The evolution of Earth’s atmosphere as recorded by continental crust

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In partnership with Durham University

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Key Words

Overview

Background: Nitrogen is the most abundant gas in today’s atmosphere, but this may not always have been the case. A recent survey of different rock types suggested that large quantities of nitrogen are stored in the mantle and continental crust (Figure 1), indicating that nitrogen can transition between the atmosphere and geosphere. This is important because the mass of Earth’s atmosphere, and fluctuations therein, exert a massive control on Earth’s deep-time climate, and the development of habitability.

Some data suggest that atmospheric pressure was markedly lower in the Archean (2.7 billion years ago) [3], which would imply that a larger fraction of nitrogen was stored in rocks at that time. On the other hand, recent measurements of Archean crustal rocks show low nitrogen abundances [4], suggesting that nitrogen was transferred from the atmosphere into the geosphere.

Figure 2: Conceptual model of the evolution of the atmospheric $N_2$ reservoir [2]. A steady decrease would be supported by low abundances of nitrogen in ancient rocks [4]; a steady increase is indicated by some paleobarometric data [3].

The most likely transfer pathway is uptake of atmospheric $N_2$ into biomass as ammonium [5], followed by biomass burial in sediments and accretion of sediments onto continental crust. However, the efficiency of this pathway is not well constrained, and it is unknown how the sequestration of nitrogen into minerals and rocks has changed, over time [6]. In short, it is unknown where nitrogen was in the past and how it got there.
Objectives: This project aims to address these questions with particular emphasis on reconstructing the growth and isotopic composition of the continental nitrogen reservoir and its relationship with atmospheric N$_2$ abundances over the course of Earth’s history. The project will be broken down into several steps:

1. Systematic comparison of sedimentary-derived granites (S-type) and igneous granite (I-type): This step will serve as a test of the hypothesis that sediments rich in biogenic nitrogen are indeed a source of nitrogen to continental crust. In addition to nitrogen abundances, the isotopic $^{15}$N/$^{14}$N ratio of the samples will be used as a tracer for potential contributions of mantle-derived nitrogen (Figure 3).

2. Development of a nitrogen database of major minerals: Identifying (in situ) the major nitrogen host minerals will allow us to understand trends in nitrogen abundances across different rock types.

3. Track nitrogen in granitic rocks through Earth’s history: A compilation of nitrogen abundances and isotopic ratios in carefully-selected crustal rocks and mineral separates will provide the basis for reconstructing the evolution of atmospheric nitrogen from the early Archean to the Phanerozoic. The linkage will be further informed with numerical box models in collaboration with Dr Colin Goldblatt in Canada.

Methodology

- **Sample collection:** Some samples require collection from curators, while others require field-work (UK, Australia, South Africa, USA).
- **Petrological characterization:** characterization of mineral assemblages by light microscopy, SEM-EDS (major elements) and LA-ICP-MS (trace elements; U. Durham); quantification of nitrogen contents by EPMA (U. St Andrews).
- **Nitrogen extraction:** bulk rocks and mineral separates will be prepared by offline combustion

References & Further Reading


**Further Information**

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