

IntCal13は何が画期的なのか Why is the IntCal13 special?

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放射性炭素年代が較正を必要とすることは広く認識されている。世界のいくつかの研究グループが較正モデルを提案しているが、その中でもっとも広範に用いられているのは IntCal と呼ばれるモデルである。IntCal は 1998 年に最初のバージョンが公表され (IntCal98)、その後 2004 年 (IntCal04)、2009 年 (IntCal09) と改訂を重ねてきた。だが 2013 年に公表された最新版の IntCal13 は、それまでの IntCal とは大きく一線を画す画期的なモデルであると評価されている。いったい IntCal13 の何が特別であるのか、また IntCal13 とそれ以前のデータセットとの比較から何が明らかになったのか、主として放射性炭素年代測定の専門家以外を対象として概説する。

キーワード: IntCal13, 放射性炭素年代測定, 放射性炭素年代較正, 年縞堆積物, 水月湖, 海洋リザーバー効果

Keywords: IntCal13, Radiocarbon dating, Radiocarbon calibration, Varved sediment, Lake Suigetsu, Marine reservoir effect

14C年代値に対する酸-アルカリ-酸洗浄法のアルカリ洗浄段階の影響評価 An evaluation of the effect on 14C dating (AMS) by alkaline treatment of the ABA method on charcoal sample

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地球科学や考古学の分野では、¹⁴C年代測定に用いる炭化物の前処理に、酸-塩基-酸処理法 (Acid-Base-Acid: ABA method or Acid-Alkali-Acid; AAA method) が広く用いられている。しかし、酸-塩基-酸 (Acid-Base-Acid: ABA) 処理法は¹⁴C年代測定法における木炭試料の前処理の基本であるにもかかわらず、同法の処理条件についての化学的指標に基づく研究例は少ない。そこで本研究は、¹⁴C年代測定法の問題点として、従来、詳細は未解明であった前処理法による誤差の発生を明らかにすることを目的とする。発表者はこの目的の為に3種類の実験を行った。第一に年代値の再現性確認実験。第二に最適なアルカリ洗浄時間の確認実験。第三に洗浄に最適なアルカリ溶液の濃度の確認実験である。

第一の結果: NaOH 洗浄済みの試料の年代値群は、 $T=0.45$ (自由度 3; 5% 危険率: $T > 12.59$) と高い収束性を示すのに対して、NaOH 未洗浄試料の年代値は $T=10.74$ (自由度 4; 5% 危険率: $T > 9.49$) と発散が大きく、NaOH 未洗浄試料 5 試料の中で有意の差が現れた。

第二の結果: 目視によってアルカリ抽出終了と判断された後にも、三次元蛍光測定が NaOH 溶液中にフミン酸を検出し、かつ、¹⁴C年代測定結果 (渥美ほか, 2009) はフミン酸による影響を示している。さらに、これらの結果はアルカリ抽出終了判定に目視は不適切であり、かつ、三次元蛍光測定が溶存有機汚染物質の存在を監視する上で効果的であることを示唆している。

第三の結果: ある考古遺跡中の同層準の 3 木炭試料を 8 つの別々の濃度の NaOH 溶液で洗浄した試料の年代測定結果を χ^2 検定で評価した。その結果、1.2 mol/l で処理した試料間で最小値を示した。三次元蛍光測定の結果では 2.1 mol/l の NaOH 洗浄溶液中の腐植物質の抽出特性と 0.5~0.001 mol/l の溶液の抽出特性との間に明確な傾向の差が出た。すなわち、0.5~0.001 mol/l NaOH 溶液は低励起光波長領域の汚染の抽出効率が相対的に弱い。この現象が年代値の収束性の差を生んでいると考えられる。結論として、¹⁴C年代測定の前処理には 1.0~1.5 mol/l NaOH 溶液の使用を推奨する。

これらの結果は、いずれも前処理の化学的条件の差異が引き起こすフミン酸の残留度の差が¹⁴C年代値に影響を及ぼすことを示している。

キーワード: 放射性炭素年代測定法, 酸-アルカリ-酸前処理法, 三次元蛍光分析, フミン酸, 木炭試料
Keywords: 14C dating, ABA pretreatment, 3-D fluorescent spectroscopy, Humic acid, Charcoal sample

沖縄トラフ海底熱水域の熱水性鉱石中の重晶石のESR及び放射非平衡による年代測定 Dating of sea-floor hydrothermal barite collected at the Okinawa Trough by ESR and radioactive disequilibrium

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The temporal change of submarine hydrothermal activities has been an important issue in the aspect of the evolution of hydrothermal systems which is related with ore formation (Urabe, 1995) and biological systems sustained by the chemical species arising from hydrothermal activities (Macdonald et al., 1980). Dating methods using disequilibrium between radioisotopes such as U-Th method (e.g. You and Bickle, 1998), ²²⁶Ra-²¹⁰Pb and ²²⁸Ra-²²⁸Th method (e.g. Noguchi et al., 2011) have been employed for such studies.

Okumura et al., (2010) made the first practical application of ESR (electron spin resonance) dating technique to a sample of submarine hydrothermal barite to obtain preliminary ages, while Kasuya et al. (1991) first pointed out that barite can be used for ESR dating. Toyoda et al. (2011) determined the optimum ESR condition while Sato et al. (2011) confirmed that the signal is thermally stable enough for an age range of several thousand years. Takamasa et al. (2013) obtained U-Th and ESR ages which are roughly consistent with each other.

The samples were taken by research cruises operated by JAMSTEC. Barite (BaSO₄) was extracted from hydrothermal sulfide chimney samples taken from two sites at the Okinawa Trough. Blocks of sulfide deposits were cut into pieces, and about 2.0g was crushed. The samples were soaked in 12M hydrochloric acid, left for approximately 24 hours. Then, 13M nitric acid was added. Finally, after rinsing in distilled water, the sample was filtered and dried. Impurities were removed by handpicking. An X-ray diffraction study was made to confirm that the grains are pure barite. After gamma-ray irradiation at Takasaki Advanced Radiation Research Institute, Japan Atomic Energy Agency, they were measured at room temperature with an ESR spectrometer (JES-PX2300) with a microwave power of 1mW, and the magnetic field modulation amplitude of 0.1mT. The bulk Ra concentration was measured by the low background pure Ge gamma ray spectrometer. Assuming that Ra is populated only in barite, the dose rate was calculated with the alpha effectiveness of 0.043 (Toyoda et al., 2012), where the decay of Ra (a half life of 1600 years) was also taken into account.

The obtained ages range from 4.1 to 16000 years, being consistent with detection of ²²⁸Ra in younger samples and radioactive equilibrium/disequilibrium between radium and daughter nuclei. The variation of the ages within each sample is mostly within the statistical error range. The relative order of the ages is consistent with the result of ²²⁶Ra-²¹⁰Pb method, where the difference in absolute ages would be explained by several hydrothermal events that form the chimney. It was found that Yoron Hole field is the youngest, then, Daiyon-Yonaguni Knoll field, Hatoma Knoll field, being nearly equal to Iheya North Knoll field, then Izena Hole field, which is consistent with the direct observation from the submersible.

キーワード: 重晶石, 海底熱水活動, 電子スピン共鳴, 年代測定

Keywords: barite, hydrothermal activities, electron spin resonance, dating

方解石の熱ルミネセンス特性 Thermoluminescence property of calcite

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地球科学において用いられる各種現象に対しての時間軸を与える要素を年代と呼ぶ。年代値をもとにして、地球や惑星さらには人類の進化等をさぐる事が可能である。そのため年代値は地球科学において最も基本的なデータの1つである。

熱ルミネセンス年代測定法とは、放射線を受けた鉱物を加熱するときに出るルミネセンスの量から年代を算出する方法である。炭酸塩鉱物を用いた熱ルミネセンス年代測定は、¹⁴C年代測定で欠落している年代を補填できることから、利用されてきた。

しかし、方解石の熱ルミネセンス年代測定には様々な問題がある;例えば、加熱中の相変化による感度変化やフェーディング、各放射線(α 線、 β 線、 γ 線やX線)に対する熱ルミネセンス特性の差などの問題がある。

本研究では、方解石熱ルミネセンス年代測定法の精度確度を向上させることを目的とし、微量元素濃度の異なる様々な方解石(フィリピン、モンゴル、合成方解石)を用い以下の研究を行った。

1. 各方解石のX線誘起熱ルミネセンス特性の測定。
2. 各放射線に対する方解石熱ルミネセンス特性の差を測定(X線に対する α 、 β 、 γ 線のルミネセンス効率をa-x-value, b-x-value, c-x-valueとする)。
3. 各不純物濃度と方解石ルミネセンス特性の相関関係を考察する。
結果は以下に示す。
 - i) ほとんどの方解石熱ルミネセンスは80と230℃のピークを示す。
 - ii) 方解石熱ルミネセンスの80℃ピークはフェーディングの影響を受ける。
 - iii) a-x-value, b-x-value, c-x-valueはMg, Mn, Fe, Srと相関関係を示す
 - iv) Feにはルミネセンス抑制効果が存在する。

Feは方解石熱ルミネセンスに大きな影響を与える。また方解石熱ルミネセンスの特性は複数の要因(Mg, Mn, Sr)によって決定されることが考えられる。様々な不純物濃度を示す方解石の分析を行い不純物濃度と方解石熱ルミネセンス特性の関係を評価することが必要である。

キーワード: 熱ルミネセンス, 方解石, 年代学

Keywords: thermoluminescence, calcite, dating

原子間力顕微鏡によるジルコンの観察：フィッショントラック？ それとも α リコイルトラック？ Zircon observation by atomic force microscope: Fission track or alpha recoil track?

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フィッショントラック (FT) 法は鉱物中に含まれる ^{238}U が自発核分裂を起こすことによって生じた損傷の計数に基づく年代測定法である。FT の密度が高くなるにつれ FT 同士が重なり合い計数が困難になるため、現在行われている光学顕微鏡を用いた FT 法では、必要なエッチング時間と分解能の限界により、測定できる密度がある程度制限される。原子間力顕微鏡 (Atomic Force Microscope: AFM) はナノオーダーの高い分解能を有し、より高密度の FT を計数することができる。しかし密度が高くなるのに合わせてエッチング時間を短くすると、期待される年代から予測される FT 数より多いトラックが計数される。これはエッチングが短いために、 α リコイルトラックと FT の形状の違いがでるに至らない状態で観察することになり適切な計数が行えないことが原因であると思われる。一方若い火山岩から採取したジルコンには、古いジルコンで観察される α リコイルトラックが原因と思われる表面構造がなく、そこでまれに見つけられる、10nm 深さの、計数可能な凹は α リコイルトラックである可能性があり、年代測定に結びつけられるかもしれない。

キーワード: ジルコン, フィッショントラック, アルファリコイルトラック, 原子間力顕微鏡

Keywords: zircon, fission track, alpha recoil track, atomic force microscope

三波川エクロジャイト中フェンジャイトの過剰アルゴン：沈み込み帯変成作用におけるアルゴン挙動についての制約
Excess argon in phengite from the Sanbagawa eclogites: Constraints on argon behavior during subduction zone metamorphism

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K-Ar system dating of phengitic mica is a powerful tool to determine cooling ages of HP/UHP metamorphic rocks. However, discordant ages in a same metamorphic unit have been often reported, particularly from rocks in Alpine-Himalayan type collisional metamorphic belts. For example, UHP-metamorphosed continental crust materials of the Dola Maira massif (western Alps, Italy) show the discrepancy due to the existence of excess argon in metamorphic minerals that has been inherited from the precursor rocks with polyphase metamorphic records. Over the last two decades, we have addressed an excess-argon free hypothesis in oceanic petrogenesis of Pacific-type convergent margins. According to the hypothesis, metamorphosed oceanic materials in Pacific-type HP metamorphic belts with only a monophase metamorphic records do not contain significant amount of excess ⁴⁰Ar; in other words, the K-Ar system in syn-metamorphic phengitic mica is significantly reset during fluid-induced metamorphic recrystallization at a Pacific-type convergent margin. Well-documented geological examples are of schists from Sanbagawa, Suo and Renge metamorphic belts in SW Japan, and from Otago metamorphic belt in New Zealand. Ar-Ar phengite analyses of HP-UHP metamorphosed oceanic lithologies of the Lago di Cignana (western Alps, Italy) also show negligible excess ⁴⁰Ar in eclogite-facies syn-metamorphic phengitic mica.

In the year 2000, as a preparation to guide participants for the IEC Conference in Japan, we have determined K-Ar ages of phengite and paragonite from the eclogite-facies Sanbagawa metamorphic rocks in Shikoku; the twenty-two results were obtained from four localities including Seba (84-89 Ma), Gongen (123-136 Ma) and Western Iratsu (78-80 Ma), and Kotsu/Bizan (82-88 Ma). Excepting for the quartz-rich kyanite eclogite from Gongen (GO), phengite and/or paragonite yields similar cooling-age ranges of metasedimentary rocks of the Sanbagawa metamorphic rocks in central Shikoku. Phengite K-Ar ages of GO eclogites are significantly older than syn-metamorphic zircon U-Pb ages at the same unit. These old ages are interpreted as the presence of excess ⁴⁰Ar in phengitic mica. The bulk-rock compositions of GO eclogites suggest a sedimentary protolith such as greywacke. When, where and how has the excess argon been trapped in phengite crystals? Considering the geological fact that the GO eclogites are closely associated with the Higashi-Akaishi (HA) meta-peridotite body, the false age obtained from phengite were likely attributed to an interaction between the meta-sediment (GO eclogite) and the meta-peridotite (HA peridotite) at eclogite-facies depth. We postulate that the fluids exchange between deep-subducted sediments and mantle material enhanced a hydration of peridotite and mantle-derived noble gas (including extreme ⁴⁰Ar) was diffused from mantle material to the sediments. During the exhumation of them, the rigid HA peridotite might have prevented a ductile deformation of GO eclogite and consequently mantle-derived argon gained from HA peridotite in GO eclogite might have been inherited by the limited-argon-depletion due to less deformation. This is not only very rare example of false K-Ar age of metamorphosed oceanic materials but also remarkable observation to explain argon behavior during sediments/peridotite interaction at a deep portion of subduction zone environment.

キーワード: 三波川帯, エクロジャイト, フェンジャイト, 過剰アルゴン
Keywords: Sanbagawa belt, eclogite, phengite, excess argon

短寿命放射性同位体系列を用いた初期地球分化の研究 Deciphering early Earth's differentiation using short-lived isotope systematics

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Knowledge of the timescale and nature of early Earth's differentiation is central to understanding the evolution of the young Earth. Here I discuss short-lived isotope systematics of terrestrial samples that extended our knowledge of early Earth's differentiation. Recent high-precision W isotopic studies revealed positive ^{182}W anomalies of up to 0.15 epsilon unit in ca. 3.8 Ga Itsaq rocks from West Greenland and 2.8 Ga Kostomuksha komatiites from Russia. I explored the geologic significance of the ^{182}W anomalies by combining with trace element and other isotopic data. In this context, the W isotopic data are interpreted to reflect early silicate differentiation events on Earth. Under the assumption that the bulk silicate Earth has a 5% higher Sm/Nd than the chondrite average, the ^{182}W - ^{142}Nd - ^{143}Nd chronometry constrains the age of the source mantle differentiation for the Itsaq samples to 4.53-4.49 Ga. The age may reflect the timing of silicate differentiation during a sequence of magma ocean solidification.

キーワード: 冥王代, 初期分化, 消滅核種, 非コンドライト質地球
Keywords: Hadean, early differentiation, extinct radionuclides, non-chondritic Earth

台湾中央山脈東部、豊田ネフライトの形成年代：NanoSIMSを用いたジルコンの低温リム (<20 μm) の年代測定
Formation age of Fengtien Nephrite, Taiwan: Dating low-temperature thin (<20 μm) zircon rims by NanoSIMS

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Nephrite in the Fengtien area is associated with serpentinites within the subduction-accretionary complex in eastern part of the Central Mountain Range, Taiwan. In addition to nephrite, there are also other metasomatic rocks, such as diopsidefels and epidotite, present between serpentinites and their country rocks (metapelites and metapsammites). Among these metasomatic rocks, diopsidefels is the most common one observed, while nephrite and epidotite are less frequently present in association with diopsidefels. When all these rocks are present at one outcrop, the common lithologic sequence is serpentinite-nephrite-diopsidefels-epidotite- metasedimentary rocks. Nephrite, diopsidefels and epidotite were interpreted resulting from fluid-rock (serpentinite+country rocks) interactions during subduction metamorphism. Field occurrence and petrographic observations clearly showed that while nephrite and diopsidefels are mainly metasomatic products after serpentinite, epidotite is after metapsammite. The formation temperature has been estimated to be 300 - 400 °C based on regional geology and thermodynamic calculations by previous studies. Timing of these metasomatic processes, however, has not been constrained, although the hosting subduction-accretionary complex was thought to be of late Cretaceous in age due to paleo-Pacific subduction beneath the Eurasia continent and to be correlated with the Sambagawa belt in Japan. Zircons were separated from one epidotite sample in this study. Most of these detrital zircons were shown to have a thin zircon rim, which is less than 15 - 20 μm in thickness. These zircon rims were considered to be newly formed during metasomatic interactions between serpentinite and country rocks, which also led to nephrite/diopsidefels/epidotite formation. The CAMECA NanoSIMS NS50 at AORI, the University of Tokyo was employed to date these low-temperature thin zircon rims with a ~ 5 nA O- primary beam confined to a ~ 15 μm diameter. Sample surface was pre-ablated for 5 minutes to remove the surface Au coating and any possible surface contaminants. Data acquisition time was 500 seconds. The resulting $^{238}\text{U}/^{206}\text{Pb}$ - $^{204}\text{Pb}/^{206}\text{Pb}$ inverse isochron gave a young age of 3.3 ± 1.7 Ma (MSWD = 2.1, n = 5). The date clearly showed that the Fengtien nephrite would have formed during the (initial) exhumation of the subduction-accretionary complex, which should be of late Cenozoic in age related to subduction of the South China Sea plate beneath the Luzon arc. The present study gave a good example that NanoSIMS is able to date zircon rims with a thickness about 15 μm formed under low temperature conditions only a few million years ago. The instrument has a great potential in future studies dating various low-temperature hydrothermal, metasomatic or metamorphic zircon overgrowths.

キーワード: NanoSIMS, ジルコン, U-Pb 年代測定, ネフライト, 中央山脈, 台湾

Keywords: NanoSIMS, zircon, U-Pb dating, Nephrite, Central Mountain Range, Taiwan

高精度 U-Pb ジルコン年代測定における結晶形態観察および微量元素存在度分析の意義：石鎚コールドロンに産する火成岩類を例に Significance of external morphology and zircon chemistry for precise U-Pb zircon dating

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Improvement of U-Pb zircon dating by microbeam analysis has been provided opportunity of discussion about more detailed geological events. Recent analytical precision of less than 2% at Paleogene zircon allows us to investigate shorter period events such as crystallization differentiation in magma chamber. However, the highly precise U-Pb age data yield an importance of confirming their accuracy and assaying disturbance of U-Pb system and incorporation of exotic components. In this study, we introduce data processing method of the highly precise ages based on zircon morphology, trace element abundances as well as statistics.

The precise U-Pb zircon dating by using a sensitive high-resolution ion microprobe (SHRIMP II) at National Institute of Polar Research, Japan, was applied to igneous rocks of the Tertiary Ishizuchi Cauldron in the Setouchi volcanic belt of Miocene age in northwestern Shikoku. A primary ion beam of about 10 nA was used to sputter an analytical spot of about 40 μm diameter. A retardation lens system was utilized as a means to increase signal-to-noise ratio, and a secondary ion optics including slits of source and collector was adjusted to maximum transmission of the secondary ion under suitable mass resolution avoiding isobaric interferences on Pb isotopes. The surfaces of grain mounts were carefully washed with diluted HCl and ultra pure water to remove Pb contamination. A correction for common Pb was made on the basis of the measured ^{204}Pb and the model for common Pb composition.

Weighted mean ages were calculated from $^{206}\text{Pb}/^{238}\text{U}$ ratios corrected by ^{207}Pb . In order to ensure the accuracy of U-Pb age, age known zircon, OD-3, was analyzed together with unknown sample. Concentrations of Hf and rare earth element (REE) in zircons were also measured at the same analytical spot of U-Pb dating by SHRIMP.

Zircon grains from the Bansyodani-biotite-rhyolite were divided to two types based on the external morphology: sharply euhedral type and relatively rounded edge of prism and pyramid type. $^{206}\text{Pb}/^{238}\text{U}$ data of whole zircon grains were widely scattered beyond analytical uncertainty and show a weighted mean of 14.78 ± 0.18 Ma (mean square weighted deviation, MSWD: 3.4). On the other hand, the euhedral zircons yielded the weighted mean of 14.21 ± 0.19 Ma (MSWD: 1.0), whereas the relatively rounded zircons were older than the euhedral zircons, which suggests the incorporation of exotic components.

Zircon chemistry supported the classification by the morphology and the U-Pb dating. An average of Hf contents of the euhedral zircons were 9523 ppm ranging from 8883 to 10496 ppm and those of the relatively rounded zircons were 8475 ppm ranging from 7616 to 8803 ppm. Hf contents of the euhedral zircons were higher than those of relatively rounded zircons. C1 chondrite-normalized REE patterns of the euhedral zircons were characterized by a large fractionation between light REE and heavy REE, large positive Ce anomalies and large negative Eu anomalies. In contrast, those of the relatively rounded zircons were enrichment of light REE, weaker anomalies of Ce and Eu. Difference of the zircon chemistry between the euhedral zircons and the relatively rounded zircons reflects source melt composition. Therefore, the external morphology, Hf content, and REE abundance are useful criteria for the data processing of the highly precise U-Pb age data.

ジルコンの外部面を用いた LA-ICP-MS による U-Pb 年代測定：隠岐島前火山への適用 LA-ICP-MS U-Pb dating of Oki Dozen volcano using non-polished zircons

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LA-ICP-MS によるジルコンの U-Pb 年代測定法は、今や広く使われ、大いに成功している。この方法は、通常、ジルコンを研磨した状態で用いるが、これは、恐らく、common Pb や Pb loss といった結晶表面付近で生じるマイナス要因を避けるためであり、また、SHRIMP のような極少量の体積（深さ 1~2 μm が掘削される）を消費する分析法では必須である。SHRIMP に比べると、LA-ICP-MS は格段に多くの体積を消費する（掘削される深さは 10 μm 以上）ため、このことは、逆に、ジルコンの表面から内部までを容易に年代測定できることを意味する。従って、研磨しないジルコンを利用すれば、結晶内部の inherited core の存在やジルコンのマグマ中での成長速度の検討にも適用可能と思われる。今回、研磨しないジルコンを対象に標準試料（Fish Canyon Tuff と OD-3）と隠岐島前火山の試料について LA-ICP-MS による U-Pb 年代測定を行った。ジルコンは波長 213nm の Nd-YAG レーザー（repetition rate: 10Hz, エネルギー密度: 4~5 J/cm²）で 30 秒間アブレーションを行った。エネルギー密度 5 J/cm² では、最終的な掘削深度は 27 μm になり、深さ 9-18 μm の ²⁰⁶Pb/²³⁸U 比を用いて年代値を求めた。その結果、研磨しないジルコンを利用した場合でも信頼性の高い年代が得られることが標準試料の年代値が一致することから確かめられた。また、隠岐島前試料は 6~7 Ma の年代を示し、既存の K-Ar 年代（5.4~7.4 Ma）と一致もしくは少し古い年代が得られたことを報告する。

キーワード: U-Pb 年代測定, ジルコン, LA-ICP-MS, 隠岐島前火山

Keywords: U-Pb dating, zircon, LA-ICP-MS, Oki Dozen volcano

東北地方太平洋沖地震の余震による大気のAr同位体変化 Crustal noble gases anomaly associated with fault movement and aftershock the 3.11 Northeast Japan Earthquake

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Noble gases have unique characteristics that they are rarely combined with other chemicals as their very stable nature. Because its main reservoir is atmosphere, their isotopic composition is well defined and believed to be uniform all over the world insensitive to disturbance from anthropogenic and/or natural emission of geologically trapped noble gases in the earth interior. Based on our preliminary friction experiment, however, detectable amount of noble gases seem to be emitted accompanied with a fault motion (Sato et al., 2009). After the extreme Northeast Japan Earthquake occurred on March 11, 2011, extraordinary increase of seismic activity as numerous aftershocks e.g. over 4000 felt earthquakes in four months, which may be a source of non-atmospheric component preserved in the earth interior. In terms of anthropogenic component, Nuclear Power Plant) is a potential source, which is frequently monitored by radioactive species of noble gases.

We widely collected atmosphere samples all over Japan from Hokkaido, Honsyu, Chugoku and Kyusyu Is. The atmospheres have been sampled into vacuumed containers, Isotube®, at each sampling site to evaluate time-series changes. The elemental and isotopic compositions of the samples were analyzed mainly by quadrupole residual gas analyzers (RGA-200, SRS Co.) and partly confirmed by sector-type mass spectrometers (GVI-5400, GV instruments). In the duplicated analyses of the selected a few samples, the measured elemental and isotopic compositions were consistent within analytical uncertainties.

The relative elemental abundances were changed at least in heavier noble gases. Argon was enriched to pre-3.11 Earthquake atmospheres associating with a high $^{40}\text{Ar}/^{36}\text{Ar}$ ratio. It might be contributed by emission of crustal Ar at aftershock earthquakes, deformation and fault movements. In addition, a frictional melting was occurred in a >M5 earthquake as reported by Kanamori et al. (1998). Further, radioactive Ar isotopes (^{42}Ar and ^{39}Ar) were slightly abundant than those in "pre" 3.11 Earthquake atmospheres. These radioactive Ar isotopes were regarded to be detected limitedly in neutron irradiated geological samples especially in Ar - Ar dating. These altered atmospheric Argon isotopic composition in Eastern Japan area were observed until typhoon season.

Keywords: noble gas, 3.11 Northeast Japan Earthquake, aftershock earthquake, nuclear power plant disaster, Ar Isotope