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POLAR SOIL CLASSIFICATION AND THE PERIGLACIAL PROBLEM

Abstract

In order to have a better understanding of Polar soils and related periglacial problems, northern polar lands are first divided into three zones: (1) Polar Desert (High Arctic), (2) Subpolar Desert (Mid-Arctic), and (3) Tundra (Low Arctic). The major Great Soil Groups within each zone are identified. Methods of subdividing Great Soil Groups into smaller taxonomic units approximating the soil series (USA) are discussed. The problem of how frost action and patterned ground formation affect polar soil properties is considered. Some examples of using fossil properties to reconstruct past climates are discussed.

Over the years, periglacial studies have expanded greatly and now include geomorphology, glaciology, stratigraphy, geophysics, pedology, botany, palynology, zoology, marine science, climatology, geography and related disciplines. Technical journals and books are now devoted specifically to the subject and numerous societies are dedicated to the spectrum of problems relating to characterization of periglacial processes and conditions, as well as reconstructing those of the past. Prof. J. Dylik invited a report on the subject of periglacial soils as a part of this volume and accordingly, the problem of polar soil processes and classification are considered along with the possibilities of using such information in furthering periglacial science. In this report, soils of the polar region as a whole are first considered.

POLAR SOIL CLASSIFICATION

Following the great work of Gorodkov (1939) in which the polar lands were divided into a polar desert zone and a tundra zone, numerous investigators continued to built on the fundamental principles he set forth.

Soil studies of the North American arctic started at a later date. Tedrow *et al.* (1958) presented a schematic arrangement of soils for northern Alaska

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which provided for classifying soils of the tundra zone at the Great Soil Group level (U. S. A.). The above report was followed by one integrating Great Soil Groups with vegetation in northern Alaska (Tedrow and Cantlon, 1958). In both of the above reports, Arctic Brown soil was shown to eventually grade into a Polar Desert soil at the high latitudes. Subsequent reports (Tedrow and Brown, 1962; Tedrow and Douglas, 1964) showed a polar desert soil zone and a tundra soil zone on a circumpolar basis, largely as had been previously indicated by the map of Gerasimov (1956). More recent investigations in the northern sectors of the Canadian Arctic Archipelago and the north coast of Greenland have indicated that it is more realistic to delineate three polar soil zones rather than two. This proposed zonation

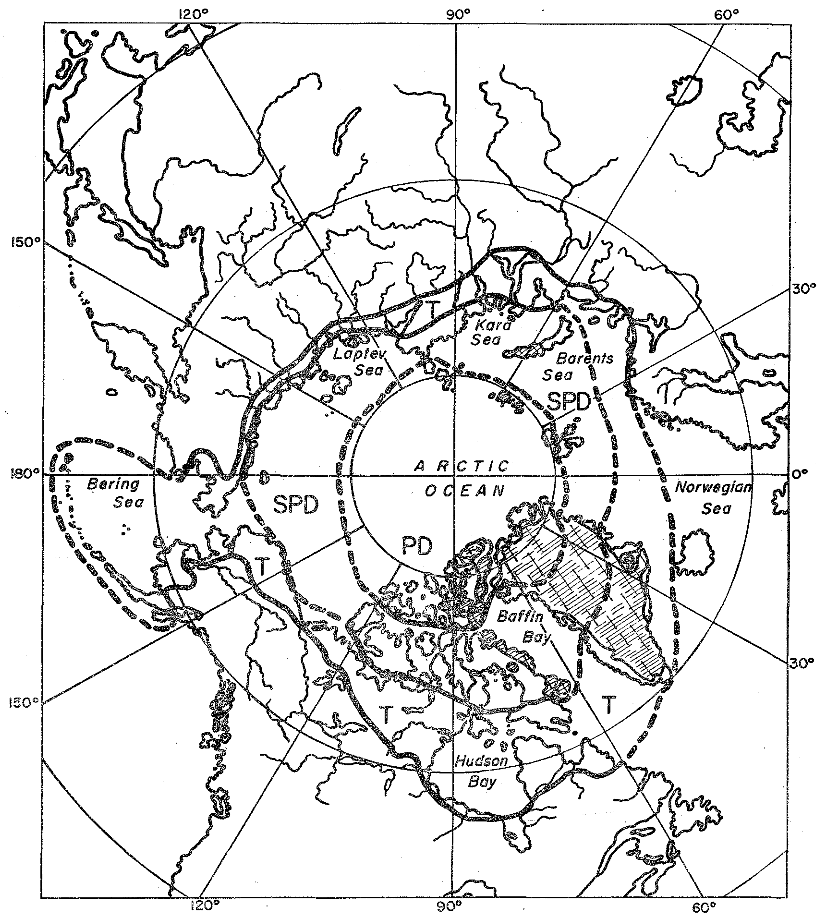


Fig. 1. Soil zones of the polar region

PD – Polar desert, SPD – Subpolar desert, T – Tundra is very similar to that proposed by Korotkevich (1967) and is further reinforced by the botanical zonation of the Canadian Arctic by Porsild (1955, 1957). If the three northern polar zones, as proposed in Fig. 1, are accepted, it would mean that nearly all of the now recognized polar desert (arctic desert) zone of northern Eurasia as proposed by Gerasimov (1956) and Tedrow and Brown 1962), would be placed within the subpolar desert soil zone while only a few extreme northern islands of the Soviet Arctic would remain in the polar desert soil zone. The polar desert zone, as proposed in this report, would center primarily in the northern Queen Elizabeth Islands and the north coast of Greenland.

Within each of the three soil zones are found a variety of soils. As Glazovskaya (1966) put it, "the once monolithic soil belts and soil zones have been assuming an increasingly mosaical character and loosing their unity".

In order to provide a classification scheme for soils of the northern polar lands, the following taxonomic units are proposed.

FIRST AND SECOND ORDERS OF CLASSIFICATION

1. POLAR DESERT SOIL ZONE (HIGH ARCTIC)

(a) Polar Desert soils (dominant) are the well-drained mineral soils with zonal character. They are without a humus layer, usually alkaline and with an active layer some 2 to 4 feet thick. Usually underlain by a dry frost condition.

(b) Arctic Brown soils (rare) occur only in tiny areas of the polar desert where there is a distinct organic mat (e. g. *Dryas*). Soils are usually alkaline, have an 18-to 24-inch active layer underlain by dry frost.

(c) Soils of the Hummocky Ground (common) occupy the slopes and are considered as the high arctic equivalent of Upland Tundra conditions. Gray brown mineral soils with a 1-to 2-inch organic mat. Usually near neutral in reaction with some salt efflorescence late in the summer. Intensive frost action.

(d) Soils of the Polar Desert-Tundra Interjacence (common) occupy the bases of the slopes and flats, which are mostly void of plant cover. Virtually no genetic features present. They are extremely wet in the early summer but become progressively drier late in the season with saline conditions and salt crusts developing.

(e) Tundra soils (common) are present along the water courses and other wet sectors of negative relief. A thick organic mat is present. Usually slightly acid, shallow development and underlain by dense ground ice.

(f) Bog soils (rare).

(g) Miscellaneous soils – shallow rocky soils, recent deposits, soils of the solifluction slopes and Rankers.

2. SUBPOLAR DESERT SOIL ZONE (MID-ARCTIC)

(a) Polar Desert soils (common) are similar to those above (1. a) but with a thin, discontinuous raw humus mat.

(b) Arctic Brown soils (rare) are similar to those above (1. b) but with a solum up to 20 inches thick.

(c) Soils of the Hummocky Ground (common) are similar to those above (1. c) but with more brown color than those of the high arctic. Usually alkaline.

(d) Tundra soils (common) are similar to those above (1. e) with an organic mat underlain by a mineral-organic mixture at the 0-to 10-inch depth. Usually alkaline in reaction. Permafrost at about the 10-inch depth.

(e) Bog soils (rare).

(f) Miscellaneous soils – shallow rocky soils, recent deposits, soils of the solifluction slopes and Rankers.

3. TUNDRA SOIL ZONE (LOW ARCTIC)

(a) Arctic Brown soil (rare) is deep, reddish brown, well-drained mineral soil. Active layer is 2 to 4 feet thick. Usually acid but alkaline on carbonate--bearing rock and certain wind-swept positions. Shallow phase of this soil is present on ledge sites.

(b) Upland Tundra soil (dominant) is a mineral gley soil of the rolling to steep land. Usually acid.

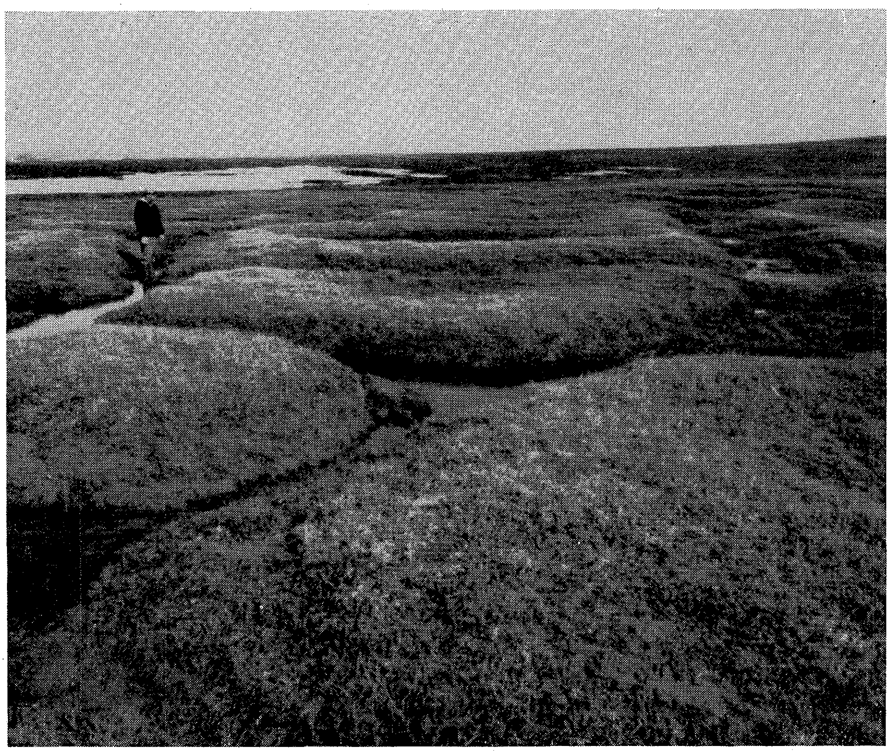
(c) Meadow Tundra soil (common) is a mineral gley soil with a thick organic mat. Usually present in level areas and depressions. Usually acid.

(d) Bog soils (common) are organic deposits of mixed peat up to 30 or more feet thick. Occur in local flat areas and depressions. Usually strongly acid.

(e) Miscellaneous soils – shallow soils, recent deposits, Rankers, Grumusol, Rendzina, Shungite and soils of the solifluction slopes.

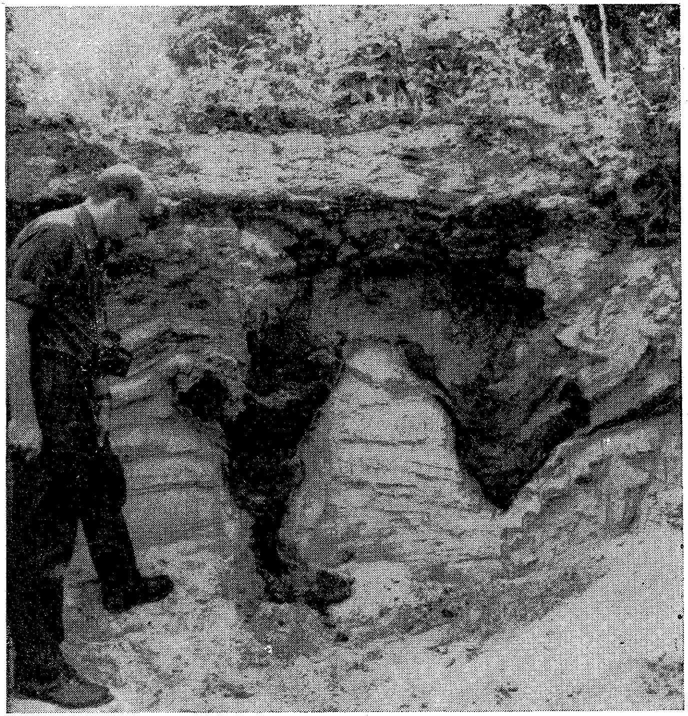
THIRD ORDER OF CLASSIFICATION

It is unlikely that there will be extensive detailed field mapping on a circumpolar basis in the near future. If, however, a more comprehensive approach is required, then further subdivisions would naturally be in order. It is suggested that third order of classification should concern the mineralogical/



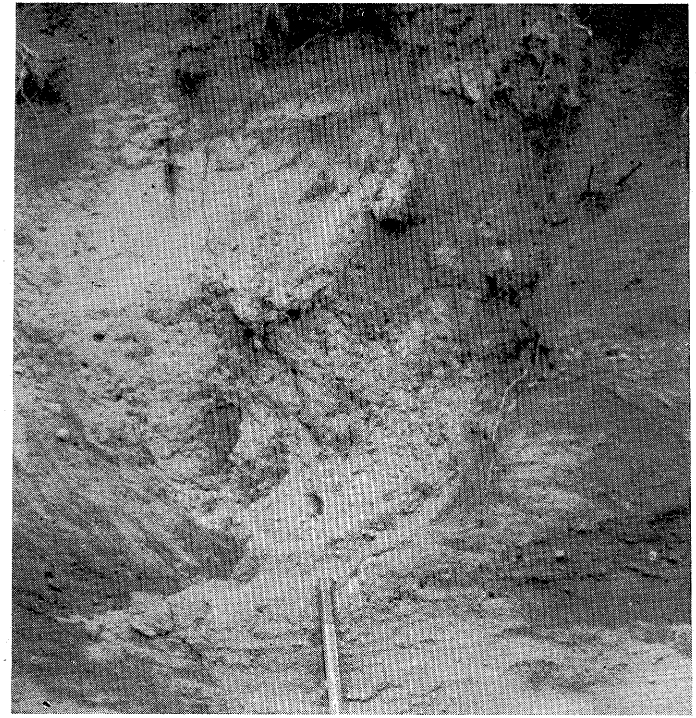
Pl. 1. View of tundra soil on Prince Patrick Island

The microrelief features developed by cryogenic processes cause extreme variation in soil moisture. The margins of the polygons are raised a foot or more and are in a semi-mesic environment, whereas, the channels of the polygons are largely under water



Pl. 2. Buried soil along the Aldan River, Siberia

The buried profile is of a Cryogenic Meadow-Chernozem Saline soil, which is quite similar to modern soils of the terraces. The ice-wedge casts are stained with organic matter. Physical conditions indicate the buried soil formed under conditions similar to those of the present



Pl. 3. Periglacial feature in a highly weathered Early Pleistocene deposit of New Jersey

The site shows lateritic affinities including iron-stained koalinite-gibbsite clays textural composition of the soil (Tedrow and Douglas, 1964). This would extend the classification to the level of the soil series or preferably, the soil type (U. S. A). It is well known that many Soviet investigators have reservations about the American concept of the soil type, because it is a dualism i.e., it considers the genetic soil together with the origin and character of the parent material. While the theoretical aspects may be questioned from the standpoint of a natural system of classification, I must strongly defend the application of the principle. For example, if the polar desert soils of the high arctic are considered, on western Prince Patrick Island they are strikingly xeric, brownish colored soils formed on acid gravelly sand of Tertiary or Early Pleistocene age. On the Mesozoic sediments of the eastern portion of Prince Patrick Island, the polar desert soils are more silty and usually alkaline in reaction with slightly more favorable moisture conditions.

In order to make the classification scheme more complete, factors such as coastal facies and latent salts will also need to be considered. The problem of base saturation, clay minerals, humus types, trace element status of the soil, among other factors, will also need to be integrated with the texonomic unit.

The above scheme assumes rather static conditions, which if projected over considerable periods of time, is rather unreal. There are instances where the age and stability of the landscape must be considered in relation to the degree of soil development but consideration should be given not only to the time elements *per se* but to possible climate changes as well. Climatic changes during the Pleistocene Epoch were outlined by Grigoriev (1925), Jahn (1956), Frenzel (1968), Dylik (1968) and Mercer (1969). At best, this problem is known only in general terms. Brown and Tedrow (1964) provided some information on the time factor in relation to development of well-drained soils in northern Alaska and it was concluded that in some instances, the mineralogical composition was as important and perhaps, at times, more important than the time factor in soil development.

FOURTH ORDER OF CLASSIFICATION

The fourth order of classification as proposed in this report concerns the wetness factor of the soil type. Earlier, it was pointed out that the Tundra and Bog soil classification, especially within the tundra soil zone, has serious limitations if one considers only the general morphologic features of the soil and relates these to the vegetative community (Tedrow and Cantlon, 1958). Pl. 1 shows an example in which a sector of Tundra soil, through frost processes, has undergone physical displacement. The channels surrounding the polygons are covered with standing water, whereas, the margins of the polygons are raised and in a much drier environment. In such a case, the channels of the polygons are in an extremely wet environment, whereas, the raised margins are in a more mesic state. The fourth order of classification provides for such a situation. The more critical situations requiring the fourth order of classification are found with Tundra and Bog soils.

PATTERNED GROUND

Most of the polar landscape is marked with some variety of patterned ground. Soil development and patterned ground formation are, in some respects, separate entities but there are certain relationships between the two. Troll (1958) summarized the global literature on patterned ground of the arctic and alpine regions, as well as that of the high mountains in the temperate and equatorial regions. Washburn (1956) in his *Classification of Patterned Ground and Review of Suggested Origins* got to the core of the problem in that he projected his studies towards establishing the major qualitative cryogenic processes operating in polar sectors. Some of the work on patterned ground formation has been quantified as exemplified by the work of Berg and Black (1966) with regard to yearly changes in frost features. These investigators found that ice-wedges in Antarctica were growing at a rate of 0.5 to 3.8 mm. per year. Still, the problem of relating the above processes and patterned ground forms to classical pedology has been studied very little. Drew and Tedrow (1962) described the various forms of patterned ground in northern Alaska as related to genetic soils. Ignatenko (1963) reported various genetic soils of the Yugor Peninsula as being associated with specific forms of patterned ground. The various frost action processes in the arctic regions and how they modify soil morphology were outlined in abbreviated form (Tedrow, 1962). Federoff (1966), working in Spitsbergen, showed that there is a degree of positive correlation between certain soils and the variety of patterned ground. The report of Brown (1966) in the Okpilak River area of northern Alaska is considered the most comprehensive information to date in relating genetic soils to frost features, in that 24 varieties of soil or soil conditions were listed and the varieties of patterned ground associated with each soil were tabulated.

It appears that if we are to develop a classification scheme for polar soils that will provide adequately for detailed mapping, both the genetic soil and the variety of patterned ground will have to be studied together. The work of Brown (1966) plus that of Washburn (1970) should serve as a base for such development.

INTEGRATING PATTERNED GROUND FORMATION AND PEDOLOGY IN THE PERIGLACIAL ZONE

When patterned ground features are studied within the periglacial zone, only minor attention is generally given to the developed soil features prior to the formation of the frost patterns. With the schematic arrangements of soils as outlined earlier in this report, one may be able to reconstruct more completely certain conditions prior to development of the frost features. Only a small percentage of northern lands escaped continental glaciation and, therefore, most of the preglacial soils have been destroyed (Hoppe, 1970). Still, there are scattered sites available for study within the glacial zone.

The periglacial zone includes the polar region plus great expanses of the northern forest region and the high mountains to the south. In all these zones, there were climatic oscillations which requires the investigator to project past environments into time and space as mentioned under the discussion of polar soil classification.

PERIGLACIAL FEATURES AND PAST CLIMATES

Great expanses of the northern forested lands have brown or yellowish colored mineral soils known by various names, including *Braunerde*, *Waldboden*, Taiga, Subarctic, Brown Wooded, podzolic and others. In some cases, such as with base-deficient rocks and in high precipitation areas, Podzols are present. Gley and Bog soils are also extensive in a circumpolar pattern. Reconstructing past climates in the periglacial zone from soil profile morphology has some inherent limitations because soils with similar morphologic features occur over vast sectors of the periglacial zone. The problem of using soil profile morphology as an indicator of past arctic climates has been outlined[1]. Nevertheless, there are some situations in which soils information can be used with reliability.

The work of Polish investigators, particularly that of B. Manikowska[2] is quite convincing, in that soil morphology, augmented with chemical data, was used to characterize certain climates of the Würm glacial stage in middle Poland.

Investigations by Lieberoth (1963) on the aeolian deposits of East

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[1] J. C. F. Tedrow, 1971 – Soil Morphology as an Indicator of Climatic Changes in the Arctic Area. Prepared manuscript, Oulu (Finland) Symposium.

[2] Guide to Excursion – Comm. on Evolution of Slopes and Comm. on Periglacial Geomorphology. Poland, 1967.

Germany are also of special interest because of micromorphologic techniques used to reconstruct past environments. Arguments relative to the "over-stamping" of certain loess deposits (e. g. cryogenically overstamped brown earth etc.) are quite convincing and such work should be expanded.

The terraces of the central Lena drainage basin in Siberia are, from the standpoint of periglacial features, ideal sites for reconstructing past climates. The soils are Cryogenic Meadow-Chernozem Saline as described by Yelovskaya (1965). Pl. 2 shows the modern, as well as the buried soil, both with similar morphologic features along the Aldan River. The two soils show the qualitative saline and chernozemic processes, as well as certain displacement from a previously existing ice wedge. Reconstructing past environment at this site, it appears that during formation of the buried soil, conditions were very similar to those of the present. Salts had effloresced on the vertical exposure of the buried profile as was the case with the modern soil. The modern soil is a youthful varient of Cryogenic Meadow-Chernozem Saline soil. The ice-wedge casts shown in Pl. 2 also consisted of saline material from the collapsed surface of Paleosol. Salt efflorescence was clearly detectable on the vertical face of the exposed soil.

A final example of using soil morphology to indicate past climatic conditions is from southern New Jersey (USA). The Bridgeton Formation is comprised of an unconsolidated clay-sand-gravel mixture and is generally thought to be of Early Pleistocene age. The formation is highly weathered to depths of 30 or more feet and shows strong evidence of tropical or subtropical weathering. Authigenic, bright red iron-stained, kaolinite-gibbsite clays are present, which sometimes make up over 35 pct. of the matrix (<2 mm) (Krebs and Tedrow 1958). Pl. 3 shows an example of a periglacial feature within the Bridgeton Formation. The horizontally bedded material is in an advanced stage of alteration as is the case of the periglacial feature itself. Based on soil properties, it can be stated that the laterite-like nature of the mineral material suggests a long continued tropical or sub-tropical environment.

With this brief review, I have tried to place the contemporary processes operating in the various zones of the arctic into realistic perspective and outlined the need for further refinement of the polar soil classification system. It was further shown that there is a need to integrate the genetic soil with various varietes of patterned ground. Finally, several situations were cited in which soils information could be used in reconstructing past events.

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