UNEXPECTED SHEAR-WAVE BEHAVIOUR

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Introduction

Seismic anisotropy is often explained in terms of effective media where an ordered ensemble of sub-seismic elements leads to a directional variation of the materials properties. Examples of such systems include aligned cracks or fractures, fine layering and correlated pore space. Therefore, measurements of seismic anisotropy potentially allow insights to physical systems which would otherwise lie outside current seismic imaging capabilities. The case of aligned crack/fracture systems are possibly the most important to the hydrocarbon industry. This is because in many situations a reservoir's performance may be critically dependent on fracture controlled permeability anisotropy. However, the interpretative step from the observations of seismic anisotropy to the underlying physical phenomenon may not be simple. One assumption that is often applied is that the fast shear-wave (*qSI*) polarization is parallel to crack/fracture direction. However, a certain class of anisotropic materials with transverse isotropy (TI) can be identified with properties which may be inconsistent with this rule. Clearly, it needs to be established whether these 'unusual' materials can be realised in terms of realistic physical systems if any confidence is to be placed in such interpretations.

Method and discussion

When the symmetry axis of a TI medium lies in the horizontal plane (TIH), as would be the case for vertical cracks/fractures, then vertically propagating shear waves can only be polarized parallel or perpendicular to the symmetry axis. The situation normally assumed is that for equivalent media due to vertical crack/fracture systems is that the vertically propagating *qSI* waves will be polarized **perpendicular** to the symmetry axis. However, certain TI materials exist for which the *qSI* waves are polarized in a direction **parallel** to the symmetry axis and contrary to the case generally assumed for crack/fracture systems. If materials with this behaviour can exist due to crack/fracture systems then the crack strike direction cannot be resolved. We investigate whether materials with this 'unusual' shear-wave behaviour can be realistically constructed from various physical systems.

If we choose the symmetry axis of the TI medium to lie in the x_1 direction, then the *qSI* polarization for vertical directions is controlled by the two elastic constants c_{44} and c_{55} . In the case that $c_{44} > c_{55}$ the *qSI*-wave will be polarized in the plane perpendicular to the symmetry axis (Figure 1a). This type of behaviour is usually assumed for crack/fracture systems. However, in the case that $c_{44} < c_{55}$ the *qSI* polarization lies in the plane containing the symmetry axis (Figure 1 b). This switch in behaviour can conveniently be described using the Thomsen γ parameter (Thomsen 1986) which is positive in the first case and negative in the second. We investigate, using equivalent media formulations, whether materials defined by $\gamma < 0$ can be realised in terms of:

- 1 -micro-cracks (Hudson 1986)
- 2-fractures (Schoenberg and Douma 1988)
- 3-ellipsoidal particles (Hudson 1994)
- 4 fine layering (Postma 1955)

Our results suggest that if the TIH anisotropy is predominantly due to aligned crack/fracture systems then the interpretation of the qSI polarization to be parallel to the crack strike remains true. We also find that systems of aligned prolate ellipsoids can generate materials for which $\gamma < 0$. Such systems may exist in sandstones in which individual sandstone particles are depositionally aligned with the direction of their long axes lying in a sub-horizontal plane.

References

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Figure 1 - Lower hemisphere' equal area plots showing the faster shear-wave polarization for TI media with the symmetry axes aligned in the x_1 direction. The plot on the left shows a material for which $c_{44} > c_{55}$ ($\gamma > 0$). In this situation the faster shear waves for near-vertical propagation (represented by the centre of the plots) are polarized in the plane perpendicular to the symmetry axis. The plot on the right shows a material for which $c_{44} < c_{55}$ ($\gamma < 0$). In this case the vertically propagating shear waves are polarized in the plane containing the symmetry axis.

Figure 2 - Schematic illustration showing some of the mechanisms leading to effective anisotropic media.