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Imaging Velocity Structure Using First Arrivals from Seismic Refraction Data

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Summary

The seismic refraction method is used to estimate the important velocity information required to interpret the reflection data in the modern exploration programs for oil and gas. The detection of low velocity layer from the refraction data is very difficult using traditional techniques. The present study shows the application of ray tracing technique to image the velocity structure including the low velocity layer. The technique has been demonstrated using the first arrivals from seismic refraction data acquired in the Maharashtra region. The obtained velocity model indicates the presence of geological units such as top alluvium, trap, low velocity sediments and granite basement.

Introduction

Seismic refraction method is a powerful technique to determine the subsurface structure. Seismic refraction surveying played a key role in locating salt domes in earlier days of geophysical exploration. Even for the modern exploration programs refraction surveys are used to obtain the important velocity information required to interpret the reflection data. Refraction surveys are also done to determine the static correction for reflection data. In addition to this refraction surveys are used for geotechnical purposes as well as for engineering purposes.

Refracted waves can be identified from the characteristics alignments of first arrivals on a seismogram. The travel time of the waves from source to geophones are estimated and plotted to obtain a travel time curve or time distance (t – x) curve. The alignment of points on a t-x curve indicate the velocities of seismic waves through rock layers and provide the information required for determining layer thicknesses.

With the expansion of speed and power of digital computers more sophisticated techniques (e.g. Zelt and Smith, 1992) are being used for the interpretation of refraction data. One of such technique is ray tracing method (Cerveny et al., 1974) which utilizes the computer capabilities more fully in dealing with refraction data from complicated subsurface structures. In this study we have illustrated the application of ray tracing method to image the subsurface using first arrivals on seismic refraction data.

Method

In the ray tracing method a subsurface model based on the available information is proposed. The ray paths of this model are calculated and travel times are determined. These estimated times are compared with the observed times. The model is then adjusted to improve the correspondence between observed and computed times. This process is continued until a realistic model is generated that produces the travel times close to the observed times. This ray tracing method is useful in case of complex subsurface structures that are difficult to treat analytically. The ray tracing method is particularly valuable in coping with the complexities such as horizontal or vertical velocity gradient within layer and irregular refracting interfaces.

Example

The ray tracing technique has been applied for the refraction data acquired using explosive source in Maharashtra region bounded by latitude 21° to 22 ° and longitude 75° to 78°. The data was recorded by 3-component geophone with spreading length of 30-35 km and geophone interval of 100 m. The data was collected

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for three shot points with the interval of 10-12 km. along a profile from West to East. The analysis has been done using the software Xmanager. Figure 1 shows the seismic section for the shot point 14 (sp 14). The first arrivals have been picked direct and refracted arrivals on this section and shown by colored lines.

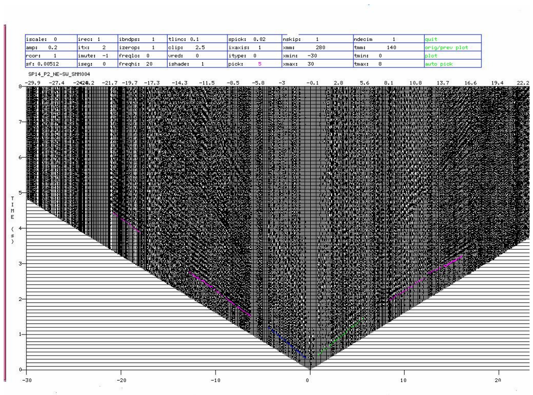
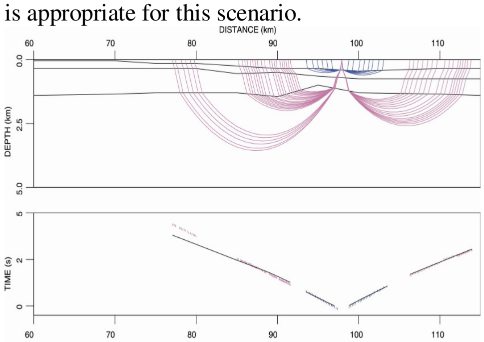
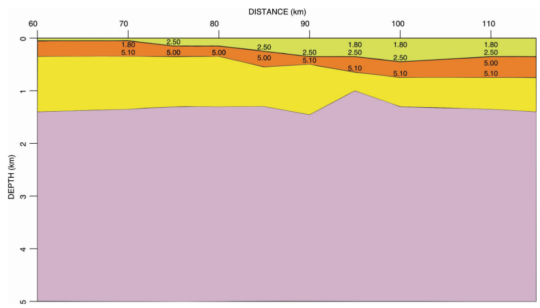


Figure 1 : Seismic section for the shot point 14. The colored lines on the section are picked first arrivals.

The plot of first arrivals versus distance is shown in figure 2a along with the ray diagram for the velocity model (figure 2b) obtained iteratively using ray tracing technique. The solid lines on the t-x curve (figure 2a) are corresponding to the velocities shown in figure 2b. The agreement of solid line with the observed first arrivals on t-x curve shows that the inferred velocity model (figure 2b) is appropriate for this scenario.



(a)



(b)

Figure 2: (a) t-x curve along with ray diagram for the shot point 14. The solid lines on the t-x curve are corresponding to the velocities shown in figure (b).

Similar analyses have been done for two more shot points in the same region. Figures 3 & 4 show the plots corresponding to these shot points.

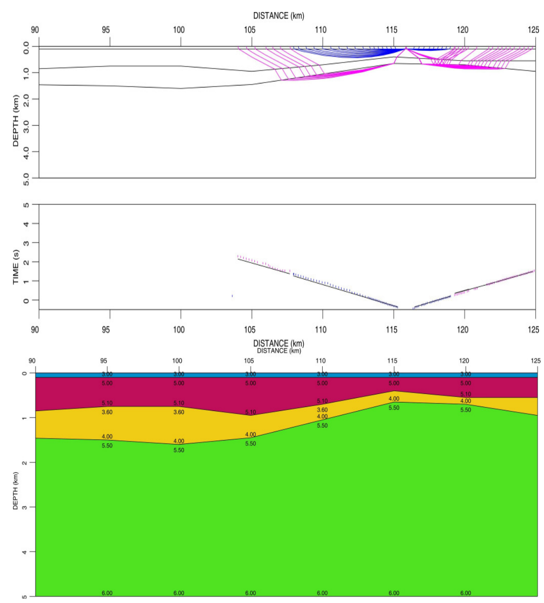


Figure 3: t-x curves, ray diagrams and obtained velocity models for the shot point 16.

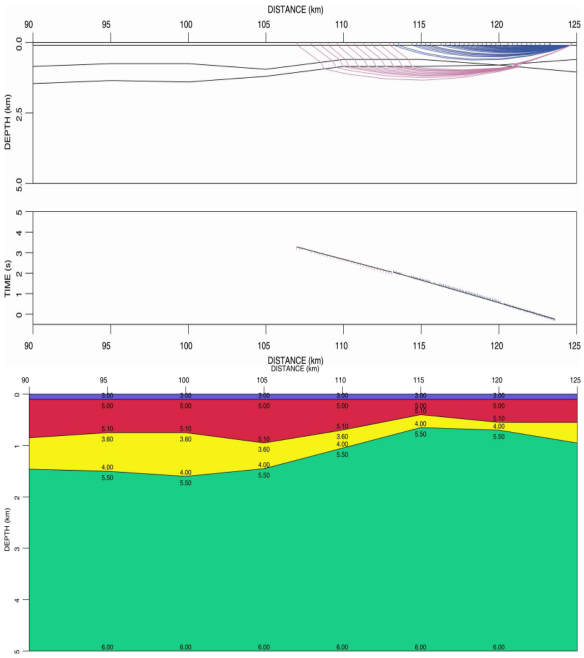


Figure 4: t-x curves ray diagrams and obtained velocity models for the shot point 17.

Figure 5 show the results corresponding to all the three shot points together. The close agreement between the solid lines and first arrivals on t-x curve show the validity of velocity model obtained for the region. The delays of the first arrivals or skip phenomenon show the presence of low velocity layer with considerable thickness.

We note that velocity in the top alluvium is 1.8 km/s underlain by the trap with velocity of 5 km/s. There is existence of low velocity sediments below the trap.

This low velocity layer cannot be detected by usual techniques due to non arrivals of critically refracted waves from the top of the low velocity layer.

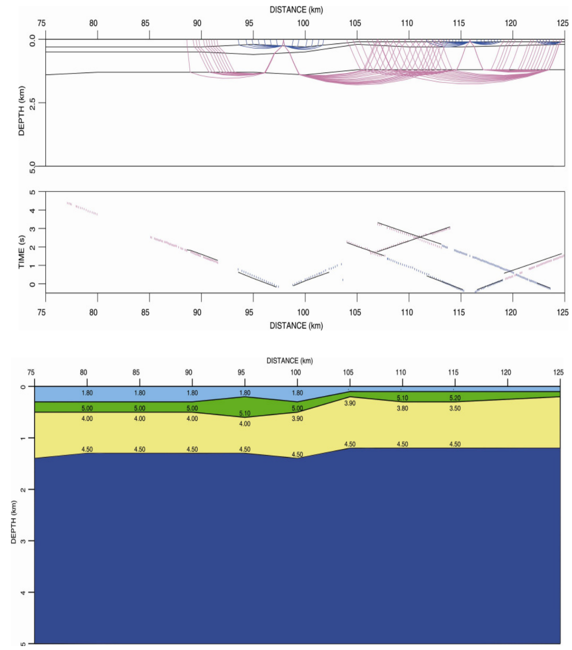


Figure 5: t-x curves, ray diagram and inferred velocity model for the region under study.

Conclusions

The application of ray tracing technique has been demonstrated to detect the low velocity layer sediments of considerable thickness using first arrivals on the seismic section. The close agreement between the estimated first arrivals with those of observed ones shows that the inferred velocity model obtained by an iterative process is appropriate. The obtained velocity model indicates the presence of geological units such as top alluvium, trap, low velocity sediments and granite basement.

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