Discussion of

Propagation of the Hawaiian-Emperor volcano chain by Pacific plate cooling stress

by

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We agree with the model of Stuart and others (this volume). Here, rather fancifully, is why.

Figure 1 is an oblique Mercator projection of part of the Pacific Plate about the Hawaiian pole of rotation (68˚N, 75˚W). Red lines highlight major linear volcanic chains. The chart is on end with lines of latitude vertical so that aspects of bilateral symmetry, which we are practiced to identify in the human figure, stand out. Phenomena in the mantle that influence the plate surface and are fixed will produce trends parallel to lines of latitude on the moving plate. Several linear chains are parallel. White lines are portions of three lines of latitude, one of which is the plate-rotation equator (PRE on the horizontal reference line at the top). There, the East Pacific Rise is spreading most rapidly, 149 km/Ma (Hey et al., 2004). The two longest linear volcanic chains on the plate, the Hawaiian (H) and Louisville (L) Ridges, are surprisingly, to within about one degree of latitude (vertical arrow), symmetrical about the PRE. Note that transform seismicity of the Eltanin Fracture Zone system (focal spheres) aligns with the Louisville seamounts.

A serrated or “W-shaped” arrangement of contour lines showing depth to the seafloor about the PRE also shows symmetry, but not the expected “U-shaped” square-root-of-time age-depth relationship, especially with respect to older arrangements of spreading ridges and fracture zones (fine white lines). The Pacific Plate thus rides over two fixed topographic anomalies beyond the Marquesas (M) and Austral (A) chains, which are equidistant from and nearly bilaterally symmetric about the PRE. The Tuamotu and Society (SO) chains straddle the PRE (and further west, the Caroline Chain, C) and so continue the symmetry. This region has been termed “SOPITA” (South Pacific Isotopic and Thermal Anomaly; Staudigel et al., 1991), but it is clearly divided into sub-regions. The isotopic anomaly extends through near-ridge seamount provinces (Janney et al., 2000; Hall et al., 2006) to a fairly wide segment of the East Pacific Rise (Mahoney et al., 1994); enriched mantle sources of the seamounts are shallow and are not affiliated with a plume.

Finally, the horizontal belt of seismicity at the Tonga-Kermadec Trench is along a line of longitude in this projection. The active ends of both the Samoan chain (S, near the trench) and the Hawaiian chain are both almost precisely along this line of longitude. The Samoan chain and the curving corner of the Tonga Trench are also close to the PRE.

We believe that these aspects of Pacific volcanism are best explained by fracture propagation (Natland and Winterer, 2005) and the thermoelastic cooling model of Stuart et al. (this volume; cf., Sandwell and Fialko, 2004). If one rotates Figure 2 of Stuart et al. (this volume) to that of Figure 1, stress couplets near Hawaii parallel the chain (also the PRE) and are determined by a combination of cooling of the lithosphere (compressive regime = blue) and regions of tension (red) on the Rise and at trenches. The maximum tensional stress occurs where the Tonga trench changes direction by 90˚ and becomes a transform fault.

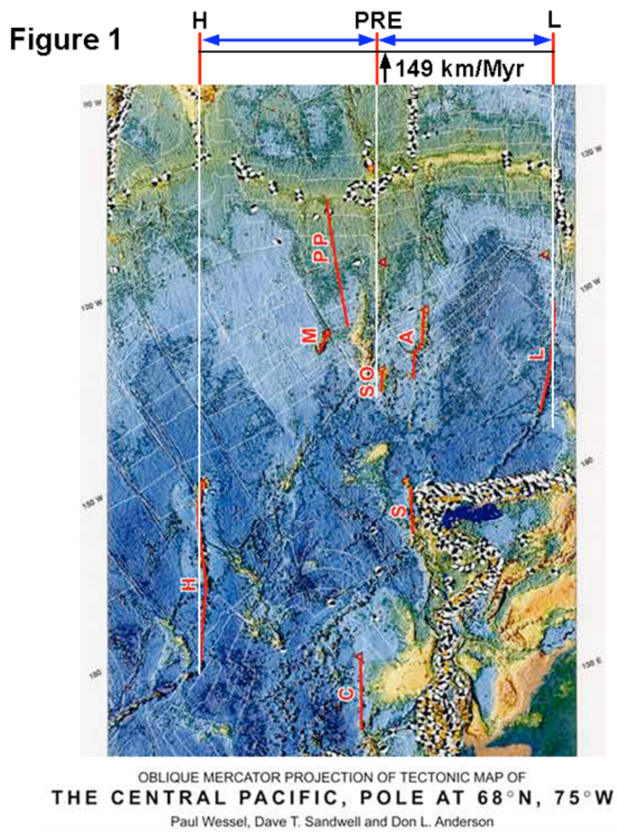

Figure 1

In this configuration, the stress field "bows" across the Pacific lithosphere between the Tonga Trench and Juan de Fuca Ridge. The Hawaiian Ridge sits precisely on the crest of the bow. A similar "bow" exists between the Tonga Trench and the Pacific-Antarctic East Pacific Rise near the Eltanin Fracture Zones. However, here, the stress field does not match the condition for tensional crack propagation except very near the ridge axis. Thus seamounts of the Louisville Ridge have only ever formed near the ridge at the western end of the Eltanin Fracture Zones. The Samoan chain sits precisely in the maximum tensional regime that is produced by bending and disruption of the Pacific Plate at the curving corner of the Tonga Trench (Natland, 1980).

Plume advocates now must explain why deep mantle plumes that are premised to start in the lower mantle, and which are supposedly independent of plate motion, happen to know 1) where the Pacific plate is spreading most rapidly so that many aspects of mid-plate volcanism, including the Hawaiian and Louisville Ridges, are symmetrical about the PRE; 2) the precise location of the curving corner of the Tonga Trench, to make Samoa; and 3) why stress regimes most favorable to fracture propagation coincidentally occur at the ends of the two longest linear chains on the plate.

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