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Si isotope ratios in ancient marine chert provide a test of hypotheses for the origin of Precambrian iron formation

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Banded iron formation is a uniquely Precambrian sedimentary rock type composed entirely of authigenic iron minerals and chert (microcystalline quartz). Iron formation has a limited distribution in the sedimentary record, presumably because of a secular change in the oxidation-reduction potential of the oceans and atmosphere. However, after decades of scientific inquiry there remain several competing hypotheses regarding the origins of these deposits.

A recent hypothesis for the origin of banded iron formation invokes a mechanism of efficient shuttling of silica to deep-water sedimentary environments by the (biologically influenced) iron cycle. Considering the isotopic behavior of silica adsorpion on iron oxides (from experimental studies) in the framework of a simple mass balance model of the Late Archean silica cycle, this hypothesis makes the prediction that there should be consistent and observable differences between the Si isotope ratios of deep-water banded iron formation and shallow water stromatolitc chert. We test this hypothesis by measuring 30Si/28Si using secondary ion mass spectrometry (SIMS) in a suite of samples of deep-water banded iron formation and coeval peritidal stromatolitc chert collected within a well-constrained sequence stratigraphic and sedimentological framework from the Late Archean to earliest Paleoproterozoic Campbellrand-Kuruman sedimentary succession, preserved in the Griqualand West structural basin of the Transvaal Supergroup, South Africa.

Our results show that the δ30Si of chert in banded iron formation is remarkably low and varies by > 3‰ on a spatial scale of a several millimeters. In contrast, coeval shallow-water silicified stromatolites are characterized by positive δ30Si and do not show as large variability. Texture specific analyses carefully tied to an understanding of sample paragenesis from petrography reveals important isotopic differences between early and late diagenetic phases. This pattern illustrates the utility of a SIMS-based approach compared to bulk-rock methods for studying these lithotypes. Our data are consistent with the predictions of the iron shuttle hypothesis, and show that there were important low temperature processes fractionating silicon isotopes in Late Archean and Paleoproterozoic seawater.