Comparison of laboratory-measured permeability with in-situ tests for the Neogene sedimentary rocks of Horonobe, Hokkaido, Japan

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Determination of underground transport properties is needed in modeling underground fluid flow, which is critically important in many problems such as fluid circulation, waste isolation, and carbon dioxide sequestration. A method to evaluate properties under the depth deeper than several km is necessary for some objectives, such as investigation of long-term fluid circulation at upper crust, or evaluation of a site for carbon dioxide sequestration needs the method.

One of methods suitable for such purpose is the method by using laboratory hydraulic tests. This method estimates hydraulic properties at the target domain based on evaluation of the dependency of hydraulic properties on stress conditions, by using laboratory tests with the fresh specimens from the same layer as the target domain, collected from outcrop or drilling cores. However, the applicability of this method has not been tested enough so far, and therefore it is necessary to evaluate the applicability at the sedimentary-rock site where there are enough data from in-situ hydraulic tests.

We addressed this issue as an example of sedimentary rocks in Horonobe area, northern Hokkaido, Japan, where Horonobe Underground Research Center of Japan Atomic Energy Agency has been conducting the investigations of the deep geological environment within the sedimentary rocks, including 11 boreholes drilled down to the maximum depths of ca. 1 km. More than 65 in-situ measurements of hydraulic conductivity were done in Horonobe, providing a rare opportunity for comparisons of laboratory and in-situ data on transport properties.

Gas and hydraulic permeabilities of specimens from the outcrops and drilling cores were measured with a flow method under constant pressure difference, using an intra-vessel deformation and fluid-flow apparatus. One of the important hydraulic characteristics of sedimentary rock is the effect of discontinuities in rock on its bulk permeability. In the case of high porosity sedimentary rock, discontinuities could not affect the bulk permeability under some stress conditions. The effect of discontinuities on rock hydraulic property should depend on rock or stress conditions, and it is very important to evaluate this property. We therefore operated laboratory tests for the specimens with discontinuity made by diamond cutter as well, and examined the possibility to evaluate the effect of discontinuities on rock bulk permeability.

The Neogene sedimentary rocks of Horonobe area consist of Yuchi, Koetoi, and Wakkanai Formations in the descending order. Hydraulic conductivity of Wakkanai Formation obtained by in-situ measurements are compared with gas permeability as measured with a flow method for intact specimens, for fractured specimens and for fault breccia zones of Wakkanai Formation. The comparison shows that the in-situ data on hydraulic permeability are bracketed by hydraulic conductivity estimated from permeability values for fault breccia and intact rock. This will lead to a very simple way of estimating possible range of underground hydraulic properties by measuring transport properties of intact and brecciated surface samples, although this has to be tested with other examples. In-situ data for hydraulic conductivity of lower part of Koetoi Formation is very close to that estimated from gas permeability of intact specimen, far smaller to those for brecciated samples. This result probably reflects the properties that the effects of fault and fractures are less for this Formation than for Wakkanai Formation. The results of specimens with a discontinuity also supported this possibility; that is, the specimen with a discontinuity from Koetoi Formation has an the almost same permeability to that of intact specimen under high confining pressure, and, on the other hand, the differences between permeability values of an intact specimen and a specimen with discontinuity are obvious even under 80MPa.