The salt-dome landscape genesis: paradoxes of rational nature management

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Abstract. The paper considers regional peculiarities of the use of natural resource potential of landscape geosystems formed in the course of halokinesis. Parameters of stability of salt-dome geosystems to anthropogenic influence resulting from the interaction of geodynamic processes and physical-geographical conditions are estimated. A method to evaluate the stability of landscape geosystems formed by salt-dome processes to anthropogenic transformation is offered. Accounting of volume of underground natural resources management connected, mainly, with salt rock extraction is significant. Excess of the total square of all forms of nature management under an area of the landscape geosystem formed by salt diapir, represented as the coefficient of nature management (CNM), acts as trigger risk. There are regularities of transforming the natural management structure in the regional models on the examples of basins: the Caspian-Cis-Urals, Trans-Carpathian, the Catalan, and Mexican. Within landscape geosystems having a salt-dome origin, the indicator of the coefficient of nature management can show as balanced geosystems, despite the development of subsurface resource management (Avery Island) or being in crisis geoeological situation (Iletskiy dome), so experienced anthropogenic catastrophes of different types (Jefferson Island, the Solotvinskiy dome). Principals of safe subsurface resource management and rational recreational-touristic use within salt structures of open kinds were developed.

1. Introduction
Salt tectonics (halokinesis – in the broadest understanding [1]) represents itself as a widely spread type of geodynamic processes referred to as pseudo tectonic movements due to salt plasticity.

The diversity of the salt tectonics emergence is conditioned by the halogen-sulfate mass effecting on various regional structural-geodynamics processes. It defines a considerable amount of hypothesis considering a mechanism of halokinesis [2].

Taking into account that salt-dome basins occupy 5% of the total lands and are located in different natural-climatic zones, the emergence of salt structures on the surface as landscape complexes and types of usage of their natural-resource potential is incredibly various.

The emergence of salt raisings on the surface within definite latitudinal-climatic zones is the principal condition to organize different forms of use of landscape geosystems' components. The culminating stage of salt-dome systems' development makes a vast opportunity to arrange other nature management systems characterized by their individuality for any rising. Still, simultaneously, they can be united in some types.

Here a tricky question arose – how to determine a degree of natural-resources potential's use of salt-dome geosystems?.
2. Materials and Method
On the one hand, we offer a relatively simple method that makes an opportunity to form spatial models of nature management. On the other hand, it promotes estimating a degree of involvement of a landscape natural-resources potential in the nature management system. It helps to determine a stability threshold of the landscape geosystem using data of catastrophes and ecological crises. Such a method consists of calculating areas operating under each type of nature management, including underground resource management.

The following materials and methods should be used: Google Earth data, open topographic and geological data, calculations of polygons' areas in GIS MapInfo 9.0. Experience received in the research in Spain (2014), and the USA (2017) was taken into account to identify nature management types. A degree of correspondence of the borders of nature management types to the depth of evaporite cover was the significant moment in the evaluation of a level of landscape geosystems transformation.

3. Result and Discussion
An area of the total underground mines is calculated in the course of salt extraction. Thus, under the full size of a salt dome (a salt bunch and adjacent recumbent oversalt rocks), for example, 1 km², the area exploited for salt extraction can reach 0.8 km², for oil and gas extraction – 0.3 km², mud-salt lakes used in resort-balneological purpose – 0.5 km². The area of agricultural cultures (as a rule, sharply differ in the composition from plants typical for this geographical space) is 0.3 km², the site of natural parks and natural monuments is 0.2 km². Thus, the total area used in all types of nature management exceeds a salt structure contour in 2.1 times. It can be interpreted as a ratio coefficient of the whole space used in all kinds of nature management to a landscape area (the coefficient of nature management (NM)), i.e., 2.1. Simultaneously, it is assumed that a sharp exceeding of the actual threshold of the total area of nature management types leads to ecological or anthropogenic catastrophe (figure 1). The most significant excess of the site used for any nature management under the landscape area is expected in mine salt extraction. Even hydrocarbon raw material extraction is mainly connected with the salt structure's wings and does not include the own salt body of the diapir (High Island) [3] (table 1).

Table 1. Examples of the nature-resource potential use of landscapes having a salt-dome origin.

| Salt structure       | Resource management       | Agricultural land use          | Touristic-recreational nature management | Square, km² |
|----------------------|--------------------------|--------------------------------|------------------------------------------|-------------|
| Avery Island         | Salt extraction (Cargil Salt Mine) | Planting of brand cultures     | Cultural-historical park, zoo             | 9.4         |
| High Island          | Oil extraction           |                                |                                          | 8.2         |
| Jefferson Island     | Oil extraction           |                                | Cultural-historical park, zoo             | 9.4         |
| Diapir de Cardona    |                          |                                | Excursion natural park (gallery)          | 1.2         |
| Iletskaya            | Salt extraction (PAO “Russol”) |                                | Resort-balneological salt and mud lakes | 1.3         |
| Solotvinskaya        |                          |                                | Resort-balneological salt and mud lakes  | 1.4         |
Figure 1. The nature management structure within salt-dome structures.  
I – High Island (Gulf Coast, Texas, USA); II – Avery Island (Gulf Coast, Louisiana, USA); III – Iletskaya (the Cis-Urals region, Orenburgskaya oblast, Russia); IV – Solotvinskaya (trans-Carpathian, Ukraine). Types of nature management: 1. – water objects; 2. – water recreational-balneological objects; 3. – agricultural lands; 4. – underground mining exploitation; 5. – sanatorium recreational areas; 6. – house construction; 7. – preserve-park areas; 8. – mining and production objects (operating); 9. – areas under oil and gas extraction’s objects.*kj

An open salt dome makes an opportunity for mine and grounds salt extraction, so is the significant factor of resort-balneological use that is fixed, in the first line, by the emergence of the dome's salt core on the surface and corresponds to the culminating phase of the salt-dome landscape genesis. Triggers of risk there are karst processes initiated by anthropogenic influence. The strategy confirms instability of the landscape geosystem that can be noted, for example, in the Iletskaya structure [4].

It should be taken into account that the coefficient of effective nature management can reduce in the course of destructive processes as a response of the landscape geosystem on the extremely anthropogenic load. The brightest examples are the Jefferson Island salt dome [5] and the Solotvinskaya structure [6] (table 2).
Table 2. A ratio of nature management forms (% of the total area).

| Subsurface resource management | Oil extraction | Salt exploitation | Underground exploitation | Touristic-recreational nature management | Lands allocated for settlements | Agricultural lands | Unused lands | Water objects | Coefficient of NM |
|--------------------------------|----------------|-------------------|--------------------------|------------------------------------------|-----------------------------|-----------------|-------------|--------------|-----------------|
| High Island                    | 47             | 10                | 25                       | 18                                       | 41                          | 0.82            |
| Avery Island                   | 6              | 33                | 1                        | 11                                       | 41                          | 0.78            |
| Iletskaya                      | 7              | 14                | 6                        | 54                                       | 17                          | 1.17            |
| Solotvinska Velya              | 19             | 21                | 9                        | 56                                       | 3                           | 0.52            |

4. Conclusion
Landslides having a salt-dome origin can sharply differ according to the degree of intensity of natural-resource potential and various types of nature management.

The formation of a definite system of nature management within the concrete salt-dome landscape geosystem is defined as regional structural-dynamic peculiarities of halokinesis so zonal-climatic belonging. At the same time, the macroeconomic factor of development of the nature management systems is not considered.

The structure of nature management on the salt-dome geosystems tightly correlates with a change of the formation depth of the halogen-sulfate mass. For example, agricultural land use on the Avery Island dome occurs only within sites with deep-lying evaporite (no less than 300 m) [7]. The rest territory represents itself as either recreational objects or separate residential buildings or unused forests with karst lakes.

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