Solubility and Diffusion of Helium in Amorphous Diopside and Anorthite: Measurements Above and Below the Glass Transition

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Introduction

Noble gases are important tracers of a wide range of geochemical processes, therefore knowledge of solubility and diffusion coefficients are essential for any quantitative interpretation of noble gas abundance in natural materials. We have experimentally determined these parameters in amorphous silicates in the system $CaAl_2Si_2O_8$ - $MgCaSi_2O_6$ (anorthite - diopside), with emphasis placed on the role of variable melt structure, due to i) changes in composition and ii) significant temperature dependent changes such as those associated with the glass transition. Glasses of composition diopside and anorthite were synthesised, then mechanically mixed to produce intermediate compositions. Beads of liquid, approximately 2mm in diameter, were suspended on Pt-wire loops and held for 24 hours at 1600°C at 1 bar under a flow of pure He.

Solubility

The Henry coefficients for solution (K_H) was determined by complete extraction of He from glass chips (typically 10 mg) heated by laser: The results for the two endmember glasses saturated at 1600°C are:

K_H (Di) = $1.88.10^{-4}$ cc STP/g.atm,

K_H (An) = $3.95.10^{-4}$ cc STP/g.atm.

Higher He solubility in anorthite is consistent with the lower density (d=2.7 g/cm^3), thus higher ionic porosity, of this glass compared to diopside (d=3.3 g/cm^3). Solubilities of intermediate compositions are found to be a linear function of composition. Our results are consistent with those reported by Carroll (1991) and underline the important relationship between solubility and silicate melt structure.

Diffusion

Noble gases in glasses were extracted by stepwise heating and analysed by static mass spectrometry in the temperature range 700-1200K. Diffusivity is found to have an Arrhenius temperature dependence, characterised by values of pre-exponential factor (D_0) and activation energies (Ea) of:

[Di : D_0 = 16.91 cm_/s ; Ea = 39.93 Kcal/mol]

[An : D_0 = 1.113 cm_/s ; Ea = 30.31 Kcal/mol]

The diffusion coefficient of anorthite is higher than that of diopside, but values for the two appear to intersect at temperatures close to 1100K. A significant finding of this study is that no discernible change in activation energy is observed across the glass transition, despite significant volume changes (Toplis and Richet, 2000). These results are consistent with the suggestion of Jambon (1982), which reported no change in diffusion across the glass transition.

Petrology of Predazzo Magmatic Complex (Trento, Italy)

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Predazzo Magmatic Complex represents the main intrusive boby of the magmatic activity which affected the South Alpine domain during the Triassic age (238-232 My).

Field observations and petrological data allow to distinguish four main intrusive sequences characterised by a clear subduction-related signature: a shoshonitic SiO_2-saturated series (M1); a shoshonitic SiO_2-oversaturated series (M2); a K-alkaline SiO_2-undersaturated series (M3) and a Granitic Unit (G).

As concerns the subvolcanics products three main series have been distinguished: 1) shoshonitic dikes, characterised by incompatible element distribution analogous to the corresponding M1 and M2 intrusive lithologies; 2) K-basanitic dikes, cutting the granitic and monzonitic M2 intrusions, genetically linked to M3 lithologies; 3) lamprophyric dikes, cutting both the granitic and monzonitic intrusions. Lamprophyres, Middle Triassic in age, are characterised by the presence of ultramafic xenoliths and carbonatite ocelli, as well as by the absence of Nb and Ti negative anomalies. Initial $^{87}Sr/^{86}Sr$ isotopic ratios of M1 and M2 Units range between 0.70385 and 0.70649 with initial $^{143}Nd/^{144}Nd$ isotopic ratios between 0.512227 and 0.51216. On the other hand the K-basanitic dikes and M3 Unit rocks show higher initial $^{143}Nd/^{144}Nd$ isotopic ratios (0.512281-0.512386) for quite similar initial $^{87}Sr/^{86}Sr$ isotopic ratios (0.70404-0.70533). As expected lamprophyric dikes show a completely different isotopic signature, with higher $^{143}Nd/^{144}Nd$ (0.512483-0.512595) and lower $^{87}Sr/^{86}Sr$ (0.70362-0.70429) isotopic ratios.

A mass-balance closed system fractionation model was developed for M1, M2 and M3 Units. According to field relationships, petrography, mineral chemistry and isotopic data, model suggests that the Predazzo plutonic complex was predominantly generated by fractional crystallisation processes, with different magma pulses injected in multiple adjacent magma chambers in a short time span. A possible sequence of the magmatic events can be summarised as follows: a first intrusion of M1 Unit (almost contemporaneous to the volcanic products), followed by the emplacement of M2 Unit. The two intrusions were followed by the Granitic Unit, which is in turn cut by both K-basanitic and lamprophyric dikes.