

日本列島下におけるマントル融解状態の推定 Geochemical tomography for melting condition beneath Japan arcs

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Slab-derived fluid (hereafter slab-fluid) plays an important role for generation of arc magmas. If the flux of slab-fluid is enhanced or reduced by variable tectonic settings and the corresponding thermal and flow regimes, it has effects on the mantle melting. The melting condition may contribute to infer the thermal, flow and fluid regimes. We focus on the melting condition in the mantle wedge beneath Central Japan, where the two overlapping slabs, Pacific and Philippine Sea plates, exist and the amount and composition of slab-fluids from the two slabs are well documented, as the regional variation of slab-fluid fluxes that are related to the geometry of the subducting plates.

Based on the chemical composition of major and trace elements, we construct forward and backward models to constrain the melting condition beneath Central Japan. The composition of the primitive rock can be corrected for fractionated phases to estimate backwardly that of primary magma, while the composition of melt generated in the mantle wedge can be forwardly modeled as a function of degree of melting (sensitive to temperature) and mineralogy (proportions of garnet/spinel peridotites, sensitive to pressure) based on the composition of fluid metasomatized mantle.

As a result, the melting condition is characterized by relatively low melting degrees and high proportions of garnet peridotite involved in melting compared to the adjacent arcs with a single subducting slab, e.g., the Izu-arc. This implies that, the melting occurred at deeper depths and lower temperature for Central Japan. This also consistently explains the existence of adakites occurred in this area, in spite of the cold setting. The same analysis for the volcanoes in the adjacent areas show transition the thermal and fluid conditions, according to the spatial variation of the tectonic regimes, suggesting that geochemical approach is useful to map the physical condition, and could be referred to as geochemical tomography.

キーワード: マントル, 融解, スラブ起源流体, 沈み込み帯

Keywords: mantle, melting, slab, slab-fluid, subduction, arc

斜長石-玄武岩質メルト間の水素の分配実験

Experimental constraints on partitioning of hydrogen between plagioclase and basaltic melt

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目的

無水の造岩鉱物は、ppm オーダーの水素を含むことが知られており、メルト中に溶存する水の量や挙動の指標、すなわち含水量計として有用であることが明らかにされつつある。斜長石はそのような無水鉱物の一つであり、赤外吸収スペクトルを用いた分光学的研究より、火山岩の斜長石に含まれる水は、OH基であると考えられている (Johnson and Rossman, 2003, *Am. Mineral.*)。本研究の目的は、島弧の火山フロントに噴出する玄武岩質の火山岩において (1) 斜長石-メルト間の水素の分配係数を実験によって決定すること、及び (2) 斜長石の OH 量をメルトの含水量計として応用することである。

手法

斜長石-メルト間の水素の分配係数を決定するため、内熱式ガス圧装置を用いて、玄武岩マグマの含水融解実験を行った。三宅島火山・澁ヶ平溶岩 (50.5 wt.% SiO₂, 18.1 wt.% Al₂O₃, 4.9 wt.% MgO) を含水ガラス化したものを出発物質として用いた。澁ヶ平溶岩の全岩化学組成は斜長石成分に富んでおり、0-6 wt.% H₂O の含水量の条件で斜長石がリキダス相として晶出する。本実験では、澁ヶ平溶岩中の斜長石斑晶 (An₉₅, 0.4 wt.% FeO*) 約 1 mg と含水ガラスの粉末 (約 10 mg) とを Au₈₀Pd₂₀ カプセルに封入して、350 MPa の圧力下における斜長石のリキダス近傍の温度で 24~48 時間融解・保持することにより、斜長石斑晶とメルトとの間で H を分配させた。実験中の酸素雰囲気は制御されていないが、Ni-NiO パッファーよりも約 3 log unit 高い雰囲気下で行われた。実験後に回収された斜長石斑晶と玄武岩質メルト (ガラス) を、フーリエ変換赤外分光光度計 (FTIR) を用いて分析し、それぞれの含水量を分析した。玄武岩質ガラスの含水量の分析に際しては、OH 基の含有量と H₂O 分子の含有量も定量化した。

結果

An₉₅ の斜長石斑晶中に分配される OH 量は、メルトの含水量の増加に伴って単調に増加する (図 1a)。メルトの含水量が 1 wt.% 以下の時、斜長石-メルト間の H の分配係数 (モル比) は約 0.01 であるが、含水量の増加に伴って分配係数は小さくなる。メルトの含水量が 4 wt.% 以上では、斜長石の OH 量は 200-250 wt. ppm H₂O で飽和に達する。斜長石の OH 量とメルトの OH 量とは相関しており (図 1b)、Johnson and Rossman (2003) が述べているように、斜長石中に H は OH 基として取り込まれていることを支持している。

応用

1986 年の伊豆大島火山山頂噴火で得られた斜長石斑晶 (An₉₀, 0.7 重量% FeO*) の含水量は、最小で <50 wt. ppm H₂O、最大で 300 wt. ppm H₂O という OH 量のバリエーションを示す (Hamada et al. 2011, *EPSL*)。Hamada et al. (2011) は、(1) 斜長石中の OH 量のバリエーション、(2) An₉₀ の斜長石を玄武岩質メルトから晶出させるための実験岩石学的制約、(3) 伊豆大島山頂噴火の地球物理学的観測事実、に基づき、メルト中に水が最大で 6 wt.% 程度溶存しており、噴火に至る過程でメルトが水に飽和して脱ガスした可能性を議論した。

本研究では、高 OH 量 (最大で 250 ppm H₂O) の斜長石は 4 wt.% 以上の含水量のメルトと平衡共存することが明らかとなった。すなわち、1986 年の伊豆大島火山山頂噴火の際に、マグマ溜まりではメルトは 4-6 wt.% の H₂O を溶存し、共存する斜長石に最大で 300 wt. ppm H₂O の H を分配させたと考えられる。これは、地下 8~10 km の深度に推定される伊豆大島火山のマグマ溜まり (Mikada et al., 1997, PEPI) における、メルトの飽和含水量に相当する。噴火に至るマグマの上昇の過程で、水に飽和したメルトは脱ガスし、共存する斜長石の OH 量を <50 wt. ppm H₂O にまで減少させたと考えられる。

実験生成物の An₉₅ 斜長石斑晶の OH 量が 250 wt. ppm H₂O で飽和してしまい、伊豆大島火山で得られるような 300 wt. ppm H₂O には達しない。その理由は、斜長石の化学組成の違い (An 量や FeO* の含有量の違い) で説明される可能性がある。

キーワード: 無水鉱物の水, 斜長石, 島弧玄武岩マグマ, 含水融解実験

Keywords: Water in nominally anhydrous minerals, plagioclase, arc basaltic magma, hydrous melting experiment

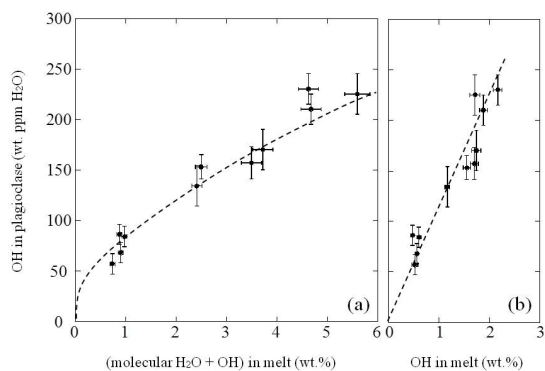


Fig. 1

スラブには何が残って何が地表へ帰るのか? 地球化学マスバランスモデル What stays in the slab and what returns to the surface? A geochemical mass balance model perspective

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We have developed the Arc Basalt Simulator (ABS), a quantitative forward model to calculate the mass balance of slab dehydration and melting, and slab fluid/melt-fluxed mantle melting, in order to quantitatively evaluate magma genesis beneath arcs. ABS models can reproduce magma compositions in many arcs.

The model suggests that the slab-derived component at volcanic fronts (VF) is mostly generated by dehydration, but successful models for most VF and all rear arc (RA) magmas also require the slab to melt. The compositions of slab fluids and melts are controlled primarily by the breakdown of amphibole and lawsonite beneath the VF and by the breakdown of phengite beneath the RA in addition to residual eclogite mineral phases including garnet, clinopyroxene, and quartz.

In the model, about 78-98% of relatively fluid-immobile elements including Nd and Hf in the arc lavas come from mantle peridotite. However, most liquid-mobile elements come from the slab. Modeled residual peridotite compositions are similar to those in some supra-subduction zone ophiolites and mantle xenoliths, providing constraints on reactions in the mantle wedge.

Altered oceanic crust (AOC) and sediment in the residual slab are modified by the subtraction of melt- and fluid-mobile elements. Unmodified AOC potentially becomes the EM I mantle component after 1 Ga, whereas melted AOC can have extremely fractionated U-Pb and become the HIMU source after 1-2 Ga. Element re-distribution beneath arcs can form the recycled materials that have been detected in ocean island basalts.

キーワード: 島弧, マグマ, 地球化学, マスバランス

Keywords: arc, magma, geochemistry, mass balance

日本列島に分布する熱水性鉱床のPb同位体比組成 Pb isotopic compositions of hydrothermal deposits in the Japanese island arc

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Quite recently, it has been pointed out that "geofluids" released from the subducting plates may be involved in various phenomena in subduction zone, such as young volcanic rocks, deep-seated hot springs and hydrothermal deposits. Systematical investigations of these various materials are needed for identifying the geochemical characteristics of the geofluids. Nakamura et al. (2008) revealed that the slab-fluids derived from two subducted plates (the Pacific plate and the Philippine Sea plate) contribute largely to the genesis of arc magmas in the Central Japan. Here we focus on hydrothermal deposits (vein-type and skarn-type) in the Japanese island arc. Hydrothermal fluids that formed sulphide mineral (galena, pyrite, chalcopyrite, sphalerite etc.) deposits are generally considered to have been derived from magmatic and/or meteoric waters based on H, C, O, and S isotopes in the deposit materials. However, ore fluids may be derived from deep slab-fluids. We report Pb isotopic compositions of hydrothermal deposits in the Japanese island arc and discuss about the origin of ore fluids.

Keywords: Pb isotopic composition, hydrothermal deposit, slab-fluid

有馬温泉のREE組成 -スラブ起源流体への示唆-

Rare earth element composition of the Arima-type brine and its implication for slab-derived fluid

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The Arima-type brine has been known as one of the oldest hot springs in Japan, as well as its distinct geochemistry: in spite of its presence in the non-volcanic region in the forearc, the oxygen and hydrogen isotope compositions show a presence of deep brine similar to volcanic fluids. Mixing between the meteoric water and a deep brine with a high $\delta^{18}\text{O}$ and $\delta^2\text{H}$ (7 to 8, -40 to -30, respectively) explains the linear trend of the brine samples. The Arima-type brines are highly concentrated in the type locality, Arima, SW Japan. The two plates subduct beneath the area: the Pacific Plate subducts from the east and underlies ~400 km below the area, whereas the Philippine Sea Plate subducts from the southeast and is seismically observed 50 to 80 km below the area. In spite of this active subduction, there is no Quaternary volcano in this area, possibly because the Pacific Plate is too deep and the Philippine Sea Plate is too shallow to fulfill the physicochemical conditions for arc magma generation.

Here we report geochemical signatures, in particular the REE concentrations, of the Arima brine, and suggest that it could have originated directly from the subducting slab without any significant modification during its ascent. High salinity, high $3\text{He}/4\text{He}$ ratio and distinct oxygen, hydrogen and carbon and strontium isotope compositions also suggest that they have been derived possibly from the subducting Philippine Sea slab, hence may bring invaluable insights for the slab-derived fluid and the related fluid processes in subduction zones. In this study, we analyzed samples from 'Kinsen'. The Kinsen brine has a high salinity and the highest abundances of the trace elements in this area. We have also sampled a solid material precipitated within the pipe, in order to estimate the elemental fractionation during cooling of the hot spring and precipitation from it. Because of its high salinity (up to 6 wt.% NaCl) of the Arima-type brine, the matrix effects are extremely large to prevent accurate analysis of any trace element. We employ a standard addition method, aiming at rapid yet accurate analyses.

The DMM normalized composition of Arima brine exhibits broadly a flat pattern around the normalized concentration of 10-3 with a convex-down shape for mid-REE, except for positive anomaly in Eu. On the other hand, the precipitates consist of aragonite and magnesite, which do not contain REE above the detection limit, except for Gd which is likely derived as flakes from the pipe.

Alternatively, based on the reported partition coefficient and the numerical modeling of the thermal structure along the subducting slab, the REE concentrations in the slab-derived fluid (as a product of slab dehydration reactions) have been evaluated. The calculation results broadly coincide with the observed REE concentrations of the Arima-type brine. Together with these analytical results and forward calculation, we conclude that the REE composition in the Arima brine is straightly originated from the dehydration of subducting slab at 450 degree.

キーワード: スラブ起源流体, 有馬温泉, 希土類元素, 酸素水素同位体比, 有馬型温泉, 沈み込み帯

Keywords: slab-derived fluid, Arima brine, rare earth elements, isotopic compositions of oxygen and hydrogen, Arima-type brine, subduction zone

北海道神居古潭帯岩内岳超塩基性岩体にみられる2段階の蛇紋岩化作用 Two-stage serpentinization reactions: an example of Iwanai-dake ultramafic rocks, Kamukotan belt, Hokkaido, Japan.

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沈み込み帯において含水鉱物から放出された水は、島弧火成活動や地震の発生など様々な地球科学的現象を引き起こすとされる。特に、マントルウェッジのかんらん岩は水と反応して蛇紋岩化作用を被るが、それにより密度、初磁化率、浸透率などの岩石の物性は大きく変化し、地球全体の水循環やマントルダイナミクスに大きな影響を及ぼすと考えられている。しかし、かんらん岩の蛇紋岩化プロセスについては不明な点が多い。蛇紋岩化作用は一般的に、多量のマグネタイトの形成を伴う。近年の研究では、蛇紋岩化反応は少なくとも2段階のプロセスであり、2段階目の反応でマグネタイトが形成されると考えられているが、この反応については様々な解釈が提示されている。例えば Bach et al. (2006) は、ブルース石の分解によるものとしたが、Frost and Beard (2007) は、SiO₂ の活動度が低い条件下で蛇紋石が分解することによりマグネタイトが形成される可能性を示した。このように、岩石の密度や初磁化率を変化させる重要な要因であるにも関わらず、マグネタイト形成に寄与している要因についてはよく理解されていない。それだけでなく、2段階目の反応が起こったことを支持する岩石学的証拠も十分には提示されていない。本研究では、北海道神居古潭帯岩内岳超塩基性岩体について、岩石記載、鉱物組成分析、密度及び初磁化率の測定から蛇紋岩化プロセスを明らかにし、どのような反応がマグネタイトの形成に寄与しているのかを考察した。

岩内岳超塩基性岩体は神居古潭帯の南部に位置し、岩体の中央部には、蛇紋岩化をまぬがれた直径約1kmの新鮮なかんらん岩体が存在している。かんらん岩体から周囲の蛇紋岩体にかけて、蛇紋岩化度は漸次的に上昇しているとされる。かんらん岩体は主にハルツパージャイトからなり、一部にダナイトを含む。かんらん岩体から東西に走る林道沿いで、様々な蛇紋岩化度のサンプルを採取し、偏光顕微鏡観察及びラマン分光装置による鉱物同定、SEM-EDSによる鉱物化学組成分析、アルキメデス法による密度の測定、及び帯磁率計による初磁化率の測定を行った。

蛇紋岩には主に蛇紋石、ブルース石、マグネタイトが含まれている。蛇紋岩のメッシュ組織を形成する鉱物組み合わせは、Mg#95-97の蛇紋石とMg#75のブルース石がインターグロースしたもの(Aタイプ)と、Mg#93の蛇紋石からなるもの(Bタイプ)の二種類が存在する。Bタイプは中心部にブルース石脈を有する。さらにメッシュ組織は、AタイプあるいはBタイプのみからなるものと、AタイプとBタイプ両方からなる二重のメッシュをなすものの三種類が存在する。ハルツパージャイトでは蛇紋岩化の進行に伴い、Aタイプ → A + Bタイプ → Bタイプという変遷がみられた。蛇紋岩化度の高いハルツパージャイトでは輝石の蛇紋石化がみられたが、ほぼBタイプの出現時期と一致していた。しかしダナイトでは、蛇紋岩化度が高いサンプルでもBタイプやブルース石脈はみられなかった。ハルツパージャイトは密度2.9g/cm³付近で急激な初磁化率の上昇がみられたが、ダナイトでは蛇紋岩化が進んでも上昇は見られず、低い値のままだった。

以上のことから、本研究地域の蛇紋岩化には以下の2段階のプロセスが考えられる。1段階目では、かんらん石と水が反応し、Mg#95-97の蛇紋石とMg#75のブルース石が形成された。そして、2段階目の反応で、Mg#93の蛇紋石が形成された。後期の反応はダナイトではみられなかったことから、輝石の蛇紋石化によるSiO₂に富む流体の供給が関与していると考えられる。また、初磁化率と密度の関係から、マグネタイトは後期の反応で形成されたと考えられる。これらのことから、SiO₂の供給がマグネタイト形成の要因になったと考えられる。今回は、Frost and Beard (2007) の提案とは異なる結果となった。しかし、Bach et al. (2006) でみられた組織は本研究のものとは異なり、今回のタイプ分けは適用できない。テクトニックセッティングや原岩の違い、流体の組成などにより蛇紋岩化反応が異なるという可能性も含めて、慎重に議論する必要があると考えられる。

引用: Bach, W., H. Paulick, C. J. Garrido, B. Ildefonse, W. P. Meurer, and S. E. Humphris (2006), *Geophys. Res. Lett.*, 33, L13306, doi:10.1029/2006GL025681.; Frost, B. R. & Beard, J. S. (2007). On silica activity and serpentinization. *Journal of Petrology* 48, 1351-1368.

一ノ目潟のかんらん岩捕獲岩中のClを含むCO₂-H₂O流体包有物 Cl-bearing CO₂-H₂O fluid-inclusions of peridotite xenoliths from Ichinomegata

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Hydrous minerals in a subducting slab carry OH- and H₂O into the Earth's interior, and at points beyond their stability conditions they release H₂O to the overriding mantle wedge (Tatsumi and Eggins 1995). The H₂O fluids transport materials from the slab to the mantle wedge. Recently, analyses of halogen elements of high-pressure metamorphic rocks suggest that saline fluids are preserved in the subducting slab as marine pore-fluids until the depths of at least 100 km (Sumino et al., 2010, EPSL). Salinity of H₂O fluids affects dissolution properties of metal ions (Keppler, 1996, Nature). It is, therefore, important to understand the salinity of the H₂O fluids in the mantle wedge in terms of subduction system of metal.

Fluid inclusions in mantle xenoliths preserve direct information of the fluids in the mantle. Mantle xenoliths from the Ichinomegata volcano, located in back-arc side in the northeast Japan arc, have CO₂-H₂O fluid inclusions (Roedder, 1965, Am Mineral). In the present study, we report salinity of the CO₂-H₂O fluid inclusions in the mantle xenoliths from the Ichinomegata volcano.

All mantle xenoliths studied are porphyroclastic lherzolite, composed of olivine, orthopyroxene, clinopyroxene, spinel and hornblende. The CO₂-H₂O fluid inclusions are occasionally present in orthopyroxene porphyroclasts. The fluid inclusions have not reacted with host orthopyroxene crystals after the formation. We suppose, therefore, that the salinity of the fluid inclusions represents the original value in the mantle. Formation depths of the fluid inclusions are estimated by the following steps: (1) estimating the bulk mole volume of CO₂-H₂O fluid inclusion using homogenization temperatures of CO₂ liquid-vapor and CO₂-H₂O (Bakker and Diamond, 2000, *Geochem. Cosmochim. Acta*), (2) calculating pressure of the formation of the fluid inclusion using equilibrium temperature estimated by a pyroxene geothermometer (Wells 1977, *Contrib. Mineral. Petrol.*) and isochore of CO₂-H₂O system (Loner AP, from Software Package FLUIDS, v.2, Bakker), (3) converting the pressure to depth by assuming densities of crust and mantle are 2.85 and 3.3 g/cm³, respectively, and Mohorovicic discontinuity is 27 km. Salinities of fluid inclusions are determined using melting temperature of clathrate (Darling, 1991, *Geochim. Cosmochim. Acta*). The depth is estimated to be about 30 km, which is consistent with the following petrographical feature. Some xenoliths have plagioclase and symplectites formed by reaction of plagioclase and olivine. This indicates that the xenoliths were from the boundary between plagioclase-peridotite and spinel-peridotite. The salinity of fluid inclusions is 3.93 ± 0.55 wt %. Using relationship between the molality of Cl and the fluid/melt partition coefficients (Zajacz et al., 2008, *Geochem. Cosmochim. Acta*), for example, the fluid/melt partition coefficients of Pb and Zn under this salinity are 7.8 and 18.6, respectively (those of Cl-free hydrous fluid are almost 0 and 8.2, respectively).

キーワード: 塩濃度, 流体包有物, 物質輸送, 沈み込み帯, マントル捕獲岩, 一ノ目潟

Keywords: salinity, fluid inclusion, material transport, subduction zone, mantle xenolith, Ichinomegata

東北地方と関東地方におけるプレートの沈み込みに伴う温度分布の数値シミュレーション

Numerical simulations of temperature distributions associated with subduction of the plate beneath Tohoku and Kanto

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1. はじめに

東北地方では太平洋プレートが沈み込んでいる一方で、関東地方には太平洋プレートの上に重なるようにフィリピン海プレートが沈み込んでいる。そこで、本研究では、まず東北地方において太平洋プレートの沈み込みに伴う温度分布の数値シミュレーションを行い、東北地方で再現した温度分布をもとにフィリピン海プレートの沈み込みを起こすことによって関東地方における2つのプレートの沈み込みに伴う温度分布を計算した。

2. モデルと手法

Yoshioka and Sanshadokoro(2002)の2次元箱型熱対流モデルを用い温度分布の計算を行った。太平洋プレートの沈み込み速度は、Sella et al.(2002)を参照し、沈み込む太平洋プレートの年齢をSdrolias and Muller(2006)に基づいて時間変化させた。Nakajima et al.(2007,2009)とHirose et al.(2008)による太平洋プレートとフィリピン海プレート上面の形状を与え、プレートが沈み込む際に与えるガイドの指標とした。地殻熱流量のデータとしては、Tanaka et al.(2004)、Yamano(2004)のボアホール、ヒートプローブ、松本(2007)によるHi-netの観測井でのデータを用いた。

高木・他(2011)のモデルでは、太平洋プレートの沈み込みに伴いマンテルウェッジ先端部に高温のマンテルの流れ込みが起こり、東北地方では観測データの地殻熱流量を大きく上回る高温場がマンテルウェッジの先端付近にできてしまっていた。そこで、マンテルの流れが入り込まない領域をマンテルウェッジの先端付近に設置し、東北地方下に存在すると考えられているcold noseと呼ばれる冷たい領域をモデル化した。東北地方の温度分布から計算される地殻熱流量の値と地殻熱流量データを比較し、観測値を再現する温度モデルを構築した。関東地方においては、東北地方で構築した太平洋プレートの沈み込みモデルに、遅れてフィリピン海プレートを沈み込ませ、関東下に広がる低い地殻熱流量をフィリピン海プレートによって説明しようと試みた。

3. 結果

東北地方においては、cold noseの導入によって、海側の地域で地殻熱流量の観測値により合致する計算結果が得られた。関東地方においては、フィリピン海プレートの沈み込みにより、cold noseよりも陸側の領域で、地殻熱流量が低くなることが分かった。関東地方の地殻熱流量の観測値をうまく説明するため、太平洋プレート上面に発生する摩擦熱の導入についても検討中である。

キーワード: プレートの沈み込み, 温度分布, 流れ場, 地殻熱流量, 関東地方, コールドノーズ

Keywords: subduction, temperature distribution, flow field, heat flow, Kanto district, cold nose

東北日本の地殻流体の3次元電磁イメージング Three-dimensional electromagnetic imaging of NE Japan

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Geofluid plays an important role in the genesis of crustal earthquakes and volcanoes. Magnetotelluric method uses natural electromagnetic fields and it can image the fluid distribution in terms of electrical resistivity. We have selected an area around Naruko volcano for our project target in order to get detailed three-dimensional distribution of fluids in the crust with a horizontal resolution of ~3km. From the analyses of previous data of 60 MT stations, we have found (1)sub-vertical conductors at the active volcanoes, like Naruko and Onikobe and (2)lower crustal conductors with SSW-NNE strike in the backarc side, and (3)upper to middle crustal conductors in the forearc. We have found high seismicity, located over or outside the crustal conductors.

In this presentation, newly obtained 81 MT data over the two large calderas, Mukaimachi caldera and Sanzugawa caldera, and three-dimensional modeling results will be presented.

キーワード: 地殻流体, 電磁探査, 比抵抗, 地震, 火山, カルデラ

Keywords: geofluid, electromagnetic exploration, resistivity, earthquake, volcano, caldera

紀伊半島下に沈み込むフィリピン海スラブ周辺の3次元地震波速度構造 3D seismic velocity structure around Philippine Sea slab subducting beneath Kii Peninsula

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1. はじめに

四国西部から東海中部に至る地域では、沈み込むフィリピン海プレートの深さ 30~40km において、深部低周波イベントが帯状に分布する (Obara, 2002; 鎌谷・勝間田, 2004; Obara and Hirose, 2006)。地震波走時トモグラフィーやレシーバ関数解析の結果から、フィリピン海プレートの海洋地殻は、低速度かつ大きな V_p/V_s 比を有することが明らかになった (弘瀬・他, 2007; Ueno et al., 2008)。近畿中部から紀伊半島にかけての地域では、前弧側にもかかわらず、温泉ガスの $^3\text{He}/^4\text{He}$ 比が高い (Sano and Wakita, 1985; Wakita and Sano, 1987)。これらの事象は、海洋地殻とともに沈み込んだ「水」が、深さ 30~40km で脱水し、深部低周波イベントの発生に参与するとともに、地下浅部まで移動するというプロセスを示唆している。

我々は、紀伊半島下に沈み込むフィリピン海プレートとその周辺の構造を推定するため、2004年からアレイ地震観測を行ってきた。約 5km 間隔で線状に配置した地震計で記録された遠地地震のレシーバ関数解析により S 波速度不連続面のイメージングを行った。前回の発表 (澁谷・他, 2010) では、フィリピン海スラブの傾斜方向の 4 測線 (潮岬 - 田尻, 新宮 - 河内長野, 尾鷲 - 京丹後, 南伊勢 - 信楽) とこれらにほぼ直交する 1 測線 (松阪 - 白浜) の結果について紹介した。今回は、レシーバ関数解析で得られた不連続面の情報と、稠密リアアレイ観測点での読み取り値も用いた地震波走時トモグラフィーの結果について報告する。

2. 地震波走時トモグラフィー

本研究のトモグラフィーでは、速度構造モデルに、レシーバ関数解析により推定した大陸モホ面、海洋地殻上面および海洋モホ面の 3 次元的形状を組み込んだ。理論走時の計算には波面法に基づく手法 (de Kool et al., 2006) を用いた。さらに、定常観測点に加えて、稠密リアアレイを構成する臨時観測点の読み取り値も使用した。臨時観測点の稠密な配置により、高い分解能が得られた。

3. フィリピン海スラブ周辺の構造

トモグラフィーの結果を図 1 に示す。深さ 40 km では海洋地殻は低速度であり、浅くなるにつれて、その低速度領域はマントルウェッジ、下部地殻へと広がっていくように見える。紀伊半島北西部では深さ 16 km を中心とする大きな低速度域が存在する。その上方の上部地殻内では地震活動が非常に活発である。また、紀伊半島の東部に比べ、西部の方が低速度の程度が強い。

レシーバ関数イメージにも紀伊半島の中西部と東部とで違いが見られた。中西部では、低速度域がマントルウェッジへ張り出し、海洋モホ面が 40km 以深で不明瞭になり、スラブが上に凸に湾曲しているが、東部では、海洋モホ面は深さ 70km まで一様に明瞭であり、スラブ形状は直線的であった (澁谷・他, 2010)。

トモグラフィーやレシーバ関数イメージに見られるこれらの特徴は、海洋地殻の含水鉱物が深部低周波イベント発生域付近で脱水分解して、その結果放出された「水」がマントルウェッジや下部地殻に移動して、低速度域を作り出していることを示している。紀伊半島の中西部と東部に見られるスラブ周辺の構造や形状における違いは、脱水分解で放出される「水」の量や 40km 以深の海洋地殻に残留する「水」の量の違いで説明できるのではないかと考えられる。

防災科学技術研究所, 気象庁, 東京大学地震研究所, 名古屋大学, 京都大学防災研究所の定常観測点の波形データを利用した。

キーワード: トモグラフィー, レシーバ関数, フィリピン海スラブ, 紀伊半島, スラブ起源流体

Keywords: tomography, receiver function, Philippine Sea slab, Kii Peninsula, slab-derived fluid

SCG65-P10

会場:コンベンションホール

時間:5月20日 17:15-18:30

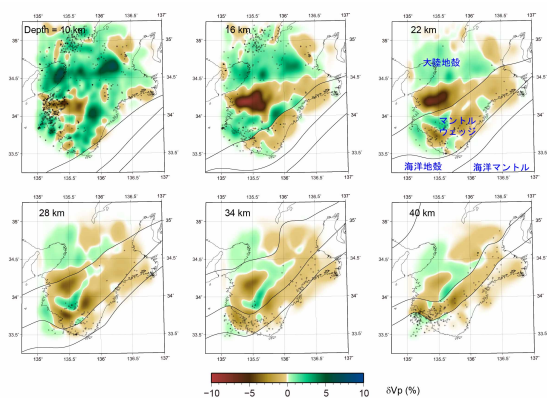


図1 P波速度の初期モデルからのパーターベーションを深さ10, 16, 22, 28, 34, 40 kmにおいて示す。初期モデルはJMA2001(上野・他, 2002)を基準とし、海洋地殻の速度を-5%、海洋マントルとマントルウェッジの速度を+5%と与えている。○はトモグラフィーに用いた地震のうち各深さ断面の近傍で発生したものを表す。太線は北から大陸モホ面、海洋地殻上面、海洋モホ面を示す。

三波川変成岩中の深部流体の Li/B 比 : その空間分布 Li/B RATIO OF CRUSH-LEACHED FLUID OBTAINED FROM THE SANBAGAWA METAMORPHIC BELT: ITS AREAL DISTRIBUTION

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We investigated species and compositions of deep fluids trapped as fluid inclusions (FIs) in high-P met-amorphic rocks formed in the subduction zones. One of major goals of our deep fluid study is to testify an idea whether peculiar fluid soluble light elements, such as Li, B and Cl, can be used as an indicator of fluid generation depths in the subduction zones or not (Scambelluri et al. 2004).

Quantitative analyses of major and trace element composition of the deep fluid are still in the hard task. We adopted crush-leach (CL) technique (e.g., Banks and Yardley, 1992) for extracting FI from quartz veins/lenses developing parallel to the main foliation of Sanbagawa metamorphic rocks crystallized at 20 - 60 km depths.

Major cations/anions of CL fluids were analyzed by ion-chromatography, and Li and B were done by ICP-MS. Raman spectroscopy is adopted to determine the liquid and gas species of fluid inclusions in quartz. Microthermometry is adopted to estimate NaCl salinity and to identify the formation stage of FIs.

We extracted CL fluids from three areas of the Sanbagawa belt, 1) Wakayama area, 2) Asemigawa area and 3) Besshi area.

In Wakayama area, CL fluids were extracted from three samples of quartz veins hosted by metabasites covering the metamorphic grade from the chlorite zone, pumpellyite-actinolite facies equivalent, to the biotite zone, amphibolite facies equivalent. Their Li/B ratios increase with metamorphic grade of the host rocks from 0.02 to 0.10 (Sengen et al., 2009). The hydrochemical facies of CL fluids are X-HCO₃ type and the intermediate type between Na-Cl type and X-HCO₃ type. The texture of quartz grains, which retain FIs, show pervasively deformed and recrystallized type for all studied samples.

In Asemigawa area, CL fluids were extracted from six samples of quartz veins covering the metamorphic grade from the chlorite zone to the oligoclase-biotite zone. Their Li/B ratios mainly vary from 0.03 to 0.38, but there is no correlation between Li/B ratio and the metamorphic grade of host rocks. The hydrochemical facies of CL fluids are X-HCO₃ type, except for one sample of Na-Cl type. The texture of quartz grains show pervasively deformed and recrystallized type for all studied samples. Some host rocks show distinct S-C fabrics. These observations suggest the rocks in the Asemigawa area pervasively deformed during the exhumation stage.

In Besshi area, studied sample were collected from eclogite facies unit and neighboring schist units, equivalent with amphibolite facies. Li/B value of CL fluids varies from 0.10 to 1.99. Among all studied samples, relatively high Li/B (> 0.4 up to 2.0) ratio is identified only in this area. The samples with high Li/B ratio are characterized by both the Na-Cl type hydro-chemical facies and undeformed polygonal quartz fabric.

Two samples of quartz vein intercalated with eclogite show high Li/B ratio (0.27, 0.44), higher ratio of which is almost identical with those of dehydrated fluid from eclogite (Sengen et al., 2009; Marschall et al. 2007). Furthermore, CL fluids extracted from three samples of quartz veins intercalated with metasediments in the neighboring schist unit show much higher Li/B ratio (0.36-1.99). Yoshida et al. (2011) pointed out that Li/B ratio of dehydrated fluids was also controlled by the chemical composition of the host rock.

Raman spectroscopy and microthermometry clearly suggest that all samples applied CL technique contain fluids trapped at multi-stages, covering from prograde, peak and/or retrograde stages. However, some CL fluids obtained from quartz veins mostly free from post-peak deformation in the Besshi area have high Li/B ratio, which is almost identical with eclogite facies dehydrated fluids obtained from meta-serpentinite in Liguria and Betic Cordillera (Scambelluri et al. 2004). These facts suggest that Li/B ratio of dehydrated fluid has a potential for the indicator of the dehydration depth after considering some controlling factors.

キーワード: 深部流体, Li, B, 高压変成帯, 三波川変成帯

Keywords: Deep fluid, Li, B, High-pressure metamorphic belt, Sanbagawa

三波川変成帯上昇期の流体流入と物質移動の変化 Fluid infiltration and change in mass transfer during the exhumation of Sanbagawa metamorphic belt, Japan

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Introduction: Individual parcel of regional metamorphic rock records physico-chemical conditions such as P-T path, mass transfer and deformation with the Lagrangian specification. On the other hand, a metamorphic belt as an ensemble of such parcels may provide a large-scale flow field of energy (e.g., temperature, entropy) and mass (including both solid and fluid phases with elements and isotopes) with the Eulerian specification. However, there are so far few models that integrate all the variables stated above. Phase petrology provides mostly the intensive variables (e.g., P-T path), whereas geochemistry provides mostly the extensive variables (time-integrated mass transfer), and these two have been treated separately. Here we combine phase petrology and geochemistry from a scale of mineral grain, and solve them under a simultaneous and consistent set of thermodynamic and mass balance equation. The results revealed the changes in mass transfer with changing P-T paths.

Method: The Sanbagawa metamorphic belt in Japan, the subduction-origin high-P type metamorphic belt, has been surveyed. To understand the nature of fluid during rehydration, we analyzed basic rocks that record retrograde reactions. Major and trace element compositions of each mineral, and bulk rock chemistry have been analyzed with EPMA, LA-ICP-MS, XRF and ICP-MS, respectively. Retrograde P-T path have been obtained by applying the Gibbs' method (e.g. Spear, 1993; Okamoto&Toriumi, 2001) to amphiboles and garnets.

Trace element budget along a specific P-T path were calculated by equating differential mass balance equation for major and trace elements as follows;

$$X_{fluid} dM_{fluid} = \text{Sum}(M_{solid} X_{solid}) + \text{Sum}(X_{solid} dM_{solid})$$

where X and M denote compositions and modes of minerals and dX and dM represent their changes along a specific P-T change. X_{solid} , M_{solid} , dM_{solid} for zoned minerals (amphibole and/or garnet) and X_{fluid} were derived from the results of Gibbs' method, X-ray map and fluid/mineral partition coefficients, respectively. Thus, the unknowns are dM s, and the equations are solved for them. As a result, the mass transfer during a specific P-T change ($X_{fluid} dM_{fluid}$) can be specified.

Furthermore, trace element budget during rehydration reactions were also constrained based on proportionality of bulk fluid-mobile element composition with H₂O (LOI (loss on ignition)). Based on a simple model that accounts for heterogeneity of protolith composition and devolatilization by dehydration reaction, the fluid composition during rehydration was estimated.

Results and Discussion: The P-T path obtained from the least rehydrated sample records the P-T path from 15kbar, 550°C to 11kbar 600°C, which corresponds to the exhumation just after the peak pressure condition. The mass balance analysis revealed that it was a dehydration reaction and Y and Cs increased whereas Ba decreased during this P-T path. No significant change was observed for Rb, Pb and Sr.

It is revealed that fluid mobile elements such as LILE elements, Sr and Pb are mostly proportional to LOI (loss on ignition). LOI and extent of rehydration are proportional in the Sanbagawa belt (Okamoto&Toriumi, 2005), thus the observed enrichment of LILE and Pb are interpreted to be associated with rehydration (from 11kbar 600°C to 3kbar 400°C). The Sr isotope ratios of the basic shists also increase with LOI, implying that the differences in bulk rock chemistry are due to an addition and/or reaction with external source of fluids with high ⁸⁷Sr/⁸⁶Sr. The estimated fluid composition is similar to calculated compositions of slab-derived fluids (Nakamura et al., 2008).

Comparing the results of (1) the mass balance analysis with early part of exhumation P-T path and (2) bulk composition analysis reveals that the mode of mass transfer changed from Y and Cs enrichment with Ba depletion, to LILE (Li, K, Rb, Cs, Sr, Ba) and Pb enrichment, associated with the change in P-T path.

キーワード: 流体, 物質移動, 変成作用, 沈み込み帯, 三波川変成帯, 微量元素

Keywords: fluid, mass transfer, metamorphism, subduction zone, Sanbagawa metamorphic belt, trace element

Isotope and Boron of Quaternary lava in Central Sunda arc, Indonesia: an assessment of slab influence to mantle wedge

Isotope and Boron of Quaternary lava in Central Sunda arc, Indonesia: an assessment of slab influence to mantle wedge

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We estimated contribution of slab-derived fluid of the arc mantle beneath Central Sunda Arc (CSA) in order to better understand the subduction processes. Sunda arc, a part of Pacific ring of fire, extends from Sumatera to Flores. Magmatism beneath Sunda arc is associated with subduction process. CSA is represented by a series of Quaternary volcanoes from fore arc toward back arc, consisting of Merapi, Merbabu, Telomoyo, Ungaran and Muria. We analyzed samples from these volcanoes by using X-Ray Fluorescence, Prompt Gamma-Ray and Instrumental Neutron Activation Analysis. Representative samples were also analyzed by Thermal Ionization Mass Spectrometer to obtain ⁸⁷Sr/⁸⁶Sr and ¹⁴³Nd/¹⁴⁴Nd ratios.

Boron is distinctively enriched in ocean floor sediment and altered oceanic crust (AOC). Higher mobility of boron from sediment to sediment-derived fluid than that of altered oceanic crust makes distinction of fluid sources. Fluid contribution to source mantle was estimated by applying ratio of boron and other mobile elements against HFSE. Estimation at CSA shows general decreasing trend of fluid contribution toward back arc with the highest contribution observed in the middle (Telomoyo) of arc transect, instead of the volcanic front (Merapi). This pattern is different from that estimated by Sr-Nd isotope ratios which are sensitive to modification of mantle by sediment-derived fluid. These isotope ratios show that influence of slab smoothly decreases from volcanic front toward back arc. Distinction between contributions from sediment-derived fluid and AOC-derived fluid was generated by plots of B/La, Rb/La, B/Nb, Rb/Nb against those of Sr and Nd isotope ratios. These plots show that the highest contributions of sediment occur at the volcanic front, whereas that from AOC occurs just a little behind the volcanic front. In addition to the variability of slab-derived fluid contribution, the small variation in isotopic and Nb/Zr, Nb/Ta ratios among fore arc volcanoes of CSA indicate little heterogeneity of the mantle source beneath them. Exception comes from the back arc volcano, Muria, which indicates relatively enriched mantle with only a little slab influence.

キーワード: Boron, Subduction, Slab fluid, Sunda arc

Keywords: Boron, Subduction, Slab fluid, Sunda arc

流体を含む岩石の微細構造と観測物性の標準岩石モデル作成の試み Development of A Preliminary Reference Rock Model for Physical Properties of Fluid-bearing Rocks

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Backgrounds: Recent advances in seismic tomography and magneto-telluric (MT) imaging have increased the potential for mapping the distribution of geological fluids (i.e., aqueous fluids and silicate melts) in the Earth's crust and uppermost mantle, since seismic velocity is sensitive to the fluid fraction, while electrical conductivity is strongly dependent on the connectivity of conductive fluid phases. To interpret the observed physical properties into the nature of the fluid, their correlation with the microstructure of fluid-bearing rocks is essential.

Sources of uncertainty: The seismic wave velocities are dependent on temperature and lithology, i.e., the phase and solid-solution compositions of the major minerals composing the rocks, besides on the fluid fraction. Especially in the middle and lower continental crusts, there is often considerable uncertainty regarding the lithology and temperature. Therefore, when the lithological and thermal structures are not well constrained, the uncertainties of the estimation of fluid distribution becomes large. On the other hand, the electrical conductivity is less dependent on the mineral compositions and phases, compared to the large contrast between those of silicate minerals and fluid phases. Although experimental data of electrical conductivity of minerals and fluids at elevated pressure and temperature are still insufficient, MT observations provide important constrains on the fluid distribution in the crust and mantle.

Scale resolutions of the geophysical imaging and length scale of geological heterogeneity: The observed seismic velocity is an average value typically in a km scale. Space resolution of the MT imaging is a few to tens of km, dependent on the depth. Given the high electrical conductivity in the middle to lower crusts of active convergent margins, interconnection of the fluid phases should be established in these km scales.

Role of heterogeneity: Since the dihedral angles between aqueous fluids and minerals in crustal conditions are generally larger than 60 degree, large fluid fraction is required for the fluid interconnection. The saline components in the fluids decrease the dihedral angle, but carbon dioxide increases, counteracting with each other. The veins and cracks can increase the fluid connectivity locally and anisotropically, but their individual length scale is much smaller than the imaging resolution. There are several other mechanisms to produce small scale heterogeneity or fabrics of the fluid distribution, but they may not responsible for the pervasive fluid interconnection in a km scale. Therefore, grain-scale fluid interconnection is still the first hypothesis to be tested. The relation between the volume fraction and connectivity of the pore fluids should be quantitatively understood for major crustal rocks.

The PROM project: In this context, we have reviewed and compiled the data of seismic velocities, electrical conductivities, and dihedral angles and other microstructural factors that determine the grain-scale fluid distribution for the rocks of crust and uppermost mantle. Although lack of the physical property data at elevated pressure and temperatures does not allow us to develop a comprehensive data base, a possible data set composed of some major rock types and their physical properties as a function of fluid fraction can be presented as a preliminary reference model for the crustal rocks.

キーワード: 岩石物性, 粒間流体, 微細構造

Keywords: physical property of rocks, pore fluid, microstructure

九州地方南部下のC-typeカンラン石の選択配向に起因するS波偏向異方性と流体の分布

Shear wave polarization anisotropy induced by C-type olivine LPO and fluid distribution beneath southern Kyushu

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九州地方南部下のスラブ上面付近には高 V_P/V_S 領域が存在し、流体や蛇紋岩などの存在が示唆されている (Matsubara and Obara, 2011)。流体や蛇紋岩の存在は沈み込み帯における火山活動や地震活動と密接に関係しているため、これらの分布は、沈み込み帯におけるダイナミクスを考える上で重要である。本研究では高 V_P/V_S 領域が存在する九州地方南部において検出されたS波偏向異方性の観測値と鉱物の弾性定数から求められたS波偏向異方性の理論値を比較し、この領域でのS波偏向異方性の成因について考察する。また、九州地方南部下における流体や蛇紋岩の分布とその形態についても議論する。

利用したデータは九州地方南部において2004-2010年にHi-net観測点において観測された深さ30km以上、マグニチュード2.5以上の地震の波形のうち、地表での変換波の影響を避けるために入射角が35度以内であるものに限定した。S波偏向異方性解析では、Silver and Chan (1991)を参考にし、1-20Hzのバンドパスフィルターをかけた水平2成分の波形を用いて、S波部分のパーティクルモーションの共分散行列からその直線性を評価し、速いS波の偏向方向と直交する2つの波の到着時間差を求めた。

九州地方南部では、東北東-西南西から西北西-東南東の偏向方向を示し、到着時間差は0.04-0.63秒であった。地殻の異方性により生じる時間差は0.3秒であるため、0.3秒以上の到着時間差のS波偏向異方性はマントルウェッジにその成因があると考えられる。0.3秒以上の到着時間差を示す波形の波線は深さ100-150kmに存在する高 V_P/V_S 領域を通過する。他の波線経路との比較から、この領域が異方性領域と考えられる。S波偏向異方性の観測値とカンラン石の弾性定数から求められた理論値との比較から、観測値を最も良く説明するのはC-typeカンラン石の選択配向であり、九州南部の深さ100-150kmにおけるスラブ上面の地震波速度異方性層の厚さは到着時間差が0.3秒を超えるS波偏向異方性を示す波線が主に通過する高 V_P/V_S 領域の厚さと、C-typeのカンラン石の選択配向を想定して理論的に求められた地震波速度異方性層の厚さと到着時間差との関係から約13-30kmであると推定される。

上記の結果は、この地震波速度異方性層に流体が分布することを示唆し、二面角の低下 (Mibe et al., 1999) によるカンラン岩内での粒間流体の移動が100km以深で容易になっている可能性が高い。

一方、九州地方のように暖かいスラブが沈み込んでいるような沈み込み帯では、マントルカンラン岩の蛇紋岩化の進行が考えられる。本研究からは、前弧域での蛇紋石の存在を示唆するようなS波偏向異方性は観測されなかった。この観測結果は、Hilaret and Reynard (2009) によって推定された層厚1-3kmの薄い蛇紋岩層の存在と矛盾はしない。

謝辞：本研究では防災科学技術研究所のHi-netのデータを用いました。記して感謝いたします。

キーワード: S波偏向異方性, C-typeカンラン石, 選択配向, 流体, 蛇紋石

Keywords: shear wave polarization anisotropy, C-type olivine, LPO, fluid, serpentine

含水鉱物・炭酸塩鉱物起源の脱水・脱炭酸流体を石英中に包有する実験 SYNTHETIC EXPERIMENTS OF AQUEOUS AND CARBONATE FLUID INCLUSIONS

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Deep aqueous fluids from subducted slab affect volcanic activity and seismicity in the subduction zone. (e.g., Schmidt and Poli, 1998) To reveal the chemistry of slab-derived fluids is crucial for understanding the material circulation in subduction zones, but as yet it is very difficult to experimentally constrain the chemical composition of these fluids. Diamond-trap experiments in combination with LA-ICP-MS analyses of frozen samples have been used to analyze chemical compositions of aqueous fluids in equilibrium with complex mineral assemblages (e.g., Kessel et al., 2004). However, in order to accurately determine fluid compositions experiments also need to be designed to account for modification of the fluid during quenching. Synthetic fluid inclusions trapped during high-pressure experiments can keep the composition of the fluids produced at run conditions. We have developed a method to trap fluids liberated during decomposition of hydrous and carbonate minerals as fluid inclusions in a quartz crystal.

The synthetic fluid inclusion technique (Stern and Bodnar, 1984) was employed in this study. Synthetic fluid inclusions were formed in synthetic quartz provided by Nihon Dempa Kogyo Co., LTD. Quartz single crystals were cut into about 1-2mm size, heated to 450 C, and then quenched in cold distilled water to make cracks within it. After drying in a vacuum oven at 150 C overnight, the quartz crystals with cracks were rapped in a piece of Pt foil (2.5um-thick) and sealed in Au or Pt capsules with various mineral assemblages, such as Mg(OH)₂, CaCO₃+SiO₂, CaCO₃+SiO₂+H₂O and mMgCO₃Mg(OH)₂nH₂O+SiO₂+Mg(OH)₂. The capsule was placed in a solid-media piston-cylinder apparatus and kept at the pressure range 0.5-1 GPa and at the temperature range 800-1100 C for 3-192 hours.

After quenching, thin sections (200-500um-thick) were prepared to examine with an optical microscope, Raman spectroscopy and microthermometry. The analyses for microthermometry were performed by referring Diamond (2001) and using the computer program Loner AP (e.g., Bakker, 2009).

Fluids liberated from Mg(OH)₂ were successfully trapped as fluid inclusions in all experiments. Microthermometry for a fluid inclusion in the sample synthesized at 800 C and 1 GPa for 3 hours showed the homogenization temperature of 251 C, molar volume of 22.8 cm³/mol. However, the calculated isochore shows that the temperature calculated for 1 GPa was 961 C, which was different from the run condition.

Fluid inclusions were not observed in experiments with CaCO₃+SiO₂, whereas were successfully synthesized in experiments with CaCO₃+SiO₂+H₂O. The size and amount of fluid inclusions in these samples were smaller than those in the experiments with Mg(OH)₂. Raman spectra showed the peaks of CO₂ but the broad peaks of H₂O were not observed clearly.

Fluids liberated from mMgCO₃Mg(OH)₂nH₂O+SiO₂+ Mg(OH)₂ were successfully trapped as fluid inclusions in all experiments. Raman spectra showed that the fluid inclusions in these samples were composed of H₂O and CO₂. Microthermometry for the three fluid inclusions in the sample synthesized at 850 C and 1GPa for 18 hours showed that the homogenization temperatures from vapor-liquid carbon phase to liquid carbon phase were 24-29.5 C and total homogenization temperatures were 255-269 C, yielding molar volumes of 24.2-26.3 cm³/mol and total mole fractions CO₂ of 12-18 mol%. The calculated isochores give 910-1033 C at 1GPa, which had wide distribution.

In the experiments of anhydrous systems, liberated fluid could not be trapped during crack healing or perhaps crack healing did not occur in the experimental conditions in present study. The temperatures estimated from microthermometry were different from run conditions.

To interpret the condition that fluid inclusions are produced, it is needed to figure out the reason of this discrepancy by more analyses with precise observations of occurrence.

Keywords: synthetic fluid inclusion, hydrous mineral, carbonate mineral, piston-cylinder

高封圧、間隙圧下における地殻岩石の地震波速度測定

Measurement of seismic velocity of crustal rocks under high confining pressure and pore pressure

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はじめに

地球内部の水は主にプレート沈み込み帯で供給されており、沈み込み帯における地震や島弧での火山活動において重要な役割を担っている。この領域で起こるスロースリップや微動はこの水が関係していると考えられている。関東地方における地震波モグラフィから、0.337の高ポアソン比領域が観測され、非地震性域となっていることが指摘された(Kamiya and Kobayashi.,2000)。また東南海、四国地方でも同様の0.3を超える高いポアソン比が観測され、これらの領域はスロースリップや低周波微動の発生域と一致している(Kodaira et al., 2004 ; Shelly et al., 2006)。関東地方から四国地方にかけて比較的若く温かい海洋プレートが沈み込んでいるため、この領域では0.29の高いポアソン比をもつアンチグライトが安定して存在しているかもしれない。この場合、高いポアソン比をもつにはマンツルの蛇紋岩化に加えて多量の水が必要である。この水の形状や量を解明することを目的とし、高封圧、間隙圧下における地殻岩石の地震波速度の研究を行った。

実験方法

地震波速度の測定には広島大学の油圧式圧力試験機を用いて、パルス反射法で算出した。試料はベルファースト産の斑禰岩と稲田産の花崗岩で、それぞれ直径20mm、長さ5~10mmの円筒形に整形されている。測定は封圧のみをかけた実験と封圧と間隙圧をかけた実験を行い、後者では50MPaの間隙圧を加えた。

結果と考察

封圧のみの実験では、斑禰岩と花崗岩の両方について最大封圧200MPaをかけて測定した。斑禰岩について各封圧(100, 140, 180MPa)における地震波速度はそれぞれ、 $V_p=6.88, 6.94, 6.83$ km/s, $V_s=3.85, 3.91, 3.79$ km/sで、花崗岩は200MPaにおいて $V_p=4.94-6.09$ km/s, $V_s=2.89-3.36$ km/sとなった。これらの値はChristensen,1996の値と比較して全体的に低いが、斑禰岩の V_s に関しては同様の値となった。加圧過程と減圧過程の両方の測定から、速度変化の再現性と封圧によるクラックや空隙の開閉の効果が確認できた。

間隙圧を加えた実験では、花崗岩のみについて封圧60MPa、間隙圧50MPaの加え、有効圧10MPaの状態に測定した。間隙圧を加える前の封圧60MPaでは、地震波速度は $V_p=5.17-5.60$ km/s, $V_s=2.84-4.36$ km/sとなった。その後間隙圧を50MPaまで加えると $V_p=5.02-5.18$ km/s, $V_s=2.13-3.64$ km/sとなり、わずかに変化した。しかし、試料の反射波の信号が非常に弱いためにそれらの値には大きな不確実性がある。このパルスの減衰は反射波の分裂やバックグラウンドとの重複、そして試料とアセンブリのスペーサーとの間の反射率が関係していると思われる。

キーワード: 地震波速度, 地殻岩石, ポアソン比, 地殻流体, 間隙圧, 沈み込み帯

Keywords: seismic velocity, crustal rock, Poisson's ratio, geofluid, pore pressure, subduction zone

東北地方 3次元上部マントル電気伝導度構造探査

A three-dimensional electrical conductivity distribution model of the upper mantle beneath Tohoku district

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While plenty of three-dimensional (3-D) seismic tomographic images has been revealed (e.g. Zhao et al., 1992; Nakajima et al., 2001), only a few 3-D electrical conductivity distribution model has been proposed in terms of wedge mantle in subduction zones (e.g. Patro et al., 2007). Introducing the state-of-the-art mobile magnetotelluric (MT) observation systems (LEMI-417 and NIMS), we have acquired MT data at Tohoku district, northeastern Japan for the aim of 3-D electrical conductivity distribution in the wedge mantle. Typical observation duration are three months at each site, and MT response functions from 10 to 20000 seconds in period have successfully collected with fine quality. The site location is arranged with ca. 20 km interval. The MT phase response functions at many sites show over 90 degrees over 5000 seconds and suggest that 3-D distribution beneath this area.

Simple checker board resolution tests have been performed to estimate resolution. Regular cubes with 40 km on side and 10 ohm-m in conductivity embedded in 1000 ohm-m matrix were clearly recovered down to 120 km in depth using the synthetic data, while those with 20 km on side were not recovered clearly.

We carried out the three-dimensional inversion analysis with WSINV3DMT code (Siripuvaporn et al., 2005). Although the inversion process is still on the way and the conversion is not enough, the east-west profile (across the Japan Arc) of the preliminary result shows that conductive region appears at about 120 km in depth beneath back-arc region and elongates obliquely towards the volcanic front. The north-south profile (along the Japan Arc) shows the vertical conductive and resistive columns appears alternatively. That basic images are well consisted with the seismic tomographic model (Nakajima et al., 2001), provided that conductive and low velocity zone should correspond with each other. Obtained the final 3-D model, our final destination is to estimate the mantle geotherm and fluid distributions in the wedge mantle using seismic tomographic and electrical conductivity images.

東北日本弧での溶融と水の量の数値的解析 Numerical analyses of water content and melting regimes in the NE Japan arc

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Melting and seismic structure beneath the northeast Japan arc considering upon the uncertainties of H₂O content is modeled to estimate the relation between melting region and H₂O content, and restrict water content distributed in mantle wedge. This model results show that increasing water content, a weak melting starts to occur beyond $C_{H_2O} = 0.07$ wt%, and the calculated P-wave and S-wave velocity structures between $C_{H_2O} = 0.10$ wt% and 0.40 wt% can explain tomographic low velocity zones. The distribution of melt production rate ($C_{H_2O} = 0.15$ wt%) shows that all three mechanism (Flux, decompression, and compression melting) are necessary to explain volcanic activity at back arc, volcanic front, and intermediate region in the Northeast Japan arc. In the case of $C_{H_2O} = 0.15$ -0.34 wt%, the model results of volcanic eruption rate can explain observed across-arc features in terms of relative intensities (i.e., spatial location and pattern). Considering into the comparison with tomographic data, melting mechanism, and the comparison with volcanic eruption data, this model results for $C_{H_2O} = 0.15$ -0.34 wt% can explain volcanic activity in the Northeast Japan arc.

キーワード: 水, 溶融, 沈み込み帯

Keywords: water, melting, subduction zone