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GEOGRAPHY

The First Computer Model of Currents in the Kurai Intermountane Basin, Altai, under Release of a Glacial-Dammed Lake

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Abstract—The first 2-D computer model of the currents (including circulation currents) inside the glacial-dammed Kurai Lake under its release caused by the dam break is simulated in the RMA2 program of the SMS 9.2 modeling system. The hydraulic parameters are calculated for several given water discharges in the transit flow (from 10 to 0.3 million m^3/s) of the basin. A consecutive change in the circulation currents during the release of the lake is identified. A comparison of the character of circulation and the calculated fields of the depths and the current velocities in the lake with the orientation of the gravel ranges on the bottom of the Kurai basin allows reconstruction of the hydraulic conditions of possible formation of the giant ripple fields.

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Numerous intermontane Altai basins were occupied by the glacial–dammed lakes during Pleistocene glaciation. The basin lakes were systematically filled and drained with probable catastrophic discharges of the lake waters [1]. The volumes of the largest basin lakes (Chuya, Kurai, etc.) were hundreds of cubic kilometers, and the discharges of the outburst floods (diluvial flows) could reach millions of cubic meters per second. The age of these flows are estimated as 23–12 kyr on the basis of the geological bodies produced.

The first paleohydrological scenarios of the lacustrine–glacial evolution of the Late Quaternary periglacial valleys of North America and mountains of South Siberia were based on deductive solution of the reverse glaciohydrological tasks by the relict forms of relief and loose sediments after the breaks of the Pleistocene glacial-dammed lakes. These qualitative models were similar in general, although the volumes of the lake waters and the velocities and depths of the flows were only approximate. Thus, the first hydraulic parameters of the diluvial flows and the volumes of the Altai lakes were probably overestimated.

The computer models of the outburst floods, which were formed after the breaks of the glacial-dammed lakes of the Chuya and Kurai intermontane basins and spread down along the Chuya River valley up to its junction with the Katun River and further down the slope into the Altai foothills, were developed about 20 years ago [2–4].

We offer the first 2-D computer model of the movement of water, including circulation currents, directly in the Kurai basin in the course of the drainage of Chuya and Kurai lakes under different water debits in the transit flow moving down along the Kurai basin. The model is simulated in the RMA2 program of the SMS 9.2 modeling system [5].

It is assumed that the debits of water flowing in and out of the lake are the same. This, with a certain degree of approximation, corresponds to the transit water movement complicated by the intralake circulation in Kurai Lake. Similar conditions, for example, could arise at a synchronous break of the upper dam between the Kurai and Chuya lakes and the lower glacial dam out of the lacustrine system.

The primary data include the digital relief model based on the data of the space sounding of the Earth (SRTM-matrix) with a resolution of 93 m from the north to the south and 60 m from the west to the east (http://srtm.csi.cgiar.org). The model was elaborated for the modern relief; thus, the solutions ascribed to the Late Pleistocene should be considered as approximated. The debits of water flowing in Kurai Lake were accepted as fixed consecutively in the range from 10 to 0.3 million m^3/s with a step up to 1 million m^3/s. The water levels in the lower transit (the area of the modern settlement of Chibit) were given so to provide stable solutions. Such an approach has no effect on the final calculation result, because the water levels in the indicated transit leaves its movement directly in the lake unaffected due to the areas with stormy flow and hydraulic jumps just below the break point of the lower dam.

The water levels in the input section and inside the lake depend on the given water debit and the rough-

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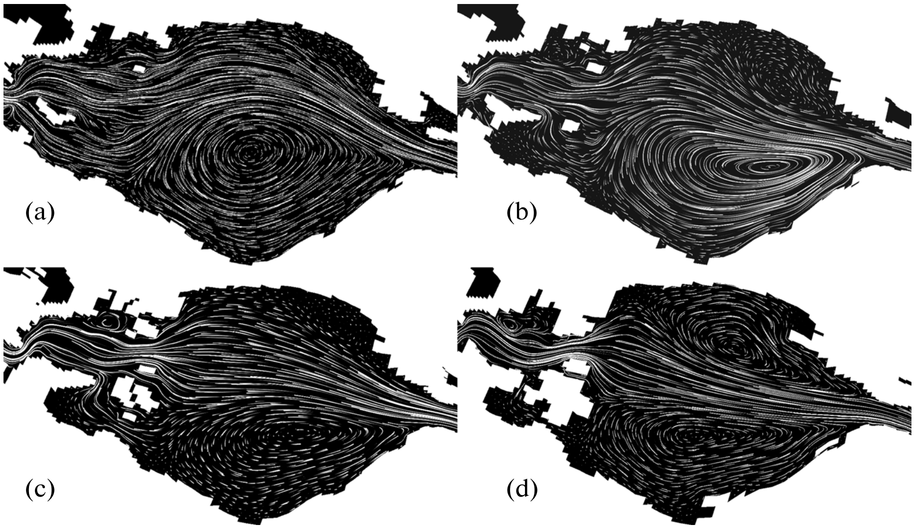

Fig. 1. Character of currents in Kurai Lake under a transit water debit of 9.6 million m^3/s (a), 5.5 million m^3/s (b), 4.5 million m^3/s (c), and 2.8 million m^3/s (d). The transit current is directed from the east to the west.

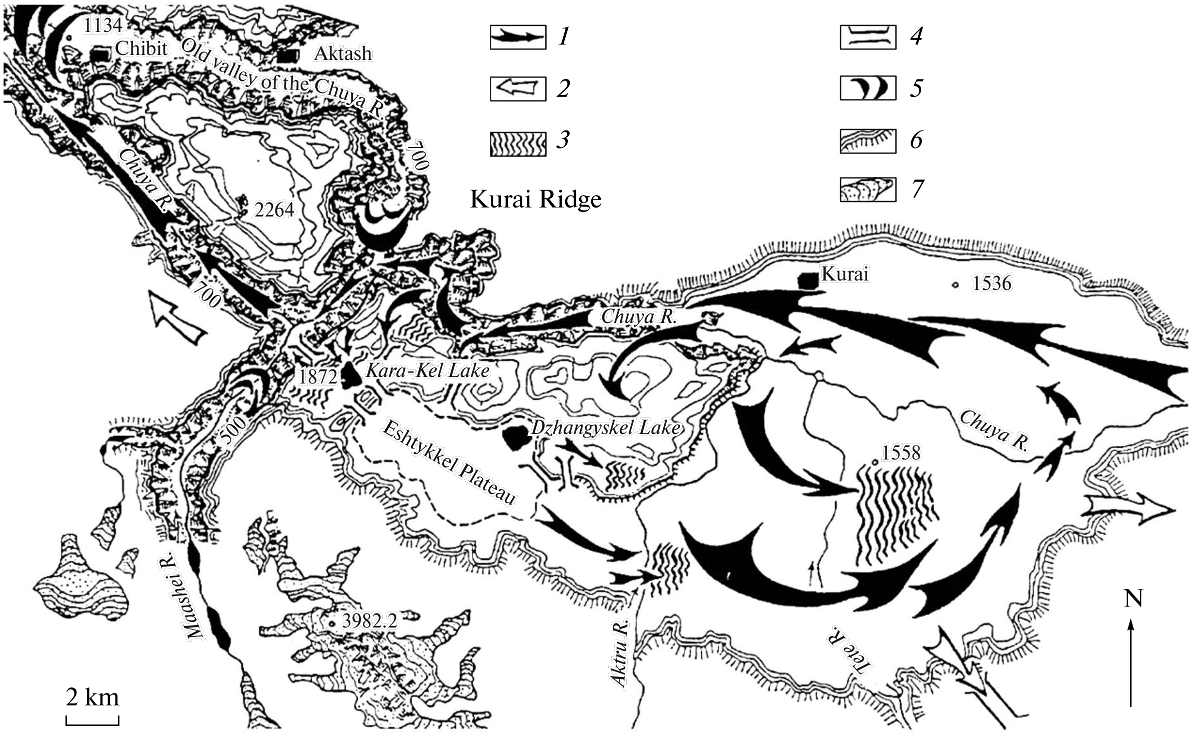

Fig. 2. Paleohydrological scheme of the Kurai intermontane basin, Altai after [7, 8]. Chronological section, about 11.5 kyr. (*1*) direction of diluvial; (*2*) possible direction of diluvial flows; (*3*) fields of the giant ripple flow marks; (*4*) spillways, canyons of break and climb; (*5*) end moraine; (*6*) margins of basin; (*7*) modern glaciers.

ness of the bottom. The coefficient of the roughness n in the Manning formula was accepted for the entire range of the modeled conditions as 0.03. The coefficient of the turbulent viscosity was given depending on the Peclet number, which was determined by the critical sizes of the cells in the calculation network. The latter is composed of 11590 elements (or 35200 points) in a range of heights from 1072 to 2315 m.

The calculation results in the 2-D model provide the instant characteristic plans of the currents in the lake according to the variable debit of the transit flow (Fig. 1). The results of modeling include the fields of the depths, the marks of the free surface, and the vertically averaged velocities of the currents (the value and direction of the velocity vector). Using this, it is easy also to determine the single water debits (i.e., the debits correspondimg to the unit of width of the concrete flow) at various areas of the circulation currents.

Figure 1 shows that, as far as the debit of the transit flow changes, the character of the circulation currents, which is caused by the configuration and relief of the basin and flow bed between Kurai Lake and Chuya Lake and also by the variable water levels in the system, is certainly transformed.

Under the highest transit water debits (10 to 4.5 million m^3/s), the clearly visible large circulation vortexes with currents opposite to the transit flow in the central and southern parts of the Kurai basin may explain the orientation of the fields of the gravel ranges (Figs. 1a–1c). The flow depth could attain 400 m, and the vertically averaged velocities of the currents over the present gravel ranges could reach 4–5 m/s at a velocity of 6–10 m/s in the transit flow branch. The modeled velocities of the circulation currents are in agreement with the values calculated on the basis of theoretical movement of the gravel on the range field on the right bank of the Tete River in the Kurai basin [6]: 1.5–8 m/s at individual water debits of 20 000–750 000 m^3/s over the field.

Two circulation vortexes with relatively weak currents in the south and north of the basin with dominant transit flow in the center could be formed at lower water debits (Fig. 1d). The decrease in the water debit leads to disappearance of the circulation vortexes.

A comparison of the circulation schemes and hydraulic characteristics under different transit water debits in the lake with orientation of the ranges (giant dunes and antidunes) on the bottom of the Kurai basin allows the suggestion on the conditions and stages of drainage of the lake necessary for the formation of the fields of the giant ripple marks (Fig. 2).

These results confirm the previous paleohydrological reconstructions based on the geological–geomorphological parameters [7]. In conclusion, the preliminary character of reconstructed currents should be emphasized, which is related to the modern relief model applied and rough assumptions of the boundary and primary conditions of the hydraulic modeling. To identify the possible formation of the current velocities necessary for the range gravel movement, as the true genesis of the ripple fields, we need further detailed studies.

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