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Experimental simulation of frost wedging-induced crack propagation in alpine rockwall

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Frost wedging is widely presumed to be the principal mechanism responsible for shattering jointed low-porosity rocks in high alpine rockwalls. The interaction of ice and rock physics regulates the efficacy of frost wedging. In order to better understand temporal aspects of this interaction, we present results of a series of laboratory experiments monitoring crack widening as a result of ice formation in an artificial crack (4mm wide, 80mm deep) cut 20 mm from the end of a rectangular granite block. Our results indicate that i) freezing direction plays a key role in determining the magnitude of crack widening; in short-term (1 day) experiments, maximum crack widening during top-down freezing (associated with 'autumn' conditions) was around 0.11mm, while inside-out freezing (resulting from 'spring' conditions) produced only 0.02 mm of deformation; ii) neither ice, nor water pressure (direct tension and hydraulic fracturing respectively) caused measurable irreversible crack widening during short-term tests, as the calculated maximum stress intensity at the crack tip was less than the fracture toughness of our granite sample; iii) development of ice pressure is closely related to the mechanical properties of the fracture in which it forms, and as such, the interaction of ice and rock is intrinsically dynamic; iv) irreversible crack widening (about 0.03mm) was only observed following a long-term (53 day) experiment representing a simplified transition from autumn to winter conditions. We suggest this is the result of stress corrosion aided by strong opening during freezing, and to a lesser degree by ice segregation up to one week after the initial freezing period, and downward migration of liquid water during the remainder of the test. Our results suggest the fundamental assumption of frost wedging, that rapid freezing from open ends of cracks can seal water inside the crack and thus cause damage through excessive stresses induced by volumetric expansion seems questionable.