Oceanic Crust Thickens Approaching the Clipperton Fracture Zone

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Abstract. A multi-channel seismic reflection image shows the reflection Moho dipping toward the Clipperton Fracture Zone in crust 1.4 my old. This seismic line crosses the fracture zone at its eastern intersection with the East Pacific Rise. The seismic observations are made in travel time, not depth. To establish constraints on crustal structure despite the absence of direct velocity determinations in this region, the possible effects of temperature, tectonism, and anomalous lithospheric structure have been considered. Conductive, advective, and frictional heating of the old crust proximal to the ridge-transform intersection can explain <20% of the observed travel-time increase. Heating has a negligible effect on crustal seismic velocity beyond ~10 km from the ridge tip. The transform tectonized zone extends only 6 km from the ridge tip. Serpentinitization is unlikely to have thickened the seafloor-to-reflection Moho section in this case. It is concluded that, contrary to conventional wisdom, the 1.4 my old Cocos Plate crust thickens approaching the eastern Clipperton Ridge-Transform Intersection. Increase in thickness must be at least 0.9 km between 22 and 3 km from the fracture zone.

1. Introduction

At a transform offset of any spreading center, a relatively cold lithospheric edge is juxtaposed against a hot ridge. A series of observed and hypothesized effects on the ridge are associated with the presence of this cold edge. Among these are decreased asthenospheric upwelling rate, decreased magma supply to the crust, increased low pressure fractionation, bathymetric lows, decreased Bouguer gravity anomalies, and the formation of thinner crust (Stroup and Fox, 1981; Bender et al., 1984; Fox and Gallo, 1984; Phipps Morgan and Forsyth, 1988). These effects upon the ridge are collectively termed the transform fault effect (TFE). Additionally, morphologic observations generally support the concept of segment centered magma supply beneath mid-ocean ridges (Francheteau and Ballard, 1983; Whitehead et al., 1984; Macdonald et al., 1988). It is hypothesized that this behavior also produces the above effects, including the formation of thinner crust approaching transform offsets, which are major morphologic segment boundaries.

On average, the crust actually within fracture zones is thinner than crust outside of these topographically anomalous zones (Minshull et al., 1991; White et al., 1993; Detrick et al., 1993). However, globally, there are only a few sets of geological or geophysical data that test the hypothesis of systematic thinning of crust approaching oceanic transform plate boundaries or their aseismic extensions. In the Bay of Islands Ophiolite, Karson and Dewey (1978) have observed decreasing thickness of the mafic crustal section approaching a structurally distinct region interpreted as a fracture zone. In this region, however, the total thickness of cumulate material actually increases due to the increased presence of ultramafic cumulates in the section. In the Blake Spur Fracture Zone area, 140 my old crust of the western North Atlantic appears to thin approaching the fracture zone, based on seismic reflection data (Mutter et al., 1984; North Atlantic Transect Study Group, 1985; White et al., 1990). Subsequent refraction data from this area suggest that the mafic crust did originally thin, although the velocity structure today is dominated by the signature of serpentinitization (Minshull et al., 1991). Hinz et al. (1989) have observed deep-lying reflectors near and beneath the Mesozoic portion of the Kane and Hayes Fracture Zones in the eastern Atlantic which may indicate...

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that the crust is thicker in these cases. Gravity studies of slow-spreading ridge segments predominantly indicate some combination of thinner crust and cooler mantle approaching transform offsets, evidenced by mantle Bouguer anomaly highs over the fracture zones (Kuo and Forsyth, 1988; Blackman and Forsyth, 1989; Lin et al., 1990; Morris and Detrick, 1991). Gravity studies over fast-spreading ridge segments show a more uniform pattern along isochrons, lacking strong evidence for systematic changes approaching fracture zones (Madsen et al., 1984; 1990; Lin et al., 1990). Thus the observational evidence does not overwhelmingly support the expectation that oceanic crust thins systematically approaching fracture zones, particularly for crust formed at fast-spreading ridges.

The Clipperton Transform Plate Boundary is an 85 km right-stepping offset of the fast-spreading East Pacific Rise (Figure 1). The ridge to the south of this offset is shallow and cross-sectionally broad (e.g. Madsen et al., 1984; 1988), and the ridge crest deepens by only 20 m approaching the transform offset. The most recent axial eruption occurred within 30 km south of the ridge-transform intersection (Haymon et al., 1990). Basalts sampled from this segment indicate high-temperature eruption; a voluminous and robust magma supply is inferred (Langmuir et al., 1986; Thompson et al., 1989;