The set of eco-geologic digital maps of the Timan-Pechora province

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ABSTRACT: The complete set of small-scale electronic digital maps displaying landscapes, climate, geology, geocryology and hydro-geology of Timan-Pechora oil & gas province has been drawn up on the basis of publications and archival data. Results of authors’ field research, in-situ investigations and regime observations were used. Geographical information systems (GIS) of regional and local levels including attributive electronic databases organized in PARADOX were also applied. The electronic maps are created by means of GEODRAW/ GEOGRAPH software. The main feature of the implemented research is the development of the geosystem technique for analysis and digital mapping of permanent frozen ground as well as for forecasting of eco-geological (environmental) changes.

1 INTRODUCTION

The Timan-Pechora oil & gas province occupies the territory of Komi Republic and Nenets district in the north-east of European Russia. This province takes the third place in Russia in the value of oil and gas resources. About 200 hydrocarbon deposits have been discovered here. More then 150 of them are the oil fields. Nowadays Usinskoye, Vozeyskoye, Pashinskoye, Yareyskoye, Vuktylskoye deposits in Komi Republic and Varandeyskoye and Vashutkinskoye deposits in Nenets district are in operation. At a number of oil and gas fields the trial operation is carried out now.

The northern part of Timan-Pechora oil & gas province is located within cryolithozone. European cryolithozone is characterized by significantly discontinuous permafrost, close to 0°C ground temperature, numerous cryopegs, high ice content, and also widespread ice-wedges. Thus, the operation of oil and gas fields here is impeded by unfavorable engineering-geocryological conditions.

The experience of geocryological research in Russian North shows, that the gradual changes of geocryological conditions are mainly caused by short-term and long-term climate fluctuations. Within the developed areas natural factors of environmental changes are supplemented by technogenic ones. As a result the character of interaction of cryolithozone to engineering structures modifies. Thus, the province development would be inevitably accompanied by significant environmental changes.

The creation of the complete set of environmental-geological (eco-geological) maps of the Timan-Pechora oil & gas province allows to carry out engineering zoning of the territory, designate areas, most adverse for economic development, implement optimum designing of engineering structures, give the forecast of technogenic and cryogenic processes caused by global climatic and technogeneous factors as well. The GIS technologies would facilitate the solution of these tasks.

2 SOURCE DATA AND METHODOLOGY

Environmental-geocryological research in the areas of economic development are directed to revealing, mapping, spatial and temporary forecasting of geocryological conditions and estimation of ecological influence of both natural environmental dynamics on engineering structures and human activity on geology, permafrost, water and landscapes.

The Timan-Pechora oil & gas province territory has been well enough and completely investigated. The basic information necessary for creation of environmental-geological GIS can be found among small-scale graphic documents presented in the literature (Komarov, 1982; Ershov, 1988; MSU, 1983), Oberman (1998, 2001) and in archives. The maps with explications by Gudilin (1980), Brown et al. (1997), Belov et al. (1990), Nalivkin et al. (1966), Churinov et al. (1972), Melnikov et al. (1999), Oberman (1980–1999 – personal communication) are most important among them. The results of the own research and the processing of different remote data were also used (Melnikov et al. 2002). A lot of data is received during carrying out national and international research programs such as Circumpolar Arctic vegetation map – CAVM (Walker, 2002), Arctic costal dynamics – ACD (Rachold, 2002) and others.

Geocryological investigations in Timan-Pechora province began at the end of 1970th along with intensive economic development of the territory associated mainly with oil and gas resources prospecting. The significant engineering-geocryological and hydro-geological results have been obtained by scientists from Yorkuta city (Oberman, Prokopova and others).
The detailed research was carried out by the employees of numerous geologic companies such as Arkhangelsk Geology, Timan Expedition, AeroGeology etc., who have created a number of both small and medium-scale complex and thematic maps on the Program of General Investigations at European North. The geocryological zoning map for the purposes of oil-fields development appeared to be one of the most interesting results of these activity.

Before now all this information has been stored traditionally – on a paper. Thus the significant part of the data is unavailable, since frequently it is located in regional and private archives.

At the first stage of the implementation of the complete set of maps the data obtained in different time from different authors would be collected and systematized. The GIS technology provides the binding of all the elements of landscape, meteorological, tectonic, geological, geocryological and other information.

The important stage of creation a GIS including maps with digital layers and tabulated data with coordinates and altitude, is the transformation of all the diverse graphic information contained in the published and archival documents, and also in author’s archives, to a uniform graphic and conceptual basis. The set of maps should include the electronic layers as follows:

- Annual air temperature
- Sums of positive and negative air temperatures
- Atmospheric precipitation rate
- Character of a snow cover
- Thickness of Quaternary sediments
- Neotectonic zoning
- Permafrost extention and thickness
- Exogenic geological processes and phenomena
- Landscape and geotechnical zoning

The processing of accumulated data was held by GEODRAW/GEOGRAPH (GeoGraph 1996) software which provide the conversion of electronic data in ARC/INFO formats. The Lambert azimuth projection with 57° axial meridian was used. Scale 1:1 000 000 ensure optimum display of examined territory.

3 DISCUSSION OF RESULTS

The meteorological data on the territory of Timan-Pechora oil & gas province has been collected through the long-term observation of 15 meteorological stations of the region. The longest observation data lists were obtained at Syktyvkar (1818–2000), Ust-Cylma (1896–1995) and Naryan-Mar (1927–2000) meteorological stations. Monthly and annual air temperature, the sums of positive and negative air temperature, precipitation rates, thickness and density of snow cover in various landscape conditions are the most important meteorological data for geocryological and environmental purposes. Meteorological characteristic of region is shown at Figure 1.

Neotectonic zoning of the Timan-Pechora oil & gas province was carried out using geologic, geophysical and landscape maps and also the spacecraft. The territory approves to have rather heterogeneous geostructures with active neotectonics (MSU 1983) (Fig. 2). It results primarily in thickness and lithology of Quaternary sediments. The thickness varies from 0 to 50 m at dome sites, up to 200–300 m within the limits of structural lowerings.

Landscape zoning of territory was implemented taking into account climatic zoning, neotectonics and geological conditions (Fig. 3). According to the developed principles of landscape zoning the units of several rank are specified: landscape zones and sub-zones, landscape provinces and sub-provinces, landscapes, localities and urochishche (stows). The minimum rank of a mapped unit at landscape zoning is determined by the tasks and scale of research.

Neotectonic conditions influence significantly the geocryological and hydro-geological conditions. Zones of deep regional faults determine the location of the sites of underground water discharge and of specific cryogenic processes – pingo, ice-hills, icing, etc. In general tectonics is one of the most important factors of cryogenic processes distribution at the Timan-Pechora oil & gas province. Wide-spread bogs and thermokarst are the characteristic of neotectonic structural lowering sites. Erosion, thermoerosion, coastal-thermoerosion, thermodestruction, polygonal ice-wedge formation occur at the sites of neotectonic raising. The exogenic geological processes can be shown on a complex map, where the whole set of processes is represented schematically. One more approach allows to show accurately the features of one or two processes and specify their genesis, morphology.
etc. A combination of both approaches can also take place (Fig. 4).

Geocryological information is expedient to be represented as isolated components at several maps. In such kind of maps it is easier to analyze each component. At the same time GIS technology allows to correlate digital spatial data on examined parameters and to carry out the overlay procedure.

The geosystem analysis approved that geocryological conditions of the province are determined by latitude and climatic zoning. Some of the local changes have neotectonic, lithogenetic and landscape
The main geocryological parameters are the permafrost extent and the temperature at the depth of absence of annual temperature fluctuation (12–16 m for the province; Fig. 5). Lithology, ice-content and cryogenic structure of subsurface sediments, composition and thickness of active layer, permafrost thickness, permafrost relic spreading and some other characters are demonstrated as well.

The most complex geologic and geocryological information is represented at the map of engineering-geocryological zoning. The map displays permafrost extent, including territories of cryopegs, lithology, age and genesis of Quaternary sediments, as well as not deep rocky socle occurrence (Fig. 6).

An explication and attributive table contain the data on ground temperature, ground-ice content, ice-wedges, and exogenic processes in each unit of zoning.

The prognostic maps are implemented for forecasting of various components of geocryological and ecological condition under different scripts of changes. It can be a script of climatic changes (increase or decrease of air temperature or humidity), or a script of various technogenic disturbances of natural environment. The forecast of change of permafrost temperature at different snow cover disturbances and various type of surface soils (Fig. 7) serves as an example of such a prognostic scheme.

The environmental-geological map characterizes ground waters safety in case of surface pollution depending on permafrost extent and presence of clay layer near surface, and also active layer safety from pollution depending on its lithology. Besides, the environmental-geological map displays the sites where dangerous exogenic geological processes occur. These processes can result in the destruction of surface and in negative influence on engineering structures and buildings.

The figures, displayed in this article, are intermediate and final product of appropriate GIS. They were drawn up using the database on the province. In each case different digital computer layers containing landscape, meteorological, geologic, tectonic, geocryological,

Figure 7. The geocryological temperature forecast at the various scripts of disturbances: A – for sand; B – for sandy-loams; C – for loams; D – for peat. Type of design model: 1 – «with snow»; 2 – «with deleted snow».
geoecological and other information are selected in order to display the most significant features according to the special-purpose designation of the particular map.

4 CONCLUSIONS

On the basis of published and archival materials on landscapes, climate, geologic structure, geocryological and hydro-geological features of the territory of the Timan-Pechora oil & gas province the complete set of small-scale digital maps was implemented. These maps are necessary for environmental-geological research. While drawing up these maps the main attention is paid, firstly, to exception of the contradictions between different sets of data sources, and secondly, to the reconstruction of an adequate picture displaying natural conditions of the Timan-Pechora province.

The first subset of maps generalizes the meteorological characteristics – precipitation, thickness of a snow cover, terms of its fall and thawing, air temperature measured at the operating as well as recently closed meteorological stations. These data correlate well with the natural boundaries of climatic zones.

Landscape and Quarternary geology maps are the data source for drawing up geocryological maps and for prognostic geocryological design. The characteristics of dynamic subsurface geocryological conditions are updated in view of modern information on landscape provinces boundaries. It basically concerns the permafrost extent in the subsurface zone and soil temperature.

The meteorological data and data on soils and ground allow to predict change of permafrost temperature under the different variants of human activity and also disturbances of covers and surface.

The environmental-geological map characterizes ground waters and active layer safety in case of surface pollution and also the sites with dangerous exogenic geological processes.

ACKNOWLEDGMENT

The research is supported by INTAS (grant 01-2332) and RFFI (grant 01-05-64256).

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