Timing of metamorphism and stabilization of Paleoproterozoic Laurentia

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The amalgamation of Laurentia included two major coeval circum-Superior craton accretionary events that are separated by over 1000 km: the 1.9-1.8 Ga Penokean (L. Superior region, USA) and Trans-Hudson (Sask-Man, CND) orogenies. Geochronometric studies utilizing the complimentary micro-analytical techniques of ion microprobe, EMP and single-crystal TIMS dating, in combination with mineral elemental mapping and Ar-Ar thermochronometry, are being carried out to dissect and reveal the orogens' peak- to post-metamorphic evolution. Monazites from both orogens exhibit complex elemental zonation and yield geochronometric evidence for two major thermal episodes at 1.83-1.80 (M1) and 1.76-1.75 Ga (M2); each event was concomitant with granitic magmatism. Thus far our work suggests that metamorphic textures (single-phase and polyphase) can be linked with geochronometric data via monazite inclusions within metamorphic minerals (garnet, staurolite, kyanite). Following M2, the two orogens record a relatively distinct mid-to-upper crustal cooling event, indicated by uniform ca. 1.75 Ga Ar-Ar hornblende and mica ages and locally lasting until ca. 1.70 Ga. The combined M2 episode and subsequent rapid cooling is interpreted to reflect orogenic collapse leading to crustal stabilization and the formation of a major Paleoproterozoic non-conformity (deposition of mature Baraboo and Athabaska quartzites). After the apparent contemporaneous metamorphic evolutions, the two orogens' histories significantly diverge. The Trans-Hudson was "armored" by surrounding Archean cratons and therefore was not structurally modified since it stabilized ca. 1.75 Ga. In contrast, the Penokean was a continental margin orogen that was strongly susceptible to continued tectonic activity along the southern margin of Laurentia. For instance, reset Ar-Ar age data from basement beneath folded quartzites show that much of the stabilized juvenile Penokean crust was strongly deformed at 1.65 Ga during Mazatzal accretion from the south. At ca. 1.47 Ga, the Penokean crust was invaded by rapakivi granites of the Wolf River Batholith, which reset some chronometers: Ar-ion laser microprobe age data documents the presence of significant age gradients across muscovite crystals; from 1900 Ma (core) to 1400 Ma (rim) in one case. Documentation of these deformation/thermal episodes establishes the Proterozoic geology of the Lake Superior region in the context of a long-lived convergent orogen model, an active margin that stretched from southern Greenland to southwestern North America.

Evidence for ~3.8 Ga meteorite bombardment of the Earth

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Introduction

Impact melts of returned lunar samples and lunar meteorites yield ages of 3.85-3.92 Ga, revealing that extensive cratering of the lunar surface was the result of late heavy meteorite bombardment (LHB). Although it is widely accepted that the Earth suffered contemporaneous LHB with the Moon, no record of this event has yet been reported from the few crustal remnants that approach the age of the LHB. Short-lived radioactive decay schemes appear to offer great promise for detection of bolide impacts. For example, using the ^{53}Mn–^{53}Cr system (half-life 3.7 Ma) Shukolyukov and Lugmair (1998) identified a carbonaceous chondrite-type impactor for the Cretaceous-Tertiary boundary. Different classes of meteorites are characterised by different W-isotope compositions (Halliday et al., 2001 and references therein; Yin et al., 2002) that differ from the homogenous W-isotope signature of the accessible Earth. We therefore determined W-isotopes of ~3.8 Ga old sediments from the Isua greenstone belt, Greenland and from closely related rocks from Northern Labrador, Canada, in order to test for significant addition of meteoritic W from the LHB to early Archaean sediments.

Results and Discussion

All published (Halliday et al., 2001) as well as our newly determined W-isotope compositions of accessible terrestrial rocks yield homogenous W-isotope compositions (here defined as $\varepsilon_W = 0$). Repeated measurements of different early Archaean sediments from Greenland and Canada revealed ^{182}W deficits in the range –0.44 to $-1.23\varepsilon_W$. These ^{182}W deficits are well correlated with siderophile-element/lithophile-element ratios such as Cr/Ti or Ni/Nb. These trends extrapolate within error to chondrite and iron meteorite datapoints. By contrast, an average early Archaean terrestrial crustal composite yields the same W-isotope composition as the accessible Earth. This implies that unradiogenic W was not a feature of the early Archaean mantle. We interpret the ^{182}W deficits in early Archaean sediments to indicate addition of meteorite W during the LHB.

References

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