ANALYSIS AND ASSESSMENT OF NATURAL RISKS FOR UNIFIED GAS SUPPLY SYSTEM FACILITIES OF RUSSIA USING PROMISING GEOINFORMATION TECHNOLOGIES

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Introduction

The length of the Russian gas transmission system (GTS) amounts to over 152 thousand kilometers, which are operated under different natural conditions. The facilities of the Unified Gas Supply System (UGSS) of Russia, as well as regions of prospective gas resources development, are subject to direct impact of all known types of hazardous geological and hydrological processes and indirect impact (due to power supply interruption) of hazardous meteorological phenomena [1,2]. The global climate change increases the probability, recurrence and distribution of natural disasters (heavy and intensive precipitation, strong winds, floods), which stimulate hazardous exogenic geological processes that are potentially dangerous for the integrity of GTS facilities.

Identification of the most significant risk factors according to corporate accident statistics shows that the role of natural hazards in gas pipeline accident rate consists in [3]:

1) the creation of short-term and specific loads that cause “instantaneous” destruction of facilities (activation of hazardous natural processes including earthquake, landslides, rainfall floods, mud flows, etc.) – over 7 % of accidents (Figure 1);

2) the formation of continuous and long-term loads (long-term impact of adverse factors including erosion processes, flooding, change in soil chemical composition, etc.) stimulating the development of hidden defects in pipelines – over 30 % of accidents (Figure 2).

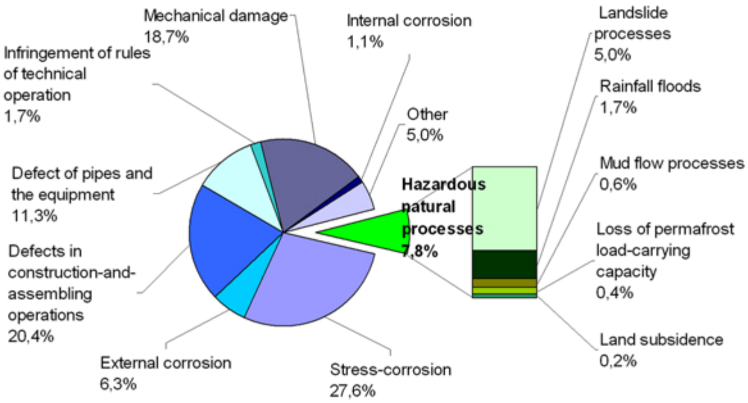

Figure 1 – The reasons of accidents at the linear pipeline portion

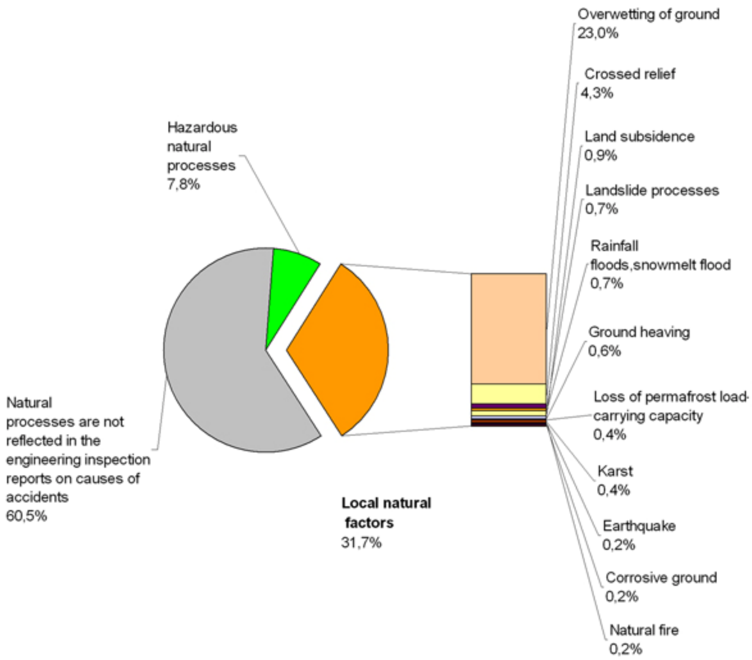

Figure 2 – Structure of local adverse natural factors, on which background there were accidents at the linear pipeline portion

Natural risks for operating UGSS facilities are created by a significant number of factors, part of which are accidental and with hardly fully predictable (during facilities construction) consequences. Therefore, there is the need for generation of problem-oriented models with data bases, which would include not only information on process facilities, but also systematized data on natural factors that form potential hazards for the integrity of gas transmission system, for the UGSS area with account of its future development.

Aims

The aim of works is creation of the information environment in the form of cartographical model for quantitative assessment of natural hazards and risk for UGSS facilities in view of its prospects of development in areas of Eastern Siberia and the Far East.

Methodological aspects

Geoinformation system (GIS) are the best media for integration of homogeneous and systematized data of various detalization to the united information environment.

Geoinformation technologies are successfully implemented in various analytical and control systems of Gazprom and its subsidiary companies. Thus, Gazprom transgaz Surgut implemented GIS of trunk pipelines: it stores the process information on facilities of the company's pipeline system (length – 7,5 thousand km) and covers main production processes – operation of linear section of pipelines, compressor and gas distribution stations, automatic and teleautomatic systems, corrosion protection. GIS includes the expert system for assessment of the condition of trunk pipelines and forecast of their safe operation [4].

To study specific issues of assessment of natural hazards and risks for gas supply facilities on the corporate level (with account of development prospects – it is almost the whole territory of Russia), Gazprom VNIIGAZ has worked out the basic information-analytical cartographic model.

At various stages of creation of model as coauthors scientists and collectives from leading institutes of Russia were involved: A.P. Karpinsky Russian Geological Research Institute; Geological Institute RAS; Institute of Earth Cryosphere SB RAS.

Basic methodological principle of construction of model is the hierarchy of data corresponding levels of management in Gazprom: 1) macrolevel – corporate level of management, the Unified Gas Supply System (UGSS) of Russia as a whole in view of prospects of its future development in Eastern Siberia and in the Far East; 2) mesolevel – objects of gas supply in a zone of the responsibility of an Subsidiary Company; 3) microlevel – functional technological blocks, pipeline section (Figure 3).

The aspect determines detail of base cartographical model depending on a level of management and solved problems.

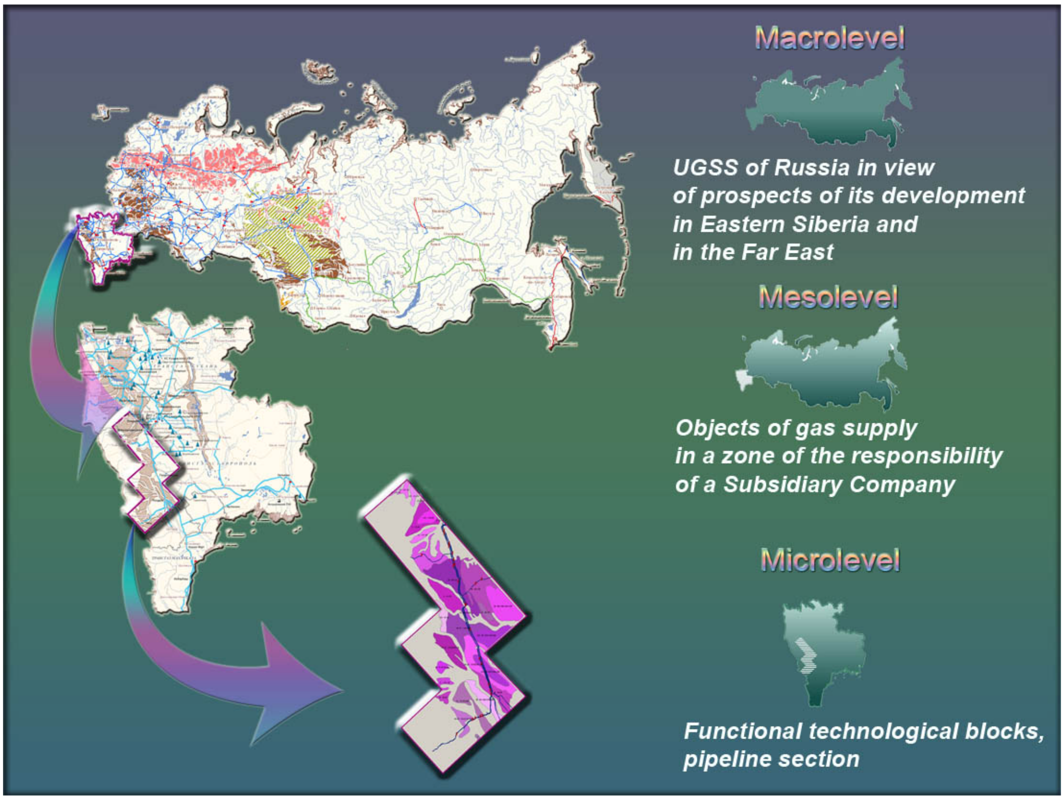

Figure 3 – Hierarchy in construction of model

Thematically the database of model for each level contains structured on groups of thematic layers the information: accident rate and technical characteristics of Gazprom's facilities, geological conditions (including faults), hazardous geological processes, hydro-geological conditions, contemporary climate changes, estimations of the permafrost zone and hazardous hydrometeorological phenomena (Figure 4).

The information products are developed on the basis of model: GIS-Atlas «Comprehensive assessment of natural hazards for Gazprom's facilities» and Geodata base for accident-dangerous pipeline sections (with two- and three- level representation of the information respectively). Method of the tentative assessment of corrosion danger on the information basis of model are offered.

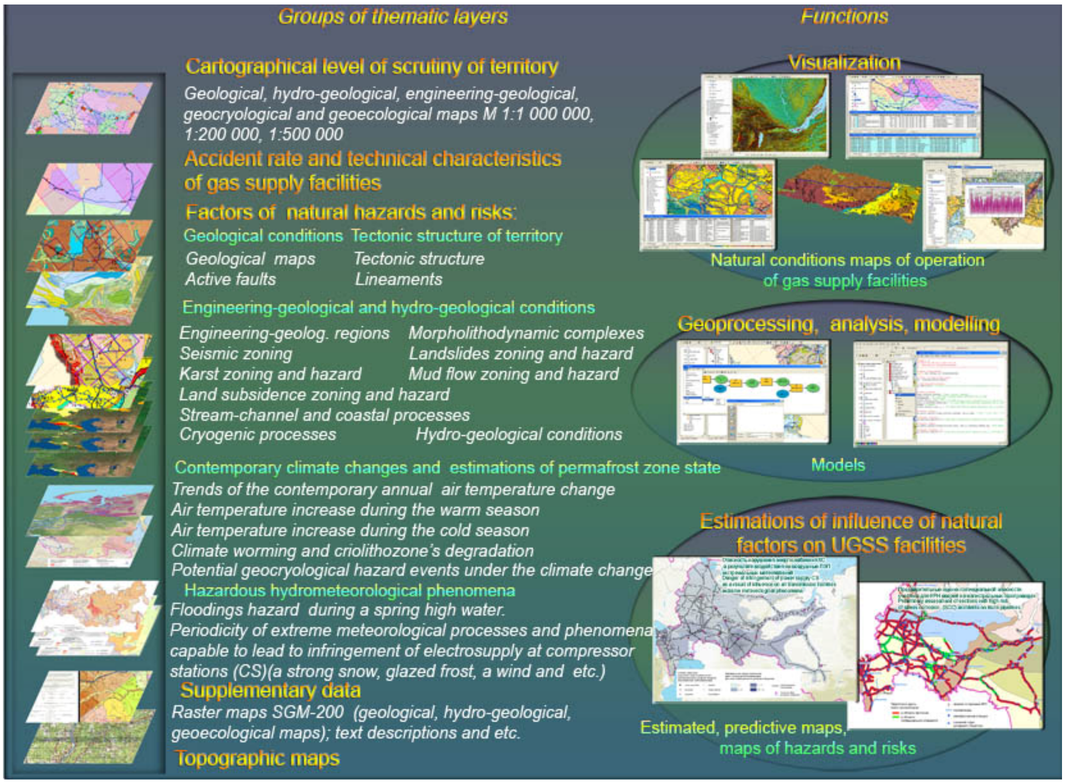

Figure 4 – Structure of basic cartographic model

Results

GIS-Atlas "Comprehensive assessment of natural hazards for Gazprom's facilities" has been worked out in soft and hard versions using modern geoinformation technologies. The GIS-Atlas comprises digital vector maps (over 150) generated on a uniform methodological basis and software. Maps are divided into 11 blocks representing the territory of Russia as a whole, responsibility zones of Gazprom's subsidiary companies and the territory of prospective development of gas resources of East Siberia and the Far East.

GIS-Atlas contains not only the thematic maps describing natural factors which can be direct sources of accidents (earthquake, landslides, karst, mud flow, flooding), but also factors which promote accumulation of damages and reduce reliability of facilities (faults, linear erosion, geocryological processes, land subsidence, stream-channel and coastal processes, composition and a mineralization of ground waters) (Figure 5).

Explanatory notes to maps reflect the distribution of hazardous natural processes, principles of their classification and mapping, influence of the natural processes on actual accident rate of gas supply facilities, the mechanism of their damage effect; location of gas supply facilities in hazardous zones. Explanatory notes are illustrated by insert maps, tables, diagrams obtained during the analysis of corporate statistics.

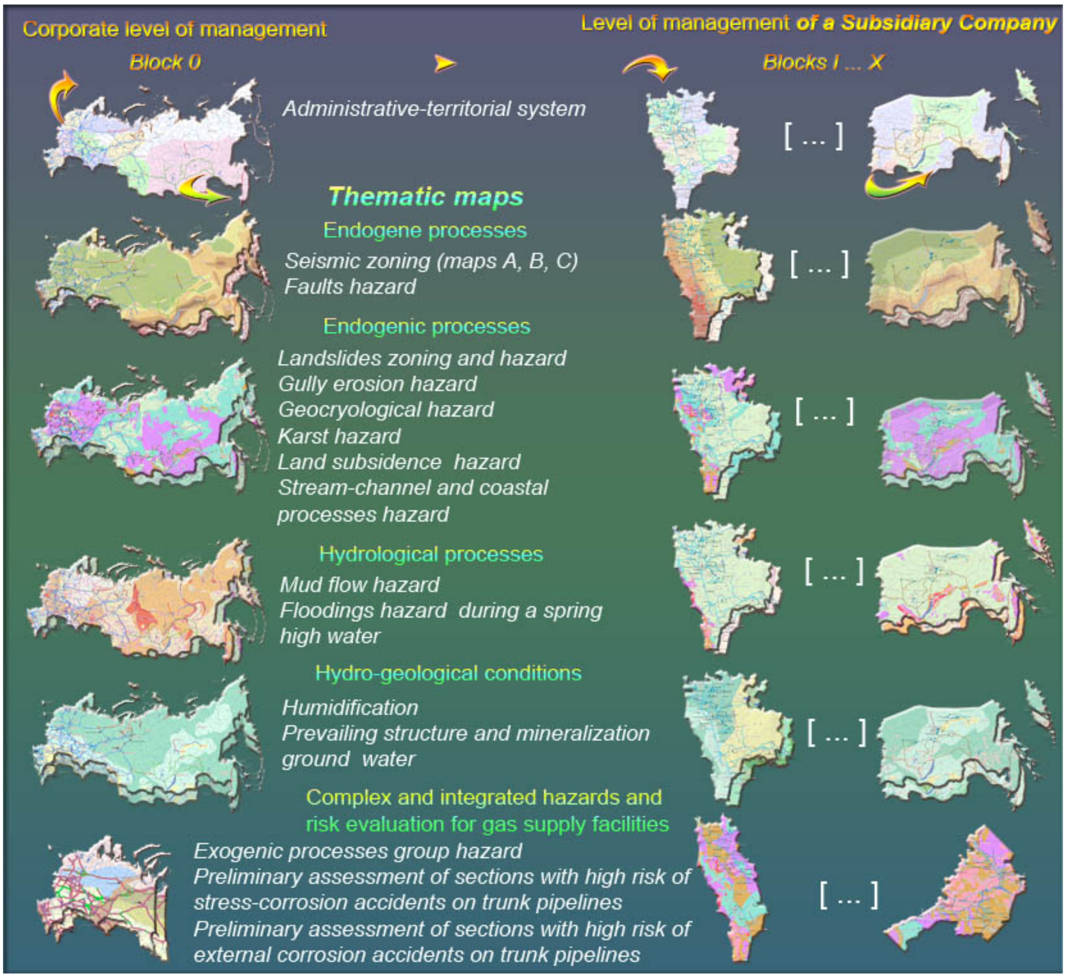

Figure 5 – Structural blocks of the GIS-Atlas based on the model

The soft version of the GIS-Atlas (interactive application) provides availability of the electronic vector information to the users without special GIS skills and is installed on workplaces of users without the additional special software.

The vector materials included in the soft version of the GIS-Atlas, irrespective of scale of "paper" thematic maps, are presented mainly in volumes of maps 1:2 500 000, and on a number of problem regions - in volumes of maps 1:1 000 000 and 1:500 000. Therefore, in spite of the fact that both versions of the GIS-Atlas have similar substantial structure, the soft version of the atlas gives to the user an opportunity to receive the expanded information on object, owing to a number of information-analytical functions (Figure 6):

- visualization of the data in volume of an initial cartographical source;
- an interactive select of feature;
- scaling;
- on-line help (information, tables);
- search of objects;
- export to a raster and print of maps (or fragments) with the scale set by the user.

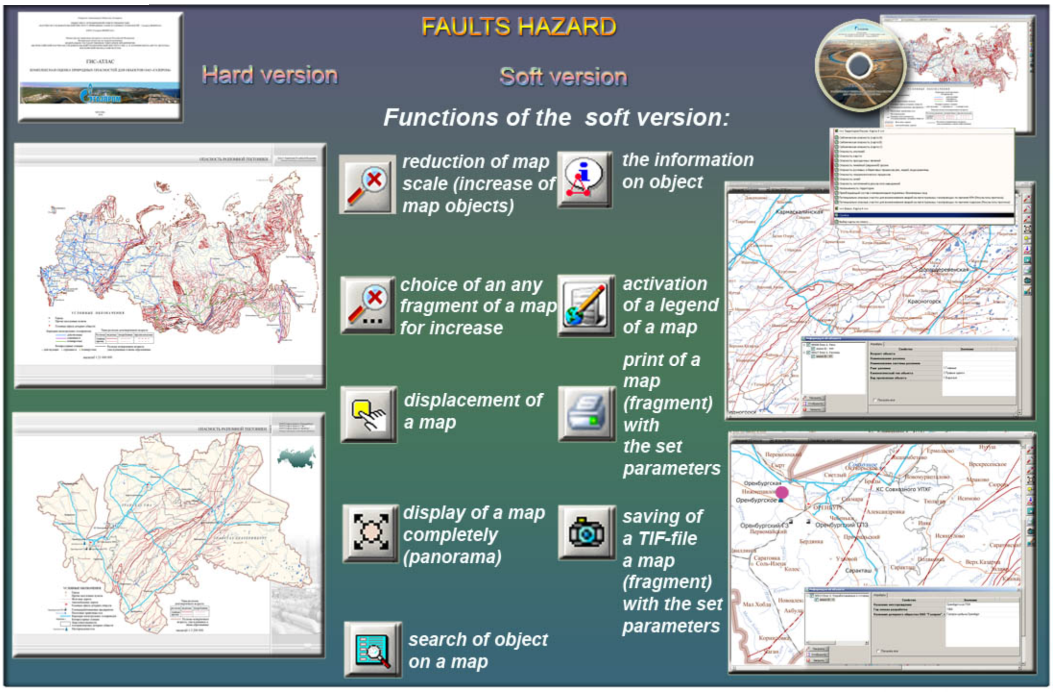

Figure 6 – Soft and hard versions of the GIS-Atlas (example for faults hazard map)

The GIS-Atlas has been developed for a long-term use, in future the number of maps will grow due to the detailed factor maps and addition of new analytical maps obtained using the data base of the model.

The extensive information base of cartographical model can be used for the profound GIS-analysis. Thus the problem-focused models are formed and new thematic maps which purpose is revealing relationships of cause and effect between conditions of an environment and reliability of functioning of gas supply facilities.

Let's give an example evaluations of natural risk factors on the basis of the model (Figure 7). Accidents are chosen (selected) from database of model for the reasons: defect of pipes, the external corrosion, stress-corrosion , defects in construction-and-assembling operations, infringement of projection (63 % from total of accidents). It is determined by means of model, that 7,5 % selected accidents (4,8 % from total of accidents) are in zones of geodynamic structures influence. Accidents are is more often dated for zones of active faults (mountainous areas), than to lineaments (platform areas). Average frequency of accidents: in zones of crossing with an active faults of 0,12 accidents (on one crossing), in zones of crossing with lineaments – 0,09 accidents(on one crossing).

Thus, for UGSS trunk gas pipelines as a whole the risk factor connected with tectonic faults , cannot be determining for identification and the forecast of under abnormal condition dangerous sites. At the same time the geodynamic factor should be considered (with use of weight factors) at a complex estimation of natural risks for facilities of gas supply. The importance of this natural factor can be received similarly for any interesting site of territory of gas-transport system functioning where its "weight" can be more or less, than average for all system.

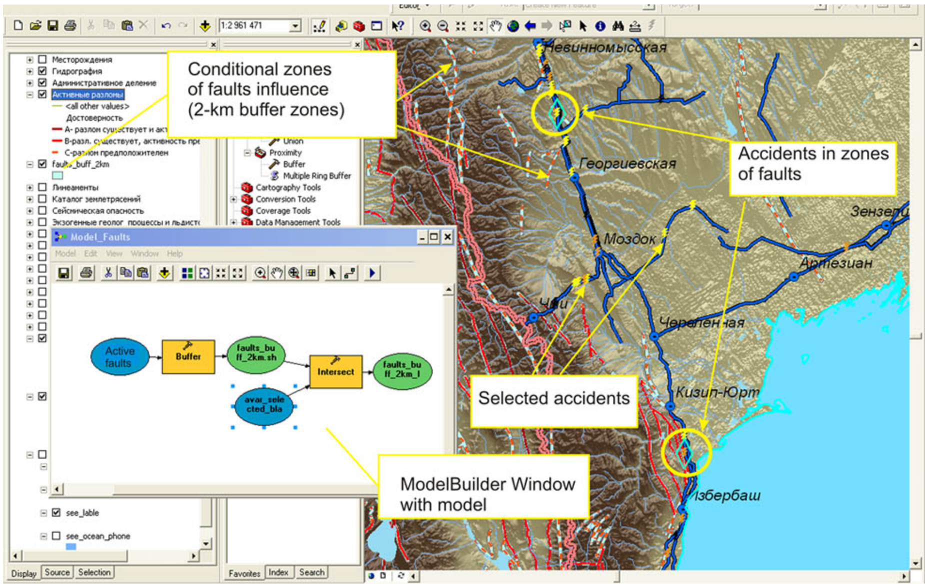

Figure 7 – Identification of the geodynamic risk factor for gas pipeline operation on the basis of the model

At the first stages of creation of information environment bazed on GIS the main directions in its use are management of data, the analysis and modeling (example above). Following important step becomes the multifactorial analysis of this constantly completed information as bases for forecasting and decisions of problems.

Example of that use of model geodatabase for the multifactorial analysis are the thematic maps included in structure of the GIS-atlas: maps of preliminary assessment of sites with high risk of stress corrosion (SCC) accidents (Figure 8) and external corrosion accidents (Figure 9) on trunk gas pipelines. The choice for forecast of danger of accidents for the reasons external corrosion and stress-corrosion is connected not only with a significant share of these reasons in accident rate: for these groups of accidents the highest contribution of local adverse natural factors (from 33 up to 55 %) is noted.

These maps are developed with use of the offered method of the forecast of abnormal condition dangerous sites on the basis of image identification method by indirect images. Conditions for occurrence of some accidents are formed at a combination of set of natural factors which are indirect attributes, so long as relationship between these factors and emergency condition is unobvious and ambiguous. The natural factors influencing occurrence of accidents, are presented in the form of cartographical objects (features) and reflected in layers of the cartographical model. Therefore thematic layers of model (natural factors, constructive-technological and operational parameters of trunk gas pipelines) are used for the forecast as indirect images. Forecasting of danger of territory is lead by calculation and the subsequent interpretation of measures of similarity of elementary cells of territory along on trunk gas pipelines route with the generated model of natural factors of accident (in this case – stress-corrosion and external corrosion).

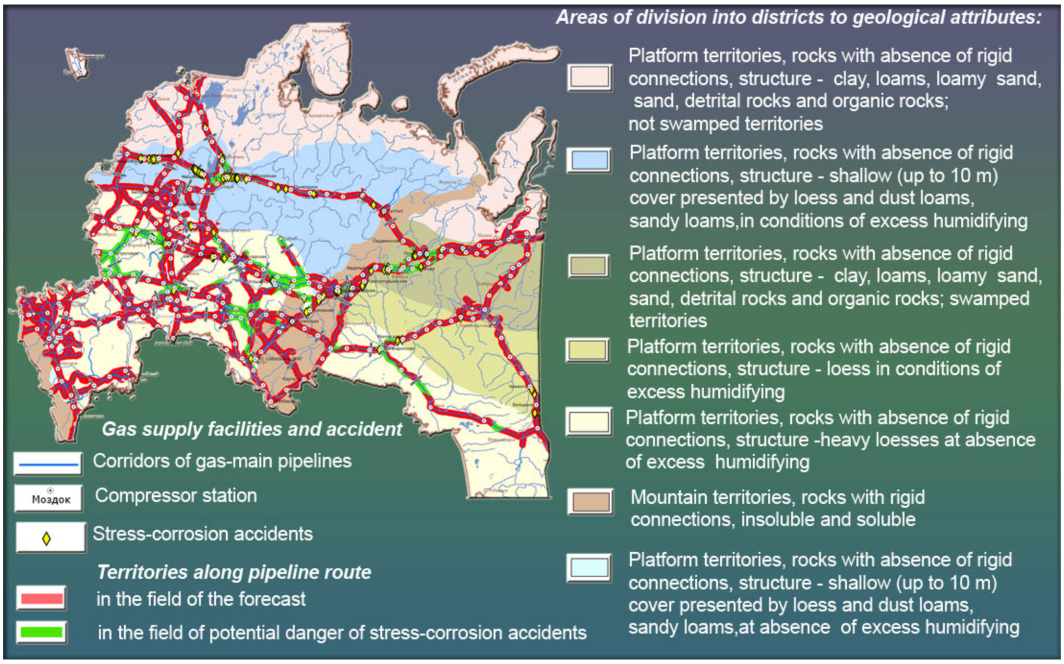

Figure 8 – Preliminary assessment of sites with high risk of stress corrosion cracking (SCC) accidents on trunk gas pipelines

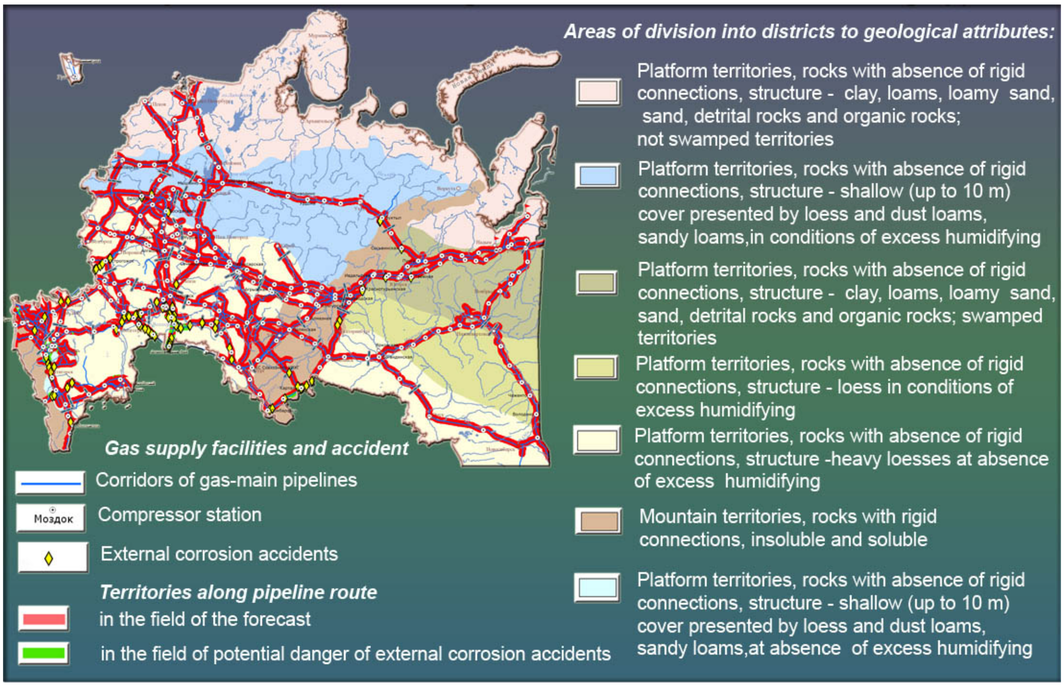

Figure 9 – Preliminary assessment of sites with high risk of external corrosion cracking (SCC) accidents on trunk gas pipelines

The preliminary forecast should be specified at the subsequent hierarchical levels, and in these cases will be necessary attraction more detailed and expanded (according to a level of the forecast) cartographical information on natural factors, constructive-technological and operational parameters of gas pipelines (any of which can be presented in the form of cartographical objects and to use as indirect images for the forecast).

Conclusion

The cartographic model and GIS-Atlas will be used:

– as scientific-information, methodical and factual support of development of activities aimed at safe and reliable operation of GTS facilities;

– for analysis of risks and technical condition of gas supply facilities (generation of hypotheses, identification of new patterns of mutual impact of pipeline system and environment, substantiation and assessment of risk factors, integral assessments);

– for drafting documents on industrial safety;

– at pre-investment stages of design and at initial stages of investment justification;

– for designing programs of further studies intended for enhancing sustainability of UGSS of Russia and its development in prospective regions.

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