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OF THE REPUBLIC OF KAZAKHSTAN

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SOVIET, RECENT AND PLANNED STUDIES OF THE BEHAVIOR OF THE BALKHASH LAKE

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Keywords: Holocene, Balkhash, bottom sediments, hydrological models.

Abstract. During the last decade the Balkhash lake has been the object of researches by part of Kazakh and international scientific teams, who brought two very important results: a sound knowledge of the multi-millennial behavior of the lake under different climatic conditions; and a growing international awareness of its vulnerability under the present climatic warming and anthropogenic activities in the basin.

During the years 2007–2012 was implemented the international research project «Historical interaction between multi-cultural societies and the natural environment in a semi-arid region in Central Asia», which involved the Institute of Man and Nature (Kyoto, Japan), the Kazakh State Scientific Research Institute of Cultural Heritage of the nomads (Kazakhstan) and the Institute of Geological Sciences named after KI Satpayev (Kazakhstan).

In 2015–2017, a new phase of research is planned in the frame of the project grant MES «Climate change and the water level of Lake Balkhash in the last 10 000 years, based on the analysis of core samples and sediments of the Uzunaral Strait and Saryesik Peninsula for predicting short-term and long-term natural and anthropogenic changes in arid areas Central Asia».

1. Present knowledge of the history and behavior of the Balkhash water reservoir. During the last decade the Balkhash lake has been object of special attention by part of Kazakh and international scientific agencies, which brought two very important results: a sound knowledge of the multi-millennial behavior of the lake under different climatic conditions; and a growing international awareness of its vulnerability under the present climatic warming and anthropogenic activities in the basin.

This decisive turn in the study and understanding of the Balkhash lake is connected with the implementation during the years 2007–2012 of the research project “Historical interaction between multi-cultural societies and the natural environment in a semi-arid region in Central Asia”. The project saw the cooperation of the “Research Institute for Humanity and Nature” (RIHN) of Kyoto with the “Kazakh State Research Institute of the Cultural Heritage of the Nomads” of Almaty, in particular with Kazakh specialists of the “Institute of geological sciences named after K.I. Satpaev” and of the “Laboratory of Geoarchaeology”.

The researches focused on the Ili-Balkhash basin (Semirechie) and concerned several fields, including: the reconstruction of climatic changes and of Balkhash water levels during the last 8000 years, together with correspondent archaeological traces of land-water use; Late Medieval historical accounts concerning the territory; and finally Soviet documents and post-Soviet interviews concerning the pastoralist and agricultural activities in the region.

Preliminary results have been communicated at the Kyoto conference of 2009, and final results at the Almaty conference of January 2012. They are both published in hard paper (Kubota J. and Watanabe M. editors: 2010, 2012) and can be read in electronic format at the internet site www.ilipro.org. The scientific communications concern a variety of different topics, but here we just focus on the new discoveries about the behavior of the Balkhash lake by the "Kazakh-Japanese Balkhash expeditions 2007–2012".

The Balkhash lake has a very long history, spanning from around 300 000 years ago to now. Knowledge about the earliest stages is still based only on the geological studies of the Soviet time. The "Kazakh-Japanese Balkhash expeditions 2007–2012" introduced new information concerning events younger than 35 000 years BP (Before Present) by studying the altitudinal position of relict gravel bars exposed on the shore, and provided a detailed reconstruction of the Balkhash history from 8000 BP to now by analyzing three cores of bottom sediments drilled in the easternmost and westernmost parts of the lake.

As a whole it can be said that several teams worked on different aspects of the Balkhash, but the complex approach necessary for the understanding of the lake is still lacking. Such a task goes beyond the aims of the present article and here below are just suggested the general lines of such synthetic reconstruction.

1.1. What is and how to study a lake. A lake is formed when an inland basin is filled by water and, geologically speaking, it is a temporary body of water. In fact any lake, in thousand or hundred of thousands of years, because filled with sediments, will gradually loose water storage capacity and transform into a swamp; and it can even disappear earlier, still unfilled, if the water input is interrupted by river diversion or by extreme anthropogenic water subtraction (like in the case of the Aral). This explains the origin and disappearance of a lake, but what about its conditions between birth and death?

The condition of a lake largely depends from its water volume, which fluctuates seasonally and yearly, conditioned by river input, evaporation, climate and other natural or anthropogenic factors. The hydrological balance of an endorheic lake (without emissary, like the Balkhash) consists in the equality between how much water is added (by surface streams, groundwater, and local precipitation) and how much water is lost (by evaporation and human use). Given the bathymetric characters of the reservoir, the values of water volume, water surface and water level are interconnected (Figure 1). During a dry climatic phase, the water input drops and so does the water volume, level and surface (regression); the opposite happens during a pluvial phases (transgression). When water volumes and water levels diminish (in the case of the present Balkhash a drop of water level by 3 m would correspond to a reduction by around 40% of the water volume and 25% of the surface!), the water composition changes in mineral and biotic content, becoming more salty and hosting higher ratios of organisms adapted to the brackish environment.

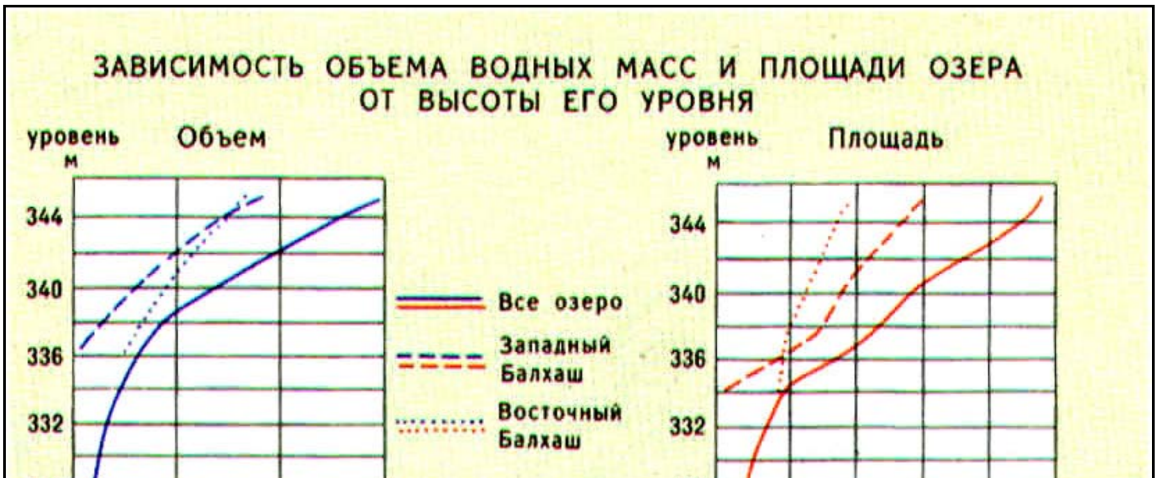


Figure 1 – Morphometry of the Balkhash lake: Correlation between water levels, water volume and water surface (Atlas Kazakhskoi SSR, 1982)

In reality the water balance model of a real lake is always more complex, including the consideration of factors like groundwater circulation, glacial deposits and sediment transport. For example, in the case of the present Balkhash, the 5% of the total input is represented by groundwater and the 14% by ice-melting water and sediments.

Depending from climate, a part of the yearly total precipitation within the basin is accumulated as mountain glaciers and, of the lasts, a part is recovered as ice-melting water, so that any discrepancy between the two values would decrease or increase the water input, postponing the effect of climatic changes on lake water volumes, levels, salinity, etc. At the start of a cold pluvial phase, the extra-accumulation of ice could postpone the rise of water level by one century or more; and, at the start of an arid phase (like now), the increase of ice melting could postpone the drop of water levels by tens of years.

Sediments are continuously transported by rivers and winds. The largest part of the sediments transported by the Ili river is trapped within the delta, but a fraction of them (today averaging 4-6 million tons per year) reaches the lake where is deposited as a stratified sequence at the bottom (a yearly average of 0.6 mm, virtually enough to fill the present water basin in less than 15-20 thousand years) together with the precipitation of all kinds of particles suspended in water. In that way sediments represent by far the most significant tracers of environmental changes. Bottom lake sediments are recording anomalies of the physical and bio-chemical constituents of the water, pointing by differential concentrations to fluctuations of water volumes (water levels) and climate. Sediments are also deposited by waves on shores as sandy gravel bars that, when dated, record the complex succession of water levels. So, together bottom and coastal sediments represent the most informative tracers of the lake’s behavior during time.

1.2. Geological history of the Balkhash lake. The modern outlines of the Balkhash tectonic depression are established around 10-15 millions years ago, but until 300 thousand years ago the Balkhash lake didn’t exist. The Ili river was forming a lake (the Ili lake) in correspondence of the modern Kapchagai reservoir, from where it proceeded straight westward until merging with the Chu river (that at the time was reaching the Aral sea). The Balkhash depression, still sloping N to S, was a lacustrine landscape made of small ponds fed by the little streams of the Northern Pre-Balkhash.

The gradual tectonic uplift of the Zailisky Alatau increased the water stock of the rivers and, around 300 000 BP (Before Present), provoked a crucial deformation that diverted the Ili northward across the Karaoi plateau, forming a delta in the south-western part of the Balkhash-Alakol depression basin (*Akdala delta*) and emptying the Ili lake into the last one. At the contrary of the modern surface relief, the Paleozoic substratum of the Balkhash depression is sloping from N to S, from +200 m asl at the Balkhash to -50 in the pre-mountain zone of the Jungarian range, and middle Quaternary deposits from +330 to +200 m asl. So, at first a lake (Bakanas lake) or a system of shallow lakelets was formed in depressions of the piedmont zone of the Jungarian range, east and north-east of Bakanas, which then had been filled and displaced north-east by the huge accumulation of sediments of the Ili river and the formation of the Ili delta. In that way, during around 200 000 years, a large lake, the *Ancient Balkhash*, inclusive of the modern eastern Balkhash and Alakol reservoirs, had been ‘sediment-dammed’ in the northeastern part of the depression, coinciding with a series of tectonic faults gathering along the axial line of the modern lake.

These geological considerations make that the modern Balkhash lake from one side is lying in the lowest part of a huge accumulation of alluvial sediments, which favor the water input from rivers and from shallow aquifers; and on the other side is located in coincidence with the most elevated part of the Paleozoic substratum, which favor groundwater circulation between the lake bottom and the deep groundwater deposits of the south, across few hundred meters of semi-permeable sediments. This groundwater dynamic, necessarily accompanied with the circulation of chemical contents, possibly explains the relatively low salinity ratio of the lake.

At the start of the Late Pleistocene (110 000 years ago) the orogenic activity of the Jungarian range lifted the Arkarly mountains above 700 m asl, dividing the Ancient Balkhash in 2 different water bodies: the *Alakol lake* on the east (today at 347 m asl) and the *Modern Balkhash lake* (inclusive of its eastern and western part) on the west (today at 342 m asl).

Concerning the evolution of the Ili delta from 100 000 BP to now, the process happened in 4 stages. At first the head of the delta moved northward, around Bakbakty, and the distributaries, under the forcing of tectonic movements, started to rotate anticlockwise feeding a lake still consisting of a single basin (*Bakbakty delta).* Then during the postglacial period the delta head moved further north around Bakanas

(500 m asl) and a further anticlockwise rotation of the distributaries created the *Uzunaral delta*: its frontal part was in correspondence with the Saryesik peninsula, where it deposited a 30-50 m thickness of alluvial sediments shaping the connection between the West and East Balkhash into a narrow and shallow straight (the Uzunaral straight, today 5 m deep). Only with the start of the Holocene, around 10 000 BC, was established the *Bakanas delta,* which discharged totally in the western part of the lake; and, just recently, during the pluvial phase of the XVII–XVIII centuries AD, the Ili delta rotated further west as *Modern Ili delta*. The last has been a quite complex event, the steps of which have been well explained by TH Dzhurkachev (Dzhurkachev, 1964).

The Karatal and Aksu-Lepsy rivers were and are still discharging into the Eastern Balkhash. The sediments of their deltas contributed to the partition of the eastern basin in three different reservoirs that, from west to east, show an increasing depth, respectively with bottom lake at 327, 326 and 316 m asl (today corresponding to a water depth of 15, 16 and 26 m). The water stock of these rivers cannot by itself support the actual water level of the eastern basin, which is co-fed by water currents from the Western Balkhash.

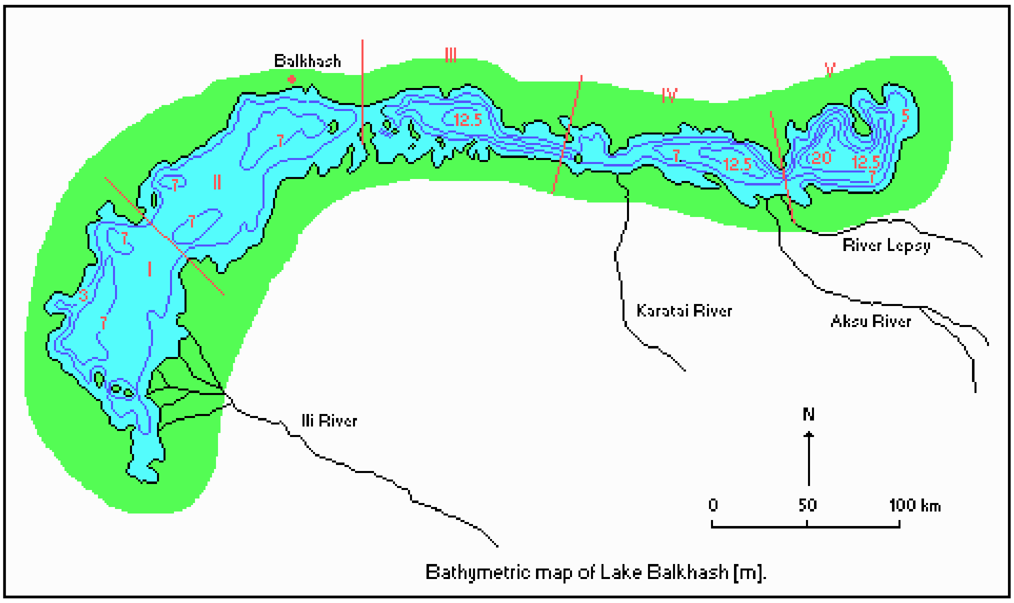


Figure 2 – Bathymetric map of Lake Balkhash. Roman ciphers I–V point to morphometric partitions of the lake; Arabic ciphers to meters of water depth

Referring to the present features of the Modern Balkhash on the basis of the average values of data collected during the last 60 years, the physical characteristics of lake consist of a water level of 342 m asl (min 340.8, max 343.1), a surface of 18210 km^2, and a water volume of 106 km^3, which makes an average depth of 5.7 m (Figure 1).

The lake hydrological balance is supported by a total yearly water input of 17 km^3 [inclusive of surface water (81%), groundwater (5%) and ice-melting water and sediments (14%)] and of an equivalent amount of evaporation. The surface water input from rivers is of 15.56 km^3, 12.3 from the Ili river (80%) and 3.26 from the Karatal, Aksu-Lepsy and Ajaguz streams. In reality the river input has a potential of 18.5 km^3 which is decreased by 3.0 km^3 on the account of anthropogenic water subtraction for irrigation.

Within the Balkhash lake, significant differences are established. The lake bottom is sloping progressively from west to east, from 333 to 316 m asl, and a western and eastern parts separated by the 6 m deep Uzunaral straight are clearly defined, a fact having serious implications on their respective hydrological balance (Figure 2). The shallower Western Balkhash (max depth at 333 m asl) receives the abundant input of Ili waters. The Eastern Balkhash, less extended but much deeper (max depth at 316 m asl) and holding the 54% of the total water volume, is fed by the other lesser streams constituting all together just the 20% of the total Balkhash inflow. Because that, it experiences a yearly water deficit of 1.15-2.80 km^3 that makes it 3 times saltier and requires an equivalent water inflow from the western basin.

Such contemporary conditions of the Balkhash lake correspond to a specific hydrological mode of Modern Balkhash, which represents the last of its three possible behaviors (see below), and characterizes the Late Holocene period (see below).

1.3. The three hydrological modes of the Modern Balkhash during the Late Pleistocene and Holocene periods. During the Late Pleistocene and Holocene, no essential tectonic shifts occurred any more, and geological processes changed very slightly the configuration and the size of the water surface of the lake. So, from this time on, the most significant changes of the Balkhash occurred in the form of sediments accumulation and transgressions-regressions of water levels. Tracers of water level variations are the absolute height of the sand bars on the shore, and the physical, chemical and biotic composition of the sediments of the bottom lake.

The behavior of the Balkhash during the last glacial period has been partly reconstructed by the "Kazakh-Japanese Balkhash expeditions 2007–2012" through the study and dating of exposed gravel bars at some bays of the northern and eastern lake shores. A high transgression of +13 m than today (to 354 m asl) has been documented at the approaches of the third Wurm (Valdai) glacial stage around 32 000 BP, and then again a transgression of around +10 m during the last glacial maximum between 25 000 and 17 000 BP. These results witness a tendency to very high water levels during very cold phases with minimal evaporation. A sharp decrease of water level will only manifests at the approaches of the Holocene (12 000 BP), and the present level at 342 m asl is reached for the first time around 8500 BP (Figure 5).

The Balkhash behavior following the 8500 BP has been reconstructed by the same Kazakh-Japanese project through the study of 2 cores (0901 and 0902) from the eastern basin and of one core (Tasaral-2007) from the western basin. All together these core analyses introduced significant amendments to the non-quantitative reconstructions implemented by N. Verzilin at the end of the Soviet period.

Cores 0901 and 0902, recovered at the water depth of 20 m in the easternmost part of the Balkhash lake, are 6 m long and represent the sediment record of the last 8000 years. The sedimentary column has been submitted to multi-proxy analyses (lithology, chemical composition and salinity, magnetic susceptibility, diatom algae and pollens, ostracods, dating, etc). The results point to a transgressive mode during the pluvial Atlantic period (7000–5500 BP), followed by 3 main regressions at 5.5–5.0 ka, 2.7–2.4 ka and 1.3–0.8 ka. The last two regressions have been quite relevant but probably not below 336 m asl (-6 m from the today water surface). Instead the first regression of 5500–5000 BP surely went below the 336 m asl of the bottom of the Uzunaral strait between western and eastern Balkhash, separating in that way the eastern basin from the western one and transforming the first into a series of few small ponds.

In fact, when submitted to lithological analyses, the columns of both cores 0901 and 0902 present sediments typical of a dry or semidry land (sandy silt, very low Ca/Si ratio, concretions, and presence of a gypsum-rich layer) at 317.5 m asl (4684 cal BP), i.e. around 24 m below the present water surface of the lake!! And Core-0901, at the same level, shows laminated sediments rich in Fe and Si, possibly deposited by active surface streams (Figure 3).

These results are confirmed by laboratory analyses of biotic components: the ratio between saline benthic and fresh-water planktonic diatom algae, the contraction and increase of different ostracod species, palynological spectra. Moreover, the geomorphological study of the paleo-terraces of the Lepsy river make suspecting that these regression events, because their extreme character, could be also correlated with temporary switches of the Lepsy riverbed, diverting its waters westward in a separate evaporation basin (in the central part of the East-Balkhash lake or even south of it in the Koyandy depression).

Actually, buried soils (peat) have been detected by Soviet scientists at a depth of 5–6 m in few sites of the lake shore, but a desiccation event of such amplitude is documented for the first time in the history of the Balkhash. It is witnessing the particular vulnerability of Eastern Balkhash that, in case of a drop of water level of the western basin by more than 6 m impeding the west-east circulation across the Uzunaral straight, would finally reduce to just a couple of easternmost ponds at 329 m asl (Figure 4).

Core-2007, recovered in Western Balkhash near the Tasaral island at the water depth of 3 m, is 6 m long and represents the last 1800 years. It provides a detailed reconstruction of the lake behavior during the last 2 millennia. Two major regressions are detected at 750 and 1150 AD. The first regression, at 750 AD, which had been very sharp and abrupt, dropped the water level by around 5 m and could have temporarily dried the Uzynaral straight, establishing for a short period a dry isthmus for a northward caravan road. The second regression of the 1150 AD has been milder but longer (Figure 5).

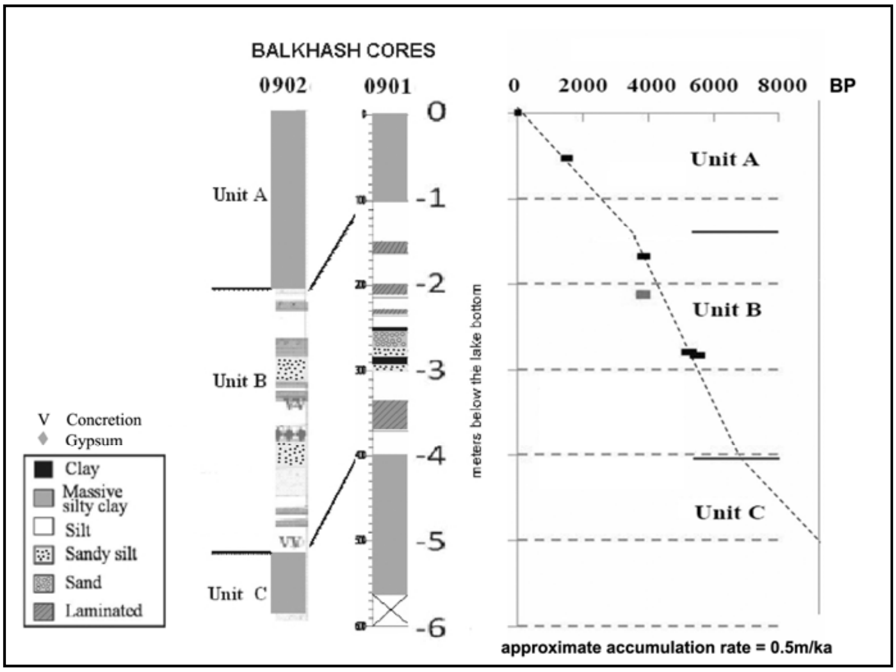


Figure 3 – Eastern Balkhash cores 0901 and 0902: lithological profile (Endo et alia 2012)

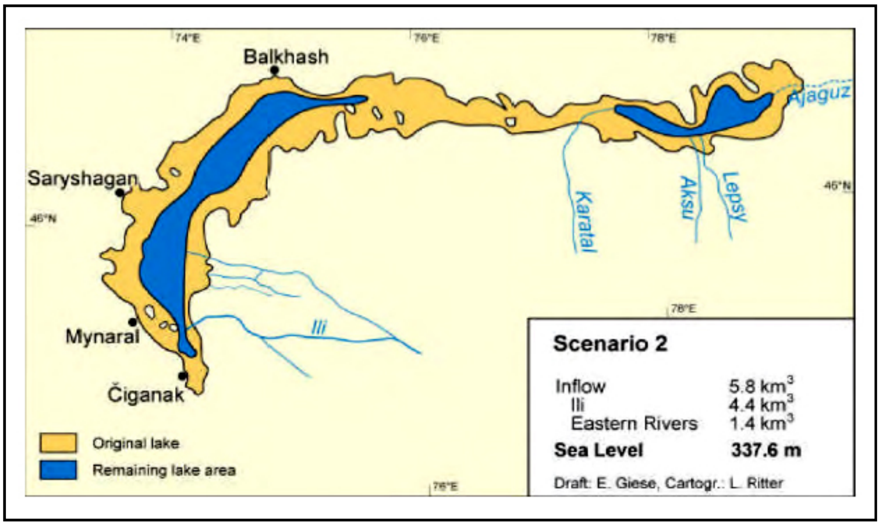


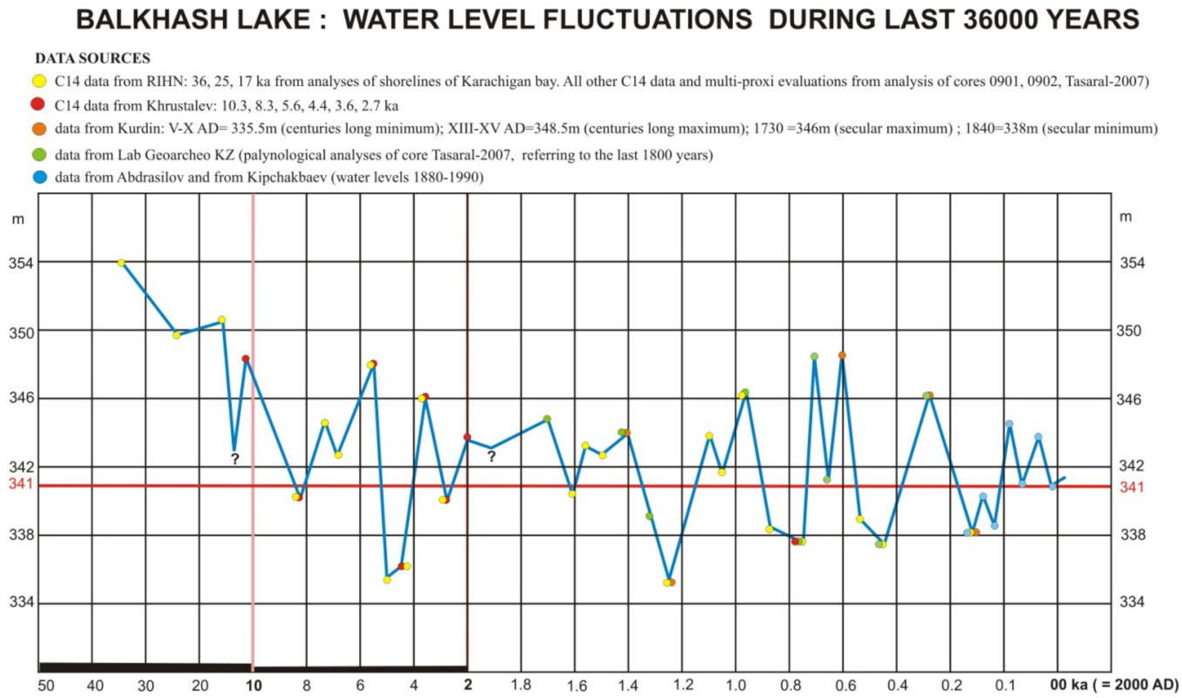
Figure 4 – Map of the Balkhash reservoir under the worst forecasted scenario, with water levels at 337 m asl (Tursunov, 2002)

These two Medieval regressions of the Balkhash coincide with the start and the end of a long dry climatic phase between the VIII-XIII AD, i.e. the Medieval Warm Period (MWP). It brought to the aridization of the piedmont steppes, favoring the displacement of economical activities in the pre-mountain zone, a large conversion from pastoralism to agriculture and commerce, and the agro-pastoral urbanization of the Tienshan and Jungarian piedmonts.

The medieval regressions of the lake are followed by a long transgressive phase under the pluvial climate of the so-called Little Ice Age, between XIV and XIX AD, which saw the dismantlement of the medieval urban complex of Semirechie and a massive reconversion to pastoralist activities.

Summarizing it can be said that the Balkhash lake manifests 3 different behavioral modes, corresponding to different climates and water levels (Figure 5):

– the first mode, with high water levels between 355 and 349 m asl, is connected with glacial stages and very low evaporation;



Figureg 5 – Balkhash lake: evolution of water levels during the last 36 000 years on the basis of various data sources (Sala and Deom, 2013)

– the second, with water levels between 348 and 341 m asl, manifests during the early Holocene interglacial, warm, moderately wet and still rich in mountain accumulation of ice;

– the third and present mode, with water levels between 348 and 335 m asl, manifests during the Late Holocene, which is characterized by an arid climate and scanty ice deposits and by relevant fluctuations between arid and pluvial phases.

The most significant contribution of the studies spoken above consists in the discovery of extreme events within this third mode, in particular the real possibility of the desiccation of the Uzynaral strait and the disappearance of the Eastern Balkhash.

1.4. Present conditions of the Balkhash lake. The meaning of the name Balkhash (in Turkic language ‘tussocks in a swamp’) is not very auspicious about the future of its water level.

In order to understand the scale of the hydrological phenomenon, it must be known that the average water volume of 106 km^3 of the Balkhash lake during the last 60 years corresponds to less than 7 years of water input (or evaporation) and to almost the same amount of water stored in the mountain glaciers of the basin.

The lake is particularly sensitive to inflow anomalies because the geomorphological bathymetric characters of the reservoir. The ratio between water surface (18210 km^2) and water volume (106 km^3) is very high (an average depth of just 5.7 m), making the related amount of evaporation particularly strong (yearly 16.13 km^3) and the lake resilience very low: in absence of water input the lake would totally disappear in less than 7 years.

During the last 40 years, the Balkhash faced three major regressive factors: the establishment of a dry climatic phase, the building of the Kapchagai reservoir (1970), and the increase of water catchment for irrigation activities (today more than 3.5 km^3 per year), mainly on the Chinese side of the Ili valley. In fact, the water level felt from 343 m asl in 1970 to 340.6 m (which means a very sensible reduction by 25% of the water surface and by 40% of the water volume!) at the worst of the Kapchagai crisis (1982), and then recovered up to 341.5 m by 2008. During the same 40 years period a compensatory effect has been represented by the melting of the 35 % of ice deposits of the Balkhash basin (down from 122 to 90 km^3, an average of 0.80 km^3/year), which represented a significant 5% of yearly surplus of river inflow that anyhow will end within the next 50 years (Figure 6).

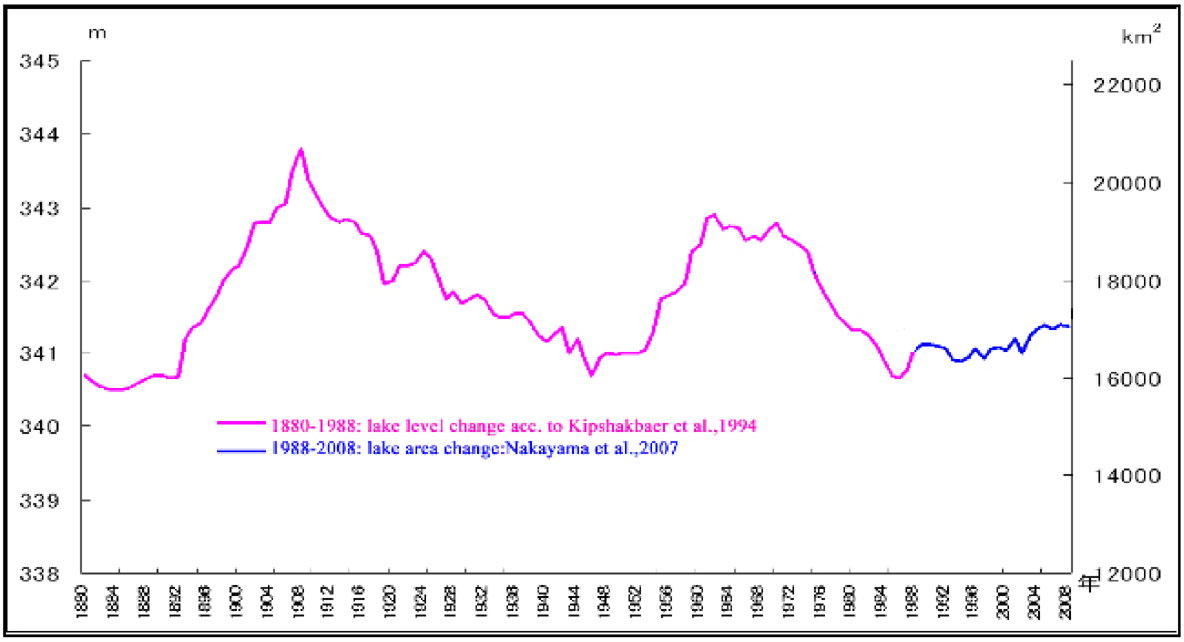


Figure 6 – Balkhash lake: Evolution of water levels between 1880 and 2008 (Kipchakbaev, 2002; Nakayama, 2007)

The present water balance at the water level of 342 m asl is supported by an average total yearly input (and corresponding evaporation) of 17 km^3, which would not stand in case of the future decrease of mountain ice run-off and of increasing climatic warming and evaporation. From now on, if we want to preserve the actual state of the Balkhash, the Ili water must be used progressively lesser and better.

Plans are quite different on the Chinese side of the Ili basin, where is projected the multiplication by 3–4 times of irrigated areas and demographic levels. Here a formidable system of water catchment has been practically completed, having the capacity of yearly subtraction of the additional few km^3 of water that would bring in short time the Balkhash levels below the critical level of 336 m asl and cause the disappearance of Eastern Balkhash.

Chinese authorities don't provide any information about their hydraulic plans, didn't cooperate to the implementation of the Kazakh-Japanese project and, up to now, didn't answered to repeated claims about the necessity of an international consortium for the management of the trans-boundary hydrological system of the Ili-Balkhash basin.

So, the near future of the Balkhash is totally depending from the collective will and decisions of human societies; and the solution would show how much Homo sapiens is today ready to establish a new friendly relation with the natural world or is still behaving as a predator compelled by necessity and greed.

2. Project proposal for the continuation of the scientific study of the Balkhash lake.

2.1. Early scientific studies of the Balkhash lake. The quaternary geological history of the Balkhash depression and the general lines of the Late Pleistocene and Holocene behavior of the Balkhash lake had been object of serious attention by part of Soviet scientists during the second part of the XX century. In particular the quaternary evolution of the Balkhash depression has been well reconstructed and such communications constitute still today the geological background of the studies of the Balkhash lake itself.

The first important studies of the geological history of the modern Balkhash lake, but with scanty information about phases of regression and transgression, had been published by L. Berg in 1904, by M. Rusakov in 1933, and then by Kostenko in 1946. Both publications constituted for decennia the main references concerning the lake. Important contributions had been added by D. Sapozhnikov in 1951, K. Kurdikov in 1958, Kvasov in 1959, D. Dzhurkashev in 1964 and 1972 (who quotes the occurrence in the early XVIII century of a short term isolation of Eastern Balkhash, wdecreasing its water level by 6–7 m), and B. Venus in 1985.

Later on, under the stimuli of the Balkhash regression provoked by the realization of the Kapchigai reservoir, N. Verzilin provided in 1991 the first qualitative reconstruction of the Holocene fluctuations of water levels, which constituted a main reference for the following studies (A. Tursunov, 2002, J. Dostai, 2009).

An overall confusing compilation of previous reports has been provided P. Krustalev and I. Chernusov in 1992, which unfortunately represents a common reference for present studies. On the basis of lithological and biotic considerations, the authors reconstruct the succession during the Holocene of 4 stages of the lake, each stage starting with a max transgression (T) and ending with a min regression (R): Ancient Balkhash (T 10300 BP, R 8300), Balkhash (T 5600, R 4389), New Balkhash (T 3580, R 2690) and Modern Balkhash (T 1960). It is also underlined the establishment of few strong regressions that reduced the eastern Balkhash into a series of "isolated or semi-isolated pools": between 8300-5600 BP, just suspected; in 3860 BP, quoted from Venus; and in 750 BP, from Dzhurkachev. The Krustalev reconstruction would strictly match the Verzilin one, if not because a fluctuation is omitted between 8300 and 5600 BP! Moreover, no information is given about the start of the Ancient Balkhash; and the disappearance of the Ili lake and the formation of a so-called 'Balkhash' lake is fixed to the end of the Atlantic period (5600 BP)!

2.2. Results of the "Kazakh-Japanese Balkhash expeditions 2007–2012". The understanding of the historical behavior of the Balkhash lake significantly improved in the last years thanks to the "Kazakh-Japanese Balkhash expeditions 2007–2012".

The research concerned several fields, among which most important has been the reconstruction of the fluctuations of climate and water levels of the Balkhash lake during the last 8000 years through the study of exposed gravel bars and through laboratory analyses of sediments exhumed by coring the bottom of the western (Tasaral) and the easternmost basin.

The researches of the Japan-Kazakhstan project "Balkhash 2007–2012" introduced important amendments to those early studies, first of all by using new technologies and quantitative methods through laboratory analyses of shorelines and bottom sediments. For example, when compared with the Varzilin reconstruction, the researches of the "Japan-Kazakhstan project" detect during the last 6000 years not 4 but 5 regressions; and their chronology and amplitudes, provided with isotopic dating and quantitative evaluations, show quite significant differences.

As already said above, the results consist in the individuation of 3 different modes and behaviors of the Balkhash lake, corresponding to different climates and water levels: a first mode with high levels up to 354 m asl, connected with glacial stages; a second mode with levels around 344m and manifests during the early-middle Holocene interglacial, still abundant in mountain ice deposits; and a third mode with levels averaging 341 m asl and cyclical fluctuations of ±5 m, characteristic of the Late Holocene, under an arid climate and scanty ice deposits.

The most relevant results consists in the discovery of an extreme event (5.5–5.0 BP) within the third mode: the real possibility of the disappearance of the Eastern Balkhash, in case the water level would drop more than -6 m, desiccating the Uzunaral strait and isolating the western and eastern parts of the lake.

Anyhow the researches of 2007–2012, based on investigations of the westernmost and easternmost zones of the lake, arrive to surely detect a single critical transgression below 336 m asl, but as a whole the reconstruction of water levels changes don't provide enough precision and resolution to point out the sequence of similar abrupt and longstanding events during the studied period.

2.3. A new project for the scientific study of the hydrological behavior of the Balkhash lake. A new project proposal has been conceived by the authors of the present article for the study of the Holocene development of the Balkhash lake. It introduces four important scientific novelties and can be described on the basis of them.

The first and most important novelty of the project consists in the choice of the study area, the Uzunaral straight and the Saryesik peninsula, the sediments of which, by its strategic position as shallow straight between the Western and Eastern Balkhash, are surely archiving information about the sequence of extreme events in the historical development of the lake.

Actually, the area of the Saryezik peninsula has been already the object of geological studies. Very interesting is the D. Djurkashev's report of 1964 where quite frequent interruptions are suspected of the Uzunaral water circulation. The author quotes the recovery by D. Sapozhnikov (1951) of three cores from a site at the western shore of the strait, presenting traces of paleosoil (peat) at 6 m from the top column. Djurkashev attributes the event to a quite recent regression (XVI–XVII century AD) that he explains not so much by extreme climatic changes decreasing the Ili water stock but by the simultaneous activation of both the Ili and Bakanas deltas. Such event on one side would induce very significant additional losses of water by infiltration and evapotranspiration, and on the other would favor the damming of the Uzunaral strait with sediments of the Ortasy distributary. In order to verify such hypotheses, the present project will also include the study by geomorphological and archaeological surveys of the intermittent activity of the Bakanas delta.

Also the report of B. Venus (1985) quotes the presence in Balkhash sediments of buried bogs dated by radiocarbon to 3860±180 years BP.

Briefly, together with the recent international researches about the Balkhash, also Soviet sources will be considered with high attention (which is today a quite rare phenomenon) and will constitute *the second important novelty of the project.*

As a whole, the laboratory analyses of the sediments of the Uzunaral straight and of the Saryesik peninsula, aside with the detection of desiccation phases, will also provide general information about the development of paleo-environmental and paleo-climatic condition within the Balkhash basin, in particular about the activity of the Bakanas delta and the complex sedimentation regimes of the southern Pre-Balkhash region. This approach constitutes the *third important novelty*: the research, in spite of its fundamental character, will provide the background for forecasting processes of very actual economical, social and geopolitical significance in the field of environmental management.

The *fourth important novelty* of the project will consist in serious efforts for promoting the cooperation between Kazakh and Chinese limnologists in the study of the trans-boundary basin of the Balkhash lake.

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БАЛҚАШ КӨЛІНІҢ ӨЗГЕРУІ:
ӨТКЕНІ, ҚАЗІРГІСІ, БОЛАШАҒЫ

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Түйін сөздер: голоцен, Балқаш, тереңсулы шөгінді, гидрологиялық моделдер.

Аннотация. Балқаш көлінің ішкі континенттік қиындықтары ОрталықАзияның барлық аридті белдеулерінде өте маңызды болып табылады. Ойластырылмаған шаруашылық иелері осы аймақта Балқаш көлінің су деңгейінің төмендеуіне, экологиялық жағдайлардың өзгеруіне әкеліп соғады.

Қазіргі таңда Балқаш Қазақстандық және шетелдік ғалымдардың басты назарын аударатын нысан ретінде қалып отыр. Өзеннің сулануындағы жағдайлар мыңдаған жылдар бойы қалыптасқан климат пен ғаламдық жылынумен және аймақтағы антропогендік іс-әрекеттермен қаншалықты тығыз байланысты екені анықталды.

2007–2012 жылдар аралығында «Historical interaction between multi-cultural societies and the natural environment in a semi-arid region in Central Asia» атты халықаралық ғылыми-зерттеу жобасы жүзеге асырылды. Аталмыш жобада Адам және Табиғат институтының (Киото, Жапония), Көшпенділер мәдени мұрасы Қазақ Мемлекеттік ғылыми-зерттеу институтының (Қазақстан) және Қ.И.Сәтбаев атындағы Геологиялық ғылыми зерттеулер институтының ғылыми ұжымдары бірлесіп жұмыс атқарды. Зерттеу жұмыстары Іле-Балқаш бассейнінің аумағында шоғырланып, бірнеше бағыт бойынша жұмыстар атқарылды: соңғы 8000 жылда Балқаш көлінің деңгейі мен климатын қайта құрастыру, ежелгі суланудың археологиялық деректемелері, кеңестік және посткеңестік құжаттарды зерттеу.

ИЗУЧЕНИЕ ИЗМЕНЕНИЙ ОЗЕРА БАЛХАШ:
ПРОШЛОЕ, НАСТОЯЩЕЕ, БУДУЩЕЕ

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Ключевые слова: голоцен, Балхаш, донные отложения, гидрологические модели.

Аннотация Проблема внутриконтинентального озера Балхаша является важной для аридной зоны Центральной Азии. Непродуманная хозяйственная деятельность приводит к негативным процессам, обусловившим падение уровня воды и резкому ухудшению экологической обстановки в регионе.

Сейчас Балхаш стал объектом особого внимания казахстанских и иностранных ученых. Достигнуто глубокое понимание зависимости обводненности озера в условиях изменения климата за несколько тысяч лет и растущая международная осведомленность об уязвимости озера в связи с потеплением климата и антропогенной деятельностью в регионе.

В течении 2007–2012 годов был реализован международный научно-исследовательский проект «Historical interaction between multi-cultural societies and the natural environment in a semi-arid region in Central Asia», который выполнялся научными коллективами Института Человека и Природы (Киото, Япония), Казахского государственного научно-исследовательского Института культурного наследия кочевников (Казахстан) и Института геологических наук им. К.И. Сатпаева (Казахстан).

В 2015–2017 гг. планируется новый этап исследований по грантовому проекту МОН РК «Изменения климата и уровня воды озера Балхаш за последние 10 000 лет на основе анализа образцов керна осадков пролива Узунарал и полуострова Сарыесик для прогнозирования краткосрочных и долгосрочных естественных и антропогенных изменений в аридных зонах Центральной Азии».

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