Metamorphic history of the pre-3750 Ma Nuvvuagittuq Supracrustal Belt, Québec (Canada)

N.L. CATES AND S.J. MOJZSIS

Department of Geological Sciences, University of Colorado, Boulder, Colorado USA (cates@colorado.edu)

The ca. 3750 Ma Nuvvuagittuq Suprucrutal Belt (NSB) in northwestern Québec is among the oldest volcano-sedimentary sequences thus far discovered; it overlaps in age with the Eoarchean Isua Supracrustal Belt and the Akilia association supracrustal enclaves in West Greenland [1]. Mapped NSB sequences are dominated by amphibolites (± Gt), ultramafic rocks, granitoid gneisses and leucogranite intrusions, but also comprise both chemical and detrital metasediments such as finely laminated banded iron-formations and quartzite. Like other pre-3600 Ma terranes, the NSB has been thermally metamorphosed and multiply deformed. Our preliminary garnet-biotite and plagioclase-amphibole geothermometry coupled with U-Pb zircon geochronology suggests that the belt last reached the mid- to upper amphibolite facies (550-600°C) in the late Archean.

To explore in detail the timing of events in the NSB, we obtained U-Th-Pb depth profiles for two zircons from a trondhjemitic orthogneiss that shares the entire deformational history of the outcrop. Both zircons were previously analysed via conventional ion microprobe techniques and their core ages correspond with the oldest ages for the NSB (3755±7 and 3752±10 Ma). Grain IN05022_26 preserves a thin overgrowth and large core with rythmic zoning. Our depth profile penetrated 6.7 μm into the zircon and the core was reached within the first 2.25 μm. The weighted mean of all core Pb-Pb ages yields an age of 3802±12 Ma and Th/U (0.31) consistent with igneous growth in a melt of the composition of the host gneiss. Grain IN05003_18 preserves an unzoned overgrowth over a rythmically zoned core. The 1 μm thick overgrowth yields an age 2736±25 Ma with very low Th/U (0.009) consistent with growth in a metamorphic fluid. The core age of 3743±26 Ma was reached at a depth of 4.6 μm and has a Th/U (0.39) consistent with igneous growth. A thin (<1 μm) intermediate age plateau of 3668±26 Ma with somewhat lower Th/U (0.25) than the core may record an earlier metamorphic event for the NSB. The ca. 2700 Ma event in the zircons corresponds to the amalgamation of the Minto block and initiation of widespread igneous activity in the vicinity of the NSB [2]. This is likely recorded by our thermometry which documents mid- to upper-amphibolite facies metamorphism. The 3650 Ma event probably corresponds to the intrusion of the Voizel suite granitoids which surround the NSB [3].

References

[1] Cates, N.L. and Mojzsis, S.J. (2007) *EPSL* **255**: 9-21.

[2] Percival, J.A. and Skulski, T. (2000) *Can. Mineral.* **38**: 345–378.

[3] Simard, M. *et al*. (2003) Géologie de la Région de la Rivière Innuksuac (SNRC 34 K et 34 L), Ministère des Ressources Naturelles, Québec, RG, **2002**-10.

Archean methane, oxygen and sulfur

D.C. CATLING[1], M.W. CLAIRE[2] AND K.J. ZAHNLE[3]

[1]Dept. of Earth Sciences, University of Bristol, Queen's Rd., Bristol BS8 1RJ, U.K. (David.Catling@bristol.ac.uk)

[2]Astrobiology Program/ Dept. of Astronomy, University of Washington, Box 351580, Seattle WA 98195, U.S.A.

[3]MS 245-3, Space Science Division, NASA Ames Research Center, Moffett Field, CA 94035, U.S.A.

Mass-independent fractionation (S-MIF) of S isotopes marks the 2.4 Ga division of Earth's anoxic and oxic atmospheres. We emphasize that S-MIF also indicates abundant Archean atmospheric CH_4. In addition, the magnitude of S-MIF reflects the size of S gas fluxes to the atmosphere. Thus, high amplitude S-MIF in the late Archean may indicate the advent of significant biogenic S gases.

Relatively inert CH_4 leaves little geochemical trace. For many years, the only evidence that Archean CH_4 was abundant came from a global distribution of 2.5-2.8 Ga ^{12}C-enriched kerogens attributed to methanogenic CH_4 incorporated into methanotrophs. S-MIF now provides independent evidence. S-MIF occurs when S exits the atmosphere in soluble sulfate and insolube polymerized sulphur (S_8) [1]. Our models [2] show that O_2 <1 ppmv and a high abundance of CH_4 are required for significant rainout of S_8. Sufficient CH_4 enables the reduction of S-bearing gases to S_8. Plentiful H_2 is an alternative but is implausible because H_2 is biologically converted to CH_4.

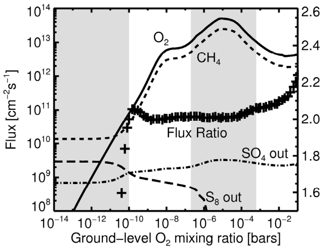

Fig. 1: Fluxes in a 100 ppmv CH_4 atmosphere. Plus symbols ("+") indicate the ratio of O_2 (ϕ_{O2}) to CH_4 (ϕ_{CH4}) bio-fluxes, on the R.H. axis. Shaded regions have implausible O_2 fluxes.

After the advent of oxygenic photosynthesis, photochemically-stable anoxic or oxic atmospheres can exist (Fig. 1). A ~3% increase in the ratio of O_2:CH_4 fluxes to the atmosphere causes a transition to the oxic state. In an anoxic environment, O_2 and CH_4 flux to the atmosphere in a 2:1 redox neutral ratio, according to $CO_2 + 2H_2O = 2O_2 + CH_4$, the net reaction of photosynthesis + methanogenesis. This ratio increases if sufficient sulfate allows microbial anerobic oxidation to change the reduced partner of O_2 from gaseous CH_4 to solid sulfide. Alternatively, with increasing sulphate, the reduced partner of O_2 may change from CH_4 to biogenic sulphur gases. These gases, unlike CH_4, are kinetically more unstable than O_2 and may have left a signal in S-MIF.

References

[1] Pavlov, A.A., Kasting, J.F. (2002) *Astrobiology* **2** 27-41.

[2] Zahnle, K., Claire, M., Catling, D. (2006) *Geobiology* **4** 271-283.