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Using Archean sedimentary rocks from the Superior Province to decipher the crustal history and composition of the Canadian Shield

Marion Garçon (1), Maud Boyet (2), Richard W Carlson (3), and Steven B Shirey (3)

(1) ETH Zurich, Switzerland (marion.garcon@erdw.ethz.ch), (2) Laboratoire Magmas et Volcans, Clermont-Ferrand, France, (3) Carnegie Institution for Science, Washington DC, United-States

The Superior Province is the largest Archean craton on Earth and makes up the core of the Canadian Shield. Rocks in the craton range in age from 4.3 to 2.7 Ga and were assembled circa 2.7 billion years ago by a process of accretion of pre-existing continental fragments. The history and composition of these continental blocks are still poorly known, yet understanding their origin is fundamental to constrain the composition of the first continents and to understand the geodynamic forces that shaped the Earth early in its history.

Here, we focus on sedimentary rocks that average the composition of large continental areas to get a comprehensive view of the crustal history of the Southern Superior Province. We analyzed 143-142Nd and Hf isotopic compositions of Archean sandstones, siltstones, and shales from different sub-provinces (Quetico, Wawa, Wabigoon, and Abitibi Sub-provinces, ca. 2.7 Ga) from different depositional settings including large- and small-scale basins, as well as alluvial-fluvial environments. In addition, we present the details of a new method that was developed to obtain the best possible precision and accuracy for 142Nd isotopic analyses on TIMS (Garçon et al., Chemical Geology, 2018). This new technique is based on a 4-line acquisition scheme to determine all Nd isotope ratios dynamically and better evaluate the quality of individual runs. Based on observations and statistics, we defined criteria for which a run should be rejected and introduced a systematic drift-correction for changing mass fractionation when using ratios from different acquisition lines. On three instruments over a 1.5 year interval, measurements yielded long-term precisions < 4 ppm (2s) increasing the across-laboratory reliability of measured 142Nd anomalies in samples.

Results on Archean sedimentary rocks from the Superior Province indicate small variations in sediment provenance depending on the depositional setting, but the vast majority of our 143Nd-Hf data show that the eroded crust was radiogenic with ε143Nd (t = 2.7Ga) and εHf (t = 2.7Ga) values between 0 and +4. This suggests that the continental fragments assembled to form the Southern Superior Province were young, extracted from the depleted mantle on average only about 100 Ma before their erosion. In contrast, the 146Sm-142Nd isotopic systematics in the same sediments show small excesses in 142Nd up to +7 ppm compared to terrestrial values. As 146Sm was only extant during the Hadean, the variability in 142Nd in the Superior sediments shows that the source rocks of the sediments were derived from a portion of the mantle affected by Hadean differentiation events. Taken together, the 142-143Nd and Hf isotopic signatures of the sediments reveals that the Southern Superior craton was in part formed from a depleted mantle reservoir that differentiated before 4 Ga. Crustal rocks in the Southern Superior craton thus sampled a mantle with inherited Hadean heterogeneities, and retained the >4 Ga geodynamic history of the Earth.