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Physical property transition and calculation of damage parameter of a fossilized subduction zone megasplay fault

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Subduction zone megasplay faults are known to cause great earthquakes and tsunamis and have been the subject of numerous geological and geophysical studies, but their initiation and evolution remains poorly constrained. Therefore, the Nobeoka Thrust in the Shimanto belt in Kyushu, a fossilized megasplay fault in ancient accretionary prism is studied to understand the mechanism of the megasplay fault. In this study, we investigate the physical property and deformation pattern of the Nobeoka Thrust from core description and logging data from the Nobeoka Thrust Drilling Project (2011).

The fracture zone (damage zone) observed in the hanging wall, fault core, and footwall of the Nobeoka Thrust have two types; cohesive/mineral vein filled fracture zones and brecciated fracture zones. The former causes high peak in resistivity and P and S-wave velocity while the latter causes rise in caliper and porosity, and drop in resistivity and P and S-wave velocity. These two types of fracture zones coexist and the brecciated zones are generally in the center of the main fracture zone, whereas the cohesive structures are distributed above and below the brecciated zones.

Here We assume that at the highest peaks in resistivity, strain is accumulating towards the main fracture zones, causing strain hardening, but eventually collapses to become strain weakening, at which point critical stress state is attained. Why does resistivity rise with strain accumulation (strain hardening), even though porosity does not show significant decrease and start to decrease after its maximum peak? Strain accumulation appears to cause strengthening, and rocks become more cohesive, and eventually, reach its yield point.

On the other hand, cross correlation with neutron porosity and resistivity at intervals of porosity increase in the fracture zones first shows sharp drop in resistivity in the lower porosity, but later once porosity reaches a certain value, decrease in resistivity becomes gradual, and porosity increase becomes more significant. Here, this porosity boundary is named <percolation threshold>.

We further set a hypothesis that the geometry and density of the cracks transit with strain accumulation. During strain hardening (resistivity increase), cracks are randomly distributed, and as number distribution increase, cracks will start to coalescence. Propagation of the cracks will occur after coalescence, and not until then would porosity start to increase. Once the geometry and distribution (distance ?between the crack) reach their critical values, and once they attain the <percolation threshold>, increase in porosity is observed. Here, We assume that this threshold corresponds with the transition in geometry (aspect ratio), size, and distribution of the cracks.

Motivated by these observations and hypotheses, I analyze what factors including the geometric attributes and distribution of cracks relate with the critical failure condition at the fracture zones in the hanging wall, footwall and main fault core of the Nobeoka Thrust. In this study, from lithology/structure data from core description and logging data, I extract number distribution as crack density, estimate crack geometry (aspect ratio of the crack: width(along depth)/diameter) from resistivity and porosity data, and parameterize these components to apply to percolation theory and damage mechanics (micromechanics) model of interactive wing cracks, which derives concepts from Griffith's crack theory that considers the effect of initially present microcracks, and critical stress formulated by inverse square root of crack length. To geometrically and physically investigate the development of fault mechanisms and evolution of the Nobeoka Thrust, I examine the dynamic transition with stress at the <resistivity peak> above the main fracture zone, <center> of the main fracture zone, and the <percolation threshold>.

Keywords: Accretionary prism, Megasplay fault, Geophysical logging, Physical property