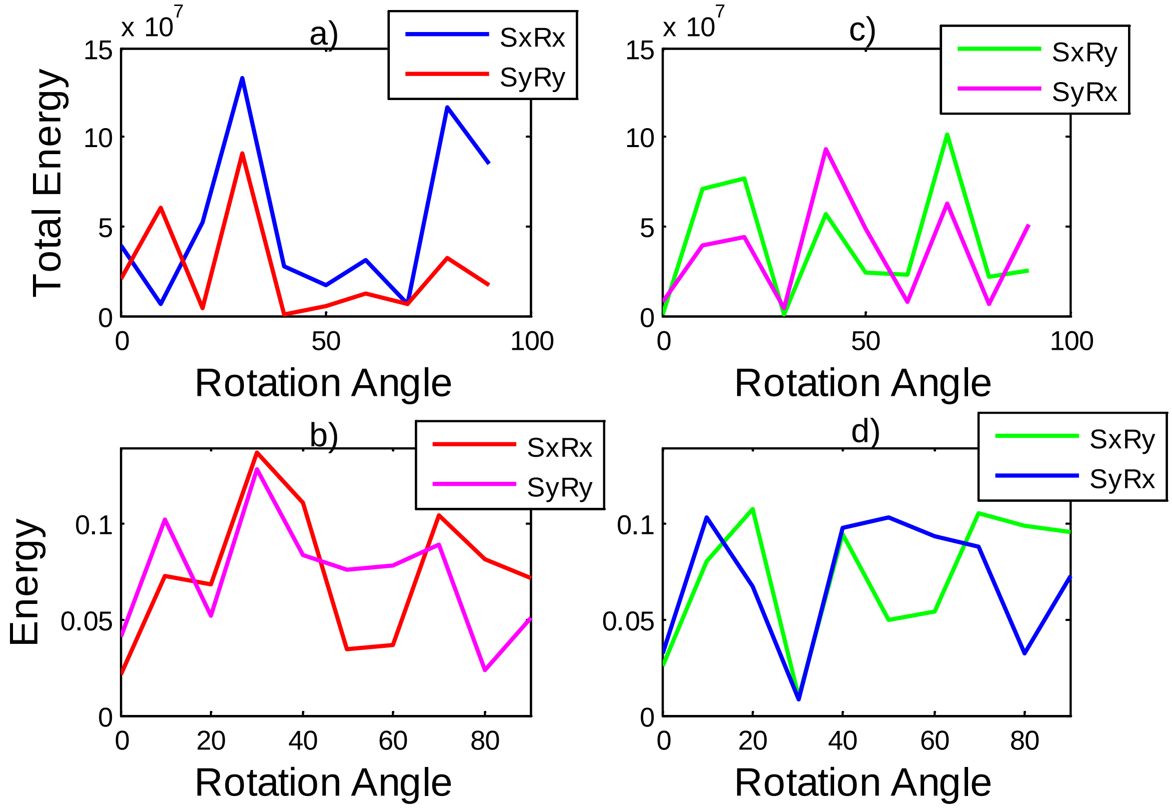
ROTATION OF SHEAR-WAVE COMPONENTS AT NON-NORMAL ANGLES OF INCIDENCE: BLACK-BEAR DATA, OKLAHOMA

Terence A. Campbell

Department of Geological Sciences
The University of Texas at Austin

ABSTRACT

Analysis of seismic shear wave information is useful in characterizing properties of the media they travel through. Alford (1986) introduced a method of rotating combinations of observed seismic traces from orthogonal pairs of shear-source and shear-receiver components to identify the azimuthal orientations of symmetry axes of birefringence. This method has been widely applied to interpretation of subsurface fracture properties. As currently applied, this analysis is limited to zero-offset reflections, which results because the normal incidence reflection response is identical for SV and SH reflectivity. For non-normal incidence angles, however, there is a pronounced difference in SV and SH reflectivity as source-receiver offsets increase, leading to significant distortion in the polarity of the reflected shear wave. Polarization distortion due to the reflection process in typical 3D acquisition geometry is demonstrated and a correction to the polarization distortion is presented. The only information required for the correction is the angles of SV and SH zero crossings, typically at angles near 20° for SV and 40° for SH for most sedimentary rocks. This correction can be applied to the four horizontal components of 9C direct shear data at non-zero source-receiver offsets. The application of this 'corrected' analysis leads to an extension of the widely applied Alford rotation method to a wide range of reflection angles of incidence, and inclusion of a wide range of source-receiver offsets in pre-stack data. Examples of this analysis are given for both synthetic and field (Black Bear, Oklahoma) data.



Results of the proposed Alford-like rotation polarization scan applied to horizontal components of 9C shear synthetic models (a) and (b)—for a range of incidence angles from 0-40°—and from polarization azimuths of 0° to 90°. The rotation process projects these polarizations to coordinates consistent with the HTI geometry, and is used to estimate where the cross-term energy is minimized. The numerical model has a 2 km thick isotropic layer over an HTI anisotropic layer with a 30° 'fracture' strike direction. The plot correctly indicates minima in cross-term energy at 30° and the X-X and Y-Y receiver pairs are maxima. At all other rotation angles, the cross-term energy is not zero, meaning it's not at the correct orientation. Results of a similar analysis applied to the four horizontal receiver components X (east) and Y (north) source and X (east) and Y (north) of the 9C Oklahoma Black Bear field data (c) and (d). A similar analysis was applied to a reflector at a shear-wave reflection time of 1.1 seconds. Similar to the synthetic data, there is energy on the cross-terms, which is indicative of anisotropy. Cross-term energy is a minimum at 30° and aligned X-X and Y-Y receiver pairs are energy maxima. Analysis of 9C VSP and crossed-dipole data in a nearby well (Texaco # 1 Brady Ranch) shows strong HTI anisotropy, at a 30° azimuth, in the entire shallow part of the section.