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Lakes of the Amut depression (Northern Pribaikalye)

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Abstract: The article considers lacustrine morpholithosystems of the Amut depression in the south of the Stanovoy upland, one of the interesting and poorly known elements of the Baikal rift zone. Lake basins vary in way of formation at the leading part of a glacial factor. Their complex characteristic (geomorphology, bottom sediments) is presented.

Introduction: a brief physical-geographical characteristic of the area

The Amut depression is situated in zone of conjugation between the Ikatsky and Barguzinsky ridges (Fig. 1). The absolute heights of the alpine-type mountains framing the depression reach 2500-2600 m, and elevation marks of its bottom vary from 1230 to 1460 m. The Upper Cenozoic filling of the depression is 300-400 m, the glacial and aqueo-glacial deposits compose about 150 m of the upper unit (Explanatory..., 1981). The graben is located within the distribution of the Late Proterozoic granitoids. It has an oval shape in plan, of lateral axes measuring 9 by 16 km, and an asymmetric morphology of the boards. The large Balantamursky fault that is marked in relief as a steep (up to 400) and high (up to 1000 m) tectonic scarp controls the southeastern board of the depression. The northwestern board is more gentle, 25-300. In the basement of Balantamursky fault is the Malanzurkhensky fault that does not have so distinct topography. These faults converge in the southwestern corner of the depression. The Yurgon River draining this part of the depression develops the zone of their convergence. It is the left tributary of the Kovyli River, in turn falling into the Barguzin River. The Barguzin River is a magistral watercourse of the Amut depression; it crosses the depression from SE to NW along its smaller diameter, dividing it into two approximately equal parts. It is of interest that the Kovyli River falls into the Barguzin River far beyond the depression, nearly where the latter comes into the Barguzin rift valley. That is, there are two streams that flow out of the Amut depression: one running northwestward, it is the Barguzin River, and another one running southwestward through the water gap in the board of depression into the Yurgon River, and then into Kovyli River and into the Barguzin River.

The graben bottom is located within mountain-woody and subalpine natural complexes (Molozhnikov, 1986). The wood cover makes 34% of the territory at a leading part of ledum larch-trees. The soil cover consists of mountain cryogenic-taiga ferruginous, surface podzolic, and mountain-tundra gley soils, and by peat bog soils in the fluvial plain of the Barguzin River. The average annual amount of precipitation varies from 600 to 1000 mm, 90% of that falls on the warm season, from April to October (Atlas..., 1967). About 5% of the bottom area of the depression are bogged up, especially near the Barguzin River channel.

The valley of this transit river between the mountains framing the depression is a typical trough. The ancient gletcher intensively melting within the Amut depression produced a typical ridge-and-hummock-and-sink morainic topography on the most part of its bottom, with a system of 100-m high lateral moraine lines curved towards the boards of depression. The gletcher also incised within the graben bottom itself (Fig. 2). Moraine deposits are composed of unsorted, mostly rubbly-pebbly-clumpy material with aleurite-pelitic cement. From our data, the content of clayey fraction in these deposits makes some-

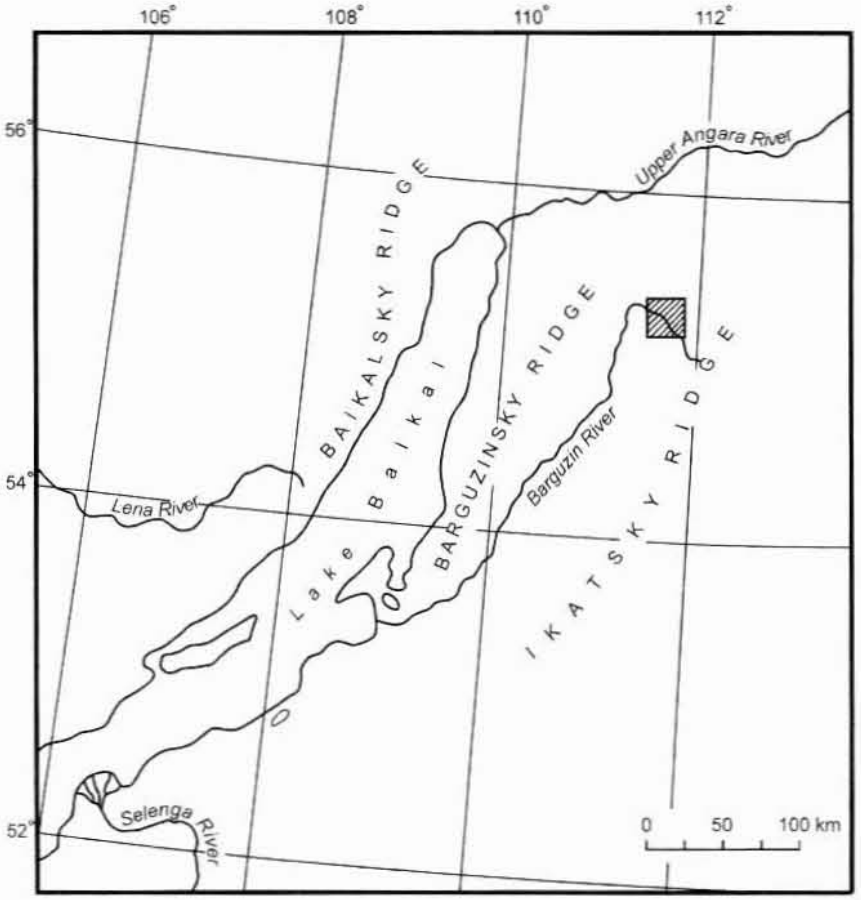

Fig. 1. Locating of the Amut depression.

times 54% and does not go lower than 18%. Numerous lake basins that vary in shape, size and mechanism of formation are in combination with glacial accumulative forms of the depression topography.

Hydrobiology and hydrochemistry of these reservoirs are well understood (Lakes..., 1986), but their geomorphology is poorly known. Up to now, a brief note of V.B. Vyrkin (1986) has been the only source of information on the structure of lake basins of the Amut depression. Bottom sediments of these reservoirs have never been investigated. In this article we undertake a partial attempt to make up a deficiency.

Bathymetric survey was done by a hand-sounding lead. The bottom sediment cores were taken from a 1-cm thick near-surface layer by a half-meter pipe. The same pipe was used to take the sedimentary columns under consideration. The analysis of the samples was pursued in the laboratories of "Irkutskgeologiya" enterprise and Limnological Institute SB RAS. Granulometric structure of the sediments was determined by sieve and pipette analyses, mineralogical structure of an aleurite-

Lakes group	In the inequalities of basal moraine			Between the lines of lateral moraines			Morainic-dammed		
	N	F	V	N	F	V	N	F	V
<0,1 km²	131	0,4	-						
0,1-0,3 km²	8	1,6	-						
>1 km²	1	1	6,0	1	1,2	12,8	2	13,3	248,3
Summary	140	3	-	1	1,2	12,8	2	13,3	248,3

Tab. 1. Characteristic of various-type lakes of the Amut depression by size.

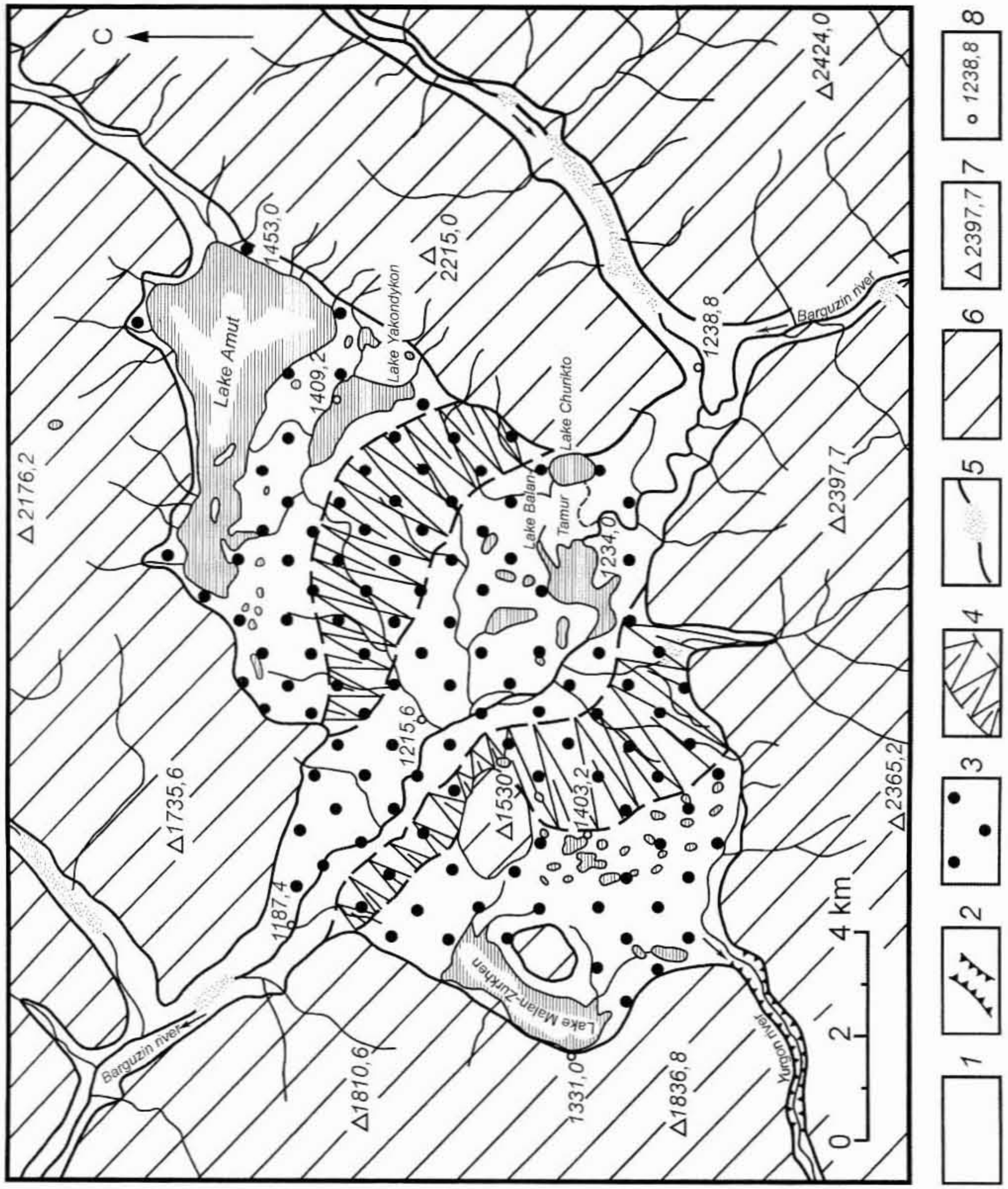

Fig. 2. Scheme of geomorphology of the Amut depression.
1-2 – bottoms of intermontane valleys including antecedent segments (2); 3 – bottoms of intermountain basins; 4 – slopes of glacial valleys within intermountain basins; 5 – naleds; 6 – medium-height mountains of an alpine type; 7-8 – absolute heights of the tops (7) and water line (8).

Name and type ofthe lakç	Absolute elevation ofthelakç level	Water piane, km2	Volume of the lake's water min. m	Maximum depth, m.	Length*, km.	Average width (square to length relation), km	Coastal linç length, km.	Coefficient of jagging of coastal linç *
Churikto (In the inequahties of basal moraine)	1234,0	0,3	2,3	14,3	0,8	0,37	2,5	1,13
Yakondykon (Between the lines of lateral moraines)	1409	1,3	13	22,6	2,7	0,48	6,2	1,05
Amut (Morainic-dammed)	14.53	10,6	235	69,8	6,75	1,57	20,4	1,11

* By the method of S.D. Muraveisky (1948)

Tab. 2. Morphometric parameters of the lakes typical of the Amut depression determined by mechanism of formation.

sandy fraction – by immersion method, clayey minerals were determined in a fine-pelitic fraction by a thermal method, and chemical composition of lake sediments – by a silicate (bulk) chemical analysis.

Lake basins of the Amut depression and their classification: the general items

The lakes are oligotrophic as a whole, but to a variable extent within a type: from ultraoligotrophic (Amut, Yakondykon, Balan-Tamur) to oligotrophic with mesotrophic features (Churicto). They are hydrocarbonaceous-potassic of low salinity in a chemical body of water (Lakes…, 1986).

All of 143 lakes calculated from large-scale aerial photographs make 16% of the Amut depression at total area of the water plane equal to 17.5 km². The reservoirs can be divided into three groups by size: less than 0.1 km², 0.1-0.3 km², and 1 km² and more (Table 1). Small-size and middle-size lakes are the most numerous, there are 139 of them, but total area of the water plane of these reservoirs only makes 2 km².

Almost all the lakes of the Amut depression are closely related with an ancient glacial activity (several negligibly small lakes of thermokarst origin in the fluvial plain of the Barguzin River are not considered). Similar in genetic type, the lakes are somewhat different in the mechanism of their formation. With regard to these differences, glacial lakes of the Amut depression can be divided in the following way: 1) lakes in the lows of basal moraine; 2) lakes between the lines of lateral moraines; 3) morainic-dammed lakes.

Lake basins located in the inequalities of basal moraine

As is shown in Table 1, the reservoirs of this type are the most typical of the Amut depression. They differ in size, shape of the coastal lines that copies the smallest inequalities of subaerial glacial accumulative relief, and also in hydrological regime. Many of reservoirs, especially small that are no more than 0.1 km² in area do not have any outlet. Larger lakes are usually running-water. One of them, Lake Balan-Tamur (Fig. 2), 1 km² in area and up to 16 m in depth, is the largest in this group and not quite typical of it. This lake is in the fluvial plain of the Barguzin River, falling into and flowing out of it. The river produced a delta in the form of a blade, protruding far in the water area. Note that this large lake of a lithoral-profundal morpholimnic type is the only one in the Amut depression, with its wide lithoral zone sharply going by a steep scarp to its profundal, related to the central part of the lake basin. Eastward of Lake Balan-Tamur is Churikto Lake that joins it through a wide watercourse. Besides, there is a flood channel connecting this lake with the Barguzin River before it falls into Lake Balan-Tamur. According to V.B. Vyrkin's data (1998), the water line in Lake Churikto rose by 1.5-2 m during torrential floods of the Barguzin River. This lake, as a morphological representative of the investigated group of lakes, will be considered in greater detail.

Its basic morphometric parameters are given in Table 2. From the west and north the lake is surrounded by forested and swamped low plain with mounting hummocks of the basal moraine, and the mountain slopes framing the Amut depression come to the lake from the east. An active recharge of the lake by swamp

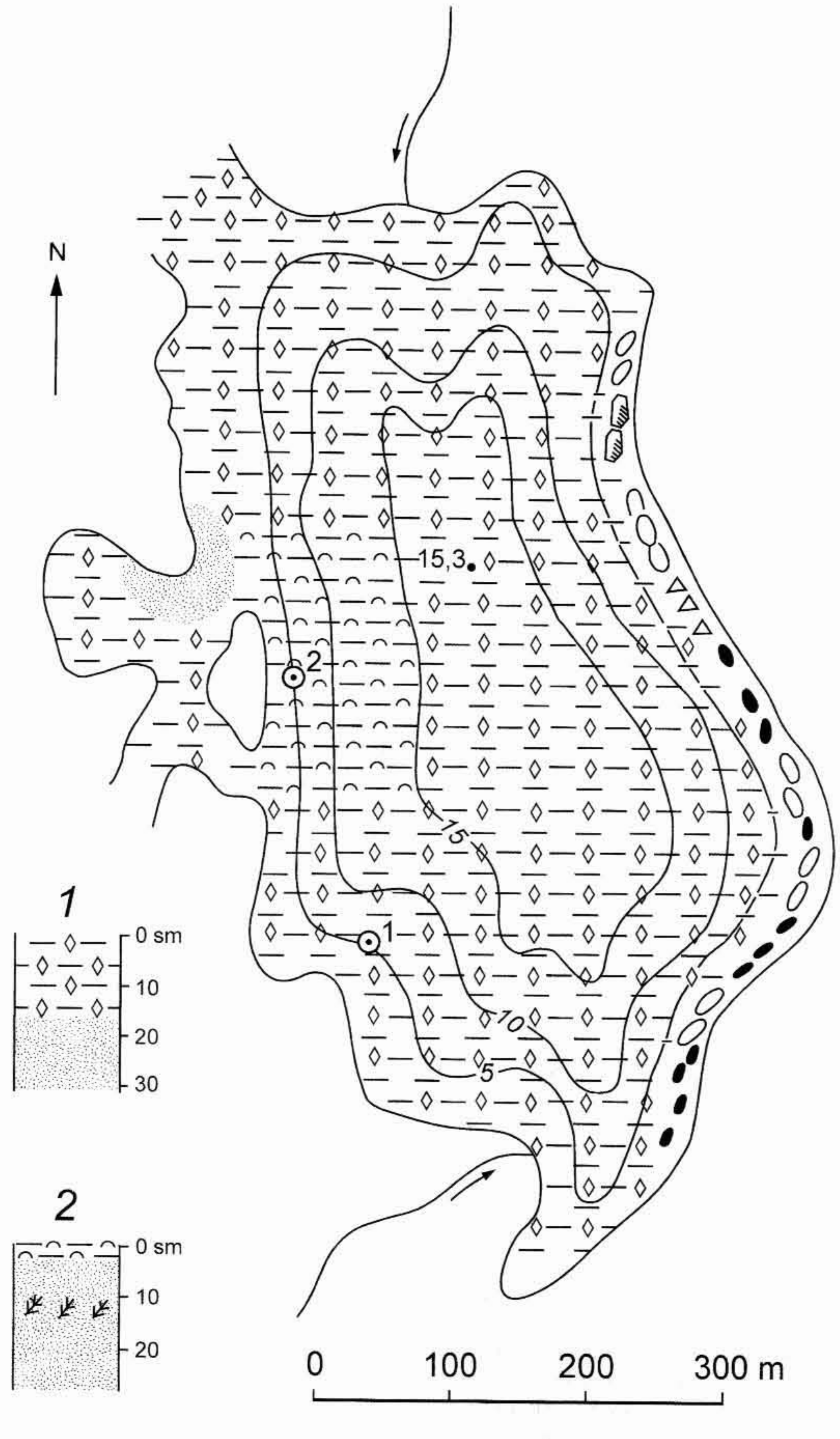

Fig. 3. Sediments and bathymetry of Lake Churikto. See notations in Fig. 5.

Average diameter of granule (M_d), mm	Coef-ficient of sorting (S_o)	Granular size, mm							
		1,0-0,5	0,5-0,25	0,25-0,1	0,1-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001
CHURIKTO									
weakly manganous-ferruginous large pelites (Mn from 0,2 to 5 %, Fe from 10 to 20 %)									
0,008	1,7		0,16-0,37 0,23	1,94-8,74 4,2	2,59-6,67 4,53	13,72-31,25 19,84	51,94-70.01 67,2	5,13-8,75 6,89	0,7-2,2 1,24
weakly sapropelic large pelites									
0,009	1,8		0,18	0,26-10,12 5,2	0,9-10,12 5,52	0,7-26,53 13,6	49,1-95,03 72,1	2,97-3,85 3,41	0,1-0,2 0,15
fine-grained sands									
0,15	2,6	0,2-0,7 0.36	9,9-35,7 20,3	36,5-54,0 44,84	5,0-18,8 9,48	2,21-14,7 10,6	5,94-23-1 13,24	0,1-1,2 0,76	0,03-0,7 0,4
YAKONDYKON									
large pelites									
0,008	2,0		3,36	0,06-26,03 7,69	0,38-7,71 3,3	0,19-13,9 8,6	46,57-98,24 72,88	0,75-8,19 4,25	0,4-5,2 2,7
weakly sapropelic large pelites									
0,009	2,1		0,23	6,25	6,6	23,93	54,18	6,87	1,94
fine aleurite silts									
0,03	4,0		1,71-3,38 2,54	25,4-33,21 29,3	9,66-10,13 9,9	17,68-20,85 19,27	29,53-41,67 35,6	1,74-2,41 2,07	1,16-1,4 1,28
fine-grained sands									
0,14	3,8	0,51-1,13 0,82	20,1-22,8 21,44	35,9-40,9 38,4	5,6-6,35 5,97	10,39-10,75 10,57	19,05-20,89 19,97	1,85-2,2 2,02	0,7-0,9 0,8
AMUT									
large pelites									
0,007	1,4	0,17-0,82 0,49	0,1-13,6 6,61	0,1-18,76 4,58	0,1-4,31 1,86	0,04-14,0 6,49	50,56-98,2 62,41	0,2-25,31 13,51	0,1-9,05 5,14
small pelites ("blue clays")									
0,0011	3,4		0,04	1,17	0,98	8,78	38,65	20,52	29,86
fine aleurite silts									
0,02	4,4	0,79-2,1 1,44	1,0-16,85 9,7	20,39-31,19 24,4	3,5-8,3 5,37	10,44-22,4 15,43	30,7-43,8 38,8	2,6-4,2 3,5	1,1-2,2 1,8
fine-grained sands									
0,11	6,3	4,64-9,2 6,2	21,69-28,8 25,24	18,38-19,48 18,97	2,5-4,3 3,42	6,8-11,5 9,57	31,64-38,9 34,9	0,8-1,0 0,9	0,2-0,5 0,35
medium sands									
0,29	3,3	6,89-30,5 14,36	39,3-56,4 48,11	2,0-19,55 12,73	1,1-2,84 1,91	0,9-4,9 2,88	15,95-24,48 19,11	0,04	0,2

Tab. 3. Granulometric structure of the basie types of bottom sediments of the łakes of the Amut depression (numerator shows the limits of change of the content of fractions, denominator shows the average content of fractions).

waters affects the character of its bottom sediments. The lake's profundal is lined by a layer of well-sorted (S0=1.6, from here on after (Trask, 1939)) dark-gray weakly manganous-ferruginous large pelites (Fig. 3, Table 3), 15 cm thick in the average. The pelites contain 0.2-0.5% of Mn and 10-20% of Fe (amorphous hydrotroilite is the basic ferrum-bearing component of these sediments). Attention is drawn to a high content of not only ferrum and manganese but also phosphorus (Table 4) concentrating in mineral forms, which is indicative of an active ore formation.

Weakly manganous-ferruginous pelites are also underlain by well sorted (S0=1.7) gray fine-grained sands intercalated with needles. Note that the sediments of this reservoir are generally distinguished for a good kind of sorting. In single parts of the lake there are also small spots of weakly sapropelic large pelites containing about 17% of organic matter (primarily macrophytes and needles). A thin pelitic fraction of the upper layer of lake sediments (~10 cm) mostly contains kaolinite and hydromicas and is noted for a high content of quartz and car-

Lake	Reference point number, depth of taking a core, horizon (cm)	OB, %	Fe, %			P_2O_5 %	MnO %	Amorphous silica SiO_2, %	CaO %	MgO %	K_2O %
			Fe	Fe^{+2}	Fe^{+3}						
Churikto	№1, 4,0 m										
	0-5	6,1									
	5-13	0,4									
	№2, 14,0 m										
	0-10	16,9	13,6	9,94	3,72	0,59	0,31	3,91	2,51	0,83	2,16
Yakondykon	№1, 5 m										
	0-10	1,1									
	0-29		2,12	0,71	1,41	0,28	0,04	4,94	2,83	0,76	3,17
	№2, 21,0 m	25,0									
	0-10										
Amut	№1, 5 m										
	0-5	8,5									
	5-10	4,2									
	10-17	5,4									
	17-35	1,0									
	№2, 58 m										
	0-10	13.3									
	№3, 2,1 m										
	0-19		2,61	2,19	0,42	0,18	0,04	2,88	1,59	1,3	2,52
	№4, 4,5 m										
	17-35		6.88	5,96	0,92	0,12	0,09	0,58	1,56	2,85	3,52

Tab. 4. Chemical composition of bottom sediments of the lakes of the Amut depression.

bonaceous rocks. Montmorillonite with kaolinite, quartz and feldspar admixtures dominate down the cross-section.

As a morphotype of the lakes under consideration, Lake Churikto differs radically in hydrochemical and hydrobiological features (including that of high-trophic) (Lakes…, 1986) and the character of bottom sediments (see Tables 3, 4) from the other lakes of the Amut depression. It is primarily due to a low hypsometric position of the lake at the level of severely swamped fluvial plain, in comparison to other reservoirs, and an intimate relationship between the lake and Barguzin River.

The next type of lakes is only represented by Lake Yakondykon (Fig. 2) located between two large lines of lateral moraine, about 80 m in height and well-marked in morphology, that are the boards of this lake basin. Two lines of lateral moraine are also observed in the opposite southwestern part of the Amut depression. But they are less marked, with a field of hummock-and-hollow microtopography extending between them with numerous small lakes in the lows.

Lake Yakondykon occupies a higher hypsometric position than Lake Churikto (Table 2). It is situated in the subalpine natural complex. The young-morphology coasts of this reservoir are covered by vast lichen fields and spots of ledum brushwood under a sparse growth of larch-trees. Two permanent watercourses fall into the lake. Lake Amut water that also falls into it during the flood period has drifted a large avandelta of mostly fine-grained sands.

The near-surface sedimentary layer of the profundal zone of this reservoir (Fig. 4, Tables 3, 4) is composed of yellowish-greenish large pelites, enriched in the deepest part by organic matter (to 20%) mainly consisting of moss remains intercalating with fine aleurite silts. A narrow lithoral of the lake is mostly lined by cobble roundstones with rock debris and blocks and fine-grained sands with gravel. Montmorillonite with hydromica and chlorite admix-

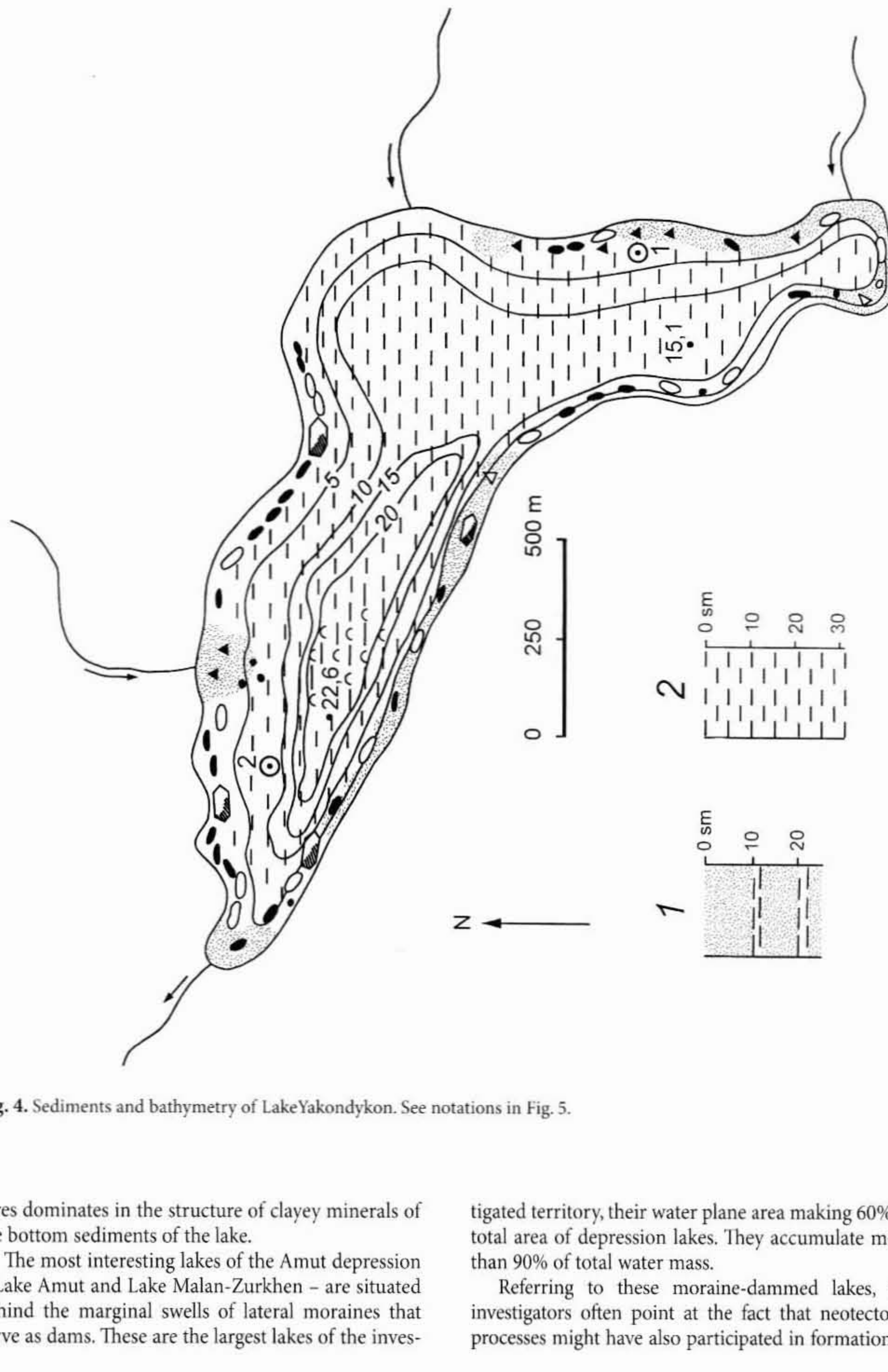

Fig. 4. Sediments and bathymetry of LakeYakondykon. See notations in Fig. 5.

tures dominates in the structure of clayey minerals of the bottom sediments of the lake.

The most interesting lakes of the Amut depression - Lake Amut and Lake Malan-Zurkhen - are situated behind the marginal swells of lateral moraines that serve as dams. These are the largest lakes of the investigated territory, their water plane area making 60% of total area of depression lakes. They accumulate more than 90% of total water mass.

Referring to these moraine-dammed lakes, the investigators often point at the fact that neotectonic processes might have also participated in formation of

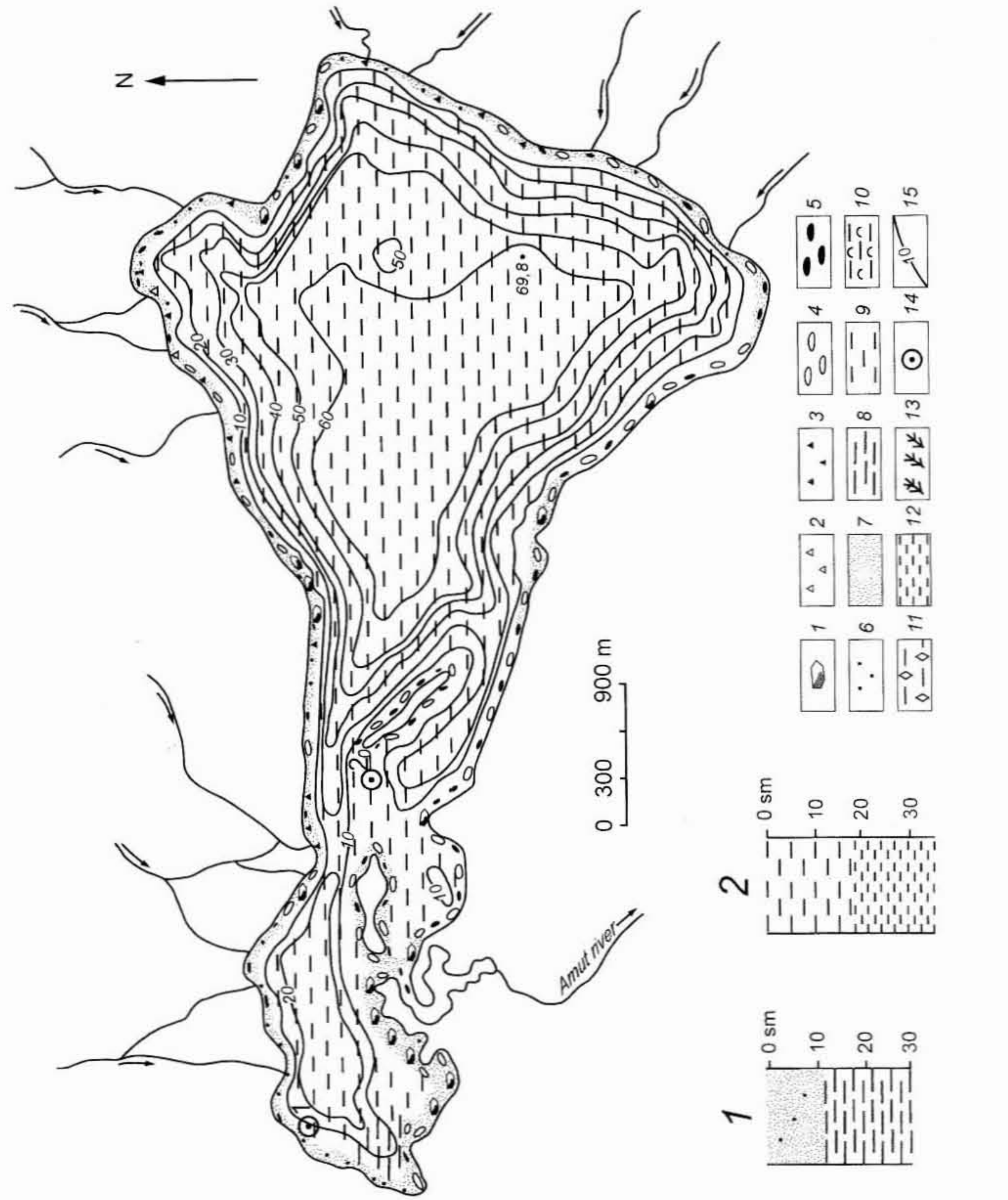

Fig. 5. Sediments and bathymetry of Lake Amut.
1 - blocks; 2 - rock debris; 3 - gruss; 4 - boulders; 5 - pebble; 6 - gravel; 7 - sand; 8 - aleurite silts; 9 - large pelites; 10 - weakly sapropelic large pelites; 11 - weakly manganous-ferruginous large pelites; 12 - small pelites ("blue clays"); 13 - detrital inclusions; points of taking bottom sediment cores by a half-meter pipe; 15 - isobaths.

lake basins (Explanatory..., 1984; Vyrkin, 1986;. Vyrkin, 1998; and others). They are primarily led to suppose like that by a large size of the lakes in scales of the Amut depression and different elevation marks of those, which may be due to the structure of crystalline basement of the depression divided into differentially subsiding blocks. It should be noted that neither geophysical investigations nor drillings were done in the depression.

The size of the reservoirs is really impressive, especially that of Lake Amut, one of the most beautiful in Pribaikalye. But the conditions of formation of these lakes are also rather specific, even unique for the Baikalo-Stanovaya mountain area. Glacial reservoirs of such size usually form there in the rear of terminal moraine complexes.

A prerequisite to the formation of the lake similar to Amut in size was absent in the southwestern part of the Amut depression because of a water gap in its board. The meltwater of the Barguzin gletcher was running in a lateral direction through this water gap, that is indicated by stratified sedimentary units widely developed on the segment from the marginal southwestern swell of lateral moraine to this antecedent gorge, with a distinct facial change into glacial sediments (Explanatory..., 1981).

Lake Malan-Zurkhen has a depth up to 14 m (Vyrkin, 1986) and an area of 2.7 km^2, almost four times less than that of Lake Amut, and more than 100 m lower hypsometric level. Two benches of the depression basement are really exposed there from under the moraine. But these intradepressional components are passive in the structure of the lake dam. Block separations are loaded there by deposits of the left-coast lateral moraine that dams the lake, with the basements of constituent lines located below the level of the lake. There are no evidences of any tectonic factor in formation of this reservoir. Old glacial activity is the only cause of originating of Lake Malan-Zurken, as well as of Lake Amut.

Of interest is also the fact that Lake Malan-Zurkhen is the only one among large lakes of the Amut depression that does not have surface runoff, though six rivers fall into it. This situation results in an extreme instability of its water line, for the last 25 years varying with amplitude of 4 m under the data of V.B. Vyrkin (1986).

Lake Amut occupies all the space between the crest of the right-coast marginal swell of lateral moraine and the slopes of the northeastern board of depression. 11 permanent watercourses fall into it, and one river of the same name flows out. In the bottom relief of the western part of the lake there is a distinct arc-like morainic ridge that complicates the relief of the main line of lateral moraine-dam and goes from under the water in the form of a chain of elongated islands. This ridge divides the lake into two basins. The coastal zone of this lake has young-morphology forms, as well as that of Lake Yakondykon.

The near-surface layer of bottom sediments of the reservoir (Fig. 5, Tables 3, 4) is rather uniform. It is composed of well-sorted (S0=1.4) yellowish-greenish large pelites, in the central part of the lake underlain by dense, viscous "blue clays" that are characterized by a low (1% and lower) content of organic matter. The latter is allochthonous, primarily consisting of mosses, as well as in Lake Yakondykon. Fine-grained gray sands with gravel, intercalating with dark-gray fine aleurite silts are beginning to dominate in the sediments nearer to the coast. It should be emphasized that in the sediments of this lake the trend has been toward a higher content of organic matter up the cross section (see Table 4). Kaolinite and hydromicas prevail in deposits among clayey minerals.

Conclusion

Having the same glacial genesis, the lakes of Amut depression vary widely in mechanism of formation, basin morphology, and character of bottom sediments. A distinct relationship is traced between the content of authigenic component of the lake sediments and the altitude on which the reservoirs are situated. One can state ore-forming processes in Lake Churicto, but there are not any of them in the reservoirs at a greater hypsometric level (Lake Amut and Lake Yakondykon), where the contribution of authigenic components to the sediments is negligibly small. It is also significant that organic matter in the cross-section of the near-surface layer of bottom sediments of all the investigated lakes is notably increasing from bottom to top. This has been convincingly demonstrated with Lake Amut sediments.

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