Diffusion compensation and application of Graham's law to noble gas diffusivities

PETE BURNARD[1*]

[1]CRPG-CNRS, Vandoeuvre-lès-Nancy, France, *peteb@crpg.cnrs-nancy.fr (* presenting author)

Diffusion Compensation

The temperature dependence (E_a) of slow-diffusing species tends to be greater than that of faster diffusing species, resulting in an interdependence between D_0 and E_a [1, 2, 3]. The net result is that the difference in diffusivity between two species in a given matrix will reduce with temperature, converging at a particular "compensation" or "isokinetic" temperature where the two (or more) species have the same diffusivities.

Graham's Law of effusion on the other hand states that, as far as gases are concerned, the relative diffusivity of two species is equal to the inverse of the square root of their masses:

$D_1/D_2 = \sqrt{(M_2/M_1)}$

In situations where experimental data are lacking, this relationship is often used to calculate the relative diffusivities of noble gas pairs. However, Graham's Law and "Compensation Temperature" relationships are mutually exclusive: according to Graham's Law, two noble gases should have the same Ea and differ only in D_0 (which should be constrained by $\sqrt{(M_2/M_1)}$). There cannot be compensation of diffusion with temperature for species following Graham's Law.

Non-Graham's Law behaviour

Recent results (Amalberti et al, this volume) show that He and Ar diffusivities in silicate glasses do infact differ in Ea: Graham's Law does not apply to diffusion of noble gases in silicate glasses (i.e. it is not possible to assume that $D_{He}/D_{Ar} = \sqrt{(M_{Ar}/M_{He})}$). The predicted isokinetic temperature for He and Ar diffusion in basaltic glasses is ~1000 K. The lack of conformity to Graham's law is easily understood: The Graham's Law relation is based on the two gas species of interest having the same kinetic energy (for example, for gases diffusing through a pinhole in the classic experiments by Graham in the 19th century). Volatile species diffusing through solid matrices are not expected to be isokinetic (they are not free gases) and Graham's law likely does not apply to diffusion of gases dissolved in solid matrices.

Implications

As a result, kinetic fractionation of different noble gases will only occur at "low" temperatures (the lower the temperature, the greater the potential for kinetic fractionation). Thus it does not appear likely that diffusion during magmatic processes (mantle melting or degassing of magmas) will be able to kinetically fractionate the noble gases. However, post-deposition (low temperature) processes out of equilibrium will create large He-Ar (and by extension, Ne-Ar, Kr-Ar etc) fractionation. The geological implications of these observations will be discussed.

[1] Winchell (1969) *High Temp. Sci.* **1**, 200 - 215. [2] Hart (1980) *Earth Planet Sci. letts* **269**, 507 - 516. [3] Zhao (2007) *Am. Mineral.* **92**, 289-308.

Identification of chromitite and kimberlite occurences in the James Bay lowland using statistical analysis of detrital chromite compositions

MARCUS BURNHAM[1*], DAVE CRABTREE[1] & RIKU METSARANTA[2]

[1]Geoscience Laboratories, Ontario Geological Survey, Sudbury, Canada. marcus.burnham@ontario.ca

[2]Precambrian Geoscience Section, Ontario Geological Survey, Sudbury, Canada. riku.metsaranta@ontario.ca

Introduction

In 2001, under the Operation Treasure Hunt (OTH) program [1], the Ontario Geological Survey carried out a stream sediment sampling program in the James Bay lowland during which over 1000 stream sediment samples were collected and processed for kimberlite and metamorphic/magmatic massive sulphide indicator minerals and gold grains. Because the primary objective of this survey was to evaluate the potential of the region to host additional kimberlite pipes, an emphasis was placed on the compositions of the garnet fraction. However, with the recent discoveries of chromite, Cu-Ni-PGE-sulphide and Ti-V mineralisation in the McFaulds Lake or "Ring of Fire" area, the chemistry of the detrital chromite grains is being re-investigated through statistical analysis of the original OTH dataset (>5500 electron probe microanalyses [2]) supplemented by analyses of chromites from the bed rock (in particular lithologies associated with the McFaulds Lake area mineralisation and Attawapiskat kimberlite diatremes).

Statistical Analysis

Initial statistical analysis of the major and minor element contents of the chromites, using agglomerative hierarchical clustering (AHC) after log-ratio transformation of the data to remove the constant-sum problem [3], suggests that at least nine compositional groups can be recognised. These groups show spatial associations with the bedrock geology, most notably in their Ti, Fe^{3+}, Fe^{2+}, and V contents (Figure 1).

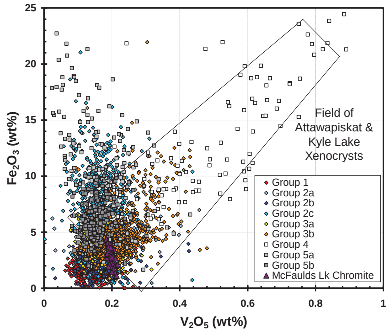

Figure 1: Compositions of detrital chromites from the James Bay lowlands. Field of Attawapiskat and Kyle Lake xenocrysts from [4].

[1] Crabtree (2003) *OGS Open File Report* **6108**, 115p. [2] Crabtree & Felix (2005) *OGS Misc. Release Data* **161**. [3] Aitchison (1986) The Statistical Analysis of Compositional Data, 416 pp. [4] Sage (2000) *OGS Open File Report* **6019**, 341p.