Transient overpressure in subglacial meltwater corridors during rapid deglaciation of the Fennoscandian Ice Sheet

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Abrupt warming at the Younger Dryas-early Holocene transition triggered rapid melt of the Fennoscandian Ice Sheet. In low relief terrain in Uppland, east-central Sweden, meltwater arriving at the bed was distributed through an arborescent network of subglacial conduits. Evidence for hydrofracture, hydraulic jacking, and the brecciation of rock surfaces on conduit floors indicates transient development of overpressure (Pw > Pi). Small rock hills were distended by fluid flowing into and dilating fractures and burst open. In rapidly opening esker tunnels, boulders up to mega-block size were released and transported at minimum estimated flow velocities of 1-8 m s^{-1}. Inversely graded, poorly sorted, rubble and gravel beds in which the boulders are seated indicate flow of hyper-concentrated, dilatant slurries. Similar damage markers are present in rock-cut meltwater channels, demonstrating that extreme pressure and flow conditions developed transiently in both Röthlisberger- and Nye-channels. Hydraulic damage markers also occur across the floors of 0.4-4.0 km wide meltwater corridors, with disruption of many small roches moutonnées and formation of spreads of angular boulders. Sharp lateral and vertical limits indicate that damage occurred within 1-4 m thick sheets of pressurized meltwater that developed during ice-bed separation. Till layers were eroded or became dilatant and fluid, moving as debris flows. Glacial transport of boulders over short distances (1-100 m) is consistent with glacial ripping of brecciated bedrock in response to brief (days to weeks) accelerations in ice flow.

Hydraulic damage to rock surfaces, release and transport of boulders, and hyper-concentrated flows are typical of ancient and Pleistocene subglacial floods and have been recorded from historic Icelandic jökulhaups. Along segments of Swedish eskers, forming mainly within 10 km of the ice margin, subglacial floods briefly exceeded conduit capacity, forcing overpressure and bursting seals at esker tunnel margins to release sheets and jets of sediment-laden meltwater. Along meltwater corridors, overpressured sheet flow advanced rapidly, before coalescing into conduits and draining. Most hydraulic damage likely occurred rapidly during peak pressure at subglacial flood wave fronts. The former Fennoscandian Ice Sheet provides an accessible testbed for understanding the impacts of transient overpressure during rapid ice sheet melt and analogue for future rapid melting of the Greenland Ice Sheet under anthropogenic warming.