Quantitative constraints on ultimate excess fluid pressure during fault slips along an underplating thrust

*Takahiro Hosokawa[1], Yoshitaka Hashimoto[1]

1. Kochi University

There are two models for behaviors of fluid pressure in seismogenic zones along subduction plate interface. One is the fault-valve model in which fluid pressure decreases during an event. The other is the thermal pressurization model, in which fluid pressure increases due to frictional heating. The two models have different time scales and may coexist in an event. It is a challenge to examine the change in fluid pressure quantitatively for both models from natural fault zones. Therefore, the purpose of this study is to quantify the change in fluid pressure from a natural fault zone, focusing on the underplating thrust zone accompanied with extension veins in the Mugi mélange, the Cretaceous Shimanto Belt, SW Japan.

The Mugi melange is an underplated accretionary complex. The fault zone we studied is thought to be related to underplating consisting mainly of basalt rocks that steeply dip to the south or north, strike in the east-northeast direction. In the terrigenous melange just above the fault zone, mineral veins filling the extension cracks and cutting the melange structures show network texture. Because the veins are observed adjacent to the fault, the mineral veins are interpreted as these related to the underplating fault zone. The network veins cut each other, suggesting that the development of the mineral veins was in repeated multiple stages.

In this study, the dike method was applied to the mineral veins, and the paleo-stress and driving fluid pressure ratio (P *) were estimated. P * is defined as the maximum excess pore fluid pressure normalized by differential stress for the extension cracks. As results, three stresses (stress 1,2 and 3) and P * for each stress state were obtained. The foliation of the fault zone was rotated to be horizontal to reconstruct the principal stress directions at the time of the formation of mineral veins. After the rotations, stress 1, 2, and 3 show normal fault stress regime (P * = 0.536), strike-slip fault stress regime (P * = 0.279), reverse fault stress regime (P * = 0.38), respectively. The change in the restored paleo-stress could be associated with the stress change in seismic cycles because the veins could be developed in repeated multiple stages. Using P* and the maximum and minimum values of fluid pressure from fluid inclusions from previous studies, the tensile strength (Ts) and depth were constrained to be about 7.3 (±1.1) MPa and about 5 km, respectively. From the rock fracture theory (Griffith theory), the minimum fluid pressure (Pfmin) at the time of mineral vein formation can be calculated using the depth and Ts. When P* is larger than 0, the fluid pressure estimated from P* and fluid inclusion (Pfmax) must be larger than the fluid pressure from rock fracture theory (Pfmin). Because the Pfmax is the maximum excess pore fluid pressure, the extension veins are developed under the fluid pressure conditions between Pfmin and Pfmax.

The Pfmax exceeding Pfmin was constrained from the natural fault zone related to the underplating accretionary complex in this study. The fluid pressure increase could be a dynamic phenomenon related to thermal pressurization because the estimated Pfmax exceeds over lithostatic pressure, which cannot be a stable condition. We also showed that the fluid pressure during mineral vein formation differs between the reverse fault stress regime and the normal fault stress regime, which could be related to seismic cycles. The difference between the Pfmax and Pfmin corresponds to the range of the fluid pressure estimated from the fluid inclusions. Therefore, the range of the fluid pressure from fluid inclusions indicates the minimum reduction in fluid pressure at least for the extension vein regime in the long-term

Fault-valve model.

Keywords: subduction zone, underplating thrust, fluid pressure