Crustal Destruction: Delamination Processes and Rates

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Narratives of Earth's continental crust formation need to devote time to both crustal creation and destruction. For creation, mantle melting yields magmas that add new mass; destruction involves sediment subduction, subduction erosion, and lower crustal delamination (foundering, dripping) and slab breakoff. Processes like relamination only involve recycling. Issues include rate and relative importance of basaltic versus andesitic magmas, criteria for identification of destruction processes and rates. Here, we examine criteria for identifying delamination and focus particularly on the role of delamination in ultimately producing an andesitic crust. In general, delamination occurs in contractional regimes, is episodic, and recycles mafic/ultramafic lower crust. On-going delamination is being observed in seismic images of the mantle and crust under areas like the high Central Andean plateau and the Sierras and Colorado Plateau of the western US. Abrupt changes in magma composition and xenolith populations along with structural changes and uplift complement and provide a temporal context to geophysical observations. Adakitic rocks that form in equilibrium with dense eclogitic residues are distinctive, as is the presence of magmatic "flare-ups". In older contractional orogens, similar thermal-compositional-structural observations, constrained by high precision chronology permit identification of delamination episodes as in the Tertiary Tibetan Plateau and in the Proterozoic Grenville. In accretionary orogens like the Palaeozoic Altaids (central Asia) identification of delamination is aided by present-day analogues. In collages of sutured arc terranes, mafic lower crust and forearcs often appear under-represented and were presumably destroyed. In contrast, regions like the Ural arc-continent collision zone appear to have remained largely intact. Integrated over a long time scale, the rate of lower crustal destruction by delamination at subduction zones and during continental collision is on the order of 2 AU (Armstrong units at km^3/year globally).

EM-like sources in Patagonian plateau basalts: Auca Mahuida case

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Plateau basalts in the northern Patagonian ~1.8 to 0.8 Ma Auca Mahuida volcanic field, which is centered at 37.8°S and 68.7°W and is ~225 km from the Andean Southern Volcanic Zone arc front, have trace element and Sr, Nd and Pb isotopic similarities to nearby early Miocene basalt flows as well as oceanic OIB basalts that are primarily mixtures of EM1 and depleted mantle. The isotopic ratios and the presence of positive Sr, K, Ba and Rb spikes on primitive mantle normalized plots of both the Auca Mahuida basalts and the early Miocene basalts indicate a mantle source containing old slab modified continental lithosphere. As similar positive spikes are absent on trace element patterns of north-central Patagonian ~48-32 Ma backarc basalts with more depleted isotopic signatures, major additions of slab-modified lithosphere and crust into the mantle source are conjectured to have occurred in the late Oligocene to early Miocene as the Andean margin adjusted to major changes in plate convergence parameters. Relatively higher Ba, Rb, Th, U and K concentrations and subtly lower La/Ta ratios in the Auca Mahuida basalts than in the early Miocene basalts are attributed to interaction of the local mantle source with slab-derived fluids or melts during the episode of late Miocene shallow subduction of the Nazca plate recorded in the near-by arc-like Chachahuén volcanic complex.

On the scale of the Auca Mahuida volcanic field, the relatively homogeneous trace element and isotopic chemistry of the basaltic lavas are consistent with their formation as melt batches of a similar mantle source. Calculated temperatures and pressures for the most primitive basalts are 1350° to 1380°C at 1.8 to 2.0 GPA, which correspond to depths of 65-74 km. These depths are consistent with independent estimates for the depth to the base of the lithosphere from xenolith and seismic studies in the same region by others. Calculated melting percentages from a moderately enriched mantle source for the most mafic basalts range from about 6% to 3%. The associated mugearitic, trachyandesitic and trachytic volcanic rocks can be modelled as being derived from fractionation of the basaltic magmas along with some mixing with evolved magmas, and possibly with partial melts of recently underplated magmas. The small range of Sr, Nd and Pb isotopic variation in the Auca Mahuida volcanic suite fits with little old crustal contamination of the magmas in the refractory crust left over from the major melting event that produced the Permo-Triassic Choiyoi granite-rhyolite province.