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Analysis of results obtained by different seismic refraction interpretation techniques over granitic bedrock

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Abstract

A refraction survey was carried out over granitic bedrock of Dharwar craton stretching for about 120 meters and data obtained was interpreted using various interpretation techniques. Individual interpretation results have been presented in this paper followed by their comparative study. Techniques such as intercept time method, delay time method, reciprocal methods and tomography were used for the purpose of interpretation.

Introduction

Seismic refraction is considered to be paramount in engineering geophysics. In earlier days it was used in oil exploration but with the advent of seismic survey method in reflection its importance is lost. It fulfil vested interest in broad geophysical domain like static correction, mining applications, environmental and engineering applications .Refraction techniques supplements the primary purpose of determining bedrock depth, rippability and assessing rock type. The technique has been successfully implemented in mapping backfilled quarries, overburden thickness and topography of groundwater. For civil purposes viz. site investigations, application of method has observed significant increase (Redpath, 1973).

Geology and location of survey profile

Survey area is comprised of granites and rock formations which date back to Precambrian period. Prospective area is present over Deccan plateau and geographically it lies in Uppal, Hyderabad.

Figure 1: Survey area.

Data was acquired using hammer as an energy source and 48 geophones were used to receive signals. Geophones were placed at 2.5 meters spacing making a total spread of 117.5 meters. Total of 19 shot points were selected, both forward and backward, comprising of far offset of 20 meters, near offset of 1 m and all others in between at a distance of 7.5 m with each other as shown in Fig.3.

Methods used

Intercept Time Method (ITM): Following equations have been used for computation of depth of the refractors:

$$\Delta T = 0.5\ (T_u + T_d\ - T_t)$$

$$Z_d = \frac{\Delta T \times\ V_1}{cos\ (\sin^{-1}(v_1\ /v_2\ ))}$$

Where, Δ**T** is delay time, $\mathbf{T_u}$ denotes up dip shooting time, $\mathbf{T_d}$ denotes downdip shooting time, $\mathbf{T_t}$ denotes average reciprocal time, $\mathbf{Z_d}$ is depth of the refractor, $\mathbf{v_1}$ denotes velocity of upper layer and $\mathbf{v_2}$ denotes velocity of lower subsurface.

Conventional reciprocal method (CRM):

$$DCF = \frac{V_1 \times V_2}{({V_2}^2 +\ {V_1}^2)^{1/2}}$$

$$Z = DCF\ \times\ T_g$$

Where, DCF denotes depth conversion factor; Z denotes depth of the refractor and T_g is the time depth analysis function.

Tomography:

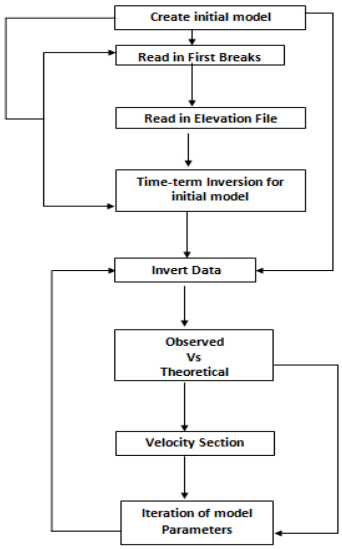

Figure 2: Flowchart depicting steps performed in tomography

Ideally the base of a weathered layer should be a perfect refractor however geological irregularities may lead to lateral velocity discontinuity and consequently affect depth of the refractor. As interpretation is based on picking of first arrivals, analysis may be erroneous since some of the first arrivals were adjusted manually from wiggle. Placing of geophones closer to each other overcomes this problem to some extent or AGC amplifier can be used. Spacing between geophones and sources and number of shot points all depends upon the purpose of survey. Detailed survey can be undertaken by less spacing and more number of geophones.

Results and discussion

Intercept time method provided the velocity model of three layered model as shown in Fig. 4. According to velocity, top layer is composed of soil underlain by layer apparently composed of wet and weathered granitic layer. Below it, presence of fractured and joint granitic layer is expected. First layer velocity comes out to be equal to 500 m/s.

In case of delay time method, third layer is found to be highly undulating as shown in Fig.5. Depth for third layer calculated by this method varies in the range of 15 to 18 m while for second layer depth ranges from 2.5 to 4 m. Reason can be attributed to the fact that small scale artefacts are not smoothened, affecting interpretation and depth. However, depth values are found to be in near agreement to that computed by others barring undulations.

In CRM, velocity analysis function is found to be varying almost linearly. In GRM, on the other hand, velocity was calculated corresponding to spacing of 10 m between the geophones as it has the least variation shown in Fig. 6.

Summing up the results of velocity analysis function and velocities plots obtained by both reciprocal methods, horizontality of refractors can be conferred and velocities obtained are found to be in near agreement to actual value. With the assistance of velocities of first and second layer and time depth function depth section for the same are evaluated. Therefore, computing depth of the second layer by CRM (Fig.7) and GRM (Fig.8), observed to be nearly equal as computed by other methods.

Tomography was applied independently on the field data and produced three layered model as shown in Fig.9.Tomography was successful in smoothening lateral variations considerably and velocity model provided by it. Depth observed is more laterally uniform compared to that of other methods. However, velocity model obtained is found to be at general agreement with one obtained by intercept time method. Here it was found that the velocity of first layer differs from that calculated through ITM by being equal to 300m/s.

Conclusion

Intercept and delay time methods provided preliminary information such as depth and velocity of reflectors and were found to deviate nominally from computations using other interpretation techniques. This deviation may be due to personal error in manual calculation and plot of travel time curve on graph. For delay time computation first arrival were picked and extrapolation of travel time curve was done to obtain second and third layer velocity and consequently depth of respective interfaces.

The delay time method tends to find out depth to the bedrock below each receiver. However, it fails in the determination of lateral velocity variation and identification of thin layer.

CRM carries the advantage of resolving simple departures from the plane interfaces and homogeneous velocities of the ITM. Reciprocal methods are computationally effective for the region having gentle dip i.e. less than 15 degrees. In case of pronounced changes in depth, assumption of plane refractor does not hold and artefacts occur. Reciprocal methods were able to accurately predict depth of second layer. But, they cannot calculate depth of third layer as velocity analysis function for the same could not be figured out. Depth section and velocity model for both conventional method and reciprocal method was found to be at par, with generalized method having more gentle lateral variation.

However the advantage of method over DTM is that lateral velocity variations can be found along with the capability of depicting the fractures and joints, causing the velocity of granitic layer somewhat less than the original value. A better velocity model could have been obtained if parallelism of travel time plots would have been worked over while processing the data.

Among all the methods discussed, tomography appears to provide optimum results. Lesser undulations, accurate depth section and precise velocities for different layers marked the operation of tomography. Its essence lies in the fact that it can tackle the discontinuities of refractor bed which was overlooked in GRM. While comparisons deduced by us are not definitive however they do offer some guidance over performance of refraction interpretation techniques over granitic bedrock. Also this fact cannot be neglected that in absence of sufficient data, tomography inversion results into erroneous models. So, a firm data worked through CRM and GRM is essential for an acceptable tomographic model. Worked out approach for interpretation is summarized in Table 1.

Figure 3: Arrangement of geophones and shot points on a survey line

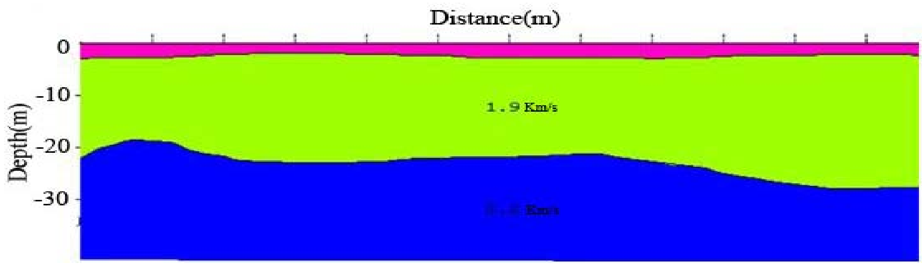

Figure 4: Velocity Model obtained from ITM

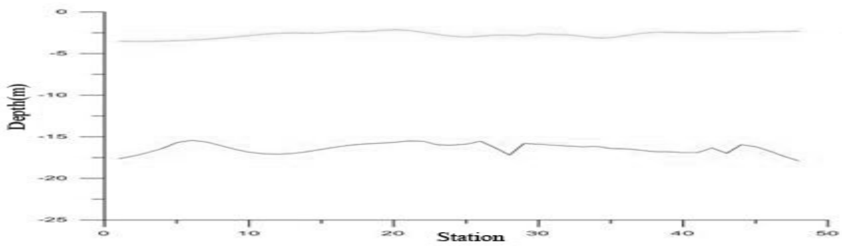

Figure 5: Depth to the second and third interface calculated through DTM

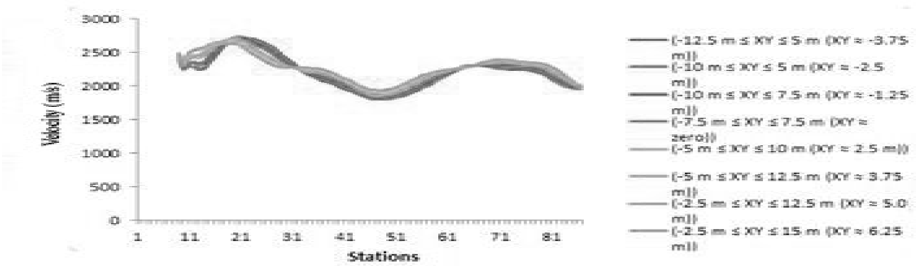

Figure 6: Shows the variation in velocity with varying XY

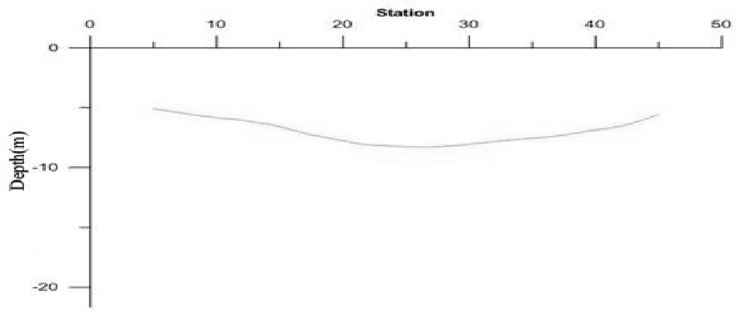

Figure 7: Variation in depth to the second layer with stations computed by CRM

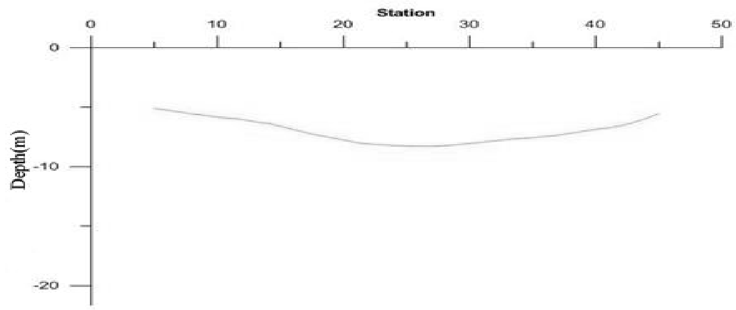

Figure 8: Variation in depth to second layer computed by GRM

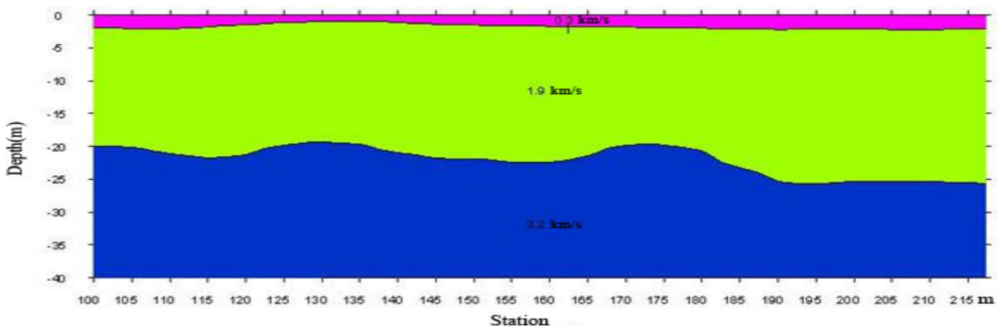

Figure 9: Velocity model after Tomography

Interpretation Method	**Application**
ITM	Picking of first arrivals
ITM	Travel time curve illustration
Travel Time Inversion	Velocity model using ITM
CRM , GRM, DTM	Computation of depth & velocity
Tomography Inversion	Velocity model using Tomography

Table 1: Illustrating refraction interpretation system for detailed Granitic mapping

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References

Barry, K.M., 1967, Delay-time and its application to refraction profile interpretation: in Musgrave, A.W. (ed.), Seismic Refraction Prospecting: Society of Exploration Geophysicists, 348–361.

Cerveny, V., and Ravindra, R., 1971, Theory of Seismic Head Waves: Toronto Press, 296p. Hawkins, L.V., 1961, The Reciprocal method of routine shallow seismic refraction investigations: Geophysics, **26**, 806–819.

Hagedoorn, J.G., 1959, The plus-minus method of interpreting seismic refraction sections: Geophysical Prospecting, 7, 158–182

Leung T.M., 1995, Examination of the optimum XY value by ray tracing: *Geophysics*, **40**, 1151–1156.

D.M., Eddleston, D.M., Fenning, P.J., and Reeves, G.M. (Eds), Modern Geophysics in Engineering Geology: Geological Society of London, Engineering Geology Special Publication No. 12, 413–416. Palmer, D., 1980, The generalized reciprocal method of seismic refraction interpretation: Society of Exploration Geophysics, 104p.

Redpath, B., 1973, Seismic refraction for engineering site investigation: Explosives Excavation Research Lab., TR E-73-4, 51p.

Zhang, J., and Toksöz, M.N., 1998, Nonlinear refraction travel time tomography: *Geophysics*, **63**, 1726–1737.