MAGNETOTELLURIC STUDIES FOR OIL EXPLORATION OVER DECCAN TRAPS, SAURASHTRA, GUJARAT, INDIA

NATIONAL GEOPHYSICAL RESEARCH INSTITUTE
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PARTICIPANTS

The implementation of the present programme was accomplished through the active participation and team work of the following members of staff:

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thickness ranging from a few tens of metres to around 1.5 km. Similarly the sediments also show significant variation in their thickness, from south to north as also from east to west. It is expected that the gravity effect of these changes in the shallow section should have considerable influence on the regional gravity field and a correction for these shallow level changes of lithology should bring about a more realistic regional picture of the gravity field.

VIII. SUMMARY AND CONCLUSIONS:

The present program, of MT studies in the Saurashtra Peninsula for evaluating the efficacy of Magnetotellurics for hydrocarbon exploration in trap covered areas has been sucessfully implemented.

The vast sheet of Deccan basalts covering huge tracts of Indian Peninsula, occupies a very significant place in Indian Geology, posing severe problems and challenges to those engaged in hydrocarbon exploration. It is known that this basaltic cover hides the much sought-after Mesozoic layer of sediments having potential for hydrocarbon reserves. The efforts so far made towards probing the subtrappean lithology adopting conventional geophysical exploration approaches have been rendered infructuous because the trap cover acts like a Geophysical shield preventing any effective probing by the above methods. Under these circumstances, efforts to examine the utility of unconventional surface geophysical methodology were initiated to achieve this objective. Since the deep electromagnetic methods were thought to be the most appropriate for handling such a problem the present project is focused to introduce "Magnetotellurics" into the complex of geophysical strategies for exploration of hydrocarbons in such difficult regions such as Deccan Trap covered areas. The present program implemented with the financial support from OIDB has been successfully completed - eliciting the application and evaluating the efficacy of this approach for hydrocarbon

exploration in Saurashtra Peninsula. In this program a total of about 90 MT sounding measurements were made to have a regional coverage of a major part of Saurashtra peninsula. The coverage included the occupation of two trans-Saurashtra profiles: one oriented in the north-south direction from Ingorala (north of Halvad) near Rann of Kutch to Una near the southern tip of the Saurashtra peninsula and the other from Alampur in the east to Memana in the west. Besides these, a major portion of central and eastern portions of the Saurashtra peninsula were also covered by a number of MT stations. The data from all the stations were systematically processed and modelled through 1-D inversion analysis. The data from a few traverses were also modelled using a 2-D modelling technique. Following are the major conclusions arrived at on the basis of the analysis and interpretation of the modelling results in conjunction with the known geology.

1. The MT studies have been successful in detecting and delineating sediments hidden beneath the Deccan Traps.

(a) The MT sounding methodology has been shown to be very successful in detecting and delineating the sediments beneath the Deccan traps. The results show that the sediments find a very typical MT response in the sounding curves in the form of a low resistive layer with resistivity ranging from 10- 25 Ohm.m. The thicker this layer is, the better will be the chances of its unambiguous detection and mapping.

(b) The Deccan Traps themselves are shown to be represented by a moderately high resistive layer with resistivities ranging from around 50 Ohm.m. to a few hundred Ohm- m, with the average resistivity that could be assigned to the traps being around 150 Ohm.m. The deviation towards the lower value from the average are to be attributed to the presence of intertrappean beds or the mixing of sediments themselves with trap

material in some cases, while the dry hard traps exhibit higher range of resistivities amounting to a few hundred Ohm.metres.

(c) The third layer is seen to exhibit the resistivities of the order of a few thousand Ohm.m (2000-5000 Ohm.m) indicating that the sediments lie directly over a granitic/gneissic basement.

2. Results deduced from inversion of MT soundings are in correspondence with the borehole data.

The modelling results at calibration sites such as Aniali (ANL) near Dhandhuka borewell and Sonpari (SNP),where the Mesozoic sediments are exposed, have clearly shown the correspondence between the sounding results and the results obtained from the borehole data.

3. Variations in subsurface lithology and basement configuration on a regional scale have been obtained from the two trans- Saurashtra profiles.

The results from the two trans-Saurashtra profiles Una-Halvad (S-N) (Fig.9) and Alampur-Memana (E-W) (Fig.10) have been extremely useful to infer the nature of variations in the subsurface lithology and the basement configuration on a regional scale across the Saurashtra Peninsula. Based on the results from these profiles it may be inferred that:

a) (i) the thickness of Deccan Trap varies considerably from south to north along the Una-Halvad profile across the peninsula. The trap thickness which is around a few tens of metres in the north i.e. north of Jasdan attains a thickness of a few hundred metres immediately south of Jasdan and further south becomes thicker and continues to show the same trend up to the tip of the peninsula; (ii) while that being the picture regarding the traps, the sediments along this profile also show considerable

variation in their thickness; they are about 1 - 1.5 km thick in the region north of Jasdan and have values around a few hundred metres in the region south of Jasdan upto Monapar from where they get thinned down amounting only to a couple of hundred metres towards further south; (iii) it is also seen that the basement along the profile shows a gentle downward slope from north to south over this length of about 250 km. It also exhibits undulations, though gentle at several places along the profile. The most prominent among these basement features is a basement 'high' near Jasdan while another basement 'high' is located at Sara, north of Chotila. It may thus be summarised that the entire profile can be broadly divided into three segments, namely, the northern one i.e. north of Jasdan characterised by thin traps and thick sediments the southern one i.e. the segment south of Monapar, with thick traps and thin sediments and the middle one assuming an intermediate stage with moderately thick trap and sediments. It is also noticed that the east-west trending basement high near Jasdan is flanked to its north by a basement depression filled with considerable thickness of sediments.

(b)(i) The Alampur-Memana profile running nearly in an east- west direction indicates a thick trap cover on its eastern side, i.e. east of Jasdan with the thickness of traps amounting to about a kilometre; (ii) the sediments tend to become thicker towards the region west of Jasdan and to attain considerable thickness with values lying in the range of 1.5 to 2.5 km with the larger values tending to occur at stations on the western end of the profile; (iii) it is seen that results along this traverse also indicate the presence of the basement 'high' near Jasdan; (iv) the basement which is at a depth of around 800 m to 1 km near Jasdan tends to become deeper towards west, attaining a depth of about 3-4 km at Memana which is the westernmost station on this profile.

4. The sediments show a trend of increasing thickness northwards and westwards, indicating areas of maximum potential for further exploration.

The electrical character of sediments in the Halenda- Memana section of the east-west profile appear to be different in that their resistivities are relatively lower, ranging from around 10-15 Ohm.m, as against the 15-25 Ohm.m range observed for the sediments along the north-south profile. This could mean a change of facies and /or increase of clay or shale content in the total quantum of sediments in this region. The Deccan Trap resistivity also tends to be lower towards the west indicating that there is a change in the nature of trap rock or presence of conductive intertrappeans.

As could be seen from the foregoing results (Fig. 19), from both the regional profiles, the sediments show a conspicuous trend of increasing thickness towards north as well as west from the centre, located at Jasdan, implying that the north-western quadrant defined by these two profiles in the Saurashtra Peninsula offers the maximum potential for further exploration for the presence of a thick sedimentary column - this being the target of oil exploration.

5. The features on the basement configuration map agree closely with those on the total conductance map.

The first order basement configuration map prepared on the basis of the results of available MT stations in the northern half of the peninsula (Fig.15) should be helpful for future studies. Some of the prominent features reflected in this map are: (a) the east-west running basement high near Jasdan and also the gentle rise at Panchvada (PNV), south of Chotila and at "Sara" (SAR) north of Chotila. These three highs are interspersed by basement depressions filled with a thick pile of sediments.

The conductance map (Fig.14) besides reflecting these anomalies corresponding to basement features also brings out a conspicuous anomaly interpreted to reflect an apparently NE-SW trending sub-basin in the region between Deroi (DRI) and Rajkot, situated in the north-western quadrant of the peninsula.

Another feature that emerges from these investigations is that the basement dips, though gently, towards south as well as west, as could be seen along the two trans-Saurashtra profiles. These results are interpreted as the manifestations of the Saurashtra Basement Arch.

6. The results obtained in the present study show that MT and gravity are complementary to each other in reflecting the subsurface structure of the peninsula.

The variation in the thickness of Deccan Trap as well as sediments spread over such long distances across the peninsula should reflect in the gravity picture of this region. The results of this study could thus be rather well utilised to estimate the effects of this shallow subsurface section on the regional gravity which in turn should help in evaluating and interpreting the regional gravity picture of the Saurashtra peninsula more effectively.

The results obtained in the present study point out that both MT and gravity are complementary to each other, as described earlier in section VII, to gain further insight into the subsurface lithology of this Deccan Trap covered area. It is therefore recommended that a judicious combination of these two approaches constituting a well-balanced geophysical strategy be employed to handle this complex problem of hydrocarbon exploration. In the present context, the north-western quadrant of Saurashtra peninsula may be covered in more detail by gravity as well as MT surveys for delineating areas of maximum interest.

To retrieve a meaningful and realistic model from any kind of geophysical data it is desirable to have some support from drill-hole data in the area. Since such data is almost non-existent in this peninsula it is desirable to have an experimental borehole drilled in this area. If the criterion for selection of a site for experimental/test drill hole is to have thin trap and thick sediments a place for such drilling could be chosen from the region around Kamalapur (KMP) and Rampara (RMP).

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