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Is the nature of the uplift initiated by the melting of an ice-sheet or the erosion of a rock overthrust really isostatic?

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Archimedes' Principle states that a boat floats on water by displacing a weight of water equal to the total weight of the boat. Achievement of this equilibrium requires the mobility of the supporting agent, the water. Likewise the concept of terrestrial isostasy assumes that a crustal element is supported by displacing an identical weight of mantle. The whole basis of GIA is called in question if sufficient Upper Mantle mobility is not available. In this contribution we discuss a variety of mantle observations which conspire to cast doubt on this sufficiency. We then show that imposition of an ice-sheet or crustal overthrust will initiate a volume-increase thermodynamic process in the deep continental crust which can provide epeirogenic uplift which, in the overthrust case, is widely seen to have totalled many times that appropriate to isostatic rebound (e.g. ~8km for Aar Massif, after Austroalpine overthrusting).

Plate tectonics, when introduced, took the view that the Earth has continental crustal plates which are being moved around by convective motions in the mantle, mobile both beneath the plates and in the oceanic areas between. Subsequent recognition of the processes of subduction and MOR spreading refined and constrained our thinking about mantle mobility in the oceanic domain. But until 1998 little had been done to assess mantle mobility beneath continents, which is where we are concerned with its constraints upon the maintenance of isostatic behaviour.

It was noted [1,2] that, below ancient cratons, the seismological appearance of the 410km and 520km mantle discontinuities consistently differs from those seen in the suboceanic mantle. These depths are well below the subcratonic change at 180-200km often thought to mark the bottom of that lithosphere. The deep discontinuities differ in that the subcratonic ones are far less sharply defined, attributed to the presence of interstitial fluid, a view supported by the C,H,O,S metasomatism seen in kimberlite xenoliths from such depths.

Geodynamic analysis of crustal motions for the past 160Ma, [3], parts of which I will present, provides further support for the reality of such 'deep keels' of cratonic tectosphere. Typically it demonstrates that, when you split a craton, oceanic mantle, entraining lesser continental elements, has been drawn from elsewhere to put beneath the nascent ocean.

The conclusion drawn is that the material forming these deep tectospheric keels of cratons is rigid enough to have remained attached throughout perhaps 2Ga of plate tectonic displacement. But how, contrary to the seismologist's rule-book, can interstitial fluid be reconciled with structural rigidity? To answer this we move to the oceanic domain. It has been shown [4,5] that the presence of minor interstitial melt will strip out, by partition, the water-weakening of the mineral structure, itself thereby becoming hydrous. Data on the suboceanic mantle led [5] to calculate that the mantle stiffening factor of the seismological Low Velocity Zone would be around two orders of magnitude. All the evidence suggests that this effect is also why the deep cratonic keels are so immobile.

The result is also the death of that bastion of mantle mobility, the divergent mantle flow model for MORs. Instead, I have devised [6] a new and versatile model for MORs, in which the effective plate thickness is already at least 150km at the axis.

Finally, we will display and discuss my above-mentioned thermodynamic calculation, published in [7], that emplacing any kind of lid on top of mature continental crust will hamper the heat loss from its deep radiogenic content, raising its temperature. The resulting deep-crust metamorphic retrogression can then provide the volume increase needed to drive the non-isostatic surface uplifts we have discussed.

[1] Gu Y., Dziewonski AM & Agee CB (1998) Global de-correlation of the topography of transition zone discontinuities. EPSL 157, 57-67.
[2] Agee CB (1998) Phase transformations and seismic structure in the upper mantle and transition zone. Rev. in Mineralogy 37. 165-203.
[3] Osmaston MF (2009) Deep cratonic keels and a 2-layer mantle? Tectonic basis for some far-reaching new insights on the dynamical properties of the Earth's mantle: example motions from Mediterranean, Atlantic-Arctic and India. Geophys. Res. Abst. 11, EGU2009-6359 Session SM 6.2 (Solicited).
[4] Karato S. (1986) Does partial melting reduce the creep strength of the upper mantle? Nature 319, 309-310.
[5] Hirth G. & Kohlstedt DL (1996) Water in the oceanic upper mantle: implication for rheology, melt extraction, and the evolution of the lithosphere. EPSL 144, 93-108.
[6] Osmaston M (2014) Mantle properties and the MOR process: a new and versatile model for mid-ocean ridges. Geophys. Res. Abst. 16, EGU2014-1750.
[7] Osmaston MF (2008) Basal subduction tectonic erosion (STE), butter mélanges and the construction and exhumation of HP-UHP belts: the Alps example and some comparisons. Inter.Geol. Rev. 50(8), 685-754. DOI: 10.2747/00206814.50.8.685.