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Building the Earth's core and D" layer by 'subduction': processes, timings and compositional implications

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

Based on the timing of siderophile element transfer to the core, the various forms of the iron-percolation model for core genesis imply that associated accretionary growth continued for upward of a few tens of Ma after T_0 (4567 Ma?), and therefore in nebula-absent conditions, dating from about 4561 Ma (youngest chondrules). The long timescales for Safronov-type impact-accretionary growth in these conditions, even if gravity-assisted, have seemed consistent with this.

But there is strong dynamical evidence that the planets were actually formed extremely quickly. Long ago it was twice pointed out [1] that the predominance of prograde satellites preserved in the Solar System implies a tidal mechanism (such as a partially melted central body) for their capture, all the retrograde ones (bar Triton) having been 'wound in' to coalescence. Such a hot state implies very rapid accretion and/or short-lived heat from ^{26}Al. Triton, indeed, evidently 'wound in' for a short time, growing to 30% of our Moon's mass by mopping up its next-inner brethren, and then stopped, thus marking the ending of Neptune's tidal attribute.

Planetary growth in (cool) nebula-present conditions transforms the core-formation problem, a new model for which is outlined. Nebular opacity (dust) ensured that distance from solar radiation was not a factor, so the cores in Jovian moons are not a special problem. Tidal and gas drag action upon planetesimals enormously increased capture cross-sections and accelerated growth. As soon as internal convection developed in the growing body, magmatically erupted FeO, reduced to Fe by the nebular atmosphere, was 'subducted' (not percolated). The dense Fe-loading of the downwelling limb ensured its deep penetration, with the Fe dropping off at the bottom, gravitationally heating and accelerating convection and speeding core build-up. Transfer to the core of mantle radiogenic Pb and (highly) siderophile elements took place across the CMB but was delayed by the expulsion of silicate dross from the core. The rather uniform (~250-fold) depletion of these siderophiles may be consistent with partition at final CMB pressure. The accumulation of radiogenic Pb in the mantle shows that the CMB must have been permanantly sealed against Pb transfer by ~4.45 Ga. This I attribute to the start of D" build-up by dense lumps derived from subducting primitive crust (see below), leaving a time-window for transfer, evident in the Hf-W data for Earth and Mars [2].

On this model, planetary core formation was terminated by nebula departure, with comets and the Great Planets incorporating some of the potentially 1000 Earth-ocean volumes of total reaction water expelled with it, so the latter are 2-stage bodies. The actual timescale for all this must have begun well before the ~4567 Ma of CAIs because these come from the outsides of asteroids, inhibition of whose mutual coalescence implies the presence, already, of a substantial Jovian mass. The model makes C and S the preferred core dilutants. Si may also be possible. Entry of H, U and Th seems possible, but K is doubtful and O impossible. Much water entered the early-Earth mantle, as seen in komatiites (e.g. -Nb anomalies), ensuring their high-melting magmagenesis.

As noted, the formation and permanence of D", now ~250 km thick, has a specific function in Earth evolution. The post-perovskite view of its composition lacks this attribute, though post-perovskite may be present. As a 'graveyard' for subducted slabs the entire lower mantle would be filled up in < 2.5 Ga. Mantle depletion rates over time (*cf*. epsilon Nd) show we need an unseen reservoir as repository for constituents of ocean-crust. Experimental work finds (surprisingly) that its partial melting at Transition Zone (TZ) conditions yields stishovitic SiO_2 residues (high density and seismic Vp) that might fall to D" and not build it up too fast. To achieve such melting in the TZ, I will reason that the widespread fading, in the 200-400 km depth interval, of the high-Vp seismic tomography signature, is actually indicative of slab reheating, not of slab drop-off. On this view D" offers an additional site for the mantle's missing 5% of Si, relative to chondrite models.

[1] McCord, T. B., 1968, *JGR* **73**, 1497-1500: Counselman, C.C., III, 1973. *Astrophys. J.*, **180**, 307-314.
[2] Lee, D.-C. & Halliday, A.N., 1998. *EOS: Trans. AGU*, **79** (17) S373.