Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

BPT23-P01 Room:Poster Time:April 30 18:15-19:30

Reconstruction of tectonic history of the Cleaverville area in Coastal Pilbara Terrane ,western Australia

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The Dixon Island - Cleaverville formations of the Coastal Pilbara Terrane, Western Australia, is one of the most complete sections of a volcano-hydrothermal sequence of the immature island arc (Kiyokawa &Taira, 1998). These formations composed of the Dixon Island (DX) Formation, Dixon pillow basalt and the Cleaverville (CL) Formation. The CL Formation is uncomformably overlain by the Lizard Hills Formation. The Lizard Hills Formation was formed in syncline basin (66 Hill Member) during collisional D1 deformation and pull-apart basin (44 Hill Member) during sinistral slip D2 deformation (Kiyokawa et al., 2002).

In this study, depositional ages of the CL Formation and the Lizard Hills Formation (44 Hill Member and 66 Hill Member) were examined by the analysis of U-Pb zircon dating. Zircons were measured using SHRIMP2 at National Institute of Polar Research. Metamorphic age of the DX Formation was obtained by the whole-rock 87Rb-86Sr isochronusing TIMS (Thermo TRITON and MAT253) at the Pheasant Memorial Laboratory, Institute for the Study of the Earth's Interior at Misasa.

As a result, U-Pb zircon age of felsic tuff in the CL Formation is 3108(+14/-7) Ma. Detrital zircon ages of the 44 Hill Member showed main peaks at 3280-3200Ma and 3030-3020Ma. Detrital zircon ages of the 66 Hill Member also showed peaks at 3300-3200Ma, 3100-3050Ma, and miner group of 3700Ma. The Rb-Sr data define clear correlation line in the 87Rb-87Sr evolution diagram which corresponds to an age of 2210+/-60 Ma.

In conclusion, sedimentation age of the DX formation is 3195+/-12Ma (Kiyokawa et al.,2002) and the CL Formation is 3108(+14/-7) Ma. The average of sedimentation rate in DX-CL formations is 2~3mm/ky as total thickness between these ages is 250m. After the sedimentation of the CL Formation, syncline basin (the Sity-Six Hill Member) was formed by D1 during 3088~3020 Ma. D2 faulting with pull-apart basin (44 Hill Member) was formed after the quartz porphyry (3020Ma) and the massive tonalite became to expose on land surface. The Rb-Sr age in the DX Formation as 2210+/-60 Ma corresponds to the timing of Ophthalmian orogeny (2145~2215Ma) in the southern margin of the Pilbara Craton (Rasmussen & Sheppard, 2005). The DX-CL formations probably had been affected by wide scale metamorphism at this timing.

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Lu-Hf isotope systematics of 3.45Ga Barberton basalts : implications for early mantle evolution

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Lu-Hf isotope systematics of Archean rocks can provide valuable insights into early crust-mantle evolution. In particular, those of Archean mafic rocks allow us to constrain the degree of early mantle depletion. Furthermore, a combination of Lu-Hf and Sm-Nd isotope systematics provides constraints on the physical condition of the mantle differentiation. Recent studies have indicated that 3.8 Ga mafic rocks from Isua have highly positive ϵHf with nearly chondritic ϵNd, suggesting that the source mantle had differentiated under a lower mantle condition. This may reflect that the differentiation of the Earth ' s deep mantle occurred much earlier than 3.8 Ga, possibly during the solidification of a magma ocean. In this study, we report new ^{176}Lu-^{176}Hf data for 3.45 Ga basalts in the Kromberg Complex of the Barberton Greenstone Belt, South Africa. The data for all analyzed samples define an isochron age of 2801$\pm$690 Ma(MSWD=49, 2σ, N=8), whereas those for relatively pristine samples yield an age of 3890$\pm$1100 Ma (MSWD=9.6, 2σ, N=4). The latter age is consistent with the formation age. We obtained the average ϵHf value at 3.45 Ga of 2.63 $\pm$ 0.33 (2σ) for the pristine samples. This indicates that the source mantle of the basalts had been depleted in incompatible elements by 3.5 Ga, but the extent of the depletion was not as strong as that of the source mantle of 3.8 Ga Isua mafic rocks. Furthermore, we found that there is no resolvable Hf isotopic difference between Barberton basalts and komatiites. This observation suggests that Barberton komatiites and basalts share the source mantle, and their formation mechanisms resulted in their petrologic difference. By combining our results with previously reported Sm-Nd isotopic data, we propose that the source mantle of the Barberton experienced early differentiation under high pressure conditions possibly during magma ocean solidification, and subsequently the differentiated mantle had been re-homogenized by mantle mixing.

Keywords: Mantle Evolution, Basalts, Barberton, Lu-Hf, Archean, Isotopic Analysis

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BPT23-P03 Room:Poster Time:April 30 18:15-19:30

Major element composition and forming condotion of the hidden reservoir

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Solidification of the magma-ocean and subsequent mantle-crust differentiation could have significant influence on the evolution of the solid Earth and hydrosphere, but its detail is still unclear. Previous studies have suggested that the difference in $^{142}Nd/^{144}Nd$ between chondrites and bulk silicate Earth (BSE) resulted from the formation of an incompatible element-rich reservoir that had formed in the early Earth and then got hidden into the Earth's interior or lost outside the Earth. Although various models for the composition and the origin of such a "hidden reservoir" have been proposed, they have not focused on the major element composition of the hidden reservoir. However, the major element composition is crucial to know the density of the hidden reservoir and to examine whether the hidden reservoir rose to form the proto-crust or sunk in the early mantle. In order to determine the major element composition of the hidden reservoir, we estimated the melting condition for the formation of the hidden reservoir with constraints of $^{142}Nd/^{144}Nd$ and $^{143}Nd/^{144}Nd$ systematics in the ancient and modern mantle.

This study assumed that the hidden reservoir had formed at pressures less than 10 GPa, on the basis of previous studies that estimated the initial depth of melt segregation to be at this pressure range in the solidifying magma ocean. Then we calculated the Sm/Nd ratio that is conformable to the difference in $^{142}Nd/^{144}Nd$ between chondrites and BSE, and estimated the melt fraction that satisfies this Sm/Nd ratio. From this calculation, the melt fraction was estimated to be $<$5.2% at 1 GPa, $<$3.2% at 3 GPa and $<$1.4% at 7 GPa. From these calculated melt fractions and previous experimental data, we estimated that the major element compositions of the hidden reservoir were incompatible element-rich tholeiite, picrite, and komatiite, respectively.

Ancient hotter mantle should have melted at higher pressure, but on the other hand, the melt fraction was estimated to be small. In order to satisfy the small melt fraction at deep melting, the lithosphere must be thick, as suggested by Korenaga (2009) who showed the possibility of thick lithosphere in the hotter mantle. From these results, a likely composition of the hidden reservoir is incompatible element-rich picrite-komatiite.

Solomatov and Stevenson(1993),*Journal of Geophysical Research*, **98**, 5407-5418
Korenaga(2009), *Geophysical Journal International*, **179**, 154-170

Keywords: hidden reservoir, proto-crust, $^{142}Nd/^{144}Nd$

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Differentiation and material recycling of Archaean mantle estimated from North pole basalt, Western Australia

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Mid-ocean ridges and hotspots are the prominent surface manifestations of mantle upwelling with different mechanisms. In these domains, two types of basalts:, i.e., mid-oceanic basalt (MORB) and oceanic island basalt (OIB) occurare occurred, in the respective settingsly. Recent statistical analysis on the global data set of the Sr-Nd-Pb isotopic compositions demonstrates that modern MORB and OIB are clearly separated: MORB is derived from a mantle source that has undergone long-term depletion in a " melt component ", while OIB is derived from a mantle source with long-term enrichment in the melt component through the recycling of subducted plate material (Iwamori and Albarede, 2008; Iwamori et al., 2010). Therefore, when plate recycling started to develop the geochemical domains is of great importance to understand the material differentiation and evolution of the Earth.

In this study, we present new trace element and Sr,-Nd isotope composition of Archaean MORB and OIB, in order to discuss the differentiation of the mantle at that period and compositional evolution of the mantle for a longer period of the Earth's history. The basaltic rocks of ca. 3.5 Ga from North Pole in northwestern Australia have been analyzed, which include have been classified as MORB and OIB by their geological occurrence and stratigraphy in by Komiya et al. (2002). The rocks have undergone greenschist to /amphibolite facies transition metamorphism (Komiya et al., 2002). The original rock compositions may have been modified by metamorphism. In order to examine potential metamorphic modification of the bulk rock composition, so we have measured composition of igneous clinopyroxene which shows original igneous texture, in addition to bulk composition, with special reference to equilibrium/disequilibrium partitioning of trace elements between clinopyroxene and the bulk rocksestimate the effect of metamorphism using partition coefficient.

The composition of North Pole MORB (NP MORB) and OIB (NP OIB) show slightly different trace element patterns. Some spikes in alkaline elements and alkaline earth metal elements and variabilityety of the initial Sr isotopic compositions may result from metamorphic modificationeffect. The initial Nd isotopic compositions of NP MORB and NP OIB are similar to each other. However, most of the samples have εNd$<$0, which is not typically expected for a mantle-derived basalt. characteristic is typical for felsic rocks. The apparent elemental partitioning between partition coefficient of clinopyroxene and the estimated ' melt ' , as well as a relatively clear correlation between Sm/Nd and Nd isotopic ratio, suggests that metamorphism has also disturbeds Nd isotopic compositions even for clinopyroxene which preserves igneous texture, resulting in εNd$<$0 of the bulk rocks. The isochron may show the metamorphic age of ca. 3.1 Ga. These approaches, therefore, may provide a quantitative measure for metamorphic geochemical modification of us, we need to gain the original composition from Archaean rocks, and will be useful, or even compulsory to discuss the true mantle signatures. to discuss the differentiation of mantle.

Keywords: Archaean, North Pole, basalt, mantle, isotope, differentiation

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Development of the African continent constrained from U-Pb chronology of detrital monazite

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Monazite, a light rare earth element phosphate, occurs as an accessory mineral in peraluminous felsic rocks and metamorphic rocks from subgreenschist- to granulite-facies. Because monazite has high U and Th and low common Pb contents, it is suitable for precise U-Pb chronology. In addition, monazite is moderately resistant to chemical and mechanical weathering, detrital monazites are well preserved and potentially record the timing and nature of peraluminous igneous activities and a wide range of metamorphic events in their provenance area. Consequently, detrital monazites from large rivers can provide valuable insights into orogenic events in the drainage basins on a continental scale (Hietpas et al., 2013). In this study, we have determined U-Pb ages of ca. 100 detrital monazite grains from the Nile and Niger Rivers, which give chronological information on orogenic events in the African continent with a high time resolution.

The African continent comprises several Archean-Paleoproterozoic cratons, which are rimmed by orogenic belts. A significant part of igneous and metamorphic basement rocks are covered by sediments and therefore inaccessible to in situ sampling at present. Considering that detrital monazites sampled from river sands would partly be derived from the currently inaccessible basement rocks over an extensive area, U-Pb dating of detrital monazite from large rivers can provide chronological information of the basement rocks complementary to studies of the exposed geology. The samples used in this study were collected at the river mouths of the Nile and Niger Rivers. The sand samples used in this study were previously used for zircon U-Pb dating and Hf isotopic studies by Iizuka et al. (2013). Monazite grains were newly concentrated from the river sand samples using the conventional magnetic and heavy liquid separation techniques. Monazites were randomly hand-picked from the aliquots of monazite concentrates and mounted in an epoxy mount. Before analysis, each grain was imaged by BSE using FE-SEM to check elemental zonation and the presence of inclusions. Monazite U-Pb isotopic dates were measured using 200nm-FsLA-ICP-MS. Reference monazite 44069 (U-Pb age 425 Ma) is used to correct for instrumental Pb/U fractionation.

The monazite grains from the Nile River gave U-Pb ages between 560 and 2100 Ma with a dominant population at 580-800 Ma. Furthermore, the U-Pb age population indicates a sharp peak at 600 Ma. The age peak at 600 Ma of Nile River suggests metamorphic and/or felsic igneous events occurred at that time in the drainage basin, probably related to the collision of the East and West Gondwana continents.

The monazite age population of Niger River is dominated by Neoproterozoic ages with the most prominent peak at 580 Ma and peaks at 625 and 645 Ma. The peaks shown in the Niger River monazite (580 Ma and 620-630 Ma) correspond with the timing of previously known orogonic events in Northwest Africa. A peak at 620-630Ma is consistent with a metamorphic event at ca. 625 $\pm$ 29 Ma, likely related to the collision of the West Africa Craton and West Gondwana continent (Agbossoumonde et al., 2007). The other peak at 590-600Ma is consistent with a ca. 576 $\pm$ 4 Ma post-collisional igneous event at the Pan-African Belt in Cameroon (Kuekam et al., 2013).

The age difference in the most prominent peaks of Nile and Niger monazites suggests that the timing of orogonenic event in Northwest Africa was prior to that of in East Africa by ca. 10 Ma.

The accumulated monazite age distribution shows populations at 580-590 Ma, 630-640 Ma and 710-720 Ma, corresponding with the timing of Snowball Earth glaciation events. The chronological correspondence can be interpreted that the multiple Pan-African orogenic events during the Gondwana supercontinent assembly enhanced the rates of erosion and weathering via supermountain building that in turn decrease atmospheric carbon dioxide concentration resulted in glaciation.

Keywords: monazite, U-Pb age, LA-ICP-MS, Pan-African

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Significance of serpentinization of lower crust in deep-sea hydrothermal biosphere

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Hydrothermal activity in the Archean-Ridge system has been considered to play a major role to maintain the oldest biosphere in early Earth. In the present ridge-system, hydrogen production in the serpentinized peridotite layer, is considered as major energy source. However, low temperature hydrothermal zone in the lower crust layer in the ridge has been recognized as hydrogen producing zone. Thickness of oceanic crust is less then 10 km in the present Earth. However, the thickness of Archean oceanic crust has been estimated as 50 km. That is, hydration process of oceanic crust in the Archean-ridge is significantly important. Hydration rate of the peridotite layer in the Archean ridge is less extensive than Phanerozoic because thicker oceanic crust prevents hydration in the peridotite layer. Lower crustal rocks of accreted oceanic plateau is one of the best sample to describe hydration process due to deep-sea-hydrothermal alteration because it is easy to observe huge outcrops and collect samples systematically in whole section. We have collected gabbroic rocks from Mikabu high P/T rocks in Toba area and from Ootoyo area, Japan because there are large scale trench cliffs in the mine. Serpentinization of olivine gabbro and troctolite and hydrogen production rate will be shown in the present poster.

Keywords: the oldest biosphere in early Earth, serpentinization, gabbroic rocks

BPT23-P07 Room:Poster Time:April 30 18:15-19:30

Production mechanism for hydrocarbons in serpentinite-hosted hydrothermal systems: Hakuba Happo hot spring

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Serpentinite-hosted hydrothermal systems have been considered to be important environment for birth or evolution of earlier life. Serpentinite is a rock that results from the geological processes of hydration and metamorphic transformation of ultramafic rock from the Earth's mantle. Although ultramafic rocks are rarely exposed at the surface of the Earth today, they were likely to be an abundant component of the early crust owing to the higher potential temperatures compared to the present-day mantle [Komiya et al., 2004]. The presence of hydrocarbons has been reported in serpentinite-hosted systems at not only seafloor but also continental settings [e.g., Charlou et al., 2002; Proskurowski et al., 2008; Etiope et al., 2011; Szponar et al., 2013]. However, production mechanisms of the hydrocarbons in serpentinite-hosted hydrothermal systems so far has not been satisfactorily understood. In this study, we conducted chemical and isotopic analyses of hydrocarbons from a continental serpentinite-hosted hydrothermal system; Hakuba Happo hot spring in central Japan. Hakuba Happo hot spring is situated in the ultramafic rock body and is a site where serpentinization processes are likely to be ongoing at low-temperature of 50-60 [Suda et al., 2014]. The water at Hakuba Happo is strong alkaline (pH $>$10.5) and rich in H_2 and CH_4. Gas and water samples were obtained directly from two drilling wells in November 2013. Water temperature, pH, dissolved oxygen level (DO), oxidation-reduction potential (ORP) and salinity were measured at the sampling points using portable sensors. The water temperatures and chemistries were almost exactly the same as that at previous investigations conducted in 2010 and 2011. The hydrocarbon constituents of CH_4, C_2H_6, C_3H_8, iso-C_4H_{10} and normal-C_4H_{10} were detected from gas samples of Hakuba Happo hot spring. We report the isotopic analyses of hydrocarbons and discuss the process of hydrocarbons generation in serpentinite-hosted hydrothermal systems.

Keywords: serpentinite-hosted hydrothermal system, hydrocarbon, isotopic analyses, abiotic synthesis