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Thermal properties of marine sediments recovered from the eastern flank of the Juan de Fuca Ridge

Shusaku Goto[1]; Osamu Matsubayashi[2]

[1] GSJ, AIST; [2] AIST-GRE

Knowledge of thermal properties of earth material provides constraints on subsurface thermal structure that controls geophysical, chemical, biological and hydrological regimes. There are three thermal properties to solve thermal equation: thermal conductivity, thermal diffusivity, and heat capacity. Heat capacity is the product of density and specific heat.

Thermal conductivity of sediments is measured with energy because it is an essential parameter to calculate heat flow and to infer steady state subsurface thermal structure. Heat capacity of marine sediment is needed to treat problems regarding as transient temperature change below seafloor, along with thermal conductivity of the sediment. If the assumption that marine sediment is uniform is satisfied, thermal diffusivity of the sediment is required to model the subsurface transient temperature problem. In spite of the importance, however, relatively few data of heat capacity and thermal diffusivity have been reported.

In this study, we present a method to estimate these three thermal properties of marine sediments from temperature data measured with needle probe, which is commonly used to measure thermal conductivity of marine sediments [Von Herzen and Maxwell, 1959; Blum, 1997]. In the method we proposed, the thermal properties are estimated as follows: (1) thermal conductivity is measured by a common needle probe method, (2) using the measured thermal conductivity as a constraint on inversion, heat capacity is estimated by an analytical solution of [Jaeger, 1956], then (3) thermal diffusivity is calculated by the ratio of thermal conductivity to heat capacity.

We apply the method to estimate thermal properties of sediments from temperature data measured with needle probe during IODP Expedition 301. Onboard thermal conductivity data is used as a constraint to estimate heat capacity. We also estimate specific heat of sediment by the ratio of estimated heat capacity to bulk density that was measured by the method of Blum [1997] during the cruise. The results of the estimates of thermal properties indicate that thermal properties of marine sediments are controlled by lithology and porosity. Thermal conductivity and diffusivity of clay in the upper 100 m decreases with depth. The vertical profiles show apparent negative correlation with porosity that decreases with depth. Whereas, heat capacity and specific heat of clay decrease with depth, as following the decrease of porosity. Discontinuous sediment recovery below 100 m prevents an analysis of trend of thermal properties. However, there are slightly changes of thermal properties between different sediment units. On the other hand, it seems that there is no significant change in thermal properties of sand through the recovered cores.

Previous studies of thermal properties suggested that thermal diffusivity and heat capacity of marine sediments are expressed by simple formulas that are function of sediment thermal conductivity only [Von Herzen and Maxwell, 1959; Hyndman et al., 1979]. We find, however, that the relations between these thermal properties are dependent on mineral composition of sediments, especially, the amount of quartz.

References

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