Deep cratonic keels and a 2-layer mantle? Example motions from Mediterranean, Atlantic-Arctic and India as a tectonic basis for insights on the dynamical properties of the mantle, probably arising from changes halfway through Earth history

Miles F. Osmaston
The White Cottage Sendmarsh, Ripley, Woking, Surrey GU23 6JT, UK
miles@osmaston.demon.co.uk

Two of the most controversial questions concerning mantle behaviour concern the great depth of cratonic tectospheric keels (e.g. [1, 2]) and whether the base of the upper mantle is a substantial barrier to flow [3]. Individually the arguments for each are indecisive and have hitherto been regarded as the province of seismologists and mantle modellers. But if both are true we can by-pass these physical arguments because there should be major dynamical consequences for plate motions, susceptible to direct observation [4]. We will here outline briefly the author's recent contention [4-7] that both are true, based on dynamical examples from the Mediterranean, Atlantic-Arctic and India. We will then discuss the implications for Earth-interior properties and behaviour, including what is going on at the deep ends of subduction zones.

Our starting-point is that if the 660km discontinuity is indeed a barrier to mantle flow and keels extend nearly that far we need to ask: (a) Where does the mantle go to as two cratons approach one another? and (b) Where does it come from to put beneath a widening ocean? Here we offer observation-anchored answers to each.

In an Alpide belt setting we have a complex example of (a)[Ref 6]. Ongoing mutual convergence of cratons in the Caucasus, since at least the mid-Cretaceous, has expelled mantle westward at depth, producing west-directed closures in the Balkans and Italy. This westward motion, ultimately of the entire Balkan Peninsula, appears first (mid-K) to have built the N-S magmatic arc on the W side of the Moesia microcraton (under Roumania), whose keel was being driven by the flow, progressing westward to the Dinarides and finally (Oligocene) to the Western Alps [8, 9] and Apennines. Thus the dominantly N-S closure of Africa and Eurasia now yields a mechanism for the broadly concurrent E-W components of compression in the Alpide belt.

In an Atlantic-Arctic context we find three examples of (b). First, the widely-evident eastward motions of the Caribbean and Scotia Sea plates appears to record the eastward flows, at depth, of mantle to put beneath the widening N & S Atlantic. In the Caribbean case the keels of Proterozoic blocks in Guatemala-Nicaragua appear to have been caught by the flow and are driving the plate. Second, the intra-Eocene Eureka folding from Ellesmere Island to Svalbard, across northern Greenland, is seen [4, 5, 7] as due to drag upon Greenland's keel by mantle being drawn to put under the widening Eurasia Basin. Significantly the compression began at the moment Greenland became detached on both sides and ended when the NE Atlantic offered a sufficient gap for the flow. Third, before this gap appeared, mantle flow had to use the West Siberian gap between cratonic keels, assisting India's northward flight to Himalayan collision. This drag/suction has compressed Asia as never before and is still evident around southern India as by far the deepest dent in the geoid (>100m) and much N-S compressive seismicity there.

Answers to four questions raised by these findings will be briefly suggested.

A. What is the character and origin of the evidently immobile subcratonic mantle beyond 200km depth which has such deceptive seismic properties?

B. How is the implied mantle 'suction' generated by an MOR process model that recognizes these properties in the oceanic domain?

C. If it's not slab mantle, what is it that we see going on into the lower mantle at subduction zones? The answer follows from those to A and B.

D. If the Earth now has a 2-layer mantle, when and how did it change from the whole-mantle convective pattern surely driven by the high heat generation in the early Earth? The answer is highly significant for us all. The interval 2.45-2.2Ga (no orogenic granitoids) marks the convective hiatus during the changeover. MOR collapse and sea-level fall led to lower atmospheric CO_2, glaciations during 2.45-2.3Ga and the Great Oxygenation Event at ~2.3Ga when oxgenic life had finally won its battle against the reducing chemical action of MORs. In this sense, therefore, we all are the living proof of that changeover.

[1] Gu, Y, Dziewonski, AM & Agee, CB (1998), *Earth & Planetary Science Letters*, **157**, p. 57-67.
[2] Agee, CB (1998) In: *Hemley, RJ (ed); Reviews in Mineralogy*. **37**, 165-203.
[3] Osmaston, MF (2003) What drives plate tectonics? Slab pull, ridge push or geomagnetic torque from the CMB? A new look at the old players *vis-a-vis* an exciting new one. *XXIII IUGG 2003, Sapporo, Japan. Abstracts CD,* p. B129, Abstr #016795-2.
[4] Osmaston, M (2005) Interrelationships between large-scale plate motions as indicators of mantle structure: new constraints on mantle modelling and compositional layout. *3rd Workshop on "Earth's mantle composition, structure and phase transitions", St Malo, France;* http://deep.earth.free.fr/participants.php
[5] Osmaston, MF (2006) Global tectonic actions emanating from Arctic opening in the circumstances of a two-layer mantle and a thick-plate paradigm involving deep cratonic tectospheres: the Eurekan (Eocene) compressive motion of Greenland and other examples. In: *ICAM IV, Proc. 4th Int. Conf. on Arctic Margins, 2003* (ed. R. Scott & D. Thurston). Dartmouth, NS, Canada: OCS Study MMS 2006-003, p.105-124: Also published on: *<http://www.mms.gov/alaska/icam>*
[6] Osmaston, MF (2007) Cratonic keels and a two-layer mantle tested: mantle expulsion during Arabia-Russia closure linked to westward enlargement of the Black Sea, formation of the Western Alps and subduction of the Tyrrhenian (not the Ionian)

Sea. *XXIV IUGG 2007, Perugia, Italy, July 2007*. http://www.iugg2007perugia.it/webbook/ Session JSS 011 Earth Structure and Geodynamics. Abstr #2105.

[7] 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: *EGU General Assembly 2009, Geophysical Research Abstracts*, v. **11**, EGU2009-6359. Session SM 6.2 (Solicited).

[8] 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: *International Geology Review*, v. **50**, no. 8, p. 685-754: DOI: 10.2747/00206814.50.9.685.

[9] Osmaston, MF (2008) Basal subduction tectonic erosion (STE) and the construction of HP-UHP metamorphic belts: A new model for the Alps and its comparison with the Maksyutov Complex, southern Urals, In: *33rd International Geological Congress, Oslo,* Session UHP-05, Abstr #13399700.