Boron cycling in the Central Andean subduction zone: Evidence for recycled components

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Subduction zones, such as the active Andean margin, form large recycling systems and are the main producers of new continental crust. Some of the material which enters the subduction zone, including terreginous and pelagic sediment and oceanic crust, is recycled to the continental crust via arc magmatism, and some re-equilibrates with the mantle. Boron has been identified as an ideal tracer for mass transfer in subduction zones, especially of recycled slab compents (eg. [1, 2]). The study area is located within the Pampean flat slab segment (~27° - 33°S) of the southern Central Andes. This segment is currently volcanically inactive due to the low angle at which the Nazca plate currently subducts beneath the South American plate. This low angle has been attributed to the subduction of the Juan Fernandez Ridge, a volcanic seamount, which began intersecting the Andean continental margin during the early Miocene (~18Ma) [3]. Volcanism terminated in the region during the late Miocene (~6Ma).

A suite of Eocene – Miocene arc volcanic rocks were sampled from the southern Central Andes (28° to 32°S). Whole rock major- and trace-element data indicate variable contamination of the magmas during this interval but the source of the contamination remains enigmatic. New *in situ* analyses of boron concentrations and isotope ratios in pyroxene and zircon hosted melt inclusions were measured by SIMS, in order to identify contributions to Central Andean arc magmas from the subducting slab and sediments. This new data has been combined with high resolution, U-Pb zircon dating to provide insight into the petrogenetic evolution of magmas along the margin.

Average boron concentrations and isotope ratios obtained for the three Miocene samples are distinctly higher ([B] = 111.7 ±9.0 ppm, $\delta^{11}B$ = 4.47 ±0.86 ‰ (2σ)) than those obtained for the four Eocene – Oligocene samples ([B] = 76.3 ±15.9 ppm, $\delta^{11}B$ = -0.09 ±1.01 ‰ (2σ)). This suggests Central Andean arc magmas received a greater influence from slab derived fluids after the intersection of the Juan Fernandez Ridge and subsequent shallowing of the Nazca plate. This work demonstrates boron isotope ratios can be used in combination with high resolution U-Pb dating and major and trace element geochemistry to provide new insights into arc processes in changing geodynamic settings.

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Microbially mediated phosphogenesis 2 Ga ago

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Modern phosphogenesis is typically associated with high productivity upwelling systems where apatite (Ca-phosphate) precipitation is mediated by large sulphur bacteria [1]. They live in the upper few centimetres of sediment at oxic/anoxic interface and thrive in close association with a consortium of anaerobic methane oxidising archaea and syntrophic sulphate-reducing bacteria.

Paleoproterozoic Zaonega Formation in the Onega Basin, Karelia, Russia, is a c. 1500 m thick succession of organic-rich sedimentary rocks interlayered with mafic tuffs and lavas, containing several P-rich intervals in its upper part. Microsructure of these P-rich intervals exhibit apatitic laminae and particularly nodules up to several hundred μm in size. Individual apatite particles in P-rich lamellas and nodules occur as cylindrical apatite aggregates 0.5-4 μm in diameter and 1-8 μm in length. Cross-sections of cylindrical apatite particles reveal a thin outer rim whereas the internal parts consist of small anhedral elongated crystallites.

The sizes and shape of the nodules are similar to those of giant sulphide-oxidising bacteria known in modern and ancient settings [2, 3]. Individual apatite cylinders and aggregates have shapes and sizes similar to the methanotrophic archaea ANME-1 and ANME-2 that inhabit microbial mats in modern seep/vent areas where they operate in close associations with sulphur-oxidising microbial communities [4]. Moreover apatite in the Zaonega Formation is found in organic rich sediments exhibiting strongly negative δ^{13}Corg values (-37 to -34 per mil) which is interpreted to reflect the occurrence of methanotrophic biomass. We conclude that modern-style phosphogenesis, mediated by sulphide-oxidising bacteria living in consortia with methanotrophs, was established at least 2 Ga ago in response to the oxygenation of the Earth.

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