DEEP ELECTRICAL RESISTIVITY SOUNDINGS IN THE DECCAN TRAP REGION

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REGIONAL gravity surveys of the Deccan trap region in western and central India were conducted by the Geological Survey of India over a period of eight years (1964-72) in connection with the International Upper Mantle Project and more than 400,000 square kilometres have been covered so far by these surveys which are now being continued in the areas to the north of the Purna, Tapti and Narmada valleys. These investigations had thus been initiated quite some time prior to the devastating Koyna earthquake of 1967 which shook some of the complacent ideas regarding the stability of the Indian peninsular shield. The gravity surveys were supplemented by spot seismic soundings at a number of selected points over the entire region covered by the gravity observations. Detailed gravity-*cum*-refraction seismic surveys were also conducted in the Koyna region to unravel the deep subsurface tectonic features having a possible bearing on the prevailing seismicity in this region. The results of these investigations have been presented in a number of published papers (Kailasam *et al.*, 1969, 1972). These surveys, besides bringing out a number of interesting and significant gravity features of deep seated causes and of tectonic significance, have also enabled the estimation, by refraction seismic soundings, of the overall thickness of the Deccan trap at a number of points.

The Bouguer and residual gravity maps have brought out a number of pronounced gravity features. The Bouguer gravity map (Kailasam *et al.*, 1972) presents some prominent gravity 'highs' in the Sangola and Nasik regions and marked zones of gravity 'low' in the Koyna–Karad and Kurudwadi–Dhond regions, as also another zone of pronounced gravity 'low' adjacent to and north of the gravity 'high' near Nasik. These pronounced gravity 'highs' and 'lows' have been interpreted as indicative of zones of marked uplifts and subsidence of a deep-seated, crustal nature.

The refraction seismic soundings have indicated an overall depth to the base of the trap of the order of 100 to 200 metres beneath the ground surface over the southern and eastern margins of the Deccan trap region, covered by these surveys while maximum depths of the order of 1,100 to 1,200 metres have been indicated in the western and northwestern parts of Maharashtra. The seismic results have further indicated a macroscopic longitudinal wave velocity varying generally from 4·8 to 5·2 km/sec. for the Deccan trap, whereas a longitudinal velocity of 5·8 to 6·4. km/sec. has been indicated for the sub-trap horizon. It was, however, observed that, while at most of the seismic sounding points the travel-time curves yielded reliable estimates to the base of the Deccan trap, yet at a few other points some ambiguity arose in the identification of the layer below the velocity interface, presumed to correspond to the base of the trap due to the overlapping seismic velocities of the Archaean and pre-Cambrian basement rocks (including limestones, quartzites, slates etc., belonging to the Kaladgi and Bhima series of pre-Cambrian age). This was further complicated by the substantially higher seismic velocity of well over 6 km/sec. exibited by the trap formation itself at depth in some parts of the area—a fact established by extensive laboratory determinations of the longitudinal wave velocity in a number of Deccan trap samples. Such high velocities were especially observed in Deccan trap samples relatively rich in olivine and these samples also showed a higher density of over 3 g/cc. It was, therefore, decided to supplement the results of the refraction seismic sounding by deep electrical resistivity depth probes in view of the fact that the resistivity contrast between the Deccan trap on the one hand, and the pre-Cambrian gneisses and the Kaladgis on the other is of the order of 1 : 5. The absolute resistivity value of the Deccan trap formation is of a low order of 50 to 200 ohm-meters while the true resistivity of the pre-Cambrian rocks, such as the gneisses and the Kaladgi limestones and quartzites, is well over 1,000 ohm-meters, thus enabling a clear identification of the Deccan trap from the latter formations, although the resistivity results do not enable us to distinguish between pre-Cambrian gneisses and Kaladgi limestones or quartzites as all these pre-Cambrian formations show a high order of overlapping resistivity.

A number of deep electical resistivity soundings were conducted employing a modern, sophisticated type of Deep Resistivity unit (DRS-7) manufactured by Scintrex, Canada, with an effective depth of exploration of more than 2,000 metres. These electrical soundings were carried out at a number of selected points distributed over the trap territory as well as along an east west traverse of roughly 360 km in length from Sholapur on the east to Guhagar on the west coast passing through the marked gravity 'high' in the Sangola area and the pronounced gravity 'low' in the Karad-Koyna region, as also along two short traverses, one in the Kurudwadi area and the other between Amaraoti and Nagpur (Fig. 1). The sounding profiles were conducted employing the Schlumberger array of current and potential electrodes with maximum current electrode spreads 'AB' of 4,000 m.

zones are of special interest from the point of view of ground water exploration, as these conductive zones are often suggestive of intertrappean horizons or vesicular portions within the trap. Such significant conductive zones indicative of ground water potentialities are brought out, for instance, in the sounding curve near Sholapur at a depth interval of roughly 30 to 200 metres (Fig. 2) and in

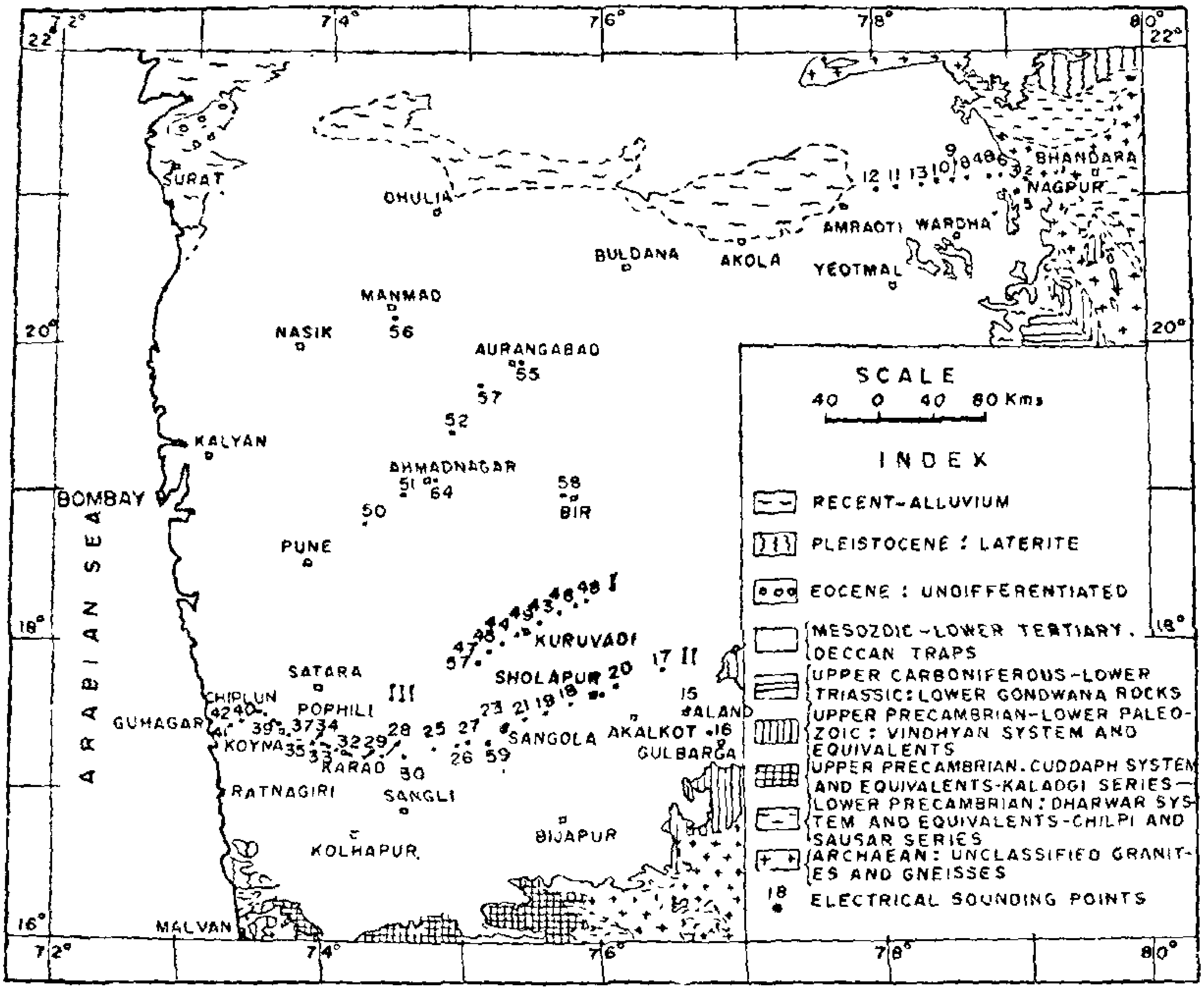

FIG. 1

Typical resistivity curves are presented for some of the sounding stations in Figs. 2 and 3, in which the computed depths to the successive resistivity interfaces are shown alongside the abscissa scale of half current electrode spread. One characteristic feature to be observed is that the Deccan trap formation as a whole shows marked resistivity stratification, apparently corresponding to lithological stratification including intertrappean formations and vesicular portions within the trap itself, presenting, however, on overall low resistivity for the Deccan trap section as a whole in relation to the highly resistive sub-trap basement. Such marked vertical variations in resistivity are restricted generally to the top one or two hundred metres of the trap within which, incidentally, conductive

the resistivity curve for sounding station, 34 to the west of Karad at a depth interval of roughly 50 to 110 metres (Fig. 3) from the ground surface.

The values of the overall thickness of the Deccan trap deducted from the deep resistivity soundings at some of the stations are presented in Table I together with the seismically indicated depths.

It may be noted that there is generally a fair agreement between the electrically and seismically determined depths, allowing for the margin of discrepancy caused by such factors as stratification and macro-anisotropy (electrical) within the trap involved in the electrical resistivity method which may vitiate the computed depths by a margin of 15% relative to the true depths. Also, the resistivity and seismic sounding stations do not coincide exactly but are shifted by a few hundred metres. Even making an allowance for these factors, it may be noted that at a few stations, the discrepancy between the electrically and seismically computed depths is considerable, the seismically deduced depth being much smaller than the electrically computed depth. In such cases, it would be reasonable to infer that the seismically computed depth corresponds to trap horizon itself, with a higher seismic velocity of more than 6 km/sec. which is of the same order of velocity of the Archaean and Pre-Cambrian basement formations mentioned earlier. In fact, this has been proved to be the case at Alore, some 6 km to the north-northwest of Pophli (Fig. 1) where a drill hole taken to depths of more than 200 metres was still within the traps. Core samples collected at depths from this drill hole showed longitudinal velocity of 6·3 km/sec. as determined in the Geophysics Laboratory of the G.S.I.

some intresting and significant features. In the region of the Sangola gravity 'high', the trap thickness is indicated to be relatively quite small conforming to a crustal uplift in this region as inferred from the gravity anomaly map, whereas in the Karad-Koyna area further to the west, a marked thickness of well over 1,000 metres of trap is indicated beneath the ground surface in the form of a synclinal sag conforming to a zone of subsidence (Kailasam *et al.*, 1972). *Another noteworthy* feature is that, between Koyna and Pophli to the west of the trap scarp, an abrupt fall in the trap base of roughly 400 metres is indicated, suggestive of a fault postulated earlier on the basis of the gravity and seismic results (Kailasam *et al.*, 1969). Further to the west along the section, between Chiplun and Rampur, another fault is suggested, also as deduced earlier on the basis of the gravity and seismic data. It is also noteworthy that no

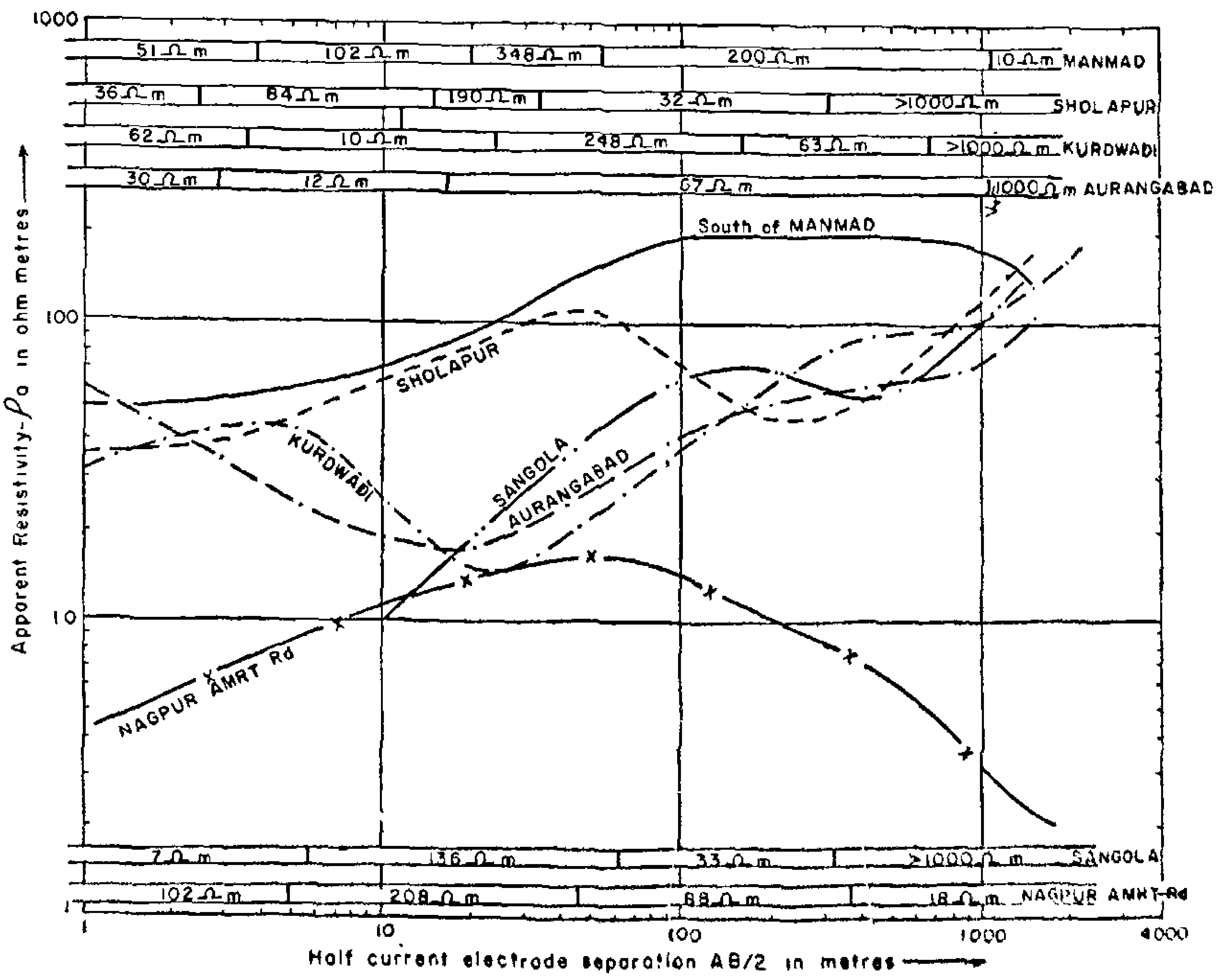

FIG. 2. Typical electrical resistivity soundings with results over the Deccan Trap in general.

The results of the resistivity sounding along the traverse from Sholapur to Guhagar (Fig. 4) are of particular interest. The base of the Deccan trap column as a whole is shown in the section along this traverse presented in Fig. 4, which brings out

major rift, as suggested by Krishna Brahmam *et al.* (1973), corresponding to the Karad-Koyna gravity 'low' has been indicated by the resistivity data, as also in the Kurudwadi area. In fact, the Bouguer gravity map presented by Kailasam

TABLE I

Stn. No.	Locality	Depth from ground surface to base of trap/high resistivity layer from resistivity soundings (m)	Depth from ground surface to base of trap/high velocity interface from seismic profiles (m)
60	Sholapur	290	260
55	Aurangabad	990	915
31	Karad	670	500
38	Pophli	530	200
41	West of Rampur	810	670
57	Velapur	580	290
59	Sangola	327	..
44	Kurudwadi	680	..
56	South of Manmad	>1000	..
4	Nagpur–Amraoti road	>1000	..

et al. (1972) and the subsequent detailed gravity surveys conducted by the GSI in this region do not at all indicate such a rift. The gravity gradient to the west of Koyna is quite steep, being roughly 3 milligals per kilometre and at some places even much higher, whereas to the east of Karad, the gravity gradient has the normal small regional magnitude of 0·5 milligal per kilometre. Furthermore, the pronounced gravity 'low' in the Koyna area is in the form of a closed, fairly restricted feature and does not conform to an extended, linear feature of a rift. The resistivity depths to the base of the trap along the Sholapur–Guhagar traverse thus bear out the earlier results and features brought out by the gravity and seismic surveys. Of particular significance is the fact that, in the Koyna–Karad region of pronounced gravity 'low', a thick section of trap is indicated, whereas in the zone of gravity 'high' in the Sangola area, a small thickness of trap is indicated, thereby establishing that the pronounced gravity anomalies are of deep-seated causes due to uplifts and subsidence within the deep crustal and crust-mantle layers. The system of parallel faults and associated fracturing indicated to the west of Koyna has

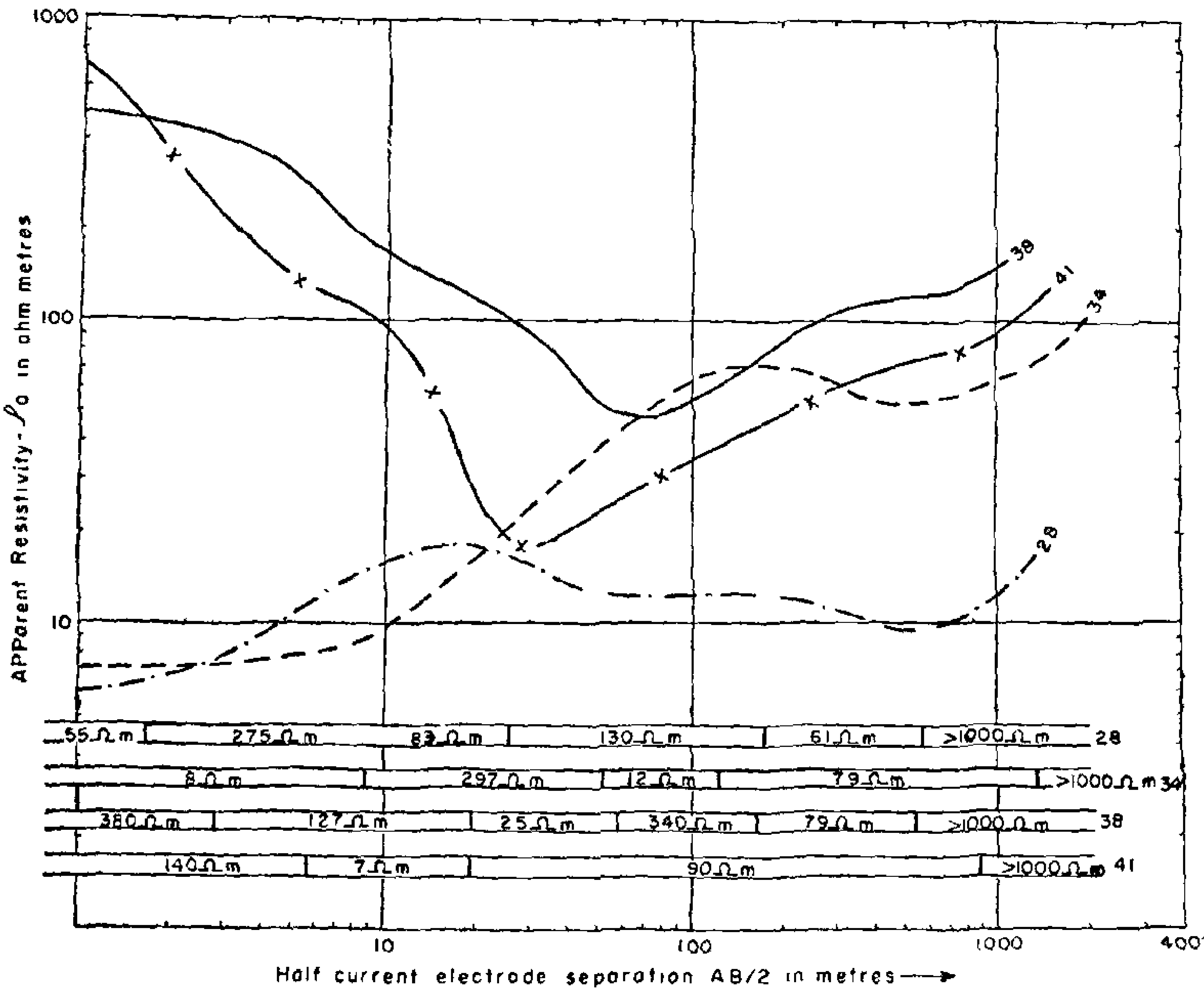

FIG. 3. Typical electrical resistivity soundings along Sholapur–Karad–Guhagar traverse.

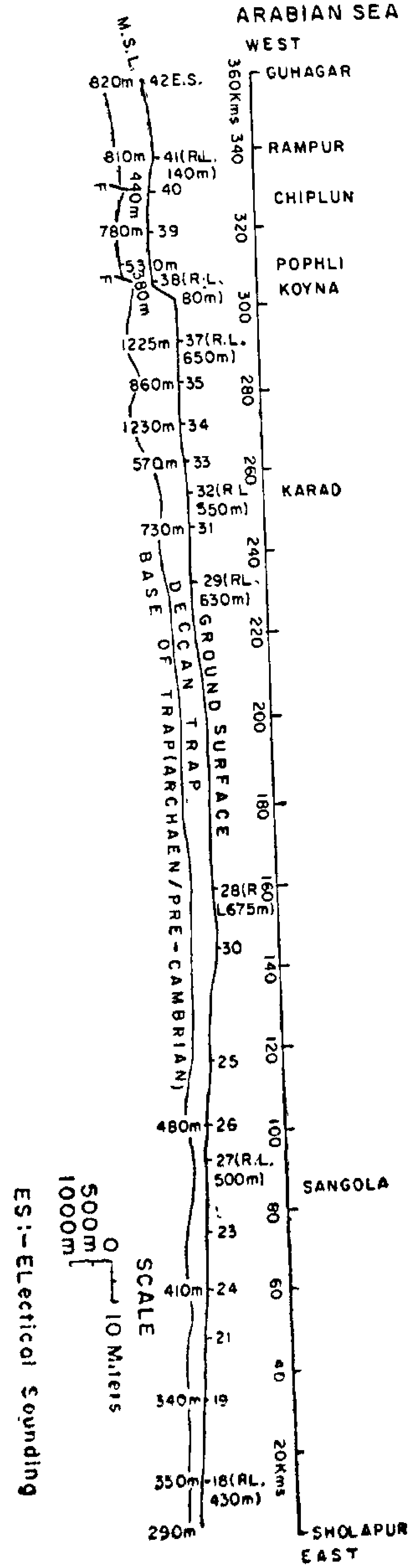

FIG. 4.

apparently a bearing on the observed current seismicity of this region.

The resistivity curves for soundings 4, 8, 9 and 10 on the Nagpur–Amraoti traverse, as also the resistivity curve for the deep sounding near Manmad, have brought out a subtrap medium of characteristically low resistivity in contrast with the highly resistive subtrap basement indicated in most of the other places. For instance, the sounding curve for station 10 (Fig. 2) between Nagpur and Amraoti (Fig. 1) has brought out a low resistive zone with a true resistivity of 18 ohm-metres at a depth of roughly 370 metres from the ground surface, possibly indicative of Lower Gondwana sandstones suggestive perhaps of a deep Gondwana basin as a north-westerly extension, under the traps, of the Gondwana rocks of the Chanda–Wardha valley. Similarly, the resistivity curve for the depth probe No. 56 south of Manmad (Fig. 2) also indicates a low resistive zone of roughly 10 ohm-metres below the trap at a computed depth of the order of 1,000 metres, which also inferably corresponds to Lower Gondwana rocks. This feature is also corroborated by the results of the refraction seismic soundings conducted earlier in the trap area immediately to the south of the Purna and Tapti valleys (Kailasam *et al.*, 1969).

The results of the deep resistivity soundings presented here show that the Deep Resistivity method can be employed as useful adjunct to the refraction seismic method for estimating the thickness of the Deccan trap and investigating the sub-trap geology.

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