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Effects of water pressure fluctuations on quarrying: subglacial experiments using acoustic emissions

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Quarrying, the growth and coalescence of cracks in subglacial bedrock and dislodgement of resultant rock fragments, is probably the most important mechanism of glacial erosion but may be one of the least understood subglacial processes. Although evidence indicates that erosion rates depend on sliding speed, rates of crack growth in bedrock may be enhanced by changing stresses on the bed caused by fluctuating basal water pressure in zones of ice-bed separation.

To study quarrying in real time, a 12 cm high granite step with a crack in its stoss surface was installed under 213 m of ice at the bed of Engabreen, a temperate glacier in northern Norway. Acoustic-emission sensors monitored crack-growth events in the step as ice slid over it. Vertical stresses on the step and bed, water pressure, and cavity height in the lee of the step were also measured. Water was pumped under high pressure to the lee of the step several times over eight days. Pumping initially caused opening of a leeward cavity, which then closed after pumping was stopped and water pressure decreased. During closure of the cavity, acoustic emissions emanating from the base of the crack in the step increased dramatically. With repeated pump tests, this crack grew with time until the step's lee surface was quarried. Fluctuating water pressure may commonly be necessary to exceed stress thresholds required for crack growth. Stress changes on the bed due to water-pressure fluctuations will increase in magnitude and duration with cavity size, which may help explain the effect of sliding speed on erosion rates.