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M.S. BOCH

BOGS IN THE TUNDRA ZONE OF SIBERIA

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(BOG TYPES OF THE U.S.S.R. AND PRINCIPLES OF THEIR CLASSIFICATION)
CHAPTER IV, SECTION 1, pp. 146-154, LENINGRAD, 1974

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PREFACE

The Division of Building Research has been carrying out investigations on the distribution of permafrost in Canada for many years as part of its programme to gain a better understanding of this phenomenon in relation to northern construction problems. The type of terrain in which permafrost exists is one of the important aspects of investigations on its distribution. The special relationships existing between the occurrence of permafrost and peat bogs is under continuous study and the extensive work by Soviet investigators on the same subject is of considerable interest for comparison with Canadian conditions. This translation of a section from a Russian book by one of the foremost Soviet workers in this field describes a specific aspect of this subject concerned with bogs in the tundra zone of Siberia. Other related Soviet technical literature will be translated in the future. The Division of Building Research is grateful to Mr. V. Poppe for translating this paper and to Dr. R.J.E. Brown of this Division who checked the translation.

C.B. Crawford,
Director.

Ottawa,
May 1977

BOGS IN THE TUNDRA ZONE OF SIBERIA
(Fundamentals of typology)

Bogs are an integral part of the tundra terrain of the plains. In the tundra zone they occasionally occupy up to 70% of the area (the Yana-Indigirka lowland, some parts of the Yamal, etc.). According to M.I. Neishtadt (1971), the area of the bogs in the tundra zone of Western Siberia is 6.1 million hectares.

However, our knowledge of the tundra bogs is inadequate. First attempts to classify them were undertaken by V.N. Andreev (1938, 1955) and N.I. P'yavchenko (1955). Extensive studies of the bogs were carried out by N. Ya. Kats (1939, 1948, etc.) and B.N. Gorodkov (1928, 1935, 1938). Brief descriptions of bog vegetation are available in a number of regional geobotanical surveys of the tundra. However, lack of a generally accepted terminology and definitions often makes it difficult to use and compare the published data. The situation is especially bad with respect to the bogs in the Siberian tundra (Central and Eastern Siberia) and the bogs in northern subarctic and arctic tundras. The southern tundra (shrub-covered tundra) of Western Siberia was extensively studied by N.I. P'yavchenko (1955) and N. Ya. Kats (1939, 1948, 1971).

In the last few years, much attention is being given to the natural resources of Northern Siberia and this requires better knowledge of its natural terrain complexes. It is very important to study the bogs in the tundra, their role, and the possibility of using them in construction and engineering (gas pipelines, hydroelectric power stations, airfields, railroads, etc.), and in other fields of economic activity.

In 1961-69 this author carried out systematic studies of bogs in the tundra and treed tundra zones in the European Northeast, at various points of Eastern Yamal, in the western part of the Taimyr, and in the northern part of the Yana-Indigirka Lowland. The studies included investigations on the ground and visual observations from the air. In every case use was made of aerial surveys. The result of this work is the typology of the tundra bogs presented in this article. It was compiled with allowances for the investigations of other authors and their synonymy, and contains new data on the bogs in the Siberia tundra.

It is still not entirely clear whether there are bogs in the tundra. Some investigators feel that the tundra does contain bogs (Korchagin, 1933; Gorodkov, 1935, 1938; Andreev, 1938, 1955; Kats, 1939, 1948; P'yavchenko, 1955; etc.). Others (e.g., V.B. Sochava, 1931; V.F. Sambuk, 1937) claim that all swampy areas are tundra and call them "hummocky tundra", "Sphagnum tundra", etc. Gorodkov (1935) was the first to differentiate clearly between "tundra" and "bog".

Such diversified views are due to the fact that: 1) the predominating life forms and even plant types in the tundra and the tundra bogs are similar (small shrubs, grasses, Hypnum and Sphagnum moss); 2) flat tundra is often sufficiently wet and has a peat horizon which makes it similar to the ridges (dry sections) of the tundra bogs. However, the present day tundra bogs are always wetter (they may even contain open water on the surface), there is a peat layer which is up to 50 cm in thickness (absent in the tundra), and vegetation includes a number of specific species (e.g., Carex stans, C. chordorrhiza, Sphagnum squarrosum, S. fimbriatum, etc.) which are not present in the tundra. Finally, the tundra bogs often reveal a specific structure of the surface, vegetation and soil, which is absent in the tundra. This structure is referred to as the polygonal structure and will be discussed later.*

The main type of tundra bogs includes polygonal bogs, which are represented by numerous morphological varieties. They occur on flat, undrained water divides, on the bottom of drained lakes, on the terraces, and in the river valleys. N.I. P'yavchenko (1955) suggested that this is the

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* It should be noted that a polygonal structure of the surface is often found in dry tundra as well. However, the outer appearance of these polygons and their vegetation are not the same as in the bogs with very wet polygons.

predominating type of tundra bogs and our findings are in complete accord with his suggestion.

The origin of these bogs was described by A.I. Gusev (1938), A.I. Popov (1953), N.I. P'yavchenko (1955) and others. The polygonal terrain forms are due mainly to the effect of frost fracturing accompanied by cryogenic and geological processes, such as thermokarst, formation of ice inclusions, etc. The polygonal bogs result from fracturing of peat and silt deposits on alluvial terraces, in drained lake depressions, and other relief forms under severe climatic conditions. Fissures, which may be several tens of meters in length, break up the surface into regular four-, five-, or six-sided units, i.e., polygons. In the spring and in the summer these fissures are filled with water. Freezing water expands the ice wedges in the fissures still further, while frozen soil which expands during the summer thaw is crushed against the ice. This results in formation of ridges characteristic of some polygonal bogs. Surface water accumulates between the ridges within each polygon. On freezing, it exerts pressure on the ridges from within the polygons. This leads to the formation of a specific microrelief consisting of three elements: fissures, ridges, and pools of water in the centre of the polygons. The polygonal network formed as a result of fracturing may be ancient (relict) or contemporary. Ancient polygons date back to other climatic periods, and may even be buried under drift deposits. Contemporary polygons were formed in the Late Holocene or are still in the process of formation. N.I. P'yavchenko (1955) was the first to divide the tundra bogs into ancient and contemporary.

Different morphological varieties of polygonal bogs have been noted before. For example, N.I. P'yavchenko (1955) identified the ridged-polygonal, concave-polygonal and flat-polygonal varieties. In so doing he expanded the classification previously suggested by V.N. Andreev (1938, 1955). On the basis of these classifications, we have developed a typological classification of polygonal bogs in the tundra zone (see Table) with allowances for their occurrence in different subzones, their morphology, vegetation, peat properties, etc.

TYPES OF BOGS IN THE TUNDRA ZONE OF SIBERIA

Type	Microrelief	Vegetation			Peat	Occurrence
		Southern Subarctic (brush-covered) tundra	Northern Subarctic (typical) tundra	Arctic tundra		
A. Uniform (mesotrophic and oligotrophic)	Not distinct	Brush and Spagnum, sedge-cotton, grass-Sphagnum, etc. (Ledum, Andromeda, Vaccinium vitis-idaea, Betula nana, Carex rotundata, Rubus chamaemorus, Sphagnum balticum S. angustifolium, S. fimbriatum, etc.).	Grass (sedge and herbs)-Hypnum, brush-covered-grassy-Hypnum (Betula nana, Salix pulchra, Carex stans, Aulacomnium turgidum, Tomenthypnum nitens, etc.).	Grass (sedge, herbs)-Hypnum (Carex stans, Eriophorum angustifolium, E. medium, Dupontia fischeri, Drepanocladus, Meesia, Mnium).	20-100 cm thick, sedge-Sphagnum, Sphagnum, sedge-Hypnum, Hypnum, pH 3.5-5.0	In all subzones, in run-off depressions, lake depressions, flood plain of rivers
B. Polygonal I. Relict Hummocky-polygonal oligotrophic (according to Andreev (1955) cracked-hummocky).						
a. Flat (high-centre ice wedge polygons in American lit.).	Flat polygons (0.1-1.5 m in height), usually square, rarely pentagons or hexagons, 15 m in width, dissected by a network of fissures 1-3 m in width	Polygons: dwarf Arctic birch, brush, cloudberry Sphagnum (S. lenense, S. angustifolium), lichen Fissures: cotton grass, sedge (Eriophorum russeolum, Carex rotundata, C. rariflora) - Sphagnum (S. balticum, S. majus)		Absent	100-500 cm thick, frozen sedge-Hypnum sedge, horsetail, Hypnum, etc. pH 3.0-4.0	More typical of southern subarctic tundra, less typic of northern subarctic tundra
b. Concave	In contrast to preceding type there is a small depression in the centre of the polygon	In contrast to preceding type, there is hydrophilic vegetation in the centre of the polygon.		Absent	Same	Same

Type	Microrelief	Vegetation: Southern Subarctic (brush-covered) tundra	Vegetation: Northern Subarctic (typical) tundra	Vegetation: Arctic tundra	Peat	Occurrence
c. With ridges (low-centre ice-wedge polygons in American Lit.).	Square ridges (0.3-1 m in height, 2-3 m in width), a square wet spot in the centre (10 x 10 m, 15 x 15 m), fissures around ridges (1.5-3 m in width)	Ridges: brush-cloudberry-Sphagnum (S. lenense, S. angustifolium, S. nemoreum) - lichen. Wet spot in the centre and fissures: sedge-Sphagnum (Carex rotundata, S. balticum, etc.		Ridges: brush-grass-Hypnum (Vaccinium vitisidaea, Arctagrostis, latifolia, Aulacomnium, turgidum, Dicranum). Wet spot and fissures: sedge, cotton grass, etc. (Carex stans, Eriophorum angustifolium, etc.	Same	Mainly in subarct tundra, very rare in arctic tundra.
II. Modern-Polygonal, oligo-mesotrophic. a. Flat polygonal Arctic polygons according to Andreev, 1955 (frost crack polygons in American lit.).	Surface dissected by fissures (0.3-1 m wide) on polygons 10 (20 x 10 (20) m which are slightly uplifted by (0.15-0.3 m)	Polygon=brush-cloudberry-Sphagnum (S. balticum, S. angustifolium, S. lenense). Fisures: sedge-Sphagnum (S. balticum, S. majus, etc.).	As in southern subarctic and arctic tundra.	Polygon: grass-Hypnum (Eriophorum angustifolium, E. scheuchzeri, Carex stans, Drepanocladus, Mnium, etc.). Fissures are usually filled with water.	10-40 cm contains remnants of sedge cotton grass, sedge and Hypnum pH 5-55	Mainly in northerr subarctic and arctic tundra.
b. Ridged-polygonal toruloidal-polygonal according to Andreev, 1955 (low-centre ice-wedge polygons in American lit.).	Ridges (0.2-0.5 m high, 1-3.5 m wide), wet spot in the centre, fissures (0.5-2 m wide) around ridges.	Absent	Ridges: willow-dryad - sedge-Sphagnum (Salix reptans, S. pulchra, Dryas punctata, Carex stans, Aulacomnium turgidum, Hylocomium splendens var. alaskanum S. squarrosum, S. fimbriatum, etc.). Wet central spot and fissures: sedge-Hypnum (Carex stans, C. chordorrhiza, Hierochloe pauciflora, Meesia, Mnium).	Ridges: willow-grass-sedge-Sphagnum (Salix reptans, S. pulchra, Luzula wahlenbergii, Sphagnum girgensohnii, S. fimbriatum, Aulacomnium palustre, Tomenthypnum nitens, etc.). Wet central spot and fissures: sedge-Hypnum (Carex stans, Dupontia fischeri, Arctophila fulva, etc.).	Ridges: 0-40 cm thick, strongly mineralized, contains remnants of willow, sedge, Hypnum, etc. Wet central spot and fissures: 0-50 cm thick remnants of Hypnum and sedge, pH 4.5-5.5.	The most common bogs in northern subarctic and arctic tundra.

In the Siberian tundra, no significant differences in the structure and vegetation of polygonal bogs have been noted on proceeding from west to east, except that some western species have been replaced by their eastern counterparts: Betula nana by B. exilis, Salix pulchra by S. fuscescens, etc. The differences between bogs in the southern and northern parts of the tundra zone are much more significant.

In many studies the relict hummockypolygonal bogs are described as hummocky bogs. However, in spite of some similarities in their appearance, the former are a result of frost-fracturing of soil, as indicated by the regular tetragonal shape of these hummocks. V.N. Andreev and N.I. P'Yavchenko also regard these bogs as polygonal and not hummocky. Proof that these bogs result from frost-fracturing is given in the study by E.B. Belopukhova (1965).

In the European part of the U.S.S.R., the polygonal bogs occur in the arctic tundra subzone, and in the northern and central parts of the subarctic tundra subzone.* In Siberia these bogs are the most common type in all tundra subzones and in the treed tundra of Central and Eastern Siberia. Occasionally they extend to the territory of the taiga (Boch, Solonevich, 1967). Therefore one cannot agree with N. Ya. Kats (1971) who divides the tundra zone of Siberia into two provinces: mineral sedge bogs and flat hummocky bogs. In our opinion (Boch et al., 1971), the term "mineral sedge bogs" is not a good one, since the polygonal bogs cannot be combined under a single and a rather meaningless heading. It is true, however, that they may have a thin layer of peat. The flat hummocky bogs in the southern parts of the Siberian tundra are evidently hummocky-polygonal bogs, as was pointed out earlier. Neither can we agree with the inclusion of the Siberian tundra in the province of relict peatlands, since contemporary bogs may be present there as well. Therefore we suggest regarding the northern part of Siberia within the limits of tundra and treed tundra as a single zone comprising polygonal and uniform bogs (See Table).

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* Our division of tundra into subzones is based on the ideas of V.D. Aleksandrova (1964) and V.N. Andreev (1966). Recently Aleksandrova (1971) has suggested a more detailed classification. However, the data available to us do not permit a typological classification of bogs in the northern and southern parts of the arctic tundra and in the subarctic tundra. Therefore we follow an older, less detailed classification (see Table).

We regard the polygonal bogs as a type of bog (a subtype according to N.I. P'yavchenko) which is formed as a result of frost-fracturing of soil in the permafrost region and which displays a specific polygonal structure; the latter in turn determines the complex characteristics of vegetation and peat found in these bogs. The specific morphological varieties represent stages in the development of this type. Their rate of development is such that it is difficult to place the polygons of different shapes in a single genetic series, since the growth of polygons is strongly dependent on the location, the nature and the water content of soil, etc. Even in one and the same bog, all parts of which were formed simultaneously, different polygons may display different development stages. Thus one is often forced to refer different parts of the same bog to different morphological varieties. Therefore, we do not regard the varieties of polygonal bogs as different types but combine them in a single type, which is then subdivided into two genetic subtypes and several morphological varieties (development stages). This classification of bogs can probably be called a morphologic-genetic classification. A purely botanical approach, as well as the geomorphological principles, are on the whole of little use for the typology of polygonal bogs and do not provide an adequate tool for their differentiation.

As may be seen from the Table, the arctic bogs are mainly oligotrophic and rarely mesotrophic. This contradicts the views expressed in the literature. It is generally assumed that Hypnum and sedge associations occur in eutrophic localities. However, this is true only of bogs in the forest zone. In the tundra, these associations occur in oligotrophic and mesotrophic localities. This has been confirmed by our investigations of the chemical composition of bog water and peat from various types of tundra bogs in different parts of the U.S.S.R. (Boch et al., 1971; Boch, 1972), N.A. Karavaeva (1969), J. Brown (1969), S. Eurola (1971), and others. The peat of polygonal bogs occurs in thin layers, contains plant remains of very few species, is strongly decomposed and has high silt and sand contents.

Another interesting characteristic of polygonal bogs is the fact that they do not extend to any significant depth and that their present vegetation is not the same as in the underlying peat. This is as it should be in the case of relict bogs. However, the peat of contemporary polygonal bogs consists mainly of sedge, although their present vegetation is very diversified. This is probably due to a rapid decomposition of plant remains in the tundra, or to the young age of these bogs. The latter view is supported by N.I. P'yavchenko. It has been suggested that deposition of plant remains in the tundra bogs proceeds very slowly (Gorodkov, 1935, 1938), which explains why the layer of the tundra peat is not thick. However, recent studies (Khodachek, 1969; Andreyashkina, 1971; etc.) of the productivity and the biomass of polygonal and other types of tundra bogs showed that the biomass above the surface of the bogs is quite considerable. According to E.A. Khodachek (1969), it is equal to 188 g/m^2 for flowering plants, 800 g/m^2 for mosses, and 4.1 g/m^2 for lichen. The subsurface biomass (in a 25 cm thick layer) reaches 18 kg in one m^2 per cm (Western Taimyr, northern subarctic tundra, ridged-polygonal bog).

These data indicate that accumulation of the biomass is quite sufficient for peat formation, especially from moss. Our studies of the rate of growth of Sphagnum squarrosum on the ridges of a polygonal bog (in Western Taimyr) showed that the average increment came to 0.6 cm in 1.5 months, which is actually quite adequate. In some cases, the increment was even 2 cm. On the other hand, there are indications that in the tundra bogs the rapidly increasing biomass decomposes just as quickly. According to long-term observations of N.I. Andreyashkina (1972) in the northern forest-tundra of Western Siberia, 18 to 26% of the foliage mass of Betula nana and Vaccinium uliginosum was lost due to decomposition in the course of one year. Similar results were obtained by many foreign investigators (the members of the "Decomposition" group of the International tundra biome).

An indirect confirmation of these observations can be found in the fact that the peat of contemporary tundra bogs contains very few species of plants (mainly Carex stans, dwarf willow and Hypnum moss). All that variety of flowering plants which can be found in the tundra bogs is not reflected in the peat. Either the remnants of these plants decompose very rapidly, so that peat formation proceeds very slowly, or these bogs are very young and their present plant cover is genetically not related to their peat which is very young also. The C^{14} age determinations of bogs on Spitzbergen (Eurola,

1971) indicated that the bogs there were 70-110 years old. Thus both points of view are supported by evidence.

Apart from polygonal bogs, there are also bogs of uniform structure in the tundra: grassy (sedge, cotton grass, Arctophyla), shrub-covered, shrub- and moss-covered, etc. These types of bogs occur around lakes, in run-off depressions, and on other terrain forms, and can be classified on the basis of their occurrence and vegetation. Their vegetation is fairly uniform and is represented by several species of flowering plants and mosses.

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