Tristan volcano complex: oceanic end-point of a major African lineament.

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No direct evidence for plumes is yet available: seismic tomography, currently the best hope, so far lacks the resolving power for plume detection (Grand et al., 1997). Hence, an assumed plume can be tested only by ground observations, or from volcanic materials. To evaluate, or to use, such circumstantial evidence it is necessary first to identify the key attributes inherent in the plume concept.

By definition, any postulated mantle plume must be independent of the overlying lithosphere, this independence (in terms of plate motions, for instance) being the foundation of the hotspot reference frame (Morgan, 1971). The plume should also be independent of lithosphere structure, and the timing of activity at other igneous complexes.

Lithosphere independence thus emerges as the only primary attribute of plumes. While it does not prove the existence of a plume, it is a necessary condition that should checked. Where magmatism is demonstrably localised by some pre-existing structure in the lithosphere, for instance, there can be no direct connection to a plume (unless by extraordinary coincidence).

The first check should be for hot spot tracks, with age progression along their lengths, consistent with the plate moving over a fixed source. These have been sought in Africa since the early days of the plume concept, with varied results. Burke (1996) reviewed this question in detail, concluding that the only plausible candidate is the Tristan-Walvis Ridge (Figure 1) on the ocean floor sector of the African plate, pointing out that even here the Tristan hot spot has been stationary for the last 30 Ma. At the continental end is the Etendeka volcanic province (130 Ma), which he takes to be the initiation of the Tristan hot spot track. Alignment of the Walvis Ridge he attributes to northward movement of the plate (with its accreting ocean floor) over a fixed plume between 130 and 30 Ma (~ Anomaly 10), from which time sea floor spreading continued, but with the African plate stationary. By implication the hot spot was near the plate margin until Anomaly 10: a fixed plume model would then require a unique stationary point on the south Atlantic spreading ridge for 100 Ma (see Bailey, 1977).

If there is a volcanic chain along the Walvis Ridge, with a completely regular age progression, then it would be a track (130 Ma old), but its mode of formation can be assessed only against the full geological context, not in isolation. An immediate question arises with the Etendeka volcanism, located at the continental margin, and erupted at the time of complete lithosphere opening. Other major structures also converge around this place, where the continental margin is intersected by:

1. Major transform fracture zones of the SE Atlantic;
2. The southern boundary of the Angola craton and the Lufilian belt;
3. The northern boundary of the African Superswell.

Hence, any magmatism initiated at this site, at the time of plate separation, was clearly not independent of pre-existing lithosphere structure. In fact, this is such a remarkable focus of pre-existing and contemporaneous structure lines that a sub-lithosphere plume is not merely inapt, but superlatively so. When the discussion is widened the need for an alternative explanation becomes even more apparent.

Basalt-quartz latite volcanism at Etendeka is not akin to the strongly alkaline eruptions that characterise Tristan, and as if to underline this, activity at Etendeka did not cease at 130 Ma. A subsequent carbonatite complex was erupted through the 130 Ma lavas. From here, through Namibia/Angola/Congo Republic there is a belt of alkaline igneous/ carbonatite/kimberlite complexes stretching 1,900 km along the extension of the Walvis Ridge. These are of various ages from 795-70 Ma with no regular age progression (although many are contemporaneous with Etendeka). Some of the young complexes are at the distal end of the belt, and one at least may be Tertiary, which would make this belt almost a continental mirror image of the Walvis Ridge.

The great circle extension of the Walvis Ridge (Figure 1) is also close to the NW margin of the African Superswell. Although this boundary verges where it rounds the SE sector of the Congo Basin the topographic break reappears on the far side, being dramatically marked by the collinear NW margin of the Ethiopian Highlands, until it reaches the Red Sea (south of Mecca). In this sector, there are clusters of alkaline igneous/carbonatite complexes in the Sudan, along a belt parallel to the highland front. Hence this great circle follows a long lived lithosphere structure, marked in the geology, and moreover by lateral density variations in the deep mantle tomography, to which the Superswell has been related. Perhaps most remarkable in the topographic re-constructions of the Superswell is that the Walvis Ridge forms its NW margin where the Swell extends into the SE Atlantic. Thus the Walvis Ridge appears as an oceanic prolongation of this major step in the continental crust/lithosphere/mantle. It follows that the most straightforward explanation of the Walvis Ridge is that it formed by continuous propagation of a profound step in the African sub-structure as new oceanic lithosphere formed during spreading. Invocation of a fixed plume below the moving plate is therefore unnecessary.

This conclusion is consistent with the absence of tracks in the rest of Africa, where in stark contrast, magmatism is found repeated at the same sites in Cretaceous and Tertiary (Bailey, 1992), not at the ends of tracks. All the Cenozoic alkaline igneous/carbonatite/kimberlite activity across the whole African plate (including oceanic extensions) may thus be seen to be lithosphere dependent. Repetition of this low volume, volatile rich magmatism suggests that lithosphere structure not only localises the sites of eruption, but provides the required conditions for melting. Fluxing of volatiles from deep mantle through lithosphere penetrating lesions, must play a key role ("pie funnel effect": Bailey, 1983). The triggering events are regional expressions of global tectonic changes (Bailey and Woolley, 1999).

Other recognised linear zones in the African plate follow similar trends to the Tristan-Red Sea great circle (W, Figure 1), imparting a distinct NE-SW grain to the continent. One such NE-SW belt (marked by the mid-Zambesi Luangwa rifts) crosses Africa from Indian to Atlantic Oceans (Z, Figure 1), with rifts and magmatism along its length

(Bailey, 1961). This, and the Tristan zone, bracket the East African highlands, where the Superswell has been said to “jog NE” from its southern portion. Hence these ancient structural trends effectively frame the modern East African plateau, and its Tertiary volcanism.

The continental end of the Walvis Ridge, where major geological and topographic features converge, marks a crucial node in lithosphere structure, and the Ridge may be the result of its propagation across newly accreting ocean floor, in a manner similar to that suggested for the Hawaiian chain (Shaw and Jackson, 1973).

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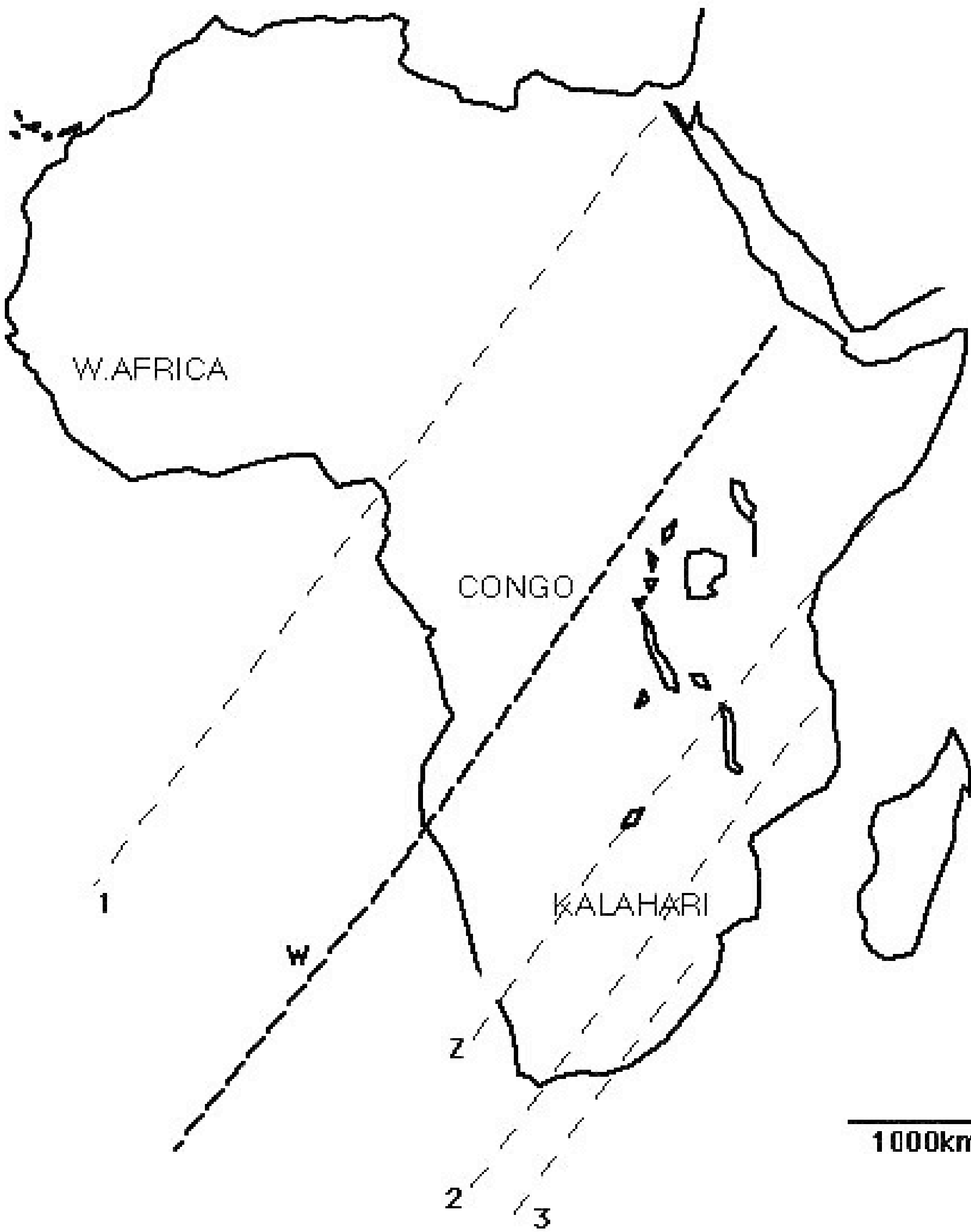

Figure 1. Linear zones across African plate: W, Walvis Ridge; Z, Zambesi-Luangwa; 1, St. Helena-Cameroon; 2, Cape Rise; 3, Shona Rise-Drakensburg.

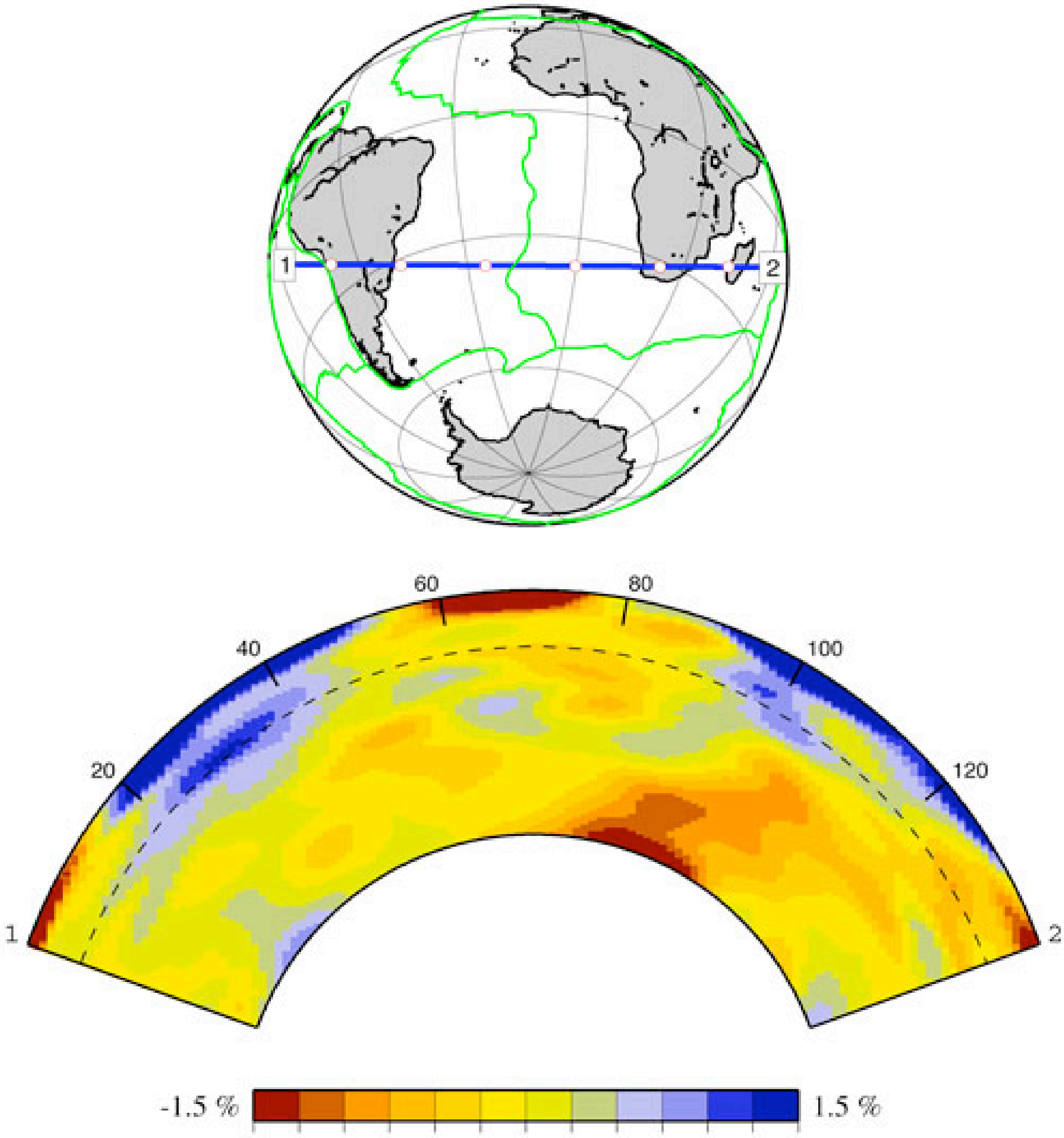

Figure 2. Whole-mantle tomography cross section through the Tristan volcano complex, using the tomographic model of Risema et al. (1999).