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ORIGINAL PAPER

Development of the "rare-earth" hypothesis to explain the reasons of geophagy in Teletskoye Lake are kudurs (Gorny Altai, Russia)

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Abstract The mineral and chemical composition of the liquid and lithogenous substances, consumed by the wild ungulate animals, at the kudurs of the Teletskoye Lake, Gorny Altai, Russia, was studied. It was investigated that all examined kudurits are argillous-aleurolitic and get in the interval from 1 to 100 µm with the predominance of the fraction 10 µm. By the mineral composition, the lithogenous kudurits present the quartz-feldspathic-hydromicaceous-chloritic mineral formations with the large content of the quartz particles (20–43%) and sodium-containing plagioclases (albite, 15–32 wt%). The lithogenous kudurits are the products of the reconstitution of the metamorphic cleaving stones as a result of the glacier abrasive effect, subsequent its aqueous deposits and then eolation in the subaerial conditions. The fontinal waters consumed at the kudurs are subsaline chloride-hydrocarbonate-sodium and sulphated-hydrocarbonate-calcium types. It essentially differs by the increased content of rare-earth elements in reference to the lake water. The acid (HCl, pH-1) extracts from the kudurits more actively extract calcium (10–35% of the gross contents; sodium extracts at the level of 1–3%). The most fluent in the microelements composition are Cu, Be, Sr, Co, Cd, Pb, Sc, Y and rare-earth elements. The transit of all these elements into the dissoluted form fluctuates about 10% from the gross contents. The reason of geophagy is related to tendency of herbivores to absorb mineralized subsoils enriched by the biologically accessible forms of rare-earth elements, arisen as a result of vital activity of specific microflora.

Keywords Kudurs · Geophagy · Geology · Geochemistry · Gorny Altai

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This article is about geological-geochemical survey of grounds and spring water, consumed by wild animals at the kudurs within the littoral zone of the Teletskoye Lake, Gorny Altai, Russia.

The kudurs are meant to be the geological-landscape complexes regularly visited by the wild animals with the purpose of consuming the rock formations

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and mineralized fontinal waters; consequently, the kudurits are the lithogenous substances consumed by the animals at the kudurs (Panichev et al. 2013). Kudurs are mostly visited by ungulates, rarely with other herbivores or omnivorous animals, e.g. rodents (Martinelli et al. 2013) or bears (Mattson et al. 1999; Seryodkin et al. 2016).

The question on the reason of the regular consumption of the mineral substances by animals at the kudurs remains unrevealed. There are only different supposals on the topic. It includes the need for sodium salts and mineral sorbents, regulating the buffering capacity of the environment in the gastrointestinal tract, that allows to reduce the intestinal disorders during the changing of the feed allowance in spring in the zone of temperate latitudes (Dalke et al. 1965; Hebert and Cowan 1971; Kreulen 1985; Panichev 1990; Klaus and Schmid 1998) or during the changing of the food allowance at the boundary between drought and rainy season in tropics (Kreulen 1985; Moe 1993). It was repetitively proposed that the mineral substances consumed at the kudurs can fill up the corresponding deprivations during lactation and unossified antlers growth (Nasimovich 1938; Fraser and Reardon 1980; Moe 1993). The consumed clay minerals can remove the chemical wastes from the organism (Houston et al. 2001) and pickup the tannins and alkaloids (Oates 1978; Kreulen 1985; Gilardi et al. 1999), and finally they can resist to the gastrointestinal diseases and some others (Vermeer and Ferrell 1985; Panichev 1990).

The kudurs occur in many mountain regions of the world. They are also spread in the mountains of the South Siberia, including the Altay-Sayan Mountains. Shaposhnikov started the investigation of the kudurs at the littoral zone of Teletskoye Lake in the 1950s. Basing on his observations, he tried to explain the reason of geophagy as a desire of animals to eliminate diarrheas with the help of clay sorbents (Shaposhnikov 1953). In the middle of 1980s, the research of Altai mountains kudurs was proceeded by Bgatov and Panichev. They have characterized the geological nature of kudurs and mineral and chemical composition of the earthy substances, consumed by animals (Panichev 1990; Bgatov et al. 1988).

We can explain the recommencement of our interest in Teletsckoye Lake kudurs by our desire to verify new «rare-earth» hypothesis of the geophagy reasons (Panichev 2016; Panichev et al. 2016). Geophagy can be caused by attempts of animals to balance chemical elements composition, which has become inadequate for some reasons in the immune system (in its cell structures and hormones). First of all, this applies to rare-earth elements, which have very important but still not studied enough functions. Our hypothesis is based on two facts. The first is the relatively high concentration of lanthanoids in the consumed earthy substances. It was found out during literature researches and our own researches (Panichev et al. 2016). The second fact is that lanthanoids have rather high biological activity, and some specialized literature proves it (Panichev 2015).

The goal of our work was to verify our hypothesis about the role of rare-earth elements in geophagy and consuming the mineralized waters by wild animals in South Siberia mountains. Among the tasks to be solved were: a description of kudurs and sampling of minerals consumed by animals; analysis of available geological information about the area of research; study of the total chemical composition of collected samples of kudurites; determination of the number of biologically accessible forms of elements (including rare earths) in samples based on the method of hydrochloric acid extracts with pH close to rennet ruminant animals; discussion of the results obtained from the standpoint of the "rare-earth" hypothesis on the causes of geophagy.

Objects and methods of research

In the vicinity of the Teletskoye Lake (the territory of the Altai State Nature Biosphere Reserve), there are a lot of kudurs, but they are located only at the south-east coast. We visited 13 kudurs known for the present (Fig. 1) in September 2015. The test items were taken from 10 of them.

The local population survey, carried out by us, from the number of people busy in service of the tourism infrastructure within the park area at the west coast of the lake, and also of the local hunters, hunting at the area west than the park is, which also do not compose the reserve, revealed that there are no kudurs, at least at the distance of 20 km from the lake.

The main part of the kudurs at the littoral area of the lake is presented by the lytomorphic variety: in the form of the meagre croppings, soft with the involvement of the fine particle fractions of the rock

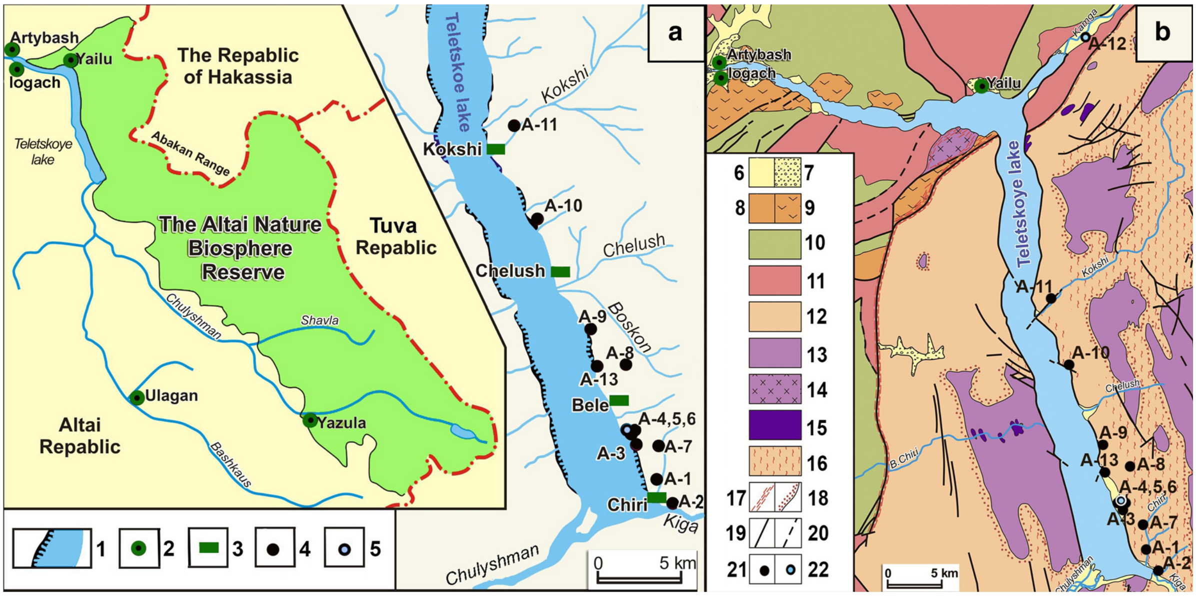

Fig. 1 Research area with the kudur location in the littoral zone of the Teletskoye Lake (**a**) and the geologic map of the research area (**b**): 1—the rocky cliffs; 2—the villages; 3—the cordons of the reserve; 4—the lithomorphic kudurs; 5—the hydromorphic kudurs on the basis of the water sources; 6—the modern alluvial sands and gravels; 7—the pre-Holocene water–ice deposits (cobble round stones, gravels and sands); 8—Devonian deposits (terrigenous sandstones and cleaving stones; 9—Devonian deposits (effusives of the average composition predominantly); 10—the Ordovician deposits (predominantly sandstones, argillous and aleurolitic cleaving stones and chalky clays); 11—Cambrian-Sinian volcanogenic and terrigenous deposits; 12—Proterozoic metamorphic cleaving stones, gneisses, metamorphic sandstones; 13—Middle Paleozoic granitesand granite-gneisses; 14—Early Paleozoic plagiogranites; 15—Paleozoic gabbro; 16—the gneiss outlets; 17—the dynamic contact interactions; 18—the metasomatic contact interactions; 19—the mapped tectonic faults; 20—the probable tectonic faults; 21—the lithomorphic kudurs; 22—the hydromorphic kudurs

formations (sometimes poorly cemented) with the significant deepenings, eaten out and licked up by the animals. Such deepenings frequently obtain the metre-long sites across and to the deep. The kudurs of this type are formed in the finely dispersed glaciolacustrine deposits of the pre-Holocene age, including on the outlets of its relict blocks among the creeps (Fig. 2). Sometimes, mainly in the lower part of the lake slope, they appear on the moraine-like deposits from the cobble round stones and glaciolacustrine silts (perhaps, of the underwater-landslide origin) and (quite seldom) on the modern avalanchine deposits, where the animals eat out the fine earth among the chippings of the bedding rocks (Fig. 3).

There is the white salt efflorescence (more frequently in the form of the fluffy incrustations upon the gravels) on the surface of the croppings of the lake aggradation terrace at the particular area, including the area of Chelush cordon. The salt efflorescence is bitterish-sour to the taste. We did not point out any evidences of licking the salts by the animals anywhere. However, the licking deepenings can be situated some metres away from the saline separations.

Among the animals, visiting the lytomorphic kudurs at the Teletskoye Lake, the maral (*Cervus elaphus sibiricus*) predominate, sometimes the mountain hares (*Lepus timidus*) come. According to the chronicle of the Altai Reserve, up to 1930, the Siberian ibex (*Capra sibirica*) back then inhabiting the lakesides actively visited the kudurs. According to the data of this very chronicle, the ultimate winter density of the maral population varies from year to year on the average from 10 to 40 animal unit/1000 ha. At that, the kudurs are attended practically the whole year. The base peak of attendances coincides with the period from April till July, and the second period of the attendance activity coincides with autumn, in September–November.

There are also kudurs on the basis of the water sources (hydromorphic variety) in the limnetic zone. There is a kudur in them, denoted as A-4 (Fig. 1a), that appeared on the basis of the poorly resolved marginal

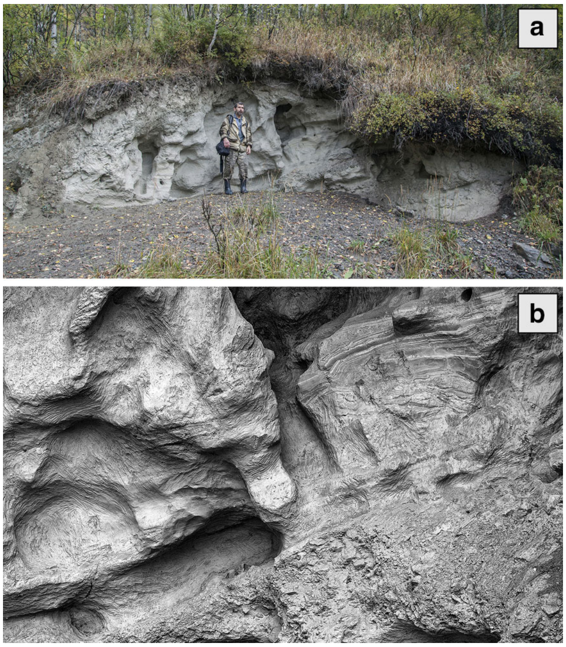

Fig. 2 General view (**a**) and the fragment (**b**) of the kudur A-8. The length of the cropping is 9 m; the height is 2.5 m. The relict of the ancient lake terrace (height above the modern average level of the lake is about 350 m) in the form of the block of the glaciolacustrine deposits, complicated by the landslide slips and the interstratified layers of the coarse-grained material. The animals eat out more actively the finely dispersed organic silts of the glaciolacustrine origin

water source, around which the muddy area appeared, trampled down by the elks. Its size is not above 10 m^2. The animals drink the fontinal water and eat out the subsoil bedrocks in the near-root parts of the trees with the formation of the depthless licks.

The second hydromorphic kudur is situated in the flood plain of River Kamga, in its wellhead part. (At Fig. 1b, it is denoted as A-12.) The kudur appeared on the basis of several well-defined water sources, which discharge into the channel hollow, in the foot of the first terrace above the flood plain. During the periods of low water, the largest spring discharges with the formation of the depthless puddle with the diameter about 1 m, at the bottom of which, at the place of water entrance, the small springs with the sand fountains are observed. Thus, the kudur is often and for a long time attended by maral and by moose (*Alces alces*), that made by walking the well-trodden ways to the spring. The apparent signs of subsoil eating at this kudur with the lick formations were not found.

Fig. 3 Licks at the kudurs A-3 and A-5 according to the moraine-like underwater-landslide deposits with the different correlation of the cobble round stones and glaciolacustrine silts (two upper images), and the licks among the slope avalanchine deposits (the lower image). The water-flooded area can be well seen at the upper image (the dark bar), along which the interstitial water trickles through

In 2015, 8 lithogenous samples from the kudurits of the fresh licks were selected at the kudurs A-1, A-2, A-3, A-7, A-8, A-9, A-10, A-11. The samples were selected from the surface to the depth up to 10 cm. Moreover, 4 water samples were taken (WA-1 was taken from the source at kudur A-4; WA-2—from the source at kudur A-12; the samples T-1 and T-2—the lake water as a background, the first one was taken near the village Yailu, the second one near the Chiri cordon).

Besides, the group of coprolites Copr.1 was taken near the kudur A-1 (the excrements of the elks with predominance of the lithogenous material).

The chemical analyses of the gathered material were carried out at the Analytical Centre of the Far East Geological Institute of Far Eastern Branch, Russian Academy of Sciences.

The determination of the total of loss on ignition (LOI) and SiO_2 in the solid samples was carried out with the help of gravimetric method; the determination of the other main elements was carried out by the atomic emission spectrometry method with the inductively coupled plasma (spectrometer iCAP 7600Duo Thermo Scientific Corporation, USA). The sample preparation is the fuse with lithium metaborate. The determination of microelements content was carried out by the mass spectrometry method with the inductively coupled plasma with the same spectrometer. The sample preparation is similar.

The determination of the chemical composition of the liquid samples was carried out by the mass spectrometry with the inductively coupled plasma with the help of the spectrometer Agilent 7700× (Agilent Techn. USA). The determination of some ions in the liquid samples was carried out by the ionic chromatography method with the help of the liquid chromotograph LC-20 (Shimadzu, Japan).

The quantitative mineral composition was determined by the X-ray diffraction method with the help of the diffractometer ULTIMA-IV by Rigaku frim (Japan) at the department of the engineering and ecological geology of the Geological Faculty of Lomonosov Moscow State University. The operating variables are 40 kV–40 mA, copper radiation, nickel filter, measuring range 3–65° 2θ, scan angle step 0.02° 2θ, the fixed system of the focusing gaping. So as to speed up the shooting and to improve the quality of the experimental data, the most advanced semiconductor detector was used—DTex/Ultra; the scan speed—10° 2θ/min. The diagnostics of the mineral composition were carried out by the correlation method of the experimental and reference spectra from the database PDF-2 in the software suite Jade 6.5, by MDI Company. For silty fractions, they used the comparative study of the oriented preparations in the air-seasoned state and after being enriched in ethylene glycol. The quantitative diagnostics were carried out in the software suite PDXL, by Rigaku Company. The calculation was carried out according to Rietveld's method in the software BGMN (www.bgmn.de).

With the aim to find out the quantitative characteristics of the chemical elements outlets from the solids under the conditions of the acidic environment in the abomasum of the ruminants, 4 lithogenous samples were subjected to the hydrochloride extracts with pH-1 in the geochemistry laboratory of the Pacific Geographical Institute of Far Eastern Branch, Russian Academy of Sciences. The weighed amount of the solid 5 g was filled by 50 ml 0.1 N solution of HCl, after it was kept for the 24-h period. Then, the extracts were filtered through the ash-free filter ("Blue ribbon"), preliminarily washed out by the hot solution of the hydrochloric acid (pH-1) and the first portions of extracts, and then were sent for examination.

So as to determine the particle size, the taken samples from the kudurits were subjected to the study with the help of the laser diffraction analyser of the granulometric composition Analysette 22 MicroTec-plus (Germany, 2014).

Most important characteristics of exploration area

The excess of the slopes of the lake basin above the sea level (up to the dividing crest) measures up to 2000 m. The ultimate absolute elevations are confined to the mountain chain east than the lake is (intrusion of granitoids) with the highest elevation 2502 m, separating the lake basin from the basin of River Abakan. On the western lakeshore in the south part of the lake, near the edge of the lake basin, the mountain group Altyn-Tuu rises (it is also the granitic intrusion). Its highest elevation is 2358 m.

The slopes of the lake basin are abrupt, often with the cliffed coasts (Fig. 1a), in places dissected by the small creek valleys and river valleys of the large stream tributary, among which are Chulyshman, Kiga, Bol'shie Chili, Malye Chili, Kamga, Kokshi and Chelush. In some places, including the areas of the villages Yailu and Bele, the low vast enough tectonic steps are formed at the foot of the native slope of the lake basin, on which the aggradational terraces with the lake and glaciofluvial deposits formed, in places overlaid by the landslide ice-hill, by alluvial and deluvial foreslope. The estuaries of the rivers flowing into the lake are relatively small and are formed by the aluvial rubbly-cobble and sand deposits of the Quaternary period.

The slopes of the lake are covered with the mountain forests with the predominance of Siberian larch (*Larix sibirica*) up to the absolute elevation

700 m, higher Siberian pine (*Pinus sibirica*) predominate. The terraces and the slopes of the south aspects of in the south part of the lake are covered with birch and aspen woods with admixed cedar and larch; sometimes, the steppificated places are met, covered with herbaceous and herbaceous-scrub vegetation.

The average annual temperature near the village Yailu is 2.8 °C, near Bele 3.6 °C. The average annual precipitation in Yailu is about 900 mm, in Bele nearly 2 times less (472 mm). In other words, the microclimate in the south part of the lake is essentially warmer and drier.

The total salt content of the lake water in its different parts varies from 80 to 235 mg/l, according to the composition water is hydrocarbonate-calcium. The regularity of the positional relation of the water chemical composition from Teletskoye Lake is established by the change in the chemical composition and the volume of the flowing stream runoff. According to the chemical composition of the waters, all the large lake stream tributaries are divided into two groups. The first one, presented by the west and south tributaries, such as Chulyshman, Kiga, Bol'shie Chili, Malye Chili, Koldor and Samysh, has the increased mineralization (more than 80 mg/l) and hydrocarbonate magnesium-sodium-calcium composition. All the east tributaries (Kamga, Kokshi, Chelush, Boskon, Chiri and others) has mineralization of 30–80 mg/l and sulphated-chloride-hydrocarbonate magnesium-calcium-sodium composition, similar to the hydrochemical type of the snow water (Shevchenko 2010).

The chemical composition of the ground waters near the lake was studied by Maloletko (2009). All the tested by him water sources between the cordons Chelush and Chiri (total 7) demonstrated the comparatively increased (with reference to the other areas of the lake's shore) containing the sulphates and the predominance of potassium upon sodium, at that, according to the cations in water, calcium acutely prevails. The predominance of chloride and sodium in the fontinal waters was educed only at the local areas, including the west lakeshore, to the south of the body of River Bol'shie Chili, at the wellhead part of River Kamga and near the village Artybash. The unique feature of practically all the fontinal waters near the lake is the comparatively high content of strontium in them (at the level 200 μm/l).

The dissolved solids concentration of the rainwaters within the lake territory varies from 17 to 30 mg/l, pH coefficient is from 4.8 to 6.4; chloride and hydrocarbonate-ion prevail among anions, and sodium prevails in the cations composition (Maloletko 2009).

Geologic framework of exploration area

The facts about the geologic framework of the area were taken from the materials to the state geologic map with the scale 1:200, 000, paper N-45-IV, 1959. The scheme of the geologic framework of the area near Teletskoye Lake is at Fig. 1b.

According to available geologic material, all the kudurs within the littoral zone of the lake, with exception of water source A-12, are among the strongly metamorphosed predominantly first sedimentary rocks of Proterozoic age presented principally by the quartz-chloritic-sericite schist, including immensely altered up to the quartz-feldspar-biotite gneisses, formed above the centre of solids fusion. The outlines of this centre are controlled by the outlets of the intrusive granitoid solids of the Middle Paleozoic age (Fig. 1b). The water source A-12 is confined to the recent split, along which the Kamga river-valley is situated. At that, the fontinal waters are formed in the fissured strata of Cambrian–Sinian age. The water source A-4 is confined to the recent split with the unimportant extension in the area of influence of the littoral discharges of the grabben-valley of Teletskoye Lake. All the lithomorphic kudurs also have the connection with the fault tectonics of the grabben-valley with the longitudinal and feathering echelon-like splits. This connection with the fault tectonics is confirmed either directly by the geologic facts or indirectly through the existence of the linear water-flooded zones among the poorly consolidated sediments (for instance, Fig. 4 upper image) and confined to them saline exudations and incrustations, framing the rubbles and cobbles in the outcroppings.

The poorly consolidated sediments in the littoral zone of the lake are comparatively better studied within the terraces Bele and Yailu (Butvilovskii 1993; Maloletko 2009). The aggregate thickness of the poorly consolidated sediments within the terrace Bele is estimated approximately at 180 m. At the base of the cut (at the level of the waterline), the light grey thinly laminated aleurites underlay, overlaid by the sand unit. The stratified shingly formation underlays higher; the cobble is badly graded with the float stones

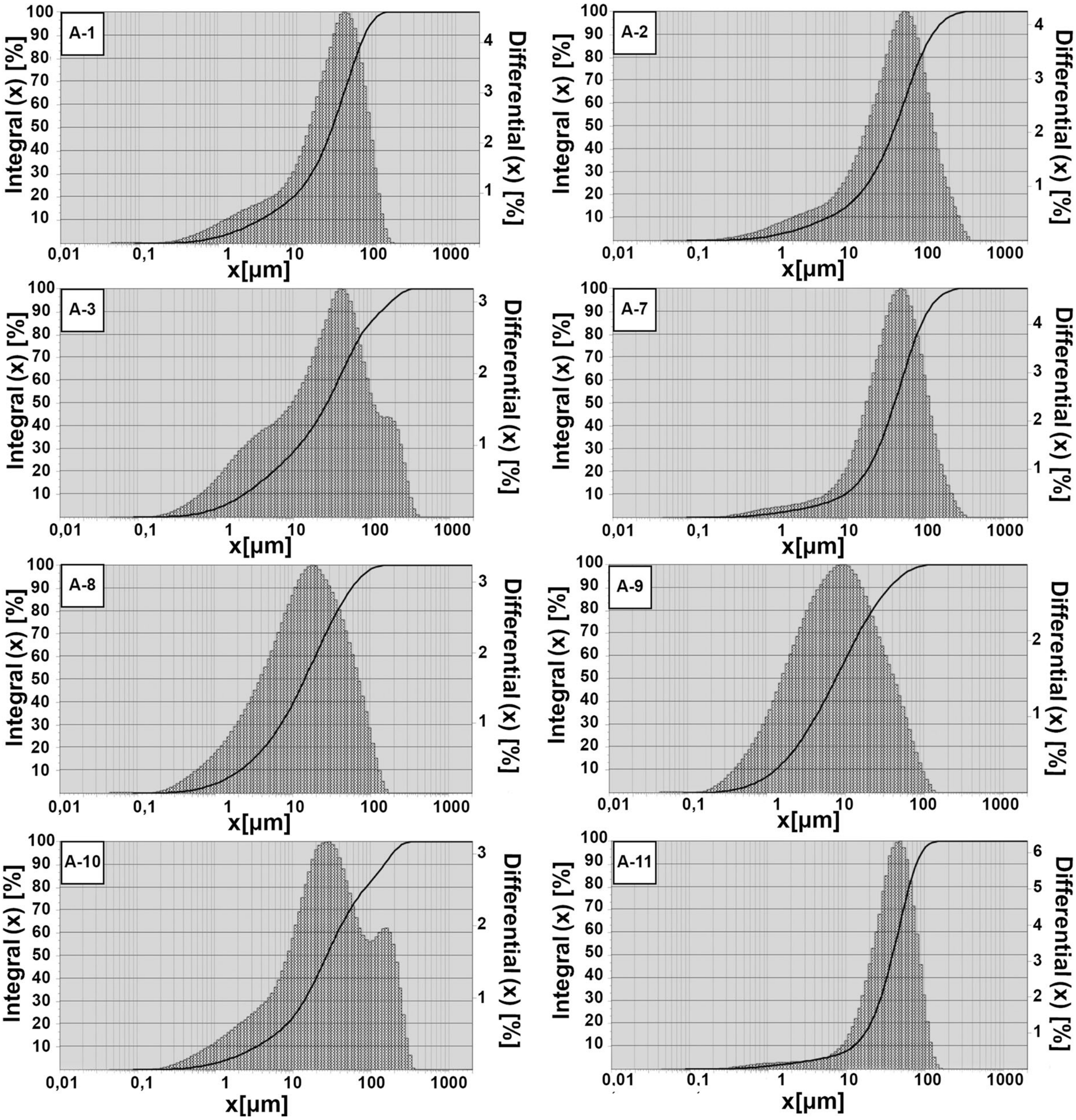

Fig. 4 Result of the study of the dimension of the main part of the mineral particles in the kudurits from Teletskoye Lake with the help of the laser diffraction analyser of granulometric composition. In the upper left corner of the diagrams, the number of the corresponding kudur is denoted

up to 1 m in diameter, sometimes immensely rolled and with the traces of eolation (ocherized). The shingle thickness is overlaid by the rubble-loam glacial drifts with the sand bands and cobble bands. The most recent rubble-loamy formation has the mudflow outlook. The accumulation period of the graded glaciolacustrine deposits of Bele open cut according to the radiocarbon dating is rated in the interval 30–15 thousand years ago with the selective localization of the quartz particles and feldspars in the argillous-aleurolitic fracture (Butvilovskii 1993). At that, the segregation of the tough microcrystals is related to the crushing influence upon the glacier rocks and also with its aeolian gain.

Results of particle size distribution testing, mineralogic and chemical study of kudur samples

The patterns (Fig. 4) present the spectra of the mineral substances dimension in the eaten ground, taken from the licks at the kudurs within the littoral zone of Teletskoye Lake.

According to the obtained diagrams, the dimension of the main part of the particles varies approximately from 10 to 70 μm that corresponds with the aleurolites dimension. The portion of particles of the clay fraction (in size from 1 μm and less) varies at the level of some per cent (maximum 5%).

Table 1 presents the results of the quantitative mineralogic analysis, pointing to the fact that the eatable kudurits in the littoral zone of Teletskoye Lake mainly consist (40–70%) of the dispersed fractions of quartz and feldspars, and also of the micaceous-argillous minerals (illite, chlorites, smectite and kaolinite), the total amount of which varies from 25 to 50%. As accessory materials may be (from 0 to 2.5%) the zeolites (clinoptilolite and heulandite) and actinolite. The fact is that the mineral composition of kudurits is the high content of sodium-containing plagioclase of albite in them. Thus, the kudurits from the Teletskoye Lake are similar to the kudurits at the Sikhote-Alin and the Caucases. (Our articles containing the facts of high assay of albite in the kudurits within the mentioned territories are being prepared for printing.) Zeolites are quite unexpected minerals in the kudurits composition. If they are properly identified, their origin, most probably, is related to the subsoil processes of the mineral formation under the conditions of salinization of the alkali-chlorine elements by the hydrocarbonates, that could occur in dryland conditions during the Holocene optimum.

The detailed petrographic analysis of the silts from the fluvial-glacial deposits at Bele, which was carried out by Butvilovskii (1993), revealed that in mineral impurities composition there are also (in decreasing order) calcite (from 0.2 to 1.5%), mineral particles of epidote group, magnetite, protobase, apatite, pyroxenes, zircon, leucoxene, sphene, tourmaline and brown hematite.

The particles of the bigger fractions in the kudurits are presented by quartz-feldspathic sand and rock fragments, which can be either rounded or non-rounded. In 1973, at the outcropping of A-8 kudur, the geologist Maloletko selected fine pebbles, from which the thin rock sections were made and the petrological thin section description was carried out. The list of the gathered solids obtained consequently: sandstone soils polymictic quartz-feldspathic, actinolitic schist with quartz, albite and chlorite; aleurolite quartz-plagioclase; amphibolic schist; biotite-sillimanite schist with muscovy glass; tuffite aleuritic (interchange of the volcanic and terrigenous particles); quartz-albite-actinolitic schist and quartz-biotite-chlorite schist (Maloletko 2009).

The chemical and microelemental compositions of the lithogenous samples of kudurits from Teletskoye Lake are listed in Tables 2 and 3. According to these data, kudurits, in content of the oxide of silicon and the most important oxides, refer to the acid and average varieties of the subsurface rocks of the normal range. In content of the main oxides and microelement

Table 1 Results of quantitative mineralogic X-ray diffraction analysis of kudurits samples from littoral zone of Teletskoye Lake (wt%)

Minerals	Sample of lick on kudurs								Coprolites near A-1
	A-1	A-2	A-3	A-7	A-8	A-9	A-10	A-11	Copr.1
Smectite	0.0	1.6	0.8	0.0	4.6	5.0	4.2	0.0	2.0
Illite + phlogopite	21.3	31.1	24.9	21.4	22.0	42.3	17.3	22.7	23.9
Kaolinite	1.0	0.0	0.0	1.7	0.6	1.3	0.4	1.1	0.3
Chlorite	9.0	4.5	3.2	1.2	5.3	5.2	4.8	2.3	2.4
Clinoptilolite	1.0	0.7	0.4	0.5	0.0	0.0	0.0	0.0	0.5
Heulandite	0.7	0.0	0.5	1.8	0.7	0.9	0.9	0.6	0.9
Actinolite	0.6	0.0	0.8	0.4	3.2	3.8	2.0	2.1	0.3
Albite	21.7	29.8	26.6	32.0	23.3	15.0	29.8	28.6	25.8
Potassium feldspar	4.4	2.1	0.0	1.7	5.3	6.4	0.0	3.0	2.2
Quartz	40.2	30.2	42.8	39.4	35.0	20.1	40.7	39.6	41.9

Table 2 Gross content of main rock-forming oxides in kudurits and coprolites from littoral zone of Teletskoye Lake (wt%)

Oxides	Kudurits								Coprolites
	A-1	A-2	A-3	A-7	A-8	A-9	A-10	A-11	Copr.1
SiO_2	60.38	57.92	69.86	70.40	64.41	55.35	64.87	62.90	62.06
TiO_2	0.88	0.76	0.59	0.66	0.77	0.93	0.61	0.86	0.79
Al_2O_3	15.91	14.68	12.65	13.84	14.23	17.42	11.64	14.35	14.56
Fe_2O_3	3.37	3.51	1.47	2.61	3.36	4.32	1.89	3.19	4.21
FeO	2.70	2.88	3.13	1.37	2.39	3.57	2.22	2.82	1.58
MnO	0.09	0.08	0.08	0.07	0.12	0.15	0.07	0.11	0.10
MgO	3.32	4.76	2.56	1.57	2.81	4.52	2.35	3.14	2.94
CaO	3.18	4.36	3.83	2.85	3.39	3.41	7.08	4.09	3.45
Na_2O	2.48	2.98	2.39	3.28	3.19	2.45	2.43	3.04	2.45
K_2O	2.30	2.32	1.45	1.36	1.71	4.07	1.26	1.77	2.14
P_2O_5	0.16	0.13	0.15	0.17	0.13	0.14	0.14	0.20	0.31
H_2O^-	0.18	0.22	0.09	0.14	0.08	0.05	0.17	0.17	0.15
LOI	5.05	5.41	1.84	1.69	3.39	3.62	5.27	3.36	5.30

LOI loss on ignition

content, they are very similar to the kudurits of the volcanogenic-aqueous genesis, consumed by the wild animals in the East Sikhote-Alin (Panichev et al. 2016). The kudurits of the East Sikhote-Alin and Teletskoye Lake are also similar in the character of spreading and concentration level of the big-ionned lithophylous and highly charged elements, except for the higher concentration of titanium and phosphorus in the kudurits from Teletskoye Lake.

Practically identical occurred to be the distribution curves of the chondrite-normalized concentrations of the rare-earth group elements (Fig. 5) in the kudurits of Teletskoye Lake and East Sikhote-Alin, differing only by the less represented europium minimum in the kudurits from Teletskoye Lake.

According to the mineral composition, microelements correlation and ion-exchange properties, the Altai kudurits are not comparable to the kudurits, typical for the volcanic area. In view of low content of the clay minerals of smectite and zeolite group, having the high cation-exchange properties, the sorbate opportunities of the Altai kudurits are low in comparison with the cations. This fact is confirmed by our previous researches of ion-exchange properties of the kudurits form Teletskoye Lake (Panichev 1990).

Chemical analysis results of water samples

Tables 4 and 5 present the results of the chemical analyses of the water samples, including the main ions and silicium in Table 4 and microelements in Table 5.

The data of Table 4 indicate that the tested fontinal waters as the lake water are ultra-non-saline and non-saline. So as to determine the water type, the ions content was used in percentage of equivalents from the total amount of ions in the concerned water, taking the total of anions and cations as 100%.

Thus, it turns out that the fontinal water from the kudur A-4 is sulphated-calcium, water from the kudur A-12 (Kamga) is chloride-hydrocarbonate-sulphate-sodium-calcium, and the lake water is hydrocarbonate-calcium.

According to the microelements composition, the water samples from the kudurs A-4 and A-12 vary widely. The more enriched in sodium and chloride waters of the Kamga source (WA-12) contain significantly less Al, Fe, V, Cr, Co, Ni, Cu, Se and also the elements of the rare-earth group. In the fontinal water WA-4, the total of rare-earth elements (REE) is two times higher. The total concentration of the dissolved forms of REE in the waters of the examined territory changes from 0.11 to 2.86 µm/l (Table 5), at that in all water types it was revealed the predominance of the light REE upon heavy REE (the total of the light REE varies from 74 to 88%). Various fontinal waters in composition are equally enriched in the light REE

Table 3 Gross content of main microelements in kudurits and coprolites from littoral zone of Teletskoye Lake (ppm)

Elements	Kudurits								Coprolites
	A-1	A-2	A-3	A-7	A-8	A-9	A-10	A-11	Copr.1
Be	1.81	1.31	1.32	1.60	1.19	2.23	1.30	1.64	1.56
Sc	20.0	18.6	14.2	12.6	19.7	24.3	13.5	18.2	18.0
V	110.3	105.5	81.13	67.13	106.2	138.0	71.08	106.2	102.1
Cr	115.9	130.7	101.0	67.18	76.98	107.7	92.98	101.4	103.2
Co	16.76	18.08	11.77	8.84	15.79	24.78	10.84	14.42	15.58
Ni	60.43	81.53	44.92	28.65	36.45	63.93	40.44	51.58	53.38
Cu	25.31	34.87	13.61	9.23	24.46	41.99	17.56	34.17	29.05
Zn	70.1	76.0	52.0	35.3	64.1	100.7	41.9	58.6	61.8
Ga	17.46	15.27	12.74	12.91	13.57	22.72	10.53	14.43	15.28
As	5.59	2.82	1.38	2.81	21.60	3.75	2.05	1.98	5.47
Rb	71.19	63.74	36.46	35.15	41.04	131.6	33.10	47.77	70.74
Sr	220	247	243	284	184	158	261	247	241
Y	32.95	23.59	22.35	33.95	32.36	22.08	25.96	36.53	28.35
Zr	211.6	161.4	181.1	185.8	181.8	130	165.5	213.4	178.1
Nb	12.32	9.41	7.74	8.74	8.20	18.34	7.07	9.37	9.46
Mo	6.28	1.04	0.33	0.29	0.52	0.33	0.18	1.26	0.97
Cd	0.21	0.21	0.36	0.30	0.31	0.23	0.35	0.77	0.71
Sn	1.19	0.58	0.41	0.69	0.90	1.22	0.23	0.77	0.83
Cs	3.02	2.14	1.66	1.37	1.73	7.12	1.32	1.98	2.35
Ba	494	467	287	307	521	597	284	404	415
La	38.60	30.68	24.67	32.57	27.63	27.33	24.03	35.95	30.76
Ce	77.37	56.17	50.52	58.12	57.82	57.17	45.65	71.22	62.37
Pr	9.58	7.78	6.16	8.10	7.04	7.07	6.08	8.89	7.77
Nd	38.57	28.89	25.20	31.75	27.09	26.76	23.41	34.83	30.95
Sm	8.30	6.83	5.07	7.61	6.55	5.97	5.89	8.12	6.42
Eu	1.72	1.25	1.06	1.53	1.27	1.26	1.02	1.56	1.50
Gd	7.60	5.60	4.89	6.81	6.24	5.07	4.73	6.99	6.55
Tb	1.17	0.88	0.74	1.07	1.06	0.73	0.82	1.15	0.81
Dy	6.96	4.66	5.10	6.69	6.31	4.28	4.72	7.79	5.89
Ho	1.21	1.06	0.88	1.48	1.36	1.07	0.94	1.42	1.08
Er	4.66	3.12	3.30	4.39	4.30	2.73	3.20	4.93	3.74
Tm	0.61	0.47	0.40	0.49	0.61	0.40	0.48	0.72	0.50
Yb	3.36	3.10	2.58	4.50	4.04	2.25	2.94	4.35	2.88
Lu	0.52	0.48	0.52	0.63	0.52	0.31	0.45	0.74	0.46
Hf	7.16	5.57	6.07	6.61	6.93	5.26	5.87	8.01	5.49
Ta	1.10	0.60	0.57	0.66	0.60	1.15	0.60	0.74	0.61
W	2.25	1.70	1.53	1.63	1.63	2.06	3.39	1.68	1.75
Pb	15.42	13.08	11.53	14.02	11.33	17.84	13.62	15.77	12.84
Th	11.42	8.12	6.23	8.00	7.38	11.22	6.15	8.82	9.16
U	2.72	2.98	2.02	1.80	2.41	2.57	1.76	2.62	2.30

87–88%. Its lowest content (about 74%) was defined in the lake water. At that, minimum of REE in the lake water is observed in the south lake part.

The diagram (Fig. 6) reveals the distribution of REE in the tested waters, normalized to the average indexes in the lake waters. The essential enrichment in

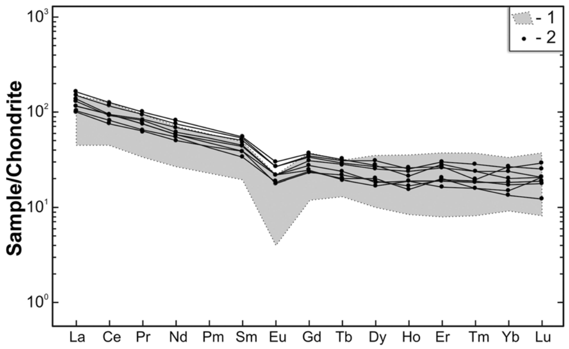

Fig. 5 Chondrite-normalized concentrations of rare-earth elements in the kudurits of Teletskoye Lake and Sikhote-Alin (according to Sun and Mcdonough 1989): 1—the field of values distribution for the kudurits of East Sikhote-Alin according to the volcanogenic-sedimentary rocks of rhyolite-dacitic composition (according to: Panichev et al. 2016); 2—the curves for the kudurits from Teletskoye Lake

REE is evident in the fontinal waters in comparison with the lake water (there is a lot of cerium in them, the content of which is in 20–60 times higher than in the water of the lake). It is interesting that the character of REE distribution in water (WA-12) from the Kamga source is similar to the character of its distribution in the water from the kudur A-4.

Results of experiment on effect upon kudurits of aqueous solution of hydrochloric acid in concentration comparable to acidity in abomasum of ruminant animals

Table 6 presents the indexes of the outlets into the muriatic solution from coprolite and kudurits of calcium and sodium, confirming firstly the low content of the fluent sodium in the acid environment in the Teletskii kudurits (on level from the units to the hundreds mg/100 g) and, secondly, inconstant content of mobile in an acid medium calcium (with variation from the first hundreds to 2000 mg/100 g). Judging by the correlation of calcium in the kudurit and coprolite calcium is not the element the animals look for. It is evident that sodium is digested by animals, but its quantity is rather low, and the capability of eating the kilograms of subsoils for getting this vey element is improbable.

There are diagrams in Fig. 7 characterizing the indexes of percentage of outlets into the extracts (from the gross content) of the microelements (A) and REE (B) from caprolites and kudurits within the littoral zone of Teletskoye Lake. The set of elements in the extracts was defined similar to Table 3, but here are cited only the data exceeding 5%. The diagram 7A demonstrates the highest value of the outlets into the extracts (over 25%) is observed in the coprolites according to Cu, Sr, As, Cd. Perhaps, this fact is explained by the wish of the animals to get rid of the excess with the help of the mineral sorbents. Among the elements, demonstrating the tendency to remain in the organism is Y and all the REE. The high solubility of REE points out to the presence of its carbon-bearing and hydrophosphate forms in the kudurits.

Figure 8 demonstrates the correlation of REE in the solutions of the acid extracts normalized to REE contents in water of Teletskoye Lake. The diagram denotes that in the abomasum of the ruminant animals the acid (HCl, pH-1) influence on the kudurits (by proportion kudurit/acid solution 1/10 consequently) leads to the outlet into the contents of the digestive tract of REE with concentration exceeding its content in the lake water in tens of thousands times. At that, the REE content in the coprolites is a thousand times lower, than in the kudurits. It can also indirectly indicate to its assimilation in the organism.

On reasons of geophagy among ungulate animals, inhabiting littoral zone of Teletskoye Lake

The history of hypothesis checking on the reasons of geophagy as the animals' need in the insufficient macro-components, such as sodium, calcium and magnesium started with the publication of the earliest study works devoted to the research of the kudurs (Murie 1934; Nasimovich 1938; Cowan and Brink 1949). As the Teletskii kudurits examined by us are enriched in the fluent forms of some alkaline and alkaline-earth elements, we shall develop this question a little deeper involving the new and earlier published by us data on comparison of the chemical composition of the consumed kudurits and coprolites. The results of the comparison are presented in Tables 7 and 8.

The data of Tables 6 and 7 confirm that the quantity of sodium available to animals in the kudurits is very insignificant to be the reason of this element search in the rock formation. According to the essential release of aluminium, magnesium and potassium from the kudur in the gastrointestinal tract, it will be consistent

Table 4 Composition of most important cations, anions and silicium in water samples taken from kudurs within littoral zone of Teletskoye Lake (mg/l)

Samples	Na^+	K^+	Ca^{2+}	Mg^{2+}	NH_4^+	HCO_3^-	SO_4^{2-}	Cl^-	F^-	NO_2^-	Br^-	NO_3^-	Si	$\sum_n$
WA-4	7.36	7.67	34.3	9.25	0.06	7.24	35.7	0.44	0.08	< 0.001	< 0.001	0.66	9.58	111
WA-12	64.2	1.04	33.2	18.0	< 0.001	22.06	21.1	77.9	< 0.001	< 0.001	< 0.001	4.08	3.89	246
Lake water*	1.4/4.7	0.8/3.8	6.0/11.0	2.0/3.7	–	42.0/73.2	0.8/7.8	1.0/10.7	–	–	–	–	2.5/2.7	56.5/117

*—According to the data of the number of authors (Shevchenko 2010); "–"—not determined

to assume that the consumed solid contains readily soluble hydrocarbonate and sulphate salts, which are common products of weathering of shale rocks. The outlet of such salts from the kudurits should be accompanied by the solid enrichment with the silicic acid anhydride at the outlet, that we do observe (Table 7). The composition of fluent cations that are capable of being displaced by ammonium ions showed (Table 8) that the sorption abilities of the Teletskii kudurits are weak and calcium and magnesium ions predominate in them. The question on the ability of solids consumption by animals because of the organism's need in magnesium and calcium is not worth paying attention as these elements are in excess within the considered landscapes.

It is worth noticing that the enrichment of the subsoils by the carbonated salts of calcium and magnesium and sometimes sodium is not unusual occurrence in the Mountains of the South Siberia; these salts are widely spread in the cryoarid subsoils within the considered territory. Thus, for instance, the researches, in the area of the Djulukul basin, of the soil-forming proluvium with the fragments of granites, gneisses and metamorphic schists (without a sign of calcareous rocks presence) revealed that in the cryoarid conditions on the dry slopes, starting with the depth of 3–50 cm the carbonates of calcium and magnesium are accumulated. In the subsoils periodically flooded by the groundwater of high hardness, the sodium salts along with calcium and magnesium are also accumulated with the main role of magnesium salts (Vasilchuk 2015). At the same time, the kudurs in the mountains of the South Siberia are not as widespread as the similar saline salts.

Thus, the passage of the soils along the alimentary canal can be accompanied by the assimilation of the insignificant quantity of sodium from them; however, this fact does not confirm the validity of the exclusively "sodium" hypothesis on the reasons of geophagy. Besides the sodium, as we found out, the range of microelements passes to the organism from the consumed solids, as well as some macro- and microelements are actively removed from the organism.

The most well-known medico-ecological problem of the Altai-Sayan area is the high incidence of hypothyroidism among the population and the widely spread hypothyroidism among domestic animals, especially in sheep (Puzanov et al. 2015). At that,

Table 5 Microelements composition in water samples taken from lake and kudurs within littoral zone of Teletskoye Lake (µm/l)

Element	WA-4	WA-12	T-1 (Yailu)	T-2 (Chiri)
Li	5.307	8.324	0.906	0.964
Be	0.019	0.009	0.004	0.003
Al	1446	411	13.7	10.0
Sc	0.283	0.064	0.026	0.033
V	4.756	0.930	0.191	0.242
Cr	4.886	1.092	0.202	0.201
Mn	23.270	15.180	0.835	0.507
Fe	1473	502	8.1	8.6
Co	1.143	0.293	0.014	0.013
Ni	3.672	0.802	0.318	0.331
Cu	9.112	0.984	1.494	1.193
Zn	3.45	1.51	0.934	1.303
Ga	0.430	0.115	0.014	0.013
As	0.430	0.439	0.344	0.327
Se	2.142	0.086	0.061	0.051
Rb	2.727	2.630	0.842	0.893
Sr	121.4	200.5	60.9	58.9
Ag	0.007	0.008	0.003	0.002
Cd	0.018	0.006	0.008	0.005
Cs	0.145	0.152	0.005	0.010
Ba	11.50	9.20	11.50	12.40
Tl	0.010	0.004	0.002	0.002
Pb	0.388	0.163	0.112	0.068
Th	0.055	0.018	0.011	0.010
La	0.5520	0.2430	0.0287	0.0214
Ce	1.1300	0.4600	0.0214	0.0149
Pr	0.1410	0.0650	0.0084	0.0059
Nd	0.5570	0.2620	0.0385	0.0268
Sm	0.1180	0.0570	0.0098	0.0069
Eu	0.0271	0.0140	0.0033	0.0028
Gd	0.1210	0.0610	0.0109	0.0077
Tb	0.0172	0.0085	0.0017	0.0012
Dy	0.0900	0.0450	0.0097	0.0065
Ho	0.0166	0.0080	0.0021	0.0016
Er	0.0449	0.0220	0.0061	0.0044
Tm	0.0057	0.0027	0.0010	0.0008
Yb	0.0352	0.0169	0.0063	0.0046
Lu	0.0053	0.0025	0.0011	0.0009
∑REE	2.8610	1.2680	0.1490	0.1064
LREE	2.5250	1.1010	0.1101	0.0787
HREE	0.3360	0.1670	0.0389	0.0277
LREE %	88.3	86.8	73.89	73.97
HREE %	11.7	13.2	26.10	26.03
Y	0.391	0.204	0.0589	0.0399
Y/Ho	23.6	25.5	28.05	24.94

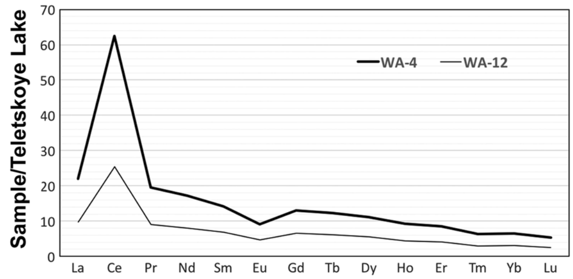

Fig. 6 Correlation of rare-earth elements in water samples, WA-4 and WA-12, normalized to the average indexes for water of Teletskoye Lake

Table 6 Calcium and sodium outlet into the extract (HCl, pH-1) from coprolite and kudurits (mg/100 g)

Sample	Ca	Na
Copr.1	1045	4
A-1	649	59
A-2	1440	108
A-3	521	50
A-7	220	16
A-8	718	60
A-9	592	51
A-10	1888	15
A-11	320	5

the hypothyroidism in people in the Altai region is spread everywhere but non-uniform. According to the data of these authors, the selenium-deficient provinces were revealed in Gorny Altai and also the provinces with the excessively high content of selenium, especially in the grassland ecosystems, where the animals may have the selenious toxicosis.

The similar biogeochemical problems were also revealed in the mountain-taiga zone of Far East. Their causes, as it turned out, are not limited only to lack or excess of selenium, or iodine deficiency, they are much more complicated and not completely determined (Ermakov and Tyutikov 2008). Besides, there are the regions on the territory of the Russian Far East, North China and DPRK, where the osteoarticular

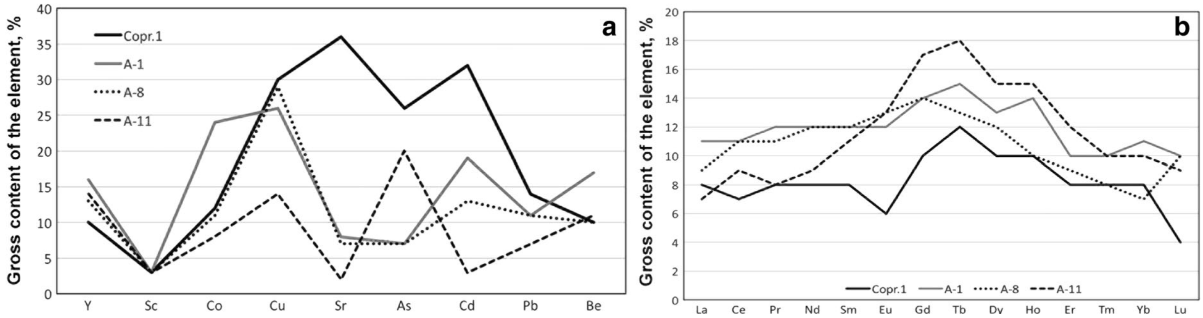

Fig. 7 Percentage of outlets into the extract of the most fluent microelements (**a**), including REE (**b**) from coprolites and kudurits within the littoral zone of Teletskoye Lake

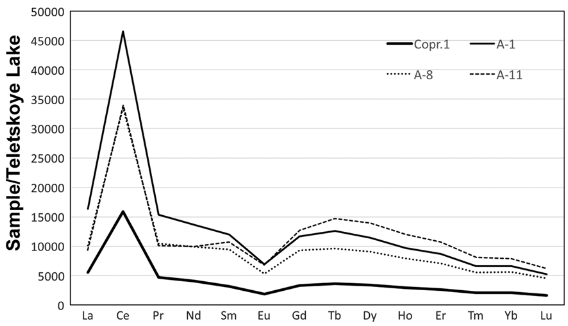

Fig. 8 Correlation of rare-earth elements in solution of acid extracts, normalized to the average indexes for water of Teletskoye Lake

diseases are often met, spread either among the residential population or among the herbivores (both domestic and wild). Such territories are known for a long time as the urovskii biogeochemical provinces (Kovalskii 1974). The reasons of such diseases are not found out still. The studiers consider the disorder of the normal correlation of the range of microelements in the feed and freshwater to be the reason of such diseases, at that always on the background of the increased intake of strontium (Ermakov and Tyutikov 2008). The high strontium content in all examined kudurits and coprolites within the lake area make refer to this fact closer.

Table 8 Composition of fluent cations in kudurits and coprolites from kudur near cordon Chelush. According to: Panichev (1990)

Sample	Mg	Ca	K	Na
Lick 1	4.3	25.7	0.6	3.3
Copr.	6.0	31.6	3.9	0.5
Diff. mg-eq/100 g	+ 1.7	+ 5.9	+ 3.3	− 2.8
Diff. wt%	0.020	0.118	0.129	0.064

If to take as a basis the biogeochemical reason of geophagy, when where almost no biologically available sodium in subsoils, then it remains to assume that the animals are able to recognize the variety of chemical elements and to find the enriched in them mineral substances. However, it is improbable, as there are a lot of biogeochemical endemic diseases (each is characterized by its own set of excessive and deficient micro- and macroelements), but at the same time, the solids at the kudurs are consumed wherever they are with approximately similar set of elements with the leading role of sodium ions.

Table 7 Comparison of main rock-forming oxides in kudurits and coprolites from kudur A-1 near cordon Chiri, wt%

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Σ
A-1	63.73	0.93	16.79	3.56	2.85	0.09	3.50	3.36	2.62	2.43	0.17	100
A-1E	65.64	0.84	15.40	4.45	1.67	0.11	3.11	3.65	2.59	2.26	0.33	100
Diff.	+ 1.91	− 0.09	− 1.39	+ 0.89	− 1.18	+ 0.02	− 0.39	+ 0.29	− 0.03	− 0.19	+ 0.16	+ 3.27, − 3.27

Loss on ignition is proportionally scattered: "A-1" is the rock from the saline lick; "A-1E" is the coprolite of maral with the impurity content about 95%; "Diff." is the difference of contents in the kudurits and coprolites; "−" is the decrease after the solid staying in the gastrointestinal tract; "+" is the increase after the solid staying in the gastrointestinal tract

In 2016, the idea (Panichev 2016) was proposed into the development of the "microelemental theory", the essence of which is that to look for the biogeochemical reason of geophagy is necessary in the context of the biochemical specificity of the immune system, defined by the participation in its composition of some more or less constant set of the chemical elements possessing the extremely important and at the same time still little or even unknown biological functions. Among the most important chemical elements, providing the continuous working of the immune system with epiphyse and thyroid gland and also at the level of the nervous cells in the cerebrum and spinal cord (we name them figuratively the elements of the nervous system) compose: Se, Y, Sc and also La and light lanthanides (Ce, Pr, Nd, Sm). We came to that proposal after the research work of the situation at the range of the kudurs in the Sikhote-Alin and analysis of the data of Africa and South-East Asia (Panichev et al. 2016, 2017). The problem with the exchange of these elements in the organism can be considerably related to the chemical antagonism between the light and heavy lanthanides able to replace each other in the biological tissues, but at that, the heavy analogue cannot fulfil the functions necessary for the organism. The analysis of the biological functions of the lanthanides in the organism was examined by us earlier (Panichev 2015). The animals' sensibility to the above-listed elements of the immune system can be somehow related to the already accepted fact of its accumulation in hypophysis, thyroid gland (He et al. 2003), in the nervous tissue (Dowding et al. 2014) and in the myocardium (Shivakumar et al. 1992).

Referring to the work (Shivakumar et al. 1992), in which the connection of pathologies of the myocardium with the abnormality of change of cerium and magnesium in it is observed, it is worth noting other two works. One of them (Raman Kutty et al. 1996) reveals that the noted pathologies are spread among people, living in some regions of India, including Kerala state, where in the rock formations, soils and also in the products grown on such soils, the high concentration of REE is revealed. The second work (Ramachandran et al. 1995) is devoted to the study of the numerous kudurs in the Chinnar Natural Park at the territory of the same state Kerala. According to it, the geophagy among wild herbivores is spread in the upper part of the same river basin, where downstream the biogeochemical endemic diseases are spread among humans related to the excess of REE in the monazite-bearing sands. At the same time, the wild animals have consumed the kudurits for a long time, formed among the silty rocks of the Proterozoic time similar to those consumed in the Gorny Altai. The only difference is that the kudurits in the Chinnar Natural Park are formed in the hot and dry climate and therefore they accumulate more sulphated and hydrocarbonated salts of aluminium, magnesium, potassium and sodium.

There is a steady feeling that the rocks are consumed by animals not only and not so much in relation to the high content of salts in them, thanks to the presence in them either some specific microelements from the group of rare and rare-earth, or (that is more probable) thanks to the presence in them of the specific microorganisms, actively developing in this mineral environment with the participation of rare and rare-earth elements. At the same time, the microorganisms are the come-between converters of the mineral (inaccessible for the mammals) forms of REE in the bioavailable forms in the type of the organo-chemical mixtures.

The fact that REE actively accumulate some kinds of bacteria is already determined by the researchers. Obtained results evidently demonstrate the own pattern of REE accumulation is indicative for different kinds of bacteria. Thus, for instance, the Japanese researchers (Takahashi et al. 2005) studying the adsorption of REE on the cell walls of bacteria *Bacillus subtilis* and *Escherichia coli* determined that the adsorption maximum was detected for Sm and Eu, and the evident reduction in sorption was observed for Nd. Another study cycle (Takahashi et al. 2007) revealed that the bacteria *B. subtilis*, *E. coli*, *Faecalis alcaligenes*, *Shewanella putrefaciens* and *Pseudomonas fluorescens* disclosed the sharp increase only in the heavy REE. It was also found out that with the help of lanthanides some microorganisms adapt to the stress conditions of existence. For example, it was determined in the bacterium *Methylacidiphilum fumariolicum*. It was firstly found in the waters of the strongly acid hot source in the crater of Solfotara eruption in Italy, while studying the structure of the ferment methanol dehydrogenase. This ferment does not contain calcium as the majority of methane-oxidizing bacteria, but REE La, Ce, Pr and Nd, that are absorbed by the bacterium from the water environment (Pol et al. 2014). The researchers also found out that the similar structure of methanol dehydrogenase is typical for different types of bacteria, from which it was concluded that they can be widely spread in nature.

Most likely that microorganisms uptaking the REE are not only widely spread in the fontinal waters, soils and earth crust of the rock formations, they also should be the extraordinarily important inhabitants of the alimentary tract of the animals. Probably, that the associations of microorganisms in particular including the ancient representatives of methanotrophes and sulphated-reducing bacteria of the autotrophes (including the Archaebacteria) participate in the assimilation of those rare and rare-earth microelements, which are the part of the immune system of any organism. Some of these groups of microorganisms are already used in the industrial technologies of REE extractions from the natural and artificial mineral substances (Barmettler et al. 2016).

It is very likely that microelements referred to above can be digested in the organism only in the composition of organo-chemical biologically active complexes, produced by the underground-soil associations of microorganisms. It is probable that these microorganisms and the biologically active substances developed by them, enriched in REE, are searched by the animals at the kudurs all over the world. At that, the consumption of the mineral sorbents by the animals enriched in microorganisms provides the passage of the acid barrier in the abomasum by the underground-soil microbiosis and its fusion with the intestines microbiosis. The second, also important reason of geophagy among animals is obviously related to the need in sodium. At that, this need can be related either to sodium itself (in case of its deficiency in the feed) or to the necessary microorganisms, for which the alkaline oxygen-free environment is necessary. The presence of sodium can also determine the alkaline nature of the environment in which the REE are fluent.

All the rest already determined biological effects of the clay minerals, zeolites and other minerals presented in the kudurits are just concomitant, a priori peculiar to them as a result of the long-duration coevolution of the minerals kingdom and the world of biological systems.

Conclusions

The field and laboratory researches of the selected material at the kudurs in the littoral zone of Teletskoye Lake, at the territory of the Altai State Nature Biosphere Reserve, were carried out. It was determined that the animals in this area consume the finely dispersed solids of the silt–clay size, consisting of 20 to 43 wt% of the quartz particles, from 1 to 32% of the feldspar particles, predominantly albite, and from 25 to 55% of micaceous, clay minerals and chlorites, which are the alteration products of the metamorphic schists as a result of the abrasive effect of the glacier and aeolian gain, and also their subsequent aqueous deposits and then eolation in the subaerial conditions.

The fontinal waters consumed at the kudurs are weakly mineralized, hydrocarbonate-chloride-sodium and hydrocarbonate-sulphated-calcium. The second type of the fontinal waters differs by the increased REE content.

The acid (HCl, pH-1) extracts from the kudurits more actively extract calcium (from 10 to 35% of the gross content). Sodium extracts at the level of 1–3%. The most fluent in the microelements composition are Cu, Be, Sr, Co, Cd, Pb (from 10 to 35%), and also Y, Sc and REE. Their transition into the dissoluted form varies from about 10% of the gross contents. At that, the concentration of REE, transiting into the soluble state, thousands of times exceeds the content of such elements in the water of Teletskoye Lake.

The conducted studies failed to prove that sodium or any other macro- or microelements can be regarded as a main reason of geophagy among wild animals. Alongside with that, the idea earlier stated by us about the connection of geophagy with the elements of the rare-earth group took the indirect acknowledgement. The analysis of the obtained results suggests that in the assimilation of REE in the organism involved some specific associations of soil microorganisms, actively developing in anoxic environments enriched with alkaline and alkaline-earth cations and sulphur.

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