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PROGRESS REPORT

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EXPERIMENTAL STUDY OF LUNAR AND SNC (MARS) MAGMAS

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ABSTRACT

The overall objectives of this research were (1) to evaluate the role of C-O-S-Cl degassing processes in explaining vesiculation, oxidation state and fire-fountaining of lunar magmas by analysis of individual lunar glass spherules, and by experimental determination of equilibrium abundances and diffusion rates of C, S and Cl melt species in lunar glass compositions; and (2) to determine possible primitive SNC magma compositions and the mineralogy of the mantle from which they were derived, and to evaluate P, T, X_{H_2O} etc conditions at which they crystallize to form the SNC meteorites.

After funding for one year, a project on the A15 volcanic green glass has been completed to the point of writing a first manuscript. Carbon- oxygen species C-O and CO_2 are below detection limits (20 ppm) in these glasses, but there is up to 500 ppm S with concentrations both increasing and decreasing toward the spherule margins. Calculations and modelling indicate that C species could have been present in the volcanic gases, however. In a second project, experiments with low P_{H_2O} have resulted in refined estimates of the early intercumulus melt composition in the Chassigny meteorite which is generally accepted as a sample from Mars.

PROJECT SUMMARY

1. Lunar Volcanic Glasses, KREEP magmas, and volatiles

A spectroscopic (FTIR, Raman) and micro-analytical study of lunar A15 volcanic green glasses is essentially complete (Rutherford and Fogel, 1993; Fogel and Rutherford; ms appended). This investigation yielded no evidence of any C-O species dissolved in 200-700 um green glass spherules. However, theoretical consideration of graphite-C-O equilibria indicate that $CO_3^=$ species in these melts would have been in very low abundance because the coexisting gas produced by carbon oxidation during magma ascent would be predominantly CO, and CO is not predicted to dissolve in basaltic melt or affect $CO_3^=$ solubility (Pawley et al, 1992). In addition, diffusion calculations for the T and cooling times involved in these eruptions predict that $CO_3^=$ would have largely diffused out of the green glass (melt) droplets in seconds. The only carbon that could still exist in the glass is elemental carbon which failed to oxidize during magma ascent for kinetic reasons, or possibly a CO or carbonyl species (the signature of a high f_{CO} in the volcanic gas). Over the next year cleaned and polished green glass beads will be analyzed for bulk carbon and for traces of elemental carbon. We will also attempt to experimentally confirm the existing data which indicates $CO_3^=$ is the only C-O species dissolved in basalt coexisting with a CO + CO_2 vapor. Recent work by McKay et al (1993) provides some evidence for the presence of a carbon-bearing volcanic gas in the form of carbon deposition on the original green glass surfaces. Colson (1993) also has suggested that the solubility of CO in basaltic melts may be much greater than previously determined.

Preliminary data on S in individual green glass spherules indicates up to 500 ppm S in various zoning profiles; some suggesting S was moving into the spherule from the surface coatings, possibly along cracks. A few traverses showed core to rim decreases similar to a diffusion-loss profile. Over the next year, the S abundance data will be confirmed by ion-probe analyses and S vs C diffusion data will be compared for various initial melt compositions in an attempt to constrain initial C, S abundances and the oxidation state of the magma. We have also arranged to make an intrinsic f_{O_2} measurement of a carefully cleaned green glass sample in Sato's laboratory if it still appears warranted after the other measurements are complete..

An experimental and theoretical project to evaluate the potential of lunar basalt to assimilate rocks of the lunar crust (Finnila et al.,1993; 1994, ms accepted by JGR-Planets) has been complete. The results illustrate that basalt superheated by an adiabatic ascent from depth could assimilate substantial KREEP (monzodiorite) both at the margins of a vertical dike, and at the roof of a magma chamber emplaced at the base of the crust. However, the amount of anorthosite or norite that could be assimilated is very limited (~7 %) under the most favorable of circumstances.

2. SNC Meteorite Studies

Danielle Ford, a second year graduate student, is working to refine previous estimates of melt compositions which existed early in the crystallization history of Chassigny (Ford and Rutherford, 1993). Previous estimates (Floran et al, 1976; Longhi and Pan, 1989; Johnson et al., 1991) indicate a low-Al_2O_3, high-FeO melt similar to the groundmass of EETA 79001 (Table 1). Given that Chassigny contains both phases as phenocrysts, we are forcing olivine (Fo_{68}) and Ca-Pyroxene (En_{76}) saturation on the A* composition determined for melt trapped by olivine in the meteorite (Table 1). These experiments are being done dry and with approximately 1.0 wt percent H_2O (forced by H_2O saturation at 100 bars pressure) in order to evaluate the suggestion (Johnson et al ,1991) that the melt contained 1.1 wt percent dissolved H_2O at the time of olivine entrapment. Experiments simulating crystallization of melt trapped in olivine where the pressure and P_{H_2O} increase to as much as 2 Kb are also being carried out as part of this project to evaluate the significance of kaersutitic hornblende in the natural melt inclusions. The Watson et al., (1993) ion probe data indicate that the H_2O is not now present in the kaersutite, which could mean that less than 1 % water was present in the trapped melt, but the stability of high-Al_2O_3 hornblende (and biotite) then become difficult to explain. The proposed experiments will be completed over the coming year. Possibly the low H_2O in kaersutitic hornblende is the result of shock; the coexisting melt phase (glass) appears to have lost its H_2O, and it must have contained ~2x the H_2O in the hornblende. During the final year of the present grant we propose to work and collaborate with Watson to find an explanation for the different water estimates. We may also prepare hornblende + plagioclase + glass samples for shock experiments to determine how maskelynite-producing shock pressures would affect OH^- in hornblende, and we will be studying two new Chassigny thin sections for possible variations in melt inclusion and/or phenocryst chemistry. We are also investigating the effect of small (10-20 percent) substitutions of F^- for OH^- on the stability and composition of kaersutitic hornblende formed.

Publications

Finnila, A.B., et al., (1993; ms), Assimilation in lunar basalts and volcanic glasses: implications for a heterogeneous mantle source region, LPSC XXIV, p 475-77.

Fogel, R.A. and Rutherford, M.J., 1993, (ms submitted, appended) Magmatic volatiles in primitive lunar glasses: FTIR and EMP analyses of A15 green and orange glasses and revision of the volatile assisted fire-fountaining theory.

Ford, D.F. and Rutherford, M.J., 1993, Primitive SNC parent magmas and crystallization: low PH2O experiments. LPSC XXIV, p 503-505.

Rutherford, M.J., and Fogel, R.A.(1993), C-O volatiles in Apollo 15 and 17 volcanic glasses, LPSC XVIV, p 1223-25.