Experimental study on anisotropy of rock thermal properties: A case study using Mio-Pleistocene sedimentary soft rocks

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Since thermal property is one of the most important physical properties of rocks, thermal conductivity is one of the minimum measurements of physical properties of cores in a scientific drilling project of the International Ocean Discovery Program (IODP). Depth profiles of sediment thermal conductivity are necessary for comprehending the thermal structure in active seismogenic zones like a the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE). In order to estimate the subsurface temperature, it is often assumed that the thermal properties that determine the subsurface temperature, such as thermal conductivity and thermal diffusivity, are isotropic, but detailed studies on the anisotropy of thermophysical properties are needed to more accurately determine the subsurface temperature structure. It is known that the elastic wave velocity is affected by the structural anisotropy originating from the sedimentary lamination, and the value of the elastic wave velocity is larger in the direction parallel to the bedding plane than in the direction orthogonal to it, however it is not known well whether there is any anisotropy in thermal properties. To evaluate the anisotropy of thermal properties, we measured thermal conductivity, thermal diffusivity, specific heat capacity and elastic wave velocity using siltstones distributed in the forearc basin at the Boso Peninsula, central Japan.

In this study, the Mio–Pleistocene sedimentary soft rocks were collected from the Miura and Kazusa groups, and a total number of block samples is seven. Block samples taken from the outcrop were cored perpendicular to the bedding plane, and cubic specimens of approximately 35 mm per side were prepared using a rock cutter. In the following, the direction parallel to the bedding plane is called the direction of x-y axis, and the direction orthogonal to it called the direction of z axis. In the following measurements, these specimens were water-saturated by purified water. The thermal properties of the specimens in the z axis and x-y axis directions were measured using the Hot Disk method in two ways: the bulk mode which assumes that the specimens are structurally isotropic, and the anisotropic mode which assumes that the specimens are structurally anisotropic. Furthermore, the elastic wave velocities in the z axis and x-y axis directions were measured by ultrasonic velocity tests.

In these measurements, the elastic wave velocity was larger in the x-y direction than in the z direction. This suggests that the specimens have a structural anisotropy resulted from the bedding structure. Results using the Hot Disk method show that the thermal conductivity tended to be larger in the x-y direction than in the z direction. This suggests that there is anisotropy in thermal conductivity because of samples' structural anisotropy. The degree of anisotropy of thermal conductivity and the elastic wave velocity was evaluated using the following equation: $V(\text{anis.})[\%]=100(V(\text{x-y})-V(\text{z}))/V(\text{ave.})$. As a result, the degree of anisotropy of the elastic wave velocity was approximately -7–10%, while the degree of anisotropy of the thermal conductivity was approximately 2–5%. Comparing both of the anisotropic degrees, anisotropy of thermal conductivity is weaker than that of elastic wave velocity. This suggests that heat transfer is less affected by structural anisotropy due to sedimentary lamination than elastic wave propagation.

Keywords: thermal properties, anisotropy, sedimentary soft rocks

