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

SGL39-01 Room:A03 Time:May 24 09:00-09:15

Assessment of fault activity by the ESR dating technique

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After the 2011 off the Pacific coast of Tohoku Earthquake, the definition of active faults, which was described as the faults having moved after 120-130 ka BP in the Advanced Safety Examination Guideline for Seismic Design for Nuclear Power Plant, was modified. As a result, we must evaluate the activity of faults having moved after 400 ka BP. However, it is not easy to evaluate the activity in case of the active faults whose tectonic topography is ambiguous or on which there is no sediment available for dating. Thus, we require a new dating technique for directly estimating the absolute dates of fault movements from fault rocks that preserve the past records of fault movement. The ESR (electron spin resonance) method is a dating technique to estimate the absolute dates of fault movements using ESR signals in minerals (quartz, clay minerals, etc.) forming fault rocks that have been once reset by frictional heating or ESR signals intrinsic to the minerals newly generated by faulting (Fukuchi, 2010).

When we apply the ESR technique to active faults, it is the most serious problem whether or not the ESR signals in fault rocks have been completely reset (Fukuchi, 2004). If the ESR signals have been incompletely reset, the ESR ages obtained from the signals will be older than the actual age (Ta) since the total dose of natural radiation is overestimated. However, the ESR ages (Te) give the theoretical upper limit of the actual age (Ta $\leq$ Te). Therefore, if the ESR ages obtained give the young ages showing the middle Pleistocene to Holocene, we can utilize the young ages for the assessment of fault activity. Moreover, when deep drill core samples are available for ESR dating, the problem on the complete resetting may be solved. On the other hand, thermally unstable signals that are bleached by light may decay under higher temperature at deeper sites and consequently may give much younger ages even though frictional heat has not been increased. Therefore, caution is necessary in using thermally unstable signals.

Here, I introduce the case of the Shimotsuburai and Hoozan faults in the Itoigawa-Shizuoka Tectonic Line (ISTL) Active Fault System, whose increase of fault activity has been pointed out after the 2011 Earthquake. As a result of ESR dating of black intrusion veins produced by the latest fault movement of the Shimotsuburai fault, which has moved during the Holocene, the Al and Ti centers derived from quartz give 1.3$\pm$0.2 Ma (Coefficient of determination; R-value is 99.8%) and 2.0$\pm$0.3 Ma (R-value is 99.2%), respectively. Although these centers have been incompletely reset by frictional heating, the age (T) of the Shimotsuburai fault is estimated as T $\leq$ 1.3$\pm$0.2 Ma, from the Al center, the most unstable signal in quartz. On the other hand, as a result of ESR dating of gray gouge produced by the latest fault movement of the Hoozan fault, whose activity during the Quaternary period is unknown, the quartet signals derived from montmorillonite and the Al center derived from quartz give 1.4-1.9$\pm$0.2 Ma (R-value: 99.2-99.5%) and 1.2$\pm$0.2 Ma (R-value: 99.0%), respectively. In addition, the hyperfine structure (hfs: g=2.0187) of the Al center gives 0.6$\pm$0.1 Ma (R-value: 98.8%). Since the whole of the Al center is overlapped with another signal and its ESR age is overestimated, the age (T) of the Hoozan fault may be estimated as T $\leq$ 0.6$\pm$0.1 Ma, from the hfs of the Al center.

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T. Fukuchi, 2010, Absolute dating of earthquake faults by the ESR technique- Its principle and application limit. Chikyu Monthly, Vol.32, No.1, p.16-23.

Keywords: ESR, electron spin resonance, thermochronology, FMR signal, fault rock, Itoigawa-Shizuoka Tectonic Line

Japan Geoscience Union Meeting 2015
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SGL39-02 Room:A03 Time:May 24 09:15-09:30

What does a ”radiometric age” mean?

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In recent years, technical developments in dating methods are remarkable and precision in obtained ages and applicable age range for each method has been much improved.

However, it is not always guaranteed that obtained ages directly correspond to some geological events. To guarantee it, it is necessary to check whether the requirements for each method are satisfied or not. Furthermore, each dating method is based on different principles, which often correspond to different geologic event. However, nawadays many researchers are concerned with the developments in analytical techniques and they do not always pay much attention to check the obtained age values by comparing their required conditions. In this presentation, I will argue for the significance to check the meaning of obtained ages based on their required conditions to represent some geological events by showing some examples(eg.,closure temperature, zircon chronology, isochron).

As a conclsion, I stress the significance to check an obtained age by multiple dating methods and to examine the achievements of conditions required for each dating method.

Keywords: dating, radiometric age, age value, geologic event, required condition, closure temperature

Japan Geoscience Union Meeting 2015
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SGL39-03 Room:A03 Time:May 24 09:30-09:45

Phengite geochronology of HP-UHP metamorphic rocks: Implication of argon release mechanism during deformation

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A systematic K-Ar age mapping along transects perpendicular to metamorphic thermal gradients have been carried out in the HP schist belts, SW Japan, revealing two contrasting age?T?structure relationships. The Sanbagawa HP schist belt in central Shikoku exhibits a thermal structure that the highest grade rocks occur in the middle part of the apparent stratigraphy and a positive correlation in age?T relationship that the ages are progressively older with increasing metamorphic temperature. The similar age-T- structure relation is observed in the Suo HP schist belt of the Ishigaki area. In contrast, the Sanbagawa HP schist belt in the Kanto Mtns area and the Suo HP schist belt in the Nishiki area, where the thermal structure for the higher grade zone is in the lower part of the apparent stratigraphic succession, display a negative correlation that younger ages are in higher-grade metamorphic rocks.

Why do these age?T?structure relationships appear in the HP schist belts, SW Japan? It is difficult to explain the reason based on the closure temperatures (CT) by the thermally activated diffusion model. CT that has been believed for long time is wrong and must be much higher (ca. 600 C) as revealed by the argon geochronology of the polymetamorphic terrains. This shows the metamorhic sequences mentioned above formed in the temperatures lower than the CT. The HP-UHP schists have been deformed severely during the exhumation of their host rocks and the phengites have experienced the argon release from the phengite crystals by their dynamic recrystallization. The K-Ar ages are related directly to the ductile deformation history of the matrix phengite during exhumation and cooling of the rocks. This suggests that the argon release cease when the ductile deformation of phengites stopped and the K-Ar ages are related to the timing of cease of ductile deformation. This means the phengite (without deformation) included in garnet give a timing of peak metamorphism.

The phengite geochronology of HP-UHP metamorphic rocks in western Alps conducts the following conclusions. Each mica crystal has experienced the different deformation - Ar depletion history during the exhumation of the host rocks and the portions within a crystal have the different history. This phenomenon may be more distinct in the rocks that have experienced the limited deformation history. K-Ar ages of the mica separates from the rocks indicate the average values of the ages from each crystal. To justify this Ar release mechanism requires further investigation using UV laser probe in-situ Ar-Ar analyses of micro-domains in phengite crystal with high sensitive noble gas mass spectrometer.

Keywords: HP-UHP metamorphic rocks, phengite geochronology, deformation, argon release mechanism, closure temperature

Japan Geoscience Union Meeting 2015
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SGL39-04 Room:A03 Time:May 24 09:45-10:00

Unspiked K-Ar dating for the central part of Kuju volcano, Kyushu, Japan

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Unspiked K-Ar dating method enables mass fractionation correction of initial $^{40}Ar/^{36}Ar$ ratio, and has been successfully applied to young lava samples, especially younger than 0.5 Ma. We measured unspiked K-Ar ages for lava samples corrected from Ogigahana, Nakadake, Mimatayama volcanoes, the central part of Kuju volcano, Kyushu, Japan. The volcanic bodies in central Kuju volcano are regarded to have formed after Handa pyrocrastic flow eruption in ca. 54 ka. However, the detailed geochronological study had not been conducted because their ages are considered to be younger than the measurement limit by conventional K-Ar dating method.

New ages for the lava on south Ogigahana Volcano is 34±3 (1σ) ka, agree with the reported TL ages (34-37 ka; Okuno et al., 2013) and the stratigraphy. The sample from the lower unit yield 65±8 ka, similar age with the TL ages for the summit of the volcano and adjacent Iwaigodake volcano (60-70 ka; Okuno et al., 2013).

The age for the lava from Inaboshi Yama, a part of Nakadake volcano, is 46±12 ka, showing it formed soon after Handa pyrocrastic flow eruption.

We measured also the essential rock in Matsunodai Debris Abaranche Deposit, probably originated from Mimatayama volcano. The obtained age is 36±12 ka, in agreement with the ^{14}C age of ca. 20ka in its error.

These results show that a several volcanic bodies were formed in ca.54-30 ka in the central part of Kuju volcano.

Keywords: Kuju volcano, K-Ar dating, Unspiked method

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SGL39-05 Room:A03 Time:May 24 10:00-10:15

Validation of X-ray interference correction methods in EPMA-CHIME dating

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The CHIME dating method provides micro-volume non-destructive U-Th-Pb dating based on quantitative electron probe microanalysis (EPMA). X-ray interference is a significant problem for the accuracy of the EPMA-CHIME dating. X-ray interferences are generally corrected using (1) peak-separation technique, (2) X-ray intensity based method[1], or (2) chemical composition based method[2]. X-ray interferences by Th and Y are validated using synthetic standard materials. X-ray intensity based correction highly depends on chosen standard materials in the determination of correction factors. On the contrary, the chemical composition based method is less sensitive to chosen standard materials.

[1]Åmli & Griffin, W.L. (1975) Amer. Mineral., 60, 599.
[2] Donovan, J.J., Snyder, D.A. & Rivers, M.L. (1993) Microbeam Anal., 2, 23.

Keywords: CHIME dating, X-ray interference correction, electron probe microanalysis (EPMA), quantitative analysis

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SGL39-06 Room:A03 Time:May 24 10:15-10:30

LA-ICP-MS U-Pb dating using non-polished zircons: Can we read magma residence time?

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It is well-known that in dating zircon by U-Pb method, LA-ICP-MS is inferior to TIMS in precision and to SIMS in spatial resolution. However, the LA-ICP-MS method usually drills zircons to ~20 μm in a single analysis (~2 μm for SIMS). This can be an advantage over TIMS and SIMS in that it can obtain age information from the surface to the core of zircons. Especially, the method can elucidate zircon crystallization time from beginning to end by using non-polished zircons. Meanwhile it should be mentioned that in LA-ICP-MS $^{206}Pb/^{238}U$ ratio increases as analysis time (as zircons are drilled deeper), known as down-hole fractionation. Here I took this into consideration and still found that the Fish Canyon Tuff, the largest known silicic eruption on Earth, has a magma residence time of more than 1 m.y., not less than 0.4 m.y. as assumed in literatures, and demonstrate the usefulness of non-polished zircon LA-ICP-MS U-Pb dating.

Keywords: U-Pb dating, zircon, LA-ICP-MS, magma residence time, Fish Canyon Tuff

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SGL39-07 Room:A03 Time:May 24 10:30-10:45

Investigation of martian surface history: NanoSIMS analyses of D/H ratios and U-Pb chronology of martian meteorites

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Introduction: Water is an important volatile for environments of terrestrial planets as well as their habitability. A number of recent studies have identified strong evidence for liquid water on past Mars, such as clay minerals and fluvial geomorphological features (e.g. [1][2]), whereas a comprehensive history of the martian environment remains complicated. The isotopic compositions of hydrogen (D/H) of present martian atmosphere is highly elevated (˜5 times that of terrestrial water; [3]), which results from the extensive atmospheric escape. Martian meteorites are useful as they potentially provide valuable records including D/H of the past surface water and the mantle primitive water (e.g. [4][5][6][7][8]). However, due to their complicated history on Mars, it is challenging to understand their isotopic records accurately. Phosphates are helpful, for they can preserve both U-Pb chronology and D/H information. Here, we report D/H ratios and U-Pb ages of phosphates in two martian meteorites; an ancient orthopyroxenite, ALH 84001 (ALH), and a young enriched shergottite, LAR 06319 (LAR). In addition, we have also measured D/H ratio of melt-inclusion glass (MIs) in LAR.

Analytical methods: For ALH, 3 merrillite grains with known U-Pb ages [9] were selected for D/H analyses. For LAR, several phosphate grains and MIs were found in a thin section, using a SEM-EDS. Both U-Pb and D/H analyses were carried out using a NanoSIMS 50 installed at AORI, Univ. of Tokyo. Before SIMS analyses, the samples were baked at ˜100 ℃ in a SIMS air-lock overnight before/after gold coating to remove adsorbed water. The analytical methods of U-Pb dating were the same as the previous study [9]. The D/H analyses were conducted on the phosphates in ALH and LAR and MIs in LAR. A Cs^+ primary ion beams with 200pA/1nA was used for phosphates and MIs, respectively. An electron gun was used for charge compensation. Negative secondary ions of $^1H^-$, $^2D^-$, $^{12}C^-$ and $^{18}O^-$ were collected. A natural terrestrial apatite from Morocco and NIST SRM 610 were used as standards. To avoid terrestrial H contamination, most of which are background H in the analysis chamber and hydrocarbon in the sample cracks, careful analytical protocols following a previous study [7] were conducted.

Results & Discussion: The δD values of ALH merrillite varied from -300 to 1970 ‰ (Fig). The obtained highest value is similar to those of ALH carbonates and maskelynite [4]. The U-Pb age of the same grains, 3990Ma, can be interpreted as an impact-induced reset age [9]. It is likely that their D/H ratios reflect 3990Ma surface water, incorporated during the impact and/or a later hydrous metamorphism. The high D/H mainly supports a previously proposed two-stage evolution [5]. On the other hand, phosphates in LAR yielded a total Pb/U age as 167+/-57 Ma. This is consistent with other radiometric ages within uncertainty, suggesting the U-Pb system in the phosphates has been preserved since crystallization of the host rock. δD values of LAR apatite, merrillite and MIs were 3340-4380 ‰, 1070-5260 ‰ and 1150-6830 ‰, respectively (Fig). The D/H may have mineral trends: MIs >merrillite >apatite. A similar trend was reported previously [7]. While apatite possibly recorded the magmatic water at the timing of crystallization, MIs might have incorporated water from another reservoir with extremely high D/H ratios.

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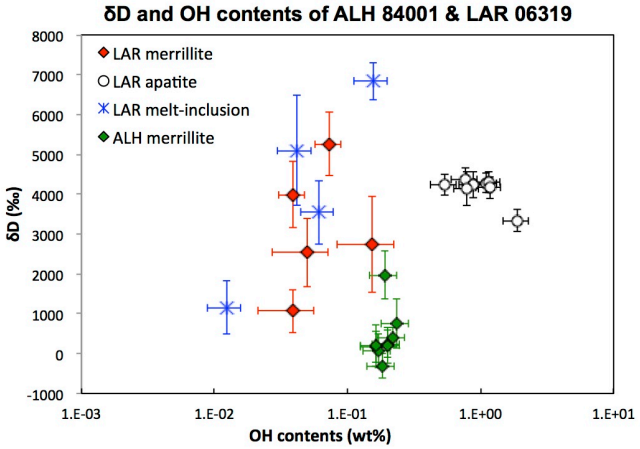
Keywords: martian meteorites, NanoSIMS, D/H ratios, U-Pb dating, phosphates, melt-inclusions

SGL39-07 Room:A03 Time:May 24 10:30-10:45



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SGL39-08 Room:A03 Time:May 24 11:00-11:15

Application of oxygen isotopic dendrochronology to Earth Science: Its potentials and challenges

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<Introduction>

Dendrochronology has been mainly used in archaeology, but also applied to Earth Science, such as dating of past earthquake and volcanic eruption by analyzing of woods excavated from landslide or pyroclastic layers. However, there are several challenges in previous dendrochronology. (1) It is necessary to establish regional standard ring width chronology (master chronology) as long as possible for dating of woods from various periods. (2) Because climate sensitivity of tree-ring width depends on tree species, it is necessary to make master chronology for each species separately. (3) To fix accurate years of geological events, it is necessary to analyze buried woods with bark. In this presentation, I will show how oxygen isotope ratios in tree-ring cellulose can solve those challenges for applying dendrochronology to Earth Science.

<Problems in Traditional Dendrochronology>

There are several difficulties in traditional ring width dendrochronology. (1) Although there are some very long ring width chronologies of more than 10,000 years in the world, they are usually established in cold regions where ice sheet covered in glacial periods, so that it is impossible to extend the chronology beyond last glacial maximum. In Japan, woods can be often excavated in glacial layers, but ecological disturbance to tree-ring width owing to the high tree density in Japanese forest usually makes it difficult to cross-date old excavated logs so that longest ring width chronology in Japan is limited to about 3,000 years made of conifer only. (2) Most wood samples of various hardwoods cannot be dated by traditional dendrochronology in Japan because there are not tree-ring width chronologies made of hardwood. (3) Small logs with barks cannot be dated by comparison of ring width time-series due to less statistical reliability owing to small ring numbers.]

<Characteristics of oxygen isotopic dendrochronology>

Recently developed oxygen isotopic dendrochronology has following advantages and disadvantages. One of disadvantages is that it is much more time-consuming and labor intensive to measure tree-ring oxygen isotope ratios than tree-ring width. Another disadvantage is that it cannot be applied to highly degraded wood which has lost cellulose by microbial decomposition in sediment. The latter problem limits the applicability of oxygen isotopic dendrochronology to many geological and archaeological samples. On the other hand, there are several merits. Because tree-ring cellulose oxygen isotopic ratio reflects only two meteorological parameters (precipitation isotope ratios and relative humidity during growing season), its inter-annual time-series coincides very well with that in different trees of different species. Besides, its inter-annual variation correlates well with summer precipitation, making good paleo-precipitation proxy. Moreover, records on seasonal precipitation can be reconstructed by slicing of year ring and analyzing oxygen isotope ratios.

<Applicability of oxygen isotope dendrochronology to Earth Science>

By utilizing those merits of tree-ring cellulose oxygen isotope ratios, three challenges mentioned above can be solved as follows. (1) The high correlation of oxygen isotope ratio time-series between different tree individuals makes it possible to cross-date several millennia old excavated logs precisely (now the oxygen isotopic chronology has extended to 4300 years ago in Japan), so that systematic excavation of old logs may establish very long tree-ring chronology over last glacial maximum soon in Japan. (2) Because of its universality over tree-species, various wood samples in sediment layers, indicating of past earthquake and/or volcanic events, can be dated by oxygen isotope dendrochronology. (3) In combination with radiocarbon measurement, small log with bark, which has only 5-10 year rings, can be dated by referring database of intra-ring oxygen isotope ratios in the near future.

Keywords: tree ring, cellulose, oxygen isotope ratio, dendrochronology

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SGL39-09 Room:A03 Time:May 24 11:15-11:30

Re-evaluation of ABA treatment for 14C dating of charcoal from the Late Holocene layer

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Radiocarbon (^{14}C) dating has been used in field of geology and archaeology. Especially, in archaeology, high resolution and high accuracy dating is required. It had been suspected and had been tried to clarify the effect of the contamination by exterior organic matter on the ^{14}C date from the beginning of development of radiocarbon dating. There exists no research with the objective method for the effect of residual external organic carbon after pretreatment on the ^{14}C date. Thus, the discussion on what is reasonable and reliable sample in the ^{14}C dating method and the discussion on the most suitable chemical treatment condition are still left unsettled. Moreover, there exists no reliable chemical method to distinguish external organic matter and humificated charcoal of sample charcoal. But we know empirically that charcoal's characteristics to resist against NaOH solution are different by burial and preserved states. Therefore, many researchers are using NaOH solution of low concentration when charcoal's characteristics to resist against NaOH are weak. The problem on the conventional ABA method is that what degree of concentration of NaOH solution is the most effective to the ^{14}C dating samples. There exists no consensus on the problem. Here, we require the adequate condition of sample and the adequate pretreatment condition to obtain reliable ^{14}C dates. However, as far as we know, there exist few data and researches on conditions of ABA pretreatment. In the present research, we try 5 steps pretreatment using alkaline solution increasing concentrations stepwise in order to search the optimum condition of alkaline treatment stage of ABA method. We make comparisons by the ^{14}C dates among residual charcoal of the individual pretreatment stages, and compare emission intensity of dissolved organic matter and absorbance of the extracted solutions of the individual pretreatment steps. Namely, the present research aims to clarify the problem of ABA method and its practical solutions. According to results of present research, we recommend 5 step-alkaline treatment by 5 concentrations (0.001, 0.01, 0.1, 1.0, 1.2 mol/L) of NaOH solution for charcoal treatment.This time, we discuss systematically about problems of the ^{14}C dating.

Keywords: Radiocarbon dating, Late Holocene, ABA method, Humic acid, 3D-Fluorescence spectroscopy

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SGL39-10 Room:A03 Time:May 24 11:30-11:45

U-Pb dating of zircons and measurement of organic carbon isotope in the sedimentary rocks from the BGB

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The Swaziland Supergroup comprises three Groups; a lower, the Onverwacht Group; a middle, the Fig Tree Group; and upper, the Moodies Group. The target of this study is the Fig Tree Group which comprises interstratified terrigenous clastic units and dacitic to rhyodacitic volcanic rocks. These strata seem to have two formation-level units; the Mapepe and Auber Villiers Formations. The Mapepe formation includes about 700m of shale, chert-grit sandstone, and chert-clast conglomerate interstratified with fine-grained felsic pyroclastic and volcaniclastic rocks. It is thought that deposition took plece in alluvial, fan-delta, and shallow to moderately deep subaqueous environments. This work have conducted the stratigraphy of the Mapepe formation by making detailed column, measuring magnetic susceptibility, dating U-Pb abundance ratio of zircons, and dating stable carbon isotope ratios of organic carbon in the sedimentary rocks from the study area. The purpose of this study is to estimate a sedimentation environment of the Mapepe formation through the use of diverse ways.

U-Pb dating of zircon is the most prevailing method of determining the depositional ages from the sedimentary rocks of Archean-Proterozoic in which the biostratigraphy has not been established. We collected 7 redsandstone samples from the Mapepe Formation and 5 intrusive ones from the Onverwacht Group, and were able to obtain zircon from only 1 sample each. U-Pb measurements of Zircons were conducted by LA-ICP-MS installed at the National Science Museum.

We measured two zircons; from the Mapepe Formation redsandstone and the Onverwacht Group intrusive rock. Zircons from the Mapepe Formation has 29 concordant ages and a peak in age about 2954±9Ma∼3546±13Ma. There are more than a few zircons younger than this age, and it is considered that there are two possibilities; the zircons reflect the depositional age of the area, and a possibility of Pb defect. In any case, these data are in contradiction with the previous research (Lowe D. R. et al., 1999), so that has quite a bit of room for improvement such as increasing the number of measured zircons to discuss statistically. Zircons from the Onverwacht Group has 6 concordant ages and indicates 3270±14Ma. This data is consistent with the previous research (Lowe D. R. et al., 1999)

Green shale from the Mapepe formation showed at an average of 0.72wt% of amount of organic carbon. Black shale, green shale, and jasper from the Mapepe formation showed between -30.6˜-20.3 ‰, which suggests a kind of possibility of biological activities.

Keywords: U-Pb Dating of Zircons, Measurement of Organic Carbon Isotope, Barberton Greenstone Belt

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SGL39-11 Room:A03 Time:May 24 11:45-12:00

D/H and Sr isotopic ratios of apatite inclusions from Archaean zircons to study Earth's evolution

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Isotopes of volatile elements H and S, and those of incompatible element Sr, presented in Archaean rocks can give unique information to understand the evolution of the Earth's interior and the state of its surface. Apatite or glass inclusions contain hydrogen, halogen, and strontium as major or minor element. When they are encapsulated in metamorphic-resistant zircon crystals, it is expected that the pristine isotopic information of these elements might be preserved. However, apatite inclusions are usually less than a hundred micrometers in diameter, which require the use of high-sensitive and high-resolution analytical methods for measuring isotopic abundances. Furthermore, discriminating between pristine compositions and later alteration is problematic. We are trying to approach these issues by using a NanoSIMS50 at University of Tokyo.

U-Pb dating using NanoSIMS50 has been carried out on zircon crystals separated from tonalitic gneisses of the Eoarchaean Nuvvuagittuq supracrustal belt, Superior province, Canada. The estimated age, 3638±19Ma, using NanoSIMS50 is consistent with previous reported age of 3661±4Ma, using LA-MC-ICP-MS. Some zircons show discordant ages suggesting that a certain amount of Pb was lost by a thermal alteration event at 980±330Ma. We excluded such discordant zircon crystals because the isotopic composition of H and Sr could have been also altered by this thermal event.

Measurements have been made by peak jumping analysis using single collector with Cs^+ primary ion beam. H and D were collected for hydrogen isotopic analyses, and ^{86}Sr, ^{87}Sr, and ^{88}Sr were collected for strontium isotopic analyses.

Obtained D/H ratios from 7 apatites suggest that δD values range from -223 to +54 ‰ (vs. SMOW). Considering the correlation between measured D/H and O/H ratios, it turned out that these values were affected by contamination with a D-poor, H-rich component. As a result, +17±40 ‰ was estimated as the D/H true value for these apatite inclusions. This value is heavier than that of reported one by Pope et al (2012) which estimated the hydrogen isotopic ratio of Archaean sea water as -25 ‰ targeting hydrogen contained in serpentine from ca. 3700 Ma Isua supra crustal belt.

Keywords: apatite, U-Pb dating, hydrogen isotopic ratio, strontium isotopic ratio, Archaean

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SGL39-12 Room:A03 Time:May 24 12:00-12:15

Geodynamic cycles of sulfur, carbon and nitrogen

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Sulfur has important roles not only in biological activities but in industry and medicine. However, its geochemical cycle between the mantle and the surface environments has not been well quantified. ^{3}He, one of the primordial noble gas isotopes, is useful to investigate to evaluate S cycles. ^{3}He fluxes from the mantle to atmosphere and ocean are well constrained, which enables us to use this isotope to estimate other volatile fluxes. The recent study reported S and C fluxes from the mantle to the surface environments based on He, S, and C isotopic compositions in MORB, hydrothermal fluids, and volcanic gases [1]. The fluxes were estimated with the recently reported ^{3}He flux at ridges, 530 mol/y [2]. The S/^{3}He ratio at MOR was calculated to be 1.9x10^{8} as an average of S/^{3}He ratios in six MORB vesicles (13N, 17S on EPR; 15N, 37N on MAR; 24S-25S on CIR) and 10 high temperature (>200 ℃) hydrothermal fluids (11N-47N, 17S-19S on EPR; 23N-38N on MAR). Multiplying this ratio and the ^{3}He flux together, S flux at ridges was estimated to be 100 Gmol/y. An average S/^{3}He ratio of 15 high temperature (>200 ℃) volcanic gases collected from circum-Pacific regions was calculated to be 6.5x10^{9}, providing S flux of 720 Gmol/y from arc volcanoes calibrating against ^{3}He flux of 110 mol/y determined by its MOR flux. This flux is higher than that from ridges. However, S in volcanic gases does not originate only from the mantle. S/^{3}He ratios and δ^{34}S values in volcanic gases can be explained by mixing of three components: the upper mantle; subducted sedimentary pyrite; and subducted sulphate. The S contribution from the upper mantle was calculated to be 2.9% in volcanic gases, providing 21 Gmol/y from the mantle at arcs, which is lower than the S flux at ridges. Carbon flux at ridges was calculated to be 1200 Gmol/y using the CO_2/^{3}He ratio of 2.2x10^{9} [3] based on compositions of MORB and hydrothermal fluids. An average CO_2/^{3}He ratio of 24 high temperature (>200 ℃) volcanic gases collected from circum-Pacific regions was calculated to be 2.0x10^{10}, providing C flux of 2200 Gmol/y from arc volcanoes. CO_2/^{3}He ratios and δ^{13}C values in volcanic gases can be explained by mixing of three components: the upper mantle; subducted organic sediments; and subducted limestone with slab [4]. The C contribution from the upper mantle was calculated to be 11% in volcanic gases, providing 240 Gmol/y from the mantle at arcs. The S and C fluxes from the mantle to atmosphere and ocean are 121 Gmol/y and 1440 Gmol/y, respectively. The C/S flux ratio was calculated to be 12, which is comparable to the surface inventory ratio of 13 [5]. This suggests that the main source of surface S and C is the upper mantle. Assuming steady-state surface environments, subducted amounts of S and C become 820 Gmol/y and 3400 Gmol/y, respectively. Then 15% of subducted S and 42% of subducted C do not return to the surface environments and recycle back into the depth. Nitrogen cycles will also be quantified and discussed in the current study.

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Keywords: sulfur flux, carbon flux, nitrogen flux, mid-ocean ridge basalt, hydrothermal fluid, volcanic gas

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Petrology, Structure and Chemostratigraphic Correlation of Chehmit inlier, Tigrai, Northern Ethiopia

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Chehmit area is one of the four exposed Neoproterozoic inliers in northern Ethiopia, which consists of both Tsaliet and Tambien Group rocks. The metavolcanics, metavolcanoclastics and phyllite rocks exposed in the area represent the Tsaliet Group whereas the mixed clastic-carbonate metasedimentary rocks constitute the Tambien Group deposited ∼800-740Ma ago. An integrated structural, petrological and carbon and oxygen isotope study has been carried out to understand the deformation, metamorphic and Neoproterozoic history of the area. Field structural data demonstrate that there are at least three phases of deformations. Earliest deformation produced minor, steep tight folds and N-S trending, pervasive regional foliation; followed by the formation of major upright folds, and latest brittle structures. Petrographic study of rock samples from the area shows predominantly lower green schist facies metamorphism coeval with the earliest phase of deformation. Stable C and O isotope analysis of the carbonates is also carried out to evaluate chemostratigraphy. The limestone unit contains anomalous C-isotope depositional signature which, together with lithological features, enabled local and global correlations with other Neoproterozoic formations. The δ^{13}C values of the limestone in Chehmit range from -5.79 ‰ to -1.99 ‰ with an average value of -3.80 ‰ whereas the value of δ^{18}O ranges from -7.119 ‰ to -14.164 ‰ with an average value of -11.300 ‰. Although negative carbon isotope excursion in Neoproterozoic era is often related to snowball earth conditions, no glaciation features and erosion surfaces are observed in this unit. Thus the negative C-isotope excursion is, instead, correlated with the Bitter Springs Stage anomaly (found in Australia and Svalbard) which is considered to be the result of inertial interchange true polar wandering. The δ^{13}C values obtained from the Chehmit limestone indicate a match with the top most excursion of the Bitter Springs anomaly. Radiometric dating and paleomagnetic studies of the rocks of the Chehmit area can be useful to further support this hypothesis

Keywords: Tambien Group, chehmit area, carbonates, Neoproterozoic, Bitter spring stage, True polar wondering