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Electrical resistivity and resistivity anisotropy of the Hidaka metamorphic rocks

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Surface electromagnetic measurements commonly reveal a low-resistivity layer in the continental middle and lower crust, and possible conductive sources include the presence of fluids and graphite (see Jones, 1992 for review). The Main Zone of the Hidaka metamorphic belt represents the thrust-up upper 23 km of an ancient arc crust (Komatsu et al., 1983). We have measured the electrical resistivity of the Main Zone rocks originally composing the arc middle and lower crust, and examined the presence of rocks responsible for a low-resistivity layer as well as the resistivity anisotropy.

We have prepared three cores from each rock sample, i.e. one parallel to lineation, the other perpendicular to lineation and parallel to foliation, and still other normal to foliation. After dried, both ends of each core sample were coated by conductive paste, and subsequently attached with a pair of platinum discs as electrodes for current measurement. A pair of platinum wires as electrodes for potential difference measurement was then wound around the core sample at 0.5-1 cm away from its ends. The measurement system consists of a function generator, a differential amplifier, a current amplifier, a digital storage oscilloscope and a personal computer. Sinusoidal AC voltages with an amplitude of +-0.5 V and frequencies of 1 Hz-100 kHz were used as input signals. Potential difference and current data of 5 wavelengths were sampled at a rate of 100 point/wavelength. We calculated resistivity and phase shit values from the amplitudes and phases obtained by the least-square fitting of data according to Takakura et al. (2000). Measurement was repeated 10 times for each core sample, and average resistivity and phase shit values were obtained.

Except for one sample, resistivity values first increase from 60k-20M ohm m at 1 Hz to the maximum of 600k-23M ohm m at 10-50 Hz, then decrease to the minimum of 16k-88k ohm m at 50 kHz, and finally increase again to 26k-130k ohm m at 100 kHz. Phase shift values first decrease from -19-73 degrees at 1 Hz to -79--42 degrees at around 500 Hz, then do not change much until 5 kHz, and finally increase to 79-114 degrees at 100 kHz. At a given frequency, core samples with higher resistivity values have a tendency to show lower phase shift values. Hornfels is an exceptional sample having almost constant resistivity values of 520-1450 ohm m from 1 Hz to 10 kHz which then increase to 2500-6600 ohm m at 100 kHz. Phase shift is negligible in hornfels at a wide range of frequencies from 1 Hz to 1 kHz, but its value increases up to about 150 degrees at 100 kHz.

Among foliation-normal core samples available for all rock samples, the resistivity value of hornfels is a few to several orders of magnitude smaller than those of the other samples throughout frequencies measured. Hornfels contains a significant amount of graphite derived from carbonaceous materials, which must be responsible for the low resistivity. Hornfels is distributed throughout the Hidaka metamorphic belt with widths of 2-10 km, and therefore likely forming a low-resistivity layer.

All samples in which anisotropies of resistivity and phase shift are observed contain biotite. Resistivity in these samples has the maximum value in the foliation-normal direction, and the minimum value in the lineation direction. Contrarily, phase shift in these samples has the maximum value in the lineation direction, and the minimum value in the foliation-normal direction. Because preferred orientation of biotite defines foliation and lineation in these samples, it is likely responsible for the observed resistivity anisotropy.