Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SSS028-P01 Room:Convention Hall Time:May 26 14:00-16:30

Detailed seismic activity beneath the Nikko-Ashio area revealed by a tomographic analysis

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The Nikko-Ashio area, the northwestern part of Tochigi prefecture, is one of the most seismically active regions in Japan. Tectonic background in the region is dominated by the Pacific plate subducting westward from the Japan Trench. The area is located on the southeast end of the volcanic front expanding from the Tohoku to the Kanto. Active volcanoes such as Mt. Shirane and Mt. Nantai and also active faults such as the Uchinokomori fault are in the region. A large amount of shallow earthquakes about 6,000 ˜ 8,000 a year have been observed around active faults by the routine observations of the Earthquake Research Institute (ERI). The specific characteristics of the activity are as follows: 1. Earthquakes are mainly located in two regions. 2. Earthquakes separate into clusters. 3. Most earthquakes occur within a depth of 15 km. 4. The distribution tends to shallower toward Mt. Sirane. 5. Obvious SxS and SxP phases reflected from a crustal discontinuity are in the seismograms. 6. Deep low frequency earthquakes at depths of 20 to 40 km occur beneath the region.

Recently, many researchers have investigated what factors cause inland crustal earthquakes. Understanding of the Nikko-Ashio earthquakes will provide information concerning the construction of solutions.

To now we conducted time series analyses and travel time analyses for Nikko-Ashio data. We have obtained some information concerning velocity structures and seismic distribution..Low-frequency earthquakes have occurred about one a month, but sometimes more than dozens of them occur at a time. After that, shallow earthquakes obviously increase. From a tomographic study we have found that low-frequency earthquakes occur at the edge of high Vp/Vs areas and high Vp/Vs, low Vp and low Vs areas spread widely at depths of 20 to 30 km. We interpret that low-frequency earthquakes occur as the results of ascending magma flow and intermittent rapid magma flow causes many low-frequency earthquakes at a time. Upwelling magma flow accumulates at a depth of ˜20 km and the dehydration from the magma weaken the strength of the crust and causes shallow earthquakes.

In this report, we investigate precise earthquake distribution to obtain an improved understanding of these systems connected with magma or fluid. In the seismograms, there are many similar earthquakes. We adopt tomoDD inversion method to the travel time data with those wave correlation data during the period from April, 2002 to December, 2009.

Keywords: seismic distribution, low frequency earthquake, magma, fluid, velocity structure

SSS028-P02 Room:Convention Hall Time:May 26 14:00-16:30

Migration of elements accompanied by the development of cataclasites in borehole penetrating the Median Tectonic Line

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Along the MTL which bounds the Ryoke shear zone and Sanbagawa belts the deformation was localized in the Ryoke shear zone with the decrease in the temperature. As a result, various fault rocks from mylonite to cataclasite were developed in the Ryoke shear zone. In the present study, the changes in volume and the element change were measured by the X-ray fluorescent analysis for the drilled core samples form the Iitaka Akou site. The drilling was conducted down to the Sanbagawa shear zone, 600m in total length. The fault rock samples used for the chemical analyses are from the drilling cores of 317m to 473m in depth. Hence, these samples all belongs to the Ryoke belt, and a host rock of the fault rock is tonalite. All the rocks experienced plastic deformation and became mylonite. Rocks suffered cataclasis as temperature decreased. To classify them by the degree of cataclasis, naked eye and thin section observations were conducted. As a result, the fault rocks were classified into four groups by the difference of the degree of cataclasis (nearly undeformed protolith, weakly deformed fault rocks, intermediately deformed fault rocks, strongly deformed fault rocks 'phyllonite'). Whole rock chemical compositions were analyzed by the X-ray fluorescent analysis to clarify the change in volume and chemical elements of these fault rocks, which were examined by the isocon method (Grant, 1986). In the present study, Al was used as an immobile element in fault rocks. Assuming that there was no density change of the fault rocks, the volume change can be estimated by the following equation. $dV=[(1/S)-1]*100$, where S is a slope of the straight line that connects the origin of isocon diagram with the plot of an immobile element. The element fluctuation rate can be calculated by the following equation for the change of each element. (Shikazono et al, 2007). Element fluctuation rate = (Elf/Alf)/ (Elh/Alh), where El is an arbitrary element, Al is an immobile element, and f and h are fault rocks and rocks of comparison, respectively.

The analyses by the isocon method were conducted for three kinds of combination. 'nearly undeformed tonalite and weakly deformed fault rocks', 'weakly deformed fault rocks and intermediately deformed fault rock', and 'weakly deformed fault rocks and strongly deformed fault rocks'. In the combination of 'nearly undeformed tonalite' and 'weakly deformed fault rocks', volume increases by 29.8 percent. Moreover, for the change of the major elements, K_2O (3.78), LOI (1.49), SiO_2 (1.46), Na_2O (1.28) increased, while TiO_2 (0.30), MgO (0.33), P_2O_5 (0.36), FeO+Fe_2O_3 (0.50), MnO (0.55), CaO (0.63) decreased. In the combination of 'weakly deformed fault rock' and 'intermediately deformed fault rocks', Volume decreases by 7.6 percent. Moreover, for the change of the major elements, TiO_2 (3.82), MgO (3.19), P_2O_5 (2.56), MnO (2.01), FeO+Fe_2O_3 (1.90), CaO (1.74), LOI (1.31) increased, while K_2O (0.76), Na_2O (0.80), SiO_2 (0.80) decreased. In the combination of 'weakly deformed fault rocks' and 'strongly deformed fault rocks', the volume decreased by 22.8 percent. Moreover, for the change of the major elements, MgO (8.76), TiO_2 (2.81), CaO (2.51), FeO+Fe_2O_3 (2.44), MnO (2.34), LOI (2.00), P_2O_5 (1.89) increased, and K_2O (0.60), Na_2O (0.56), SiO_2 (0.50) decreased. It is noted that the increase and decrease in the major element change show an opposite sense for 'nearly undeformed tonalite and weakly deformed fault rocks' and the other two combinations. The formation of new minerals correlated with the element change in the fault rocks is as follows. In the combination of 'nearly undeformed tonalite and weakly deformed fault rocks', an increase of K_2O corresponds to the formation of the muscovite and an increase of SiO_2 corresponds to the precipitation of quartz. In the other two combination an increase of CaO corresponds to the formation of calcite, and an increase of MgO and FeO+Fe_2O_3 corresponds to an increase of chlorite.

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Development of intrafolial folds at deeper extension of seismogenic fault

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It has been considered that the main ruptures of large inland earthquakes start in the brittle-plastic transition zone, as their hypocenters are generally located in the deepest region of the seismogenic zone. This suggests the significance of plastic flow in the brittle-plastic transition zone for the generation of large inland earthquakes. The Hatagawa Fault Zone (HFZ) in the north-eastern Japan consists of various kinds of fault rocks such as cataclasite, pseudotachylyte and mylonite, indicating the HFZ were formed under brittle-plastic transition zone.

We found intrafolial folds within the granitic ultramylonite in the HFZ. Intrafolial folds in the ultramylonite are different from other intrafolial folds grew in sedimentary or metamorphic rocks, because the observed intrafolial folds are developed in initially non-foliated granitic rocks. Fukudome (1986) proposed that intrafolial folds were developed by Kelvin-Helmholtz instability due to strain rate differences across the interface between foliations. Such plastic instability occurs at deeper extension of seismogenic fault may cause significant stress accumulation to upper seismogenic fault locked during interseismic period.

We analyze the quartz LPO and grain size, using SEM-EBSD analysis, and estimate the deformation condition. We explain the formation mechanism of the intrafolial folds that causes stress concentration in seismogenic faults.

Intrafolial folds are observed on the plane normal to the foliation and parallel to the lineation (XZ thin sections) of the ultramylonite. The folds consist of monominerallic recrystallized quartz aggregates. The folds show asymmetric profiles and wavelength are below 1cm order. The wavelength / thickness ratio is 1.2 - 4.5. The folded quartz aggregates have LPO, indicating that quartz aggregates were deformed by dislocation creep. On the other hand, matrix consists of fine-grained mixtures of quartz, feldspar and mica without significant LPO, indicating that matrix was deformed by diffusion creep.

EBSD analysis clarified that the LPO pattern of quartz in the folded part is parallel to Y of the strain ellipsoid (Ymax). The average grain size measured by EBSD orientation maps is in the range of 6.32 +/- 3.86 - 14.27 +/- 6.67 micrometers. Stipp and Tullis (2003)'s piezometer predicts differential stresses of 81 - 154 MPa. Presence of syndeformational hornblende and Ymax LPO indicate that the ultramylonite was formed at a temperature of 450 - 500C. Strain rates of folded quartz layer are estimated on the order of 10^{-12} and 10^{-10}/s, using Hirth et al. (2001)'s quartzite flow law. The strain rate folded quartz layer is 5 orders faster than current east-west contraction strain rate estimated from GPS observations in the NE Japan (10^{-15}/s: Miura et al., 2004). Because the intrafolial folds are developed by the difference in strain rates (Fukudome, 1986), the fine-grained matrix might be deformed at higher strain rates than the competent quartz layers. This implies that the strain concentration in deeper extension of seismogenic faults results in stress accumulation to upper faults locked during interseismic period.

Keywords: intrafolial fold, plastic instability, ultramylonite, Hatagawa Fault Zone, inland earthquake