A new perspective on the 2.7 Ga event on Earth

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Of the many changes that have been proposed to occur in the late Archean centered around 2.7 Ga, only seven are well documented: 1) a decrease in the Eu anomaly in hydrothermal cherts and BIF; 2) a large decrease in the proportion of komatiites in greenstone belts and in the Mg# of komatiites; 3) a decrease in the average degree of melting in the upper mantle as recorded by such incompatible element ratios as La/Yb and Nb/Yb in tholeiitic basalts; 4) an increase in the volume of preserved juvenile continental crust; 5) an increase in the volume of depleted mantle as recorded by such geochemical indices as εNd(T) and Nb/Th in non-arc related basalts; 6) production of a thick depleted ultramafic root beneath late Archean cratons; and 7) an increase in the proportion of sediment in sources of granitic magmas as recorded by $\delta^{18}O$ in detrital zircons.

These changes might be related to the onset of widespread subduction at about 2.7 Ga. This subduction regime could have increased the rate of production of continental crust to such an extent that arcs collided with each other *before* being recycled into the mantle, forming the first volumetrically significant cratons. Likewise, the 'capture' of juvenile felsic crust in stable cratons reduced the recycling rate of this crust into the mantle accounting for the first significant growth of a depleted reservoir in the mantle in the late Archean. The widespread onset of subduction at 2.7 Ga has three effects on the mantle: 1) it produces new continental crust that partially blankets the mantle from loosing heat, 2) it leaves the mantle depleted in radiogenic heat-producing elements, and 3) for the first time, a large volume of dead slabs begin to accumulate in the lowermost mantle. This results in a decrease in mantle potential temperature, possibly responsible for changes 1 through 3 listed above. Our geodynamic modeling is consistent with a relatively small drop in global mantle potential temperature and in mantle heat flow (~ 20°C and 18 mW/m2) for production of 20-30% of the volume of existing continental crust over a time interval of 150 My at 2.7 Ga. This reduces effective melt fraction in the upper mantle by 4-20%, depending on depth of melting.

Although either of the current ideas for the origin of thick late Archean lithospheric roots remains viable (plume head restite or incompletely subducted oceanic plates), incompletely subducted plates are consistent with geophysical data beneath Archean cratons and with geochemical data from Archean basalts that suggest shallow sources of magma production. An increase in the volume of continental sediments, some of which contribute to sources of granitic magmas, is also an outcome of the production of volumetrically significant cratons in the late Archean.

A model explaining ^{210}Pb-excesses observed in magmatic enclaves and segregation veins

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We propose a simple model, involving a magma column, filled with a magma having homogeneous Ra concentration and loosing Rn from the deeper part, due to degassing of major gas species that accumulate in the shallower part and generate ^{210}Pb-excesses. In such a model of internal Rn redistribution, the whole magmatic system (Rn-degassing magma of mass M_d + Rn-accumulating magma of mass M_a) should remain in radioactive equilibrium, which can be written using a mass-balance equation: $M_a\,(^{210}Pb)_a + M_d\,(^{210}Pb)_d = (M_d + M_a)(^{210}Pb) = (M_d + M_a)(^{226}Ra)$.
By introducing $R = M_d/M_a$, this equation becomes:

$$(^{210}Pb)_a + R\,(^{210}Pb)_d = (R + 1)\,(^{226}Ra), \text{ and:}$$

$$(^{210}Pb/^{226}Ra)_a = 1 + R\,[1 - (^{210}Pb/^{226}Ra)_d].$$

$(^{210}Pb/^{226}Ra)_d$ is given by equation (11) in the paper by Gauthier and Condomines (1999), where f is the fraction of ^{222}Rn degassed. Thus,

$$(^{210}Pb/^{226}Ra)_a = 1 + R\,f\,[1 - \exp(-\lambda t)].$$

Note that assuming f = 1 gives the minimum estimate of R, and that the steady state value of the $(^{210}Pb/^{226}Ra)_a$ ratio is 1 + R.

The ^{210}Pb-excess measured in a segregation vein in the 1966 lava flow on Surtsey island, can be explained by the model above and constrains the time for the formation of the segregation vein. Another example comes from mafic enclaves found in the 1939 and 1950 dacitic lava flows at Kameni island, Santorini, that have $(^{210}Pb/^{226}Ra)_0$ as high as 6.9, implying a ratio R (mass of Rn-degassing magma over mass of Rn- accumulating magma) between 5 and 20 beneath the Santorini caldera in the first half of the 20th century.