Extension of delay time analysis for 3-D seismic refraction statics

Jocelyn Dufour and Don C. Lawton

ABSTRACT

This current research is on the extension of delay time method using traveltime differences for 3-D seismic refraction statics. 3-D seismic data have been acquired over a physical model to procure an example, which will later serve to apply the delay time method.

INTRODUCTION

The purpose of refraction statics is to compute weathering statics corrections during the processing of reflection seismic data by using the traveltimes of critically refracted seismic energy (first breaks). There are already different techniques in the application of refraction statics corrections for 3-D seismic processing such General Linear Inversion method (GLI-3D) by Hampson and Russell. In that method, an initial subsurface model is input by the user, consisting simply of a number of flat, constant-velocity layers. The model is then iteratively updated, by using a generalized linear inversion (GLI) algorithm, in such a way as to reduce the difference between the observed breaks and those calculated from the model. The advantages of the GLI algorithm are the full redundancy of observed breaks reducing the sensibility of the solution to picking errors, and the final answer reasonably close to the input geological model. The inconvenience of generalized linear inversion is that the reliability of inversion schemes depends primarily on the sophistication of the modeling program and the constraints imposed upon the possible solutions. There is a method for 2-D seismic data processing that is an extension of the reciprocal method by Hawkins (1961). This method is called delay time analysis (Gardner, 1967) and has been developed by Lawton (1989).

METHOD

Differences in first-arrival traveltimes between adjacent records in reflection surveys can be used to compute the depth and velocity structure of near-surface layers. The procedure uses the redundancy of first-break data in multifold surveys to enable a statistically reliable refraction analysis to be undertaken for either end-on or split-spread recording geometries. The traveltime differences as a function source-receiver offset provide a direct indication of the number of refractors present, with each refractor being defined by an offset range with a constant time difference. For each refractor, the time difference value at a common receiver from two shotpoints is used to partition the intercept time into the delay time at each shotpoint. This procedure should be repeated until the delay times at all shotpoints and for all refractors have been computed. Refractor depths and velocities are evaluated from this suite of delay times. A surfaceconsistent static correction to a selected datum level is then calculated at each surface station, using a replacement velocity equal to that of the deepest refractor.

DATA ACQUISITION

To test that method with 3-D seismic data, a physical model has been designed and data have been acquired with a specific geometry (figure 1). The model consists of a low velocity layer made of silicone (*P*-wave velocity = 915 m/s) of variable thickness underlain by a high velocity layer of PVC (*P*-wave velocity = 2350 m/s), used to simulate a real case. The geometry was made of a patch of 9 receiver lines with 7 receivers per line and one shot line with 7 shots (figure 1b and table 1). This patch was moved 7 times across the model. The model parameters were determined to world units by using a scaling factor of 1 : 10000.

no. shot lines	7
no. shots per line	7
no. receiver lines	9
no. receiver per line	7
shot line separation	2 cm (200m)
shot spacing	1 cm (100m)
receiver line separation	1 cm (100m)
receiver spacing	1 cm (100m)
source	*P*-wave
receiver	*P*-wave
orientation	*in-line*
near offset	2 cm (200m)
pulse	*auto-tune*
size	2.7 Meg
sample rate	100 *ns*
field sample rate	1000 *us*
no. sample points	1500
distance scale factor	10000

Table 1. Geometry and parameters.

ANALYSIS

Some processing was necessary to properly establish the geometry before the first-breaks could be picked. Figure 2 presents an example of a shot gather after the geometry was properly established. In figure 3, the data have been sorted by offset to obtain a linear increase of the first break traveltimes. The direct arrivals are represented by the near offset first breaks, and the refracted arrivals by the farther offset, beginning with the inflection of the traveltime slope. The velocity of 921 m/s corresponds approximately to the *P*-wave velocity of the first layer, and the velocity of 2263 m/s to the second layer *P*-wave velocity.

FURTHER WORK

The initial analysis will be undertaken manually to evaluate this method for a 3-D seismic survey. A fortran program will be written to apply the delay time method efficiently if the results are satisfactory. Finally, a comparison with the other refraction static methods will be undertaken.

REFERENCES

Barry, K.M., 1967, Delay time and its application to refraction profile interpretation, in Musgrave, A.W., Ed., Seismic refraction prospecting: Soc. Expl. Geophys., 348-361.

Gardner, L.W., 1967, Refraction seismograph profile interpretation, in Musgrave, A.W., Ed., Seismic refraction prospecting: Soc. Expl. Geophys., 338-347

Hampson, D., and Russell, B., 1984, First break interpretation using generalized linear inversion: J. Can. Soc. Expl. Geophys. Prosp., **7**, 158-182.

Hawkins, L.V., 1961, The reciprocal method of routine shallow seismic refraction investigations: Geophysics, **26**, 806-819.

Lawton, D.C., 1989, Computation of refraction static corrections using first-break traveltime differences: Geophysics, **54**, 1289-1296.

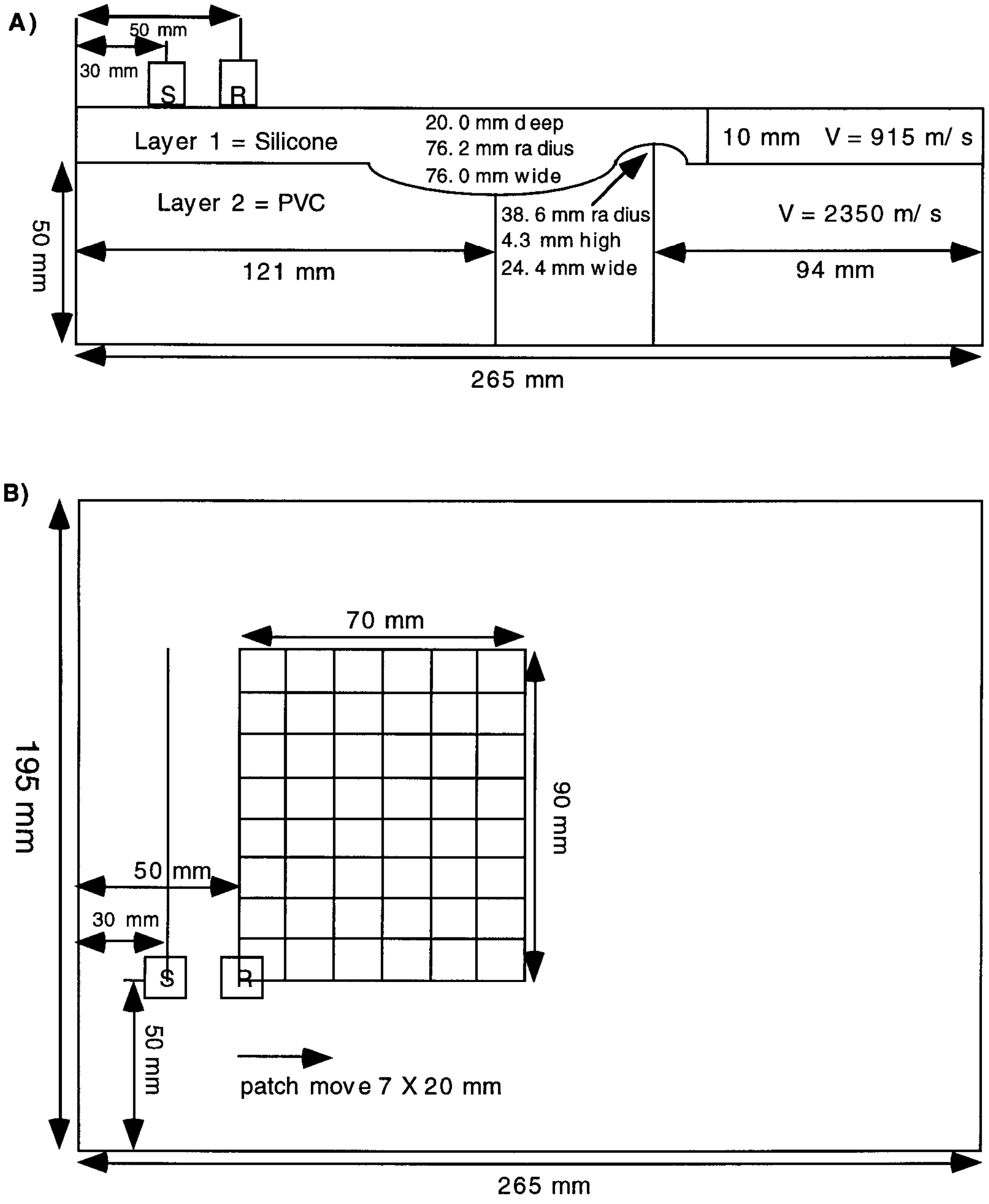

FIG. 1 A) Cross-section of the ground model B) Plan view of the ground model with the geometry. The figure is not at the exact scale.

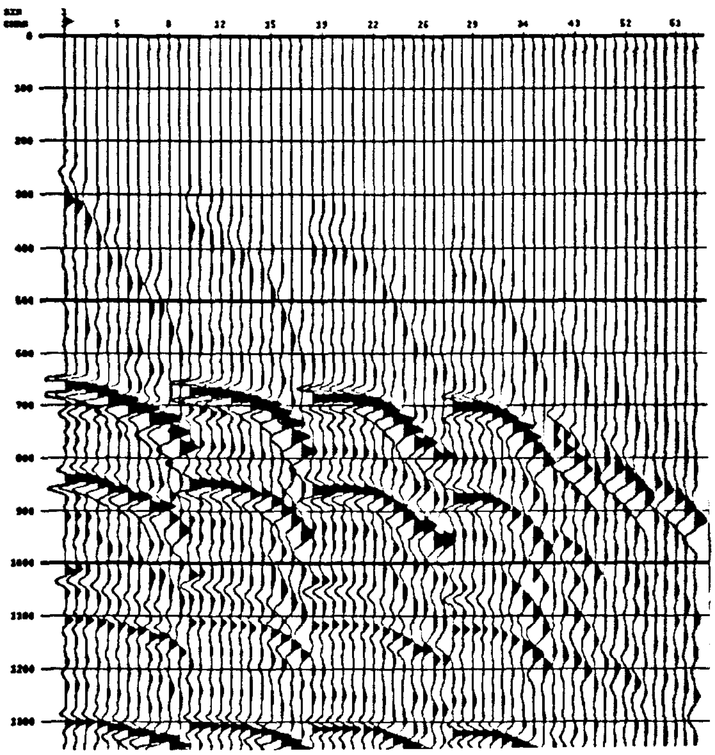

FIG. 2 Shot gather no.1 with correct geometry.

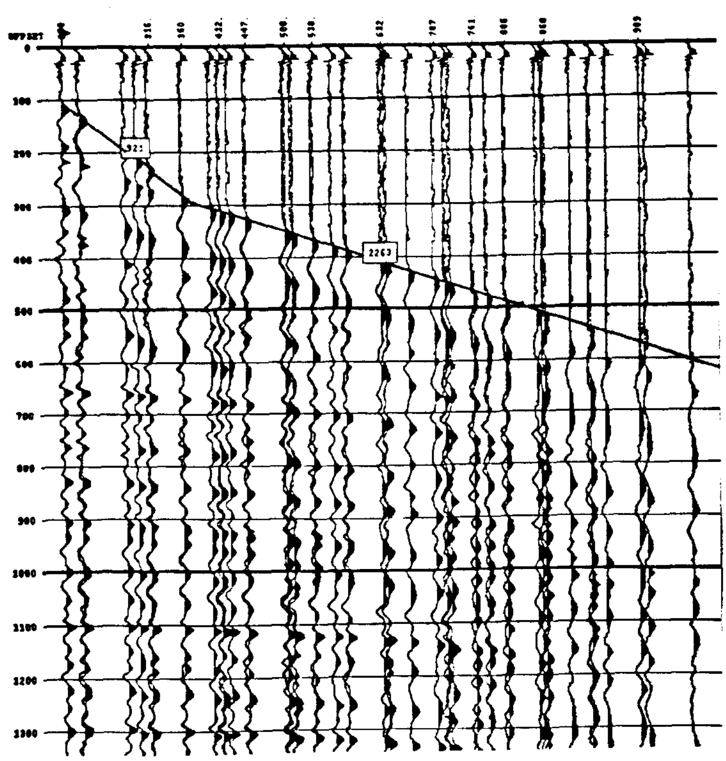

FIG. 3 Shot no.2 sorted by offset showing direct and refracted arrivals.