Over recent years the Edinburgh Anisotropy Project has developed and tested display, processing, and interpretation techniques with the specific aim of enhancing (without distortion) and estimating the information contained in split shear-waves from multi-component seismic data. These techniques, incorporated into a shear-wave analysis package, permit an assessment of the vector seismic wavefield in terms of several characteristic parameters of shear-wave splitting. In addition to estimation techniques, algorithms have been developed to test the acquired data for the degree of experimental control, assessing the consistency of the source generation and recording. Examples of shear-wave field data are analysed using this sequence of algorithms, to illustrate our coordinated approach to the analysis of multi-component shear-wave data. This presentation concentrates only on those subsets of data which record vertical/sub-vertical shear-wave propagation, so that the feasibility of estimating subsurface anisotropy using present recording practice may be investigated. These one-dimensional studies provide an opportunity to investigate the shear-waves under favourable conditions, without the interpretative complexities of offset data.

Three field datasets are presented, one generated by dual horizontal, orthogonal, shear-wave sources, and two generated by a single shear-wave source. The data are taken from various geological regions and degrees of experimental control. In the first example, dual source VSP datasets are analysed from the 1500m deep Varian Hole well, situated 1.4km NE of the San Andreas fault, near Parkfield, California. This well penetrates friable sandstone, mudstone, and fine clay in a structurally complex area, which is on the southwest limb of the Parkfield syncline. In the second example, shear-wave VSP data from the Paris Basin, France, are analysed. The data are acquired over 1000m to 2060m depth, penetrating a horizontally-bedded sedimentary limestone/shale formation. The final example is taken from VSP data with relatively poor experimental control, acquired in the Geysers steam field between 792m and 1401m, in the northern California Coast Ranges. Here, geophone misorientations, well deviations, and a tow-velocity surficial layer produce interesting complications in the results which can be detected and interpreted using shear-wave analysis procedures.

Each set of vector wavefield data is initially assessed using attribute and multi-component plots. These data may then be pre-processed using vector deconvolution or f-k filtering, before being analyzed using algorithms designed specifically to check the consistency of the propagation, related to the degree of experimental control. Subsets of the recorded data which exhibit consistent behaviour can now be analyzed to estimate the parameters of the best anisotropic model over a specified depth interval using analysis techniques based upon a convolutional model for anisotropic shear-wave propagation (Zeng and MacBeth, 2000).
These methods can accommodate single, dual, or multi-source directions. The final results are displayed in conjunction with wireline and lithologic logs, and structural geology (if available) for a possible joint interpretation. A final check on the anisotropic solution is furnished by comparing full-wave synthetic seismograms with the observations.

Analysis of shear-wave splitting in the Varian Hole experiment shows an upper region (above 985m) of stable polarizations, with directions which follow the axis of the Parkfield syncline and a lower section where the polarizations swing abruptly about a value apparently unrelated to any features of structure, regional stress, or lithology. The shear-wave splitting estimates can be modelled by 2-3% anisotropy in the upper section, followed by an increase firstly to 15%, and then 25% anisotropy with a dip in the anisotropic material such that the axis of symmetry lies along the limb of the syncline. The results from the Paris Basin, which has a horizontally layered structure, have an approximately constant polarization direction between 1000m and 1680m coinciding with the regional stress direction (Bush and Crampin, 1991). Below this section, the polarization directions change and are more scattered, with apparently no lithologic change at this transition. Although the near-offset data from the Geysers steam field is beset with interpretational difficulties due to geophone misorientations, and poor vibrator coupling, it is still possible using the shear-wave analysis techniques to make certain judgements about the anisotropy (Campden et al. 1990). It is found that the component of anisotropy in the vertical direction of propagation is small (less than one percent) for the entire depth range. Other published cases have cited progressive/systematic increase in delays with depth and a constant polarization with depth (Alford, 1986). and also possibly abrupt changes (Winterstein and Meadows, 1991a,b). It is apparent that more VSP data from a wide range of geological situations must be studied before the character and significance of such changes in shear-wave behaviour can be correctly assessed.

REFERENCES: