Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

SGL43-01 Room:106 Time:May 23 15:30-15:45

Thermal Anomaly and Strength of Atotsugawa Fault, Central Japan, Inferred from Fission-Track Thermochronology

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Fission-track (FT) thermochronology was applied to the Atotsugawa Fault, central Japan, to detect fault related thermal anomaly (Yamada et al., 2009). Six fracture zones are found within an outcrop 20 m long near the portal of the Kamioka Mine prospect tunnel, located on the right bank 1.5 km upstream from the confluence of the Atotsugawa and the Takahara rivers (c. 370 m alt.). Each zone consists of a 1 - 3 cm wide gouge without visible pseudotachylyte, and fractured rocks 10-15 cm wide on its both sides. We collected samples from the gouge and fractured rocks 10 cm apart in each zone, and two reference samples from less fractured rocks. Most of zircon (120 - 150 Ma) and apatite (44 - 60 Ma) ages agree with emplacement ages for the granites that intrude the Hida Belt. A thermal anomaly was identified at one gouge sample that showed an exceptionally younger apatite age (c. 32 +- 3.2 Ma) with a unimodal FT length distribution. This anomaly in such a narrow zone may have been induced by frictional heat at the first fracturing at the apatite age, not by the circulation of hot geofluids within the zone.

Frictional coefficient (*mu*) and the ancient depth of gouge samples (H) are evaluated by the thermal modelling, assuming that the thermal anomaly is cause by a single frictional slip, and that all of the frictional work converts into heat without pore water. The effect of accumulated heat by multiple slips is negligible because the recurrence interval of fault activities is sufficiently long for the thermal diffusion in rocks. FT data and the geometry of sample occurrence give the constraint that the apatite FT age in the gouge was thermally reset although that in the fractured rock 10 cm apart was not. One-dimensional heat transfer model is used to calculate the temporal change in the temperature in and out of the gouge. The model space is composed of a 10 cm wide central slip zone and the 1000 cm wide surrounding zone with a homogeneous temperature distribution at a depth H in the initial stage. Constants of geothermal gradient, rock density, heat capacity, thermal conductivity, and slip rate are given as 30 deg. C/km, 1000 J/kg K, and 3.0 W/m K, and 1 m/s, respectively. Total slip of 5 m long is given by referring to the estimates of Mw 7.0-7.9 for the 1858 Hietsu earthquake along this fault system. The calculation results indicate that the effective heating time is significantly longer than the slip duration, and that samples in the distance to the frictional centre are not necessary heated instantly after the slip. For different combinations of *mu* and H, the maximum temperatures (T_{max0}, T_{max10}) at the centre (D_0) and at 10 cm apart (D_{10}) are different although the time during which the temperature in a specific location is maintained at its maximum is invariant. The effective heating time at D_0 and D_{10} at T_{max0} and T_{max10} are estimated as the order of 100 s and 10000 s, respectively. These estimates and annealing kinetics of zircon and apatite FT give the constraints of $400 < T_{max0} <$ 750 deg. C, and $T_{max10} < 250$ deg. C. To generate the amount of heat for these temperature ranges, *mu* is evaluated as 0.4 - 0.8 for H = 3 km, and > 0.6 for H = 2 km. These rather high estimates of frictional strength are concordant with those measured in laboratory experiments using the gouges taken from the same fault. In the case of pore water exists in the gouge zone, the increase in temperature will be smaller than that calculated above because the pore pressure may decrease the stress on the fault and the frictional heat may be diffused by fluid flow. Therefore, the estimate of *mu* in the dry condition can be regarded as a lower bound.

Yamada, R. et al, 2009, In: Thermochronological Methods: From Paleotemperature Constraints to Landscape Evolution Models, Lisker, F., Ventura, B., Glasmacher, U. A. (Eds.), 331-337, The Geol. Soc., London, 324.

Keywords: Thermochronology, Fault strength, Frictional heat, FT, Atotsugawa Fault

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SGL43-02 Room:106 Time:May 23 15:45-16:00

Experimental study for argon release and possibility of rejuvinated age after frictional heating granite

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Isotope ratios of noble gas in certain minerals are believed to be modified easily by their ambient reservoirs when the minerals reach higher temperatures than their closure temperature. The thermal history of a rock or a geologic event, even a fault movement, can therefore be determined quantitatively by applying radiometric dating methods to a set of different minerals. However, neither traditional K-Ar nor Ar-Ar dating methods can be applied easily to faulted rocks because, in the case of faulting, it is difficult to prove that the temperature of an event was greater than the closure temperatures of minerals.

Frictional heating experiments performed on fine grain homogeneous gabbros with high temperatures induced by frictional heating using a high-velocity friction apparatus were used to test whether rapid fault movement can rejuvenate the argon isotope ratio of fault rocks by the Argon released. The temperature on the artificial fault plane is flashing and above the closure temperature of the K-Ar system, as expected from the calculated cooling age. The anticipated rapid equilibration of volatiles during the frictional heating of rocks implies that the Argon isotope composition/ratio was released to an atmospheric value during this experiment.

Privious result of gabbroid analysis, we could observed that the reset was occurred only frictional plane, and we setted that second fuse enviroment (stable melted and pseudotachylyte was made) at the time. Rejuvenation and/or apparent increases in the K-Ar ages were only observed in a narrow, 3-mm-wide zone around the fault plane that appears thermally altered and mechanically fractured in thin sections.

In this study, for the granite friction experiment, the Argon gas released timing is faster, which called ”first fuse” (Hirose et al., 2005) in the time. The granitoid, which is composed upper crust, include the potassium rather gabbroid, which composed lower crust, because the radiogenic Ar is more abundant in the nature. After granite friction experiment, Argon and other gases released by the sample were collected in a small aluminum tube in a nitrogen atmosphere before and after the frictional heating granite experiment, also. Therefore, we could not observe glass and glassy material after granite experiment, but the argon gas released at ”first fuse” stage. We report that the measured noble gas isotopes in an Aji granite sample analysis, compared with gabbroid analysis.

Keywords: K-Ar age, Ar isotope, frictional heating, granit, gabbro

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SGL43-03 Room:106 Time:May 23 16:00-16:15

The method and issues of ESR dating of hydrothermal barite

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At an initial stage of studies of sea floor hydrothermal activities, their changes with time was not an issue. However, it has become important since it was found that such sea floor hydrothermal activities support the biological communities. We have been making progress in developing dating method using ESR (electron spin resonance) signals in barite contained in hydrothermal sulfides.

Kasuya et al. (1991) first pointed out that barite is possibly suitable mineral for ESR dating. Okumura et al. (2010) first practically applied this method to barite in sulfide made by sea floor hydrothermal activities, however, the work investigated neither if the properties of the signals are appropriate for dating nor the method for appropriate dose rate estimation. Subsequently, Toyoda et al. (2011) and Sato et al. (2011) studied these topics but they are still insufficient. Currently, most critical issue of ESR dating of sea floor hydrothermal barite is appropriate dose rate estimation.

The dose rate estimation for barite is quite different from that for other minerals, which are

(1) Ra and its daughter elements are the source of natural radiation, but not U or Th.

(2) Radiation from other minerals is negligible.

(3) Internal alpha particles give significant contribution to dose rate (40-60 %)

(4) Shape of the sulfide deposits (chimneys) have to be considered in estimating gamma ray dose.

The first two items are easy to be taken into account. For the third, Toyoda et al. (submitted) determined the alpha effectiveness, which is the ratio of formation efficiency of the signal by a unit dose of alpha particles to that of gamma rays. However, the variation of dose response is so large that re-examination is necessary. For the last item, this shape correction is necessary when the radius of the chimney is less than 20 cm or when the sample is taken from the position other than its center. We will report how we can make this correction in the presentation. Results of actual gamma ray measurements revealed that the contribution of dose to barite from the radioactive nuclei in sea water with hydrothermal activities is negligible. White and Rood (2001) found that Rn escapes from barite but we found that it is not the case.

The ESR ages of barite are roughly consistent with U-Th ages but much older than 226Ra-210Pb ages. Results of our ^{226}Ra-^{210}Pb age estimates will also be presented.

Keywords: ESR, dating, barite, sea floor hydrothermal activity, natural radiation

Japan Geoscience Union Meeting 2012
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SGL43-04 Room:106 Time:May 23 16:15-16:30

Thermoluminescence Dating of Calcite Veins in the Zambales Ophiolite, Luzon, Philippines

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A Deep geological repository of radioactive wastes from nuclear reactors is composed of several barriers including cement and bentonite. High alkaline groundwater might be produced through the alternation of the cement, thus the stability of bentonite during the interaction with high alkaline groundwater is one of the important issues to be studied as bentonite plays an important role to prevent an outflow of the contaminated groundwater to the environment owing to its cation exchange and swelling properties.

To understand bentonite-alkaline groundwater reaction with the geological timescale, it is useful to investigate a similar phenomenon occurred in nature. There is an ophiolite suites covered with bentonite layer in Luzon, Philippines. High alkaline groundwater originated probably from the serpentinization of mafic rocks has been circulating along cracks in a rock and bentonite layers. To determine the timescale of fluid-bentonite interaction, calcite precipitated from high alkaline groundwater was dated using thermoluminescence (TL) dating method.

First, TL color of calcite samples was investigated, and they emit red TL. Paleodose was measured using this red TL and SARA(single-aliquot regeneration and added dose) method was applied to evaluate sensitivity change of calcite occurred through repeated heating of samples.

In annual dose measurement, we measured radioactive element concentrations of calcite and a surrounding mafic sample using XRF, EPMA, LA-ICP-MS analyses. Cosmic ray contributions to annual dose was calculated by an equation of Prescott (1994).

To know the annual dose of a heterogeneous sample, detailed three-dimensional rock distributions around the sample is necessary. Unfortunately, the analyzed sample was very small in size, therefore we do not know accurate distribution of surrounding rock facies. By assuming the ratio of calcite and the surrounding mafic rock, the age of calcite was calculated.

As a result, the order of calcite age is ˜10 ka (younger than 100 ka and older than 20 ka). For accurate dating, it will be necessary to consider errors in added dose, exact distribution of rock which contributes the annual dose, and development of a method to estimate an annual dose for a heterogeneous sample.

This study is a part of a project to develop an integrated natural analogue programme in the 2011 fiscal year in Japan, which was funded by Agency for Natural Resouces and Energy of the Ministry of Economy, Trade and Industry , Japan.

Keywords: Thermoluminecsence dating, calcite vein

Japan Geoscience Union Meeting 2012
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SGL43-05 Room:106 Time:May 23 16:30-16:45

Re-Os geochronology of the Hitachi VMS deposit, Ibaraki Prefecture: The oldest sulfide deposit in the Japanese Island

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We applied the Re-Os isotope dating method to the Fudotaki and Fujimi sulfide ores from the Hitachi Deposit in the Ibaraki Prefecture. The Re-Os isochron of the Fudotaki sulfides yielded ca. 540 Ma which is the oldest age among the all other metal deposits in the Japanese Island. This isochron exhibited excellent linearity and the Re-Os age of the Fudotaki sulfides is much older than a timing of contact metamorphism by the Irishiken Granites (Late Cretaceous). Thus, we interpreted this Re-Os age as a primary depositional age of the Fudotaki sulfides on a paleo-seafloor. On the other hand, the Re and Os isotope compositions of the Fujimi Deposit showed no correlation in the 187Re/188Os vs. 187Os/188Os space. The Fujimi sulfides underwent higher grade metamorphism than that of the Fudotaki sulfides up to epidote-amphibolite facies or granulite facies, and the Re-Os isotope system of the sulfide ores was disturbed by metamorphism. Since the Hitachi Deposit is a syn-genetic sulfide deposit, the eruption age of the wallrock (basic volcanic rock) is also estimated to be ca. 540 Ma. This Re-Os age obtained here will be an important age constraint to clarify the geological history of the Japanese Island.

Keywords: Re-Os age, VMS deposit, Hitachi Mine, Fudotaki Deposit, Hitachi metamorphic belt, Japanese Island

Japan Geoscience Union Meeting 2012
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SGL43-P01 Room:Convention Hall Time:May 23 13:45-15:15

Closure temperature of single grain biotite by laser step heating experiment

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The concept of closure temperature has been applied in estimating regional cooling and uplift in various geologic settings. It was first applied in K-Ar system, but several problems were pointed out such as complex geometry in diffusion, or distribution of domain sizes in minerals. These findings made difficult for geologists to apply the concept. As a result, it is applied in various cases without assuming an appropriate cooling rate, or a broad range of temperature is assigned (650 - 900^{o}C in U/Pb zircon T_c).

Closure temperature was calculated using ^{40}Ar/^{39}Ar data in laser step heating experiments of single grain biotites assuming simple cylindrical geometry. The diffusion parameters were calculated from Arrhenius plot in the temperature range where dehydration effects are minimal (below 800^{o}C). Although the characteristic radius r is about 250 microns, it always appears as D_0/r^2. Change of r does not affect the results.

Three types are recognized in Arrhenius plots, depending on the activation energy and dehydration effects. However, these differences do not seem to affect very much on the resulting closure temperature. Relation between the characteristics of diffusion and age spectra is discussed.

Keywords: closure temperature, laser step heating ^{40}Ar/^{39}Ar, biotite

Japan Geoscience Union Meeting 2012
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SGL43-P02 Room:Convention Hall Time:May 23 13:45-15:15

Development of un-irradiated and un-spiked laser fusion K-Ar dating for single grain minerals (2nd report)

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[1]IFREE, JAMSTEC

A laser fusion K-Ar dating has been developed as an in-situ micro measurement of radiometric ages applicable for less-abundant minerals found on thin sections [1, 2]. Strong induced radio-activities in Fe-rich minerals by neutron irradiation prohibits collecting sufficient amount of mineral separates, which partly limits applications of Ar-Ar method[3]. Nonetheless, once K-Ar method establish for a single grain mineral containing trace K with $<$0.1 wt%, much wider applications are anticipated, e.g. fine minerals of hydrothermal origin. Thus, we have installed a laser fusion apparatus to GVI-5400He noble gas mass spectrometer of JAMSTEC, as a part of the TAIGA-project: Grant-in-aid for Scientific Research on Innovative Areas.

Quantitative determination of K for trace concentration, approx. 0.1wt%, using EPMA sometimes faces poor accuracy and/or precision for a requirement of accurate dating. Thus we have been tested single grain K measurement under a low blank protocol using graphite furnace atomizer to ensure high sensitivities. This K measurement follows a laser fusion Ar measurement applied to the retrieved single melted mineral grain itself. An accurate K-Ar age determination requireds complete retrieval both K and radiogenic Ar. Thus, conditions laser irradiation and K quantitation have investigated using SORI-93 K-Ar standard [4].

Our preliminary results show a 15% older averaged age with more than 10% deviation for recommended age for SORI-93 (92.6+/-0.6Ma, [4]), which is still under investigation.

[1] Sato et al. (2008) Chikyukagaku, 42, 179-199.
[2] Sato et al. (2011) JpGU annual meeting 2011.
[3] Ishibashi et al. (2009) J. Geogr., 118, 1186-1204.
[4] Sudo et al. (1998) Geochemical J., 32, 49-58.

Keywords: K-Ar dating, laser fusion, single grain, SORI-93 K-Ar standard

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SGL43-P03 Room:Convention Hall Time:May 23 13:45-15:15

Evaluation of the influence of alteration on K-Ar dating for Hawaiian tholeiites

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To obtain reliable K-Ar ages, the lava samples need to meet various requirements, and lack of K and Ar loss during weathering or alteration is one of the most important considerations. It is desirable to choose fresh rock samples that have not been affected by weathering/alteration; however, such samples are generally not available among the tholeiitic lava of shields older than about 1 Ma. In order to evaluate the influence of alteration on K-Ar dating for Hawaiian tholeiites, unspiked K-Ar ages were measured for 21 samples from four lava flows with varying degrees of alteration collected from the Makapuu Head section of Koolau volcano, Hawaii. The samples were classified based on freshness of olivine phenocrysts and the groundmass olivine, and the presence of secondary minerals in vesicles. The age data was evaluated by means of K_2O/P_2O_2 ratios, ^{36}Ar volumes, and calculated atmospheric Ar contamination. The results indicate that the ages for samples with fresh groundmass olivine are reliable, even though olivine phenocrysts may be slightly altered (thin reaction rims) or secondary minerals may have crystallized in the vesicles.

Keywords: K-Ar dating, alteration, tholeiites, Hawaiian volcano

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SGL43-P04 Room:Convention Hall Time:May 23 13:45-15:15

Observation of radiation damage in zircon by atomic force microscope and its application to geochronology

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Fission track (FT) method is a dating technique based on the observation of damage (tracks) by spontaneous fission of 238U left in a mineral. The number of tracks is counted under an optical microscope after etching (chemical expansion of a track). However, as FT density per unit area rises, it becomes difficult to count the number of tracks. This is due to the fact that FTs overlap one another and are unable to be readily distinguished. This research examines the potential of atomic force microscope (AFM) for FT dating using zircons after a short time etching.

Zircons with track densities of about 4, 6.5, 10, and 20 (10^6/cm^2) are observed. The clearer image for a short time etching is obtained after polishing with colloidal silica solution. Several tracks were found connected through step-etching. Thus, to measure the exact track density, correction in number of tracks is necessary by comparing the images before and after etching. FT ages were calculated using the corrected track densities, and agreed with the ages obtained by conventional methods.

In addition to fission tracks, there were numerous topographic lows in an AFM image. Due to these topographic lows, the cross sections shows cyclic waves. Number of these lows are estimated from the wavelength of the cyclic waves under the assumption that these topographic lows distribute on the surface evenly. As the result, the value obtained from wavelength of 0.10 micron was matched in the order to the expected number of alpha recoil tracks.

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

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SGL43-P05 Room:Convention Hall Time:May 23 13:45-15:15

ESR dating of tephra with quartz: inconsistency between signals

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Determining the age of tephra is important for reconstructing the history of environmental change during the Quaternary epoch. To this end, we consider dating of quartz using the electron spin resonance (ESR) method. Quartz was first found to be useful for ESR dating of fault gouge while the mineral was also used for dating of tephra, heated flints, and sediments.

The first investigation pertaining to ESR dating of tephra using quartz was published using the Al center (a hole trapped at Al site replacing Si). Subsequently, several other successful results on tephra have been reported (e.g. Imai and Shimokawa, et al., 1988, Imai et al., 1992, Toyoda et al., 1995, and Yokoyama et al., 2004). Buhay et al. (1992) reported that the ESR age (45-49 ka) of a tephra from New Zealand is consistent with the 14C age (42-44) within statistical errors.

However, in other studies, systematic discrepancies were observed between the ages obtained using the Al center and Ti-Li center (an electron trapped at a Ti atom replacing Si, accompanying a Li ion as a charge compensator). Toyoda et al. (2006) systematically investigated the ESR and RTL (red thermoluminescence) ages of tephra with a known age range of 30 to 900 ka, and found that ESR dating has problems in obtaining equivalent doses. Using the same dose rate, the RTL ages were consistent with the expected ages while the ESR based results were inconsistent and involved lage scatter in data. The scatter in ESR ages was found to increase with age. Toyoda et al. (2009) proposed a new protocol, the multiple-aliquot regenerative-additive dose method, which provides equivalent doses estimates with smaller errors than the traditional additive dose method. In the present paper, we have analyzed the same Nm-Sb tephra and A-Fm tephra and Ft to check the reproducibility of dating results and to test if known doses can be recovered using the multiple-aliquot regenerative-additive dose procedure.

The age obtained from Ti-H center is consistent with the age reference for Nm-Sb while the ones from Al and Ti-Li center overestimate. The ages obtained from Al and Ti-H center are consistent with the age reference for A-Fm while the ones from Ti-Li center overestimate. The dose recovery test indicates that the equivalent dose estimate based on the Ti-H center of Nm-Sb and A-Fm agrees within error of the expected dose (370 Gy). We consider the dose recovery test to be a useful procedure for choosing the signal appropriate for dating.

Keywords: quartz, ESR, dating, tephra

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SGL43-P06 Room:Convention Hall Time:May 23 13:45-15:15

Re-evaluation of ABA pretreatment for 14C dating of fossil charcoal from late Holocene layer

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It had been suspected and had been tried to clarify the effect of the contamination by exterior organic matter on the 14C date from the beginning of development of radiocarbon dating. A comparison between ABA method and Acid-Base-Oxidation (ABOX) method confirmed the effect on the 14C date of contaminated carbon using AMS. However, the research didn't examine objectively of the chemical quality of late Holocene charcoal samples. And, there exists no research with the objective method for the effect of residual external organic carbon after pretreatment on the 14C date . Furthermore, in the researches of quality control of samples and pretreatment as described above, there were many cases where alkaline extraction time were less than 3 hours hence it was strongly suspected of the remnant of humic acid in dating samples. Thus, the discussion on what is reasonable and reliable sample in the 14C dating method and the discussion on the most suitable chemical treatment condition are still left unsettled. Recently, a few researches are reported which based on objective chemical indicator for the ABA method. The assessment for charcoal using raman spectrometry has attempted, and the result shows the existence of humic acid in charcoal samples. But, the relation between the pretreatment and the 14C dates has not been investigated yet. The mechanism of humification has been deduced from the comparison of fossil and recent charcoal. But it only shows humification under special desert environment, and has not investigated the effect of humification on the 14C date. 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 14C 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 14C 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 14C 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.

The results of the 14C dates, UV-vis and 3-DF (3-dimensional fluorescence) show that there exists no correlation between the visible color of the solution and the intensity of humic emission of the solution. And, the results show that the multiple step treatment using NaOH solution of concentration from 0.001 M to over 1.2 M can enhance the effctivity of humic extraction in relatively short time (18-20 days). Furthermore, the multi-step extractions from low concentration of 0.001 M to high concentration of 1.2 M are necessary, because we can't predict the concentration of NaOH solution which yields high humic extraction effect. In addition, 3 DF meter must be necessary to confirm treatment effect by ABA method indirectly. The dating results show that the 14C dates converge or saturate between from 1.0 to 2.0 M in concentration of NaOH solution.

Keywords: ABA(AAA) pretreatment, 14C dating, late Holocene

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SGL43-P07 Room:Convention Hall Time:May 23 13:45-15:15

Thermochronological study of the dip-slip displacement and timing of initiation of the Atera fault

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Fission-track analysis was performed for 5 samples collected from 5 surface outcrops and 6 samples from the Kawaue boring core around the Atera fault, which is a large-scale, left-lateral active fault with dip-slip component of displacement. The results were ~76 Ma of mean zircon fission-track age from SW of the fault, 69 Ma from NE of the fault, ~42 Ma of mean apatite fission-track age from outside of the fault zone and ~22 Ma from inside of the fault zone. Mean track length from U-4 zircon, collected from the fault zone, was only shrunk and the length distribution was apparently bimodal. An interpretation of the distribution was that this sample would have been slowly cooled down from ~300oC, since around 40-60 Ma, derived from some forward calculations with annealing kinetics. In addition, we calculated the excess erosion of the hanging wall (NE of the fault) and true dip displacement of the fault, assuming that the age difference across the fault was caused by dip-slip displacement of the fault and difference of exhumation rate across the fault. The results led us to obtain the following three conclusions. 1. The dip-slip displacement of the Atera fault after 70 Ma is ~1km. 2. The present fracture zone along the fault was widely heated at after 20 Ma but before at least the Quaternary. The displacement is similar to the geomorphologically estimated displacement of basement rocks or topography across the fault. 3. Some minor intrusions or other heating and slow cooling events would have occurred only near U-4 at ~40-60 Ma. Therefore conclusion 1 is consistent with previous studies that indicated the present Atera fault activity restarted after the early Quaternary. Conclusion 2 indicates that the fracture zone already existed at from ~20 Ma to at least the Quaternary and perhaps the ancient fault activity had already initiated.

Keywords: Atera fault, dip-slip displacement, timing of initiation of active fault, fission-track

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SGL43-P08 Room:Convention Hall Time:May 23 13:45-15:15

Lower boundary of the Caledonian Barrovian metamorphic belt at Loch Leven, Scotland: Phengite K-Ar ages of metapelites

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Since the Barrow's report (1893), the Barrovian metamorphic belt in the Caledonides of Scotland has become one of the best-studied orogenic belts in the world. Based on many geological and isotopic studies, this belt has long been considered to be formed by arc-continental collision in the Ordovician-Silurian (the Grampian orogeny: ca. 480-430 Ma) (Dewey and Bird, 1999; Oliver, 2008). However, many controversies and fundamental uncertainties remain. For example, in terms of the polarity of subduction, Ryan and Dewey (1991) and Oliver (2008) assumed that the polarity of subduction was toward the NW, but Clift et al. (2004) proposed the opposite. Also, the main reason for the "orogeny" and metamorphism for several decades has been just burial at depth caused by thrusting, which we consider to be a dated, unlikely concept.

The Barrovian metamorphic rocks in Loch Leven belong to the biotite zone, have been folded and thrusted northwestwards (e.g., Treagus, 1974; Piasecki, 1980), and they overlie weakly metamorphosed rocks (Eilde Flags). Inferring from our understandings of the occurrence and exhumation of HP rocks in Japan (Aoki et al., 2008; 2009), and in many Barrovian orogenic belts worldwide (Agard et al., 2009), we predicted that the lower tectonic boundary of the Barrovian metamorphic rocks should have occurred at Loch Leven. In order to examine this model, we determined K-Ar ages of phengite-rich mineral separates from 6 metapelites in the area.

Our new phengite K-Ar ages are 398.2 +/- 10.4 (sample no. LL46), 406.4 +/- 10.6 (LL20), 405 +/- 10.5 (LL19), 399.7 +/- 10.5 (LL24) and 445.0 +/- 11.6 Ma (LL16). One samples (LL13) has an "anomalously young" age of 340 +/- 8.9 Ma, probably because of its low K2O content (1.3 wt%). The main results indicate a K-Ar age-gap between ca. 445 Ma and ca. 400 Ma, which, when integrated with previous metamorphic-age (e.g., Oliver, 2008) and structural data from Loch Leven (Roverts, 1976; Atherton, 1977) suggest that the lower boundary of the Barrovian metamorphic belt formed at 445-400 Ma.

The lower boundary of the E-dipping, Barrovian metamorphic belt at Loch Leven has long been considered to be an extension of the 430-413 Ma Moine Thrust (MT) displaced by the Great Glen Fault. The shear sense of the E-dipping MT is top-to-the-WNW/NNW (Butler, 2004). Moreover, we have recently discovered that the upper boundary of the originally E-dipping Barrovian metamorphic belt crops out near Portsoy in NE Scotland, the shear sense of which was top-to-the-SW (Kawai et al., in prep.). In terms of the internal thermobaric Barrovian zones of Scotland, the grade of metamorphism decreases symmetrically upwards and downwards from a central highest-grade zone (Kennedy, 1948), which contains relicts of retrogressed HP rocks. Integration of all multi-disciplinary data provides robust evidence that the Barrovian metamorphic zones were exhumed from a HP depth by N-directed wedge extrusion. The lower wedge boundary was the Moine thrust-Loch Leven thrust, and the upper extensional boundary at Portsoy enabled the downward emplacement of the overlying, lower pressure Buchan metamorphic zonal belt. Thus, formation of the whole Caledonian orogenic belt of Scotland was controlled by wedge extrusion.

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U-Pb geochronological map of Unazuki area

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The Unazuki area, situated at the northeastern part of the Hida Belt, which is one of crucial sites for deciphering the Permo-Triassic orogeny in East Asia, has experienced the kyanite-sillimanite type metamorphism characterized by a clockwise P-T path. The Unazuki area is classified into the Hida gneiss region (Katakaigawa group), the Unazuki schist region (Unazuki group), and the Unazuki plutonic complex. Radiometric ages of the Unazuki schists, previously determined by Rb-Sr and K-Ar methods, are scattered from 248 Ma to 175 Ma primarily because of multi-phase metamorphism and deformation. Geochronological data for the Unazuki plutonic complex are limited. In this study, U-Pb geochronology of zircon and titanite was applied to the schists and the plutonic complex to discuss about timing of the kyanite-sillimanite type metamorphism and thermal history.

Protoliths of the Unazuki schists are sedimentary and felsic volcanic rocks. Probability of U-Pb data of detrital zircons in pelitic schist shows some peaks centered at 453, 365, 347, 320, 310, and 298 Ma, which suggests that protolith of the Unazuki metamorphic rocks were deposited after 298 Ma. U-Pb data of quartzo-feldspathic schist derived from felsic volcanics yield an eruption age of 258 +/- 2 Ma, indicating that regional metamorphism occurred after 258 Ma. On the other hand, U-Pb age of a granite in north part of the Unazuki area is 253 +/- 1 Ma. The granite contains some xenoliths of the Unazuki schist, in which staurolite is replaced by andalusite and cordierite due to thermal flux from granitic magma. Therefore, regional metamorphism occurred between 258 and 253 Ma, suggesting a rapid metamorphic progression. 251 +/- 1 Ma of gneissose quartz diorite containing the Unazuki schists supports the timing of the regional metamorphism.

The granite in central part contains Eoarchean-Paleoproterozoic zircon inheritance and shows 256 +/- 2 Ma, whereas that in south part is 250 +/- 1 Ma. Hornblende quartz diorite in central part yields 191.1 +/- 0.8 Ma, whereas biotite quartz diorite in south part is 275 +/- 2 Ma. Meta-gabbros in central part yield 260-256 Ma. Some parts of zircon in meta-gabbros were recrystallized at ca. 236 Ma.

Eboshiyama mylonite in the Katakaigawa group shows 250.0 +/- 0.4 Ma, which suggests that mylonitization of the Katakaigawa group occurred after the regional metamorphism of the Unazuki group.

Keywords: geochronological map, U-Pb age, zircon, Unazuki, Hida belt

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Age distribution of detrital monazites in the sandstones from the northern Borneo and its tectonic setting

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Late Cretaceous to Late Eocene turbidite is widely distributed in the northern part of Borneo. It is known as the Rajang Group. Heavy minerals were collected from the four rivers that flow through this stratum. Detrital monazites were analyzed by EPMA to obtain their ages. The monazite age distributions of the four rivers show three main peaks at 200-300 Ma, 400-500 Ma and 1850-1900 Ma, and a weak cluster at 700-1100 Ma. Such age distributions show that the detrital grains were not supplied from Southeast Asia, but from the southern part of China. There is a huge unconformity, called as Sarawak Orogeny, which occurs after deposition of the Rajang Group. The age is the Latest Eocene, close to the opening of the South China Sea which began as early as the Early Oligocene. Hence, it is probable that the Northern Borneo situated at oceanic side of the South China have been moved to its current position during the opening of the South China Sea. There is no clear tectonic event after the opening of the South China Sea between the northern Borneo and western Indonesia Archipelago. Assuming that Borneo and western Indonesia Archipelago were moved at the time of the opening of the South China Sea, the reduced connection between the Indian Ocean and the Pacific Ocean at Miocene and also the Wallace line for fauna and flora may be explained more simply than the recent reconstruction models.

Keywords: monazite, age, Borneo