The Distribution of Gallium in the Nechalacho REE deposit, NWT, Canada

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The layered Nechalacho Nepheline Syenite at Thor Lake, which is located within the alkaline to peralkaline Blachford Lake Complex near Yellowknife, Northwest Territories, is a potential source of exploitable gallium. It also contains large reserves of Rare Earth Elements (REE), Y, Nb, Ta and Zr, which are most enriched in the Basal Zone, an altered eudialyte cumulate layer [1]. Intense hydrothermal alteration involving replacement of primary magmatic mineral assemblages by a potassic assemblage comprising K-feldspar, biotite and magnetite, was followed by late albitisation.

Bulk-rock geochemical analyses and analyses of secondary minerals indicate that the Nechalacho Nepheline Syenite has unusually high concentrations of gallium, and that this element was both enriched and depleted by hydrothermal processes. Gallium occurs in concentrations more than a magnitude higher than its average concentration in crustal rocks. Similar enrichments are rare in nature, and the Nechalacho deposit therefore provides an excellent opportunity to identify the geochemical and mineralogical factors controlling the distribution of this element. Gallium can substitute for Al^{3+}, Fe^{3+} and other elements with similar valence and ionic radius, but is rarely found in a mineral dominated by this element.

Aluminium-bearing minerals from samples of the Nechalacho Nepheline Syenite with bulk rock Ga contents of 150 ppm or higher were analysed using the electron microprobe, following petrographic analysis. These samples are not unusually enriched in the REE. Analyses over the entire depth of a single drill hole were used to evaluate the relative importance of magmatic and hydrothermal processes to gallium enrichment.

Albite, orthoclase, biotite, chlorite, and allanite, in order of decreasing modal proportion, contain appreciable gallium. By contrast, the content of Ga in the Fe^{3+} mineral, aegirine, is below the limit of detection (≈140 ppm). Median Ga concentrations were ~ 250 ppm in albite, biotite, and chlorite and ~150 ppm in orthoclase. Variations of 200 ppm Ga or higher were observed in individual albite and orthoclase grains, and are linked to hydrothermal alteration. Fluid inclusion-rich zones in albite and orthoclase are characterised by significantly lower Ga contents than fluid inclusion-poor zones, in both albitised and non-albitised samples. Previous studies of the aqueous mobility of gallium suggest that hydroxyl and fluoride complexation may play a role in the hydrothermal mobilisation of gallium [2]. Chloritisation of biotite resulted in a Ga enrichment of ~ 150 ppm. Trends in gallium concentration for individual minerals along a single drill hole vary with the degree and nature of the alteration of the host rocks. Based on the observations presented here, albite and biotite are the principal hosts of Ga in the Nechalacho Nepheline Syenite, Ga enrichment was partially independent of REE concentration and Ga was both enriched and depleted by hydrothermal processes.

[1] Sheard *et al.* (2012) *Economic Geology* **107**, 81-104. [2] Wood & Samson (2006) *Ore Geology Reviews* **28**, 57-102.

Ten millennia of North Atlantic seasonality: evidence from stable isotope values of micromilled molluscs

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Seasonality in temperature, the difference between winter low and summer high temperatures, is one of the dominant causal variables that determines the distribution of species through time. Bivalves are particularly valuable proxies of seasonality because growth bands of bivalve shells archive high-resolution records of temporally discrete environmental information, including water temperature recorded by $\delta^{18}O$ and diet/metabolism by $\delta^{13}C$ values. Here, we present a record of North Atlantic Holocene seasonality derived by computer-controlled micromilling of well-preserved mollusc shells recovered from a near shore marine core in NW Iceland. Thirty-seven aragonitic bivalve specimens retrieved from the core were sequentially micromilled concordant with growth banding to retrieve carbonate aliquots with subseasonal resolution, and then analysed for $\delta^{18}O$ and $\delta^{13}C$ values. Previous research [1] observed significant variations in seasonal temperature in this region over the period ~360 B.C to ~A.D 1660. Here, we extend this seasonality record back to ~10,650 cal years BP, thus providing the first ~10,000-year record of climatic snapshots ~1 to 9 years in duration for the North Atlantic.

Our sampling resolution (generally 30-50μm) generated subseasonal (*e.g.* weekly to bi-monthly) $\delta^{18}O_{(CaCO3)}$ and $\delta^{13}C_{(CaCO3)}$ records from molluscs that recorded ambient seafloor water temperatures during their lifetimes. Most of the molluscs were from the genera *Macoma*, *Nuculana*, and *Thyasira*, all recovered from a single core (core ID: MD99-2266). The temperature record archived as $\delta^{18}O_{(CaCO3)}$ values was calculated assuming a constant bottom water value of 0.1‰ (based on ~50 years of $\delta^{18}O$ measurements from the bottom waters of our study region) and using an aragonite temperature-fractionation relationship [2].

Our results indicate that the oldest 1/3 of the record (~10,100 – 7,600 cal yr BP) displayed maximum summer temperatures ~2°C higher than the subsequent period from ~7,000 – 4,500 cal yr BP, while the winter temperatures were similar throughout both periods. Sporadic warm periods after 4,500 cal yr BP are evident, where the maximum summer temperatures reached ~7 to 9°C at ~4,500 and ~3,400 cal yr BP. The highest reconstructed temperatures of the entire 10,000-year record occurred during the Roman Warm Period (~200 B.C. to A.D. 400), higher than modern temperatures (typically ranging between -1 to 11°C). Temperatures calculated for the Little Ice Age were similar to those from ~10,100 to 7,600 cal yr BP and 4,500 – 2,000 cal yr BP.

[1] Patterson *et al*. (2010) *PNAS* **107**, 5306-5310. [2] Patterson *et al*. (1993) *Geophysical Monograph* **78**, 191-202.