P050 THREE-COMPONENT RECORDING DISTORTION AT A WATER-SEDIMENT INTERFACE

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Introduction: It has been demonstrated that sea-bottom recordings have potential in providing converted shear-wave information valuable in interpreting reservoir structure (Berg 1994) or AVO effects for fracture-induced anisotropy (Li, Kuhnel and MacBeth 1996). For these situations far offset amplitude information is essential, which depends upon faithful recording of the amplitude and phase. Unfortunately, even for ideal coupling, 3C sea-bottom recording may not preserve the character of the waves from the target formation, as it depends upon the water and sediment properties. A theoretical investigation has examined the extent of this effect and its influence on AVO interpretation.

Theoretical approach and predicted behaviour: The 3C particle motion \( \mathbf{v}(0) = (v_r(0), 0, v_z(0))^T \) from a plane monochromatic wave incident upon the water-solid interface has been evaluated for both isotropic and anisotropic (TIV) elastic sediments. The calculations are based on Schoenberg and Protazio’s framework (1992), producing similar solutions for isotropic and weakly anisotropic (Thomsen’s parameters |\( @| \) and |\( \delta| \) less than 0.15) sediments. The general slowness dependency for \( \mathbf{v}(0) \) is illustrated in Figures 1(a), (b) and (c) together with synthetic seismograms in Figure 2. Both radial, \( v_r(0) \), and vertical, \( v_z(0) \), components experience differential amplitude scaling and phase changes which depend upon the slowness (incidence angle). For isotropy, shear-waves reflected from the target zone which are incident beyond the first critical angle \( \sin^{-1}\left(\frac{\beta}{\alpha}\right) \) have a significant phase change. There are also amplitude departures from that expected by simple projection of the polarization vector onto the interface. Sediment \( \alpha/\beta \) larger than 2.5 may extend the useable vector amplitude beyond this critical angle. For anisotropy, the broad features of the curves are sensitive to \( \delta \), with the critical angle now being \( \sin^{-1}\left(\frac{\beta_v}{\alpha_v}(1-\delta)\right) \), where the subscript indicates vertical velocities. Although the P-waves do not change phase, there is differential scaling of the amplitudes, which leads to incorrect predictions of the wave normal direction (10° difference for 30° incidence).

Consequences of recording at an interface: For shear-waves the AVO must be corrected to account for significant variations beyond incidence angles of approximately 37° in most cases. The P-wave recordings are also found to exhibit differential amplitude variations which could affect migrations. As the behaviour above is related to a similar free-surface phenomenon in land recordings (Evans 1984) we denote these critical angles generically as the ‘marine shear-wave window’.

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References
Figure 1. Components of vector motion due to shear-waves incident on a water-sediment interface reflected from a target layer: (a) amplitudes; (b) phase angles. Both (a) and (b) are for $\alpha/\beta = 5$. (c) vector modulus for various ratios in the sediment; (d) amplitude variations for a TIV anisotropy.

Figure 2. Synthetic seismograms for a marine gather, with shear-waves propagating from a target layer at depth incident upon seabottom receivers: (a) embedded in a whole space; (b) at an interface between an isotropic sediment and water layer. The source pulse is zero phase, with the range of incidence angles extending to 45 degrees. A change of phase on both radial and vertical components is evident for the interface recording. Only the upgoing leg of each reflection is computed.