II. 4. PERMAFROST AS A GEOMORPHIC PROCESS

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(Summary)*

Geomorphology, as the science of landforms, is both descriptive and interpretative in approach. Recently, increased attention has been paid to geomorphic process in the interpretation of landform development, "process" being loosely defined as any physical or chemical modification of the earth's surface.

Permafrost is a very important northern geomorphic process underlying about half of Canada's total area. It has, however, received only scant attention as a process, per se. Although papers have appeared on individual features, as for example, pingos, there has been little attempt to assess its overall importance. The present summary briefly considers the relationship between permafrost and major geomorphic features and processes. The published paper will endeavour to synthesize present knowledge of permafrost as a geomorphic process in the development of northern landforms.

FEATURES

Pingos

Pingos are among the most spectacular individual geomorphic features attributable to permafrost. Because J. R. Mackay's paper, "Origin of the Pingos of the Pleistocene Mackenzie Delta Area" is included in these Proceedings, the topic will not be developed here. There is no doubt that permafrost is of paramount importance in their development.

Patterned Ground

Patterned ground, a very well known, but little understood, phenomenon of permafrost and other areas, is a group term for a wide range of geometric forms, including: circles, stripes, nets, and the "mark" of the north, the polygon, which in its largest form, the tundra polygon, reaches diameters exceeding 100 metres. A large unorganized body of literature has developed, with little agreement on the relative significance of the several processes involved in the formation of patterned ground, although permafrost is undoubtedly important.

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Thermokarst

Thermokarst, a form of karst topography exclusive to permafrost regions, is defined as the settlement of soil over thawing rock or unconsolidated material containing large amounts of ice. Thermokarst relief, determined by structure of the material and quantity of ice contained, forms only when thawing proceeds below the active layer. The resulting settlement of the surface leads to continued thawing which cannot be compensated by seasonal freezing.

Thermokarst seems to be initiated by a number of causes, including climatic change, forest fires, breaks in the surface by animals, and such human activities as deforestation, cultivation, and construction of buildings and highways. Among the commonest landforms produced by thermokarstic processes are: (1) surface cracks or fissures which may be associated with polygonal structure, (2) cave-in lakes or thaw lakes occupying depressions developed by the thawing of ice, (3) thaw-depressions, as above, without water, and (4) thaw-sinks which are closed depressions with subterranean drainage believed to have originated as thaw lakes.

Ground Ice

Ground ice features are widely distributed, although their areal extent is unknown. They may be responsible for rapid gulleying when exposed. A recent study showed that melting of ground ice triggered erosional action bringing about removal of large quantities of unconsolidated material.

Asymmetric Valleys

East-west trending asymmetric valleys are attributed to one-sided stream erosion when the ground is perennially frozen. On the southern slope the active layer thaws slowly permitting little erosion from melting snow cover, and, as a consequence, slopes have a low gradient. On the other hand, the permafrost table is much deeper on the more highly warmed northern slopes, and here rapidly melting snow moves material speedily, producing steep slopes.

Miscellaneous Features

Numerous other features, such as oriented lakes, altiplanation terraces, rock glaciers, nivation hollows and talus slopes have been described as resulting partly from permafrost, although space does not permit discussion here.

PROCESSES

Solifluction

Solifluction is the most important mass-wasting process in permafrost areas. A very slow gravity movement of mantle over permafrost, it is measurable in centimetres per year. In addition to such minor features as solifluction lobes, fronts and terraces, there is an overall downslope movement on a wide scale. The end result is a levelling of the landscape and a smoothing of the contours producing a subdued, non-angular relief.

Although the processes involved in solifluction are not fully understood, permafrost is important. First, it provides a hard impermeable base or slip-plane on which earth materials move downslope. It concentrates underground drainage near the surface facilitating plastic flow of the soil. Furthermore, it maintains soil temperature near the freezing point, permitting alternate freezing and thawing with resultant displacement of soil particles, and possibly some mechanical weathering.

Running Water and Tides

The work of running water in permafrost regions is chiefly concentrated or restricted to stream run-off. Perhaps the most important point is that both down-cutting and lateral side-cutting of streams are considerably reduced by permafrost which presents a resistant erosion surface to the water. The period of maximum run-off and erosion occurs in late Spring or early Summer when unconsolidated material forming their channels is still frozen or has thawed only slightly. It is thus difficult for the stream to pick up sediment at this time as it is forced to expend its energy on the extremely resistant permafrost. Later, when conditions are more favourable, the volume and erosive power of the stream has decreased. However, the load of sediment may be heavier, resulting in deposition, and the development of braided streams and floodplains common to permafrost areas.

Permafrost along a coastline will also inhibit erosive action of waves and tides, although, if ground ice should be uncovered, erosion may proceed rapidly.

Mechanical and Chemical Weathering

Permafrost influences the rate and type of weathering in northern lands. Mechanical weathering, usually by frost action, is important, almost to the exclusion of chemical weathering, which

does occur, however, in some limestone regions, especially if precipitation is heavy.

It has long been assumed that alternate freezing and thawing has been the important mechanism in mechanical weathering in permafrost regions. Recent studies suggest that the diurnal cycle is restricted to the top few centimetres of mantle and may be of less importance than previously thought. The annual range of temperature, however, with its effect on expansion and contraction, may be very significant, particularly in permafrost with high moisture content.

Organisms

Permafrost retards microbiological processes in the active layer, and none whatever occurs in permafrost, although bacteria may be present. Consequently, vegetative residue decomposes slowly, leading to the accumulation of organic material. Peat may be formed, in addition to string and palsa bogs, and a number of other vegetative forms. All of these forms are influenced by this retarded process of decomposition, in addition to the ponding of water and interference with surface and subsurface drainage by permafrost.

Permafrost also places a limitation on the movement of earth worms and burrowing animals as geomorphic agents.

Permafrost is also a physical barrier to the downward growth of roots, acting as a cold shield compelling the roots to spread horizontally on the thin upper strata of its upper layer. Winds and other forces may then cause trees and other vegetation to be tipped or tilted in different directions, resulting in the "drunken" or "dancing" forests sometimes encountered in permafrost areas.

CONCLUSIONS

Permafrost has considerable effect on the landforms and processes present in northern regions. A special type of subdued landscape results, the movement of surface and ground water is confined, and extreme dissection of the earth's surface discouraged. The role of mechanical weathering is accelerated, chemical and biological action is greatly reduced, and a number of minor landforms develop which are peculiar to permafrost regions.