Why so much gold in the Archean? Some thoughts linking the Witwatersrand gold endowment to hydrothermal processes

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Archaean cratons constitute a tiny fraction of today's continental surface, but are disproportionately endowed by gold mineralization, amounting to more than half of the known economic resources. Through Earth's history, gold ore accumulation in veins and shear zones by metamorphic and/or deep-seated magmatic fluids broadly correlates with the rate of continental crust formation, both showing a prominent peak in the Archean at 3.2 – 2.5 Ga. The Witwatersrand basin in the Kaapvaal Craton also formed in this period, hosting some 40% of economic gold ore in fluviatile conglomerate layers that also contain pyrite pebbles, uraninite grains and reduced carbon. The enrichment of these minerals within conglomerate layers occurred near the paleosurface, but the mechanism of gold deposition (clastic or early hydrothermal), the transport medium (fluvial or shallow marine water; mechanical or chemical) and the source of the gold remain debated.

Mass-balance estimations indicate that craton-scale erosion of normal crustal rocks could deliver enough gold to produce the Witwatersrand ores. However, if transport and enrichment occurred mechanically in placer deposits, this requires that particles of native gold were available in the eroding crust. The process that may have precipitated these primary gold particles may well be a critical step in the exceptional endowment of Archean crust with economic gold deposits. In today's surface environment, most of the hydrothermal flux of gold through the upper crust becomes dispersed, ending up in slightly gold-enriched black shales that are liable to recycling, but only locally contribute to later ore formation. By contrast, the acid surface environment in Archean times may have acted as a near-perfect "screen" for the precipitation of all the gold transported upward from the lower crust or the mantle by crust-forming processes. Vein deposits in greenstone belts probably trapped only a small fraction of this hydrothermal gold flux, while a far greater fraction of native gold may have been precipitated near the land surface, also above widespread granitoids. Gold particles would have been ready for further concentration by mechanical transport into conglomerate reefs, but some direct precipitation of dissolved gold by reduction on local organic material in permeable aquifers may have upgraded the ore.

Changing mantle wedge geometry and magma generation processes in the Central Andes

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Miocene andesitic volcanoes in the Central Andes typically overly plateau-forming ignimbrites. These "early" andesites form low angle volcanic shield volcanoes succeeded by more evolved steep-sided strato-cones. These cover smaller areas and are characterized by amphibole phenocrysts. Such a transition could be either due to a change in the melting regime in the mantle wedge from decompression (hot and dry?) to flux melting (wet and lower T?) or to different magma production and effusion rates.

We studied samples that represent different ages, petrography, composition, and volcanic style in order to test differences in processes of magma generation. Based on a survey of >4000 chemical analyses (http://andes.gzg.geo.uni-goettingen.de/) and the distribution of SiO_2 we selected three representative sample types 1) the most mafic samples (50-55 % SiO_2), 2) the intermediate andesites representing 63 % of the data (55 -60 % SiO_2) and 3) felsic samples (60-65 % SiO_2) which were identified before as important endmember magma type in the Central Andes. Using a range of geothermometers and hygrometers, we show that the most significant parameters regulating viscosity at the time of eruption remained surprisingly constant throughout Andean history (e.g. 940°C to 1020°C for 2 pyroxene thermometry). Therefore, the rate of effusion, and by implication, magma production and upper crustal stress regime rather than eruption temperature are the primary factors that influenced flow length and flow field type.

Another important parameter maybe preferential erosion of Miocene stratocones relative to distal lava fields. An increase in slab dip after a time of flat-slab subduction may increase melt production in the mantle wedge and result a change in stress regime in the upper Andean plate. Ensuing high effusion rates during the Miocene produced lava shields with stacks of long lava flows at the base of (now eroded) steeper stratovolcanoes. Erosion of the central stratocone left isolated lava fields. By contrast, lower melt production and effusion rates during the Pliocene the Quaternary reflect more diverse ascent paths and crustal magma systems with more diverse cooling, crystallization, assimilation, and mixing histories. At the same time, the depth of magma evolution changed as represented by increasing garnet signatures from Miocene to Pleistocene lavas.

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