EDU-ARCTIC

Permafrost and periglacial processes

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What is permafrost?

Where permafrost exists?

Terrain features in permafrost areas

Changes in periglacial environment - influence of warming permafrost on infrastructure

Permafrost

(permanent + frozen)

ground that has a temperature lower than 0°C continuously for at least two consecutive years

Permafrost is found in cold climates of **high latitudes** or **high altitudes**, where the ground does not thaw completely even in summer

Aoraki/Mount Cook
New Zealand

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- The definition of permafrost is based entirely on **temperature** and is independent of the water and ice content of the soil or rock
- Freezing increases soil strenght (important for constructions)
- Freezing water becomes a bonding agent making ground **impermeable** for liquid water

What influences the temperature of the ground?

- air temperature
- the thermal and humidity properties of the soil
- solar energy that changes with the height of the Sun over the horizon
- depth of the permafrost

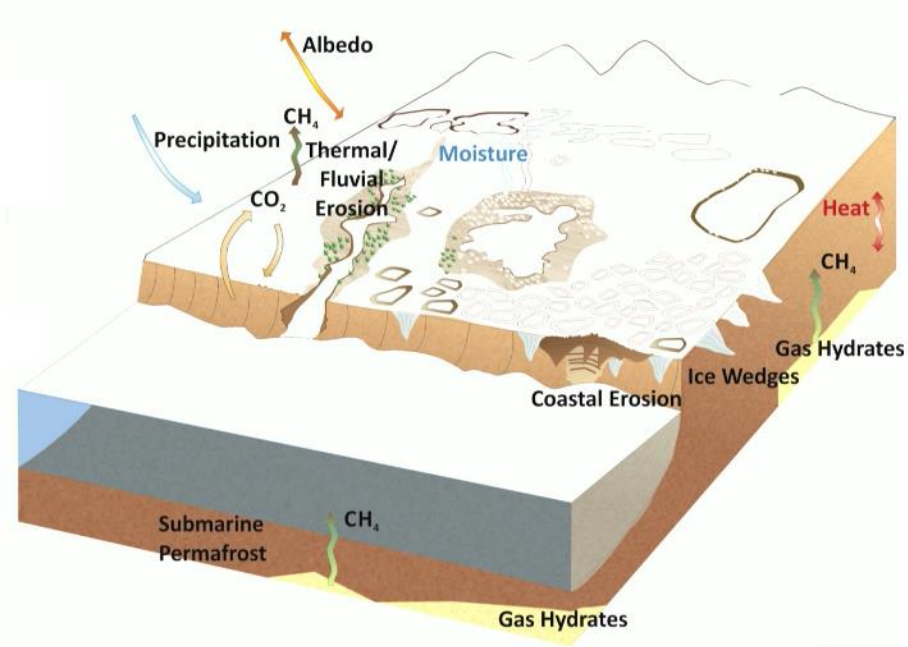
The amount of incoming energy is conditioned by changes in cloud cover, atmospheric precipitation and exposure

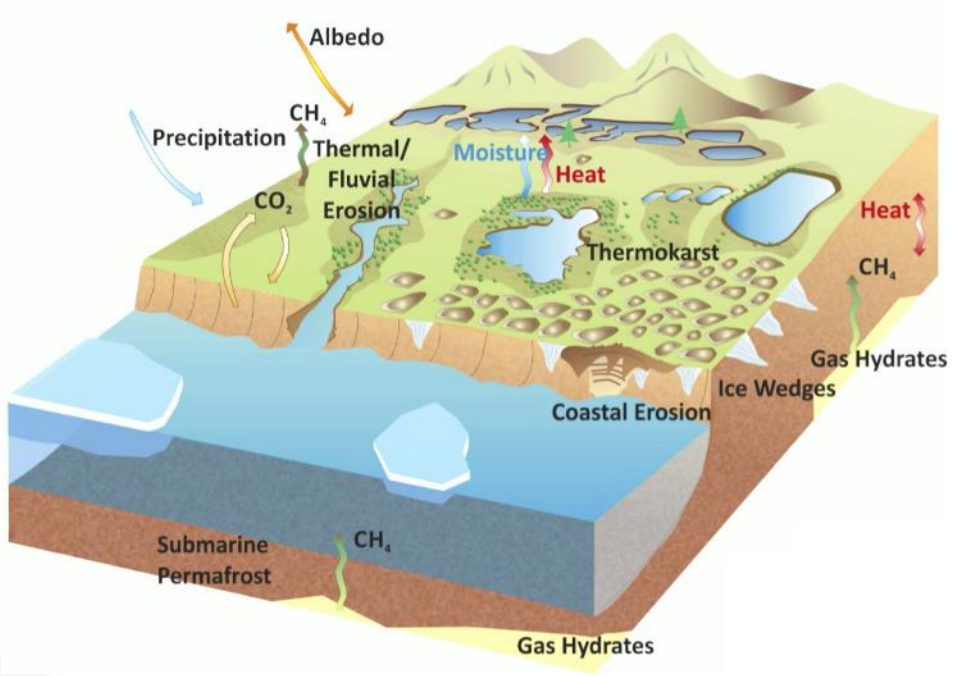
The thickness and duration of the snow cover and vegetation can isolate the soil from violent changes in air temperature

Permafrost system

complex processes between atmosphere, hydrosphere and land

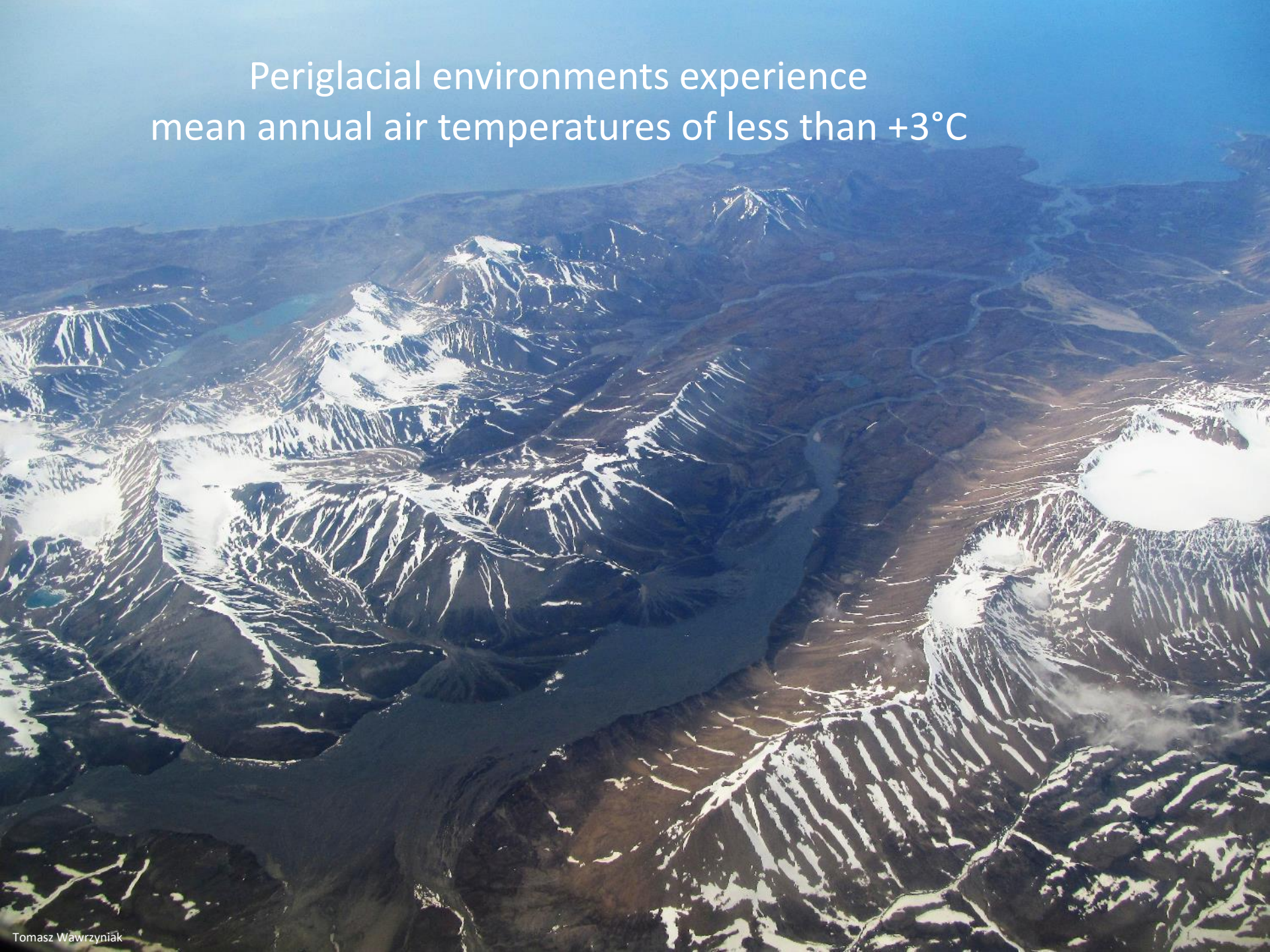
Freeze - thaw cycles





Periglacial zone

The term ***periglacial*** was first used in 1909 by a Polish geologist, Walery von Łozinski, in the context of the mechanical disintegration of sandstones by the previous action of intense frost that characterize the mountain summits of southern Carpathians. It referred to the climatic and geomorphic conditions of the periphery of the Pleistocene ice sheets and glaciers (from 2.5 million to about 12,000 BP years)


Periglacial environments experience
mean annual air temperatures of less than +3°C
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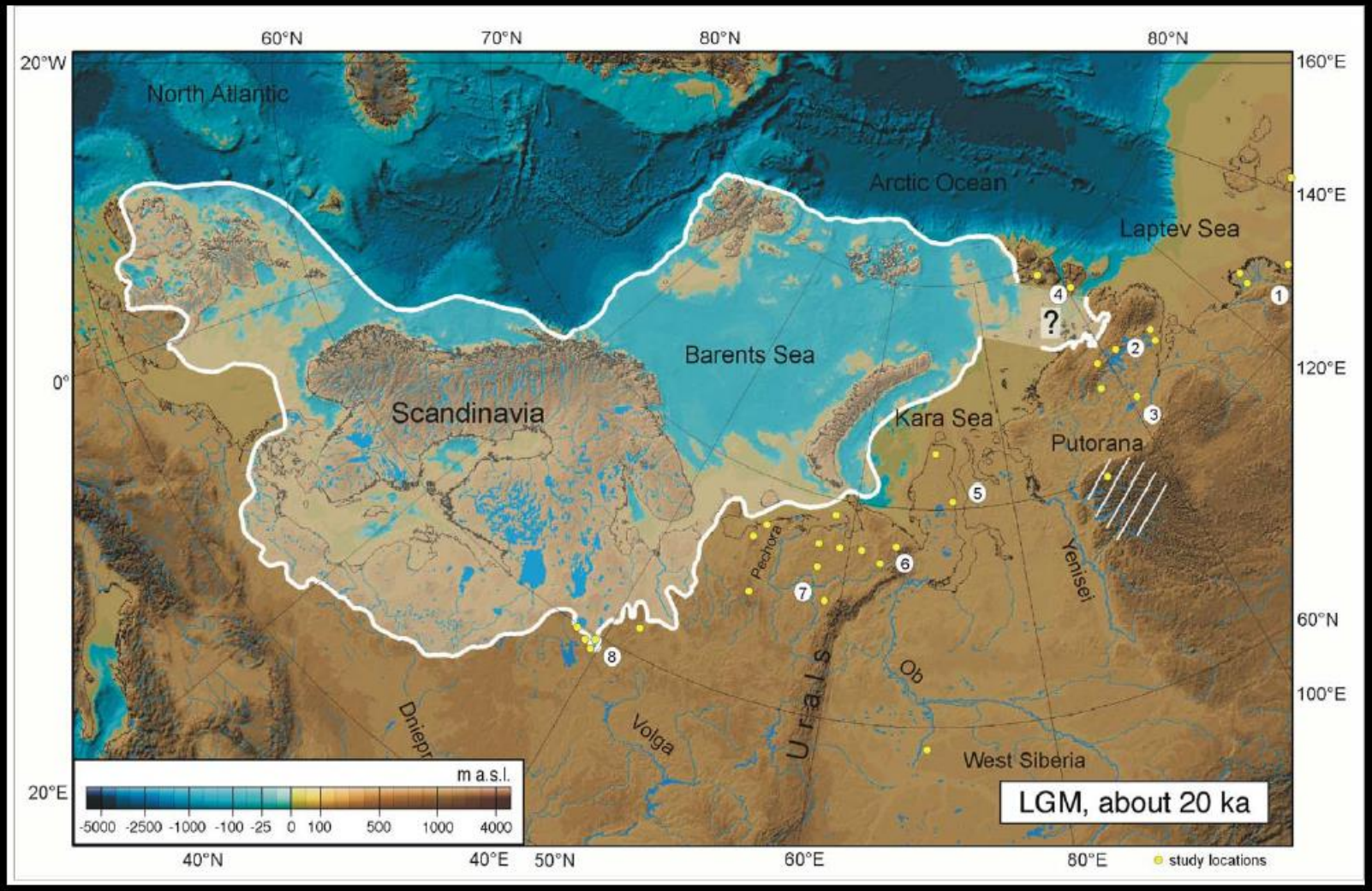
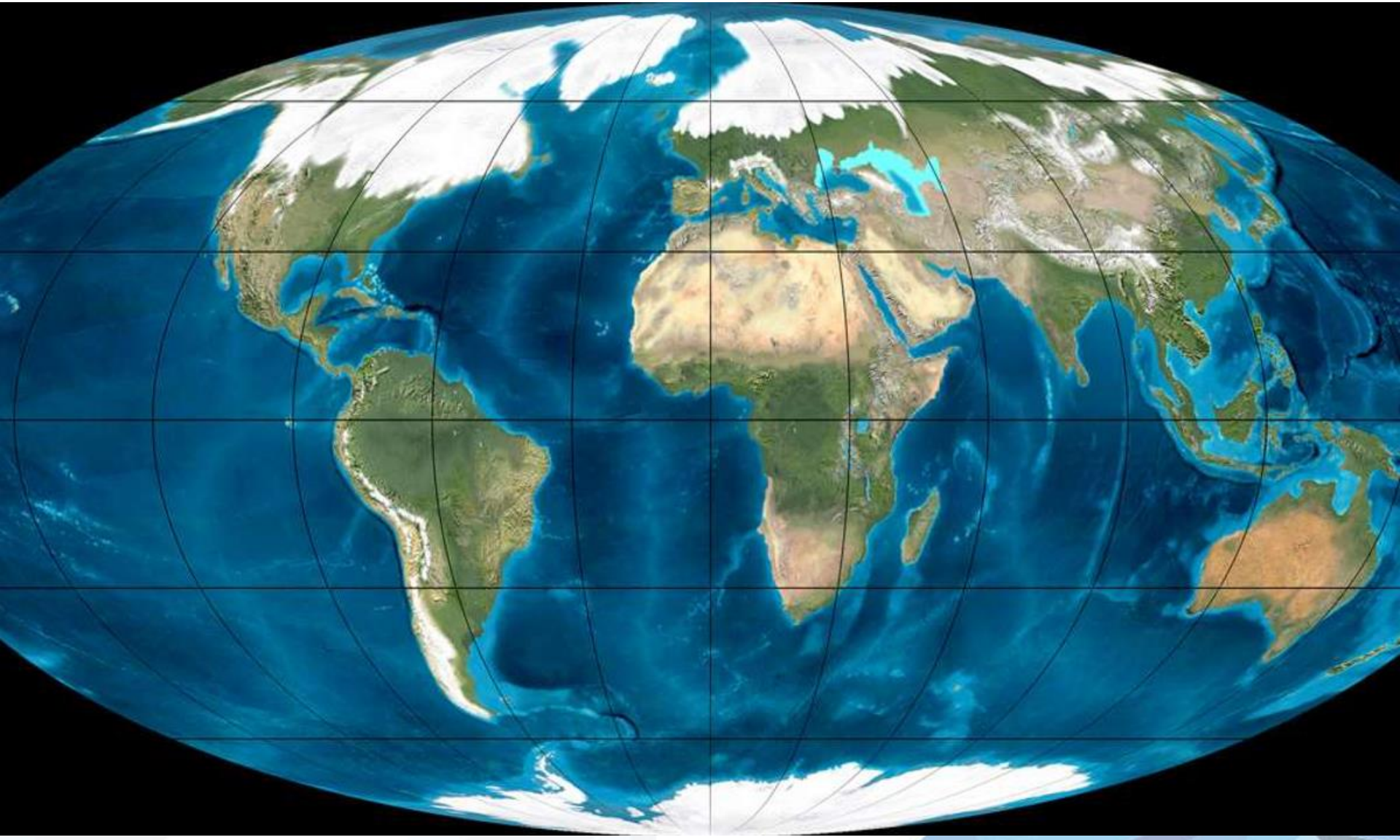
Most of present day permafrost formed during or since the last ice age



Eurasian Icesheet during the LGM period, from Hubberten et al. 2004, QSR.

The Earth 15,000 years ago



Moraines - material deposited by glacier

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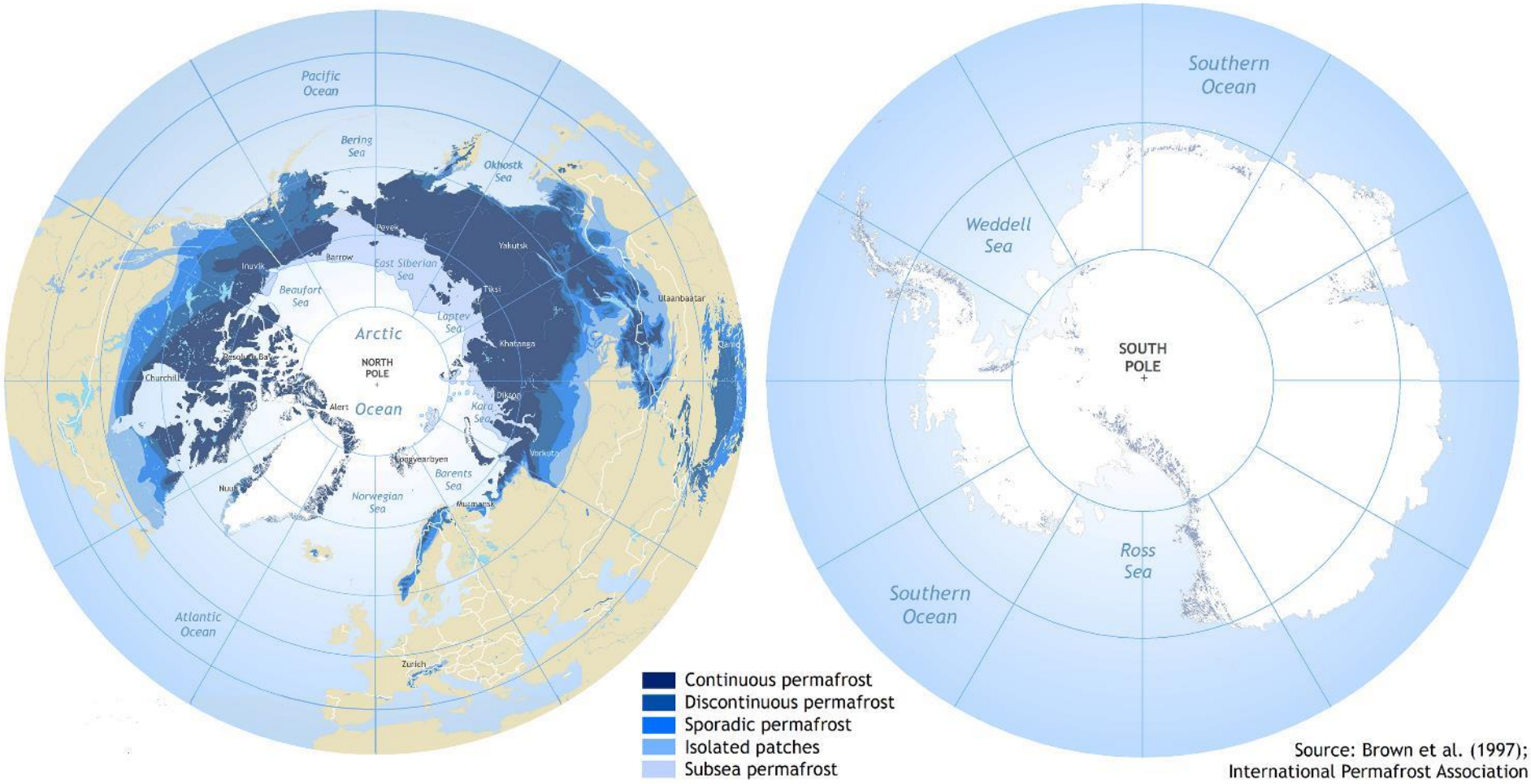
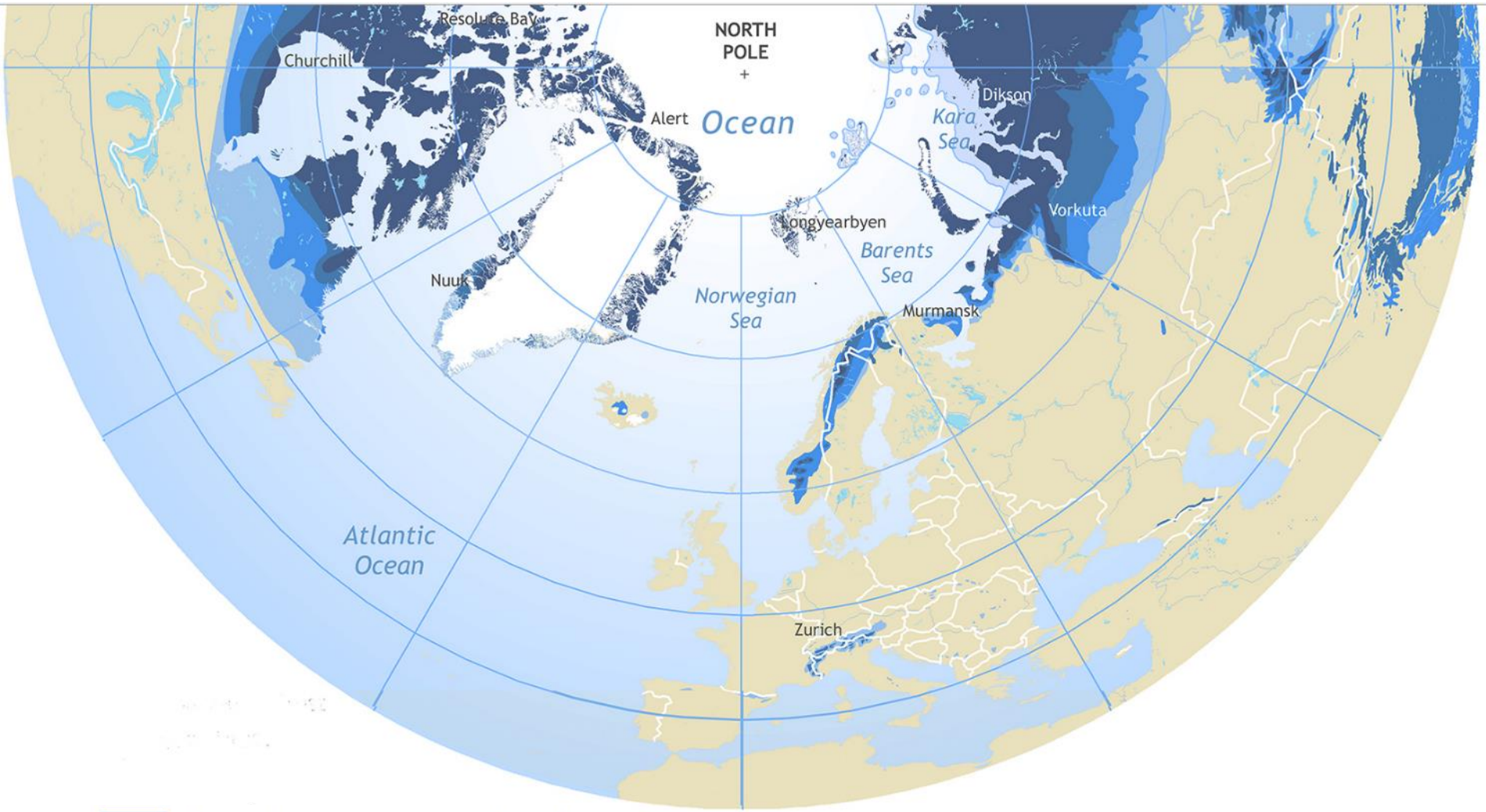
© YANAO/The Siberian Times

The occurence of permafrost – one-fifth of the Earth's land area



Source: Brown et al. (1997); International Permafrost Association



Continuous permafrost
Discontinuous permafrost
Sporadic permafrost
Isolated patches
Subsea permafrost

Source: Brown et al. (1997); International Permafrost Association

Svalbard (78°N 16°E)

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The **Scandinavian Mountains** (65°N 14°E)

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The **Alps** (46°N 09°E)

The **Pyrenees** (42°N 01°E)

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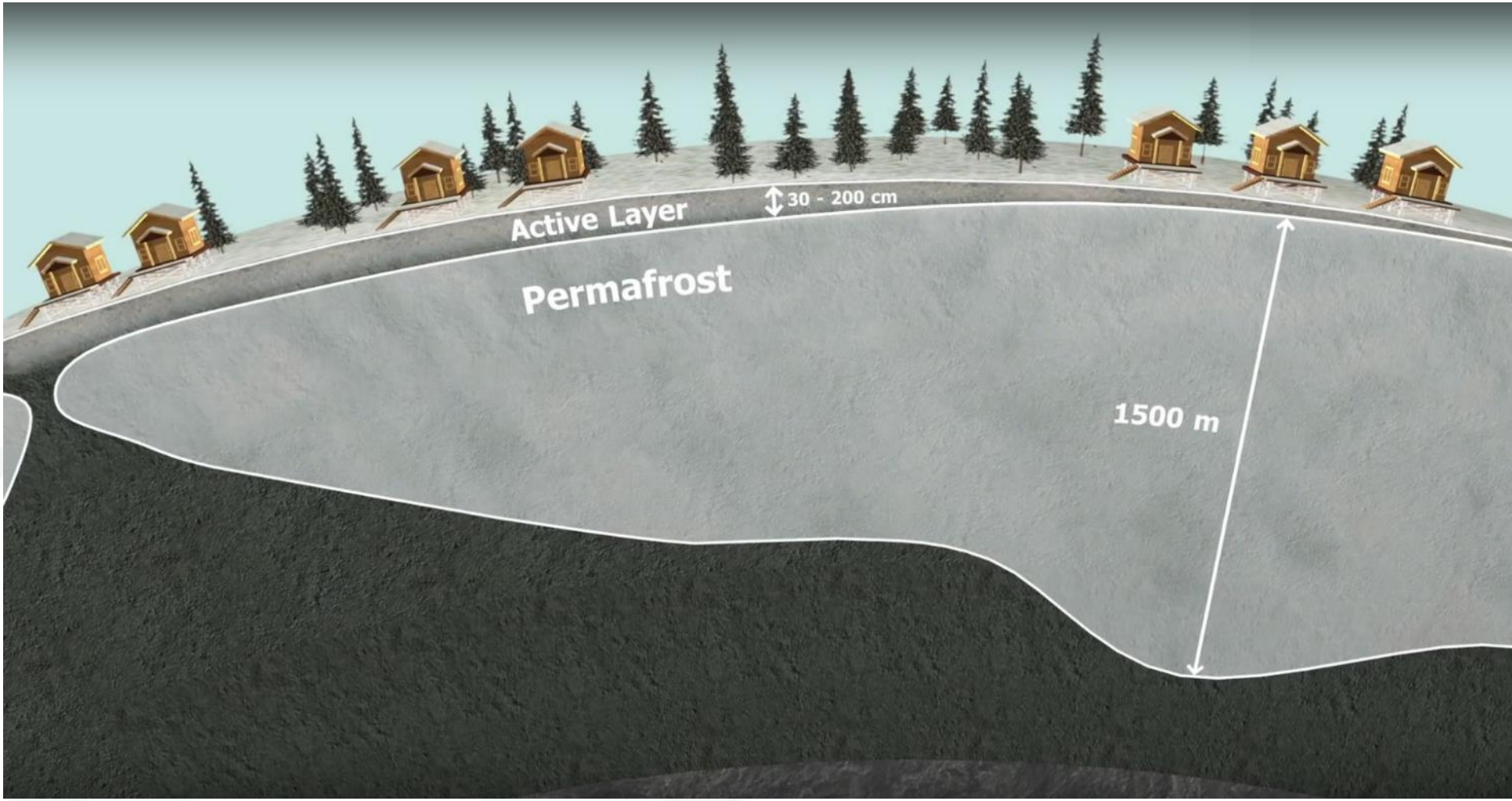
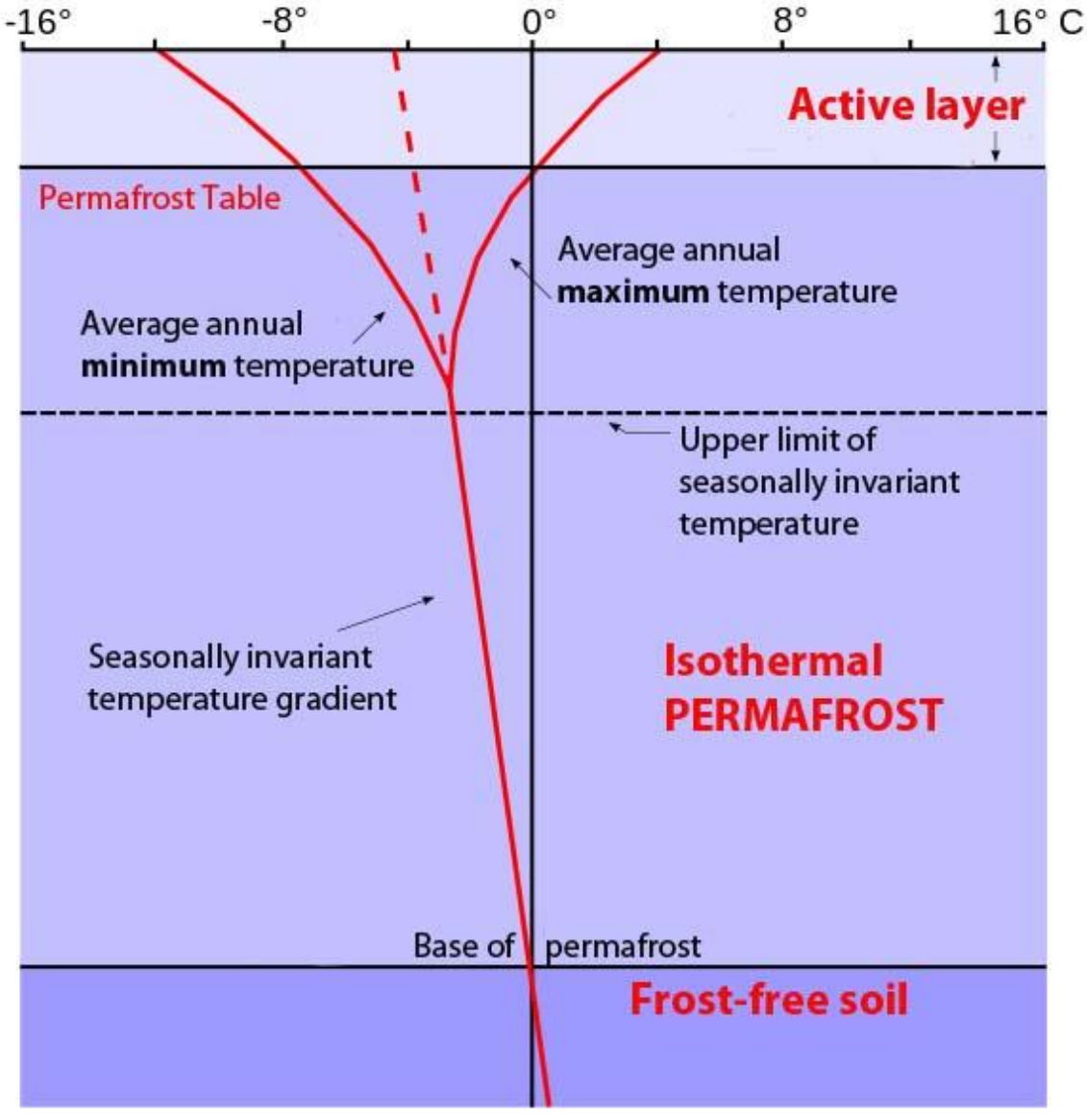
Active layer

A thin layer of soil that forms on top of permafrost – it thaws during summer and freezes again during autumn and winter

- areas with cold summers - very thin (eg. 10 cm on Ellesmere Island in Canada)
- areas with warmer summers - the active layer is thicker (eg. 2.5 metres in Yakutsk, Russia)
- areas of discontinuous permafrost - the active layer can be also very thick (5 metres in Yellowknife, Canada)


Active Layer
30 - 200 cm
Permafrost
1500 m

Ground temperature trumpet curve



Periglacial proceses

1. Frost weathering – freeze-thaw cycles

When water freezes to ice, its volume increases by 9%. Under specific circumstances, this expansion is able to displace or fracture rock.

Frost Cracking, Frost Heave (water expands and lifts the ground upwards)

2. Chemical weathering – common in coastal areas

Growth of salt crystals – eg sodium carbonate in cracks in rocks – eg saline water gets into cracks or rocks and breaks them down

3. Downslope mass movement

Frost creep, Solifluction (part of ground NOT frozen), Gelifluction (ground is frozen)

Periglacial proceses

3. Nivation (snow related)

Ice patches on the snow result in localised weathering and erosion by freeze thaw; this can lead to small depressions

4. Fluvial (rivers)

Frozen sediments can be removed by riverbank erosion

5. Aeolian (wind)

Erosion by strong winds creates deflation surfaces; the vegetation, soil and fine material debris is removed

Periglacial landforms

- Blockfields
- Rock Glaciers
- Solifluction lobes
- Flattened Summits
- Thermokarst (Lakes)
- Ice Wedge Polygons
- Scree / Talus
- Gelifluction Lobes/benches
- Nivation Hollows
- Pingos
- Sandurs
- Palsas (frost push on peat)

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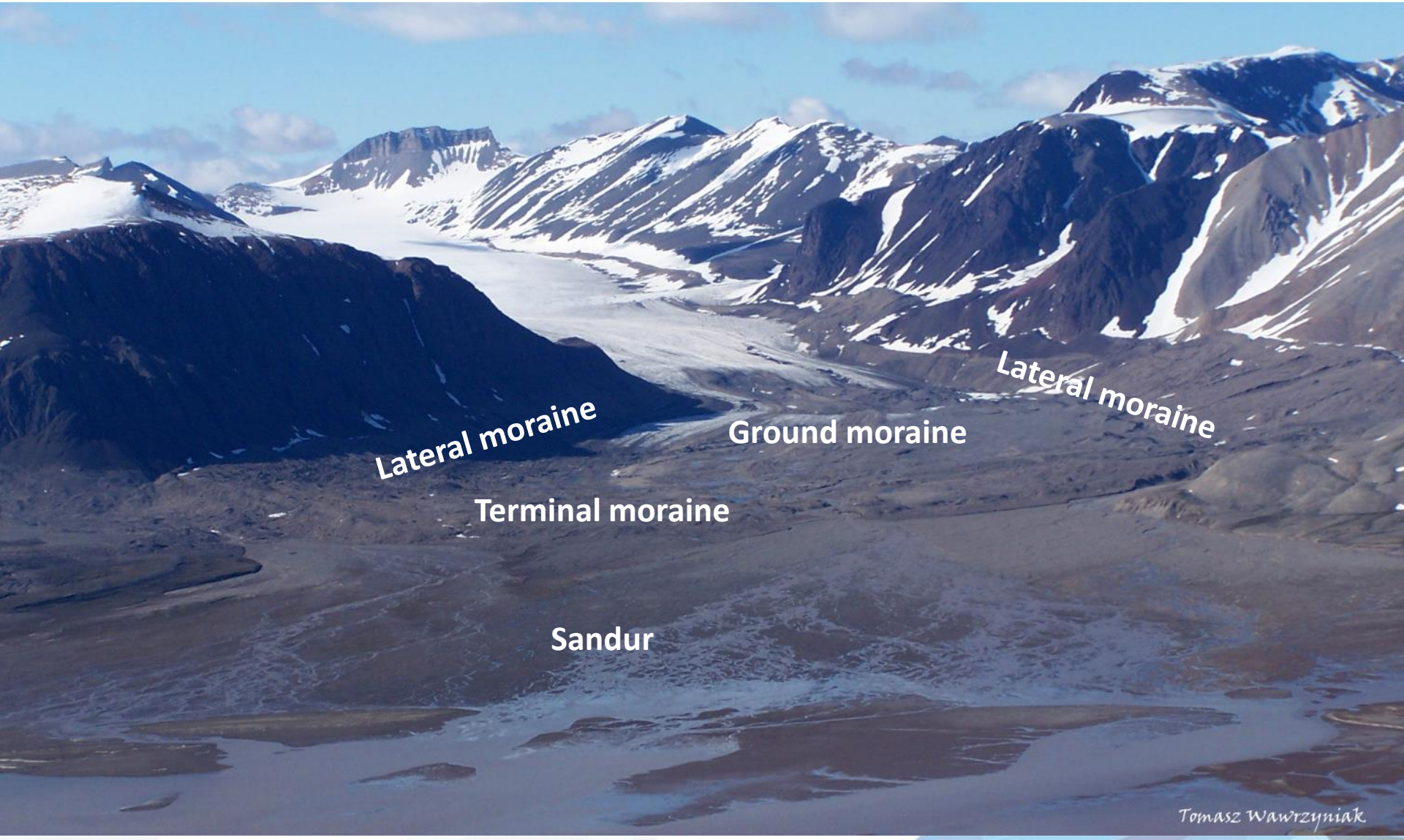
Lateral moraine
Ground moraine
Lateral moraine
Terminal moraine
Sandur
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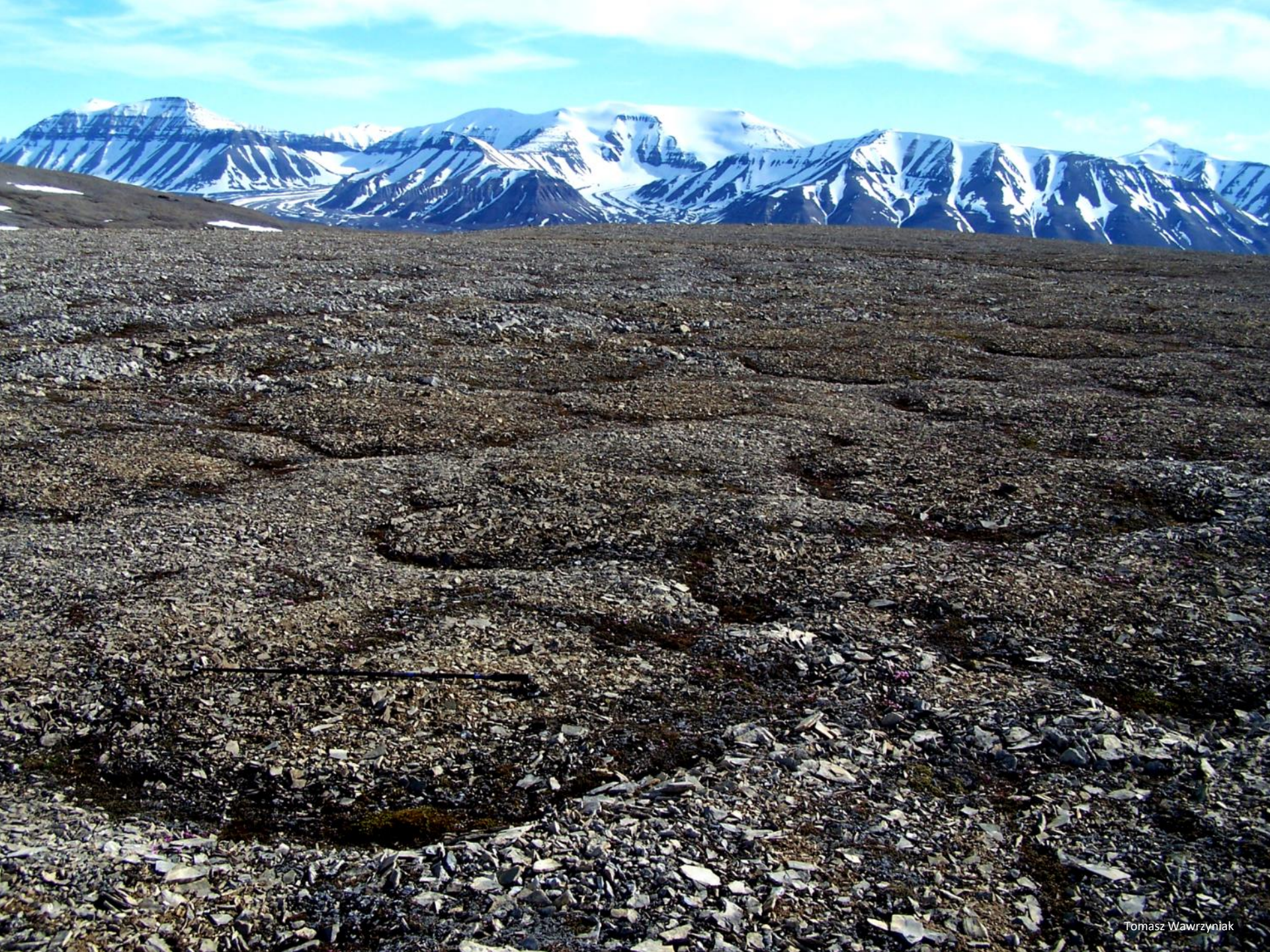
The repeated freezing and thawing of the active layer can produce interesting patterns on the ground – ice wedge polygons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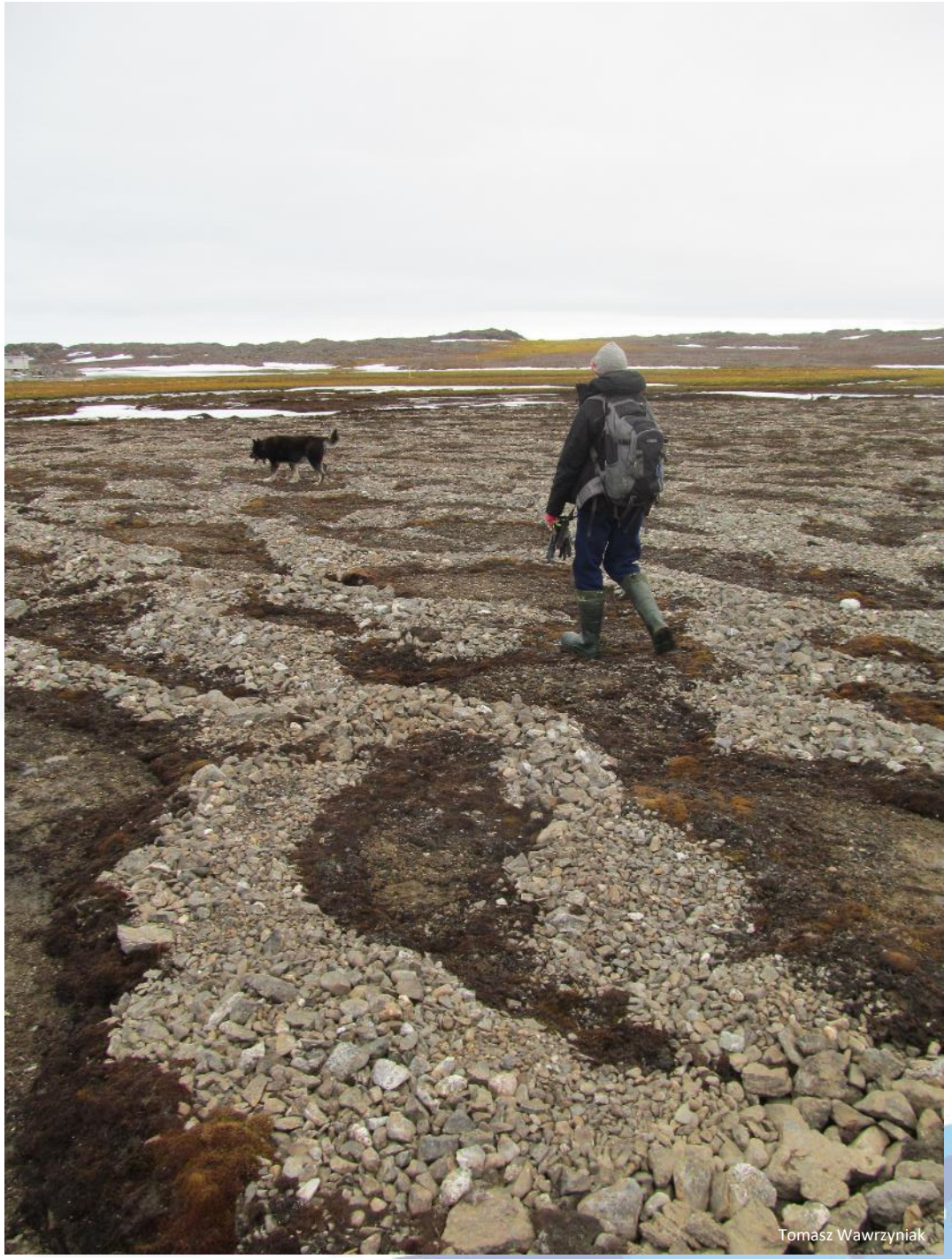
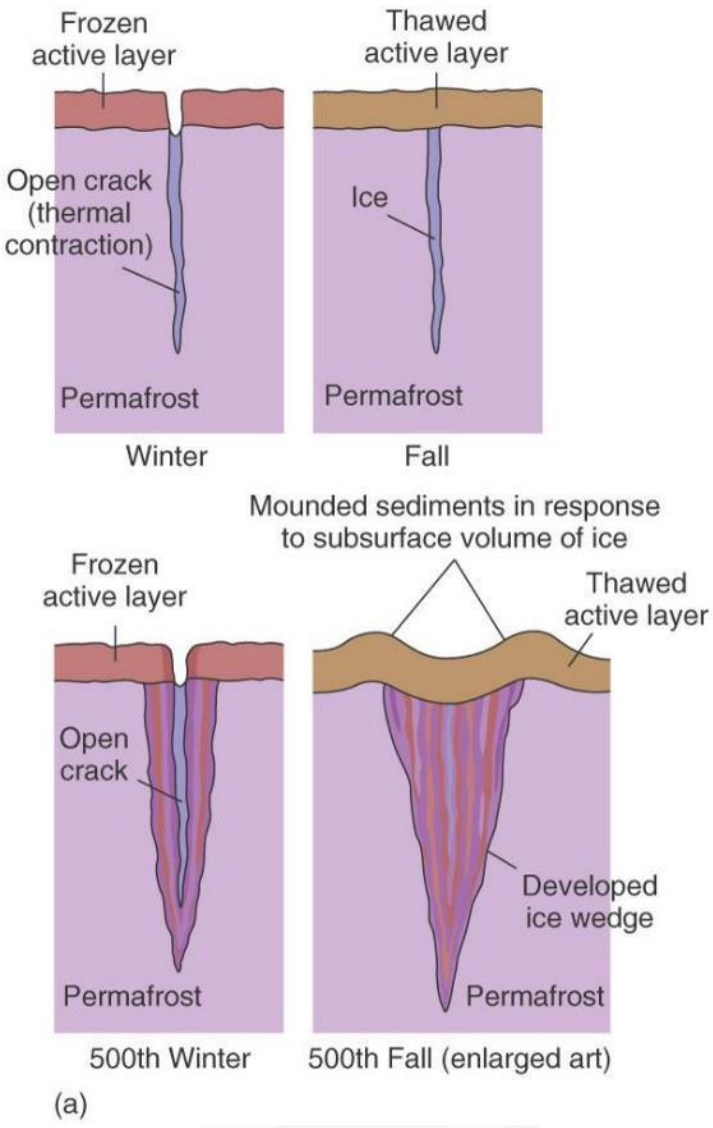
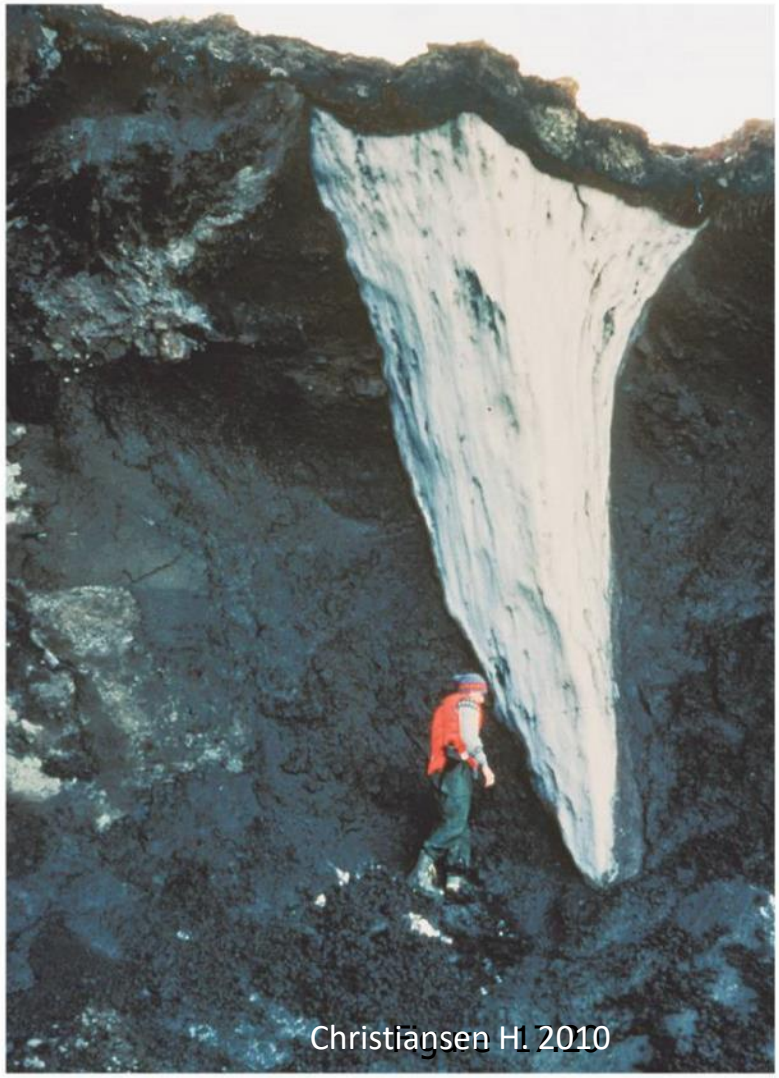


Ice wedges – contract and crack – vertical veins





(b)

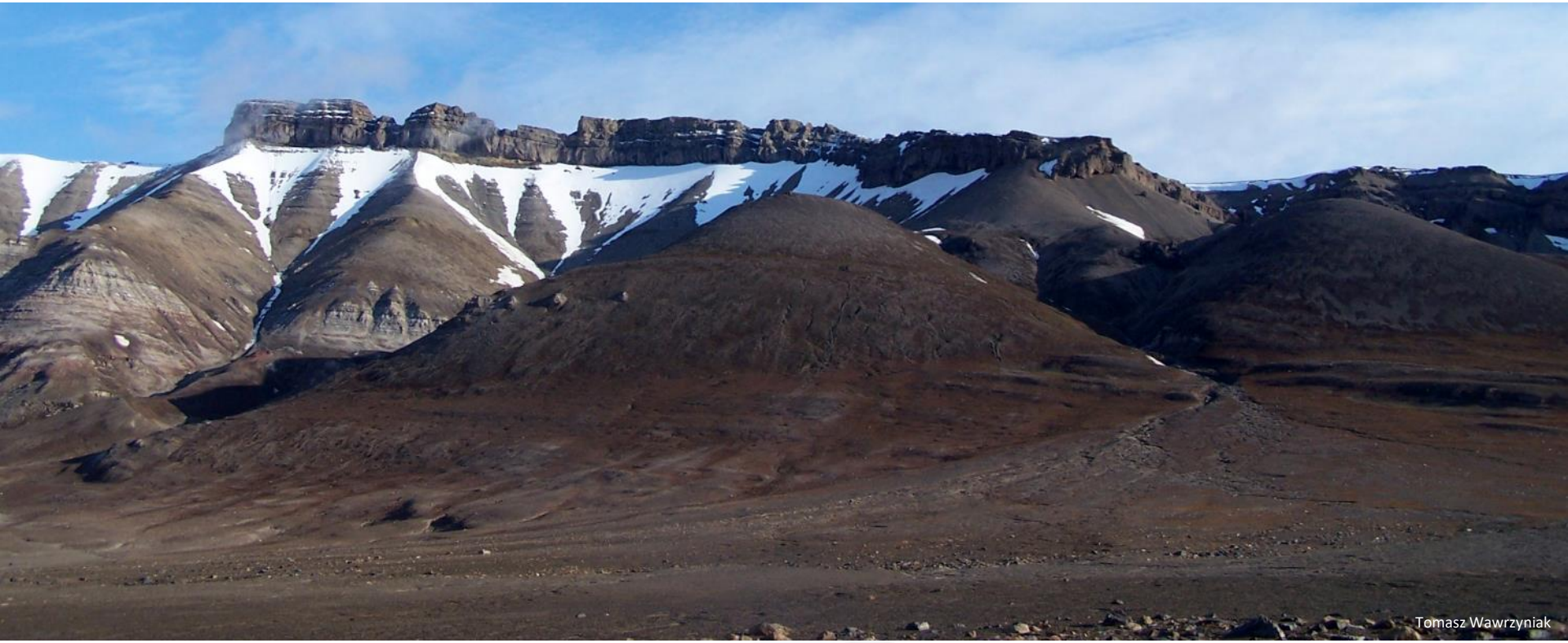
Patterned ground near Bielski Podlaski / Poland (D. Krasnodębski)

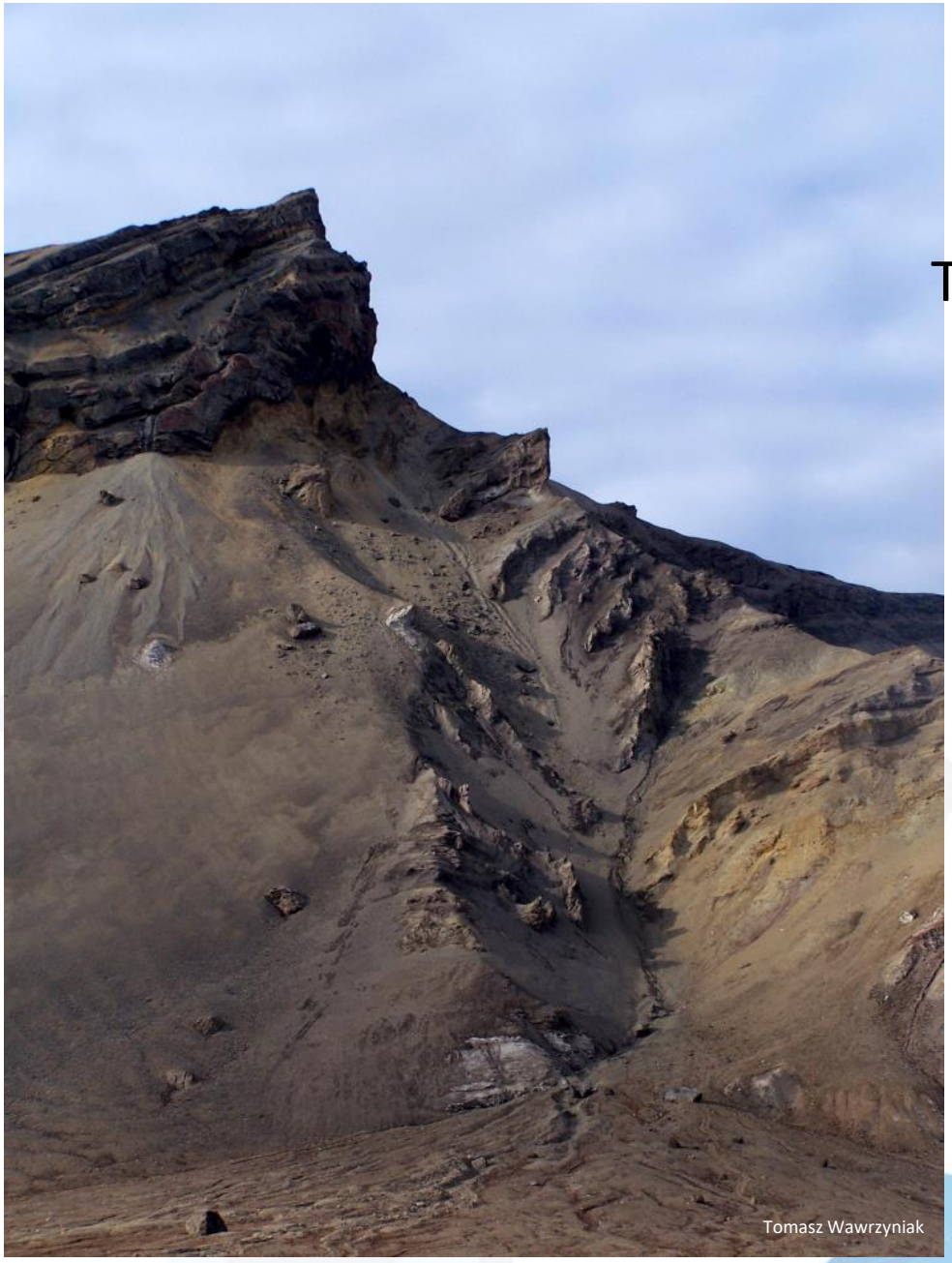
Solifluction lobes

Riverbank erosion

Effect on slope stability

Over the past century, an increasing number of alpine rock slope failure events in mountain ranges around the world have been recorded





Talus slope

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Active layer detachment


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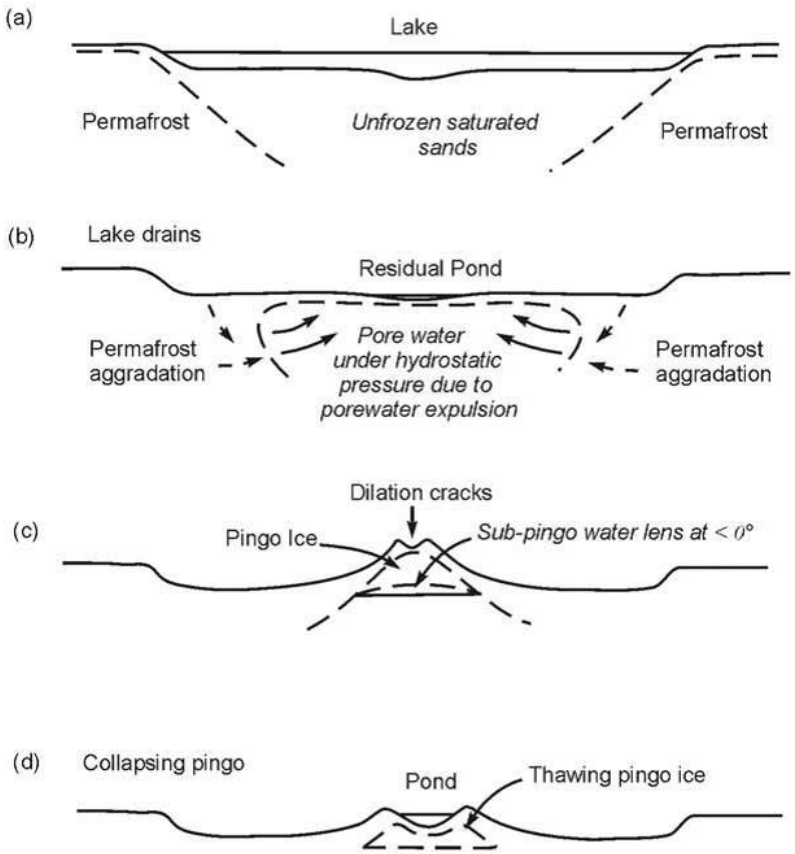
Palsa

Pingo

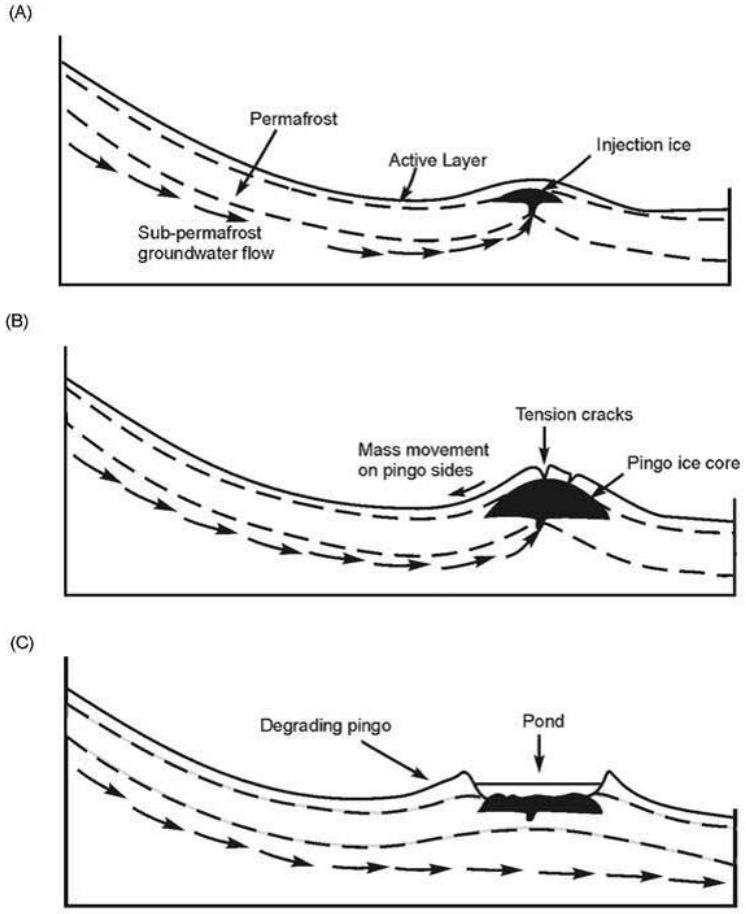
a conical or elongated hill, or even a dome-shaped mound consisting of a layer of soil covering a large core of ice

A pingo contains massive layers of ice formed under hydrostatic pressure

Formation of closed system pingos (after Mackay 1998):



Cycle of formation and decay of open system pingos (after Holmes *et al.* 1968; and Ballantyne and Harris 1994):

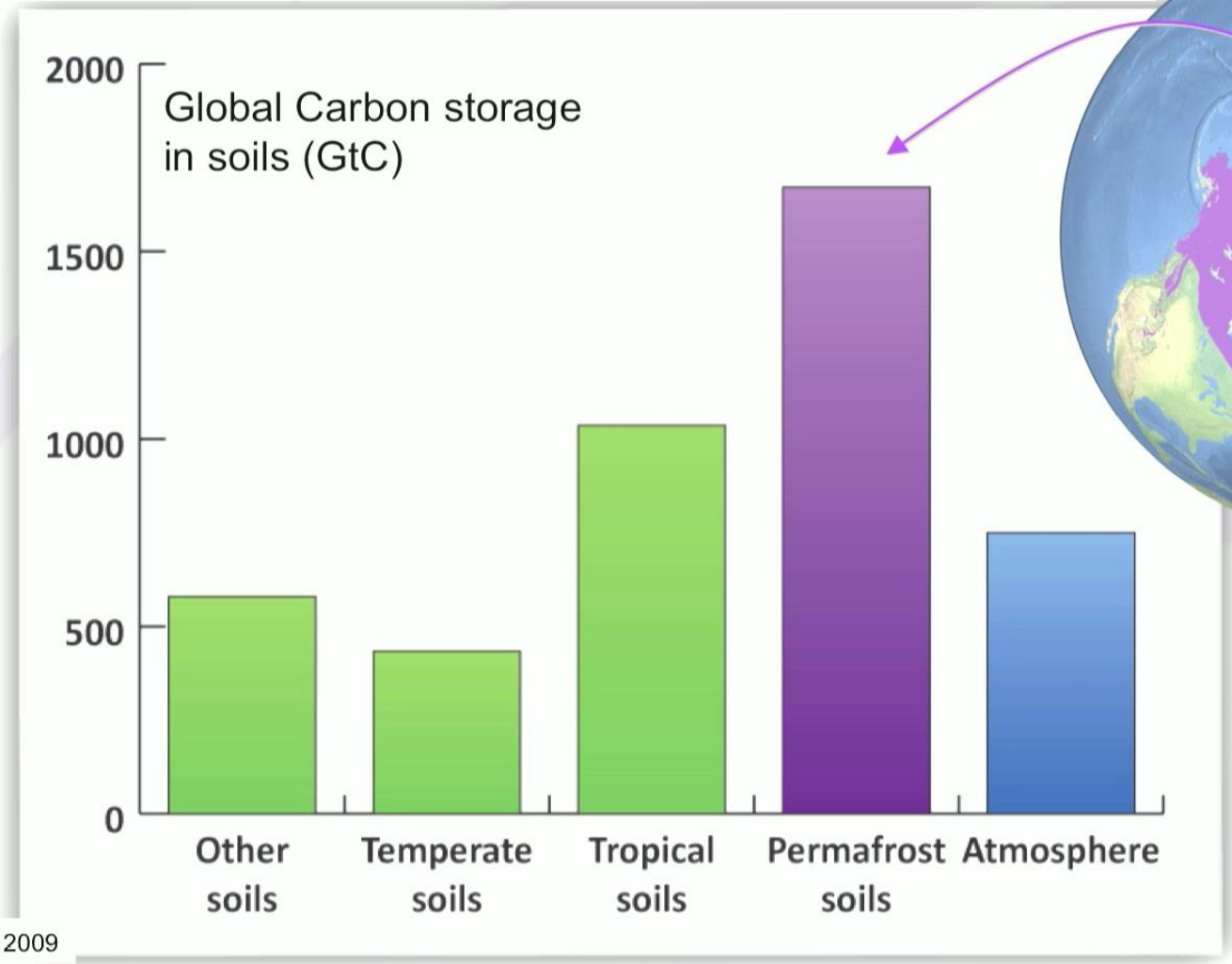


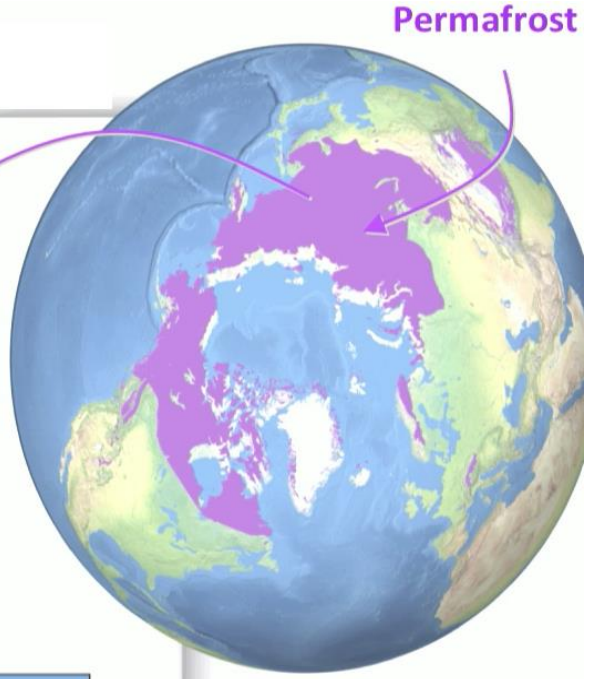
Climate warming has severe consequences for the permafrost on regional and global scales:

- **Increase of permafrost temperature**
- **Increase of magnitude and rate of development of the active layer**
- **Development of periglacial processes and landforms**

Permafrost reactions to climate change (degradation) influence biogeochemical reactions and the basic geotechnical properties of the ground

Carbon in permafrost





Tarnocai et al. 2009

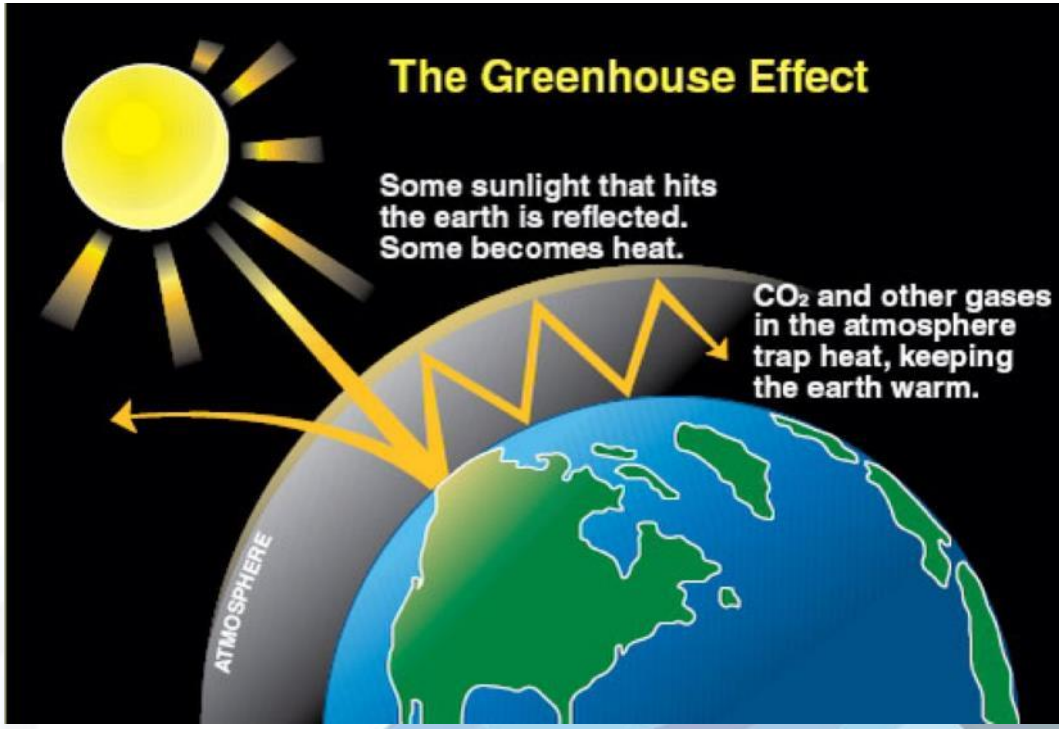
Greenhouse gas - gas in the atmosphere that absorbs and emits radiation within the thermal infrared range; has a global warming potential

The most abundant greenhouse gases in Earth's atmosphere are:

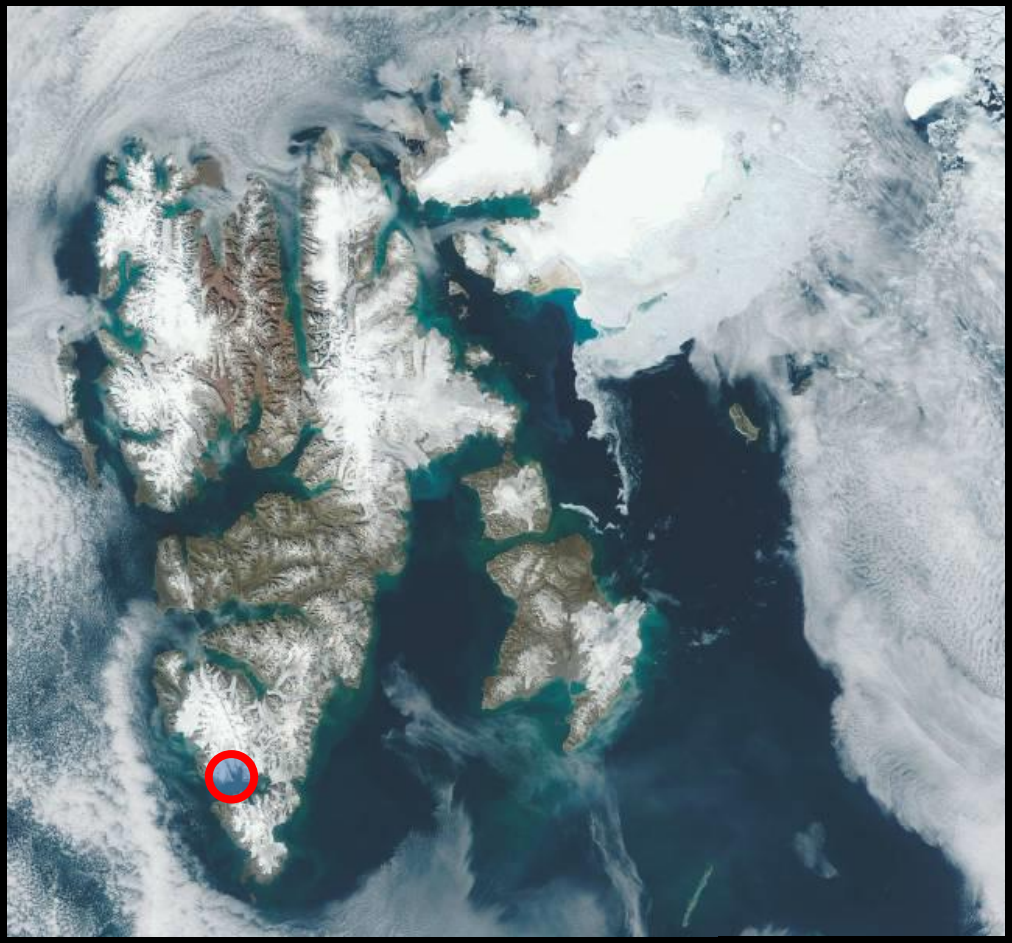
Water vapor (H2O) - the largest component of the greenhouse effect 36-72%

Carbon dioxide (CO2) - 9-26%

Methane (CH4) – 4-9%

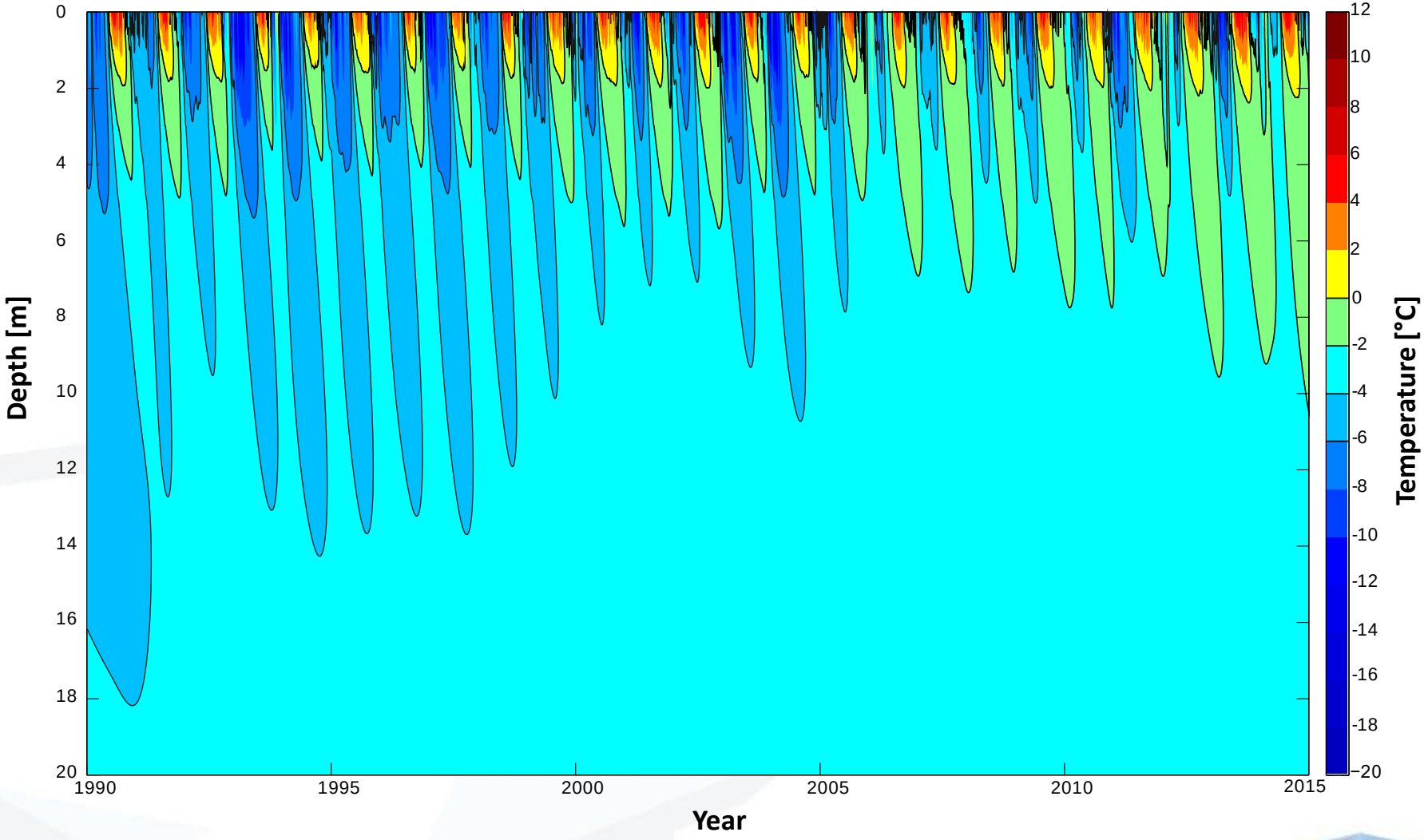


Hornsund / Svalbard




Loggers– with sensors

The distribution and evolution of subsurface temperatures at Polish Polar Station Hornsund in the period 1990-2014



Wawrzyniak T., Osuch M., Napiórkowski J., Westermann S. (2016) *Modelling of the thermal regime of permafrost during 1990–2014 in Hornsund, Svalbard*. Polish Polar Research. doi: 10.1515/popore-2016-0013

All constructions in periglacial areas are set on the piles drilled into the frozen ground

Pile driver

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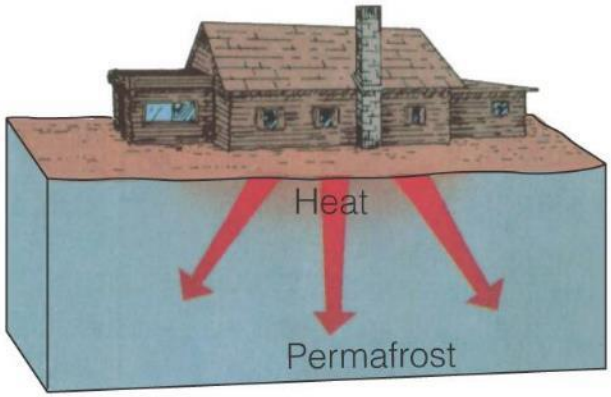

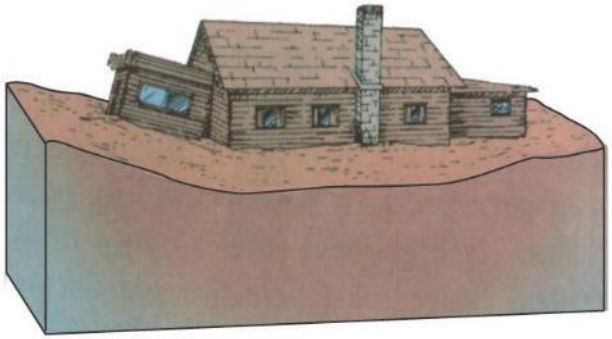

Christiansen H. 2010


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http://www.hamnqvist.org/

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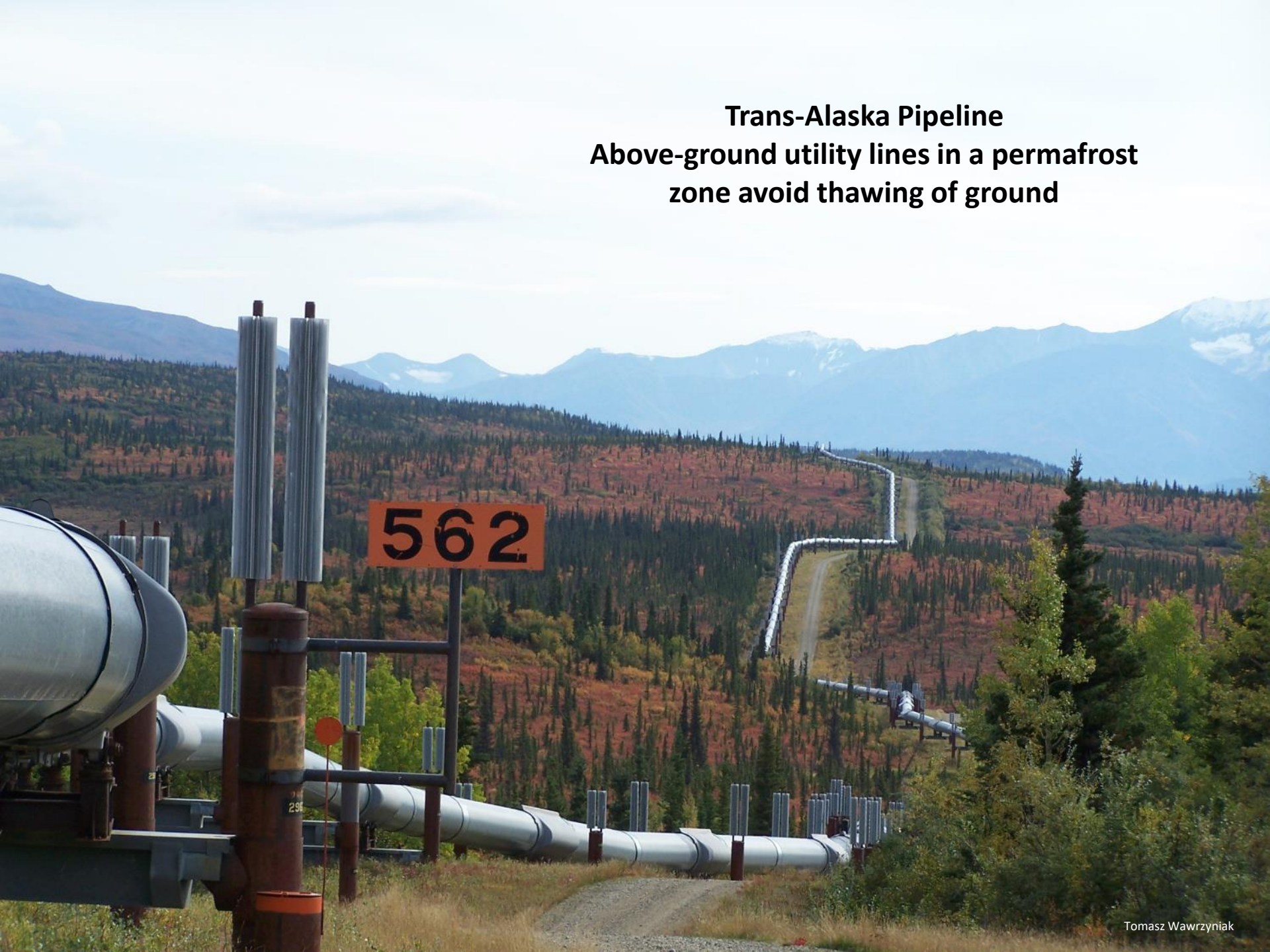
Trans-Alaska Pipeline
Above-ground utility lines in a permafrost zone avoid thawing of ground



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Thank you for your attention