

Tau- p refraction tomography

A robust, near-surface solution for static corrections

Main features

- Inverts both head waves and diving waves
- Stable in the presence of pick errors
- Requires no initial model

Tau- p refraction tomography is an emerging technology for modeling the near surface and producing static corrections. This method of travelttime inversion differs from conventional tomographic approaches in that it performs no explicit ray tracing, although its formulation is implicitly based on ray theory. The approach combines the robustness of delay-time methods, as it does not require an initial model, and the flexibility of ray-based tomography, as it inverts both head and diving waves over the complete offset range.

Several forms of ray-based refraction tomography have become popular. Diving-wave, or turning-ray, tomography adds more degrees of freedom to the model and generally fits the observed first-arrival moveout better than conventional delay-time (head-wave) solutions. Unfortunately, tomographic results are also more sensitive to the initial model and to pick quality than are delay-time solutions. Therefore, a desirable goal for tomography is the reduction or elimination of these sensitivities while still extracting maximum information about the velocity structure of the earth from the data.

WesternGeco has developed a unique 3D refraction tomography which accomplishes this goal. It works in the tau- p domain. This two-step process first decomposes the first-arrival picks to a best-fit 3D tau- p representation using linear inversion that does not require explicit ray tracing or an initial model. The second step is an integral transformation that builds the 3D velocity-depth model from the tau- p representation. This model-building process may incorporate *a priori* information such as upholes and can handle velocity inversions.

Figures 1 - 4 show the results of applying tau- p refraction tomography to a Vibroseis survey in Tunisia (courtesy of Petro-Canada). The surface geology is dominated by outcrops ranging in age from Upper Triassic in the east to Upper Cretaceous in the west. Each of these broad age divisions is composed of alternating strata of shales, limestones, dolomites, and evaporates resulting in significant lateral and vertical velocity variations. The topographic relief is primarily controlled by 50- to 150-m high, north-south trending escarpments stepping down

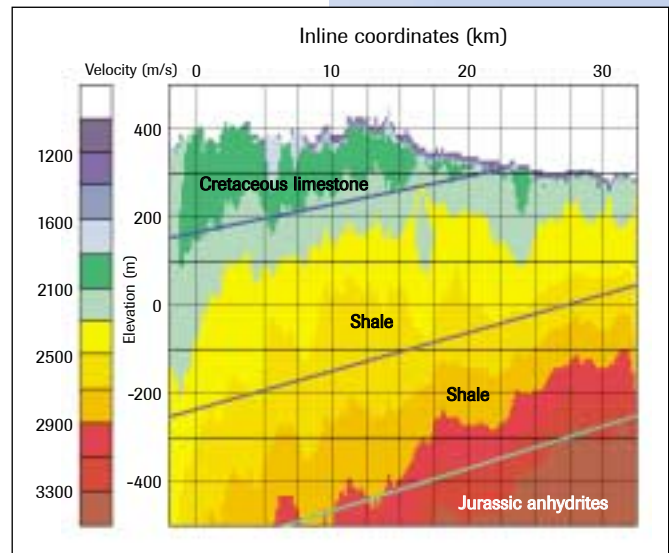


Figure 1 Tomographic velocity/depth model. The lines correspond to the regional interfaces between different geological layers interpreted from well information. The lateral extent is the same as for Figures 3 and 4.

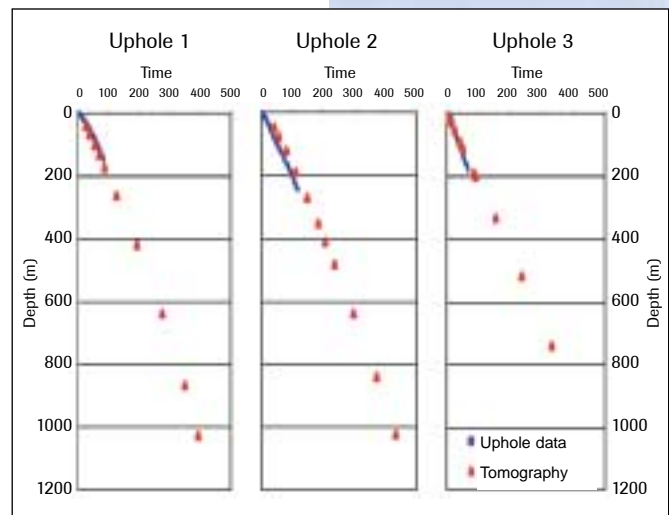


Figure 2 Comparison of vertical times through the tomographic model in Figure 1 with the uphole times.

to the east. The largest of these coincides with the surface termination of the Cretaceous rocks. Large deposits of Tertiary infill are found at the base of these escarpments, further complicating the near-surface velocity variations.

Figure 1 shows the velocity-depth model as a result of applying tau- p refraction tomography. The interpreted lines correspond to the regional interfaces between different geological layers that were created by correlating and interpolating 20 deep upholes and 3 well checkshot surveys acquired in the area. In general, the tomographic model follows the geological trends. Figure 2 illustrates a good match of vertical times through the tomographic model with the uphole times. To illustrate the accuracy of the derived velocity model, the uphole information was not included as *a priori* information in the tomographic inversion.

Figure 3 shows the stack after applying the statics corrections corresponding to the tomographic model in Figure 1. The trends of the seismic structure correspond well to the geological interpretation in Figure 1. In comparison, Figure 4 represents the stack after applying static corrections for a single-layer delay time method that has an approximately constant weathering velocity. While the short-wavelength solution is comparable to the previous result, there is a problem with the long-wavelength solution evidenced by the break in slope on the right side of the section. This is primarily due to an inaccurate weathering velocity. Typically, in the delay-time method, a procedure using uphole information and refractor modeling helps resolve weathering velocity variations, but this requires data and knowledge other than the seismic data and it may not entirely resolve the weathering velocity. For these data, the holes are too shallow to constrain the velocity to the deep refractor. On the other hand, tau- p tomography constrains and resolves the velocity model directly by using picks in the complete offset range.

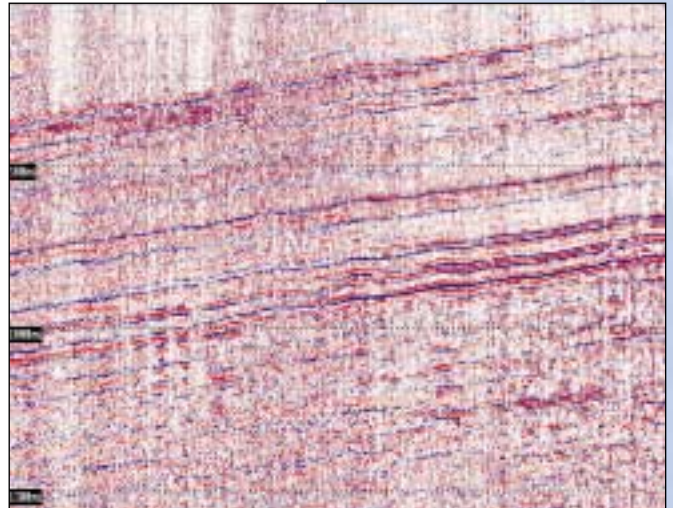


Figure 3 Stack after the application of statics corresponding to the tomographic model in Figure 1.

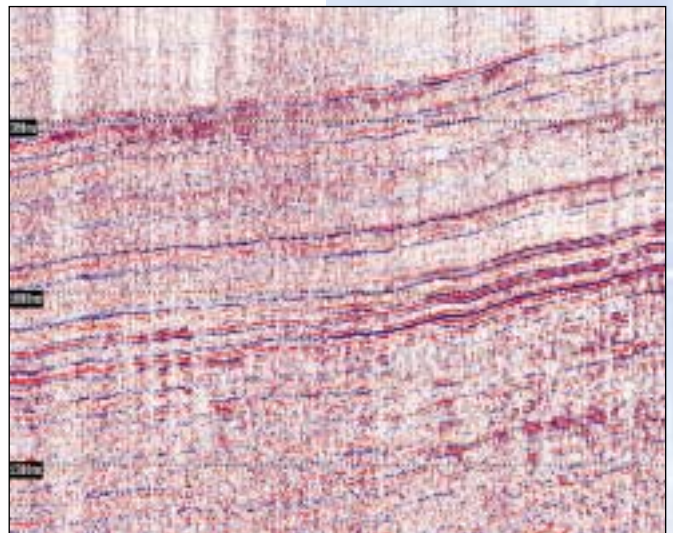


Figure 4 Stack after the application of the statics for the delay-time method.