Volatiles (Halogens, N) in volcanic front magmas, Miyake-jima, Northern Izu-Bonin Island Arc, Japan

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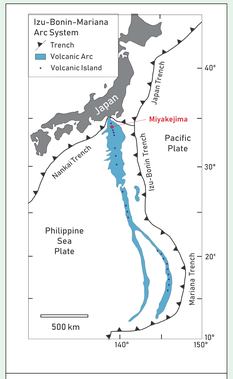
INTRODUCTION

Volatile elements are concentrated in atmosphere and surface environments. They are brought deep into the mantle via subducting slabs, and released back into the surface environment from the degassing of arc magmas.
Volatile elements such as F, Cl are important ligands for metallic elements, such as Cu, which are concentrated in subduction zones.

OBJECTIVES

Few data exist for the a whole suite of volatiles in arc magmas, including the halogens (F, Cl, Br, I) and N. The first objective is to determine the abundance of halogens in whole-rock samples in subduction-related basalts, and determine the extent of volatile degassing occuring on these basalts. The next objective is to indentify possible source(s) of halogens in subduction zones, as well as analyse melt-inclusions to estimate concentration of Cl before/during any degassing that took place.
In addition, we will attempt to measure N content of arc magma, and determine possible source(s). Finally, we will investigate the occurence of Cu in these rocks, and compare its concentration to Cl, a common ligand of Cu.

GEOLOGICAL SETTING



Geologic Map of the Izu-Bonin-Mariana Arc System showing location of Miyake-jima in the Izu-Bonin Arc (Modified from Tamura and Tatsumi, 2002)

The Izu-Bonin arc is a young oceanic arc (~50Ma) formed by the west-ward subduction of the Pacific Plate under the Philippine Sea Plate. Miyake-jima is a small volcanic island (~8km across) in the northern part of the Izu-Bonin Arc.

The island is composed of tholeiitic basalt erupted through 5 distinct eruption stages between 10,000 y.b.p. to 2000A.D. The most recent eruption in 2000 released 15Mt of SO_2 over 20 months, with emission rates greater than 40000 tonnes of SO_2/day (Kazahaya et al., 2003), and is comparable to total SO_2 released by the explosive eruption of Pinatubo in 1991.

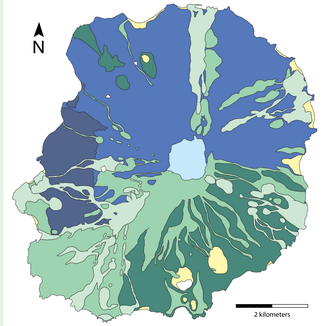


Figure X: Typical basalt sample from Shinmio eruption stage. Vesicular basalt with plagioclase and olivine phenocrysts

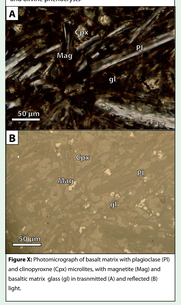


Figure X: Photomicrograph of basalt matrix with plagioclase (Pl) and clinopyroxene (Cpx) microlites, with magnetite (Mag) and basaltic matrix glass (gl) in transmitted (A) and reflected (B) light.

MELT INCLUSIONS

Melt inclusions trap primitive melt during mineral crystallization, before or during degassing. 28 glassy melt inclusions hosted in olivine were selected from 5 eruption samples and analysed with an electron microprobe. Chlorine concentrations in melt inclusion glass were compared to whole rock chlorine concentrations to compare the primitive melt to final whole-rock concentration. The average concentration of Cl in melt inclusion glass (600ppm) is only slightly above the whole rock samples (480ppm).

Sulfur in melt inclusions is present at 0.02-0.33wt% (average = 0.16wt%), above the solubility of sulphide in magmas, indication that magmas are oxidixed and sulphur is likely present as sulphate rather than sulphide

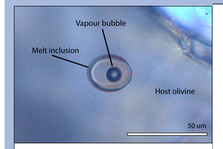


Figure X (above): Glassy melt inclusion with vapour bubble hosted within an olivine phenocryst.

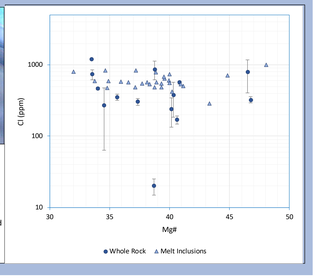
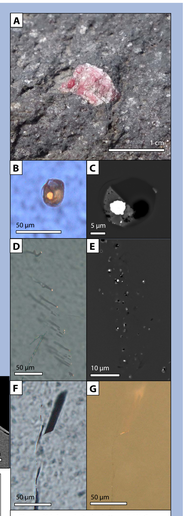


FIGURE X (right): Chlorine concentration in whole rock basalt samples (n=14) and glassy melt inclusions (n=28) from 5 olivine populations. WR samples are average between doubles run, with error showing maximum and minimum values.

COPPER

The Izu-Bonin Arc is known for its high copper content, as well as plagioclase coloured red from the presence of um-scale native copper inclusions. These Ca-plagioclase megacrysts are present in basalts from the Ofunato (8000-4000 y.b.p) to the Shinmio stage (1469-2000AD) of the Miyake-jima volcano.
Copper occurs in these Ca-plagioclase megacrysts as native copper in melt inclusions, planar-aligned tubules, and filling fractures. The occurrence of native copper in these megacrysts suggests that high concentrations of copper in the melt during and after the growth of the plagioclase.
Copper is also present as Cu-Fe-sulphides in several devitrified melt-inclusions in olivine, suggesting the presence of S during the growth of olivine.



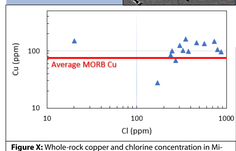


Figure X: Whole-rock copper and chlorine concentration in Miyake-jima basalt. Copper concentration in basalt is above average MORB Cu concentration (Gale et al.,2013). Chlorine and Copper cluster, indicating similar behaviour in basalt, remaining in the melt and are not degassed.

Figure X (above): (to be lettered) (A) Copper-bearing red-coloured Ca-plagioclase megacryst
(b) Melt inclusion in red-coloured plagioclase with rounded native copper bleb in transmitted and reflected light photomicrograph and (c) BSE image.
(d) Planar-aligned copper tubules in transmitted and reflected light photomicrograph
(e) Native copper in um-scale melt-inclusions along growth-zone
(f) Native copper filling fracture in transmitted and (g) relected light photomicrograph.

WHOLE ROCK VOLATILES

Whole rock halogen concentrations (F (45-190ppm), Cl(20-1200ppm), Br (0.37-9.7ppm) and I (0.01-0.11ppm) were collected from 15 basalt samples, and plotted against Yttrium. Yttrium is considered to be an incompatible, insoluble element that concentrates in the melt during fractional crystallization. Elements that positively correlate with Yttrium indicate that they remain in the melt during crystallization and are not lost to degassing.

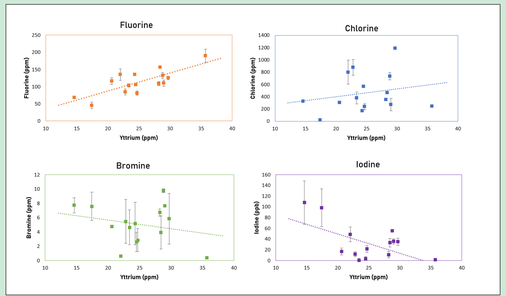


Figure X: Whole Rock Halogens plotted against Yttrium.
Yttrium is an incompatible, insoluble element in melt, Correlation with Y suggests that elements were retained in the magma, as element concentration increases with increasing Yttrium content. Decreasing trends suggest loss of volatiles from remaining melt through degassing to the atmosphere or loss to fractional crystallization. Fluorine and Chlorine show positive correlation with Yttrium, suggesting limited degassing is occuring. Lowest fluorine measured at lowest Y, Mg#, suggest a concentration of F >/= 36 in primitive magmas. Bromine and Iodine display negative correlations with Yttrium, suggesting loss from the remaining melt, likely from degassing.

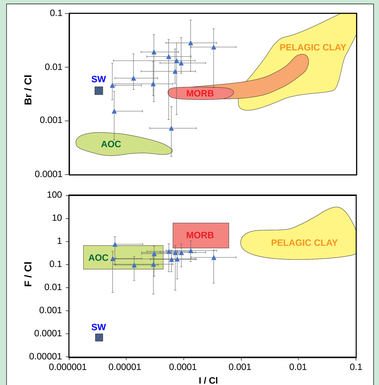


Figure X: Halogen ratios of Miyake-jima whole rock samples
- altered oceanic crust signature.
- Halogen ratios are indicative of sources of arc magmas, as each geologic source has a particular ratios of halogen based of the separation of halogens through different geologic processes
-Shows the range of compositions expected for AOC (Altered Oceanic Crust), MORB (Mid-Ocean Ridge Basalt), Pelagic Clay and SW(Seawater).
- F/Cl shows source AOC as likely source of large halogens (F, Cl)
- Br and Iodine are more highly varied, high Br shows possible influence of seawater and subducted ocean sediments

NITROGEN

The Nitrogen content of Miyake-jima basalts varies from 20-60ppm, greater than unaltered and altered MORB values (≤ 20 ppm, (Busigny et al., 2005, Li et al., 2007).

In addition, nitrogen correlates well with Rubidium, a fluid-mobile element that is present in marine sediments in high concentrations and plots on a mixing line between the depleted mantle and marine sediments, indicating marine sediments are a likely source of nitrogen in subduction zones.
When plotted with Iodine, the highest value of Iodine also plot on the same mixing line (loss of Iodine likely due to degassing).

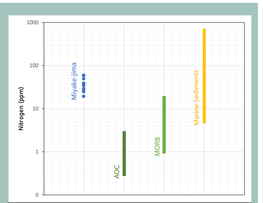


Figure X: Whole-rock nitrogen concentration of Miyake-jima samples compared to range of nitrogen concentrations of nitrogen sources in subduction zones. Mid-ocean ridge basalts (MORB): (Busigny et al., 2005), Altered oceanic crust (AOC) (Li et al., 2007), Marine Sediments (Sadofsky and Bebout, 2003)

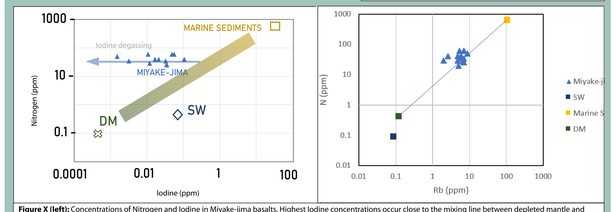


Figure X (left): Concentrations of Nitrogen and Iodine in Miyake-jima basalts. Highest Iodine concentrations occur close to the mixing line between depleted mantle and marine sediments, with spread of Iodine to left attributed to degassing of Iodine in magmas.
Figure X(right): Miyakejima whole-rock nitrogen and Rb broadly correlate along a mixing line between depleted mantle and marine sediments.
(Modified from Page et al., 2019, references there-in)

SUMMARY

- F, Cl remained in the melt with limited degassing, and chlorine has only a slightly lower concentration in whole-rock samples compared to melt-inclusion glass.
- Br, I show loss from arc magmas through degassing.
- Nitrogen likely has a sedimentary source, as indicated by correlation with Rb and Iodine.
- F, Cl show altered oceanic crust as possible source for light halogens.
- Presence of native copper in plagioclase megacrysts and Cu-Fe-S inclusions in olivine melt inclusions and suggest Cu remained in the melt and was not lost by degassing.
- **sulphur concentrations measured in melt inclusions suggest sulphur is present as sulphate in primitive arc magma.

ACKNOWLEDGMENTS

REFERENCES