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A cost effective strategy in conducting integrated geophysical studies in trap covered country

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ABSTRACT
Even though it is well known that seismic refraction is the most efficient technique to map the basement configuration, it is not commonly used due to the high cost involved in acquiring the seismic data. Keeping in view the importance of identifying potential hydrocarbon bearing sedimentary structures, after going through the derived success in different Trap covered terrains, it is strongly opined that a realistic data acquisition management module has to be selected to derive maximum benefit through optimal utilization of inputs. The suggested strategy, especially in the Trap covered area is as follows: To start with it is essential to look at the Bouguer/isostatic anomaly details of the area of interest to properly select the location, direction and extension of seismic refraction profiles. Once this is done, the suggested follow up action is to have Magneto-Telluric (MT) / Deep Resistivity Sounding (DRS) studies to identify broad features of potential structures, as the resistivity contrast between the Trap cover and the underlain sedimentary column is good to yield favorable results. This combined approach of having gravity and MT/DRS information prior to starting seismic studies, would then localize the area of study for seismic investigation. Similarly, the joint inversion of various data sets would narrow down the ambiguity and lead to production of better subtrappean structural details. Implementation of such a strategy has yielded very fruitful results in Saurashtra peninsula and Deccan Syneclise. Some salient sequence of events is given in this paper.

INTRODUCTION

Increasing demands of energy have necessitated development of new strategies for hydrocarbon exploration throughout the world. While on one hand efforts are being made to explore the gas hydrates, deep-sea hydrocarbon resources and coal bed methane, exploration of hydrocarbons in complex geological situations on land is being also considered important. The complex situations include thrust environments and shallow carbonate covered areas (Warren 1996), highly folded tectonic areas (Galibert, Guerin & Andrieux 1996) and the volcanic covered provinces. Volcanic covered provinces like the Deccan in India, the Columbia in North America, and the Parana in South America are regions where thick lava flows overlie sediments that could be promising targets for hydrocarbon exploration (Milani et al, 1990 and Morrison et al. 1996). In these situations it is either very difficult or too costly or at times not feasible to get reliable seismic images. Therefore, alternative geophysical methods become necessary to supply additional data. EM methods, which rank second to reflection seismics for their accuracy and depth of penetration (Galibert, Guerin & Andrieux. 1996) are the best suited to supply these data.

In volcanic covered areas the seismic methods, in general, fail to resolve the low velocity sediments lying below high velocity basalts. This is a typical case of the low velocity layer (LVL) problem in which the absence of any refraction information from the top of the LVL inhibits its detection in first arrival data and the feeble reflections from the LVL at short offset distances are difficult to pick up because of high noise level and reverberations.

The resistivity contrast between basalts and sediments, on the other hand, provides a suitable setting for the application of electrical and electro-magnetic methods. In recent years the magneto telluric (MT) method has been extensively used to delineate sediments below basalts (Morrison et al. 1996). This acceptable model could then be utilized to better understand the density variations (Bouguer and isostatic gravity information).

Recently, cooperative interpretations of seismic and MT data have been attempted for such difficult geological situations (Jones 1998; Manglik & Verma 1998). The general approach followed is to obtain the electrical structure first and then use it to modify seismic structure to finally arrive at a more acceptable model (Warren 1996). However, it is proved beyond doubt the efficacy of seismic refraction technique, during the studies in Saurashtra peninsula, Kutch on land and Deccan Syneclise (Technical Report 1998; Technical Report 2000 and Technical Report 2003). Using skips in the first arrivals in conjunction with sub-critical wide angle reflections, subtrappean velocity-depth models have been generated by the CSS project of NGRI in all the above three regions. Keeping all the above details and practical experiences as data base some suggestions are made in this paper to bring into focus the efficacy of organized sequential execution of integrated geophysical studies.

DISCUSSION

Oil industry, after noting that world over Mesozoic sediments are potential oil bearing formations, has decided to explore different regions that have Mesozoics either as exposures or as hidden subtrappean formations. Under this program oil industry asked NGRI to carry out integrated geophysical studies (Technical Report 1998) in the Trap covered Saurashtra peninsula. Prior to sanctioning the grant-in-aid project to NGRI, it has gone through the results produced by a regional magneto-telluric profile across Lodhika. Lodhika bore hole, drilled as per results from MT has shown presence of thick Mesozoic sedimentary column below Traps. In addition to litholog details from Lodhika and Dhanduka deep wells the oil industry exploration strategists have gone through the gravity data acquired by Oil and Natural Gas Corporation (ONGC) to pin point the area of study. This exercise, in general, has shown absence of potential structures in the eastern part of Saurashtra peninsula. So, in nutshell, the initial results from MT and gravity have helped in restricting the integrated geophysical studies to the middle and western parts of Saurashtra peninsula (Fig.1). This prior information has also helped in

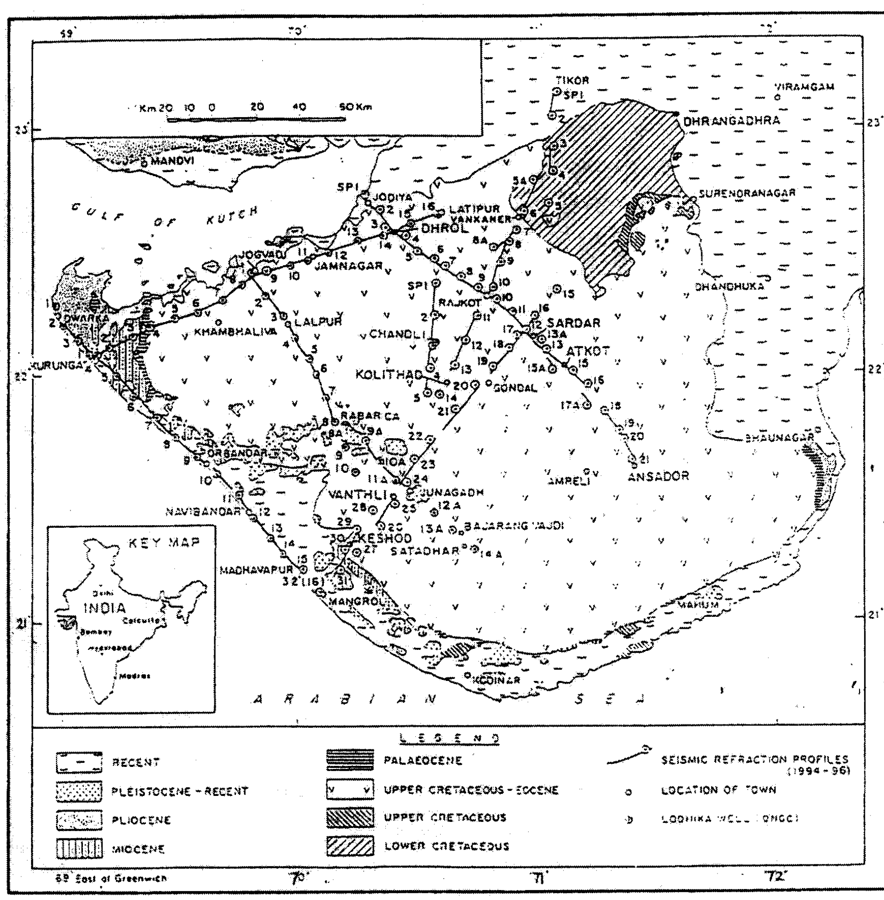

Figure 1. Seismic refraction profiles of NGRI in Saurashtra Peninsula.

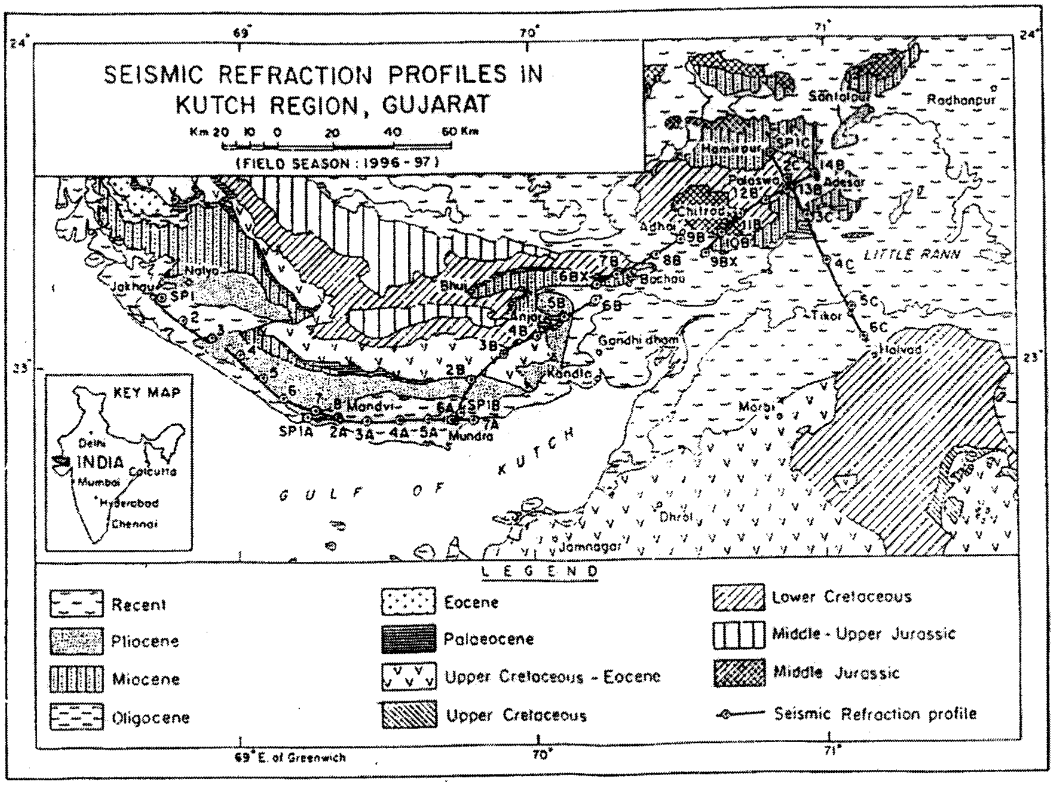

Figure 2. Seismic refraction profiles of NGRI in Kutch region, Gujarat.

confining the seismic coverage to four profiles strategically located at the peripherals of northern and western flanks of Saurashtra peninsula and across Lodhika deep bore hole. Subsequently, when studies have been planned in Kutch mainland (Fig.2), the seismic coverage was restricted to mainly to the coastal region, as the results from integrated geophysical studies (Technical Report 2000) carried out by NGRI have clearly suggested probable northward extension of thick Mesozoic sedimentary formations, off Jamnagar and Dwarka basins. But for the above detailed sequential data acquisition exercise we would have incurred considerable expenditure in acquiring various sets of data. Subsequent to the success of integrated geophysical studies in Saurashtra and Kutch, while exploring a segment of Deccan Syneclise (Fig.3), a planned strategy has been adopted in acquiring integrated geophysical data sets. In this part of Deccan Syneclise (Technical Report 2003), which is closer to Ankaleswar oil fields, the integrated geophysical data acquisition exercise was started with MT and DRS studies in the western and eastern segments of the region of study respectively to broadly locate presence of subtrappean sedimentary formations. This exercise has also been planned taking into consideration the velocity-depth structural details obtained along Thuadara-Sindad DSS profile (Kaila et al. 1989) and existing data of subsurface structural formations in and around Ankaleswar. This planned data acquisition strategy has not only yielded quality data but also helped in overcoming logistic constraints introduced by the unrest in Gujarat state.

In addition to a planned sequential data acquisition module, we also suggest a processing sequence as detailed below. To start with individual structural details are to be obtained from all the four geophysical data sets. This is to be followed by joint inversion of MT & DRS and seismic & gravity separately. This simultaneous joint inversion exercise would produce two models from two sets of entirely different geophysical techniques. Finally, the two sets are vigorously cross checked to narrow down ambiguities and build up a model out of total synthesis of all the four data sets.

So, in nutshell what we advocate is that instead of randomly conducting integrated geophysical studies we can adopt a strategy that would help in not only reducing overall cost of data acquisition but also in

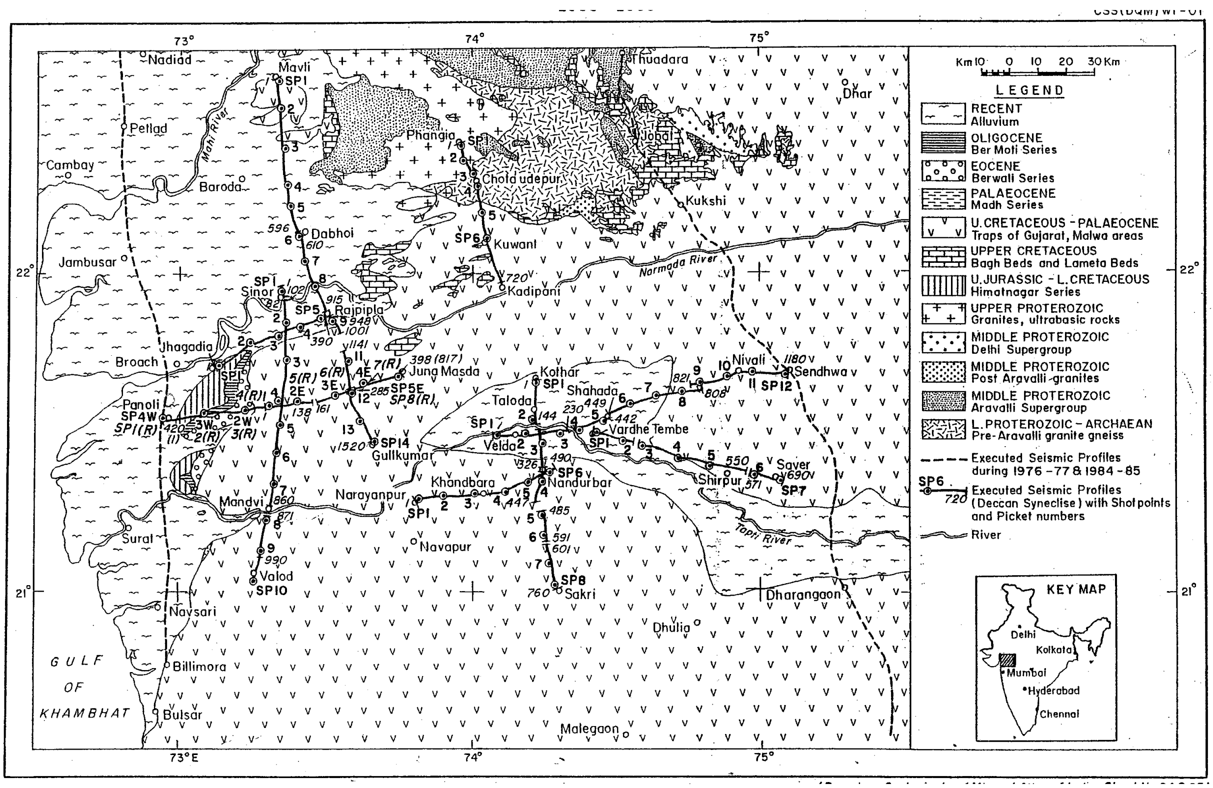

Figure 3. Seismic refraction profiles of NGRI in Western Deccan Syneclise region.

getting the needed results in a limited time, by phasing out properly different data acquisition and processing exercises.

CONCLUSIONS

Cost effective and sophisticated high quality data acquisition modules are essential for a focused hydrocarbon exploration in problem areas like volcanic covered regions. However, to achieve this one has to effectively plan in advance a sequential data acquisition and processing schedule followed by a realistic interpretation set up. Such a planned exercise by taking up regional gravity surveys followed by magneto-telluric and deep resistivity sounding prior to seismics has yielded fruitful results both in Saurashtra peninsula, Kutch on land and Deccan syneclise. Finally, joint inversion of all the data sets has yielded more acceptable structural details.

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