Geophysical Research Abstracts
Vol. 12, EGU2010-2284-1, 2010
EGU General Assembly 2010

Influence of temperature and water on subcritical crack growth in sandstone

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Understanding time-dependent brittle deformation due to slow crack growth is important in many geological applications. Time-dependent fracture propagation has been invoked as the key mechanism responsible for the increase in seismicity preceding earthquake ruptures and volcanic eruptions. In addition, when designing sub-surface structures in the rock mass, such as repositories for radioactive waste and underground power plants, it is essential to consider their long-term stability. In order to ensure long-term stability, it is necessary to evaluate the long-term strength of the rock. In turn, this requires an understanding of time-dependent fracture propagation such as subcritical crack growth. Environmental dependence of subcritical crack growth in igneous rocks has been studied well. However, that in sedimentary rocks has not been clarified yet.

In this study, the effects of the temperature and water on subcritical crack growth in sandstone were investigated. Berea sandstone and Shirahama sandstone were used as rock samples. The load relaxation method of Double Torsion (DT) testing method was used to measure the crack velocity and the stress intensity factor under controlled environmental conditions.

In water, it was shown that the crack velocity at a given stress intensity factor increased when the temperature increased. This agrees well with the theory of stress corrosion.

In air, however, it was shown that the change of the crack velocity at a given stress intensity factor was not clear when the temperature increased under a constant relative humidity. On the other hand, the crack velocity at a given stress intensity factor increased by several orders of magnitude when the relative humidity increased threefold or fourfold under a constant temperature. This increase is much larger than that expected from the conventional concept based on the theory of stress corrosion. Additionally, the increase of the crack velocity was larger for Shirahama sandstone which contained larger amount of clays.

It is important to investigate the water content of rock specimen in each condition in air. It was found that the water content decreased with increasing the temperature under the constant relative humidity. This can be the main reason why the change of the crack velocity was little when the temperature changed in air.

It is also important to consider the influence of clay on crack growth in sandstone. In general, the strength of clay decreases when the water content of clay increases. When the relative humidity increased, the water content of a sandstone specimen also increased. This can lead to the decrease of the strength and resistance to crack propagation for clay in sandstone.

It is concluded that subcritical crack growth in sandstone in air is affected remarkably by the relative humidity and the amount of clays in rock. Considering that the long-term strength relates to subcritical crack growth, it is concluded that the control of the humidity in air and retardation of water migration into and through a sandstone rock mass are essential to ensure the long-term stability.