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Analog modeling of pressurized subglacial water flow: Implications for tunnel valley formation and ice flow dynamics

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Tunnel valleys are elongated and overdeepened depressions up to hundreds of kilometers long, several kilometers wide and hundreds of meters deep, found in formerly glaciated areas. These drainage features are interpreted as the result of subglacial meltwater erosion beneath ice sheets and constitute a major component of the subglacial drainage system. Although tunnel valleys have been described worldwide in the past decades, their formation is still a matter of debate. Here, we present an innovative experimental approach simulating pressurized water flow in a subglacial environment in order to study the erosional processes occurring at the ice-bed interface.

We use a sandbox partially covered by a circular, viscous and transparent lid (silicon putty), simulating an impermeable ice cap. Punctual injection of pressurized water in the substratum at the center of the lid simulates meltwater production beneath the ice cap. Surface images collected by six synchronized cameras allow to monitor the evolution of the experiment through time, using photogrammetry methods and DEM generation. UV markers placed in the silicon are used to follow the silicon flow during the drainage of water at the substratum-lid interface, and give the unique opportunity to simultaneously follow the formation of tunnel valleys and the evolution of ice dynamics.

When the water pressure is low, groundwater circulates within the substratum only and no drainage landforms appear at the lid-substratum interface. By contrast, when the water pressure exceeds a threshold that is larger than the sum of glaciostatic and lithostatic pressures, additional water circulation occurs at the lid-substratum interface and drainage landforms develop from the lid margin. These landforms share numerous morphological criteria with tunnel valleys such as undulating longitudinal profiles, U-shaped cross-sectional profiles with flat floors, constant widths and abrupt flanks.

Continuous generation of DEMs and flow velocity maps during the experiments gives access to the temporal evolution of tunnel valley morphologies together with their impacts on ice flow dynamics. The first results illustrate highlight a close correlation between tunnel valley formation and migration and ice stream shifting locations.