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Detection of Shear Heating from the Sanbagawa Belt nearby the Median Tectonic Line by using Raman Spectral Analysis

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Recognition of shear heating has potential to help in estimating the shear stresses that operate on major faults when they move. Surface heat-flow and fission track thermochronology in the vicinity of the major San Andreas Fault show no clear evidence for major shear heating. This is commonly used to infer a much lower shear stress than that expected based on rock deformation experiments. The cause of this discrepancy between experiment and observation remains unresolved. The Median Tectonic Line (MTL) is the largest on-land fault of the Japanese Islands with a movement history from the Cretaceous to the present, and is a suitable candidate for studies of shear heating and to investigate whether a low degree of shear heating such as that associated with the San Andreas Fault is a general characteristic of regional long-lived faults. Within the Ryoke belt to the north of the MTL, a progressive younging of fission track ages towards the MTL suggests shear heating was important. However, the thermal structure in the Sanbagawa belt to the south of the MTL has not been determined and the detailed thermal structure around the fault is not known. Our study aims to fill these gaps in our knowledge by clarifying the peak temperature attained in the Sanbagawa belt.

A semi-continuous core passing through the MTL was recently drilled by AIST in the Kii peninsula. The availability of this core enables us to conduct detailed analyses in key samples close to the fault. To study the broader thermal structure, we also sampled on a kilometer scale and studied the regional structure using field mapping techniques. Pelitic rock is the main rock facies of the Sanbagawa belt in the study area. This pelite was metamorphosed at temperatures < 400 ^{o}C and minerals suitable for typical Fe^{++}-Mg exchange thermometers are poorly developed. As an alternative way of estimating peak temperature, we used Raman spectral analysis of carbonaceous material. Results show a consistent regional temperature of 341 ^{o}C - 348 ^{o}C at distances between 400 m and 4 km from the MTL. There is a significant rise within 200 m from the MTL to temperatures of 362 ^{o}C - 408 ^{o}C. These results show no evidence for a heat-anomaly on km-scales to the south of the MTL, but do show a clear temperature increase near the MTL. The spatial association of the heat-anomaly with the fault implies shear heating, but the anomaly is only observed in a narrow zone close to the MTL.

To evaluate these results in terms of shear heating on the MTL, we compared them to the temperature distributions calculated using simple analytical solutions for one-dimensional conductive heat flow with a planer heat source. Results of calculations for single fault movements show a clear temperature increase in a narrow zone close to the fault ($<$ ~100 m from the fault), but the duration times at high temperature nearby the fault are short ($<$ ~100 years). In contrast, results of calculations for constant slip rates show that high temperatures can be achieved near the fault if sufficient time has elapsed: of the order of 0.5 million years since the onset of fault movements. However, in this case the associated thermal anomalies are broad and developed over distances of $>$ ~10km from the fault.

The thermal data obtained around the MTL show the characteristics different from the San Andreas Fault, and suggest that the shear heating can be generated by movements of regional long-lived faults. The heat anomaly in the Sanbagawa belt nearby the MTL and the results of the thermal calculations suggest that not only the heat conduction but also the other mechanisms involved with the heat-transport of shear heating.

Keywords: shear heating, Median Tectonic Line, Sanbagawa belt, boring core, raman spectral analysis, carbonaceous material