UNITING BASIS FOR CREATION OF ECOLOGICAL MAPS FOR THE RUSSIAN CRYOLITHOZONE

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Abstract

A set of nature-protection maps of the geological environment is a necessary component of atlases. The set of cryolithozone maps should include separate maps for cryolithological texture, ground temperature, active layer, physical-geological cryogenic (periglacial) processes, pollution of the geological environment and prediction of its stability. Only a geosystem (landscape) map, correlated with territorial units of GIS-hierarchy, can serve as a uniting basis for all the maps being a part of an ecological atlas. Electronic maps using a geosystem framework are being compiled in Russia; these include permafrost and ice content as a part of circumarctic map of the world (scale 1:10,000,000); physical-geological cryogenic (periglacial) processes (1:7,500,000) and landscape units for an ecological atlas (scale 1:4,000,000).

Introduction

Ecological mapping requires complex interdisciplinary research of various parts of the Earth's environment (atmosphere, hydrosphere, biosphere, lithosphere and technosphere), carried out and displayed on a uniform cartographic framework.

A block of environmental-geological maps for the cryolithozone should contain the following maps:

- seismic-geologic;
- near-surface sediments;
- cryolithological structure;
- permafrost distribution and ground temperature;
- active layer;
- cryogenic physical-geological (periglacial) processes;
- pollution of the geological environment;
- prognosis of the stability of the geological environment.

It is obvious that a soil map is closely related to this block.

Historical overview

Until the 1980's, geocryological maps in former USSR were compiled mainly on the basis of geological formations. They were a product of various geological surveys (e.g., Quaternary, hydro-geological, engineering-geological) performed by the State Geological Survey. The geocryological map of the USSR (scale 1:2,500,000, 1996) was compiled on the same basis. At the beginning of the 1980's, however, the attention of society was attracted to the problems of using nature rationally, and to the protection of environment (Sergeev, 1981) and to the development of ecological maps (Everett et al., 1978; Isachenko, 1985). Simultaneously, or a little bit earlier, the conception of close interrelation between geocryological and engineering-geological conditions, and the geological-geographical environment (or with types of landscapes) was developed (e.g., Kudryavtsev and Nekrasov, 1975; Melnikov, 1978, 1981). It was shown that the most effective way to study these interrelationships is on a landscape or geosystem basis. The construction of such a framework leads to differentiation and mapping of natural and natural-anthropogenic geosystems within the limits of which there is the interaction of various environments. This framework also provides for the construction of a geosystems hierarchy and its division into various types.

Hierarchies of types of cryogenic geosystems were developed first for the northern part of West Siberia (Melnikov, 1983), the plains of the Russian cryolithozone (Melnikov, 1988) and Yakutia (Melnikov, 1989). Then they were implemented for the whole permafrost region of Russia (Heginbottom et al., 1993), and the Russian Arctic (Melnikov et al., 1995).

Recent advances

In recent years in Canada and the USA (e.g., Heginbottom and Dubreuil, 1993), small-scale geoc-
The essence of GIS technology consists of subdividing study areas (using various techniques) into polygons based on topography (using one of the systems of coordinates), and implementing computer digitizing (on a planimetric basis) and inputting specialized (in our case - geocryological) information.

The principal distinction between western and Russian methodologies is in the technique for the identification of geosystems. In North America, an image processing system that classifies the spectral signatures of remote sensing imagery has been used (Walker et al., 1992). In Russia, the traditional experience of aerial-photo landscape interpretation according to pattern and shading of the photo-image is commonly employed at a large scale. Nevertheless, the results of the various technologies used for separating territorial units are quite similar (Table 1).

In the preparation of ecological maps of the Arctic, a landscape map of the USSR, scale 1:2,500,000 (Gudilin, 1987) is used. On it, more than 3500 types of landscapes, including some hundreds of cryolithozone types are characterized.

According to the principles of type and hierarchy scaling of natural geosystems, the Landscape Map of the Russian Arctic (1:4,000,000) demonstrates:

1. Zonal, sub-zonal and altitudinal types and subtypes of landscapes (landscape provinces and sub-provinces, altitudinal belts).

<table>
<thead>
<tr>
<th>Name of spatial units¹</th>
<th>Area and scale of mapping¹</th>
<th>Name of landscape (geosystem) unit²</th>
<th>Area and scale of mapping²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsite/Mesosite/Macrosite</td>
<td>100 m² - 100 km²/100 - 1:500</td>
<td>Facie</td>
<td>0.001-0.01 km²/1:1,000-1:10,000</td>
</tr>
<tr>
<td>Microregion/Mesoregion</td>
<td>100 - 10,000 km²/1:5,000 - 1:25,000</td>
<td>Stow</td>
<td>0.01-1 km²/1:10,000-1:100,000</td>
</tr>
<tr>
<td>Macroregion</td>
<td>10,000-1,000,000 km²/1:250,000-1:2,500,000</td>
<td>Locality/Landscape</td>
<td>1-100 km²/1:25,000-1:1,000,000</td>
</tr>
<tr>
<td>Megaregion</td>
<td>1,000,000-1,000,000,000 km²/1:25,000,000</td>
<td>Landscape region, province</td>
<td>100-1,000,000 km²/1:500,000-1:1,000,000 and smaller</td>
</tr>
</tbody>
</table>

¹After Walker et al. (1992)  
²After Melnikov (1988)
In mountains:
- mountain tundra (T);
- mountain open woodland (OF);

II. Morphogenetic groups and types of landscape.

In platform areas:
On plains: landscapes of accumulative plains, connected with mainly neotectonic subsidence:
- marine (1);
- alluvial, lacustrine and lacustrine-alluvial (2);
- glacial and glacio-fluvial (3);
- accumulative non-differentiated (4).

On high plains and plateaus: landscapes, connected with flat neotectonic uplifts:
- alluvial, lacustrine and lacustrine-alluvial (5);
- glacial and glacio-fluvial (6);
- erosional-denudation and socle (7);
- landscapes of tablelands, shields and folded basis of platforms, connected with neotectonic upwarping and block uplifts (8).

In orogen areas:
Landscapes of intermontane and intermountain depressions, piedmont plains and piedmonts:
- marine (9);
- alluvial, lacustrine and lacustrine-alluvial (10);
- glacial and glacio-fluvial (11);
- deluvial, alluvial, alluvial-proluvial and solifluction (12);
- accumulative non-differentiated (13);
- erosional-denudation (14).

Landscapes of mountains (15).

According to lithogenetic criteria, the landscapes were divided into following types: peat (p), clay (c), sandy (s), clastic (d), rock and semi-rock insoluble (r) and soluble (k). It is proposed that this categorization will be used in the compilation of a soil map, a map of vegetation and a predictive permafrost map.

On the Circumpolar map of permafrost and ground ice, scale 1:10,000,000 (Heginbottom et al., 1993) boundaries are shown only for landscape provinces (tundra and taiga), while boundaries of morphogenetic groups and types of landscape are shown in the legend of the landscape map described above. Boundaries of landscape sub-provinces generally coincide with those of permafrost extent: continuous (sub-zone of northern and middle tundra); discontinuous (sub-zone of southern tundra and forest-tundra), and island and sporadic (sub-zone of northern and middle taiga).

The variety of genetic and lithological types of landscapes determines distinctions in ground ice content, the combination of physical-geological cryogenic (periglacial) processes and the stability of geosystems to anthropogenic impact.

A map of natural complexes of the northern part of West Siberia for purposes of geocryological prediction and planning of nature protection measures at a scale 1:1,000,000 was developed in VSEGINGEO in 1988-1989. The geosystem basis for this map was formed by the boundaries of landscape sub-provinces, regions, landscapes and localities (Melnikov and Moskalenko, 1991). The geological-geocryological characteristic of these units includes geomorphologic and tectonic features, permafrost distribution, ground temperature, origin and composition of deposits, ice content and a complex of physical-geological cryogenic (periglacial) processes. Changes of geocryological conditions for 20 years after disturbance of vegetation and snow covers for each type of locality were predicted.

In 1988-1989, a map of the resistance of geological environment to anthropogenic impact at a scale 1:100,000 was compiled for the central part of the Yamal Peninsula. The landscape basis of this map contains the boundaries of landscapes, localities, and combinations of dominant urochishche (smaller units). These units are characterized by lithology, cryogenic structure, distinctions in massive ground ice contents, ground temperature, seasonal thaw, and restoration of vegetation after destruction, as well as resistance of geological environment to anthropogenic impacts.

References


Gudilin, I.S. (ed.) (1987). Landscape map of the USSR, scale 1:2,500,000. Leningrad, VSEGEI.


Melnikov, E.S. (ed.) (1978). Guidebook on engineering-geological survey, scale 1:200,000 (1:100,000 to 1:500,000). Nedra Publisher, Moscow (391 pp).


