A maximum age of the Nuvvuagittuq supracrustal belt, northern Québec (Canada) at 3.77 Ga

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The Nuvvuagittuq supracrustal belt (NSB) is the oldest granitoid gneiss complex so far discovered in Canada's Northeast Superior Province (NESP). U-Pb zircon ages for ortho- and banded gneiss sheets which transect NSB volcano-sedimentary lithologies (banded iron-formation, quartz-biotite schists, and various amphibolites) established a minimum age for these rocks of 3.75 Ga [1, 2]. Mineral-pair thermometry, zircon U-Th-Pb age vs. depth profiles, REE-partitioning and Ti_{Zr} thermometry, shows that the NSB subsequently experienced several episodes of deformation and thermal metamorphism which began at 3.6 Ga with granitoid intrusions surrounding the belt, and culminated with terrane assembly at upper amphibolite facies in the late Archean [3]. NSB rocks preserve abundant cummingtonite-rich amphibolites with unusually low Ca-content [4]; based on field relations they are unlikely to be gabbroic, and geochemistry indicates the protolith may have been an altered tuff. A recent study of the cummingtonite rocks, and a 3.75 Ga granitoid gneiss at Porpoise Cove, reported resolvable deficits in ^{142}Nd relative to the terrestrial standard [5]. Yet, these same rocks also preserve conventional ^{147}Sm/^{143}Nd isochron ages of ca. 3.8 Ga [5]; consonant with U-Pb zircon geochronology [1]. If the NSB amphibolites represent ancient crust isolated from the evolving mantle around ca. 4.28 Ga as proposed [5], it makes sense to independently verify the possibility. The amphibolites are characteristically low in Zr (<50 ppm), and no igneous zircon has so far been found. Our fieldwork (July 2008) identified four candidate detrital quartzites (Qtz+Fuch+Po±Mag±Zirc) in the NSB, including one sample from within the ^{142}Nd-deficient cummingtonite reported in [5]. We find that the oldest, most concordant zircons which also have igneous Th/U compositions and Ti_{Zr} temperatures in these samples is 3.77 Ga. Based on these results, we propose that the maximum age of the NSB is ca. 3.8 Ga and that earlier ^{142}Nd deficits may have been inherited by isolated remelting of some remnant of Hadean crust.

[1] Cates and Mojzsis (2007) *EPSL* **255**, 9-21. [2] David *et al.* (2009) *GSA Bull.* **121**, 150-163. [3] Cates and Mojzsis (2009) *Chem. Geol.* doi:10.1016/j.chemgeo.2009.01.023. [4] O'Neil *et al*. (2007) *Dev. Precamb. Geol.* **15**, 219-250. [5] O'Neil *et al*. (2008) *Science* **321**, 1828-1831.

Evidence that barely-contained nearly-explosive venting of large volumes of magmatic volatiles initiated porphyry Cu formation

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Conversion of hornblende to biotite through the addition of K at high temperature is the earliest, most extensive alteration in porphyry copper deposits. In the Butte deposit in Montana a 7 x 4 x 2 km deep rock volume is altered by the addition of ~1 wt% K at ~600°C. The transition to fresh quartz monzonite occurs over a distance of only ~230 m. The pre-main stage porphyries and the main stage veins sit within a small portion of the K alteration.

The volume of magmatic volatiles vented is measured by the K altered rock volume; the rate of volatile expulsion by the width of the transition zone. Division gives the duration of venting. The most likely parameter values at Butte indicates that the alteration occurred in ~900 years when ~100 x 10^9 m^3 of magmatic volatiles were expelled from an ~8.3 km diameter magma body. Uncertainties in matrix porosity, pore tortuosity, and fracture spacing and the fraction transmitting fluid at any one time suggest range of 1/3rd to ~50 times the 900 year estimate.

The K altereration requires 22 times the volatile volume needed to heat the rock to 600°C. Thus the Butte system started by heating a rock volume ~3 times larger than that potassically altered, and the K alteration occurred under isothermal conditions. The two pre-main stage porphyry deposits formed as the venting wained and the system cooled to ~450°C, allowing SO_2 to disproportionate to H_2SO_4 and H_2S. System life was ~500,000 years- the conductive cooling time of the heated volume. This is a reasonable estimate provided weak venting did not significantly prolong nor convection accelerate the cooling. The spectacular 3 m wide main stage chalcocite veins formed ~1.8 Ma after the pre-main stage as a consequence of a less contained venting of volatiles from a second intrusion.

Porphyries are susceptible to explosive eruption (Mt Pinatubo, sector failure, pebble dikes). The evolution from rapid to slower, cooler venting with mineralization and acid attack matches geological observations. Rapid initial venting requires rapid magma crystalization and it is challenging to understand how this might occur.