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カナダラブラドル地方、ネーン岩体の地質：最古の海洋地殻の発見に向け
Geology of the Nain complex in Labrador, Canada: Discovery of the oldest oceanic crust

小宮 剛 [1*], 下條 将徳 [1], 山本 伸次 [1], 澤木 佑介 [2], 石川 晃 [1], 青木 一勝 [1]
KOMIYA, Tsuyoshi[1*], SHIMOJO, Masanori[1], YAMAMOTO, Shinji[1], SAWAKI, Yusuke[2], ISHIKAWA, Akira[1], AOKI, Kazumasa[1]

[1] 東京大学　駒場　総合文化研究科, [2] 海洋研究開発機構
[1]Dept. Earth Science & Astronomy, Komaba, The University of Tokyo, [2]JAMSTEC

The Hadean is the most mysterious period because no rocks and geologic bodies are preserved except for only the zircons in Western Australia, Canada, China and Greenland (Froude et al., 1983, Nature; Nelson et al., 2000, EPSL; Mojzsis & Harrison, 2002 EPSL; Iizuka et al., 2006, Geology; Wang et al., 2007, CSB). But, it is the most important period because the early evolution possibly clinched the history of the earth. We try to find the earliest supracrustal rocks in the world to investigate the Hadean tectonics and decode surface environments. As far, the oldest supracrustal rocks are found in Akilia association in West Greenland, Nuvvuagittuq in Quebec, and Nain Complex in Labrador (Nutman et al., 1996, Precamb. Res.; O'Neil et al., 2008, Science; Schiotte et al., 1989, Can Jour Earth Sci.). Because the Akilia association suffers from severe metamorphism and alteration, the precursors are highly in debate (e.g. Fedo & Whitehouse, 2002, Science). Recent geological works in the Nuvvuagittuq, Quebec showed the sequence contains amphibolite with a pyroclastic rocks affinity, ultramafic sills, felsic sediment, BIF and conglomerate. Although a pseudoisochron age of $^{147}Sm/^{144}Nd$-$^{142}Nd/^{144}Nd$ implies the Hadean age (O'Neil et al., 2008, Science), the supracrustal belt possesses 3811 Ma by conventional U-Pb zircon ages (David et al., 2009, GSAB).

We made geological survey in the Nain Complex, and reinvestigated the occurrence of the supracrustal rocks and their relationship with the ambient orthogneisses. Previous works focused on distribution of the supracrustal belts within the orthogneisses (e.g. Bridgwater et al., 1974 Geol Surv Canada, Paper), but the detailed field occurrence of the supracrustal rocks within the belts is still ambiguous. Therefore, we focus on their internal structures.

The supracrustal belts are repeatedly intruded by granitic intrusions with some ages and their original structures are obscured, but their lithostratigraphies are relatively well preserved in Nulliak, Big and Shuldham islands and St Jones Harbor. The supracrustal belts in Nulliak and Big islands comprise ultramafic rocks, mafic rocks and mafic sediments intercalated with feldspathic sediments and banded iron formations in ascending order. In the St Jones Harbor, it is composed of ultramafic rocks, mafic rocks, banded iron formation, and clastic sediments, intercalated with chert in the middle and with bedded carbonate rocks in the upper part, respectively, in ascending order. In the Shuldham Island, it consists of ultramafic rocks, layered gabbro with precursors of plagioclase and pyroxene accumulation layers, mafic rocks and terrigenous sediments in ascending order. The lithostratigraphies are very similar to oceanic plate stratigraphy. The fact that some supracrustal belts are intruded by Uivak I orthogneisses, and presence of $>$3.86 Ga zircons in the supracrustal rocks suggest that the supracrustal belts have early Archean ages. In addition, despite of the still ambiguous relationship between Nanok Gneiss and supracrustal rocks, presence of Nanok Gneiss (3.85 to 3.91 Ga) in this area (Collerson, 1983 in Abstracts for Early Crustal Genesis Field Workshop, LPI, Technical Report 83-03; Shimojo et al., 2012, Goldschmidt Conf.) implies that the supracrustal belts date back to the earliest Archean.

キーワード: 冥王代, ラブラドル・ネーン岩体, 初期地球, ジルコン, 表成岩, 縞状鉄鉱層
Keywords: Hadean, Nain Complex, Labrador, Early Earth, zircon, supracrustal rocks, banded iron formation

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貫入岩体周辺の面構造ダイヤグラムに基づく東ピルバラの花崗岩複合岩体の貫入様式について
Type of granite complex intrusion in East Pilbara terrane based on foliation pattern diagram around intrusion body

松村 太郎次郎 [1*], 増田 俊明 [2]
MATUMURA, Taroujirou[1*], MASUDA, Toshiaki[2]

[1] 静岡大学大学院理学研究科, [2] 静岡大学理学部
[1]Graduate School of Science, Shizuoka university, [2]Faculty of Science,Shizuoka University

Theoretical analysis of stressed two-dimensional elastic material with a circular hole filled with a viscous material revealed that three types (TT, TX and XX types) of distribution pattern of maximum principal stress orientation around the hole can be produced as a function of far-field stress S1 ,S2 and internal pressure of viscous material p. The TT type is characterized by tangential orientation of S2 axis in all directions around the hole, while the TH is characterized by S2 axis of tangential and normal orientations to the circular hole in orthogonal orientations. The XX type is characterized by normal orientation of foliation all around the hole. Assuming that S2 axis is parallel to the foliation, we consider the stress state for actual foliation patterns in aureoles of granitic intrusions. We can find some natural examples of TT and TX type patterns, whereas we have never found the XX type patterns in nature. In this poster we present TT a type foliation pattern around the Mount Edgar Batholith in Pilbara area, Western Australia, and discuss how the TT type pattern foliation can be produced as a function of internal pressure of granitic body.

キーワード: ピルバラ, バソリス, 太古代, 貫入イベント
Keywords: Pilbara, batholith, Archean, intrusion event

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中央海嶺沈み込みに伴うタイタオ半島花崗岩の岩石学的研究
Petrogenesis of the ridge subduction-related granitoids from the Taitao Peninsula, Chile Triple Junction Area

昆 慶明[1*], 小宮 剛[2], 安間 了[3], 平田 岳史[4], 渋谷 岳造[5], 山本 伸次[2], 丸山 茂徳[6]
KON, Yoshiaki[1*], KOMIYA, Tsuyoshi[2], ANMA, Ryo[3], HIRATA, Takafumi[4], SHIBUYA, Takazo[5], YAMAMOTO, Shinji[2], MARUYAMA, Shigenori[6]

[1] 産総研・地質調査総合センター, [2] 東大, [3] 筑波大, [4] 京大, [5] 海洋研究開発機構, [6] 東工大
[1]GSJ, AIST, [2]Univ. Tokyo, [3]Univ. Tsukuba, [4]Kyoto Univ., [5]JAMSTEC, [6]Tokyo Tech.

It is the essential to study the geochemical evolution of the solid earth to understand the growth and origin of granitic continental crust. The Taitao Peninsula is the youngest site of ridge subduction in the world, where a young oceanic plate subducts, possibly equivalent to an Archean subduction zone environment. It is proposed that granitic magmatism in the Taitao Peninsula is closely concerned with the subduction of young oceanic crust. This paper presents REE from whole rock analyses of the granitic rocks so that we obtain the detailed compositional characteristics of the granitic magmas. There is a triple-junction (Trench-Trench-Ridge) off the Taitao Peninsula, southern Chile. The compositions of the Taitao granitoids are tonalitic to granitic with SiO2 ranging from 64% to 78%. Trace elements are characterized by low Sr (50-300 ppm) contents, moderately both high Y (10-45 ppm) and Yb contents (1-5 ppm) and low Sr/Y ratios (1-25). Chondrite-normalized REE patterns are characterized by moderately high [La/Yb]N ratios (5-20). These chemical characteristics are similar to typical calc-alkaline arc magmas rather than adakitic granitoids. The characteristics suggest that the magma was generated by partial melting of amphibolite rather than eclogitic rocks. These geochemical compositions suggest that the granitic magma was generated under 10 km depth below the fore-arc region. Contrary to previous belief, our result suggests that Taitao granitoids, which possibly generated by partial melting of subducted oceanic-crust, have TTG composition in major element, but no HREE-depleted signature in trace elements.

キーワード: 中央海嶺沈み込み, スラブ溶融, TTG, アダカイト, 希土類元素
Keywords: ridge-subduction, slab-melting, TTG, adakite, REE

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日本における白亜紀の構造浸食作用
Tectonic erosion in Pacific-type orogenic belt: zircon response to Cretaceous tectonics in Japan

青木 一勝 [1*], 磯崎行雄 [1], 山本伸次 [1], 牧 賢志 [2], 横山 隆臣 [2], 平田 岳史 [2]
AOKI, Kazumasa[1*], Yukio Isozaki[1], Shinji Yamamoto[1], Kenshi Maki[2], Takaomi Yokoyama[2], Takafumi Hirata[2]

[1] 東京大学　広域科学, [2] 京都大学　地球惑星科学
[1]The University of Tokyo, Department of Earth and Astronomy, [2]Kyoto University, Department of Geology and Mineralogy

The U-Pb chronological analysis of detrital zircons for the Lower Cretaceous Sanbagawa and Upper Cretaceous Shimanto HP metamorphic rocks in Japan showed the abundant occurrence of Precambrian (ca. 1500-2000 Ma) grains. In contrast, the coeval non- to weakly metamorphosed accretionary complex and fore-arc basin sediments completely lack these older remnants that are common in the older Jurassic accretionary complexes that tectonically superpose above the Cretaceous accretionary complexes. This remarkable contrast in age spectrum likely indicates that tectonic erosion has occurred to recycle older detrital material twice along the active margin of Cretaceous East Asia; i.e. the first in the Early Cretaceous to tectonically remove the Jurassic accretionary complex from the sole of the hanging wall of the subduction zone, and the second in the Late Cretaceous to erode Lower Cretaceous accretionary complex together with the Sanbagawa high-pressure metamorphic rocks

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カナダ、ラブラドール地域に産する超苦鉄質岩の強親鉄性元素組成
Highly siderophile elements in 3.8 Ga ultramafic rocks from Labrador, Canada

石川 晃 [1*], 下條 将徳 [1], 鈴木 勝彦 [2], COLLERSON, Kenneth D.[3], 小宮 剛 [1]
ISHIKAWA, Akira[1*], SHIMOJO, Masanori[1], SUZUKI, Katsuhiko[2], COLLERSON, Kenneth D.[3], KOMIYA, Tsuyoshi[1]

[1] 東京大学大学院総合文化研究科, [2] 海洋研究開発機構, [3] クイーンズランド大学
[1]The University of Tokyo, [2]JAMSTEC, [3]University of Queensland

The overabundance of highly siderophile elements (HSEs) in the modern terrestrial mantle, relative to predicted composition is frequently attributed to the late influx of chondritic materials (late veneer) after the efficient stripping of HSEs to the metallic core. Although this model is not universally accepted due to insufficient knowledge of metal-silicate partitioning under high pressure and temperature conditions, broadly chondritic ratios of HSEs in fertile peridotites from a variety of tectonic settings provide strong support for the late veneer model. A recent discovery of ^{182}W enrichments in ˜3.8 Ga crustal rocks from Isua, West Greenland suggests that this area of Earth's surface has escaped addition of the late veneer, and remained unaffected by subsequent replenishment. Furthermore, possible secular increase of HSE abundances for the komatiite source has been attributed to the progressive pollution of the HSE-poor deep mantle by the late veneer component between 3.5 and 2.9 Ga. These studies raise the possibility that ˜3.8 Ga ultramafic rocks recognized from West Greenland and its eastern extension in Labrador, Canada, can be used to establish HSE abundances of the Earth's mantle before the arrival of the late veneer.

We present HSE abundances and Re-Os systematics for a set of ultramafic rocks from Saglek-Hebron area of northern Labrador. Based on field and geochemical data, they were classified into two suites: residual peridotites occurring as tectonically-emplaced slivers of lithospheric mantle, and metakomatiites comprising mostly pyroxenite layers in supracrustal units. The samples analysed here have been investigated previously for Sm-Nd and Pb-Pb systematics, supporting their >3.8 Ga formation. Thus, the primary aim is to test whether the meta-peridotites and komatiites record peculiar HSE signatures of the early Archean shallow and deep mantle, respectively. The two suites display contrasting HSE patterns that are consistent with their inferred protoliths. The harzburgitic to dunitic metaperidotites are typically marked by depletion of Pt, Pd and Re relative to Os, Ir and Ru, resulting from extensive melt extraction. In contrast, metakomatiites show smooth patterns with gentle positive slopes (except for Re). Overall, in terms of HSE patterns and abundances, both suites do not differ from their late Archean equivalents, such as the harzburgitic to dunitic xenoliths from North Atlantic Craton and the 2.7 Ga Belingwe/Abitibi komatiites. Moreover, a rare lherzolitic sample has a very similar HSE pattern to that of primitive upper mantle (PUM) estimated on the basis of dataset of post-Archean peridotites. These observations suggest that 3.8 Ga mantle has already been influenced by the late veneer. We will discuss the possible reasons for the decoupling between W isotope evidence from crustal rocks and HSE signatures in mantle-derived materials.

キーワード: 強親鉄性元素, かんらん岩, コマチアイト, 太古代, レイトベニア
Keywords: highly siderophile elements, peridotite, komatiite, Archean, late veneer

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第 2 大陸説
The second continent model

河合 研志[1*], 山本 伸次[2], 土屋 卓久[3], 市川 浩樹[3], 丸山 茂徳[1]
KAWAI, Kenji[1*], YAMAMOTO, Shinji[2], TSUCHIYA, Taku[3], ICHIKAWA, Hiroki[3], MARUYAMA, Shigenori[1]

[1] 東京工業大学, [2] 東京大学, [3] 愛媛大学
[1]Tokyo Institute of Technology, [2]University of Tokyo, [3]Ehime University

At subduction zones continental crust is predominantly created by arc magmatism (Rudnick, 1995) and is returned to the mantle via sediment subduction, subduction erosion, and continental subduction (Scholl and von Huene, 2007). Granitic rocks, the major constituent of the continental crust, are lighter than the mantle at depths shallower than 270 km, but we show here, based on first principles calculations, that beneath 270 km they have negative buoyancy compared to the surrounding material in the upper mantle and transition zone and thus can be subducted in the depth range 270-660 km (Irifune et al., 1994). This suggests that there can be two reservoirs of granitic material in the Earth, one on the surface and the other at the base of the mantle transition zone (MTZ). The accumulated volume of subducted granitic material at the base of the MTZ might amount to a few times the present volume of the continental crust. Our calculations also show that the seismic velocities of granitic material in the depth range from 270 km to 660 km are faster than those of the surrounding mantle. This could explain the anomalous seismic-wave velocities observed around 660 km depth. The observed seismic scatterers and reported splitting of the 660 km discontinuity could be due to either jadeite dissociation and/or chemical discontinuities between granitic material and the surrounding mantle.

キーワード: 花崗岩, 構造浸食, 遷移層
Keywords: granite, tectonic erosion, mantle transition zone

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隠岐島後・吉備の捕獲岩ジルコン年代から推定される西南日本下部地殻の発達過程
Evolution of the lower crust under southwest Japan constrained from ages of zircon in the xenolith

越田 渓子 [1*], 岩森 光 [1], 平田 岳史 [2]
KOSHIDA, Keiko[1*], IWAMORI, Hikaru[1], HIRATA, Takafumi[2]

[1] 東京工業大学地球惑星科学専攻, [2] 京都大学大学院理学研究科地球惑星科学専攻
[1]Department of Earth and Planetary Sciences, Tokyo Institute of Technology, [2]Graduate School of Science, Kyoto University

The present-day continental crust contains a very large proportion, about 20-70%, of the incompatible elements by mass in the Earth (Rudnick and Fountain, 1995). Therefore, it should have enormous effects on evolution of the Earth both chemically and physically. Although the upper crust has been investigated extensively in terms of its composition, structure, and evolution process, those of the lower crust which extends to 35 km depth on average has been poorly investigated.

The main purpose of this study is to decipher process of formation and evolution of the lower crust, aiming at understanding the evolution of continental crust and the Earth. As a first case study, we try to constrain the evolution process of the lower crust in SW Japan, the Oki-Dogo and Kibi areas, based on zircon ages and geothermometers in the xenoliths.

These two areas are located on the continental margin, and may provide useful insights regarding how the lower crust is formed or destructed associated with subduction.

At Oki-Dogo, peridotite, pyroxinite, gabbro and granulite were found as xenoliths in alkali olivine basalts (Takahashi, 1978) erupted at 3.61Ma (whole rock K-Ar age, Kaneoka et al., 1977). At Kibi, peridotite, pyroxinite and granulite are found as xenoliths in alkali olivine basalts (Iwamori, 1985) erupted at around 9 Ma (Uto, 1989).

To estimate the equilibrium temperature and the U-Pb age of zircon, we sampled gabbros from Oki-Dogo and granulites fromat Kibi, and analyzed them by using EPMA and LA-ICP-MS.

Major constitutent minerals in the gabbros from Oki-Dogo are olivine (ol), clinopyroxene (cpx) and plagioclase (pl), and they have a diameter of 1~2mm. Equilibrium temperature estimated by ol-cpx geothermometer (Loucks, 1996) is approximately 1100^{o}+-50^{o}C. Zircon grains have been obtained from only one gabbro (out of total seven gabbros processed), and are almost anhedral and homogeneous. The total forty grains have been dated to give ages approximately ranging from 2 to 4 Ma, which are broadly the same with that of the host alkali basalt and indicates that zircon grains lost almost all Pb during the magmatic event exceeding the closure temperature for zircon U-Pb dating (i.e., above 900^{o}C).

Major constitutent minerals in the granulite from Kibi quartz, K-feldspar, garnet, kyanite and spinel are the major constituent minerals, and they have a diameter of 500~1000 um. Based on the stability of kyanite and assuming the maximum depth of 30 km based on the present-day Moho depth estimated from the seismic profile (Ito et al., 2010), the equilibrium temperature is constrained to be less than 800^{o}C. Zircons obtained from the granulites are various in shape, exhibiting a wide age range from 420 to 10 Ma. We classified these zircons into igneous and metamorphic origins based on the U/Th ratio, and distinguish the overlapping events recorded in the grains. Bulk rock composition of this granulite from Kibi is aluminous and pelitic (Kushiro, 1987). From these results, we propose a model that a sedimentary material subducted with an oceanic plate, and accreted the material to the continental crust. Then at 28Ma, a part of the Philippine Sea Plate started spreading to create the Shikoku Basin and the spreading ridge had subducted. Because of this, the subduction angle became gentler and accrete more materials and push the formerly accreted sedimentary material further to the rearc region at the same time, accreted prism was metamorphosed by the heat.

In summary, these two examples from Oki-Dogo and Kibi suggest that (1) the lower crust beneath Oki-Dogo were heated by magmatic events that erupt alkali basalts and may reset the U-Pb age of zircon now found in the xenolith, and (2) subducted sedimentary materials can accrete to the lower crust at deep levels, which may be promoted by ridge subduction. Therefore, at this area, a part of lower crust develop independently of the upper crust.

キーワード: 下部地殻, ジルコン, 年代, 捕獲岩, 西南日本
Keywords: Lower Crust, zircon, age, xenolith, southwest Japan