Depth to Basement and Geoid Expression of the Kane Fracture Zone: A Comparison

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Abstract. Geoid data from Geosat and subsatellite basement depth profiles of the Kane Fracture Zone in the central North Atlantic were used to examine the correlation between the short-wavelength geoid (\(\lambda = 25-100 \text{ km}\)) and the uncompensated basement topography. The processing technique we apply allows the stacking of geoid profiles, although each repeat cycle has an unknown long-wavelength bias. We first formed the derivative of individual profiles, stacked up to 22 repeat cycles, and then integrated the average-slope profile to reconstruct the geoid height. The stacked, filtered geoid profiles have a noise level of about 7 mm in geoid height. The subsatellite basement topography was obtained from a recent compilation of structure contours on basement along the entire length of the Kane Fracture Zone. The ratio of geoid height to topography over the Kane Fracture Zone valley decreases from about 20-25 cm km\(^{-1}\) over young ocean crust to 5-0 cm km\(^{-1}\) over ocean crust older than 140 Ma. Both geoid and basement depth of profiles were projected perpendicular to the Kane Fracture Zone, resampled at equal intervals and then cross correlated. The cross correlation shows that the short-wavelength geoid height is well correlated with the basement topography. For 33 of the 37 examined profiles, the horizontal mismatches are 10 km or less with an average mismatch of about 5 km. This correlation is quite good considering that the average width of the Kane Fracture Zone valley at median depth is 10–15 km. The remaining four profiles either cross the transverse ridge just east of the active Kane transform zone or overlie old crust of the M-anomaly sequence. The mismatch over the transverse ridge probably is related to a crustal density anomaly. The relatively poor correlation of geoid and basement depth in profiles of ocean crust older than 130–140 Ma reflects poor basement-depth control along subsatellite tracks.

Introduction

Rapid development of remote sensing and data imaging techniques in recent years allows the uniform mapping of the geoid over the oceans. High-frequency anomalies in the height of the ocean surface can be used to map linear topographic features on the ocean floor. In order to interpret the location of fracture zones from geoid data as recorded by satellite, the exact correlation between the geoid and the topography of fracture zones must be determined. A generalized model for correlation between geoid, deflection of the vertical and fracture-zone topography (Figure 1) was used by Gahagan et al. (1988) to construct a preliminary global tectonic-fabric map of the ocean floor, based on the interpretation of deflection-of-the-vertical data from Seasat and Geosat. Although the tectonic development and the geoid expression of fracture zones in fast-spreading Pacific crust is fairly well understood (Sandwell and Schubert, 1982), no detailed comparison between the topography and geoid of a complete fossil trace of a fracture zone in the Atlantic or Indian Ocean has been reported. Better 'ground truth' for such fracture zones in slow-spreading crust is required if Geosat data are to be used to map the ocean floor in regions where bathymetric data are sparse, such as in remote high southern latitudes.

The relation between geoid, deflection of the vertical, and bathymetry of six fracture zones in the North Pacific was established by Sandwell and Schubert (1982). Their flexure model explains the distinct depth/age step of large-offset Pacific fracture zones in a fast spreading regime (Figure 1). Because of the apparent absence of vertical slip along fault planes of fossil fracture zones, this age/depth step seems often
Fracture Zones in slow-spreading regimes (Figure 1), as in the Atlantic and western Indian Ocean, have distinctly different topography. In contrast to the Pacific, Atlantic fracture zones exhibit a more complex morphology (Collette, 1986), and the expected depth/age step commonly is overprinted by the high-amplitude fracture-zone topography (Colette et al., 1984; Colette, 1986; Fox and Gallo, 1986; Potts et al., 1986; Roest and Collette, 1986). A characteristic feature of Atlantic fracture zones is a central trough having a graben-like character (Van Andel, 1971; Fox and Gallo, 1986). Collette (1974) and Turcotte (1974) invoked the concept of thermal contraction of the lithosphere parallel to the spreading axis to explain the existence of such fracture-zone troughs. Francheteau et al. (1976), however, pointed out that this mechanism results in too little extension to be significant. Fox and Gallo (1984) developed a tectonic model that explains the formation of fracture-zone troughs on slow-spreading ridges by a change in isostasy of the lithosphere, which is caused by a change in lithospheric properties (e.g., composition and mass distribution) at ridge-transform intersections.

Three distinctly different types of fracture zones have been identified in slow-spreading regimes. Small offsets of the spreading ridge axis less than ca. 20 km (~1.5 m.y.) are characterized by faults trending 45°–75° relative to the adjacent spreading axes and exhibit a shallow fracture valley. In contrast, large offsets more than about 30 km (~2 m.y.), show a rectilinear system of transform shears and have a well-developed transform valley (Macdonald, 1986; Tucholke and Schouten, 1988). The best examples of such large offsets in the North Atlantic are the Oceanographer, Hayes, Atlantis, and Kane fracture zones. There is a third type of fracture zone in slow-spreading ocean crust that displays features of both fast- and slow-spreading large offsets. Very large offset transforms (several hundreds of kilometers) have complex morphologies that combine a depth/age step typical for Pacific-type fracture zones with the Atlantic characteristics of rugged topography and the presence of a central valley. Examples of this type of fracture zone are the Romanche Fracture Zone (offset ~900 km), characterized by a depth/age step as well as a large-amplitude topography (Sandwell, 1984), and the Charlie-Gibbs Fracture Zone, which is an unusual double fracture zone with an offset of 350 km (~25 m.y.). The Charlie-Gibbs exhibits two parallel east-west trending troughs (Olivet et al., 1974) accompanied overall by a significant depth-age step (GEBCO-Sheet 5.04).

Vogt et al. (1984) compared 9300 km of marine geophysical data along suborbital tracks with Seasat data in the central North Atlantic. They showed that there is a good correlation between geoid height, free-air gravity, and seafloor topography, and that grabens along fracture zones usually are accompanied by a geoid low (schematically shown in Figure 1). Roest (1987) also found good correlation between along-track gravity from Seasat with seismic-reflection and free-air gravity data by comparing selected profiles over the Fifteen-Twenty and the Tyro fracture zones in the central North Atlantic.