Gas permeability and porosity of Neogene and Quaternary sedimentary rock of Horonobe area, Japan, as a function of stress history

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Deep underground has been brought to attention as a site of geological deposit of high/low-level radioactive waste or CO_2. It is obviously important to evaluate the distribution of hydraulic properties in deep part of sedimentary basin for these usages. Hydraulic properties of sedimentary rock have changed through processes of sedimentation and diagenesis, and should highly depend the history of stress conditions which the sediments has experienced. It is very important to understand how these processes affect hydraulic properties, because it can make possible to evaluate properties in underground space from geological settings and properties at ground surface. We performed permeability and porosity measurements by laboratory test under high pressure of Neogene and Quaternary sedimentary rock specimens from Horonobe area, northern Hokkaido island, Japan. Japan Atomic Energy Agency (JAEA) has been performing various and systematic investigations on geological environment of this area in these days, including 11 research drillings of several hundred meters length. We therefore can be offered many rock samples from deep part, and also can evaluate the results by comparing with results of various studies. We collected specimens used in measurements from Yuchi (sandstone), Koetoi (siliceous mudstone), and Wakkanai (shale) formations, which distribute widely in Horonobe area. Specimens used in measurements were collected from the drilling cores, and also from outcrops. We prepared cylindrical specimens from samples having a diameter of 25 or 20mm and a length of approximately 10 to 40mm. We performed measurements of permeability and porosity with intra-vessel deformation fluid-flow apparatus in Kyoto University, using nitrogen as pore fluid, at room temperature, under hydrostatic stress. The confining pressure, P_c, was incrementally increased from 3 MPa to a peak value, 80 to 120 MPa, after which it was decreased incrementally to the initial value. Permeability and porosity was measured at several stages in the P_c cycle.

Porosity changes as a function of P_c showed the similar tendency as common clay; the slope of the curve at loading path changes at certain P_c in general, such as over-consolidation and normal-consolidation state in soil mechanics. The gradients of the curves at each state are similar to other specimens from the same rock, in both porosity and permeability-log P_c relations, although the value itself is different from each other. In the case of soil, the stress state around the transition from over-consolidation state and normal-consolidation state, or bending of the curve, is close to the maximum pressure which sample has experienced. We estimated the maximum burial depth based on geological data and the knowledge that the phase transition of amorphous silica from Opal-A to Opal-CT, corresponding to the boundary between Wakkanai and Koetoi formations, occurs under a certain temperature, and compared the depth with P_c around the bending of porosity-log P_c curves. The results indicate that P_c corresponding to bending of porosity-log P_c curve has positive correlation with maximum pressure which sample has experienced. The values of pressure itself, however, do not agree well with each other. Logalism of measured gas permeability is in proportion to porosity, and the slope is similar to those of other specimens from the same kinds of rock in general. The permeability values themselves of outcrop specimens tend to be larger than these of specimens from drilling cores, which is probably because size of small pore controlling flow rate increased by weathering. The permeability value of Koetoi drilling core specimen from the bottom of the formation is smaller than that from other parts of the core. This may reflect that the phase transition from Opal-A to Opal-CT has partially progressed, and therefore the size of pore decreases.