Updated version (2017) of article published in: 'News' of the National Academy of Sciences of Kazakhstan, series of Geology and Technical sciences, Vol.2, №416, 2016, pp.76-86

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

Sala R[1], Deom JM[1], Nigmatova S[2], Endo K[3], Kubota J[3]

[1] *Laboratory of GeoArchaeology (LGA, Ksri-Nomads), Almaty, Kazakhstan*
[2] *Institute of geological sciences named after KI Satpaev, Almaty, Kazakhstan*
[3] *Research Institute for Humanity and Nature (RIHN), Kyoto, Japan*

CONTENTS

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 trend and the 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 KI 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 in electronic format at the internet site www.ilipro.org. These scientific communications concern a variety of different topics. The present article just focuses on one of them: 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 300000 years BP (Before Present) to now. Knowledge about the earliest stages is still exclusively based on geological studies implemented during Soviet times. The "Kazakh-Japanese Balkhash expeditions 2007-2012" introduced new information concerning events younger than 35000 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 systematic approach necessary for the understanding of the lake behavior is still lacking. This task goes beyond the aims of the present article, and here below are just suggested the tentative lines of a synthetic reconstruction.

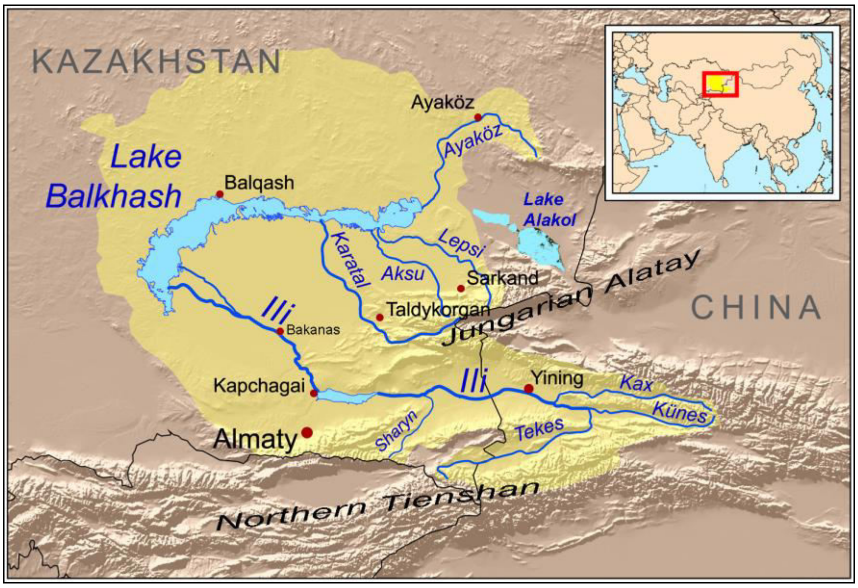

Fig 1 - Hydrological basin of the Modern Balkhash lake

1.1 - What is and how to study a lake

A lake is formed when an inland depression 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 extreme draught or by river diversion or, like in the case of present Aral, by extreme anthropogenic water subtraction. This explains the origin and disappearance of a lake, but what about its evolution between birth and death?

The main character of a lake is 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 tributary surface streams, groundwater, and local precipitation) and how much water is lost (by evaporation, infiltration and human use). Given the bathymetric characters of the reservoir, the values of water volume, water surface and water level are interrelated (Fig 2). During a dry climatic phase, the water input drops and so does the water volume, water level and water surface (regression); the opposite happens during a pluvial phases (transgression). When water volumes and water levels decrease, the water composition would change in mineral and biotic content, becoming more salty and hosting higher ratios of organisms adapted to the brackish environment.

In reality the model of hydrological balance of a real lake is always more complex, including the consideration of factors like groundwater circulation, glacial deposits and sediment transport. 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 lake 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 (which is much quicker) could postpone the drop of water levels by few tens of years.

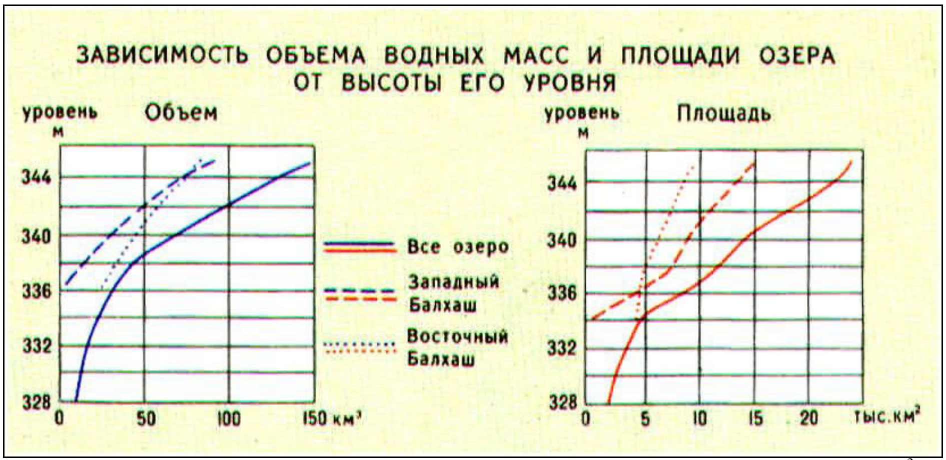

Fig 2 - Morphometry of the Balkhash lake: correlation of water levels (m) with water volume (km³, in blue) and with water surface (km², in red). Continuous lines=all-Balkhash; traits=W-Balkhash; dots=E-Balkhash (Atlas Kazakhskoi SSR, 1982)

For example, in the case of the present Balkhash, its average water volume of 106 km³ (as calculated 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 as ice in the mountain glaciers of the basin. The 81% of the annual total input (17 km³) is represented by surface water, the 5% by groundwater and the 14% by ice-melting water and sediments. Its morphometry makes that a drop of water level by 3 m would correspond to a reduction of water surface by 25% and of water volume by 40%!.

So, the main characteristics of the geological history of the Balkhash lake system are the hydrological fluctuations induced by climate forcing as changes in precipitation and evaporation rates, and as transfer of water volumes from the mountain ice deposits to the lake basin and viceversa.

The data archive of such history is preserved in the lake's sediments. Sediments are continuously transported by rivers, winds and waves, and deposited in the delta, at the lake bottom and as coastal bars. In the case of the Balkhash, the largest part of the sediments is transported by the largest tributary, the Ili river, and trapped within its delta, but a fraction of them (today averaging 4-6 million tons per year) reaches the lake and is deposited at its bottom as a stratified sequence (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 bottom lake sediments represent most significant tracers of environmental changes. They are recording anomalies of the physical and bio-chemical constituents of the water, pointing by differential concentrations to fluctuations of water volume (water surface, water level) and climate. Sediments deposited by waves on shores as sandy gravel bars (coastal sediments), when dated, record the complex sequence 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 was a lacustrine landscape made of small ponds fed by the little streams from North and South Pre-Balkhash.

The gradual tectonic uplift of the Zailisky Alatau increased the water stock of its rivers and, around 300000 BP, provoked a crucial deformation that raised the Karaoi plateau diverting the Ili course northward, forming a delta (*Akdala delta*) in the south-western part of the Balkhash-Alakol depression and emptying the Ili lake into it.

At the contrary of the modern flat surface relief of the southern pre-Balkhash, its Paleozoic substratum is sloping from +200 m asl under the Balkhash lake and from -100 in the pre-mountain zone of the Jungarian range to a central depression at -180 in correspondence of Bakanas, which has been largely filled by Neogene and Early Quaternary sediments of northern and southern origin. Finally, during the Middle and Late Quaternary, an upper sedimentary layer 10-20 m thick has been deposited, which is continuously sloping N to S from +410 m asl at the pre-mountain zone to +342 at the Balkhash shore (Fig 3).

So, following the Ili diversion of 300 ka, at first a lake or, better, a system of shallow lakelets (Bakanas lake) was formed in depressions at the piedmonts of the Jungarian range and at the 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 northward expansion of the Ili delta. In that way, during around 200000 years, a large lake, the *Ancient Balkhash*, inclusive of the modern eastern Balkhash and Alakol reservoirs, was 'sediment-dammed' in the northeastern part of the depression.

At the start of the Late Pleistocene (110000 years ago) the orogenic activity of the Jungarian range lifted the Arkarly mountains at 780 m asl, dividing the Ancient Balkhash in 2 different water bodies 100 km apart: the *Alakol lake system* on the east (today at 347-350 m asl) and the *Modern Balkhash lake* (divided in an eastern and western part) on the west (today at 342 m asl).

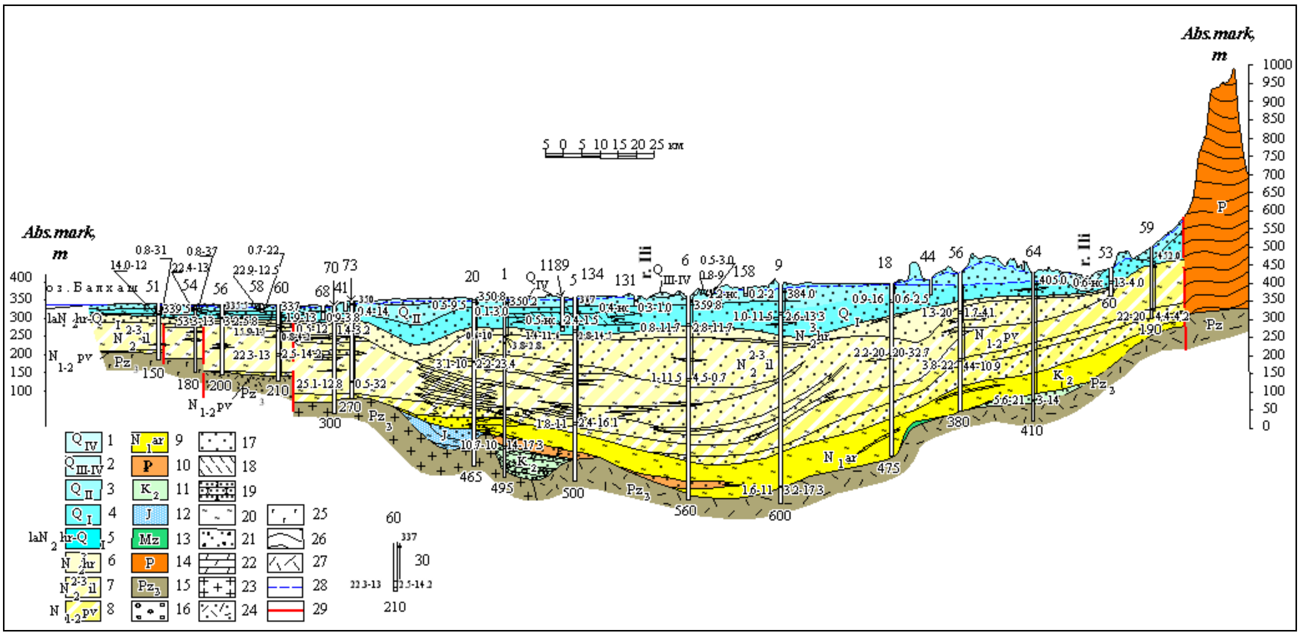

Fig 3 - Hydrogeological section of the sediments of the southern pre-Balkhash depression along the line of the Ili course, from the mountain output (right) to the estuary (left) (Akhmedsafin et al. 1973)

So, on one side the modern Balkhash lake is lying in the lowest part of a huge accumulation of Mid and Late Quaternary alluvial sediments, which favor the water input from rivers and from shallow aquifers; and on the other side is located in coincidence with the northern most elevated part of the Paleozoic substratum and of the Neogene sediments. This location favors *groundwater circulation* between the lake bottom and the deep groundwater deposits lying under and south of it, which is necessarily accompanied with the circulation of chemical contents, explaining the relatively low salinity ratio of this endorheic lake.

Concerning the evolution of the Ili delta from 100000 BP to now, the process happened in 5 stages. They are all characterized by a progressive northern advance and westward rotation of the delta, respectively under the forcing of sedimentary and tectonic factors.

The head of the first delta (*Akdala delta)* was at the first outlet from the mountains (Tasmuryn area), and its distributaries were discharging into the eastern part of the Modern Balkhash lake.

Then, during the postglacial period (after 18000 BP), the *Bakbakty delta* was created: fed by the so-called Paleo-Ili river course, with head 30 km north of the former delta (at Bakbakty village), an anticlockwise rotation of the distributaries, and front up to 50 km far from the modern lake shore.

With the start of the Holocene, around 10000 BP, the *Uzunaral delta* (or *Older Bakanas delta*) was created, with the head displaced 30 km further north-west (between Birlik and Bakanas, 400 m asl) and the frontal part reaching the present lake shore in correspondence with the Saryesik peninsula. The last is a 5-10 m thick sandy tongue lying on a 30-50 m thickness of alluvial sediments, today emerging by 2-4 m and shrinking the connection between the West and East Balkhash as a narrow (4 km wide) and shallow (5 m deep) strait, the Uzunaral strait.

Only around 2000 years ago the New Ili river course became active and fed a delta much reduced in size, with head at Bakanas and distributaries twisted further west: in that way the *Bakanas delta* (or *Younger Bakanas delta*) was established, discharging totally in the western part of the lake and in that way changing the patterns of the lake's currents.

Just recently, during the pluvial phase of the XVII-XVIII centuries AD, out of a quite complex process of which the steps have been well reconstructed by TH Dzhurkachev (Dzhurkachev 1964), the delta rotated further west as *Modern Ili delta*. (Abdrasilov 1994). Its is made of 5 distributaries: the main course recently switched from the Ili to the Zhideli (90% of the runoff), of which the last 30 km are sometimes considered as the sixth delta stage. (Fig 4)

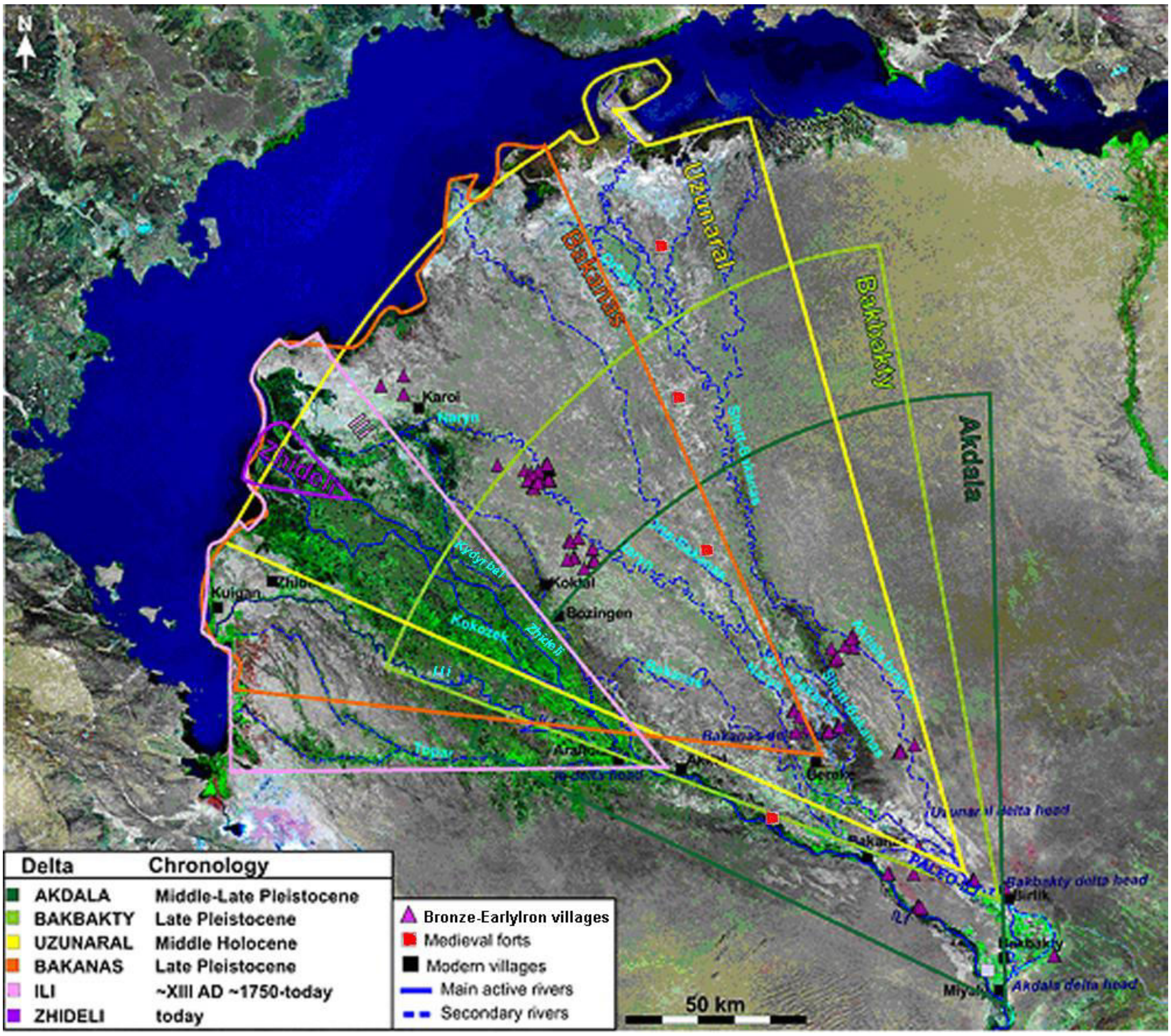

Fig 4 - Map of the Ili delta, showing the chronological succession of 5 main deltas (elaborated from the scheme of Abdrasilov, superimposed on Landsat image).

The Karatal and Aksu-Lepsy rivers have always been and are still today discharging into the Eastern Balkhash. The deposition of their sediments contributed to the partition of the eastern basin in three different reservoirs that, from west to east, show increasing bottom lake depth, respectively 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 by itself cannot support the actual water level of the eastern basin, which is co-fed by water currents from the Western Balkhash.

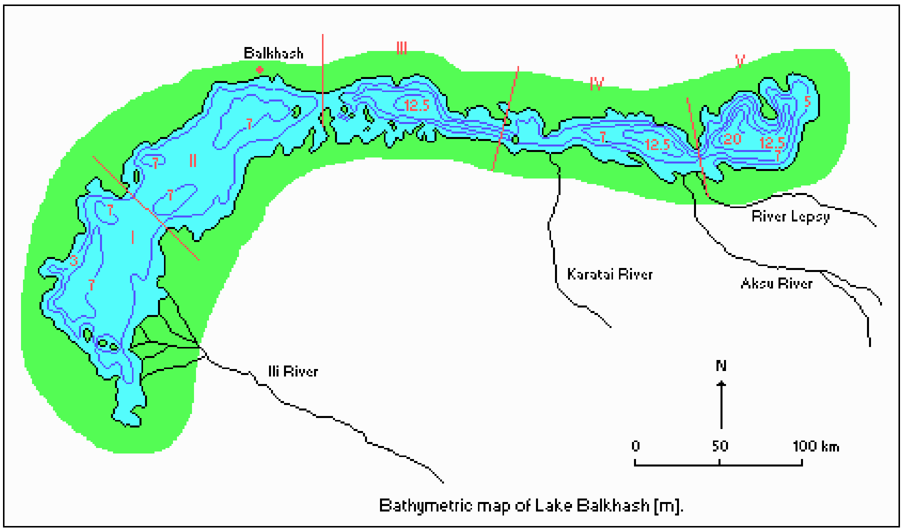

Fig 5 - Bathymetric map of Lake Balkhash. Roman ciphers I-V point to morphometric partitions of the lake; Arabic ciphers to meters of water depth.

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

The 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%)] compensated by 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 due to anthropogenic water subtraction for irrigation.

The Balkhash lake presents within itself significant morphometric and hydrological differences. The lake bottom is sloping progressively from west to east, from 333 to 316 m asl; and a western and eastern parts are clearly defined because separated by the 6 m deep and 4 km wide Uzunaral straight. This fact has serious implications on their respective hydrological balance (Fig 5). The shallower Western Balkhash (max depth at 333 m asl, today of -9m) receives the abundant input of Ili waters, which gives him a yellow-gray tint. The Eastern Balkhash, less extended but much deeper (max depth at 316 m asl, today of -26m) and holding the 54% of the total water volume, is fed by the other lesser tributaries constituting all together just the 20% of the total Balkhash inflow. Because that, besides having more transparent emerald-blue waters and being 5 times saltier (3.5 g/l), it experiences a yearly water deficit of 1.15-2.80 km^3 that is balanced by an equivalent water inflow from the western basin.

These contemporary conditions of the Balkhash lake correspond to a specific hydrological mode of Modern Balkhash, i.e. one of its three possible behaviors, the one characterizing 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 in the area, and geological processes affected very slightly the configuration and the size of the water surface of the lake [1]. So, from this time on, the most significant changes of the Balkhash occurred under the action of rivers and climate, 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 lake shore. 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 32000 BP, and then again a transgression of around +10 m during the last glacial maximum between 25000 and 17000 BP. These results witness a tendency to very high water levels during cold phases with minimal evaporation. A sharp decrease of water level possibly manifested at the approaches of the Holocene (12000 BP), and the present level at 342 m asl is reached for the first time around 8500 BP. (Fig 8)

The Balkhash behavior following the 8500 BP has been reconstructed by the 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 the analyses of these core 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 that connects the western and eastern Balkhash, separating in that way the two basins and reducing the second to a series of small ponds.

In fact, lithological analyses of 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 (Fig 6).

These results are confirmed by laboratory analyses of biotic components: ratio between saline benthic and fresh-water planktonic diatom algae, contraction and increase of different ostracod species, palynological spectra.

Moreover, geomorphological studies of the paleo-terraces of the Lepsy river make suspecting that to the most abrupt regressions and transgressions of the Balkhash could have contributed temporary switches of the Lepsy river course, from the present final bed to its northward diversion into an inter-dune evaporation basin (Kly) located between the Balkhash and Alakol lakes (Sugai et al. 2011, Dzhurkashev 1972 [2]).

[1] The Khrustalev's affirmation "The western basin during the second half of the Holocene was characterized by tectonic movements of negative sign of about -1.0-1.2 mm / year" (Khrustalev et Chernusov 1992, p.169), if true, would mean a significant deepening of lake depth by 1 m per millennium, which would not affect so much the coastal morphology but would have serious implications in core analyses by overestimating paleo water levels.

[2] Dzhurkashev attributes the extreme Balkhash regression and transgression around the 5000 BP to the northern switch and subsequent reactivation of the Lepsy course by tectonic movements.

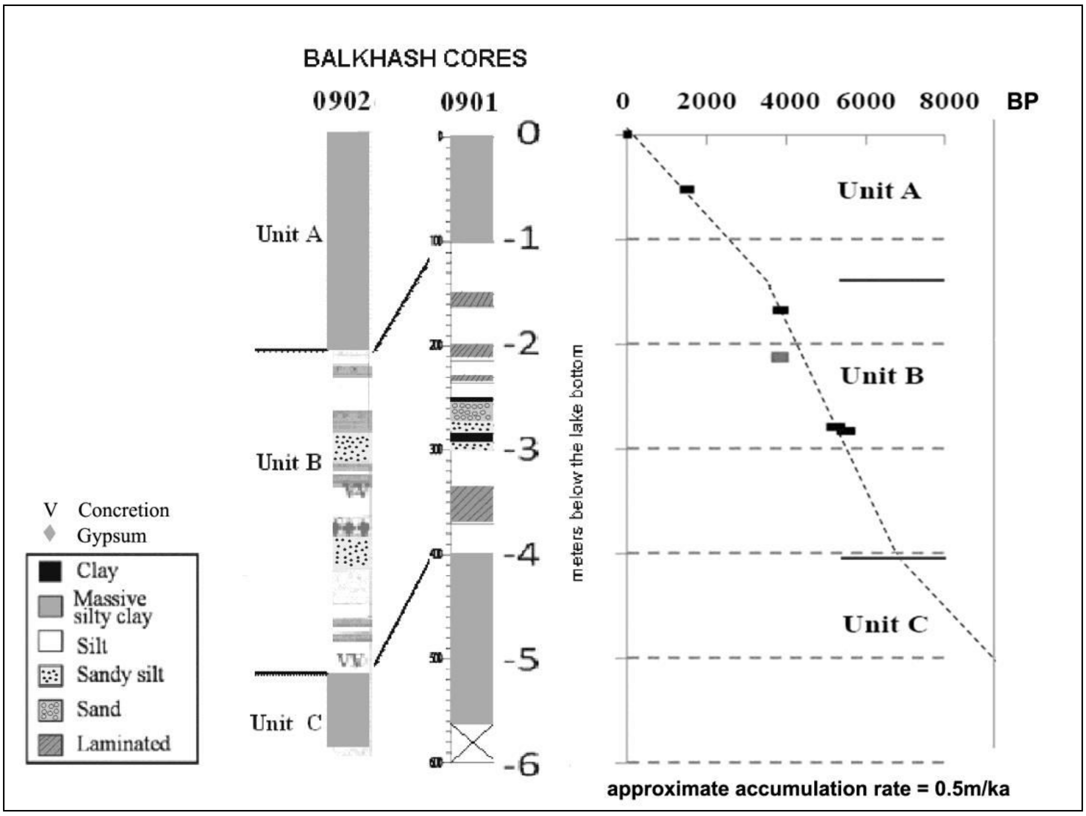

Fig 6 - Eastern Balkhash cores 0901 and 0902: lithological profile (Endo et alia 2012)

Actually, buried soils (peat) have been detected by Soviet scientists at a depth of 5-6 m in few sites of the lake shore (see below par 2.3), 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 the Eastern Balkhash that, in case of a drop of water level by more than 6 m impeding the west-east circulation across the Uzunaral straight and due to the slower reduction of its evaporation surface in comparison to the Western Balkhash, would finally reduce to just few easternmost ponds (Fig 7).

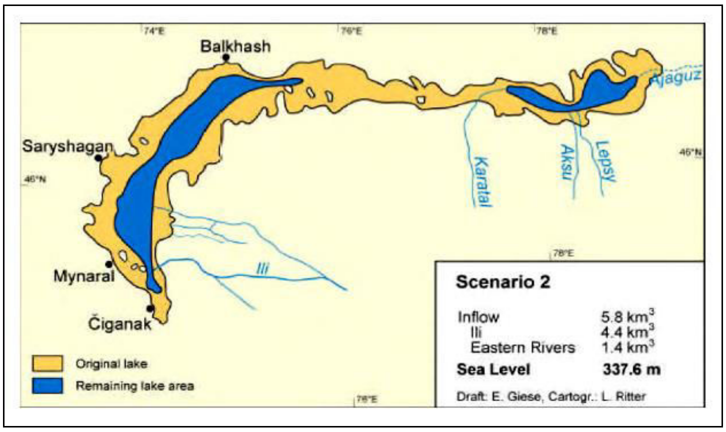

Fig 7 - Map of the Balkhash reservoir under the worst forecasted scenario, with water levels at 337 m asl (Tursunov 2002)

Core-2007, recovered in Western Balkhash near the Tasaral island at the water depth of 3 m, is 6 m long and 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 (that apparently has been crossed by a northward caravan road). The second regression of the 1150 AD has been milder but longer (Fig 8).

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.
These medieval regressions of the lake are followed by a long transgressive phase between XIV and XIX AD, under the pluvial climate of the so-called Little Ice Age, 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 (Fig 8):

- the first mode, with high water levels between 355 and 349 m asl, is connected with glacial stages and very low evaporation;
- the second mode, with water levels between 348 and 341 m asl, manifests during the early Holocene interglacial, which has been 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, reduction of ice deposits and 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.

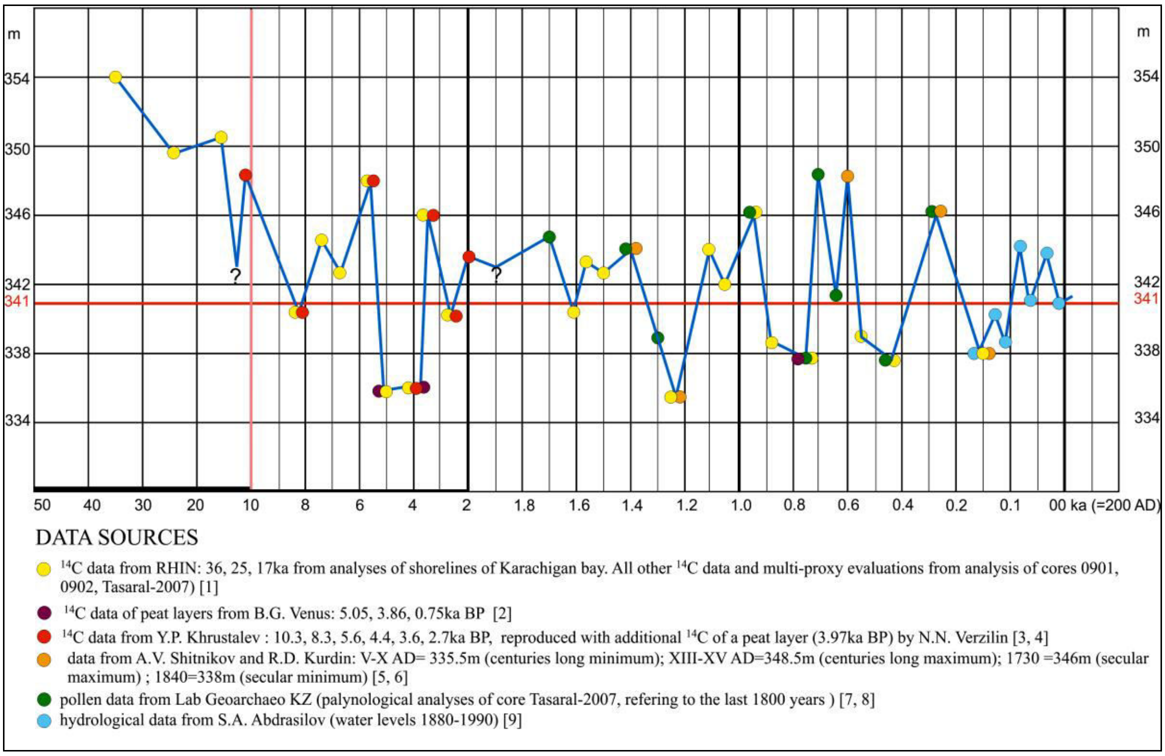

Fig 8 - Balkhash lake: evolution of water levels during the last 36000 years on the basis of various data sources (Sala and Deom 2013)

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 Balkhash hydrological phenomenon, it must be remembered that the average water volume of 106 km^3 of the Balkhash lake corresponds to less than 7 years of water input (or evaporation) and to almost the same amount of water stored as ice 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 (1970-2010), the Balkhash faced three major regression threats: 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) on the Chinese side of the Ili valley. In fact, at the worst of the crisis induced by the establishment of the artificial Kapchagai lake (1982), the water level felt from 343 m asl in 1970 to 340.6 m (which means very sensible reduction by 25% of the water surface and by 40% of the water volume!); and then, thanks to reduction of the Kapchigai water surface, it recovered up to 341.5 m by 2008. During the same 40 years period a compensatory effect to the warming trend has been represented by the melting of the 35 % of the total volume of the ice deposits of the Balkhash basin from 122 to 90 km^3, an average of 0.80 km^3/year (corresponding to a reduction by 21% of the total glacial surface), which represented a significant 5% of yearly surplus of river inflow that anyhow will end within the next 50 years. (Fig 9)

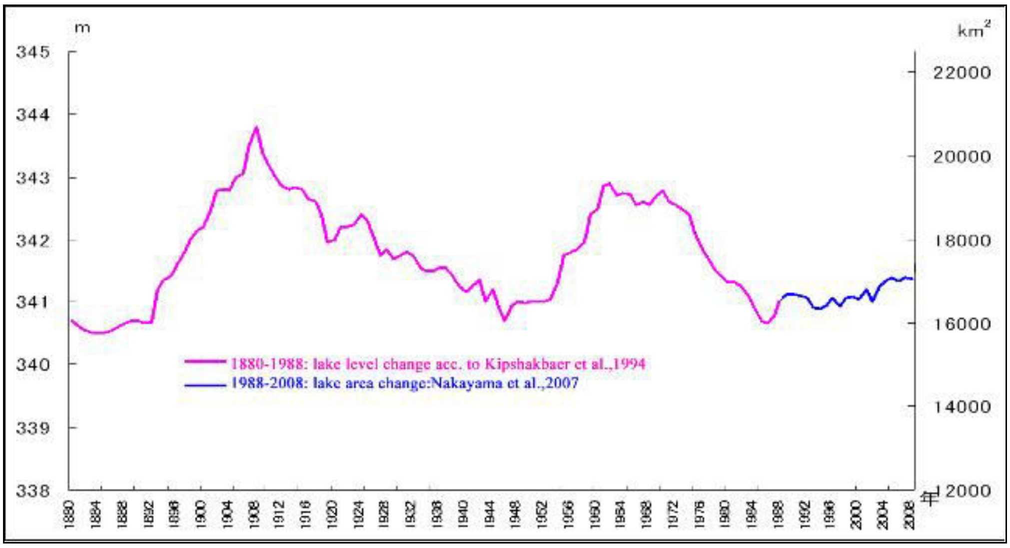

Fig 9 - Balkhash lake: Evolution of water levels between 1880 and 2008 (Kipchakbaev 2002; Nakayama 2007)

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 answer 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 constitute still today the geological background of the studies of the Balkhash lake. Three phases of investigation can be distinguished.

The first important studies of the Balkhash lake concerned its geological history, with scanty information about sedimentation processes, paleoclimate, water levels and phases of regression and transgression. They are represented by the works of L. Berg in 1904, M. Rusakov in 1933, H. Kostenko in 1946, and M. Vyatkin in 1948, which for decennia constituted the main references concerning the lake.

Sedimentological studies had been implemented starting from the 50ies. Important works are the ones of D. Sapozhnikov about the bottom lake sediments (1951), of K. Kurdyakov about shorelines (1958), of D. Dzhurkashev about the Quaternary history of the basin (1964, 1972), and of B. Venus about sediments from the lake and from the coastal area (1985).

Only during the 80ies, under the stimuli of the Balkhash regression provoked by the realization of the Kapchigai reservoir, researches started focusing on the reconstruction of water level fluctuations. N. Verzilin in 1991, on the basis of studies of the geochemistry of the lake sediments by P. Khrustalev and I. Chernusov (1980), elaborated a profile of the average stratigraphy of the Holocene sediments of the Eastern basin.

Unfortunately the present knowledge of the lake is often based on an overall confusing compilation of previous reports provided P. Khrustalev and I. Chernusov in 1992. On the basis of lithological and biotic considerations, the authors reconstruct the Holocene history of the lake as a succession of 4 stages, each stage starting with a max transgression (T), ending with a min regression (R) and providing a new name for the lake: Ancient Balkhash (T 10300 BP, R 8300), Balkhash (T 5600, R 4389-3970), New Balkhash (T 3580, R 2690 BP), and Modern Balkhash (T 0 BP, i.e. 1960 AD). Moreover, no information is given about the pre-Holocene history anteceding the ‘Ancient Balkhash’ and few fantastic hypotheses are advanced: the Ili diversion and disappearance of the Ili lake is correlated with the middle Holocene formation of the so-called ‘Balkhash’ (?!); and are estimated water level fluctuations of amplitude higher than 10 m.

Some qualitative graphics of water level fluctuations have been recently elaborated (A. Tursunov 2002, J. Dostai 2009): they are based on the Verzilin stratigraphy and Khrustalev reconstructions but differ from the last ones by adding 2 water level fluctuations, respectively between 8300 and 5600 BP (T at 8000, R at 6000, most probably erroneous) and between 2690 and 0 BP (T at 2300, R at 800 BP).

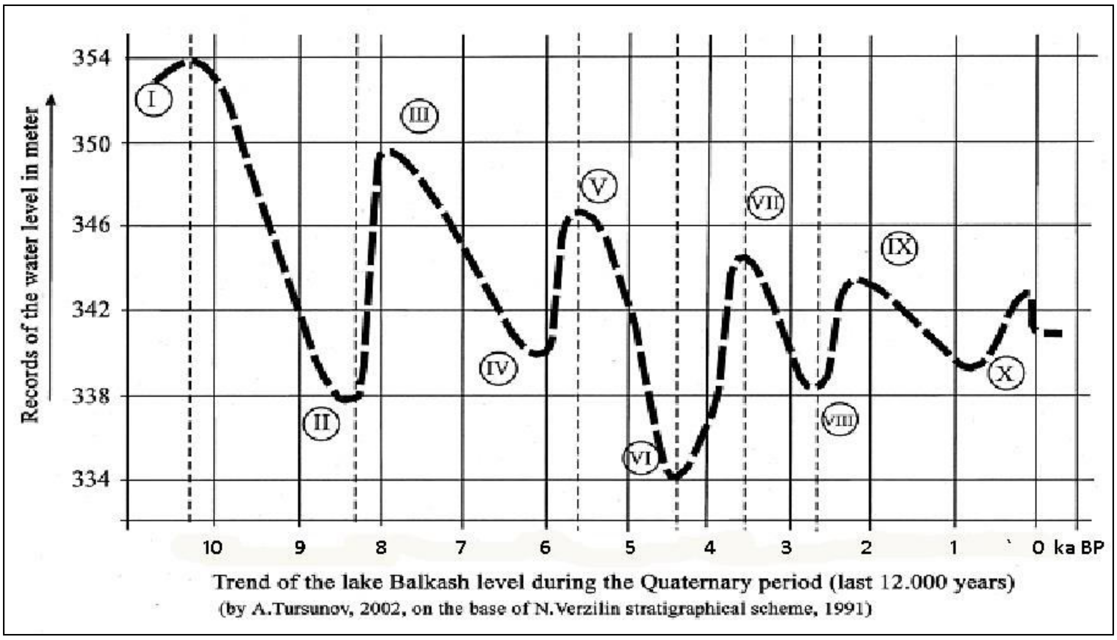

Fig 10 - Transgressions and regressions of water levels of the Balkhash lake, reconstructed by A. Tursunov (2002) on the basis of N. Verzilin stratigraphic scheme (1991).

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 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 of the easternmost basin.

The researches of the Japan-Kazakhstan project "Balkhash 2007-2012" introduced important amendments to early studies, first of all by using new technologies and quantitative methods through laboratory analyses of shorelines and bottom lake sediments. For example, when compared with the Tursunov-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 significant differences.

As already said above, the results of the last researches 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 354m asl, is connected with glacial stages; a second mode with levels around 344m 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 ±5m, is characteristic of the Late Holocene, under an arid climate and scanty ice deposits.

The most relevant results consist in the discovery within the third mode of an extreme event (5.5-5.0 BP): the 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 their reconstruction of water levels changes don't provide enough precision and resolution in order to point out the sequence of similar abrupt and longstanding events during the study 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*. In fact the sediments around this area, by its strategic position as shallow communication corridor between the Western and Eastern Balkhash, are surely archiving information about the activity of the strait and the historical alternate of water level regressions and transgressions.

Actually, the area of the Saryesik peninsula has been already the object of Soviet geological studies intended for reconstruction of water level fluctuations, but they are few and not really reliable. D. Sapozhnikov, analyzing the stratigraphy of 3 cores retrieved west of the Saryesik peninsula at 336 m asl (-6 m below the present water level), found a layer 2-10 cm thick of turf (soil including remains of hydrophilic vegetation) under 90 cm of silty sand (Sapozhnikov 1951). Venus retrieved a buried peat attributed by radiocarbon to 3860±180 and 750 ± 50 BP (Venus 1985). Khrustalev and Chernusov quote 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; at 3860 BP and 750 BP, quoted from Venus (Khrustalev and Chernusov 1992).

Interesting is the D. Djurkashev’s article of 1964 where he alleges frequent interruptions of the Uzunaral water circulation, of which the cause is in some cases attributable to factors other than climate change. The author, referring to the peat inclusions in the three cores recovered by D. Sapozhnikov at the west of the Saryesik peninsula (see above) and comparing their sedimentary depth with the average sedimentary rate, attributes the event to a quite recent regression (early XVIII century AD) that separated the Balkhash into 2 different basins and decreased the water level of Western one by 6-7 m. He attributes the event not to extreme climatic changes that lowered the Ili water stock and/or increased evaporation, but to the simultaneous activation of both the Ili and Bakanas deltas: a combination that would induce very significant additional infiltration, evapo-transpiration and water losses, and also favor the damming of the Uzunaral strait by the sediments of the Ortasy distributary (Djurkashev 1964, p 45) [3].

In order to verify such hypothesis, the present project will also include the study by geomorphological and archaeological surveys of the *Ili delta*, in particular of the intermittent activity of the Bakanas delta.

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 this 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 and protection of the trans-boundary basin of the Balkhash lake.

[3] These Dzhurkashev’s considerations are inspired by the works of Vyatkin and by a map of the Jungarian region, drawn in 1716-1733 by the Swedish traveler JG Renat, where it is shown a bifurcating terminal course of the Ili river.

References

Abdrasilov SA, Tulebaeva KA (1994) "Dynamics of the Ili delta with consideration of fluctuations of the level of Lake Balkhash". *Hydrotechnical construction*, vol 28, nº8, pp 9-12

Akhmedsafin U.M., Dzhabasov M.Kh., Oshlakov G.G. (1973). *Southern-Pribalkhashski artesian basin*. In the book "Formation and hydrodynamics of artesian waters of Southern Kazakhstan". Alma-Ata: Nauka,. pp. 18-22 (in Russian)

Aubekerov BZ, Nigmatova SA, Sala R, Deom JM, Endo K, Haraguchi T (2009) "Complex analysis of the development of the Balkhash lake during the last 2000 years". In: Watanabe M., Kubota J. (eds) *Reconceptualizing cultural and environmental change in Central Asia,* Kyoto, RIHN

Aubekerov B, Koskin V, Sala R, Nigmatova S, Deom JM (2010) "Prehistorical and historical stages of development of lake Balkhash". In: Watanabe M., Kubota J. (eds) *Reconceptualizing cultural and environmental change in Central Asia,* Kyoto, RIHN

Aubekerov B, Sala R, Nigmatova S (2003) "Changes of Atmospheric Circulation, Paleoclimate and Paleogeography in the Tienshan-Balkhash System". In: *PAGES news vol 11 n°2-3*. www.lgakz.org

Berg HR (1904) "Preliminary report on research of the Balkhash lake during summer 1903". *Изв.* РГО, tome 40, vol 4.

Dostai ZD (2009) "*Upravlenie ghidroekosistemoy basseyna ozera Balkhash"* (Management of the hydro-ecosystem of the lake Balkhash basin). Almaty

Dzhurkashev TH (1964) "*The Uzunaral straight and some questions about the recent history of the Balkhash lake". In: Изв. АН КазССР*, Geological Series, vol 4

Dzhurkashev TH (1972) "*The anthropogenic history of the Balkhash-Alakol depressions"*. Alma-ata

Endo K et alia (2012) "Lake level changes and environmental evolution during the last 8000 years based on Balkhash lake cores in Kazakhstan, Central Eurasia". In: Kubota J., Watanabe M. (eds) *Toward a sustainable society in Central Asia: an historical perspective on the future*, Kyoto, Ili Project 2007-2012, RIHN

Khrustalev Y.P., Chernousov I.S.Y. 1992. On the Holocene history of the Balkhash lake. *Izvestiya Russian Geographical Society*, No 124, p. 164-171. (in Russian)

Kipchakbaev NK, Abdrasilov SA (1994) "Effects of economical activity on the hydrological regime and dynamics of the Ili delta". *Hydrotechnical construction*, vol 28, nº8, pp 9-12, pp 5-8

Kurdin RD (1989) "Long term fuctuations of the Lake Balkhash level". In: *Hydrology and water management aspects of the Ili-Balkhash problem*, Hydrometeo Isdat, Leningrad (in Russian)

Kurdyakov KV (1958) "About the geological development of the Pre-Balkhash during late Cenozoic". In: *БМОИП*, new series, dept Geol, tome 33, vol 3

Nakayama Y and Ogino S (2007) " Recent change in the water area of Aral Sea and Lake Balkhash by satellite data". Proc. of the 2007 Meeting, *JALS*, pp.17-18 (in Japanese)

Samakova A (Ed.) (2003) *"Problemy gidroekologicheskoi ustoichivosti v basseine ozera Balkhash"* (Problems of hydroecological sustainability of the lake Balkhash basin). Almaty

Sapozhnikov DG (1951) "Sovremennye osadki i geologiya ozero Balkhash" (Modern sediments and geology of the Blakhash lake). *Trudi Instituta Geologicheskix Nauk*, vip. 122 Geologicheskaya Seriya (n. 43). (in Russian)

Smolyar VA, Mustafaev (2007) *Hydrogeology of the basin of Balkhash lake*. Almaty

Stratigraphic schemes of the Balkhash region and the Balkhash lake. In: *Stratigraphic schemes of Kazakhstan,* Alma-ata, 1990, p 200

Sugai T. et alia (2011) *"*Holocene climatic changes of the Balkhash lake region, Kazakhstan, reconstructed from high-resolution XRF scanning analyses of the lake sediments coupled with geomorphic investigations of the catchment area". *Poster presentation at the INQUA Conference VII-2011*, Bern

Tursunov AA (2002*) "Ot Arala do Lobnora. Gidroekologiya besstochnykh basseinov Tsentralnoi Azii (From the Aral to Lob Nor. Hydroecology of inland basins of Central Asia)"*. Almaty, p.238-253.

Venus B (1985) "Particularities of the development of lacustrine depressions in humid and arid zones". In: *Paleo-limnology of lakes in arid and humid zones*. Nauka, pp. 5-29

Vyatkin MK (1948) O geomorfologii i nekotoryx momentax noveishei geolocheskoi istorii Yuzhnogo Pribalkashya (About geomorphology and some aspects of the new geological history of Southern Prebalkhash). *Vestnik AN KazSSR*, n.8

Watanabe M., Kubota J. (eds) (2010) "*Reconceptualizing cultural and environmental change in Central Asia"*. Kyoto, RIHN. www.ilipro.org