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Short Note

Wave-equation extrapolation of land data with irregular acquisition topography

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INTRODUCTION

Seismic data gathered on land is distorted by irregular acquisition topography. Most seismic imaging algorithms are applied to data which is shifted to a planar datum. In regions of mild topography a static shift is adequate to perform this transformation (Jones and Jovanovich, 1985), however as the necessary shift increases in magnitude, the static approximation becomes inadequate. In this situation a procedure based on wave-equation extrapolation is more appropriate than static shift (Wiggins, 1984; Shtivelman and Canning, 1988). The procedure is similar to wave-equation datuming of marine data (Berryhill, 1986; Yilmaz and Lucas, 1986). However for data to be continued through some media, the velocity structure of that media must be known. The process of continuing the data and finding the velocity structure at the same time makes the process of wave-equation extrapolation difficult for land data.

I propose a method based on wave-equation extrapolation to be applied to data gathered in regions with irregular acquisition topography and where the near-surface velocity structure is unknown. The method is intended as an alternative to large static shifts.

THE PROPOSED METHOD

The effect of irregular acquisition topography is that it distorts seismic data. This is a serious problem in mountainous regions where there is extreme topographic relief along seismic lines. Wave-equation extrapolation provides a useful method of transforming data to a planar datum and then determining the near-surface velocity structure. This could in principle eliminate the distortions and allow standard

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processing methods such as velocity analysis, DMO, and migration to be successfully applied.

Shtivelman and Canning (1988) show how data can be continued through known near-surface velocity structures. McMechan and Chen (1990) implicitly include effects due to topography and near-surface velocity variation in prestack migration. In order for both of these methods to work, the near-surface velocity must be known. The more general situation I plan to addressed is one for which the near-surface velocity structure is unknown. In this situation I propose upward continuing the data to some planar datum above the topography with some fictitious extrapolation velocity. This should unravel the distortions caused by the irregular acquisition topography and allow standard imaging techniques to be applied to the data. Finding the correct extrapolation velocity which unravels the distortions may turn out to be an interesting optimization problem. One can envision an iterative velocity scheme with the objective of creating hyperbolic trajectories in the output space.

The proposed method is similar to wave-equation datuming applied to marine data to compensate for irregular water-bottom topography (Berryhill, 1979, 1984, 1986; Yilmaz and Lucas, 1986). In the marine case, the data are downward continued to the water-bottom with the water velocity, and then upward continued with the water-bottom velocity. This removes the distortions due to the irregular water-bottom.

I claim that land data is like the marine data which has been continued to the water-bottom. I propose that the land data be extrapolated upward to some flat datum with an appropriate velocity. This extrapolation velocity should be close to the near-surface velocity. Once the data have been extrapolated to the flat datum, standard velocity analysis methods may be used to determine the near-surface velocity. Processing and imaging can be performed at the new datum or the data can be downward continued to some lower datum.

The proposed method can be thought of as an inverse problem where the upward continuation is the reverse of the downward continuation step performed in the marine layer replacement methods.

IMPLEMENTATION

A Kirchoff based kinematic scheme

Berryhill (**?**) presents a simple algorithm based on the Kirchoff integral to perform the wavefield transformation from one datum ($U(x, z = z_1, t)$) to another ($U(x, z = z_2, t)$) Each individual trace $U_j(t)$ comprising $U(x, z = z_2, t)$ is calculated by performing the sum:

$$U_j(t) = \sum_j \triangle x_i cos\theta_i \frac{t_i}{r_i} Q_i(t - t_i) \tag{1}$$

where $Q_i(t-t_i)$ is a filtered input trace recorded at location i and delayed by traveltime t_i. $\triangle x_i$ is the input trace interval, θ_i is the angle between the normal to the surface at $z = z_2$ and the line r_i connecting U_j and U_i. The geometry of the transformation is illustrated in Figure **??**. A complete derivation of this equation is presented in Berryhill (1979).

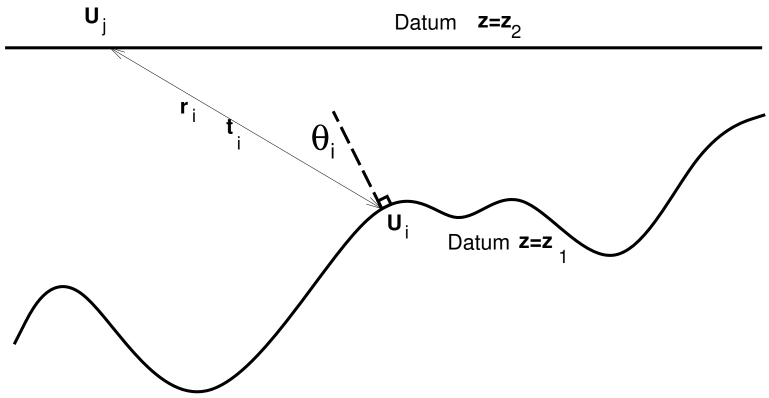

Figure 1: Geometry for the continuation of a wavefield between an irregular topography and a planar datum (after Berryhill, 1984) dimitri2-datum [NR]

My proposed method may be summerized in three steps:

- Extrapolate the data upwards to a flat datum (by using equation (1)). This should unravel the distortions caused by the irregular acquisition topography.
- Perform velocity analysis at the flat datum. This determines the near-surface velocity structure.
- Either perform the processing and imaging or extrapolate downward to some flat datum below the acquisition topography.

DISCUSSION

The method is likely to work better than static correction in regions where large static shifts are required. Two methods commonly applied in regions of extreme topography are refraction statics or some stochastic method like simulated annealing. Refraction statics are unsatisfactory in regions of extreme topography because the model no longer fits the data (Bevc, 1991). When simulated annealing is used the static corrections are usually large, which means that the assumption of straight ray-paths is not valid. Wave-equation extrapolation solves these problems.

Although equation (1) offers one implementation of the extrapolation, it may not be the best for my purposes, so further scrutiny of the problem is required.

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