# The role of lower crustal recycling in continent formation

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It has been known for over one hundred years that the the continental crust is andesitic in bulk composition (e.g., Clarke, 1889). The origin of this unique, thick and buoyant crust is difficult to understand in the context of modern crustal growth, which occurs by accretion of intraoceanic arcs or hot-spot generated plateaus, both of which are dominated by basalts. Moreover, a multitude of experimental data demonstrate that basalts (not andesites) are the primary melts of mantle peridotite. Assuming that continental crust grows by igneous processes, these collective observations require the presence of an additional process that recycles mafic to ultramafic materials from the crust into the convecting mantle (see review of Rudnick, 1995). One such process is that of lower crustal foundering (also called “delamination”, Kay and Kay, 1991). In this process, thickening of a chemically stratified crust results in the transformation of lower crustal mafic and ultramafic lithologies to eclogite-facies rocks, which have densities exceeding those of underlying peridotitic mantle. Given appropriate viscosity conditions, this dense package will founder into the convecting mantle, carrying underlying mantle lithosphere with it (Jull and Kelemen, 2001). There it may become dispersed through convection or possibly remain as discrete entities that are sampled by later mantle-derived magmatism (Tatsumi, 2000). However, a challenge of the lower crustal recycling hypothesis is that it is difficult to test from observables.

One place where removal of ancient continental mantle lithosphere is well documented is the North China Craton (see Gao et al., 2003, and references therein). This likely occurred in the early Mesozoic, when a significant magmatic flare-up is registered by intrusion of voluminous granites. Early Cretaceous high Mg andesites and dacites have chemical characteristics that suggest they interacted with mantle peridotite, features that are usually attributed to the interaction of a slab melt with overlying mantle wedge. However, in this case the magmas have inherited Archean zircons and Archean Nd model ages, suggesting that they may represent melts derived from foundered Archean mafic lower crust.

## References

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# Interpreting Isotopic Records of Atmospheric Photochemistry in Surface Deposits

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Terrestrial mass-independent stable isotope fractionations (MIF) in oxygen and sulfur isotopes originate during photochemical reactions induced by solar UV light in the atmosphere (Thiemens 1999 *Science* 283, 341; Farquhar et al 2001 *JGR* 32829). The modern and Archean records of (MIF) in both sulfur and oxygen isotopes differ considerably. These differences provide clues that aid in interpreting the history of atmospheric photochemistry.

The modern geologic record shows that MIF in oxygen isotopes is transferred from ozone via sulfate and nitrate aerosols and continuously deposited at Earth’s surface (Bao et al. 2000, *Nature* 406, 176-178; Michalski et al. 2000, *EOS* 81, F120). The MIF anomalies in oxygen are always positive in sign and up to $\Delta^{17}O = +21‰$ for nitrate. The known ancient record of oxygen isotope MIF extends only to the Miocene.

The modern geologic record of sulfur MIF anomalies is restricted to discrete layers in stratified polar ice cores and measured values are small ($\Delta^{33}S < 1‰$) (Savarino et al. 2002 *EOS* 83 B61D-11). The presence of sulfur MIF in ice cores correlates with the occurrence of sulfate aerosols formed when giant volcanic eruptive clouds such as that from Pinatubo (15 June 1991) penetrated into the stratosphere. Magmatic anhydrite in Pinatubo ash has zero MIF anomalies for both oxygen and sulfur (Ono, Bao pers. comm.). The contrast between Pinatubo’s non-zero anomalies in sulfate aerosols and zero anomalies in magmatic sulfate emphasizes the crucial importance of homogeneous gas phase chemistry in producing MIF anomalies.

Archean sulfur MIF anomalies are large ($\Delta^{33}S$ up to 8‰), both negative and positive in sign, distributed pervasively throughout continuous drill cores samples and correlate with depositional environment (Ono et al *EPSL* in press).

Modern occurrences of S- and O-isotope MIF anomalies confirm the elements of the Pavlov-Kasting model (2001 *Astrobiol.* 2, 27): ie, production by UV photolysis, particle formation, and transportation to the surface in aerosols. The disparity in magnitudes and distribution between modern and Archean S-isotope MIF support model calculations indicating that large $\Delta^{33}S$ anomalies can only be preserved in an anoxic atmosphere.