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Inadequacies in the Technique of Resistivity Method for Location of Waterwell Sites in Hard Rock Areas

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Large scale exploratory work for groundwater in hard rock region of South India has been carried out by the authors during the last ten years, using electrical resistivity method. The standard methods of data interpretation were found to be inadequate in locating water well sites and determining the existence and depth of occurrence of water bearing fractures and joints. Wenner and Schlumberger type vertical electrical sounding (VES) curves were interpreted by matching against theoretical model curves and also by inverse slope method. The interpreted results were correlated with the actual driller's logs. No satisfactory correlation could be observed either between the geo-electrical interpreted layer boundaries and the layer boundaries from the wells or between the resistivity in the hard rock and the water yield. A more pragmatic approach to the problem is desirable to minimize the failures of wells in hard rock terrain.

Introduction

Electrical resistivity methods are generally used for groundwater exploration in hard rock terrain of South India, comprising mainly granites, gneisses, schists, basalts and granulites of archaean age. Though the water yielding capacity of these formations is limited, their exploitation is necessary as other sources of sustained water supply are limited in these areas. Much of the published work in the field of resistivity investigation is confined to unconsolidated and soft rock formations. Its application to hard rock area presents many problems, particularly in locating and assessing groundwater sources.

The present study examines the viability of the methods presently followed in evaluating field data. Its scope is limited to crystalline formations such as granites and gneisses with particular reference to the detection of saturated fractures and joints present in the relatively hard bed rock.

Occurrence of Groundwater in Granites and Gneisses

Two water bearing zones can be generally identified in hard rock area. 1) The decomposed zone and 2) Water bearing joints and fractures. In the weathered and decomposed part of the bed rock, the groundwater occupies the intergranular spaces of the formation material. The yielding capacity of this zone is often limited and is seasonal in character. In general, this zone does not contribute appreciably to tubewell yield and the contained water can be tapped only by constructing large diameter wells. In most cases, this zone is entirely shut off by the lining in a tubewell.

The saturated fractures and joints found in the relatively unweathered bed rock at greater depths are capable of yielding a substantial quantity of water. These fracture and joints are mostly horizontal in nature and interconnected with a net work of joints and fissures. The yield from these zones is not readily affected by seasonal changes. In the granites and gneisses of South India, such saturated zones are normally encountered at depths ranging from 10 to 50 m. In tectonically disturbed area they may even occur at greater depths of 100 m or more. These zones are usually weathered and have a small vertical extent of a few tens of centimetres. The normal yield of a tube well tapping such zones is around 1,200 gallons per hour (5.45 m^3/hr.). Very low yields of about 100 to 200 gph. are frequent, whereas quite large yields upto 20,000 gph. have been reported from a few isolated tubewells.

In tectonically disturbed area, large vertical fracture zones may also contribute substantially to the yield of borewells.

Present Practices

Resistivity investigations are generally employed in the location of well sites. The hydrogeological conditions are inferred by carrying out horizontal profiling and vertical sounding investigations. In hard rock terrain, the practice is to carry out vertical soundings at zones with low resistivit anomalies as observed from profile measurements. This may not always result in a successful well as a low resistivity value may not necessarily be due to a saturated layer in the subsurface. A clay lens on the ground surface or a weathered layer with high clay content may also cause a low resistivity anomaly. The value of formation resistivity generally depends on the direction of electrode spread as well as the nature of top layer in a hard rock area. A site with a thick low resistivity layer is generally recommended for drilling a borewell, but such considerations may result in failures because of the fact that neither low apparent resistivity on horizontal profiling nor thick low resistivity layer above the hard rock on the vertical electrical sounding unambiguously indicates the presence of water bearing zones. A few empirical guidelines have been suggested to locate wellsites, most of which are based on the resistivity spectrum of the rock formations. Generally granites and gneisses having resistivities less than 100 ohm-metres are considered to have good water bearing zones (Rao 1976; Ramanujachary 1974; Rao 1978). Prediction of probable yield of a well based on the resistivity of the weathered layer and the water level of the area has also been attempted (Patange et al. 1977) in same area.

Analysis of Data

By and large, two methods are followed in analysing VES data qualitatively and quantitatively. The most commonly used method is the curve matching technique. However, a number of field geophysicists use empirical and semi empirical methods with successful results. Mention may be made here of the Inverse slope method, suggested by Sankaranarayan and Ramanujachary (1967).

The aim of electrical resistivity prospecting is to provide specific information about the hydrogeological conditions of the area such as the existence of saturated formations, their depth of occurrence etc. When the subsurface is horizontally layered and is laterally more or less isotropic, a VES curve can be interpreted in terms of lithological layers making use of the standard curve matching technique. However, in hard rock terrain, the subsurface lithologic layers are neither homogeneous nor the layer boundaries parallel to each other. Even the boundary between two layers is not well defined. The layers tend to change gradually from one to the other, since the overlying layers are the decomposed product of the bed rock below. The thickness of any one of these layers may vary widely within a short distance due to differential weathering of the bed rock. Under these conditions an exact solution of a field curve may be extremely difficult if not almost impossible, using theoretical apparent resistivity curves.

Correlation of Computed and Field Results

A large number of VES curves, of stations where subsequent drilling have been carried out were interpreted by matching against theoretical model curves and by the inverse slope method. The objective is to correlate the analytical results with

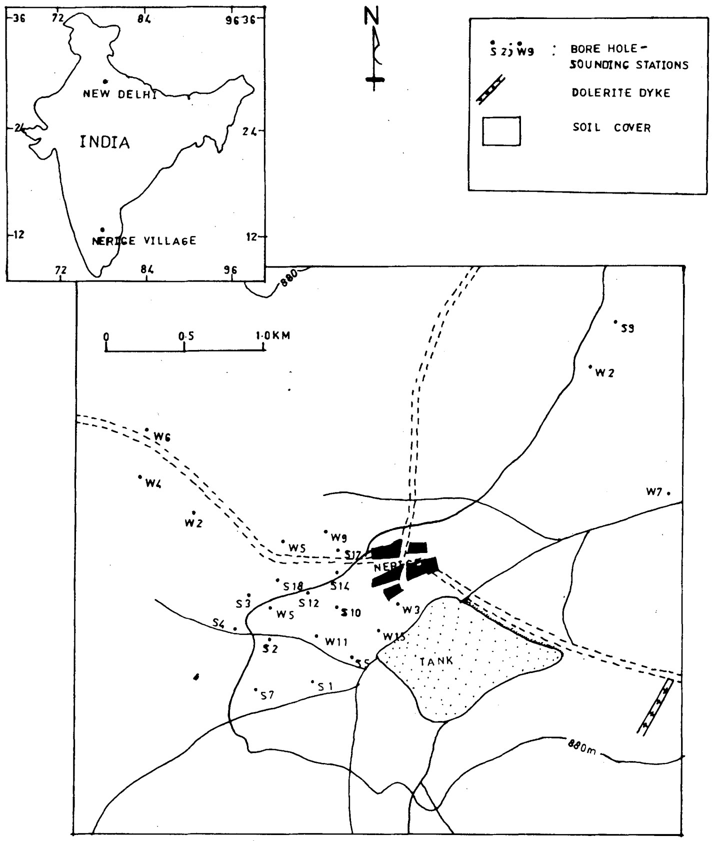

Fig. 1. Map of Nerige village showing sounding sites cum borewells.

the actual drilling results. Seventeen sites from a compact block of about 1 sq. km area, situated about 20 km east of Bangalore, India (Fig. 1) have been examined. Some VES curves were also selected at random from the neighbouring area. A few of these curves with their respective geoelectric and hydrogeological particulars are presented in Figs. 2a to 2e. A study of the curves and the results clearly indicate that in most cases the saturated zones are in the relatively hard bed rock which is generally represented as infinitely thick layer in VES curves. The resistivity values of these layers containing the productive zones show a very wide range and do not exhibit any yield-resistivity value relationship. It can be observed that in some cases similar water yields are obtained at sites having very low as well as infinitely high resistivity. This is true even for a small area where the hydrogeological conditions can be expected to be fairly uniform (Fig. 1). Apparently, the presence of saturated formation or their nonexistence in the bedrock do not seem to influence the values of formation resistivity in hard rock area.

An important observation that can be made from the correlation studies is the

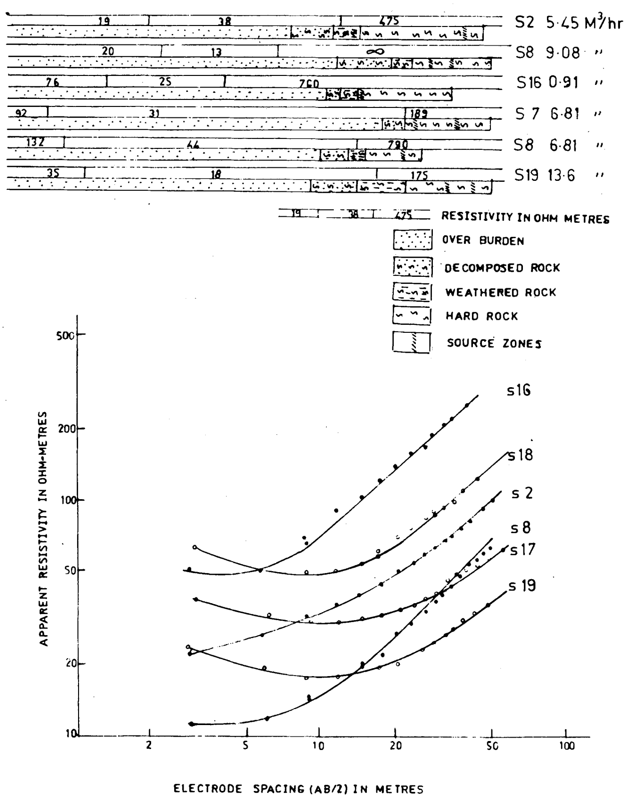

Fig. 2a. Resistivity curves with interpreted and hydrogeological information.

fact that the layer thickness as obtained from curve matching analysis does not correspond well with the thickness of actual layers. In most cases, the overburden thickness is under estimated. The principle of equivalence and suppression may contribute to this discrepancy, apart from the inhomogeneous nature of subsurface layers. A more reliable layer analysis was observed from the inverse slope results. However, the analytical results apparently do not indicate the presence or absence of water bearing zones in the bed rock.

Discussion

It is apparent from the above studies that there is no realistic approach at present for the location and detection of water bearing zones in hard rock area. More often, a number of empirical methods are used to locate water-well sites and to determine the depth to aquifers. A usefull analysis of resistivity data is expected to provide information like

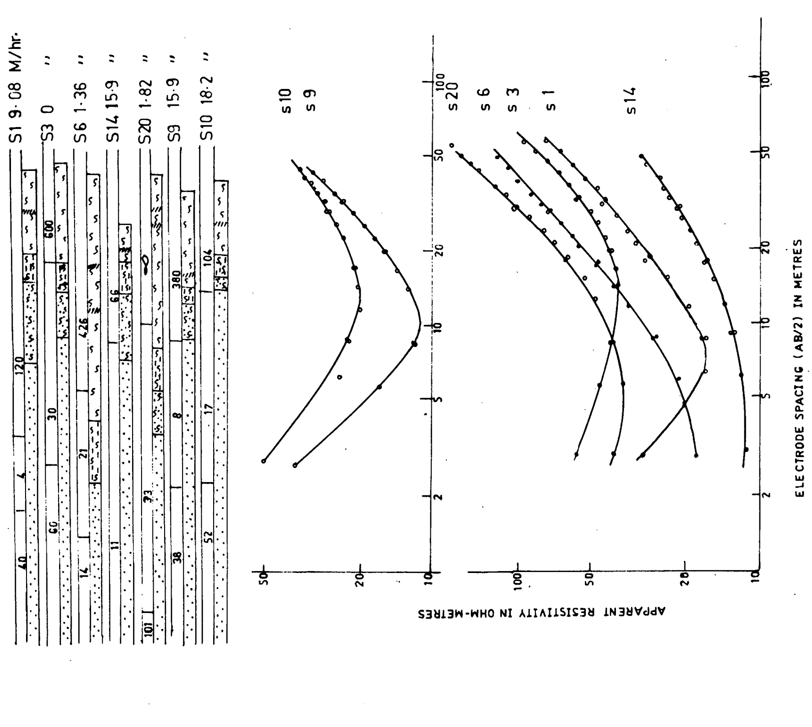

Fig. 2b. Resistivity curves with interpreted and hydro-geological information

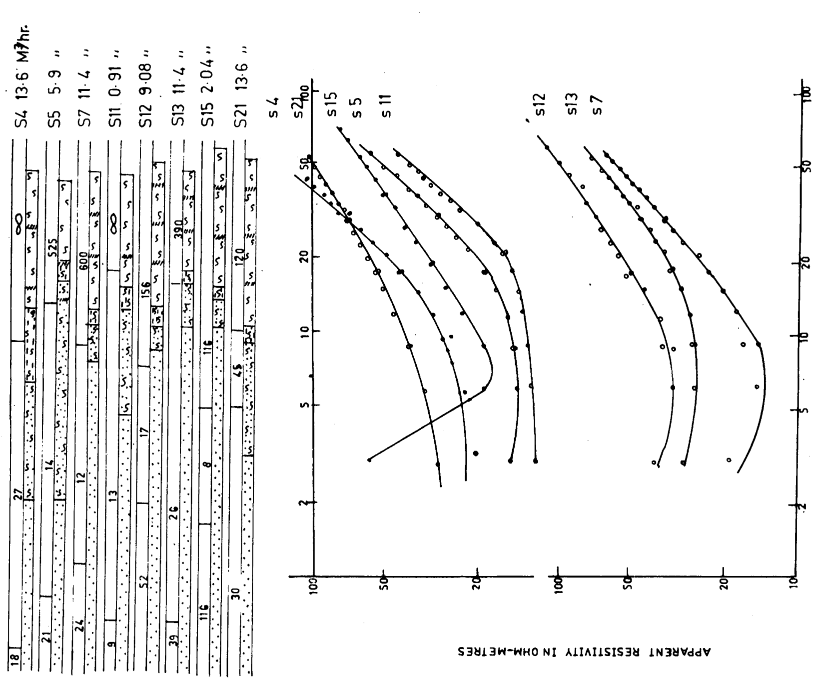

Fig. 2c. Resistivity curves with interpreted and hydro-geological information

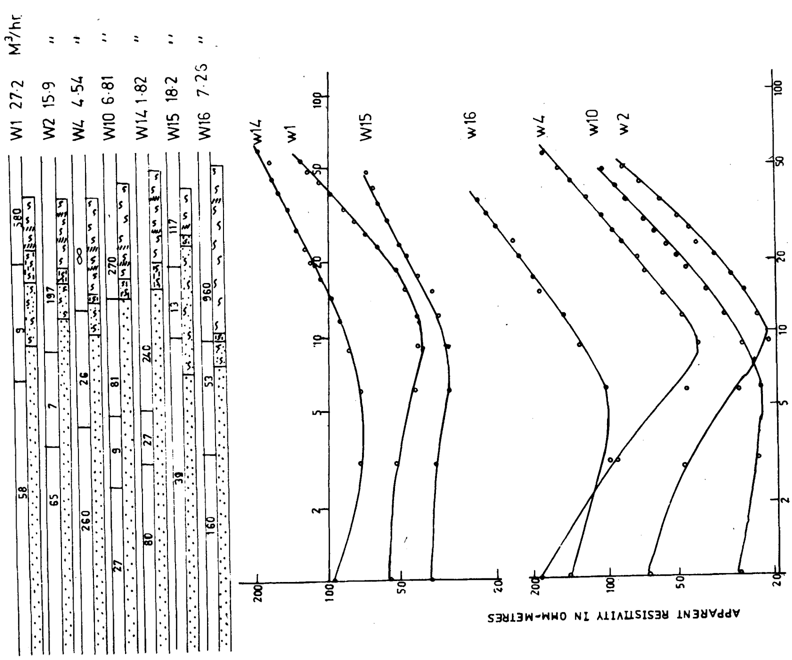

Fig. 2d. Resistivity curves with interpreted and hydro-geological information

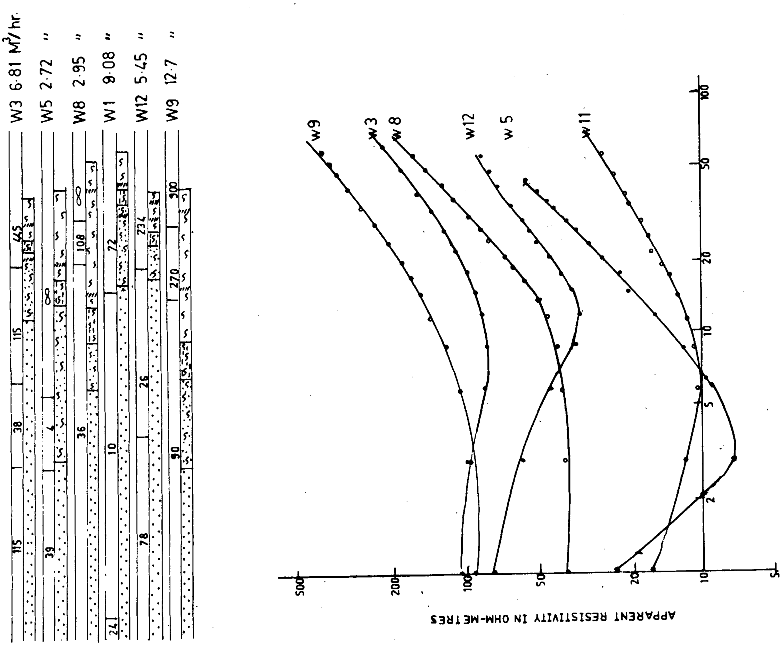

Fig. 2e. Resistivity curves with interpreted and hydro-geological information

1. The existence or otherwise of water bearing fractures/joints,
2. the depth of occurrence of these aquifers from ground surface,
3. nature and thickness of overburden material,
4. quality and probable quantity of water.

This information is desirable with acceptable accuracy in order to locate successful well sites in hard rock area. It is apparent that the standard curve matching techniques or the inverse slope method are not suited for this purpose. Any scientific investigation should have definite and logical reasoning. Is it fortuitous that wells yield substantial quantity of water or is it the result of a proper resistivity data interpretation? One is inclined to agree with the former. It would be very helpful if a technique of interpretation could be developed enabling identification of thin saturated fracture zones present in hard rock. It may be mentioned that research is being carried out in this direction by the authors and it is hoped that this study may result in further discussion of the problems connected with resistivity investigations in hard rock area for hydrogeological studies, particularly borewell site locations.

References

Baratan, R., and Ballukraya, P.N. (Unpublished data)

Mooney, H.M., and Wetzel, W.W. (1956) The Potentials about a point Electrode and apparent resistivity curves for a Two-three and four – layered earth. The University of Minnesota press, Minneapolis.

Patangay, N.S., Srisailanath, A., and Bhimasankaran, V.L.S. (1977) Prediction or groundwater yield of wells in Granites by means of Resistivity sounding method, *Geophysical Case histories of India,* Vol. 1, pp. 161-168, 1977, Hydrabad.

Ramanujachary, K.R., (1974) Geophysics for Groundwater; Paper presented at the Panel Discussion on Applied Geophysics to Civil Engineering and Ground Water Problems, NGRI, Hydrabad.

Rao, Jagadeeshwara (1976) Prospecting for Ground·Water (Unpublished pamphlet).

Rao, P.V.L.N. (1978) Predicting the yield from Borewells, (Unpublished pamphlet).

Sankaranarayan, P.V., and Ramanujachary, K.R., (1967) Short note – An inverse slope method of determining absolute resistivity; *Geophysics, Vol. 32,* No. 6, 1967.

Van Dam, J.C., and Meulenkamp, J.J., (1969) Standard graphs for Resistivity prospecting by Rijkswaterstat, The Netherlands.

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