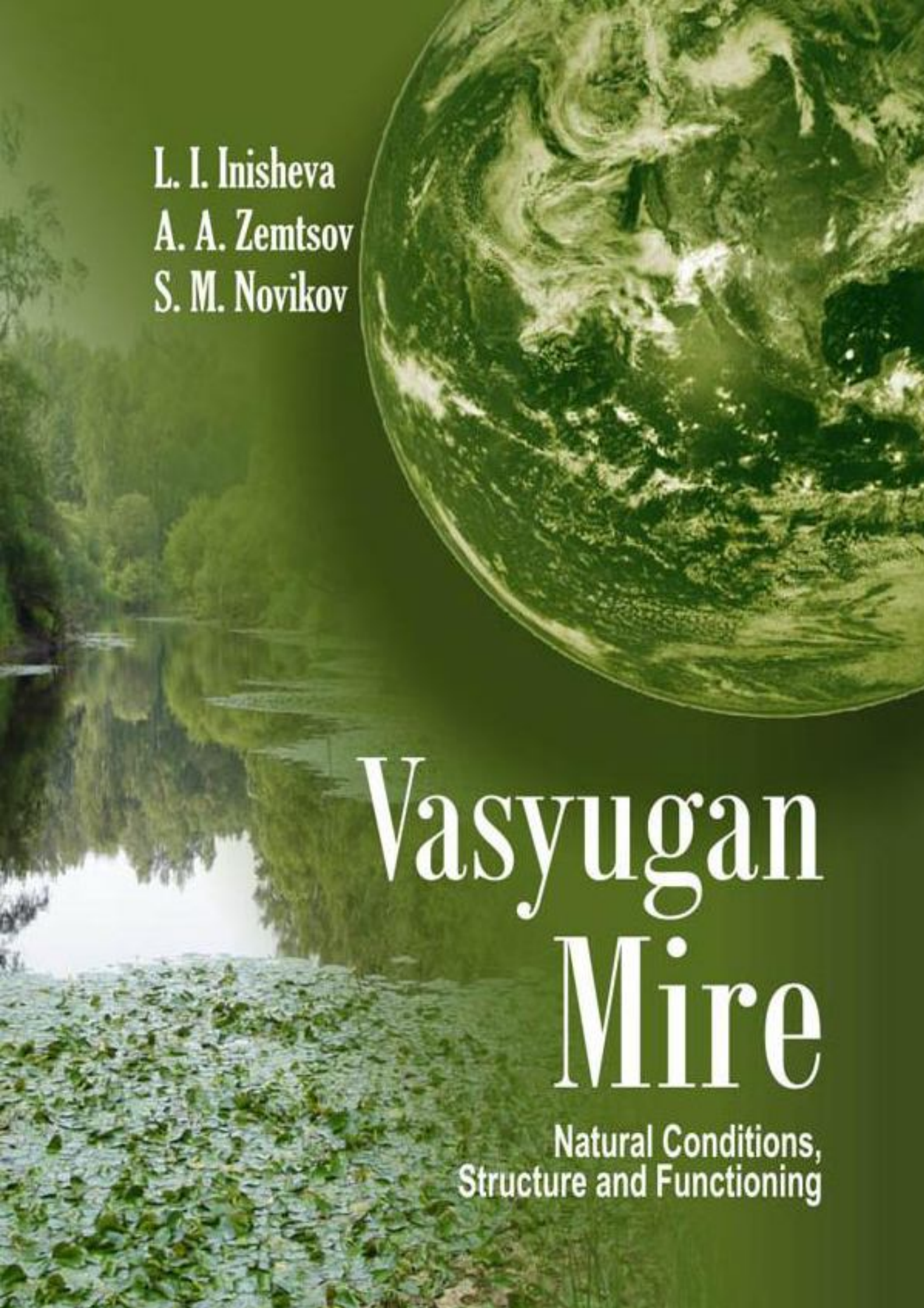


The background of the book cover is a composite image. The upper right portion features a large, detailed view of the Earth from space, showing swirling white clouds over a blue and green surface. The lower left portion shows a calm body of water reflecting a dense forest of green trees. In the immediate foreground, there is a field of green, leafy plants, possibly a wetland or mire.

L. I. Inisheva
A. A. Zemtsov
S. M. Novikov

Vasyugan Mire

Natural Conditions,
Structure and Functioning

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Natural Conditions, Structure and
Functioning

Tomsk 2011

Russian Academy of Agricultural Sciences
Ministry of Education and Science of the Russian Federation
Tomsk State Pedagogical University

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Vasyugan Mire
Natural Conditions, Structure and Functioning

Under the general direction
of Corresponding Member of the Russian Academy of Agricultural Sciences,
Prof. Dr. L. I. Inisheva

Tomsk 2011

Vasyugan Mire (natural conditions, structure and functioning) / Edited by Corresponding Member of the Russian Academy of Agricultural Sciences, Prof., Dr. L. I. Inisheva. Translated from Russian by Dr. B. M. Klenov. – Tomsk: Tomsk State Pedagogical University Press, 2011. – 162 p.: tabl. 42, ill. 32, refer. 147.

The data on Vasyugan mire are provided based on contemporary research. The history of the research of Vasyugan mire starts in 1876 and lasts until present time. Natural conditions and biogeocenosis structure are described; the calculations of carbon sequestration in the peat deposit are given. The structure of peat resources and chemical properties of the peats of Vasyugan mire are considered. The results of regime research are given for geochemically connected oligotrophic landscapes.

The monograph is of interest for specialists in environmental science, biology, telmathology soil and peatland science.

Review by:

Prof. Dr. of Geography Y. I. Vinokurov

Academician of the Russian Academy of Agricultural Sciences B. S. Maslov

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Abbreviations

A, %	– Ash content, %
NPP	– Net Primary Production
BGC	– Biogeocenosis
Categories A, B, C	– Explored estimated
Category C ₂	– Preliminarily estimated
Categories P1, P2, P3	– Predicted estimated
ChOC	– Chemical oxygen consumption
E	– Eopleistocene
EEF	– Environmental and economic funds
F	– Fen type
FA	– Fulvic acids
GOST	– State standard
HA	– Humic acids
HTF	– Hydrothermal factor
MPA/SAA	– Ratio of meat- and peptone agar to starch-and ammonia agar
MWT	– Mire water table
NP	– Neopleistocene
OM	– Organic matter
p.	– Point under research
R	– Degree of decomposition, %
RHC	– Ridge-hollow complexes
Rt	– Raised type
RAAS	– Russian Academy of Agricultural Sciences
SB RAS	– Siberian Branch of the Russian Academy of Sciences
SHI	– State Hydrological Institute
SPNT	– Specially protected natural territories
T	– Transitional type

INTRODUCTION

Vasyugan mire. How often these words are said when we speak about something big and immense. Yes, this is the hugest mire in the world, the area of which is about 5 269 437 hectares. It captured the Ob-Irtysh watershed and stretches out between 55°40'–58°60' N and 75°30'–83°30' E. The greatest extent of this mire makes 573 km from west to east and about 320 km from north to south (Fig. 1).

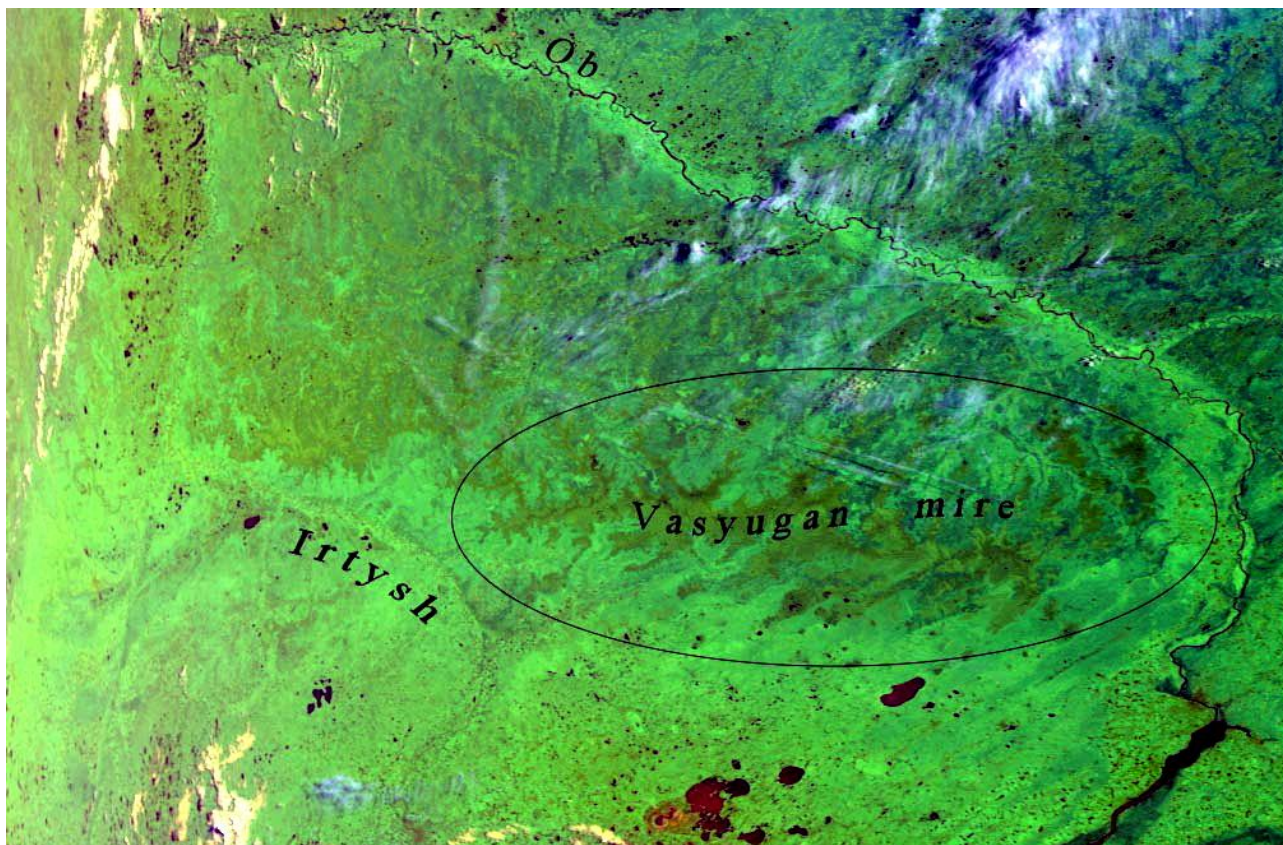


Fig.1. Vasyugan mire

Geographically Vasyugan mire is mainly situated almost in equal shares on the both sides of the border between Novosibirsk and Tomsk regions and its very insignificant part is located in the northwest of Omsk region.

But this mire is not only the biggest one; it is also the most unique in the mire territory of Western Siberia, which by concentration of mires, their arrangement and intensity of paludification has no analogs on the globe.

Vasyugan mire occupies the highest part of Western-Siberian lowland (Vasyugan plateau) and is located in two natural and geochemical subbelts: southern taiga and forest-steppe (Fig. 2). More than 200 rivers flow down from Vasyugan mire. In Vasyugan mire the central part of the raised moor is above its borders by 7.5–10 m.

Specific natural and geochemical conditions formed here a wide variety of vegetation, types of peat deposits and peats composing them. Vasyugan mire is a unique place of a wide spreading of transitional mires. The important factor is the formation here of the overmoistened Hypnum-sedge fen on the very top of the Vasyugan ridge with the highest point for West Siberian flat plain – 146 m above sea level.

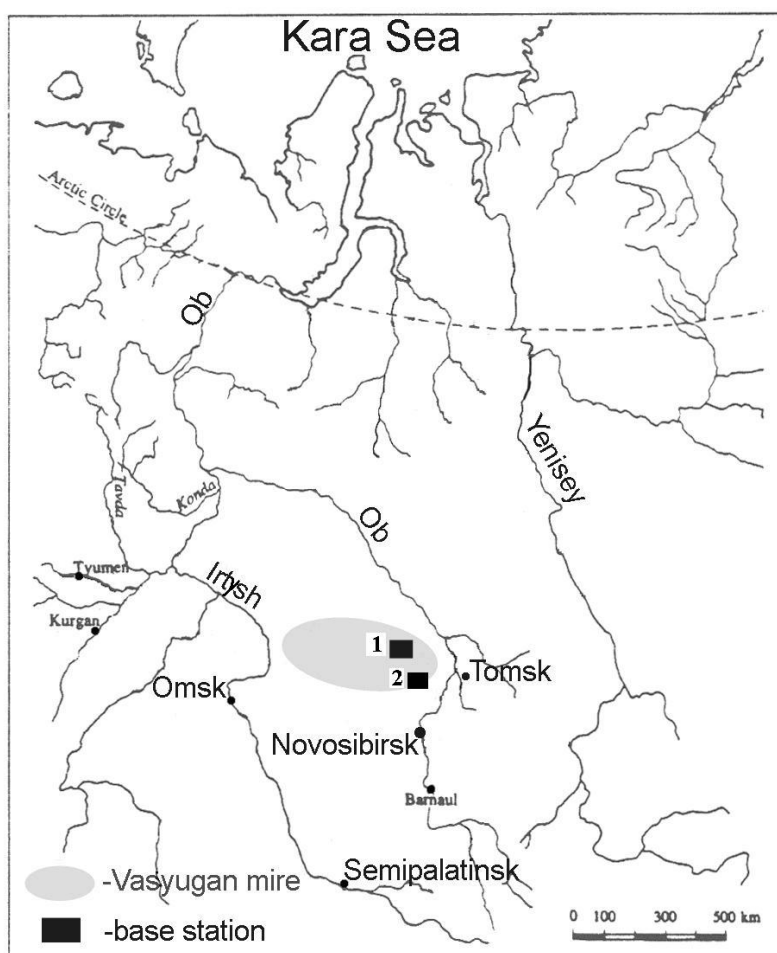


Fig.2. Schematic map of Vasyugan mire: 1 – field research station of Polynyanka, 2 – field research station in sources of rivers Shegarka and Iksha

On Vasyugan mire the peat accumulation reaches 18.7 billion tons, it amounts to 16 % of peat stock in the West Siberian region. Only 25.5 % of this stock has been surveyed. The content of the deposited carbon in Vasyugan mire reaches 5.1 billion tons or 12 % of carbon deposited in peat deposits of Western Siberia and 4.4 % of the deposited carbon of Russia.

In the 50-ties when the interest to peat resources of Russia was especially high it was decided to survey Vasyugan mire as a more perspective one from the economic viewpoint. As a result, from 1950 to 1993 the prospecting works were carried out on the territory of Vasyugan mire.

The following tasks were set up: to survey the territory; to define the borders of spreading of the peat deposit, its area, peat stocks; to give the qualitative characteristics of peat and to establish the structure of the peat deposit.

It was a heavy expedition work in the region difficult of access. The solution of this problem demanded an application of new methods of revealing, accounting, estimation of peat resources and the big courage of peat explorers. Thanks to their work the part of all peat stocks of Vasyugan mire (as high as 25.5 %) was considered as investigated and the rest its part (as high as 74.5 %) as predicted.

Unfortunately the incomplete data on Vasyugan mire are found in scientific

literature dedicated to mires either throughout the whole territory of Western Siberia, or mires of Naryn territory, Near-Vasyugan area, western and eastern parts of Vasyugan area and Vasyugan area as a whole. At the same time, there are few works devoted to Vasyugan mire directly. Vasyugan territory is a vast geographical concept, which includes not only Vasyugan mire but also the basins of the right tributaries of the Irtysh River and the left ones of the Ob River. As for Vasyugan mire, it occupies the territory of Vasyugan plateau and has a clear boundary determined in the course of prospecting works.

Therefore, one of the principal tasks of the authors of this book was to gain information on Vasyugan mire and its generalization based on the research data. In this book, which is brought to the notice of the reader, the conditions of formation of Vasyugan mire, brief history of the research and surveys are considered as a paying tribute to the researchers of this mire.

This publication deals with the structure of mire biogeocenoses, modern dynamics and carbon balance. The special chapter is devoted to the structure of peat resources on the basis of systematization of the results of research of prospecting expeditions. Besides, the authors present their own data obtained during the expeditions to Vasyugan mire (sections 2 and 3).

As for Vasyugan mire, the study of its biospheric functions and elaboration of scientific bases of regional monitoring is important. Therefore, the authors had another important objective, for example, to investigate mire regimes under field conditions.

We began such research in 1994. A special testing area was selected to carry out the regime observations with several investigation objects on the plot of the northeastern part of Vasyugan mire. Among these objects the landscape profile (catena) was chosen as a model object in the basin of the River of Klyuch. During the process of studies the basin approach was used, i.e. the hierarchy of the landscape units in the river basin was taken into consideration. The basin under question is an integrated functional geosystem, from geochemically autonomous ones to geochemically subordinate landscapes of the catena.

The originality of the profile is in the accessibility to carry out the research on a small territory of the basin of swampy river within the limits of 1 km where there are practically all-possible varieties of geomorphologic elements and biogeocenoses. This fact permits to carry out the studies of turnover by balance method under Siberian conditions. The total area of swamp here reaches often 50000 ha.

Under field conditions the studies have been strongly developed on the dynamics of hydrological, water, thermal and hydrochemical regimes and their balances; transformation and exchangeable processes have been studied in detail in the peat deposit, as well as carbon circulation, gaseous regime, emission of hotbed gases and other processes. It should be supposed that the scientists absolutely correctly consider that scientific field stations should be considered as the national wealth of the country. Therefore in the book the particular attention has been paid to the results of the field studies conducted in Vasyugan mire.

An important problem, in our opinion, is also the elaboration of scientific bases of complex wildlife management on mires as a whole and on Vasyugan mire, in particular. The authors propose to think about the problem of revealing the ecological and economic "price" of the mires of various kinds as well as about the ways of their development and protection and about the elaboration of criteria of sustainable use.

L. I. Inisheva (Introduction, 3.1–3.3, 4, 5, 6, the Conclusion), A. A. Zemtsov (1, 2.1, 2.2) and S. M. Novikov (2.3) worked at this book.

The authors are grateful to the Russian Foundation of Basic Research for financial support of the projects on Vasyugan mire (Nos. 98-05-79016, 99-05-64233, 99-04-63078, 01-05-64189, 04-05-64197, 05-05-64048, 06-05-64170, 09-05-00235, 09-05-99007-r-ofi). This work has also been supported by the grant of the President (NSH.3938.2008.5) and Federal Agency of Science and Innovations (State contract No.02.740.11.0325).

1. SHORT HISTORY OF RESEARCH

M. I. Neishtadt [99] names paludification of West Siberian plain as a world natural phenomenon. On the globe there is no other territory where the mires would occupy such huge areas. Only the taiga zone includes 141.0 million ha. The part of this territory as large as 70.4 million ha. is under paludification. Especially, a lot of mires are spread in the south of Western Siberia, within the limits of Vasyugan territory (70 % of total area).

Separate isolated data on the nature of Vasyugan territory appeared at the end of the 19-th century although the Russians came here much earlier. One of the first persons who visited Vasyugan territory was naturalist **B. P. Shostakovich**.

In 1876 he undertook a trip along the rivers of Vasyugan and Chizhapka in order to examine there the availability of gold and coal [131,124]. However, he found no gold, and coal pieces were found only on the riverbank in the form of amulets of foreigners. During his stay in Vasyugan territory B. P. Shostakovich gave a very sketchy and not entirely true description of the nature, but he in detail characterized the crafts and life of the native population. He strongly exaggerated “ruination of the land”.

B. P. Shostakovich did not discover anything new; he only repeated the old legend about Vasyugan Sea, because in earlier editions Vasyugan mires were depicted as an enormous swamped lake, i.e. sea. **S. U. Remezov** in his “Drawing of all Siberian cities and lands” [118] at the site of Vasyugan mire depicted a lake from which the tributaries of the Ob River flow out.

In 1882 the West Siberian department of the Russian geographical society charged **N. P. Grigorovsky** with the research of the colonization of Vasyugan territory for the last 25 years. He had to examine the validity of the fact that “along the upper course of the river of Vasyugan and along small its tributaries the peasants from Russian provinces, Old Believers-dissenters had settled; allegedly had constructed own settlements, had got arable lands and cattle and lived, secretly praying fanatically” [41, p.1]

N. P. Grigorovsky [40, 41] provides information on geology of the land; describes the structures of the coastal steep banks where white sands with lime are exposed, but limy mountains are not found there.

According to his description, Vasyugan territory takes up more than 500 versts (1 verst is equal to 3500 ft.) from west to east and up to 400 versts from north to south. Small and large rivers and lakes some of which bear names whereas the others are nameless almost quite often dissect this area.

This territory is covered with low coniferous, cedar and mixed deciduous forests, and in the south it is covered with impassable mires which during spring tides merge together and native tribes and neighboring peasants of Tarsky district call it “Vasyugan sea” [41, p. 50]. As it was evidenced by **N. P. Grigorovsky**, “726 souls of the both sexes including young children lived” throughout Vasyugan territory at that time in 30 yurtas and it was throughout more than 2000 versts!

In 1901 A. F. Plotnikova published “Historical and statistical sketches of Narym territory”. This author also draws special attention to the paludification of Vasyugan mire.

“Concerning the amount of mires Narym territory occupies highly important place in Tomsk province. There is such a multitude of mires here of different sizes, so that these are countless and nameless. But we shall mention one of the most large-sized and hitherto not investigated yet. This is just Vasyugan-Abinsk mire” [112, p. 13]. This mire is 400 verstas long and 50 verstas wide, this was named by local inhabitants as “Vasyugan Sea”.

The interest for studying the nature of Western Siberia considerably increased at the beginning of the 19-th century. It was encouraged by the following: the realization of the reform of 1861 and especially Stolypin’s land reform of 1906 which led to large-scale land dispossession of the peasants of the central Russian provinces and by their migration to the new lands; the engineering of the Trans-Siberian Railway.

It is enough to note that only in 1907 about 200 000 families and 75 000 walkers came to Tomsk province. It was necessary to investigate the new area as ploughlands. The swamped Narym territory was also put on a waiting list where **A. P. Vydrin** was sent in 1903 on a mission by the Department of State Land Belongings in order to “ascertain the consecution, direction, character and techniques of more detailed research of the territory and to define what basins of the tributaries of the Ob River are the most probable to be settled in the future”. In other words, it was necessary to bring forward the future plan of more detailed inspection, which at that time could not be carried out.

From 1895 to 1904 a hydroengineering group worked in Baraba along the railroad line under the leadership of **I. I. Zhilinsky** [147]. The Department of Land Improvement of the Central Administration of Land Management and Agriculture sent this group on a mission. This group laid the main and lateral channels of the total extent of 1670 km, carried out experimental works on drainage and partial development of the mires. These works gave favorable results and showed absolute advisability of soil reclamation of Baraba.

In 1908 two groups were sent on a mission to Narym territory by Emigrant Management of Tomsk area. One of them, with assistance of **N. A. Sborovsky and A. V. Otryganiev** [107], passes a trail line from village of Orlovka through Vasyugan mire to yurtas of Chertalinsk and down the river of Vasyugan (Fig. 3). The results of these works were summarized by A. A. Prazdnikov and N. A. Sborovsky [116].

It is necessary to assess a rather exact characterization, which was given by these authors to geographical landscapes of Vasyugan area. From the riverbed to watershed they observed the following order of arrangement of natural complexes:

Small bank of the last river loads, then narrow strip of coastal vegetation (bushes of red and black currant, bird cherry, willow) and, finally, the rest of the valley overgrown by aspen, birch, mountain ash, dogrose, dropwort etc.

When climbing the ridge of the native riverbank through one or two terraces one can cross a wide strip of urman or taiga, which is mainly formed by coniferous stands such as cedar, fir, fur-tree, larch and birch.

Then follows a strip of mixed forest, coniferous one with significant admixture of hardwood species (aspen, birch); a narrow strip of hardwood stands throughout the area of the superficially swamped forest; birch ryam, fine-grain low birch on mossy mire where, however, the thickness of the moss cover is no more than 2 ft. Next is the strip of pine ryam and, finally, it is replaced by pure mossy swamp with the spots of lakes and floating mires. This swamp is absolutely woodless.

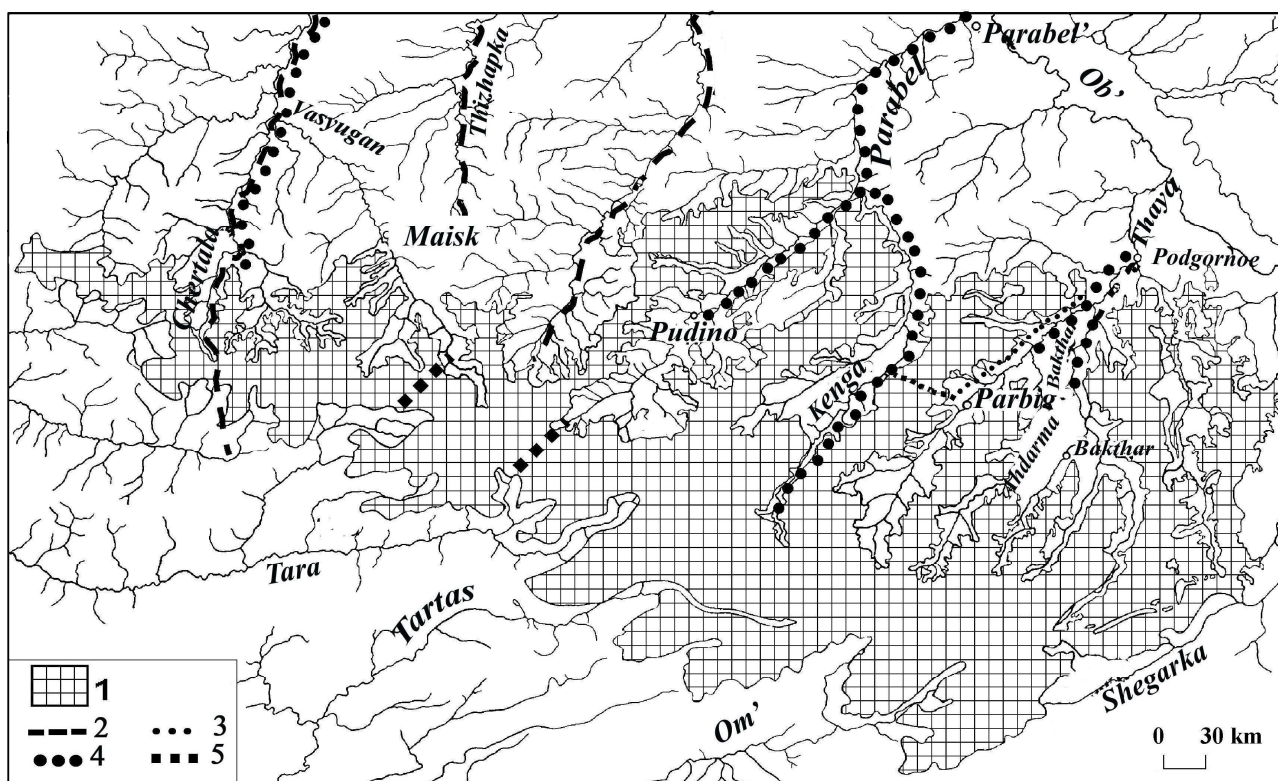


Fig.3. Schematic map of expedition research: 1 – Vasyugan mire; 2 – Sborovsky N. A., Otryganiev A.V. in 1908-1909; 3 – Dranitsyn D. A., in 1915; 4 – Bronzov A.Ya. in 1930; 5 – Zemtsov A. A., in 1945, 1965

In essence, the emigratory expeditions and parties performed early studies of the nature of Vasyugan territory; however, they were reconnoitering and sketchy in many respects.

Speaking of the value of the data obtained by these expeditions, it is necessary to notice the following. If it is quite possible to agree with **D. A. Dranitsyn** [21, p. 43] who wrote that “though the territory was lately strenuously visited by researchers, our information on geology of the country didn't benefit as the former uncertainty was replaced by pseudo-knowledge, extremely sketchy descriptions of sedimentary rocks, and by obviously erroneous indications to the exposures of crystalline ones” it is impossible to tell it with regards to general results of the expeditions. The authors stated fairly objective assessment of the environmental conditions having dissipated the former legends about “ruination of the territory”.

Later on, Narym territory became again a research goal of soil and botanical

expeditions on investigation of colonization's areas of Asian part of Russia under supervision of soil scientist **D. A. Dranitsyn** and botanist **N. I. Kuznetsov** (Fig. 3).

It should be noted the qualified and rather valuable descriptions of the relief, geological structure of soils and mires as well. D. A. Dranitsyn [21] and N. I. Kuznetsov [74, 75] came to the conclusion that the paludification of the territory was the result of spreading of the mires over dry land under influence of humid climate and favorable orographic conditions rather than overgrowing of hypothetical huge lakes.

D. A. Dranitsyn [21] proved that in Vasyugan there was no exposure of solid rocks or ancient rubble; furthermore, horizontally bedded fresh-water deposits, which were accumulated in fresh-water reservoirs, form this territory. The absence of the shells in the deposits indicates the unfavorable conditions for organic life.

Some of the above mentioned statements by D. A. Dranitsyn have not lost the significance until recent times, others are purely of historical interest, and some proved to be erroneous (for example, his idea of double-ply glaciation of Vasyugan territory).

N. I. Kuznetsov described the vegetation and regularities of its spreading over relief elements and individual mire tracks as well.

The works of these researchers made fundamental contribution to the study of nature of Vasyugan territory and gave a rather clear idea of it. It is quite fair, in our opinion, that the legends about the huge mire (lake-sea) are being rejected and even some scientific editions used these legends where fearless adventurous seafarers over Vasyugan sea had been depicted, the Ostyaks (the Ostyaks is an archaic name of some Siberian folks) going across the mire on transitive poles and the bears who became proficient to pull along the heavy stumps of trees for ramming the swamps [21, p. 22].

The First World War, which began in 1914, suspended research of Vasyugan territory. Only after the October revolution they were resumed. The works on the study of the mires of the Ob-Irtysh interfluvium were of cardinal importance. These were conducted by the Siberian expedition of the Institute of Grass Farming under supervision of **A. Y. Bronzov** (see Fig. 3).

The results of long-term works of this expedition (1925-1930) were published in the monograph "Raised Moors of Naryn Territory" [11]. A. Y. Bronzov crossed Vasyugan mire in several places, he described the vegetation, mires, studied the structure of the peat deposit.

A. Y. Bronzov's work is distinguished by careful implementation and profound analysis. M. I. Neishtadt [100, p. 10], wrote: "This research which had been carried out until the beginning of the 50-ties started the second stage of the scientific study of these original natural formations".

According to the instructions of the Siberian Department of Emigration **R. S. Ilyin** [44] began his research in 1928 and organized a series of routes in the

basin of the River of Vasuygan and other rivers. In his monograph “Nature of Narym Territory” the relief, geological structure, landscapes and soils were characterized. A special attention was also paid to the mires, which were mostly widely spread on the territory.

The relief offered by R. S. Ilyin was considered as a basis for the original classification elaborated by him for the swamp-coniferous zone of Western Siberia; he described the types of paludification and characterized them in detail.

R. S. Ilyin came to the conclusion that “... the peats of Narym territory are the capital for the future when stocks of coal will be exhausted and mankind will recognize the necessity to use peat not so much as fuel but also in chemical industry” [44], with. 99].

In 1932 **M. I. Neishtadt** started to study the mires of Barabinsk forest-steppe. It can be said that this research lasted entire his life. He is the author of many monographs and articles and he is one of the outstanding researchers of the mires of Western Siberia.

In 1951–1956 the mires of the central part of Western Siberia were explored by peat-prospecting expeditions Guiprotorfrazvedka in order to reveal the peat deposits. Namely, during this time interval Vasyugan mire was explored as well. New technics were applied such as aerial photography, landrovers, helicopters and flying boats. This research marked the third stage of study of Vasyugan mire, i.e. the stage of peat-prospecting works, which had been carried out until 1993.

At the same time interval the mires of Tomsk Region were studied by scientists of Tomsk State University (**L. V. Shumilov**, **V. M. Yelisseyev**, **Y. A. Lvov**, **G. G. Yasnopolskaya** and others),

Hydrological research of the mires started in 1958 by researchers of the State Hydrological Institute (**K. E. Ivanov**, head, **S. M. Novikov**, **E. A. Romanova** and others).

Following field research stations were established at the same time by the institutions of the USSR Academy of Sciences:

1. Tomsk where the works have been carried out regularly since 1960.
2. Bakchar, Bakchar district of Tomsk region (since 1963).
3. “Plotnikovo”, Bakchar district of Tomsk region, on the spurs of Vasyugan mire (since 1956).

The first two stations belong to the Forest Institute of SB RAS, the third one to the Botanical garden of SB RAS and then to the Institute of Soil Science and Agrochemistry of SB RAS.

The considerable contribution to the study of nature of West-Siberian flat plain was made by the scientists of some faculties of Moscow State University who in 1965 on the basis of prospecting works of the expedition had begun research on the problem of “Natural Resources of Western Siberia and their Economic Use”.

This research is of a special interest to us, first, because of its complexity. Practically, all the elements of the geographical landscape were studied (geological structure, and neotectonic movements, relief and contemporary relief-forming exogenic processes, climate, soils and vegetation of the mires). A special attention was paid to the mires, their formation and peat accumulation. Second, the research of the Muscovites covered the whole central part of West-Siberian flat plain.

The southern border of their research area passes along the line Omsk–Novosibirsk and the northern one, approximately from the estuary of the river of Demiyanka (the right tributary of the river of Irtysh) to the lower course of the river of Tym (the right tributary of the river of Ob). Vasyugan mire, the object of our research, is entirely included here.

The West-Siberian complex expedition was organized by the Institute of geography of the USSR Academy of Sciences, its main tasks were the study and analysis of the natural conditions of West-Siberian flat plain and elaboration of scientific fundamentals of the transformation of nature to make the most efficient use of natural resources and the most efficient economic development of the territory.

By present day the mires of Western Siberia and partly Vasyugan mire have been studied comparatively well, the hundreds of articles and large monographs have been devoted to them [23, 25, 26, 29, 79, 80, 87, 88, 89, 104, 106, 144], the collected articles “Environment of Western Siberia” 1971–76].

The specific feature in the study of nature including the study of the mires of Western Siberia in the 70-ties is an active participation of many leading research institutes of the USSR Academy of Sciences (geography, forest and wood and wood), State Hydrological Institute, West-Siberian Research Prospecting Oil Institute, Geology and Geophysics Institute and others.

The participation of Moscow, Tomsk, Tyumen universities, Tomsk Polytechnic Institute and others was active as well. The complex and detailed research of the natural conditions and resources of Western Siberia performed by these institutions was of the greatest importance; they stimulated intensive economic development of the extensive and richest oil and natural gas fields.

The development of oil and gas industry, building of oil and gas pipelines, electric mains, railways and main roads on the basis of this research led to the radical change of nature. It could not help affecting the evolution of the mires and ways of their development.

Due to reconstruction (known as Perestroika) and introduction of market reforms the priorities and directions of the development including the development of science have now been changed distinctly in Russia. But now it is another stage, our descendants will give the assessment of that.

2. ENVIRONMENT OF FORMATION OF MIRES IN TAIGA AND FOREST-STEPPE SUBBELTS OF WESTERN SIBERIA

2.1. Geological aspects

In the geological structure of Western-Siberian plate the foundations and friable Mesozoic-Cenozoic cover are distinguished. In its turn, the foundation consists of two structural floors:

1. Lower folded one formed by strongly metamorphosed Precambrian and Paleozoic rocks, crumpled into abrupt folds and broken by numerous intrusions of various composition and age;

2. Upper one presented by a complex of Paleozoic and Lower Mesozoic deposits, which were accumulated in postgeosynclinal stage of development of separate parts of the plate. These deposits are strongly deformed and do not have continuous spreading; they fill more or less vast cavities and caving in the foundation relief [128]. Some geologists include the floor of the foundation into the structure of sedimentary cover.

The left-bank area of the Ob River within the limits of Tomsk region where the Vasyugan mire is located, is a part of West-Siberian folded system which is here presented by the Tom'-Kolyvan folded zone.

The rocks of this zone are particularly exposed in the vicinities of Tomsk, and to the north they plunge deeply into Mesozoic-Cenozoic cover. For example, at Mezhevsk area, located in the southern peripheral part of Vasyugan mire, foundation granites were revealed by boreholes at the depth of 2120 and 2465 metres [91].

Structure of Mesozoic-Cenozoic cover. As a result of slow lowering of foundation during the Mesozoic and the Cenozoic dissected by mountainous relief proved to be buried by thick cover of friable sedimentary rocks. The latter were pulled down from simultaneously rising adjacent mountains; these rocks filled the cavities of foundation and graded its relief.

The cover's thicknesses in Vasyugan area reaches 2–2.5 km. Sedimentary rocks of the cover are of rhythmical structure. Each rhythm (or a sedimentary series) is formed from below by continental rocks and from above by marine or coastal clayey rocks for the most part. Periodically repeated tectonic earth movements cause the sedimentation rhythm.

In the sedimentary cover, nine series are distinguished which are classified into three megacycles: Trias-Ant, Apt-Oligocene and Oligocene-Quaternary [103].

Our interest is the deposits of the third megacycle, i.e. Nekrasov series in the composition of which the grey sands, aleurites and clays alternate with brown coal strata. These deposits were formed in lake, lacustrine-alluvial and lacustrine-marine conditions. In the course of Neogene the accumulation of the deposits occurred under continental conditions (Burlinsk) where non-uniformly alternate grey sandy-argillaceous rocks with the strata of brown coals and lignites. Geological profile of

Ob-Irtysh interfluvial published in the monograph by S. B. Ershova [28] the Paleogene and Neogene rocks of Vasyugan area are illustrated (Fig. 4).

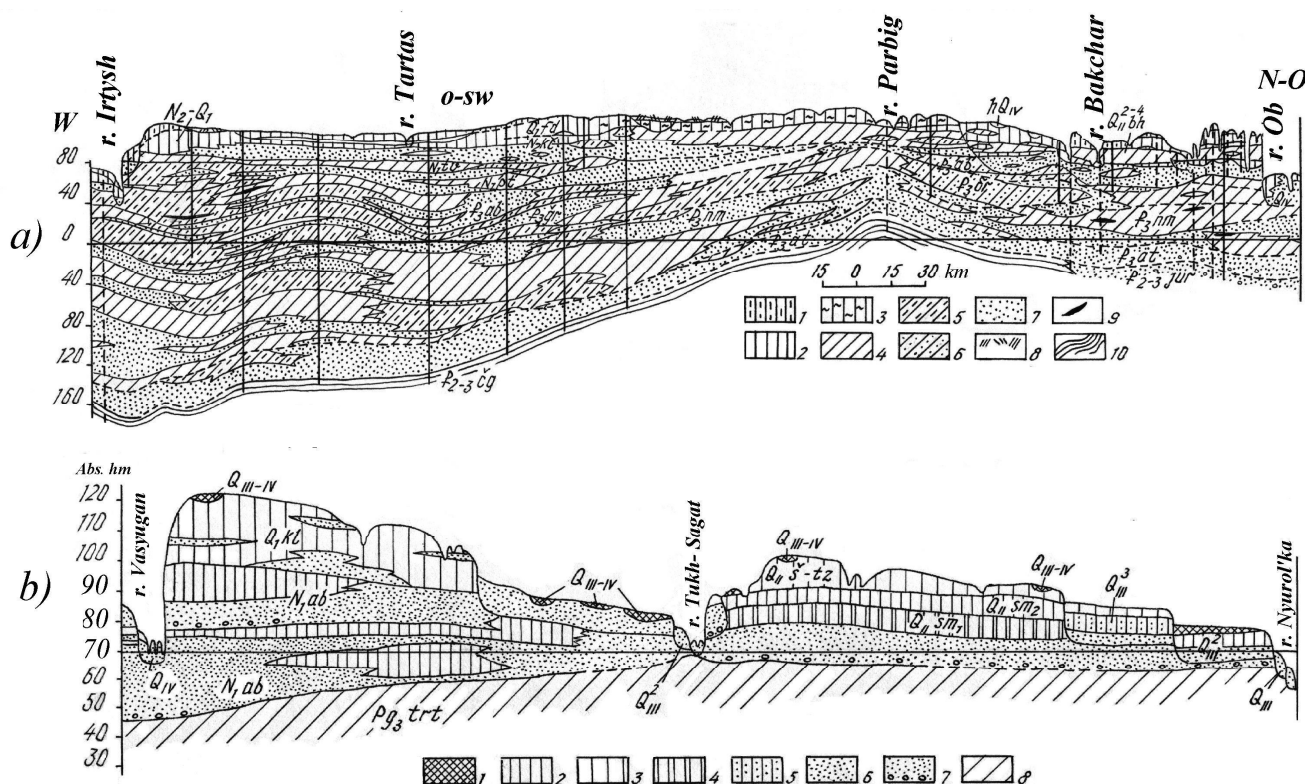


Fig. 4. **a)** Geological profile of central part of OB-Irtysh interfluvial: 1 – loess-like loams, 2 – loams, 3 – silty loams, 4 – clays, 5 – siltstones, 6 – siltstones stratificated with sands, 7 – sands, 8 – peats, 9 – lignites, 10 – marine clays. **b)** Geological profile of Vasyugan plain and valleys of Vasyugan, Tukh-Sigat and Nyuro'l'ka rivers: 1 – peat, 2 – clay, 3 – loams, 4 – stratification of loams and clays, 5 – stratification of loamy sands and sands, 6 – sands, 7 – sand with rubble, 8 – pre-quaternary rocks.

Marine Paleogene deposits of the left bank area of the Ob River are spread in the Vasyugan River basin. They represent dense clays, sometimes thin-layered sands and sandstones with powders and small lenses of aleurolite, sands and sandstones. They lie down on the deposits of Upper Chalk.

Sea deposits, mainly by clays, present the Eocene. In concrete chink's profile holed in Chuzika and Kengui interfluvial and described in [123], the deposits are observed of alluvial geological-genetic complex of Lower and Middle Oligocene. This complex was formed as a result of increase in activity of tectonic movements. The mall and medium granular sands of feldspar composition prevail here. The sands often contain strata and lenses of aleurolite clays and aleurolite.

Gradual weakening of oscillatory movements and tectonic plate bending favored to appearance of flat wetlands formed by lacustrine, swampy and lacustrine-alluvial sediments, i.e. by clays and aleurolite with and packings and strata.

The third, not yet complete megacycle includes also deposits of the Quaternary system, i.e. subsections Pleistocene (P) and Holocene (H). As the line between the borders of Quaternary systems is not always well observed the suites are necessary to

be dated as N – P. Such deposits are found in Smirnovskaya and Kochkovskaya suites.

The deposits of the former are subdivided into the following parts:

1. Lower, mainly arenaceous one with the rare strata of clays and loams.

2. Upper, presented by the stratificated thickness of clays, loams and small- and fine-granular sands. These deposits contain lime and marlaceous concretions and numerous shell remains of fresh-water mollusks. These types of Vasyugan mire form the bottom of Vasyugan mire.

It should be noted that the cover deposits were studied better. In 1951-1957 some profiles and plots were holed by West-Siberian petrochemical company in the bottom of the Vasyugan River and its tributaries.

In 1958 the large iron ore field was discovered here. Later on, within the bounds of Vasyugan mire, oil field in upper course of Chuzik River was also opened. The prophecies of our predecessors were not justified that “mineral riches in Naryn Territory, Territory of swamps and waters, are out of the question” [112, p.5]. Vasyugan mires contain not only precious resource such as peat but also have many minerals from human sight. Consequently, the study of Vasyugan mire is extremely necessary in this respect as well.

In Barabinsk forest-steppe calcareous clays, loamy sands and sands were formed in the course of the Upper Pliocene and the Lower Eopleistocene. Within the bounds of Vasyugan plane the Kochkovskaya suite is subdivided into two packings, which were formed under lacustrine and lacustrine-alluvial deposits. These deposits are widely spread within the limits of vast interfluvial plains at the depth from 5 to 30 m in flexures of Vasyugan-Kamensk syncline [128].

The epoch of tectonic activity of the beginning of Early-Kochkovsk time gave place to flexures, which included Vasyugan-Kamensk syncline. A series of insignificant climate fluctuations of Late-Kochkovsk time was concluded by the fall of temperature. Within the limits of vast lacustrine plain the clays of greenish-brown colour were deposited, calcareous loams with fragments of mollusk shells as well as small ferriferous and manganese inclusions and lime concretions were more rarely found [28].

Quaternary system. To Eopleistocene (E) the silty calcareous loams and clays of Fedosov suite belong which were developed in northeastern Baraba. Their thickness reaches 20-60 m [28], they were formed in cold environmental conditions.

The deposits of the Neopleistocene (NP) as a continuous cover block interfluvies and fill the river valleys within the bounds of Vasyugan. Their thickness fluctuates from several meters to 20 m. They lie down with washout on the rocks of the Paleogene and the Neogene (Fig. 4 b). Their genesis is different.

The Middle Neopleistocene is characterized by general rising of the West-Siberian plateau, reorganization of its structural plan and considerable climate changes with periodic fluctuations. There was rising of southern, central and

immersing of the northern parts of the plateau.

The inclination to the north was formed. Within the bounds of the Vasyugan-Kamensk ridge the transit hydrological network was put of the former rivers of Ob and Irtysh and watersheds connected with the area of rising of Vasyugan-Kamensk antecline.

In the deposits of the former valleys Tobolsk horizon is distinguished, which is mainly represented by the deposits of the former riverbed of the plain. These deposits fill over-deep valley of the former Ob River.

In the foundation of the horizon the riverbed alluvium lays, i.e. sands of different size of light grey and yellow color. They are sometimes gravelly, with pebble, rounded with pieces of underlying Oligocene clays and wood fragments. The alluvium cleavage is slanting and lens-like, with plant detritus, wood bark and rounded pieces of peat.

2.2. Geomorphology

There were classified nine regions according to geomorphologic regioning of wetlands in the area of convex oligotrophic sphagnum swamps. The largest among these regions in this zone is the Irtysh one. It is divided into Demiyan-Vasyugan and Tartas-Irtysh subregions. The former occupies the central part of the region where the largest oligotrophic swampy systems are concentrated which are situated on the watersheds of the 1-st order and as separate tongues they occupy the watersheds of the river of the second order. The largest part of the river of Vasyugan mire is located here.

The latter is the most southern and the most swampy and watered. There are strongly supplied with water eutrophic and mesotrophic marches which occupy 27 % of the swamp area[129].

In orographic and geomorphologic relations Vasyugan mire is basically located in Vasyugan inclined plain. By its genesis it is a bed-accumulative inclined sub horizontal plain. The latter is a heterogeneous morphological structure with various structurally tectonic plans where both positive as well as negative ones are distinguished.

They were united into uniform morphological structure in the Neogene-Pleistocene. Absolute heights of Vasyugan inclined plain fluctuate within the bounds of 116–146 m. The maximum height mark is located in the sources of the River of Bakchar.

The dissection of the relief is up to 20, sometimes to 30; horizontal one to 0.6 km per sq. km. and the depth of dissection is up to 10 m. The intensity of partition of relief in points mainly to 20, places to 30; horizontal to 0.6 km per sq.km, and the depth of the partition – to 10 m.

On the map of the latest tectonic movements within the limits of Vasyugan area the Vasyugan newest ridge is distinguished where the total amplitude of the newest risings fluctuates from 100 to 150 m (see Fig. 4). Tectonic linear disturbances have

NE and NW orientation. In the western part of this ridge the wall-like elevations are distinguished. The amplitude of these elevations reaches 150–175 m, and tectonic disturbances have NW orientation.

Modern morphotectonic structures in Vasyugan area were formed in the neotectonic stage the beginning of which falls on the second half of the Oligocene. This stage of tectonic movements is characteristic of the following: the general ascending orientation, periodicity, non-uniformity and intermittence of displays.

The coincidence of the basic newest tectonic movements is often observed with large elements of the sedimentary cover. The plicative type of the newest tectonic movements prevails here.

However, one cannot help taking into consideration discontinuous, disjunctive disturbances as the most part of the flexures of the Earth crust is reflected in the newest tectonic plan. The border of many neotectonic elements coincides sometimes with the lines of the more active ancient fractures.

The valleys of the rivers of Upper Vasyugan are partially orientated up to the emptying of Chertaly at the left. But such coincidences are seldom. The same Vasyugan River crosses the fractures in the middle and upper course.

Having compared the card of the newest tectonic movements of West Siberian plain with the card of swamp spreading in its limits, one can see that the swamps are developed on all tectonic structures.

The basic and greatest system of Vasyugan mire is located in the area of tectonic rising. It seems to be paradoxical the presence of low hypnum-sedge very watered swamps bogs in the most raised part the watershed the height of which here reaches 146 m [144].

Low swamps seem to be appeared in the hollow, which later was raised by modern tectonic movements above the surrounding periphery, occupied now with high swamp.

This assumption was suggested by S. N. Tyuremnov [133, 134] for some swamps of Ket-Tym interfluve. Tectonic movements probably have not led to swamp drainage, and have only changed its hypsometric position.

It is not excluded that these bogs were formed on already existing height which surface abounds in saucer-like depressions. In particular, the latter were as the centers of swamping.

So, the Vasyugan plain, which corresponds to the large tectonic structure, i.e. Vasyugan ridge with total amplitude of the newest risings to 100–125 m, is occupied by the greatest in the world Vasyugan mire.

Modern tectonic movements do not impede by no means the development and wide spreading of swamps. On the contrary, Vasyugan mire is a classical example of active swamping where all signs of this process are expressed in the most distinct form.

Undoubtedly, swamps are sensitive indicators of the newest movements. However positive movements themselves do not impede the spreading of mires and become apparent one way or another in swamping degree, number of lakes and other features of swampy systems.

In the routes over Vasyugan mire the author often observed signs of progressive swamping, swamp's approach to surrounding forests. Only several areas can be named which are developed on wittingly actively rising tectonic structures with obvious signs of drainage of swamps.

On economic development of this zone it is necessary to know behavior and development of mires in future. Any building should be carried here taking into account possible progressing swamping or drainage of swamps. In this respect the research by V. I. Orlov [104] and the maps charted by him are of interest.

The speed of the tectonic rise in the Holocene seemed to be less than that of peat accumulation. If the last surpassed the speed of tectonic rise it would lead to full drainage of the boggy areas and degradation of bogs.

And on the contrary, at more rapid sinking of tectonic depressions than growth of peat accumulation, these depressions would be strongly watered at the expense of water flowing down from the surrounding areas. It leads to the full cessation of peat accumulation. In such cases the reservoirs are formed at the scene of bogs [102].

Let us cite the data on speed of accumulation of peat in Vasyugan where in the Early Holocene it was 0.5 mm/year; in the Middle Holocene it was on average 0.4–0.7 mm/year, and in the Late Holocene it was 0.88 mm/year [81].

According to the data by N. A. Khotinsky, A. L. Devirts and N. G. Markova [68], the benthic sample of 4 meter thick peat land in Vasyugan is dated as 5760+130 years, i.e. mean annual increase in peat thickness amounted to 0.7 mm. At the depth of 3.85 m the peat land is dated as 3380 + 120 years and mean annual increase in thickness averaged 1.1 mm during Holocene. As for the peat land the depth of 1.75 m, its age is dated as 4570 + 170 years; the increment is equal to 0.6 mm.

The speed of the Shegarka and Ui-Vasyugan cupola-like raising ranges from 150 to 200 m. However, here modern tectonic movements have a negative sign, and their speed makes up 10 mm a year. The vertical growth rate of peat changes from 0.21 to 2.1 mm a year. The speed of movements fluctuates from 3 to 20 mm a year [71, 30].

As it can be seen, their magnitude is almost of the same order; therefore lowering sites also will be swamped more actively, than the rising ones.

So, we have defined the scales and the reasons of swamping of the southern part of the West Siberian plain into which Vasyugan mire is included. These reasons are of the geological and geomorphologic plan. The role of this factor is great in the development of grandiose processes of swamp formation and relief transformations.

Let us dwell on formation of the phytogenous relief.

Modern processes of mire development and relief transformation. Vasyugan mire is mainly situated in the zone of convex ridge-hollow swamps, where now the

climate is the most favorable for peat accumulation. The process of peat accumulation is intensively developed both in horizontal and vertical directions.

Some researchers consider that influence of environment on these mires is inferior to the processes of self-development of peat lands. Before swamping, the land relief, i.e. the future bed of swamps, could be various both by morphometry and genesis. It was comparatively flat and abounded in numerous rather shallow depressions, which are, in our opinion, mainly thermokarstic and suffosive by its origin. The depressions were close to each other. It is well fixed by stratigraphic profiles constructed on the basis of instrumental survey and sounding of peat deposit.

The relief of the mires bed defines substantially the course of the development of swamps. From this it follows that the relief of peat deposit newly formed by swamp-forming processes is, to some extent, predetermined.

For example, the swamps arising in rather large closed or semi closed hollows or at the site of lakes, develop by central oligotrophic type, it is peculiar to simple swampy tract.

In the extended erosive watershed depressions, on the surface of young terraces, in river valleys the swamp formation takes place by peripheral type. In both cases geomorphologic features defined the process of swamp formation.

In case of central oligotrophic type of swamp development seven stages are distinguished [31, 32, 61, etc].

In the first stages the filling with peat of hollows and smoothing of the surface occur. Then the relief of the mire surface becomes convex (III, IV and V stages), the turned relief appears. At the site of the deepest part of the hollow the convex top is formed.

In the last stages (VI and VII) the relief of common swampy tracks planoconvex, with abundance of secondary lakes and hollows. The formation of the latter is connected with the reduction of inclines and permanent stagnant overmoistening of this part of the tract where unfavorable conditions are created for development of plant cover, which becomes degraded.

Peat accumulation ceases or occurs more slowly than at the peripheral area. In the final stages well-expressed slopes with ridge-hollow complex and flat central part with lakes and hollows characterize the relief of common swampy tracks.

The confluence of common swampy tracts into complex system occurs in the early stages of development. Complicated systems of some swamps of Vasyugan territory were mainly formed in the early stages of development of the tracks.

For example, the swamp of Bakchar-Iksa interfluvium is as thick as about 3 m but it is a single whole.

As for Vasyugan swamps with more thick peat lands, the depression in their bed relief is usually filled with sedge-woody and sedge-cotton grass peat the thickness of which is not more than 1–2,5 m. The rest of the thickness (7–8 m) is homogeneous by composition sphagnum peat; it evidences the fact that the mire system has been

developing for a long time as a single whole.

According to the data by N. Y. Kats [64], Vasyugan peatlands passed to oligotrophic stage of development still earlier in boreal period of the Holocene than peat bogs of the European part of Russia.

It is possible that already before the boreal period all relief irregularities were filled with peat. The leveling of the relief contrasts of the bed happened then. The comparatively flat surface of peatlands, which filled negative relief forms, flows together with adjacent plots of dry land.

Afterwards some differentiation is observed in the peatland development. In the center of the mire the intensive upward growth of peat takes place, and in the periphery the simultaneous superficial peat accretion occurs.

Such uneven and differently directed development of peatland proves the fact that its central part becomes convex by shape. In Vasyugan mire the central part of the bog, for example, rises above its edges by 7.5–10 m.

As showed the data of instrumental survey and sounding of the peat deposit, in some tracts of Vasyugan the raised bogs occupied the depressions between mane-like elevations, whereas the transitional ones narrow mane-like elevations.

Nowadays the picture has changed drastically. Mane-like elevations are distinguished by depressions on the surface of the peat deposit; inter-mane depressions of the bed correspond to convex tops. The turned relief is more clearly pronounced.

By intensive peat accumulation the new watershed is formed sometimes. Its ridge on Vasyugan mire, in particular, along the line connecting the sources of the rivers Icha and Chuzinka, dislocated southwards more than by 10 km as compared to previous one existed here before the formation of the mires [11, 66].

Having analyzed three profiles of railway investigations through different parts of Vasyugan mire, R. S. Il'yin [1928] came to the conclusion “at both edges of Vasyugan mire, in all profiles, its bottom proves to be pressed down as compared to adjacent area; suffusion depressions cover completely the whole bottom of Vasyugan mire but in consequence of its vast extent this bottom keeps crooked profile” [43, p. 57].

Thus, in the process of developments of mires the relief of plains is simultaneously transformed. The phases of this transformation are as follows:

1. Leveling of mire bed and formation of even surface of peat deposit flowing together with the surrounding dry land. Formerly the swamps were separated from one another.
2. Wide spreading and formation of convex mires, their junction into tremendous complicated mire systems. The beginnings of the turned relief, displacement of watersheds. The most favorable conditions for development of similar mire systems were in the Early and mostly in the Middle Holocene from 8500 to 4500 years ago.

In the Atlantic period “the explosion of peat formation” took place, sphagnum moss was intensively formed which is considered to be a predominant part of the deposit of the swampiest systems. Relative fall in temperature and deceleration of peat accumulation were noted at the border of the Atlantic and the Subboreal periods, approximately 4500 years ago for the whole north of Eurasia [138].

3. Later on, in the Holocene (at about 2000–2500 years ago) the climate became more humid. In the late stages the formation took place of ridge-lacustrine complexes on flat or weakly convex central slopes and of those of ridge-hollow on clearly expressed peripheral slopes.

Another structure has the belt of polytypic swamps, i.e. eutrophic and convex sphagnum-pine ones. For example, within the bounds of 34 km profile through Vasyugan mire in the watershed of the rivers Icha and Chuzik one can distinguish:

1. Swampy forests and wooded swamps of transitional type (1–2 km).
2. Sedge-hypnum swamp with thin elongated (gaunt) ridges and islets of high swamp (3–23 km).
3. Stripes of woodless low-level and transitional sphagnum swamps alternating with the stripes of high swamps (23–28 km).
4. Wooded swamp of transitional type (29–32 km).
5. Transitional swamp in the valley of the river Chuzik (32–34 km).

This part of Vasyugan mire is completely occupied by peatlands almost without mineral islets [12]. The relief of wet woodless swamps represents everywhere scattered long (up to 1 km), narrow (1–2 m) and low (10–25 cm) ridges, which are sometimes remote from one another, sometimes interflow with each other. Usually on the ridges the dwarf arctic birch grows.

In Barabinsk forest steppe the following types of mires are distinguished: 1) reed swamps; 2) reed mires with sedge lower layer; 3) high sedge swamps with different species of sedges [65]. The ryams are widely spread here, i.e. convex sphagnum peatlands, which differ from surrounding swamps by its relief, by sharp convexity in their central part (up to 3.5 m). They are scattered as islets among reed swamps [12, 98].

It should be noted that in Baraba the swamp formation occurred in the reservoirs, rather than at the expense of swamping of dry land as in taiga belt. As for dry swamping, it occurs nowadays only as a result of temporary watering of relief depressions. The swamps degrade in Baraba, the salts are accumulated, and mineralization increases.

Thus, it should be noted in conclusion that the surface of Vasyugan mire is exclusively flat; it is complicated by relief microforms, i.e. combination of mane-like elevations with depressions between them and innumerable quantity of scattered depressions different by size and depth. The monotony of relief of this plain is disrupted by peculiar micro- and mesaforms of the surface of peat deposits. In Baraba

the flat relief is broken by run-off dingle and ryams.

2.3. Hydrogeological and Hydrological Conditions

Quaternary deposits of Vasyugan mire are of covering character, their thickness ranges from 24 to 48 m. Particular feature of quaternary deposits of the area under description consists in the presence of confining layer of loams and clays which is situated in upper horizons directly beneath the peat deposit, and its thickness is up to 9 m and more.

According to A. Y. Bronzov [11], the clays and loams within the bounds of Vasyugan mire are calcareous. During the process of prospecting when the grounds were studied up to the depth of 0.1–0.3 m, the calcimorphic feature was noted in some single plots.

Peculiar natural conditions of Vasyugan mire (high wetting in combination with broken relief and development of predominantly weakly permeable deposits) lead to complicated interactions between subterraneous and surface constituents of the discharge. The rocks of Upper Chalk and Lower Tertiary age forming this area have several water-bearing horizons, which are isolated from each other by argillite-like clays.

It can be supposed that the main conditions of the formation of Vasyugan mire, which is based on thick layer of weakly permeable clayey and loamy deposits, are superfluous moistening and flat relief. The atmospheric precipitation is directly accumulated within the limits of peat horizon beneath of which pressure waters are separated by clay deposits [96].

Therefore, the swampy water is low in mineralization, and peat is low in ash content.

Moreover, chemical composition of swampy waters is different from that of subterraneous and surface waters by its strongly pronounced reductive medium, nitrogen-methane and methane composition of free and dissolved gases, and abundance of organic acids in swampy waters leads to formation of peculiar type of organo-mineral waters.

The direction of the process of swamping is determined by relief of the plot under swamping, type of nutrition, stage of development of peatland, bioclimatic conditions.

On weakly drained interfluves microdepressions become the centers of swamping, which is subsequently spread to micro- and mesoelevations forming swampy tracts.

On watersheds with swampy tracks to which Vasyugan mire counts, the peatlands in the process of self-development become still more active tracks of contemporary swamping.

In the river basins with strongly developing processes of peat accumulation the active infill of river valleys with peat as well as the flattening of river valleys and elevation of base level takes place.

Thus, the swamps weaken anyway weak erosion activity of river network causing further deterioration of drainage conditions of the territory.

The sources of contemporary rivers of Western Siberia were located in the past at the highest levels of the watersheds [90] and caused the drainage of adjacent parts of the basin. Gradually the river sources began to overgrow, cover themselves with peat, the stream run-off almost ceased and turned into swampy streams and river beds proved to be separated from mineral ground and submerged into peat.

Namely, such swamped sources of contemporary rivers with preserved current in peaty beds represent swampy rivers of primary origin (Fig. 5).



Fig. 5. Mire rivers of primary origin

In case of progressive swamping of the territory the swampy river network of secondary origin is formed.

Its formation is determined by the development of the swamps such as, their junction into large tracts, which form peculiar “swampy” relief of the surface, i.e. combination of elevated and depressed plots. In the latter the gradual formation in the peat of river and brook beds of secondary origin happens.

All the rivers flowing through Vasyugan mire belong to two basins, of the Ob and Irtysh rivers respectively. From the main swell of Ob-Irtysh watershed the dense river network goes aside in northeastern and southwestern directions which flows into the Ob and the Irtysh, from these rivers the dense branch of tributaries of the second, third etc. order goes aside. On watersheds of all the tributaries the peat deposits are situated. They are the spurs of Vasyugan mire.

Vasyugan mire is the source of more than 200 large rivers, such as the Iksha, the Tara, the Tartas and others.

The river of Tara springs from Tara-Tartas peat accumulation, which is the southwestern part of Vasyugan mire. It is almost impossible to ascertain the source of the river Tara, as when leaking out imperceptibly of the mire it has not any bed and acquires it only on going out from the mire. The river of Tartas is the largest tributary of the river of Om. As distinct from the Tara the Tartas springs from a lake.

Let us consider hydrological aspects of the process of development of swampy tracts in primary centers of swamping and the formation of swampy systems.

As it was mentioned above, the swamping of the plots of dry territories occurs if stagnant overmoistening of soil surface is available, which is usually observed in depressed relief elements (slightly drained kettle depressions, hollows etc.).

As a result of weak flow in central parts of swamping centers the process of peat accumulation occurs here more strongly than in the periphery; and then the surface of the swamp, concave initially, becomes flat and convex in the course of time.

If at the initial (eutrophic) stage of development of swampy tracts the aqueous and mineral feeding is formed from surface and ground waters and atmospheric precipitation as well, at the final (oligotrophic) stage the feeding is almost exclusively atmospheric.

The change in the relief of swampy track, in its turn, leads to the change of conditions of the runoff of swampy waters; it leads to the change of hydrological regime.

As a result, new conditions of plants habitat appear which lead to new changes in composition of plant cover, which again lead to the changes in intensity of peat accumulation, relief and others. And then, the continuous course of these mutually determinant processes is biophysical essence of development of swampy processes.

As distinct from dry areas, in the mires a common water-bearing horizon exists through which the runoff is carried out from the swamps. The water flows down as a filtration stream, dispersed over the area of the swamp. Virtually, all water flows

down there were classified nine regions by filtration way through upper relatively thin layer (30–70 cm), the so-called active horizon.

According to the calculations of K. Y. Ivanov [61] in high bogs the part of runoff through this horizon is up to 99 % of the total runoff. It would hold for simple isolated swampy tracks, i.e. tracks developed in separate primary centers of swamping and not yet interflown with adjacent swamps. At such tracks intra-swampy water stream are lacking.

On junction of simple mire tracks the swampy systems are formed with complicated relief of the surface, which causes the development of specific swampy hydrographic network. It includes marshes, intraswampy lakes, brooks and small rivers.

Marshes, which are strongly overmoistened, are characterized by a high water level and bad passability. They are associated either the places of accumulation of swampy water (flat plots of the tracks, their mouthless edges) or with the places of junction of filtration streams (dingle between prominences of interflown tracts, the plots of water pinch on their slopes).

Intraswampy water streams as brooks and small rivers originating from the swamps are typical of swampy systems (Fig. 6).



Fig. 6. Dried-up bed of mire brook

The sources of such water streams are either intraswampy lakes or marshes. In the upper course the beds are usually interior and are discovered by surface discharge at marshes and by chain of “water windows”.

Downstream the beds are open, meandering; the valleys and floodplains of small rivers are not pronounced within the bounds of the swamps and are observed only on going out to the dry area. Through the intraswampy water streams the abstraction of the most part of surface water is realized from swampy systems into the rivers, which are drainage.

Somewhat smaller part of swampy waters is for diffusion discharge, i.e. for filtration flow directly to adjacent dry areas. It is diffusion flow, which creates favorable conditions for swamping of adjacent dry territories and overgrowing of swampy tracks.

The intraswampy lakes also belong to hydrographic network of the mire. Intraswampy lakes are secondary for the most part, i.e. they were formed in the process of self-development of swampy tracks. They are usually of small size, and shallow depth (1–1.5 m), their bottom is peaty.

The shores of these lakes are low and peaty, they rise by 0.2–0.5 m above the water level, and sometimes they represent trembling bogs.

Primary lakes, which are found at swampy systems, are of large size and depth as compared to secondary ones. Their bottom is usually mineral although the peaty one can be found due to peat of destroying peaty shores.

As distinct from small lakes, middle and relatively large intraswampy lakes, as a rule, are connected between each other with brooks and channels. A considerable amount of lakes with connecting channels forms at swampy systems a lacustrine-fluvial system, which is complicated in its structure.

Over all territory of the Vasyugan bog lakes of various sizes, configuration and depth are scattered. The majority of lakes are of a secondary origin (ridge-lacustrine complexes), but there is a lot of primary origin.

Here is a description of Lake Gryaznoye, which is of secondary origin. The diameter of the lake is about 400 m, the depth of water in 5–10 m from coast reaches 0.5 m and gradually increases to the centre up to 1.3 m. Approximately at 15–20 m from the coast, the bottom of the lake is peaty, in the centre it is covered with clay, on which the thickness of lacustrine deposits amounts to 2.5–3.0 m (without carbonates).

The general depth of the lake in its center reaches 4,5 m. From the northern side the coastline it is surrounded by the ridge, which rises above water level by 0.6–0.8 m. Its width amounts to 2.0–2.5 m; the birches and seldom pines grow here, their height and diameter amount to 2–8 m and 3–12 cm respectively.

Over-soil cover consists of Cassandra, iris, bog rosemary, cranberries, sedge and sphagnum mosses. Behind the ridge there is a depression – a trembling bog, the surface of which is at the same level as that of water in the lake. The coast does not overgrow. In small lakes of secondary origin, which are predominant here and spread over ridge-lacustrine complexes the depth of water ranges from 0.2 m to 1.0 m.

Northwards from lake Gryaznoye, in proximity to it, the lake of primary origin Tergach is situated, its diameter comes practically to 1200 m and depth to 4 m in the

central part. The moss high bog with pine (riam) comes up to the lake from southwards and the lakeside raises above water level by 2.0–2.5 m. The lakeside sinks gradually in the eastern and western parts. As for the tree cover, small birches appear in the direction to the northern lakeside, then they prevail and become infrequent. The color of water is light brown and the fish is plenty.

The researchers assumed that the rest of lakes of Vasyugan mire were of similar origin.

Let us consider the characteristics of hydrological regime of Vasyugan mire.

At swampy track under consideration the hydrological observations were not carried out directly by institutions of hydrometeorological service, although such investigations were conducted at adjacent territories.

Thus, the West-Siberian expedition of the State Hydrological Institute (SHI) worked in 1959 in swampy territories. Its program included a wide complex of research of water and heat regimes of the swamps, their typology and morphology and stratigraphy of peat deposit. In 1968 the Department of Hydrometeorological Service established swampy posts in the neighborhood.

In 1960 similar works were carried out on the watershed of the rivers of Baksa and Kargat. The research station was situated close to some village. The observations were conducted here to determine the level of swampy waters, freezing thawing of peat deposit.

North-westwards of Vasyugan mire track, in the basin of Vasyugan River, the Department of Hydrometeorological Service established in 1966 two new posts: the first one in the neighborhood of settlement of New Vasyugan, the second one nearby the settlement of Myljino (basin of some river). The following observations were conducted: measurements of levels of swampy waters, freezing and thawing of peat deposit.

From 1965 to 1968 the hydrological group of Tomsk State University worked at Bakcharsky mire within the limits of the basin of the Klyuch River (in the settlement of Polynyanka). Its program included a series of observations of influence of swamp water regime on water regime of the swamped catchment during the spring tide.

The short characteristic of the hydrological regime of Vasyugan mire is given on the basis of the observations data of the above-mentioned posts, and also based on the data of SHI [8] for adjacent areas.

It should be noted that such approach to the characteristics of water and thermal regime of unstudied swampy tracks is quite acceptable and scientifically well founded.

As it has been shown [62] every swampy microlandscape possesses quite a certain hydrological characteristic that includes the annual level of swampy waters, thickness of active layer, interconnection of factors of water return and water filtration with the level of swampy waters, swamp escape gradient within the limits of microlandscape, average annual flowage; **(swampy microlandscape is understood**

as a bog plot which is homogeneous by vegetative cover, microrelief of the surface and water-physical properties of the active layer of peat deposit). Furthermore, the magnitude of the named parameters and connections has quite certain values and state.

The availability of the same hydrological characteristic for the same type of swampy microlandscapes located at the same or different swampy tracks is explained by the fact that the vegetation close by its composition to contemporary one is as a peat-former of the whole active layer of peat deposit or its greater part.

Thus, by using this approach in the presence of the observation data for any track one can gain rather a clear idea about the hydrological regime of any similar unstudied swamp.

Water level regime. One of the main elements, which characterizes the hydrological, and hydrophysical regimes of swamps, is the level of swampy waters with regard to the swamp. This level defines the course of hydrological and hydrophysical processes at the swamps (run off, evaporation, water and heat exchange, freezing and thawing).

Therefore, having the available data on the level regime one can not only estimate the degree of water impounding of the swamps but also using the known dependences calculate all other hydrological characteristics of the regime and elements of water balance on the basis of meteorological information.

The course of level has a general regularity during the year which is peculiar to all types of bog tracts and separate microlandscapes: rather a sharp rise of levels in spring during snow thawing, their gradual lowering after spring maximum, then the summer minimum and the autumnal rise caused by precipitation and at last winter lowering of level, proceeding until the beginning of spring melting of snow.

The spring rise of levels begins usually at the end of March or at the beginning of April, practically from the beginning of intensive melting of snow. The duration of rise of level in different years is various and depends, first of all, on rapidity of spring.

The maximum spring level, which is usually also a maximum annual one, is observed on average in 15 days after the beginning of rise. In years with sharp fluctuations of intensity of snow melting some peaks are observed in the course of spring level. The smoothness in lowering of the spring level is quite often broken by abundant precipitation; it causes a new rise, which often surpasses the maximum level during melting of snow.

During the spring tide the rise of level in different bog microlandscapes is distinct; it is the largest in moss-forest and moss (with pine stands) microlandscapes (80 cm), and the least in swamps and hollows of ridge-hollow complexes (10–15 cm). This fact is explained by appreciable distinction of water return factors in active layers of these microlandscapes and by relatively high standing of level in complex microlandscapes during the winter.

Despite rather a high value of the spring rise of levels in microlandscapes of forest, moss-wood and moss groups, and also on ridges of marsh complexes the levels appear seldom on of mire surface, covering with water only the lowest depressions between hillocks. In moss-grassy microlandscapes and also in hollow complexes the level in spring is often above mire surface.

Rather a smooth spring lowering of levels caused by run-off and boggy evaporation gradually turns into summer lowering. The smoothness of the level course is broken in this time interval by separate rises owing to precipitation. In strongly watered microlandscapes the level is lowered in summer below mire surface. The minimum summer levels are usually observed in August and September.

The small rise of level is observed in autumn owing to some increase in precipitation and decrease in evaporation. In rainy years the autumn rises of level can be rather considerable, however, they reach seldom spring maximum. Usually starting with the third ten days period of October gradual lowering of level begins in all bog microlandscapes. It occurs owing to lowering of air temperature and stopping of atmospheric nutrition of mire. Gradual lowering of the level lasts during the whole winter until the beginning of spring snow thawing.

The minimum annual level can be observed during winter and summer-autumn low-water period, it depends on specific meteorological condition of the year. The value of the average minimum level in microlandscapes of moss woody group is up to 60 cm, moss group 30–55 cm, and moss grassy group 20 cm from the average surface of the swamp. In complex microlandscapes an average minimum level on the ridges amounts to 40–60 cm.

Due to the presence at the mire of a single water-bearing horizon and high standing of water level, its fluctuations are synchronous at different mire microlandscapes. It is indeed the explanation of rather a close connection between corresponding levels in different microlandscapes of mire massif.

Mire freezing regime. The data on increase in the frozen layer at the mires and the depth of their freezing are of great interest and first of all for solution of transport problems. As it is known, the bearing capacity of mires in a frozen state is dozens times higher than in thawed ones.

The freezing process of the peat deposit is defined by many factors among which there are air temperature, soil moisture, height and density of snow cover, heat-physical peat soil properties. The resultant influence of the factors defines the freezing depth of the mires in one or another geographic region or at different plots of the massif. Considerable distinctions in the structure of active layer of mire microlandscapes, their microrelief cause relatively great changes in intensity of peat deposit freezing in the area, especially in autumn period.

The freezing of mires begins at negative air temperature. However, the stable increase in the frozen layer thickness is observed by the time of steady passage of air temperature through 0°C, therefore, while performing practical calculations the data of this passage is taken into account as the beginning of freezing.

The beginning of freezing of Vasyugan mire occurs usually after 20-th of October. At the initial period when the height of snow cover does not exceed 10 cm, the intensity of freezing of elevated microrelief elements amounts to 0.5–1.0 cm per day. The intensity of freezing of lowered microrelief elements is considerably smaller. As the height of snow cover increases, the growth of frozen layer decreases, by the end of winter its value is minimum (0.1 cm).

In case of medium inclement winter with medium height of snow cover the largest depth of in microlandscapes of moss woody group amounts to about 50 cm and 35 cm at elevated and lowered microrelief elements respectively. In inclement winter with thin snow cover the freezing of mires can reach 60 cm and more.

Some features in freezing regime can be observed on the plots of not stagnant swamps where as a result of high flow of relatively warm swampy waters the intensity of the process of peat deposit freezing goes down. This fact can account for some delay of the beginning of freezing in the swamps of such kind and for considerably smaller values of the frozen layer here.

3. STRUCTURE OF MIRE BIOGEOCENOSES

Vasyugan mire, as a type of landscape (it has been already noted above), is highly peculiar. Its position in the transitive strip from the zone of deciduous woods caused the great diversity of vegetation and peat deposits; the principal cause of this fact is, most likely, various degree of salinity and leaching of the grounds [144].

It should be supposed that the formation of Hypnum sedge fen at the very top of watershed with the highest mark for this area, i.e. 146 m above sea level is an important factor.

Another feature of Vasyugan mire is the availability of special veretia-swampy mesh-polygonal fens. (Veretia represent polygonal swamps of transitional type). The specific feature of these mires is polygonal meshy image of the surface and a high degree of watering. The borders of their spreading are very well observed from the plane and in aerial photographs.

The comparisons of this data with the data over-land instrumental survey show that polygonal mires are associated with saucer-like depressions at the non-drained top of the watershed. At least slightly inclined slopes of watershed are occupied either by fens with ridges which are perpendicular or by raised bogs with pools and ridges.

The mosaic and complex transitional mires are not less original; definitely they resemble the aapa-complexes of the northwestern areas of the European part of Russia. It is necessary to notice especially that Vasyugan mire seems to be a unique place of wide spreading of transitional mires. Further let us consider everything step by step.

3.1. Vegetation

In the offered scheme of regionalization of mires of Western Siberia [78] the least regioning rank is the ***mire district***. The area of elementary complex of types of mire biogeocenoses outlines its borders.

Mire province is a groupment of mire districts. Its borders outline the area of subzonal complex of types of mire biogeocenoses.

The ***mire region*** is a groupment of mire provinces. Its borders define the area of zonal complex of types of mire biogeocenoses.

The ***mire country*** is a groupment of mire regions. The whole spectrum of zonal here-provincial complexes of types of biogeocenoses is included into this groupment. The territory of mire country includes the pieces of natural zones within the limits of one bioclimatic sector.

The mires of Western Siberia are included into ***West-Siberian moderately continental country of homogenous and heterogeneous mires of different ages and irregular mire formation***.

According to the elaborated mire regionalization Vasyugan mire forms a part of one mire region.

Region III. West-Siberian taiga region of boreal-atlantic convex oligotrophic mossy mires of active mire formation and intensive peat accumulation.

Province III.3 – southern taiga province of oligotrophic pine-shrub-sphagnum ridge-hollow, mesotrophic and eutrophic pine-birch-sedge-hypnum (or sphagnum) and sedge-hypnum (or sphagnum) mires;

2 – **mire district**: 11 – **Vasyugan district** of southern taiga oligotrophic ridge-hollow. Mesotrophic and pine-shrub-sphagnum mires in combination with eutrophic and heterotrophic spruce-cedar—birch-sedge-shrub-sphagnum mires and 12 – **Bakchar district** of southern taiga oligotrophic ridge-hollow, pine-shrub-sphagnum mires in combination with eutrophic and mesotrophic pine-spruce-cedar-birch-sedge-hypnum (or sphagnum) and sedge-hypnum (or sphagnum) mires.

Province III.4 – subtaiga province of west-siberian Atlantic eutrophic sedge-hypnum mires; swampy **North-Baraba district 16** of subtaiga eutrophic sedge-hypnum mires in combination with pine-shrub-sphagnum mires. The southeastern borders of Vasyugan mire are included into this mire district.

Before changing the principal subject one should note that while moving from the isles of Vasyugan mire to the center it can be observed how taiga “coastal” forests give place to swampy vegetation of high and transitional type.

The composition of dominants which determine the aspect of different plant associations changes depending on degree of watering, groundwater table, stagnation and chemical composition of swampy waters.

At Vasyugan mire the following types of vegetation can be classified:

High – 1. Ridge-hollow, 2. Ridge-pool, 3. Pine-sphagnum, 4. Sphagnum fuscum.

Transitional – 1. Wood-sedge, 2. Wood-sphagnum, 3. Pine-sphagnum, 4. Sedge, 5. Sphagnum, 6. Sedge-hypnum, 7. Forest.

Low – 1. Forest 2. Wood-sedge.

The amount of different phytocenoses at Vasyugan mire is rather large. In different types of mires they consist of definite chain of plant groupings, which characterizes the state of development and age of individual plots of Vasyugan mire. **We shall dwell only on generalized types of swampy vegetation of Vasyugan mire.**

Pine-shrub-sphagnum phytocenoses. Pine-shrub-sphagnum phytocenoses are widely spread at Vasyugan mire. They are associated with mire borders or with well-drained slopes with surface gradient 0.001–0.006 [120].

As well they occupy the most convex central plots of the mire and very often alternate with ridge-pool and ridge-hollow complexes, and create mosaic picture of the surface of Vasyugan mire.

In peatland science Siberian oligotrophic mires with pine-shrub-sphagnum groups are named as ryam (ryam is pine-sphagnum phytocenosis with swampy pine) (Fig. 7, 8).

Ryams are also found among vast eutrophic sedge-hypnum mires (province III.4, mire district 16) where their appearance and development are connected with conditions of scanty water and mineral regime and precipitation nutrition.



Fig. 7. Pine-undershrub-sphagnum phytocenosis (high ryam, p. 2)

Let us consider first of all the ryams of oligotrophic mires.

At Vasyugan mire the following variants of such ryams are found: **ryams with *Pinus sylvestris* f. and *uliginosa* and ryams with *Pinus sylvestris* f. *litwinowii*.**

First ryams (with *Pinus sylvestris* f. and *uliginosa*) are associated with the most convex central plots of the tract. In these so called “tall ryams” the height of trees amounts to 6–10 m, diameter of stems 8–15 cm, density of crown 0.5–0.8. The admixture of *Pinus sylvestris* f. *litwinowii* and *P. sibirica* is insignificant.

The undershrub layer is very luxuriant. The degree of undershrub coverage reaches quite often 70–80 %. *Ledum palustre* and *Chamaedaphne calyculata* are dominant and *Oxycoccus microcarpus* is rather luxuriant. The microrelief is hummocky.

Sphagnum fuscum is dominant in the mossy layer. On the tops of hummocks the spots of green mosses are found: *Pleurozium schreberi*, *Dicranum polLisetum*, *D. affine*. At the hummock basis and in the depressions between hummocks the spots of *Sphagnum fuscum* are common; they are thickly pierced with stalks of *Mylia anomala*.

In tall ryams of the peripheral zone of Vasyugan mire (Fig. 7) the woody layer consists of *Pinus sylvestris* f. *uliginosa*. The young growth is mainly represented by *Pinus sylvestris*, *Betula pubescens*.

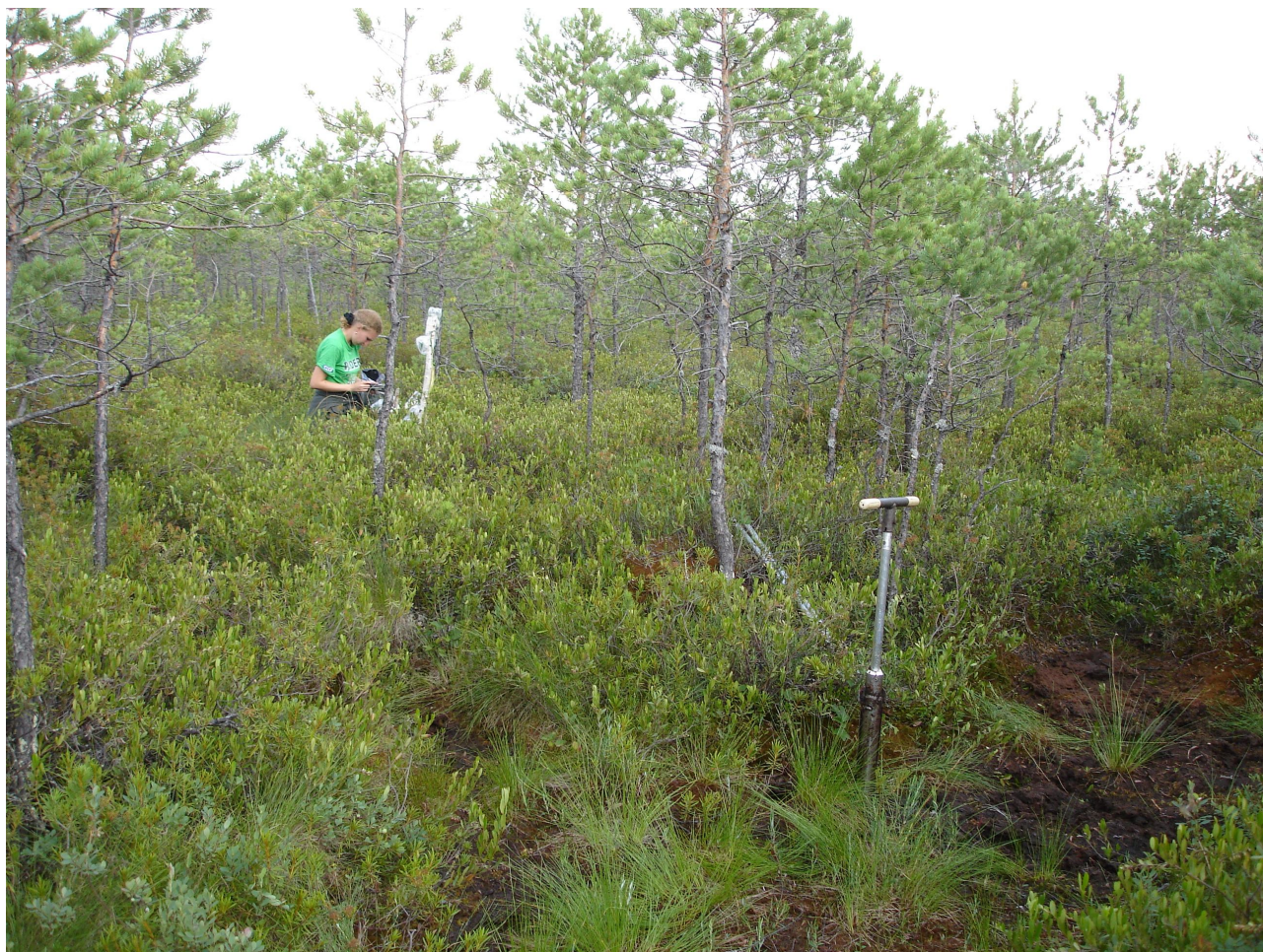


Fig. 8. Pine-undershrub-sphagnum phytocenosis (low ryam, p. 3)

As for the undershrub layer, *Ledum palustre* and *Chamaedaphne calyculata* are dominant. They are associated with mossy cushions and near-stem elevations.

Carex globularis is abundant in the grass cover of the extreme ryams. *Sphagnum magellanicum* and *Sph. angustifolium* are dominants of moss cover. On the tops of hummocks of 40 cm high and on near-stem hillocks *Sph. fuscum* is found.

At pine stems and branches, shrub stems considerable quantity of lichens (epiphytes) is found. By A. A. Khramov and V. I. Valutsky [69], *Cetraria pinastri*, *Usnea hirta*, *U. comosa*, *Hypogymnia physodes*, *Parmelia olivacea* are most common.

Variant of ryams with *Pinus sylvestris* f. *litwinowii* is more widely spread. It can be considered as one of the first stages of development of woodless oligotrophic sphagnum and grass-sphagnum swamps in afforested phytocenoses.

The ryams with *Pinus sylvestris* f. *litwinowii* are especially typical for slopes of mire tracts (Fig. 8). The arborescent layer in the ryams with *Pinus sylvestris* f. *litwinowii* is more thinned out: density of crown is 0.4–0.6; sometimes it falls to 0.3–0.2. The height of trees is 4–5 m, the stem diameter is 3–7 cm. *Pinus sylvestris* f. *wilrommii*, which grows here, is 1–2 m high, 1–3 cm in diameter.

The degree of undershrub coverage is high and amounts to 60–80 %. The ratio between individual species of undershrubs depends on the groundwater table. At the groundwater table below 50 cm the *Ledum palustre* is either dominating, or grows

together with *Chamaedaphne calyculata*. *Andromeda polifolia* is the indicator of higher groundwater table (20–30 cm). *Betula nana* is rarely found. The associations such as *Pinus Sylvestris* f. *litwinowii* – *Ledum palustre* – *Sphagnum fuscum*, *Pinus sylvestris* f. *litwinowii* - *Ledum palustre* + *Chamaedaphne calyculata* - *Sphagnum fuscum* are most often spread.

Sph. fuscum; *Sph. magellanicum* and *Sph. angustifolium* are dominant in the moss cover, these are associated with hillock basis and depressions between hillocks. Their participation in the composition of in moss cover is not higher than 3–5 %. On the periphery of such ryams the depressions between hillocks are occupied by *Sphagnum angustifolium*, *Sph. Magellanicum* is sharply pronounced on the slopes of the hillocks.

Let us return to the phytocenotic features of the ryams of eutrophic sedge-hypnum swamps the mention of which has already been made. *Pinus sylvestris* f. *litwinowii* is dominant in woody layer. As the degree of drainage and fluctuation of groundwater table from periphery to the center of the ryams increases one can observe the following change of the dominants of undershrub layer: *Andromeda polifolia* → *Chamaedaphne calicylata* → *Ledum palustre*.

At the end of the Middle and especially the Late Holocene the part of atmospheric nutrition of the mires increased and the change in their plant cover has been outlined. In some cases eutrophic sedge and sedge-hypnum phytocenoses were transformed into sedge-sphagnum and sphagnum.

The transfer to the oligotrophic stage is connected with the appearance of *Sph. russowii*, which was relatively rapidly displaced by typical oligotrophic species *Sph. fuscum*. Sometimes mesotrophic sphagnum phytocenoses turned into oligotrophic sphagnum ones where *Sph. magellanicum* and *Sph. angustifolium* were dominants.

So, in spite of the fact that the zonal mire type of the subbelt of birch-aspen forests represents eutrophic sedge-hypnum mires, oligotrophic pine-undershrub-sphagnum mires occupy considerable area of contemporary plant cover. Gradual but permanent transfer to oligotrophic stage is a principal contemporary tendency in the development of sedge-hypnum mires.

In the central part of Vasyugan mire the pine-undershrub-sphagnum formations appeared among vast eutrophic sedge-hypnum swamps prevail on small detached oligotrophic plots. Sometimes oligotrophic islets combine with each other and form larger and more complicated by configuration systems. In their plant cover on more elevated plots the pine-undershrub-sphagnum communities prevail which on the lower part of the slope give place to ridge-hollow phytocenoses, which alternate with narrow stripes of ridge-hollow-pool complexes.

Ridge-hollow complexes. Ridge-hollow complexes (RHC) are widely spread on Vasyugan mire. The plots of mire tracts occupied by ridge-hollow communities are usually as long stripes (from several tens cm to several hundreds m wide), they branch off as radial lines from central parts of the mire towards their extremes (Fig. 9). Depending on ratio of areas occupied by positive and negative relief forms

the three variants of ridge-hollow complexes are classified: large-hollow, medium-hollow and small-hollow. The shape of ridges and correlation between the areas of ridges and hollow is closely connected to a considerable degree on surface incline. The area of hollows increases as the incline decreases.



Fig. 9. Ridge and hollow complex on raised peatlands of watershed

Let us consider RHC on the example of the ridge small-hollow complex (Fig. 10). Ridge-small-hollow complexes are found in the contact with *Fuscum*, *pine-eriophorum-sphagnum* or *pine-undershrub-sphagnum* phytocenoses with which they are connected genetically.

In ridge-small-hollow complexes the hollows occupy 20–30 % of total surface. The hollows are slightly elongated without any strict orientation by relief. The watering of hollows is low. The water level is usually below 10–15 cm moss cover. The ridges are 3–10 m wide, sometimes 10–15 m; their height is 0.5–0.8 m (Fig. 11).

Not infrequently the ridges join and form islets occupied by *pine-undershrub-sphagnum* phytocenoses. On the ridges grows *Pinus sylvestris f. litwinowii* 3–5 m high, 5–10 cm in diameter. The admixture of *P. sylvestris f. willkommii* is insignificant, its height is 1–3 m, diameter 3–5 cm. Tree stand density amounts to 0.1–0.3, and the dead wood is common. *P. sibirica* of 6–10 height is typical.

The undershrub layer is rather well developed on the ridges, the degree of coverage rises up to 50–60 %, and sometimes it reaches 80 %. *Chamaedaphne calyculata* is abundant on the ridges under conditions of good drainage and *Ledum palustre* overgrows strongly. As the drainage becomes worse and groundwater table rises

Andromeda polifolia becomes prevalent. The thin grass cover is represented by *Eriophorum vaginatum*. In moss cover the *Sphagnum fuscum* is prevalent.



Fig. 10. Ridge and hollow complex

Along the slopes and at the ridge basis the dissemination of *Sph. angustifolium* and *Sph. magellanicum* are typical. In weakly watered hollows *Chamaedaphne calyculata*, *Andromeda polifolia* *Oxycoccus quadripetalis* are diffusively scattered. Total coverage is not more than 20 %.

Eriophorum vaginatum, which forms hillocks 10–15 cm high, is luxuriant in the grass layer of the hollows. The hillocks occupy 35–45 % of total surface of the hollows. The coverage of *Scheuchzeria palustris* и *Carex limosa* decreases up to 10–15 %. The moss layer is represented by *Sphagnum balticum* and *Sph. fallax*. In the center of the hollows where groundwater table is at the depth of 10–15 cm from the surface, *Sph. majus* appears. The hollow extremes are occupied by *Sph. angustifolium*.

The ridge-hollow complexes of all three types are reciprocally connected with each other depending on the value and direction of the surface runoff.

Wide spreading of RHC is explained by the fact that they as pool-ridge-hollow complexes are the most sustainable forms of existence of the plant cover.

Pool-ridge-hollow complexes. In the pool-ridge-hollow complexes the strongly watered hollows alternate with secondary lakes or the lakes occupy central plots of large hollows. The lakes are elongated or rounded by shape. Their size varies strongly. Lakeside line is strongly broken. The water depth is 0.8–1.3 m and the

bottom is peaty. The lakes and hollows alternate with the ridges. The ridges take up 20–50 % of the surface. The ridge width is 1–3 m and the height is 0.2–0.4 m. The hollows and lakes take up 50–80 % of the surface.



Fig.11. Ridge in ridge and hollow complex

Pinus sylvestris f. *Litwinowii* grows on the ridges, its height is 3.5–5, diameter 8–10 cm and f. *willkommii* 1.0–3.5 m high and 5–7 cm in diameter, *Pinus sibirica* is found seldom. The density of crown is 0.2–0.3; often it falls to 0.1 and more. The undershrub layer is strongly developed; coverage amounts to 60–70 %; *Chamaedaphne calyculata* and *Ledum palustre* are mainly prevalent, *Andromeda polifolia* is also found. The grassy cover is represented by *Rubus chamaemorus*.

Sphagnum fuscum is prevalent in the moss cover. Along the slopes and at the hillock basis the spots of lichen are common. The groundwaters on the ridges are rather low. The grass cover in the hollows is formed by *Carex limosa*, *Scheuchzeria palustris*, *Rhynchospora Alba*. The coverage is 40–50 %; in the sites without moss cover the *Drosera rotundifolia* is common. As for the moss cover of the hollows, *Sphagnum majus* and *Sph. Papillosum* are predominant; *Sph. balticum* is common on the peripheral part of the hollows.

It seems to be interesting to pay attention to such an interesting phenomenon as the development of regressive phenomena which become apparent in temporal cessation of peat formation and replacement of peat-forming plants by not peat-forming ones (lichen, liverworts, algae, (Fig. 12).



Fig. 12. Regression on ridge and hollow complex

Not dwelling on different opinions on this problem [9, 10, 86 a.o.], let us take into account as follows: in Western Siberia where the main part of the mires is self-regulating systems. It has a certain attitude towards Vasyugan mire as well where dystrophic plots are insignificant, the development of regressive phenomena should be considered as one of homeostatic mechanisms of the existence of oligotrophic

mire. The interruptions in peat accumulation give place to overgrowing and subsequent peat accumulation.

It is worth while noting that A. Y. Bronzov [11], when investigating Vasyugan mire paid attention to this phenomenon and then confirmed that this was a substantial evidence of the beginning of the quaternary (final) stage of their development.

The development of regressive phenomena in the hollows leads to appearance of “black hollows”. The process of destruction of vegetation begins from the settling of *Sphagnum maius*, *Cladodiella fluitans* on the surface. Simultaneously the *Sphagnum compactum* appears in the moss cover. As a result, the associations such as *Rhynchospora Alba* – *Sphagnum compactum* – *Cladodiella fluitans* - *Rhynchospora Alba* – *Cladodiella fluitans* appear (see Fig. 12). Gradually on the bare oxidized substrate only liverwort mosses and algae remain.

The next stage is the formation of bog pools, which, in its turn, begin to overgrow by mosses adapted to the conditions of regressive stage of the development of oligotrophic mires. These mires are characterized by wide amplitude of fluctuation of medium acidity

Sedge-hypnum phytocenoses. The southern and southeastern part of Vasyugan mire is included into the province of subtaiga West-Siberian Atlantic eutrophic of sedge-hypnum mires. Sedge-hypnum phytocenoses are associated at the territory of Vasyugan mire with tremendous hollows with comparatively even vegetation.

The grass layer is rather thin in the hollows. As for the sedges, the species are mostly spread as follows: *Carex diandra*, *C. chordorrhiza*, *C. limosa*, *C. omskiana*, sometimes – *C. rostrata*, *C. lasiocarpa*. *C. Heleonastes* and *Rhynchospora Alba* are found as solitary species. *Scheuchzeria palustris*, *Triglochin maritimum* are found in small amount but grow more often. Small accumulations are formed by *Equisetum limosum*.

The species such as *Menyanthes trifoliata*, *Comarum palustre*, *Cicuta virosa*, *Epilobium palustre*, *Pedicularis palustris* and *Utricularia intermedia* are mainly spread among the herbs. *Drepanocladus vernicosus* and *D. Sendtneri* is prevalent in the moss layer. The former is prevalent in less watered sites; the latter grows in small watered depressions. *Calliargon trifarium* grows here as well.

Monotonous sedge-hypnum swamps are crossed in the direction perpendicular to surface runoff by narrow (1–2 m) and long (up to 1 km) peat bank (local name “veretiya”). These peat banks rise above sedge-hypnum swamps by 10–25 cm. In the sites without incline these peat banks stretch in different directions. The distance between these banks ranges from several meters to 50–200 m.

In addition to peat banks (veretiya), the single islets of oligotrophic pine-undershrub-sphagnum phytocenoses are scattered on the surface of sedge-hypnum swamps. The diameter of such islets varies within the limits of several tens m (local name “shelomochki”). Shelomochki rise above the surface of sedge-hypnum mires by 50–90 cm [12].

Betula pubescens and *Pinus sylvestris* grow on peat bank one by one or as small groups; as for shrubs, *Salix lapponum* and *S. rosmarinifolia* are found here. Undershrub layer is rather luxuriant. *Betula nana*, *Andromeda polifolia* are mainly spread. *Ledum palustre* and *Chamaedaphne caliculata* are somewhat thinner. The grass layer of peat banks does not differ essentially by floristic composition from the grass cover of sedge-hypnum depressions.

The analysis of geobotanical descriptions by A. Y. Bronzov [12] for the southern part of Vasyugan mire evidences that notwithstanding rather numerous general floristic list of 46 species of undershrub, grass and moss layers, only two species such as *Carex limosa* and *Carex diandra* can be named as permanent ones for sedge-hypnum phytocenoses of eutrophic mires of Ob-Irtysh interfluvium. Four species such as *Betula nana*, *Andromeda polifolia*, *Carex chordorrhiza*, *Menyanthes trifoliata* are found very frequently.

Sphagnum warnstorffii is prevalent in moss cover of the peat banks; *Tomenthypnum nitens* is dominant on the lower peat banks. *Sphagnum angustifolium*, *Sph. magellanicum*, *Sph. fuscum* grow at stem basis depending on the height of hillocks. The appearance of mesotrophic as well as oligotrophic “shelomochki” relates to subatlantic period. As it was noted above, the prevalent eutrophic sedge-hypnum stage, which was delayed in this zone up to present time, is caused by edaphic factors.

As the peat deposit increases, the influence of bedding rocks on deposit structure decreases, ash content of peats decreases and favorable conditions spring up for development of sedge-hypnum phytocenoses into grass sphagnum peat banks (veretiya) and pine-undershrub-sphagnum (shelomochki).

As it was mentioned above, the abundance of different phytocenoses becomes evident at Vasyugan mire. We have not examined wood-undershrub-moss, wood-grass-moss and many other types of phytocenoses, which are not deciding for Vasyugan mire. But we can recommend some references for those who show more interest to this problem [11, 37, 70, 86].

3.2. Stratigraphy

Geomorphologic, hydrogeologic and other factors determine the formation and accumulation of all peat types. As a rule, peat field with deposits of highbog and mixed peats occupies all the elevated territories of the watershed, and plots and single tracts with deposits of fen and transitional peats occupy the southern slopes of the watersheds.

In order to characterize the structure of different types of deposits in the northern and southern parts of Vasyugan mire which are included into different regions of mire regioning (see 3.1), two profiles are being given through the mires of these regions from south to north [96].

Figure 13a illustrates the profile through the peatland “Tatarsky ryam” and adjacent saimishe situated in the southern part of the area of sedge-hypnum peatlands, in “saimishe-ryam peatlands” of the forest steppe belt.

It is seen that sharply convex “cap” of the ryam consists entirely of sphagnum peat, i.e. fuscum. A small layer of reed-sedge peat deposited on sapropel underlies this big thickness. In itself saimishe is composed of reed-sedge or sedge peat the thickness of which is not more than 2 m. The availability of highbog peatlands among sedge-reed saimishe is a specific feature of this territory.

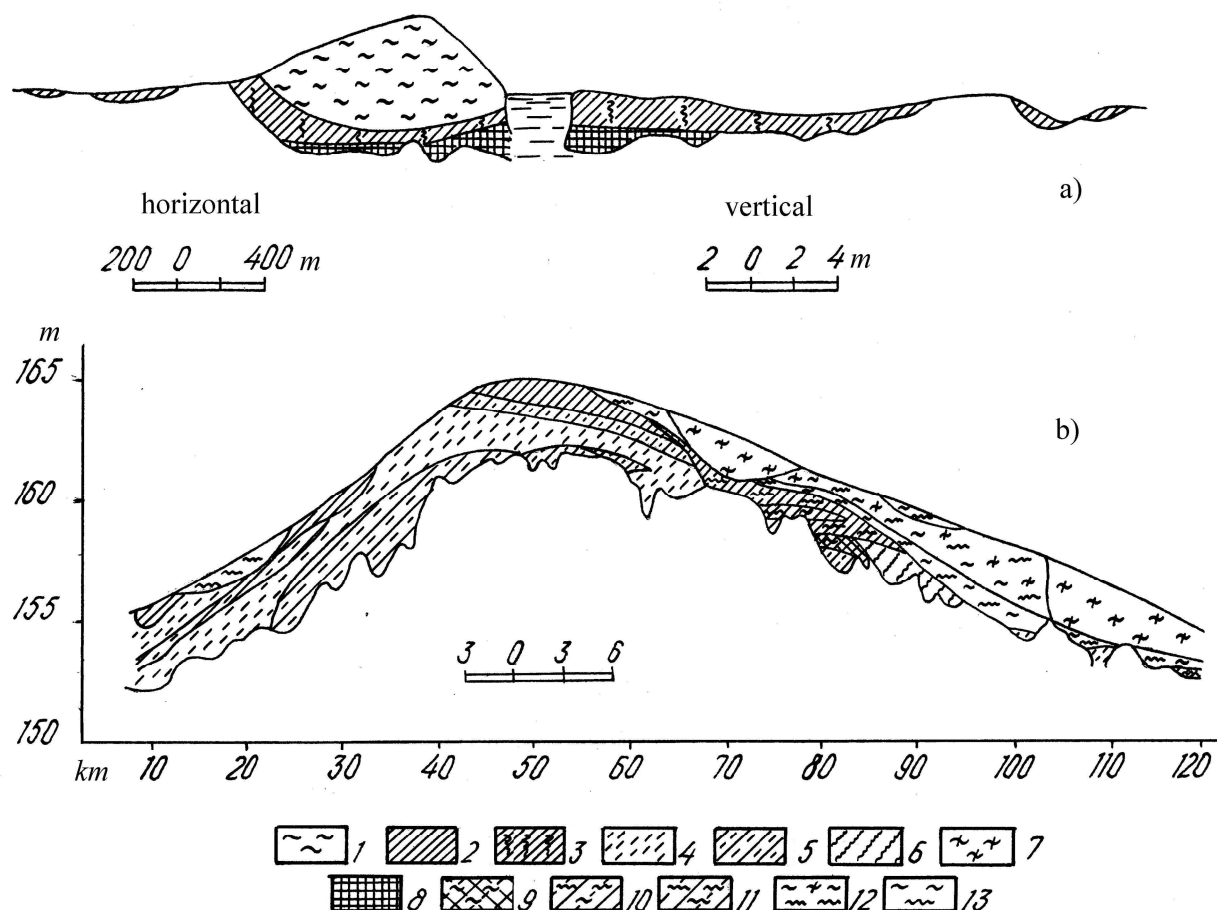


Fig.13. Profiles through: a) mire of “Tatarsky ryam”, b) Ob-Irtysh watershed (Vasyugan mire). Kinds of peat: 1 – sphagnum, 2 – sedge, 3 – sedge-reed, 4 – fen hypnum, 5 – fen sedge-hypnum, 6 – grassy, 7 – phuscum, 8 – sapropel, 9 – fen grass-mossy, 10 – grass-mossy transitional, 11 – sedge-sphagnum transitional, 12 – raised complex, 13 – sphagnum-hollow

Figure 13b illustrates also the profile across Vasyugan mire and its crest. The southern part of the profile (the left one) including the watershed as well belongs to the “region of sedge-hypnum peatlands”, in the northern part of the profile (the right side) begins already “the region of atlantic convex moss mires”

As it can be seen, in the left part of the profile dominates completely low moor deposit, which consists of hypnum, hypnum-sedge and sedge peats. Their degree of decomposition ranges varies from 20 to 50; the degree of decomposition of 20–25 % is most common, ash content of peats amounts to 5.1–8.1 % (with the exception of several saline samples on the bottom of peat deposit).

In the right part the stratigraphy of peat deposit is absolutely different. It is

composed by different species of sphagnum raised bog peats and in the part, close to low moor deposit, is underlain by bigger or lesser layer of low-mire peat, northward the peat of raised type begins almost or directly from the peatland.

Here the complex sphagnum raised bog or fuscum peats are prevalent and in compliance with this the complex high-moor deposit. The degree of decomposition ranges from 5 до 25 %, the degree of decomposition of 5–10 % is obviously prevalent. The ash content varies from 1.2 до 8.9 %, the most common amplitude of the values is observed to be from 2 to 4 %.

The difference between both parts of the profile is evident. The character of grounds can explain this fact. The left part of the profile displays strong effervescence with hydrochloric acid. The grounds of the right part covered by raised moor do not reveal effervescence but show signs of salinization.

A. Y. Bronzov [12], with reference to foregoing data, assumes that before the peat formation on Ob-Irtysh watershed the border was between steppe and forest steppe, at that this border corresponded approximately to that one which separates sedge-hypnum part of Vasyugan mire from that of sphagnum.

The following most spread kinds of peat deposits can be found on the territory of Ob-Irtysh watershed: low moor type with sedge, sedge-hypnum, hypnum, forest-swampy and forest kinds; **transitional type** with transitional-swampy kind of deposit; **raised moor type** with complex raised, fuscum, medium and *Sheuchzeria-sphagnum* kind of deposits a.o.

The ratio of raised moor and low moor types of deposits is turned to advantage of raised one in the direction from the south to the north.

The aforecited brief characteristics of the peat deposits stratigraphy of Vasyugan mire will be worked out somewhat in detail in the fourth part of this book when considering peat resources of Vasyugan mire.

3.3. Results of the research on the watershed in the sources of the rivers Shegarka and Iksa

In August, 2001 the research was conducted on the territory of the southeastern part of Vasyugan mire within following bounds: the sources of the river of Shegarka, lake of Dedushkino and sources of the river of Iksa, lake Bykovskoye (Kolyvansky district of Novosibirsk region. The maximum height of the area under investigation amounts to 146 m above sea level.

The territory under research is situated on the watershed of the rivers, which is characterized by high paludification, with the exception of coastal sites of dry lands, which are occupied by mixed tall herbaceous forests. The stand of such forests consists of fir, spruce and birch; pine is infrequent here. In the valley of the river of Shegarka (Fig. 14) birch forests with admixture of coniferous species are predominant, and in the source of the river of Iksa pure cedar forests are common (height of trees 15–20 m), grassy and moss layers are typical for such kinds of

forests. There are various types of mire ecosystems on the paludificated areas.



Fig.14. River of Shegarka in upper course

Within the limits of biogeocenosis the geobotanical descriptions of vegetation were carried out by standard technique, the depth of peat deposit was determined as well. Field characteristics of the deposit included the measurement of its temperature (up to the depth of 1 m) and redox-potential. On each point of the profile the peat was sampled to study botanical structure of peat deposit, its microbiological and chemical properties.

For estimation of the productivity of vegetative communities within the limits of the described biogeocenoses the vegetation was cut off at the level of standing dead part of the moss; it was divided into fractions (litter standing dead, grasses, leaves of low shrubs, non-photosynthesizing perennial organs, i.e. shoots, living parts of mosses), dried up and weighed.

To study the influence of human impact on the structure and productivity of vegetative communities the description of vegetation and phytomass sampling were conducted on the plot of the middle ryam subjected to the fire.

The general structure of vegetative cover and peat deposit of the profile is shown in Figure 15. The aspen forest on mineral soil was chosen as a zero point of the profile. The rich specific composition of the forest of this type is caused by soil moistening by superficial and ground waters.

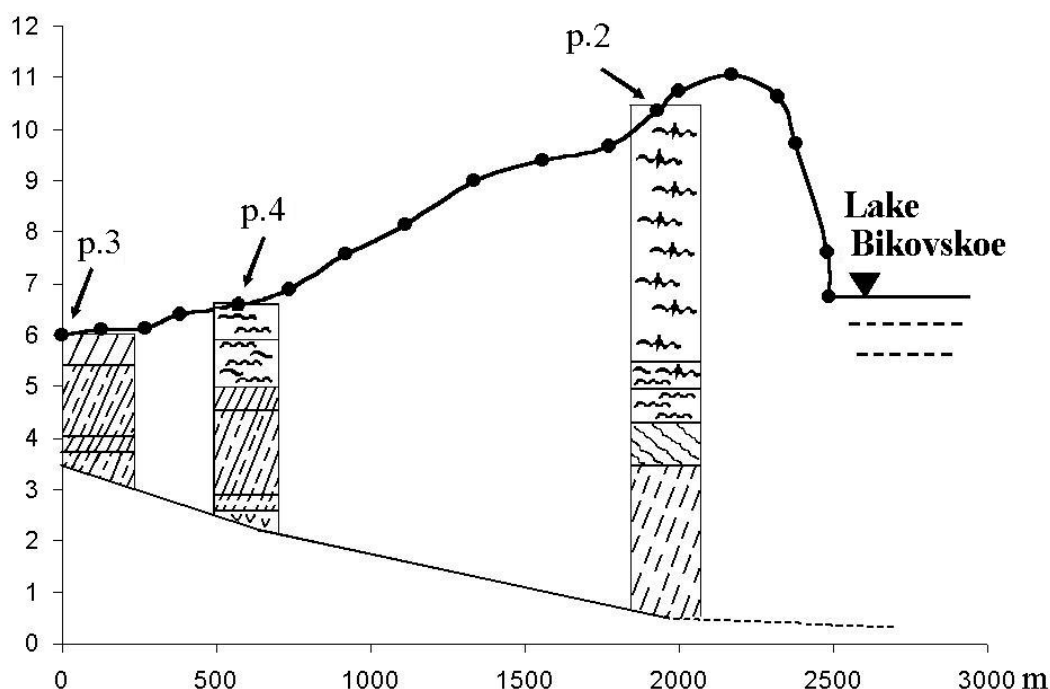


Fig. 15. Structure of peat deposit in landscape profile along research route

The arborescent layer is formed by aspen (*Populus tremula*) of 20–22 m high; eight species of shrubs were found in the composition of the undergrowth. The herb layer is characterized by frequent occurrence of the species, which is for 30–40 specimens of typical wood trial area.

The moss cover occupies not more than 10–20 % of the area Hypnum mosses. As for the vegetation beyond the layer, epiphytic mosses and lichens as well as grassy liana such as hop (*Humulus lupulus*) are found.

The paludification of mineral soils is determined by the change of aspen forest to the birch one of herb-swampy or sedge group. At the same time the formation of various types of birch forests takes place through a series of stages in which the birch gradually increases numerically; it can be illustrated by the change of structure of forest stand: 5Birch5Aspen – 6Birch2Aspen2Pine – 8Birch2Aspen – 10Birch +Aspen+Pine.

On the landscape profile the reedgrass (on more elevated drained plots) and sedge birch forests are illustrated (Fig. 16). Such communities are formed on peat deposit of the fen type the depth of which varies within the limits of 1 m (Fig. 15, point 5). The forest stand height makes up 8–10 m, diameter of trunk reaches 12–15 cm, density of crown amounts to 0.6–0.7.



Fig. 16. Birch-sedge phytocenosis (p. 5)

The microrelief of the communities under consideration is hummocky. The hummocks, which are as high as 20–30 cm, occupy 60–70 % of the territory. It should be noted that the formation of the most part of the hummocks, especially in sedge birch forest) is connected with vital functions of the sedges.

The layer of shrubs is composed by honeysuckle (*Lonicera xylosteum*), currant (*Ribes nigrum*) and buckthorn (*Frangula alnus*). The coverage of herbaceous undershrubby layer reaches 70–90 %. Here the mixture of plants of different phytocenotypes is observed. The species are found such as forest (*Trientalis europaea*, *Pyrola rotundifolia*, *Majanthemum bifolium* and boggy) *m*, and marsh ones (*Comarum palustre*, *Menyanthes trifoliata*, *Thelypteris palustris*, *Ledum palustre*,

Thyselinum palustre, *Naumburgia thyrsiflora*, *Oxycoccus palustris*).

The moss cover has not more than 30 % of coverage and mainly consists of Hypnum mosses (*Climacium dendroides*, *Hylocomnium splendens*, *Pleurozium schreberi*, *Aulacomnium palustris*, *Mnium rugicum*, a.o.). On near-trunk elevations *Sphagnum warnstorffii* is found.

The increase in humidity of the substratum causes the occurrence and the increase in number (up to 30 %) of dwarf birch (*Betula nana*); as a result, that of yernik-sedge, and on separate sites replaces the sedge birch forest by – yernik-forbs. (Yernik is a dwarf shrub formation with *Betula nana* a.o. in boreal ecosystems).

It is necessary to notice that in the course of such change of the phytocenoses the viability of birch decreases. Its height decreases and makes up 5–7 m, the diameter of the trunk is up to 8–10 cm and density to 0.3–0.4. In the undershrub layer of the phytocenoses under consideration willows (*Salix lapponum*, *S. cinerea*, *S. myrsinifolia*) are found.

The forbs-undershrub layer has the coverage of 65 % and it is characterized by sedge domination of slender sedge (*Carex lasiocarpa*) and a dwarf birch (*Betula nana*).

The moss cover occupies not more than 25 % and is also represented by Hypnum mosses. Such communities are formed in the conditions of rich water and mineral nutrition on low mire peat.

The structure of peat deposit allows classifying it as a deposit of sedge-Hypnum type. Two types of the peat such as sedge low mire and woody sedge compose this deposit. The degree of decomposition of such peat is as high as 20–35 %.

The analysis of stratigraphic column for the bog plot under investigation permits to establish the fact that the paludification began from the stage of sedge-hypnum phytocenoses. It is evidenced by botanical composition of near-bottom peat samples. Gradually in the vegetative cover the wood layer began to be formed, it is represented by birch that testifies the increase in birch residues from 5 to 25–30 % from bottom to the top layers of the peat deposit. The proper upper layer (0–25 cm) is formed by woody (birch) low mire peat.

While moving along the profile to its central part the gradual increase in the mire surface is connected with the increase in the thickness of the peat deposit which reaches 2.4 m.

The change of water and mineral nutrition, along with high mire groundwater table, causes the disappearance of the birch from the forest stand, which is changed by bay-leaf willow (*Salix pentandra*). The analysis of the botanical residues of the peat deposit permits to suppose that it began recently as in the top layer of the peat the content of birch residues is no more than 25 %, the content of willows residues amounts to 1–3 %. In the vegetative cover it is confirmed by age-specific spectrum of willow by prevalence of the stands of pregenerative and generative young state, which have shrub-like form.

Hence, the change of birch phytocenoses by those of willow is in the first stage. Furthermore, this assumption requires additional research.

The willow phytocenoses are represented by yernik-sedge and yernik-forbs associations (Fig. 17) which are formed on low mire peat deposit which was formed by sedge low-moor sedge-Hypnum kinds of peat having degree of decomposition as high as 15–45 % (Fig. 15, point 3)



Fig. 17. Willow-yernik forbs phytocenosis (p.3)

In the forest stand of such phytocenoses the birch is rare in occurrence besides the willow. The height of trees is not more than 5 m. In forbs-undershrub layer the dwarf birch (*Betula nana*) and slender sedge (*Carex lasiocarpa*) are predominant as well as ferns (*Thelypteris palustris*, *Phegopteris connectilis*), horsetail (*Equisetum fluviatile*), (*Menyanthes trifoliata*), potentilla (*Comarum palustre*), sedge (*Carex vesicaria*) are found, less are in occurrence marshmarigold (*Caltha palustris*), (*Andromeda polifolia*), cranberry (*Oxycoccus palustris*), (*Naumburgia thyrsiflora*).

The moss cover is represented by green mosses and hepatics (*Marchantia polymorpha*). Its coverage is up to 25 %. Mosses grow on the microelevations the height of which makes up 20–30 cm.

The rise of mire surface causes the change of the features of water and mineral nutrition and character of vegetative cover.

The eutrophic vegetation is replaced by that of mesotrophic one, which is represented by undershrub-sedge-sphagnum pine forest (Fig. 18, point 4). The

microrelief of such communities is hummocky. The height of hummocks can reach 40–50 cm, their sizes are as large as 50x70 cm. The hummocks occupy 60–70 % of the area. The features of microrelief cause the difference in vegetative cover of microelevations and microdepressions.



Fig. 18. Pine-undershrub-sedge-sphagnum phytocenosis (p.4)

The wood layer is formed by Scotch pine of Litvinov's form (*Pinus sylvestris* L. f. *Litwinowii*). This tree is of 5–7 m high; the diameter of its trunk is 10–12 cm at the level of standing dead. The density is 0.3–0.4. The coverage of herb-undershrub layer ranges within the limits of 65 % on hummocks to 85 % in microdepressions.

The *Chamaedaphne calyculata* is predominant among the undershrubs; it is more often associated with hummocks where its coverage makes up 30 % (in the microdepressions not more than 8–10 %). The same is characteristic for cotton grass (*Eriophorum vaginatum*) the coverage of which on hummocks amounts to 5–7%, as well as for *Carex rostrata* (10 %), *Andromeda polyfolia* (3 %).

On the contrary, slender sedge (*Carex lasiocarpa*) has maximum coverage in the lowered elements of microrelief (25 %). A dwarf birch (*Betula nana*), cranberry (*Oxycoccus palustris*) and *Menyanthes tryfoliata* are spread rather uniformly, their coverage ranges within the limits of 20–30 %. The moss cover is represented by Sphagnum mosses (*Sphagnum magellanicum*, *Sph. balticum*) with rare occurrence of green mosses (*Polytrichum strictum*).

The type of communities in question is formed on sedge fen deposit the depth of which makes 4.4 m. The paludification of this began with the eutrophic stage, which was represented by grassy (*Scheuchzeria*) and hypnum grassy sedge phytocenoses.

The most part of the deposit is formed (not more than 2.7m) by sedge hypnum species of peat with degree of decomposition of 20–45 %. The upper part of the deposit from depth of 75 cm is composed by sedge-sphagnum, sphagnum and medium-peat with the degree of decomposition of 10–15 % (point 4 on fig. 15).

The type of community in question was formed on sedge fen peat deposit the depth of which is up to 4.4 m. The paludification of this plot began from the eutrophic stage, which was represented by grassy (*Scheuchzeria*), Hypnum and grassy (sedge)-Hypnum phytocenoses.

The most part of the deposit is formed by (not more than 2.7 m) by sedge-hypnum kind of peat with the degree of decomposition of 20–45 %. The upper part of the peat beginning at the depth of 75 cm is formed by sedge-Sphagnum transitional, Sphagnum transitional and medium peat with degree of decomposition of 10–15 % (point 4, Fig.15).

Oligotrophic vegetation of the profile is represented by ryam communities that are notable for prevalence of different forms of pine and height of forest stand respectively.

According to leveling data, on the highest part of the mire profile where the thickness of peat deposit is more than 8 m, the pine-underhrub-sphagnum phytocenoses are formed (point 2, Fig.15), and the forest stand is represented here by Wilcom's pine (*P. s. L. f. willkommii*). Such communities are called as low ryam (Fig.19).

The height of the trees is 2.5–3.0 m at the age of 70–80 years, the trunk diameter is 5–7 m, and the density is 0.4. The microrelief is hummocky. The height of the hummocks is 30–50 cm; their sizes are 50x70 cm. The hummocks occupy 85 % of the territory; the main coverage of grass-undershrub layer is associated with hummocks. The undershrubs such as ledum (*Ledum palustre*) and leatherleaf (*Chamadafne calyculata*) are predominant species; in total, they amount to 70 % of the coverage. Cranberry (*Oxycoccus microcarpus*) and cloudberry (*Rubus chamemorus*) occur as well. Mountain cranberry (*Vaccinium uliginosum*) is the most frequent on the hummocks' slopes and in the depressions between hummocks.

The moss cover is represented by sphagnum, green species and hepatics and occupies 97 % of the coverage. *Sphagnum fuscum* forms the coverage on the tops of the hummocks. In some cases the hepatics of *Mylia anomalia* are found on the tops of *Sphagnum*. *Sphagnum magellanicum* is found on the slopes of the hummocks and the species such as *Sphagnum balticum*, *Pleurozium schreberi* and *Dicranum polysetum* as well as various species of lichen of *Cladonia* genus are found in the depressions.

The pine-undershrub-sphagnum communities under consideration are developed on fuscum peat (the degree of decomposition 5–15 %), this peat occupies the most part of the deposit. In the lower part of the deposit the residues *Sphagnum*

magellanicum peat medium (the degree of decomposition 15–20 %) were found out.

As it can be seen, the formation of the convex part of the mire tract is connected to the occurrence and dominance of fuscum peat in the deposit. The development of such phytocenoses in plant cover seems to be conditioned by exceeding of the surface of biogeocenoses over general surface of the mire.



Fig. 19. Pine-undershrub-sphagnum phytocenosis, low ryam

This fact, in its turn, favored to improvement of drainage and intensive increment of sphagnum mosses (*Sphagnum fuscum*). It is evidenced by low degree of decomposition of the peat up to the depth of more of than 4 m.

The change of water and air regimes connected with lowering in the direction to the lake of Bykovskoye favors to the change of intensity of tree growth and to formation of medium, and in some cases, raised ryam. The tree stand is represented here by pine species such as *Pinus. s. L. f. litwinowii*, *P. s. L. f. uliginosa*. As for the belt that is directly near the lake of Bykovskoye, it is represented by green mossy pine forest of 4-th-5-th quality class. Along the lakeside the thickness of the peat layer is more than 5 m.

According to stratigraphy of the peat deposit of the prospecting profile, which was laid somewhat southwards the lake of Bykovskoye (Fig.19), this territory is characterized by prevalence of fuscum and complex deposit.

For example, in boring point 22 the deposit is composed up to the depth of 7 m by fuscum peat with the degree of decomposition of 5–10 % and ash content of 2.6–3.2 %. This deposit is underlaid by both sphagnum transitional (the degree of decomposition 10–25%, ash content 4.2–6.6 %) and Hypnum (the degree of decomposition 35 %, ash content 17.3 %) peats. It is of interest to notice the feature of points 23 and 24 where the deposit is practically decomposed by complex and fuscum peats up to the mineral bottom.

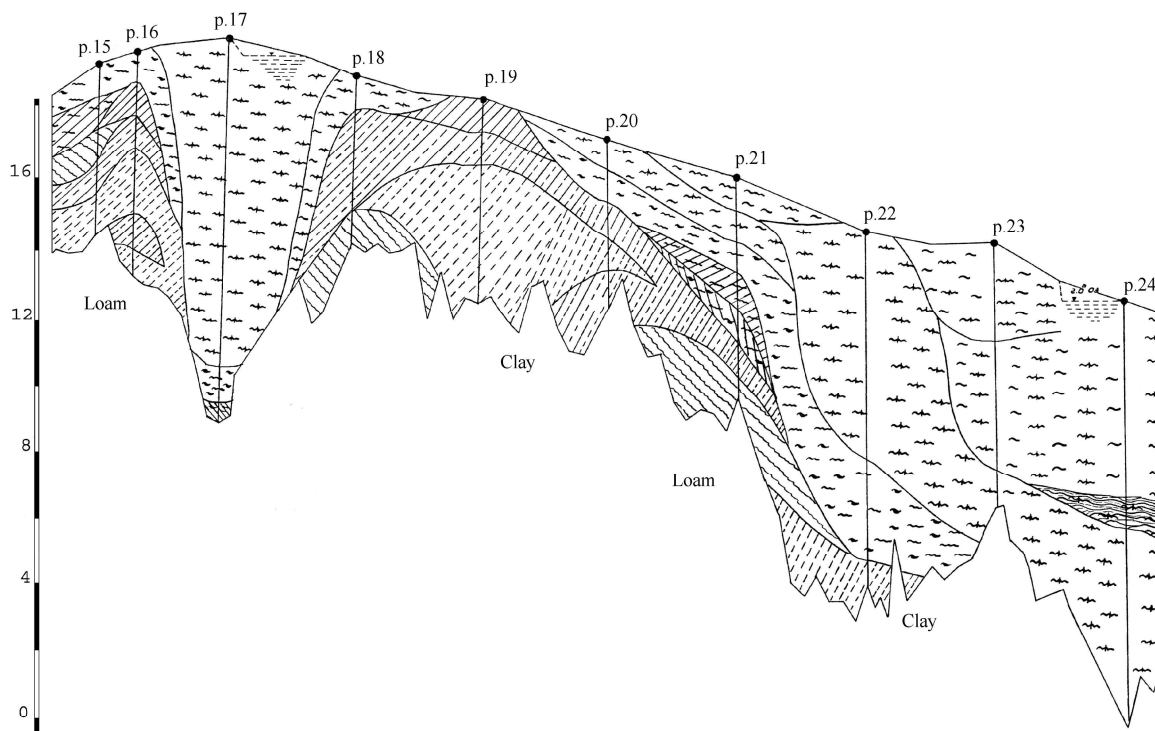


Fig. 20. Stratigraphy of peat deposits within geological routes nearby landscape profile (p. 2, Fig.15)

The analysis of stratigraphy of the profile (Fig. 20) in question confirms the opinion on the character of mire forming process in Vasyugan mire. This process is determined by weak run-off from the watershed and different degree of salinization of the grounds. This fact is evidenced by the occurrence of both fuscum (point 17) and sedge (point 19) deposits, which were found out in one of the highest point of the mire.

Such phenomenon can be caused by tectonic processes that favored to rising of the territory as a whole and, correspondingly, the plot under paludification. The run-off from such plots as well as the specific features of parent surface of the mire caused various characters of vegetation and further course of mire-forming process. In some plots the mire formation began from the eutrophic stages.

The vertical increment of the mire caused the change of plant cover and transition to oligotrophic vegetation. The paludification of other plots began directly from the oligotrophic stage. In these phytocenoses the intensive increase in basic peat formers such as sphagnum mosses (*Sphagnum fuscum*, in particular) causes the further more rapid upward peat increment.

This fact is the reason of the formation of convex shape of this part of the profile (the exceeding over mire borders is more than 4.5 m within the limits of the profile under study).

The spatial change of vegetation in the profile in question permits to construct the following series of phytocenoses (their correlation with type of peat deposit, its depth and specific features of water and mineral nutrition were indicated above) : aspen forest (mineral soils) – reedgrass birch forest – sedge birch forest – yernik sedge birch forest – Yernik forbs birch forest – sedge, yernik sedge and yernik forbs willow forest (eutrophic vegetation) – undershrub sedge sphagnum pine forest (mesotrophic vegetation) – undershrub sphagnum pine forest (oligotrophic vegetation) represented by high, medium and low ryams.

Productivity of different types of phytocenoses of Vasyugan mire. The assessment of overground productivity was performed in the landscape profile. For that the vegetation was cut at the level of the dead and divided into fractions (debris, standing dead, grasses, undershrub leaves, non-photosynthesizing perennial organs, i.e. sprouts and living parts of mosses), dried out and weighed. The data are given in Table 1.

Table 1

Stocks of phytomass and mortmass in overground part of phytocenoses (g per sq. m.)

Type of phytocenosis	Stalks of shrubs	Leaves of shrubs	Cran-berry	Cloud-berry	Sedges	Bogbean	Comarum palustre	Horsetail	Other herbs	Mosses	Plant residues	Standing dead	Sum total
Birch-yernik sedge	197.4	19.9	–	–	80.9	11.5	45.6	14.8	1.9	80.0	56.1	120.6	628.7
Willo-yernik forbs	182.0	6.5	5.4	–	73.2	7.8	11.5	9.5	13.2	65.7	41.8	237.6	654.2
Pine-undershrub-sedge-sphagnum	37.8	50.4	44.8	–	23.4	13.6	–	–	–	317	12.1	11.8	511.4
Pine-undershrub-sphagnum, hummock/depression	$\frac{328.4}{274.4}$	$\frac{167.4}{125.4}$	$\frac{3.9}{-}$	$\frac{4.8}{4.8}$	–	–	–	–	–	$\frac{385}{307}$	$\frac{105}{73.7}$	–	$\frac{995.1}{785.3}$

The data obtained permit to draw the conclusion that hummock phytocenoses of the low ryam is the most productive, i.e., 995.1 g per sq. m. (point 2, Fig.17). The productivity of microdepressions is somewhat lower – 785.3 g per sq. m.

The main part of the overground phytomass in pine undershrub sphagnum community falls on undershrubs (49.8–50.8 %). Photosynthesizing organs of the undershrubs make up 16–17 % of total production. The phytomass of cloudberry is insignificant and does not differ in various microrelief elements (0.5–0.6 %).

Bog cranberry contributes insignificantly to general productivity of hummock

communities (0.4 %). Essential contribution on productivity of plant communities makes mosses (38.6–39.0 %), it is determined by their intensive growth.

The mortmass in the communities of the low ryam is represented by plant debris only. The absence of standing dead is explained by the fact that the overground organs are practically perennial at all plants with the exception of cloudberry.

Mesotrophic phytocenoses are notable for low productivity which is not more than 511.4 g per sq. m (point 4, Fig.15). Mosses form the main part of phytomass. Their productivity is estimated as being equal to 317.5 g per sq. m., it corresponds to 62 %. Low coverage of swampy undershrubs and dwarf birch results in lowering their part in total productivity of the communities, it is equal to 26 %; but for all that the part of both synthesizing and non-synthesizing organs decreases.

One should note that in such phytocenoses the productivity of European cranberry increases the phytomass of overground organs of which reaches 44.8 g per sq. m., it is equivalent to 8.7 %.

Eutrophic species, which appear in the composition of the communities, contribute to some extent to productivity but their part is not yet high and amounts to 7 %. These deciduous species form the standing dead as well, which makes up 2–3% of overground phytomass and 50 % of mortmass. The values of standing dead are higher here than in oligotrophic phytocenoses, however, they are lower than in those of eutrophic. It is connected with participation of xeromorphic swampy undershrubs in the plant cover. The value of plant debris is commensurable with the mass of standing dead. On the whole, the mortmass of pine undershrub sedge sphagnum phytocenoses is not higher than 4–5 % of total production.

The belt of eutrophic vegetation that is represented by willow-yernik forbs (point 3, Fig.15) and birch-yernik-sedge (point 5, Fig.15) phytocenoses is characterized by productivities of 654.2 and 628.7 g per sq. m respectively. The revealed insignificant distinctions are connected with differences in coverage of the herbs-undershrub layer.

In the sequence willow stand – birch forest the phytomass of the undershrubs increases from 29.6 to 34.4 %. One should note that if in willow-yernik-forbs communities this group of productivity includes besides dwarf birch, cranberry (0.8 %) and seldom Andromeda, in yernik-sedge birch forest it is formed by the dwarf birch only; but for all that the participation of photosynthesizing and non-photosynthesizing organs of these species increases as compared to the previous type of the community.

The same tendency is peculiar to herbaceous plants as well, the participation of which in the productivity increases from 17.6 % to 24.4 %. The role of sedges is the most essential in this group (11.2–12.8 %). The role of *Comarum palustre* and *Equisetum* increases essentially in birch forest only, it amounts to 7.2 and 2.3 % respectively the contribution of *Menyanthes trifolium* and other herbs (*Peucedanum*, *Galium boreale*, *Galtha palustris* and ferns) are less significant.

The moss cover, which is represented by hypnum mosses and has coverage of 25 %, is notable for low productivity (65.7–80.0 g per sq. m.). Its participation in the total phytomass content ranges within the limits of 10.0–12.7 %.

As for the eutrophic phytocenoses, the maximum mass of standing dead is noted as being equal to 19.2–36.3 %. This fact is explained by deciduous nature of the species, which form the community (with the exception of cranberry and Andromeda in willow-yernik-forbs phytocenoses). The plant debris amounts to 6.4–8.9 %.

Thus, in the landscape profile of Vasyugan mire in the direction from oligotrophic mires to those of eutrophic one can observe as follows:

- 1) Increase in total phytomass of overground part of phytocenoses;
- 2) Decrease in productivity of undershrubs and mosses;
- 3) Increase of phytomass of herbaceous plants;
- 4) Increase in mortmass of phytocenoses.

Influence of human activity on the structure of the vegetative cover and productivity of ryam's phytocenoses. Versatile human activity affects various aspects of functioning of natural ecosystems, directly being reflected on the structure of vegetative cover.

Let us consider the fire influence on the plot under investigation of the medium ryam (point 2, Fig.15). The fire affected the vegetative cover eight years ago. This form of impact favored to the destruction of wood, herbs-undershrub and moss layers. After eight years the regeneration of the stand (6Birch4P+Cedar) was noted, but for all that the stands of birch and pine are characterized as being the highest (1.5–2.5).

The herbs-undershrub layer has a coverage of 70 %. It is formed by ledum (*Ledum palustre*), leatherleaf (*Chamaedaphne calyculata*), cowberry (*Vaccinium vitis-idaea*), cloudberry (*Rubus chamaemorus*) and bilberry (*Vaccinium myrtillis*) is rare in occurrence.

High vitality of undershrubs is as a consequence of after-fire mineralization of plant debris. In the moss cover (total coverage amounts to 80 %) *Polytrichum strictum* (45 %); *Sph. fuscum*, *Sph. Balticum* are dominant; others were also found. The layers of *Cladonia sp.* make up 10 % of the coverage.

Thus, at the early stages of after-fire demutation of pine-undershrub-sphagnum phytocenoses the ledum prevails in its herbs-undershrub layer and *Polytrichum strictum* in the moss layer. Man-made impact of such kind results not only in changing the structure and composition of plant communities, but also their productivity (Table 2).

Original "explosion" of the abundance of the undershrubs which have perennial shoots, and indicator of fires *Polytrichum strictum* cause the increase in productivity as compared to natural phytocenoses.

For the plot under research the productivity makes up 2112.3 g per sq. m. The greatest participation in its formation belongs to undershrubs as it has been shown above. Their part counts to 42.3 % of total phytomass but for all that the parts of stalks and leaves amount 27.1 % and 15.2 % respectively.

At the given stage of regeneration of the vegetative cover the cranberry is not

found. The coverage of the cloudberry makes up 15 %, it occupies “a free ecological niche”, but its participation in the general production is insignificant (1.2 %).

Table 2

Stocks of phytomass and mortmass in overground part of phytocenosis after fire effect
(g per sq. m.)

Undershrub stalks	Undershrub leaves	Cranberry	Cloudberry	Mosses	Plant residues	Standing dead
572.8	321.2	–	25.5	657.6	535.2	–

The intense growth of *Polytrichum strictum* and regenerating sphagnum accounts for significant productivity of the moss layer. In general, the mosses count to 31,1% of the overground production.

Human-impacted phytocenoses as compared to those of natural are also characterized by the increased values of plant debris that are at different stages. The most decomposed their part seems to be left after fire. In general, plant debris amount to 25.3 % of overground part of phytocenoses. The standing dead is almost not found.

On the basis of aforesaid one can come to the conclusion that the productivity of such phytocenoses estimated by overground phytomass, increases greatly (on average by the factor of 2.3). The most part of productivity fall on undershrubs and green (hypnum) mosses.

In all the points of the biogeocenosis the peat was sampled to investigate its chemical and biological properties as well as redox potential and temperature (Table 3).

Table 3

Characteristics of peat of landscape profile

Points	Depth, cm	Type of peat	Redoxpotential, mV	Temperature, °C
p.2	0–25	Fuscum, *R _t	481	12.9
	25–50	Fuscum, R _t	380	7.1
	100–125	Fuscum, R _t	326	3.6
	275–300	Fuscum, R _t	404	–
	475–500	Fuscum, R _t	400	–
p.4	25–50	Fhagnum, T	288	10.1
	75–100	Sedge-hypnum, F	248	7.2
	125–150	Sedge-hypnum, F	275	–
	225–250	Sedge-hypnum, F	251	–
	350–375	Sedge-hypnum, F	163	–
p.3	25–50	Sedge-hypnum, F	236	12.8
	100–125	Sedge-hypnum, F	247	9.5
	225–240	Sedge-hypnum, F	197	–

Note:* R_t – raised type, T – transitional type, F – fen type

The highest values of redox potential, which were not practically changed with the

depth, were marked for fuscum peat (point 2, Fig.15).

A higher reduction medium was typical for peat deposits of two other points. The values of redox potential decreased with depth and were less by a factor of 2–2.4 as compared to the fuscum deposit. The observation of temperature regime at the same depths permitted to reveal the lowest values in sphagnum deposit, which is equal to – 3.6 °C at the depth of 1 m.

Microbial association of the peat deposit is formed under conditions of high content of organic matter and high moisture. The peat deposits of the landscape profile are characterized by particular general technical properties of the peats and are peculiar to conditions for the development of one or another group of microorganisms; at the same time they exert a specific effect on functioning of the microbial association (Table 4).

The total number and microbial biomass were determined by the direct method with sixfold repetition. The preparations were looked through by means of a luminescent microscope. Prokaryotes's biomass was estimated by P. A .Kozhevin a.o. [72] and eukaryotes microbial biomass by L. M. Polyanskaya [114].

The microbiological analysis was performed by taking into account microflora number on solid elective media [93]. The isolation and calculation of micromycetes were conducted by plating from multiple dilutions on Czapek's agar medium, species identification by generally accepted determinants [4, 18, 24, 34, 82, 111].

The decomposition of nitrogen-containing organic substances of the peat mainly occurs at the expense of ammonifiers.

The destructors of nitrogen-free organic substances are slightly less in quantitative respect, than the ammonifiers, sometimes even outnumber them. The microflora ratio of meat-and-peptone agar to starch-and-ammonia agar (MPA to SAA) along the points of the landscape profile is the evidence of the predominance ammonifiers in active horizons, in particular (Table 5).

At the same time, it is known that high potential microbial number by no means corresponds to the activity of producible biochemical processes.

A low number characterizes cellulolytic flora and its activity becomes apparent in hypnum fen's peats at the edges of the mire (p. 4 and point 3, Table 5). In raised sphagnum peat the cellulolytic bacteria were not found.

In the peat deposits of the landscape profile the limits of variation of bacteria number (counting on 1 g dry peat) amount to 1.32–53.12 billion cells, fungal spores and yeast-like cells to 3.00–58.58 mln. The length of actinomycetes' mycelium varies from 0 to 648 m per g and fungal mycelium from 0 to 4.67 km per g (Table 6).

Table 4

Characteristic of botanical composition of the peats

Point of sampling	Depth, cm	Kind of peat, type of deposit	R, %	Botanical composition	Ash content, %	Redox potential, mV
p. 2	0–25	Fuscum, *R _t	5	<i>Sph. balticum</i> (30 %), <i>Sph. magellanicum</i> (5 %), <i>Sph. angustifolium</i> (1 %), <i>Sph.fuscum</i> (40 %), Cranberry (40 %), <i>Ledum</i> (4 %)	1.56	481
	25–50	Fuscum, R _t	5–10	<i>Sph. fuscum</i> (35 %), <i>Sph. balticum</i> (25 %), <i>Sph. magellanicum</i> (5 %), Cranberry (25 %), <i>Pinus</i> (10 %)	1.19	380
	100–125	Fuscum , R _t	10–15	<i>Sph. fuscum</i> (60 %), <i>Sph. magellanicum</i> (25 %), Other sphagnum (<i>cen. Cuspidata</i>) (+) undershrubs: <i>ledum</i> (15 %)	1.51	326
	275–300	Fuscum, R _t	15–20	<i>Pinus</i> (2 %), Undershrubs (3 %), <i>Sph. fuscum</i> (55 %), <i>Sph. magellanicum</i> (40 %)	1.59	404
	475–500	Fuscum, R _t	15–20	<i>Sph. magellanicum</i> (15 %), <i>Sph. balticum</i> (30 %), <i>Sph. fuscum</i> (45 %), <i>Sph. angustifolium</i> (5 %), Undershrubs (5 %), <i>Pinus</i> (+)	1.74	400
p. 4	25–50	Sphagnum, T	10–15	Undershrubs (15 %), <i>Carex rostrata</i> (10 %), <i>Eriophorum</i> (10 %), <i>Scheuchzeria</i> (2 %), <i>Eguisetum</i> (2 %), <i>Sph. magellanicum</i> (20 %), <i>Sph. angustifolium</i> (10 %), Other sphagnum (20 %), <i>Betula</i> (10 %)	3.84	288
	75–100	Sedge, F	15–20	<i>Phragmites</i> (2 %), <i>Eguisetum</i> (5 %), <i>Comarum</i> (5 %), <i>Carex limosa</i> (10 %), <i>C.rostrata</i> (18 %), <i>C.lasiocarpa</i> (25 %), Mosses (40 %), <i>Sph. obtusum</i> (10 %)	4.77	248
	125–150	Sedge-hypnum, F	20–25	<i>Betula</i> (3 %), <i>Salix</i> (5 %), <i>Scheuchzeria</i> (2 %), <i>Eguisetum</i> (10 %), <i>Comarum palustre</i> (5 %), <i>C.rostrata</i> (10 %), <i>C.lasiocarpa</i> (20 %), <i>Sph.giparium</i> (5 %), Hypnum mosses (40 %)	5.29	275
	225–250	Sedge-hypnum, F	20–25	<i>Eguisetum</i> (10 %), <i>C.rostrata</i> (5 %), <i>C.lasiocarpa</i> (25 %), <i>Eriophorum</i> (+), <i>Scheuchzeria</i> (5 %), Hypnum mosses (30 %)	5.49	251
	350–375	Sedge-hypnum, F	25–30	<i>Betula</i> (5 %), <i>Salix</i> (5 %), <i>Eguisetum</i> (10 %), <i>C.rostrata</i> (5 %), <i>C.lasiocarpa</i> (30 %), <i>C.limosa</i> (5 %), Hypnum mosses (40 %) – <i>Drepanocladus</i> , <i>Calliargon</i> , <i>Scorpidium</i>	5.51	163

p. 3	25–50	Sedge-hypnum, F	20	<i>Betula nana</i> (5 %), <i>B. pubescens</i> (5 %), <i>Carex lasiocarpa</i> (5 %), <i>C. vesicaria</i> (20 %), <i>Comarum palustre</i> (5 %), <i>Menyanthes</i> (+), <i>Eguisetum</i> (10 %), Hypnum mosses (40 %)	6.20	236
	100–125	Sedge-hypnum, F	30	<i>Betula</i> (5 %), <i>Carex lasiocarpa</i> (25 %), <i>C. rostrata</i> (15 %), <i>C. vesicaria</i> (5 %), <i>Eguisetum</i> (10 %), Other herbs (5 %), Мхи (30 %) – <i>Drepanocladus</i> , <i>Calliergon</i>	6.41	247
	225–240	Sedge-hypnum, F	40	<i>Betula</i> (10 %), <i>Pinus</i> (2 %), <i>Phragmites</i> (+), <i>Carex lasiocarpa</i> (25 %), <i>C. rostrata</i> (20 %), Hypnum mosses (33 %)	36.30	197

Note: * R_t – raised type, T – transitional type, F – fen type, R – degree of decomposition

Table 5

Microorganisms' number in peat deposits of the landscape profile, clony forming units (CFU)×10³ g dry peat

Point of sampling	Depth, cm	Kind of peat, type of deposit	Ammonifiers	Mcrorg. SAA	MPA/SAA	Denitrifiers	Aerob. cellulolytics	Anaerob. cellulolyticsp
p. 2	0–25	Fusum, *R _t	52.21	28.88	1.8	33.33	5.55	0
	25–50	Fusum, R _t	149.26	55.07	2.7	43.48	4.35	0
	100–125	Fusum, R _t	28.00	40.00	0.7	4.00	9.33	0
	275–300	Fusum, R _t	111.94	146.47	0.8	13.58	4.75	0
	475–500	Fusum, R _t	96.13	65.37	1.5	38.45	5.13	0
p. 4	25–50	Sphagnum, T	62.48	19.44	3.3	20.83	6.94	0
	75–100	Sedge fen, F	24.35	14.74	1.7	1.54	5.77	0
	125–150	Sedge-hypnum, F	31.00	32.55	0.9	8.84	10.08	0.42
	225–250	Sedge-hypnum, F	42.78	37.70	1.1	8.27	6.53	0.22
	350–375	Sedge-hypnum, F	61.88	53.15	1.1	23.80	11.11	0.14
p. 3	25–50	Sedge-hypnum, F	75.18	37.98	2.0	23.25	17.83	0.42
	100–125	Sedge-hypnum, F	59.50	49.19	1.2	23.80	23.80	0.14
	225–240	Sedge-hypnum, F	47.53	34.79	1.4	5.59	1.96	0.02

Note: * R_t – raised type, T – transitional type, F – fen type

It is known that mycelial fungi are the main destructors of sphagnum mosses. While comparing the obtained data with analogous ones of oligotrophic landscapes within the limits of the eastern part of Vasyugan mire [38] one can note that the density of microorganisms in the peatlands under study is considerably lower.

Table 6

Microorganisms' number in peat deposits of the landscape profile

Point of sampling, depth, cm	Kind of peat, type of deposit	Bacteria, billion per g	Mycelium		Fungic spores, mln. per g
			Actinomycetes m per g	Fungic, km per g	
p. 2					
0-25	fuscum, R _t	44.52 ± 3.34	412.83 ± 57.15	3.50 ± 0.84	58.58 ± 27.23
25-50	fuscum, R _t	53.12 ± 3.96	648.00 ± 22.83	4.67 ± 1.21	44.37 ± 9.88
100-125	fuscum, R _t	2.13 ± 0.14	45.50 ± 2.32	0.0	5.95 ± 0.93
275-300	fuscum, R _t	1.32 ± 0.15	14.83 ± 2.30	0.0	4.42 ± 1.36
475-500	fuscum, R _t	2.97 ± 0.16	68.83 ± 3.72	0.0	6.23 ± 1.39
p. 4					
25-50	sphagnum, T	3.32 ± 0.15	23.33 ± 2.56	0.67 ± 0.52	6.40 ± 2.40
75-100	sedge, F	4.63 ± 0.65	79.00 ± 3.05	0.0	4.12 ± 1.83
125-150	sedge-gypnum, F	3.72 ± 0.32	80.00 ± 3.44	0.0	3.00 ± 0.93
225-250	sedge-hypnum, F	1.95 ± 0.31	39.00 ± 2.78	0.0	5.53 ± 1.72
350-375		1.35 ± 0.29	15.67 ± 2.32	0.0	3.87 ± 1.74
p. 3					
25-50	sedge-hypnum, F	3.28 ± 0.15	0	0	6.38 ± 1.44
100-125	sedge-hypnum, F	3.30 ± 0.17	23.67 ± 2.56	0	4.40 ± 1.51
225-240	sedge-hypnum, F	3.55 ± 0.18	24.50 ± 3.00	1.00 ± 0.00	4.00 ± 0.73

Note: * R_t – raised type, T – transitional type, F – fen type

One should suppose that it could be explained by the oligo-mesotrophic character of aqueous nutrition of oligotrophic peatlands of the eastern part of Vasyugan mire where calcareous loams, as distinct from the territory under research, serve as bedrocks.

The highest microbial number was noted in the active layer of the peat deposit. The thickness of this layer varies from 30 to 100 cm, as the level of swampy waters is changeable. In this layer the favorable conditions are formed for vital functions of microorganisms. The microbial number decreases with the depth.

The decrease in microbial number downward the profile was observed by a lot of research [38, 94, 117, 126, 137]. For example, M. V. Smaguina [126] showed as a result of the research of peaty soils of Tverskaya Region that especially clearly pronounced decrease in microbial number depending on the depth is observed in the high-moor deposit.

Fungal spores, actinomycetes mycelium and bacteria were observed throughout the entire profile of the peat deposits; as for fungal mycelium, it was only observed in the upper horizons of oligotrophic and mesotrophic deposits.

The association of fungal mycelium with active layer of the peat deposit is

explained by the fact that the fungi are saprotroph organisms. They follow lightly hydrolysable organic matter [94].

Namely sphagnum mosses are the main peat-formers of oligotrophic and mesotrophic type. They are characterized by the high content of lightly hydrolysable substances, i.e. hemicelluloses as well as by low content of cellulose (15–20 %) and sparingly hydrolysable substances [117].

It is known that the content of lightly hydrolysable organic matter downward the profile of the peat deposit decreases; in consequence, the fungal mycelium was not found in the lower horizons. In low-moor deposit the fungal mycelium was observed in insignificant amounts at the depth of 225–240 cm.

The concentration of microorganisms in the peat deposit serves as the index of their abundance. The total concentration varies depending on the type of the deposit from 0.11 to 9.82 mg per g (Table 7).

On transition from the upper to the lower layers the concentration of microorganisms is reduced (p. 2, 4).

The increased concentration of microorganisms in the lower layer (p. 3) can be explained by a high ash content of the peats.

On the whole, the total concentration of microorganisms in the active layer of the peat deposits was higher in the oligotrophic one (p. 2). It is not inconsistent with the literature data as it is accepted that in the sequence of oligotrophic – mesotrophic – eutrophic mires the peat deposits of oligotrophic type possess the least biological activity.

The research by S. Y. Trofimov and Y. I. Dorofeeva [132] shows both the distinctions of rate of decomposition between eutrophic and oligotrophic peat deposits. Thus, the samples from peat deposits of eutrophic type decompose more rapidly by the order of two than the peats of oligotrophic deposits.

Practically, in all peat deposits the decrease in the rate of decomposition was observed downward the profile. The distinctions in mineralization rates correlated with pH, ash content, carbon and nitrogen both within the limits of the peat deposits and points of the landscape profile.

Maximum decomposition rates are typical of the peats with neutral reaction of the medium and rather high content of nitrogen and ash elements. Namely eutrophic peat deposits represent such kind of peats. At the same time, our research as well as those of other authors' evidence of high potential biological activity of the peat deposits of oligotrophic type.

The low rate of mineralization of organic matter of oligotrophic peat deposits at the high content of microbial biomass seems to be caused by specific makeup of the plants peat-formers rather than to be a consequence of their low potential biological activity.

The general regularity of the excess of eukaryote biomass over that of prokaryote, which was revealed at the structural analysis of microbial biomass of the most types

of the peat deposits [114], was also confirmed when studying the peat deposits of Vasyugan mire.

In the prokaryote complex the most part falls on actinomycetes. The upper (upto 50 cm) and lower (from 50 cm) layers of oligotrophic and mesotrophic peat deposits differ in ratio of the basic compounds of microbial biomass.

In case of the upper layers, the fungic mycelium prevails (83.20 %, p.2; 82.83 %, p.4), whereas in the lower layers fungic spores and yeast cells (65.60 %, p.2; 60.83 %, p.4). The lower layers are notable not only for the high portion of fungic spores but also bacterial cells (about 30 %).

The peat deposits of point three are characterized by prevalence of fungal spores in the upper layers and fungic mycelium in the lower.

The availability of considerable number of fungi in the very upper layers of slightly decomposed peat is the evidence of the fact that the first destruction of dead plants is carried out by fungi.

As the aeration becomes worse with the depth the fungi are 36 cultures of micromycetes, which mainly belong to the class of *Deuteromycetes* (92.2 %, (Table 8).

The number of micromycetes in the points under research is not high and ranges in different layers from 1.1 до 59.4 thou. colony-forming units.

On the whole, the distribution of micromycetes in the studied deposits is rather uniform, gradual decrease in micromycetes number is noted with the depth, with the exception of the layer of 100–125 cm (p.2) where considerable increase in number was observed at the expense of the abundant development of *Trichosporiella cerebriformis* (de Vries & Kleine Natrop) Gams. This layer is distinguished by the high content of the raised mosses, *Sph. Fuscum*, in particular (see Table 4).

The minimum micromycetes number in the surface layer was noted for point three the botanical composition of which is represented by the hypnum mosses. The micromycetes number in point two and four is quite comparable. The highest diversity of micromycetes was noted in point four, which is a transit part of the profile under consideration. The species diversity seems to be explained by this fact.

The occurrence of viable structures of micromycetes at large depth is of interest, but for all that their species diversity is rather high. These seem to be spores or other dormant structures (chlamydospores and the like).

Table 7

Supply of microbial biomass and percentage ratio of its compounds in the peat deposits of the landscape profile

Point of sampling	Depth, cm	Kind of peat, type of deposit	Microbial biomass, mg per g	Microbial biomass, %			
				fungic mycelium	fungic spores	actinomycetes	bacteria
p.2	0–25	Fusum, R _t	9.82 ± 3.52	82.50 ± 6.78	7.48 ± 4.58	0.03 ± 0.05	10.00 ± 3.23
	25–50	Fusum, R _t	9.43 ± 2.41	83.20 ± 3.77	5.08 ± 3.27	0.03 ± 0.05	11.68 ± 1.86
	100–125	Fusum, R _t	0.13 ± 0.04	0	63.48 ± 12.83	0.13 ± 0.15	36.38 ± 12.89
	275–300	Fusum, R _t	0.11 ± 0.09	0	65.60 ± 17.16	0.02 ± 0.04	34.38 ± 17.18
	475–500	Fusum, R _t	0.14 ± 0.03	0	54.18 ± 9.74	0.20 ± 0.23	45.62 ± 9.69
p. 4	25–50	Sphagnum T	1.34 ± 0.30	82.83 ± 8.80	11.98 ± 8.85	0	5.15 ± 1.28
	75–100	Sedgefen, F	1.03 ± 0.30	84.42 ± 5.40	5.70 ± 5.04	0.03 ± 0.05	9.85 ± 3.79
	125–150	Sedge hypnum, F	0.11 ± 0.02	0	27.73 ± 11.52	0.27 ± 0.23	71.88 ± 11.54
	225–250	Sedge hypnum, F	0.12 ± 0.07	0	60.83 ± 19.67	0.22 ± 0.37	38.95 ± 19.45
	350–375	Sedge hypnum, F	0.08 ± 0.02	0	62.52 ± 12.79	0.07 ± 0.16	37.42 ± 12.78
p. 3	25–50	Sedge hypnum, F	0.14 ± 0.03	0	52.35 ± 10.60	0	47.65 ± 10.60
	100–125	Sedge hypnum, F	0.13 ± 0.04	0	46.28 ± 14.98	0.07 ± 0.16	53.65 ± 15.02
	225–240	Sedge hypnum, F	2.10 ± 0.70	91.97 ± 4.65	4.35 ± 3.72	0	3.67 ± 1.10

Note: * R_t – raised type, T – transitional type, F – fen type

Table 8

Distribution of micromycetes in the peat deposits of the landscape profile

	Depth, cm											
	p. 2					p. 4					p. 3	
	0-25	25-50	100-125	275-300	475-500	25-50	75-100	125-150	225-250	350-375	25-50	125-150
Micromycetes number, thou. per g	1.84	0.64	4.1	0.2	0.36	1.58	1.24	0.41	0.45	0.13	0.3	0.24
Acremonium breve							0.02					
Acremonium strictum			0.05									
Acremonium sp.						0.02						
Aspergillus versicolor											0.02	
Aureobasidium pullulans								0.05				0.2

Beauveria alba					0.02							
Chrysosporium pannorum							1.15			0.02		
Conytrichum sp.										0.02		
Cylindrocarpon olidum											0.03	
Eupenicillium schearil					0.02					0.03		
Exophiala sp.						0.55						
Heteroconium chaetospora			0.12								0.03	
Mortierella ramanniana	0.4											
Mucor sp.	0.02											
Mycelia sterilia (Moniliaceae)						0.33			0.02		0.1	
Mycelia sterilia (Dematiaceae)											0.07	
Oidiodendron tenuissimum								0.18		0.02		
Paecilomyces sp.												0.02
Penicillium aurantiogriseum												0.02
Penicillium claviforme					0.02				0.05			
Penicillium funiculosum								0.07	0.23			
Penicillium lividum						0.02	0.02		0.08			
Penicillium montanense	0.1		0.05	0.02		0.03		0.02				
Penicillium olsonii								0.03				
Penicillium puberulum		0.2							0.05			
Penicillium spinulosum	1.17	0.24	0.03									
Penicillium thomii								0.02				
Penicillium variable										0.02		
Ramichloridium schulzerii				0.03								
Sporothrix schenckii				0.12	0.15						0.03	
Talaromyces stipitatus			0.02			0.05						
Tolypocladium sp.											0.02	
Trichoderma koningii	0.15	0.17					0.03	0.02	0.02			
Trichosporiella cerebrifomis			3.83		0.15	0.53						
Unidentified								0.02				
Yeast-like		0.03		0.03		0.05	0.02			0.02		

Thus, the conducted microbiological research permits to come to the following conclusion: the mire-forming process on the landscape under the research began from sedge-hypnum phytocenoses and in the course of the subsequent changes of phytocenoses turned into the oligotrophic stage forming thick deposits of fuscum peat; the investigated peat deposits of geochemically connected landscapes are differed by character of distribution of microorganisms and degree of their saturation by various microbial groupings; botanical composition of the peats, which form peat deposits of the landscape profile (in point 2, in particular) do not favor to active display of microbiological processes and only in point three (transaccumulative part of the landscape profile) their activity is noted; the stock of microbial biomass reach 9.82 mg per g in some layers of the peat deposit; in the peat deposits of the landscape profile in question the biomass of eukaryotes is higher than that of prokaryotes.

As for the microbiological structure of micromycetes, the mycelium prevails over spores; in prokaryotes complex considerable part falls on actinomycetes; it was isolated and identified 36 cultures of micromycetes in the peat deposits of the landscape profile.

4. STRUCTURE OF PEAT RESOURCES

4.1. History of research

At the end of the 50-ties and in the middle of the 60-ties the necessary national economic prerequisites were formed to accelerate activity of new trends for use of peat. It was caused by the perfection of structure of fuel and energy balance and also by policy of chemicalization of national economy. All these facts determined an accelerated development for exposure and study of peat resources.

Vasyugan mire attracted special attention for many reasons. First of all it was caused by the abundance of peat stocks. Of no less importance was also the fact that the development of Vasyugan mire became possible by joint efforts of the two regions, Tomsk and Novosibirsk that border it. And besides it was considered that Vasyugan mire was situated close to industrial and agricultural regions. This fact shows a considerable promise for the comprehensive use of peat for the production of valuable peat materials.

In the program of works on forwarding inspection of Vasyugan tract (in the 50-ties it was named as Vasyugan peat deposit) the following main tasks of the planned expeditionary works were set up: revealing of peat deposits, definition of stocks and quality of the deposit by means of laying routes on the most typical sites. It permitted to reveal peat deposits in the shortest possible period of time and at the lowest costs (the stage of searches for peat deposits). The schemes of routes, which would allow gaining the expected result at the least number of routes, have also been elaborated.

Along with the above-mentioned, the scheme of the route courses elaborated on the basis of research and cartographic data should be coordinated with the creation of possible working conditions for peat explorers. At the same time, large extension of the area under study, with its small density of population and difficult practicability should be taken into consideration.

It should be noted that the sites of prospecting were simply unsuitable even for a very short stay there. Melnikov-Pechorsky told expressively about these places: "These are ruinous places for an inexperienced person. Those who have never been to these unknown jungles before should keep their eyes open".

Actually, many people who found themselves in this "hell swamp" and managed to get out of it curse it and pledge not to approach it ever again. But there are such people who fall in love with these bogs and do not leave them for their whole life. Their name is "researchers".

The scheme developed by peat explorers was presented by three routes and covered the whole territory of the peat deposit of Vasyugan tract planned for inspection.

Route No. 1 had to describe, basically, the central part of Vasyugan tract where the highest point between the sources of the rivers of Om and Bakchar (146 m above sea level) of the Ob-Irtysh watershed was located.

A network of passes in cross-section and lengthwise directions covered the central part of the basic watershed engirdled by the counter line of 140 m, according to the developed scheme. In total, there were planned eleven transitions and six callings to watersheds of the local order on route 1. Their total extension is up to 364 km.

Route No. 2 was aimed to define the borders and the quality of the peat deposit on the spurs of the Vasyugan tract, which were spread on the local watersheds of the rivers.

The two east spurs named “Iksha deposit” which are located between the rivers of Shegarka and Iksha, have an extension of 150 km from south to north; another one, “the Bakchar deposit” with the extension of 180 km is situated between the rivers of Iksha and Bakchar (now in this territory the experimental field station of the Siberian Scientific Research Institute of Peat is located, the results of its research will be given in chapter five).

The third spur within the limits of the route is located between the river of Bakchar and its left tributary the Teterenka and is 60 km long.

In total, seven passes have been planned across the peat deposits on route No. 2.

Route No. 3 had to characterize the western part of the Vasyugan tract, which was known for the presence of the considerable amount of lakes occupying up to 40 % of its territory. In total, two passes and six callings with the general extent of 133 km. were planned.

The conducted search works allowed defining the borders of the Vasyugan tract, to predict the estimation of its peat recourses. However, the further profound research was necessary to be carried out.

Special (preliminary investigation) peat-exploring works on the territory of Vasyugan mire has been carried out since 1952. The West-Siberian peat-exploring expedition was organized to fulfill those works. This expedition began to work in Vasyugan mire under the supervision of P. E. Loginov.

The expedition was given the task to survey the territory, to define the area, placing, peat stocks, qualitative characteristics and the structure of the deposit.

On the instructions of the Central Administrative Peat Board of the Russian Soviet Federative Socialist Republic, Vasyugan mire had to be explored by the expedition method, which at that time represented a new direction in peat exploration.

The expedition method, in its turn, consisted of three **stages: 1) method of office studies and analysis; 2) land survey; 3) aero visual survey.** The final stage of works included office studies of the obtained materials through the application of all above-named methods.

The method of office studies and analysis includes revealing of contours of the peat deposits with the help of large-scale maps. The contouring of Vasyugan mire was carried out with the help of maps of 1:100000 scales. In all, the area as large as 4,

5 million ha. was contoured in 1952. Then the contour of the peat deposit was transferred on the survey map of 1:750000 scales, where the horizontal surfaces with the section of 10 m were mapped to reveal the relief position of the isolated Vasyugan mire. This map was the basis for designing routes for land and aero visual inspection.

The method of land survey included the route passes according to the project with carrying out such works as: the survey (transferring to the nature of the planned passages), sounding, peat exploration, description of wood stands and plant cover, calculation of the area of small lakes, ridges and hollows within the bounds of the peat deposit, description of the rivers which cross the route and many other tasks.

And finally, the **aero visual method of survey** according to the specially projected route was carried out by plane. The essence of this method consisted in the establishment of regularities of mire development on large areas. Following the example of Tomsk region it was earlier made by L. V. Shumilova [125] whose unpublished data served as the basic point in the work of the expedition [144].

This method allowed filling in those territorial blanks the data on huge Vasyugan mire that had not been covered by land routes because they were rare. Aerovisual shooting was also performed in 1952 on 18 routes with the general extent of 1318 km.

The route survey was conducted by plane PO-2 from the height of 200 m at the speed ranging from 100 to 135 km per hour. Especially it is necessary to notice that in practice of peat-exploring works during the inspection of Vasyugan mire this method was applied for the first time.

It was supposed that the detailed description of the "top view" would allow marking out typical plots according to the classified vegetative groupings on the abrise. Recommendations of Professor S. N. Tyuremnov and his classification of peat swampy vegetative groupings, which were found out from air and were characteristic for this or that site of Vasyugan mire, were thus used.

The researchers of mires felt romanticism especially sensitively when it was necessary to live in taiga conditions for at least one month and more. On the laid land routes it was necessary to overcome water inaccessible obstacles, extensive hollows and to spend the night on fenny marshy places.

P. E. Loguinov [83] tells in his description about the work of pioneers of Vasyugan mire. During the expedition work **V. D. Markov**, who with his group, was the first to cross Ob-Irtysh watershed. The general extent of this route amounts to 116 km across Vasyugan mire with ridge and hollow complexes.

The essential contribution to mire studying which necessarily should remain in the memory of people was made by **A. V. Predtechensky**, **I. G. Dobrutsкая**, **A. F. Nagaitseva** and **A. K. Filatov**.

It is impossible not to mention the passage to Ob-Irtysh-Vasyugan interflaves of fine people and excellent organizers such as **G. A. Braguin**, **V. G. Kuzmichev** and

A. A. Grigoriev. During four months they overcame the rivers routes of 1000 km long with motor boats and reached the upper courses of the rivers of B.Yugan and B.Salym having overpassed the territories, which are the most difficult to overcome, at the same time they were carrying out leveling works.

The definition of the area and the name of the explored territory is the history as well. In 1952 when the borders of the explored peat deposit were described for the first time, the peat deposits of this area were named “Vasyugan peat tract”.

The description of Vasyugan mire is given based on the report of 1952. According to the researcher’s opinion “the separate sites which are distinguished as an industrial deposit, are integrally connected to some extent with the general tract file (Vasyugan mire, editor’s comment.), with which the latter is separated either with paludification or hardly noticeable peats.

All this was considered by us as a single whole marsh space“. Namely in 1952 the area of Vasyugan mire was estimated as being equal to 4702682 hectares.

From 1952 up to 1976 the separate sites of Vasyugan peat deposit was a subject of various kinds of investigations (Fig. 21).

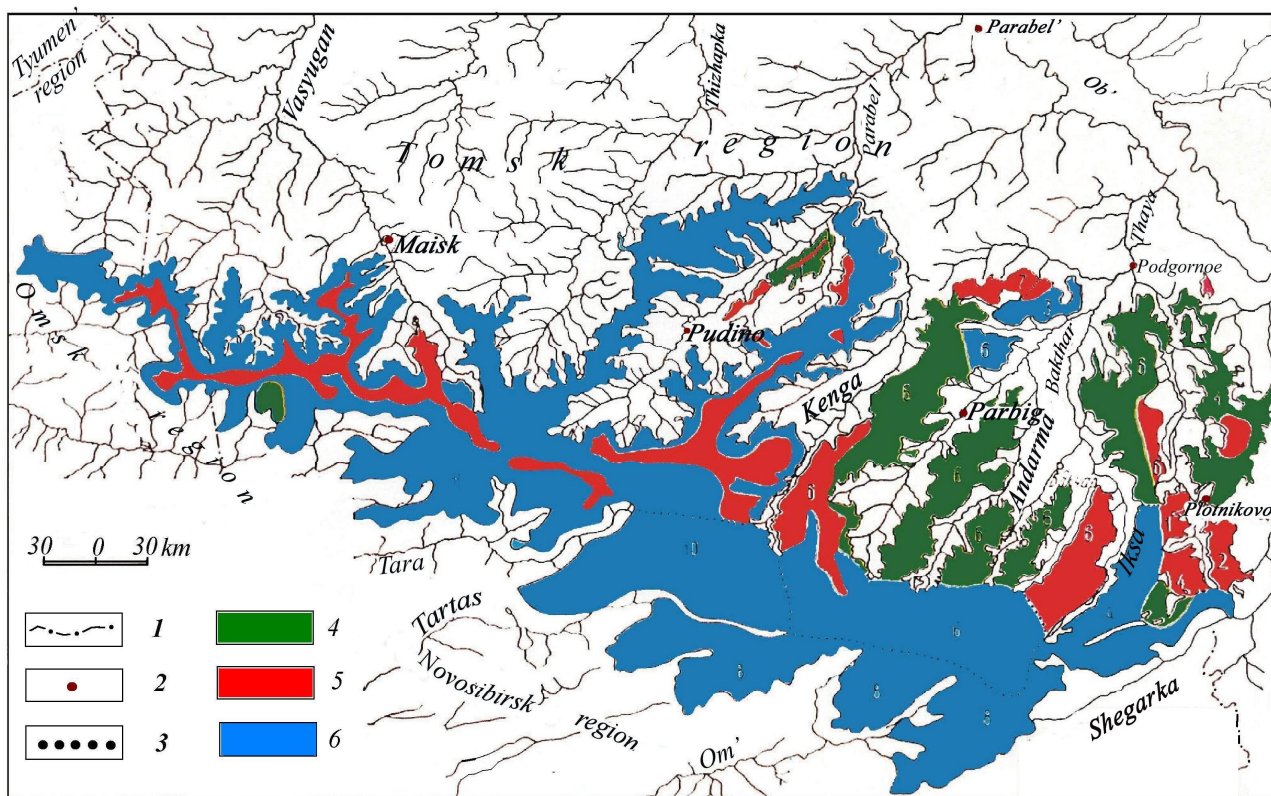


Fig. 21. Peat deposit of Vasyugan. 1 – borders of regions, 2 – settlements, 3 – borders of plots. Types of peat deposits: 4 – fen, 5 – raised, 6 – transitional

Preliminary investigation has been carried out on the following plots:

- The southern plot was explored in 1952–1960;
- The plot “Tara-Tartasskoye” was explored in 1950;
- The 1-st turn of the eastern plot was explored in 1964;
- The plot “Kaitas” was explored in 1964;
- The 2-nd turn of the eastern plot was explored in 1965–1968;

– Plot No.22 was explored by in 1975.

The explorations were carried out by Novosibirsk geological expedition in 1975–1976 on the plot 20, 5, 6 and 7. The latter three sites are within the bounds of the eastern plot (the 1-st turn) explored in 1964–1965.

Besides, in 1952 there discovered the prognosticated stocks of peat of 12911931 thousand tons in the area of 2998970 hectares within the bounds of the industrial depth of peat deposit.

This period of investigations was already a little bit easier for the techniques of works had been worked out and the researchers had already surveyed the area of Vasyugan bog partially studied by previous researchers.

With the adoption in 1982 of the Food Program of the USSR for the period until 1990 the new problems of geologists-explorers were defined: strengthening of prospecting works in order to increase the base of agrochemical raw materials.

Peat, peat phosphates, sapropels, chalky clays, limestones, zeolites, small and medium-scale deposits of phosphorites represented namely the agrochemical raw materials reserve which in future the mining industry was likely to be headed for.

The main place among agrochemical raw materials was given to peat and marsh formations. Almost 70 % of stocks of Russia's peat are concentrated in Western Siberia. Detailed study of peat resources of this region therefore began.

The peat deposit of Vasyugan area was also covered by the detailed investigation. In 1983 near the settlement of Krasny Bakchar the detailed research of plot five began; in 1987–88 in plot five near the settlement of Plotnikovo; in 1990 in plot 22; in 1993 in the southwestern plot (the peat deposit of Tara-Tartasskoye).

4.2. Peat Fund and its Structure

The combination of climatic, soil, geographical, geological conditions and other natural factors defined the features of the process of peat accumulation on Vasyugan mire:

- a) Large-scale paludification of the territory when not only the lowered elements of relief, but also watersheds are occupied by peat deposit. Thus, according to M. I. Neistadt [99] the intensity of paludification on Vasyugan mire was very high. On average the area as large as 1 800 hectares is swamped every year. Therefore, 25 % of the territory of Vasyugan mire belong to the paludal plots of the age of not more than 500 years at the lower age limit of 9 000 years;
- b) Variety of stratigraphic structure.

The perfection of practice of geological prospecting permitted to develop scientific research on the study of qualitative properties of peats and peat deposit of Vasyugan. And this fact, in its turn, resulted in the determination of directions of the usage of the deposit peat recourses.

All the research and pioneering performed on Vasyugan mire allow us to get rather

an authentic view about the structure of the peat resources. The geologists revise periodically the structure; it is connected with the changes of conditions and state standards. Therefore, we assumed the results of calculations of geological reserves on as a basis for analysis of peat resources of Vasyugan deposit from 01.01.96.

The area of zero border of Vasyugan peat deposit amounts to 5 269 437 ha including the areas of 1 945 007 ha (36.9 %) and 3 324 430 (63.1 %) of explored and predicted recourses respectively (Table 9).

Table 9

Characteristics of peat reserve on 01.01.1996

Category of peat prospecting	Area at zero border, ha	Area at the border of industrial depth of the peat, ha	Stocks of peat at moisture of 40 %	
			thou. tons	%
Sum total, including:	5269437		18728527	100
a) prospected	1945007	1559983	—	—
b) predicted	3324430	3303397	—	—
Balance				
A			92944	0.5
B			40156	0.2
A+B			133100	—
C ₁			2180698	11.6
C ₂			2470206	13.2
Sum total:			4784004	25.5
Balance			—	—
Unexploitable peat reserves			31053	—
Predicted, including:			13944523	74.5
P ₁			1161677	6.2
P ₂			1278903	68.3

Note: A, B, C₁, C₂, P₁, P₂ – see abbreviations.

The peat reserves as well as the reserves of other solid minerals are subdivided into those of explored (categories A, B and C₁) and preliminarily estimated (category C₂) according to the classification of the reserves of the fields and predicted recourses of solid minerals. Predicted recourses are subdivided according to their validity into categories P₁, P₂ and P₃.

According to the Classification of solid minerals, the peat reserves are subdivided into groups by their national economic significance:

– **Balance reserves**, the use of which is economically expedient according to the established standards;

– **Unexploitable peat reserves (overbalance reserves)** represent ill-conditioned ones, their use nowadays is inexpedient but later on they can be transferred to balance reserves.

In Vasyugan peat deposit two predicted groups such as P_1 and P_2 have been defined.

Predicted reserves of P_1 are revealed as a preliminary stage of detailed prospecting. This category includes peat deposits explored earlier which reserves were classified during the reevaluation as predicted ones, and new peat deposits where the amount of fulfilled works does not permit to foresee the stocks by category C_2 ;

Predicted reserves of P_2 signify the recourses revealed during the general prospecting; these have been estimated based by analogy with the other peat deposits. Let us note that the geological survey is conducted stage by stage:

1-st stage implies the search for peat deposits, i.e. revelation of peat deposits that are worthy of being prospected in the future (P_2 , P_1 , C_2);

2-nd stage means a preliminary survey on the peat deposit, which is carried out in order to determine the expediency of its industrial and agricultural use and substantiate the carrying out of detailed prospecting work (C_1);

3-d stage is a detailed prospecting which is carried out with the purpose of getting data on the project of peat deposit exploitation (A).

The area of Vasyugan peat deposit at the industrial depth of the peat amounts 4 863 380 ha or 92.2 % of the area in zero border.

The border of industrial depth of the peat deposit means a conventional unit determined at the definite depth of the peat deposit. The calculation of the peat stock is performed within the bounds of the contour of the deposit industrial depth. The zero borders are the total area of a peat deposit including peatified and non-peatified parts of the deposit.

Vasyugan peat deposit contains as much as 18 728 527 thou. tons or 18.7 billion tons of peat that is equivalent to 16 % of the total stock of the West-Siberian region. The percentage of explored area corresponds to 25.5 including by categories of reserves: A – 92 944 thou. tons (0.5 %), B – 40 156 thou. tons (0.2 %), C_1 – 2 180 698 thou. tons (11.6 %), C_2 – 2 470 206 thou. tons (13.2 %, Fig. 22b).

The following deposits (of total reserves) prevail on Vasyugan peat deposit: fen (56.4 %), raised (25.9 %), the rest of the reserves are classified as being transitional and mixed, altogether 17.7 % (Fig. 22a).

If we analyze only the explored peat stocks the picture will be somewhat different. Only 11 plots were investigated with the total peat stock of 4 784 004 thou. tons (Table 10) with the prevailing C_1 and C_2 categories which amount to 48.9 % and 48.4 % respectively (Fig. 22a).

The ratio of peat types has been changed in the explored peat recourses in comparison with the total reserves. For example, the stocks of raised and transitional deposits increased by 8.3 % and 4.3 % respectively.

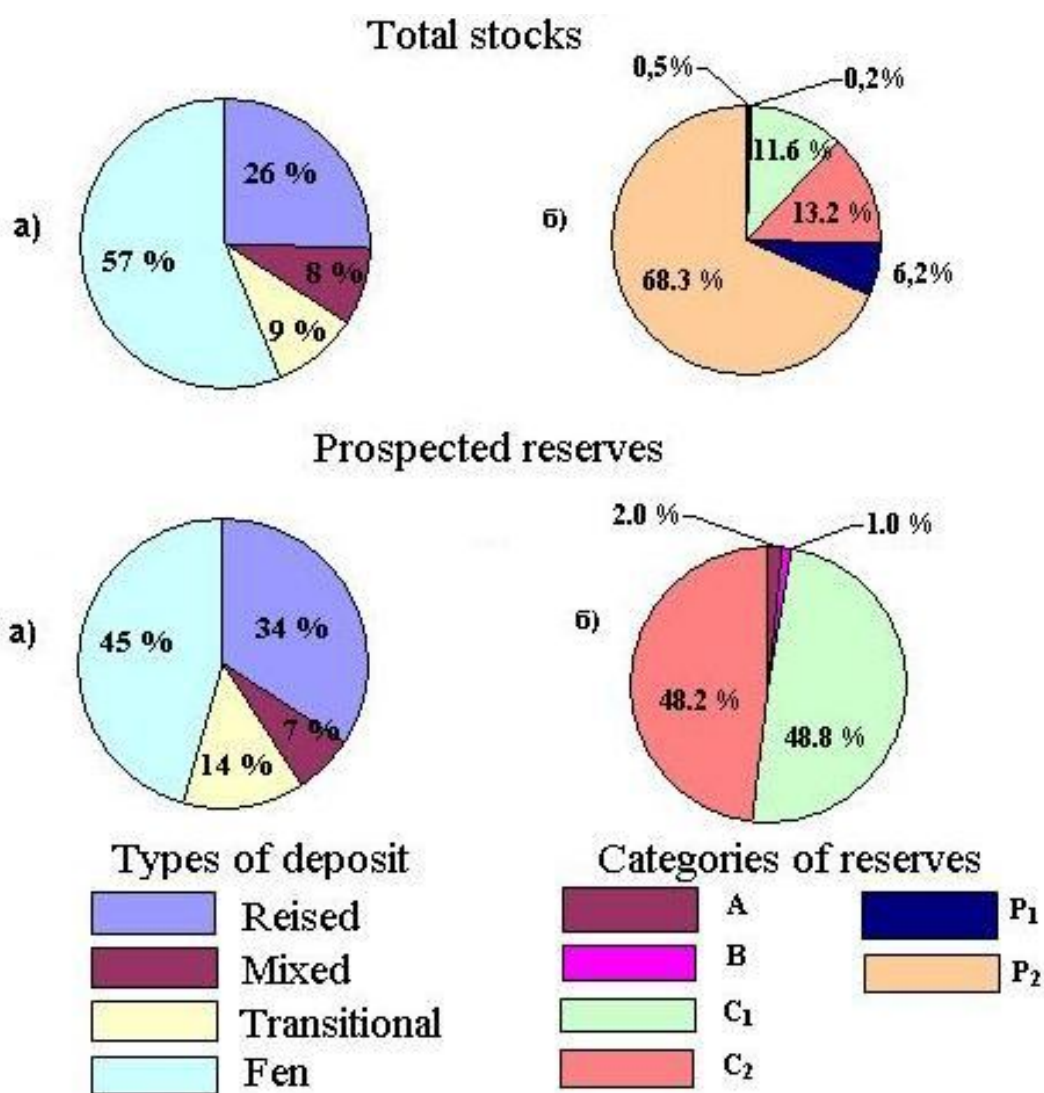


Fig. 22. Characteristic of peat resources of Vasyugan mire: a) type of deposit, б) category of reserves

Unexploitable peat reserves of Vasyugan peat deposit amount to 31 053 thou. tons. More detailed information on the explored peat reserves of the plots in question is given in Figure 23.

The reserves of the raised peat amount to more than half of the total stocks on three explored plots only, fen type is prevailing on the remaining plots. Hence, the conclusions about the prospective trend of peat use of Vasyugan peat deposit can be made.

It is known that the territory of Vasyugan peat deposit, which is situated in the southern part of western Siberia is regarded like the whole Western Siberia as the area of weakly studied peat stocks taking into the account the state of knowledge about the peat reserves.

However, to a greater extent it concerns the peat recourses of the whole Western Siberia whereas Vasyugan peat deposit suffered the best fate and the explored stocks of this deposit come to 25.5 %, and as far the area of this deposit concerns it amounts to 36.9 % of the total area.

The fact is worth noting that the detailed prospecting of Vasyugan peat deposit is obliged to the special attention focused on Western Siberia by the whole county at that time. It is noteworthy that Kolpashevo iron-ore basin was opened in 1956 году (the reserves counts 300 billion tons), this fact served as the basis for expansion of prospecting works.

Table 10

Characteristic of prospected peat reserve of 01.01.96

Name of the plot	Area (ha) at		Peat reserve, thou. tons, ha					
	zero border	the border of industrial depth of the peat, ha	balance				*Unexploitable	Sum total
			A	B	C ₁	C ₂		
Eastern plot (plot 5, Krasny Bakchar)	25319	12411	19943	4879	10802	–	532	35624
Eastern plot (plot 6, Plotnikovo)	74687	57070	–	–	156752	–	2937	156752
Eastern plot (plot 5, Plotnikovo)	26470	18210	29052	23202	–	–	1062	52254
Plot 22	14917	12215	38462	12075	–	–	874	50537
Eastern plot, the 1-st turn	360829	238805	–	–	–	754909	16889	754909
Plot of Yurginskoye Pudino, town of Kedrovyy	11805	10100	–	–	58203	–	5215	58203
Eastern plot, the 2-nd turn	788829	634941	–	–	2047689	–	771	2047689
Plot 20	27820	17725	–	–	50996	–	–	50996
Southern plot	580230	534075	–	–	–	1513281	716	1513281
Plot 7	1506	397	–	–	–	900	–	900
South-western plot, peat deposit Tara-Tartass	32595	24034	5487	–	13008	44364	2057	62859
Sum total for the deposit	1945007	1559983	92944	40156	2337450	2313454	31053	4784004

Note: * Unexploitable (overbalance) peat reserves. A, B, C₁, C₂ – see abbreviations.

The results of prospecting were the evidence of the wide areal spreading of iron-ore in the region of Bakchar River southwards and eastwards (preliminary reserves were estimated as being equal to 11 billion tons).

The deposits of manganese ores, ilmenite and zircon were discovered in the same area. Joint aerial deposition of large reserves of iron-ore and peat in the large Vasyugan peat tract served as a basis for the subsequent deep estimation of the peat

deposit, first of all with the purpose of revelation of peat stocks suitable for the industrial creation of metallurgical fuel.

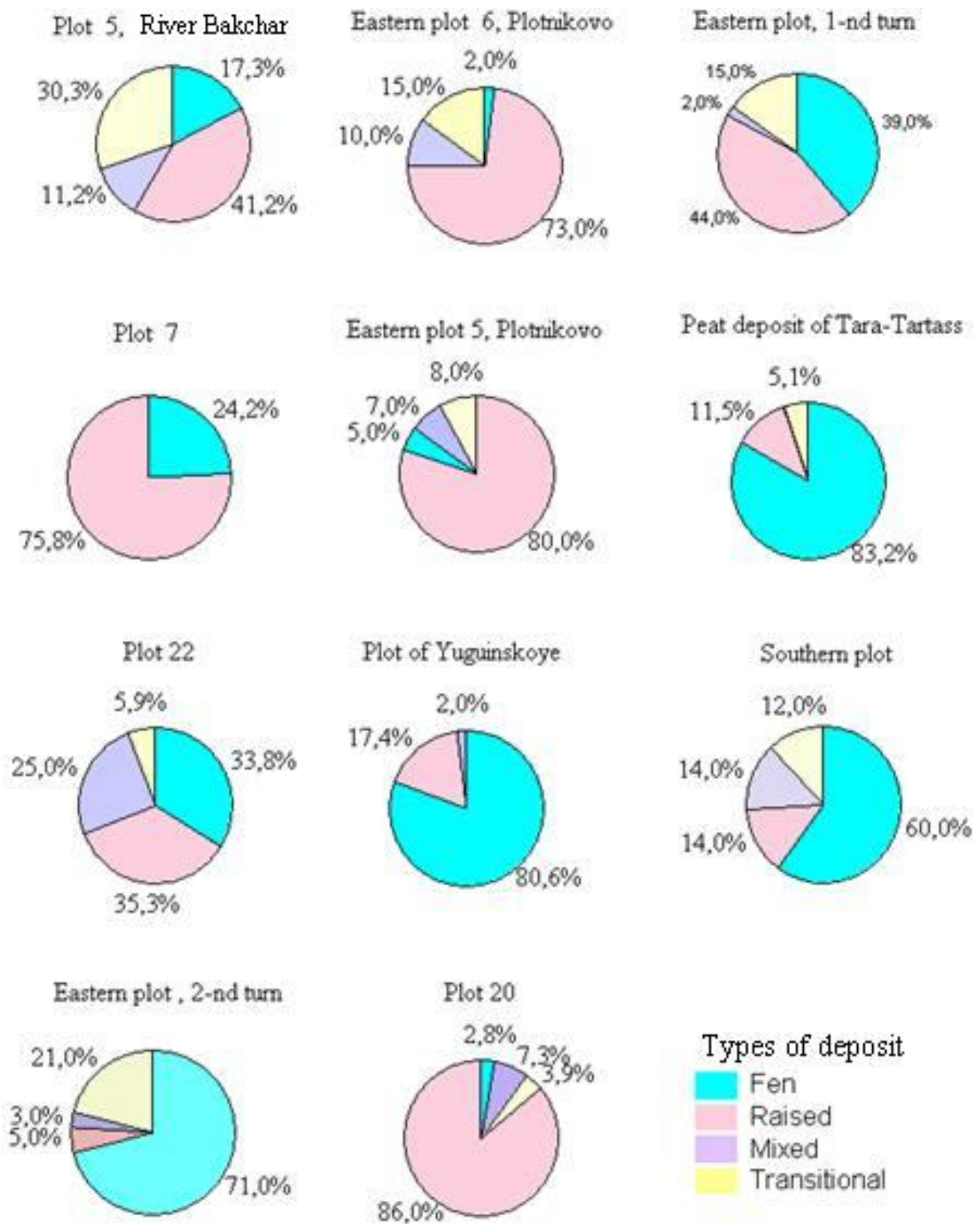


Fig. 23. Characteristics of the prospected peat deposits

And there is another circumstance. At the same time the problem of transference of the runoff of the boreal rivers to Middle Asia was under consideration.

The calculations showed that when the territory (including the territory of

Vasyugan peat deposit) was drained some more amount of water as large as 60–80 cubic km would be withdrawn.

Thus, the problem of drainage of Vasyugan peat deposit was solved simultaneously with the irrigation of arid southern areas. At that remote past the research and prospectors were sure that the solution of the problem of the comprehensive use of West-Siberian peat deposits was the subject matter of the nearest future. And Vasyugan peat deposit would be as the beginning of the development of these deposits.

This was an incitement for the further geological study of the largest in the world peat deposit, because simultaneously with the geological surveys the other works are also carried out (research in branch of peat science, hydrogeology and chemistry etc.).

These works allows us to determine the characteristics of peat and peat deposit, the specificity of stratigraphy, thermal, physical and mechanical and geochemical properties of peat and the character of underlying grounds.

The results obtained by geologists permit to have a clear idea about the possibility and the ways of drainage of the peat deposit and to determine the research trend based on chemical properties of the peats.

4.3. Carbon Content

Nowadays a special attention is paid to the study of reasons of disturbance of the carbon balance because this can lead to the climatic change with respective consequences. In these processes the peat mires are of no small importance. Earlier this problem was in detail examined by us in the book “Mires of Western Siberia, their part in biosphere” (1998). Here we only give the results of the determination of the deposited carbon stock in Vasyugan mire.

Total stocks of the peat amount to 275 billions tons in Russia, they deposit 118.1 billion tons of carbon including the West-Siberian region where this stock amounts to 42.3 billion tons [22]. In doing so, the authors suppose that the precision of carbon determination of the peat deposits is equal to $\pm 20\text{--}30\%$.

In order to increase the reliability of the information on deposited carbon in the mire biogeocenosis it is necessary to have at one's disposal the specified data on their areas, investigation of physical and chemical properties of the peat deposits and trend of the process of peat organic matter transformation in the active anaerobic layer and under the conditions of anaerobiosis.

We have performed calculations on determination of deposited carbon in Vasyugan mire. The calculations of peat deposits and total carbon were performed on the basis of explored and deposited stocks taking into account the type of the deposit in all plots of Vasyugan mire (Table 11).

In doing so, the volume of all types of the deposits was taken into consideration. It is known that the carbon content in the peats of Russia ranges within the limits of 34–

65%. The specific features of elemental composition characterize the peats of Western Siberia.

Therefore, in order to obtain the average values within the limits of peat types the data on the elemental composition of great number of samples should be taken into account (up to 3000 samples of West-Siberian peats [44]); the average carbon values were calculated as being equal to 55.3, 56.03 and 55.5 % for fen, transitional and raised and mixed mires respectively.

Table 11

Reserve of deposited carbon

Name of the plot	Absolutely dry peat mass, thou. tons	Carbon, thou. tons
Plot 5, Krasny Bakchar	19214.4	10687.5
Eastern plot 6, Plotnikovo	87324	48524.8
Eastern plot 6, Plotnikovo	29213.5	16221.7
Plot 22	19579.9	10873.2
Eastern plot, the 1-st turn	402270.2	223188.1
Plot of Yuganskoye	32166.7	17805.2
Eastern plot, the 2-nd turn	1076333.6	597421.7
Plot 20	28094.6	15596.3
Southern plot	779407.4	432181.9
Plot 7	470	262.6
Peat deposit of Tara-Tartas	69945.9	18129.3
Predicted reserve	6689509.4	3704674.8
Sum total for Vasyugan deposit	9233529.6	5095567.1

The obtained data shows that the content of the deposited carbon amounts to 5 095 567.1 thou. tons or 5.1 billion tons or 12 % of the deposited carbon in the peat deposits of the whole west-Siberian region and 4.4 % of total carbon stock of Russia.

4.4. Properties of Peats and Trends of Their Use

Nowadays the facts on the specific analysis of peat samples, degree of their decomposition and ash content (3572 samples [27]) have been accumulated.

This gives a chance to reveal some specific features of the peats and peat deposits of Western Siberia, their species composition and physical and chemical properties and to elaborate a variant of genesis classification of peat kinds and kinds of structure of the peat deposits for Western Siberia which was elaborated and carried out in the research [14, 92] based on the analysis of plant fiber of the peat of almost 100 000 samples taken in 1 400 peat deposits of Western Siberia.

As for the classification in question, the 85 peat kinds were included; among them there are 44 samples of fen, 25 samples of transitional type and 16 samples of raised

peat.

In contrast to the peats of the European part of Russia, the fiber of West-Siberian peats is represented by residues of cedar, larch and fir apart from the residues of pine, alder and birch. The grassy part of the peat fiber consists of species of sedges which are common in the European part of Russia and some specific species such as *Carex limosa*, *C. chordorrhiza* Earth, *C. rostrata* Stokes, *C. diandrea* Schrank, *C. omskiana* Meinsh, *C. caespitosa*, *C. globularis*, *C. acuta*, *C. C. buxbaumii* Wahlenb. The presence of the residues of sphagnum mosses such as *Sp. Lindsberg*, *Sph.*

Ongstream and compact sphagnum can be considered as a specific feature of sphagnum fiber of West-Siberian peats. *Sphagnum fuscum* is a dominant species among sphagnum mosses; it amounts up to 50–100 % of fiber of raised peat samples.

At the same time, the availability of this moss species is also a permanent feature of transitional and fen peats, whereas *Sph. magellanicum*, sphagnum narrow-leaved which are widely spread in the peat deposits of the European part of Russia, are of minor importance in the botanical composition of Western Siberia.

As for the fen sphagnum mosses, one should note the frequent presence of *Sp. warnstorffii* in the peat fiber of West-Siberian peats. It is interesting to note the availability of green moss species such as *Drepanocladus lycopodioides* in the moss fiber part of fen peats; in individual species this species amounts to 50–60 % of the fiber.

Floristic features of the plant cover of West-Siberian peats, environmental factors, which accompany the process of peat formation, are also responsible for specific features of the chemical composition of West-Siberian peats. For example, West-Siberian peats are rich in nitrogen and water-soluble and lightly hydrolysable substances, they contain less sulfur and are notable for reduced ratio of humic and fulvic acids.

Every peat deposit can contain a lot of peat kinds. It was shown in the previous chapters that the raised deposit in Vasyugan peat deposit included 25 % of the total reserve, fen deposit – 56.4 % and rather a low percentage (9.3 %) pertains to the transitional deposit.

Such diversity of deposit kinds is explained by the conditions of formation when individual plots of this area ran gradually in the course of their development into a single peat tract. Therefore, Vasyugan peat deposit is a great reserve of potentially valuable raw material.

Let us use the research results obtained by the Problem Research Laboratory of Fossil Fuels of Tomsk Polytechnical University [13] on the composition and properties of typical peat kinds of the Vasyugan peat deposit; later on we shall supplement them with the research from the geological reports of these authors conducted directly on the concrete plots of this peat deposit.

Mixed samples were taken by authors in order to characterize the properties of typical peats; every sample was taken in 3–4 spots from the middle part of the genetic

layer of the peat deposit.

The botanical composition and the degree of decomposition were determined by the Russian state standard GOST 28245-82, ash content and elemental composition by GOST 11306-83, 2408.1-88.8606-72, 2408.2-75, group composition according to the method by Instorf (variant of benzene extraction).

With a view to characterize chemical composition we took the peat samples, which are relevant to the territory under consideration (Table 12).

The authors consider the peats as being typical if the frequency of their occurrence is more than 3 %.

The frequency of occurrence of one or another peat type is implied as the percentage ratios of the registered number of peat samples of the given kind on the given territory to the total number of peat samples investigated on this territory.

Thus, 10 peat kinds were classified on the Vasyugan peat deposit:

3 kinds of raised type, i.e. fuscum, magellanicum, complex;

4 kinds of transitional type, i.e. sedge, Scheuchzeria, Scheuchzeria-sphagnum, sphagnum;

3 kinds of fen type, i.e. sedge, sedge-hypnum, hypnum.

Fuscum and magellanicum-fuscum peats are characterized by the low degree of decomposition (5–10 %) and the low ash content. The specific feature of the elemental composition consists in the low content of C, N, H, S (Table 12).

Table 12

General technical properties and elemental composition of typical kinds of peats

Kind of peat	Number of samples	Degree of decomposition, %	Ash content, %	Elemental composition, % of combustible peat mass				
				C	H	N	S	O
Raised type								
Fuscum	6	7	1.6	53.5	5.89	1.26	0.15	39.2
Fuscum magellanicum	3	7	2.5	53.0	4.81	1.09	0.14	41.0
Transitional type								
Sedge	3	35	5.1	57.8	6.08	2.75	0.21	33.2
Fen type								
Sedge-hypnum	2	35	8.8	57.0	5.76	4.10	0.44	32.7

The group composition is notable for prevalence of water-soluble and lightly hydrolysable substances (Table 13).

Because of the low degree of decomposition the content of humic acids in the peats in question is low. Such peat is suitable only for production of nutrient yeast, sugared peat, nutrient sugar, carbohydrate-proteinaceous forage in animal breeding, as well as for some consumer goods such as peat nutrient briquettes, peat-mineral ground “Fialka”, substrate peaty blocks, peaty cored pots, microhotbeds, peaty soddy carpets.

Table 13

Group composition of typical peats

Kind of peat	Number of samples	Group composition, % of combustible peat mass						
		bitumen	WSS	EHS	HA	FA	L	C
Raised type								
Fuscum magellanicum	6	4.2	4.0	46.8	13.6	17.3	6.5	7.6
	3	3.4	3.4	39.7	12.9	18.6	8.5	11.7
Transitional type								
Sedge	3	6.5	3.6	25.6	33.8	15.1	15.4 (L+C)	
Fen type								
Sedge-hypnum	2	3.7	3.4	32.8	33.8	15.6	8.4	2.3

Note: WSS –water-soluble substances; EHS – easy hydrolysable substance; HA –humic acids; FC – fulvic acids; L – lignin; C – cellulose

Sedge transitional peat is characterized by rather a high degree of decomposition and low ash content. Elemental composition is notable for high nitrogen and increased sulfur content.

Group composition is distinguished by higher bitumen and respectively water-soluble and highly hydrolysable substances content. Such peat can be of interest for chemical processing, in particular, for the production of valuable products such as: montan wax and activated carbon.

Fen sedge-hypnum peat has a high content of nitrogen and sulfur; it is distinguished by high yield of bitumen, lightly hydrolysable substances and high content of humic acids. Such peat is raw material for the production of humic preparations, activated carbon and biostimulants.

The geologists assessed the properties of peat of the Vasyugan peat deposit as raw material for manufacturing different kinds of peat products.

Generalized data for the whole peat deposit are given in (Table 14); these are based on the results of chemical composition of the peat of all the explored plots.

As it is evidenced by the data of Table 14, the peat resources of Vasyugan peat deposit give a chance to obtain various production of broad assortment. The enormous peat reserve (18.7 billion tons) of the Vasyugan tract creates favorable outlooks for the development of the largest modern enterprises for the complex chemical and biochemical peat processing.

Thus, in order to obtain nutrient yeasts, up to 9 mln. tons of peat are needed with the annual productive capacity of the enterprise of 10–15 thou; as for the litter (with productive capacity of 10 thou. per annum) 0.6 mln. tons of this material are required; it is needed not less than 1 mln tons of peat in order to obtain 5.5 mln. of fuel briquettes (with the productive capacity of 30 thou. tons).

If we compare these requirements with the peat resources of the Vasyugan peat deposit one may see that the duration of exploitation will last up to 200 thou. years.

The peat resources suitable for the fuel-energy sector and for the production of

peat fertilizers are, as a matter of fact, inexhaustible. It means, on no account that we appeal to use this vast peaty mire for only economic purposes. Certainly not; but it may be assumed that the partial use of its reserves is possible for the production of peat products, in particular, in the places where infrastructure has been developed or, on the contrary, there is no infrastructure but some settlements still exist, there is a chance to provide people with jobs and the regions with peat production including cheap local fuel.

Table 14

Possible directions of the use of prospected peat reserve of the peat deposit of Vasyugan area, % of the reserve of the plot

Name of plot, total peat reserve, 40 % moisture, thou. tons	Peat-insulation	Litter	Hydrolytic production	Waxes	Coke, activated carbon	HA and preparations	Fuel briquette	Municipal fuel	Fertilizers on the basis of peat
Plot 5, village of Krasny Bakchar, 36156	27	27	25	–	–	65	72	68	73
Plot 6, village of Plotnikovo, 159689	34	41	41	–	–	50	55	55	59
Plot 5, village of Plotnikovo, 53316	39	46	46	0.4	0.4	46	49	52	54
Plot 22, 51411	17	23	–	–	31	73	76	76	77
Plot of Yurguinsky 63418	9	11	9	–	–	49	79	79	89
Eastern plot, the 2-nd turn, 2048460	–	21	21	–	–	73	51	68	73
Plot 20, 50996	33	42	42	3	3	51	54	55	58
Tara-Tartass, 62859	–	8	8	–	–	82	3	89	92

For example, the production of granular peat as a fuel in field conditions is characterized by many positive properties of the peat miller [33]. They include the low power and steel intensity, large poured mass, good flowability and many other properties. Small sizes of the granules permit to mechanize and stabilize the process of combustion.

This leads to the increase in the efficiency of heating systems and the considerable saving of fuel. Special fuel equipment has been elaborated for the granular peat. This fuel can be used for heating and for common needs.

More than 40 kinds of peat production are known.

In remote settlements one can obtain a broad assortment of organic and mineral fertilizers, sugared peat (forage for cattle), litter and many other things apart from everyday fuel.

Furthermore, one cannot help leaving the dream of creation of the largest modern peat-chemical industrial complex on the basis of the Vasyugan peat plot deposit which has been developed by the environmentalists, economists and other specialists.

For this purpose a survey was conducted on the quarter of the territory and some

detailed data on natural conditions and peat characteristics were obtained there. Hence, there is a subject to discuss, but this discussion should be well founded.

4.5. Description of Explored Plots

Proceeding with the discussion of the data on properties of the peats forming the Vasyugan peat deposit, which started in the previous chapter, one should note that there are two principal trends in the study of the world peat resources.

The first one consists in the revelation of physical and geographical specific features of the processes of peat formation; phytocenological, paleobotanical and palinological study, elaboration of principles of peat kinds and peat deposits classification, creation of fundamentals of regioning and mapping of the peat resources as one of the components of geographical medium. This trend can be considered as an environmentally geographical one.

The second one consists in the revelation of the most reliable data on peat resources, assessment of potential significance of the peat and availability of their more rational use.

This trend can be considered as a resource one and at the same time the peaty mire can be considered as a peat deposit. If in the preceding chapter we considered Vasyugan mire first of all as being a recourse mire here we try to combine both trends on the example of two explored plots.

One of them is located in the eastern part of Vasyugan mire (plot 5 near settlement of Krasny Yar, Tomsk Region); the other is situated in its southern part (peat deposit of Tara-Tartass, Novosibirsk Region) (see Fig. 21).

4.5.1. Plot 5 near Settlement of Krasny Yar

The detailed prospecting was performed by specialists' survey expeditions in the period of 1983–1985 on the basis of preliminary prospecting during 1964–1965.

As a result of detailed prospecting the specified data were obtained on the area of the explored plot, peat reserves and peat properties (Table 15).

Table 15

Characteristics of plot areas

Name of areas	Area, thou. ha	Mean depth of peat deposit, m	Volume of raw peat cu. m.
Prospected plot within the limits of industrial depth of the deposit	12411	1.95	242605
Ditches	77		
Dry lands	1240		
Borders	4190		
Sum total for prospected plot	17918		

The territory under exploration is situated on the watershed plateau between the

middle courses of the rivers of Bakchar and Iksa (Fig. 24). It seems interesting to pay attention first of all to separate factors of peat formation of the given plot. Its extension from north to south amounts to 1.5–8.8 km and 3.6–19 km in latitudinal direction. The heights of the plot range from 110.9 to 122.1 m.

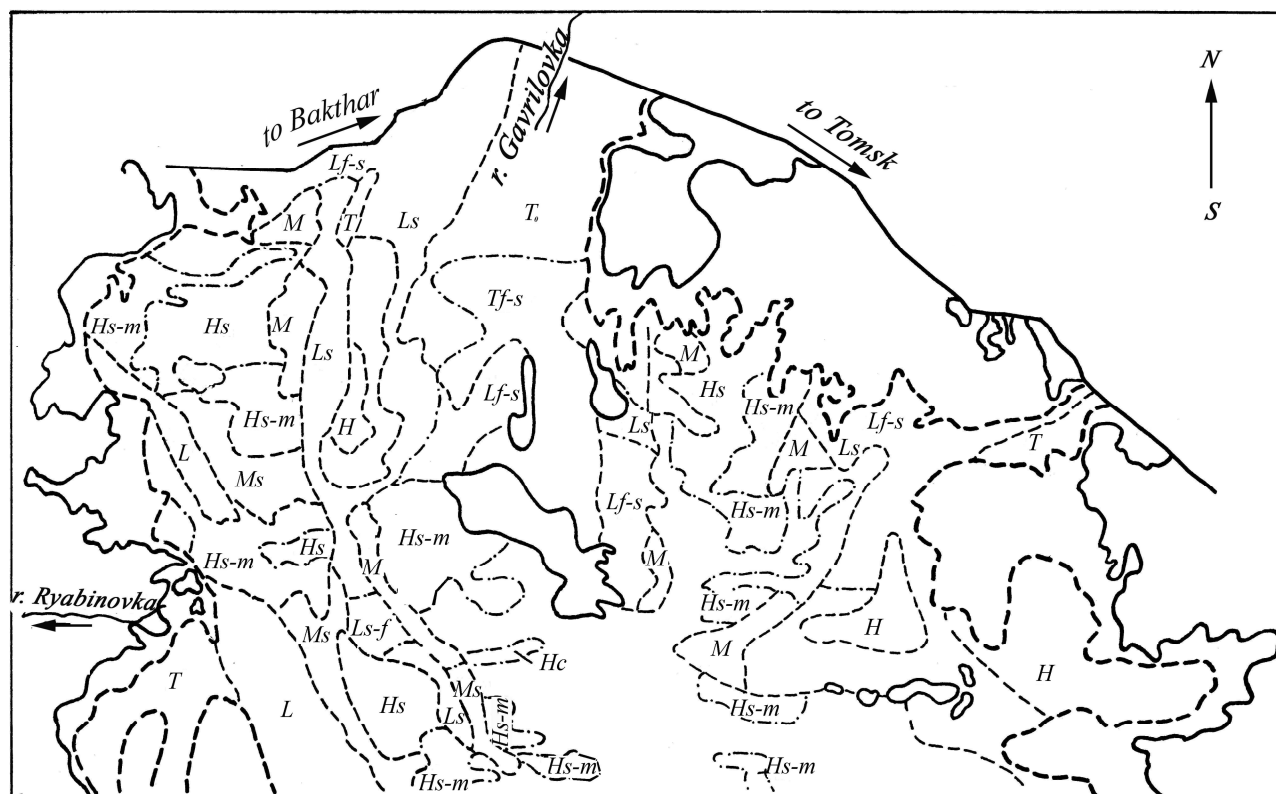


Fig. 24. Plan of peat deposit (plot 5 near the village of Krasny Bakchar): H – high-moor deposit, Hs – sphagnum high-moor peat deposit, Hs-m – sphagnum medium high-moor peat deposit, Hc – complex peat deposit, Tf-s – forest-swamp deposit, T_0 – sedge deposit, L – transitional deposit, Ls – transitional swamp deposit, Ls-f – transitional swamp-forest deposit, Lf-s – transitional forest-swamp deposit, M – mixed deposit, Ms – mixed swamp deposit

On the explored plot one can distinguish: water-bearing horizon of modern swampy deposits; water-bearing complex of quaternary lacustrine and alluvial deposits; water-bearing complex of Paleogene deposits.

Let us dwell on characteristics of water-bearing horizon of swampy deposits.

Fen, transitional and raised peats are water-holding rocks, which are characterized by a wide variety of filtration properties.

The waters associated with the peats are free-flow (gravitational), their table is at the depth of 0.1–1.0 m, and more often at the depth of 0.2 m. Medium thickness of water-bearing horizon of swampy deposits is equal to 1.9 m.

As for the chemical composition, the waters are hydrocarbonate-calcic and hydrocarbonate-sodic, weakly mineralized (48.8–276.9 mg per l), these are from strongly acid to moderately alkaline (pH 3.5–7.4), from very soft to moderately hard (total hardness is equal to 0.1–4.0 meq) with a high content of organic substances (oxidability is equal to 31.21–159.98 mg per l).

On the whole, hydrocarbonate-sodic water in comparison with the

hydrocarbonate-calcic one is characterized by a weaker mineralization of not more than 100.9 mg per l, a higher acidity (pH 3.5–5.6), low total hardness (0.1–0.4 meq) and a higher content of organic substances.

The feeding of water-bearing horizon is mainly realized at the expense of direct precipitations and to a less extent of the surface discharge waters from surrounding dry lands and very seldom at the expense of inflow of vadose water from clayey deposits into the extreme parts of the peat deposits.

The rivers of Bakchar, Iksa and their tributaries such as the Ryabinovka, the Stepanovka and the Gavrilovka are water receivers in the peat deposit of the 5-th plot.

The formation of the peat deposit occurred through dry land paludification, mainly under the conditions of feeding by surface and atmospheric waters, it led to the formation of the peat deposit of raised, mixed and transitional type with a maximum depth of 5.5 m.

On the plot of the peat deposit the plant groupings are represented by nine phytocenoses of raised, transitional and fen types.

Pine-undershrub-sphagnum phytocenoses occupies the plots with the peat deposit of raised and mixed types. Pine prevails in the arborescent layer; birch and cedar are also found sometimes.

The undershrub layer is well developed (height is 40–50 cm), the coverage amounts to 70 %. It consists of ledum, leatherleaf, blueberry, cranberry and foxberry.

The grass cover is non-uniformly developed and represented by cotton grass; cloudberry and single specimens of *Carex limosa* are found among these plants. The sphagnum mosses such as *magellanicum* and *fuscum* form a dense coverage.

Cotton grass-sphagnum phytocenosis is situated in the peripheral parts of the typical plots with the peat deposit of raised and mixed types. The arborescent layer consists of single specimens of strongly oppressed pine.

The undershrub layer is represented by butterbur and cranberry. The grass layer is above the mossy one; here prevails cotton grass with admixture of *Rhynchospora*.

The moss cover is represented by *Sphagnum angustifolium*; more moistened sites are taken by *Sph. balticum*, *Sph. cuspidatum*. The moistening is medium and high.

The ridge and hollow complex is with rare oppressed pine, which grows on ridges and hummocks-hillocks. The number of the undershrub is not high. There is leatherleaf, butterbur, cranberry and heather among of them.

Cotton grass grows on the ridges and hillocks; *Scheuchzeria* grows on the slopes; in the hollows *Rhynchospora Vahl.*, *Carex limosa* and bogbean (*Menyanthes trifoliata*) can be found.

On the hummock-hillocks and ridges the mosses prevail such as *Sph. fuscum* and *Sph. Magellanicum*; *Sph. Angustifolium*, *Sph. Balticum* and *Sph. rubellum* Wils occupy the depressions between them.

Sph. majus (Russ.) and *Sph. cuspidatum* are common in the hollows. The ridges are 50–300 m long, 0.5–2.0 m wide and 0.10–0.15 m high.

In the eastern part of the plot the ridge and hollow complex is replaced by the ridge-pool complex, which occupies an insignificant area on the explored plot. Tremendous overmoistened hollows of 50–100 m wide, up to 300 m long, occupy the most part of the ridge-pool complex.

Secondary small lakes are spread among the hollows, they occupy 15–20 % of the total area of the complex; their depth amounts to 0.3–1.0 m; the lakesides are marshy, the bottom is peaty. The herbaceous layer consists in the hollows of *Carex limosa*, *Rhynchospora Vahl*, *Scheuchzeria*.

The rare moss cover is formed by *Sph. cuspidatum*, *Sph. dusenii*, *Sph. jensenii* H.Linb., *Sph. balticum*, *Sph. papillosum* H.Lindb. Oppressed pine and single specimens of cedar afforest the ridges.

The undershrub layer consists of leatherleaf and ledum with admixture of cranberry, butterbur and dwarf birch. In sphagnum-hollow cover the *Sph. fuscum* is predominant. The lichen is rare, like spots.

Fuscum phytocenosis is represented by strongly oppressed pine, leatherleaf (*Chamaedaphne calyculata*, butterbur (*Petasites*), ledum and cranberry. *Sph. fuscum* with small admixture of *Sph. angustifolium* and *Sph. magellanicum* prevail in the herbaceous layer. Mossy hummocks and cushions occupy up to 50–60 % of total area; these are up to 0.3 m high and 0.2–1.5 m in diameter.

Woody undershrub-sphagnum transitional phytocenosis is mainly represented by low pine and birch stands. Leatherleaf, ledum, butterbur, cranberry and dwarf birch are predominant in the undershrub layer.

The herbaceous layer of the hummocks and hillocks is represented by cotton grass and cloudberry and the depressions between hummocks are occupied by *C. lasiocarpa* Rhrh, *C. rostrata* Stokes, *C. limosa* L. Moss cover consists of *Sph. magellanicum*, *Sph. fuscum*, *Sph. angustifolium*, *Sph. central* C.Jens. ex H.Arnell et C.Jens. The microrelief is mossy.

Undershrub-sphagnum transitional phytocenosis. Here one can note single specimens of strongly oppressed pine and birch.

The undershrub layer is well developed. Dwarf birch, butterbur, leatherleaf, ledum and cranberry are common here. As for the herbaceous layer, here such species as *C. lasiocarpa*, *C. rostrata*, *C. limosa* and *Eriophorum vaginatum* are predominant; *Menyanthes trifoliata*, *Comarum palustre* and *Equisetum* can also be found.

Hypnum mosses (calliergon, drepanocladus) and sphagnum mosses (*Sph. angustifolium*, *Sph. fallax*, *Sph. obtusum*) form a continuous carpet. The watering is high.

Woody sedge-sphagnum fen phytocenosis. The arborescent layer is represented by pine and birch, sometimes the admixture of fir, aspen, cedar and abundant undergrowth of pine and birch is found. The undershrub layer is weakly developed

and represented by dwarf birch, ledum, leatherleaf, cranberry, foxberry and blueberry.

The herbaceous layer is well developed and consists of *C. lasiocarpa*, *C. rostrata*, *C. cespitosa*, *C. omskiana*, *Meyanthes*, *Equisetum*, *Comarum*; *Eriophorum polistachyon* is found as well. The rare moss cover consists of hypnum and sphagnum mosses.

The microrelief is hummocky. The sedge hummocks are 0.2–0.4 m high, 1.5–0.3 m in diameter; they cover up to 50 % of the total area. The watering of the surface is high.

Undershrub-sphagnum fen phytocenosis. The undershrub layer is well developed. Dwarf birch, andromeda, leatherleaf prevail here. The herbaceous layer consists of *Eriophorum polistachyon* and different species of sedges.

The moss cover is formed by sphagnum mosses (*Sph. central*, *Sph. obtusum*, *Sph. subsecundum*) and hypnum mosses (calliergon, drepanocladus). The sedge hummocks occupy 5–15 % of the phytocenosis area. The watering is high.

Rather a high diversity of peat kinds was revealed in the peat deposit. The following species of the peat deposits (among 13 discovered) are the most widely spread: fuscum (40 %), magellanicum (20 %), mixed marshy (11 %), transitional marshy (10 %).

The peat deposit is formed by 38 peat kinds represented by all types. Seven peat kinds are most widely spread, for example: fuscum, magellanicum, sedge transitional, sedge-sphagnum transitional, complex, angustifolium, woody sedge transitional.

Let us consider the characteristics of the peat deposit of the plot.

Peat deposit of the raised type occupies the area as large as 44.6 % of the total one, the maximum peat thickness amounts here to 4.8 m, on average 2.3 m. 25 stratigraphic plots were distinguished altogether.

The peat deposit is represented by 17 peat kinds, such kinds as fuscum, magellanicum, mixed marshy, complex raised, transitional marshy are widespread. The structure of the peat deposit is formed by 31 peat kinds. For example, such kinds as fuscum, magellanicum, sedge-sphagnum transitional and sedge transitional are most widely spread.

Peat deposit of the mixed type occupies 10.5 % of the area (Table 16); the highest thickness of peat reaches 5.5 m, 2.4 on average. Within the limits of the explored territory 13 stratigraphic plots were distinguished.

The peat deposit is represented by mixed marshy and marsh-forest kinds, it is structured by 17 peat kinds, such types as magellanicum, transitional sedge, fuscum-peat, transitional sedge-sphagnum, raised sphagnum-hollow and transitional wood sphagnum.

Peat deposit of the transitional type occupies 29.1 % of the total area, average thickness of the peat deposit reaches here 1.8 m, the maximum thickness is equal to

4.2 m. Altogether there were distinguished thirteen stratigraphic plots. Five peat types are distinguished here: transitional marsh, forest and forest-marsh and fen sedge.

Table 16

Characteristics of the peat deposit

Types of peat deposit	Area, thou. ha	Stocks of dry peat, thou. tons	% of total stocks	Category of the study
Raised	5539	14912	41	A+C ₁
Mixed	1302	4046	12	A+B+C ₁
Transitional	3617	10954	80	A+B+C ₁
Fen	1953	6244	17	A+B+C ₁
Sum total for the plot	12411	36156	100	

Note: A, C₁, B – see abbreviations.

The peat deposit is composed by 30 peat kinds among of the following prevail: transitional sedge, wood-sedge, sedge-sphagnum, sphagnum, magellanicum.

Fen type of the peat deposit occupies 15.7 % of the total area, its mean depth amounts to 1.5 m, the maximum 3.9 m.

The peat deposit is represented by the four following kinds: raised sedge, forest-marsh, wood-sedge, transitional forest-marsh, they are composed by 14 peat kinds but the following types prevail: fen-sedge, wood-sedge, woody.

According to the peat quality the balance reserves were revealed in the peat deposit. These reserves include the peats of low, medium and high degree of decomposition with ash content of 35 %. The over-balance reserves are also distinguished; they include the peats of medium and high degree of decomposition with ash content from 36 to 50 % (see table 10).

It should be noted that the degree of decomposition and ash content are of great significance for the assessment of the raw material for the purpose of production of different peat materials.

In order to produce organic fertilizers on the peat basis the peat reserves with ash content up to 35 % and degree of decomposition more than 20 % (for raised and transitional types of deposits) and more than 15 % (for fen deposits) are suitable. This is the largest group of the reserves. Therefore, all the peat reserves are practically suitable to use as organic fertilizers.

The peats having ash content up to 23 % and degree of decomposition more than 15 % (for raised and transitional types) and more than 10 % (for fen type) are suitable for the production of fuel.

The peat with ash content of 15 % and degree of decomposition up to 15–25 % is required for the production of peat litter, substrate slabs, nutritious briquettes, forage hydrolytic sugars and some other kinds of chemical peat processing.

The peat of the raised type with the degree of decomposition from 35 % and more

and ash content up to 6 % can be used as a raw material for production of activated carbon.

The balance peat reserves count to 35 624 thou. tons (at conventional moisture of 40 %) on the explored plot including those calculated by categories: A – 19 943 thou. tons, B – 4 879 thou. tons, C₁ – 10 802 thou. tons. Mean peat thickness (without standing dead) amounts to 1.94 m.

The qualitative indices of the peat balance reserves are the following: degree of decomposition – 21 %, ash content – 5 %, moisture – 90.2 %. It should be noted that the peat reserves equal to 8 167 thou. tons of low degrees of decomposition have been revealed on the explored plot as an especially valuable raw material.

With the purpose of study of qualitative properties of the peats of plot five, there were put 713 spots for peat sampling; here the agrochemical properties, ash content, heat of combustion and reducing substances were determined.

Based on the obtained data on the properties of the peats it is possible to use them according to the directions given in Table 17.

Table 17

Direction of use of balance reserve

Category of raw material	Peat reserve, thou. tons	Peat insulation raw material	Litter	Hydrolytic raw material	Humic acids and preparations	Domestic and energetic fuel	Fuel briquettes	Fertilizers on the basis of peat
Rt; R upto 12 % and A upto 5 %	4759	4759	4759	4759	–	–	–	–
Rt; R upto 20 % and A upto 10%	1471	1471	1471	1471	–	–	–	–
T; R upto 20 % and A upto 10%	512	512	512	–	–	–	–	–
Rt; R 21–34 % and A upto 10%	765	–	–	–	765	765	765	765
T; R 21–34 % and A upto 10%	10396	–	–	–	10396	10396	10396	10396
F; R 16–34 % and A upto 10%	3168	–	–	–	3168	3168	3168	3168
T, F; R 35 % and A up to 10%	1879	–	–	–	1879	1879	1879	1879
Rt, T; R>20% and A from 11 to 23%	1361	–	–	–	–	1361	1361	1361
F; R>15% and A upto 35 %	511	–	–	–	–	511	511	511
Sum total	24822	6742	6742	6230	16182	16849	17816	18080
%	100	27	27	25	65	68	72	73

Note: Rt – raised type; T – transitional type; F – fen type; R – degree of decomposition, %; A – ash content, %.

Thus, transitional and fen peat types of the peat of medium and high degree of decomposition are widely spread in the peat deposit.

They are suitable for production of peaty composts and fertilizers. Fen peat can be used for the production of hexapeat and peat-humic fertilizers. Considerable peat reserves are raw material for the production of milled fuel peat as well as lump peat for municipal services.

According to its composition the balance reserves can fully be used. It means that a lot of kinds of peaty products can be obtained from the raw material of this plot.

4.5.2. Tara-Tartass Peat Deposit

The peat deposit is geographically situated in the latitude $58^{\circ}30'$ north and in the longitude $78^{\circ}30'$ east.

Firstly it was explored by routes in 1950 but more detailed surveys were performed in 1991–1993. The survey of the peat deposit was foreseen in order to produce dry humates on the basis of fen peats.

The peat deposit Tara-Tartass is situated in the northern part of Novosibirsk region and is at the disposal of the land tenure of Verkh-Tara State Woodland of the Northern forest farm of Verkh-Tara forest husbandry (Fig. 25).

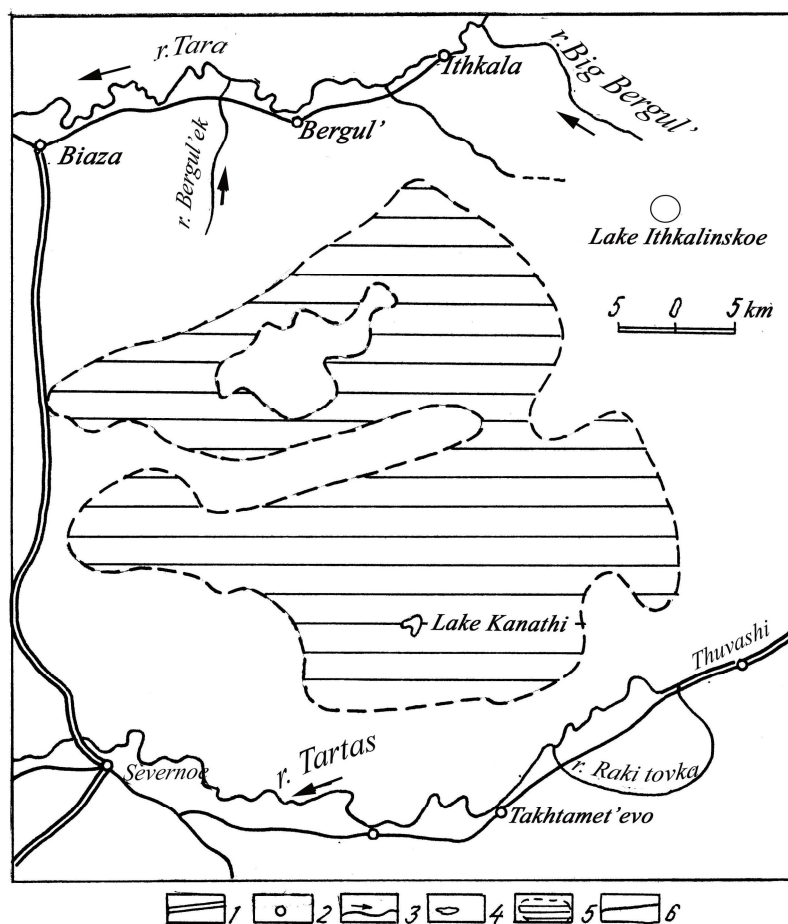


Fig. 25. Scheme of location of peat deposit Tara-Tartass. 1 – improved dirt roads; 2 – settlements; 3 – hydrographic network; 4 – lake; 5 – peat deposit; 6 – dirt roads

In geomorphological respect the plot is situated on the watershed of the rivers of Tara and Tartas, its width is 22.5 km, length is 22 km. the surface is uneven, general inclination of the surface is directed to the south and south-east, to the rivers.

The formation of the peat deposit happened due to paludification of dry lands within the limits of the forests and meadows as well; it can be evidenced by availability of forest, marsh-forest and marsh kinds of the peat in the bottom of the peat deposit.

Initial seats of paludification appeared in the depressions and vast hollows on the surface of the watersheds where the surface overmoistening occurred because of the presence of weakly permeable clays and loams.

At present the process of paludification lasts along the northern and southern border of the peat deposit at the areas adjacent to the rivers of Tara and Tartas.

The territory under study is situated in Barabinsk lowland, which is an accumulative plain, evened off by lacustrine and lacustrine-alluvial deposits of the Upper Pliocene and the Quaternary age.

On the basis of landscapes and morphology as well as the principal relief-forming processes, two types of relief are distinguished, i.e. accumulative and erosion-accumulative.

A complex of quaternary deposits forms the ***geological structure*** of the territory. Those of the Upper Pliocene and the Low Quaternary represent the most ancient quaternary deposits.

The alluvial-lacustrine Upper Pliocene and Low Quaternary deposits are widely spread and lie down with outwash on the sediments of Turtas Tavolzhan suites. These are found at the depth from 6 to 20.6 m.

The Middle Quaternary sediments (Fedosov suite) are widespread and not found only within the bounds of the valley of the river of Tara.

The sediments are revealed at the depth of 2–5 m and lie down without breaking on the Upper Pliocene and the Low Quaternary sediments and only in single instances the thin (0.1 m) outwash horizon is observed in the suite foundation; this horizon is represented by weakly rounded clay debris and broken cockle-shells.

Alluvial sediments of the first and second above-floodplain terraces of the rivers of Tara and Tartas belong to the Upper Quaternary covering deposits. The thickness of the sediments reaches 13.2 m. The floodplain and riverbed deposits as well as mire deposits are classified as contemporary sediments.

The territory under research is situated in the southern part of West-Siberian artesian basin (Itrysh basin). As a matter of fact, three water-bearing horizons are distinguished within the limits of the upper hydrogeological complex:

1. Water-bearing horizon of contemporary mire deposits.
2. Water-bearing horizon in contemporary and the Upper Quaternary alluvial sediments of floodplain, first and second above-floodplain terraces.

3. Water-bearing horizon of the sediments of Fedosov suite of the Middle Quaternary age and overlaying covering deposits of the Upper Quaternary age.

Let us dwell more in detail on the description of the first horizon. The ***water-bearing horizon of contemporary mire deposits*** is developed within the limits of the zero border of the peat deposit of Tara-Tartas.

The peats of various kind and quality are as water-holding rocks. The thickness of water-holding thickness varies from 0.2 to 6.0 m. In the character of deposition the mire waters are poral and layer; these are free in hydrodynamic respect.

The waters are weakly mineralized, very soft; their reaction varies from neutral to acid. The salt composition is hydrocarbonate magnesium-calcium-sodium, calcium-sodium, sodium-magnesium and magnesium-sodium.

On the whole, as concerns the chemical composition of waters all the horizons are hydrocarbonate calcium-magnesium with insignificant sodium content; dry residue reaches up to 1 g per l.

The hydrographical network of the plot is weakly developed; main receiving waters such as Tara, Tartas, their small tributaries and Lake of Karachi represent it. The tributaries of Tara, i.e. the rivers of Bergulen (6 km long) and Biazinka (12 km long) have their source directly from the peat tract.

The plant cover is represented by the following phytocenoses:

Transitional wood-sedge phytocenosis. The arborescent layer is represented by birch with admixture of aspen (up to 20 %) of 8 m high on average; the diameter of tree stands is 10 cm, density 0.3. As for the undershrub, the leatherleaf and ledum are found; these occupy up to 20 % of the total surface.

The sedges are predominant in the herbaceous layer (up to 40 %) of the surface. The moss cover consists of sphagnum mosses, green mosses are found on the hummock tops. The microrelief is gentle and hummocky.

The hummocks are associated with tree trunks. The height of the hummocks is 0.2–0.3 m, with the diameter 0.4–0.9 m. The hummocks occupy 50 % of the surface. The watering varies from medium to high.

The raised sedge-sphagnum phytocenosis. The arborescent layer consists of pine 4–10 high, its diameter amounts to 6–14 cm, density 0.3–0.4. The undershrub is represented by leatherleaf, ledum and cranberry (up to 50 % of the area). The herbaceous layer (cotton grass, Scheuchzeria, sedge, sometimes sundews) is rare.

Sphagnum mosses such as fuscum, magellanicum, and angustifolium and others represent the abundant moss cover. The microrelief is hummocky. The hummocks occupy up to 50 % of the surface and the watering is medium.

The transitional woody phytocenosis is situated along the dry land of the border zone of the peat deposit. The arborescent consists of birch and pine. The height of tree stand varies from 4 to 18 m, with the diameter of 4–32 cm, and the density is 0.5–0.8.

The undershrub layer is represented by ledum, leatherleaf and cranberry (the coverage amounts to 65–80 %). The herbaceous layer is too rare (cotton grass, sedge). Sphagnum and hypnum mosses form the moss cover.

The hummocks are of 0.4–0.7 in height, 0.7–1.5 in diameter and occupy up to 40 % of the area. The watering of the territory varies from low to medium.

The raised fuscum phytocenosis. The arborescent layer of this phytocenosis consists of pine up to 4 m in height, up to 6 cm in the diameter and 0.1–0.3 in the density.

The undershrub is represented by ledum and leatherleaf. Cotton grass is abundant in the herbaceous layer, which occupies up to 30 % of the surface.

The moss cover consists of sphagnum mosses among of which sphagnum-fuscum is prevailing with insignificant admixture of sphagnum-angustifolium and magellanicum.

The hummocks are 0.3–0.7 m in height, 1.0–1.5 m in the diameter, these occupy up to 70 % of the surface. The watering of the territory varies from low to medium.

Fen wood-sedge phytocenosis. The arborescent layer is presented by birch, seldom with insignificant admixture of pine, spruce and aspen. The tree stand is 4–8 in height, 10–16 cm in the diameter, 0.4–0.7 in the density.

As for the undershrub, willow and dwarf birch are found. The sedges prevail in the herbaceous layer; bogbeen, horsetail and reed are found as well. As for the moss cover, the hypnum mosses are observed on 20–30 % of the surface.

The hummocks are 0.3–0.5 m in height, 0.3–0.4 in diameter and occupy up to 50% of the surface the watering of which is medium.

The survey of the southwestern plot of Tara-Tartas peat deposit performed in 1992–93 permitted to specify the characteristics of the deposit (Table 18), it should be added that 8 % of the area were explored in detail.

The plot has the area of 32 595 ha in the zero border and 24 034 ha in the border of industrial depth of the peat deposit; there are 46 inner plots of dry lands with the total area of 2 134 ha which are completely deforested. The adjacent dry land plots are weakly pronounced in the relief; these are by 0.2–0.5 m above the surface of the deposit.

Let us consider the characteristics of the peat reserves according to every category.

The plot explored in detail (category of study A) occupies the area in the zero border of 1 597 ha, mean peat depth amounts to 2.7 m. The average qualitative indices of the balance reserves are as follows: the degree of decomposition – 15 %, ash content – 7 % and the moisture – 90.6 %.

Table 18

Characteristics of plot areas

Name of areas	Total for south-western plot	Plot of prospecting and evaluative works	Plot of preliminary prospecting	Plot of detailed prospecting
Prospected plot within the bounds of industrial depth of the deposit	24034	18523	450	1461
Inner dry lands, ha	2134	2122	–	12
Lakes, ha	19	3	–	16
Borders, ha	6408	6140	160	108
Sum total within the bounds of zero border of the plot, ha	32595	26788	4210	1597

The raised peat deposit is mainly represented by complex kinds of the deposit. The peat deposit is composed by 6 kinds of the peat among of which fuscum-peat, raised complex, sedge-sphagnum and transitional are predominant.

The peat deposit of the mixed types is represented within the limits of the explored plot by mixed marshy, transitional forest-marshy and transitional marshy kinds of the peat. The peat deposit is composed by 13 kinds of peat. Transitional sedge-sphagnum, fuscum-peat and transitional sedge are predominant kinds of the peat.

The plot with the peat deposit of the transitional type, the peat deposit is represented by the transitional marshy kind of the deposit. As a matter fact, eight peat kinds take part in the formation of the peat deposit. The following kinds of the peat are predominant: transitional sedge, transitional sphagnum, transitional sedge-sphagnum, transitional grass-sphagnum and complex.

The plot of fen type with the peat deposit occupies the northern part of the area explored in detail. The fen sedge deposit is composed by 3 peat kinds such as raised sedge-hypnum (5 % of the plot with peat deposit of the fen type), fen sedge (92 %) and fen grassy (3 %).

On the plot with the preliminary survey (category of study C₁) the area of 4 040 ha), a standard was distinguished. The peat deposit of the fen type is of 1.81 m of average thickness, the maximum standing dead reaches 3.9 m.

The peat deposit is composed on the plot by two kinds: fen sedge (91.4 %) and fen marsh-forest (8.6 %). As a rule, nine peat kinds take part in the structure of the peat deposit, among them fen sedge is prevailing, it amounts to 89.4 % of the deposit.

The plot of prospecting works and their assessment (category of study C₂). The area amounts to 18 523 ha within the limits of industrial thickness of the peat deposit. Mean qualitative indices of the balance reserves are as follows: degree of

decomposition 25 %, ash content 8 % and moisture 88.4 %.

The raised complex deposit of the plot is structured by five peat kinds; raised complex (45 %), raised Scheuchzeria-sphagnum (22 %), fuscum-peat (11 %), transitional grass-sphagnum (11 %) and transitional sphagnum (11 %).

The transitional marshy deposit is formed by grass-sphagnum (37 %), transitional Scheuchzeria-sphagnum (27 %), transitional Scheuchzeria (18 %), raised complex (9 %) and transitional sphagnum (9 %) peat kinds.

The fen peat deposit is represented by fen forest, fen sedge and forest-marshy kinds of the peat deposit; it is formed by 4 kinds of the peat such as fen sedge, wood-fen, fen sedge-sphagnum and fen wood-sedge.

Let us consider the characteristics of the peat resources of the whole peat deposit of “Tara-Tartas”.

The area of the whole plot of the peat deposit amounts to 32 595 ha in the zero border including the areas according to the category of the study; A – 1 597 ha, C₁ – 4 210 ha, C₂ – 26 788 ha: within the limits of the industrial depth of the peat deposit this area amounts to 24 034 ha including the areas by categories: A – 1 461 ha, C₁ – 4 050 ha, C₂ – 18 523 ha.

Total peat reserves are estimated at 64 916 thou. tons including by categories; A – 5 512 thou. tons, C₁ – 13 258 thou. tons, C₂ – 46 146 thou. Tons (Table 19). The deposits of sapropel as thick as 0.4–0.9 m and the reserves of 32 thou. tons have been revealed below the peat deposit. The average sapropel ash content counts to 30 %.

Table 19

Characteristics of the peat deposit

Types of peat deposit	Area, thou. ha	Stock of dry peat, thou. tons	% total stocks	Category of study
Raised	804	1868	2,9	A, C ₂
Mixed	503	1820	2,8	A
Transitional	1968	4758	7,3	A, C ₁
Fen	20759	56470	87,0	A ₁ , C ₁
Sum total for the plot	24034	64916	100	

Note: A, C₁, C₂ – see abbreviations.

As for the lake of Karachi, the mean sapropel thickness is estimated at 2.11 m and the peat reserves at 140 thou. tons. The average qualitative sapropel indices are as follows; ash content – 35 %, acidity – 6.5 %, CaO content – 2.55 %, Fe₂O₃ – 1.25 %. Sapropel belongs to organic and organo-silicate classes.

As environmentalists note it, the southwestern plot of the peat deposit, from ecological point of view, is of no special nature protective value. The valuable tree stands and plants do not grow here; there are not found any rare species of animals, birds or fish.

The study of the properties was conducted in the selected peat samples. The

agrochemical analysis of the peat samples did not permit to reveal any deviation in the content of CaO , Fe_2O_3 and P_2O_5 from the average statistical data for West-Siberian peats.

The results of spectral analysis showed the excess over mean content of the elements such as copper (1.5–40 times in 30 samples from 52) and elevated content of arsenic (1.2–1.6 times more in 3 samples from 52).

The chemical analysis showed an increased content of humic acids in the fen peat as compared to the raised one, 33.8 and 20 % respectively.

On the basis of the data obtained on peat properties the estimation of the possible was made as concerns the use of the balance reserves (Table 20).

Thus, the peats in question can be used as raw materials to produce litter, humic acids, everyday and energetic fuel, fuel briquettes, peaty and nutritive briquettes, fertilizers on the peat basis.

As a matter of fact, as much as 57 % of the peat reserves of the plot of the detailed prospecting can be used for production of dry humates and 14 % of the peat can be used for production of nutritive briquettes.

Table 20

Direction of the use of balance reserve

Category of study	Reserve, thousand tons, 40% moisture	Litter	Humic acids and preparations	Domestic and energy fuel	Peaty nutritious briquettes	Fuel briquettes	Fertilizers on the basis of peat
A	5487	1713	3144	3390	743	3390	3786
% of total reserve	100	31	57	62	14	62	69
C ₁	13008	–	11588	12909	–	12909	13008
% of total reserve	100	–	89	99	–	99	100
C ₂	44364	3617	36564	39634	853	39634	40814
% of total reserve	100	8	82	89	2	89	92
Sum total	62859	5330	51296	55933	1596	55933	57529
To A+C ₁ +C ₂	100	8	82	89	3	89	92

Note: A, C₁, C₂ – see abbreviations.

The duration of functioning of dry humates enterprise can be as long as thirteen years and six years respectively of the enterprise producing peat nutritive briquettes.

5. ON THE PROBLEM OF RATIONAL USE OF VASYUGAN MIRE

As any natural system, the mire should be considered from the viewpoint of its reproductive possibilities of life and recourses for a human being.

Therefore, the economic development of the peat recourses that has already begun and exhibits a tendency to increase in the years to come, provided the development of productive forces, is connected with the problem of assuring the environmental equilibrium.

At the same time, multifunctional importance of mires makes a special responsibility for the development of the peat resources. The modern strategy foresees the transfer from arrangements on elimination of unfavorable consequences of man-made effect to the preventive measures.

Therefore, when we consider the role of Vasyugan mire in the biosphere for the purposes of substantiation of nature-protective measures, we have to estimate its positive aspects and then the possibilities of weakening negative affects by means of reclamation including those in the peat development.

However, until now there are no criteria to select peat deposits in order to preserve them under natural conditions. Such a selection is conducted on the basis of expert's estimation.

As a result we have no protected peat deposits or their plots if they are not proved to be within the limits of specially protected natural territories (SPNT).

Nowadays in Russia there is no common methodical approach on distributing the peat recourses between environmental and economic funds. In part, it is because of the fact that the resources are of dual character and belong simultaneously both to the land areas and to the earth bowels.

This specific feature, on the other hand, as well as their close interconnection with the forests, meadows and waters causes a need to establish an equitable position of peat-swampy fund among other natural recourses.

The hydrogeological and hydrological research was performed in the explored plots of Vasyugan mire; heat engineering, physical and mechanical and chemical properties of the peats were also studied.

As a result the idea about the possibilities and methods of its drainage was obtained; the direction of use of peat chemical properties and reserves of the peats was determined.

For example, in order to obtain the fodder yeasts in the plant of productive capacity of 10–15 thou. tons annually up to 9 mln. tons of peat are required; in order to obtain the litter (with a productive capacity 10 thou. tons per annum) 0.6 mln. tons of peat would be required; for the hydrolysable products – 5.5 mln. tons; fuel briquettes (with productive capacity of 30 thou. tons per annum) – not less than 1 mln. tons of peat.

If one compares these requirements with the peat recourses of the Vasyugan peat

deposit it would become clear that the period of its exploitation would last out for 200 thou. years.

It should be noted that the research of that period was based on the prior attention to the aspects, which were aimed at obtaining the optimal result, which implied the maximum and long-term effect under other conditions being equal.

It can be achieved through the complex use of the peat recourses and concomitant raw material. As it was mentioned above, the availability of iron ores in the vicinity of the river of Bakchar, south- and eastwards (preliminary reserves were estimated as being equal to eleven billion of tons) as well as the deposition of manganese, ilmenite and zircon ores served as a basis for further profound assessment of the peat deposit, first of all to reveal the peat reserves suitable to obtain metallurgical fuel.

In 1970–80 on the determination of use of the research it was taken into consideration that peat is not only a natural recourse but also a landscape covering which performs a series of functions such as hydrological, geomorphologic, climatic and others.

In this connection, the proportionality was supposed to be observed; this was conditioned by unbiased value of the peat recourses, degree of their study and their qualitative characteristics as well as the requirements in peat production, land and biospheric need in the conservation of the part of the swamp in natural conditions.

Until recently the paradigm of nature use the essence of which consisted in the search for acceptable compromises between environmental and social-economic imperatives has changed.

The world community concerned with the nature degradation is looking forward to observing the principles of sustainable (balanced) development. It is important because these principles imply the use of natural recourses under conditions of their reproduction in order to preserve the functions peculiar to them.

In connection with the above said it is quite possible to give the status of a preserve to the whole Vasyugan mire [12–14].

Such a movement began on the background of All-Russian campaign on inventory of especially valuable water-swampy lands [93] and as early as at the interregional meeting of representatives of the interregional association “Siberian consent” in 1998 in Novosibirsk the intentions for the creation of the “Vasyugan reserve” were determined; this reserve was given a status of the water-swampy area of international significance.

Later on, in 2002 the International scientific and practical conference “Problems of conservation and efficient use of the Vasyugan mire system” was held in Tomsk. As a result, 799 thou. ha. were marked out for the creation of the landscape reserve of federal significance in Vasyugan mire. This reserve was created thanks to the support of the International organizations *Global Peat Initiative*, *Wetland International* and Russian specialists who were financed by them.

One plot (509045 ha.) is situated on the territory of Bakchar district of Tomsk

region, the other one is located on the territory of Novosibirsk Region and their total area amounts to about 290 thou. ha.

At the same time, the territory of the reserve includes the peat deposit Tara-Tartas, the southern and eastern parts of the 1-st and 2-nd order.

It is necessary to note that actually these plots are not so hopeless from the industrial viewpoint. As for the Tara-Tartas peat deposit, it is characterized in the part 4.5.2. The peats of the given peat deposit can be used as raw material for the production of humic acids, common and metallurgical fuel, fuel briquettes.

On the basis of raw material of the plot explored in detail (category of study A, the area in the zero border of 1 597 ha) one can organize production of dry humates and nutritive briquettes, the duration of their use amounts to 13 and 6 years respectively. At present time it is projected to attach to the reserve of Vasyugan a status of UNESCO Universal natural heritage.

The campaign for the allotment of protected areas with peaty swampy ecosystems will also carry on in the years to come. In this respect we would like to mention that the allotment of the protected fund (including wetlands as well) should be well founded from the scientific viewpoint. In this case it is done by means of allotment of environmental and economic funds (EEF).

Environmental and economic fund of the peat recourses means the total peat resources and their plots as a special natural territorial unit which performs definite environmental, economic or environmental and economic functions and which is used at this moment (existing EEF) or is planned to be used (predicted EEF).

The determination of the existing EEF is carried out on the basis of the data of prospecting, project and other materials.

After the revelation of the existing EEF the formation of the predicted EEF is performed. In this case the dormant fund is distributed in the direction of its most efficient use taking into account the criteria of allotment of EEF (Fig. 26).

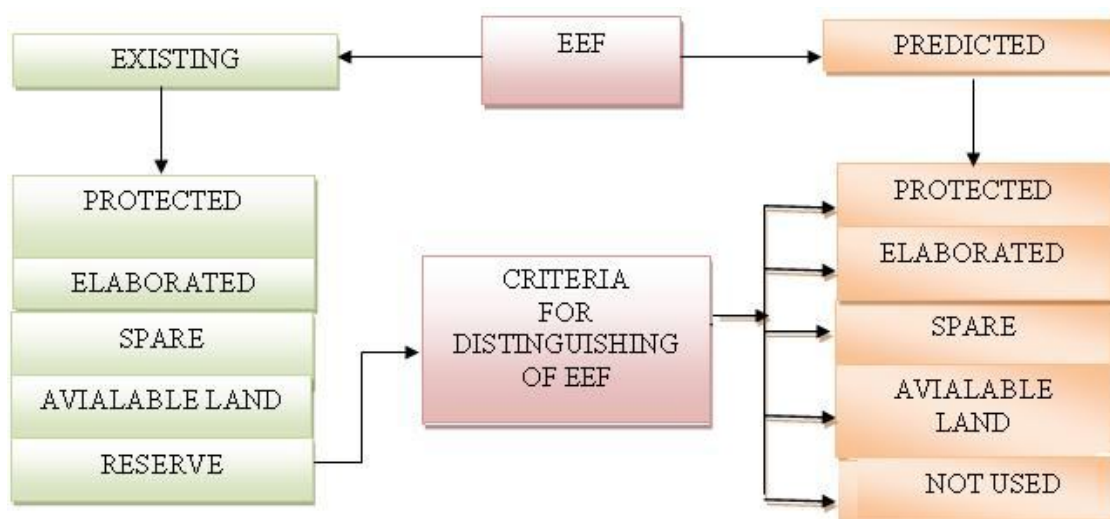


Fig. 26. Spreading of peat recourses of Environmental and economic fund (EEF)

It should be noted that with the regard to the areas with weakly studied and unstudied peat resources the distribution of the peat fund according to the predicted data of EEF can be changed when the new information becomes available, but it can be changed not only because of redistribution of the unused fund but on the whole because of the revision of all the funds marked out earlier.

The guarded fund of the peat resources means total peat deposits or their plots, which are conserved in natural state with respective complex of nature-protective measures.

The distribution of the peat resources within the limits of the EEF is performed first of all with the allotment of the guarded fund. The area of the nature-protective fund is recommended to occupy up to 15 % of the total area of the region.

The existing guarded fund means peat deposits or their plots within the limits of the known nature-protective zones (reserves, game-reserves, green zones of the towns, scientific research stations etc.).

The predicted guarded fund includes additionally to the exiting one the peat deposits or their plots, which are recommended to be conserved on the basis of the elaborated criteria after conducting research.

It is proposed to take into account the following regulations for allotment of the peaty mires and their plots into protected fund, in particular, if they have been already explored for industrial use:

1. Objects of water-protective importance:

a) These are situated on the watersheds; water flowing from them is a feeding source of small rivers and large lakes at a mean water expense of 1 l per second and more of the principal source;

b) In case of availability of springs used in balneology or as a source of drinking water with production rate of 0.2 l per second;

c) Objects of the area from 1 to 10 ha situated on agricultural lands and from 1 to 30 ha if they are regulators of water regime and a source of fauna water nutrition;

d) If the underlying ground of the peat deposit and the ground of adjacent territories are formed by sands and if it is impossible to provide a necessary groundwater table.

2. The typical floodplain deposits and deposits which protect agricultural lands from erosion (they are revealed by means of survey) are preserved in order to protect river floodplains from soil erosion.

3. The peat deposits are kept in reserve for the protection of wild-growing berries and medicinal herbs:

a) When the area of cranberry plots amounts to 15 % and more of the total area; furthermore, the average annual cranberry yield should be more than 100 kg per ha.; the total area of cranberry plot should be more than 10 ha on one peat deposit.

b) In every natural region 3–4 typical deposits are kept in reserve (they are

revealed by special surveys) with the largest amount of species and reserves of medicinal plants.

4. At least two reserves are created in every natural region in order to preserve rare and close to extinction species of fauna and flora.

5. The peat deposits are preserved for the scientific purposes where the research is being conducted as well as the deposits, which are unique in genetic and geochemical respects (by conclusion of the scientists).

6. For the recreation and health purposes it is prohibited to exploit the peat deposits for peat extraction within the bounds of 5–10 km and 10–25 km if they are situated near the towns of 20–100 thou. and more than 100 thou. inhabitants respectively. The protective zone should be increased by 25 % if there are enterprises of chemical industry in the towns.

7. For hunting and fishing purposes the peat deposits, which play the dominant role in the reproduction of valuable species of hunting fauna, are preserved, as well as all the unique lakes rich in fish (it is performed by proposal of the Nature Protection Committee, Administration and Society of hunters and fishers).

8. The peat deposits and territories, which are used by migratory birds for the rest and food during passage, are included into guarded fund (by conclusion of the scientists).

9. Furthermore, the peat deposits are reserved in order to keep up the equilibrium in the environmental systems if the area of the mires kept in natural state (according to the above-said criteria) occupies less than 15 % of the total territory.

10. The peat deposits that are within the limits of the especially protected natural territory are included into the guarded fund.

11. The peat deposits which satisfy the criteria of international significance and which are the unique land for the given territory are included into the guarded fund.

12. All the oligotrophic mires situated on the watersheds and as much as 40-50% of the rest of mires are included into the guarded fund in the sites of widespread drainage works.

The deposits, where bituminous and hydrolysable raw material is found, are included into the **reserve fund**. The same fund includes the deposits having raw material for the production of metallurgical fuel, activated carbon and humic acids. As for balneology, the proper criteria are given in (Table 21).

The peat deposits having raw material for production of traditional kinds of peat products such as fuel, organic fertilizers and composts, litter, building thermal protection belong to the **fund under elaboration**.

The criteria of the classification of such deposits are based on the requirements for standard and conventional raw material. The requirements for the peat deposits on the same deposit are estimated based on annual capacity of the reprocessor of the raw material; and at the same time the factor of extraction of 0,5 and the period of

extraction as long as 25 years are taken into account.

Table 21

Principal criteria for determination of stock fund

Criteria	Production				
	Hydrolysis products	Metallurgical fuel	Bitumen	Active coals	Humic substances
Location of peat deposit	Close to arterial roads				
Minimum peat stocks, with humidity of 40 %, mln.t.	40	470 (for agglomelations)	Total peat stocks for obtaining bitumen active coals, humic acids, 4 mln. t		
Type and kind of peat	Raised, sphagnum, Scheuchzeria-spagnum	All kinds with the exception of raised forest	Raised	Raised of Eriophorum group, raised sedge	All kinds of peat
Botanical composition				Low content of Scheuchzeria and timber crust	
Degree of decomposition, %	Not more than 20	Medium and high	30 and more	More than 30	25 and more
Ash content, %	Not more than 5	Not more than 7	Not more than 6		Upto 10
Chemical composition	Content of reducing substances not more than 45%		Bitumen content in benzene extraction more than 5%		Content of humic acids not more than 30%

Note: Peat to be utilized in the rotating ovens may contain ash elements as much as up to 20 % but for all that ash melting point can be above 1300 °C, and the ratio CaO+MgO/S can be not less than 3.

The generalized criteria of separation of the fund under the elaboration are given in (Table 22). It should be noted that the peat used for obtaining litter and heat-insulated slabs is also suitable for manufacturing of some kinds of agricultural products, for example, substrate slabs, nutritive blocks, peaty pots, microhotbeds, peat-soddy carpets.

The raised sphagnum weakly decomposed peat, which contains less than 10 % of ash, is used for obtaining the baled exportable peat.

Land fund. Some deposits can be efficiently used after drainage as agricultural lands (ploghlands, pastures and haylands) or for foresting.

The experience showed that the best results had been obtained in this direction on the deposits of raised and fen types.

The deposits located in the promising agricultural zone can be recommended to be used as expedient agricultural lands. The more swamped remote areas can represent the forest fund with the greater thickness of the peat deposit.

Table 22

Principal criteria for isolation of the elaborated fund

Criteria	Fuel pea, milled peat	Milled peat for briquetting	Pert for agriculture		Peat for thermoinsulating slabs
			Composts	Litter	
Location of peat deposits	In the regions with outlook of industrial development я		In the regions of developed agriculture		Close to arterial roads
Minimum peat stocks, with humadity of 40 %, mln.t.	75	1	10	10	1
Type and kind of peat	Of all the types	Swampy ones of all the types	Of all the types	Raised, transitional	Raised sphagnum
Botaincal composition				Eriophorum. Less than 15%	Sphagnum mosses, more than 85-90%
Degee of decomposition, %	More than 10– 15	More than 30	More than 15	Less than 15	5–12
Ash content, %	Less than 23	Less than 23	Less than 25	Less than 15	
Chemical composition			Fe ₂ O ₃ , CaO les than 5%		
Acidity			pH = 2.5–5		

Note: In order to prepare the compost in some cases the use of peat is permitted with ash content up to 35 %, and up to 40 % in case of the presence of vivianites and carbonates

The following objects can belong to the land fund:

- 1) Low in thickness peat deposits where the average depth is not more than 1.3 m;
- 2) Peat deposits with high ash content (more than 35 %) and iron protoxide content more than 3 %;
- 3) Peripheral plots of the peat tracts situated on the territories perspective for foresting;
- 4) Peat deposits of fen and transitional types on the territories provided for forest management.

Non-used or reserve fund includes peat deposits, which direction of use has not been determined yet or which are not used nowadays for some reason.

When one reviews the criteria of the guarded fund it can be noted that some criteria (for example points 4, 5, 7, 8) which are not connected with natural and climatic peculiarities of the regions can be regulated by proper normative documents; furthermore, these criteria (points) have a definite protection regime and can be used on any territory.

At the same time, it is quite probable that namely these criteria can be changed at more detailed review or supplemented in accordance with the specific features of formation of horizontal and landscapes connections and borders between man-made and natural landscapes.

Such specific features can influence, for example, the size and shape of the health zones of the towns, water-protective zones of the reservoirs, river etc. These criteria can be named as the criteria of general significance.

Another group of criteria (points 1, 3) requires scientific study in accordance with the conditions of Western Siberia.

Thus, if the guarded fund is distinguished by the presence of lakes on the mire as the Belarusian scientists recommend it, Vasyugan mire, for example will prove to be the guarded one.

Therefore, it is necessary to work out other criteria of the guarded fund for the territories, which are characterized by abundance of large mire systems with a high spreading of lakes and a unique mire hydrographic network.

The creation of such criteria would competently permit to distribute them into the environmental and economic funds. Without these criteria it is impossible to start the establishment of environmental and economic fund of the peat recourses of Vasyugan mire.

It should be emphasized that it is necessary to perform the regioning of water balance of the swamped area based on the study of the mires position in the geodynamical system, underlying rocks, interaction of surface and underground waters, feeding conditions and run-off from the swampy tracts.

Long-term field research is necessary, to our mind, within the bounds of the basins of the mire rivers of various kinds in order to work out the criteria for setting up the guarded fund of the mire systems of strongly swamped territories.

The subordination of the landscape units of the river basin, as a functionally integrated geosystem, is taken into account in the basin approach to the problem; as a matter of fact, the geosystem in question consists of elementary landscape systems of different hypsometric levels, which are connected between each other by streams of matter and energy.

The complex research should be carried out in order to cover a wide range of questions, i.e. from the study of environment-forming part of the mires to the properties of the peats which compose the peat deposit and their influence on the elements cycle in the biosphere.

6. CONTEMPORARY REGIMES IN GEOCHEMICALLY CONNECTED LANDSCAPES OF OLIGOTROPHIC SERIES

In 1994 there emerged a need to establish a field observation station on the mire on the implementation of the subject matter “Working out of the system of the efficient use of the peat recourses with the regard to environmental part of the mires in the drainage basins” by the contract with the Ministry of Environment and Natural Recourses Protection of the Russian Federation.

This field station organized on the spurs of Vasyugan mire began to function in 1995 in the outskirts of the settlement of Polymaynka of Bakchar district of Tomsk region. The study of the directions of the rational use of the peat recourses of Western Siberia was the principal purpose of the research.

The following tasks were set up:

- Study of water and geochemical run-off from the mires and swamped basins;
- Study of hydrothermal regime of the peat deposits;
- Study of the role of the mire ecosystems (MES) in biogeochemical turnover of chemical elements;
- Study of the processes of the transformation of organic matter in the peats and peat deposits and the elaboration of scientific fundamentals of their directional regulation;
- Elaboration of criteria for distributing special funds and definition of the directions of the efficient use of the peat recourses of Western Siberia.

Taking into account that the research should be conducted both in natural and drained mire ecosystems (MES), the testing area had to cover 208 sq. km. The geographical position of the area under the research is as follows; between latitudes of 57°03' and 56°57' North and longitudes of 82°22' and 82°42' East.

The research of virgin MES was performed within the limits of the spurs of the Vasyugan peat deposit on the oligotrophic landscapes of the basin of the River of Klyuch (in the original state).

The observations were conducted on three objects of man-disturbed MES: Sukhoye-Vavilovskoye (cadastre number 10) used for peat extraction; Sukhovskoye (cadastre number 755) and “The fifth plot” near the settlement of Plotnikovo of the Vasyugan peat deposit used for the silvicultural reclamation.

The planned task was solved based on the following methods: field research (comparative and descriptive, regime observation under field conditions), laboratory assays (chemical and analytical, microbiological, enzymological) and office studies (model experiments, use of various ways of mathematical data processing and mathematical modeling). The book gives the results of the study of regimes and of the peat deposits on geochemically connected landscapes of oligotrophic series (landscape profile).

Landscape profile (catena) is a three-dimensional regularly organized body, which has its taxonomic distinctness, structure and proper spatial and temporal properties. As for the catena, the mire systems are coordinated in the landscape with geology (stratigraphic study of lithogenesis and peat genesis), hydrology, meteorology and natural regime cycles.

The catena as a geosystem model permits to conduct the scheduled natural complex research; furthermore, the most efficient results can be obtained in the drained basins. The complex research was conducted in the water-thermal, hydrological, biological and geochemical regimes in the landscape profile of the oligotrophic mires.

The balance research of the substantial composition of the stratigraphic deposits of the mire systems and their movable compounds permitted to use the obtained data in the model of substance turnover at the paludified territory of Western Siberia.

The objective of this part of the unit is to show the results of the field research. The researchers, postgraduates, students of Tomsk State Pedagogical University, National Research Tomsk State University, the Institute of Petroleum Chemistry of SB RAS, the Institute of Peat of the Russian Academy of Agricultural Sciences, the Geological Institute of the University of Neshatel (Switzerland), the Research Institute of Ecology of Agriculture and Forestry of the Polish Academy of Sciences etc. participated in this project in different periods of time.

The All-Russian school of young scientists “Mires and biosphere” is organized on the basis of our field research.

6.1. Specific Features of Environmental Conditions

According to the landscape regioning [58] the area under the research belongs to the type of West-Siberian landscapes, group of low-lying alluvial and lacustrine loamy flat plains.

According to the landscape-geochemical regioning of West-Siberian flat plain [97], the area under the research belongs to swampy-taiga low and medium-productive region with a slow and low capacity biological cycle of calcium-nitrogen type in combination with silicon-nitrogen, acid and acid gley classes of water migration with iodine, iodine-bromine and bromine underground mineral waters.

Climate. The climate of the territory under the research is continental. The average annual air temperature is 1.6 °C, the coldest temperature (January) is –20 °C.

The absolute minimum is –51.3 °C; the absolute maximum is +36.1 °C. The passage of the average daily air temperature through 0 °C is observed in spring on average on the 16th of April, in autumn on the 17th of October.

The region is situated in the zone of excessive moistening. The annual precipitation amounts to 469–506 mm; during the warm season the precipitation is equal to 329–375 mm; it makes up 70 % of the total precipitation.

The stable snow cover is formed in the third ten-day period of October. The most

average thickness of the snow cover amounts to 40–60 on the open plots, and 60–80 cm on those of protected. The destruction of the stable snow cover takes place in the second or third decade of April. The mean snow cover period amounts to 175 days [1].

Geology and geomorphology. The territory is a hilly paludified flat plain of 90–130 m above the sea level. Two types of relief of the first order are distinguished: the erosion-accumulative relief (floodplain and the third above-floodplain terrace of the river of Bakchar) and the erosion one (ancient lacustrine-alluvial Medium Quaternary flat plain and its slope).

Contemporary lacustrine-swampy deposits are widely spread on the watersheds as well as on the surface of the terraces and floodplain.

The mire deposits are represented by peat, their age is not more than 10 000 years, and solid waterproof clays of the unified Shirtin and Tas horizons underlie these.

In its foundation the lacustrine-mire deposits have a layer up to 0.8 m thick, it is represented by strongly developed bog mucky dark grey rich in humus clay which sometimes contains shells of freshwater mollusks. The thickness of the deposit ranges from 0.5 to 4 m in the central part.

Soils and vegetation. According to the soil geography regioning by G. V. Dobrovolsky and co-authors [17] the territory of Bakchar district belongs to the West-Siberian province of southern taiga subbelt.

The main part of the territory is occupied by soddy gley soils of different degree of moistening and by wetlands.

The total degree of paludification reaches 50%. The territory under research is entirely situated within the bounds of the ancient valley of the former Ob River; this circumstance defines not only the configuration of the mires and their location but also specific features of the composition and structure of the peat deposit.

The ridge and ridge-hollow raised bogs with simple convex surface are widely spread on the watershed plateaus; their thickness reaches up to 3.4 m.

The specific feature of these bogs, which distinguishes from the bogs of the adjacent territories, consists in rather a common bilayer structure of the peat deposits. As a rule, the bottom strata of the peat are formed by sedge or sedge-hypnum peats [78], which have rather recently been surpassed by the contemporary deposits of raised sphagnum peats.

Such a diversity of the types of the peat deposit is explained by the prolonged phase of their development; in its turn, it is caused by the increased calcareousness of the underlying rocks.

On the periphery of the watershed the wetlands with tall arborescent layer and thin peat deposit are widely spread.

Because of the regular development of the complex oligotrophic tracts of the mires the plant cover usually consists of the following component parts which alternate

each other from the borders to the centre: eutrophic associations of swamp subors with reedstands; narrow mesotrophic stripe; oligotrophic facies – pine-undershrub mossy (ryams), cotton grass- sphagnum communities and transit marshes.

On the whole, “vast mire tracts, in essence, are component parts of the Vasyugan mire which like tongue-shaped inclusions get into the watersheds of the Iksa-Shegarka, the Iksa-Bakchar, the Bakchar-Teterenka, the Andarma-Galka and others.” [69, p. 63].

Field component descriptions, office interpretations of airphotos of 1: 16 000 scale (1986) have been conducted in order to reveal the influence of natural factors and to obtain quantitative indices; these data served as a basis to chart the landscape typological map of 1: 25 000 scale.

The kinds of landscapes (by V. A. Nikolayev [101]) and all the tracts dominating in the landscape have been taken into account as mapping units. The kinds of landscapes have been unified into genera by geological and geomorphologic signs (lacustrine alluvial flat plains); the genera into sybtypes the by zonal sign (southern taiga); subtypes have been grouped into types by soil and botanical signs (wetlands). The types serve as indicator of landscape degree of hydromorphism.

It means that in the name of natural territorial complex (NTC) the taxonomic landscape series are found: kinds, sequences, subtype; it is in compliance with the compiled map. Altogether as much as 56 NTCs were distinguished and described on the territory [53].

6.2. Characteristics of Geochemically Connected Landscapes of the Basin of the River of Klyuch

Separate research was conducted within the bounds of the watershed mire ecosystem (MES) on oligotrophic landscapes of the basin of the River of Klyuch. The catchment of the Klyuch River (the right tributary of the River of Bakchar, the area amounts to 58 sq. km.) is practically represented by MES in question and thus, swampy waters of the spurs of the Vasyugan mire are the main source of feeding of this water stream (Fig. 27).

The hydrological regime of the River of Klyuch depends on water exchange between MES and the surrounding territory. In the middle and upper courses the valley of this river is weakly developed. In the estuary part (where it flows into the River of Bakchar) the riverbed is cut up to the depth of 20–25 m into the strata of loams and clays[110].

The degree of paludification of the basin of the River Klyuch amounts to about 70%. The river sources are on the periphery of the raised bog tract. The length of the slopes (without riverbeds) amounts to 2.5–6.0 km along the running-off line from the source of the River of Klyuch to the watershed.

The plot under research, which includes the biogeocenoses connected geochemically with the landscapes, is the model system for the Bakchar mire district [78]. According to our data, the age of the mire is dated back to 2500–4800 years.

Point 1 (birch-pine green mossy paludified forest) is in the estuary of the River of Klyuch having its source from the mire (Fig. 27).

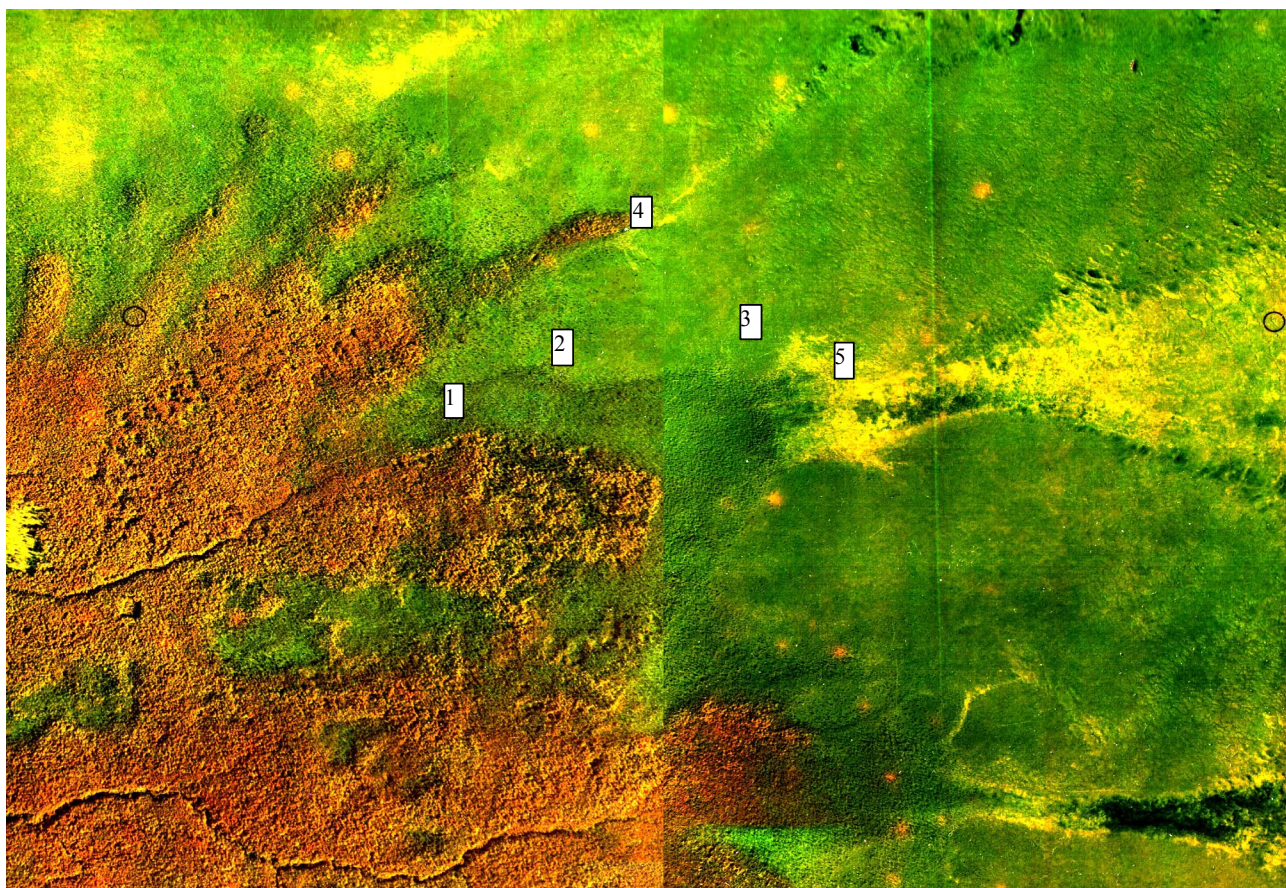


Fig. 27. Points of description of phytocenoses on landscapes of the River Klyuch basin

Point 2 (pine-undershrub-sphagnum biocenoses, high ryam, (Fig. 7). It is a border of the peaty mire.

The peat deposit of tall ryam (Fig. 28) is 90 cm thick; its structure is forest-marshy. It is formed by five kinds of peats. Only two of them, i.e. fen sedge and pine-cotton grassy, are of 20 cm thick (each of them takes part in the structure of the peat deposit as much as 29 %), the remaining peat kinds reach up to 10 cm in thickness (the percentage of participation of each of them amounts to 14).

As for point 2, the layer of fen sedge peat of high degree of decomposition (65 %) is located in its foundation.

Later on, the mesotrophic stage becomes apparent in the development of the mire. At this stage the plat groupings formed the layer of well-decomposed transitional peat of three kinds: wood-sphagnum, cotton grassy and wood-herbaceous.

The mesotrophic stage of development of the mire vegetation is changed by the oligotrophic stage during which the raised peat of two kinds was formed; pine-cotton grassy and peat-magellanicum. The raised peat is notable for the medium and low degree of decomposition. Mean degree of decomposition of the peat deposits amounts to 39 %.

Therefore, the stratigraphic features of the peat deposit define the development of

the border part of the peat tract where plant associations of forest-marshy type were predominant in the course of a long-term period.

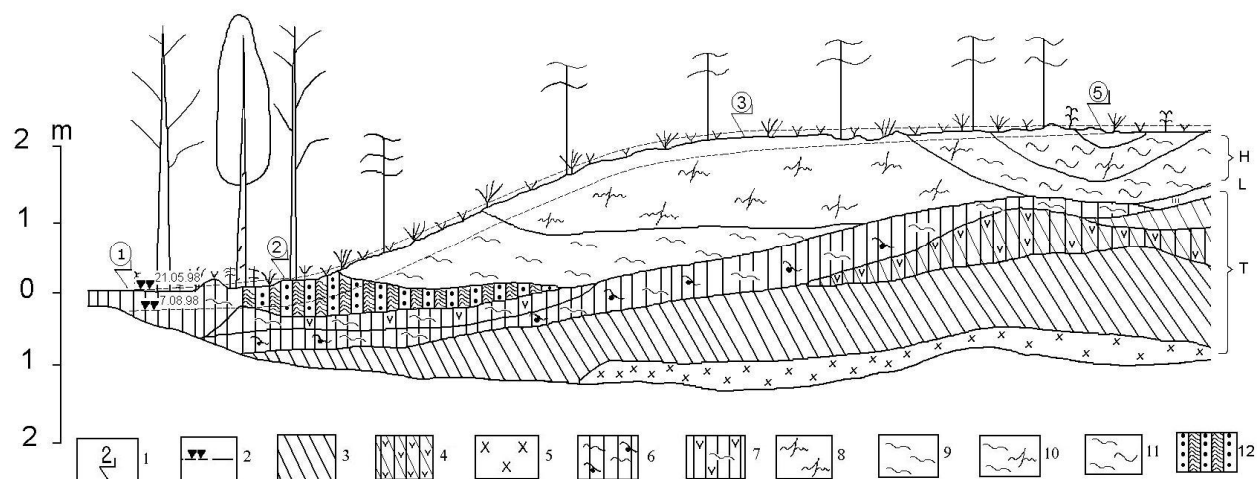


Fig. 28. Criteria for placement of observation points within landscapes of the basin of the River of Klyuch: 1 – observation points; 2 – mire water table. Kind of peat: 3 – fen sedge, 4 – fen wood-sedge, 5 – fen horsetail, 6 – transitional wood-sphagnum, 7 – transitional wood-grass, 8 – fuscum peat, 9 – magellanicum peat, 10 – raised complex, 11 – peat of mire depressions, 12 – raised pine-cottongrass. Observation points on mire phytocenoses: 1 – birch-pine-green moss paludal forest; 2 – high ryam; 3 – low ryam; 5 – sedge-sphagnum swamp. Types of deposits: H – raised; L – transitional; T – fen.

Point 3 (spine-undershrub-sphagnum phytocenosis, low ryam) is spread along the profile (850 m) and is a typical ryam (Figs. 8, 27).

The structure of the peat deposit defines the most widely spread facies of the peat tract under the research, i.e. ryam (Fig. 28). The largest revealed thickness of the peat is equal to 3 m in this point; the deposit is of a mixed marshy type.

The raised peat is represented by two kinds such as fuscum of a weak degree of decomposition (40 % of participation) and magellanicum of a medium degree of decomposition (10 % of participation), these kinds of the peat form a thicker layer of the raised peat (1.5 m) as compared with the other points.

The layer of the fen peat is situated in the foundation of the peat deposit; its thickness is equal to 30 cm (10 % of participation) and a degree of decomposition accounts to 50 %. The thicker layer of the fen sedge peat (40–50 % of participation) is located above it.

At the turn of two layers, i.e. raised and fen peats, the peat layer of transitional type is situated which was formerly formed by existing here mesotrophic plant communities such as wood-sedge and wood-sphagnum.

The availability of the great part of herbaceous remains among the fossil plants in the peat is the evidence of the decrease in moistening and climate warming at the mesotrophic stage of the mire development.

Point 4 (Fig. 27) is also, just the same as in the case with point 2, represented by pine-undershrub-sphagnum phytocenosis on the border of the raised bog; but within

the bounds of this territory the mire does not grow upwards but inwards occupying the adjacent dry lands.

It is evidenced by the structure of the peat deposit. The upper layer (0–20 cm) is formed by raised fuscum peat of medium degree of decomposition, the layers of transitional wood-herbaceous, herb-sedge and fen wood peats are found below.

When moving to the center of the mire one can notice that sedge-sphagnum formation (herb-moss class of formation) is followed by the pine-undershrub-sphagnum group of formations.

The ridge and shallow-hollow complex of the groups of formations is situated at the interfaces between them; this complex resembles a stripe of 50–80 m wide (point 6, Fig. 27).

The peat deposit is of a complex structure, i.e. the ridge and hollow. The stratum of the raised peat is found above it as in all the other boreholes of oligotrophic landscapes of the basin of the River Klyuch.

The combination of the layers is diverse below the ridges and hollows. The layers of complex (25 % of participation) and hollow (17 % of participation) kinds of the peat alternate below the hollows, the layers of fuscum (14 % of participation), magellanicum (4,5% of participation) and cotton grass-sphagnum (18 %) kinds of peats are below the ridges.

The raised peat is weakly decomposed only on the surface and from the depth of 0.5 m the peat deposit is of a medium degree of decomposition.

It should be supposed that the transitional stage was short-term, it can be judged by the thickness of the deposited transitional kinds of the peats; the thickness amounts to 10 cm below a hollow of Scheuchzeria peat type and 30 cm below a ridge of sedge and a wood-herbaceous type.

Fen peat type is found below the transitional peat on ridges and hollows, two peat kinds are predominant here such as the wood-herbaceous peat and the sedge peat of a high degree of decomposition.

Point 5 is a peripheral part of the open sedge-sphagnum marsh (Fig. 27). The layer of the raised peat defines the oligotrophic stage of the mire development, which is revealed in the successive change of peat kinds: hollow, raised complex and fuscum ones (Fig. 28).

The process of replacement of plant groupings occurred very quickly in case of transfer of the mire from the stage of ground feeding to that of the atmospheric one; furthermore, the transfer did not reflect on the peat deposit. Therefore, the transitional peat is not found here.

The hollow forms the underlying layers from the depth of 120 cm, mostly by sedge peats (34.6 %). The average degree of hollow peat decomposition accounts to 35 % with fluctuations of 25 to 40 % in different layers.

Therefore, the history of evolution of the mire tract in the basin of the River of

Klyuch is extremely clearly pronounced by the stratigraphy of the peat deposit beginning with the predominance of the eutrophic herbaceous phytocenosis, for example, horsetail and then sedge.

The essential predominance of the eutrophic and mesotrophic stages is worthy of noting.

The transfer to the oligotrophic stage is accompanied by the formation of pine-undershrub-sphagnum communities. Nowadays the biggest part of the peat deposit of oligotrophic landscapes of the basin of the River of Klyuch changed to the oligotrophic stage of evolution, the thickness of the raised peat reaches 120 cm.

6.3. Chemical and Biological Properties of Peat Deposits of Geochemically Connected Mire Landscapes

The general technical characteristics of the peats are given in (Table 23). The upper layer the peat deposit (point 3) consists of peats of mossy group, below it the peat deposit is represented by fen herbaceous species. As for the peat deposit of point 2, here the transitional wood-herbaceous peat kinds are the most common.

The individual plant associations such as sphagnum mosses (*fussum*, *magellanicum*), cotton grass and sedges are mainly developed. These define the degree of decomposition, which increases with the depth of deposition in transition from mossy peat kinds to those of arborescent ones from 5 to 65 %.

The ash content in raised slightly transformed peats is low and amounts to 2, 1–5, 2 %. Transitional and fen peats are notable for the normal ash content, which reaches 10.9 %. The mineralization is greatly increased in the underlying grounds only.

The density and porosity are the most important characteristics, which many parameters of functioning of the peat deposits depend on.

Their values are essentially distinct in the active layer and underlying inert horizon. The natural research on the determination of peat density in the upper horizon of the landscape profile conducted by us is given in (Table 24). The regular depthwise increase in the skeleton density of the peat is observed.

The pH value gradually changes from weakly acid to acid from periphery to the center of the mire tract. The pH value of salt suspension changes depthwise from strongly acid-to-acid.

Hydrolytic acidity changes throughout the profile of the peat deposits from the upper horizons to those of lower ones as well as in the sequence: paludified forest – low ryam.

Table 23

Characteristic of botanical composition of peats

Depth, cm	Peat kind, deposit type	Botanical composition, %	R/A, %
High ryam, p. 2			
0-25	Pine-cotton grass-sphagnum, Rt	Pinus-35; Sph. Magellanicum-20; Sph. Angustifolium-10; Eriophorum-25; Undershrubs-10	35/5.8
25-50	Wood-cotton grass, T	Pinus, Betula-30; Undershrubs-10; Sph. Magellanicum-5; C. Lasiocarpa-rare; C. Rostrata-10; Eriophorum-45	55/4.7
50-80	Wood-cotton grass, T	Pinus, Betula-25; Undershrubs Sph. Magellanicum-5; Sph. Flexiosum-5; C. Rostrata-10; C. Lasiocarpa-5; C. Globularis-5; Eriophorum-40; Equisetum- rare.	55/6.8
Low ryam, p. 3			
0-100	Fussum peat	Undershrubs-solitary; Sph. Fussum-90; Sph. Magellanicum-10; Sph. Angustifolium-rare,	5/1.5
100-150	Medium peat	Undershrubs-5; Sph. Fussum-25; Sph. Magellanicum-40; Sph. Angustifolium-25	10/3.1
150-200	Pine-cotton grass-sphagnum, Rt	Pinus-25; Undershrubs-10; Sph. Magellanicum-15; Sph. Angustifolium-10; Sph. Fussum-10; Eriophorum-30	50/4.6
200-250	Sedge, F	Wood-solitary; Eriophorum-10; C. Rostrata-10; C. Lasiocarpa-35; Menyanthes trifoliolate-10; Fern-5; Equisetum-units, Sph. Centrale-10; C. Limosa-solitary;	45/4.0
250-300	Herbaceous, F	Wood-5; C. Rostrata-5; C. Lasiocarpa-20; Fern-35; Menyanthes trifoliolate-5; Drepanocladus sendtneri-10; Meesia triquetra-rare; Sph. Centrale-10; Sph. Riparium-5; Carex sp.-5	40/6.2
Sedge-sphagnum marsh, p. 5			
0-50	Fussum peat	Sph. Balticum-10; Sph. Jensenii-rare; Sph. Flexuosum-60; Sph. Fallax-10; Sph. Magellanicum-10; Eriophorum-5	0/2,3
50-100	Complex, Rt	Sph. Majus-10; Sph. Jensenii-15; Sph. Obtusum-35; Sph. Papillosum-10; Sph. Flexuosum-10; C. Rostrata-5; C. limosa-solitary; Eriophorum-5; Equisetum-5	15/3.1
100-150	Sedge-sphagnum, T	C. Rostrata-20; C. Lasiocarpa-10; Scheuchzeria palustris-5; Menyanthes trifoliolate-5; Equisetum-10; Sph. Majus-solitary; Sph. Jensenii-5; Sph. Obtusum-20; Sph. Magellanicum-5; Undershrubs, Pinus, Betula-15	35/5.5
150-200	Sedge, F	C. Rostrata-25; C. Lasiocarpa-15; Carex sp.-10; Wood-5; Menyanthes trifoliolate-10; Equisetum, Fern-10; Sph. Fallax-5; Sph. Obtusum-10; Sph. Papillosum-5	50/5.8
200-250	Herbaceous, F	Equisetum-5; Fern-35; C. Rostrata-10; C. Lasiocarpa-15; Carex sp.-solitary; Sph. Fallax-5; Menyanthes trifoliolate-20; Sph. Obtusum-5	50/9.2
250-300	Fern, F	Wood-10; Fern-60; Horsetail-5; Bogbean-10; Carex rostrata-5; C. asparatilis-5; Carex sp.-solitary; Sph. dusenii-solitary; Sph. apiculatum-5	40/6.8

Note: Rt – raised type; T – transitional type; F – fen type; R – degree of decomposition, %; A – ash content, %.

Table 24

Water and physical properties of peats

Point	Depth, cm	Density, g/cm ³	Density of solid phase, g per cu. cm	Porosity, %
Paludal forest	10	0.135	—	—
	20	0.180	—	—
High ryam	10	0.058	1.45	95.99
	20	0.081	1.42	94.30
	30	0.108	1.41	92.34
	40	0.113	1.45	92.22
	50	0.115	1.42	91.87
Low ryam	10	—	—	—
	20	0.021	1.64	98.73
	30	0.032	1.62	98.03
	40	0.046	1.61	97.17
	50	0.047	1.55	96.94
Open swamp	10	0.021	1.53	98.63
	20	0.054	—	—
	30	—	1.48	—

The total sum of absorbed bases and the degree of the base saturation increases downwards the profile of the peat deposits; this fact is defined by calcareousness of underlying rocks (Table 25).

Table 25

Physical and chemical properties of peats (extreme values)

Parameters	Depth, cm	High ryam	Low ryam
pH salt suspension	0–100	3.26–5.07	2.39–2.66
	100–200		2.83–3.68
	More than 200		4.18–4.54
Exchangeable bases, meq per 100 g soil	0–100	48–118	6–18
	100–200		12–52
	More than 200		70–74
Hydrolytic acidity, meq per 100 g soil	0–100	45–84	102–111
	100–200		81–105
	More than 200		39–69
Base saturation, %	0–100	36.4–72.4	5.2–14.3
	100–200		10.0–43.0
	200–300		52.6–64.2

The distribution of movable iron and aluminium downward the profile simultaneously changes with the pH value: maximum of their content is concentrated in the lower part of the profile where the reaction is weakly acid.

The highest content of movable aluminium (35.87 mg per 100 g) is common for the peats of the fen peat deposit. Movable phosphorus is accumulated in the upper horizons (11.37–32.08 mg per 100 g) and lower part of the profile (7.31–18.67 mg per 100 g) (Table 26).

The content of movable potassium also increases in the upper horizons of the peat deposits. In the peat deposit of the sedge-sphagnum marsh the content of movable potassium amounts to 110.17 mg per 100 g, in the deposit of the high ryam it accounts for 50.08 mg per 100 g soil and in fen peat deposit of paludified forest – 21.28 mg per 100 g.

The insignificant increase in movable potassium content in the low part of the profile of the raised peat deposits in the low ryam is explained by the change in botanical composition.

As potassium is capable to be accumulated to a larger extent in horntails, its content increases in the layer of 275–300 cm of the peat deposit of the low ryam.

Table 26

Content of movable compounds in peats, mg per 100 g dry peat

Parameters	Depth, cm	High ryam	Low ryam
Fe ₂ O ₃	0–100	25.6–119.7	15.3–28.6
	100–200		16.5–31.8
	200–300		53.7–76.1
Al ₂ O ₃	0–100	8.8–29.3	3.9–6.1
	100–200		3.5–7.4
	200–300		6.9–17.49
K ₂ O	0–100	0.0–50.1	7.6–53.4
	100–200		5.2–10.1
	200–300		2.1–10.1
P ₂ O ₅	0–100	3.6–32.1	2.0–30.8
	100–200		0.4–2.8
	200–300		0.4–18.6
N–NH ₄	0–100	21.5–44.1	44.7–149.5
	100–200		35.5–89.2
	200–300		45.1–68.8
N–NO ₃	0–100	2.6–32.9	2.7–6.5
	100–200		4.4–5.5
	200–300		2.0–3.9

Now the chemical composition of organic matter (OM) of the peats, which forms the peat deposit of the landscape profile, will be considered.

It is significant that the botanical characteristics of the peat exert an essential influence upon its composition.

For example, the appearance of cotton grass defined the increase in bitumen content.

If we analyze comparatively the composition of OM of the surface (oxidative conditions) and lower (reductive conditions) horizons, first of all, the essential differences can be noted in the content of humic acids, lightly and sparingly hydrolysable substances (LH and SH). The process of humification is more clearly pronounced in the lower horizons.

Therefore, the increase in LH and SH substances content is noted in the layer of 0–

100 cm in the point 3 (transit part of the profile) and point 2 (transaccumulative part) (see (Table 27).

At the same time, the high content of LH is observed in the water-unloading zone (point 2, geochemical barrier of the profile).

The redistribution of water-soluble compounds can be seen in the horizon with the oxidative conditions; such fact is observed in the most contents of the transaccumulative part of the landscape throughout the whole landscape profile. This phenomenon confirms also the availability of the migration process of the substances.

The elemental composition of the peats under the research varies depending on the type and kind of the peat within the following limits: carbon 43.7–57.2 %, hydrogen 5.2–6.6 %, nitrogen 0.6–3.1 % and oxygen 33.1–56.2 %.

The average values of sulfur content range within the limits of 0.1–0.4 %. Its content increases up to 1.3 % in the underlying clays only. As the degree of decomposition and depth increases, the carbon and nitrogen content goes up and the oxygen content decreases.

Table 27

Total technical and chemical characteristics of peat deposits of biogeocenoses of landscape profile

Position in landscape profile	Layer, cm	Botanical composition	R, %	A, %	Group composition of organic matter, % of mass					
					WS	LH	SH	HA	B	R
Autonomous part (sedge-sphagnum swamp)	0–50	Peat of Sphagnum hollows	5	10.9	0.4	43.0	12.3	31.3	0.6	12.4
	50–100		5	6.0	0.3	33.4	10.5	30.5	0.2	25.1
Transit part (ryam)	0–50	Fuscum-peat	5	2.7	0.9	30.6	15.2	25.1	2.6	25.6
	50–75		5	2.0	1.2	16.6	16.4	25.2	1.7	38.9
	75–100		5	2.1	0.4	32.6	14.3	19.8	0.6	32.3
Transaccumulative part (Raised ryam)	0–25	Pine-Eriophorum-sphagnum raised Wood-Eriophorum transitional	45	5.2	1.6	22.4	4.2	27.6	3.9	40.3
	25–50		55	6.5	1.6	28.3	8.1	22.7	3.6	35.7
	50–75		60	8.0	1.2	36.6	9.2	23.3	2.6	27.4
	75–100		60	9.8	0.4	32.7	11.0	39.8	0.9	15.2

Note: R – degree of decomposition; A – ash content; WS–water-soluble; LH – lightly hydrolysable; SH – sparingly hydrolysable; HA – humic acids; B – bitumen; R – residue

The research on biogeochemistry of the peaty mires showed that the peat deposit contained considerable amounts of elements acting, therefore, as a global sorbent (Table 28).

If we compare the degree of elements accumulation in the peat deposits of the landscape profile with the average background values which we obtained earlier for the peats of oligotrophic type [56], we can see the following: the content of S, Br, Sr is commensurable with the content of the West-Siberian peats of the raised type. As for the content of Co, Zn, Sc, Cr, Sr, Hg, La, a small exceeding is noted in

comparison with the average background values.

As a matter of fact, Ca and Fe are found considerably more in the studied peats. Their background values are 0.28 and 0.2 % respectively and the highest concentration is observed in the transaccumulative part of the landscape.

Rather a high microflora activity is noted in the peat deposits of the landscape profile (Table 29).

An active part of the microorganisms in decomposition of the complex the specific features of their metabolism cause peat OM. Only relatively simple OM can be included into the microbial cell.

Therefore, the microbes decompose the peat high-molecular compounds outside the cell to form simple sugars, amino acids, fatty acids etc.

The decomposition of the peat OM occurs mainly by means of ammonifiers, destructors of nitrogen-free OM, humus-destructing microorganisms. The activity of the latter is practically identical throughout the whole profile of the peat deposit.

Earlier we observed the availability of silty dark-grey humified clay at the bottom of lacustrine and swampy deposits; this clay contained the shells of freshwater mollusks, this fact exerted influence on the formation of chemical composition of the strata of the peat deposit, changed the regime of water and mineral nutrition and led to the formation of deposits rich in mineral compounds.

This also influenced the structure of microbiocenosis.

Extreme values of microbial number in the peat deposits are characterized by the highest limits in the sedge-sphagnum marsh where the high content of easily assimilated substances is noted; and the level of swampy water does not descend below 25 cm.

The processes of mineralization are predominant in this part of the profile. It is evidenced by the SAA/MPA ratio (***the ratio of microorganism growing on starch ammonia agar to those growing on meat peptone agar is the evidence of the proportion of the processes of mineralization and humification; if this ratio is more than one the mineralization processes are prevailing and vice versa***).

As for of the peat deposit of high ryam which is a geochemical barrier of the runoff of substances from the paludified catchment of the River of Klyuch, here the ratio of SAA/MPA is the evidence of predominance of the processes of humification rather than mineralization.

Thus, the biochemical process of polymerization of the substances occurs in case of increased concentration of organic and mineral compounds introduced into transaccumulative part of the profile (point 2).

It is very interesting to examine the structure and stocks of microbe biomass in the peat deposits. This method, in contrast to that of inoculation, permits to reveal the reserve of viable microbe biomass.

Table 28

Elements content in the peat of landscape profil, $10^{-4}\%$

Biogeocenosis	Laeyr, cm	Ca*	Sc	Cr	Fe*	Co	Zn	Br	Sr	Hg	Ba	La	Ce	Sm
Sedge-sphagnum swamp	0–50	0.8	4.7	21.5	1.0	4.3	<6	27.9	<50	<20	<20	6.8	17.8	1.3
	50–100	1.8	1.6	16.5	0.9	3.7	68.5	54.4	279	20.1	97.3	2.3	7.0	0.6
Low ryam	0–50	0.7	1.1	20.9	0.6	2.0	148.0	33.4	84	72.8	58	3.4	7.0	0.6
	50–75	0.9	0.8	15.7	0.5	1.3	124.1	27.6	72	54.9	<30	1.4	3.8	0.3
	75–100	1.7	0.9	18.3	0.5	1.7	130.0	36.4	76	58.0	45	2.1	5.4	0.3
High ryam	0–25	1.4	2.4	18.1	1.1	2.8	41.4	25.2	303	92.8	129	3.4	9.9	0.3
	25–50	1.9	2.4	18.1	1.1	4.0	6.9	40.2	324	31.3	103	3.1	9.2	0.2
	50–75	2.6	3.0	18.3	1.5	6.2	<6	56.5	320	284.7	103	5.5	15.3	1.3
	75–100	2.1	2.0	16.4	1.5	5.5	31.0	55.5	396	<20	96	3.5	6.1	0.8
Background content		0.28	0.56	7.6	0.2	1.1	6.6	39.4	79.4	0.4	46.9	1.5	4.8	0.5

Note: * – less than 6%

Table 29

Limits of microbial number in pats of landscape profile in 2000 g. ($j \times 10^n$ cells per 1 g of dry matter during vegetation season)

Physiological groups	Biogeocenoses					
	Sedge-sphagnum swamp		Low ryam		High ryam	
	Layers, cm					
	0–50	50–100	0–50	50–100	0–50	50–100
Ammonifiers, j×10 ⁵	77.7–264.3	173.0–529.8	12.5–42.4	14.6–449.3	17.2–68.0	9.9–79.7
Microorganisms on SAA, j×10 ⁵	13.9–192.0	22.8–262.7	7.9–20.5	1.2–440.3	4.6–30.9	0.9–79.4
SAA/ MPA	0.1–0.8	0.1–0.5	0.3–1.6	0.1–1.0	0.1–0.6	0.1–2.1
Cellulose-destructors, anaerobes, j×10 ³	118.1–352.3	40.7–242.3	0.0–464.0	0.0–414.1	47.0–182.5	12.7–185.7
Cellulose-destructors, aerobes, j×10 ³	126.8–506.0	80.8–317.9	15.9–82.0	9.8–194.2	7.0–180.7	3.8–16.1
Activity of humus-decomposing microorganisms, %	10.1–15.1	11.4–16.1	8.2–12.7	2.3–10.3	4.1–19.3	5.4–24.2

Natural variability of the amount and concentration of microorganisms has been revealed throughout the entire depth of the peat deposit but more clearly it is revealed in the active layer.

The reserve of microbe biomass in the peat deposits of the landscape profile varies in the layer 0–100 cm from 0.18 to 1.42 kg per sq. m.; it is also the evidence of high microbiological activity in of the peat deposits of the oligotrophic sequence.

At the same time, the reserve of microbe biomass in the peat deposit of the sedge-sphagnum marsh is four times higher than in the deposit of the low ryam. The difference is noted in the main components of the microbe biomass in the surface and underlying horizons.

The fungal mycelium is prevalent in the surface layer of the deposit (43–83 %), whereas fungal spores and yeast cell prevail downwards the profile (57–93 %). There are more spores and bacterial cells in the lower part of the peat deposit (9–42 %).

Thus, the availability of active biochemical processes can be verified throughout the entire depth of the peat deposit, but the direction of the processes is different in the surface and lower horizons of the deposit.

The assessment of the reserve and taxonomic structure of fungal communities is necessary to study the biochemical processes of the destruction of peat OM in the peat deposits.

The research of the micromycete complexes was conducted by method of inoculation (the number and the list of species were analyzed) [33, 146].

As for the knowledge on the mycelium part of the complex of soil micromycete and fungal pool on the whole, it is difficult to obtain it because it is known that as much as 90 % of colonies appear on the agar-containing medium from fungal spores [141].

The method of direct microscopic calculation is more efficient for the quantitative counting of microorganisms [93].

This method permits to reveal more completely the abundance of microscopic fungi in the soil, investigate simultaneously the fungal mycelium and spores (in other words, get some idea of the morphological structure of the micromycete complex) and differentiate dark- and light-colored mycelium. It should be mentioned that the figures obtained by this method depend to a smaller extent on technical procedures; it is very essential in carrying out the assessment of indices of microbe abundance.

The analysis of the taxonomic composition of micromycete was limited to making up the list of species and determination of the relative abundance of all species found in the given ecotope.

If we consider the composition of microscopic fungi as the index of definite environmental conditions we do not need to go into details to distinguish the complete lists of species.

It will be more important to emphasize a typical complex of micromycete and describe it by means of strict quantitative criteria such as the number, concentration, stock, morphological structure and taxonomic composition of the micromycete complex.

The total micromycete number and biomass was determined directly through luminescence microscopy. The cells were preliminarily desorbed by means of ultrasonic dispersant. White calcofluor was used to stain the fungal mycelium and spores [93]. Eukaryote microbe biomass was counted taking into account the measured diameter of fungal spores and mycelium by formula ($0.836r^3 \cdot 10^{-12}$ g for spores and $0.628r^2 \cdot 10^{-6}$ g for mycelium) [114].

The number and taxonomic composition of soil micromycete were studied by the inoculation of acidified agar-containing Czapek's medium [20]. The identification of species was performed by generally accepted determinants [18, 24, 111].

The number and composition of yeast fungi was studied by the inoculation of must-agar medium acidified by lactic acid. The isolates were obtained at the room temperature and identified by the standard methods [5] with the help of a determinant [73].

The peat deposits of the landscape profile differ in their micromycete concentration and character of fungal biomass depthwise distribution.

The total concentration of eukaryote microorganisms is higher in a thin peat deposit of high ryam (point 2) than in the peat deposits of points 3 and 5 (shallow ryam and sedge-sphagnum marsh), the highest concentration is observed in the upper layer of 50 cm thick.

The distribution of these microorganisms is even within the limits of the profile in the peat deposits of points 3 and 5. The stock of the eukaryote biomass ranges from 200 g to 1.3 kg per sq. m in the deposit of 1 m thick and from 300 g to 1.2 kg per sq. m in the deposit of three m. thick (Table 30).

The stock of microscopic fungi is rather high (2–13 tons per ha), but it is insignificant in comparison with their enormous reserve of vegetative mortmass.

The portion of carbon of microbial origin (eukaryote microorganisms) is not more than 3 % in the layer of 0–50 cm, 2 % in the layer of 1 m thick and 1 % in the layer of 3 m thick (Table 30).

Table 30

Fluctuation in concentration of microscopic fungi (A), fungal biomass reserve (B) and carbon of fungal biomass (of total carbon pool (C) in peat deposits of landscape profile

	Layer, cm	High ryam	Low ryam	Sedge-sphagnum swamp
A (mg per g)	0–50	13–44	2–8	2–26
	50–100	16–56	10–21	5–30
	100–300	–*	13–24	11–36
B (kg per sq. m.)	0–50	0.2–0.9	0.05–0.1	0.05–0.7
	50–100	0.4–1.3	0.2–0.4	0.2–0.9
	100–300	–	0.3–0.5	0.5–1.2
C (%)	0–50	1–2	0.2–1	0.2–3
	50–100	0.5–1	0.4–0.8	0.3–2
	300	–	0.1–0.2	0.3–1

Note: *Data are not given for the peatland thickness is equal to 1 m.

The structure of eukaryote microbe biomass (*ratio of active compounds of the*

complex of microscopic fungi, i.e. mycelium, and those of inactive, i.e. spores) has its specific features in each peat deposit.

Thus, fungal spores prevail throughout the whole profile in the peat deposit of epy low ryam (point 3); furthermore, their proportion was higher by 10–30 % than that of mycelium in the upper layers, in the lower layers the spore prevalence became absolute (100 %).

The peat deposit of the sedge-sphagnum marsh (point 5) occupies according to the morphological structure of the micromycete complex (point 5) an intermediate position between the peat deposits of points 2 and 3.

Fungal mycelium dominates here up to the depth of 1.5–2 m and fungal spores in the deeper layers. It should be noted that fungal spores couldn't be practically distinguished from yeast cells in the electron microscope.

Therefore, it can be supposed that the high number of eukaryote cells is determined more likely by the yeast-like cell rather than the fungal spores.

Oligotrophic peat deposits are a favorable ecotope for this group of micromycetes due to the high content of plant residues, low pH value and capacity of the yeasts for oxygenic metabolism.

The yeast concentration in the peat deposit ranges from several hundreds to millions of colony-forming units per g of the peat. The spreading of the yeasts is even in the deposit, the their lowest number was noted only in the deepest layers of the peat deposit.

The yeasts are considered as a group, which is ecologically connected with the initial stages of the succession of plant residues. In fact, a negative dependence between the two parameters was discovered, i.e. a yeast number and a degree of decomposition of the peat (correlation factor $r = -0.44$ at level of significance of $p < 0.05$); this dependence indicates the existence of the back connection (the lower is the degree of decomposition, the higher is the density of the yeast groupings).

However, 114 strains were singled out during the work. The collection was represented by 17 species (both banal cosmopolitan and those peculiar to the peat deposits [39, 113]). from seven genera and a group of isolates of asporous yeasts of genera of *Candida*, *Cryptococcus* and *Rhodotorula*; these are not identified in the composition of the known species (Table 31).

Three species such as *Cryptococcus albidus* Skinner and “red” epiphyte *Rhodotorula glutinis* Harrison, *Sporobolomyces roseus* Kluyver et van Niel. prevailed in all the communities under the study.

It should be also noted the isolation of the species of *Candida paludigena* Golubev et Blagodatskaya is considered to be ecologically connected with the raised mire ecosystems [39].

Therefore, the content and the yeast species diversity in the raised peat deposits are notable, as a rule, for high indices.

The high number of yeasts is the evidence of high colonization of the peat deposit by other groups of micromycetes (it was defined by the method of inoculation), this number ranges from 0.2 to 28.6 colony-forming units per g of peat.

As a matter of fact, 55 species of micromycetes, which belong to 24 genera, were isolated and identified.

Table 31

Occurrence of yeast genera in peat deposits in oligotrophically connected landscapes

Genus	Number of species of the given genus	Occurrence
Basidiomycetes affinity		
<i>Cryptococcus</i>	5	67
<i>Rhodotorula</i>	6	71
<i>Sporobolomyces</i>	1	55
<i>Trichosporon</i>	1	19
Ascomycetes affinity		
<i>Candida</i>	4	19
<i>Debaryomyces</i>	1	7
<i>Pichia</i>	1	7

Their most part is represented by typical saprotrophes of *Deuteromycetes* class (94.6 %). The micromycetes of *Penicillium* as well as sterile mycelium *Mycelia sterilia* prevailed by frequency of occurrence (Table 32). It is known that sterile mycelium is a predominant component of micromycete communities of paludified tundra soils [109].

The high percentage of species of the genus of *Trichoderma* was found. The micromycetes of the genera of *Phialophora*, *Odiiodendron* as well as unidentified mycelium and yeast-like fungi are classified as being scarce. The spectrum of rare genera was the most impressive (Table 32).

Table 32

Taxonomic structure of micromycetes communities in peat deposits of landscape profile

Classes of abundance according to occurrence	Genus
Dominant (>60 %)	<i>Penicillium</i> , <i>Mycelia sterilia</i> ,
Frequent (30–60 %)	<i>Trichoderma</i>
Rare (10–30 %)	<i>Phialophora</i> , <i>Oidiiodendron</i> , <i>Aureobasidium</i> , <i>Candida</i> , not identified mycelium
Casual (< 10 %)	<i>Chrysosporium</i> , <i>Septonema</i> , <i>Acremonium</i> , <i>Hainessia</i> , <i>Aspergillus</i> , <i>Mortierella</i> , <i>Chloridium</i> , <i>Doratomyces</i> , <i>Geotrichum</i> , <i>Gliocladium</i> , <i>Gliomastix</i> , <i>Mucor</i> , <i>Paecilomices</i> , <i>Torula</i> , <i>Zygodesmus</i> , not identified yeast-like mycelium

On the whole, light-colored micromycetes of family *Moniliaceae* (genera *Penicillium*, *Trichoderma*, *Acremonium*, *Aspergillus*, *Geotrichum* and others) were predominant; this fact is a typical one for the micromycete complex of undisturbed boreal territories.

The relative abundance of dark-colored micromycetes of the family of

Dematiaceae (genera of *Aureobasidium*, *Oidiodendron*, *Phialophora* a.o.) varied depending on the depth of the peat deposit from 0 до 43.5 %.

The genus of *Penicillium* was represented, i.e. 20 species. The species such as *P. funiculosum* Thom, *P. lividum* Westling, *P. thomii* Maire, *P. spinulosum* Thom were the most frequent by occurrence and relative abundance; they were revealed in all depths of the peat deposit. The slowly growing populations prevail in the structure of the fungal community.

The revealed peculiarities of biochemical processes exert influence upon the formation of hydrochemical runoff from the paludified territory in the peat deposits of the landscape profile.

It should be taken into account that chemical composition of mire water and subsequently migrating stream is formed due to mixture of atmospheric precipitation with swampy waters. As for the composition of swampy water, it is defined by the arrival of movable compounds from the peat deposit, which underwent a regular biochemical transformation.

The peat deposit is subdivided by biophysical properties into two horizons, i.e. active and inactive ones.

In consequence of availability of water-bearing horizon in the peat deposit of the mire tract, the general direction of water filtration coincides with the superficial running off in active and inactive layers.

The main part of the mire waters is removed on snow melting along the active horizon into the extreme narrows on the border between the peat deposit and non-paludified part of the catchment; this water flood the narrows and form weakly running extreme marsh.

As for the summer time period, the lateral runoff from the lateral part of the autonomous part of the mire tract either ceases in the active layer or stops suddenly.

The thickness of the active layer is accepted to be equal to the distance from the mire surface to the average long-term minimum value of MWT observed during the warm season of the year.

Our research showed that the average minimum values of MWT are equal to 49.21 and 11 cm in transaccumulative, transit and autonomous pars respectively. Therefore, these depths can be accepted as an active horizon where the main runoff of mire waters occurs into the River of Klyuch. Later on, we shall consider this thesis in detail.

6.4. Contemporary Regimes

Hydrological regime. The specific features of the autumn-winter-spring season define, to a great extent, the state of the basin, character of spreading and melting of the snow cover.

The water reserve in the snow cover is a principal factor, which determines the value of spring runoff. The snow reserves in the near-swampy forest (point 1, Fig. 27) and swamp (point 5) are practically identical and are bigger on average by 20 % in comparison with the open field plots. The most nonuniform distribution of the snow

cover is noted in the ridge and hollow complex.

Snow-measuring surveys conducted on the oligotrophic landscapes of the basin of the River of Klyuch permitted to reveal the absence of any essential difference in maximum snow reserve both on paludified plots and wetlands; it permitted to use mutually results of snow-measuring surveys.

The variation factors, which characterize the spatial irregularity of spreading of snow, reserve amount to 0.10–0.15 in the forests, 0.10–0.20 in pine-sphagnum complexes, 0.40–0.70 m in ridge-hollow and ridge-pool complexes.

The analysis of water reserve values in the snow cover showed that the period of research includes winters both with the average and extreme magnitudes of snow water supply.

The intensive snow on the open mire plots and subsequent snow melting on the forest-covered one give rise to the coincidence of “swampy” and “forest” spring tide; it leads to the formation of single-model spring tide hydrograph.

The spring-summer season is notable for synchronism concerning the water levels of mires and the River of Klyuch.

The extent of spring tide defines the snow reserve and precipitation during the snow melting. The precipitation is characterized by changes in the course of the year from 99 to 214 mm.

For example, the runoff was 1, 6 times higher as compared to that of normal in a humid year when snow water reserve amounted to 129 mm and total precipitation during snow melting amounted to 95 mm.

On the contrary, during an arid year when the precipitation during spring tide and snow water reserve were 35 mm and 188 mm respectively, the runoff amounted to 70 mm; it was twice less in a humid year.

A relatively upper thin layer of the peat deposit of natural mires, the so-called active mire horizon, serves as an active zone of the hydrological cycle and heat exchange.

An unhindered filtrational water movement takes place thanks to the high porosity of the upper layer. Therefore the MWT is directly dependant on the precipitation. Seasonal fluctuations of MWT are determined by the speed of water snow running off and distribution of liquid precipitation. The irregularity of snow cover distribution on the territory of the oligotrophic mire gives rise to the irregular moistening.

According to the research by K. Y. Ivanov[61, 129], the runoff is formed after the ground water table rises upwards the upper horizons of the active layer which is characterized by high factors of filtration; these factors many times exceed possible intensities of the snow water yield and liquid precipitation.

It leads to the fact that thawing is completely consumed at the initial stage of thawing for the replenishment of water supply of the peat deposit and rising of MWT on the slopes of the raised bog tract and its borders. The essential runoff begins its formation after the rise of MWT.

Because of the late snow melting the thawing water of the open mire is partially

consumed for the saturation of snow and upper horizon, the remaining part enters the riverbeds. It proves that the level ground and swampy waters exerts an essential influence on the runoff regime before snow melting.

The frequent coincidence of “swampy” and “forest” waves of the spring tide leads mainly to the formation of a single modal hydrograph.

The highest rising of levels amounts to 0.4 m per day during the spring tide. The floodplain is submerged for 30–40 days.

The spring tide recession occurs gradually with the most intensity of 0.3 m per day and the least one of 0.3 m per day; it comes to the end in the second half of June or at the beginning of July.

During the spring tide the runoff is on average 82 mm (minimum 10 mm and maximum 267 mm).

By D. A. Burakov [13] and our observations the ground-swampy constituent in similar basins with small sinking of the riverbed does not participate in the formation of the spring tide. It is also evidenced by the fact that depth of freezing reaches 0.3–0.4 during this time.

The ground and swampy waters, which were accumulated as a result of autumn rainy precipitation, participate in the formation of the runoff after snow melting.

A close connection between the runoff of the River of Klyuch and MWT in this period of time is revealed (Fig. 29).

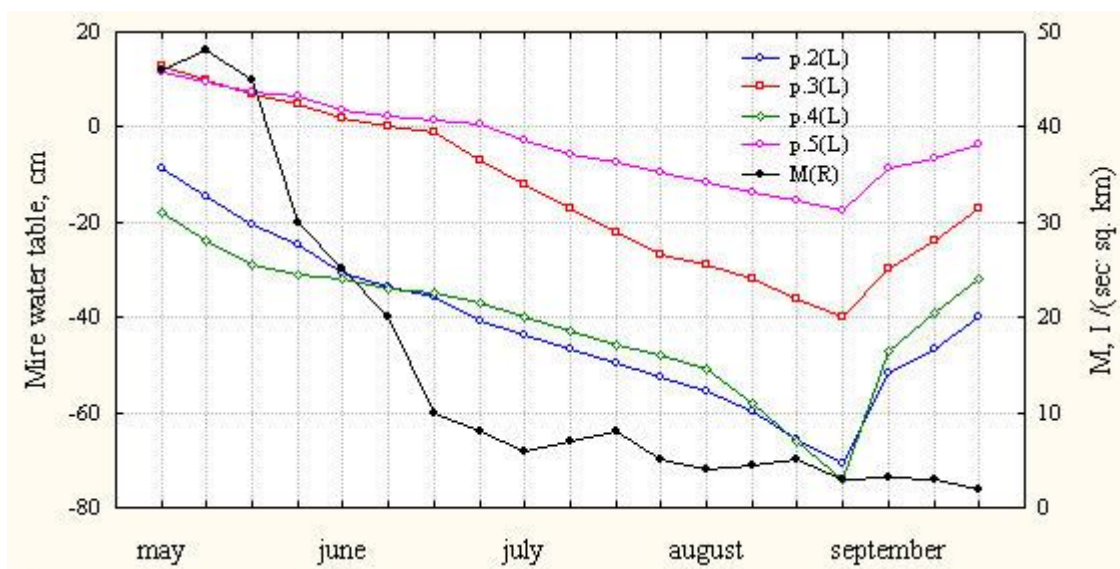


Fig. 29. Dynamics of mire water table and runoff of the Klyuch River. (M – runoff modulus; p. 2 – high ryam; p.3 – low ryam; p.4 – paludal forest; p. 5 – sedge-sphagnum swamp)

The total length of MWT rising amounts to 5–35 days and depends on air temperature and precipitation.

Let us consider the dynamics of lowering of ground waters upon the example of the year with the average water supply. The lowering of MWT below medium level

began on the 19th of July and the earlier one (on the 12th of July) started on the mire periphery. MWT lowered on average by 1–2 cm per day and up to 5 cm in the period without rains.

At this time the runoff of the River of Klyuch was defined by filtration properties of the peat deposit; on the oligotrophic mire under the research it reaches 0.2–0.6 m. in some plots. The highest porosity and water permeability is characteristic for this layer. The factor of filtration in the active layer is within the limits of 1.2–9.7 m per day [96].

The conducted research showed that the alteration of the layers with different filtration properties was noted in the peat deposit of the mire ecosystem.

Thus, the water inflow from the upper horizons into the bore pit with the area of 0.126 sq. m. amounted to 0.21 l per sec., whereas from the lower ones it reached 0.042 l per sec.

The runoff is reduced in the summer period at the total lowering of MWT. For example, MWT descends in the central part of the mire tract (open marsh, point 5) up to the depth of 8.6 and 2.6 m respectively; as for the points 2 and 4 situated at the mire border; these values are 24.8 and 26.6 respectively.

The highest amplitude of MWT fluctuations (up to 42 cm) is common for the mire periphery; in the central part of the mire it is equal to 14 cm. The moisture of the active layer changed insignificantly.

Therefore, the natural drainage is put into effect to a less extent under the conditions of a flat relief and a highly pronounced paludification.

For example, the runoff of summer mean water in 1998 was estimated as being equal to 24 mm when the total runoff amounted to 97 mm. In arid years the waterway dries up. The runoff recommences only during the autumn rainy period.

Hydrothermal, oxidative and reductive regimes.

The fundamental works of a lot of research [59, 60, 63, 85, 119, 140] illustrated that the peat deposit is subdivided by biophysical properties into horizon, i.e. the upper one (relatively thin, no more than 1 m) and the lower one, which is the main part of the peat deposit.

First of all, the differences between these two layers consist in the intensity of their physical and biochemical processes.

By the suggestion of V. D. Lopatin [85], the upper horizon is called an active layer (or acrotelm in the West); the lower one is called an inactive layer (or catotelm).

The study of the processes, which take place in the active layer, permits to judge about the evolution of the peat-forming layer; it is the layer where the processes proceed from the incomplete decomposition of the dying part of the vegetation and peat formation.

It is known that the exact position of the border between the active and inactive horizons is always conventional to some degree.

The principal factor which determines the intensity of biological processes in the active layer is, in hydrologists and peat scientists opinion, the periodical fluctuations of MWT and their amplitude and as a consequence, as K. Y. Ivanov thinks [63], periodical oxygen access of atmospheric air into the thickness of organic deposits.

As it is obvious from the foregoing, the thickness of the active layer, which is common for every type of the mire microlandscape, can be accepted as being equal to the distance from the mire surface to the average annual minimum MWT observed during the warm season.

But for all this, the low positions of periodically iterant minimum levels in the course of some repeated years (as compared to their average position) are no longer of any influence on the processes of peat formation [63].

In our opinion, it should be taken into account at the same time that from the modern viewpoint, the peat is considered to be a semicolloidal high-molecular plural-component polifractional hydrophilic system [77]. Such properties of the peat define also the intensity of biochemical processes in the peat deposit.

We give our view that starting from the aforecited data that the thickness of the active layer in the peat deposit is more than K. Y. Ivanov determined it about the active layer [63].

This supposition can be verified by the analysis of oxidative and reductive conditions and the activity of biochemical processes in the peat deposits. The latter question has already been examined above.

Now it will be analyzed how the values of redox-potencial of the active horizon correlate with MWT in different peat deposits of the landscape profile.

For example, the redox-potencial was changing during the observation period from -274 to $+928$ mV; it is the evidence of spatial and temporal heterogeneity of oxidative and reductive conditions.

At the same time interval the MWT had been changing in different types of the mire landscapes from $+12.4$ cm up to -71 cm; but for all this, the lowest levels were noted in the peat deposit of the high ryam.

The investigation period included moderately humid years (with the hydrothermal factor, HTF, of 1.1) and the arid period with HTF of 0.6.

Taking into account that some observations are numerous, the indices of the average annual levels were used. If one considers a mean MWT during the warm year interval (Table 33) the active peat layer changes in different biogeocenoses from 4 up to 27 cm. The analysis of the three-year data permits to make a conclusion that the active layer thickness is not more than 30 cm.

Now the obtained data will be compared with the redox-potencial data (Table 34). All the redox-potencial values are more than 200 mV in the layer of 0–50 cm.

This index is considered to be a transition border of reductive conditions to those of the oxidative ones. Redox-potential values of more than 350 mV are the evidence of the stable predominance of the oxidative processes [105].

Table 33

Medium levels of swampy waters 1998–2000, cm.

Years	Point of observation		
	2	3	5
1998	13	4	0
1999	37	9	6
2000	33	8	7
Average/ average minimum	<u>27</u> 49	<u>7</u> 21	<u>4</u> 11

The reactions of oxidation and reduction proceed. As a rule, in the presence of oxygen, which is contained in the heterogeneous multiphase medium even, a submerged peat deposit is a medium of this kind.

Table 34

Dynamics of Eh in the peat deposit, mV (numerator is as a layer 0–50 cm. denominator is as a layer 50–100 cm)

Years	Points of observation	Months				
		May	June	July	August	September
1998	Sedge-sphagnum swamp	<u>399</u>	<u>401</u>	<u>289</u>	<u>255</u>	<u>273</u>
		115	22	–65	–78	–55
	Low ryam	<u>690</u>	<u>491</u>	<u>476</u>	<u>463</u>	<u>657</u>
		331	203	–40	–28	439
	High ryam	<u>542</u>	<u>231</u>	<u>469</u>	<u>414</u>	<u>404</u>
		152	–224	–181	–167	–168
1999	Sedge-sphagnum swamp	<u>622</u>	<u>605</u>	<u>414</u>	<u>230</u>	<u>489</u>
		556	551	217	36	–78
	Low ryam	<u>604</u>	<u>558</u>	<u>658</u>	<u>596</u>	<u>665</u>
		573	521	519	66	276
	High ryam	<u>387</u>	<u>229</u>	<u>356</u>	<u>429</u>	<u>585</u>
		121	3	–135	–165	2
2000	Sedge-sphagnum swamp	<u>314</u>	<u>419</u>	<u>489</u>	<u>293</u>	<u>295</u>
		–54	–10	–8	–44	–35
	Low ryam	<u>687</u>	<u>700</u>	<u>665</u>	<u>558</u>	<u>592</u>
		63	608	276	86	411
	High ryam	<u>468</u>	<u>513</u>	<u>585</u>	<u>427</u>	<u>418</u>
		–140	–35	2	–152	–156
2001	Sedge-sphagnum swamp	<u>318</u>	<u>233</u>	<u>227</u>	<u>256</u>	<u>176</u>
		25	–36	33	–19	29
	Low ryam	<u>467</u>	<u>587</u>	<u>594</u>	<u>516</u>	<u>514</u>
		35	171	147	9	108
	High ryam	<u>415</u>	<u>438</u>	<u>431</u>	<u>387</u>	<u>414</u>
		–141	–156	–158	–152	–146

The reductive processes prevail in the layer of 50–100 cm (Table 34); these are the evidence of the oxidative and reductive systems in the peat deposit of the following type:



But in this case the dynamics of redox-processes is noted which is revealed in the alternation of the periods with various redox-values.

It should be noted that namely in this time interval the spatial heterogeneity is expressed in the evolution of oxidative and reductive processes. In particular, it is discovered in the peat deposit of the low ryam and open mash.

It is significant that the peat consists of 70 % of organic matter, which belongs to the most important compounds determining the course of oxidative and reductive processes.

Peat organic matter contains up to 40 % of humic acids which possess a strongly pronounced reductive capacity; hence, the given here usual scales of estimation of oxidative and reductive conditions are not entirely acceptable for the peat deposit.

It should be supposed that this estimation trends forward the overstatement of reductive conditions.

Thus, it implies that the limit of 200 mV, which is the transit border to the reductive conditions in the mineral grounds, should be much lower.

Therefore, while describing oxidative and reductive processes one can imagine that it would be more correct to accept the redox-potencial of 0 mV as the transitional one to the reductive conditions. Undoubtly, this clause should be studied later on.

The isopleths “0” mV which is characteristic of reductive conditions passed at the depth of 90 cm (Fig. 30) since July in the arid year; the redox-potencial was equal to 0–800 mV; this fact was common for contrast conditions.

Similar data were obtained under the moderately humid conditions when redox-potencial changed within the limits of 0–800 mV during the whole warm season, in August the whole thickness of 1 m was characterized by oxidative conditions (400–600 mB).

At the same time, the dynamics of redox-potencial of the open marsh is notable for a depthwise variation rather than for the temporal one (Fig. 30).

In the course of long-term studies (during the warm season) it was noted that the isopleths of the redox-potencial are spread up to the depth of 50–70 cm. These facts permit to accept that the peat genesis in the peat deposit of the sedge-sphagnum marsh is formed under conditions of flowing of swampy waters, which stream down from the territories differently saturated with oxygen.

Based on the above said facts one can suppose that the thickness of the active layer of natural oligotrophic mires can be larger (when judging by redox-potencial) than that supposed by K. Y. Ivanov by the average annual MWT.

The above said clause is confirmed by penetration of active temperatures depthwise the peat profile (Table 35); it is also the evidence of energization of biochemical processes in the layer of 1 m thick of the peat deposit. Let us consider the temperature conditions on the observation spots upon the example of the year of 1998.

The year of 1998 was characterized as hot and arid. The total precipitation amounted to 136.1 mm or 57 % of the average annual rate. As for the temperature conditions, July was the hottest and the most arid month. The average temperature was + 20.5 °C in July, the maximum + 27.4 °C, the precipitation was equal to 5.9 mm.

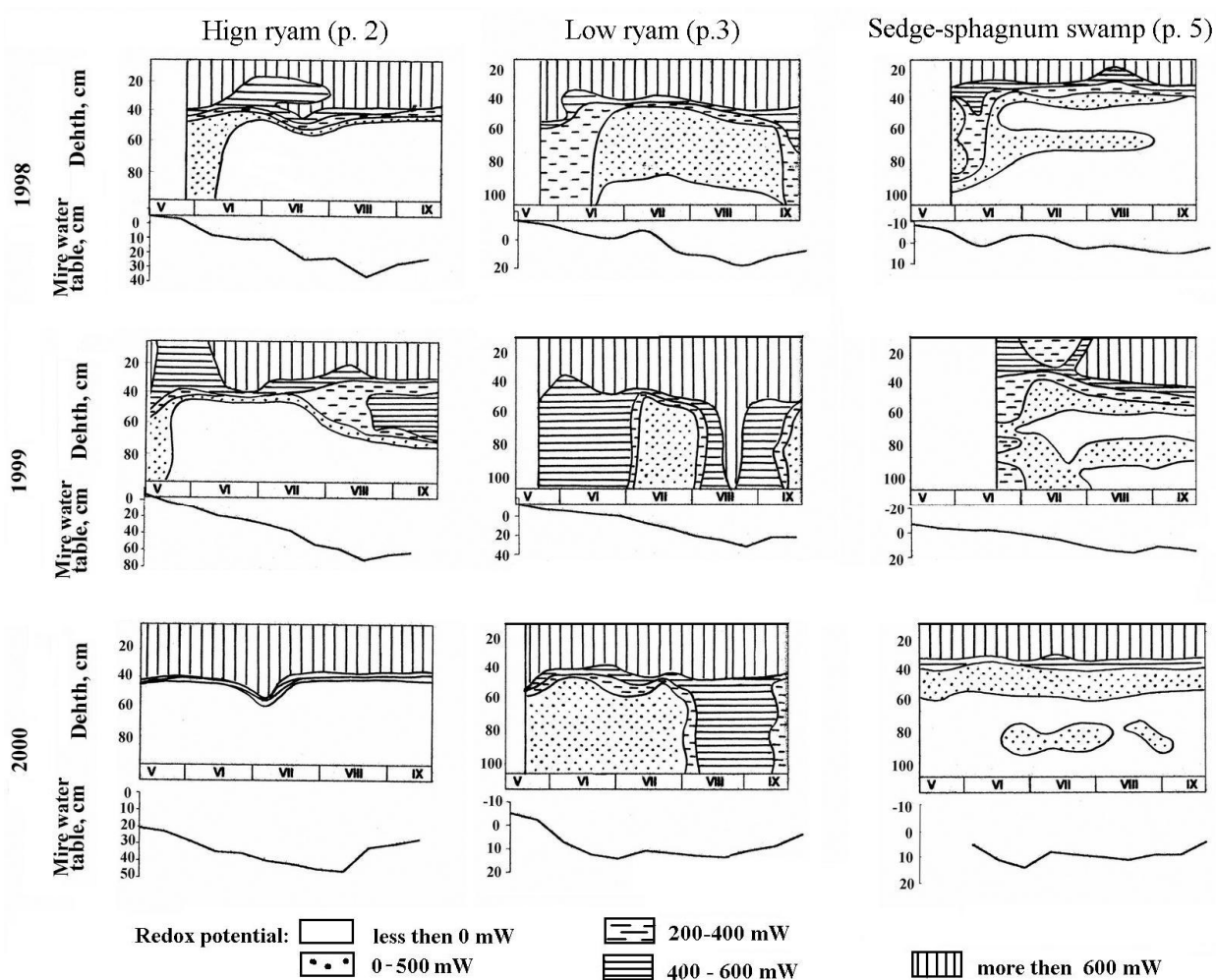


Fig. 30. Dynamics of redox potential in peat deposit of landscape profile in 1998–2000 years

It is known that in contrast to the mineral soils, at the same heat flow the heating of the surface layer occurs mainly in peaty soils; it is explained by the high water saturation.

The absolute accordance of temperature regime was observed with the air temperature in the layer of 0–20 cm in the peat deposit of the paludified forest.

The temperature transition through 5 °C in the layer of 0–10 cm was noted in the middle of May; as for the depth of 20 cm it was observed only at the beginning of June.

The layer of 0–20 cm was heated and got warmed thoroughly up to 10 °C in the first ten-day period of July; the period of active temperatures (more than + 10 °C) amounted to 65 days.

The temperature transition of the peat deposit (high ryam with the thickness of 90 cm) through 5 °C took place on the 27th of May. It should be noted that the temperature fluctuations decrease essentially depending on the weather conditions.

Table 35

Characteristics of temperature regime of peat deposit in the points of observation in May-September

Index	Years	Spots of observation		
		2	3	5
Date of transit of isotherm of 10°C at the beginning of the warm period at the depth of 50 cm	1998	20.06	20.05	25.05
	1999	10.06	5.06	20.06
	2000	none	15.08	1.07
Depth of penetration of the isotherm of 10°C, cm	1998	>100	>100	>100
	1999	60	>100	>100
	2000	40	72	>100
Duration of the period above 10°C at the depth of 50cm, days	1998	100	120	120
	1999	15	68	70
	2000	0	13	20

Note: p.2 – high ryam, p.3 – low ryam, p.5 – sedge-sphagnum samp.

The peat layer located deeper than 60 cm is characterized by relatively stable temperature within the limits of 2.6–8.6 °C. The period of active temperatures lasted 65 days as in the peat deposit of the paludified forest. The peat deposit got warmed thoroughly up to 15.6 °C at the beginning of August.

The peat deposit of the low ryam (point 3) was characterized by higher temperatures. The layer of 0–50 cm got warmed thoroughly up to 5 °C in the middle of May and the 1-m thick layer at the end of May.

The high temperatures in July and at the beginning of August favored the heating of the whole one-meter layer up to 15 °C. The period of active temperatures lasted 100 days in the layer of 0–50 cm.

The absence of the arborescent layer and the active intrasoil replacement of the moisture running off from the area adjacent to the territory lead in the sedge-sphagnum marsh to the formation of the layers (point 5) different by temperature conditions.

For example, the upper horizon of the sedge-sphagnum mash got warmed thoroughly up to 10 °C at the beginning of June, but later on, as it should be supposed, the sharp decrease in MWT in the subordinate landscapes caused the replacement of non-heated swampy waters; therefore, in the layer of 25–55 cm the temperature lowering up to 7–10 °C was noted from the beginning of July and up to the beginning of August.

As for the depth of 75–85 cm, the heating up to 15–17 °C lasted up to the middle of September; but for all that the average temperature of the peat deposit was 10–15 °C.

Therefore, the hydrological regime and temperature conditions of the mire tract are closely dependant on each other; water and physical properties and temperature conditions of the mire tract as well as the degree of decomposition and the peat kind are of no small importance in this case.

The degree of the microlandscape or the mire system on the whole could play a crucial role in the distribution of heat and precipitation throughout the territory of the mire.

Hydrochemical regime. The mires occupy as much as 4 % of dry land and accumulate at about 4.3 thou. cubic km of water; the composition of this water has some specific features, for example, it is rich in organic matter of humic nature, this water does not almost contain dissolved oxygen, it is of low mineralization.

By oxidative and reductive conditions the mire waters represents a system, which is characterized by association of oxidizing (O_2 , Fe^{3+}) and reducing agents (dissolved humic acids and Fe^{2+}).

Two groups of acids are distinguished between humus acids such as humic acids (HA) and fulvic acids (FA).

FA are more soluble, this fact can explain their high contribution into the structure of carboxyl groups and phenol oxygroups.

Therefore, the content of FA in swampy waters is higher by one order than that of HA. The high exchange capacity of HA secures the formation of stable complex compounds with metal ions. In particular, the complexation with HA plays a crucial role in the processes of solubilization, transfer and deposition of the elements in the hypergeny zone.

Geochemically, the influence of mires on the composition of the river and underground waters has not been practically studied.

On the one hand swampy ecosystems are a geochemical barrier [63], they fix many contaminants from the atmosphere and remove them from the biological cycle thanks to absorbing capacity.

However, on the other hand, complex chemical composition of the peats in the peat deposit of swampy ecosystem, their physical and colloidal structure forms the proper hydrochemical composition of swampy waters.

Atmospheric precipitation passes through the stage of mire genesis before coming to underground water-bearing horizons. The groundwater feeding mire is also transformed in organogenic medium of the peat deposit. As a result, freshwaters rich in carbonic acid, methane, iron, manganese and swampy components are formed.

A special kind of mire water is formed in such a way, which composition and the processes of interaction have been studied incompletely.

All the processes of interaction of water with the products of vital activity of

biogeocenoses can be considered, to some degree, as a special regional thermodynamic system (sun-basin unit by [67]) where the living substance is predominant. Furthermore, the bogs of the raised type are autonomous in eluvial and geochemical respect; this fact permits to follow migration flow of the substances in the balance variant.

The mire water was sampled in every well of swampy phytocenosis (points 2, 3, 4, 5), as well as in the River of Klyuch and River of Bakchar before the Kyuch falls into it.

The macrocomponents were analyzed by generally accepted methods [135], HA and FA was examined by the method described in [15].

The determination of heavy metals concentration was performed by the certified method of quantitative atomic emission analysis with the preparation of ash residue according to the State Standard 27784-88.

The removal of the elements of the River of Klyuch runoff was estimated by daily intervals. The consumption of every element was estimated based on concentrations of the respective elements and the average daily water consumption as a product of concentration and water consumption.

The removal for the longer time intervals was counted by the summation of daily removal values. The runoff volume, its dynamics and the conditions of formation define migration flow of the substances from the oligotrophic landscapes into swampy rivers.

The data of chemical elements concentration in the River of Klyuch show their considerable variability during different years and hydrological stages of the runoff (Table 36).

The swampy origin of the small waterway of the River of Klyuch determines the lowered content of average values of ions in water such as Ca^{2+} , HCO_3^- , SO_4^{2-} , but to some extent the increased content of total Fe, NH_4^+ and appearance of the intermediate reduction product such as NO_3^- – NO_2^- , which can appear in the reductive conditions only.

The water of the River of Klyuch is rich in organic matter; it is confirmed by high values of chemical oxygen consumption (ChOC) and HA and FA (Table 37).

The chemical composition of the River of Bakchar, which springs from the swamps and flows through them, is to a greater extent, of the same chemical composition as that of the River of Klyuch.

The analysis of the obtained data permits to draw a conclusion on the influence of mire waters of the active layer of the peat deposit which passed through the biochemical cycle of the exchange processes in the peat-water, on the hydrochemical composition of the river.

The highest concentration of practically all compounds is noted on the mire border in the paludified forest (spot 2) which is a transaccumulative part of the landscape profile of geochemically connected landscapes and which serves as a geochemical

barrier for swampy waters running off from the autonomous part of the profile.

The peculiarity of the organo-mineral type of swampy waters is also revealed in the elemental composition (Table 38). The peat deposit contains a considerable quantity of dispersed elements operating as a global sorbent which regulates their content [16].

It was shown by different authors that finely dispersed particles, sesquioxides and humic acids in the large amount of the swampy water [43, 121] participate mainly in ion absorption.

Table 36

Chemical composition of river and mire waters in 1994–1998, mg per l

Components	River of Bakchar	River of Klyuch	Mire waters				Solid precipitations**
			Paludal forest, p. 4	High ryam, p. 2	Low ryam, p. 3	Open swamp, p.5	
PH	<u>6.5–7.5</u> 7.2	<u>6.6–7.1</u> 6.7	<u>3.8–4.6</u> 4.1	<u>4.6–5.6</u> 4.7	<u>3.6–4.3</u> 4.0	<u>3.9–4.5</u> 4.1	7.0
Ca ²⁺	<u>9.3–45.3</u> 32.5	<u>8.0–28.0</u> 17.6	<u>0.5–15.6</u> 3.6	<u>3.0–7.2</u> 5.2	<u>0.6–6.2</u> 1.9	<u>1.0–6.0</u> 2.6	0.7
Mg ²⁺	<u>7.3–18.8</u> 12.1	<u>6.7–15.2</u> 9.9	<u>0–2.2</u> 1.0	<u>0.5–6.3</u> 2.6	<u>0–3.0</u> 1.6	<u>0–4.3</u> 1.7	0
Na ⁺	<u>1.4–14.0</u> 5.3	<u>1.7–2.6</u> 2.2	<u>0.2–0.8</u> 0.6	<u>0.1–1.9</u> 1.2	<u>0.4–0.7</u> 0.6	<u>0.1–1.1</u> 0.7	1.5
* NH ₄ ⁺	<u>0.2–3.8</u> 1.6	<u>0.4–3.9</u> 1.8	<u>0.2–2.5</u> 1.4	<u>0.4–4.1</u> 2.3	<u>0.2–2.9</u> 1.4	<u>0.2–2.3</u> 1.4	1.2
* Fe _{total}	<u>1.5–4.9</u> 3.1	<u>2.0–5.9</u> 3.6	<u>1.4–4.8</u> 3.1	<u>1.6–7.0</u> 4.7	<u>1.6–3.8</u> 2.8	<u>1.0–3.8</u> 2.5	0.01
HCO ₃ [–]	<u>54.3–160.0</u> 96.5	<u>24.4–109.1</u> 56.6	<u>0.0–20.0</u> 6.5	<u>4.8–24.5</u> 11.8	<u>0.0–13.5</u> 3.6	<u>0.0–12.8</u> 3.5	8.5
SO ₄ ^{2–}	<u>0.0–0.8</u> 0.3	<u>0.0–3.8</u> 1.8	<u>0.0–1.3</u> 0.3	<u>0.0–1.0</u> 0.3	<u>0.0–2.9</u> 0.5	<u>0.0–3.3</u> 0.7	1.0
NO ₃ [–]	<u>0.23–1.7</u> 0.63	<u>0.3–2.4</u> 1.5	<u>0.0–1.7</u> 0.6	<u>0.3–0.8</u> 0.5	<u>0–1.9</u> 0.7	<u>0.2–1.4</u> 0.7	0.3
* NO ₂ [–]	<u>0.002–0.07</u> 0.03	<u>0.002–0.1</u> 0.03	<u>0.0–0.07</u> 0.02	<u>0.0–0.01</u> 0.004	нет	<u>0.0–0.009</u> 0,004	Her

Note: * – data of 1998, ** – average values.

Table 37

Content of organic substances, mg per l, 1994–1998

Components	River of Bakchar	River of Klyuch	Mire waters			
			Paludal forest	High ryam	Low ryam	Open swamp
Carbon (C)	$\frac{14-49}{30}$	$\frac{28-85}{55}$	$\frac{36-82}{53}$	$\frac{56-106}{78}$	$\frac{46-109}{65}$	$\frac{37-96}{54}$
ChCO	$\frac{94-200}{146}$	$\frac{81-293}{181}$	$\frac{81-220}{155}$	$\frac{108-269}{175}$	$\frac{60-222}{142}$	$\frac{103-216}{166}$
Humic acids	$\frac{3.5-16.7}{9.2}$	$\frac{5.8-25.1}{17.8}$	$\frac{5.9-27.9}{14.3}$	$\frac{10.6-27.0}{16.8}$	$\frac{4-26.1}{12.5}$	$\frac{6.1-20.0}{11.0}$
Fulvic acids *	$\frac{28.6-32.7}{30.6}$	$\frac{41.5-61.6}{51.3}$	$\frac{47.6-59.5}{52.3}$	$\frac{81.0-92.4}{87}$	$\frac{51.4-60.2}{56}$	$\frac{42.6-53.3}{49.6}$

Note: in numerator – extreme values; in denominator – average values ; * – in 1998.; ChCO – Chemical consumption of oxygen.

As it was shown earlier [56], the content of trace elements in the peat deposits is determined to a greater extent by their botanical composition; to a smaller extent they are concentrated in the raised peats.

Table 38

Content of elements in mire water and runoff of river of Klyuch, average values in the course of vegetational season, mcg per l

Point of sampling	Pb	Cu	Mn	Zn	V	Cr	Ni	Yb	Ti	Ga	Hg	Sr
Open swamp, (p. 5)	0.95	0.95	159.16	11.38	0.95	2.59	1.95	0.12	6.18	0.39	0.08	27.03
Low ryam (p. 3)	0.75	6.80	45.12	7.52	1.78	2.39	1.43	0.14	7.99	0.63	0.08	31.05
High ryam (p. 2)	1.06	4.62	52.87	5.95	2.44	2.52	1.42	0.20	8.35	0.63	0.13	49.51
Paludal forest (p. 1)	0.72	5.38	76.53	8.77	1.30	1.84	1.33	0.13	6.84	0.47	0.08	30.89
River of Klyuch (upper course)	0.57	0.57	36.44	2.28	0.76	1.52	0.81	0.12	4.81	0	0.08	31.69
River Klyuch (lower course)	0.56	0.56	170.9	7.48	0.99	2.15	1.38	0.17	7.25	0.67	0.11	50.96
Water from raised bog [10]	0.60	0.50	41.90	5.70	–	–	0.70	–	2.60	–	–	–
Water from raised bog [10]	–	3.80	10.00	38.00	–	–	–	–	–	–	–	–
Water from raised peats of Western Siberia [10]	3.10	7.00	74.70	6.60	2.10	7.60	–	0.36	–	–	0.45	79.40

Note: – element is not found.

Therefore, the element's content in the mire waters of the open marsh (point 5) deposited from the surface by the raised sphagnum peat of the weak degree of decomposition, is less than at the mire periphery (point 2, high ryam).

The compounds of Ti and Sr the content of which is the same in the peat deposits of all geochemically connected landscapes of the river of Klyuch are an exception.

The high content of heavy metals is practically noted in the studied swampy waters of all phytocenoses compared to the data of other researchers [6, 96].

Biochemical processes which proceed in the peat deposits determine the chemical composition of swampy waters which are an averaged sample of the layer of 0–100

cm of the peat deposit of every biogeocenoses of the landscape profile under the research.

It is known that carbon as well as soluble phenol, aldehyde, carboxylic fulvic and humic acids range within the limits of 20–105 mg per l.

The maximum content of water-soluble carbon in the swampy waters amounts to 145.6 g per l in the transaccumulative part of the landscape profile and 80.5 mg per l in the autonomous one.

High carbon content is noted in the estuaries of the rivers of Klyuch and Bakchar (the river flows from the Vasyugan mire, the area of catchment amounts to 2024 sq. km.). The registered regularity becomes also apparent in the indices of oxidability.

Water-soluble humic acids, especially fulvic acids play a decisive role in the formation of hydrochemical composition of swampy waters.

The waters of mires are characterized in this case by yellowish color and the value of oxidability usually ranges on average within the limits of several tens of O₂ per l; mean values amount to 200–300 mg O₂ per l.

For example, the content of carbon in snow is not more than 8 mg per l, oxidability is 12.3 O₂ per l. The excess of FA content with the regard to HA amounts in the studied waters to 5–20 times, most often 10, it is in the accordance with their content in peats.

The high content of movable compounds in the peats and rather a high microbiological activity throughout the whole profile of the peat deposit confirm that chemical composition of the runoff from the paludified catchment is determined not only by atmospheric precipitation, as some researchers assert, but also at the expense of transformation processes in the peat deposit.

On the whole, swampy runoff occurs by means of the runoff from the surface and within the bounds of the deposit. According to our research, the formation of the runoff inside the deposit is determined by the thickness of the active layer, as it was considered earlier.

As the intensity of the processes of the peat decomposition increases on the raised bog from its center to the border part (autonomous transaccumulative part of the profile), the increase in content of all compounds of the geochemical runoff takes place in the same direction.

At the same time, the high migratory capacity of FA explains the fact that the most stable soluble high-molecular fulvate complexes of anionic type represent the principal migratory form.

The complexation with natural ligands explains the mechanism of very diverse processes, which proceed in the hypergeny zone.

Therefore, the general runoff of mineral and organic substances agrees with above-mentioned regularities of water removal and migration of the substances in the landscape profile.

On the whole, the dynamics of the elements runoff is mainly defined by the course of water runoff which index is a synchronism of distribution of water expenditure and chemical elements.

The total runoff of chemical elements amounted in the course of the runoff to: Ca^{2+} – 1398, Fe_{total} – 311, SO_4^{2-} – 391, NO_3^- – 236, NO_2^- – 1, Pb – $2.253 \cdot 10^{-3}$, Mn – $317.29 \cdot 10^{-3}$, Zn – $41.191 \cdot 10^{-3}$, Ni – $8.151 \cdot 10^{-3}$, Ti – $29.651 \cdot 10^{-3}$ kg per sq. km. The annual runoff losses of dissolved organic matter proved to be equal to 6945 kg per sq. km. or 6.9 g per sq. m.

The dynamics of the OM runoff is characterized by regularities, which can be explained by complicated processes of synthesis and resynthesis of OM in the peat deposit, as well as by microbial and enzymological transformations of the peats as well.

The research data permit to reveal the general trend of migratory processes from the open marsh to the paludified forest; and the final composition formation of the mire water occurs in the transaccumulative part of the landscape where this water falls into the receiver (the river of Bakchar).

Now the given supposition will be considered more in detail upon the example of IR spectra of the substances of phenol nature, which can amount to 3–5 up to 41 % of the total content of water-soluble OM.

The comparative study of IR spectra (on the example of peats and mire water sediments within the limits of the landscape profile) and their spectral coefficients, which indicate the ratio of hydrophilic and hydrophobic constituents of polyphenols molecules permitted to reveal the peculiarities of migration of water-soluble OM.

As a rule, the number of hydroxyl, phenol-hydroxyl and carboxyl groups as well as aromatic fragments rises in water-soluble substances in August and September; this fact is explained by the high microbiological activity in the system of peat deposit-mire water which is warmed up to 15 °C at this time interval.

The ratio of optical densities of hydroxyl groups D_{3400}/D_{1460} varies in swampy water of the autonomous part of the landscape from 0.89 to 1.49, that of phenol hydroxyl D_{1270}/D_{1460} from 0.78 to 0.86, carboxyl groups D_{1720}/D_{1460} from 1.16 to 1.28 and aromatic fragments D_{1620}/D_{1460} from 1.20 to 1.85. The number of phenol hydroxyl D_{1270}/D_{1460} and carboxyl groups D_{1720}/D_{1460} increase up to 0.96 and 1.73 respectively in water-soluble substances of the transit and transaccumulative parts compared to the autonomous one.

Insignificant content of the above-mentioned functional groups is noted in the rivers of Klyuch and Bakchar; this fact is caused by the dilution of migratory flow with surface waters, which flow down, from the non-paludified part of the territory.

Thus, when the conditions of the formation of chemical composition of swampy water waters are considered, firstly, it should be taken into account the hierarchy of the landscapes in the river basin and the participation of surface and inner-swampy flow during the vegetational season.

Second, it is significant to take into account the botanical composition of the peat deposits of MES.

Thus, when analyzing the chemical composition of mire waters we have taken into consideration the generally accepted concept of the structure of the peat deposits along the landscape profile.

It was shown that the active horizon (of 1 m thick) of the autonomous part of the profile was composed by the sphagnum peat, of the transit part by fuscum and medium peats and of the transaccumulative part by pine-cottongrass-sphagnum peat which was replaced downwards the profile by the wood-cottongrass peat.

At the same time, for example, sphagnum deposit of the active layer consists of 9 sphagnum species and includes also sedges, horsetails and cotton grass, which results in the fact that swampy waters are diverse by composition.

Different peat formers contain water-soluble substances from 3 to 21 %. In their turn, water-soluble substances include mono- and polysaccharides and pectin.

Therefore, their ratio in peat formers will be different as well and, furthermore, the degree of polymerization and mobility of peat OM will be different at various depths of the peat deposit. This fact should be taken into account.

Third, biochemical processes in the active and inactive horizons of the peat deposit exert influence upon the formation of the runoff composition.

The development of the ideas on geological runoff (georunoff) will be one of the main tasks in the future.

The total river water runoff of water, alluvium, dissolved substances, heat can be considered as a georunoff. The hierarchy of the particular catchments, elements of the riverbed network and typical physical, chemical and biological processes is evidently of the system character.

Therefore, the study of the concrete water objects and physical, chemical and biological processes of transformation of substance and energy flows on the catchment areas typical for them, seems to be perspective to the chemical constituent of the georunoff.

It should be supposed that this problem would be solved on the basis of elaboration of the runoff model for small-scaled catchments, which are under different environmental conditions compared to the above-mentioned paludified catchment of the River of Klyuch.

A mathematical model was worked out with regard to chemical substances runoff from the catchment surface and their movement in the riverbed network based on long-term research in small catchment of the river of Klyuch.

The following suppositions were taken into account in this case: runoff of chemical substances during spring tide and rainy floods takes place mainly simultaneously with the surface water runoff which changes not only in time but in the catchment area.

The spatial heterogeneity of runoff-forming conditions is accounted by the distribution of the catchment area according to the landscape characteristics.

The following assumptions were introduced in calculation of movement of the dissolved substances.

1. The task is solved in one-dimensional arrangement. The concentration of ingredients under consideration is accepted to be averaged on the basis of the real flow section or effective slope area section for area for the slope runoff, i.e. it changes in length and time.

2. It is considered that the dissolved substances are spread due to the movement of water and together with its particles, at the same time they are not capable to move on their own (molecular diffusion and the like).

3. The processes of water self-purification are not taken into account in the first approximation. It is possible if the depth of decomposition of substances is low (for example, at low water temperature) or the water passes through the rated section during a relatively short time interval.

The distinctive feature of the model is the fact that it is realized with the regard to the expense of the ingredient in question, i.e. the mass of the substance, which is transported through the prescribed flow cross-section per time unit.

If required, one can pass to the admixtures concentrations. Daily expenditures of admixture and its concentration can be calculated in the trailing range at time moment t starting from the furl integral by formula

$$C_h(t)Q_h(t) = \sum_{j=1}^N \int_0^t C_{\bar{o}j}(t-\tau)q_{\bar{o}j}(t-\tau)p_{\bar{o}j}(\tau)d\tau, (1)$$

where $Q_h(t)$ and $C_h(t)$ are water expense and average concentration of dissolved substance in the trailing rang respectively at time moment t ; $q_{\bar{o}j}(t-\tau)$, $C_{\bar{o}j}(t-\tau)$ is the same for lateral inflow from j particular basin at time moment $(t-\tau)$; $p_{\bar{o}j}(\tau)$ –is the same for j -lag curve of the lateral inflow; N is the number of basin particular areas which define the lateral runoff.

The lag curve is interpreted as a density of lag distribution time of elementary water volumes and is approximated by the statistical distributions (gamma-distribution and distribution by G. N. Brovovich), which are well studied and widely applied in practice.

The density of the distribution can be accepted as constant in definite conditions. Its parameters are determined on the basis of the assessment of respective statistical moments of distribution.

The parameters of the lag-curve are estimated by lag-moments on the in flow plot. The general expression for the moments is as follows:

$$m_{hk} = \int_0^{\tau_L} f(\tau) m_{\mu}(\tau) d(\tau), \quad (2)$$

where $f(\tau)$ is the density of the lateral inflow distribution along the river; m_{hk} is the initial moment of k -order of lag time of elementary volumes of the lateral inflow; $m_k(\tau)$ is the initial lag time moment of the volume entering the elementary section of length of $dl = V dt$ which is remote to a distance l from the trailing range ($\tau = l/V$, where V is a mean flow speed on the plot); τ_L is a mean lag time along the whole plot ($\tau_L = L/V$, where L is the length of plot).

The first three moments are expressed by the following formula (3):

$$\begin{aligned} m_1(\tau) &= \tau; \\ m_2(\tau) &= a^2\tau + \tau^2; \\ m_3(\tau) &= ka^4\tau + 3a^2\tau + \tau^3, \end{aligned} \quad (3)$$

where a is a parameter of the longitudinal dispersion; k is a ratio of coefficients of asymmetry and lag time.

Having different kinds of function of $f(\tau)$ as an object, the expressions for the moments can be obtained which meet the requirements for various cases of lateral inflow distribution along the plot. The function can be represented as a ratio

here $q(\tau)$ is a lateral inflow per length unit per time unit (the length is expressed in

$$f(\bar{\tau}) = \frac{C(\tau)q(\tau)}{\int_0^{\bar{\tau}_L} C(\tau)q(\tau)d\tau}, \quad (4)$$

units of mean lag time $\tau = l/V$; $C(\tau)$ is an admixture concentration.

If we take into account the distribution of concentrations of lateral admixture inflow which dispersedly enters along the riverbed as being constant during the rated period (for slopes along running-off line to effective sections), the lag moments of water and admixture inflow will be the same.

It should be taken into account that this distribution is uniform because of the lack of information. In other words, lag curves of elementary water volume and dissolved substance will be identical.

The calculation of the slope runoff and the inflow of water into the riverbed network were performed on the basis of the mathematical model of the runoff formation from the paludified territories; furthermore, the principal processes, which proceed on the catchment and the near-riverbed part of the basin, were taken into account.

The estimation of water supply in the snow cover was accepted by data snow-measuring surveys before snow thawing. Daily water supply on the catchment surface was determined by the results of calculation of snow thawing intensity and

water removal from snow by method of A. G. Kovzel, in this case the unevenness of snow cover thickness was taken into account in different landscapes.

The snow water distribution was approximated within the bounds of each landscape by gamma-curve distribution to parameters obtained during the snow-measuring survey.

Everyday water loss of the basin was determined as a difference between the water excesses, which are above the expenses to infill its water-holding capacity. The value of water-holding capacity depends before thawing on moistening of the basin in the previous autumn.

The autumn river runoff is accepted as the index of the infill degree of water-holding capacity before snow thawing.

It is supposed that the process of water accumulation takes place on the slopes, and the nonlinear relation is in existence between the water supplies and the slope runoff.

The data of annual humic acids removal during high water from the surface of the landscape profile (catena) are given in Fig. 31.

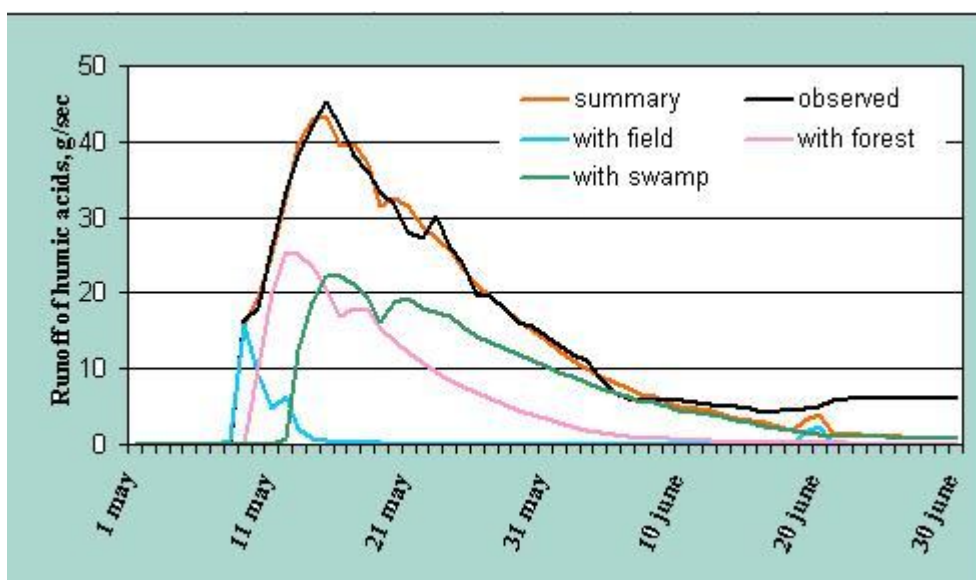


Fig. 31. Factual and calculated hydrographs of removal of humic acids

These data were obtained by the model in question and characterize the year when the moistening factor is equal to 1.26. Moistening factor means the ratio of precipitation and possible evaporation (translator's commentary).

The obtained data is the evidence of the satisfactory coincidence of the calculated and virtually observed losses of humic acids with the surface flow from catena; furthermore, these data are also the evidence of application of the approach in question for modeling of dissolved substances removal from the paludified territories.

The calculations show that the annual carbon removal in the form of humics (0.29 per sq. km.) amounts in some years to 98 % of the total carbon removal by surface and inner-swampy runoff, but for all that the most part belongs to carbon of fulvic acids (annually 5.79 kg per sq. km.).

Water supply reaches 1000 cubic km in the peat reserve of Siberia, i.e. 1000 mm falls on average per one unit of the paludified area, and it is considerably more than the annual river runoff on this territory (100–300 mm per annum).

When one considers the conditions of formation of chemical composition of swampy, fluvial waters of the paludified catchments and the role of mires in this process, it is necessary to take into account the hierarchy of landscapes in the river basin and the organic constituent of swampy waters.

The role of OM as a final product of peat formation (peat genesis) on the territory of Vasyugan mire and its part in the subsequent migration with lateral and inner swampy runoff into the rivers are required to be studied in detail and improved in future.

Biological productivity. It has been already mentioned above that the research of the carbon cycle in MES is of special interest.

At present time when increase in atmospheric CO₂ is noted that the most valuable are the biogeocenoses, which are capable to absorb and retain it.

The most part of aboveground biogeocenoses are notable for the restriction of the biological cycle [139], i.e. by zero balance of income and outcome of the substances in the course of turnover. The biogeocenoses acts at different temporal intervals both as the absorbent of CO₂ or as its source of emission.

The peculiarity of the biospheric function of mires is determined by the fact that they return fewer substances than take away into environment. And so, the growing mires are unique ecosystems of runoff of atmospheric carbon, which is accumulated as peat deposits.

At the same time, the intensity of the process of carbon exchange can be not the same in different mires and in different developmental stages depending on weather conditions. The current carbon balance of any ecosystem assumes its income and outcome to be taken into account.

The research of biological productivity within the limits of the landscape profile was performed in the following way.

Biomass stock was determined during its maximum development, i.e. at the end of July or beginning of August.

The aboveground production was defined by the cutting method (without taking into account the arborescent layer), the underground one is defined by the monolith method of Shalyt (1960). The points for the control account (50x50 cm) were chosen in five repeatabilities for each microrelief elements (hummocks, inter-hummocky spaces). From these plots the plants were cut off at the level of moss surface.

The cut off plants were divided by fractions: living phytomass (annual and perennial photosynthesizing phytomass, annual shoots, perennial non-photosynthesizing phytomass) and dead phytomass (mortmass) such as standing dead, litter; then the samples were air-dried and weighed.

The determination of underground biomass was carried out at the same plots as that of the aboveground biomass. For that purpose the monoliths (10x10x10 cm) were chosen up to the depth of 20 cm from which living roots were removed. The moss standing dead and roots were dried up and weighed.

The cutting of plant cover was performed on the plots of 50x50 cm in every biogeocenosis in five repeatabilities in order to study the increment dynamics.

The determination of the biomass increment was monthly conducted from May to September. Seasonal dynamics of the increment of swampy plants is formed from the monthly growth of green parts of plants and growth of branches during the current year.

Net primary production of the above-ground cover was calculated based on monthly data as the annual sum total to the growth of all plant species per area unit. Plant dying off and increment of woody part of the undershrub were not taken into account in this research during the vegetational season.

The biomass stock of biogeocenoses in question changes depending on the weather conditions in the following way: it was maximum in warm arid year in all the spots of the naturally occurring oligotrophic mire, whereas the biomass stock is reduced in the year of moderate moistening; this fact is explained by the high level of swampy waters.

The biomass stock changes in all biogeocenoses depending on microrelief within the limits of 2794–9656 g per sq. m.; moreover, biomass amount was higher in the inter-hummocky depressions (Table 39); it can be explained by the fact that moss standing dead is of more dense structure because of compacting on mire water movement, whereas on mossy cushions the mossy standing dead is more friable and, hence, less dense.

The phytomass amount of biogeocenoses of the landscape profile amounts on average to 20 % for three years of research and ranges within the limits of 9–34 %. The phytomass stock decreases gradually in the sequence of high ryam → low ryam → open marsh and amount to 1285→1089→889 g per sq. m. respectively.

The amount of photosynthesizing phytomass in biogeocenoses of the landscape profile is equal on average to 8 % and ranges within the limits of 4–16 % of total biomass stock. The highest phytomass stocks are typical for the low ryam at the expense of the moss cover.

Thus, the biomass structure is determined in different biogeocenoses of the landscape profile by the following regularity: biomass, phytomass and mortmass stocks are gradually reduced from the high ryam to sedge-sphagnum marsh.

The NPP changes annually in different biogeocenoses of the landscape profile during the research period within the limits of 206–337 g per sq. (Table 40) and its distribution from the edge (spot 2) to open marsh (spot 5) looks the following way: low ryam 284, high ryam 258, and open marsh 240 per sq. m. annually.

Table 39

Structure of plant material in biogeocenoses of landscape profile, g per g. sq.

Biomass component	Years	High ryam (p.2)		Low ryam (p.3)		Sedge-sphagnum swamp (p.5)	
		H	IHD	H	IHD	H	IHD
Photosynthesizing phytomass	1999	363	334	535	365	373	253
	2000	361	440	455	387	436	466
	2001	400	373	622	410	332	346
	average	379		462		367	
Phytomass	1999	1708	1395	2063	1183	1096	759
	2000	1359	1177	1145	564	905	868
	2001	1017	1055	1000	580	894	813
	average	1285		1089		889	
Mortmass	1999	5138	8135	4034	7876	3612	4306
	2000	3095	7271	4909	5608	1889	3008
	2001	3394	4442	3321	4219	2339	3196
	average	5246		4995		3058	
Biomass	1999	6846	9529	6097	9059	4708	5065
	2000	4454	8448	6054	6173	2794	3876
	2001	4411	5497	4321	4800	3234	4009
	average	6531		6084		3948	

Note: H – hummock, IHD – interhummock depression.

The main part in NPP of the high and low ryam (points 2 and 3) is played by undershrub (42–55 %) and mosses (17–48 %), the part of herbs amounts to 0–9 %. The most part of ANP of the open marsh is represented by mosses (21–64 %) and herbs (28–41%); the part of undershrub is considerably lower and amounts to 8–38 %.

Table 40

Elements of carbon balance in different types of biogeocenoses

Biogeocenoses	Years	Annual phytomass productivity, g C per sq. m	Annual emission, g C per sq. m
Landscape profile, high ryam (p. 2)	1999	251(121)	80
	2000	277(133)	111
	2001	245(117)	79
	average	258(124)	90
Landscape profile, high ryam (p. 3)	1999	337(162)	61
	2000	301(145)	60
	2001	214(102)	31
	average	284(136)	51
Landscape profile, sedge-sphagnum swamp (p. %)	1999	206(99)	66
	2000	293(140)	45
	2001	222(106)	33
	average	240(115)	48

The ANP is the index of the annual runoff of atmospheric carbon. The part of the Vasyugan mire under research takes annually from the atmosphere on average 125 g C per sq. m.

The carbon runoff can be changed from 108 to 139 g C per sq. m. depending on weather conditions of the current year (Table 40). At the same time, the maximum carbon runoff is observed in the low ryam, and the minimum is observed in the open marsh.

Emission of CO₂. It is known that the evolution of CO₂ characterizes the functional state of the ecosystem, as a whole. The main part of carbon, which enters with plant material, is mineralized in aerobic conditions of the active layer of the peat deposit.

The joint result of activity of aerobic and anaerobic microorganisms defines the evolution of CO₂ from the peat deposit.

The specific feature of the landscape profile as an object of the research consists in the regular change of vegetation types and the structure of the peat deposit which reflects different developmental stages of mire biogeocenoses; it permits to follow the regularities of CO₂ emission as a result of peat organic matter transformation in different stages of development of mires of the landscape profile.

On the whole, the decrease in the intensity of CO₂ evolution is found in the sequence from the high ryam to the open sedge-sphagnum marsh. The mean values of the intensity of CO₂ evolution amounted in points 2, 3, 5 during research period to 133, 77, 59 mg per sq. m. per hour respectively (Fig. 32).

The highest limits of CO₂ evolution were recorded in the high ryam of the objects under the research (from 29 to 356 mg CO₂ per sq. m per hour) and the lowest – in the sedge-sphagnum marsh (from 0 to 208 mg CO₂ per sq. m. per hour).

At the same time, the maximum values of CO₂ were observed in spot 5 in July and the first half of August, whereas high values of emission were noted in points 2 and 3 for a more extended period.

The general trend of CO₂ evolution during the vegetational season consists in the increase of CO₂ evolution by the middle of July; later on it is reduced.

The intensity of CO₂ evolution in May was caused by the high mire water level and the availability of the frozen layer. The increase in CO₂ is noted in June because of the lowering of the level of mire waters and heating of the active layer of the peat deposit.

The heating of the active layer of the peat deposit happens in July at a high air temperature and an inconsiderable precipitation; it favors to intensive evolution of CO₂. September is characterized by the low intensity of CO₂ evolution, which is comparable with that in May.

The estimation of total CO₂ flow during the vegetational season is of special interest. The maximum total annual CO₂ flow was obtained in the high ryam (90 g C per sq. m.) and that of minimum – in the sedge-sphagnum marsh (48 g C per sq. m.).

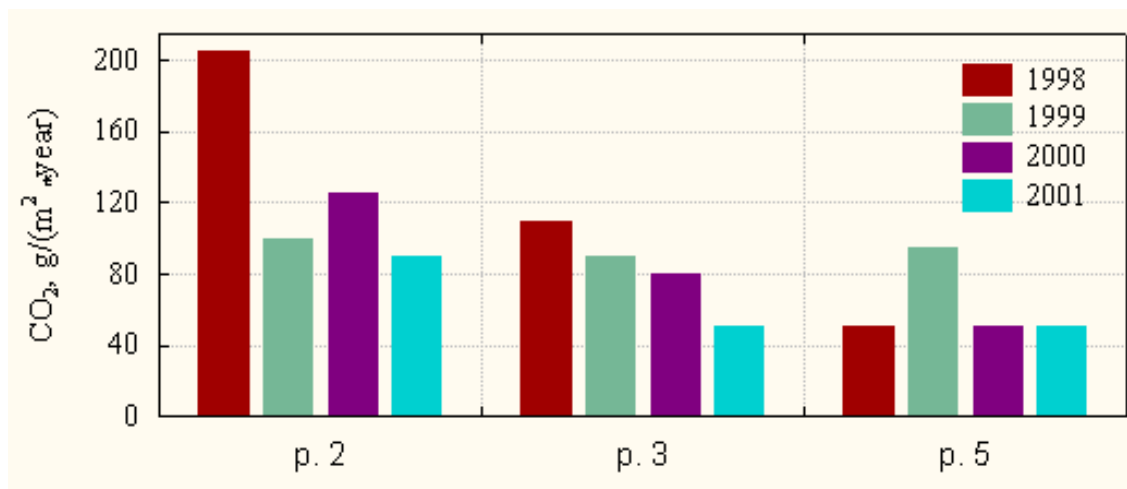


Fig. 32. Emission of CO₂ in different biogeocenoses

The sum total CO₂ flow amounts on average to 229 g CO₂ per sq. m (or 62 g C per sq. m. annually); this value is twice less of the annual carbon arrival in the form of plant phytomass, it is the evidence of progressing process of paludification on Vasyugan mire.

Elements of carbon balance on the plot of forest amelioration of Vasyugan mire.

Our research showed that the forest amelioration of the oligotrophic mire leads to a decrease in the mire water level.

Because of the growth on different microrelief elements the intensive plant biomass becomes even and is strongly accumulated in the inter-hummocky depressions; it occurs at the expense of the increase in aeration of the rhizosphere of the peat deposit.

The total biomass stock is 1.2 times higher on the forest amelioration plot (spot 6) compared to that of the undrained one (point 7) (Table 41).

Table 41

Elements of carbon balance in different types of mire biogeocenoses

Biogeocenoses	Years	Annual phytomass productivity, g C per sq. m.	Annual emission, g C per sq. m
Spot 5, Vasyugan, drained area (point 6)	1999	311(149)	91
	2000	316(152)	71
	2001	262(126)	47
	average	296(142)	70
Spot 5, Vasyugan, natural area (point 7)	1999	198(94)	67
	2000	168(80)	82
	2001	147(71)	73
	average	171(82)	74

The same regularity is noted for the structure of plant material (Table 42). Forest drainage results in the increase of phytomass stock by 20–30 % as compared to the undrained plot.

The stock of photosynthesizing phytomass is higher by 20 % on the drained plot as compared to that of the undrained one; the highest values are typical for the arid year. The positive effect of drainage is revealed in the phytomass increment.

The net primary production of the aboveground layer decreases regularly on the plot of forest amelioration from the arid year to a more humid one (Table 41).

The ANP is mainly composed on the plot of the forest amelioration by undershrub (45 %) and mosses (49 %), the part of herbs amounts to 4 %.

The primary production was on average 1.7 times higher during the research period on the drained plot (spot 6) as compared to that of the undrained one (point 7).

Table 42

Structure of plant material in biogeocenoses on the plot of forest amelioration, g per g. sq.

Phytomass component	Years	Drained point (p. 6)		Natural point (p.7)	
		H	IHD	H	IHD
Photosynthesizing phytomass	1999	556	875	367	381
	2000	521	440	373	427
	2001	633	499	495	535
	average	587		430	
Phytomass	1999	1661	1329	1323	790
	2000	1230	881	926	739
	2001	1158	690	984	757
	average	1158		920	
Mortmass	1999	7995	7961	6345	10470
	2000	3541	5866	4149	6505
	2001	3872	5106	3710	4634
	average	5723		5802	
Biomass	1999	9656	9290	6668	11260
	2000	4771	6747	5075	7244
	2001	5029	5796	4695	5391
	average	6882		6722	

Note: H – hummock, IHD – interhummock depression.

The estimation of the carbon runoff on the drained plot showed that as much as 142 g per sq. m. of carbon is annually deposited in the form of phytomass, whereas on the undrained plot this value amounts to 82 g per sq. m.

The conducted research showed that the forest drainage did not exert any influence on the intensity of CO₂ emission, it was practically identical on average on both plots during the years of investigation and amounted to 86.6 and 90.1 mg CO₂ per sq. m. per hour in points 6 and 7 respectively.

Mean values of CO₂ flow differ slightly on the plot of the forest amelioration during the whole research period and annually amount to 70 and 74 g C per sq. m. on plots 6 and 7 respectively.

The wider fluctuation amplitude of total CO₂ flow on the plot of the forest amelioration is the evidence of the higher intensity transformational processes of proceeding here.

CONCLUSION

The specific feature of the West Siberian plain is its clearly pronounced paludification. The large mire systems, which were formed as a result of junction of a great number of mire tracts, are widely spread on this territory. Among such large mire systems Vasyugan mire (53 thous. sq. km.), which is considered the world's natural phenomenon is distinguished. It has been established that nine thousand years ago Vasyugan mire consisted of 19 separate plots that had formed the unified mire tract by now.

The origin of Vasyugan mire has not been ascertained completely yet. The fact that the basic and greatest part of Vasyugan mire is located in the place of tectonic rising is of great interest. The following fact that the strongly watered hypnum-sedge fens occur on the most elevated part of the watershed of Vasyugan mire, i.e. at the height of 146 m. above sea level, seems also paradoxical. It is supposed that the hypnum-sedge mires appeared in the cavity, which later rose over the modern surrounding bogs as a result of modern tectonic movements. It is also inconceivable that these mires were formed on already existing eminence which surface abounds in saucer-like depressions. The latter turned out to be the nuclei of paludification.

The process of paludification on Vasyugan is not over yet. This is proved by the results of field experimental research, which is given in this book.

The process of deposition of carbon (input) prevails over its output in the form of emission of hotbed gases. For example, the research on carbon balance confirms this statement: annual input of carbon in the form of organic substance of plants into different biocenoses of the landscape profile ranges from 98.9 to 161.7 g C per sq. m. If one estimates the general removal of carbon from Vasyugan mire in the form of CO₂, CH₄ and carbon of mire waters (on average 45.1–136.6 g C per sq. m. annually) the annual carbon output will be defined by total value of 77.4 g C per sq. m. This value is considerably less than that of the carbon input.

Natural conditions favor to the activation of the process and spreading of the mires to the river watersheds. That is why the Vasyugan mire resembles a spread monster with numerous tentacles on the map.

For the first time the history of studying and research of this huge mire tract is published. It turned out that "Vasyugan Sea" long time ago attracted attention of scientists and the earliest explorers who got here "by swimming" even in the 18-th century.

The organization of the field research station in the northeastern part of the Vasyugan mire and long-term research have permitted to obtain here the new data on

hydrological, hydrothermal, microbiological, hydrochemical regimes of the mires; on dynamics of biochemical processes in peat deposits; on the gaseous regime and emission of hotbed gases [2, 19, 45, 47, 48, 49, 50, 51, 52, 54, 55, 95, 115, 130].

It seems to us that the complex geoinformational systems based on field research can be worked out for meteorological, hydrological, water-balance and other situations of the swamped territory not only of Vasyugan mire but also of all Western Siberia; it can be performed upon the example of the representative swamped reservoirs. Such elaborations would permit to distinguish risk zones based on the parameters of paludification, to create forecasting models of functioning of mire ecosystems at different levels of the anthropogenic impact.

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Natural Conditions, Structure and Functioning

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