Geological Survey of Canada
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GROUND ICE MAP OF CANADA

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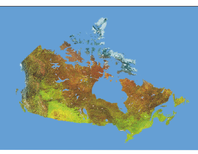

Ground ice in Canada

Ground ice is an important component of the permafrost environment. Its formation is responsible for characteristic features such as ice-wedge polygons, earth hummocks, pingos, palsas, and lithalsas. The melt of ground ice as permafrost thaws can trigger a suite of thermokarst processes including surface subsidence, thaw lake development, hillslope failure, and thermo-erosional gullying. Thaw of ice-rich permafrost can damage infrastructure, contribute to the mobilization of previously-frozen carbon, and alter the hydrologic regime.

Ground ice occurs in various forms in excess of the pore space of the soil. The maps in the right panel depict three common types: (1) relict ice, which may occur as large bodies of preserved glacial ice, (2) segregated ice, which may form an ice-rich zone of ice lenses, layers, and veins near the top of permafrost, and (3) wedge ice, which are downward-tapering bodies of nearly pure ice that accumulate in near-surface permafrost. Here, relict ice is indicative of glacier ice preserved in permafrost within glacial sediments. Segregated ice forms in permafrost following the migration of unfrozen water toward frozen ground. Wedge ice accumulates over many years due to cracking of the ground in winter and the subsequent infiltration and refreezing of meltwater in permafrost in spring.

The central map shows the estimated total excess ice volume in the upper metres of permafrost from relict, segregated, and wedge ice, based on modelling by O'Neill et al. (2019)[1] (see maps in right panel). The estimates of excess ice content are informed by published observations for different surficial geology and permafrost conditions, and expert knowledge.

The distribution and abundance of modelled ground ice reflects the post-glacial environmental and climatic history, soil texture, and the time since terrain exposure following deglaciation. Relict ice reflects the distribution of thick glacigenic sediments that have remained in cold tundra environments since deglaciation. Segregated ice is widespread in Canada in areas with fine-grained, frost-susceptible soils that favour ice segregation. The highest modelled abundance occurs in areas of fine-grained lacustrine and marine sediments. Wedge ice occurs in highest abundance in fine-grained soils that were terrestrially exposed early in the Holocene and remained within tundra environments, allowing thousands of years for ice accumulation. See O'Neill et al. (2019)[1] for further information on the modelling methodology and limitations.

This map offers an improved depiction of ground ice abundance at the national-scale in Canada, incorporating current knowledge on associations between geological and environmental conditions and ground ice type and abundance. It provides a foundation for hypothesis testing relating to broad-scale controls on ground ice formation, preservation, and melt. Additional quantitative field data on ground ice will allow further assessment and refinement of the mapping. Continued research will focus on improving the lateral and vertical representation of ground ice required for incorporation into Earth system models and decision-making.

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Ground ice abundance
(Estimated % excess ice volume in top 5 m of permafrost)

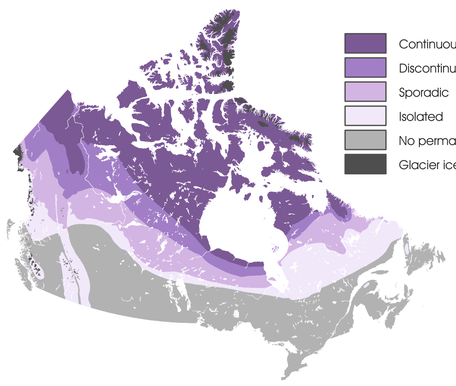
	None	Negligible	Low	Medium	High	Very high	Glacier ice
TOTAL	0	>0-5	>5-10	>10-20	>20-30	>30	
RELICT	0	>0-2	>2-5	>5-10	>10		
SEGREGATED	0	>0-2	>2-5	>5-10	>10		
WEDGE	0	>0-2	>2-5	>5-10	>10		

See right panel →

Permafrost distribution zone boundary[2]

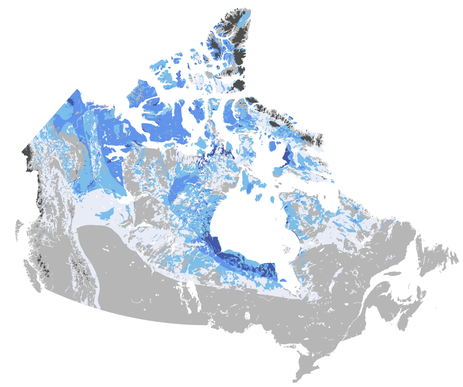
Total estimated % excess ice volume is derived from the addition of estimates for relict, segregated, and wedge ice (right panel) by map algebra. For these estimates, the soil pore space is assumed to be ice saturated, such that relict, segregated, and wedge ice contribute to excess ice. See accompanying report for details.

PERMAFROST DISTRIBUTION[2]

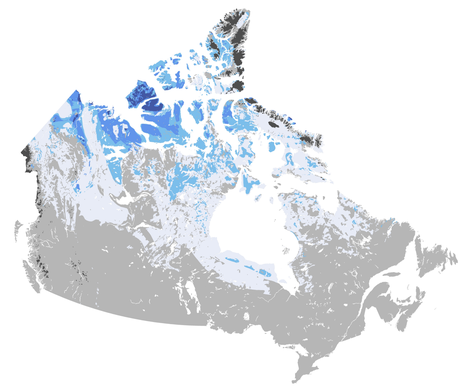


RELICT ICE

SEGREGATED ICE



WEDGE ICE



References:

[1]O'Neill, H.B., Wolfe, S.A., and Duchesne, C., 2019. New ground ice maps for Canada using a paleogeographic modelling approach, The Cryosphere, 13, 753–773, https://doi.org/10.5194/tc-13-753-2019

[2]Heginbottom, J.A., Dubreuil, M.-A., and Harker, P., 1995. Permafrost – Canada, National Atlas of Canada MCR 4177, Scale 1:7,500,000, Department of Energy, Mines and Resources Canada. https://doi.org/10.4095/294672

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