Petrology of two pre-orogenic granites, Damara Orogen, Namibia

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The Damara Orogen sensu strictu of Namibia was formed during the late Archean/early Proterozoic Pan-African orogenic event. It is characterised by medium p/high T regional metamorphism and large-scale granitoid intrusion. The two plutons investigated in this study are part of the Damaran Northern Central Zone within the Okombahe district and can readily be distinguished by field criteria. LA-ICP-MS U-Pb geochronology on zircon yielded similar ages of 576±6 Ma and 571±5 Ma. This is the earliest date of granite intrusion discovered in the Central Damara Orogen. Both plutons consist of granodiorite and granite that are metaluminous to slightly peraluminous. Both rock types have high calculated zircon saturation temperatures up to 890°C, show only limited fractionation and exhibit no signs of shallow crustal contamination. Chemical and isotope data overlap almost completely in which the granodiorites and granites are characterized by a range in K_2O (3.1-5.9 wt.%) and moderate to high HFSE and LREE abundances (up to 620 ppm Zr and 250 ppm Ce) and a strong enrichment of LREE over HREE (La/Yb: 19-49) with variable negative Eu anomalies (Eu/Eu*: 0.82-0.19). Initial Sr and Nd isotopic compositions vary over a narrow range (init $^{87}Sr/^{86}Sr$: 0.704 - 0.706; init. ε Nd: -1.9 to -3.9). Relatively young Nd model ages (T_{DM}: 1.2-1.4 Ga) and 1.7 Ga-old restitic zircon suggest a derivation from a juvenile source rock of probably meta-igneous composition. As the intrusion ages precede the minimum age of high-grade regional metamorphism, crustal heating as the cause of granite formation can be ruled out. Previous studies have shown that the meta-igneous basement of the Damara orogen has an average heat production of 6.8 HGU (1 HGU=10^{-13} cal/cm^3*sec; Haack et al. 1983). This value is significantly higher than that of average continental crust (2.14 HGU; Rudnick & Gao 2004) hence, a major contribution from pre-existing continental crust is possible. In addition, intrusion of large scale mafic bodies in the lower crust could also potentially provide some extra heat for crustal melting, however, seismic refraction studies gave no evidence for the existence of large volumes of mafic rocks in the lower crust (Green 1983). We therefore suggest that emplacement of numerous sill-like intrusions (Petford & Gallagher 2001) may have provided the necessary heat for melt generation.

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Mercury Isotopes in the Precambrian

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Mercury (Hg) is an active redox-sensitive metal with a complex biogeochemical cycle that displays a wide range of stable Hg isotopic fractionation. In addition to mass-dependent fractionation (MDF), Hg isotopes also display large (up to 10‰) mass-independent fractionation (MIF). The large MIF in Hg isotopes is commonly expressed only for the odd isotopes (^{199}Hg, ^{201}Hg). To date, the large MIF in the odd Hg isotopes is thought to occur during kinetic photochemical reactions due to the magnetic isotope effect. In the first photochemical experiments (Bergquist and Blum, 2007), Hg(II) species were photo-reduced to Hg(0) in the presence of fulvic acid. It was found that the odd isotopes were preferentially enriched in the reactant in the aqueous reservoir. In these experiments, the Hg/DOM ratios were such that Hg was likely bound to carboxylic ligands. However, subsequent experiments show that the sign and ratio of MIF can be changed during photo-reduction in the presence of different organic ligands or in presence of UVC. In particular, Zheng et al. (2010) demonstrated that photoreduction of Hg bound to reduced S containing ligands results in the odd isotopes being depleted in the reactant in the aqueous phase.

The chemistry of the atmosphere and ocean changed drastically in the Precambrian due to the evolution of life and rise of oxygen. The large changes in the redox conditions and the sulfur cycle of the surface Earth along with changes in UV penenetration likely had large impacts on the biogeochemical cycle of Hg and on the Hg isotope system. It is also likely that the nature of the organic ligands binding Hg changed dramatically in response to evolution of different groups of organisms. The goal of this research was to study Hg isotopes preserved in the sedimentary and metasedimentary geologic record where major changes in either UV shielding or major changes in the nature of DOC may have occurred. Preliminary Hg isotope analyses show that the younger samples mostly show negative MIF with $\Delta^{199}Hg/\Delta^{201}Hg$ close to 1 whereas the older samples have positive MIF with $\Delta^{199}Hg/\Delta^{201}Hg$ greater than 2. The timing of the shift is consistent with the first major glaciation and suggestion of an organic fractal haze, which would have blocked higher energy UV. The timing is also consistant with a change in S isotopes that is thought to occur because of an increase in sulfate and sulfate reducing bacteria. Both possible explanations will be discussed in the context of experimental constraints. These are preliminary results, but they reveal the potential of Hg isotopes to add to our understanding of the eveolution of life and chemistry of the early Earth.