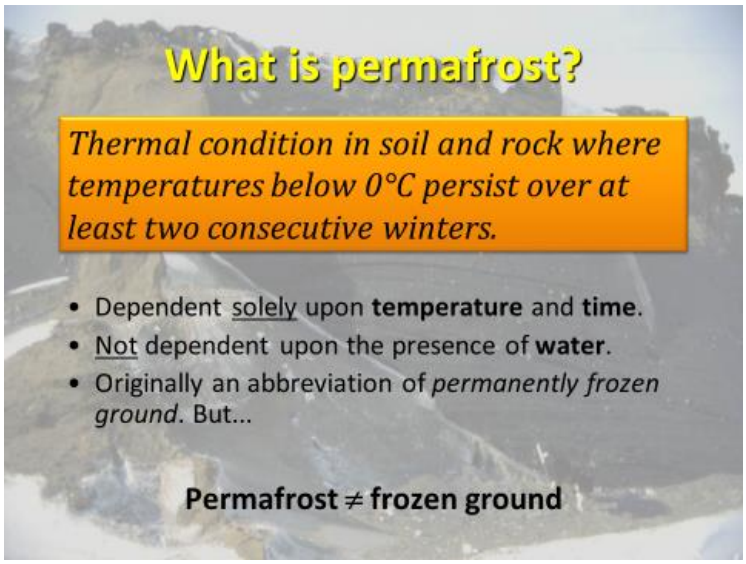
Permafrost

Richard Waller – University of Keele

December 2018

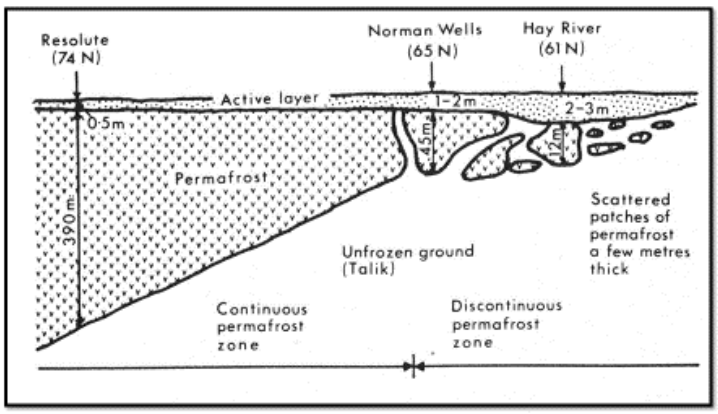
Introduction

Permafrost was described by Richard as the 'Cinderella' of cold landscapes having been the subject of far less research than for example glaciers. It is very much the world of 'Underground Ice'. He has carried out his own research over many years and started with a definition of Permafrost:



Permafrost Landscapes

Permafrost can reach depths of up to 1600 metres in Siberia with the thickness decreasing and the surface layer thickness increasing from North to South.



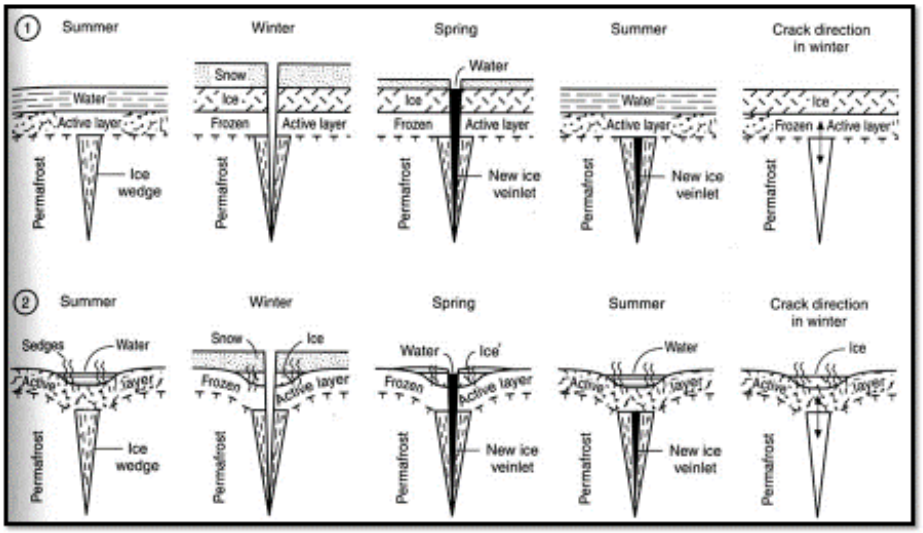
Transect running up through the Mackenzie Valley to the Canadian Arctic (right to left). (Selby, 1981)

Vegetation exists above regions of Permafrost namely circumpolar Boreal Forest further south and Tundra with stubby vegetation further north.

There is some evidence remaining of permafrost ground features in the UK which would have existed ahead of past retreating glaciers.

Permafrost landscapes have distinctive polygonal features:

These features are created by the cyclic annual freezing and thawing of the top surfaces above the permafrost. The surface melt water percolates down into the permafrost and refreezes as underground ice wedges:

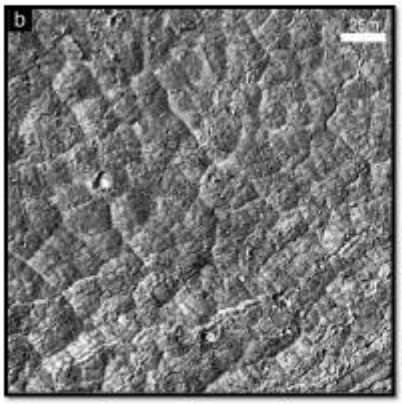


Stages of formation of wedge ice associated with both shallow lakes (1) and saturated ground (2).
(From French, 1994, p93)

Extra-terrestrial Permafrost?

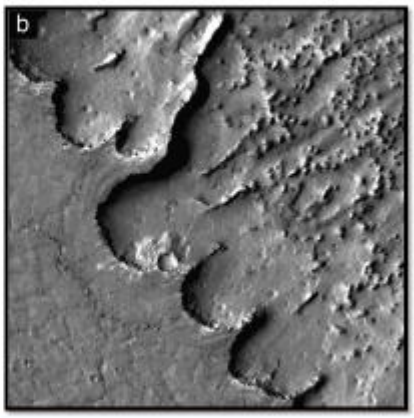
Recent images from orbiters show polygonal landscape features that suggest permafrost may exist on mars:

Extraterrestrial Permafrost?



Ice-wedge polygons?

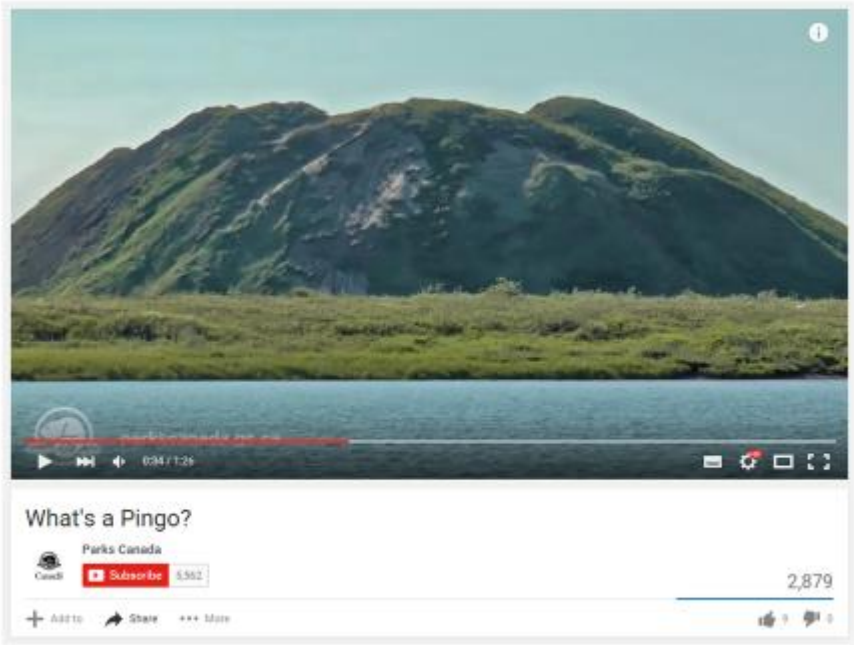
Retrogressive thaw slumps?



Balme, M.R. & Gallagher, C. 2009. An equatorial periglacial landscape on Mars. *Earth & Planetary Science Letters*, 285, 1-15.

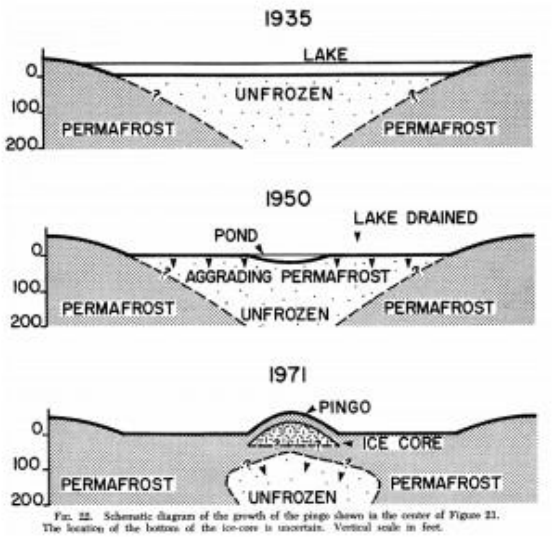
Pingos

Another feature of permafrost regions are ‘Pingos’:



https://www.youtube.com/watch?v=j2DNo_kNt4I

Pingos are ‘ice core hills’ formed when a lake in a permafrost region slowly drains over many years. This is illustrated in the following diagram:



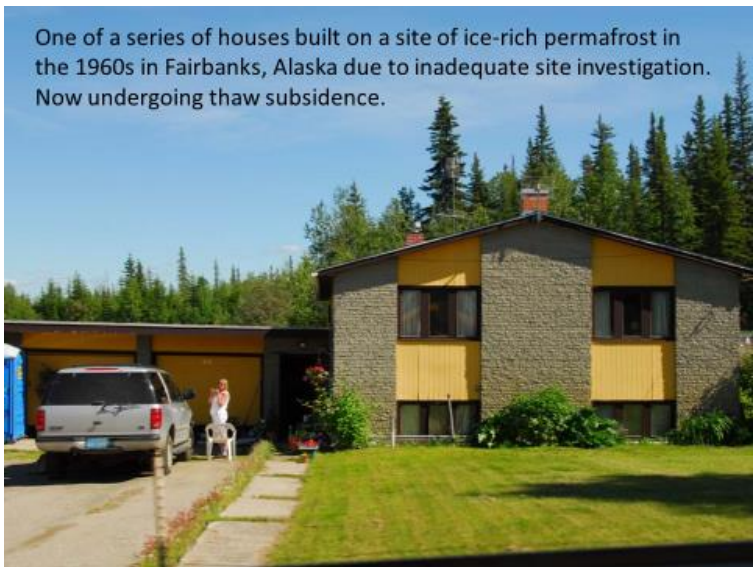
Schematic illustration of the formation of a closed-system pingo following lake drainage

Mackay, J.R. 1972. The World of Underground Ice. *Annals of the Association of Geographers*, 62, p19.

Engineering Challenges

With the discovery of 'supergiant' oil fields in the arctic regions of Canada and Siberia during the last few decades much construction and building work has gone on in these areas. Building on permafrost land presents unique challenges and solutions.

Early house building did not take proper account of the effect of heat from the building melting the underlying permafrost. This has resulted in subsequent sinking as shown in the following picture:

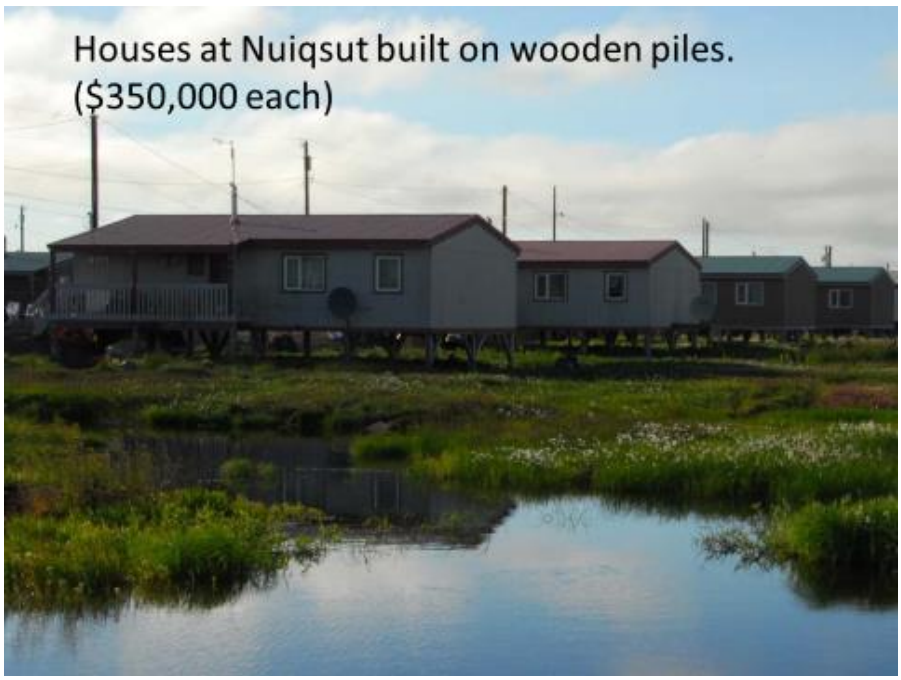


Apart from the sinking no structural damage has occurred as the house was built on a concrete raft!
Oil pipelines in permafrost regions also suffer from damage due to permafrost ground movements under annual thermal cycling:

Frost jacking of a pipeline in the Russian Arctic
http://www.permafrost.ca/images/Russian%20Pipelines%20in%20Permafrost%20001.jpg

Engineering Solutions

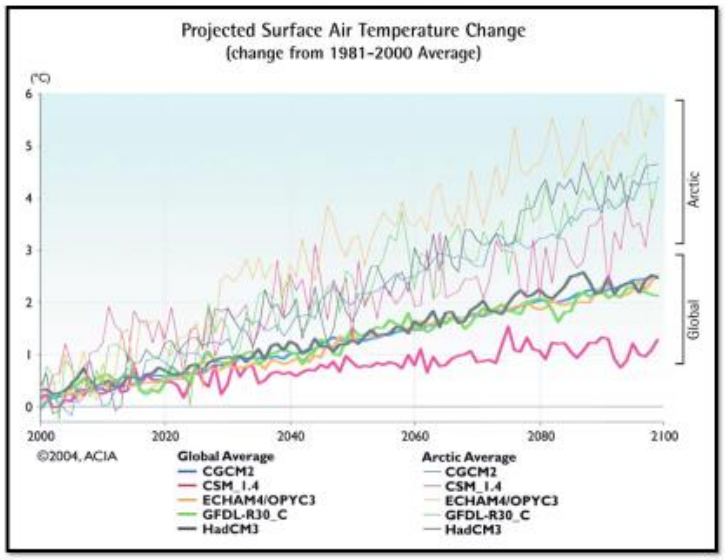
Essentially the solutions to these challenges is both to insulate the structures from the ground and to remove any introduced heat from the permafrost. The simplest example of this is simply to build houses and service piping on stilts as shown here:



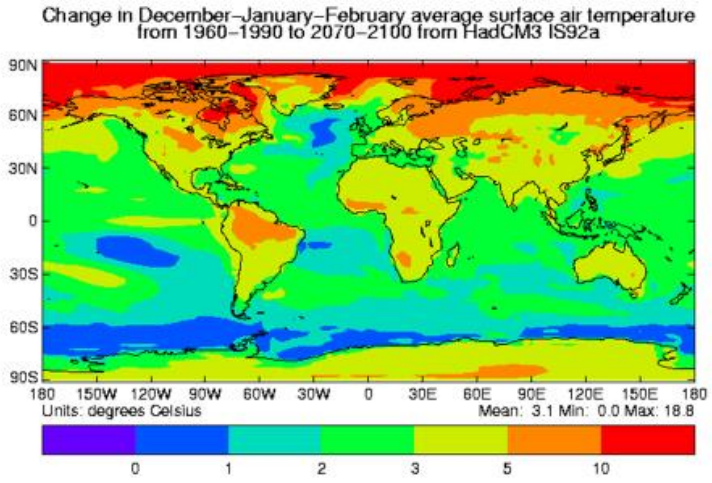
Oil field pipelines are now built on stilts and also have passive heat pumps embedded in the permafrost to remove heat and keep the permafrost frozen as shown here:

Effect of Climate Change

The Arctic region is the fastest warming area of the Earth as shown in the following charts:



http://amap.no/acia/



Hadley Centre for Climate Prediction and Research, The Met. Office

The effects can already be seen in **coastal erosion**:

Coastal erosion in Shishmaref, Eastern Alaska
http://s3.amazonaws.com/dana-lixenberg-production/images/227/lightbox.jpg?1279380486

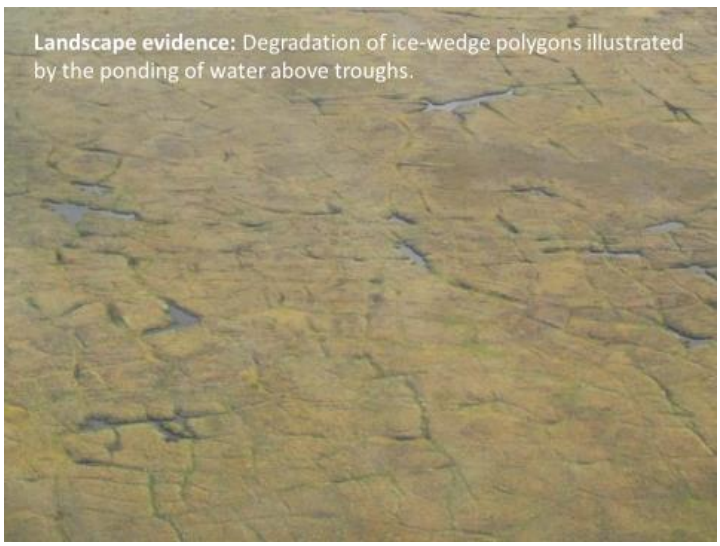
Building collapse:

Building Collapse?

http://www.nbcnews.com/news/photo/what-real-russian-winter-looks-n21251

- 1.3 million people in Russia live in urban areas underlain by permafrost. E.g. Norilsk (176,000).
- Rapid building during 1960s – 1980s has resulted in permafrost degradation between 70% of buildings.
- In 2010 deformation had affected 174 buildings and over 12,000 people.
- New phase of construction involving much lighter designs.

Degradation of Ice-Wedge Polygons:



Possibly the most dramatic effects of global warming on permafrost landscapes is so called **'Megaslumping'** where the underlying permafrost has melted causing the overlying soil to collapse:

Overview of the Batagaika megaslump
(Image courtesy of Julian Murton)

Conclusions

In summary Richard drew the following conclusions:

- Permafrost environments are globally extensive.
- Location of a variety of key natural resources (e.g. oil, gas, diamonds, various metals).
- Range of unique landforms associated with the formation and degradation of ground ice.
- Various engineering solutions have permitted development but at a cost.
- Rapid ongoing climate change poses the greatest challenge to permafrost engineers.
    - *Rising temperature reduces load bearing capacity*
    - *Subsequent dramatic failures of major new builds*

Dick Harris
December 2018