Seismic tomography applied to complex, faulted formation

Data from the Vienna basin shows reflection tomography provides good model for pre-stack depth migration, acoustic impedance compares to that from conventional methods

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Several important hydrocarbon reservoirs located in the Vienna basin are characterized by fractured rocks in a complex fault system. Pre-stack depth migration is a basic tool for identifying the major geological formations. This method is particularly effective when the necessary macro-model for the velocity field and layer interfaces is provided by seismic tomography. There is a trade-off, however, from the practical point of view: Seismic tomography is more necessary for relevant complexities, but in such cases, picking traveltimes becomes extremely difficult, if not impossible. So a goal was to verify the effectiveness of the tomographic imaging in this difficult area.

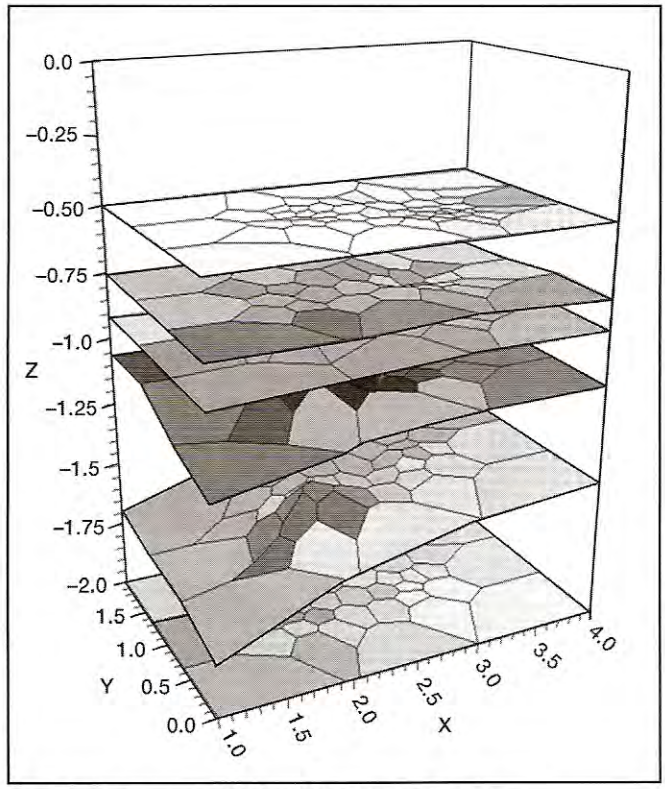

Fig. 1. Velocity macro-model from 3-D adaptive tomography.

Some physical rock properties can be estimated by seismic response at the Earth surface, possibly integrated by well-log information. Acoustic impedance is a classical example. Its low-frequency components are obtained by the estimated velocity field. This discussion compares results obtained by OMV Energie for both imaging and impedance estimation by two different approaches: seismic tomography and stacking velocity analysis, after DMO correction.

The data. A 3-D data set acquired by OMV in the Northern Vienna basin in 1994 was processed using dynamite as a seismic source. The offsets range from 30 to 2,200 m, the sampling rate is 2 ms.

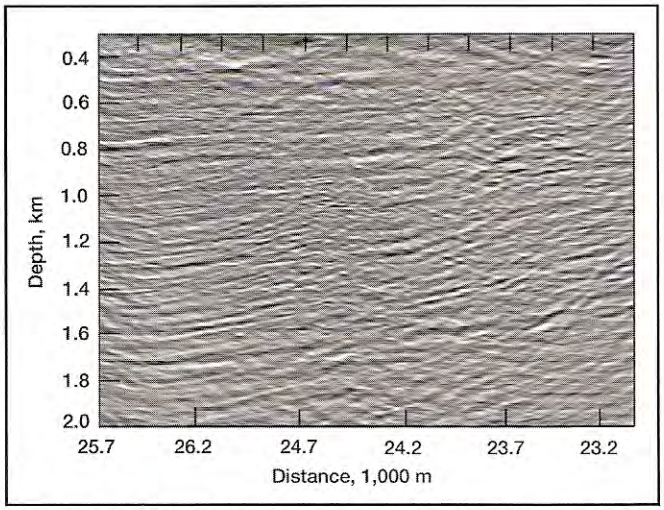

Fig. 2. Pre-stack depth migrated section, by using DMO corrected stacking velocities.

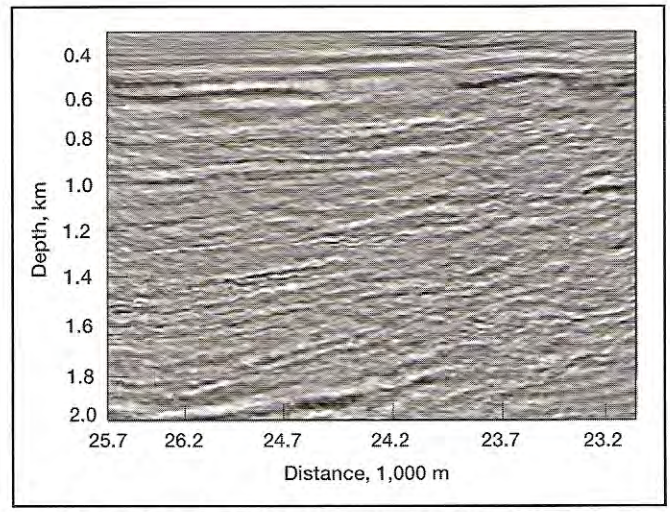

Fig. 3. Pre-stack depth migrated section, by using tomographic velocities.

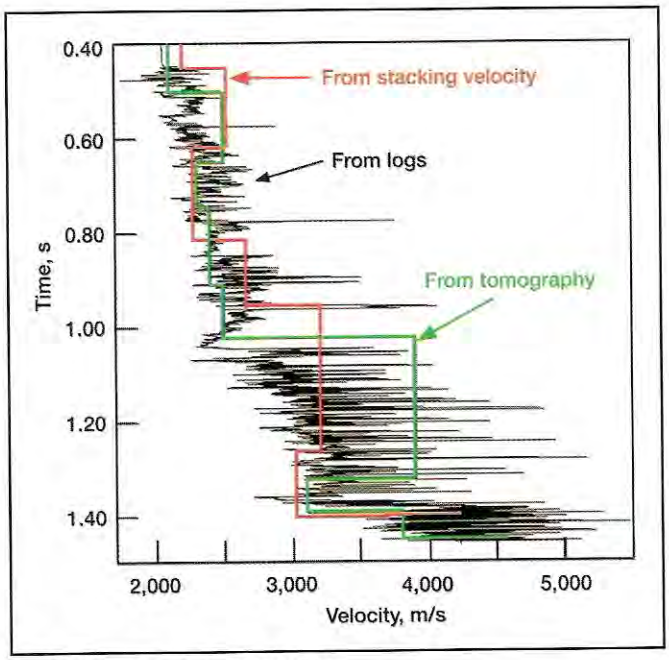

Fig. 4. Estimated velocities vs. well log.

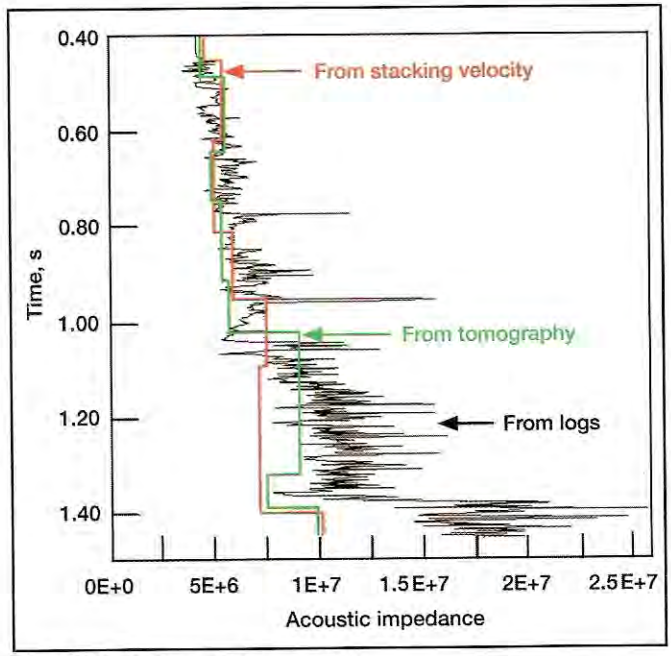

Fig. 5. Estimated impedances vs. well log.

Sources and receivers were placed areally, along lines located 150 or 300 m, at regular intervals of 50 m. As a consequence, azimuth coverage in the bins is excellent, but traveltime picking is more difficult, i.e., we cannot rely on the familiar hyperbolic pattern of the gathers in 2-D profiles. This problem was overcome by an iterative approach, i.e., a few certain arrivals were picked and inverted for a preliminary model. With this model, traveltimes in the more difficult areas were predicted and the picking was extended. So the tomographic model and its input of traveltimes in sequence was enhanced.

Tomographic imaging. The Earth model used comprises homogeneous isotropic blocks, i.e., a parallelepiped whose base is shaped as Voronoi polygons. This choice allows fitting the tomographic model to the available ray paths and to the physical resolution limits, e.g., to the size of the Fresnel radius.[1,2] The density of blocks is increased locally where the velocity gradient is larger and the ray coverage is optimal; it is reduced elsewhere.

Fig. 1 displays the 3-D velocity model obtained by adaptive reflection tomography. The resolution is larger in the central part, and decreases as a function of depth due to the poorer ray coverage. Both the irregular grid for the velocity field and the shape of the layer interfaces were obtained automatically. Significant velocity variations, both lateral and vertical, are noticed.

In a standard approach, the velocity field is estimated by DMO-corrected velocity spectra in the time domain, and then converted into depth by the Dix formula. Fig. 2 shows the 2-D pre-stack depth migrated section obtained in this way. It may be directly compared with the one in Fig. 3, obtained in the same way except for the tomographic velocities, extracted from the field in Fig. 1. A much higher resolution is obtained using the tomograhic approach.

Acoustic impedance. This is an important lithologic property that can be estimated by surface and well data. Since the method OMV is adopting works in the time domain, the tomographic velocity model was converted from depth to time by a procedure based on the zero-offset ray tracing in 3-D. The velocity field allows computing low frequency components of the acoustic impedance. Fig. 4 displays the velocity estimated by reflection tomography, stacking velocities and the sonic log. The agreement between log and estimated velocities is quite good. In the tomographic estimate, a velocity inversion occurs between 1.3 and 1.4 s, which is not present in the curve from stacking velocity.

A macro-model for the acoustic impedance was computed by averaging values of the available density log within the same time intervals of the stacking and tomographic velocities, then multiplying average densities with the corresponding interval velocities. Finally, high-frequency components of the acoustic impedance—derived by the reflectivity measured at the well and by surface seismograms—were added. Fig. 5 compares impedance at the well with values estimated by stacking and tomographic velocities. Once again, it is seen that both estimates are not too far from the truth, but the tomographic solution seems better for times larger than 1 s.

In conclusion, reflection tomography provides a good macro-model in depth for the velocity field and interfaces structure, to be used as input for the pre-stack depth migration. The well-resolved images obtained with the data from the Vienna basin prove that this approach is effective also in complex areas. The acoustic impedance estimated by tomographic velocities is not inferior to that obtained by a more conventional stacking velocity analysis, after a DMO correction.

ACKNOWLEDGMENT

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