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FIRST-BREAK INTERPRETATION USING GENERALIZED LINEAR INVERSION

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ABSTRACT

The computation of detailed near-surface information using the refracted arrivals on seismic shot records has been the subject of much research since the early days of the seismic method. This near-surface information is used to compute initial static values for the seismic data.

In this paper, the redundancy found in CDP shooting is used to enhance the accuracy of the solution and reduce the effect of picking errors. An initial subsurface model is input by the user, normally 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. These model breaks are calculated by ray-tracing. Two advantages of the GLI algorithm over previous approaches are that the full redundancy of observed breaks reduces the sensitivity of the solution to picking errors, and that the final answer is constrained to be reasonably close to the input geological model.

The paper is divided into four parts. In the first part, we describe the procedure conceptually. In the second, we look more closely at the theory of the algorithm. In the third, model results are shown which demonstrate the convergence of the method through several iterations. Finally, the fourth part of the paper shows the performance of the method on several real data examples.

INTRODUCTION

The presence of shallow, low-velocity weathering anomalies can cause serious problems in the processing of seismic data. This paper is concerned with compensating for these effects by estimating a set of static corrections using refracted arrivals.

Two of the major effects that result from such near-surface conditions are the deterioration of the stack due to misalignment within the CDP, and distortion in the structural times of deep reflectors. Both these effects result from time delays introduced by geological layers of varying velocity and thickness. If this time delay pattern is Fourier-analyzed, it may be shown that components whose wavelength is shorter than the cable are primarily responsible for deteriorating the stacking quality, while longer-wavelength components cause structural errors in the deeper reflectors. Since it is known that residual statics programs that analyze the reflection data itself are incapable of estimating these long-wavelength components accurately (Wiggins *et al.*, 1976), such residual statics programs may improve the stacking quality while leaving errors in structural times. An alternative procedure for estimating static shifts is to analyze the first breaks that result from refractions in the shallow low-velocity layers. If the shot-receiver offsets are properly distributed, those breaks should contain all the information necessary to correct both long- and short-wavelength static components.

The analysis of refracted arrivals has been the subject of research for many years, and a number of methods have been proposed. However, while these methods are most suitable for hand-interpretation of individual records, they tend to suffer from a number of limitations when applied to the computer-analysis of multifold data. These limitations include restrictive assumptions placed on the near-surface model, estimation of the long-wavelength static component only, difficulty in computer automation, sensitivity to errors in the picked arrival times, and inability to use the full redundancy implied in CDP shooting. In order to avoid these limitations, we have devised a method that develops a near-surface model by iterative ray-tracing.

ITERATIVE REFRACTION MODELLING

All refraction analysis methods assume some model of the near-surface geology. This is normally considered to be a series of layers whose thicknesses and velocities may vary both laterally along the line, and vertically with depth. The arrival times of the first breaks depend on the layer thicknesses and velocities, and the problem is to determine those parameters from the measured first arrivals. The direct approach is to perform some calculation using the observed breaks that yields the parameters themselves. An example of this is fitting a straight line through a selected segment of breaks, and measuring the slope and intercept (Knox, 1967). The problem with this type of approach is that it depends on a very restrictive model — for example, the line-fitting approach assumes that the refractors are locally flat with no short-wavelength anomalies.

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