Density and porosity changes in microstructures and faults: evidence from X-ray computed tomography scan image analysis

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X-ray computed tomography (CT) scanner was used to reveal density and porosity changes related to the development of microstructures and faults at the toe of the Nankai Trough accretionary prism. CT scan analysis demonstrates that the argillaceous sediments in the upper part of the prism dewatered through core-scale deformation structures and a seismic-scale fault and that consolidation due to concentration of deformation in the deeper part of the prism resulted in the similar density values between undeformed parts and fault zones. The fine-scale density distribution deduced from CT scan analysis suggest that heterogeneous consolidation in the decollement zone and that the decollement zone prevents the consolidation of underlying sediments.

X-ray computed tomography (CT) scanner is a tool to reconstruct a CT image of materials penetrated by X-rays based on the X-ray linear absorption coefficients. The CT scanner is useful to observe non-destructively internal structures and fine-scale density distribution in materials. Here, we used the CT scanner to reveal density and porosity changes related to the development of microstructures and faults in the argillaceous sediments. Since the X-ray linear absorption coefficients depend on not only bulk density but also chemical composition of the material, we also examined the chemical composition using microprobe. The samples for CT scan analysis were collected from the toe of the Nankai Trough accretionary prism during Ocean Drilling Program Leg 190.

Deformation structures in the accretionary prism are characterized by deformation bands, small faults, proto-thrust, and fractured and brecciated zones. Deformation bands and small faults in the CT images are represented by bright bands and seams, respectively. The results of CT scan and chemical analyses elucidate that deformation bands and small faults are featured by 0.06 g/cm3 to 0.12 g/cm3 increase in bulk density and 0.04 to 0.07 decrease in porosity with respect to undeformed parts, indicating that the consolidation has progressed within these structures. Proto-thrust also shows 0.02 g/cm3 to 0.06 g/cm3 increase in bulk density with respect to undeformed part, indicating shear-induced consolidation associated with prism faulting. These results demonstrate that the argillaceous sediments in the prism dewatered through core-scale deformation structures and a seismic-scale fault.

On the other hand, fractured and brecciated zones in deeper part of the prism display similar density values to undeformed parts. Based on the magnetic fabrics obtained from the anisotropy of magnetic susceptibility (AMS) data, the inclination of minimum AMS axes in the deeper part of the prism decreases toward the plate boundary decollement zone, suggesting concentration of deformation in the deeper part of the prism. Thus tectonic mineral fabrics are pervasively developed in the deeper part of the prism, although they are not apparent on core-scale. We interpret that consolidation due to concentration of deformation in the deeper part of the prism resulted in the similar density values between undeformed parts (on core-scale) and brecciated zones. The decollement zone shows high and various density values, and there are sharp density values decrease immediately below the decollement zone. These features suggest that heterogeneous consolidation in the decollement zone and that the decollement zone prevents the consolidation of underlying sediments.

Finally, the CT scanner is very useful to quantify physical properties changes associate with deformation. It could be also applied to reveal density and porosity changes related to fault movements and paleoenvironment change.