Automated Stacking Velocity Computation in Thrust Belt Areas – A Case Study from Upper Assam

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Summary

Estimation of velocity during processing of seismic data in thrust belt areas are difficult as the CMP gathers may not show consistent coherency function from one gather to another. The lack of coherency is mainly due to steeply dipping reflectors, strong lateral variation in velocity and rough topography. In such cases, either the velocity picking should be made at finer intervals or an independent guide for velocity picking should be made available. In this paper, effort is made to estimate velocity-depth model using travel-time inversion to be used for processing of seismic data from thrust belts. In this study, the seismic first arrivals are picked in shot domain at a regular interval after making corrections for polarity of the data. The elevation and other co-ordinate details were also the input. With all these and a broad velocity function / model as input, travel time inversion of the first arrivals were carried out using the algorithm of Zelt and Smith (1992 hereafter referred as ZS 92) for obtaining a velocity-depth model along the seismic profile. Repeated runs of travel-time inversion were performed until the results were within the permissible limits.

The quality of inversion was checked by the following procedure:

i) Average and rms velocity functions were derived using the velocity-depth from the inversion;

ii) The seismic data was processed using the same velocity.

The inversion was carried out on first breaks and thus, the accuracy of the velocity-depth model was within limits upto a depth of about 1.5 km. Considerable improvement was observed to such depths in the seismic section, processed using the inverted velocities even in the sub-thrust area. Thus, this technique is quite useful in deriving accurate velocity-depth model of geologically complex areas.

Introduction

The processing of seismic data from any geologically complex areas like thrust belts is difficult. Such areas are charcterised by presence of high dips, severe tectonism which has major effect on the data quality. Moreover, in view of difficult near-surface conditions, generally associated with such complex geological settings, dissipation of seismic energy adversely affect the seismic data. The proposed method is based on estimation of seismic velocities using travel-time inversion from first breaks of shot records. The processed output using the velocity-depth model derived from inversion gave better results than that obtained by carrying out conventional processing mainly in the shallower part even in the sub-thrust section.

Methodology

The methodology of automatic computation of stacking velocities is based on travel-time inversion of first arrivals. In thrust belt areas, in view of its complex geology and high formation dips (>30 degrees), the quality of data deteriorates near and below the thrust.

The high formation dips and noise content of the data have impact in carrying out processing of such seismic data. The computation of stacking velocities becomes difficult near and below the thrust. Apart from this, the noise has severe effects on the reflector continuity as observed in the seismic data of such areas.

The methodology comprises basically of the following few steps:

i) The data is required to be pre-processed such that it is corrected for phase reversals, and dead and noisy traces are edited

ii) The first breaks from shot gather data are picked for shots with better data quality. This picking is done nearly at every alternate shot depending on the quality of the seismic data and the geology;

iii) The main horizons are marked in the processed seismic section to generate an initial velocity-depth model.

The stacking velocities are used for preparing the initial model. The stacking velocities are suitably scaled with respect to any well data, if available;

iv) The next step in the process is carrying out of travel-time inversion. The input to first pass of the inversion is the picked first breaks from the shot gathers and the initial depth model as discussed in Para (iii) above;

v) The travel time inversion is carried out using ZS82 algorithm developed by Zelt and Smith (1992). The travel-time inversion, in short, consists of ray-tracing to the marked horizons and then comparing the first break picks with those obtained from the model derived from the inversion. The model is adjusted so that the error or the difference between the actual picks and inversion derived first break picks are minimized. After every pass, the output is studied with respect to its geological significance;

vi) The process is repeated with the outputted velocity-depth model from the previous pass of travel time inversion and the picked first break times as input. The same is continued till the error is reduced to an acceptable limit and a geologically acceptable velocity-depth model is arrived at;

vii) This velocity-depth model gives the velocity field along the seismic profile. This velocity model which is automatically computed through travel-time inversion is then used for processing of the seismic data.

It is worthwhile mentioning that the travel-time inversion as described above is done on the first breaks and thus, offset between the farthest trace and the shot is a major constraint in this imaging technique. In view of this, with data from conventional seismic reflection surveys having, typically, offsets to the tune of deepest target, only the shallower horizons can be imaged with sufficient degree of accuracy.

Application to Field Data

The method was tested on seismic data pertaining to the Naga Thrust belt of Upper Assam Basin The Upper Assam Basin is one of the earliest known petroliferous basins of India. It is a part of the Assam-Arakan geological province. The formations, which constitute the main reservoirs, belong to Tertiary age. These formations comprise of shelf, geosynclinal and deltaic to fluvial facies. The basin is bounded on three sides by major thrust systems viz. the Himalayan boundary thrust in the north-wets, the Mishmi thrust in the north-east and the Naga thrust in the south-east.

The data was acquired with the following parameters:

No. of channels per record	: 120
Group interval	: 40m
Shot interval	: 80m
Fold	: 60
Shooting geometry	: end-on
Maximum offset	: ~5000m

The data was initially processed with standard parameters which includes pre-processing of the data, application of statics, application of nmo and dmo corrections and computation and application of residual statics. The stacked data of a representative seismic profile of the area is presented as Figure 1.

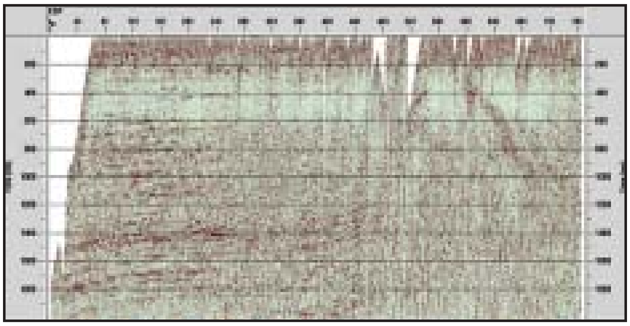

Fig. 1: Conventionally processed seismic section

As discussed in the methodology, first breaks were picked in shot-domain for every alternate shot. A picked shot gather is presented as Figure 2. Stacking velocity function along the line was used as the initial model for travel time inversion using ZS92 algorithm.

The final velocity-depth model derived from travel-time is presented as Figure 3. The inversion was carried out with

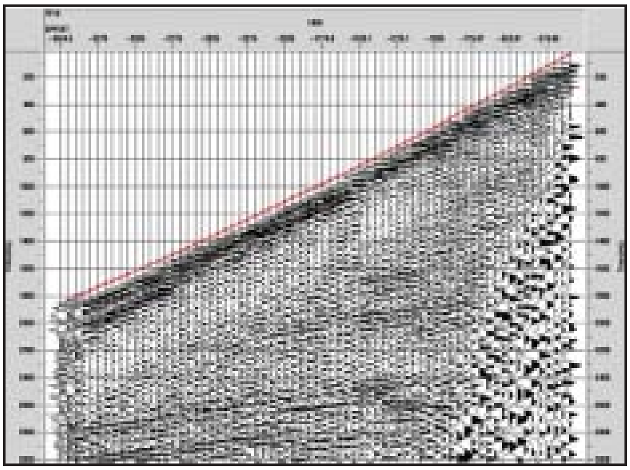

Fig. 2: Picked first break from a shot gather

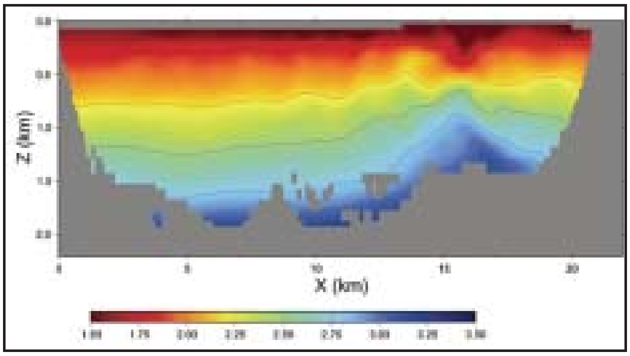

Fig. 3: Velocity-Depth Model from travel-time inversion

the first breaks on a data of maximum offset of about 5000m. In view of this, inversion could only provide velocity-depth model along the seismic profile to a depth of about 1500m.

The velocity-depth model along the seismic profile was thereafter converted to rms velocities and used for re-processing of the data. The stacked data processed with the inverted velocity data is presented as Figure 4.

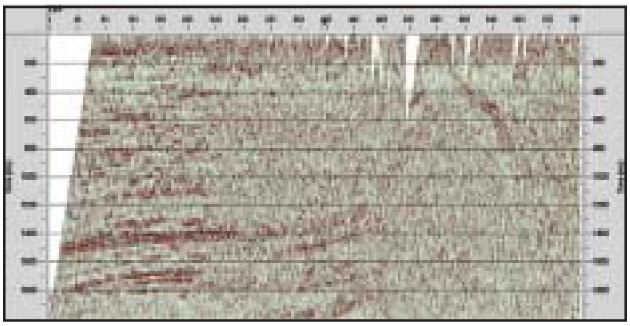

Fig. 4: Seismic Section processed with velocity from travel time inversion

Conclusions

The processed output, using of velocity resulting from inversion, showed significant improvement in the shallower part of the data. In view of the offset limitation of the data (~5000m), the improvement is limited to the shallower part of the seismic section. The case study reveals that the technique may be of use in extracting velocity quite accurately of different formations especially in geologically complex areas like thrust belts where conventional processing techniques do not yield desirable results. The technique is now planned for use on data with longer offset so that deeper targets can be imaged with more accuracy.

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Reference

Zelt, C.A. and Smith, R.B., 1992: Seismic travel-time inversion for 2D crustal velocity structure; Geophys. J. Int., 108, 16-34.