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Efficacy of Electrical Resistivity Tomography Technique in Mapping Shallow Subsurface Anomaly

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Abstract: Electrical Resistivity Tomography is a versatile, fast and cost effective technique for mapping the shallow subsurface anomaly. It covers a wide spectrum of resistivity ranging from <1 Ohm.m to several thousands of Ohm.m. In this paper applications and utility of two-dimensional Electrical Resistivity Tomography (ERT) technique are discussed to look into huge data density coverage, different signal strengths of data from subsurface and their implications in resolving the aquifer zones, related geological structures etc. of the substratum ranging from alluvium to tectonically disturbed hard rock ridge region of the country. The major advantages and flexibility of ERT over conventional resistivity methods are also discussed.

Keywords: Electrical Resistivity Tomography, Subsurface Mapping, Groundwater Hydrology.

INTRODUCTION

In Resistivity Tomography Technique the two dimensional (2D) resistivity data generated using multi-electrodes which resulted in high density pseudo-sections with dense sampling of apparent resistivity measurements at shallow depth ranging from surface to a depth of 300 m in a short time. The two dimensional (2D) data generated using multi-electrodes resulted in high density pseudo sections with dense sampling of apparent resistivity measurements at shallow depth ranging from surface to a depth of 300 m in a short time. The 2D measured resistivity data later being edited, processed, inverted using 2D inversion approach gives 2D true resistivity models. The maximum depth of investigation is shown in the resistivity models along the vertical axis (Figs. 1 to 4) and is determined by the spacing between the electrodes and the number of electrodes used in the specific type of array. Nevertheless it also depends on geology and heterogeneity of the subsurface formation. The advantage of multi-electrode tomography survey over conventional resistivity method are many (1) to interpret the subsurface geo-physical anomaly quantitatively from 2D resistivity models of the sub-surface geological formations, (2) extract the range of true resistivity from the inverted resistivity models, (3) large density data coverage for better resolution and less time for data acquisition etc. The geophysical anomaly is directly seen and demarcated from the 2D resistivity models.

INTERPRETATION OF 2D RESISTIVITY MODELS: RESULTS AND DISCUSSIONS

Bedrock Depth and Basement Topography

Bedrock depth and basement topography are important to know in a geological rock formation in terms of groundwater prospecting. This is studied in a granitic area located 30 km south of Hyderabad, Andhra Pradesh (Kumar, 2004). The geological sequence of the area consists soil cover of about 1 m, followed by highly weathered granite about 12-18 m, followed by fissured layer of about 15-20 m and then the bedrock or basement rock (Kumar et al. 2007). The 2D sub-surface true resistivity model using Wenner array (Fig.1a) clearly delineated the weathered zone saturated with moisture up to a depth of ~10 m with resistivity of 60-75 Ohm.m (Fig.1a) The model shows the deepening of the bedrock at 60 m and 124 m lateral distance along the profile at a shallow depth of 27 m as shown in Fig.1a. The 2D section clearly shows the basement granitic rock had been delineated with resistivity of the order of 700 -1000 Ohm.m and is quite undulating in nature showing no major indication of groundwater potential zone. On the other hand, another granitic area had been studied located in Nizamabad district, Andhra Pradesh for groundwater problem. Here, hydrogeological investigaton shows deep water levels in borewells with less yield and in summer season shallow depth borewells <100 m went dry (Rao et al. 2008). The resistivity model section (Fig.1b) at this site clearly

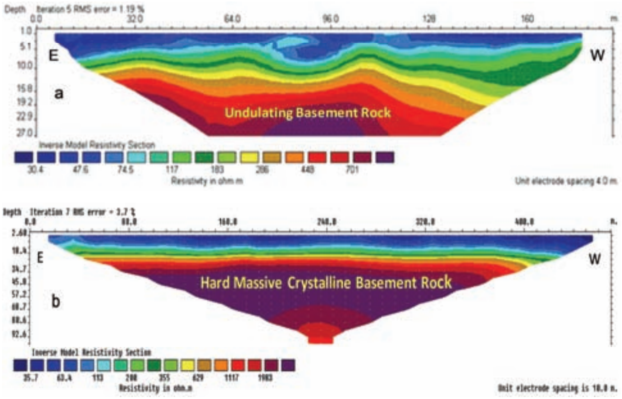

Fig.1. 2D resistivity models showing (**a**) undulating basement rock mapped using Wenner array in a granitic hard rock aquifer and (**b**) delineated thick massive crystalline basement in granitic rock using Wenner-Schlumberger array.

shows a flat thick chunk of massive granitic basement rock right from 34 m to 92 m depth (Fig.1b) showing no sign of groundwater prospect zone. This crucial information helps in planning for the groundwater exploration in the area.

Dyke Characteristics

Multi-electrode resistivity tomography technique deployed over several *in situ* dykes and studied both concealed and exposed dykes in Ranga Reddy and Medak districts of Andhra Pradesh in a granitic terrain to understand their characteristics property. The 2D resistivity models resolved and delineated the shape and position of *in situ*

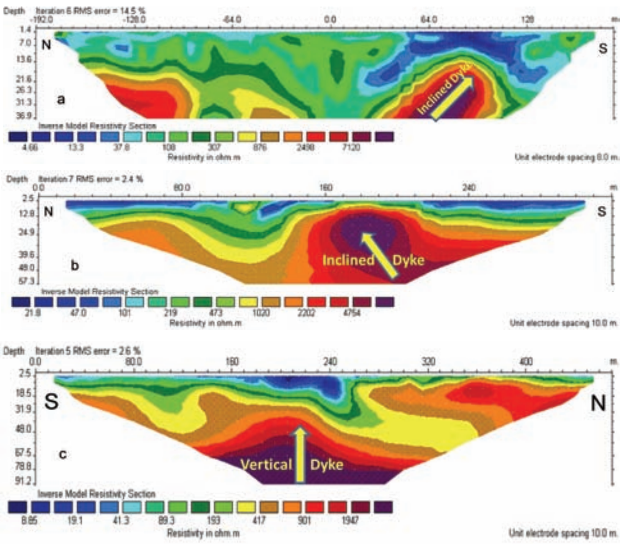

Fig.2. 2D resistivity models showing different *in situ* dykes intruded in hard granitic rocks, (**a, b**) inclined dykes identified and demarcated using Wenner array and (**c**) vertical dyke precisely revealed using Wenner-Schlumberger array.

dykes in the hard rock granitic environment based on the substantial resistivity contrast as shown in Figs.2a, b and c. The study helped in mapping the lateral variation of dyke using Wenner array (Fig. 2a and b) as well as vertical sharp change had been revealed using Wenner-Schlumberger array (Fig.2c). In these figures the resistivity over the dykes show high values ranging from 2000 to >10000 Ohm.m an important finding and characteristics of dyke. They show significant differential weathering in association with the granite host rock especially near the contacts and such area are hydrogeologically potential sites for groundwater reserve and targeted for groundwater exploration. It is seen and observed that the resistivity value is low on one side of the dykes and behave as a conduit and acts as a promising target for groundwater exploration and development, while the other side acts as a barrier for groundwater flow. Such identified hydrogeological zones are found to be favourable sites for groundwater reserve and are true aquifer(s).

Deeper Groundwater Resource

The water levels in weathered part of most of the aquifers had been depleted and it had gone down in hard rock aquifers (Kumar et al. 2003; Maréchal et al. 2004). The deeper sources of groundwater in hard rocks namely quartzite and granite had been studied in the quartzitic hard rock region located on the flank of the ridge which forms the northeastern extension of the Aravali hill range, New Delhi. The area under investigation lies between 77°15’10" E longitude and 28°31'15" N latitude (Rao et al. 2006). The results are presented as shown in Figs 3a, b and c. It consists of network of joints, fault planes, bedding planes, weathered and fractured zones which act as a secondary porosity and forms the aquifer system in the area and mainly consists of weathered/fractured quartzite formations. The water table in quartzitic aquifer varies from 40 to 65 m below ground level (bgl) in this area (IGGS, 2001). The 2nd area studied in granite region located at about 160 km from Hyderabad in Nizamabad district, Andhra Pradesh. The country rock is granite and the water table is deep and in summer season shallow depth borewells <100 m went dry (Rao et al. 2008). Each variety of said rocks responds differently in terms of groundwater prospecting and availability in the present study. Examples are presented here from quartzitic and granitic hard rock regions and the deeper aquifers are delineated and resolved based on the joint study of the two different array data viz., pole-dipole and pole-pole and using suitable inversion and optimization schemes. It is seen from true resistivity model (Fig.3a) using pole-dipole array that the southern part of the 2D resistivity profile shows

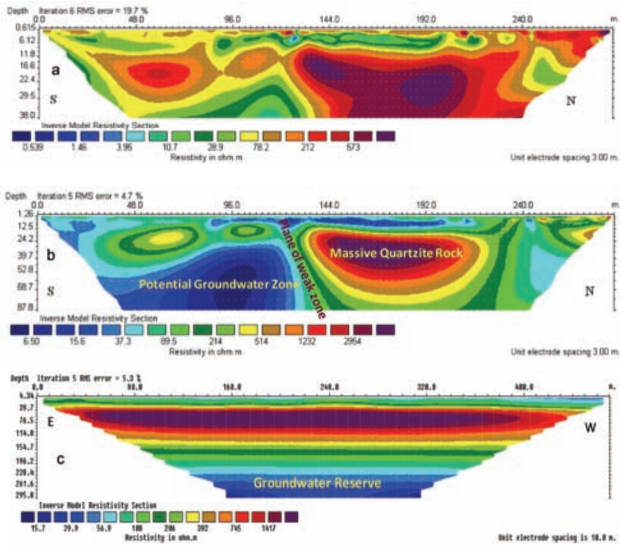

Fig.3. 2D resistivity models showing (**a**) partial visibility of aquifer at <40 m in quartzite hard rock using pole-dipole array, (**b**) huge potential aquifer at <100 m depth in quartzite hard rock using pole-pole array and (**c**) Potential groundwater reserve in stratified rock at ~300 m depth in granitic hard rock terrain using pole-pole array.

comparatively low resistivity <100 Ohm.m except below at 48 m lateral distance and at a depth of 22 m (Fig.3a) an oval shape resistive body >200 Ohm.m which geologically indicates rind formation a common phenomenon in quartzite rock. On contrary, the model in northern part indicates a contrasting high resistivity body originating from deeper depth ranging from ~200 to 1500 Ohm.m showing prominent 2D geological structural anomaly protruding towards south and north end of profile (Fig.3a). This high resistivity anomaly is clearly delineated in the pole-pole resistivity model (Fig.3b). Between lateral distance of 140 - 220 m the zone is devoid of groundwater (Fig.3a) while at a depth of 38m and between lateral distance of 96–144 m, a low resistivity zone 10-15 Ohm.m opening towards bottom depth (Fig.3a) and bounded by comparatively high resistivity material 20 - 40 Ohm.m near the contact of high resistivity body with sharp resistivity contrast acts as weathered saturated material suggests a potential site for groundwater (Fig.3a). The extension of the said deeper large groundwater resource between lateral distance 96–144 m is nicely picked up by the 2D resistivity modeling for pole-pole data and is presented in Fig.3b. It is also clearly separated by the plane of weak zone and the massive chunk of quartzite rock.

The major and minor hydrologeological structural features are truly exaggerated in pole-pole inverse resistivity section (Fig.3b) at a deeper depth of ~88 m. Nevertheless very clearly it reflects two distinct electrical resistivity low (<20 Ohm.m) and high (>1500 Ohm.m) anomalous zones almost towards south and from centre of the profile to north respectively (Fig.3b). The low resistivity anomaly occurred below lateral distance of 96 m on 2D line at a depth of ~35 m bgl and extends to the bottom depth and is continuing still deeper (Fig.3b). Its width is increasing towards deeper depth indicating huge potentiality of groundwater and is a huge aquifer as depicted in Fig.3b. The resistivity of this aquifer zone varies from <15 Ohm.m to 50 Ohm.m representing the deposition of clayey sand and sand saturated with water while the higher resistivity indicates a highly fractured quartzite rock saturated with water (Fig.3b). This is a potential site for exploitation of the groundwater resource at deeper depth for long term sustainability of the aquifer system in the area. On the other side, the high resistivity body in the form of cusp ranges from ~500 Ohm.m to >3000 Ohm.m indicating boulder type quartzite rock is completely massive and devoid of groundwater between lateral distance of 140-220 m (Fig.3b) and this corroborates very well with pole-dipole resistivity model (Fig.3a). Interestingly at 250 m towards north end (Fig.3b) the resistivity section possess a resistivity variation ~40-100 Ohm.m extending to the bottom of the section appears to be favourable for tapping another deeper groundwater potential zone, which had a close resemblance the one presented in Fig.3a. Likewise another typical example of still deeper groundwater reserve in granitic complex region at a depth of up to 300 m delineated using ERT technique with pole-pole array data as shown in Fig.3c depicting the substantial groundwater reserve below the thick massive granitic rock.

Mapping Fault Zone

Mapping fault zone is an important issue in terms of groundwater hydrogeology especially in hard rock terrain. The 2D true resistivity model using data from pole-dipole array reflects quite heterogeneous and complex subsurface geological formation (Fig.4) in a quartzitic hard rock formation near New Delhi. The area under investigation lies between 77°15'10" E longitude and 28°31'15" N latitude. The top surface is highly heterogeneous showing resistivity

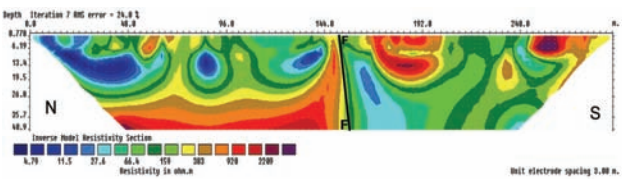

Fig.4. 2D resistivity model showing highly heterogeneous subsurface geological medium with lows and highs resistivity anomaly and demarcating a fault zone in quartzite hard rock region using pole-dipole array.

ranging from <10 to >1000 Ohm.m as clearly seen in Fig.4 indicating highly weathered moisture saturated and hard quartzite formation. This is followed by low and high resistivity zones from north to south end of the resistivity section. In northern part a low resistivity zone <10 Ohm.m at a depth between 10-15 m seems to be connected to the recharge area near the surface (Fig.4). This low resistivity zone is much localized and may not be a good potential source of groundwater as it is at a shallow depth which is bounded below by a weathered and semi-weathered quartzite rock. At a centre of the 2D profile as seen in Fig.4 a sharp contrasting anomaly suggests structural feature separating very high resistivity of the order of ≥1000 Ohm.m and very low resistivity <20-50 Ohm.m conducting zone from bottom depth ~41 m till close to the surface (Fig.4). This type of structural dislocation result is an indication of fault and is a good source of groundwater on one side of the fault structure (Fig.4). It is clear from Fig.4 the geological formation in the south side near the fault is a potential target for groundwater exploration where the source is connected to deeper depth >41 m with appreciable resistivity contrast with the surrounding quartzitic rock. Water levels measured during the field investigation also suggest the aquifer lies at a depth ≥40 m in the region of study. The situation in south is much more favourable compared to north side in terms of hydrogeological perspective as seen in Fig.4 and the significance of fault is seen in the present geological quartzitic hard rock set up.

CONCLUSIONS

Electrical Resistivity Tomography technique proved to be versatile, fast and cost effective in groundwater hydrology in delineating aquifers and mapping shallow subsurface anomalies. It had a wide flexibility in covering large data with dense sampling for a given block of rock mass and at the same time intelligent in acquiring different strength of signals from the subsurface geological characteristics. The true resistivity models resulted from mathematical computation, standard and advanced inversion approaches in conjunction with the measured apparent resistivities had been helpful in resolving the geological formations, structures, basement topography, depth to bedrock, dyke characteristics, and the groundwater resources in different geological terrains with much more confidence and with high resolution as compared to conventional resistivity methods. The essence of this unique technique is seen and proved worth in the present day geoscientific study.

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