Ecological Change in the Balkhash Region during the last two Millenia

Bolat Z.Aubekerov [1)], Saida A.Nigmatova[1)], DimitriVoyakin[2)]

1) Institute of Geological sciences, Kazakhstan
2) Institute of Archaeology, Kazakhstan

CONTENTS

Introduction

The problem of the inland lake Balkhash is of crucial importance for all the arid zones of Central Asia. If after the Aral sea the Balhash lake will disappear, a huge territory of Central Asia will appear in a zone of progressive and irreversible desertification. The consequences of these processes are unpredictable, as the world has not yet met such an ecological disaster. The study of the lake and its geological history is therefore of extreme importance.

In human history, the lake Balkhash plays a vital role: with a length of more than 500 km, it divides the nomadic pastoral areas of the Central Kazakhstan uplands from the marginal piedmont regions. In the historical plan all the largest nomadic civilizations, such as the Mongols for example, have always occupied both areas of Central Kazakhstan and Semirechie. They both served as arteries of the main historical migrations, therefore the historical study of lake Balkhash is an integral part of the understanding of the evolution of the landscapes of the arid zones of Kazakhstan and of the nomadic cultures closely related to them.

The Kazkakh-Japanese researches lead under the management of the Research Institute for Humanity and Nature and successfully directed by the manager of international level Jumpei Kubota under a program of complex researches, supervised by the well known Japanese geologist K.Endo, have shown that in a 4 years period, new useful data about the ecological changes of the Balkhash could be obtained. The complex study of the Balkhash region has also a big applied value in respect of the study of the redistribution of water resources of the transboundary river Ili and the influences of this redistribution in the ecological conditions of Balkhash region. The complex geoarcheological international (Kazakhstan, Japan, the USA, China) study of the Balkhash started in 2006 has collected new interesting information on the geology of this region. The Japan-Kazakhstan researches of the northern and eastern shorelines the lake Balkhash through different kinds of analyses provided data on the climatic change, on the evolution of the structure of its microfauna, its salinity, speed of sedimentation, etc. enabling a more detailed historical reconstruction of the lake. The researches are still going on and all the analyses haven't been processed, the referred data are therefore still unachieved results.

Quaternary history of the Balkhash basin

The Balkhash lake and the Prebalkhash region constitute an integral part of the Late Alpine orogenic megasystems of Central Asia – Eurasia (Aubekerov et alt, 2010). This structure can be divided by tectono-geomorphological elements and geological development in two subsystems: the first is the southern mountain-foothills region in the background of the Balkhash-Alakol depression, the second are the Central Kazakhstan uplands. The Balkhash in its modern location divides precisely these two subsystems in a "cicatricial" zone.

Since the Cretaceous (140-70 Ma BP) till the end of the Neogene (2,6 Ma BP) this extensive area was under peneplanation. The area made of Central Kazakhstan, Prebalkhash and the Dzungarian-Tienshan ranges can be considered as a uniform tectono-orographical system where since the Paleogene (65-23 Ma BP) the north and the south are set apart by a line formed by the Balkhash coinciding with the modern axial line of the lake. The tectonic opposition of these two areas in sharp forms occurred only during the Eopleistocene and the Early Quaternary (1,7-0,75 Ma BP; Khorgos, Upper Gobi suites).

The northern and western coast of the lake are uplifted on neotectonic faults of the Northern Prebalkhash Paleozoic basement. The southern and western borders between the lake basin and the Balkhash Ili watershed (its barrier limit) are represented by a system of faults forming the horst-shaped uplifted blocks of the western and northern Prebalkhash.

The basic features of the modern relief of the Balkhash-Alakol depression was created by tectonic movements succeeding each other from the Oligocene (34-23 Ma BP) until now especially during neotectonic phases associated with increased tectonic activity.

During the Early and Middle Quaternary, the Ili valley formed a big lake along the foothills. During the Middle Pleistocene it broke through the Karoi plateau by the Kapchagai gorge and produced the Ancient lake Balkhash.

At different historical stages the Paleo-Balkhash changed its surface in the large southern Balkhash piedmont depression from a unified lake to separated large reservoirs. The following history of Balkhash is connected basically with the climatic events determining the fluctuations of its water level.

The final shape of the modern Balkhash followed a cryogenic stage (Velichko, 1973) causing a deep impact on the northern Prebalkhash desiccation of the hydrographic network, changing the process of sedimentation and a hiatus in the development of Paleolithic cultures in Central Kazakhstan. N.G.Kassin (1947) was the first who paid attention to the degradation of the hydrographic network initiated during the Riss-Wurm interglacial and not restored during the Wurm glaciations. Later, A.G.Medoev confirmed that this time marks a long hiatus in the development of Stone Age cultures in Central Kazakhstan (Saryarka). The Late Paleolithic cultures river terraces as campsites but the «tribes of the microlith culture which appeared on the southern slope of Saryarka not earlier than the fifth and more likely with the fourth millennium BC, found a dead hydro-network and settled at springs » (Medoev, 1979 p.7-8)

The degradation of the hydro-network confirms the structural change in balance of the Northern Prebalkhash valleys related to the neotectonic movements of the Northern Balkash level (B.Z.Aubekerov, 1990 p.303-308).

The postglacial stage of Balkhash is characterized essentially by the reduction of its size till modern borders (Fig. 1).

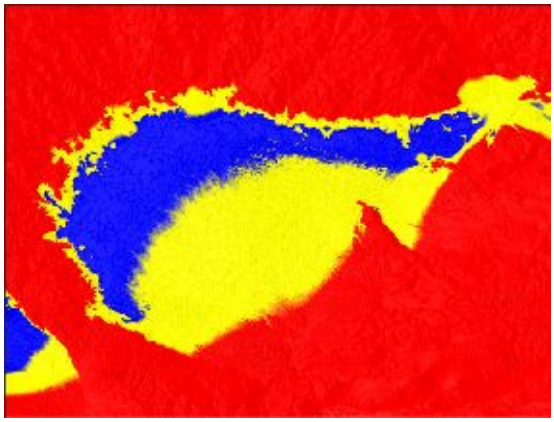

Fig. 1 Reconstruction of the water surface of Balkhash during the Batpaktinsk delta (18-12.000 BP). Computer reconstruction by T.Haraguchi, 2008.

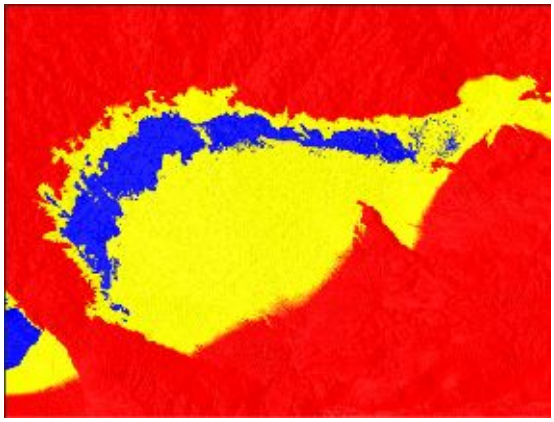

Fig. 2 Reconstruction of the water surface of Balkhash during at the end of the Late Pleistocene-Early Holocene (10-8.000 BP, regressive stage).Computer reconstruction by T.Haraguchi, 2008.

The reduction of the lake water surface implicated the formation of new Batbaktinsk deltas, moving forward and pushing aside the lake to the north (Dzhurkashev, 1964). But quick and deep reduction of water stopped the Batbaktinsk delta to reach the modern coast.

The displacement of the lake to the north and the formation of its modern delta happened during the Upper Quaternary when the Ili river ran in a more western part of the lake as did the ancient Ortasu river forming a delta at the west of the modern peninsula Uzun-aral (Dzhurkashev, 1964). The channels of the previous Uzun-Aral rivers got consequently destroyed and their relief are not visible anymore (Dzhurkashev, 1972)

The Bakanas delta starts from the town Bakanas and extends in a length of 200 km. A.I.Mushketov (1886) recorded settlements and irrigation canals connected with these «*bakanas*» (delta branches) and reported that they disappeared between 1733 and 1785, and the main active river was concentrated in the modern riverbed.

The Modern delta of the Ili river has considerably reduced its size, it begins in the village of Araltobe and proceeds on a distance of 125 km till the Balkhash. During the last century, the branches of the river Ili lost their inflow becoming shallower and from 1957, 90 % of the water flow of the Ili goes through the Zhidely branch forming the new Zhidely delta.

With a size approximately similar to the modern one from the beginning of the Holocene, the lake Balkhash crossed a complex history determined by the fall or rise of its water level (transgressive and regressive phases).

Our researches enable the distinction of the following stages:

After a high water level (Atlantic period), the Balkhash met a regressive phase (4380±150 years BP according the Khrustalev, 1992). During the Subboreal and Subatlantic periods another regressive phase dated by radiocarbon to 2690 ±120 BP was observed (Khrustalev, 1992).

The historical stage (last 2000 years) is characterized by two main regressions and two transgressions of the water level in the Balkhash. The general climatic fluctuations were typical

for all the arid zones and the schedule of water level changes in the Balkhash is well correlated with the fluctuations of the Aral sea (Endo K. at alt. 2009, Borovka. et alt 2006, Sorel P., 2006).

A fundamental aspect of the researches has been the complex study of the Balkhash bottom sediments near the peninsula Tasaral.

The six-meter core drilled in 2007 under the directive of Chinese geologists was further investigated independently by experts of Kazakhstan and Japan. The complex study included analyses of the plankton and other organic chemistry, radiocarbon dating, palynology, residual magnetization, granulometry, color of sediments and salinity (Fig.4).

The analyses clearly show that climatic and landscape changes occurred in a similar way during the last 2000 years in all the inland lakes of the arid zones of Kazakhstan Balkhash, Alakol, Aral.

The climatic fluctuations influenced the glacial history in the mountain areas and the water discharge in the valleys which predetermined the fluctuation of water level in the inland reservoirs and the humidity of the foothill zones.

The landscapes of the Balkhash-Alakol region are characterized by deserts of central type changing in foothill semi-deserts in their southern borders and in mountains by vertical belts with glaciers in the snow zone of the high mountains. As an oasis among deserts the delta of the river is endowed with a unique fauna among figured the tiger.

During the last 2000 years this region was occupied by successive waves of immigrations. Semi-nomadic states and societies practicing agriculture were dominant in the south of Balkhash-Alakol lakes while in its north periphery was inhabited mostly by nomadic pastoralists.

The data concerning the change of salinity, the microfaunal content and structure and the specificities of the spore-pollen spectra have demonstrated that the lake met significant fluctuations of water level during the Holocene which sometimes determined its division in two parts - western and eastern.

These fluctuations are most probably at the origin of the building of medieval caravan roads going across the Balkhash shores by the Uzunaral peninsula and of seasonal settlements and camps around the lake at different epochs.

This is demonstrated by the network of ancient forts and caravanserais joining the Saryarka uplands with the desert of Saryesikotrau. The climatic fluctuations affected also the location and size of the Ili delta and the direction of its main channels which led to topographical change of the irrigation systems in the areas adjoined to the Ili delta and also determined the biotic development in the water and in the adjacent lands.

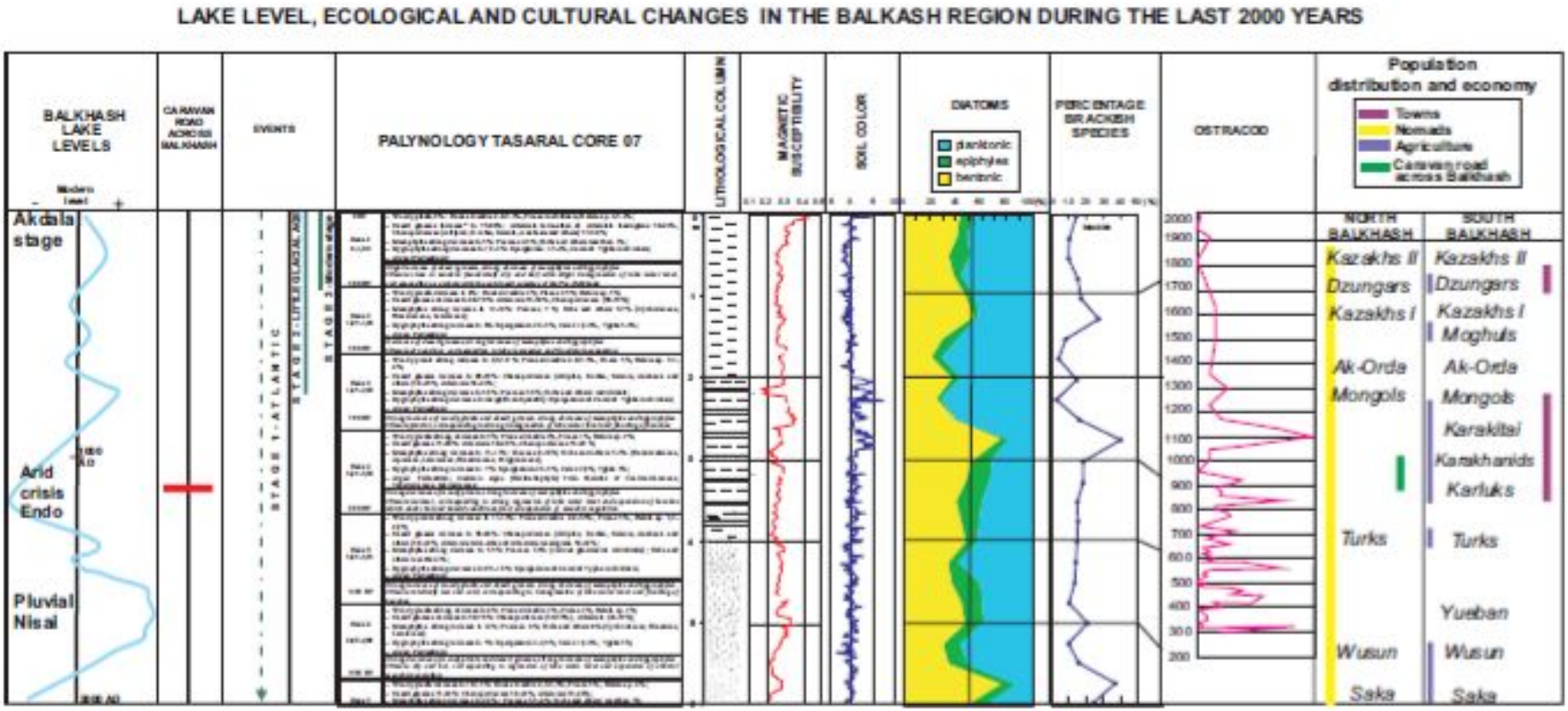

Fig. 3 Table of correlated data form natural and cultural changes in the Ili-Balkhash basin during the historical period

Palynological data

The results of **palynological study** enabled the division of 8 stages clearly distinguished by rhythmically repeated climatic changes occurring during the last 2000 years and well correlated with other proxy data on the climatic change of the Prebalkhsah during the late Holocene (Aubekerov et alt., 2003, Aubekerov et alt., 2010).

The reconstruction and correlation of the climatic changes took account of the percentage parity in the group of herbaceous plants. It has been established that the structural change of the spore-pollen spectra depend on the ecological conditions, both in the coastal and catchment area of the lake basin, and depends also on the morphology of the lake bottom determining the speed of reaction of the coastal line in the increase or reduction of the lake depth. If the lake depth doesn't exceed 3-7 meters or even less, the lake shallowness will quickly cause the expansion of the coastal zone and the grow of water vegetation.

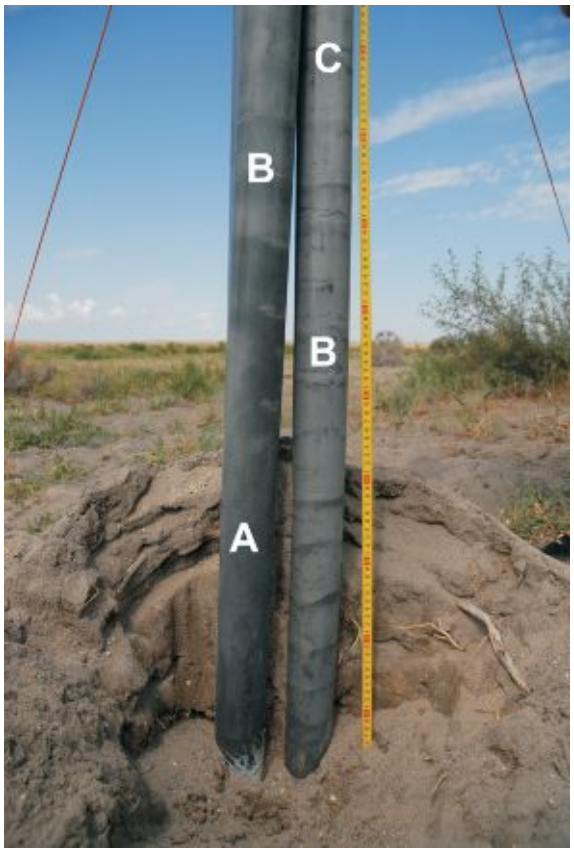

Fig.4 View of Tasaral core (2007). A: series of quartzite sand; B: rhythmic layers from clay, sand and aleurolite; C: non layered series of aleurolite

Wet periods (pluvial phase) are defined by an increased depth of the lake, a reduction of the shallow coastal zone on the steep shores of the western Balkhash and, consequently, a reduction of the amount of water vegetation (reeds, etc.), that in turn affect a reduction of pollen of coastal water vegetation in the bottom layers.

Arid phases are defined by the reduction of water inflow in the rivers, a shallowing of the reservoir and, accordingly, the expansion of the coastal zone due to the desiccation of the bottom and the growth of reeds, macereeds and sedges. In the palynospectra collected during arid phase a pollen increase in motley grass, riparian water plants and also the prevalence of Chenopodiaceae over the Artemisia is observed. The structure and ratio of arboreous pollens remain practically constant.

Thus, the water level fluctuations of the lake Balkhash is both natural and repetitive. During the last 2000 years two large phases have been allocated, they reflect the trends of water discharge from high water level to the subsequent decrease (transgressive and regressive aspects) to the lowest level below the modern one.

The analysis of diatoms

Diatomaceous algae living in various ecological conditions are good indicators of the quality of the water, its depth and other ecological factors. Their type and number can be successfully used for the reconstruction of changes of the Balkahsh water level. This change is connected with the change of salinity in closed lakes. The reconstruction is based on the modifications of benthic diatoms and planktonic species, on the water salinity, on the amount of fresh-water and the various coastal plants (epiphytic).

The analysis of diatomaceous algae from the Tasaral core revealed fast and significant changes of depth and salinity of the lake Balkhash (Fig.4). The clearest diatomic changes are seen at the core depths of - 580 cm and - 280 cm, indicating a rapid drop of lake level and increase in salinity.

Above these horizons, the quantity of fresh-water plankton increases, indicating a rapid increase of lake level and desalinization.

Similar changes but of smaller amplitude are observed on the core depths of - 150 and - 500 cm.

In general, it can be said that the climatic change tended to an increase aridisation and to a progressing desertification. According to the palynological data, only during the Little Glacial Age can be seen an optimization of the environment, the consequent growth of glaciers and an increase of water level in the Balkhash. However this short time amelioration got reduced nowadays by anthropogenic disturbances such as the Kapchagai hydropower dam, rice agriculture, copper-smelting plants, military bases and other technogenic troubles.

Drastic changes happened in the ichthyofauna because of the introduction of new species altering radically the content and quantity of fishes. To these tragedies the extermination of the Ili delta tigers should be added.

Among the main results of the project are the reception of absolute ages and the improvement of the history of the lake enabling a precise dating of the major events in the Balkhash-Alakol region and their correlation with global climatic events and also with related processes that occurred in the adjacent internal water bodies like the sea Aral sea and the lake Zaisan.

Lake Balkhash phases during the last 2000 years

It has been possible to distinguish several main stages of the Balkhash history during the last 2000 years.

The first stage occurred 2000-1800 years ago. It is characterized by a serious fall of temperatures recorded in all palynograms made during the last decade. Interestingly, soil samples collected in Semirechie (Talgar delta, Chu-Ili Mts,…) and dated to this period show an extraordinary high contents of iridium. On the base of ash and coal samples collected in coal layers of the Chu-Ili mountains (Almaty province) and resting under cryogenic structures, a testimony of the strong cooling of temperatures for the region, it has been possible to connect this chilly phase with a fall of meteorite (oral information provided by professor B.S.

Zeilik who analyzed the samples with abnormal high contents of iridium exceeding the average earth's crust content 550-1100 times).

The second stage, 1800-1600 BP, constitutes the maximum of an optimal phase (called pluvial Nisai, after the Chinese leading geologist who projected the Tasaral core) characterized by high water level of the lake, high temperatures and favorable conditions for water and soil organic. To this period is associated an accumulation fine grained quartz sand in the western coast of the Balkhash, probably connected with good watering of the river Ili.

From the end of this stage starts the accumulation of rhythmically layered bottom sediments reaching a thickness of almost 2 m.

The second half of these rhythmically layered sediments is crossed by layers ascribed to the X-XIII and probably XIV centuries determined by a super arid stage (called crisis Endo, after the Japanese leading geologist of the RIHN project). This regressive period saw adverse conditions for the plankton and coastal vegetation and the shallowing of practically all large reservoirs (Aral, Balkhash, Alakol, etc.). At this time happened the desiccation of small lakes and the wide distribution of salted marshes.

To the end of this period is connected the foundation of settlements (Kerdyri 1 and others) and irrigated fields on the dried bottom of the Aral shore near the island Barsakelmes. Probably, the building of the trans-Balkhash road through the Uzun-Aral straight and of caravanserais at the south of the lake is dated to the early stage of this arid phase.

The Uzun-Aral ferry joining both shores of the Balkhash can be reconstructed in the following way. Today, the width of the straight doesn't exceed 5 m but on the satellite image are visible the forward displacement of the Ortasu delta. It has been washed away and has rounded off shape. The washout of the final trails of the modern delta is connected with an overflow of water form the western part of the Balkhash to the east. In the case of a sharp decrease of water in the lake Balkhash, the conditions will change extensively. The overflow from West to East will not occur and the deltas of the two facing rivers, Ortasu in the south and Tokrau in the north, will be pushed forward approaching each other in a very close distance that might have promoted the formation of a ferry at this junction.

In the literature it is known that the lake bottom at the Uzun-Aral straight include buried soils, possibly dated to this period and possibly attesting the existence of an overland ferry from one shore to the other. The overflow of water from West to East could happen only through small channels. In later periods, with the return of high water level in the Balkhash and the increase of discharge from West to East, the final fans of the deltas got eroded and the delta received its modern shape.

After the "Endo" crisis came the rather short-term favorable period when the lake met a transgressive phase visible in the Tasaral core by sediments of non layered dark grey aleurolites.

Similar conditions extended with small fluctuations almost till modern times when the dam of the Kapchagai Hydorelectric Power Station was built. This stage constitutes an adverse period for Balkhash, its ecology, its ground and water fauna (the ichthyofaunal species

content) and the expansion of agricultural fields in the desert zone. This stage connected with the development of rice field can be called the Akdala phase.

During the last 2000 years, the environmental, landscape and climatic changes of the western and northern littoral of the Balkhash have caused its specific settlement pattern (Fig. 3). In general lines, it can be said that if the northern Prebalkash was occupied mainly by nomadic civilizations, the southern region, situated between Balkhash and the mountains and enjoying a rather wide variety of ecological conditions, was occupied by mixed pastoral-agricultural civilizations.

References

Aubekerov B.Z (1990) The newest tectonic stage and its influence on modern engineering-geological conditions. In: *Engineering geology of the USSR: Urals Mountains, Taimyr and the Kazakh folded country*. Nedra

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.

Aubekerov B.Z., Koshkin V.Y., Erofeeva, I.V. Sala R., Nigmatova S.A., Deom J.-M., Endo K., Haraguchi T. (2010), Prehistorical and historical stages of development of the Balkhash Lake, In: Reconceptualizing cultural and environmental changes in Central Asia: an historical perspective on the future, Kyoto- RIHN, p.49-76.

Aubekerov B. Z., Nigmatova SA, Sala R, Deom JM, Endo K, Haraguchi T (2010) Complex analysis of the development of the Lake Balkhash during the last 2000 years. In: Reconceptualizing cultural and environmental changes in Central Asia: an historical perspective on the future, Kyoto- RIHN, p.77-92.

Boroffka, N., Oberhansli, H., Sorrel, P., Demory, F., Reinhardt, C., Wunnemann, B., Alimov, K., Saratov, S., Rakhimov, K., Saparov, N., Shirinov, T., Krivonogov, S. K. and Rohl, U. (2006) Archaeology and climate : settlement and lake-level changes at the Aral Sea. Geoarchaeology, 21, 7, 721-734.

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

Dzhurkashev T.N. (1972) Antropogenovaya istoriya Balkhash-Alakolskoi vpadiny (Quaternary history of the Balkhash-Alakol depression), Alma-Ata, Nauka, pp.125.

Endo K, Komori J, Sohma H, Haraguchi T, Chiba T, Yoshinaga Y, Miyata K, Nakayama Y, Oginj S, Sugai T, Kubota J, Aubekerov B, Sala R, Deom JM (2009) *Reconstruction of lake level change and paleoenvironment from a core from Balkhash lake*. In: Reconceptualizing cultural and environmental changes in Central Asia: an historical perspective on the future, Kyoto- RIHN, p.93-104

Medoev A.G (1979) *Graviuri na skalakh* (Engravings on rocks). Alma-Ata, pp 7-8.

Musketov I.V (1886) *Turkestan: geographical and orographical description according to data collected during the travel period 1974-1880*. SPb, tome 1

Khrustalev Y.P. and Chernousov S.Y., 1992, K golotsenovoi istorii razvitiya ozera Balkhash (On the Holocene history of the Balkhash lake), in: Izvestiya russkogo geograficheskogo obschestva, 124-2: 164-171.

Sorrel, P., Popescu, S. M., Head, M. J., Sue, J. P., Klotz, S. and Oberhansli, H. (2006) Hydro-graphic development of the Aral Sea during the last 2000 years based on a quantitative analysis of dinoflagellate cysts. Palaeogeography, Palaeoclimatology, Palaeoecology, 234, 304-327.

Velichko AA (1973) *Natural processes during Pleistocene*. Moscow, pp 126-129