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Sheeted Dike Complexes in Contemporary Oceanic Crust: Implications for Spreading Processes and the Interpretation of Ophiolites

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As anticipated from studies of ophiolite complexes, direct investigations of the oceanic crust confirm that basaltic dikes are an integral part of the upper 2 km of the oceanic crust. Currently available information suggests that at mid-ocean ridge spreading centers, tectonic extension is accommodated by dike intrusion to varying degrees. Where the magma supply is large (high magma budget) sheeted dike complexes maybe essentially continuous beneath overlying lavas. Where the magma budget is low, spreading is accommodated by faulting and ductile deformation. Dikes are sparse and sheeted dike complexes are absent. Sheeted dike complexes have been documented in only a few places on the seafloor, despite the many tectonic escarpments with sufficient vertical relief to provide "tectonic windows" into the upper few kilometers of the oceanic crust. This is in part a function of the paucity of major escarpments in relatively fast-spread crust, but also an indication that seafloor spreading does not require substantial dike intrusion.

Investigations of the upper oceanic crust exposed along major seafloor escarpments and crustal drilling document the contact relationships and internal structure of sheeted dike units. Structural, magnetic, and geochemical investigations of *in situ* sheeted dikes provide insights into how these rock units form beneath spreading centers. These geological relationships have important implications for the interpretation of ophiolites.

Sheeted dike complexes have been described from 2 deep crustal drill holes (ODP 504B and IODP 1256D) and 4 major tectonic escarpments (Blanco Transform Fault, Hess Deep, Endeavor Deep, and Pito Deep Rifts). Although the exposed crustal sections in these areas formed under a range of spreading rates (50-150 mm/yr. full rates) the sheeted dike complexes in them show some consistent relationships that vary with rate (and possibly magma budget). Key relationships are as follows: 1) Dikes are generally not vertical; they dip "outward" (away from the spreading center where they formed (Fig. 1). 2) Paleomagnetic data show that the dikes were intruded vertically and later tilted (typically 20° to >50°). 3) The tilting occurred during seafloor spreading (i.e., within ~1 km of that spreading axis) as evidenced by cross-cutting vertical dikes and high-T hydrothermal veins, and horizontal overlying lava flows. 4) Tilting was accommodated by slip on dike margins and locally intense cataclastic deformation (Fig. 1). 5) The amount of faulting and fracturing correlates with the amount of tilting. 6) "Inward" tilting of overlying (intensely fractured) lavas matches the tilting of the dikes so that dikes and lava flows are generally orthogonal. 7) Dikes protrude upward into the overlying lava/dike transition zone in a way that may correlate with the width of the axial spreading zone. 8) The dikes and lavas have similar compositions but calculated liquid densities of the dikes are somewhat higher than those of adjacent lavas. 9) Underlying gabbroic rocks commonly have similar compositions to the overlying lavas and dikes. 10) Gabbroic rocks have a relatively sharp contact (~100 m, but not yet clearly documented) with the much more intensely fractured sheeted dikes.

Collectively, these observations suggest dramatic subaxial subsidence beneath spreading centers that accommodates the thickening of the lava units beneath an area of very low relief. Subsidence of the lavas and sheeted dikes demand substantial mass redistribution in the underlying gabbroic units. There is not yet sufficient information to indicate if similar relationships and processes occur in areas of relatively high magma budget, but slow spreading rate (for example, spreading segment centers or proximal to hotspots).

Dikes within the sheeted dike units are commonly used as vertical reference planes in reconstructing ophiolites, but this assumption can lead to substantial errors if spreading-related tilting is not taken into account (Fig. 1). The observed spreading-related tilting in seafloor outcrops

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could result in errors in unit thickness of as much as 50%. Paleomagnetic constraints or other independent evidence of the orientation of structures in ophiolites could help reduce uncertainties in these reconstructions.

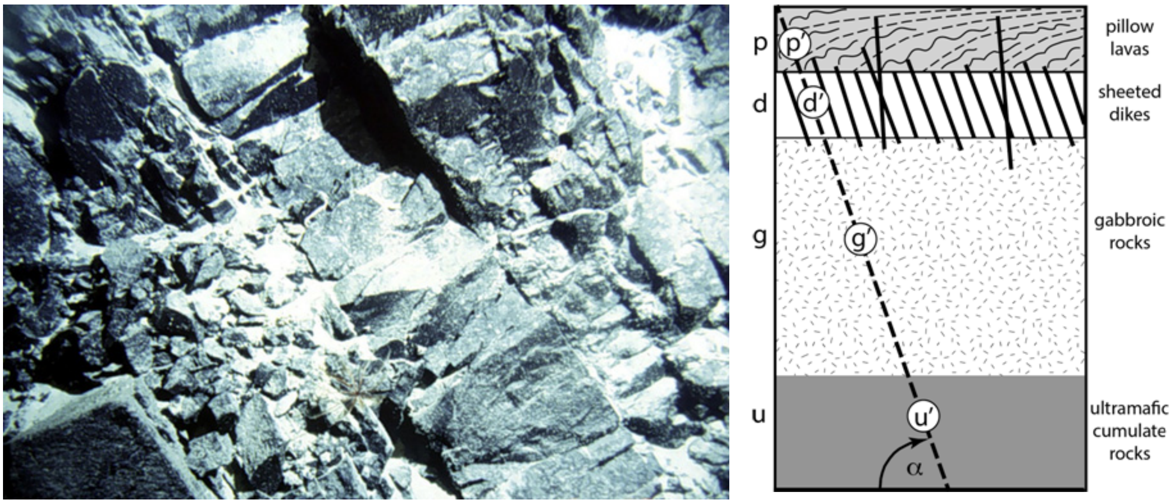

Fig. 1. Left: Fractured sheeted dikes at the Hess Deep Rift. Dikes dip ~60° away from the East Pacific Rise where they formed. Image is ~ 4 m across. Right: Vertical thickness of rock units in an ophiolite complex (p, d, g, u) is less than the thickness based on the assumption that the dikes (with dip α) represent vertical planes. For example, p'=p sin α.