

Structure of the fault zone by logging in a borehole of the Neodani fault Midori drilling site

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Drilling, in-situ downhole measurements and coring within and around active fault zones are required to gain a better understanding of the structure, material properties and the physical state within and around active fault zones and intra-plate crust. The National Research Institute for Earth Science and Disaster Prevention (NIED) has drilled through the fault zone of the Neodani fault, which activated during the 1891 Nobi earthquake ($M=8.0$), the greatest inland earthquake to have occurred in Japan.

Two boreholes were drilled at the same site close to the Neodani fault in the Neo-Midori district, Gifu Prefecture. A 1393-m long main borehole was drilled vertically and bended 15 degrees at 450 m deep to penetrate the fault zone at the deeper part. A 350-m slant hole was drilled straightly with a 55 degrees angle to the ground to go through the fault zone at the shallower part. In-situ measurements including hydraulic fracturing stress measurement were performed using these boreholes. Various laboratory measurements were also carried out using the core samples collected at different depths. We report results of loggings in the main borehole (down to 1300m depth) and discuss on physical properties and structure of the fault zone.

The physical logging items that we performed in the main borehole were as follows. SP (spontaneous potential, mV); Electrical log: SN (short normal, ohm-m), LN (long normal, ohm-m), Micro1 (micro log 1 inch, ohm-m), Micro2 (micro log 2inch, ohm-m); Vp (P wave velocity, km/sec); DL (density, g/cm³); NL (neutron porosity, %); GR (natural gamma ray, API); Spectra gamma ray (SPGR-K, %; SPGR-Th, ppm; SPGR-U, ppm); Caliper log: Caliper-X (caliper x-axis, mm), Caliper-Y (caliper y-axis, mm), Temperature (Temperature, C).

According to cores and cuttings, lithofacies around the borehole were mainly slate, sandstone/slate alternate layer, silicic slate, silicic mudstone, and chert. In perspective, the slate, silicic mudstone and chert were dominant in the depth interval of 0 - 800m, 800 - 1060m, and 1060 - 1300 m, respectively. The apparent resistivity distributes within 100-1000 ohm-m range irrespective of lithofacies. But, the natural gamma ray, neutron porosity, density, P wave velocity change systematically depending on the lithofacies: natural gamma ray - slate 100 - 200 API, silicic mudstone 25 - 100 API, chert 25 - 75 API; neutron porosity - slate 15 - 30 %, silicic mudstone 3 - 20 %, chert 10 - 25 %; density - slate 2.3 - 2.4 or 2.6 - 2.75 g/cm³, silicic mudstone 2.3 - 2.4 or 2.6 - 2.7 g/cm³, chert 2.3 - 2.5 g/cm³; P wave velocity - slate 4 - 5.5 km/sec, silicic mudstone 2.5 - 5 km/sec, chert 4 - 6km/sec.

On the other hand, the apparent resistivity decrease down to 10 ohm-m locally in a narrow region with the decrease of P wave velocity. The narrow region seems to be fault fracture zone because the neutron porosity and natural gamma ray increase in the narrow region.

Within the region of the same lithofacies, the apparent resistivity and P wave velocity decrease with the increase of neutron porosity. It support the neutron porosity corresponds to the volume content of pore water in the rock around the borehole. However, on the other hand, the density changed little with the neutron porosity. In addition, the neutron porosity has positive correlation with the natural gamma ray. It is indicated that the neutron porosity does not correspond to only a quantity of water which occupies cracks and pores, but also reflects, for example, an existence of clay minerals (and water incorporated in the crystal structure). Decrease of the apparent resistivity and P wave velocity within the fractured zone, which we mentioned above, may be influenced by clay minerals as well as pore water.

These results physical properties in the fault zone change primarily according to the lithofacies, and also change due to the physical and chemical reaction, such as a formation of fracture zone, in the same lithofacies.