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Salt flank imaging by integrated prestack depth migration of VSP and surface

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Since Vertical Seismic Profile (VSP) data include wavefields which can measure directly physical properties between surface and geological interfaces, it is usually used for detecting dip, anisotropy, and reflection amplitude or waveform with respect to incidence angles. Though VSP covers the vicinity of the borehole comparing to the surface seismic, it gives high resolution and it is helpful to find the precise location of a well in the 3-D image from surface seismic data. Normally VSP data are smaller Fresnel zone and wider bandwidth than surface seismic data due to less absorption of the higher frequencies. It gives high fidelity reservoir image for effective reservoir monitoring such as 4D time-lapse seismic and carbon capture and storage. Prestack reverse time migration (RTM) is widely used for imaging the complex subsurface structures. RTM is a method for imaging the subsurface in depth domain using inner product of source wavefield extrapolation in forward and receiver wavefield extrapolation in backward. Since RTM is applicable to any source-receiver geometry, we can apply the same algorithm to VSP and surface seismic data. In this study RTM is implemented the integrated depth imaging of walk-away VSP and surface seismic data in order to have high resolution salt flank image. A synthetic test example includes a schematic flank of salt body with horizontal layers. The model - 8 km wide by 4 km depth - represents a simple salt body and background with velocity of 3.0 km/s for salt body and background velocity of 2.0 km/s. The source wavelet is zero-phase with a central frequency of 10 Hz for surface seismic and 20 Hz for VSP data. VSP data were recorded in the central borehole located 4.0 km from the left side of the model and the 151 receivers in central borehole were on a 20 m spacing between the depth of 0.5 km and 3.5 km. We acquired the surface seismic data using 101 surface sources on 40 m spacing between 2.3 km and 6.3 km. The 101 receivers on the surface were on a 20 m spacing between the left origin of the model and 6.0 km.
The result of VSP prestack depth migration shows a weak image of horizontal layers and good salt flank and the result of surface RTM shows good horizontal layers and weak salt flank image. The result of integrated VSP and surface seismic data shows clear image of horizontal layers and salt flank. For VSP prestack time migration separation of
up-going and down-going wavefields is usually needed but VSP prestack depth migration by RTM is conducted the inner product of back-propagated wavefields and the virtual sources without separation of
up-going and down-going wavefields. The numerical example shows the integration of prestack depth migration of VSP and surface seismic gives a better image than that obtained from the migration of VSP data set alone. The integrated migration may be used for improving migration velocity analysis.