Shear Wave Velocity, Crustal Anisotropy, and In Situ Stress in the Vicinity of the Kane Fracture Zone

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Dipole shear-wave velocity logs were used to determine the orientation of shear-wave splitting in ~7 Ma crust in shallow oceanic crust near the Kane fracture zone. In combination with borehole imaging logs, this allows a direct link to be made between Vs anisotropy and volcanic structure, natural fractures and drilling-induced features (Fig. 1). A parametric method was used to improve the accuracy and reliability of the estimate (Tang and Chanduru, 1999), especially in low- to medium- anisotropy environments such as the upper oceanic crust. Horizontal Vs anisotropy decreases with depth in this crustal section. Vs anisotropy is caused in part by fracturing and variation in pillow morphology on a localized scale, and in part to the far-field borehole stresses (Goldberg et al., 2002) The fast azimuth is parallel to the strike of crustal heterogeneity or perpendicular to the far-field maximum compressive stresses that are present. Our estimates of the fast Vs azimuth are corrected for the declination (latitude) of the site and for rotation of the tool during data acquisition and agree well between two independent logging passes, as shown in Fig. 1.

Recorded during ODP Leg 174B, these data represent the first dipole shear-wave velocity logs and Vs anisotropy profiles measured in the oceanic crust (Becker et al., 1997). Based on these results, the inferred maximum compressive stress orientation is sub-parallel to the compression axis of earthquake focal mechanisms along the Kane, and oblique to the Atlantic plate motion vector. Oblique stresses in the crust, persisting since crustal formation at non-transform ridge discontinuities over the last 6-7 Ma, may become incorporated laterally in the crust as it migrates beyond the rift zone. As lithospheric age and strength increase with distance from the ridge axis, it is possible that residual ridge-oblique stresses decrease and the orientations rotate parallel to the dominant spreading direction, but this possibility cannot be addressed by the data recorded at this one site alone (Hole 395A). Dipole anisotropy measurements at older crustal sites, such as Hole 417A in the western Atlantic, could be made in the future to investigate the relationship between crustal age and horizontal stress orientation. Borehole anisotropy measurements offer a viable means to extend the global stress map and improve our understanding of the evolution of crustal stress at tectonic plate boundaries, as well as within plate interiors.

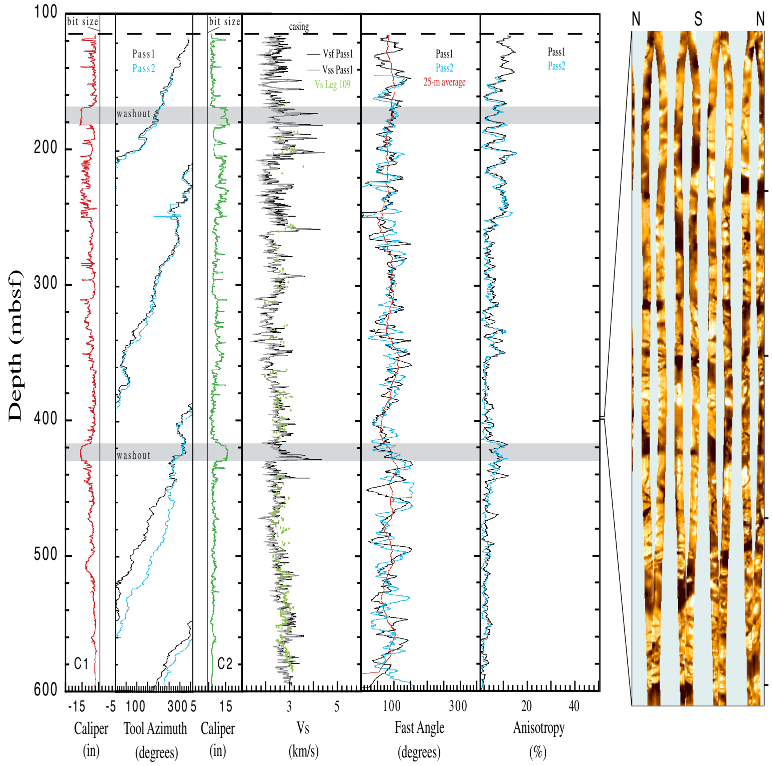

Figure 1. (a) Bit and hole size (caliper) profiles recorded during two logging passes in Hole 395A. (b) Vs logs using the DSI tool and previous monopole sonic tool log, which agree well. (c) Raw and smoothed (25-m running average) fast Vs direction determined using parametric inversion of the DSI waveform data. The mean orientation of the fast Vs azimuth is N83°E over the entire interval; mean azimuth is N 75°E over the lower 120 m with variation around the mean of approximately ± 27°. (d) Vs anisotropy estimated from DSI waveform data in two separate logging runs. The mean shear-wave anisotropy in Hole 395A is 5.3% with variation around the mean of ±3.2%. Anisotropy tends to decrease with depth and increase in zones where more fracturing is present. (e) Superimposed FMS traces from two passes over a 3-m interval show pillow contacts and cm-scale fracturing within and between individual pillows and more massive flows, illustrating structural heterogeneity of the crust.

References:

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