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Interrelationships between large-scale plate motions as indicators of mantle structure: new constraints on mantle modelling and compositional layout

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Two suggested features of the mantle are still much debated. Do we have a two-layer mantle? Do craton tectospheres extend nearly to the bottom of the upper mantle (e.g. [1])? If true, these set important constraints on mantle modelling, including the distribution of composition. The latter depends strongly on when was the change from a whole-mantle pattern.

Rather than discuss these propositions individually this contribution will set out a variety of plate motion evidence consistent with both being true. Then, and to the extent that time permits, a basis for each of them separately will be outlined.

If cratonic keels approach the depth of the 660km discontinuity and the 660 is a barrier to mantle flow, a very obvious consequence is that if a craton splits, the upper mantle to fill in below the nascent ocean has to be got by a circuitous route. Conversely, if two cratons approach one another, a lot of intervening upper mantle has to be extruded sideways. Here are some probable examples.

1. When the South Atlantic opened, splitting the Africa/S America craton, the eastward movements through the Caribbean and Scotia gaps resulted from the demand for Pacific mantle.

2. Prior to the 2-stage opening of the Arctic ocean, the region was surrounded by cratonic keels except for a substantial gap below the West Siberian basin. During the first (Cretaceous) stage the needed mantle appears to have been drawn northward through this gap and may have initiated the northward 'flight' of the Indian craton from Gondwanaland.

3. The Tertiary stage of opening of the Arctic began when the progress of N Atlantic opening had loosened Greenland at the Labrador Gulf. Mantle was now available from beneath the Atlantic. Its flow towards the Arctic dragged the keel of Greenland, producing the widespread Eureka (Eocene) folding from Svalbard to Ellesmere Is.

4. Closure (Cretaceous) of Africa-Arabia toward the Baltica-Russia craton expelled mantle westward. This flow appears to have thrust the keel of the Moesian microplate (of Bulgaria-Roumania) westward and opened the western Black Sea. Related action is seen further west.

For the purpose of 1, 2, and 3, we need the new MOR model [2], one of whose properties is that it forces the plates apart by within-plate solid-state phase change action, thus 'sucking' in, from below, the mantle it needs for plate construction. This model recognizes that interstitial melt in the LVZ greatly stiffens the mineral structure [3], so the LVZ, with its heat content, is an integral part of the oceanic plate. The widespread tomographic fading of slab signatures at 200-400km depth in subduction zones (e.g. [4]) is therefore attributable to slab reheating, not slab drop-off. This will be shown to open interpretation of deeper features as a two-layer mantle, with very slow addition to the lower mantle.

[1] Gu, Dziewonski & Agee, EPSL 1998; [2] Osmaston, 31st IGC 2000, Gen. Symp. 4.1; [3] Hirth & Kohlstedt, EPSL 1996; [4] Fukao et al, Rev Geophys 2001.