INTRODUCTION

A fractured carbonate reservoir within the Upper Permian in the North-western part of the Southern Gas basin is imaged using a marine VSP. The specific objective is to determine details of likely fracturing within a 76m thick target layer at a subsea depth of 1106m. This layer is characterized by high seismic velocities, being encased in Zechstein evaporite sections with lower seismic velocities. The high seismic contrast generates a strong converted shear-wave from the incident compressional wave at moderate angles of incidence. The polarization properties of the resultant shear-waves are governed by the fracture-induced anisotropy of the Plattendolomit. Interference of the shear-wave with the direct compressional arrival creates a distinctive motion in the horizontal plane. This signature depends upon the density and orientation of the fractures within the Plattendolomit. Waveform modelling to match this behaviour indicates a high fracture intensity of about 50%, consistent with expected fracture intensity for this lithology. This technique may be of value for other future analyses of fractured reservoirs, as it is local and independent of the overburden.

DATA ACQUISITION AND ANALYSIS

Field acquisition

As part of a more extensive acquisition to image the subsurface anisotropy (MacBeth et al. 1994), a receiver package is conveyed along a deviated well into a short horizontal section (500m) in the Plattendolomit, and positioned at three closely spaced (30m) locations. Walkaway offsets ranging from 500 to 3200m from the wellhead are shot with a spacing of 25m, and along two azimuths of N65°E and N95°E. The borehole trajectory is N35°E, roughly perpendicular to the expected NW-SE fracture trend.

Wavefield interpretation

A standard step in the interpretation of multicomponent data is the rotation of the recorded vector displacement into radial and transverse directions. This procedure is necessary to correct an otherwise arbitrary horizontal orientation of the tool (Figure 1). An interesting behaviour became apparent when we attempted to rotate each three-component trace set about a vertical axis into a local coordinate set. using the particle motion of the compressional wave in the horizontal plane. The compressional wave motion in this plane is initially linear, but becomes increasingly elliptical and finally quite circular with increasing offset (Figure 2). This strong systematic increase in the transverse component of motion can only be explained by the arrival of QS waves converted locally from the top of the Plattendolomit, with polarizations controlled by the anisotropic properties of the medium. An isotropic layer cannot explain this particular feature as a converted SV-wave polarization would be confined to the sagittal plane. A phase change combined with a deviation of the compressional wave polarization from the propagation direction is not significantly large to produce this effect. Full-wave modelling using the anisotropic reflectivity method (Taylor 1991) confirmed that the experimental results can only be matched by a strong anisotropy of 50% or greater in the Plattendolomit. The converted wave is very sensitive to the fracture direction and the line azimuth, with the modelling giving a fracture direction of roughly NW-SE, similar to the direction of maximum compressive stress.
DISCUSSION AND CONCLUSIONS

Most of the gross features of the data from the six walkaway VSPs can be successfully modelled using a plane layered isotropic model. However, in order to match the large transverse component for the compressional wave, it is necessary to introduce substantial anisotropy in the Plattendolomit layer. Strong anisotropy in the Plattendolomit is also indicated in the offset VSP data by a building up of shear-wave splitting time-delay. The result appears consistent with likely fracture intensities for this lithology (Nelson 1985), for which rocks with a high percentage of brittle constituents have close spaced fractures. This current technique may provide a way of characterizing reservoirs where fluid flow through low permeability rocks such as dolomites is dominated by the fracture processes rather than the matrix permeability. However, it should be emphasized that the result is specific the dolomite/evaporite combination of seismic velocities. It is a useful measure of anisotropy as the conversion process is not sensitive to the properties of the overburden, nor the source signature, and occurs directly after the first arrival.

![Diagram](image1)

**FIGURE 1.** Plan view of relative positions of walkaway lines and the wellhead, with necessary local coordinate axes for each receiver-source pair.

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REFERENCES

