GELISOLS

Hari Eswaran and Paul Reich
USDA-NRCS
Soil Survey Division
World Soil Resources

In the cold northern parts of the world, water in the form of solid ice dominates the system. This glacier, near Juneau, Alaska shows the dynamic nature of ice accumulations. The changing temperature and moisture conditions from freezing and thawing imparts special attributes to these soils called Gelisols.

Gelisols have either or both the following properties:

- Permafrost within 100 cm of the soil surface, or
- Gelic materials within 100 cm of the soil surface and permafrost within 200 cm of the soil surface.

Picture shows a glacic layer in a Glacistel; the layer is in the form of ice lenses or wedges > 30 cm thick.

Gelic Materials

Are mineral or organic soil materials that show evidence of cryoturbation and/or ice segregation in the active layer (seasonal thaw layer) and/or the upper part of the permafrost.

Warping of soil material: evidence of cryoturbation

Permafrost

- Is a thermal condition where the soil material remains below 0^{o}C for two or more successive years.
- The upper limit of the permafrost layer is dynamic and varies with surficial conditions.

KEY TO SOIL ORDERS

- **GELISOLS**
- **HISTOSOLS**
- **SPODOSOLS**
- **ANDISOLS**
- **OXISOLS**
- **VERTISOLS**
- **ARIDISOLS**
- **ULTISOLS**
- **MOLLISOLS**
- **ALFISOLS**
- **INCEPTISOLS**
- **ENTISOLS**

The Gelisols are keyed out first in the classification. These soils have permafrost or Gelic materials within the prescribed depths. With these defining properties, they bring together a group of soils that have commonality with respect to geographic location, a predominant diagnostic feature, and sets of processes that provide their specific attributes.

If they possess diagnostic features characteristic for the subsequent Orders, these are used to define the lower categories in the Gelisols.

THE SUBORDERS

HISTELS → Have large amounts of organic matter that accumulate under anaerobic and the cold conditions. The organic matter may also fill up voids in fragmental, cindery or pumiceous materials.

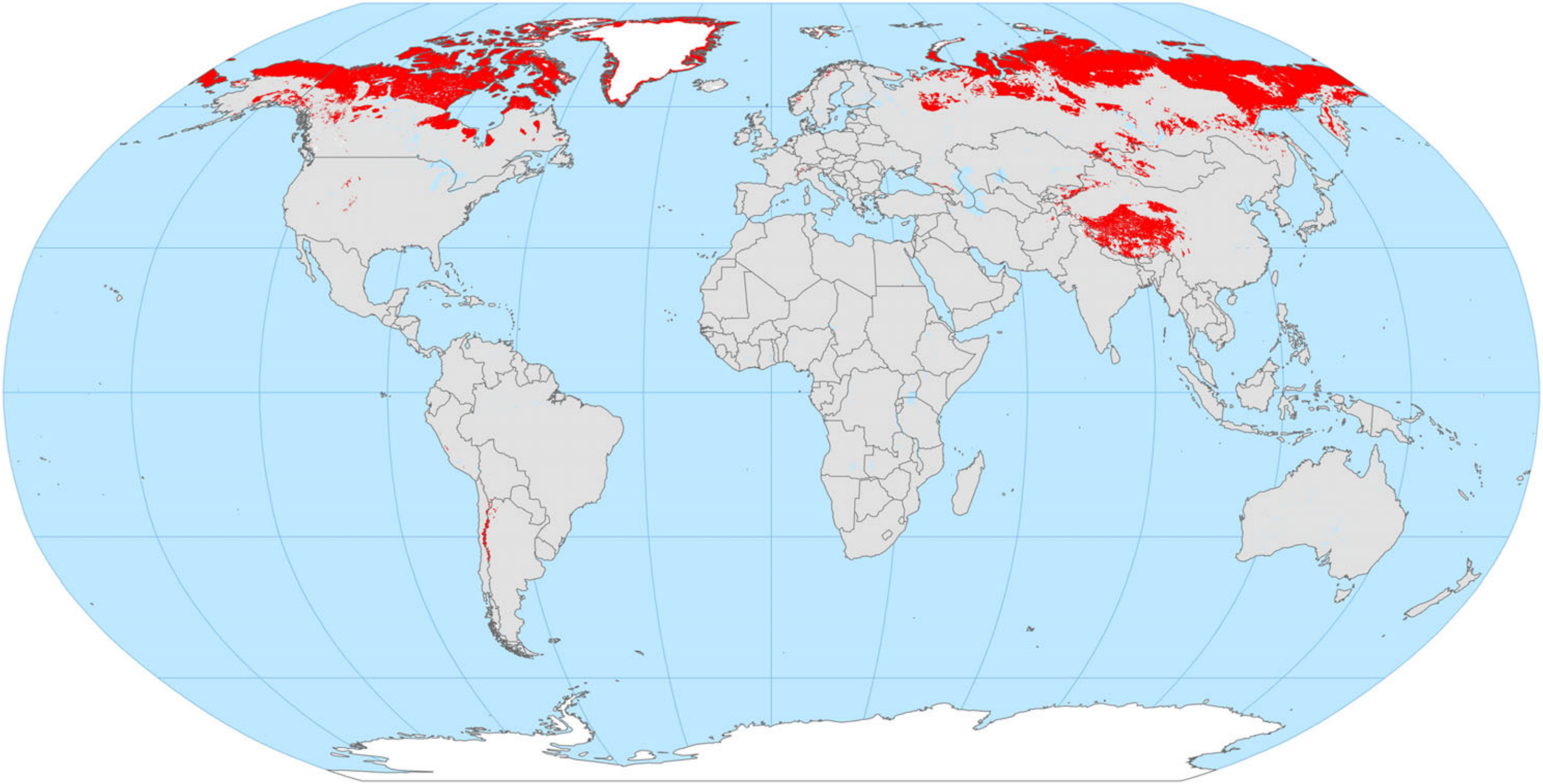
TURBELS → Show cryoturbation in the form of irregular, broken, or distorted boundaries, involutions, the accumulation of organic matter on the top of permafrost, ice or sand wedges, and oriented rock fragments.

ORTHELS → These soils lack evidence of cryoturbation. They are drier or better drained and less perturbed by freezing and drying cycles. Many are also coarse grained or with high amount of skeletal materials.

GREAT GROUPS

Prefix	HISTELS	ORTHELS	TURBELS
Fol.	Folistels		
Glaci.	Glacistels		
Fibri.	Fibristels		
Hemi.	Hemistels		
Sapri.	Sapristels		
Hist.		Historthels	Histoturbels
Aquo.		Aquorthels	Aquiturbels
Anhy.		Anhyorthels	Anhyturbels
Moll.		Mollorthels	Molliturbels
Umbr.		Umbrorthels	Umbriturbels
Argi.		Argiorthels	
Psamm.		Psammorthels	Psammoturbels
Hapl.		Haplorthels	Haploturbels

Distribution of Gelisols



Map shows the zone (in red) where Gelisols dominate. As this is a new Order in Soil Taxonomy and a new class in other classification systems, there is no reliable database of the spatial distribution of such soils.

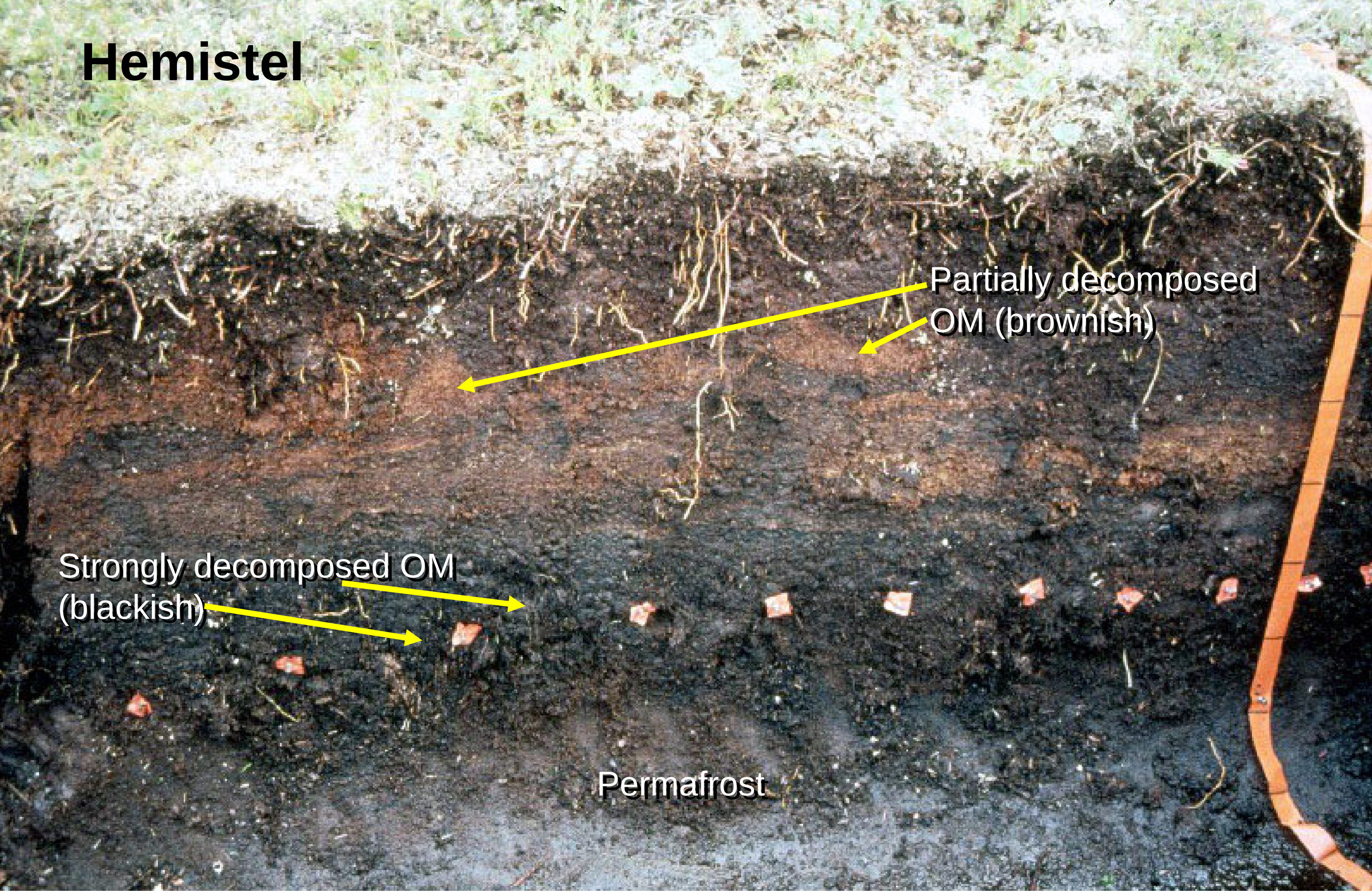
The Arctic Circle, a unique geographic marker; perhaps also a pedological marker. Around here, soils are different from those further south and accidental or intentional disruption of soil processes rapidly deteriorates the ecosystem.

Landscape, land surface properties and associated soils

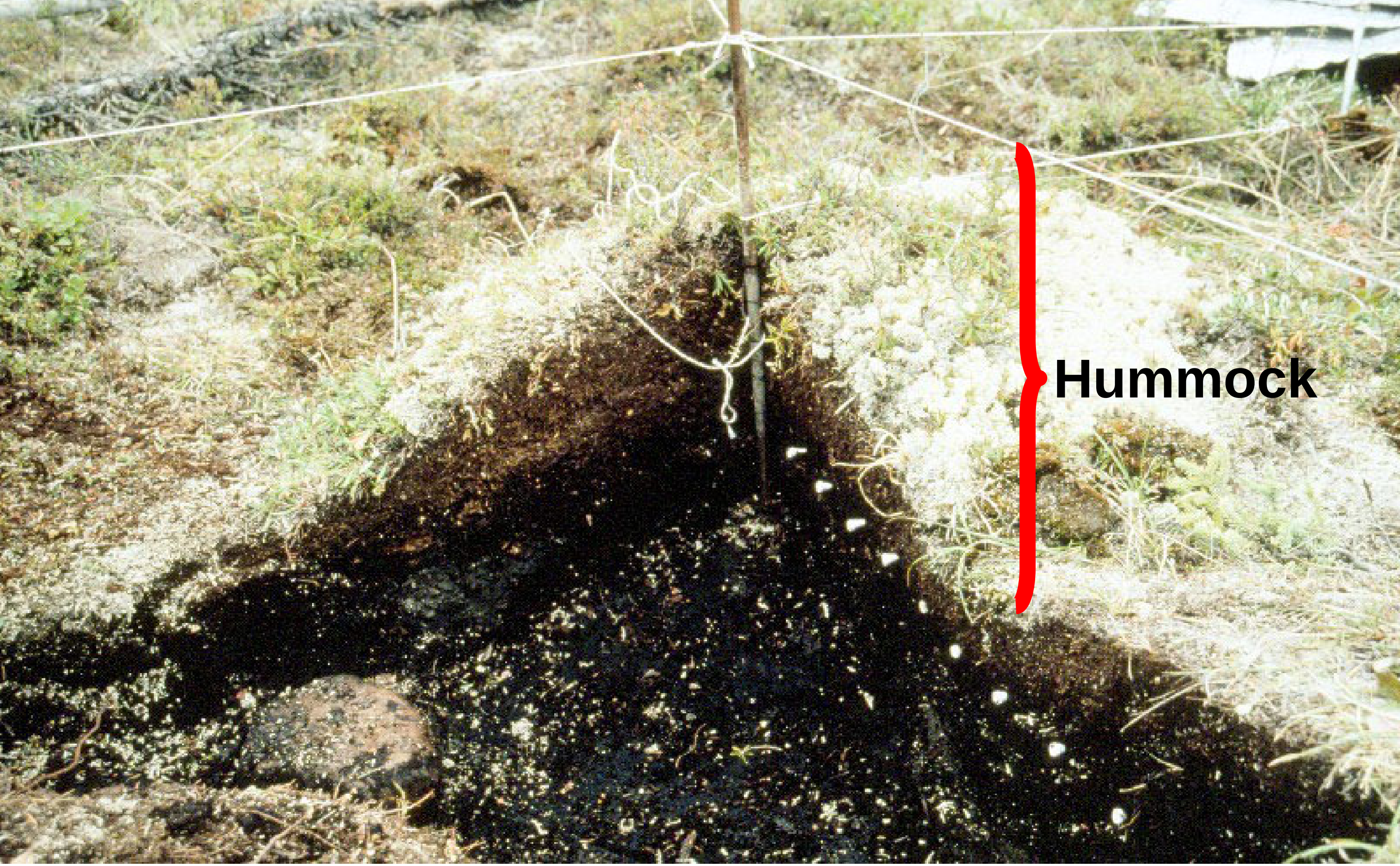
Glaciers gouge out long narrow valleys and leave marks on the landscape.
Glacial deposits vary in thickness and composition.

Peat (club moss and sphagnum peat) develop here and result in a thick insulating mantle. Such areas are called peat plateaus as they are slightly elevated. Peat hummocks characterize the surface and the layer protects the permafrost underneath.

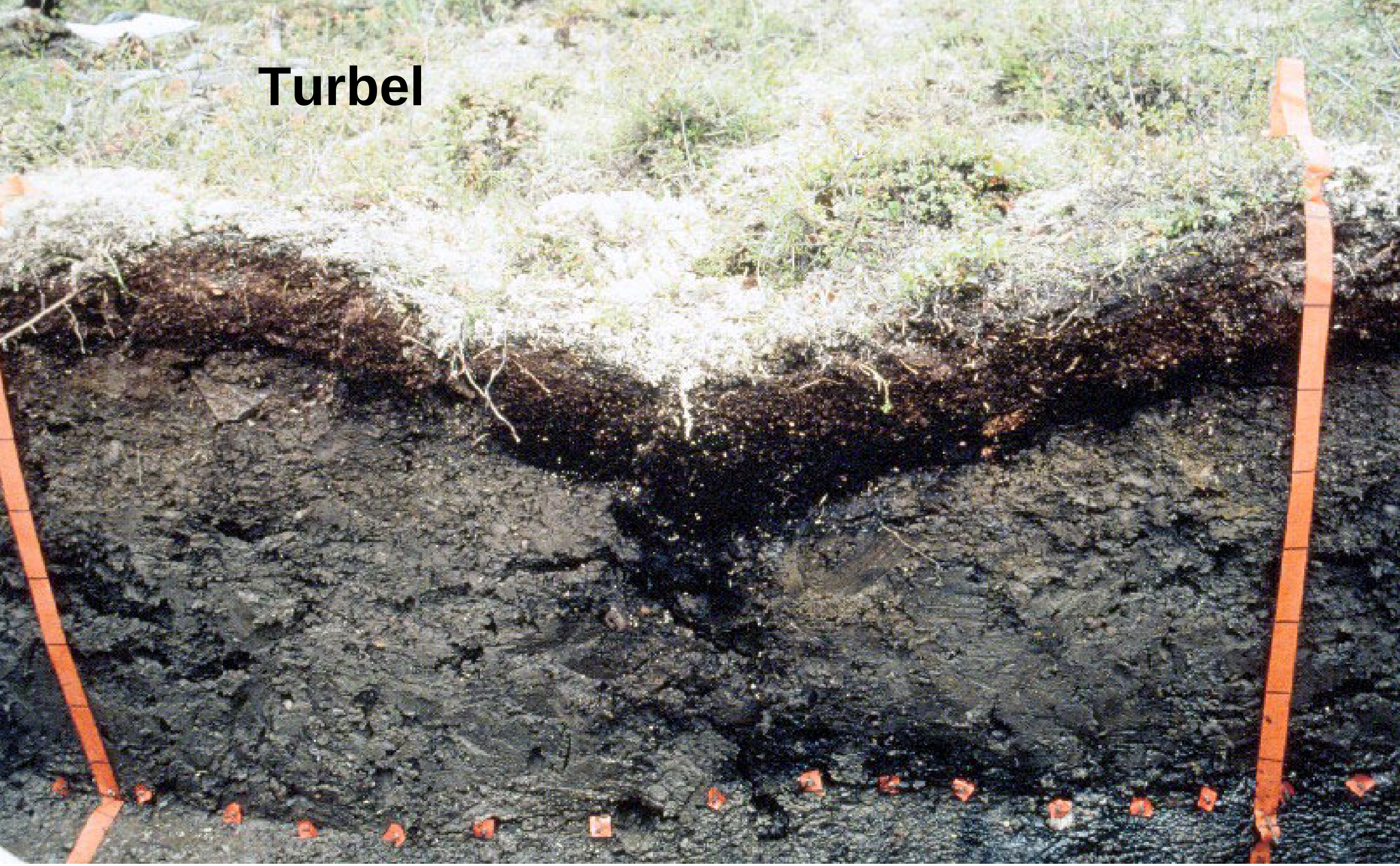
Hemistel



An organic matter rich Gelisol. The permafrost layer is located below the horizontal orange markers.



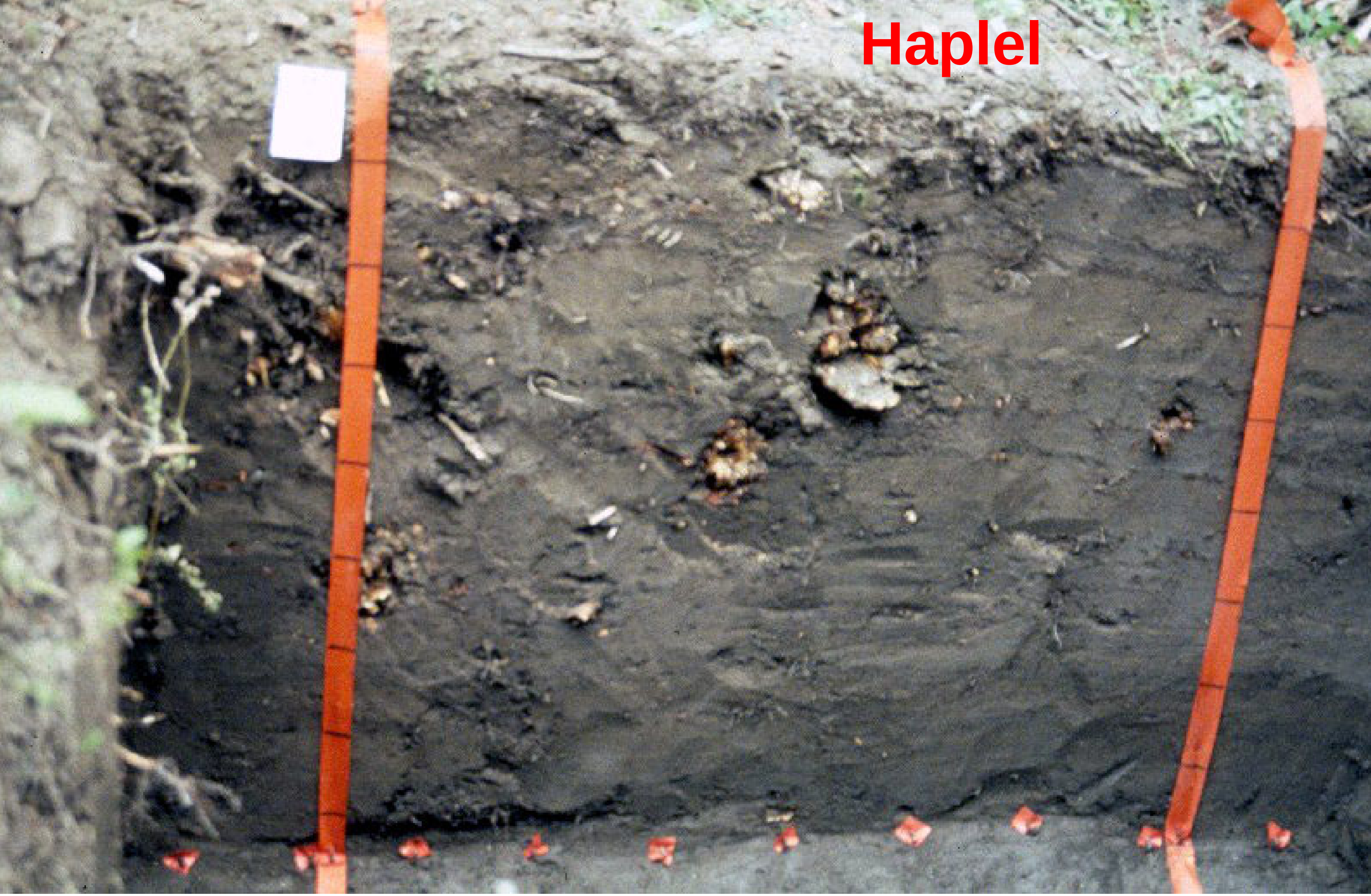
Section of a hummock. Hummocks develop when vegetation establishes preferentially at points on the landscape that have been pushed up by the ice. As peat accumulates locally, successive vegetation has better foot-hold and hummocks develop. The permafrost layer is indicated by the row of white nails.



The volume change of the underlying ice disrupts any layering of the soil and surface organic rich soil is incorporated deeper in the soil layers. This internal turbation characterizes a group of soils. The orange markers delimit the permafrost layer. The hummock distribution shows a cyclic tendency.

Understanding the changes in soil temperature and moisture is essential to managing this resource. Climate stations monitor soil and air climate parameters.

Vegetation establishes on river terraces. With better drainage, shrubs and trees grow; in areas frequently flooded, only grass grows or the sediment remains bare.



The recent and young terrace deposits are not prone to the turbation. The underlying permafrost layer does not alter the nature of the deposit or contribute to formation of hummocks. Canadians refer to this as “Static Cryosols”.

At slightly higher elevations from the river terraces, thermokarst lakes may form by melting of permafrost. The alluvium in such lakes appear similar to the terrace deposits and do not show any effects of turbation.

Dr. Sokolov (Russia) probes the soil with a stiff wire to detect depth to permafrost. New landscape conditions require new tools.

Tussocks are formed by the bunch grass that clump together and form a dense sod. The tundra tussock give the surface its roughness. The bare spot is called a frost-boil.

A bare surface created by freezing near the surface. The recurring periodic freezing at shallow depths creates this frost-boil or bare surfaces.

A permafrost influenced wet soil. Note the tussocks and the slightly thicker layer of organic matter underneath each of the grass clumps.

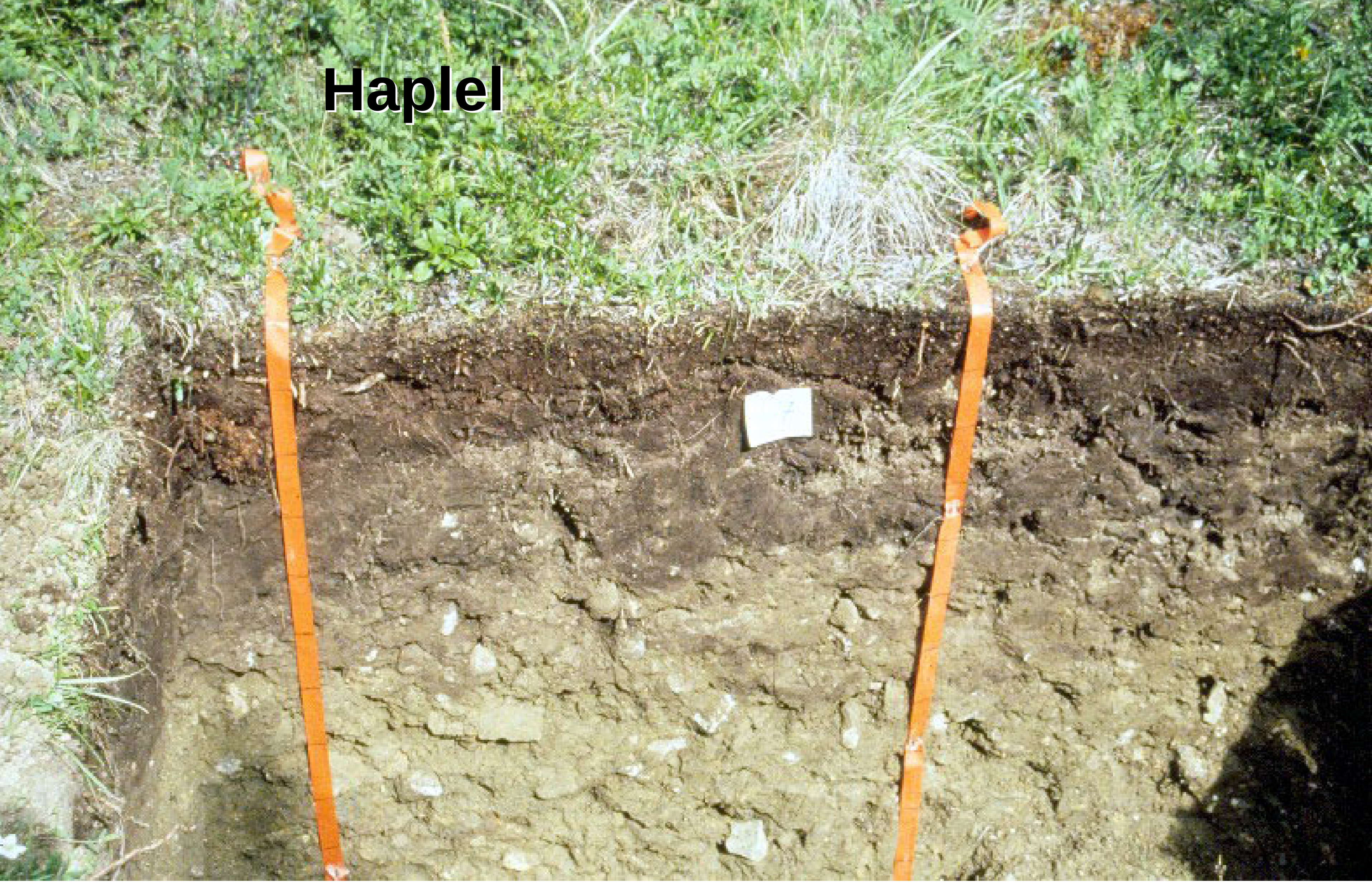
A permafrost layer is rock hard and requires a pneumatic ice chipper to break.

Sorted stone polygons. Bedrock occurs at shallow depth. Shattered rock.

A river and its floodplain with several terraces. Erosional surfaces suggest that geomorphic evolution of the landscape is active in this climate with extreme winters.

Differences in slope and aspect influence soil quality and the associated vegetation. Tall spruce on south facing slopes.

Earth scientists from different countries and backgrounds meet to decipher the properties and functioning of soils in this unique climatic system.



A soil on the warmer, south facing slope. The soil is well drained, permafrost is deep and is probably only influenced by the low hydraulic conductivity of the surface horizons, resulting in organic matter accumulation.

Convection currents promote afternoon rain showers. Moisture and temperature determine the course of soil formation.

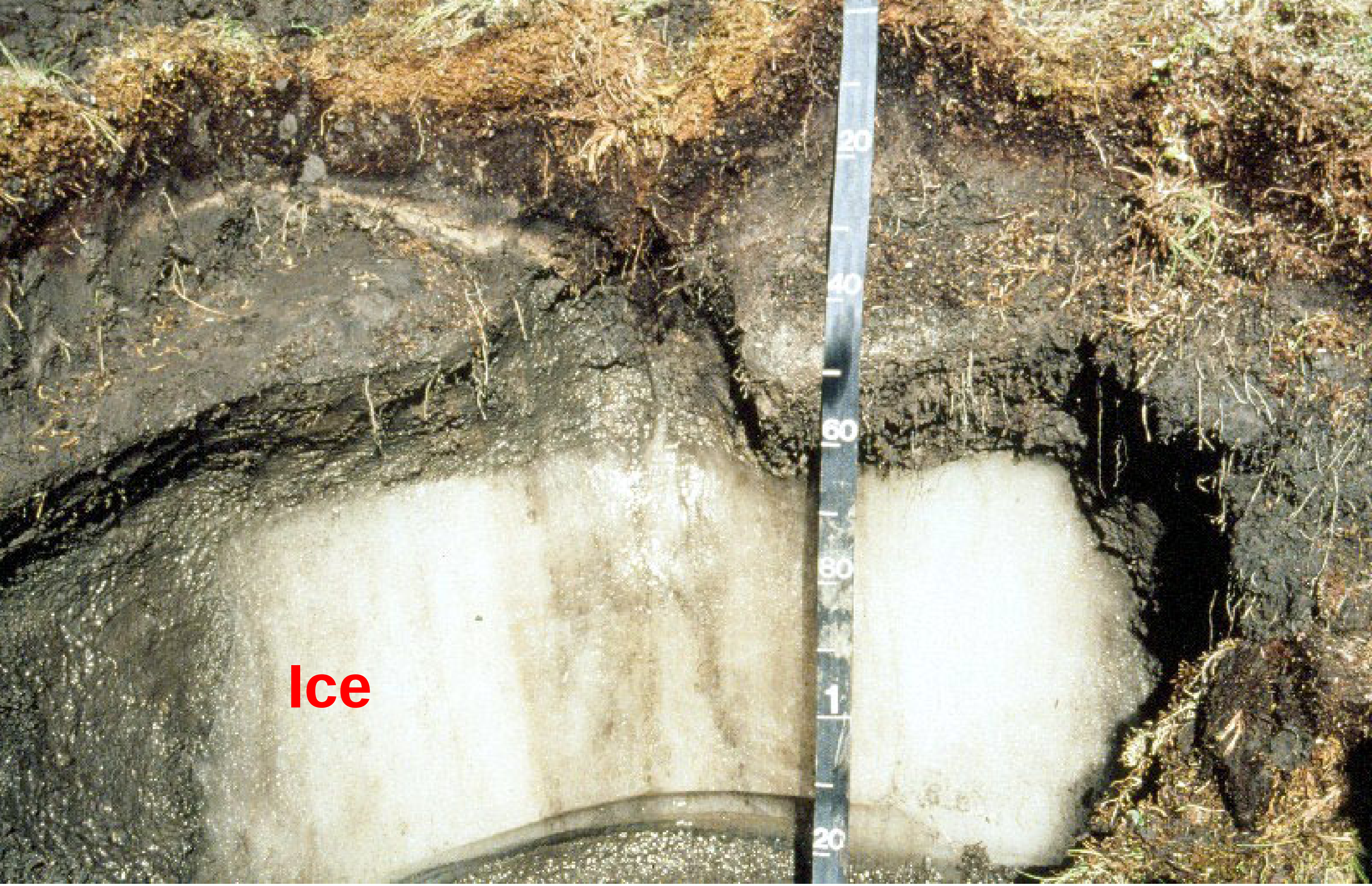
Freezing-thawing fragments rocks into stones, which move down slope to form a scree slope. Geomorphic evolution of the landscape.

A ferry in the Yukon. When the river is about to freeze, the boat is dry-docked.

Protecting the permafrost is the basic consideration in any construction. A layer of logs covered by 2-4m of gravel forms the base of this highway. Ditches are not used; natural drainage ways remove excess water.

With supply of food and water, other forms of life appear. A moose with its young graze close to Dawson City.

An ice karst. Apparently, a rerouting of an adjacent highway caused melting of the ice layers below ground. The land surface becomes irregular and hummocky as it tries to adjust to the new set of ecological conditions.



Ice wedge. Cracks in the soil surface become conduits for water movement. The water freezes in the subsoil.

When the frozen soil starts to thaw, surface soil erosion, gully erosion, takes place. These are other examples of landscape forming processes.

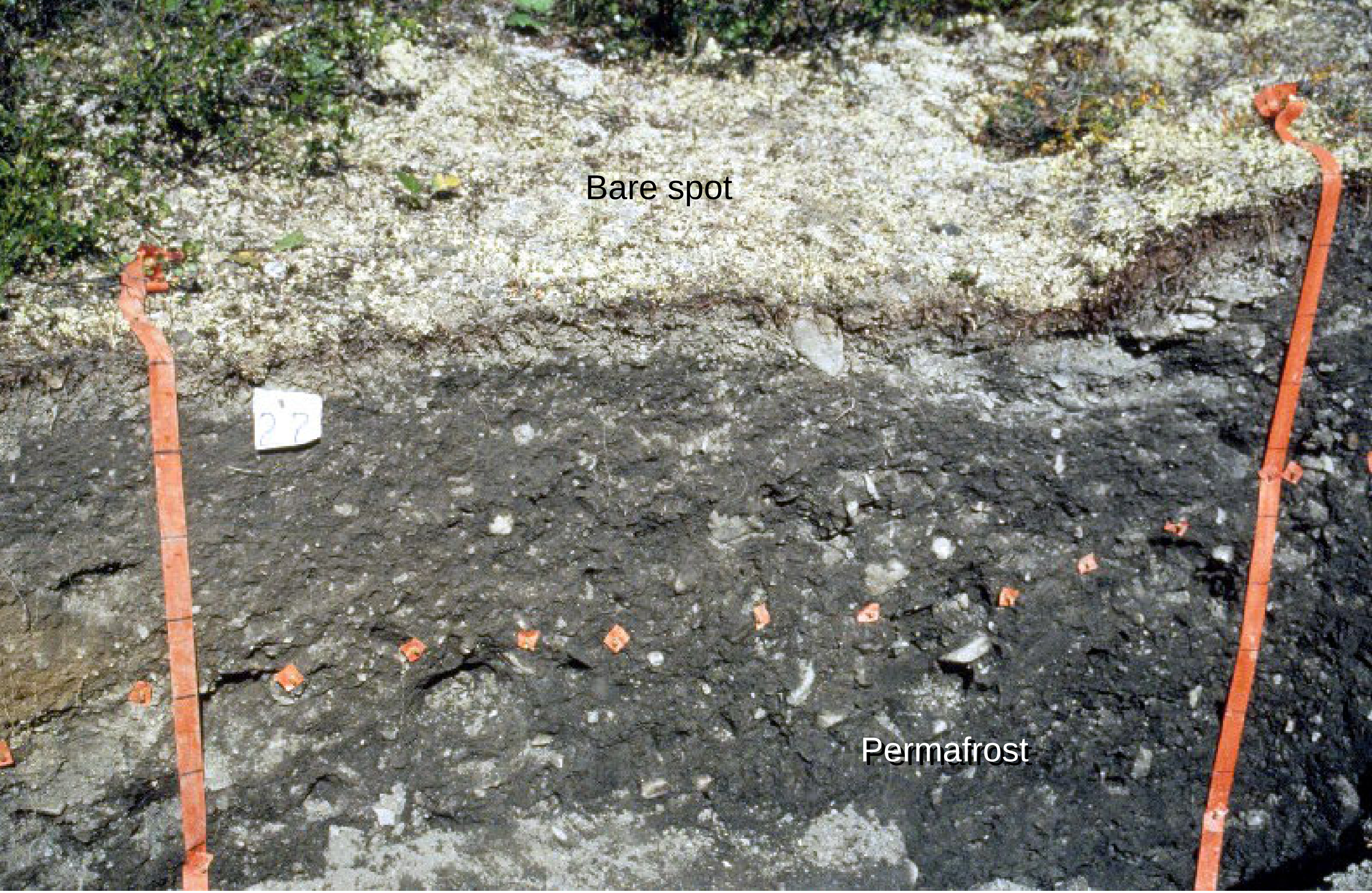
What causes ice-wedges to form and how do they influence the soil and landscape features? Some of the questions that need more investigations to answer.

Thermokarst landscapes. Water at the bottom of a gulley, ice-wedges, tussocky surface are all linked. Features, linkages, roles, and consequences – the basis for understanding.

Lichen, contributes to the diversity of the flora. What is the significance?

A “U” shaped valley – sculptured, eroded, and modified by peri-glacial features.
The force of moving ice – geomorphology in motion!

“Solifluction lobes”. Small bare surfaces with sparse vegetation. There are no satisfactory explanations of their formation.



Soil under the solifluction lobe. Few evidences of sorting though permafrost layer is at shallow depth.

Reclamation of permafrost-affected land is a slow process taking several years. Clearing vegetation and accelerating the melting of permafrost, a first step. Land is then allowed to settle before farming.

A cleared field waiting to be cultivated. Much of the forest in this area close to Dawson City has been exploited for construction.

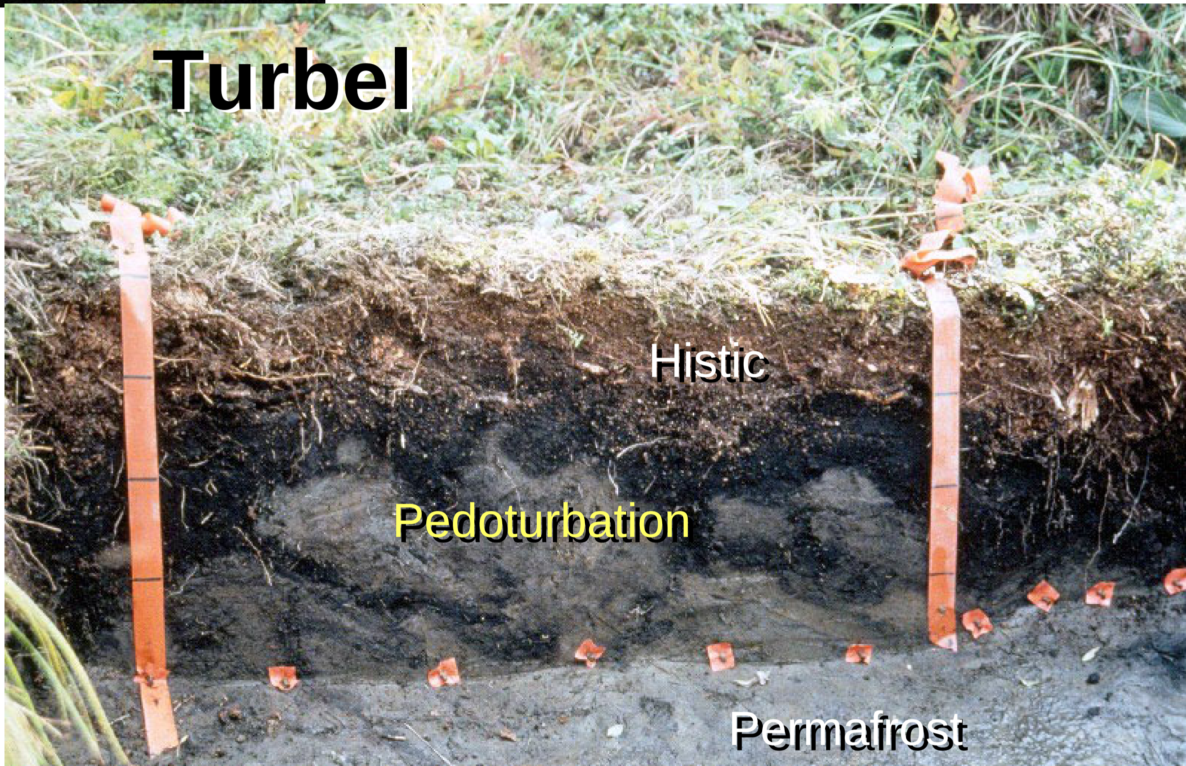
The vegetation (darker green and better growth) in the inset photo shows that despite the reclamation, the polygons are still recognizable.

Stone polygons

Sorting of stones is a surface feature; the soil may be stone-free.

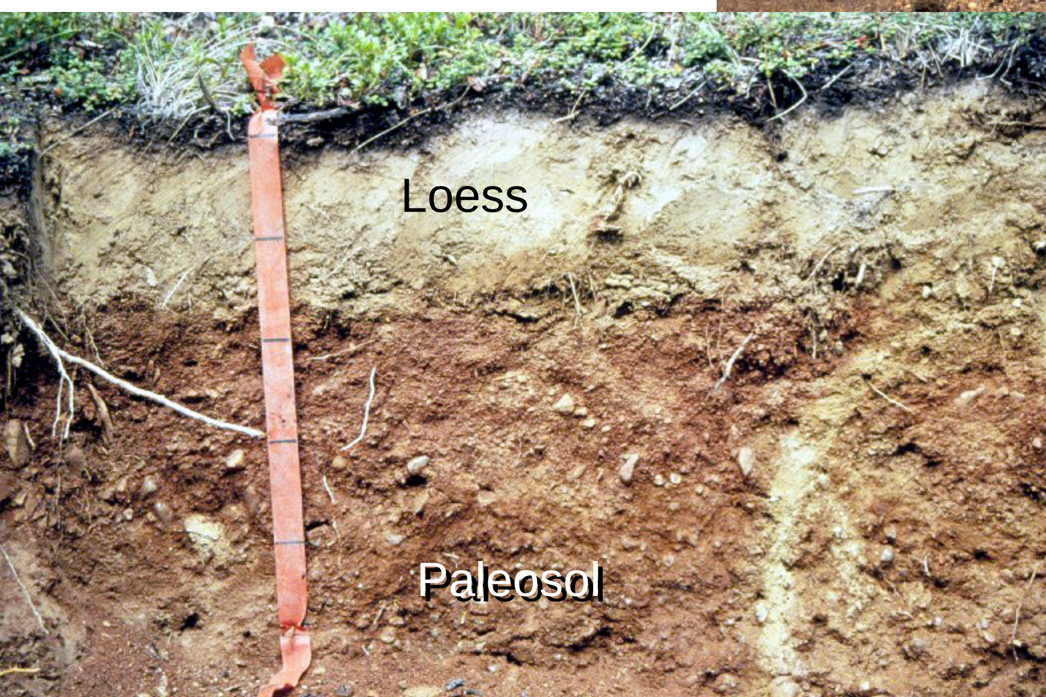
Soil of a drained wetland.

The land is used for hay.

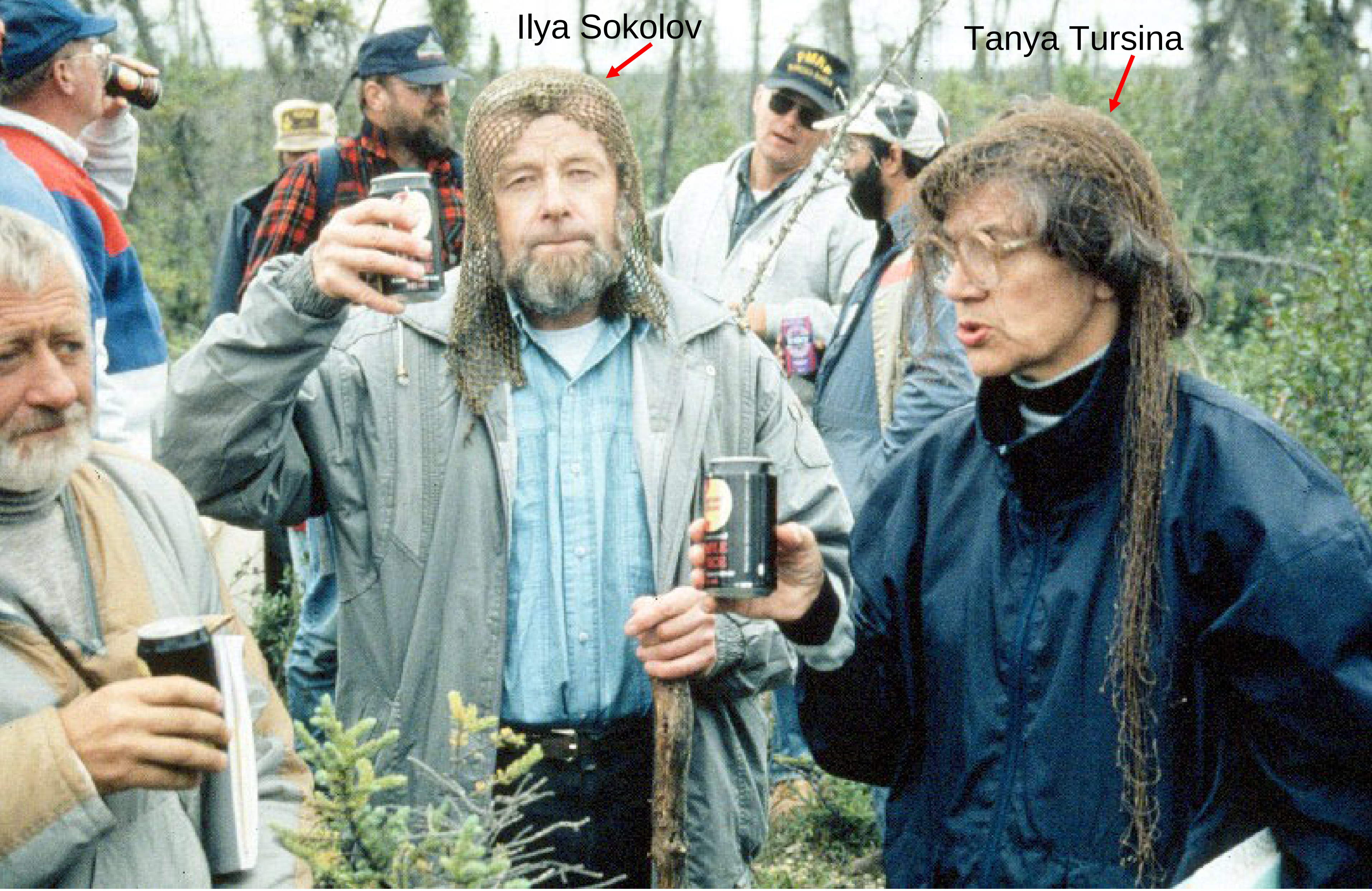


Soil in an adjoining forested land (with trees of about 80 years old). The permafrost layer is marked by the orange markers. The soil below the histic epipedon is pedoturbated.

On higher and older terraces, water-table and permafrost is absent. Road construction techniques similar to those in warmer climates.



On the higher landscape positions, the soil is overlain by a thin mantle of Holocene loess. A red soil, “a Paleosol”, underlies this loess. The red, buried soil is >10,000 years, a period when this part of Canada must have been much warmer.



Just like plants, the animals adapt to the short summers. Mosquitoes invade. Nets treated with insect repellants reduce discomfort.

Evidence of human influence. Pack horses grazing while waiting for the tourist season in the Yukon.

"YEDOMA" – a Russian term from the Kolyma river basin in Eastern Russia. This is a ice-rich silty deposit with gold. Miners use hydraulic pumps to dredge the deposit to recover the gold.

Ecosystem concerns. Not for me says the miner.

The majestic landscape of the Yukon. The thawing of the frozen river alluvium yields bones of mastadons – animals that roamed these parts about 10,000 years ago. Raises questions of ecology, survival and ……

As one moves away from the influence of permafrost as on the south facing slopes, the soil changes. Here, we have a Cryochrept, an Inceptisol.

On the north facing slopes, permafrost occurs at shallow depth and the soils are rich in organic matter and wet.

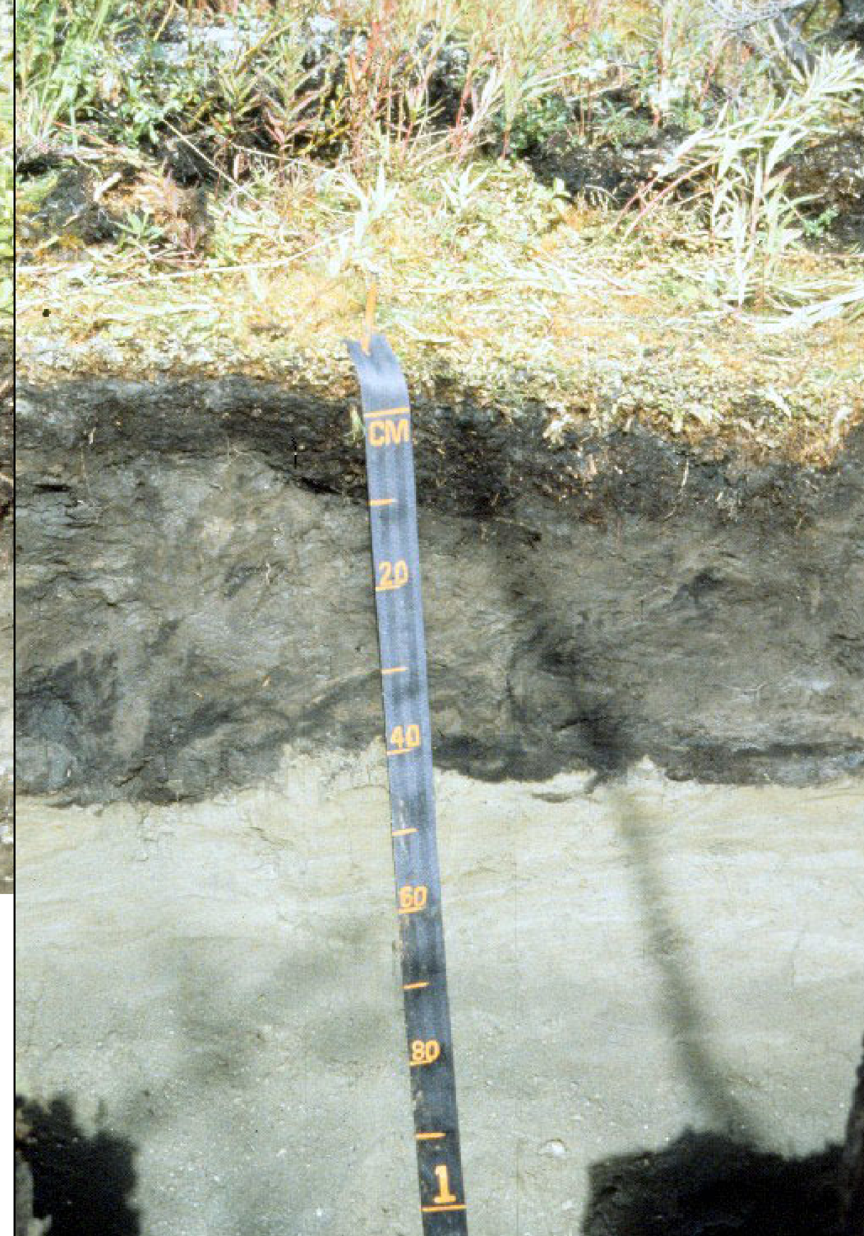

Soils,
soil conditions
and land use
in Alaska

U.S. border post. Soils and soil conditions do not adhere to political demands.

Forest fire damage. Ecosystem takes long time to heal and recover. Tok, Alaska.
In the next picture, a profile from the forest and from the burnt area is shown.

Soil under forest

Perhumid conditions under forest promotes moss formation. The permafrost layer is at about 50 cm depth. A Turbel. In the burnt area, distinct changes in soil evident. Permafrost is much deeper in the profile.



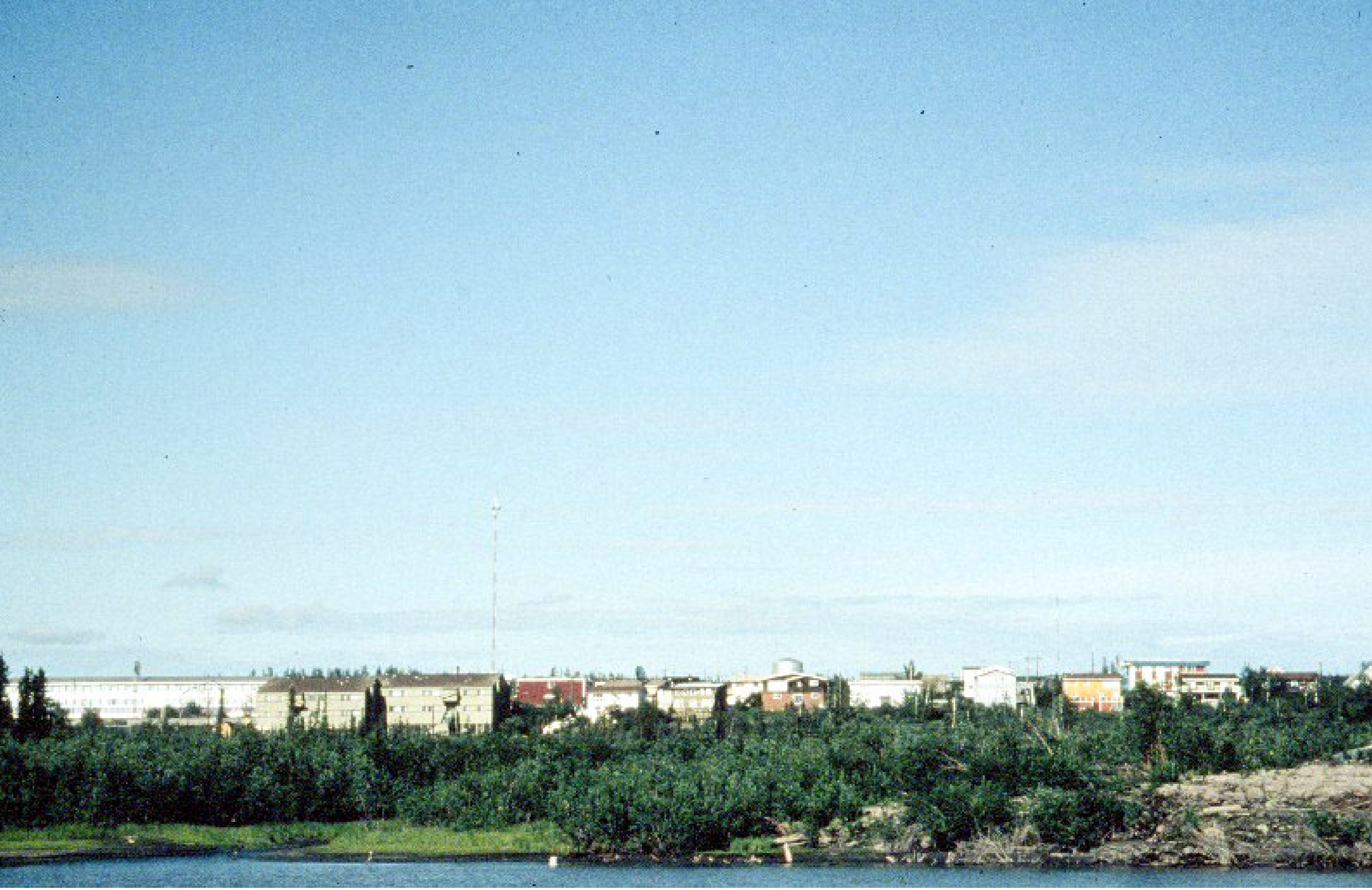
Soil in burnt area

A braided stream will join the Tanana to the Arctic Ocean. Deposits are sorted and laid, sometimes in spectacular forms as these silt patterns shown on the right.

Delta Junction, Alaska. Developing or adapting agriculture in this harsh environment. Experts discuss issues. Having good data as with the climate station (inset) an essential first step.

Land cleared over several years. Permafrost has retreated to several meters depth. The silty surface soil produces good tilth. Short summers, a major obstacle.

Farmer explains the difficulties in maintaining agriculture in this environment.



Inuvik City, Northwest Territories, Canada, in summer is just like any other city. But in winter, it demonstrates the struggles of humans to survive in this extreme cold ecosystem. It also provides examples of human adaptation to extreme conditions.

Adapting to the environment. This gymnasium of the Arctic College is built on pilings and a gravel pad several meters thick shields the underlying permafrost. Technology to suit the environment, but is the impact on the environment acceptable?

Water lines, heat pipes, waste water returns, and anything that emits heat must be shielded from the permafrost and also to prevent fractures at the -50^{o}C winter temperatures. Soil properties that dictate its use.

A foundation supports the house. In areas with permafrost, deigning the foundation involves not merely providing the mechanical strength but also the means to minimize the melting of the permafrost.

When the permafrost layer is destroyed, houses crack or subside.

A consequence of not understanding the soil system that we are working with.

The beauty of the Tundra varies with the season. In summer in Yukon, Canada, the fireweed bloom and provide color and a touch of life to this previous frozen landscape.


THE END