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Geospatial potential and environmental changes: Case study of complex nature of the Altai Geopark

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Abstract

The geopark Altai has a set of unique geological, geographical, and archaeological objects. Its basis is made by geological space with a specific relief that plays an important role, and on certain sites, it takes the first place in comparison with other types of objects. The peculiar feature of the geopark Altai is that in its territory there is a landscape connection among archaeological, geological, and geographical objects, which at certain sites is penetrated by mental and cultural fluids causing a deep interest of tourists in this territory. In this regard, the authors consider the relief as an object of cognitive, educational, and practical activities of the geopark Altai. Therefore, the following tasks were set up: to find a site for the realization of several types of activities by the geopark and to develop a theoretical scientific and a popular science base for their implementation. As a result of the work done, the authors allocated the site within the boundaries of the geopark Altai where modern dynamics of the relief are characterized by the maximum speed. On this site, it is possible to recreate the processes that created the relief in the geological past and to study these processes now. The specifics of weather and climatic conditions in this region made its relief very important for economic activity of the population inhabiting this territory. Therefore, as of today, the study of the condition of certain surface sites and forecasting the development of relief-forming processes is an important part of any activity on the described territory. The long-term geological, ecological, geographical, and archaeological research conducted by the authors on the territory of the Altai Republic served as materials for this study. The geological materials were collected by the methods adopted in this field of research (field survey of structures and rocks, cartographic methods, analysis of general geological data, and others). The ecological and geographical results were obtained using geochemical, hydrochemical, analytical, and others.

Key words: *Altai, environmental changes, geological objects, geopark, geotourism, rural development*

INTRODUCTION

Geotourism and geoparks are relatively new concepts in tourism. However, they have been developed rapidly in the past decade. Geotourism has developed partly in response to the need to minimize the negative impact of mass tourism in tourist environments, providing at the same time a catalyst for sustainable development of rural areas [LAWAL-ADEBOWALE 2019; ÓLAFSDÓTTIR, DOWLING 2014].

Today, mankind faces complex challenges [HWANG 2015; JUSTICE 2018; HOSE 2012]. This was highlighted at various forums, including the 7th International Conference on UNESCO Global Geoparks with participants from 63 countries [DOWLING 2018].

One of the most burning issues is the dynamics of the environment, the most important aspect of which is the determination of its direction. Unfortunately, the general tendency is negative. Environmental degradation has a negative impact on those peoples who are to the greatest degree connected with nature. Separation from it and deterioration of its state negatively influence people, making them search for new ways to solve a complex set of problems [ALEKSANDROVA *et al.* 2019; BAUMFLEK *et al.* 2015; MOVCHAN *et al.* 2019; YEMELYANOV *et al.* 2020]. It is recorded that the state

of the environment, natural complexes, and residential areas are getting worse. All these problems cause a decline in living standards and quality of life everywhere [CHASHHIN *et al.* 2014; KAZNACHEEV 1980]. A number of studies have identified a wide range of dependence between people's health and high levels of pollutants, including neurobehavioral, immunological, and endocrine effects [ADLARD *et al.* 2018; BOYKO *et al.* 2019; MALAREV *et al.* 2020; MOVCHAN, YAKOVLEVA 2017]. The number of negative phenomena in the relief also increases: landslides, rock slides, and the collapse of various retaining structures often make impossible the further use of the affected areas for the same purposes as previously. This is particularly evident in the mountains. The aforementioned indicates the need for the study of the relief formation and its current state to forecast its changes.

The society develops approaches to the solution of these problems [HWANG 2015]. The study of adaptive capacities of people, ecosystems, and society to changing conditions (IGUMNOVA and TIMCHENKO [2003], DE SAINT PIERRE [2017]) is one of the topical issues. A new possible solution can be the establishment of geoparks. The practice has shown that geoparks provide a synthesis of research findings and their practical application [KOMO, PATZAK 2008].

UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development [MENSAH 2017]. Their bottom-up approach of combining conservation with sustainable development while involving local communities is becoming increasingly popular. At present, there are 147 UNESCO Global Geoparks in 41 countries [JUSTICE 2018]. Geoparks were created as a tool for better understanding the geological heritage and sustainable use of mineral and geological inheritance by raising public awareness on a balanced relationship between mankind and the Earth. The activity of UNESCO geoparks makes a unique contribution to the solution of many modern problems [DOWLING 2018]. Thanks to the geoparks, tourism can become a leader in addressing challenges associated with adaptation to current changes.

The work of regional geoparks is not regulated by the international public [HENRIQUES, BRILHA 2017]. However, joining the Global Geoparks Network (GGN) assumes compliance with some requirements. One of the key requirements regulates the number of geological heritage sites that should not be less than 50 [KOMOO, PATZAK 2008]; the important parameter is the geological diversity of the territory. Today, there are official documents describing the basic provisions and requirements for obtaining the status of the UNESCO Global Geopark [JUSTICE 2018]. The study of the experience of some territories and available publications [JUSTICE 2018; KOMOO, PATZAK 2008] indicates that each Global Geopark is characterized by its own theme that makes them unique, competitive, and recognizable. The paper by KOMOO and PATZAK [2008] of the majority of geoparks is based on one or two geological directions that are caused by the presence of strongly pronounced geological objects.

One major aspect of the discussion of a problem of the geopark establishment and its functioning is the role of local residents that are underlined in many documents published on the UNESCO website, as well as on the websites of certain geoparks, for example, the UNESCO Geopark of Haute Provence. In the given context, man is regarded not only as of the user of the territory and its resources but also as their creator. Today it is important to pay attention to the individual and society, which act as the factor accelerating an information exchange in natural complexes. Assuming that there are communities, which are able to accumulate the best practices in environmental management, to adapt them, and transpose into the objects essential to the functioning of a society, preservation of natural resources, and increase in efficiency of natural complexes, one can understand the great attraction of Altai and the traditions of its population.

The foregoing demonstrates the urgency of developing geoparks in various territories, including Russia. In this light, the overall objective of the group of experts on the development of a geopark in the Altai Republic is the preservation of natural and cultural-historical heritage through the work of the geopark Altai that should be well-balanced with the livelihoods of the local population. This article describes the first stage of the establishment of the geopark Altai, namely, the systematization of accumulated knowledge and expertise on the geopark's territory. At this stage, the inventory of geological heritage was made, and the linkages between geological structure and relief, peculiar features of natural-climatic conditions, and economic development of the territory were identified. Complex consideration of the results of the study on these and other issues allows us to make a conclusion about the potential of the geopark Altai to illustrate the geological history and processes which form the basis for sustainable livelihoods of the local population.

MATERIALS AND METHODS

The results of long-term geological, ecological, geographical, and archaeological research conducted by the authors on the territory of the Altai Republic served as materials for this study. That made it possible to make a list of geological sites to be included in the geopark Altai and to define its boundaries. Mapping was made with the help of open electronic resources QGIS and Google Earth and by using our own data. The illustrative material was formed on the basis of our own archives.

The Altai Republic is situated in the southeast of Western Siberia. It has external borders with Mongolia, China, and Kazakhstan (Fig. 1) and internal borders with the

Fig. 1. Location of the Altai Republic; source: http://kostya-sergin.narod.ru/pohod/pohod2009/asia2009/map/map-yandex-m.jpg with authors' refinement

Khakas Republic, the Tuva Republic, Altai Krai, and Kemerovo Oblast.

The republic is a part of Altai-Sayan mountain country. It is characterized by interesting geology, unique hydrology, breathtaking landscapes, exceptional archaeology, and the original culture of its indigenous inhabitants.

Since long ago, the whole territory of Altai (the geopark Altai is a part of the Altai Republic) has drawn the attention of scientists. Vast open spaces promoted the study of the environment: geological structure, relief, vegetation, fauna, hydrology, etc. A special place in the environmental studies was occupied by modern glaciers and traces of ancient glaciation.

The great Russian critic V.G. Belinsky among "scientific, educational, and other worth reading book" that "should please the patriotic feeling of the Russian" mentions the work of Petr Chikhachev "Scientific Journey in East Altai ..." The academicians P.P. Semyonov-Tyan-Shansky, A.V. Grigoriev, I.I. Stebnitsky, Élie de Beaumont, the member of the French Academy of Sciences, Armand Dufrénoy, the director of the École des Mines, Armand de Quatrefages and other Russian and foreign scientists attached great importance to the Chihachev's Altai journey [CHIKHACHEV 1967]. Today, the studies are being conducted not only in various areas of the natural sciences but also include economic, sociopolitical and other branches of knowledge. As a result of numerous studies, the rich store of research materials has been accumulated to date.

The geopark is located in the central and southeastern parts of the Altai Republic and partially includes three administrative districts: Ongudai, Ulagan (administrative centre is Ulagan village: 50°37' 40"N, 87°57'05"E) and Kosh-Agach (administrative centre is Kosh-Agach village: 49.5933, 88.3949). Ulagan and Kosh-Agach villages are located within the geopark's boundaries. The nearest and the only city in Gorno-Altaisk (the capital of the Altai Republic), which is situated at a distance of 250 km from the northern boundary of the geopark.

The geopark stretches along the federal highway M-52 historically called Chuiskiy Tract (Chuiskiy Highway). The territory in immediate proximity from the highway includes widely known objects. As you move away from it, you get the opportunity for studying little-known and previously unknown objects. This is particularly relevant to the taiga part of the geopark, which stretches along the local road connecting Chuiskiy Highway and the Chulyshman River valley. Along the Chulyshman valley and further along Lake Teletskoye to Korbu waterfalls (Fig. 2) the width of the "strip" of the geopark coincides with the valleys of the rivers, where there is a road. Such position of the boundaries and the size of the territory, in the authors' opinion, allow all categories of tourists to get familiarized with sights of natural genesis, unique archaeological sites, traditional way of life, and peculiar features of the local population, and also meet the GGN requirements.

RESULTS AND DISCUSSION

The geopark's territory (as a part of other areas in the Altai Republic) was studied by researchers representing different branches of science and practice: geology, geomorphology, engineering geology, hydrology, geography, climatology, botany, and others. The extensive bibliography is provided in the fundamental edition of recent years [BUSLOV*et al*. 2013; DEL BEN *et al*. 2008; NOVIKOV *et al*. 1998]. At present, thematic maps of various scales of the latest generation, including geological, geochemical, mineral resources maps and others are available [FEDAK *et al*. 2011]. The VSEGEI electronic resource allows getting acquainted with traditional cartographic materials and other sources of information on the geological structure of the territory of Russia and its regions, as well as gaining some idea of unique geological objects through an interactive platform.

The results of long-term studies conducted by the authors allowed them to distinguish 50 objects (in accordance with the UNESCO requirements) that play the leading role in excursion activity on this territory. In spite of the fact that all these objects are characterized by huge information content, currently, they are mainly used for their aesthetic attractiveness. In fact, however, the number of objects of various origin situated in the territory of the geopark Altai is much more than fifty [ERNST *et al*. 2020].

Precambrian, Paleozoic, Mesozoic, and Cenozoic rocks crop out here. On a greater part of the territory rocks of metamorphic origin prevail, while in the southern part of the geopark, rock formations from the Devonian and Carboniferous periods are widely distributed. Large areas are occupied by magmatic formations of various composition. The geological structures, peculiar features of rocks composing the territory, tectonic processes, and other aspects of the geological framework create a good basis for developing various activities in the geopark: research, tourist, educational, etc. The brightest geological objects have been grouped into several categories.

Category of mineral and petrographic objects. This category includes outcrops and massifs of distinctive rocks, as well as their association with visible composition, structure, and texture; reference deposits of minerals; specific forms of introduction, bedding, and relationships between products of intrusive and effusive magmatism; places with rare mineral complexes, separate minerals, their associations and aggregates. The following sites located on the territory of the geopark Altai fall into this category: mercury deposits (in the vicinity of the villages of Aktash and Chagan-Uzun); Khrustalnaya Gorka (literally meaning "cristal hill" in Russian, in the vicinity of Inya village); a white limestone massif (Belyi Bom village); limestones with the remains of sea fauna (the mouth of the Chuya River); organic rocks of Silurian age and volcanogenic rocks (the Yarbalyk River); carbonaceous deposits (Kurai village); a polymetallic deposit and a weathering crust (the Kyzyl-Chin River) and others.

Category of stratigraphic objects includes studied in detail stratotypes of geological units important for understanding the nature of the development of the region: the weathering crusts in the Kyzyl-Chin River valley; the Precambrian–Lower Paleozoic section in the valley of the Akaya River; the section of coal carbonaceous siltstones and

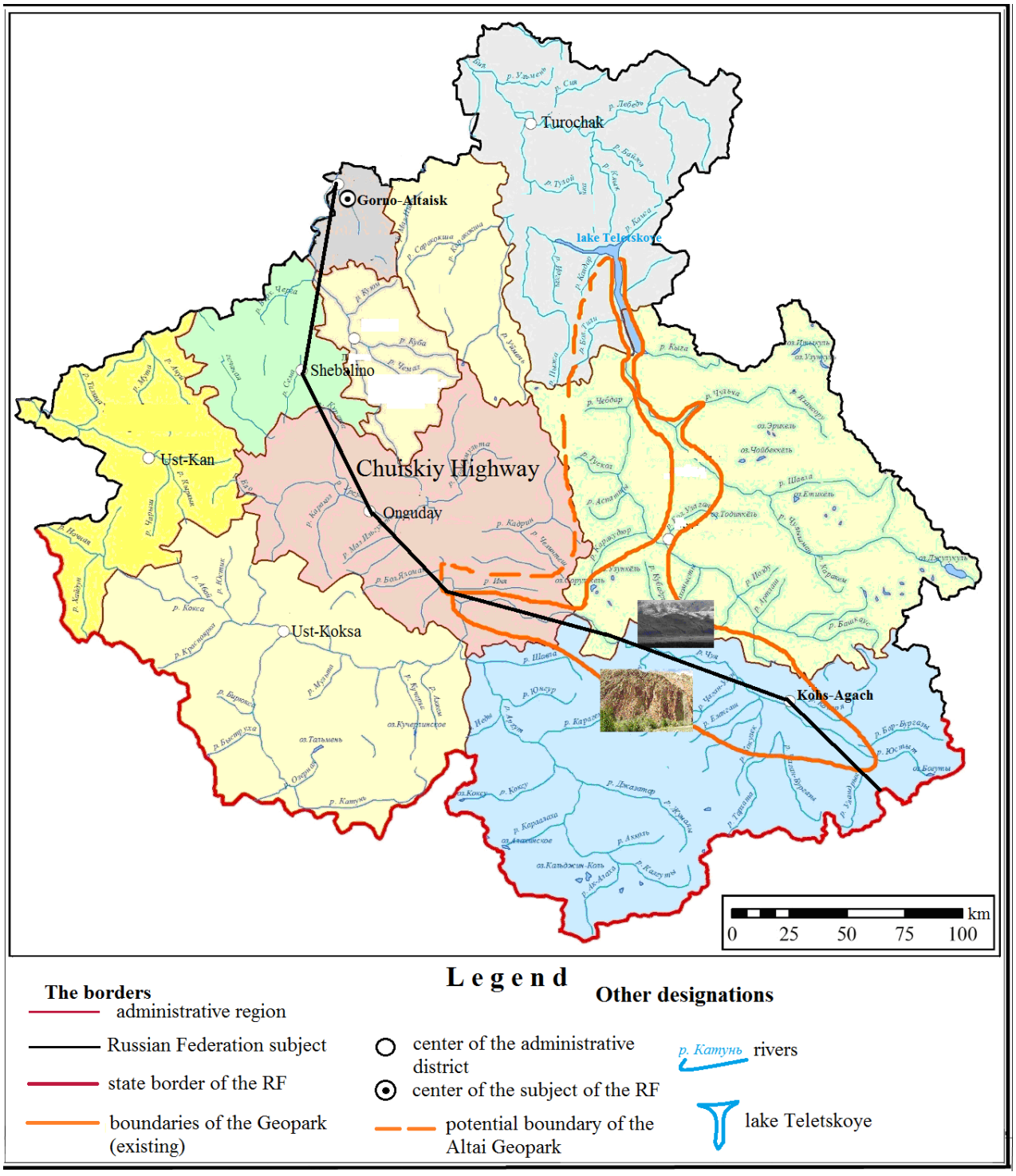

Fig. 2. Map of the administrative-territorial division of the Altai Republic with the boundaries of the Altai Geopark plotted; source: ROLDUGIN *et al.* [2019]

the Permian conglomerates; the section of lake deposits in the Kurai depression, and others.

The category of objects that illustrate the history of geological processes can be subdivided into three subcategories "Geological work of the rivers", "Carst" and "Accumulative and erosion work of ancient glaciers". The first one includes the Kyzyl Tash and Kuraika River valleys; high terraces of the Chuya and the Katun; the Tydtuyaryk River valley; meanders of the Chuya River; alluvium in the natural boundary Barotal and on the site of Chibit hydroelectric power plant; the mouth of the Bashkaus River; the valley of the Chulcha River, and others.

The second subcategory is represented by the objects characterized by manifestations of cavity-forming processes in rocks, namely, superficial and underground karst in the form of sinkholes, wells, caves, grottoes, and passages. In the explored territory, a wide variety of caves is noted. Shapes of caves depend directly on tectonic jointing of

carbonate rocks (limestone, marble, dolomite). The best examples of karst processes are the Belyi Bom massif, the natural boundary Barotal, the 'geyser' lake in the vicinities of Chagan-Uzun village, the Tydtuyaryk River valley, the Kuskunur River, and others. The subcategory "Accumulative and erosion work of ancient glaciers" includes Chibit, Kuekhtanar, Chagan, Kubadrin, Ulagan, Kyndyktykul, and other moraines; "stone mushrooms" and other sites in the Chulyshman River valley; and also the Rivers of Chuya, Chagan-Uzun, Bar-Burgazy, Kuekhtanar, Tydtugem, and others.

Category of tectonic objects includes fracture zones and sites in natural and artificial exposures, and also fold dislocations. Here occur dynamic processes, which start deep inside the Earth and manifest themselves at the surface as specific formations: Chibit gorge (in the vicinity of Chibit village); the Myen River valley (in the vicinity of Aktash village); spurs of high ridges in the Kurai depression; the rapids of the Chuya River near the village of Chibit; a tectonic landslide (in the vicinity of Beltir village); the Chulyshman River valley; Uchar waterfall, etc.

During the study, the authors made a list of more than 50 geological and geographical objects that includes their coordinates, object type, accessibility, and other necessary information [ERNST*et al*. 2020].

According to the authors, the brightest manifestation of the connection between geological and geographical aspects in the territory of the geopark Altai is the relief. The largest part of the territory is well studied with regard to the history of its relief formation. The relief of the geopark's territory differs a lot in the valleys of big rivers (near the federal highway) and in the axial parts of ridges. Many studies have been devoted to the problems of its formation. Towards the south, the height of ridges and the average surface height increase. The northern part of the geopark and depressions located in its southern and eastern parts refer to midlands, while the mountain framing of the Chuya, Kurai, and Ulagan depressions is characterized by high-mountain alpine relief with all its typical features.

However, there are still many places, which cause scientific disputes on the genesis of their relief as well as on the time and factors of its formation, which makes the territory of the geopark Altai attractive to researchers. These aspects may also be of interest to tourists.

Currently, the conditions of the southern part of the geopark are characterized by an intensification of the relief--forming processes. The most active reprecipitation of the quaternary period occurs on slopes. Here deep washouts, gutters and Rachels originate. At the foot of slopes, alluvial fans (of fragmentary material) are formed (see Photo 1).

Vast expanses of slopes of various steepness are almost deprived of vegetation due to their specific climatic conditions. The increase in the number of heavy rains, the amount of snow, and some other factors cause mudflows, strong temporary water streams, washouts (Photo 1), and so forth.

Currently, the number of tourists wishing to visit the red deposits of the Devonian Period in the Kyzyl-Chin River valley, so-called "Mars", is increasing every year. Local people are anxious about the condition of this site. First of all, its aesthetics are changing; and the second most visible and dynamic changes concern its relief. The increase in the number of heavy rainfalls causes the formation of wide washouts, the bottoms of which are covered by a layer of fine-grained debris and walls are washed away by slurry, which collectively impedes observation of the geological structure. Landslides caused by seismic events also occur frequently.

Recent exposures allow for the observation of the results of relief-forming processes that occurred in the past. For example, the earthquake of 2003 induced a huge landslide. Today, one can see traces of solifluction in the cliffs formed on the landslide boundaries (see Fig. 3).

Photo 1. A washout in the red Devonian deposits (phot. *N.A. Kocheeva*)

Fig. 3. A landslide formed by the earthquake of 2003 on the right wall of the Taltura River valley: a) argillaceous deposits with flow lines under the soil (photo *N.A. Kocheeva*), b) scheme of deposits; QIII–IV = quaternary deposits, Pz = the Paleozoic deposits; source: compiled by *N.A. Kocheeva*

The Chagan River basin is one of the most interesting sites of the geopark Altai for observing the current dynamics of its relief. The left and the right valley walls significantly differ in their dominating landscapes. In particular, the left wall of the Taltura River valley to the mouth of the Dzhelo River is almost deprived of vegetation, which is the reason for the predominance of semiarid landscapes. Here landslide and mudflow phenomena prevail. The right wall is better sodded, causing the spread of steppe landscapes at the foot of the slopes and larch forests in their middle parts. Thus, in the complex of relief-forming processes predominate those that are characterized by a smaller contrast, a longer duration, and a greater aesthetic attractiveness.

In the context of the study of current dynamics of relief, the authors paid special attention to the section of the valley located between the mouths of the Dzhelo and the Kuskunur Rivers. On this territory, there is a complex of modern geological processes that influence the formation of a relief.

For example, nearly every year in the lower current of the Kuskunur River there occurs the washing away of clay fraction from morainic deposits making a high right wall that leads to the failure of the soil followed by the subsequent collapse of arches and carrying out of topsoil to the foot of the slope. Such a phenomenon is sometimes called clay karst and is uncommon. However, in the geopark Altai, there are several places where this phenomenon actively manifests itself, and its traces are available for observation and study. On the valley slopes, there are many places where underground waters accumulate and exit to the surface. Water in small rivers often disappears underground, and after several hundred (sometimes tens) of meters appears in its course again. Frost cracks and cavities resulting from the weathering of limestone create fancy pictures in the rocky parts of the left slopes of the Taltura and Dzhelo River valleys. The bright examples of the existence of perennially frozen rocks are fault polygons of soil cover, nonsorted circles, and other frozen-ground phenomena.

Within the boundaries of the geopark Altai, there is a field of "giant ripples" ("transverse to the current of streams, sharply asymmetric ridges with oval depressions, twisting and arc-shaped, being morphologically giant copies of small current ripples") [BUTVILOVSKII 1993] located in the Kuraiskaya depression. According to the United States Geological Survey, the catastrophic glacier burst of Lake Kuraiskoye created a specific relief and was the first by its hydraulic characteristics [BLOMDIN*et al*. 2016].

However, within the boundaries of the geopark, there are many traces of ancient and modern lakes outbursts. The size of these lakes is different as well as the traces of their geological work and outburst of glacial water. Opposite to the mouth of the Kuskunur River, on the right bank of the Taltura River, there is a field of ripples, which were probably created as a result of the glacier break during the period of degradation of glaciers. The size of this site and the ripples themselves are incomparable to those located in the Kuraiskaya depression, however, if tourists do not have a chance to visit 'giant ripples', then this site can be a good place to get acquainted with the features of a glacier-dammed lake and its outburst. The small size of the site is its advantage because the visitors can see the whole area having climbed to the nearest hill. The research on this site remains insufficient, which makes it a very perspective for further studies.

The slope of the left wall of the Taltura River valley is pitted with ditches created by temporary water streams of various genesis. Sometimes the accumulation of snow and weather conditions cause the overflow of a small lake basin, and soft sediments unprotected by a vegetable cover are easily eroded, increasing flow force downhill. As a result, swash channels of various length (50–1500 m) and depth

(from 0.3 – 4 to 5 m) are formed. Some of them are visible in satellite images. The emergence of the destructive flow occurs due to the merging of small creeks, traces of which are hardly visible after they dry out. On the slopes built by friable or disturbed by human activities, earthquake etc. deposits, where these creeks join, a big washout is formed [AGADZHANYAN *et al.* 2006]. In the walls of such washouts, the composition of ice-borne sediments and features of the friable deposits structure, their thickness, and their ratio to bedding rocks of the valley slopes are available to studying (see Photo 2).

Photo 2. Changes in the sedimentation environment reflected in the different size of the sediments deposited. A washout on the left wall of the Taltura River valley (phot. *N.A. Kocheeva*)

Frequent change of deposits of different dimension indicates fast changes in geographical conditions during their accumulation. Most often, they are glacial and water-glacial formations, which replace each other. That is why in the territory of the study one can see the inherited and modern relief forms, as well as the processes which caused its changes and continue to do this geological work now. Fast changes, especially high-speed geological processes, significantly changed the relief that represents the life arena, one of the main components of the biosphere [IRIN, FRYER 2020].

The entire territory of the geopark is used by people in their economic activities [SEMENOV *et al.* 2003]. River valleys and foots of slopes are the most convenient for this purpose. However, frequent mud streams destroy fruits of hard long-term work on preservation of comfortable sites having sufficient amount of water. On the Kuskunur River, there is an irrigation system that supports one of the biggest hayfields in the area. Every year the river destroys the dam. Floods take out a great number of large boulders on the levelled sites and deposit them on fertile earth. Huge efforts are required to clear these areas. Often the expenses become unprofitable and such sites are gradually converted from agricultural use. These and other features of local land-use practices are well illustrated in the territory of the geopark. Numerous archaeological sites are located here. Found artifacts allow for the reconstruction of the living conditions of people who inhabited this area.

Thus, one of the key aspects of the activity of the Altai Geopark is the formation of a new paradigm. Instead of the industrial paradigm of "conquest" and "use", the axiological paradigm of the value of a recreational resource should come to life [GOLUBCHIKOV *et al*. 2019].

CONCLUSIONS

The conducted research has shown that the geopark Altai has the whole complex of objects, which contain information that illustrates the dynamics of geographical conditions throughout a long period of geological time. The development of a database of geological objects has become one of the results of the study. The geopark Altai has the required number of objects necessary for its functioning. Their quality leaves no doubts that they illustrate almost all aspects of natural development. For example, stadial moraines demonstrate the process of glacial retreat and the occupation of glacier free areas by various species of flora. The available geological and geographical base allows creating a comprehensive program that would include the issues relating to the change of all landscape components, including the relief. For this purpose, the authors propose to use a model site that has objects of all categories and degrees of geologic certainty, that would allow organizing educational and scientific work.

Observation on the geological objects of the geopark Altai has shown that even small climate changes (precipitation and temperature) cause significant changes in local ecosystems. It is known that mountain territories are particularly sensitive to any changes. Under Siberian conditions, it necessitates regular redevelopment of the territories appropriate for agricultural practices: clearance, reconstruction of irrigation systems, reseeding, etc.

Today it is also important to emphasize the distinctive features of the mentality of local indigenous peoples, which is also a product of happening changes. The popularization of best practices of the Altai-Kizhi and the Telengits, the indigenous peoples of the Altai Republic and the largest ethnic group inhabiting the geopark Altai, is of great importance for all people living here. Today one can observe the revival of interest in local traditions and customs almost everywhere in the region. It is very important in terms of fostering respect for oneself, for the one's way of life, and consequently for cultural traditions of other peoples.

An important aspect of the functioning of the geopark Altai is tourist services. Today there is a great demand for information about traditions of the local population, peculiar features of their daily life today, and back in the past. Therefore, the work done shows that it is quite possible to reveal the integrated characteristics of natural climatic and historical-cultural features of the territory on the basis of the geopark.

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