Seismic reflectivity of the deep crust based on laboratory-measured acoustic velocities and densities of exhumed metamorphic rocks

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Exhumed metamorphic rocks are remnants of the past deep crust, and in many cases continue to their equivalents in the present deep crust. Density, acoustic-velocity and acoustic-impedance structures of metamorphic belts obtained from laboratory-measured densities and acoustic velocities of such metamorphic rocks provide useful information in seismic experiments of the deep crust as well as of intraplate seismogenic faults. We illustrate an example of laboratory measurements of densities and acoustic velocities of the Hidaka metamorphic rocks, and compare the laboratory-derived seismic reflectivity with the results of a series of recent seismic reflection profiling across the Hidaka metamorphic belt.

The Main Zone of the Hidaka metamorphic belt represents a partial section through the ancient Kuril arc crust, whose upper 23 km are estimated to be exposed at the surface along the Hidaka Main Thrust by collision of the Kuril arc against the Northeast Japan arc since middle Miocene (Komatsu et al., 1983). In fact, a series of recent seismic reflection profiling across the Hidaka metamorphic belt, including 94 Hidaka (Arita et al., 1998), 96 Hidaka (Ikawa et al., 1997) and 97 Hidaka (Tsumura et al., 1999), reveals a delamination-wedge structure of the Kuril arc crust, with its upper part being thrust up along the Hidaka Main Thrust, while its lower part descending downward (Ito, 2000). It also reveals a strongly reflective and laminated feature of the lower Kuril arc crust as well as a relatively transparent feature of its upper crust, with the upper lower crust and its upward being thrust up.

The Hidaka metamorphic Main Zone is composed of greenschist to amphibolite facies felsic metamorphic rocks and tonalite with migmatite in its upper main part, while it is dominated by granulite-facies amphibolite frequently intercalated with 5-200 m thick layers of felsic granulite and tonalite. Felsic metamorphic and igneous rocks have densities of 2.7-2.8 g/cm^3, and P-wave velocities of 5.3-5.8 km/s in the foliation-normal direction at 150 MPa confining pressures where the effects of cracks are negligible. In contrast, amphibolites have densities of about 3.0 g/cm^3 and P-wave velocities of about 6.2 km/s. Hence the boundary between the upper main part composed of felsic metamorphic and igneous rocks and the basal part dominated by amphibolite is a distinct discontinuity of density and P-wave velocity. This discontinuity is estimated from metamorphic conditions to be located at about 17 km depth in the ancient Kuril arc crust, and likely corresponds to a Conrad discontinuity. Overall similarity in acoustic impedance values of felsic metamorphic and igneous rocks suggests lack of strong seismic reflectors in the upper main part. In contrast, the interlayering of amphibolite and felsic rocks with large contrasts in acoustic impedance suggests abundance of strong seismic reflectors in the basal part. In fact, 1-D seismic reflection modeling of foliation-normal ray propagation with frequencies of 5-30 Hz, which are dominant in the 94-97 Hidaka seismic reflection data, shows scarce and weak reflections in the upper main part while many strong reflections in the basal part. Such seismic reflectivity inferred from the acoustic impedance structures of the Hidaka metamorphic belt is well correlatable with that above the Hidaka Main Thrust revealed by the recent seismic reflection profiling, which supports that the uppermost part of the Kuril arc's lower crust and its upward is exposed at the surface along the Hidaka Main Thrust.