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Technical note

P-wave propagation in dry rocks under controlled temperature and humidity

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1. Introduction

Pre-existing cracks are ubiquitous at a wide range of scales in crustal rocks. In the upper crust, the presence of cracks has remarkable effects on the physical, transport, strength and fracturing properties of rock. Therefore, investigations of the distribution of cracks in rock can be important.

The existence of cracks makes rock more compliant,[1] and also makes them more permeable if the cracks are linked.[2,3] In the case of granite, the preferred orientation of pre-existing cracks produces anisotropies in strength[4,5] and fracture toughness,[6] In particular, it has been shown that fracture toughness is lowest when fracturing occurs in the direction parallel to the rift plane in which most pre-existing cracks are distributed.[6]

Humidity is known to affect strength and fracturing in rock. For example, Fujii et al.[7] reported that the strength of sandstone in Kushiro Coal Mine in Japan (Kushiro sandstone) decreases as water content rises. According to,[7] rock fall is common in a mining gallery in Kushiro Coal Mine during summer when the relative humidity is high. Also, Nara et al.[8,9] reported from subcritical crack growth measurements that the crack velocity at a given stress intensity factor increases when the relative humidity increases in air. Nasseri et al.[10] reported that the fracture toughness of granite decreases as the density of cracks increases. Nara et al.[11] showed that the fracture toughness of rock in air decreases when the relative humidity increases. Kataoka et al.[12] reported that the fracture toughness of rock decreases as water vapor pressure increases. These reports indicate that mechanical properties such as strength and resistance to fracturing in rock are dependent on the relative humidity of water vapor pressure in the surrounding environment. In addition, the conditions of pre-existing cracks and pores in rocks may change; i.e., some pre-existing cracks and pores may open while others close when the relative humidity in the surrounding environment changes. Therefore, it is important to investigate the opening and closing of cracks and pores under different relative humidities.

In that regard, the effects of relative humidity on crack opening and closing in rock have not been sufficiently investigated. In general, P-wave velocity in rock depends on the density of the crack[13–16] and the porosity.[17] An effective method for investigating the influence of the relative humidity on rock cracks is, therefore, the measurement of P-wave velocity under different relative humidity conditions. Temperature and relative humidity can be controlled precisely in a laboratory. Thus, measurements of wave velocity in a laboratory under controlled temperature and relative humidity conditions can be made effectively.

In this study, we measured P-wave velocities in samples of the Berea, Shirahama, and Kushiro sandstones and Oshima granite in air

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under a controlled temperature and relative humidity. In particular, we investigated changes in velocity under various humidity conditions to assess whether the opening or closing of crack and pores happens in the rock in response to changes in the relative humidity of the surrounding environment. Simultaneously, we measured the water content of the rock. Note that temporal changes in the P-wave velocity and water content were investigated at the same time under controlled humidity conditions.

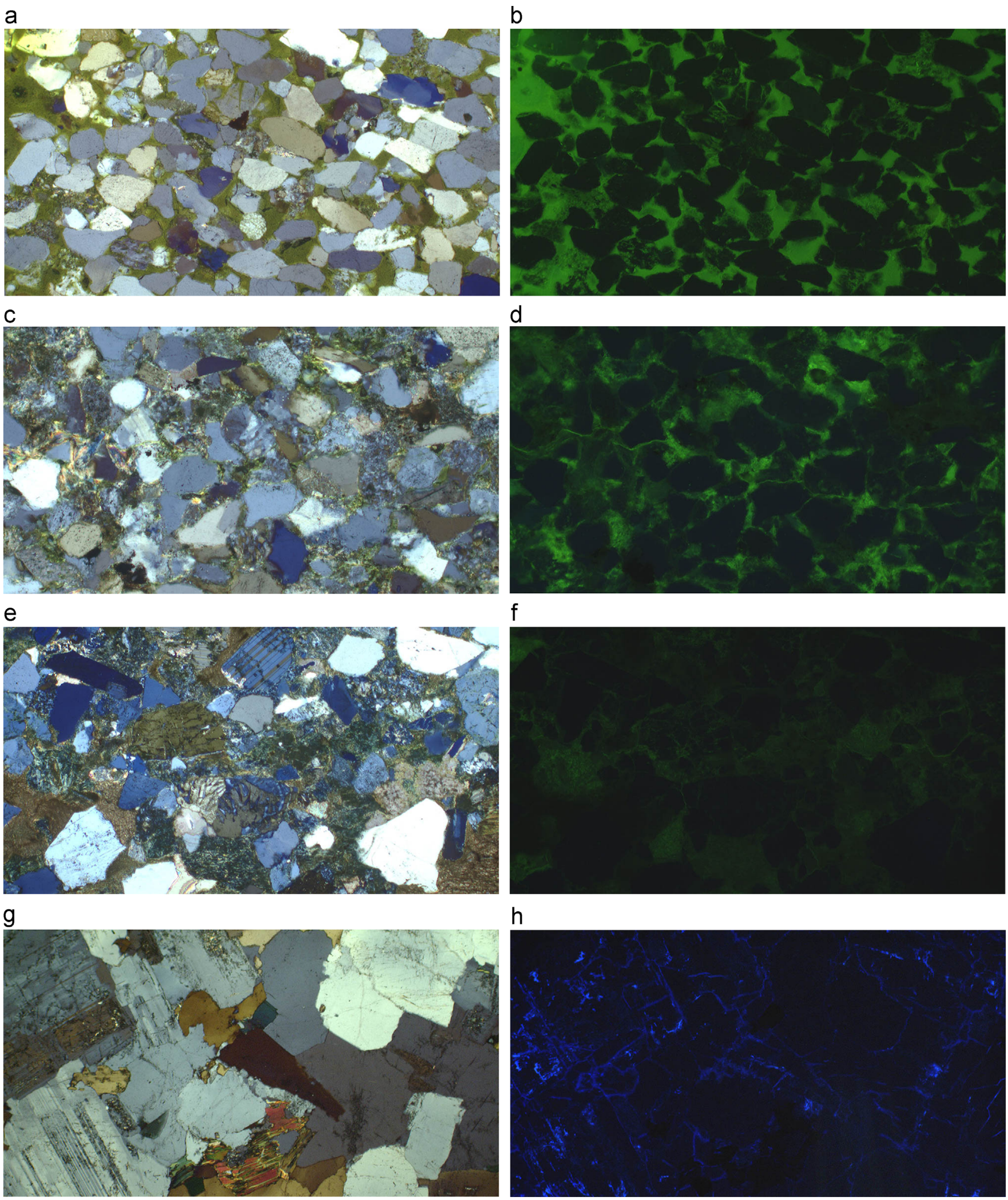

Fig. 1. Photomicrographs of Berea sandstone ([a] and [b]), Shirahama sandstone ([c] and [d]), Kushiro sandstone ([e] and [f]), and Oshima granite ([g] and [h]). The height and length of the photomicrographs of Shirahama sandstone are 0.53 mm and 0.98 mm, respectively. The height and length of photomicrographs of other samples are 1.85 mm and 3.42 mm, respectively. (a), (c), (e), and (f) were taken under crossed nicols. (b), (d), (f), and (h) were taken under ultraviolet light.