Uplift and denudation history of mountains and low-temperature thermochronology

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Thermochronology is a branch of geochronology, which can reconstruct thermal history of rock samples because the apparent ages get younger than the formation ages depending on the thermal history. By applying thermochronology to rocks formed in a high-temperature zone at a great depth, regional denudation history can be estimated. Low-temperature thermochronology, e.g., fission-track and (U-Th)/He dating methods, are especially useful to constrain denudation history at the upper crust shallower than several kilometers from the surface. Low-temperature thermochronology has been applied to various tectonic settings all over the world, such as continental collision zones, passive margins, shields, sedimentary basins, continental arcs, and island arcs (see also compilation of Herman et al., 2013, Nature) since the first application in the Swiss Alps (Wagner et al., 1977, Mem. Instit. Geol. Mn. Univ. Padova). Although low-temperature thermochronology is now amongst the most common approaches in tectonic geomorphological and structural geological studies, interpretations of thermochronometric data are often confusing especially for beginners and laypeople; for a successful interpretation, cooling, denudation, and uplift should be taken into accounts as well as geochronological and analytical discussions. This presentation primary aims to expand understanding of thermochronology to wider people, especially to beginners and laypeople. I will review the basic concepts and fundamental terminology in terms of thermochronometric applications to mountaneous regions. In addition, I am planning to introduce some case studies and thermochronometric mapping in the Japanese Islands.

Keywords: uplift, denudation, low-temperature thermochronology

Cooling history of the Higher Himalayan Crystalline nappe and underlying the Lesser Himalayan Sediments in eastern Nepal revealed by fission-track dating of detrital zircons.

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Fission-track (FT) dating of detrital zircon has been applied to the Higher Himalayan Crystalline nappe and the underlying Lesser Himalayan sediments (LHS) distributed along a 120 km long section from Mt. Everest to the Main Boundary Thrust (MBT) in eastern Nepal. In this paper, we report the results of 70 km long southern section between the Main Central Thrust (MCT) and the MBT. We collected rock samples from the Higher Himalayan Crystalline nappe of eastern continuation of the Kathmandu nappe and underlying autochthonous middle Proterozoic sequence of the LHS. Zircon FT ages show younging toward the north from 12.1 Ma just behind the MBT to 3.0 Ma just below the MCT in the root zone at southern slope of the Everest massif. It suggests that the LHS was covered by hot crystalline nappe comprising of metamorphic rocks, and fission-tracks of the detrital zircons have been annealing since 12 Ma. On the basis of retreating rate of isotherm line of closure temperature of ZFT, we estimated average cooling rate of the nappe and underlying LHS as about 7 mm/y, which is as same as 8-7mm/y, reported from the Katmandu nappe in central Nepal (Hirabayashi, MS, 2017). If we applied this rate to the HHS to the north of the MCT in the Everest massif, the location of ZFT age of 0 Ma would be located at 23 km to the north of the MCT, beneath Mt. Kantega (6685 m). It suggests that the underground of Mt. Everest is even now under hot condition higher than 220-350℃ Thus, heat source of hot HHC is ascribed to partially melted middle crust of Tibet, which southern front is located at about 100 km to the north of Himalayan giants.

Keywords: fission-Track age, Himalaya, nappe, zircon

Influence of surface condition on data quality of U-Pb zircon geochronology: an example from AS3 zircon, the Duluth Complex, U.S.A.

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U–Pb zircon geochronology by using microbeam analysis such as SIMS and LA–ICP–MS has played a pivotal role in geochronology because one of the advantages of microbeam analysis in U–Pb geochronology is to select the appropriate analytical spot for U–Pb dating. Many analysts empirically believe that accuracy and precision of microbeam analysis strongly depend on the surface condition of analytical spots. Especially, existence of fractures within the analytical spots is considered to decrease the data quality, but there is no quantitative evidence that the fractures result in some negative effect on the data quality. In this study, we quantitatively discuss influence on the data quality from the surface condition of the analytical spots. AS3 zircons collected from gabbroic anorthosites of the Duluth Complex, Minnesota, U.S.A., were used in this study. Previous work reported that some grains in AS3 zircons yield discordant data due to Pb loss caused by thermal diffusion (Schmitz et al., 2003).

Observation of thin sections by optical microscope and electron microprobe reveals chloritization of amphibole in AS3, which suggests hydrothermal alteration. U–Pb analyses of some AS3 zircon grains yielded discordant data. The analytical spots that yield discordant data can be classified into (1) altered domains characterized by high contents of LREE and non-formula elements, such as Ca, Al, and Fe, and (2) domains containing undersurface fractures. In the case that analytical depth is close to the undersurface fractures, the second domains also show high LREE contents. When the fractures in zircon worked as channels of hydrothermal fluid (Carson et al., 2002), there are possibilities that areas around the fractures was altered like a clad by the fluid. Therefore, selection of the analytical spots for U–Pb zircon dating should be based on observation of fractures not only on the surface but also under the surface. When AS3 zircon is used as U–Pb reference material, it is important to carefully choose analytical spots on the basis of the backscattered electron and optical microscope images for achieving more precise analysis.

Reference

Schmitz, M.D., Bowring, S.A., & Ireland, T.R. (2003) *Geochimica et Cosmochimica Acta* **67**, 3665-3672.
Carson, C.J., Ague, J.J., Grove, M., Coath, C.D., & Harrison, T.M. (2002) *Earth and Planetary Science Letters* **199**, 287-310.

Preliminary report of zircon oxygen isotope record in western part of the Napier Complex, East Antarctica

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The oxygen isotopic composition of zircon is a powerful tool to characterize parental magma, complementing trace element data. Recently technical improvements of a secondary ion mass-spectrometer allow us to obtain highly accurate and precise oxygen isotope data of zircon from thin sections or grain resin mounts. Numerous studies show that non-metamicted zircons can preserve their oxygen isotopic ratios ($\delta^{18}O$) from the time of crystallization, even though high-grade metamorphism and anatexis. The zircon oxygen isotope record is generally preserved despite other minerals that have been disturbed by high-grade metamorphism or intense hydrothermal alteration due to slower diffusion rate.
The Napier Complex in East Antarctica has attracted considerable interest from a viewpoint of long Archaean crustal history from 3800 Ma to 2500 Ma and >1000℃ ultrahigh-temperature (UHT) metamorphism in a regional scale. There are many petrological, geochronological, and geochemical reports, but the zircon oxygen isotope data completely lack. In this study, we tried to analyze the zircon oxygen isotopes in garnet-bearing quartzo-feldspathic gneiss (YH05021606A) collected from Fyfe Hills in the Napier Complex.
The quartzo-feldspathic gneiss, YH05021606A, was collected by Y.H. during the field work at the 2004-2005 Japanese Antarctic Research Expedition. The zircon U-Pb ages of the YH05021606A sample are already reported in Horie et al. (2012) and shows multiple age peaks centered at ca. 3025, 2943, 2883, 2818, 2759, 2674, 2518, and 2437 Ma. Horie et al. (2013) picked zircon grains afresh and analyzed U–Pb ages, Th/U ratios, and rare earth elements (REE) compositions. The oxygen isotope analyses were performed on same resin disc as Horie et al. (2013). The zircon oxygen isotope analyses were carried out by a sensitive high-resolution ion microprobe (SHRIMP II) with the 5-head advanced multi-collector (AMC) at the National Institute of Polar Research, Japan. ^{16}O, ^{17}O, and ^{18}O were detected by the Faraday cups at low mass (LM), Axial, and high mass (HM), respectively, and were measured on 10^{11} ohm resistors in current mode. The surface of the grain mounts was coated by aluminum prior to the analysis.
The U-Pb analysis of zircon yielded similar age population to Horie et al. (2012) and revealed younger ages of ca. 2273, 2195, 2106, and 1980 Ma. C1-chondrite-normalized REE abundance patterns of the YH05021606A zircons were characterized by a large fractionation between light REE (LREE: La, Pr, and Nd) and heavy REE (HREE: Tm, Yb, and Lu), positive Ce anomalies, and negative Eu anomalies. The inherited zircons shows highly fractionated patterns between LREE and HREE. The zircons of ca. 2505 Ma and ca. 2490 Ma are characterized by weakly fractionation between middle REE (MREE: Gd, Tb, and Dy) and HREE. The HREE of ca. 2490 Ma zircons are more depleted than those of ca. 2505 Ma zircons, which indicates that growth of garnet had continued from ca. 2505 Ma to ca. 2490 Ma. The REE patterns of the younger age zircons are characterized by a large fractionation between MREE and HREE. Although the YH05021606A zircons have various U-Pb ages and trace element composition, the oxygen isotope analyses yielded homogeneous $\delta^{18}O$ ratios among zircon grains with various ages (5.68 ±0.30 ‰). The $\delta^{18}O$ values of the YH05021606A zircons are consistent with those of zircon in equilibrium with the mantle (5.3 ±0.6 ‰: Valley et al., 1994). In this presentation, the homogeneous $\delta^{18}O$ ratios in the Fyfe Hills zircons will be discussed. ℃

Keywords: zircon oxygen isotope, SHRIMP, Napier Complex

Precise determination of $\delta^{137/134}$Ba stable isotope ratios by double-spike thermal ionization mass spectrometry

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Barium has seven stable isotopes: ^{130}Ba, ^{132}Ba, ^{134}Ba, ^{135}Ba, ^{136}Ba, ^{137}Ba, and ^{138}Ba. Recent researches focus on seawater, igneous rocks, carbonates, sulfates, and soil-plant systems using the Ba isotope fractionation. Barium is a large ion lithophile element and is usually incompatible in the mantle minerals. Barium is mobile in aqueous fluids and thus an important tracer of water recycling in the Earth's mantle. Miyazaki et al. (2014) first applied stable Ba isotope ratios to igneous rocks using double-spike Multiple Collector-Inductively Coupled Plasma-Mass Spectrometry (MC-ICP-MS) and observed significant difference in $\delta^{137/134}$Ba between JB-2 (slab fluid influenced) and JA-2 (slab or crustal melt influenced). They found that the ratio of BHVO-2 (oceanic island basalt) was between JB-2 and JA-2 and could not distinguish it either from JB-2 or JA-2 because of overlapping analytical errors. Although their analytical repeatability was far better than the previous reports, development of a more precise analytical method is required to apply stable Ba isotopes to igneous processes.
The double-spike method is effective for Ba isotope analyses either in thermal ionization mass spectrometry (TIMS) or MC-ICP-MS. However, isobaric interferences of Xe in Ba isotopes prevent further higher precision analyses due to instability of Xe blanks in the matrix plasma support Ar gas in MC-ICP-MS. We here report development of a high-precision Ba isotope measurement using double-spike TIMS. We modified double spike TIMS method developed for Pb isotopes by Miyazaki et al. (2009). Longer baseline measurement preformed before and after sample measurement is the key technique. This avoids unnecessary sample waste during baseline measurements within sample runs. Use of double Re-filaments and exponential law mass fractionation correction were combined to improve repeatability of $\delta^{137/134}$Ba. The measured repeatability of the Ba standard solution SRM3104a was $\delta^{137/134}$Ba = ± 0.023‰ (2SD, n = 26), 1.4 times better than that achieved by MC-ICP-MS. The SRM3104a normalized $\delta^{137/134}$Ba value of IAEA-CO-9 was 0.013 ±0.029‰ (2SD, n = 24) which is identical with the reported values 0.017 ±0.049‰ (Nan et al., 2015) and 0.014 ±0.046‰ (van Zuilen et al., 2016). Analyses of geological rock standard samples are ongoing and the results will be reported in the talk.

Miyazaki, T., Kanazawa, N., Takahashi, T., Hirahara, Y., Vaglarov, B.S., Chang, Q., Kimura, J.-I, Tatsumi, Y., 2009. JAMSTEC Report of Research and Development, Special Issue, 73-80
Miyazaki, T., Kimura, J.-I., Chang, Q., 2014. Journal of Analytical Atomic Spectrometry, 29, 483-490.
Nan, X., Wu, F., Zhang, Z., Hou, Z., Huang, F., Yu, H., 2015. Journal of Analytical Atomic Spectrometry, 30, 2307-2315.
van Zuilen, K., Nägler, T.F., Bullen, T.D., 2016. Geostandards and Geoanalytical Research, 40, 543-558.

Keywords: Stable Ba isotope, Thermal ionization mass spectrometry, Double spike

The paleo environmental research in southern part of Mongolia by lake sediment analysis

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Lake Boontsagaan, Orog and Olgoy are located in the Valley of the Lakes, Gobi-Altai transition zone, which stretches from central to western Mongolia. The surface area of the lake is 252 km^2 for Boontsagaan, 140 km^2 for Orog lake and 1,79 km^2 for Olgoy lake. The sediment cores were collected from these three lakes in 2014-2016. The sedimentary features (e.g., water content, grain density, grain size, chemical composition) and ages (RI measurenment) were analyzed and correlated to meteorological data of the area (annual temperature, precipitation and wind 1975-2015, Bayankhongor station).

The mean annual temperature was 1.5˚C, mean precipitation is 205 mm and average daily temperatures reached to 15–20˚C (www.ogimet.com/gsodc.phtml).

Totally 6 sediment cores were collected from these three lakes in different locations by Sateke plastic corer and were sliced into 1.0cm intervals from the top. The content of water was measured directly by drying a given amount of the sediment at 105˚C (Lambe and Whitman, 1969; Dringman, 2002). Samples of 50 mg were dried at 77˚C for 24 hours and were then treated by 10% hydrogen pyroxides (H_2O_2) for 24 hours to estimate organic matter concentration. Calcium carbonate in the sediment was dissolved by 1-N hydrochloric acid and concentration was calculated. Analysis of the biogenic silica content follows the method described in Mortlock and Froelich (1989). Grain size was measured for whole sediment and mineral fraction with SALD2200 laser diffraction particle size analyzer. The chronology of sediments was established by ^{210}Pb measurement. We collected outcrop sediment and analyzed by OSL dating method. These outcrops consist of paleo lake deposit and are indicative of high lake water level.

From the result of the unsupported ^{210}Pb, sedimentation rate of Olgoy lake was about 0.5 cm per year for last 40 years. Sedimentation was faster before that. Physical and chemical properties of sediments are compared to meteorological data to interpreted the effect by the local climate change. OSL ages indicate the time when water level was high.

Keywords: lakes, sediment feature, climate data

