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Continental growth by successive accretion of oceanic lithosphere: Evidence from tilted seismic anisotropy

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Although many studies indicate that subduction-related accretion, subduction-driven magmatism and tectonic stacking are major crustal-growth mechanisms, how the mantle lithosphere forms remains enigmatic. Cook (AGU Geod. Series 1986) published a model of continental 'shingling' based on seismic reflection data indicating dipping structures in the deep crust of accreted terranes. Helmstaedt and Gurney (J. Geoch. Explor. 1995) and Hart et al. (Geology 1997) suggest that the Archean continental lithosphere consists of alternating layers of basalt and peridotite derived from subducted and obducted Archean oceanic lithosphere. Peridotite xenoliths from the Mojavian mantle lithosphere (Luffi et al., JGR 2009), as well as xenoliths of eclogites underlying the Sierra Nevada batholith in California (Horodynskij et al., EPSL 2007), are representative for oceanic slab fragments successively attached to the continent.

Recent seismological findings also seem to support a model of continental lithosphere built from systems of paleosubductions of plates of ancient oceanic lithosphere (Babuska and Plomerova, AGU Geoph. Monograph 1989), or by stacking of the plates (Helmstaedt and Schulze, Geol. Soc. Aust. Spec. Publ. 1989). Seismic anisotropy in the oceanic mantle lithosphere, explained mainly by the olivine A- (or D-) type fabric (Karato et al., Annu. Rev. Earth Planet. Sci. 2008), was discovered almost a half century ago (Hess, Nature 1964). Though it is difficult to determine seismic anisotropy within an active subducting slab (e.g., Healy et al., EPSL 2009; Eberhart-Phillips and Reyners, JGR 2009), field observations and laboratory experiments indicate the oceanic olivine fabric might be preserved there to a depth of at least 200-300 km. Dipping anisotropic fabrics in domains of the European mantle lithosphere were interpreted as systems of 'frozen' paleosubductions (Babuska and Plomerova, PEPI 2006), and the lithosphere base as a boundary between a fossil anisotropy in the lithospheric mantle and an underlying seismic anisotropy related to present-day flow in the asthenosphere (Plomerova and Babuska, Lithos 2010). Deep dipping reflectors in the Slave Craton were modelled as tops of a fossil oceanic lithosphere (Bostock, Lithos 1999). Using S-wave receiver functions, Miller and Eaton (GRL 2010) also interpreted mid-lithosphere discontinuities beneath British Columbia as remnant oceanic slabs. Strong radial anisotropy from global surface-wave data (Babuska et al., PAGEOPH 1998; Khan et al., JGR 2011), as well as differences between body-wave tomography images from SH and SV waves (Eken et al., Tectonophys. 2010), both showing strong anisotropy only down to $\sim$200 km, are in agreement with the models of inclined olivine fabrics found in Phanerozoic and Precambrian mantle lithosphere (Plomerova et al., Solid Earth 2011). Models of assemblages of microplates with their own inclined fossil fabrics do not support a lithosphere growth by simple cooling processes, which should result in horizontal fabrics. The models with dipping fabrics also contribute to mapping boundaries of individual blocks building the continental lithosphere.