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Gelifluction of soil on the Antarctic Peninsula

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Gelifluction is a large drop in the mechanical stability of soil that occurs at the onset of freezing and thawing. On slopes it causes a downward migration of soil, producing characteristic large lobes in the landscape of many polar terrestrial environments. At the microscale, the loss in stability and fluxes in soil water potential associated with gelifluction may influence microbial habitats as ancillary impacts of swelling on freezing rearranges the solid matrix of soil. With climate change predictions for the Antarctic Peninsula, cycles of freezing and thawing will likely increase, resulting in greater impacts from gelifluction. Little research has quantified the process in these soils, however, with traditional geotechnical characterisation hindered as the large volumes of soil required are at odds with conservation concerns for the area. In this study, we quantified gelifluction under highly controlled conditions using small samples in a parallel plate rheometer. Soils were collected from Signy, Greenwich, Wiencke, and Livingston Islands, as well as from the northern tip of the Antarctic Peninsula. An oscillating 10 Pa shear stress was applied to sieved samples equilibrated to -0.5 kPa water potential. Freezing and thawing was controlled with a peltier temperature controller, with temperature ramps consisting of 5ºC to -10ºC over 2 hours, followed by -10ºC to 5ºC over two hours, and finally at constant 5ºC for 1 hour. Two freeze-thaw cycles were measured followed by a shear stress ramp until failure.

After two cycles of freezing and thawing, all soils had similar viscosity (54 kPa s) and yield stress (1.1 kPa). However, due to gelifluction, viscosities dropped to 23% of the 5ºC value at the onset of the second thaw cycle, with the extreme values ranging from 10% at Byers Peninsula on Livingston Island to 34% at Wynn Knolls on Signy Island (P <0.01). Expansion of the soil on freezing ranged from 6.2% to 12.5% and was significantly different between all sites (P <0.01). So far, no correlation between gelifluction and other soil properties has been observed, although on-going analysis will investigate the rate of viscosity change with freezing and thawing, freezing point depression, soil texture and the presence of organic compounds in greater detail. From this initial investigation, however, a massive drop in mechanical stability of soil through cycles of freezing and thawing has been demonstrated. Climate change will accentuate the frequency of gelifluction, so its potential impact on landform formation, soil physical stability and microbial processes in Antarctic soils could have major implications.