Are the Hawaiian and Emperor chains tectonic in origin?

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Almost all midplate volcanism and volcanic chains can be related to pre-existing tectonic features and to regions of extensional stress (Favela and Anderson, 1999; Natland and Winterer, 2005; Jackson et al., 1975; Smith, 2004; Anderson, 2004). Essentially all the volcanic features in the Pacific basin have a plausible tectonic explanation [http://www.mantleplumes.org/TopPages/PacificTop.html.] The Hawaiian and Emperor chains, which may be unrelated, and their relation to the Shatsky and Hess Rises, and the giant Mendocino fracture zone, have been enigmatic. The chains do not lie along obvious tectonic features although stress may still control their location and orientation (Turcotte and Oxburgh, 1973; Turcotte, 1974; Hieronymus and Bercovici, 1999; Stuart et al., in review; Natland and Winterer; 2005). The problems with conventional explanations of these chains have been summarized by Foulger and Anderson (2004) and Raymond et al. (2000) but a plate tectonic model has not been put forward.

The Pacific plate grew by annexation and triple junction (TJ) jumps. Old ridges and TJ can still be productive and incipient ridges can also be magmatic (these are often called hotspot tracks). The fabric of the Pacific plate clearly shows evidence of many plate reorganizations including ridge migrations and TJ jumps. TJs focus magma more effectively than ridges; new or relocated TJs are expected to tap previously undrained mantle and to therefore be temporarily more productive. A relation between TJs and ridge-transform intersections is expected. What has slowed down progress is the lack of magnetic stripes during critical plate reorganization periods. It is clear that Shatsky Rise formed at a jumping triple junction (Sager et al., 1999) but the other large plateaus in the Pacific ocean formed during the Cretaceous quiet period and detailed reconstructions are impossible. It is likely, however, that all oceanic plateaus formed at TJs, ridges or ridge-fault junctions. That is, these large intraplate constructs were formed at plate boundaries. The Hawaiian islands are virtually the only large volcanic constructs that, to date, have not been associated with pre-existing tectonic features.

Ian Norton has provided the tectonic context for the north Pacific and has shown that a shallow origin is plausible for what are now midplate volcanoes. He thus adds Hawaii to the list of tectonic hotspots (Anderson, 2005a). The recognition that the Hawaiian and Emperor segments may be unrelated is an important step. The relation of both chains, and the Hess/Shatsky Rise, to the Mendocino fracture zone and other possible former plate boundaries may hold the key to these most impressive and enigmatic of all volcanic chains. The Hess and Shatsky Rises straddle the Emperor Seamount Chain (ESC), which terminates at the Mendocino fracture zone, but the relationships of these features are generally ignored. The relationship of Emperor seamount chain to the cusp in the Aleutian arc and the Emperor Trough are also generally ignored. In Norton's plate reconstruction model, these features are all related.

Although plate architecture and stress clearly control the locations of magmatism, the volume of magma may depend on the fertility of the asthenosphere. Volume can be increased by focusing and edge effects, and by transient effects, but one does not expect the mantle to be uniform in composition, melting point and fertility (Anderson, 2005b). Subducted aseismic ridges, seamount chains, plateaus, island arcs and young oceanic plates, and delamination of continental crust all contribute to lithologic variability of the asthenosphere. Fertile blobs in the upper mantle are an alternative to high absolute temperatures for creating melting anomalies. A continuously productive long-lived volcanic chain may simply reflect an underlying aseismic ridge that has been over-ridden by the surface plate.

The combination of lithospheric vulnerability and asthenospheric fertility seems capable of explaining midplate volcanism without particularly high temperatures or deeply seated upwellings. Norton's paper indicates how detailed plate reconstructions can contribute to the understanding of what have been called 'hotspot tracks'. All of these effects, plus recycling, are part of plate tectonics and the top-down or plate hypothesis (Anderson, 2001; Foulger et al., 2005; www.mantleplumes.org).

A fertile afterthought

Although it has been controversial, the idea that melting of eclogite is responsible for some aspects of ocean island basalt geochemistry is becoming increasingly popular (Sobolov et al., 2005; Yaxley and Green, 1998; McKenzie et al., 2004). The authors in these papers include several who have been, and still are, strong advocates of the thermal plume hypothesis. Some even propose that fertile spots in the mantle represent subducted seamounts or plateaus. If this is true, the origin of melting anomalies is essentially trivial; seamount chains and oceanic plateaus result from the remelting of subducted seamount chains and plateaus. Since eclogite melts at temperatures some 200˚C below the melting point of peridotite it is likely that melting anomalies are due to high homologous temperature rather than high absolute temperature, and that the volume of magma represents the volume of eclogite rather than being a proxy for mantle absolute temperature. Norton's plate tectonic mechanism combined with variable mantle fertility eliminates the need for high mantle temperatures to explain melting anomalies.

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