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地殻・上部マントル圧力での含水メルトの密度・圧縮率モデル
The density and the compressibility model of hydrous silicate melts at crustal and upper mantle conditions

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上昇、噴火、結晶分化やマグマ混合などのマグマプロセスにおいて、メルトの密度は非常に重要な要素である。これまで、地殻からマントルウェッジの圧力（~5GPa）での含水メルトの密度や圧縮率はきちんとは制約されてこなかったが、近年、X 線を用いたメルト密度のその場測定の手法が確立され (e.g., Sakamaki et al., 2009)、高温高圧での含水メルトの密度の実験値が充実しつつある。統一的にこれらの実験結果を説明するとともに熱力学的にも整合性があるメルトの物理パラメーターのデータセットを構築することは、火山モデリングだけではなく地球物理データの解釈や熱力学モデル作成の過程においても非常に重要である。

本研究は、0-5GPa の圧力、コマチアイト、フォノライトやライオライトまでの幅広いメルト組成に適用可能な含水メルトの密度モデルの構築を行った。状態方程式としては、バーチマーナガン方程式を用いた。無水のメルトのモル体積とバルクモジュラスは、高圧実験との整合性を確認した上で、Lange and Carmichael (1990) の実験値を用いて計算した。ドライメルトの K’（バルクモジュラスの圧力微分）は、メルトの SiO_2 含有量に線形と仮定してパラメーター化を行った。これらの方程式とパラメーターの組み合わせは、これまで報告されている無水メルトの実験結果を適切に再現することを確認した。メルト中の水成分の圧縮率、熱膨張率および、部分モル体積と K’に関して、先行研究で報告された常圧および地殻から上部マントル実験値を参照して、コンパイルおよびキャリブレーションを行った。

構築したパラメーターセットを用いて様々なメルト組成や含水量に於いて密のどの計算を行った結果、過去の論文が提示していたパラメーターを使用するよりも高精度で、幅広いバルクや含水量でのメルトの密度を再現することに成功した。本研究で作成した密度モデルは、沈み込み帯メルトの圧力、化学組成、含水量の幅をカバーしており、噴火や分化モデル計算の際の固相とメルトの密度差の計算のほか、地震波速度からのインバージョンによるマントルや地殻のメルト分率やメルト組成の推定、そして、含水メルトを含む系の熱力学モデル作成に向けて有用である。含水メルトの体積や圧縮率は、ドライメルトと水成分の線形重ね合わせで表現できた。この結果は、メルト中の水成分の体積や圧縮率には、含水量やメルト組成への依存性が存在していないことを表している。このことは、含水系の溶融の熱力学モデル作成に向けて大きな制約となる。

キーワード: マグマ, 密度, 含水
Keywords: magma, density, hydrous

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Effect of the bonding and the speciation of water on the polymerization and the viscosity of silicate melts

Effect of the bonding and the speciation of water on the polymerization and the viscosity of silicate melts

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Degassing of water during the ascent of hydrous magma in a volcanic edifice produces dramatic changes in the magma density and viscosity. This can profoundly affect the dynamics of volcanic eruptions. The water exsolution history, in turn, in part is driven by the water solubility and solution mechanisms in the silicate melt and in part by the decompression history of the magmatic liquid. Previous studies pointed to dissolved water in silicate melts as molecules (H_2O_{mol} species) and hydroxyl groups, OH. The laters are commonly considered bonded to Si^{4+}, but may form different bonding, such as with alkali or alkaline-earth cations. Those various bonding mechanisms influence the structure of hydrous melts in different ways, and therefore, the melt properties. As a result, exsolution of water from magmas may have different eruptive consequences as a function of the initial solution mechanisms of water dissolved in the magmatic liquid.

However, and despite their importance, the bonding mechanisms of water in silicate melts are not clear, particularly in regards of their variation with the chemical composition of the melts. In this experimental study, pieces of such information are reported from determination of how water bonds with the ionic network of alkali (Li, Na and K) silicate quenched melts. From ^{29}Si Single-Pulse Magic-Angle Spinning Nuclear Magnetic Resonance (^{29}Si SP MAS NMR) and Raman spectroscopy, decreasing ionic radius of alkali in silicate melts results in decreasing the fraction of water dissolved as OH groups as well as in changing the OH bonding mechanism. Indeed, in K silicate glasses, water resides mostly as OH groups bonded to Si, whereas in Li silicate glasses, the OH content is low and the OH groups are not bonded exclusively to Si. Therefore, present data support previous inferences about a control exerted by the ionic field strength of alkali and alkaline-earth cations on the H_2O_{mol}/OH ratio as well as on the bonding of OH groups with the ionic network of hydrous silicate melts.

This implies that water has different effects on the polymerization of melts as a function of their chemical composition. Such dependence can be modeled through the following reactions:

$H_2O_{mol} \rightleftharpoons H^+ + OH^-$, [1]

$H^+ + OH^- +$ T-O-T $\rightleftharpoons 2$ TOH , [2]

$H^+ + OH^-$ + T-O-M $\rightleftharpoons$ TOH + MOH , [3]

where T = Si, Al and M is an alkali or an alkaline-earth cation. Equation [1] is the self-ionization reaction of water. The product ions can react with bridging oxygen in T-O-T bonds (eq. 2) or with non-bridging oxygen in T-O-M bonds (eq. 3). The fraction and ionic field strength of the various T and M elements will influence the equilibrium constants of equations 1, 2 and 3. As a consequence, the water effect on the melt viscosity must change with its chemical composition, because equations 2 and 3 have different implications for the melt polymerization. Such effect is highlighted when comparing the viscosity reduction produced by water solution in rhyolitic and andesitic melts for instance. Indeed, solution of 1 wt% water produces a viscosity reduction $\sim$ 1 order of magnitude greater in a rhyolitic melt than in an andesitic melt.

This conclusion, in turn, may affect the eruptive processes linked to viscous phenomenon, such as, for example, the fragmentation of magmas in explosive eruptions. Indeed, the fragmentation of an ascending magma in a conduit can occur when the elongation strain rate of the magmatic flow becomes greater than the magma viscous relaxation time, because at this point the magma behaves as a fragile solid. Magmas with different compositions will present differences in the equilibrium constants of equations 1, 2 and 3 as well as in water solubility, because the formers define the latter. This will define different evolution paths as a function of depth for their viscous relaxation time and their vesicularity that will eventually affect their fragmentation threshold.

キーワード: water speciation, water bonding, silicate melt, silicate glass, viscosity of magma, fragmentation
Keywords: water speciation, water bonding, silicate melt, silicate glass, viscosity of magma, fragmentation

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Interpreting water contents of submarine pumice: insights from water speciation

Interpreting water contents of submarine pumice: insights from water speciation

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Studies of submarine eruptions are hindered by the logistical difficulties and costs of directly observing and sampling submarine volcanic edifices, and by the difficulties of identifying the eruption source of pumice rafts that may drift for great distances. Many questions remain about the impacts of the overlying water column on eruption processes and, in particular, at what depth explosive pumice-producing eruptions can occur. H2O solubility in magma increases with increasing pressure so if the magma is saturated with respect to H2O, the dissolved H2O content of volcanic glasses provides a way to estimate the pressure at the time of quenching; hence the eruption depth. Silicic pumice however is particularly susceptible to post-eruption hydration by seawater at ambient temperature, which causes high glass H2O contents with anomalous H2O speciation. Obtaining meaningful data thus requires distinguishing between the original dissolved magmatic H2O content and the H2O subsequently added via post-eruption hydration. H2O speciation data may enable us to do so. Since H2O added during hydration is added in the form of molecular H2O (H2Om), and the species interconversion reaction between H2Om and hydroxyl (OH) species is negligible at ambient temperature, the measured OH content of hydrated pumice should remain unaltered. Using H2O speciation models, the corresponding original H2Om content can be estimated from the measured OH content, thereby allowing reconstruction of the original H2O content of the glass. By measuring H2O speciation in silicic submarine pumice by FTIR, we will examine whether this methodology provides a means to get at the magmatic H2O content, which can then be used to estimate eruption depths and help locate potential sources of rafted pumice deposits.

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Diffusion experiments of chlorine in rhyolitic melts using a pure chlorine source
Diffusion experiments of chlorine in rhyolitic melts using a pure chlorine source

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<Introduction>
The chlorine degassing in magma is crucial in the control of vapour-induced magma differentiation, ore formation, hydrothermal alteration, and volcano-atmosphere interactions, because the chlorine-rich fluids have high chemical reactivity. Since the degassing is a process involving diffusive transport of the volatiles, it is necessary to quantify the diffusivity of chlorine in silicate melts for the detailed understanding of these phenomena. Bai and Koster van Groos (1994) carried out systematic experiments of chlorine diffusion in rhyolitic melts by using molten NaCl or NaCl aqueous solutions for the chlorine source. In these cases, however, it is possible that sodium infiltrates into the melt to modify the original composition, resulting in the increase of the diffusivity because sodium efficiently cuts the silicate network. In this study, I carried out diffusion experiments of chlorine in rhyolitic melts using pure chlorine to measure the diffusivity without any significant change of the alkali content.

<Experimental>
Chlorine was generated by means of electrolysis of a sodium chloride solution, and it was then purified cryogenically in a vacuum line. A rhyolitic glass slab prepared from natural obsidian was sealed in a quartz glass pressure vessel together with the pure chlorine, and annealed in a furnace at 750 to 950 ℃ for up to 20 days. The pressure in the vessel was calculated to be 12 to 128 bars. In a selected experiment, water was added to chlorine in the vessel to examine the water-content dependence of the chlorine diffusivity. After quenching, the chlorine contents were quantified along the diffusion profile using an EPMA.

<Results and discussion>
The diffusivity of chlorine under the dry condition was determined to be 3.5×10^{-17} to 5.9×10^{-16} m^2/s at 750 to 950 ℃. These values are about three orders of magnitude smaller than those previously measured for dry rhyolitic melts using the molten NaCl for the chlorine source (Bai and Koster van Groos, 1994). This difference may be attributed to the difference in the melt composition caused by sodium infiltration. The activation energy of the chlorine diffusion was calculated to be 89 kJ/mol, and is similar to that of Bai and Koster van Groos (86 kJ/mol). This indicates that the mechanism of chlorine diffusion is identical irrespective of the chlorine source. In the water-added experiment, the diffusivity was an order of magnitude greater than that in the dry experiments. Here, the water content of the melt was calculated to be 1.2 wt%.

<Implications>
The present study showed that the diffusivity of chlorine was much lower than previously considered. The chlorine diffusivity showed a strong dependence of the water content. These observations may indicate that the chlorine degassing occurs only when the magma has the high water content before eruption. This idea is consistent with the observation that the groundmass glass of obsidian pyroclasts, pumice, and lavas from Mukaiyama volcano, Niijima island, have the constant chlorine content (0.13±0.01 wt%), while the melt inclusions in quartz contained 0.18±0.02 wt% chlorine (Yoshimura, in preparation).

キーワード: 塩素, 脱ガス, マグマ
Keywords: chlorine, degassing, magma

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Lava Domes: Eruptions in Chemical Disequilibrium
Lava Domes: Eruptions in Chemical Disequilibrium

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Active lava domes display a range of eruptive behaviours which are defined by the local rheological properties of the magma. Magma ascent results in changes in P-T-X which forces volatile exsolution and crystallisation; yet, as these conditions are transient, the magma remains in constant disequilibrium with its surroundings. Volatiles, and principally water, have been argued to be the most important control on magma rheology; they influence the viscosity of the melt and the total production of gas bubbles, which define ascent rates via buoyancy and challenge the physical coherence of magma prompted to fragment. Decompression has long been considered the main variable controlling volcanic eruptions; however, here we assess the effects of temperature.

We present field and experimental results which argue for the importance of thermally-driven disequilibrium in water content. First we test effects of cooling using in situ hydration measurements in a unique simultaneous thermal analyser: Cooling is shown to increase the solubility of water in the melt (both in the relaxed and unrelaxed states), which we find resorbs at rapid rates with the implication that sintering can be accelerated several-fold. This may have significant implications for tuffisite formation in volcanic conduits. Second we test the effect of rapid heating using a high-velocity rotary shear apparatus. Rapid heating is found to trigger foaming and melting of surrounding crystals. The textures developed in these experiments match those observed in ash collected from gas-and-ash explosions at Santiaguito volcano. We use these results to elaborate a new model of fragmentation, in which the mechanical work of ascending magma may induce superheating that triggers partial melting, foaming and fragmentation. Comparison of our findings with current water solubility models suggests that heat may be an overlooked control on eruptive behaviour.

キーワード: foaming, volatiles, fragmentation, fault, frictional melting, sintering
Keywords: foaming, volatiles, fragmentation, fault, frictional melting, sintering

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テフラガラスの地球化学と日本列島の大規模酸性マグマの起源
Geochemistry of tephra glasses and sources and origins of huge-volume felsic magmas in Japanese subduction zones

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Dacitic to rhyolitic glass shards from eighty widespread tephras erupted in the past 5 Mys from large calderas in Kyushu, and SW, central, and NE Japan were analyzed. Laser ablation inductively coupled plasma mass spectrometry was used to determine 10 major and 33 trace elements and 207Pb/206Pb-208Pb/206Pb isotope ratios in the glass shards. The tephras were classified into three major geochemical types and their source rocks were identified as intermediate plutonic, sedimentary, and amphibolite rocks in the upper crust. Few tephras from SW Japan were identified as adakite and alkali rhyolite and regarded to have originated from slab melt and mantle melt, respectively. Pb isotope ratios of the tephras are comparable to those of the intermediate lavas in the source areas but are different from the basalts in these areas. The crustal assimilants for the intermediate lavas were largely from crustal melts and are represented by the rhyolitic tephras. A huge heat source is required for forming large volumes of felsic crustal melts; these are usually supplied by the mantle via basalt. Hydrous arc basalt formed by cold slab subduction is voluminous and its high water content lowers the solidus of the crustal rocks leading to effective felsic magma production. The frequency of caldera eruptions is thus thought to be fundamentally controlled by the basalt production rate depending on the subduction setting either cold-wet or hot-dry and by the subduction rate of the oceanic plate slab, which controls the amount of water being transported beneath subduction zones.

キーワード: 大規模テフラ, 化学組成, 地殻融解, 沈み込み帯
Keywords: Large volume tephras, Geochemistry, Crustal melt, Subduction zones

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顕微 FT-IR 反射法による諏訪之瀬島火山 1813 年噴火ガラス包有物の含水量測定
Water content of glass inclusions in the 1813 ejecta at Suwanosejima volcano by micro FT-IR reflectance method

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火山噴火は主に爆発的噴火と非爆発的噴火を二極として様々なものがある．この噴火多様性の要因のひとつとして，噴火直前のマグマ中の揮発成分量（大部分を水が占める）の違いが指摘されてきた．近年の研究ではこの初期含水量よりもむしろマグマの火道上昇中における脱ガス効率の違いが噴火様式を左右すると指摘されているが，依然として爆発的噴火の潜在力＝初期含水量についての知見は重要である．また，爆発的噴火の強度を考えると，その起こり得る最大の噴火を想定する上で初期含水量を知ることが重要である．一方，斑晶鉱物中のガラス包有物はその含水量測定により，噴火直前のマグマ含水量を推定できる数少ない手法の一つとして用いられてきた．しかし，従来は測定のための試料調整の困難さから，比較的含水量の多く包有物径の大きい試料を除いて，測定数が限られていた．最近，安田（2013）は真空装置を併用した顕微 FT-IR 装置に従来の透過法ではなく反射法を用いることにより，格段に容易に試料調整が可能な含水量測定法を確立した．

諏訪之瀬島火山は日本でも有数の活火山であり，現在もストロンボリ式噴火をはじめとする活発な火山活動を継続している．一方，最近の研究では，当火山は数百年程度の間隔でプリニー式噴火に匹敵する大規模な噴火を行っていることが明らかとなっている（嶋野ほか，2013）．このように規模の異なる噴火で噴出したマグマの初期含水量について知ることは，大規模噴火に至るマグマの準備過程を理解する上でも重要であろう．これまで，嶋野・小屋口（2001）は 1813 年噴火について異なる噴火様式で噴出した噴出物の岩石学的な特徴（全岩主要元素微量元素組成，鉱物組み合わせ，斑晶鉱物・石基鉱物の化学組成）に加えて全岩含水量を測定し，脱ガス程度の違いによって爆発的噴火から溶岩流出噴火へ移行したことを示した．一方，初期含水量については，ガラス包有物が少量かつ微小であるため測定は行わず，Housh & Luhr (1991) の含水量計を用いて推定を行った．この際，斜長石斑晶リムと石基部分が平衡状態にあったと想定して見積もりを行い，約 3 重量％であったと結論付けた．しかし，Housh and Luhr (1991) による見積もりはしばしば実測値と一致しない場合があることが指摘されている．また，斑晶リム組成はコア組成に比べて An 成分が有意に高く，晶出直前にマグマ混合などの不均質化プロセスを経ている可能性が指摘されており，マグマ全体が約 3wt ％であったという直接的なデータは得られていない．そこで本研究では，反射法を用いてガラス包有物の含水量を測定し，嶋野・小屋口（2001）による見積もりとの比較を行った．また，1813 年噴火より大規模な活動と考えられる 1 万年前の火砕噴火堆積物中の斑晶ガラス包有物の含水量も測定した．

1813 年噴出物の斑晶ガラス包有物の含水量は斜長石が 1.0-2.0wt.%程度，輝石は 0.6-1.2wt.%程度， 1 万年前の斑晶ガラス包有物の含水量は斜長石が 1.4-3.0wt.%程度，輝石が 2.0-2.4wt.%程度となった．

まず，1813 年噴出物については，嶋野・小屋口 (2001) の推定値である約 3.0wt%と比較するといずれのガラス包有物も低い測定値を示しており，このことは 1 ）嶋野・小屋口（2001）の過大見積り，２）ガラス包有物が同見積値とは異なるタイミングの含水量を反映している，の 2 点の可能性が挙げられる．斑晶ガラス包有物はいずれも斑晶中央部のコア付近に包有されている．また，斜長石斑晶，輝石斑晶いずれも明瞭な逆累帯構造を示していることを考慮すると，２）の可能性が高い．すなわち，斑晶コア生成時点では最大 2wt.%程度の含水量であったが噴火直前により含水量の高いマグマ（あるいは水）の混合によりマグマ含水量の増加と斑晶リムの逆累帯構造が形成されたと解釈することができる．ホストの斑晶によって含水量が系統的に異なる（輝石の方が低含水量）ことは，結晶化段階の違いを示していると考えられるが，今後，ガラス包有物の主要成分組成測定などにより検証が必要である．

次に，約 1 万年前の噴出物中の斑晶ガラス包有物の含水量については，1813 年噴火噴出物より系統的に高い含水量であった．約 1 万年前の噴火の方が 1813 年の噴火よりより大規模であったと考えられており，初期含水量の違いがこのような結果の違いを生んだのかもしれない．今後より多くの試料について測定を行って詳細を明らかにする必要がある．

キーワード: ガラス包有物, 含水量, 顕微 FT-IR 反射法, 諏訪之瀬島
Keywords: glass inclusion, water content, micro-reflectance FT-IR, Suwanosejima

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Chronology of degassing and magma mixing at Surtsey (Iceland, 1963-67)

Chronology of degassing and magma mixing at Surtsey (Iceland, 1963-67)

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In 1963-67, Surtsey (Iceland) provided the type example of shallow-emergent explosive volcanism; however, magma ascent and degassing in this benchmark eruption remain unconstrained. We use major/trace elements and volatiles in olivine-hosted melt inclusions and glasses to show that multiple distinct melts were stored at 9.5-12 km and subsequently mixed at 6-8 km below Surtsey. The chronological contribution of each melt body to surface processes can be tracked by correlating volatile (H/C, S/C), trace element (HSFE/LILE), and rare earth element (LREE/HREE) ratios of inclusions to the time series of gas and lava compositions that were measured syn-eruptively. This captures progressive shallowing and mixing of melts through time, and allows time-stamped modeling of degassing and melt+gas redox evolution over a 3-year period. Novel correlation between inclusions from surface tephra and historical measurements permits temporal and spatial controls on activity at Surtsey to be determined >50 years after the eruption.

キーワード: volatiles, degassing, geochemistry, pyroclastic, subaqueous, Iceland
Keywords: volatiles, degassing, geochemistry, pyroclastic, subaqueous, Iceland

Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

SVC11-09 会場:A04 時間:5 月 24 日 12:00-12:15

メルト包有物分析から見積もられるマグマ脱ガス量：霧島火山2011年噴火と西之島火山2014年噴火
Degassed-magma volume estimated from melt inclusion analysis: Kirishima 2011 eruptions and Nishinoshima 2014 eruptions

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Magma ascent and degassing process is essential in order to know how eruption occurs and what controls eruption styles. Melt-inclusion analysis is a powerful method for estimating volatile content of melt in magma before eruption. Combining the melt-inclusion analysis with observation of volcanic gas, we can estimate degassed-magma volume. In this study, degassed-magma volume of recent two eruptions in Japan, Kirishima 2011 eruptions and Nishinoshima 2014 eruptions, was estimated from melt inclusion analysis. Comparing the degassed-magma volume with geological and geophysical observations, magma ascent and degassing processes is discussed.

(1) Kirishima 2011 eruptions. Eruption activity of Shinmoedake began with phreatomagmatic and subplinian eruptions in January 2011, followed by lava effusion within the summit crater, vulcanian explosions, and ash emissions from February-September 2011. The amount of degassed magma was estimated, based on sulfur and chlorine contents of melt inclusions of the mafic and felsic magmas, SO_2 flux and volcanic gas composition during the period of January 2011 to September 2012. The amount of degassed magma was larger than that of eruptive products in 2011, indicating the degassing of magma in the chamber due to convection in a conduit. Considering the mixing ratio of mafic and felsic magmas (0.4), the estimate of degassed mafic magma ($19x10^6$ m^3) is of the same order of magnitude as the observed inflation of the magma chamber during February-November 2011 ($10x10^6$ m^3), suggesting injection of mafic magma into the chamber from deeper down is likely to have caused the inflation and eruption activity of Shinmoedake in 2011.

(2) Nishinoshima 2014 eruptions. The Nishinoshima eruptions started on 20 November 2013 and lava effusion has continued up to present (February 2015). The amount of degassed magma ($3x10^6$ m^3/d) was estimated, based on sulfur content of melt inclusions in products by eruption on 6 June 2014 and SO_2 flux (500 t/d) on 29 January 2014. The amount of degassed magma is similar to lava effusion rate ($3x10^6$ m^3/d, Earthquake Research Institute, The University of Tokyo), suggesting that gas-melt separation did not occur during its ascent from a magma chamber before the eruption.

キーワード: マグマ, 脱ガス, 揮発性成分, メルト包有物, 霧島火山, 西之島火山
Keywords: magma, degassing, volatile, melt inclusion, kirishima volcano, nishinoshima volcano

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SVC11-10 会場:A04 時間:5 月 24 日 12:15-12:30

Real-time atmospheric measurements of CO_2 and δ13C in volcanic gases emitted from Mt. Etna (Italy)

Real-time atmospheric measurements of CO_2 and δ13C in volcanic gases emitted from Mt. Etna (Italy)

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RIZZO, Andrea[1] ; JOST, Hj[2*] ; AKIYAMA, Ken-ichiro[2] ; HAMILTON, Doug[2] ; ANCELLIN, Marie-anne[3] ; CARACAUSI, Antonio[1] ; MARTELLI, Mauro[1] ; PAONITA, Antonio[1] ; LIOTTA, Marcello[4]

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We present new data of real-time measurements of concentration and isotope (δ^{13}C) composition of CO_2 in fumarolic-plume gases emitted from Mt. Etna volcano, performed by using a Delta Ray Isotope Ratio Infrared Spectrometer. The first two campaigns of measurements were carried out on 11 July and on 5-6 September 2013, while a third campaign was performed in mid-July 2014. With the assumption of a two components mixing, a simple linear regression was applied to the data in order to obtain the volcanogenic δ^{13}C of CO_2 emitted from the volcano.

Data acquired along the route Catania?Etna, while car was moving, showed an excess of ^{13}C-depleted CO2 when passing through inhabited centers due to atmospheric pollution produced by the cars exhaust. A similar signature was obtained when measuring car exhaust of our car. Fumaroles of Torre del Filosofo (2,900 m a.s.l.) displayed a δ^{13}C between -3.2±0.03 ‰ and -3.7±0.05 ‰, comparable to IRMS measurements of discrete samples collected in the same date and in previous investigations. Diluted plume gases were collected at more than 1 km from the craters and showed δ^{13}C=-2.2±0.2 ‰, accordingly with collected crater fumaroles.

Data collected in 2014 campaign are under processing, but preliminary results confirm a less negative signature of δ^{13}C of CO_2 emitted from Central Craters if compared to Torre del Filosofo fumaroles, with some interesting variations over time that must be compared with other parameters simultaneously acquired.

Considering the huge amount of data that may be acquired in a very short time by Delta Ray, we demonstrate that the addition to the atmospheric CO_2 content of ˜100 ppm of CO_2 from an unknown source is enough to allow a mathematical calculation of the end-member with an uncertainty generally $<$0.15 ‰. This is feasible with the assumption of a binary mixing. We thus infer that these measurements performed at Mt. Etna, if performed continuously, may contribute to a better comprehension of the magmatic processes.

キーワード: Isotope Ratio Infrared Spectrometer, volcano gas monitoring
Keywords: Isotope Ratio Infrared Spectrometer, volcano gas monitoring

Japan Geoscience Union Meeting 2015
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SVC11-11 会場:A04 時間:5 月 24 日 14:15-14:30

The role of volatiles during magma storage, decompression and eruption at Stromboli Volcano

The role of volatiles during magma storage, decompression and eruption at Stromboli Volcano

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Open system volcanoes are natural laboratories to investigate how volatiles migrate and concentrate under dynamic conditions. Among them Stromboli plays a key role due to its persistent activity. Fluid phases are involved in magma decompression and pressurization, modulate Strombolian activity and rule magma rise and fragmentation processes.

Thermobarometric estimates indicate that the deeper detected part of the plumbing system is located in the upper mantle, at approximately 34-24 km. During their ascent basaltic magmas will interact with lower crust materials represented by cumulates of earlier Stromboli-type basalts at 13-10 km depth. This zone is also the sector of the plumbing system where the feeder dike is entering the chamber. Current primitive Stromboli basalts equilibrate at about 0.3-0.13 GPa for temperatures approaching 1150-1200 ℃, and progressively crystallise, cool and degas before being erupted. Crystal Size Distributions on lavas and juvenile tephra recently erupted give variable residence times. Although further refinements are needed to identify the time-related variations in fluid diffusion coefficients, the estimated times for the exsolution of the gaseous phases, based on average bubble distances, range from 44-126 minutes for the lavas and scorias, down to about 12 minutes for the pumices ejected during paroxysmal explosions.

Pure extensional regimes and geophysical data indicate the existence of a prolate ellipsoidal magma chamber below Stromboli. To assess its volume we calculated the magma volumes associated with SO_2 degassing (during the 2007 major eruption) by applying a refined petrological model to estimate the magma flux entering the degassing zone. The trend of this magma flux follows an exponential decay, typical of pressurised magmatic systems. This trend has been interpreted as due to the release of elastic strain accumulated either by pressurisation of the rocks surrounding the magma reservoir, or by pressurisation of the magma itself, or both. The reservoir elastic response during magma decompression suggests that Stromboli magma chamber volume may be constrained to 1-2 km^3.

キーワード: magma, volatiles, magma storage, decompression, eruption
Keywords: magma, volatiles, magma storage, decompression, eruption

Japan Geoscience Union Meeting 2015
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SVC11-12 会場:A04 時間:5 月 24 日 14:30-15:00

Magmatic processes and eruption triggers at openly-degassing volcanoes

Magmatic processes and eruption triggers at openly-degassing volcanoes

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Open vent volcanoes typically have a prominent volcanic plume that passively releases abundant gas for months, or years between eruptive events. Some examples of such types of volcanoes are Etna, Mayon, Llaima, and surely some others in Japan (e.g, Asama, Satsuma-Iwojima). The fact that there is a permanent or semi-permanent volcanic plume during quiescence shows that there are some pathways or connections between the magma (perhaps the reservoir itself) and the surface. This allows the coupling of theoretical numerical models, monitoring gas data, and petrological/geochemical data from the erupted rocks, in a holistic model that can be used for improved eruption forecasts. In this study we focus on the quiescent degassing at Mayon volcano (Philippines) using a combination of numerical modeling and petrologic observations.

Our new lumped parameter model correlates the pressure of shallow magma reservoirs with the mean degassing rates measured with monitoring systems. The model accounts for the conduit and reservoir sizes, the viscoelastic properties of the crust, the exsolution and expansion of bubbles at depth, the magma density changes, and the connectivity between the shallow reservoir and deeper magma sources. Our theoretical analysis demonstrates that there are many realistic scenarios under which depressurizations between 1-10 MPa occur in only a few months or years, that is, within the inter-eruptive timescale of persistent degassing volcanoes (Girona et al., 2014). Our results suggest that degassing-induced depressurization could induce new magma replenishment, sudden bubble expansion at depth, collapse of the crater floor, and fractures in the reservoir wall-rock.

On the other hand we also studied the petrology and geochemistry from several historical eruptions of Mayon that span over 35 years of activity (1947, 1968, 1978, 1984) to see if we can identify any magmatic processes that could be related to triggering of the eruption. We concentrated on orthopyroxene crystals, which show a variety of compositions and zoning patterns (reverse, normal or complex) with Mg# (= 100 ∗Mg/[Mg+Fe]) varying from 67 to 81. The variety of core compositions and patterns can be interpreted simply as mixing and mingling between an evolved resident magma and a more mafic one. There is a general increase in the maximum Mg# of the Opx from 1947 to 1984, indicating a higher proportion or/and more mafic intruding magma. Mg-Fe diffusion modelling of orthopyroxene from all four eruptions indicates that time interval between magma injection and eruption is between 2 to 4 months. Thus these times appear to be characteristic of Mayon, and are consistent with the results from our numerical simulations.

We propose that many eruptions at Mayon could be driven by a complex series of events that involve underpressure followed by overpressure. The sequence starts with the underpressure created by the gas loss at the top, which triggers new magma replenishment from depth when depressurization reaches a critical value in turn. This is what ultimately what drives the eruption by creating an overpressure. The complexity lies in being able to identify, with monitoring datasets (e.g. gas, deformation, seismicity), the cycles of decompression and compression of the system. This is especially important as open vent volcanoes are notoriously seismically silent and do not appear to deform significantly during or before eruptions, possibly because the magma is close to the surface most of the time.

Girona, T., Costa, F., Newhall, C., Taisne, B. (2014) On depressurization of volcanic magma reservoirs by passive degassing. Journal of Geophysical Research, Doi: 10.1002/2014JB011368.

キーワード: eruption, forecasting, petrology, geochemistry, Mayon, degassing
Keywords: eruption, forecasting, petrology, geochemistry, Mayon, degassing

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SVC11-P01 会場:コンベンションホール 時間:5 月 24 日 18:15-19:30

イエローストーン、ローンスター間欠泉において観測された噴火規模の二極化
Bimodal Distribution of Geyser Preplay Eruptions: Lone Star Geyser, Yellowstone National Park, USA

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Geyser eruption intervals are determined by rates of water and heat discharge into shallow subsurface reservoirs and the conduit. In some geysers, small amounts of water discharge prior to a main eruption ('Preplay') can affect eruption intervals. Water discharge during preplay reduces the hydrostatic pressure, which in turn, induces boiling of water that is at, or near the critical temperature. Ascending steam slugs from depth can also lead to shorter eruption intervals (Namiki et al., 2014). In April 2014, we carried a five day experiment at Lone Star Geyser, Yellowstone National Park. Eruptions and their preplays were recorded with an infrared sensor that measured temperature variations immediately above the geyser cone (3.4˜m high), temperature loggers that measured water temperature at the base of the cone and in the outflow channels, water discharge, and visual observations. At Lone Star Geyser, during the preplay phase of the eruption, mainly liquid water is erupted, whereas the main phase of the eruption begins with the liquid-water dominated eruption and turns into the steam discharge. The temperature rise in an outflow channel indicates the occurrence of preplays and initiation of the main eruption. The acquired data suggests that the preplay patterns of Lone Star Geyser are vigorous and complex, consistent with previous observations (Karlstrom et al., 2013). Our new observations reveal two typical styles: 1) vigorous preplays with few events (<5) and long intervals (>20˜minutes), and 2) less vigorous preplays that include several events (>5) with short intervals (few minutes), and continue approximately for one hour. Probability distributions of preplay durations show two peaks indicating the bimodal activity. The bimodality of Lone Star preplays may be a result of subtle change of temperature distribution in a convecting reservoir which has been observed in laboratory experiments (Toramaru and Maeda, 2013).

キーワード: geyser, preplay, bimodal
Keywords: geyser, preplay, bimodal

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SVC11-P02 会場:コンベンションホール 時間:5 月 24 日 18:15-19:30

マグマだまりの底面および壁に付着した気泡が地震波により離脱する条件を調べるアナログ実験
The analogue experiment to investigate the condition of bubble detachment from magma chamber wall by seismic wave

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Volatile components, such as SO_2, CO_2 and H_2O, are saturated in magmas. These components are nucleated as bubbles when magmas are further oversaturated. Seismic waves will reduce the nucleation barrier to facilitate the heterogeneous bubble nucleation under a low supersaturation. Bubbles which heterogeneously nucleate on the wall or bottom of magma chamber get buoyancy then detach the wall or bottom and ascent with keeping internal pressure. According to the principle of advective-overpressure, the magma chamber is overpressurized. This overpressure may trigger eruptions and other geophysical phenomena such as low frequency earthquakes at geothermal fields. Thus the detachment condition of bubbles from wall or bottom surfaces is a key factor to control the onset of seismic triggering. In order to evaluate the effect of seismic wave and surface tension on the detachment condition, we conduct the analogue experiment.

Using a carbonated water as magma and experimental vessel as magma chamber, we design the experimental setup to find out that what kind of waves cause the bubble departure. We oscillate the experimental vessel containing a supersaturated carbonated water at various frequency and amplitude. In addition, we conduct the experiment to evaluate the effect of the bubble shape on the detachment condition because buoyancy to drive the detachment is controlled by bubble shape, such as contact angle and bubble radius. The contact angle is decided by surface tension which varies with ethanol concentration in carbonated water. Further, we investigate the effect of oscillation on the bubble morphology such as bubble radius or contact angle.

From a series of experiments, we obtained following results. 1) If the amplitude is small, the bigger CO_2 bubbles are detached and when the frequency is higher, the amplitude is small at the moment of detaching of bubble. 2) The increase in the ethanol concentration decreases the contact angle and detachment bubble radius. 3) When the experimental vessel is oscillated at the same frequency and amplitude, the increase in the ethanol concentration decreases the detachment bubble radius but contact angle is various and has no systematic features.

We consider that the reason why the contact angle has no systematic features is that during vertical oscillation, the contact angle has different value because the contact angle becomes small, when the experimental vessel goes down, whereas when the experimental vessel goes up, the contact angle becomes large.

Integrating experimental results, we summarize the detachment condition as follow: The thresholds of oscillation amplitude and bubble radius at the detachment condition decrease as the frequency of oscillation increases and as the contact angle decreases. In natural systems, it has been reported that the contact angle is small approximately 20 degrees for silicate minerals such as quartz or feldspar in magmas rather than oxide minerals (larger than 90 degrees) such as magnetite. So we can speculate that the seismic triggering for overpressure may occur in the ordinary magma chamber with silicate minerals-rich walls. Furthermore, the addition of other volatile components reduces the surface tension, leading to less threshold of oscillation amplitude and bubble radius.

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SVC11-P03 会場:コンベンションホール 時間:5 月 24 日 18:15-19:30

Significance of vapor bubbles to the volatile budget of melt inclusions from West Zealandia seamount, Mariana arc

Significance of vapor bubbles to the volatile budget of melt inclusions from West Zealandia seamount, Mariana arc

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Vapor bubbles are common in glassy silicate melt inclusions. They can develop during post-entrapment cooling and crystallization because the melt phase contracts more than the host crystal and crystallizing minerals resulting in the formation of a void within the melt. If the melt contains volatiles, such as H_2O or CO_2, that become less soluble with decreasing pressure, the decrease in pressure associated with melt contraction causes some of the volatiles to exsolve into the void (bubble) (1, 2). A significant proportion of the volatiles originally dissolved in the melt at the time of entrapment can reside in the bubble once the inclusion and its host have been erupted and quenched. If the volatiles in melt inclusion-hosted vapor bubbles are not considered, this could result in a significant underestimation of the original volatile budget of the trapped melt. Volatiles in the vapor bubble can be analyzed directly by Raman spectroscopy and then added to the volatiles still dissolved in the melt to reconstruct the volatile content of the melt at the time of entrapment (e.g., 1, 3). Alternatively, prior to analysis of the quenched, glassy melt inclusion, the inclusion can be heated until the bubble dissolves and the melt inclusion rehomogenized (e.g., 3). However, for an inclusion that has already been analyzed, if a vapor bubble was present, sample preparation is likely to have opened the bubble resulting in its volatiles being lost. In this case, calculations based on the volume of the inclusion, the volume of the vapor bubble and the ideal gas law can indirectly estimate the contribution from the vapor bubble to the overall volatile budget of the melt inclusion (e.g., 4).

The melt phase of olivine-hosted glassy basaltic melt inclusions from West Zealandia seamount (16^o 53' N) in the southern Mariana arc have already been analyzed for H_2O and CO_2 (by FTIR spectroscopy), major elements, S and Cl (by EPMA), and trace elements (by LA-ICP-MS). Dissolved volatiles range from 1.9-4.5 wt % H_2O, below detection (20 ppm)-856 ppm CO_2, 952-2260 ppm S and 454-2590 ppm Cl. Vapor bubbles were present in most of the inclusions, but as the inclusions were prepared for micro-analysis, the bubbles have been opened and the vapor phase lost. As a result, after correction for post-entrapment crystallization and Fe-loss, the measured volatile concentrations underestimate the original volatile content of the melt, and indirect calculations of the amount of volatiles that these bubbles could contribute to the overall volatile budget of each inclusion need to be performed. Firstly, we estimate the volatiles that were in the bubble based on the volume of the bubble after quenching, using photomicrographs of the inclusions collected during their preparation for analysis. However, because the bubble may grow during the final quench from eruption temperature to the glass transition temperature on a timescale too fast to allow significant diffusion of volatiles from the melt to the vapor phase, this may result in an overestimation of the volatiles residing in the bubble. Thus, secondly we estimate the volatiles that were in the bubble based on the volume as a function of the difference between the trapping and pre-eruption temperatures calculated using the olivine liquidus temperature of the measured melt inclusion composition and the extent of Fe-loss that has occurred in the melt inclusions during cooling between trapping and eruption. We will evaluate the effects that volatiles in the vapor phase estimated in these two ways have on the total volatile budget of each inclusion. In turn, we will examine how this affects inclusion trapping pressures inferred from the volatiles in the melt inclusions, and the significance this has for interpreting the magma plumbing system and crustal structure beneath West Zealandia.

1 Moore et al., In Press, Am Min.
2 Wallace et al., In Press, Am Min.
3 Hartley et al., 2014, EPSL, 393, 120.
4 Shaw et al, 2008, EPSL, 275, 138.

キーワード: arc volcanoes, melt inclusions, volatiles, vapor bubbles
Keywords: arc volcanoes, melt inclusions, volatiles, vapor bubbles