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The soils of the High Arctic were entirely unstudied until recently. Isolated works (Refs. 7, 18) had given only fragmentary information on the nature of these soils. The pioneer in the systematic study of arctic soils in B. N. Gorodkov. /521*

B. N. Gorodkov studied the zones of the tundra and of the arctic wastes, pointed out the basic characteristics of these zones, and analyzed their division into subzones and provinces. He believed that the soils of these zones belonged to the podzolic and boggy types. In recognizing the podzolic soils as zonal in contrast to the boggy intrazonal types, Gorodkov extended the podzolic soil zone to the most extreme northern limits of the mainland of the Soviet Arctic. Was this a mistake on Gorodkov's part? No, his views are in accord with the Linka-Neustruyev soil classification existing at that time.

In the pedology of the prewar years, the inductive method of soil classification prevailed. S. S. Neustruyev, whom Gorodkov quoted, wrote, "Combinations of these [soil-forming-(I.M.)] elementary processes produce an infinite number of individual types of soil, but among them are included the typical combinations to which the observed phenomena also correspond. These typical combinations, or types of soil formation, are not numerous, but they inter-combine, and -- appearing in different amounts -- they lead to the entire infinite mass of individual phenomena. Such types of soil formation are produced by the following processes as K. D. Glinka assumes: (1) the lateritic process, (2) the podzolic, (3) the steppe, (4) the solonetz process, and (5) the palustrine. The remaining 'types' may be derived from those indicated. They are intermediate transitions or combinations of the given main processes" (Ref. 12, p. 146).

It is known (Refs. 3, 10) that elements of podzolization are encountered on light rocks in the tundra. In tundra soils there is also an observed movement of certain elements downwards along the profile toward the surface of the perennially frozen rocks. The wide distribution of palustrine processes in the tundra zone is well known. Taking our start from all this and guiding ourselves by Neustruyev's views, we must assign the tundra soils to the podzolic and palustrine. Thus, Gorodkov's assumptions are in complete consonance with the inductive method of soil classification.

Even when adopting this system of calssification, B. N. Gorodkov still admitted the possibility that an independent soil zone existed in the High Arctic. He wrote, "If any characteristic soil zone must be discriminated in the Arctic, it may be done for the zone of the polar wastes" (Ref. 4, p. 1520).

In many papers Gorodkov objectively notes the features of both tundra and polar desert soils. He gives the first detailed characteristics of the soils of the polar wastes, and from his descriptions it clearly follows that they

*Note: Numbers in the margin indicate pagination in the original foreign text.

cannot be assigned either to the podzolic or the palustrine.

In describing the soils of the polar deserts of the Kotel'nyy Island, he dwells in detail on their characteristic features, "The mineral levels of the soil are greatly enriched with organic matter because of the abundance of frost cracks which have formed at various times and become filled to different degrees with organic material. There is leaching out of the soil. The reaction is neutral -- there is slight akalinity on the congelation boundary, but no effervescence because of acid. The soil is almost 100% saturated with bases" (Ref. 6, p. 76).

Somewhat earlier, B. N. Gorodkov notes, "It [soil of the polar deserts -- I.M.)] has a characteristic structure and differs greatly from tundra soil by the absence of gleization which is perceptible to the eye. This gleization appears in a very slight degree only directly under the turf and in the lowest layers over the congelation. The reason for so small a gleization, of course, is that the soil is well aerated because of the torn-up nature of the covering of the soil and the severe jointing of the rock ..." (Ref. 6, p. 75). Gorodkov calls this soil, arctic gleyish, but everywhere he notes the weakness or even the absence of the gleyic process. He probably called this soil gleyish by analogy with the very similar soils of the arctic tundras.

Gorodkov repeatedly pointed out the close connection between soils and the plant cover and spoke of the soil-vegetation complexes of the polar deserts (Ref. 5). That this complex nature be present he considered to be one of the most important characteristic features of the soil-vegetation cover of this zone. He wrote that the development of soils in the Arctic proceeded under the action of different factors, of which the most important were bioclimatic. In giving the correct objective descriptions and explanations of the soil-formation processes in the Arctic, Gorodkov took his stand on the Dokuchayevian genetic positions in pedology. His works on the study of soils in the Arctic have immense scientific significance and many of his positions will remain as guides for arctic pedologists -- his students and successors.

After Gorodkov, his students continued a study of the soils of the polar deserts and tundras. It is particularly necessary to note the work of V. D. Aleksandrova and that which is being carried on by the Arctic and Antarctic Scientific-Research Institute on the initiative of Ye. S. Korotkevich under the scientific direction of B. A. Tikhomirov.

We will pause below on the main features of the soils of the polar deserts. At present, it is accepted that a group of specific soils which are associated by unity of origin, transformation, and motion of the material may be called a soil type. In a soil type the following must exist: (1) similar processes /521 of substance transformation and migration, (2) similar nature of thermal and aqueous behavior, (3) similar ecological types of vegetation, (4) similar structure of soil profile with respect to genetic horizons, and (5) similar level of soil fertility (Ref. 13).

First let us characterize the aqueous and thermal behavior determined by climatic factors.

The soils of the polar deserts develop under very severe conditions. For a large part of the year, they are in a frozen state and thaw only for 2 - 2.5 months to a slight depth. The thickness of the seasonal thaw layer averages about 30 cm -- in favorable instances, up to 50 cm. In the first two or three weeks after its start, the thaw proceeds rapidly, then slows down, and in the second half of the summer thickness of the seasonal thaw layer remains almost constant. The temperature gradients in this layer are considerable, and on individual days may be as high as 15 - 20° at a distance of 0.5 meter.

The aqueous behavior of these soils is very individual. The snow cover is nonuniform because of the small amount of precipitation and the redistribution of the snow by the winds. Certain areas remain snow-free the year round. Waters from thawed snow play an insignificant role in moistening the soil, because for the most part they are shed before the start of thawing. Summer precipitation is small. Drizzling rains incapable of deeply wetting the soil predominate. Therefore, gravitational water does not play a great role in the process of soil formation. Far more significant under these circumstances is the pellicular water, i.e., the water present on the surface of the soil particles in the boundary and limiting phases. As research by I.A. Tyutyunov (Ref. 16) and Z. A. Nerseseva (Ref. 11) indicates, this water does not freeze at considerable negative temperatures and is capable of moving to regions of lower temperatures and accumulating there. Moisture in this phase is chemically active, and assists exchange reactions and the migration of elements inside the soil profile. In summertime, part of the accumulated moisture is expended on vaporization and transpiration, and part migrates downwards to the surface of the perennially frozen rocks. The relationship between winter motion of substances upwards and the summer motion downwards along the profile determines one of the essential differences between tundra and polar-desert soils. While the second type of motion predominates in tundra soils, in polar-desert soils, on the other hand, the first is predominant and accumulation of elements occurs in the upper levels. This accumulation is best expressed on the surface of the rocks of the "oases" in the Antarctic (Ref. 2).

The winter accumulation of moisture is nevertheless insufficient to cause overmoistening, and therefore the soils of the polar deserts are aerobic. Numerous tests with potassium ferricyanide have shown that gleization processes are not characteristic of this zone, but the lack of gleization may be occasioned not only by the aerobicity of the soils, but also by the insufficiency of thermal energy for reduction of the iron oxide by microorganisms.

At the same time, we must go to the other extreme and assign these soils to the arid type with carbonates and salinity. As Gorodkov has already remarked (Ref. 4), carbonate and saline differences are found among the soils of the polar wastes, but they are merely rock variants. As a rule, the soils on noncarbonate rocks do not effervesce.

One of the most important features of the polar deserts was considered by Forodkov to be the disjoined and disconnected nature of plant cover. The soil cover under these conditions repeats the surface distribution of the vegetation. The morphological levels in the polar desert soils vary in thickness. Individual levels are not spread in a continuous cover, but form separate spots, pockets, and "soil hills." This is particularly true of the humus levels which are disseminated under beds of vegetation and are associated with them. This complex nature of the soil cover is linked with the congelation processes and the retarded nature of the chemical development of the soils. In areas enriched with nutrient substances (biological hummocks, nitrophyll grasslands, and congregations of birds) the plant cover becomes continuous and the soil levels lose their discontinuous nature.

Complexity is also inherent in certain varieties of tundra soils, but in this case it is secondary and caused by the permafrost migration within the soil profile. The complexity of the soil-vegetation cover of the polar deserts, however, is primary, and we observe no motion of the soil levels at all.

The level of acid organic litter so characteristic of tundra soils is not developed on the surface of typical soils of the polar deserts. Notwithstanding this, however, the quantity of humus, even in the low-humus differences of these soils, is not less than 2-3%. It is probable that the principal coformers of humus in these soils are not the higher plants, mosses, and lichens, but the diatom and blue-green algae, encountered in abundance on the surface of the bare spots. Highly dispersed, easily soluble substances found in combination with sesquioxides predominate in the humus compositions. The humates and fulvates of alkaline-earth metals play a great role in the composition of the organic matter.

There are few clayed particles, and their distribution corresponds to the organic matter content in the soil profile. The absorptive complex is not large, but is almost completely saturated with calcium and magnesium, which determine the good structure of these soils, as well as their neutral reaction.

The soils of the polar deserts develop at low, for the most part, negative temperatures, Until recently, the opinion prevailed in science that at temperatures below zero the soil was in a state of absolute rest, but investigations /522 of the last few years show that soil development continues even under these conditions.

A. Ye. Kriss (Ref. 9) points out that the vital activity of arctic soil microorganisms does not cease even at negative temperatures. The activity of microorganisms drops as the temperature falls. Unfortunately, the lower temperature threshold of vital activity on the part of microorganisms is not known, but it undoubtedly exists.

I. A. Tyutyunov reports that the energy of chemical reactions may increase as temperature falls in permafrost layers (Ref. 17).

This relationship between the chemical and biochemical reactions in the soil determines soil development. Cations passing into a solution of the boundary phase from the primary minerals migrate to the surface levels during the winter, and there they enter into an absorptive complex of organogenic colloids. In tundra soils, this upwards-drawing of the cations does not compensate for the acid organogenic products which form, and the absorptive soil complex is not saturated. In the soils of polar deserts, cryogenic accumulation of iron in the upper levels occurs and is better expressed here than anywhere else. The result is that weathering products with predominantly iron-containing compounds similar to laterites are formed. Similar formations have been observed on Oktyabr'skaya Revolyutsiya [October Revolution] Island. M. A. Glazovskaya (Ref. 2) reports on the ferrite-allite nature of the surface formations in the unglaciated areas of the Antarctic continent. Laterization elements in the polar-desert soils of Spitzbergen were noted as early as 1919 by Blank. Tyutyunov's research also confirms the fact that these processes are present (Ref. 17).

We have therefore established that the soils of the polar deserts are a unique type of soil possessing uniform transformation and substance movement.

Only the most general patterns of development of the soils of polar deserts are listed above. In this type of soil, subtypes and species of polar desert soils may be discriminated (depending on local climatic features, the relief, the soil-forming rocks, and the age of development).

In the period of the postglacial climatic optimum, the natural zones shifted northwards (Ref. 15). The boundary of the tundra zone ran considerably farther north than it does today. Therefore, in a number of soils of the polar deserts we may observe relict features of tundra formation. Primary soils of the polar deserts and the secondary soils, which arose in place of the degraded tundra soils, may be distinguished.

The soils of the polar deserts are spread over the extreme northern and southern unglaciated areas of the continents. The drawing of zonal boundaries is complicated by the fact that this zone is situated in separate sectors divided by seas or glaciers. The transition to tundra soils is accomplished through a number of intermediate varieties combining the qualities of the various soils. Tundra soils penetrate northwards along the river valleys, flat slopes with southern exposure, and depressions.

Based on study of the plant cover, B. N. Gorodkov included all the islands of the Soviet Arctic, except the South Island of Novaya Zemlya and the islands of Vaygach and Kolguyev, in the region of the polar deserts. V. D. Aleksandrova proposed shoving the boundary of this region northwards and assigning to the polar deserts the part of Novaya Zemlya to the north of 75° north latitude, Franz-Joseph Land, Severnaya Zemlya, and the De Long Islands (Ref. 1). She admitted the possibility of finding polar deserts in the northern part of the Anzhu Islands. V. O. Targul'yan arrives at similar conclusions (Ref. 14). It is at present generally impossible to disagree with this viewpoint. The precise boundary of this region will become clear in the course of further work.

Very little is known about the distribution of polar-desert soils in the Arctic beyond our boundaries. There are isolated reports on their location on Spitzbergen (Ref. 18). It is very probable that they spread over Peary Land in Greenland (Ref. 19).

The primary soil formations are encountered in areas free of glacial cover in Antarctica where, in Ye. S. Korotkevich's view, the most severe southern subzone of the polar deserts is located (Ref. 8).

Such are the main features of the soils of the polar deserts and their distribution. The study of these soils is still merely begining. In a short time we will obtain much new information on these unique and interesting soils.

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