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OPTIMUM GEOMETRY FOR ROLL ALONG IN SEISMIC REFRACTION TOMOGRAPHY FOR ADEQUATE SAMPLING AND COVERAGE OF THE SUBSURFACE

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ABSTRACT

Seismic refraction is mostly used in geotechnical work to determine the velocity of the overburden and the refractor velocity. Roll along, in seismic refraction tomography, is important for three reasons. These are to increase the profile length beyond the distance dictated by the source and the instrument (number of receiver and cable length), to increase the signal to noise ratio and to ensure an adequate overlap in the subsurface data coverage. Some pitfalls often encountered by geoscientists employing refraction tomography and examples of the wrong methodology often employed in refraction roll along tomography with their effect on tomographic section are presented. At the end of filtering and data analysis it was obvious from the ray tracing and results obtained that roll along in seismic refraction tomography principle help in achieving adequate subsurface data coverage, improvement in signal to noise ratio and achieving the desired profile length when compared with two distinct independent profiles taken along the seismic line.

INTRODUCTION

Seismic refraction method is based on the measurement of the travel time of seismic waves refracted at the interfaces between subsurface layers of different velocities. It is mostly employed in the determination of depths and velocities of the overburden and the refractor within the subsurface (Keary and Brooks, 1984). When the refractor is suspected to have a dip, the velocities of the beds and the dip of the interface can be obtained by shooting a second complementary profile in the opposite direction (Lowrie, 1997).

Seismic tomography is an imaging technique which generates a cross-sectional picture (a tomogram) of an object by utilizing the object’s response to the nondestructive, probing energy of an external source (Tien-When Lo and Philips, 2002). Near-surface seismic refraction tomography is a geophysical inversion technique designed for subsurface investigations where seismic propagation velocity increases with depth.

Unlike reflected ray which travel at normal incidence to the reflector after normal moveout correction (NMO), the doubly refracted ray impinges on the interface between the overburden and refractor at critical angle i_{c}, hence the total length of subsurface coverage is less than the spread length (Dobrin, 1976). In a situation where two independent profiles are taken along the same profile line, with the incident ray impinging at the interface between the overburden and refractor at critical angle, a greater area of the subsurface will be left uncovered. This has necessitated the design of a method that will enhance effective subsurface coverage. The output of refraction tomography analysis is a model of the distribution of seismic velocities in the subsurface; thus, additional interpretation must be carried out to generate a geologic model to help explain what the velocities represent (Gregory, 2002).

The false impression created by using wrong geometry can lead to wrong estimate of geophysical parameters thereby resulting in wrong interpretation, This could carefully be avoided by employing the right principles of roll along seismic refraction tomography.

The aims and objectives of this paper therefore are to: to outline the principles involved in roll along refraction tomography and show how roll along refraction tomography can be used for maximum subsurface coverage and elimination of edge effect.

INSTRUMENTATION

The major instruments employed in this survey include a 24 channels digital Seismograph (Terraloc Mark 6), sets of 25 vertical Geophones, reels of cables and sledge hammer. The multi-channel digital seismograph records 24 traces at the same time and has a very high dynamic range which gives a very high resolution for both refraction and reflection survey. It can be used any where in the world and in all weather conditions (Sandmeier, 2003). The sets of 25 vertical geophones, with one acting as the trigger geophone, has a frequency range of 4 -100Hz. It is used to pick the seismic signals generated by the energy source (the sledge hammer).

METHODOLOGY

The field procedure involves putting source and receivers in a straight line. The geophones were planted vertically along the profile at an interval of 5m, which formed an initial spread length of 115 m. An initial offset distance of 60 meters was employed on both side of the spread, and shot were also taken at each geophone point. Half of the geophones were moved ahead of the last geophones, and shots were taken at the appropriate shot points which resulted in a total profile length of 300 meters. The layout geometries are shown in Fig 1 and Tables 1 and 2. From an initial offset of 60m before the first receiver and 60m after the last geophone, shots were taken at 5m interval, covering all the receiver points within the entire spread length. The last shot was taken at an offset of 60m from the last receiver. Twelve of the receivers, which constitute half of the geophone numbers, were moved ahead of the other twelve which were still fixed at their various positions. The layout geometry was updated and new sets of shots were taken at an offset of 60m from the position of the last Geophone for the first layout, at each geophone point and 60m after the last geophone in the second spread. Finally, half of the geophones were moved ahead of the spread, and new shots were taken as in the previous spread. The total length of profile was 415m, but this was reduced to 300m after getting rid of edge effect in the tomographic section.

An independent profile was also carried out, but this time with a different geometry. An initial offset distance of 5 m was taken, and shots were fired before the first geophone, at each geophone point and beyond the last geophone. All the receivers were removed and placed 5 m beyond the position of the previous last geophone. Shots were now deployed at the position of the previous last geophone, at each geophone point and beyond. This however, is to serve as a control to the first technique.

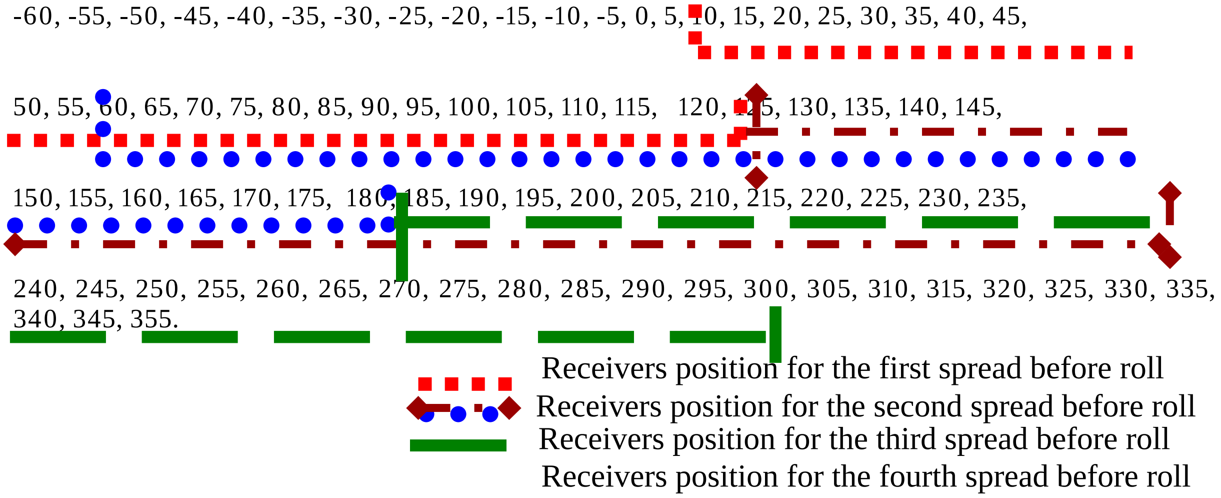

Figure1: Correct layout geometry in metres, of the various spread along the profile

Table 1: *Correct Geometry for Refraction Roll along Tomography*

Shots Position (m)	Corresponding Receivers Position (m)
-60 to 175	0 to 115
0 to 235	60 to 175
60 to 295	120 to 235
120 to 355	180 to 295

Table 2: Geometry for the control profile

Shots Position (m)	Corresponding Receivers Position (m)
-5 to 115	0 to 115
115 to 235	120 to 235
235 to 355	240 to 355

The recording parameters for both profiles include a geophone spacing interval of 5m spread along 24 channels; a geophone frequency of 10 Hz and recording time of 1 second; and 4096 samples collected at 0.25ms sample interval. Sledge hammer was used as energy source and the data was recorded in SEG-2 format.

DATA PROCESSING

The data processing was carried out with the application of bandpass filter with a lower cutoff (High Pass) frequency of 5 Hz and a higher Cutoff (Low Pass) 200 Hz, which lies in the frequency range of the seismic signals determined after spectrum analysis. This helped in getting rid of the seismic noise outside this frequency band. Gain filter was then applied in order to enhance the amplitude of the weak signals. The first arrivals were picked under the travel time picked module, which was jointly inverted using wave front inversion to generate a model. This model was subjected to different iteration to generate a tomographic section.

RESULT AND INTERPRETATION

The resulting tomography models for the two profiles are as shown in Figs 2 and 3. The models on top are drawn to scale while the models below are vertically exaggerated. Optimum Geometry for roll along in seismic refraction tomography was employed in obtaining the data for Fig 2, while conventional method of refraction which adopt the old method of forward and reverse only, was employed in data collection for Fig 3. A total spread length of 300 m and optimum subsurface coverage was achieved by making use of the principles of seismic refraction tomography to image the subsurface, which was used to overcome the problem of limited initial spread length of 120 m that was dictated by the instruments (cable length and number of receivers). Although the wrong methodology of refraction tomography was also able to achieve the same spread length, it left a great percentage of the subsurface unsampled. A comparison of the raytracing in Figs 2 and 3 indicated that the ray tracing in Fig 2 has quite a large number of interlocking traces, which led to redundancy in the sampling of a particular point within the subsurface, and has helped in the improvement of signal to noise ratio (S/N) of the seismic signals. Unlike the wrong methodology employed for Fig 2 which left approximately 350 m^2 of the subsurface uncovered for a distance of 300 m, the signal to noise ratio will be very low for a noisy data if this technique is employed. A close look at the tomography section of Fig 3 indicates that two fractures exist within the subsurface, at a distance of 105 and 220m along the profiles. However looking at the ray tracing, in the same Fig 3, it shows that these particular areas of the subsurface were not sampled. So, the apparent existence of fractures within the subsurface at those points which appeared like a weak zone can be misleading.

Secondly, from Fig 3, what appeared as a steep depression within the subsurface at the beginning of the profile is not an intrusion, but a feature referred to as edge effect, which occurs as a result of the absence of data coverage over that region. What is shown is nothing but mere extrapolations. This same mistake is often made by those who employed resistivity method in imaging the subsurface. At the end of one measurement, they tend to move the whole electrode ahead of the profile, instead of moving 2 electrodes after each measurement. This is difficult to notice in the resistivity tomography section because of the extrapolation of the data by the software on inversion.

CONCLUSION

From the analysis and results obtained, there is clear evidence that by employing optimum geometry for roll along in seismic refraction tomography, the imaging of the sub surface can be carried out beyond the spread length dictated by the survey equipment without compromising adequate subsurface coverage. Secondly it helped in achieving adequate redundancy in subsurface coverage and improvement on the data signal to noise ratio. This principle can conveniently be adopted to ensure that no area within the subsurface is left unsampled.

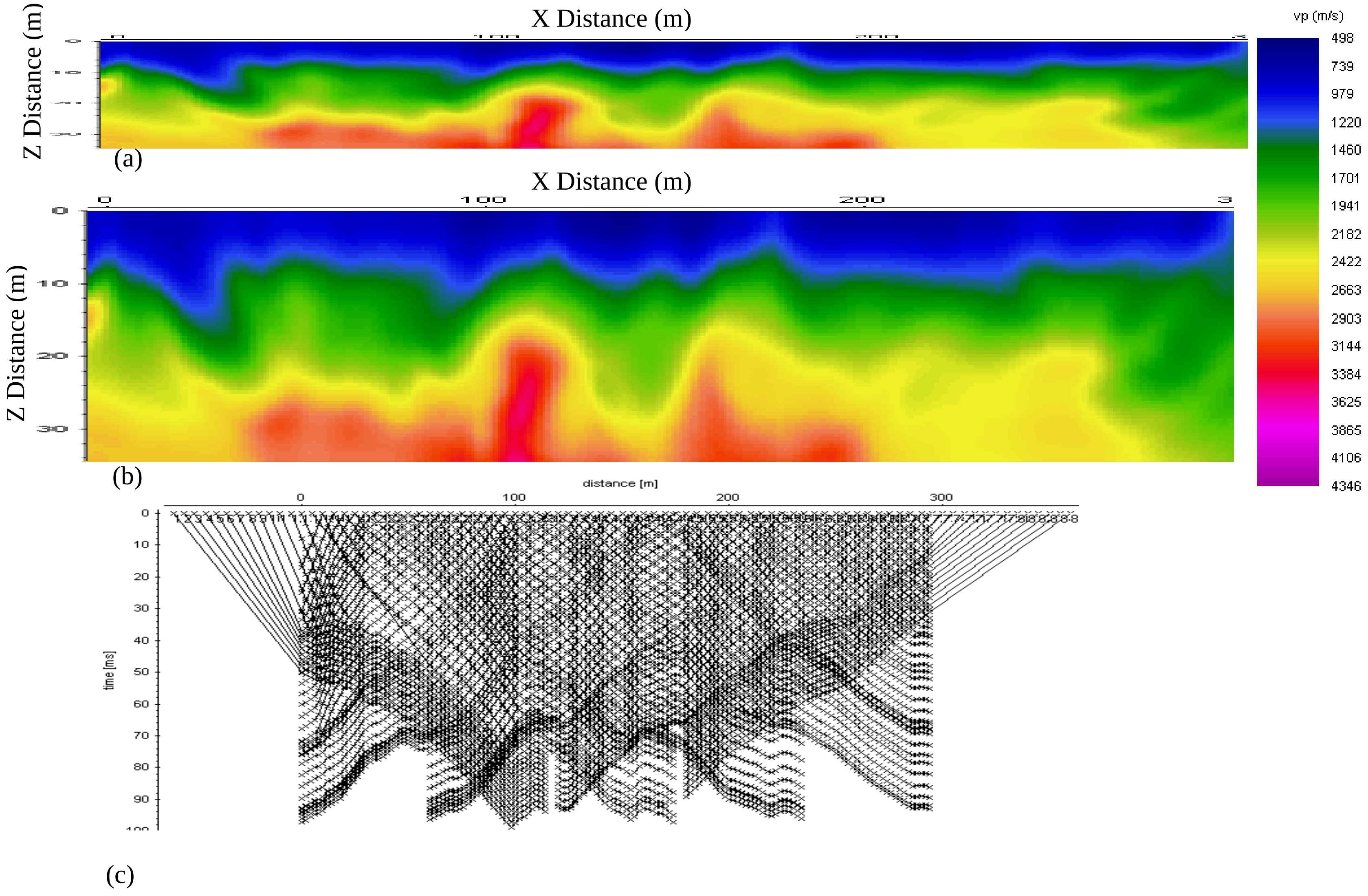

Figure 2: (a) Real dimension of Tomographic section (b) Vertically exaggerated Tomographic section (c) Ray tracing

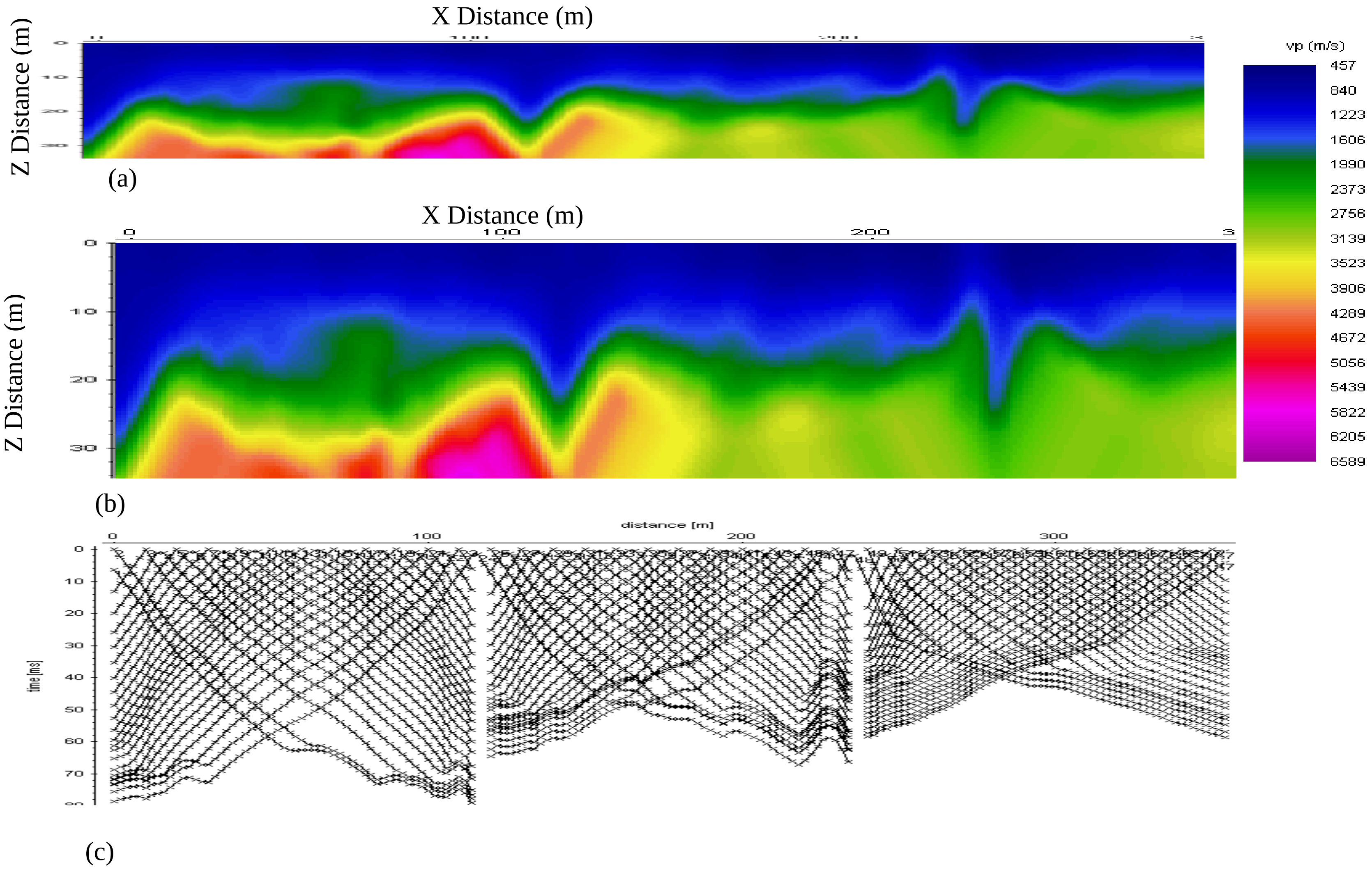

Figure 3: (a) Real dimension of Tomographic section (b) Vertically exaggerated Tomographic section (c) Ray tracing

REFERENCES

Dobrin, M. B. (1976): Introduction to Geophysical Prospecting (3rd Edition), Mcgraw-Hill, New York.

Gregory, A. (2002): Application of Tomography, Brookfield Press, Brisbane Australia.

Keary, P. and Brooks, M. (1984): An Introduction to Geophysical Exploration, Garden City Press, Letchworth.

Lowrie, W. (1997): Fundamental of Geophysics, Cambridge University Press London.

Sandmeier, K. J. (2003): User's Guide Manual on Reflex Software, Zipser Strabe Karlsruhe, Germany.

Tien-When, Lo. and Philips, L. (2002): Fundamentals of Seismic Tomography. Geophysical Monograph Series; no. 6, Society of Exploration Geophysicists Tulsa.