



Evolution of permeability and microstructure of experimentally-created shear zones in Neogene siliceous mudstones from Horonobe, Japan

Shin-ichi Uehara^{a,*}, Miki Takahashi^b

^a Department of Environmental Science, Faculty of Science, Toho University, 2-2-1 Miyama, Funabashi, Chiba 274-8510, Japan

^b Active Fault and Earthquake Research Center, Geological Survey of Japan, The National Institute of Advanced Industrial Science and Technology (AIST), Central 7, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan

ARTICLE INFO

Article history:

Received 7 April 2012

Received in revised form

1 December 2013

Accepted 9 December 2013

Available online 31 December 2013

Keywords:

Fault

Permeability

Mudstone

Rock mechanics

Laboratory experiment

Micro-focus X-ray CT

ABSTRACT

We report experimental measurements of bulk permeability changes due to a shear zone that is induced in siliceous mudstones collected from the Koetoi and Wakkanai Formations, northern Hokkaido, which are known to show different relationships between fault/fracture distribution and groundwater flow. We evaluate distributions of volumetric deformation in the induced shear zones by using micro-focus X-ray computed tomography. Measured permeability evolution while achieving the peak axial stress for specimens differed for the samples of the two formations. Permeability did not change obviously during shear for the Koetoi Fm. specimens, but in the Wakkanai Fm. specimens, the bulk permeability increased by a factor of 2.5 after reaching the peak stress. The difference in permeability change in these experiments can explain the differences in relationships between in situ groundwater flow and fracture distribution for the two formations. Analyses of the X-ray images reveal that this difference should reflect the differences of the volumetric deformation in the induced shear zones. Pore collapse occurred in the shear zone in the Koetoi Fm. specimen, which leads to porosity reduction, whereas fracture damages developed in the Wakkanai Fm. specimen, increasing porosity. These differences in the microstructure may reflect differences in yielding criteria for these host rocks.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Characterizing the fluid flow properties of mudstones or siltstones is important when considering topics such as fluid flow in sedimentary basins (Bjørlykke, 1993) and accretionary prism (Behrmann, 1991; Brown et al., 1994), hydrocarbon accumulations (Fisher and Knipe, 1998) or geological sequestration of industrially-produced greenhouse gases (Cappa and Rutqvist, 2011). Fault zones play an important role in controlling the fluid flow in mudstones (Ingram and Urai, 1999). Fluid-flow properties of fault zones in mudstone depend on several factors such as mechanical properties of the host rock. For instance, in general, dilatant and permeable shear fractures form in rocks during deformation under small confining pressure and/or in relatively strong or brittle rocks, while compactive shear fractures occur during deformation of rocks at large confining pressure

and/or during deformation of weak or ductile rocks (Ingram and Urai, 1999). To fully understand how such factors affect flow properties of fault zones, it is important to study in detail the fluid flow properties of fault zones in mudstone, including in situ measurements, characterization of fault-zone structure, and the geological setting.

The Neogene sedimentary basin in the Horonobe area, northern Hokkaido (Fig. 1), is a suitable place for this type of study. The Japan Atomic Energy Agency (JAEA) established Horonobe Underground Research Center in 2001 and has conducted very detailed geological and hydraulic studies, including drilling 11 boreholes and completing 66 in situ measurements of hydraulic conductivity (Horonobe Underground Research Center, 2004; Niizato et al., 2007; Ota et al., 2007; Kurikami, 2007; Kurikami et al., 2008; Funaki et al., 2009; Ishii et al., 2010, 2011; Uehara et al., 2012).

At this site, the Koetoi Fm. (late Miocene to Pliocene, diatomaceous mudstone) and the Wakkanai Fm. (middle to late Miocene, siliceous mudstone) differ in their relationships between fault/fracture distribution and groundwater flow. Funaki et al. (2009) detected fracture distributions and locations of fast water flow in a drill hole at this site from core logging, acoustic televiewer and

* Corresponding author. Tel.: +81 (0)47 472 5596; fax: +81 (0)47 472 7039.

E-mail addresses: shinichi.uehara@sci.toho-u.ac.jp, shin1uehara@gmail.com (S.-i. Uehara), miki.takahashi@aist.go.jp (M. Takahashi).

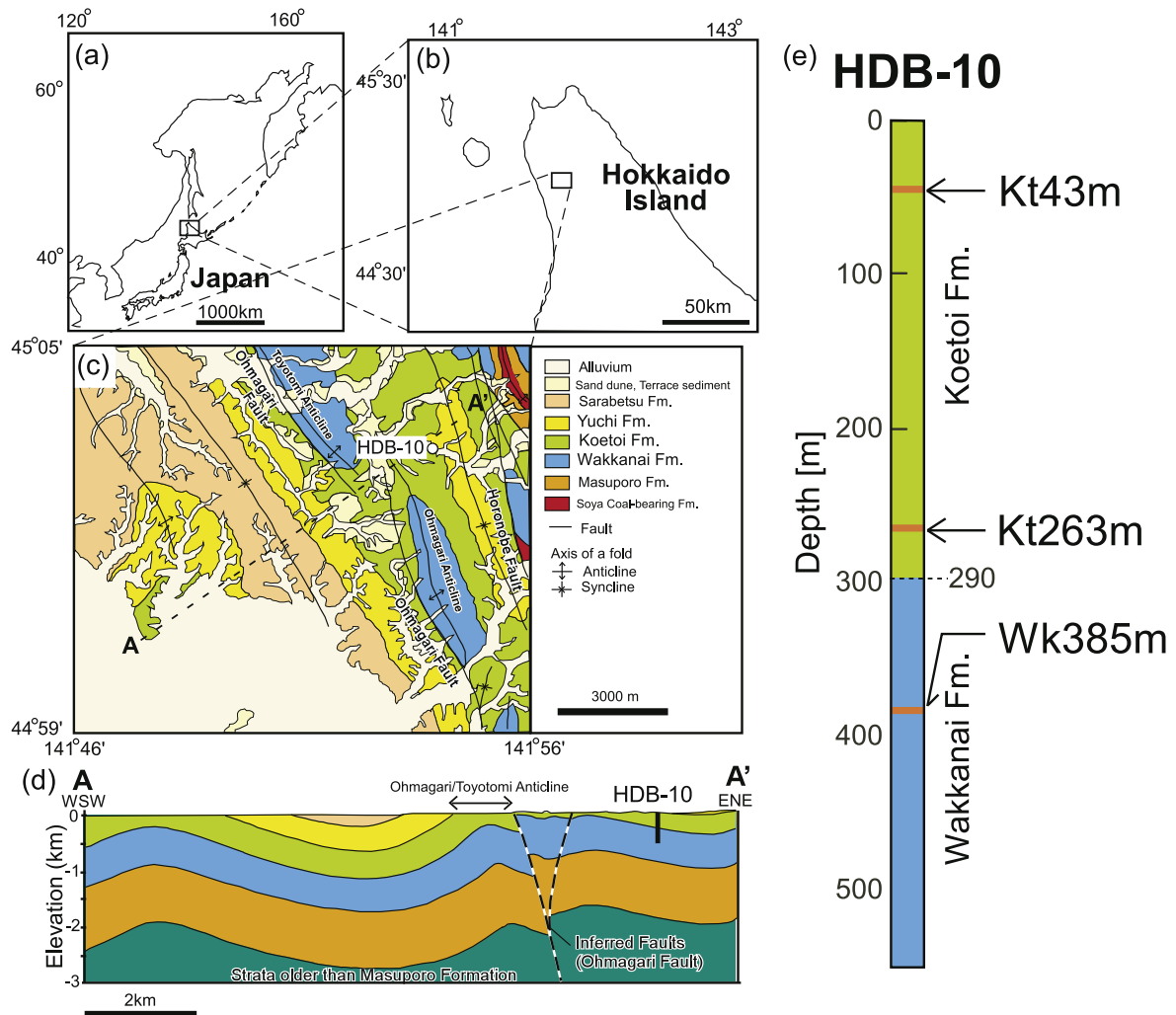


Fig. 1. (a), (b) Location maps (upper-left). (c) Geological map of the study area (middle-left), a open circle is bore hole site. (d) Geological cross section (lower-left) along the A–A' line in the geological map (compiled from previous studies, e.g., Ota et al., 2007). Borehole HDB-10 projected into profile as a black line showing penetration depth. (e) Sedimentary formations in the borehole of HDB-10 (right).

fluid electric conductivity logging. They determined that in the Wakkanai Fm., the fracture distribution strongly correlated to locations of fast groundwater flow into the drill hole, whereas a weak correlation existed for the Koetoi Fm. This difference in flow properties can be explained by differences in deformation, i.e., brittle or ductile, and can be characterized using a brittleness index (BRI) from laboratory tests, which is the ratio of unconfined compressive strength to effective vertical stress (Ishii et al., 2011). To further understand the relationship between deformation behavior and the flow properties at the Horonobe area, and to reveal factors controlling the flow properties, we conducted laboratory experiments to measure permeability evolution during shear deformation of these Horonobe mudstones. In addition, we imaged the pore distributions of the induced shear zones by using micro-focus X-ray computed tomography (CT) to investigate microstructural textures and their relationship to flow and mechanical properties.

2. Specimen preparation and experimental method

The samples were taken from drill cores of the borehole HDB-10 drilled by JAEA (Fig. 1; e.g., Ota et al., 2007). The HDB-10

borehole penetrated the Koetoi and Wakkanai Fms. The Koetoi Fm. consists mainly of diatomaceous mudstone. The Wakkanai Fm. consists mainly of siliceous mudstone and is more strongly cemented than the overlying the Koetoi Fm. Fukusawa (1985)

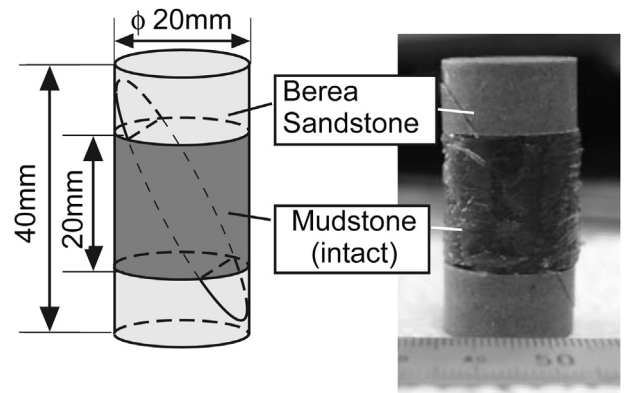


Fig. 2. Schematic illustration and photograph of specimen geometry. Note that the mudstone specimen is intact and there is no pre-cut surfaces prior to the experiments.

Download English Version:

<https://daneshyari.com/en/article/6444929>

Download Persian Version:

<https://daneshyari.com/article/6444929>

[Daneshyari.com](https://daneshyari.com)