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The investigation of dangerous geological processes resulting in land subsidence while designing the main gas pipeline in South Yakutia

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Abstract. The number of gas main accidents has increased recently due to dangerous geological processes in underdeveloped areas located in difficult geological conditions. The paper analyses land subsidence caused by karst and thermokarst processes in the right of way, reveals the assessment criteria for geological hazards and creates zoning schemes considering the levels of karst and thermorkarst hazards.

1. Introduction

According to Gazprom VNIIGAZ LLC, currently there are risks of accidents through dangerous geological processes. While investigating the influence of natural factors on the continuity of the Unified Gas Supply System (UGSS) it is important to take into account the experience of gas transmission network operations under dangerous natural processes. One of the factors of potential accidents is UGSS expansion in underdeveloped areas where there are no statistics for long-term observations of dangerous geological processes. Subjective hazards are mistakes made during the gas pipeline design and construction [1].

The main loads influencing gas mains are the following:

- Gas pipeline weight;
- Coating weight;
- Backfill stress;
- Voltage (due to elastic bending);
- Internal pressure;
- Piped product weight;
- Thermal stresses;
- Special loads.

Special loads on gas mains are those which are caused by ground deformations. Such loads should be calculated on the basis of analyzing ground conditions and their potential change while constructing and operating the pipe [2]. Subsidence processes are one of the main reasons for special loads on gas mains. They influence the surface relief substantially by forming large areas of subsidence. Such processes while impacting on the gas main create additional mechanical stresses thus increasing the influence of other defects in the pipe wall. Due to these sources, stresses beyond design limits are the most common and dangerous as it is often impossible to take them into account [3]. However, it is possible to determine the stresses beyond limits during the construction and operation stage by calculating stress-deformed state of the gas main in the areas of subsidence.

Currently the investment project “The Power of Siberia” is one of Gazprom’s largest projects. The implementation of this program will allow increasing the level of social and economic development of the Republic of Sakha (Yakutia), the Amur Region, as well as the export potential within Asia-Pacific Region [4].

The paper will consider the potential subsidence hazards in the section “Chayanda-Lensk” (160 km long) of the gas main “The Power of Siberia”, which is being built in South Yakutia. In this section both karst and thermokarst may cause land subsidence, which creates mechanical stresses in the pipe and leads to the loss in its reliability.

As mentioned before, there are no time-lapse data concerning dangerous geological processes. Therefore, it is necessary to develop the methods assessing the impact of these processes on the pipe despite the absence of long-term observations.

2. Experimental design

The following stages of fulfilling the task can be singled out. During the first stage the analysis of available information on complex engineering testing was carried out and the relevant map material was selected. The data were processed by means of such software programs as GIS MapInfo Professional, AutoCAD. During the next stage karst and thermokarst processes were ranked according to hazard levels. The overall procedure is presented in Fig.1.

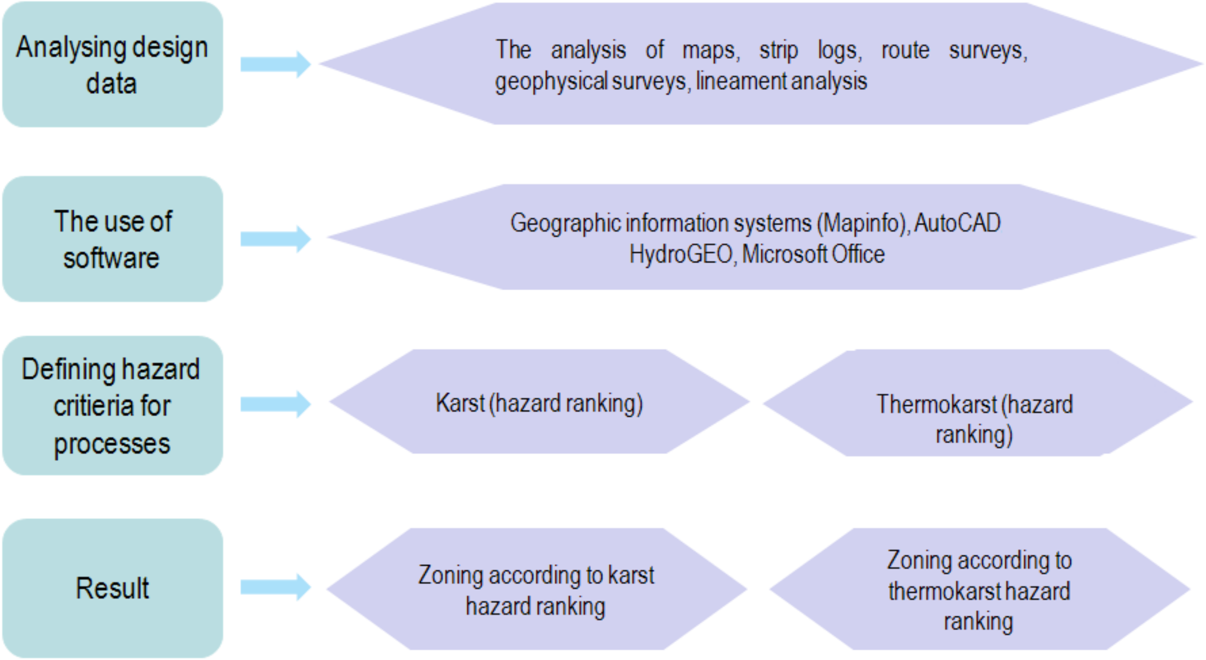

Figure 1. The Overall Procedure

GIS “MapInfo Professional” organized information with layers. The following tables of information (layers) were constructed: wells, the state geological map, the map of quaternary deposits, hydrography, geophysical research, karst development segments (Fig.2). The factual evidence on the wells comprises more than 1500 elements. Thus, the database of geological conditions in the construction area was created.

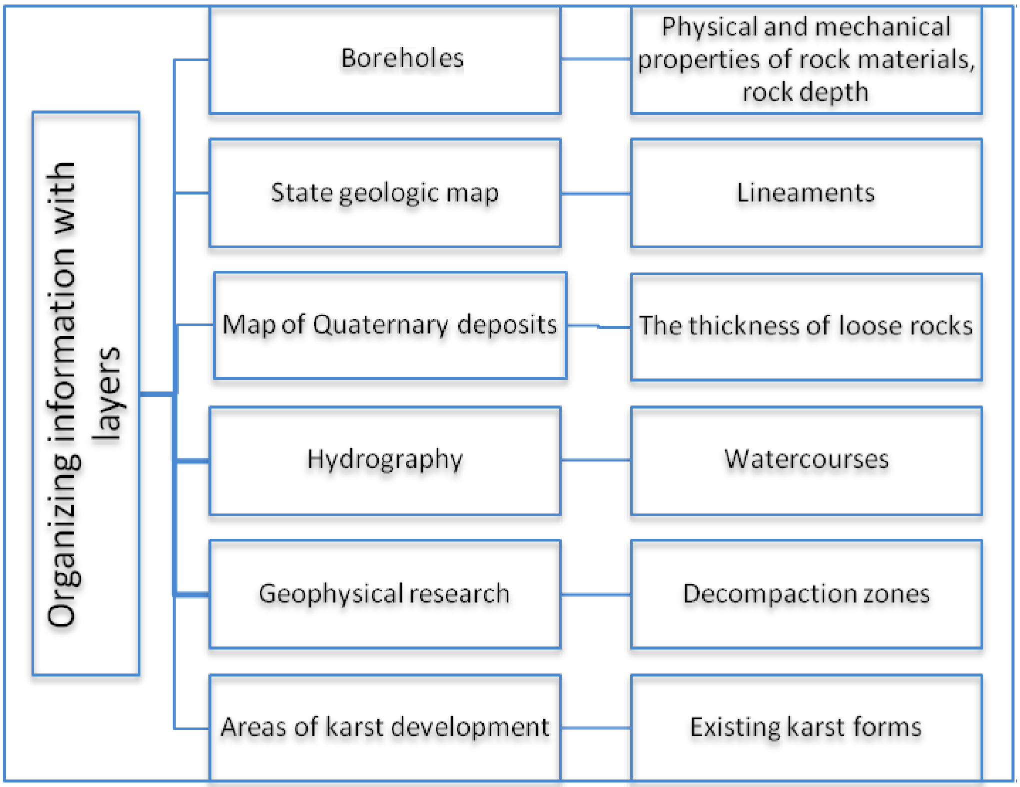

Figure 2. Data Structure in GIS «MapInfo Professional»

We suggest assessing hazards by employing the integral criterion of potential karst development. The following groups of indicators should be mentioned: structural and tectonic, hydrogeological, geological, geomorphological and geophysical groups. Among the indicators characterizing karst hazards are the number of crossing lineaments, groundwater depth, indicator of groundwater aggressiveness, existence of karsting rocks, existence/ absence of aquiclude, the remoteness of river networks, existence of karst landforms, existence of loosening zones. Thus, we suggest ranking the main gas pipeline route depending on its proneness to karst processes according to such criteria as:

- Dangerous area: (the number of crossing lineaments >2 crosses/km, groundwater depth > 3 m, indicator of ground aggressiveness <-1, presence of karsting rocks, absence of aquiclude, presence of karst landforms, presence of loosening zones according to geophysical research);
- Potentially dangerous area: (the number of crossing lineaments >1 crosses/km, groundwater depth > 5 m, indicator of ground aggressiveness 0> A >-1, presence of karsting rocks, presence of aquiclude < 1 m, presence of karst landforms);
- Safe area (the number of crossing lineaments <1 crosses/km, groundwater depth > 10 m, indicator of ground aggressiveness A>0, presence of sufficiently powerful aquiclude).

This resulted in the zoning according to karst hazard ranking in the right-of-way (Fig.3).

While assessing thermokarst hazards it is necessary to take into consideration the construction and operation experience of the first gas main in cryolythic zone – VSTO-1. In our case the main factor increasing the thermokarst hazard is the heat transfer change on the ground surface when seasonal deicing depth exceeds the depth of seasonal ice bedding or icy permafrost due to human impact – tree-cutting due to pipe operation [5,6,7].

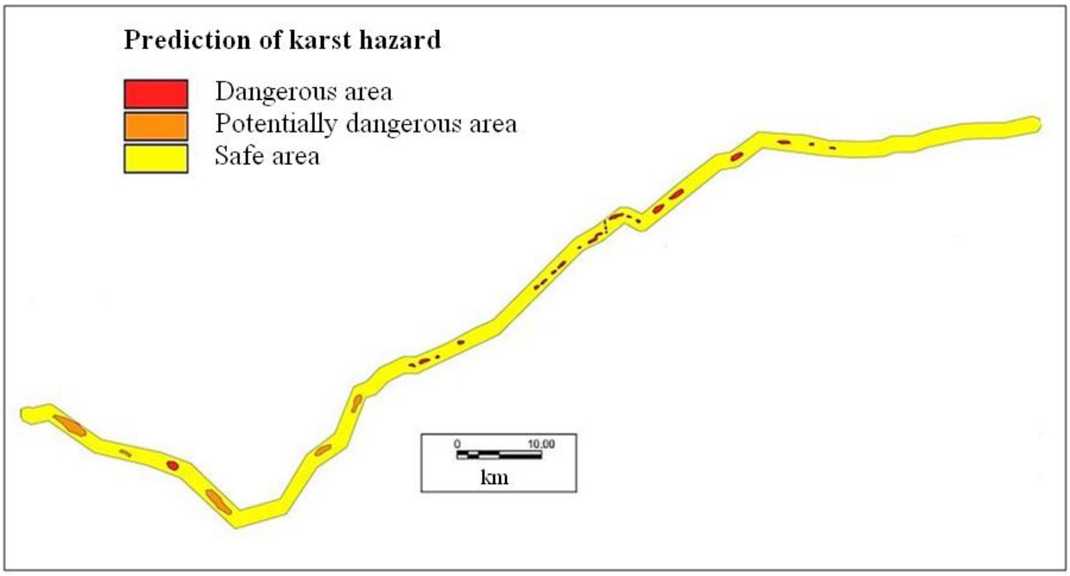

Figure 3. Zoning according to Karst Hazard Ranking

There are also hazards in areas with embedded subterranean ice and polygonal wedge subterranean ice. To define dangerous areas we propose the following algorithm: the analysis of geologic-lithological columns for detecting the areas with ice bodies based on the ranking (table 1).

Table 1. Indicators

Area	**Indicators**
Dangerous area	The presence of monomineralic ice (depth more than 0.1 m) in geological column
Potentially dangerous area	The presence of ice content in rocks (unit fraction > 0.3) in geological column
Safe area	The absence of ice content rocks (unit fraction > 0.3) and monomineralic ice in geological column

After selection in GIS “MapInfo Professional”, the areas prone to thermokarst hazards were identified according to the indicators mentioned in table 1. Potentially dangerous areas were also identified along the main gas pipeline route (Fig.4).

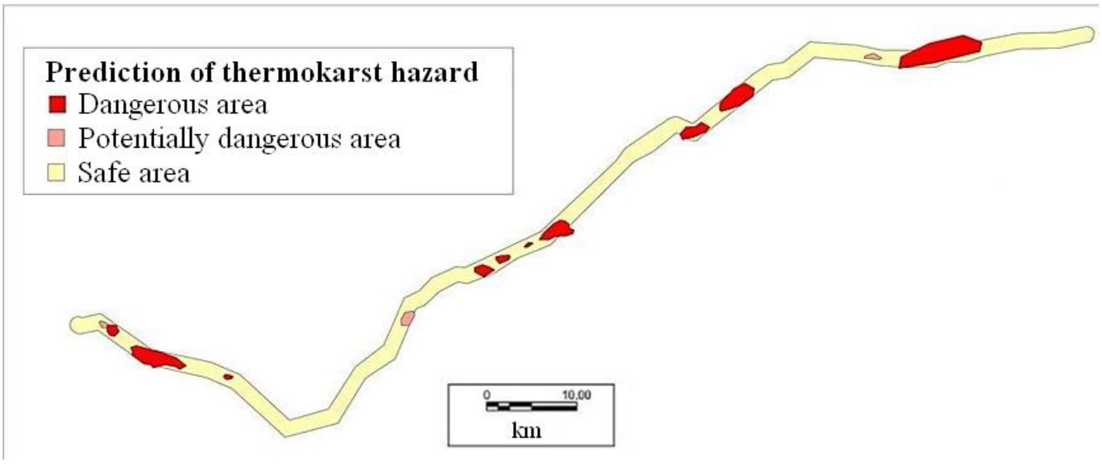

Figure 4. Zoning according to Thermokarst Hazard Ranking

Thus zoning according to karst and thermokarst hazards was made.

3. Summary

We propose to classify dangerous areas according to the degree of karst and thermorkarst hazards by mapping geological information on the base material in GIS “MapInfo Professional” and executing query in the existing database. The data obtained (the length of the area with the maximum degree of danger and the vesicle depth) are the basis for assessing the endurance capability and consistency of the gas main. The proposed procedure of assessing the impact of karst processes on the gas main may be applied while designing and operating in order to take into account engineering measures in project documentation on the operational stage including the operation with geotechnical monitoring.

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