Estimation of damage zone thickness of the Median Tectonic Line in Shikoku, SW Japan

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A fault is generally divided into a narrow fault core and a wide damage zone. The fault core consists of fault rocks, and surrounded by the damage zone. Many previous studies have proposed architecture and geometry of the damage zone from outcrop, observation of drill core and microstructural analysis (Mitchell and Faulkner, 2009; Williams et al., 2016). The damage zone thickness (*T*) seems to evolve in proportion to the fault displacement (*D*) for $D < 300$ ˜ 3000 m (Mitchell and Faulkner, 2009; Savage and Brodsky, 2011). However, the distribution of the *D*-*T* relationships is scattered because of several factors (e.g. Choi et al., 2016). One of the factors is a lack of quantitative estimation of *T*. The edge of the damage zone generally represents the point at which fracture density drops to a background level. However, data uncertainties can occur in determining the edge of the damage zone because many researchers define background level subjectively. In this study, we propose a process for measuring fracture density from X-ray computer tomography (X-CT) images of drill core samples to quantify the damage zone thickness objectively.

We first obtained a geological core sample (125 m-long) penetrating the inactive zone of the Median Tectonic Line (MTL) in Japan. The lithology of drilling core was composed of the alternation of sandstone and mudstone of the Cretaceous Izumi Group at 3.4–109.45 m and pelitic schist and psammitic schist with tuffaceous rock lenses of the Sanbagawa metamorphic rocks in 109.45–125 m. Altered dike with a thickness of approximately 1.3 m distributes along the MTL. The fault core consists of ˜ 6 cm thick fault gouge originated mudstone and altered dike at 109.45 m.

Secondly, X-CT data was measured by a medical-use XCT scanner (Aquilion PRIME Focus Edition, Canon Medical Systems Co., Ltd.) located at the Center for Advanced Marine Core Research, Kochi University, Japan. Each core was scanned with an excitation voltage of 120 kV and a current of 100 mA for the X-ray source. The CT numbers were obtained with resolutions of 0.126 mm/pixel for the core-axis-normal (X and Y) directions and 0.5 mm/pixel for the core-axis-parallel (Z) direction.

Next, X-Z slice images were reconstructed from X-Y slice images of the drilling core using Image J. X-Z slice image files were imported into Adobe illustrator™. Fracture was automatically detected using the Image Trace Tool in Adobe illustrator™. The damage zone thickness was determined from auto-traced fracture density (AFD) per 1 m depth and a curve of cumulative number of AFD.

AFD is within 100 fractures/m at 45-80 m depth and considered to reflect the intact rock of the Izumi Group. While, AFD locally increases to ˜300 fractures/m at 33–34 m, 38–39 m and 43–44 m depth. This would be caused by minor faults from geological observation. The remarkable features of AFD were identified at 5–20 m and 81–111 m depth. The AFD increased to ˜1000 fractures/m at 5–20 m depth could be ascribed to the affecting of the rock weathering near earth’ s surface from the geological observation. In contrast, the AFD increased to ˜400 fractures/m at 81–112 m depth would be formed by fault damage zone. Additionally, a curve of cumulative number of AFD indicates that MTL hanging wall damage zone is divided into the Inner zone (103–109.45 m) and Outer zone (81–103 m). On the other hand, the footwall damage zone consists of the only Outer zone (109.45–112 m). The hanging wall damage zone is more than ten times wider than the footwall damage zone. This asymmetric structure is inferred to be affected by lithology and/or structural geometry around the MTL. Moreover, the damage zone is concordant with the decreasing zone of averaged CT value and rigidity ratio (%).

In this study, *T* was accurately estimated using our process for drill core samples. We will demonstrate the growth process of the MTL damage zone based on *T* and occurrences of fault rocks as future works.

Keywords: Median Tectonic Line, damage zone thickness, fracture density, X-CT image, elastic wave velocity, geological observation

