphs. From these azimuthal plots in the study area three fracture directions long with homogeneous rock mass are identified on the basis of the relative of increasing order of apparent resistivity values. This fracture zone detection and rock mass identification using polar plots considerably helps to identify the groundwater level in the study area (Fig. 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7 and 3.8).

The longest axis of the ellipse in the polar plot indicates maximum resistivity of the rock mass. When the polar diagram conforms to an ellipse, it is taken to represent the anisotropy. The circular pattern of the plot exhibits rock mass without fault / fracture orientation i.e., the rock is isotrophic. The intersection of the fault planes oriented in two directions assumes the cross shape. Majority of the ellipses in the location 2 are in NE-SW and NW- SE direction and three of the single faults are in NE-SW direction indicates that the fractures are oriented in NE-SW direction. In the second spot fractures are oriented in E-W directions whereas in the location 7, they are directed mainly along NS direction.

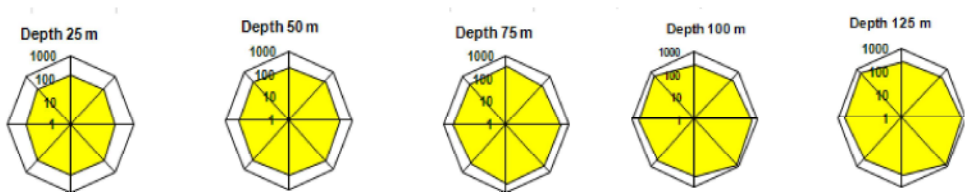

Fig. 3.1: Azimuthal polar plot in Edaikkal profile 1.

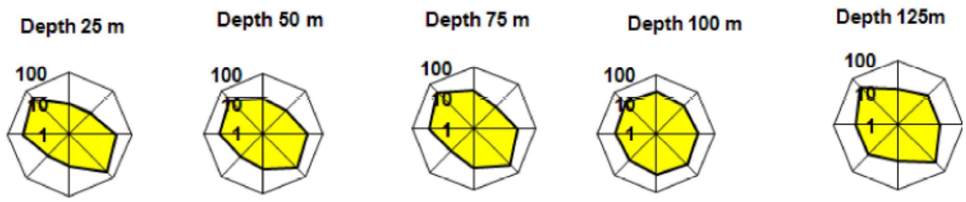

Fig. 3.2: Azimuthal polar plot in Edaikkal profile 2.

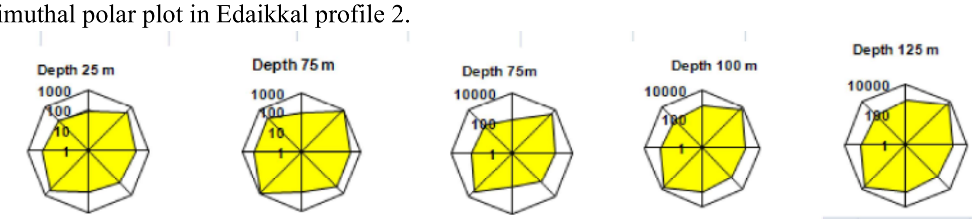

Fig. 3.3: Azimuthal polar plot in Edaikkal profile 3.

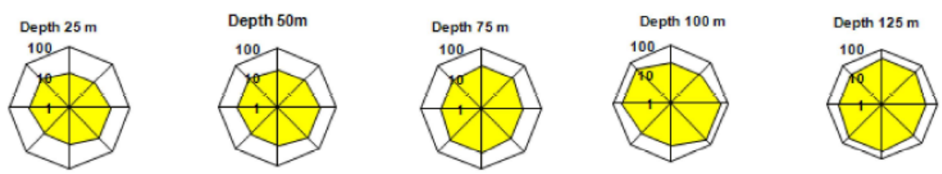

Fig. 3.4: Azimuthal polar plot in Edaikkal profile 4.

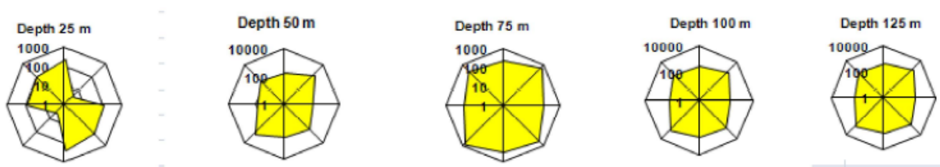

Fig. 3.5: Azimuthal polar plot in Edaikkal profile 5.

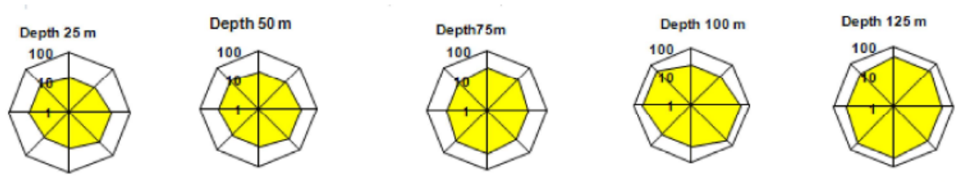

Fig. 3.6: Azimuthal polar plot in Edaikkal profile 6.

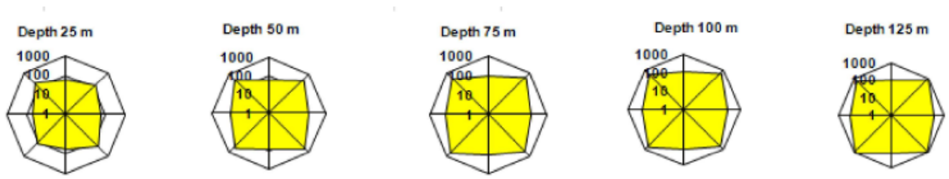

Fig. 3.7: Azimuthal polar plot in Edaikkal profile 7.

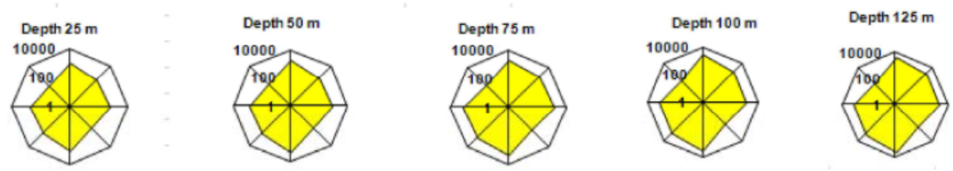

Fig. 3.8: Azimuthal polar plot in Edaikkal profile 8.

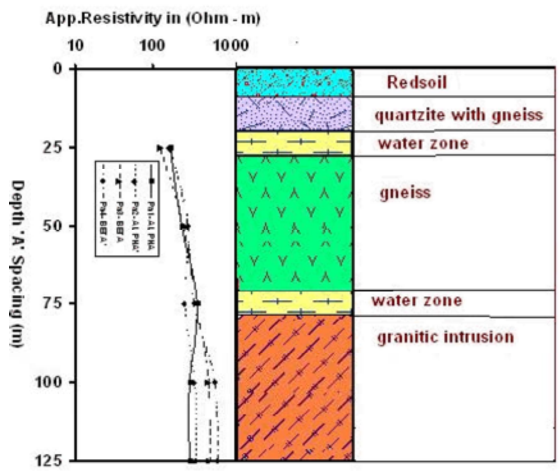

Fig. 4.1: Geoelectrical azimuthal square array resistivity study for suitable freshwater aquifer identification.

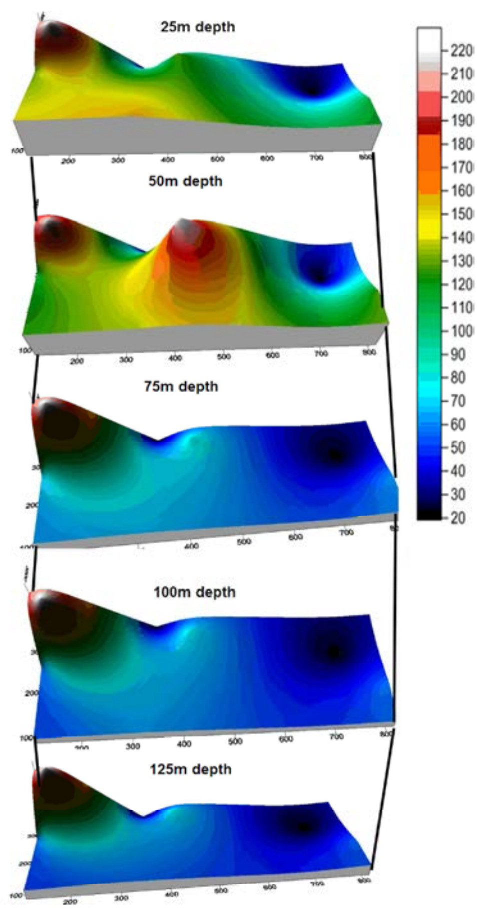

Fig. 4.2: Contour plotting in the depth of 25, 50, 75, 100 and 125m in Edaikkal profile 1-8.

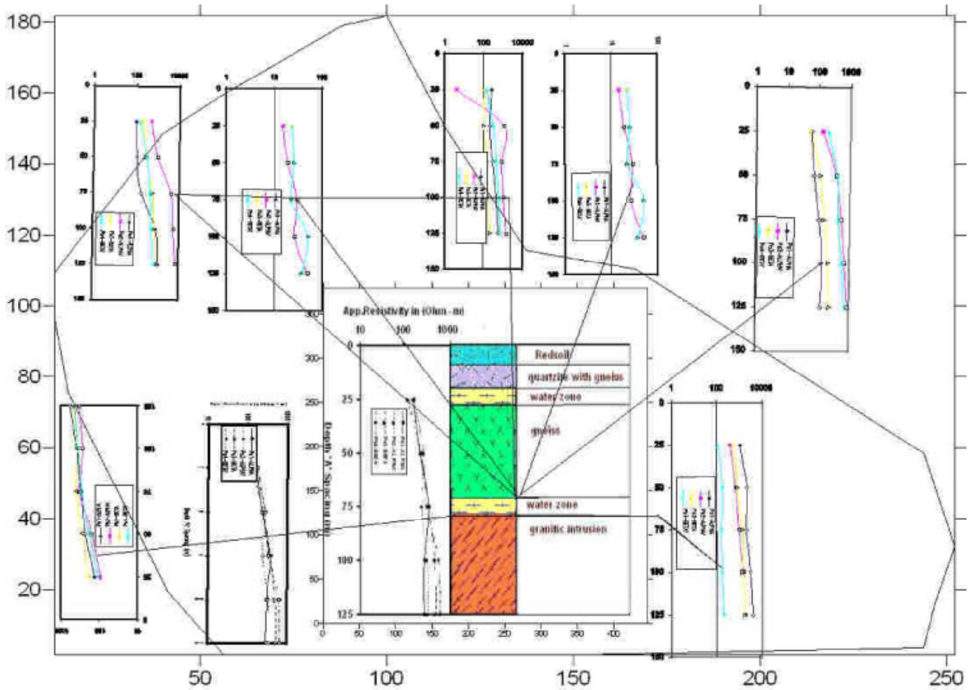

Fig. 4.3: Lithostratigrpahic sequence of resistivity profiles in Edaikkal village.

The circular patterns are seen at the depth of 125 m in location 5, 6, 7. The circular patterns are identified in the location in all profiles at a depth of 100,125m.

Square Array Method and Depth Sounding Graphs: Depth sounding curve is plotted between apparent resistivity and ‘A’ spacing. Plotting of ‘A’ spacing versus apparent resistivity values obtained from alpha, alpha’, beta’, beta’ orientation imply the horizontal resistivity zones. In the square array, ‘A’ spacing is equal to depth. The maximum resistivity in this area is 1275 ohm m (Fig. 4.1, 4.2 and 4.3).

Table 1: Depth and Orientation of fractures in the Edaikkal

Profile	1	2	3	4
Ellipse		25,50,75		
	100,125	100,125	25,50,75	25,50
Single fault	NW-SE	NW-SE	Nw-SE	NW-SE
Double Fault				
Cirucular fault	25,50,75	100	125	75,100,125
Profile	5	6	7	8
			25,100	
Ellipse	75		NW-SE	25
		25,50	50,75	
Single fault	50	NW-SE	NW-SE	50,75,100,125
Double Fault	25			
Cirucular fault	100,125	75,100,125	125	

CONCLUSIONS

Azimuthal Square Array (DC) Resistivity method is used to study the fracture zone of the subsurface and to investigate the groundwater level of the Edaikal village in Ambasamudram, Tirunelveli District. Edaikkal is a high anisotropy region. High anisotropy implies the presence of rocks with different physical properties in different orientations in the subsurface of the study area. Azimuthal polar plots shows that, in location 1 single faults are found between 25m – NE SW, 50 - NE SW, 75 – NE SW and 100m - EW. Elliptical features are identified in the depth of 25m - NE SW. In the square array, the depth is equal to ‘A’ spacing. Plotting of depth versus apparent resistivity values obtained from alpha, alpha’, beta, beta’ orientations imply the horizontal conductivity zones. Since, the study area is situated in sedimentary and gneous rocks; the maximum recorded apparent resistivity in this terrain is 1270 Ohm-m and the resistivity range for the conductivity zone is arbitrary fixed as less than 38 Ohm-m. Horizontal fracture/ permeability independent of direction and also contribution from vertical or steep fracture sets vary with azimuth creating anisotropic distribution. The Edaikkal Water table zone 1 at a depth of 25m and 75m.

From the study on Azimuthal square array resistivity method held at Edaikkal, it is concluded that fresh water is identified at a depth of 75m. The borehole drilling geological data compared with geoelectrical logging.

They are obtained good freshwater from the recommended geoelectrical site at Edaikkal village profile 1 and 2. In 3, 4, 5 Elliptical features are discovered at 25, 50 and 75m. The apparent resistivity displays the upper layer quartzite with weathered charnockite deposits identified the resistivity ranges from 7-80 Ohm.m. The range of resistivity of the freshwater horizon in the profile varies from 110-124 Ohm in the intermediate layer of weathered gnessic rock. The lower part of the charnockite rock occurred in the range of resistivity ranges from 1300 Ohm.m. In 6, 7, 8 single faults are found between Ellipses are noticed at 25m – NS, 75m – NE-SW. Single fault is in-between the depth of 10m - NE –SW, 50m NE-SW. The upper layer or the first layer covered by Quartzite resistivity ranges from 200-600 Ohm.m. The intermediate layer is formed by weathered gnessic rock with ground water the horizon resistivity ranges from 100-134 Ohm.m. The lower layer of granitic rock resistivity ranges from 600-7000 Ohm.m. The Azimuthal square array method is one of the useful techniques for groundwater exploration in hard rock area.

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