Sub Trappean Mesozoic (?) Sediments in the Narmada Basin Based on Amplitude Studies – A Revisit to the Old DSS data

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Summary

Energy is basic requirement for rapid development of any economy. The primary source of energy includes hydrocarbon natural gas, oil, coal, solar energy, wind etc. Hydrocarbons are extremely versatile, non-renewable source of energy and can be adaptable to environmental standards. As such, the quest for locating energy resources is always needed. Of late, the search for hydrocarbons amidst hidden Mesozoic sediments has gained prominence, making their precise delineation very important. A direct evidence for the presence of Mesozoics is in the form of an LVL seen prominently on refraction records. To get an idea about the occurrence of these sediments, seismic refraction/wide angle reflection studies were carried out in different parts of the country. The inference of the LVL is not possible from refraction data alone because no refracted rays bottom within the LVL. However, when the thickness of the low velocity layer is relatively high we can see the skip in the refraction travel times and this has been used to identify and delineate the low velocity layer. Data from reciprocal shoot points are used for confirmation and precise delineation. In order to obtain the structural information up to the basement the shot points were located at about 10 km interval. The analog seismic records from seven shot points were digitized and the trace normalized record sections were plotted. These seismograms were used to identify the reflections from the top and bottom of the LVL. A lot of iteration was carried out until a significant comparison is arrived between the observed and computed amplitudes (synthetic seismograms). The seismic data from the DSS profile in the western part of the Narmada Son Lineament (NSL) that passes through both the rivers Narmada and Tapti is used for this study. Most of the profile area is covered by Deccan Traps and a few exposures of marine Cretaceous sediments (Bagh Beds) in the northern part and a patch of alluvial deposits seen in the southern part of the profile. The velocity in the Mesozoic exposures has been recorded as varying between 3.2 and 3.6 kms^{-1}. The same velocity has been ascribed to the Mesozoics below the Deccan Traps. Mesozoic beds have been identified based on the shift of travel times of the first arrival. There is a noticeable shift of about 200 ms in the travel time from different shot points. The analysis of the seismic refraction and wide-angle reflection data showed possible existence of Mesozoic sediments of considerable thickness and the presence of huge thickness of Deccan Traps.

Introduction

Starting from 1972, the Deep Seismic Sounding (DSS) technique has been successfully employed in India by the National Geophysical Research Institute (NGRI). The NGRI has acquired refraction and wide-angle reflection data for crustal studies, in analog as well as digital form for over 5000-line km. These data have been acquired by continuous profiling, along 20 profiles in various geological settings in the peninsular shield and in the Himalayas. A large percentage of the data acquired is for studying the crustal configurations and velocity models. However, along a few selected profiles the data were acquired more densely to delineate the near surface structure as well. The Thuadhara-Sendhwa-Sindad profile across the Narmada rift basin, the results along which are presented in this study, falls in latter category. The first interpretation of the data (Kaila et al., 1989) was mostly confined to the crustal structure and the ray tracing technique for basement configuration was carried out only from a few shot points with large data spacing. Sridhar and Tewari (2001) felt necessary that all the available data sets along this 260 km long NS profile, in the western part of the Narmada zone, be analyzed and interpreted fully so as to find the thickness of the Deccan volcanic, detect underlying low velocity zones, delineate the basement
configuration etc. In the present study we use the synthetic seismograms and the reflections from the top and bottom of the low velocity layer (Probably the Mesozoics) for confirming the earlier findings.

The Thuadhara-Sendhwa-Sindad Profile

The 260 km long, N-S Thuadara-Sendhwa-Sindad profile situated in the western part of the Indian shield runs across the Narmada Son lineament in Central India. It traverses mostly the region of exposed Deccan Traps (Fig. 1). Other geological formations exposed along this profile include the Mesozoics Bagh and Lameta beds, the Proterozoic Aravallis and equivalent rocks and the Archean granitic gneisses in the northern part. The profile crosses the Narmada and Tapti rivers around SP 80 and SP 190 respectively. A patch of alluvial deposits is exposed in the southern part. The elevation of the region is between 150 m and 400 m above the mean sea level.

Methodology and approach

Seismic refraction method is generally used for delineating subsurface structure that has continuous increase of velocity with depth. In case of velocity inversion viz. a low velocity layer (LVL) underlying a high velocity layer, the first arrival refraction data does not normally possess information that can indicate the velocity and thickness of the LVL. But in some favorable environments where high velocity layer is thinner than the underlying low velocity layer, a shadow zone (skip/shift) may be observed in the refraction travel times. This is due to the fact that refraction takes place from the top of the high velocity layers above and below the low velocity layer, thus exhibiting a shadow zone/skip. The magnitude of skip is a function of the velocities and relative thickness between high and low velocity layers, other parameters remaining constant. Such a skip in travel time, if observed from several shots, suggests a velocity inversion in the subsurface structure. Delineation of subsurface structure that contains velocity inversion could be achieved through 2-D forward modeling technique involving first arrival travel time data and using the skips. In addition to the first arrival refraction data, the sub critical and wide angle reflection data from top and bottom of the hidden sedimentary layers is made use of to delineate the LVL.

The Deccan traps cover a significant part of the Indian landmass, extending over more than 500,000 sq. km. Though it is difficult to recognize low velocity layers under high velocity layers in the refraction data, the analysis of travel time shifts in the first arrivals make it possible to identify these low velocity layers (Jarchow et al., 1994, Tewari et al., 1995).
Data analysis and Conclusion

During the present study an attempt has been made to compute synthetic seismograms using the generated models used for modeling the first arrival refraction data. Then the reflections from the top and bottom of the low velocity layer are generated along with the synthetic seismograms. Until a near clear satisfactory model which matches with the original to that of the computed travel times and then the synthetic seismograms, minor adjustments were carried out by alternately changing the velocity and depth parameter. The analog records of playback records where the reflections are clearly identifiable are selected and these record sections were digitized. The trace normalized record sections were plotted. Six shot points were selected among the 25 shot points keeping in view for mapping the thickness of Deccan traps and the probable Mesozoic sediments sandwiched between the Deccan Trap and the Granitic basement.

The trace normalized record sections from Shot Points 40, 80, 110, 140, 170 and 190 were used for the present experiment. The initial model was taken from Sridhar and Tewari 2001. During the earlier study Sridhar and Tewari used the then available software Cerevny's SEIS81 package. No amplitudes study was then carried out. Now with the availability of the latest seismic software which is user friendly an attempt has been made to verify the delineated structure up to the basement and reconfirm the probability of the presence of Mesozoic sediments.

Basement configuration of the Thuadhara-Sendhwa-Sindad profile was generated through two-dimensional modeling of the refraction data and analysis of travel time skips and amplitudes. In order to attempt this way of working both travel times and amplitudes, the results obtained through one dimensional program were taken as initial models and the same were refined till a satisfactory match of the first arrival travel times was obtained from most of the shot points. The analysis of the travel time skip between SP 80 and SP 190 (examples in Figures 2a and 2b) from about 7 shot points aided by high density of data make it possible to identify the subtrappean low velocity layer during the present study.

Between 2000 and 3000 m thickness of the low velocity sediments (3.2-3.6 km/s) is identified which is a basement depression between SP 80 and SP 180. The depth to the basement (6.0-6.2 km/s) is about 3000 m between SP 80 and SP 120 and 5000-5500 m between SP 140 and SP 170. South of SP 190 till the end of the profile the basement directly underlies the Deccan Trap. The velocity recorded in the Bagh beds to the north of Narmada is similar to the velocity in the Gondwana (Permo-Carboniferous) sediments in India which varies normally between 3.2 and 3.7 km/s. The development of a 2 D model under the volcanic cover (Figure 3) showing the thickness of the Deccan Traps and sediments depth to the basement is once again confirmed by the present study.
Figure 2a: SP 140 recorded north to 50 km. The travel times both computed and observed (middle) along with the ray diagram (Bottom) and the generated synthetic seismogram (Top).

Figure 2b: SP 140 south recorded to 50 km. The travel times both computed and observed (middle) along with the ray diagram (Bottom) and the generated synthetic seismogram (Top).

Figure 3. 2D velocity depth section delineating the probable Mesozoic sediments.

References

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