Influence of fault activity to hydration thickness of quartz: Application of SIMS analysis

*Masakazu Niwa[1], Koji Shimada[1]

1. Japan Atomic Energy Agency

Occurrence of recent activity of faults is often evaluated based on displacements of young subsurface sediments covering the faults. However, this evaluation is not applicable for faults that occur where young subsurface sediments are not found. Faulting in brittle regimes often results in the development of fault gouge along a slip plane. In addition, the formation of hydrous silica gel has been proposed as one of indicators of paleo-earthquakes within the rock record (Faber et al., 2014). Analysis for silica hydration along faults as well as structural, mineralogical and geochemical analyses of a fault gouge may assist in reconstructing the history of fault activity, and also contribute to identification of recent faulting.
Hydration thickness measurement of silica glass has been applied for dating for archeological artifacts such as a stone figure and axe made from obsidian (Katsui and Kondo, 1967; Stevenson et al., 1989). Hydration thickness of volcanic glass estimated from refractive index analysis using optical microscopy has positive correlation with its sedimatation age (Yamashita and Danhara, 1995; Ikuta et al., 2016). Hydration rate of volcanic glass is about 1 μm/1,000 yr, depending on sedimentary environment. In contrast, hydration rate of quartz is too slow; diffusion coefficient values of quartz and glass at ambient temperatures are about 10^{-21} and 10^{-17} cm^2/s, respectively (Ericson et al., 2004). However, examinations of natural fault mirror surfaces and experimental studies for siliceous rocks have suggested that silica gel lubrication could cause coseismic weakening (Hayashi and Tsutsumi, 2010; Kirkpatrick et al., 2013). Near-surface faulting possibly facilitates a growth of quartz hydration.
In this study, we examined the relationship between development of quartz hydration and fault activity. The hydration thickness was estimated by secondary ion mass spectrometry (SIMS), Physical electronics PHI 6650 or PHI ADEPT 1010 housed at Foundation for Promotion of Material Science and Technology of Japan. Cesium ion was used as primary ion, and depth profile of secondary ion intensities of hydrogen, silicon, oxygen and aluminum ion was obtained for a 10 μm depth from a sample surface. Hydrogen ion concentration was calculated from normalization using a quartz standard sample. Primary accelerated voltage was 5.0 kV, and analyzed area was approximately 20 μm ×20 μm.
We analyzed chert samples from the Franciscan Complex in California and Mino Belt in central Japan. We compared depth profiles of hydrogen ion concentration between (1) mirror surfaces along fault plane, (2) natural, flat surfaces without fault slip, and (3) inside of the samples exposed by cutting and polishing. The analysis suggests that hydrogen ion concentration from the mirror surfaces to >1 μm depth increases severalfold compared to inside of the samples, while the natural surfaces without fault slip have no clear concentration change for depth. This study shows that the SIMS analysis could be applicable for the estimation of hydration thickness of quartz along faults as well as the measurement of obsidian hydration thickness (Liritzis and Laskaris, 2009). The tests for still more samples should be further studies to examine geochronological application for fault activity.

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Keywords: Fault, Quartz, Hydration, SIMS

Luminescence measurement of quartz from Nojima Fault Trench

*Kazumasa Miura[1], Noriko Hasebe[1], Yoshihiro Ganzawa[2], Takahiro Tagami[3], Aiming Lin[3]

1. Kanazawa University, 2. Hokkaido University of Education, 3. Kyoto University

1. Introduction
The Southern Hyogo prefecture earthquake occurred by the activity of the Nojima fault in 1995. The southeastern side of this fault was uplifted by 1.4 m with horizontal displacement of 2.1 m along the fault to southwestward. In this study, we investigated the effect of fault activity on luminescence signal and estimated dose in quartz from samples from trench of Nojima fault.
2. Luminescence measurement
In this study, the blue thermoluminescence (BTL) often observed for dating of granite-derived quartz sample and the ultraviolet region thermal luminescence (UV-TL) which is the same emission wavelength as the OSL method were measured. Luminescence signals are reset by heating or bleaching (Obata et al., 2015). When considering the temperature and time conditions necessary for resetting the signal, the τ value (the average lifetime) is calculated as an index of the time required for attenuation of the signal under a certain temperature. This temperature and time condition is very low and short compared with ESR and K-Ar methods. Therefore, this method has a potential to specify the latest activity of fault (Ganzawa et al., 2013).
3. Peak temperature of TL signal
The luminescence sites and their emission temperatures were determined by T-Tmax method perfomed by 10 ˚C interval. The host rock collected from Rokko granite (Host rock) and the granite sample (E1) collected about 5 m away from the gouge in trench were measured. As a result, the peak emission temperatures were 200 ˚C, 270 ˚C and 320 ˚C. These values were concordant for BTL and UV-TL.
4. Luminescence signal for granite
Quartz was extracted from Host rock, and several samples from the trench with different distance from the fault. Then, each TL emission curve was obtained. The shape and intensity of these signals are different among samples.
Furthermore, the signal growth rate against amount of dose were also not constant for each peak in all samples.
5. Dose of samples from trench
The dose (Gy) of each sample was calculated for each luminescence site after peak separation of the emission curve. Different peaks showed different dose values in all the samples. The dose estimated by peak at 200 ˚C showed the minimum value.

Keywords: luminescence dating, quartz, active fault

Development of direct dating methods of fault gouges focused on the latest fault slip event

*Masahiro Miyawaki[1], Jun-ichi Uchida[1]

1. Regulatory Standard and Research Department, Secretariat of Nuclear Regulation

We started a research project to develop methods to determine the age of the latest fault slip event using fault gouges. The methods would be used for evaluation of activities of faults without overlying sediments. In order to estimate the latest fault slip event, it is necessary to use fault gouges which have been experienced age resetting (AR) by frictional heating. Near-ground surface fault gouges have been sometimes dated to be older than the true age because the gouges have not been completely reset at the AR temperature. Therefore, we investigate fault gouges at deep depth (300-1,500m) to compare thelatest fault slip event with known recent historical earthquakes.

This study includes the following 1)-3): 1) AR condition check: We conduct a deep borehole observation throughthe target fault damage zone to measure physical temperature, pressure and geological conditions in which the sample expecting a reliable dating can be acquired. We are now drilling a deep borehole with multiple depths through the Nojima Fault ruptured during the 1995 Hyogo-ken Nanbu earthquake to understand conditions of AR. 2) Luminescence and electron spin resonance (ESR)dating: We apply the luminescence and ESR dating techniques to estimate precisely determination of the age of the latest fault event. 3) Friction test: Rotary-shear high-velocity friction tests using natural fault gouge under water-pressure conditions are expected to clarify frictional behavior of faulting and AR conditions. Combining results from 1)-3), integrated analysis on fault activity will be performed. Our goal of this study is to establish the dating methods of fault gouges for precise determination of the age of the latest fault slip event.

Keywords: fault gouge, fault activity, dating, deep borehole drilling, high-velocity friction test, fault damaze zone

New authigenic illite age and hydrogen isotope data to constrain the geochronological and geochemical framework of brittle faulting within the Nojima fault zone, Japan.

*Horst Zwingmann[1], Andreas Mulch[2], Takahiro Tagami[1]

1. Department of Geology and Mineralogy, Kyoto University, 606-8502 Kyoto, Japan, 2. Institute of Geoscience, Goethe University Frankfurt, 60438 Frankfurt, Germany and Biodiversity and Climate Research Centre (BiK-F) and Senckenberg Research Institute, 60325 Frankfurt, Germany

Numerous recent case studies have successfully constrained the timeframe of brittle faulting through dating of clay-size fault gouge fractions. However, the involved fluids sources are not well constrained. K-Ar dating of fault rocks coupled with hydrogen isotope analysis allows to both constraining the timing of brittle faulting and to constrain the influx of variable fluids sources into such fault systems. We present a novel application of hydrogen isotope-based analyses that explores the hydrogen isotope values of fluid sources in Paleocene to Miocene clay gouge-bearing faults from outcrops and drill core samples from the Nojima fault (Awaji island, Japan; [1]). K–Ar ages provide have an age range from 63.4 ±1.3 Ma (Early Palaeocene) to 42.2±1.0 (Palaeogene–Middle Eocene). Several <0.1 and <0.4 μm fractions in proximity to a pseudotachylyte zone are thermally influenced with loss of radiogenic Ar. The illite age data support a model that the Nojima fault zone was initiated ~ 55 Ma ago by ZFTA data [2]. Hydrogen isotope (δD) values of −119 to −97 for fault gouges and cataclasite zones and document meteoric fluids infiltrating the upper crustal brittle fault zones. The data document elevated temperatures and a heterogeneous thermal history within the study area and influence of a secondary thermal heating event probably caused by circulation of hot fluids within the fault zone about 31–38 Ma ago and even a potential influence of Quaternary faulting.

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Keywords: brittle fault, authigenic illite, K-Ar dating, Hydrogen isotopes, Nojima fault, Japan

