ASSESSMENT OF GROUNDWATER RESOURCES THROUGH ELECTRICAL RESISTIVITY SURVEYS IN HARD ROCK TERRAIN: A CASE STUDY IN KADIRI SCHIST BELT, ANANTAPUR DISTRICT, ANDHRA PRADESH.

K. S. Sai Prasad, D.B.Sankar, K. Sankaraiah and N.B.Y.Reddy
Dept. of Geology, S.V.University, Tirupati
ksspsvu@gmail.com

ABSTRACT:

Vertical Electrical Resistivity soundings by using Schlumberger configuration is carried out for exploration of groundwater to decipher the geometry of aquifers and its potentialities in a part of Kadiri Schist Belt, Anantapur district, Andhra Pradesh. Curve matching technique has been adopted for interpretation of field data. The values so obtained by resistivity method were correlated with the available lithology and the data utilized to draw the geological sections. Finally an attempt has been made to demarcate the area broadly into high resistivity and low resistivity zones.

Key Words: Kadiri schist belt, Electrical Resistivity, Schlumberger configuration, vertical electrical soundings.

INTRODUCTION:

The ever-increasing population in India as well in other countries makes a heavy demand on natural resources including water. Where the surface water resources are not sufficient it becomes imperative to find additional sources in the form of groundwater of desired quality in adequate quantities for catering to the increasing demands for agricultural, industrial and domestic purposes. Such a need is more acutely felt in arid and semi-arid regions.

The investigated area forms a portion of Kadiri schist belt, lies between North Latitudes 14^{o} 00' and 14^{o} 10' and East Longitudes 78^{o} 05' and 78^{o} 15', It is a linear greenstone belt situated in the eastern part of the Dharwar Craton and southwestern part of the Cuddapah Basin. The schist belt comprises predominantly of acid volcanics with minor basic volcanics belonging to the Dharwar Supergroup. It is enveloped on all sides by migmatites and granites of Peninsular Gneissic complex. Dolerite dykes, Pegmatite veins, quartz reefs, calcite veins are traversing all the lithounits in the study area (Fig.1).

The area under study is a chronic drought-prone area with inadequate erratic rainfall, and the inhabitants mostly depend on groundwater not only for domestic but also for agriculture purposes. As the area is a hard rock terrain, occurrence of groundwater is not uniform throughout the area due to variation in the degree of weathering and fracturing. As unscientific selection of well locations is proved a failure, systematic and scientific approach is essential to solve the problem. The utility of the hydrogeological methods for the groundwater exploration on a regional or a detailed scale is too well known to be emphasized. However, application of geophysical methods (electrical resistivity surveys) besides hydrogeological methods helps a great deal in solving the problem. Many workers like Shiftan (1967), Patangay (1973), Zohdy (1974), Stoller and Rouse (1975), Balakrishna et al. (1979), Kean (1980), Ballukraya et al. (1981), Schimschal (1981), Urish (1981), Verma (1983), Yadav and Singh (1985), Araffn and Lee (1985), Yadav and Lal (1990), Anderson et al. (`1992), Chapman and Lane (1996), Murali and Patangay (1998), Mack et al. (1998), Krishna Murthy et al. (2003) and many others have utilized this method successfully in different geological terrains in order to understand the sub-surface hydrogeological conditions by understanding the variation in resistivity with depth, the sub-surface geology, the thickness of weathered and fractured zones and the position of bedrock.

METHODOLOGY:

Schlumberger electrode configuration is used to conduct 64 vertical electrical soundings (VES) in the study area (Fig.2). The VES curves have been interpreted following partial curve matching techniques of Orellana and Mooney (1966), and Bhattacharya and Patra (1968).

RESULTS AND DISCUSSION:

The apparent resistivity data has been plotted on log-log graph with modulus 6.25cm and these field curves have been quantitatively interpreted with the help of master curves. The interpreted results of each sounding are given in Table- 1. The letters A, H, K and Q are used to describe the relation between e_1, e_2 and e_3 in the geoelectric section and to describe the corresponding sounding curve. Results of resistivity data from 64 selected locations reveal that out of 64 soundings 3 are of three-layer type and the rest four-layer type. The following are the characteristic resistivities obtained for various formations based on the sounding interpretations which conformed with the existing well logs:

Soil---------------------	20 – 180 Ohm-m
Weathered zone-------	20 – 80 Ohm-m
Semi-weathered/ Fractured zone----------	80 – 320 Ohm-m

Bedrock------------------ >320 ohm-m.

In general A-type curves indicate the low resistivity soil cover that overlies the weathered zone and bedrock. In H-type curves, the soil behaves as a highly resistive layer when compared to weathered layer, which is beneath the soil cover. The top layer is soil and its thickness varies from 1.0 to 5.0m with resistivity variation from 13 to 150 Ohm-m. The thickness of second layer is in between 5.5 and 20.0m with resistivity values varying from 17 to 160 ohm-m, followed by hard rock basement with high resistivity values (> 320 Ohm-m). In a few curves, whose resistivities exceed 150 Ohm-m (having range of 150 and 300 Ohm-m) represent a semi-weathered / fractured layer. Out of these three layers, second layer seems to be good for groundwater potentialities as its resistivity values are relatively low when compared to other two layers, and in four layered soundings second and the third layers are good for groundwater locations.

By this interpretation, it is noticed that the weathered rock is proved to be a good aquifer under water table and artesian conditions. The weathered rock with 12m thickness and resistivity values between20 and 80 Ohm-m are considered to be good water potential zones.

CORRELATION OF SOUNDING RESULTS WITH GEOLOGICAL SECTIONS:

The results of the few resistivity soundings that fall close to the dug wells are compared with the available geological sections obtained from well sections (Fig.3). The thickness of the soil layer (having a range of 1.0 to 5.0 m) obtained from the interpretation of sounding curves is in good agreement with the geological section. The second layer weathered rock whose resistivity varies from 25 to 165 Ohm-m also agrees with the geological section. The boundary between the second layer and the third layer of the geological section i.e., between weathered and fresh rock is not so well brought out by the resistivity soundings. Although the geological sections indicate the presence of various layers—the soil, the weathered, the semi-weathered/fractured and the hard rock, the interpretation of the soundings in many cases show only three layers. This indicates that the weathered layer thickness as interpreted from soundings partly corresponds to the semi-weathered/fractured layer as well. Therefore, the four layers are electrically equivalent to three layers, which may not be having sufficient resistivity contrast to bring out the difference between them.

From these observations, it is found that the reliable information regarding the electrical properties of the sub-surface could be obtained by using this resistivity survey.

The electrical properties are interpreted in terms of the degree of water saturation or degree of weathering of underlying rocks.

GEOLOGICAL SECTIONS:

In order to know the accuracy of interpretations of the VES the values are compared with the geological formations of the existing wells.

An attempt has been made to study the variations in thickness of different layers i.e., soil, weathered and semi-weathered/fractured rock in subsurface only along four profiles to cover all formations encountered in the present study area (Fig.4). Two profiles (A-B & M-N) are in east-west direction and the remaining two (P-Q and X-Y) profiles are in northeast-southwest direction. The results obtained from various soundings have combined, along each profile to produce geoelectric sections.

1. Section A-B (Ekkulacheruvu to Middevare Palle): This section is based on the results of four soundings (S3, S23, S32 and S59) taken along a profile in East–West direction. The section presents quite a simple picture of the subsurface geology. As is clear from the Fig.5, the thickness of weathered zone varies from place to place and maximum (13 m) being at sounding 59. The resistivity of soil cover varies from 13 to 90 Ohm-m. The next layer is weathered rock, which is beneath the soil cover. Its resistivity varies from 45 to 80 Ohm-m. The third layer that follows is semi-weathered/fractured zone. This layer extends from 13m to 30m in thickness with 100 to 250 Ohm-m. At soundings S32 and S59, the resistivity is low (110 to 120 Ohm-m) with 18 to 22m. of thickness. Along this section deep dug wells or dug-cum-bore wells is recommended as the resistivity values indicated the presence of saturated fractured/weathered zone (Reddy and Saleem, 1986).

2. Section M-N (Diguva Palle to Pulikunta Palle): This section (Fig.6) is also in the East-West direction having the results of four soundings (S11,S14,S49 and S50). The geological sections obtained on AB and MN are more or less similar. Along this section, the thickness of weathered rock varies from 7 to 14m, and its resistivity from 17 to 68 Ohm-m. The semi-weathered/fractured layer is encountered after this weathered layer with 4 to 18m thickness and having 148 to 320 Ohm-m of resistivity. Along this profile well is recommended at S11 and S50, where the weathered zone is having 10 to 14m thickness with a resistivity of about 68 to 80 Ohm-m. S49 is the place to be recommended for a bore well as the thickness of the fractured zone extends up to 22m, with low resistivity of 100 to 148 Ohm-m.

3. Section P-Q (Eguvapalle to Virannagattu Palle): This section between Eguvapalle and Virannagarru Palle (Fig.7) is in NE-SW direction, having the stations at (S7, S5, S22, S32 and S63). The top layer soil has the resistivity of 24 to 90 Ohm-m. The thickness of the weathered zone varies from 6 to 13m, and its resistivity from 40 to 100 Ohm-m. Then comes the fractured layer between 1.2m and 15m of thickness, with resistivity varying from 72 to 200 Ohm-m, and followed by the basement rock. Along this profile wells are recommended at S32 and at S63 to a depth of 15m.

4. Section X-Y (Cherlopalle to Godduvelagala): This section is also in NE- SW direction having six soundings (S10,S8,S18,S56,S60 and S62) as shown in Fig.8. Along this section the thickness of weathered rock varies from 3 to 17m. The fractured layer with 4 to 29m of thickness is followed by weathered zone with resistivity values lying in between 110 and 240 Ohm-m. Bedrock with >420 Ohm-m is present beneath this fractured zone. Along this profile bore wells are recommended where the fractured zone is of 7 to 30m of thickness.

From these sections it is apparent that the thickness of weathered rock, which is nothing but an aquifer is quite variable in the study area. It is observed that along the section X-Y, the fracture zone extends more than 35m thick at sounding S62, whereas it is up to 30m at S10 and S15, which are favourable sites for bore wells. In rest of the sections, the weathered zone varies in its thickness from palace to place. Dug wells are recommended where the weathered zone extends up to 15m. Dug-cum-bore wells are preferred in low resistivity fractured/ semi-weathered zones.

LOCATION OF GROUNDWATER POTENTIAL ZONES:

From quantitative interpretations the groundwater potential zones are identified when the resistivity values are less than 80 Ohm-m and thickness more than 8 m (weathered zone). The map (Fig.9) showing ground water potential zones are presented.

The groundwater potential zones deciphered by qualitative interpretation (180 ohm-m contour) are in good agreement with those found by quantitative interpretation. The qualitative and quantitative interpretations complement each other in giving locations for dug-wells or bore-wells for drinking and irrigation purposes.

CONCLUSIONS:

The results of the resistivity data indicate that out of 64 soundings 44 are of three-layer type and the rest four-layer type. In three-layer type 36 are of A-type, 6 H-type and the rest K-type. In general all the locations of the soundings shows vertical variation in lithology; i.e. the soil zone followed by weathered zone, semi-weathered / fractured zone and basement. Sounding results are correlated with geological sections. The groundwater potential zones deciphered by qualitative interpretations (180 ohm-m contour) are in good agreement with those found by quantitative interpretations. The qualitative and quantitative interpretations complement each other in giving locations for dug wells / bore wells for drinking and irrigation purposes.

REFERENCES:

Anderson, T.W, Geoffry, W., Freethey and Patrick Tucci. (1992). Geohydrology and water resources of alluvial basins in South Central Arizona and parts of adjacent states, U.S.Geol. Surv. Prof. Paper 1406-B.

Araffin, M.S. and Lee, C.Y. (1985). A resistivity survey for groundwater in perlis using offset Wenner Array. Indian Assoc. of Hydrologists, Publication No. 161, pp. 221-232.

Balakrishna, S.,Ananda Rao, V., and Bhalla, M.S. (1979). Electrical investigations in Tadipatri shales for groundwater. Geophy. Res. Bull., Vol.17 (2), pp.85-90.

Ballukraya, P.N., Santhvadivel, R., and Baratan, R. (1981). Inadequacies in the technique of resistivity method for location of water well sites in hard rock areas. Jour. Nordic Hydrology, Vol.13 (3), pp.185-192.

Chapman, M.J., and Lane, J.W.(1996). Proceedings of the Symposium on the applications of Geophysics to Environmental and Engineering Problems, Keystone, pp.833-842.

Kean, W.F. (1980). Monitoring groundwater contamination at a fly ash disposal site, using surface electrical resistivity methods. Jour. Groundwater, Vol.18 (5), pp.472-478.

Krishnamurthy, M.S., Dewashis Kumar, Ananda Rao,V., Jain, S.C., and Shakeel Ahmed. (2003). Comparision of surface and sub-surface geophysical investigations in deliniated fracture zones. Curr. Sci., Vol.84 (9), pp.1242-1245.

Patangay, N.S. (1973). Application of electrical resistivity method for solving certain hydrogeological problems in Hinghra Penneri Area, Chengalput district, Tamil Nadu. Ph.D. Thesis submitted to Osmania University, Hyderabad.

Mack, J..J, Johnson, C.D., and Lane, J.W. Jr. (1998). Geophysical characterisation of a high yield fracture bedrock well, Senrock, New Hamphire. U.S.Geol. Surv. Open-file report, 98-176, 22p.

Murali, S., and Patangay, N.S. (1998). Principles and applications of groundwater. Geophy. Asso. of Explo. Geophy., p.419.

Orellana, E., and Mooney, H,M. (1966). Master tables and curves for vertical electrical sounding over layered structures. Madrid Interciecia, 150p., 66 tables.

Reddy, P.R., and Saleem, M.A. (1986). Hydrogeological and geoelectrcial investigations in Atmakur, Karimnagar district, Andhara Pradesh. Geo. Phy. Res. Bull., Vol.24, pp.140-146.

Schimschal, V. (1981) The Relationship of geophysical measurements of hydraulic conductivity at the Brently Damsite, New Mexico. Geo. Exploration, Vol.19, pp.115-125.

Schlumberger Marcel, (1939). The application of telluric currents to surface prospecting: Trans. Amer. Geophy. Union, Part-3, pp.271-277.

Schwartz, F.W. and Mc Clymant, G.L. (1977). Application of surface resistivity methods. Groundwater, Vol.18, (3), pp.197-202.

Shiftan, Z.I. (1967). Integration Geophysics and Hydrology in the solution of regional Groundwater problems. Mining and Groundwater Geophysics. Canadian. Geol. Surv. Econ. Geol. Bull. No.26.

Stoller. R.L., and Rouse, P. (1975). Earth Resistivity Survey – A method for defining groundwater contamination. Groundwater, Vol.13, (2), pp. 145-150.

Urish, D.W. (1981). Electrical resistivity/hydraulic conductivity relations in glacial outwash aquifers. Jour. Water Res., Vol.17, (5), pp.1401-1408.

Verma, R.K. (1983). Geoelectrical soundings over lower Gondwana Formations of Damodar Valley. Geo. Phy. Res. Bull, Vol.21, (1), pp.101-102.

Yadav, G.S. and Lal, T. (1990). Invistigations of groundwater resources at selected levels in drought-prone area of Pahari Block, Mirzapur district, U.P., India. International Workshop on "Appropriate Methodologies for Development and Management of Groundwater Resources in Developing Countries". Natl., Geophy. Res. Inst., Hyderabad, Vol.1, pp.209-219.

Zohdy, A.A.R. (1974). Applications of surface geophysics to groundwater investigations. U.S. Dept. Interior, Geol. Surv. Book, No.2, 9p.

Table- 1: Results of Vertical Electrical Soundings

S.No.	e1	e2	e3	e4	h1	h2	h3	Depth to basement	Type of Curve
	<------------Ohm-m----------→				←------------Mts.----------→				
1	36	54	235		1.8	9	6.4	17.2	A
2	60	54	143	430	1.2	7.8	18.6	27.6	HA
3	30	67	250		1.3	11.5	13	25.8	A
4	62	22	120	620	2.9	10.7	5.7	19.3	HA
5	48	90	72		2.8	14		16.8	K
6	14	35	115	470	2.2	9	16.4	27.6	A
7	43	100	140		3	6	15	24	A
8	58	40	240		2	2	8	12	H
9	31.2	51.6	360	160	1.8	9	18	28.8	A
10	98	65.2	108.6		1.1	5.5	16.4	16.4	A
11	20	100	380		3.7	11	10	24.7	HA
12	60	140	430		1.2	12.8	8.6	22.6	A
13	188	78	689		0.53	8.13		8.66	A
14	36.8	17	383	626	1.38	7.28	4.42	13.08	H
15	40	68	314		1.93	11.9		13.92	HA
16	111	50.4	80.5	813	1.2	6.8	9.42	17.42	A
17	69.5	34.8	106	227	1.02	2.23	13.4	16.65	HA
18	131	203	422		2.96	17.66		20.62	H
19	119	111.2	140.6	358	1.11	2.1	18.64	21.63	A
20	84.7	47.2	129	485	2.25	3.08	16.39	21.72	HA
21	242.7	56.4	116.4	435	0.94	3.05	12.23	16.22	HA
22	23.7	46.6	201.8		1.43	8.26		9.69	HA
23	21	45	133		1.05	2.4	28.06	31.52	A
24	52	48	103.6	521	4.03	3.62	20.47	28.12	A
25	23.6	99.2	115	469	1.7	13.64	6.42	21.76	HA
26	65.6	34.6	183.1	446	1.65	2.25	23.75	27.66	AA
27	45.7	88.6	106.3		2.61	6.2	18.32	27.13	HA
28	58.2	97.4	290		1.2	12	6.2	19.4	A
29	57	85.5	285		1.2	12.6	7.1	20.9	A
30	55.6	32.8	120		1.4	14	6.8	22.2	A
31	58	84.4	360		1.5	12.5	2.8	16.8	H
32	90	100.2	120.6	460	2.6	13	9.4	25	A
33	96	110.6	140.2		2.8	8.4	11	20.1	A
34	60	140	430		1.2	12.8	8.6	22.6	A
35	17	25.5	110.2		1.5	15	6.6	23.2	A
36	100	65.6	202.4		1.1	5.5	16.4	23	H
37	18	27	98.6		2	20	3.2	25.2	A
38	43	110	164	380	3	8	16.2	27.2	AA
39	43	170	95.6		1.3	6.8	18.6	26.7	K
40	100	150	380		1.3	13	4.2	17.5	A
41	12.7	68.5	382.6		2.6	18	5.5	26.1	A
42	120	162	302		2.4	14.6	3.2	20.2	A
43	140	74.8	250.6	600	5	10	16.2	31.2	HA
44	150	80.2	420		4.5	9	12	25.5	H
45	20.65	78.7	326.9		1.4	12.5	7.6	21.5	A
46	33	49.5	165		1.4	14	13.4	28.5	A
47	48.7	77.3	240		1.3	12.8	6.2	20.3	A
48	34.3	113.5	361.4		1.2	15.9	3.2	20.3	A
49	120	68.2	148.2	560	3.7	8.6	18.5	30.8	HA
50	24.4	79.6	321.6		1.2	13.9	6.2	21.3	A
51	26.4	62.8	195		2.2	14.6	8.2	24.9	A
52	38	56.2	120.4	420	1.8	9.6	18.3	29.7	AA
53	74	34.6	156.7	562.8	1	12.5	9.2	22.8	HA
54	26	39	240		1.5	12.5	6.2	21.2	A
55	25	60	120.6		2.3	16.5	7.6	26.4	A
56	17	25	110		2.2	17.4	6.6	26.2	A
57	18	80	170		5	16	9.6	30.6	A
58	18.6	60.2	242.6	380	1.31	12.6	18.8	32.5	AA
59	12.7	68	110.3	520	1.5	12.6	18	31.1	AA
60	38.6	119.4	730		1.5	15.5	4.2	21.2	A
61	31	58.6	225	400	1.8	12	18	31.8	A
62	63.8	59.3	221.5		1.7	2.8	28.9	33.4	HA
63	74	44	156		1	11.5	6.8	18.8	HA
64	23.6	66	320		1.4	8.2	6.6	16.2	A

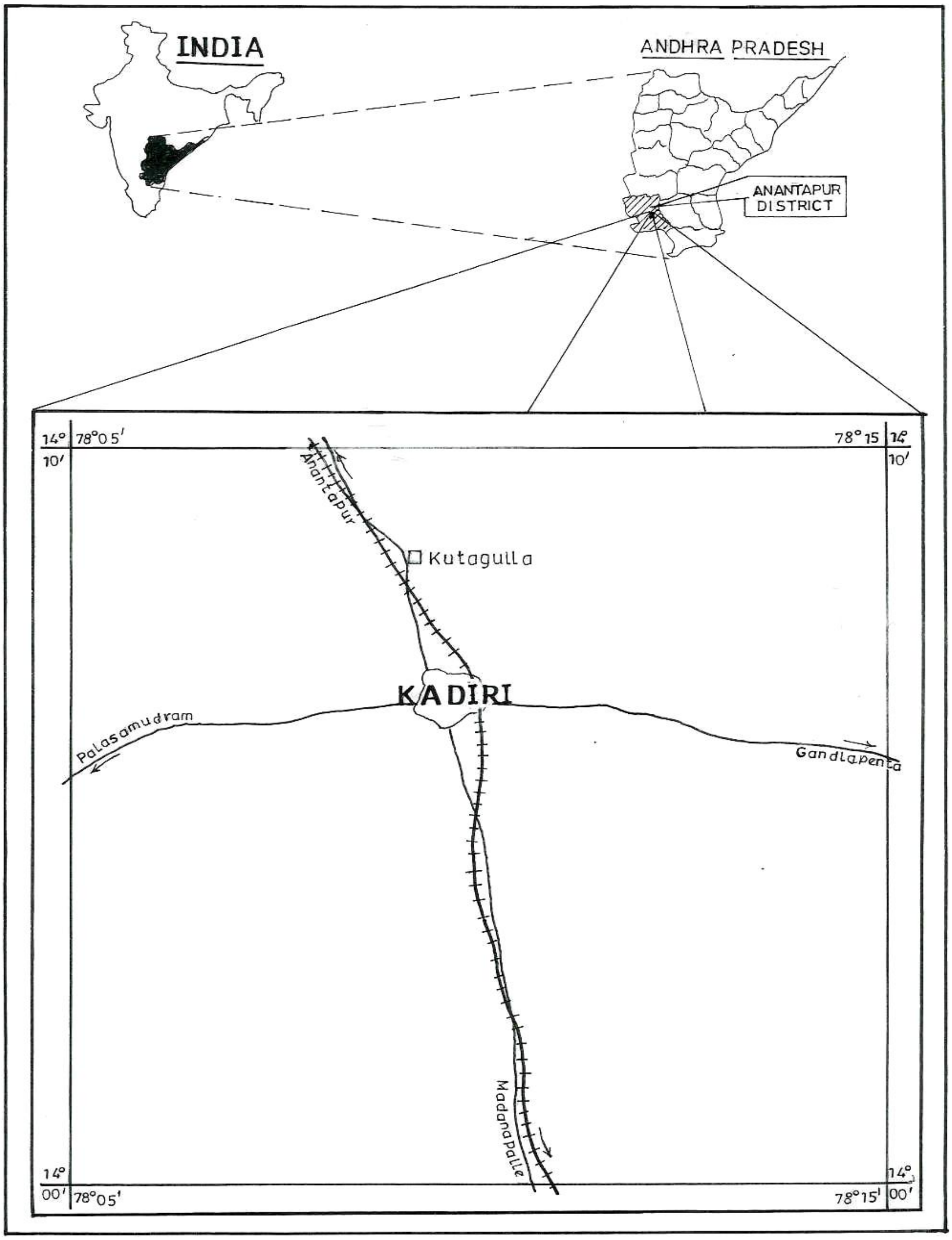

Fig. 1: Location and geology of the study area

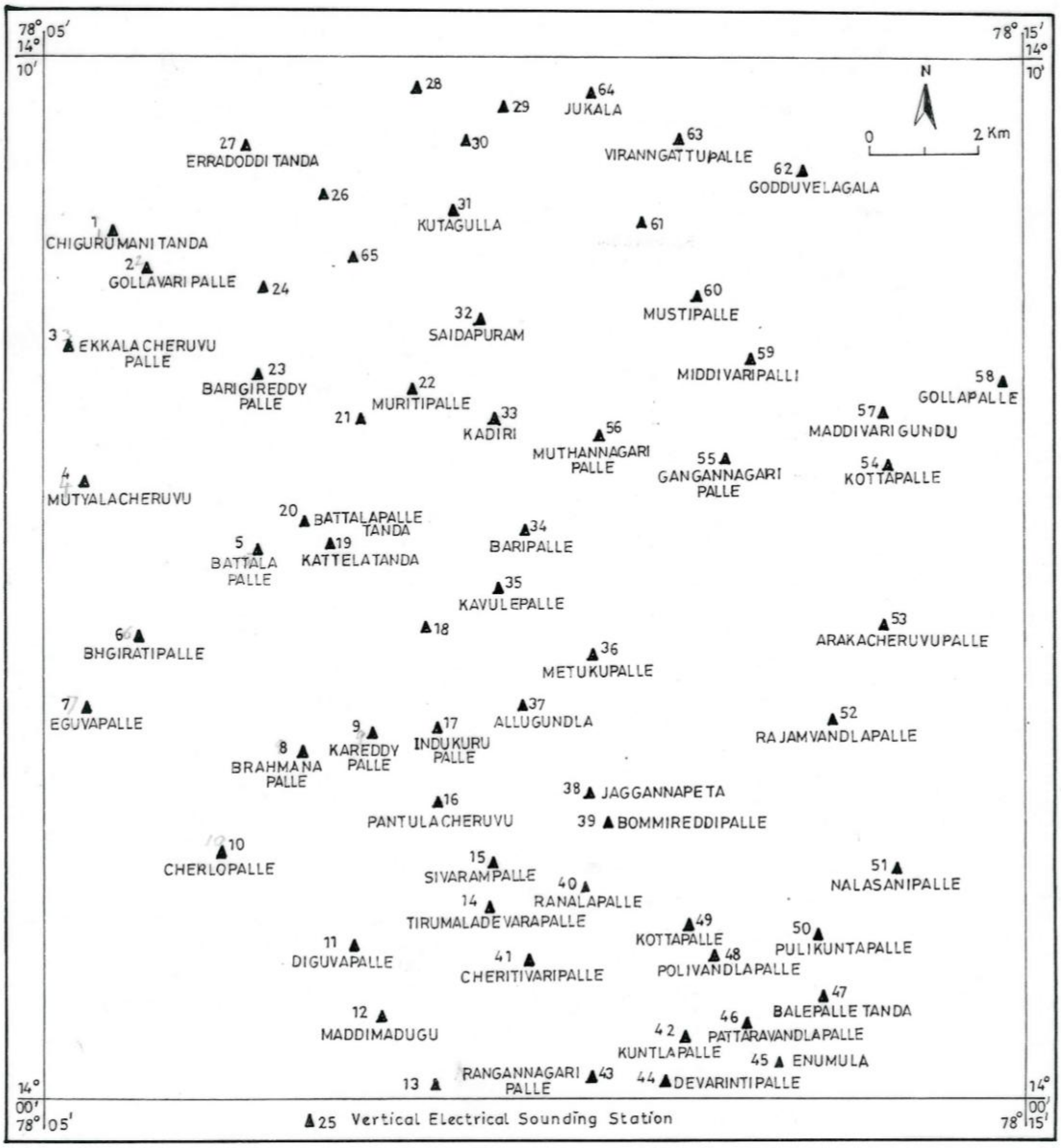

Fig. 2: Vertical electrical sounding locations of the study area

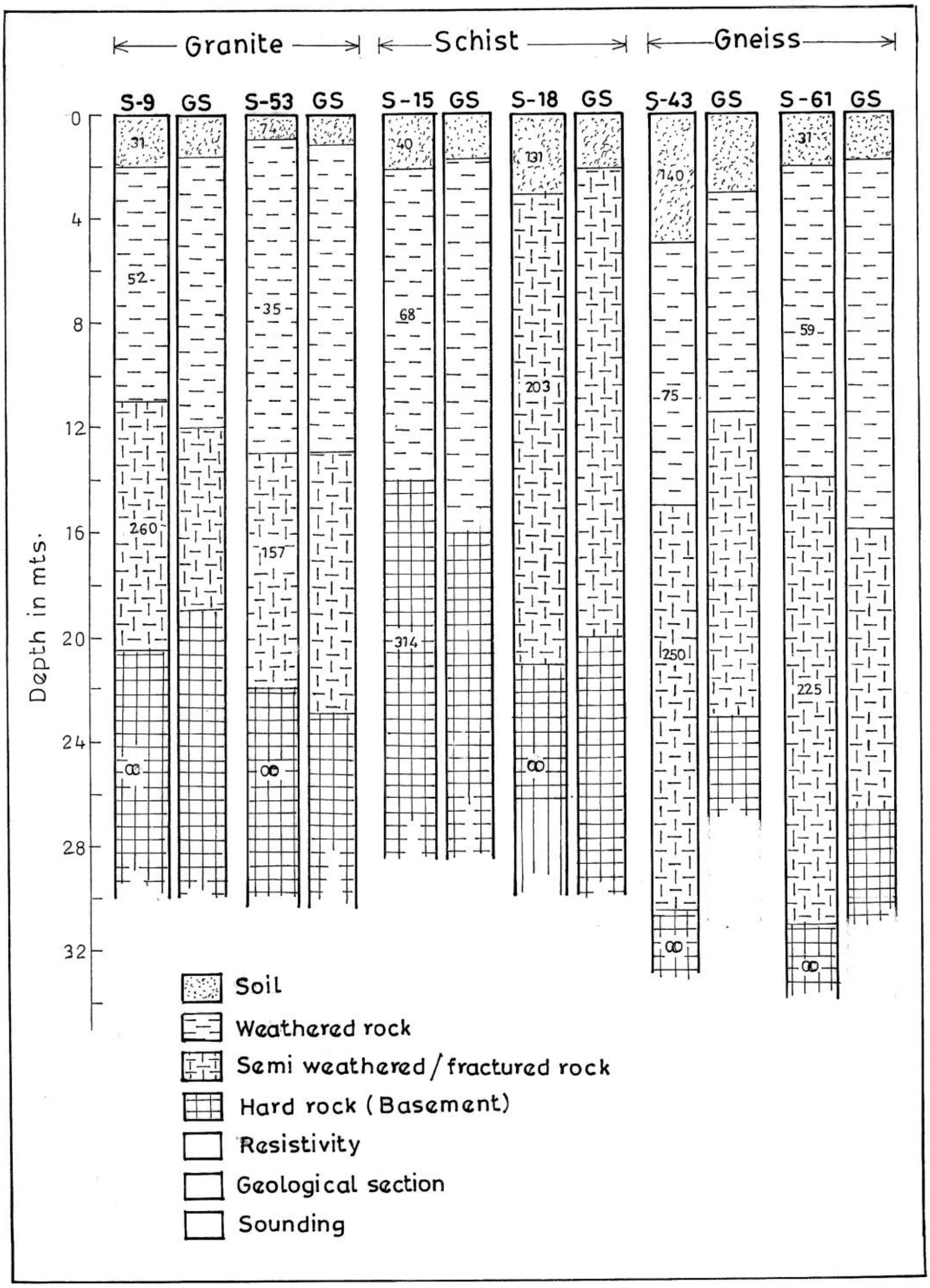

Fig. 3: Well sections showing geological formations

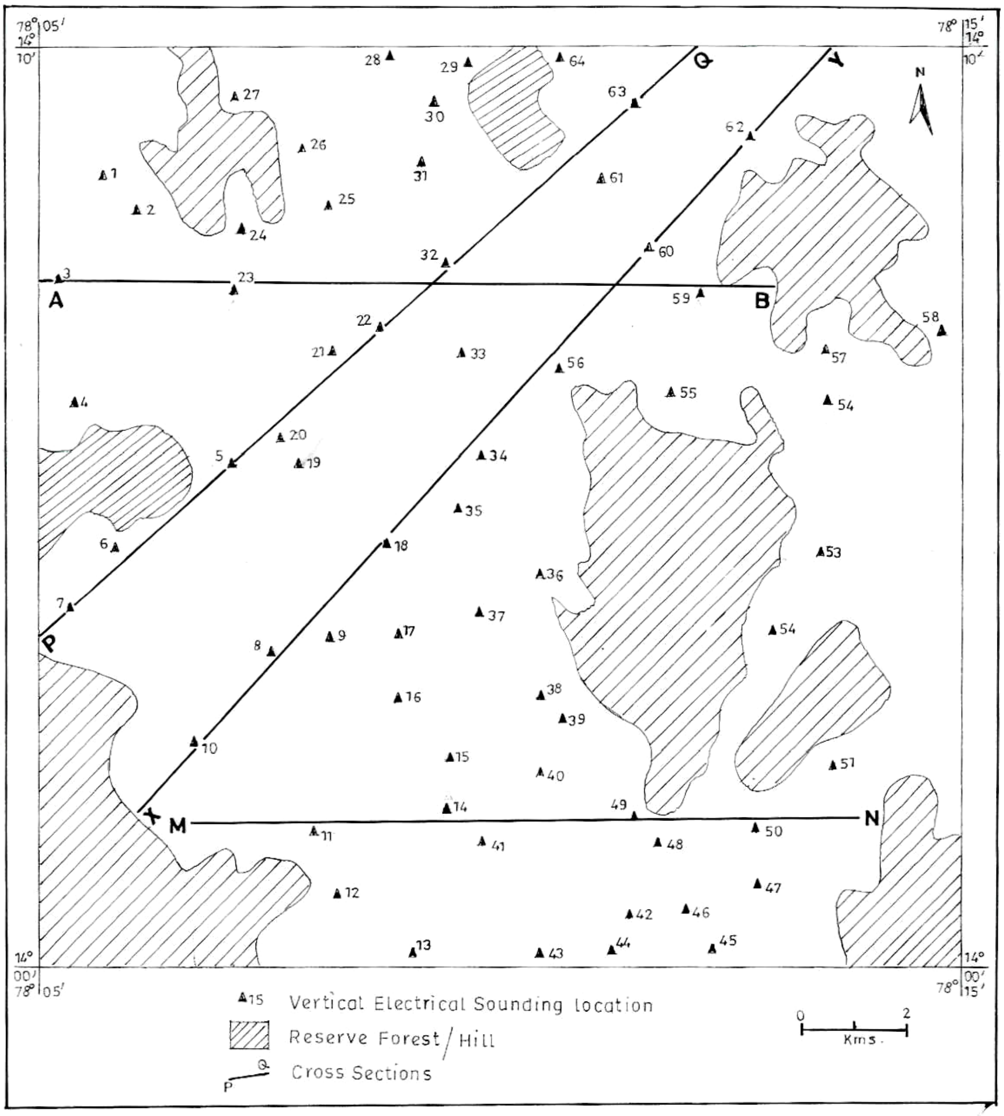

Fig. 4: Locations of different profiles in the study area

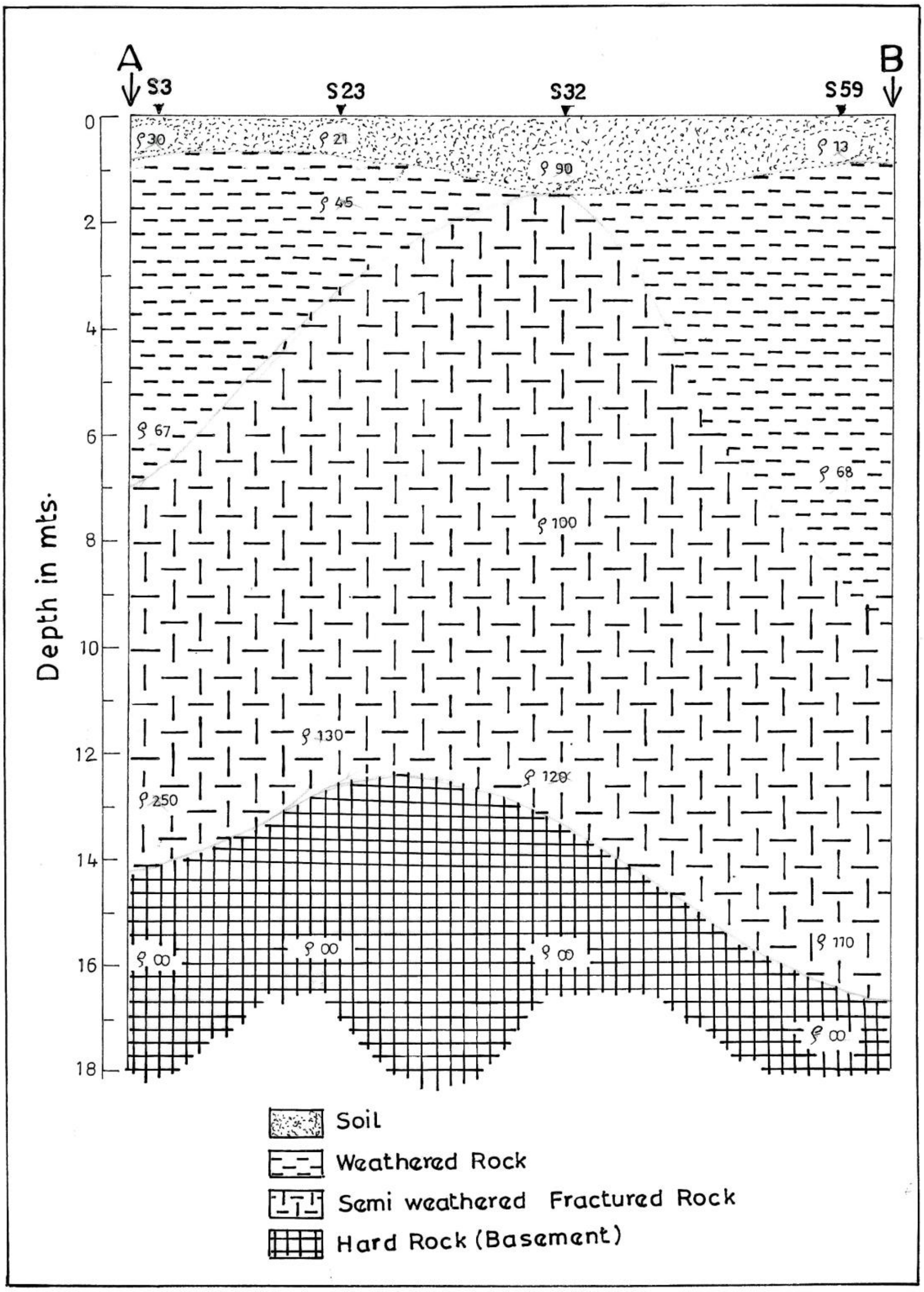

Fig. 5: Section A – B from Ekkulacheruvu to Middevari palle

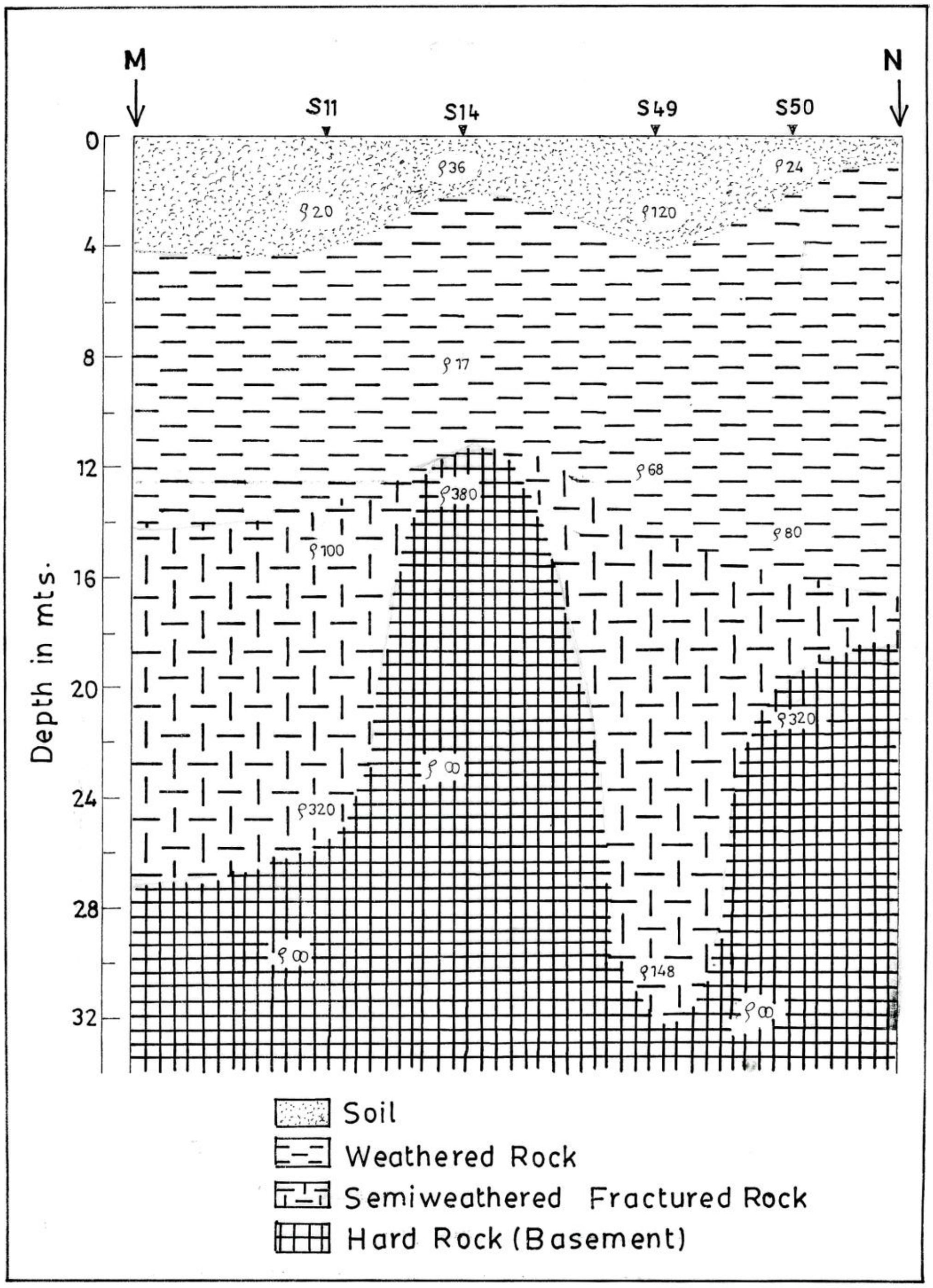

Fig. 6: Section M – N from Diguva palle to Pulinunta palle

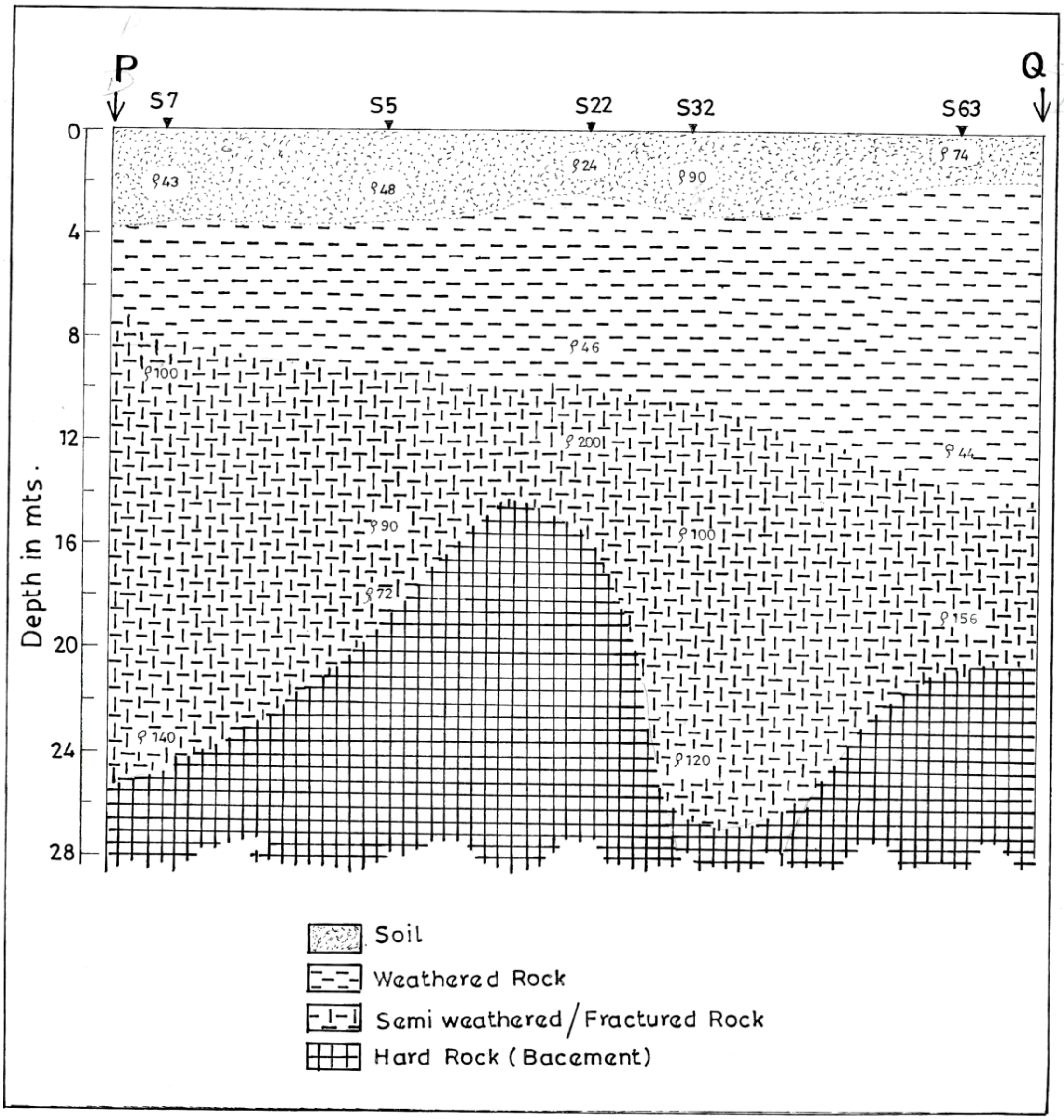

Fig. 7: Section P – Q from Eguvapalle to Virannagattu palle

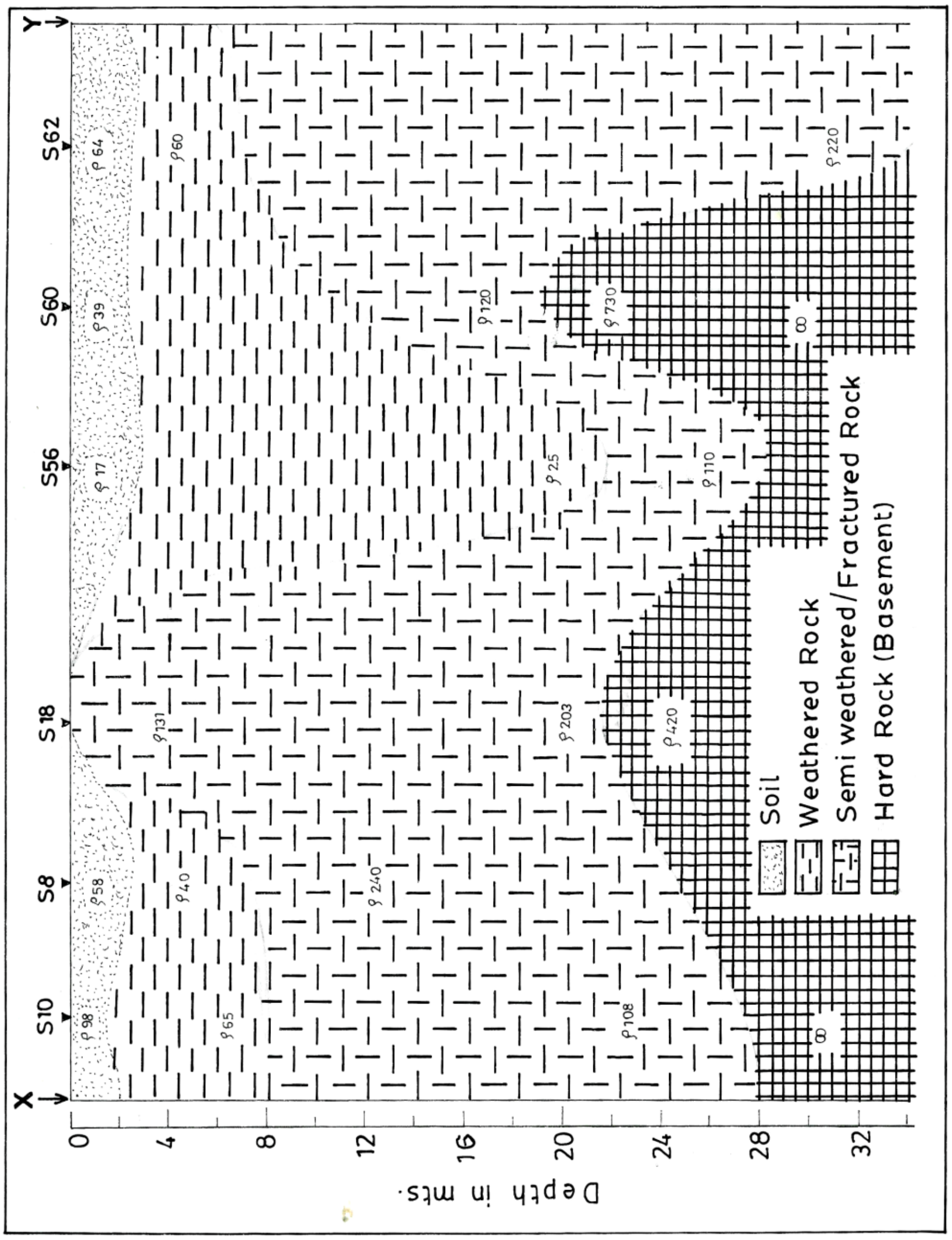

Fig. 8: Section X – Y from Cherlopalle to Godduvelagala

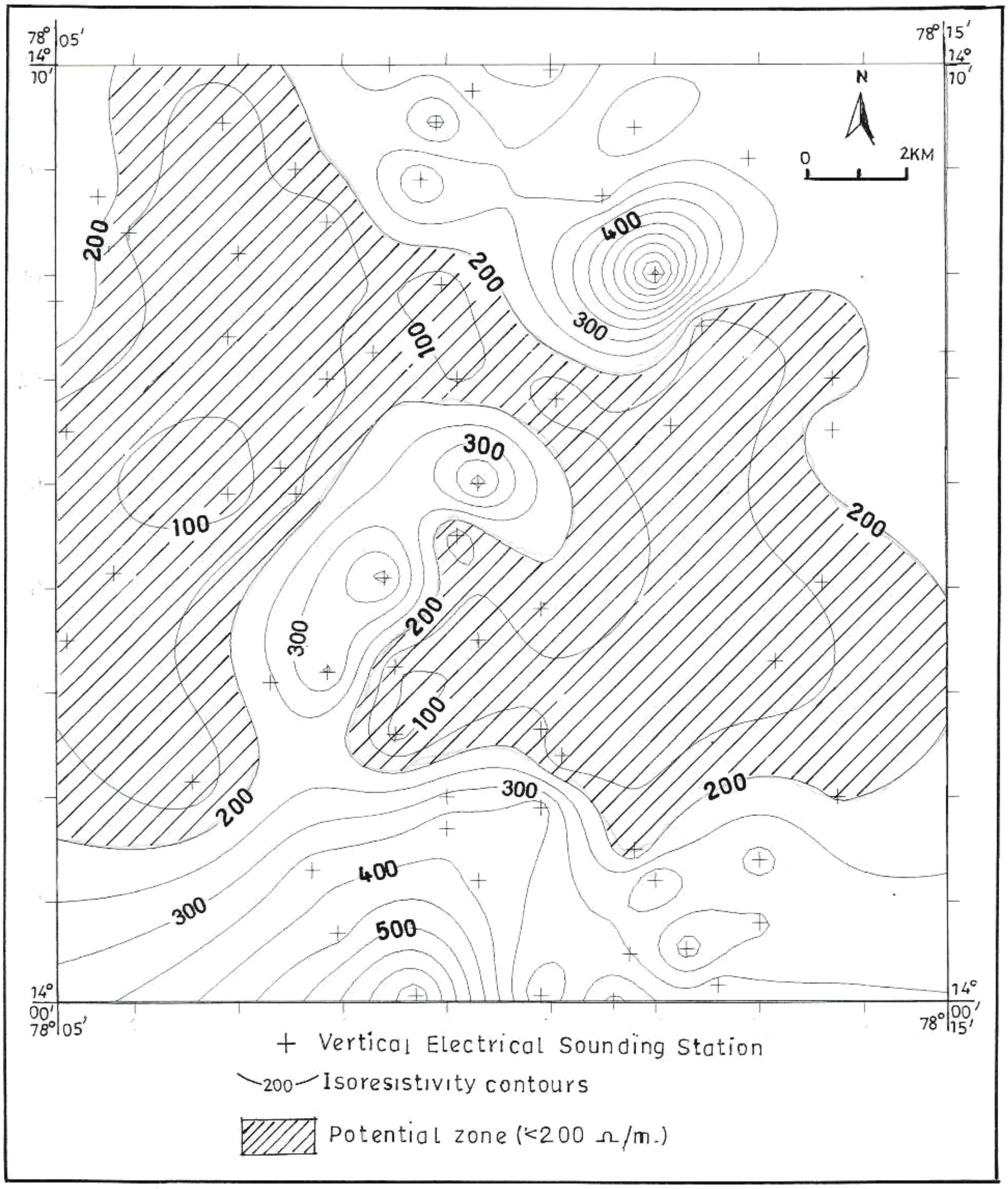

Fig. 9: Groundwater potential zones in the study area