Mechanisms of subglacial groundwater recharge as derived from noble gas, ^{14}C, and stable isotopic data

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Major ion, noble gas, stable isotope and ^{14}C data collected from a transect along groundwater flow path within a confined Paleozoic aquifer in northeastern Wisconsin, USA are used to deduce the effect of the Laurentide Ice Sheet (LIS) on the underlying aquifer. Major ion trends, ^{14}C ages and $\delta^{18}O$ derived temperatures that decrease to -5.6 °C during the last glacial maximum (~10 kyr. B.P. to ~26 kyr. B.P.) indicate that recharge continued when ice covered the area. A $\delta^{18}O$ derived temperature record that extends well below freezing, a contrasting noble gas temperature record that remains constant at ~3° C (Figure 1), high excess air (ΔNe) values
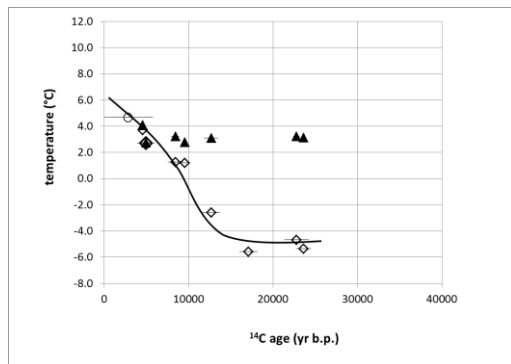

Figure 1: Oxygen isotope temperature (open diamonds) and noble gas temperatures (solid triangles) versus corrected ^{14}C ages.

and strong noble gas fractionation patterns indicate that supraglacial melt was the dominant constituent of aquifer recharge. Recharge occurred within the ice sheet as a part of a very dynamic englacial hydrologic system that experienced recharge heads of as much as 7.8m. Comparisons to a similar transect taken 150 km to the south [1] show different recharge mechanisms occurring near the terminus of the ice sheet. To the author's knowledge this is the first time that noble gas and isotope tracers have been used to deduce the mechanism of aquifer recharge beneath continental ice sheets.

[1] Klump, Grundl, Purtschert, and Kipfer (2008) *Geology* **Volume 36(5)**, 395-398.

Enrichment of Li in fluids exsolved from the Harney Peak leucogranite Black Hills, South Dakota

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Fluid inclusions provide a way to directly sample the composition of magmatic fluids and are therefore a key to investigating the role of fluids in differentiation of magmas and element mobility within plutonic systems. Laser ablation (LA) ICP-MS analysis and microthermometry were used to determine quantitatively the chemical compositions of individual fluid inclusions in the Harney Peak granite-pegmatite (HPG) system in South Dakota. HPG has a simple mineralogy, it has had no interaction with meteoric fluids and it has not been metamorphosed [1]. In the HPG system, magmatic fluids were key to development of pegmatitic segregations and a broad field of Li-bearing pegmatites. Moreover, Wilke et al. [2] attributed an enrichment of Li in the metamorphic aureole of the HPG to expulsion of Li-bearing fluids from the HPG. The objective of this study was to determine the composition of the putative magmatic fluids in order to evaluate their potential role in the differentiation of the HPG and development of the pegmatite field and metasomatic aureoles.

All analyzed fluid inclusions were hosted in quartz. Types of inclusions are: type 1 (H_2O-CO_2+salts), type 2 (H_2O+salts), type 3 (CO_2-rich) [3]. Concentrations of Li, B, Na, K, Rb and Cs were measured by LA-ICP-MS. Raw data were reduced using the AMS data reduction software [4].

Results indicate elevated concentrations of alkali elements in the fluid inclusions. The inclusions are primarily composed of Na (up to 25.7 wt.%), K (up to 0.8 wt.%) and Li (up to 0.9 wt.%), but also contain minor concentrations of Rb (≤ 0.01 wt.%) and Cs (up to 0.05 wt.%). Initial analysis also suggests a significantly higher Li concentrations is secondary type 2 inclusions compared to primary type 1 inclusions. Secondary type 2 inclusions on average have concentrations of 0.3 wt.% Li whereas primary inclusions contain less than 0.1 wt.%. This suggests that these elements were concentrated in the magmatic fluid when it seperated from the HPG magma, and that Li was further concentrated in the aqueous fluid when the magmatic fluid unmixed into carbonic and aqueous fractions.

Li is important in pegmatite formation as at elevated concentrations it can reduce the viscosity of a magma and inhibit crystal nucleation, leading to the crystalization of few large crystals [5]. The results suggest that Li in magmatic fluid was important in the formation of the pegmatite field and the metasomatism of the aureole.

[1] Nabelek & Ternes (1997) *Geochim. Cosmochim. Acta* **61**, 1447-1465. [2] Wilke et al. (2002) *Am. Mineral.* **87**, 491-500. [3] Sirbescu & Nabelek (2003) *Geochim. Cosmochim. Acta* **67**, 2443-2465. [4] Mutchler et al. (2008) *Mineral. Assoc. Can. Short Course* **40**, 318-327. [5] Nabelek et al. (2010) *Contrib. Mineral. Petrol.* **160**, 313-325.