The chemical behaviour of fluorine in volcanic systems

Supervisory Team

• Dr. Jon Wade
  https://www.earth.ox.ac.uk/people/jon-wade
• Prof. Bernard Wood
  https://www.earth.ox.ac.uk/people/bernie-wood/
• Prof Chris Ballentine
  https://www.earth.ox.ac.uk/people/chris-ballentine/

Key Words

High pressure experiments, Volcanic fluorine emissions, fluorine storage in the Earth

Overview

Fluorine is an element which, when ingested, has a range of effects on organisms. At very low concentrations it contributes to the development and strengthening of bones and teeth. At higher concentrations it has the opposite effect weakening bones and causing osteoporosis and kidney damage. Fluorine is present in very low quantities in Earth’s mantle but is concentrated in silicate melt during partial melting and brought into the crust as these melts ascend. Volcanic activity is, therefore, the mechanism by which fluorine becomes concentrated in the crust where, at high temperatures it may be degassed during eruption as volatile hydrogen fluoride. An example of major environmental damage caused by volcanogenic fluorine is the 1783 eruption of Laki (Iceland) in which about 8 million tonnes of hydrogen fluoride were released. A large fraction of the island’s sheep and cattle died of fluorosis as did 25% of the human population in the ensuing famine. Despite these important environmental effects, the properties and behavior of fluorine in volcanic melts are very poorly known. It is not certain, for example, where fluorine resides in the mantle even though it can dissolve to some extent in mantle olivine and pyroxene. It also dissolves to significant extents in the crustal phases biotite, amphibole and apatite and is assumed to be very soluble in silicate melt.

The aim of this project is to determine the solubility of fluorine in silicate melts of a range of compositions from basalt to granite and to develop a model of the conditions under which fluorine is degassed from such melts and the quantities and compositions of the degassed species.

Figure showing piston-cylinder apparatus constructed in the departmental workshop
Methodology

The project will involve the use of the piston-cylinder apparatus (Figure) to develop high pressures (up to 25 Kbar) and temperatures (up to 1600°C). Under these conditions most rock compositions of interest are fully molten. The sample is held in a welded platinum capsule typically 3mm diameter and 5 mm long. Inside the capsule will be the rock powder intimately mixed with an assemblage of silver and silver fluoride which together control the chemical activity of fluorine. After an experimental duration of about 1 hour the sample is rapidly quenched to room pressure and temperature. The molten rock “quenches” to a homogeneous glass which can be analysed for fluorine and other elements. After polishing the experimental product is analysed using the electron microprobe. DTP student Richard Thomas has considerable success studying chlorine in melts using a similar experimental procedure.

Timeline

Year 1: Training in high pressure experimental methods, sample synthesis, welding. Training in use of the electron microprobe and electron microscope. Initial experiments to establish range of fluorine solubilities in basalt and granite.

Years 2 and 3: Experiments to determine the pressure temperature and compositional effects on fluorine solubility in melts. Training in thermodynamic modelling and performance of speciation calculations. First presentation at national meeting. First manuscript for publication.

Year 4: Development of comprehensive model for fluorine solubility and speciation in melts and coexisting fluids and gases. Writing of thesis. First presentation at an international conference. Preparation of manuscripts 2 and 3.

Training & Skills

The training which accompanies this project prepares the student for a wide range of positions in academia and industry. Experimental and analytical skills are highly-prized and widely sought. Students from our group now hold professorships, run analytical facilities, work in materials and environmental science laboratories and in the nuclear fusion and fission industries.

References & Further Reading


Further Information

jon.wade@earth.ox.ac.uk; bernie.wood@earth.ox.ac.uk; chris.ballentine@earth.ox.ac.uk

D.Phil student Catherine Goddard using the electron microprobe