AVA OBSERVATIONS IN AZIMUTHAL VSPS

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Introduction
In 1986 two azimuthal VSP (AVSP) experiments were conducted at the Conoco Borehole Test Facility (CBTF), Oklahoma with a major objective being the investigation of fracture induced shear-wave anisotropy (Queen and Rizer 1990). In addition to in-line and cross-line horizontal shear-wave vibroseis sources, vertical vibroseis sources were also employed. Geophones were deployed over different depth ranges in two closely spaced wells. In well 33-1 the geophones were positioned at five equi-spaced depth levels between 580m and 620m. For well 33-2 twelve geophones were evenly distributed in the depth range 30m to 365m. The vibroseis source locations were distributed at 15° intervals starting at N75°E on an arc of radius 290m centred upon well 33-1 (Figure 1). Previous studies from the CBTF have shown the shear-wave anisotropy to be in good agreement with the fracture systems observed in surface outcrops, cores and borehole images indicating a systematic crack set striking approximately N75°E (Queen and Rizer 1990, Horne and MacBeth 1994). In this paper we investigate the behaviour of the direct transmitted P-waves excited by the vertical vibroseis sources. This study is motivated by the current interest in fracture characterisation through azimuthal variations of reflectivity.

Discussion and Conclusions
P-wave arrivals generated using the vertical vibroseis sources are clearly identifiable at all depth levels in well 33-1 although some data is absent due to field acquisition problems. In well 33-2 the P-wave arrivals can only be reliably identified over the lower half of the geophone depth range. These arrivals are windowed and the instantaneous peak vector amplitude computed from the three component recordings. All arrivals show a considerable Amplitude Versus Azimuth (AVA) response (Figure 2). The deeper recordings for both AVSPs show a maximum amplitude for sources located at shot point 1 which coincides with the dominant fracture orientation. The amplitude rapidly decreases as the source moves around the arc with a possible secondary maximum occurring at shot point 7 which lies almost perpendicular to the dominant fracture strike direction. For the shallower recordings a reverse of this behaviour is observed and a maximum is observed for the source at shot point 7. There are many mechanisms which can produce an AVA response, for example source radiation patterns in anisotropic media, dipping interfaces and non-spherical divergence. However, preliminary results suggest that anisotropic attenuation is the most likely cause, as might be expected for wave propagation in porous fractured media (Hudson, Liu and Crampin 1996). This study suggests that interpretations of azimuthal amplitude variations in surface data need not be solely due to anisotropic reflectivity effects. Furthermore, these results suggest that fracture characterization may be possible using AVSP surveys with only P-wave sources.

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References

Figure 1 - Plan view of the acquisition geometry showing the relative shot point locations (labelled SP) to the two receiver wells (after Queen and Rizer 1990).

Figure 3 - Amplitude Versus Azimuth (AVA) responses observed in a) well 33-2 and b) well 33-1.