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Change in Permeability of Cretaceous Sandy Shale in Kushiro Coal Mine due to Axial Stress Disturbance

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Abstract

Earthquake-induced stress disturbances caused the water level change in the far-field wells. During the Cold War, the artificial surface vibration in Russia to confuse the source location of underground nuclear tests by Western countries promoted the increase of natural gas production of the nearby wells. The above phenomena might be due to the increase in permeability by the transient stress disturbances resulting from the new pathways being created or the existing pathways being unclogged. Thus, the research was aimed to investigate on the change in permeability due to transient stress disturbance. The permeability change principle might be promoted the enhancement of methane gas recovery, prevention of large earthquake by inducing small earthquakes and de-routing of contaminated ground water flow in the future. The permeability of Cretaceous sandy shale tended to decrease by the disturbances. The smaller the stress amplitude, the larger the decrease in the permeability was. However, the decrease amount was smaller at no disturbances. Increasing and decreasing factors may be working together.

1. Introduction

Earthquake-induced stress disturbances caused the water level change in the far-field wells (Manga et al., 2012). During the Cold War, the artificial surface vibration in Russia to confuse the source location of underground nuclear tests by Western countries promoted the increase of natural gas production of the nearby wells (Roegiers, 2016). The above phenomena might be due to the increase in permeability by the transient stress disturbances resulting from the new pathways being created or the existing pathways being unclogged (Manga et al., 2012).

Thus, the research was aimed to investigate on the change in permeability due to transient stress disturbance. The permeability change principle might be promoted the enhancement of methane gas recovery, prevention of large earthquake by inducing small earthquakes and de-routing of contaminated ground water flow in the future.

2. Material and method

Kushiro Coal Mine is the only one underground coal mine situated in southeastern Hokkaido, Japan. The mine is located along with the Pacific Ocean, and mining coal under the sea floor. Methane gas has been extracted from Cretaceous underlying the Paleogene coal bearing formations (Fig. 1). The specimens of Cretaceous sandy shale were sampled from borehole No. 72, in the depth of 322.65 to 323.50 m, and from the second drilling pit at the inclined shaft 650 m from the entrance (Fig. 2a). Under the polarizing microscope, a sandstone sampled in the vicinity showed fine dispersed organic matter fragments and small lenses of carbonaceous matters (Fig. 2b). The amount of organic carbon was about 0.15 to 0.59% and the C/N ratio was in the range of 7.0 to 14.0.

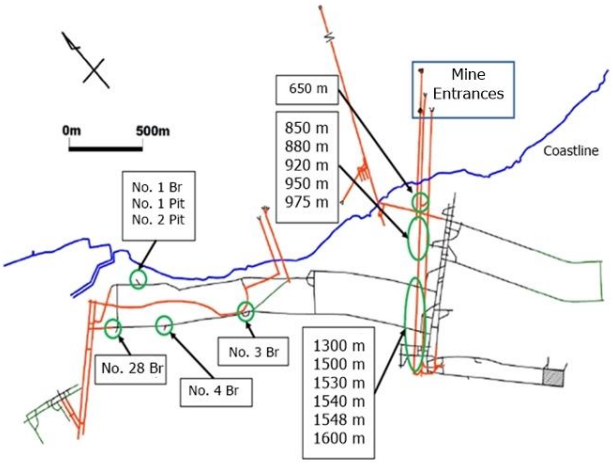

Fig. 1 Location of gas wells for Cretaceous rock mass at Kushiro Coal Mine (Matsumoto et al., 2014).

(a) (b)

Fig. 2 (a) Cores of Cretaceous sandy shale, and (b) polarizing microscope image of a sandstone (the width is 3.5 mm, Matsumoto et al., 2014).

A cylindrical specimen with a diameter of 30 mm and length of 60 mm was attached to the stainless steel endpieces. These endpieces have the central holes to allow water pass through the specimen. The silicon sealant for maintaining the water flow within the specimen was applied to the surface of the specimen. A heat-shrinkable tube was jacketed to the endpiece-attached specimen to prevent direct contact of the confining fluid with the specimen.

The specimen was inserted into the triaxial cell (Alam et al., 2014) then saturated for 24 hours by pure water in a water-submergible vacuum jar. The pore water pressure of 1 MPa was applied at the bottom of the specimen and the upper end was opened to the atmospheric pressure (Fig. 3) after the confining pressure of 3 or 10 MPa was applied.

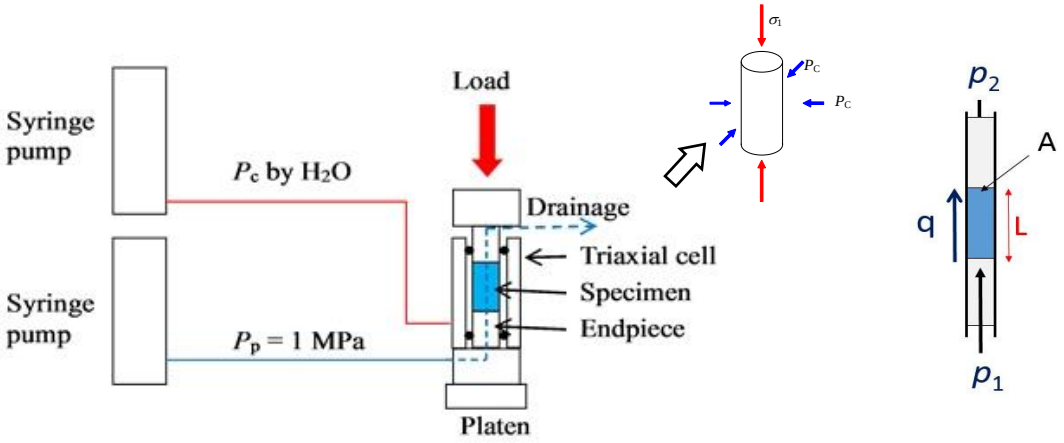

Fig. 3 The schematic diagram of experimental apparatus showing the permeability measurement using the constant flow method.

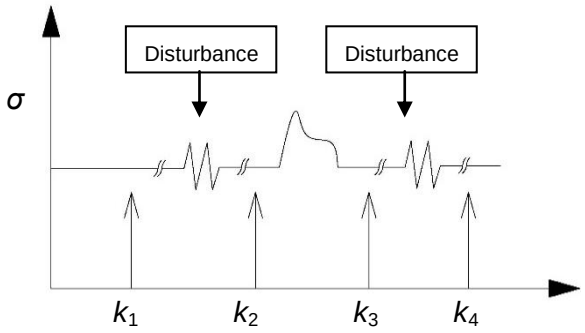

Fig. 4 The schematic of permeability measurement for each test stage.

The intact specimen was kept under constant hydrostatic pressure for 24 hours, then the axial stress disturbance of 0, 1 and 5 MPa with the frequency of 0.5 Hz in the duration of 200 seconds was applied. The specimen was kept once more under constant hydrostatic pressure for 24 hours. The axial compression was applied at 10^{-5} s^{-1} until the residual strength state was confirmed, then it was held on under constant hydrostatic pressure for 24 hours. Axial stress disturbance was applied and the constant hydraulic pressure was carried out again.

The permeability of the intact rock was measured as permeability k_1 (Fig. 5a), before the stress disturbance (Fig. 5b), and disturbed rock permeability as k_2 (Fig 5c). After the triaxial compression (Fig. 5d), the permeability of the post-failure rock was measured as k_3 (Fig. 5e).

The same stress disturbance was again applied (Fig. 5f) and the permeability k_4 was measured (Fig. 5g).

The permeability k (m^2) was evaluated by the constant flow method.

$$k = \frac{q\mu}{A}\left(\frac{\mathrm{d}p}{\mathrm{d}x}\right)^{-1} \qquad \text{(eq.1)}$$

where q is the flow rate (m^3/s), μ is the fluid viscosity (Pa·s), A is the cross-sectional area (m^2) of the specimen, and dp/dx is the pressure gradient (Pa/m). The viscosity of water (μ) is 9.57 x 10^{-4} (Pa·s) at 295 K.

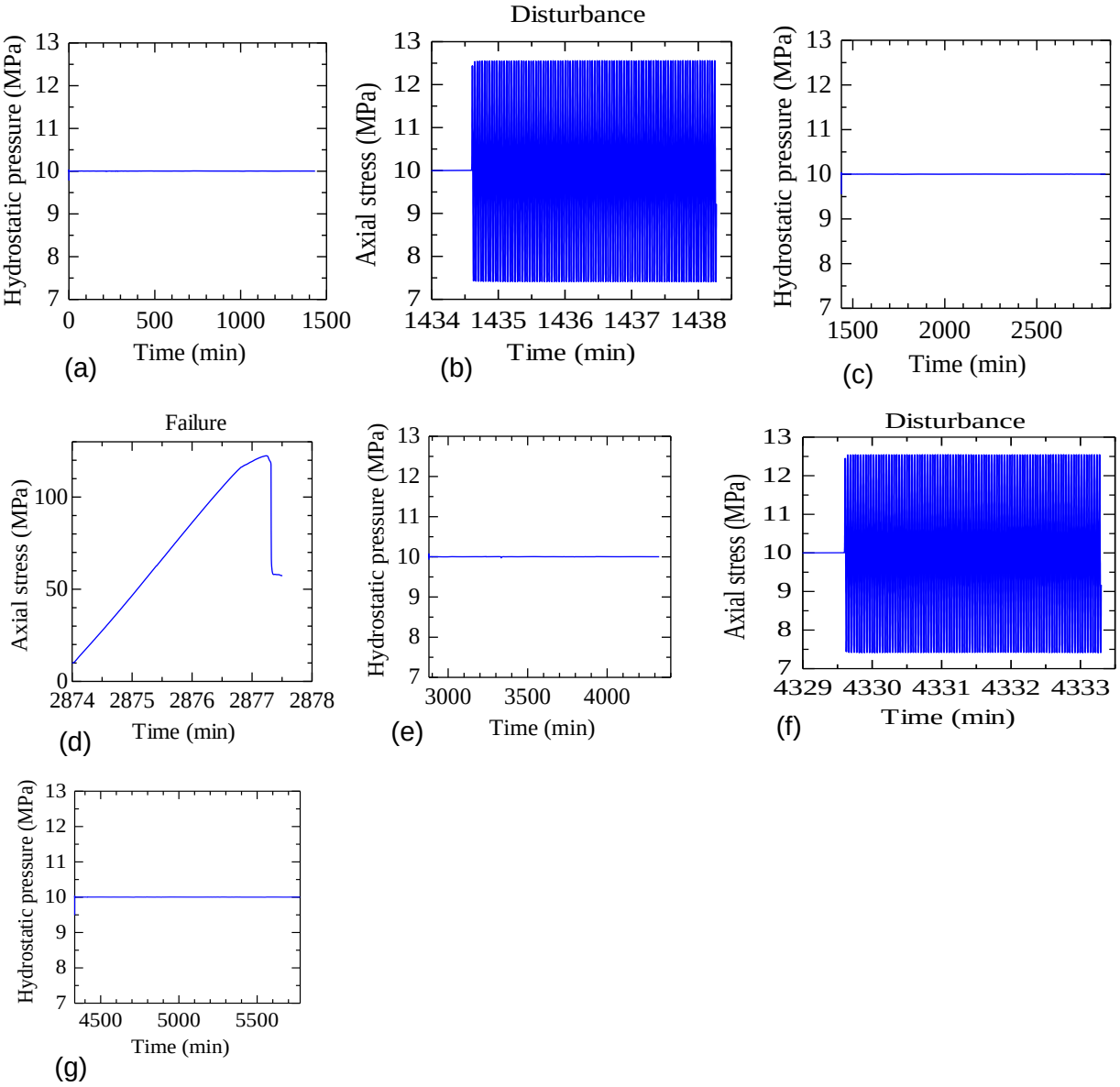

Fig. 5 The applied axial stress (P_c = 10 (MPa) and $\Delta\sigma_A$ = 5 (MPa)) in the experiment, (a) Hydrostatic pressure for 24 hours, (b) stress disturbance with the amplitude of 5 MPa, (c) applied hydrostatic pressure for 24 hours on the disturbed rock, (d) triaxial compression, (e)

hydrostatic pressure for 24 hours, (f) stress disturbance, and (g) hydrostatic pressure for 24 hours.

3. Result and Discussion

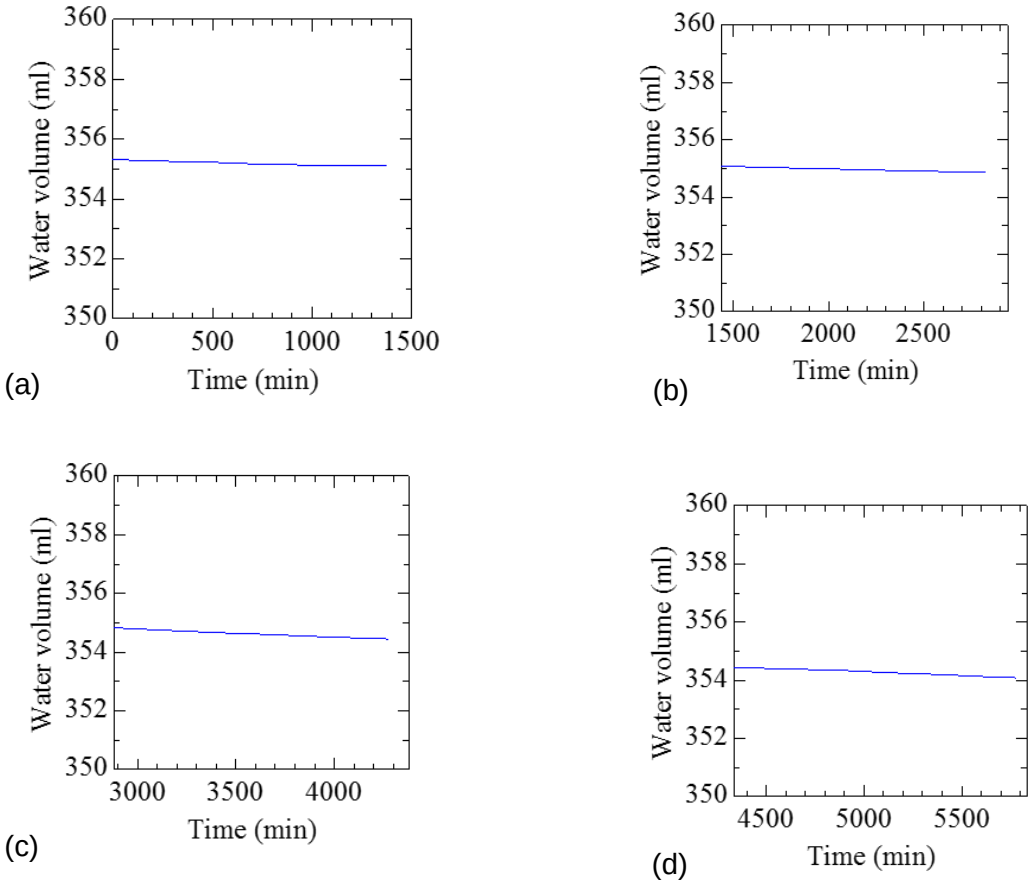

Fig.6 Water volume change in syringe pump for (a) intact rock, (b) disturbed rock, (c) post-failure rock, (d) disturbed post-failure rock (P_c = 10 (MPa) and $\Delta\sigma_A$ = 5 (MPa)).

The permeability was calculated based on the change in water volume (Fig. 6). The permeability of the intact rocks from the test was in the range between 2 and 3 x 10^{-19} m^2. The permeability tended to decrease from k_1 to k_2 and k_3 to k_4 due to the axial stress disturbances. This might be due to the consolidation. Manga et al. (2012) suggested the stress disturbances produced the dissolved mass transportation by diffusion within water films into the pore space. The permeability increased from k_2 to k_3 by rock fractured (Fig. 7a). This is natural under low confining pressure (Alam et al., 2014).

The rate of decrease in permeability was the minimum for the small stress disturbances (Fig. 7b and 7c). This may be because the increase of the permeability by displacement of the rupture plane under larger stress disturbance (Fig. 8b) is offsetting the permeability decreases by consolidation (Fig. 8a).

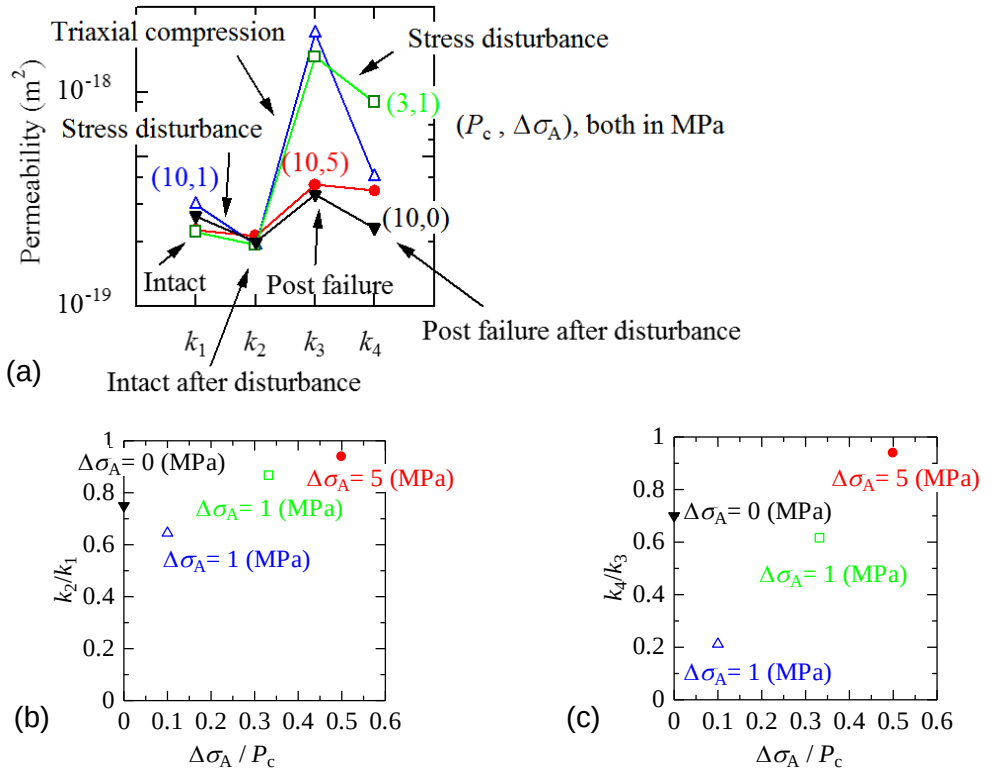

Fig. 7 (a) Change in permeability due to stress disturbance and triaxial compression, (b) permeability change in pre-failure, and (c) permeability change in post-failure as a function of $\Delta\sigma_A/P_C$.

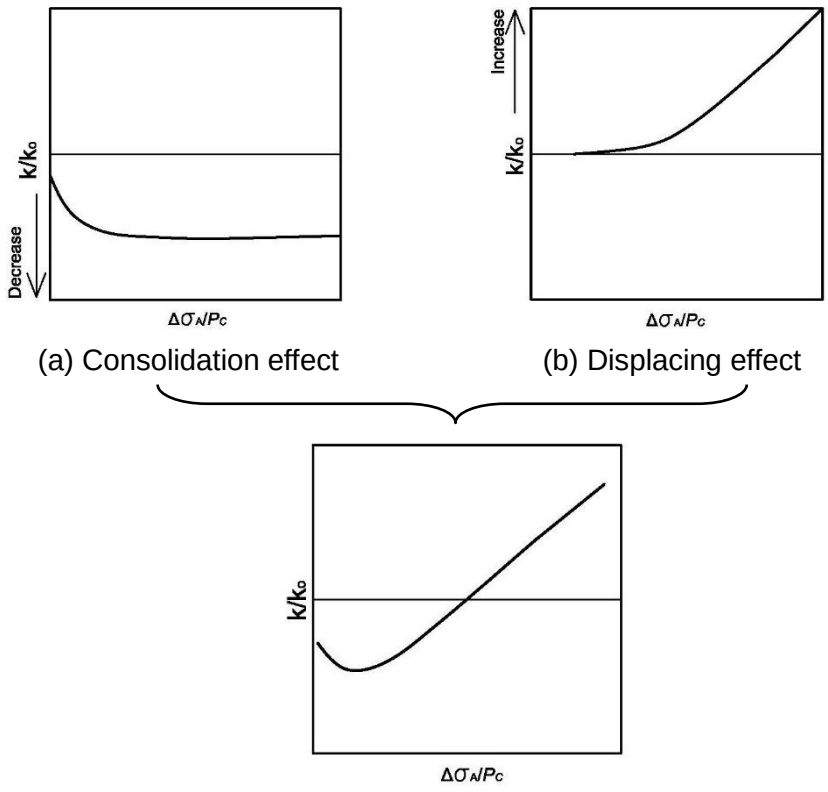

Fig. 8 Effect of consolidation and displacement effect on permeability.

4. Concluding remarks

The effect of the axial stress disturbance on permeability was elucidated in this research. The permeability of Cretaceous sandy shale tended to decrease by the disturbances. The smaller the stress amplitude, the larger the decrease in the permeability was. However, the decrease amount was smaller at no disturbances. Increasing and decreasing factors may be working together. The data accumulation for various rocks under various conditions is regarded to clarify the controlling factors of permeability change.

References

Alam, A. B., Niioka, M., Fujii, Y., Fukuda, D., & Kodama, J. (2014). Effects of confining pressure on the permeability of three rock types under compression. *International Journal of Rock Mechanics and Mining Sciences, 65*, 49-61.

Manga, M., Beresnev, I., Brodsky, E. E., Elkhoury, J. E., Elsworth, D., Ingebritsen, S., Wang, C.-Y. (2012). Changes in permeability caused by transient stresses: Field observations, experiments, and mechanisms. *Reviews of Geophysics, 50*(2).

Matsumoto, H., Uchida, K., Takahashi, T., Fujii, Y., Kodama, J., & Ayizawa, J. (2014). *2nd Report of Activity of Rock Formation Gas Exploration Subcommittee.* A4-2, Proc. MMIJ2014 (Kumamoto), Japan.

Roegiers, J.-C. (2016), Personal Communication at ARMA2016 Meeting in Houston, June 29.