

MIS002-01

会場:104

時間:5月27日 14:15-14:45

深部炭素循環の証拠としてみる超高压変成炭酸塩岩、マイクロダイヤモンド、流体、マントル交代作用 Evidence for Deep Carbon Cycle: UHPM carbonates, microdiamonds, aqueous fluid and mantle metasomatism

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In calculated P-T grids for dolomite-bearing carbonate system, CaO-MgO-SiO₂-CO₂-H₂O (Ogasawara et al. 1995), a large "no-reaction" P-T space (excepting phase transitions) exists at high-P and low-T side, and its extent is affected by fluid conditions as XCO₂. This suggests that along P-T path of cold subduction the chance of "no reaction" in subducted carbonate rocks is high and carbonate rocks can survive up to great depths in the mantle. Deep carbonate subduction process can play as an important carrier of CO₂ as carbonates from Earth's surface to the mantle. The potential of CO₂ influx could be affected by aqueous fluid infiltrated in subducted materials. Such speculation based on the thermodynamic results was a trigger of my study on Ultrahigh-Pressure (UHP) metamorphic carbonate rocks and microdiamonds.

UHPM carbonate rocks have preserved variable information about not only P-T conditions, but chemical systems and related reactions within deeply subducted continental materials, and are the direct evidence for deep carbon cycle from Earth's surface to deep upper mantle. The occurrences of those precious materials including metamorphic diamonds are very rare in world UHPM terranes; the representative example is a diamond-bearing dolomite marble in the Kokchetav Massif, northern Kazakhstan. The Kokchetav microdiamonds are concentrated in a carbonate rock, impure dolomite marble; the highest diamond concentration domain in garnet showed about 2700 carat/ton. Microdiamonds in this marble formed at two different stages and the second stage diamond could formed from a multicomponent aqueous fluid (not from graphite). Garnet-biotite gneiss is the second highest diamond concentration. Protolith of this diamond-bearing dolomite marble is late-Proterozoic platform sediments (impure dolostone) on the basis of the local geology and the stable isotope data on the carbonates. This indicates that limestones and dolostones can subduct into the great depths at least to the low-P limit of diamond stability field. A similar UHP carbonate rock, Ti-clinohumite-bearing dolomitic marble whose assemblage aragonite-dolomite-Ti-clinohumite was stable at extremely low XCO₂, occurs at the same area, but diamond was unstable in this marble. Such strong contrast between two dolomite-bearing UHP carbonate rocks can be explained by the H₂O-rich fluid condition and its heterogeneity under UHP metamorphism. Another important evidence is exsolved coesite from supersilicic titanite discovered in titanite-bearing calcite (after aragonite) marble. Reintegrated precursor composition showed that excess Si in octahedral site, 0.145 gave corresponding minimum-P as 6 GPa; this impure limestone subducted to the depths over 200 km. Exsolved coesite in titanite also discovered in "skarn-like" garnet-clinopyroxene rock that suggests strong metasomatism at UHP conditions. These two exsolved-coesite-bearing rocks lack diamond except for a thin diopside-rich layer in the calcite marble (only 61 grains and no second stage growth).

Such features of the Kokchetav UHPM carbonate rocks strongly suggest that entire decomposition of carbonates is difficult during deep continental subduction and carbonate can survive at depths over 200 km although the metasomatism within subducted materials by H₂O-rich fluid ("Intraslab UHP Metasomatism") occurs at great depths. Abundant carbonate could be stored in the mantle than we expected before. Deep carbonate subduction is the most important carbon carrier into the mantle and makes strong compositional heterogeneity of the mantle. To clarify the fate of deeply subducted carbonates could be an important next step for Deep Carbon Cycle project.

キーワード: 超高压変成作用, 炭酸塩岩深部沈み込み, 変成作用起源ダイヤモンド, ドロマイト, 離溶コース石, 沈み込みスラブ内超高压交代変成作用

Keywords: UHP Metamorphism, deep carbonate subduction, metamorphic diamond, dolomite, exsolved coesite from supersilicic titanite, Intraslab UHP Metasomatism

MIS002-02

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時間:5月27日 14:45-15:00

多結晶ダイヤモンドカルボナドから見た地球深部炭素リザーバー Deep carbon reservoir inferred from natural polycrystalline diamonds, carbonado

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天然多結晶ダイヤモンドであるカルボナドは、マントル起源のダイヤモンドとは大きく異なる特徴を持ち、その成因は未だに決着がついていない。たとえば、生物起源の炭素に匹敵するほどの炭素同位体組成が低いこと、マントルに典型的な鉱物が包有物として見いだされないこと、ウランの核分裂起源の希ガスや強い放射線損傷などが知られており、地殻起源のダイヤモンドであると主張する研究者も多い。一方で、カルボナド内部に1GPa程度の残留圧力が観察されたという報告もあり、マントル起源のダイヤモンドである可能性も残されている。

我々はカルボナドダイヤモンドの微細組織をFIB-TEMにより詳細に観察し、カルボナドを構成する結晶の内部にブライマリーな流体包有物を取り込まれていることを見いだした。この実験結果は、カルボナドの成長が流体の共存する条件下でダイヤモンドの熱力学的な安定領域で起こったことを強く支持するものである。カルボナドがマントル起源であるとすれば、マントルに低い炭素同位体組成を持つ炭素リザーバーが存在するか、あるいはカルボナドの生成過程で炭素同位体組成が低下するプロセスがあったことになる。講演ではカルボナドダイヤモンドの微細組織、フォトルミネッセンススペクトルから推測される熱履歴などの情報に基づき、カルボナドダイヤモンドの成因と炭素リザーバーについて議論する。

キーワード: ダイヤモンド, カルボナド, マントル, 炭素同位体

Keywords: diamond, carbonado, mantle, carbon isotope

MIS002-03

会場:104

時間:5月27日 15:00-15:15

モホール：深部炭素循環の理解に向けて

Ultra-Deep Drilling to the Oceanic Mantle: towards understanding the deep carbon cycle

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The Integrated Ocean Drilling Program (IODP), an international scientific research program supported by 24 countries, advances scientific understanding of the Earth by monitoring, drilling, sampling, and analyzing seafloor environments. One final goal of IODP is full penetration of oceanic crust and the first sample return from the Earth's mantle in history, known as MoHole project. We here emphasize that MoHole could contribute greatly to understanding the whole-mantle-scale carbon cycle. One reason for believing so is recent discovery of diamond and other ultra-high-pressure minerals from podiform chromitites in ophiolites, i.e., fossil oceanic crust/mantle. A possible scenario of these diamond-bearing chromitites is that they were originally formed at the Moho transition zone via melt/harzburgite reaction, transported to the lower mantle and recycled to the uppermost mantle by convection. The recovery of diamond from the in situ oceanic mantle, together with characterization of carbon and other volatiles in high-pressure phases, should provide new insights into geochemical evolution of the solid Earth.

キーワード: 統合国際深海掘削計画, モホール, 海洋マントル, ダイヤモンド, 深部炭素循環

Keywords: IODP, MoHole, oceanic mantle, diamond, deep carbon cycle

MIS002-04

会場:104

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Almahatta Sitta TC₃ のユレイライトに含まれる炭素の産状 The occurrence of a carbon in ureilite of Almahatta Sitta TC₃

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Asteroid 2008 TC₃ exploded in air in the Earth around northern Sudan on October 7, 2008. Its remnants were recovered immediately and called Almahatta Sitta TC₃. Almahatta Sitta TC₃ is a first asteroid we could trace its passage during prior to falling on the Earth after tracing its path in the space by astronomic observation. Almahatta Sitta TC₃ consists mainly of coarse-grained and fine-grained ureilite fragments, OC, EH and EL chondrites. Both ureilites studied by us contain several carbon species. Here, we report the occurrence and nature of the carbon material in them.

The major constituent mineral of the coarse-grained ureilite is olivine (Fa₁₈₋₂₁). Minor low-Ca pyroxene, troilite and metallic Fe are also encountered. Raman spectroscopic analyses indicate that fine-grained diamond and graphite exists in the interstices of the olivine grains. The chemical compositions of olivine (Fa₄) surrounding the diamond + graphite assemblages are depleted in Fe compared with those of the olivine (Fa₁₈₋₂₁) in a host-rock. Many metallic Fe blebs are contained in the Fe-depleted olivine around the diamond + graphite assemblages. The Fe-depleted olivine and metallic Fe bleb assemblage would be reduction products of olivine by the carbon material.

The petrographic feature of the fine-grained ureilite is much more complicated than the coarse-grained ureilite. The fine-grained ureilite contains olivine, low-pyroxene and metallic Fe but appears to be a conglomerate of different fragments including carbon-bearing clasts. Graphite exists in clasts of metallic Fe. Fibrous graphite is observed on the surface of low-Ca pyroxene or olivine grain adjacent to the metallic Fe. The fibrous graphite might have grown when the metallic iron was molten. Few diamonds could be identified by Raman in few clasts in the fine-grained ureilite.

キーワード: グラファイト, ダイヤモンド, ユレイライト

Keywords: graphite, diamond, ureilite

MIS002-05

会場:104

時間:5月27日 15:30-15:45

Quantification of CO₂ dissolved in silicate glasses and melts using Raman spectroscopy: implications for geodynamics

Quantification of CO₂ dissolved in silicate glasses and melts using Raman spectroscopy: implications for geodynamics

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Understanding Earth degassing is fundamental in global studies of our planet history, as well as in studies of its recent climate. Degassing occurs mainly at Mid Ocean Ridges via exsolution of CO₂ vesicles in ascending tholeiitic magma, and probably begins at some 30 km under the ridge. Therefore, a precise knowledge of how carbon solubility varies during ascent from the source region is mandatory, a process for which the effect of pressure remains poorly known. A pressure increase induces melt compression, known to diminish argon dissolution with respect to Henry's law at pressures above ~10 kbar, but this effect is poorly documented for carbon where things are complicated by the transformation of CO₂ into carbonate ion, CO₃²⁻. Early experimental investigations on carbon solubility in various silicate melts up to ~20-30kbar have shown that Henry's law is not followed at high pressures.

We have performed an experimental study of C dissolution in basaltic melts using high-pressure facility in Clermont-Ferrand (France). Analysis of dissolved C was performed using a micro-Raman spectroscopy. Dissolved carbon appears as clear bands due to carbonate ions (an intense peak at ~1100 cm⁻¹ and a doublet in the 1350-1600 cm⁻¹ region), molecular CO₂ being not detectable. Calibration of Raman spectroscopy for quantitative analysis was done by preparing standards at atmospheric pressure and analyzing them using a stable isotope mass spectrometer.

The results show that carbon concentration increases steadily with increasing pressure, a behavior consistent with (rare) previous studies on basaltic melts. We also have performed molecular dynamics simulations to investigate the dissolution of CO₂ in a silicate melt. The calculated solubility is consistent with the data, which help understanding how pressure acts on fluid and melt, and yield insight into the details of how CO₂ and CO₃²⁻ interact with the melt network. However, the fact that the carbon solubility in a MORB is continuously increasing with pressure is somewhat surprising, and will be discussed.

This work has shown that

- (i) Raman spectroscopy can be used to quantify C content in natural samples
- (ii) The C solubility measured in basaltic melt exhibits a behavior with pressure different from that exhibited by rare gases.
- (iii) Our results have important implications concerning the history of the atmosphere degassing and structure of the mantle.

キーワード: CO₂, Raman spectroscopy, silicate glasses and melts

Keywords: CO₂, Raman spectroscopy, silicate glasses and melts

MIS002-06

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時間:5月27日 15:45-16:00

Role of alkali carbonates in the mantle magmatism, metasomatism, and diamond formation

Role of alkali carbonates in the mantle magmatism, metasomatism, and diamond formation

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There are much direct and indirect evidences of carbonatitic and hydrous melt/fluid segregation in the deep mantle in the past Earth's history. One particular example is the source regions of carbonatites, kimberlites, and lamproites some of which originate from more than 250 km depth. On the basis of experimental studies they appear to represent opposite ends of the volatile spectrum; carbonatites and kimberlites clearly require abundant CO₂ in the source, whereas lamproites require H₂O rich sources.

Another example is the natural diamond forming medium. Experimental data suggest that water-bearing alkali carbonates and CO₂-H₂O fluid are only species which are capable to initiate diamond crystallization at pressures and temperatures that correspond to those of natural diamond formation. Analysis of data on micro-inclusions in "fibrous" diamonds from different localities indicates that the diamond-forming media at the stage of inclusion entrapment constituted of super-critical fluid or melt with different ratios of carbonates and water. These integrated results strongly support the concept of diamond crystallization from either hydrous fluid or alkali carbonate melt.

In accordance with the current geotherms for the upper surfaces of subducted slabs and the phase equilibria computed for an oceanic metabasalt and subducted marine sediments the local abundance of water and carbonates in the mantle can be attributed to the subduction. However, for much of geological time (>500 m.y.) subduction geotherms have been too hot to allow carbonate and water subduction. This means that water-bearing silicates and carbonates rather underwent decomposition and melting at shallow depth leading arc magmatism than were transported into the deep mantle. In accordance with this and since the average mantle concentrations of carbon and hydrogen do not exceed 100 and 120 wt ppm respectively, the volatile segregation in a broad mantle region should be involved to explain the local abundance of CO₂ and/or H₂O. Enrichment of these fluids in incompatible trace elements (specifically, K, Rb, Sr, Ba, light REE, Ti, Nb, Zr, P, U, and Th) also implies their long infiltration history through the large volumes of mantle rocks. However, mechanisms and forces driving fluid transport and segregation in the deep mantle are poorly understood.

In this talk we would like to highlight following subjects.

- 1.PT conditions of carbonatite magma formation. Mantle solidus.
- 2.Mechanism of carbonate melts segregation.
- 3.Migration rate of carbonatite melt through solid no-porous silicate mantle.
- 4.Proto-kimberlite magma composition. Experimental constrain.
- 5.P-T conditions of natural diamond formation in presence of carbonatite melt.
- 6.Effect of carbonate-silicate ratio on kinetics of diamond formation.

キーワード: carbonatite melt, kimberlite, metasomatism, diamond, mantle

Keywords: carbonatite melt, kimberlite, metasomatism, diamond, mantle

MIS002-07

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時間:5月27日 16:00-16:15

マントル条件下におけるメタンの分子重合と olivine への影響

Formation of hydrocarbons and graphite by polymerization of methane molecules under the Earth's mantle conditions.

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High-pressure and high-temperature experiments of olivine-methane-water and olivine-methane systems were performed using a laser-heated diamond anvil cell at a pressure range from 5.4 to 29.4 GPa and a temperature range from about 1600 to 2000 K corresponding to conditions of the upper mantle to the top of lower mantle. X-ray diffractometry, Raman spectroscopy, and transmission electron microscopy revealed that methane molecules polymerized under existence of olivine to form heavier hydrocarbon, graphite. A difference in the products was not observed between the present study and the previous studies of sole methane. The present result suggests there is no effect of olivine to polymerization of methane molecules. The present study demonstrates polymerization of methane occurs in the Earth's mantle and that is consistent with previous studies on finding some hydrocarbons in mantle-derived minerals.

キーワード: メタン, カンラン石, 水素, 分子重合, レーザー加熱ダイヤモンドアンビルセル

Keywords: methane, olivine, hydrogen, polymerization, laser heated diamond anvil cell

MIS002-08

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時間:5月27日 16:30-17:00

COH Solubility, solution behavior and $^{13}/^{12}\text{C}$ fractionation melt-fluid systems at mantle redox, P, and T conditions COH Solubility, solution behavior and $^{13}/^{12}\text{C}$ fractionation melt-fluid systems at mantle redox, P, and T conditions

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The solubility and solution mechanisms in melts and speciation in coexisting fluid of reduced and oxidized C-bearing volatiles in the system C-O-H have been determined as a function of melt composition (from haplobasalt to haploandesite) and redox conditions in the range from the MH to the IW buffer to upper mantle temperatures and pressures. Sample characterization was conducted with samples quenched from high temperature and pressure and with melt+fluid samples in-situ in hydrothermal diamond anvil cells. Raman, FTIR, and NMR spectroscopies were employed as structural tools for studies of glasses, melts, and fluids. Carbon solubility and carbon isotope fractionation between melt and fluid were determined mass-spectrometrically and interpreted with the aid of speciation of C-O-H in melt and in coexisting fluids (see also [1]).

Methane solubility increases from 0.2 wt percent to about 0.5 wt percent in the composition range between haploandesite and haplobasalt and increases by 150 percent between the IW and MH oxygen buffers at constant temperature and pressure. Carbon isotope fractionation between methane-saturated melts and (CH₄+H₂+H₂O)-fluid changes by 14 per mil with the melt compositions studied (haploandesite to haplobasalt). In the COH-silicate system at redox conditions of the NNO oxygen buffer and more oxidizing, carbon exists in melts as carbonate complexes and in the fluid as CO₂. Carbonate occurs in two forms, as CO₃-groups sharing one or more oxygen with the silicate melt network structure and as isolated CO₃-groups bonded to metal cations. Isolated CO₃-groups become more abundant the less polymerized the melt (more mafic melts). Reduced (C+H)-bearing species were detected in silicate melts at the redox conditions of the MW buffer and more reducing. From diamond cell (HDAC) experiments conducted in-situ from ambient temperature and pressure to 800 C and 1435 MPa under redox conditions near those of the IW buffer, the dominant fluid species in the fluid are CH₄, H₂, and H₂O. In coexisting melt, CH₃-groups linked to the silicate melt structure via Si-CH₃ bonding occur together with molecular CH₄. There is no evidence of changes in hydrocarbon species or polymerization with temperature and pressure.

The melt composition-dependent solubility and change in carbon isotope fractionation is because of silicate composition-dependent changes of C-bearing species in the melt. The composition- and redox-dependent solution mechanisms of C-species in melts governs how melt properties can change with redox conditions. Redox melting in the interior of the Earth has been explained with the aid of the solution mechanisms of oxidized and reduced carbon in silicate melts. Further, effects of oxidized and reduced carbon on melt viscosity and on element partitioning between melts and minerals have been estimated from relationships between melt polymerization and dissolved carbon combined with existing experimental data that link melt properties and melt polymerization. With total carbon contents in the melts on the order of several mol percent, mineral-melt element partition coefficients and melt viscosity may change by several tens to several hundred percent as a function of redox conditions in the range of the deep crust and upper mantle of the Earth.

[1] Mysen, B. O., Cody, G. D., and Morrill, P. L. (2009) *Geochim. Cosmochim. Acta.* 73, 1699.

キーワード: carbon speciation, COH fluid, silicate melt, solubility, solution mechanism, isotope fractionation

Keywords: carbon speciation, COH fluid, silicate melt, solubility, solution mechanism, isotope fractionation

MIS002-09

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時間:5月27日 17:00-17:15

惑星核中の炭素 Carbon in Planetary Cores

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Carbon is one of the candidates for the light elements in the core. Phase relations of the Fe-C system have been studied to the lower mantle conditions. These studies revealed that Fe₃C and Fe₇C₃ compounds can exist under the conditions. On the other hand, there are few data on the solubility of carbon in molten iron, and the effect of carbon on physical properties such as density and compressional wave velocity of molten iron at high pressure. Thus, we made experiments on partitioning of carbon and silicon between metallic iron and silicate under various oxygen fugacity conditions at high pressure. We made two sets of experiments. First is the density measurement of Fe-C liquid at high pressure using the sink-float test of a composite marker after quenching from high pressures and temperatures, and the in situ X-ray absorption imaging method. The second set of the experiments was to measure the solubility of carbon and silicon in molten iron coexisting with silicates at high pressure and temperature. The first result revealed that carbon can reduce density of the molten iron at high pressure, whereas it increases the velocity of molten iron. Thus, it can be a candidate of the light elements of the outer core. The second set of the experiments revealed that light elements dissolved into metallic iron change with the oxygen fugacity; i.e., under the extremely reducing conditions of fO₂, about -4.5 log units below the iron-wustite buffer, only a limited amount of carbon can be dissolved into molten iron, whereas silicon is the major light elements dissolved into metallic iron. On the other hand, carbon can be dissolved into molten iron under relatively higher oxygen fugacity conditions. Thus, carbon can be a light element of the core only when the oxygen fugacity during the core formation is relatively high.

Keywords: Carbon, Core, phase relation, density, velocity, Fe-C liquid

MIS002-10

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Carbon isotope fractionation during the formation of the Earth's core Carbon isotope fractionation during the formation of the Earth's core

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Carbon, the fourth most abundant element in the solar system, is believed to be an important light element constituent in the Earth's core. The high carbon content of CI chondrites (3.2 wt.%) compared to bulk earth estimates, the presence of graphite/diamond and metal carbides in iron meteorites, the high solubility of carbon into iron melts in the Fe-C system suggests the plausible presence of carbon in the Earth's core. However, the distribution of carbon isotopes in the core is not understood. We present here new experimental data in the Fe-C system and results on the equilibrium carbon isotope fractionation between graphite/diamond and iron carbide melt at 5 GPa and 10 GPa at a temperature range of 1200 to 2100 °C. Our results suggest that iron carbide melt will preferentially gather ¹²C than ¹³C, which is temperature dependent. It is intriguing that our results are consistent with the carbon isotope distribution observed between graphite and cohenite (Fe₃C) in iron meteorites. The temperature dependent fractionation between iron carbide melt and graphite/diamond finds potential application in determining the temperature of formation of meteorites and metallic core of planetary materials. Furthermore, we anticipate that the temperature dependent fractionation of carbon isotopes between iron carbide melt and graphite/diamond is an effective mechanism that created a ¹²C enriched core with large scale differences in the distribution of the carbon isotopes in the metallic core and bulk silicate Earth during the accretion and differentiation of early Earth. Our findings also have implications on the deep carbon cycle of the Earth, where the light carbon from the core might have transported to the mantle and crust through deep mantle plumes.

キーワード: core, carbon isotope fractionation, iron carbide, graphite, diamond

Keywords: core, carbon isotope fractionation, iron carbide, graphite, diamond

MIS002-11

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時間:5月27日 17:30-17:45

二酸化炭素フラクシングによる炭素同位体組成変化の予測 Carbon isotopic variation during CO₂ fluxing in crustal magmatic systems

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< 研究背景 >

ガラス包有物の分析的研究が進められた結果、地殻のマグマシステムでは、深部を起源とするCO₂流体（またはガス）がマグマの中を流れ、系全体をCO₂に富む組成に変化させる“CO₂フラクシング”が起きていることが判ってきた。この現象は、ガラス包有物のCO₂/H₂O濃度比が通常の脱ガスから予想されるよりもはるかに高く、外部からのCO₂供給がないと説明できないために提案された。多くの火山（流紋岩質～玄武岩質）でそのような高いCO₂/H₂O濃度比が報告されていることから（Metrich and Wallace, 2008）、地球上の火山では一般的に起こる現象と考えられる。そのため、地球での炭素循環においては、地球内部のCO₂を地表へもたらす主要なプロセスであると考えられる。火山学的には、マグマのH₂O活量を低下させることで結晶作用を促進したり、メルト粘性を増加させるなど、火成活動に影響を与える現象と捉えられる。また、メルトの脱水により流体体積分率を急激に増加させ、バルク密度を低下させるため、火山噴火をトリガーする可能性もある（Yoshimura and Nakamura, 2010）。しかし、CO₂がどのように輸送されているのか、そのメカニズムは殆ど知られていない。

最近、わたしたちは反応輸送モデルを用いてCO₂フラクシングを定式化し、その基本的性質を明らかにした。また、これを天然のガラス包有物データに適用することで、CO₂流体の輸送メカニズムを議論した（Yoshimura and Nakamura, 投稿中）。本研究ではこれをさらに発展させ、炭素同位体組成変化までを含めたモデルを構築した。

< 反応輸送モデル >

H₂Oに富む地殻マグマの柱を想定する。その高さ方向のH₂O・CO₂濃度およびd13C値の分布は、底部から最上部（地表）に向かって圧力低下による閉鎖系脱ガスのトレンドにしたがっているとすると、このようなマグマ柱の底部にCO₂/H₂Oモル比およびd13C値が一定の流体（CO₂に富む）が連続的に注入され、メルトと揮発性成分の交換を行いながら上昇し、系全体が再平衡化してゆく様子をシミュレーションした。流体とメルトは各深さで瞬時に化学・同位体平衡に達すると仮定した。以上は、H₂O、¹²CO₂、¹³CO₂の3成分の移流方程式、H₂O・CO₂の溶解度則、¹²CO₂・¹³CO₂のガス・メルト間の同位体平衡の式により記述される。

< 結果と考察 >

メルトのCO₂/H₂O濃度比は時間と共に増加した。その間、流体はメルトから放出されるH₂Oで希釈され、組成を変えながら上昇した。その効果は、再平衡化が進むと徐々に弱まった。以上は、Yoshimura and Nakamura（投稿中）でも示されていたことである。一方、今回新たに加えた炭素同位体に関しては、注入した流体の炭素同位体値と平衡な値に徐々に変化していったが、その変化はH₂O・CO₂濃度の変化に比べて速く、短時間のうちに完了した。底部で注入された流体が初めて最上部にたどり着いたとき、d13Cはすでに全ての深度でほぼ一定で、注入された流体と平衡な値と等しくなっていた。その間、CO₂/H₂O比は、メルト、ガスともはまだ大きく変化している最中である。このように炭素同位体が速く収束したのは、流体とメルトの間で交換する¹²CO₂と¹³CO₂の物質量は、もともとそれぞれの相に存在する¹²CO₂、¹³CO₂の量に比べて圧倒的に小さいこと（数%程度）による。

以上より、CO₂フラクシングにおいては、d13CはH₂O・CO₂濃度・組成によらず常に一定で、ソースの値を直接反映していることがわかった。将来、火山ガラスの炭素同位体組成を分析できるようになれば、このような特徴と比較することでCO₂のソースやフラクシング機構を解明することができるようになるであろう。

キーワード: CO₂フラクシング, 脱ガス, 反応輸送系

Keywords: CO₂ fluxing, degassing, reactive transport

MIS002-12

会場:104

時間:5月27日 17:45-18:00

The impact of Human intelligence on the global carbon cycle The impact of Human intelligence on the global carbon cycle

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The human brain consumes about one fourth of the total energy spent by the human body or ~ 25 W. For the present human population this leads to an average global energy consumption of ~ 0.4 mW/m² for the collective human brain activity. However, Human thought has far greater consequences than the direct metabolic activity of the brain. The idea of thermodynamics has allowed humans to spend more energy than we can obtain through our own metabolism. We have overcome the constraints of maximum appropriation of the primary photosynthetic productivity.

On a global scale, photosynthetic organisms capture solar energy equivalent to about 250 mW/m² of Earth's surface 1. About 1 per mil of this is deposited in sediments and either returned to the mantle via subduction on relatively short geologic timescales or sequestered in the crust on long geologic timescales. The thermodynamic insights have allowed us to convert the stored photosynthetic energy to work and heat at a rate of ~ 30 mW/m² ref 2. This is equivalent to 1/3 of Earth total inner energy conversion expressed in volcanism, plate tectonics and geothermal heat, and 20 times greater than the physiological energy conversion of humankind. By analyzing the impact of human thought relative to the energy requirement of our physiology we can evaluate the impact of societal structure and culture on the global carbon cycle.

1. Field, C. B., Behrenfeld, M. J., Randerson, J. T. & Falkowski, P. Primary production of the biosphere: Integrating terrestrial and oceanic components. *Science* 281, 237-240 (1998).

2. Doman, L. E. in DOE/EIA-0484(2010) (ed U.S. Energy Information Administration) 9-21 (U.S. Energy Information Administration, Washington, DC, 2010).

キーワード: Global Carbon, Human, photosynthesis, subduction, energy

Keywords: Global carbon, Human, photosynthesis, subduction, energy

MIS002-13

会場:104

時間:5月27日 18:00-18:15

地球浅所と深部起源岩石中の炭素含有物 Carbon-bearing nano-grains in shallow and deep-related rocks

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本研究結果は、以下の通りにまとめられることができます。

1) 地殻表面で採集できる大きな結晶面のダイヤモンドは、Fe, Mg Si に富む捕獲岩粒子を含み高圧深部のマントルで形成されています。しかしカーボン C または二酸化炭素ガスの軽い元素分子が惑星地球形成の後にマントルのより深い場所の方へ移動するのは非常に困難です (大衝突による影響以外)。

2) その場 ASEM (Scanning Electron Microscopy) 解析から、民主共和国 (RD) コンゴ産ダイヤモンドはマイクロ捕獲岩として浅い起源の岩塩組成と炭酸塩方解石を含みます。そして、それは炭素が浅所衝突によって変動したことを示唆します。

3) その場 ASEM 分析法は、南アフリカのキンバーライト産ダイヤモンドに Fe, Mg に富むケイ酸塩と Ca, Fe, Mg 炭酸塩 (Na と Cl は含まない) の捕獲マイクロ粒子を含みことが分かりました。

4) リビア産衝突ガラスは、浅い海衝突で形成された方解石炭酸塩と海水起源の岩塩のマイクロ粒を含むことがわかりました。

5) 同じその場 ASEM 方法での微粒子の解析に、炭素を含んだカーボナタイトとシュンガイト試料にも適用しました。

6) 深所起源の炭素の直接証拠は、玢珉隕石のプレッサイト中の混合領域に残存している炭素含有物のあることから確認できます。

キーワード: 炭素含有ナノ粒子, ダイヤモンド, カーボナタイト, シュンガイト, インパクト, 海中残留物

Keywords: carbon-bearing nano-grains, diamonds, carbonatite, shungaitite, impact, seawater remnants