Geophysical Research Abstracts
Vol. 14, EGU2012-2529, 2012
EGU General Assembly 2012

Is subduction really in the plate tectonics driving seat, or do two other global mechanisms do the driving? A review in the 'deep-keeled cratons' frame for global dynamics

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

Introduction. The title poses a question very like that of my talk in 2003 [1], concluding then that, as a driver, subduction comes 'a doubtful third'. My purpose here is to show that subsequent developments now cause even that limited status to be denied it with great assurance, except in a rare situation, of which there is no current example. The key point is that studies of subduction have been importantly mistaken as to the nature of the plate arriving for subduction.

Deep-keeled cratons? The 'deep-keeled cratons' frame for global dynamics [2 - 5] is the result of seeking Earth-behaviour guidance on the following outside-the-box proposition:- "If cratons have tectospheric keels that reach or approach the 660 km discontinuity, AND the 660 level is an effective barrier to mantle circulation, then obviously (i) when two cratons separate, the upper mantle to put under the nascent ocean must arrive by a circuitous route and, conversely, (ii) if they approach one another, the mantle volume that was in between them must get extruded sideways." Remarkably it has turned out [2 - 5] that Earth dynamical behaviour for at least the past 150 Ma provides persuasive affirmation of both these expectations and that the explanation for the otherwise-unexpected immobility of subcratonic material to such depths is a petrological one *which is also applicable to the behaviour of LVZ mantle below MORs* [6 - 8]. Straight away this result has major consequences for the character of the plate arriving for subduction.

First, to construct them, we need a 'thick-plate' (>100km?) model of the MOR process which recognizes that this LVZ immobility renders invalid the existing concept of divergent mantle flow below MORs. I show that my now not-so-new model [1, 8 - 10], based on a deep, narrrow, wall-accreting sub-axis crack, possesses outstandingly relevant properties, even appropriately dependent on spreading rate. **Second,** the oceanic plate arriving for subduction is no longer just the cooled mantle boundary layer habitually assumed, but its LVZ content gives it **(i)** residual heat content, **(ii)** corresponding buoyancy, and **(iii)** a flexural strength which demands a reconsideration of its mode of downbend, hitherto widely regarded as flexural, but still be able to explain outer rises and their differences. Solutions for (ii) and (iii) are convincingly supported by widespread exposure of the resulting rocks in the Alps, telling us how they and other UHP metamorphic mountain belts have been built [11]. I will illustrate the essential points. In particular, the buoyancy (ii) provides the upward mechanical contact essential for the shallow basal subduction tectonic erosion of the upper plate as preparation of thin imbricate crustal slices to subduct to UHP. And a seismologically supported through-plate step-faulting mode of downbend copes with the flexure problem (iii) and provides the tectonic erosion mechanism.

In tackling these matters, important intrinsic properties of the materials are, notably:- **(1)** the thermal conductivity of non-migrating interstitial melt is >20 times less than its parent rock, so the LVZ heat is effectively trapped during the plate's journey across the ocean, only to be released when subduction raises the pressure and the melt freezes; **(2)** the garnet-to-spinel peridotite phase change, typically at 50 to 90 km depth, gives some 50 times more volume change per joule than pure expansivity, and it does so with the big force of solid-state recrystallization. This force is the crack-wall push-apart force provided by our thick-plate MOR model, which thereby develops at least an order more ridge push than the divergent flow model.

We now consider the post-downbend evolution of the subducting plate, recognizing both the heat content of its ex-LVZ material and that, within the 2-layer mantle picture established by the plate dynamics of 'deep-keeled cratons' [2 - 5], there is no substantial mantle transport across the 660 km level. Examination of tomographic transects shows at once that in by far the majority of cases, the 'slab' signature begins to fade at some depth in the 180 - 350 km interval, but that a second high-*Vp* signature begins near 400 km and may continue far into the lower mantle. The fading, whose onset depth varies both with the age of the plate and with the subduction rate, is clearly due, not to slab drop-off, but to reheating of the slab component by its underlying ex-LVZ heat. In either case, reheating or drop-off, this invalidates slab pull as a reliable item in the tectonics toolkit. Instead, there is a thick-plate mechanism to provide back-arc opening in the presence of ridge-push [3, 11].

Slab-reheating may proceed to the stage of partially melting the interface oceanic crust. On experimental evidence, this will, at TZ depth, produce high-density, high-*Vp* stishovitic residues, lumps of which I see as causing the second high-Vp signature, as they shower through the 660 into the lower mantle. This interpretation escapes the slab-view paradox that the world's longest-lived *young-plate* subduction zone also has the world's *biggest* high-*Vp* signature in the lower mantle, whereas Izu-Bonin, subducting very old plate, has one of the smallest. Young-plate heat would surely melt more of the interface crust and generate more of the high-density residue. The early Proterozoic date at which this mantle layout replaced whole-mantle overturn is well shown by the behaviour of the mantle depletion index, epsilon Nd.

At this point I conclude unhesitatingly that subduction is *neither* ***the,*** *nor even* ***one*** *of the drivers of current plate motions,* but is primarily driven by the powerful ridge-push from the thick-plate version of the MOR process. That push is what compresses the ocean plate if step-faulting at the downbend has temporarily locked subduction ('seismic coupling'), with the potential to release the energy for an M9 earthquake. But our system is dynamically incomplete. Ridge push cannot split a continent, so how does that occur? My original proposal [1] for that function was the long-term clockwise rotation of Antarctica and its coupling to the other plates. In another contribution at this meeting [12] the observational basis for its reality is now shown to be very strong. So the conclusion is that plate tectonics has only two primary drivers - this rotation and ridge push - subduction being a wholly passive consequence.

[1] Osmaston M. F. (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,* B129, Abstr. 016795-2.

[2] Osmaston M. (2005) Interrelationships between large-scale plate motions as indicators of mantle structure: new constraints on mantle modelling and compositional layout. In *3rd Workshop on "Earth's mantle composition, structure and phase transitions"*. http://deep.earth.free.fr/participants.php.

[3] Osmaston M. F. (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 *Proc. ICAM IV, 2003* (ed. R. Scott & D. Thurston). OCS Study MMS 2006-003, pp.105-124: Also at ; http://www.mms.gov/alaska/icam.

[4] Osmaston M. F. (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, Session JSS 011* Abstr #2105, http://www.iugg2007perugia.it/webbook/.

[5] Osmaston M. F. (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.Abstr* **11**, EGU2009-6359 (Solicited).

[6] Karato S. (1986) Does partial melting reduce the creep strength of the upper mantle? *Nature* **319**, 309-310.

[7] Hirth G. & Kohlstedt D. L. (1996) Water in the oceanic upper mantle: implication for rheology, melt extraction, and the evolution of the lithosphere. *EPSL* **144**, 93-108.

[8] Osmaston M. F. (2010) On the actual variety of plate dynamical mechanisms and how mantle evolution affected them through time, from core formation to the Indian collision. *Geophys. Res. Abstr.* **12**, EGU2010-6101.

[9] Osmaston M. F. (1995) A straightness mechanism for MORs: a new view of ocean plate genesis and evolution *XXI IUGG,* Abstracts p. A472.

[10] Osmaston M. (2005) The ridge push mechanism of MORs as the agent of seismic coupling, tsunami, convergence partitioning and landward thrusting at subduction zones; insights on an interactive family of mostly-jerky mechanisms. *IASPEI 2005 Gen. Assy, Santiago, Chile*, Abstr. No 303.

[11] Osmaston M. F. (2008) Basal subduction tectonic erosion (STE), butter mélanges and the construction and exhumation of HP-UHP belts: the Alps example and some comparisons. *Internat. Geol. Rev.* **50**(8), 685-754 DOI: 10.2747/00206814.50.8.685.

[12] Osmaston M. F. (2012) Did clockwise rotation of Antarctica cause the break-up of Gondwanaland? An investigation in the 'deep-keeled cratons' frame for global dynamics. *GD6.1. Geophys. Res. Abstr.* **14,** EGU2012-2170**.**