Reconstructing the past fluctuations of Urmia Lake

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Abstract The aim of current study is to reconstruct the water level fluctuations of Urmia Lake during Pleistocene and Holocene. Evaluation of biostratigraphy evidences in sedimentary terraces and studying the sub bottom sediments sequences have illustrated that the water level of the lake was 45 meters higher, during upper Pleistocene, in comparison with the levels of its wet years at 1999, and also the lake area was twice bigger at that time. The main results show that the Urmia Lake was widely dried up in two steps, 4,000 and 12,000 years ago and the deserted environment was dominant. Also it has been obvious that the climatic changes effects during glacial and interglacial periods cause the biofacies variability of Quaternary sediments.

Keywords Urmia lake; Sediments; Fluctuation; Holocene; Drought

Introduction The impact of global warming on the open seas, oceans and lakes in different parts of the globe is quite distinct (Khoshravan 2014). So that in recent decades along with the increasing rate of greenhouse gasses concentrations (CO2) in atmosphere, the icebergs and glaciers have been more vulnerable to gradual ice melting which causes the increment of water levels in seas and oceans. But rainfall reduction and occurrence of more evaporation amounts in most parts of continental areas, have caused vast droughts and most of the lakes have been intensely shrunk due to runoff degradation (Khoshravan 2014). In this regard some examples are as follows: Great Salt Lake in USA and the lakes in Iran such as: Maharloo, Parishan, Bakhtegan, and finally Urmia Lake. It is noticeable that the impact of climatic factors on Caspian Sea in recent 15 years caused 80 cm shrinkage of water level (Khoshravan 2014). Considering the area of this sea (about 400,000 km²), it can be resulted that about 320 billion cubic meters of water has been lost which equals 10 times of Urmia Lake water volume at its wet years on 1999 (Khoshravan 2014). So the impact of global warming on the lakes located at the North West part of Middle East is widely accepted. The Urmia Lake has been shrunk suddenly and so intensely since 1999, as over the past 15 years, the 8 meters water level degradation has been designated. The scientists have mentioned a wide range of reasons for the event such as: the effect of causeway structure to prevent hydraulic flows in south-north directions and sedimentary blockage of estuaries, evaporation increment and rainfall reduction, salt deposition on lake bed and therefore elevating the bed level, reducing the runoff's leading to the lake because of dams and water structures constructed in watershed, and finally the development of agricultural practices in region despite of its low efficiency (Barzegar 1992, Javanmard 2001). Considering the fact of drought incidence in our country, it seems that natural factors such as global temperature increasing about 1.5°C over the past 15 years, along with rainfall reduction, have caused the reduction of Urmia Lake water level, and human activities have merely aggravated the speed of phenomenon (Khoshravan 2014). It is necessary to determine if climatic and geologic factors in the past effected the hydrological regime of the lake or not, and obtain information about oscillatory behavior of the lake in the past, in order to predict the lake fluctuations in future. In current study, by the help of geological and biological evidences and clues in the old sedimentary sequences, and in order to find...
an appropriate response for mentioned questions, it is tried to reveal the hidden secrets of Urmia Lake. In this regard, the few studies have been conducted by researchers. For the first time, Bobek (1934), identified sedimentary terraces around Urmia Lake in 45 and 55 meters elevations above from the lake level, and after him Schreiber (1978) detected more old sedimentary terraces on the heights overlooking the lake, also the age of invertebrates mollusk shell showed that the sedimentary materials belonged to upper Pleistocene or 35000 years ago, so it can be resulted that the lake with brackish to fresh water was dominant in so larger areas at that time, in comparison with current position (Keltz and Shahrabi 1986). The studies conducted by Jamali on the pollens existed in the most bottom 100-m long cores of sediments, in the axis line of bridge, have illustrated that the oldest sediments in the lake bed belongs to 200,000 years ago or upper Pleistocene (Djamali 2008). He identified the performance of glacial and interglacial periods which were affected by biochemical and chemical sedimentary regimes in wet and dry periods respectively (Djamali 2008). Besides, the seismic geophysical studies in the axis of Urmia lake causeway have identified that the bedrock has been formed from volcanic materials and is located under colloidal – clastic and carbonate sediments (Tarh No Andishan Company, 2003). Now by the help of results obtained from previous studies and findings from field studies, we will try to reconstruct the past fluctuations of Urmia Lake.

1 The study area
The Urmia Lake with the area about 51,460 km² is located between 28° 29’ and 35° 40’ northern latitudes and 44° 13’ and 47° 53’ eastern longitudes. This watershed contains 3.21% of the country total area (Seivani, 1991). This plain is the small part of the Iran central watersheds, which is limited in north by Aras river watershed, in east by Sefidrood river watershed, in south by GhezelOzan watershed, Sirvan and west by Zab river basin at border and finally is limited to Iraq and Turkey borders. The Urmia lake watershed is surrounded by the northern parts of Zagros Mountains, southern slopes of Sabalan Mountain and also northern, western and southern slopes of Sahand Mountain (Figure 1). The elevation of different parts in watershed varies from 1271 m up to 3800 m, but most of it is morphologically a plain with the height of 1380 m up to 2000 meters. The most elevated point is Sabalan Mountain top with the height more than 3850 meters and the lowest is the lake coastal line about 1271 m. The Urmia super saturated salt lake with tectonic structure is located in a closed intercontinental basin. The length of lake 125 km and its width is estimated about 15 to 50 km, and average width is about 40 kilometers. The area of the lake surface is various upon water level changes and currently the average depth is about 1.5 meters.

2 Materials and Methods
In order to identify the geographic and climatic conditions and previous fluctuations of the lake, some evidences and markers are required to illustrate the development rate of coastal line, since the formation up to now. The most important detectable evidences and clues have been recorded in the sediments as biological residuals. Actually regarding the uniformity principle of stratigraphy which considers current situation, as a key to solve past questions, it can be possible to reconstruct and identify the old geographic and climatic conditions of the lake by the use of geological markers. In order to do this, it is required to have access to the sediments of deposited lake bed and
the sedimentary terraces surrounding the lake. Because during the evolution of lake, the sediments have been remained in lake bed and edge, which physicochemical and biological conditions of lake in previous periods can be identified through studying these sediments depositories. As a result, the previous fluctuations of Urmia Lake can be reconstructed by evaluating the results of stratigraphy studies on sedimentary layers of terraces around the lake and the sedimentation sequences under its bed.

2.1 The bio stratigraphy evidences of sedimentary terraces

For the first time, Bobek (1934) detected sedimentary terraces around the lake in 45 and 55 meters elevations from the lake water level, after him Schreiber (1975) found 4 other sedimentary terraces around the lake in 30, 65, 85 and 115 meters elevations (Keltz and Shahhabi 1986). Results from age surveying by $^{14}C$ on limestone mollusk fossils have illustrated that these sediments belong to 35,000 years ago. The sedimentary terraces with sandstone, conglomerate and lime components in the eastern and western edges of lake in Bonab, Bandar Golmankhane, Heydarabad, Shabestar, Gamichi village, the north part of Sharafkhane port and Malekkandi regions have illustrated the existence of lake and wetland sedimentations combined with brackish water in Pleistocene period. The study on sedimentary terraces which is located in North-eastern part of Urmia city near to GachBashi County showed that the thickness of sedimentary sequence is about 15 meters and they contain frequent mollusks and Ostracods fossils which belong to brackish and fresh water environments. The chononostratigraphy results determined approximately 46000 years ago for this formation (Sabouri 2009). On the base of conducted field studies on the GachBashi village sedimentary terrace and evaluating the sedimentary sequence of repeating colloidal – clastic and carbonate sediments it was identified that the river-alluvial, flood plain, intermediate and lake sedimentary environments were dominant sequentially in Urmia Lake watershed (Figure 2). Presently, the above mentioned terrace is located at the elevation of 1311 meters from sea level and is higher about 40 meters than current water level of lake. It means that less than 46,000 years ago the water level of the lake was located about 40 meters higher than current position, and because of abundant fresh water infiltration in the region, the salinity of lake water was decreased and wetland species of brackish to fresh water were living in the lake. The old coastal line with mentioned elevation code on the map of lake surroundings, clarifies that the large parts of eastern and southern cities such as: Bonab, Maraghe, and Myandoab were under water at that time, and it means that the area of the lake was twice of current area (Figure 3). This issue nicely shows the impact of climatic factors on physiographic transformation of Urmia Lake watershed. The cross bedding sedimentation structure in sandy and fine gravel sediments is an identifier of powerful river flows with often changing flow directions and on the other hand graded bedding sedimentation structure illustrates the gradual reduction of watershed energy level and increment of the lake water level and formation of the lake environment which is detectable with calcareous marlstone sediments (Figure 2). The start of sedimentation with well-rounded gravel sediments, is an evidence of affecting rocks by mechanical weathering in flow paths and is a marker of erosive performance of coastal flows and previous lake waves, which mostly entered the coastal line because of flash floods (Figure 2). After the mentioned sedimentation type, the coarse sandy materials along with well-rounded pebble and finally calcareous clay and marl sediments are deposited which are full of brackish water fossils and special Paratethys period invertebrates, which illustrates the dominance of old lake in the region (figure 2). On the base of biostratigraphy evidences in mentioned terrace, three complete swinging periods with specific recessions and advances during upper Pleistocene, have been identified (Figure 2). The interesting point is that there didn’t exist any Artemia fecal pellets in mentioned sedimentary structure, while in simultaneous deposits in lake bed, the Aragonitic pellets were recorded (Djamali, 2008). This issue is a reminder of structural differences between marginal basins of lake and its central parts. It is the same as ongoing procedure in south west coastal parts of lake near a pond in northern part of Mahabad Rood river delta, at the presence of brackish to fresh water ponds. The deserted ochre muds without any fossils, in the upper layers of mentioned terrace, shows that the watershed was out of water because of vast warming and disappearance of brackish to fresh water lake at early Holocene about 10,000 years ago (Figure 2).
2.2 The bio stratigraphy evidences in bed deposits of Urmia Lake

For the first time, the thin sedimentary layers of different parts of Urmia Lake bed were studied under the attention of Iranian geological survey (Keltz and Shahrabi, 1986). Then during the study phase of ShahidKalantari plan in 2005, the geological and geophysics investigations on the lake bed have been conducted from east (Islami Island) to west (Zanbil Mountain) by drilling four 100-m long observation holes under the bed, and by high resolution seismic profiling the sedimentary sequence of lake up to 800 m depth has been evaluated and studied (Tarh No Andishan Company 2005). The obtained results illustrate that the sedimentation sequence under the lake bed isn’t uniform or homogeneous and the deposition components are variable with the layers thickness. Keltz et al (1986), have conducted a study on Urmia lake bed and chosen a region in bed near IsalmiIsland with 7.3 meters depth as a type section. Interpreting of seismic waves, identified two distinguished borders in 3.5 and 5 meters depths. The sedimentary sequence of mentioned site consists of 5 stratigraphy units, and two rock facies have been identified in deposits: an aragonite pellet mud (APM) facies and a playa lake mud (PL) (keltz and Shahrabi 1986). The studies on sedimentary facies equipped geologists with lots of valuable evidences about past geographic and climatic conditions of Urmia Lake. On the base of relative age determination by $^{14}$C of residual fossil’s lime shells in these sediments, it is obvious that the sedimentation rhythm of the lake is about 0.175 to 0.3 mm per year. As a result, the age of sediments in deepest core is about 12,000 to 14,000 years old. So the Urmia Lake has been completely dried up and turned to a deserted environment 4,000 and 12,000 years ago. The lake environment hasn’t experienced any serious changes from 4,000 years ago up to 90 s. now it is possible to estimate the duration of drought periods of lake, considering the 3 and 5 deposition units sedimentation thicknesses which are 56 and 48 cm respectively and the average rate of sedimentation, which is about 0.2 mm per year. The obtained results illustrated that the length of wide rollback period of Urmia Lake was about 2400 to 2800 years.High resolution seismic profiling records on Urmia Lakefloor determined four fluvial and calcerous sedimentary sequences (A, B, C, D) that were overlaid on volcanic rocks in Holocene – Pleistocene Periods (Tarh No Andishan Company 2005) (Figure 4).
Figure 4 The stratigraphy sequence of Urmia Lake sub bottom sediments

The available facies markers in mentioned sedimentary units illustrate the transformation of the depositional environment of lake from late Cretaceous up to now (Amini 2010). The active faults in the lake bed lead to layers vertical displacement and are important effective factors in bed subsidence and changing its facies nature (Figure 4). Consequently, the lake environment has been dominant from Holocene up to now about 10,000 years, which its level has been affected seriously by climatic factors (rainfall and evaporation), also the existence of gypsum and salt horizons in clay and silty sand layers, is an obvious evidence of variable hydrochemical situation of Urmia Lake at mentioned period under the effect of climatic parameters (the markers of layers in A and B units). But in C and D sedimentary units, the deposits are mostly sedimentary facies of brackish to fresh water lake type and belong to Pleistocene period (Figure 4). There is a good structural similarity between these sediments and the residual deposits in sedimentary terraces (Djamali 2008).

Main results of seismic survey have distinguished that Urmia lake bed rock was located under 178 meters and the thickness of bed rock is approximately 734 meters with pyroclastic composition and volcanic breccia and Islami Island was made during the last volcanic eruption phase in Pleistocene (Tarh No Andishan Company 2005).

Due to locating the volcanic masses on the Miocene sedimentation layers, they are probably belong to upper Miocene up to Pleistocene or lower Pleistocene, and upper layers, which located with an identifiable sedimentary discontinuities belong to the beginning of Pleistocene. Consequently the sedimentary hole of Urmia Lake, realistically formed in lower Pleistocene and continuing the sedimentation process up to now leads to deposition of a very thick lake sedimentary material layer. The conducted studies on pollens in sedimentary 100-m long cores of Shahid Kalantari highway (Djamali 2008) indicated that the lower deposits of this part of lake belong to 200,000 years ago. In this study the different pollen species of glacial and interglacial periods have been detected in sedimentary sequences. Generally the adaptable plants with past coastal environment of Urmia Lake, lived in various habitants such as: salty marshes and salty mud zones with special order of algae: Chenopodiaceae, mountainous regions dark forage steppe plants such as Artemisia type and forestry plants in mountainous high elevated areas, such as different species of oaks in west part of Urmia Lake at the border of Iran and Turkey. Five pollen bio zones have been detected in 100-m depth sedimentary layers under the lake bed by the help of palynology studies. The pollens were divided in to two parts: Arboreal pollens and non-Arboreal pollens and their relative amounts were studied in cores (Djamali 2008). The obtained results showed that along with the beginning of interglacial period and increasing the earth temperature and therefore more evaporation rates, the amount of forage plants pollens (Artemisia) have been increased in Urmia Lake watershed. At the same time the chemical and evaporative sediments were dominant, the vegetation cover around the lake was lower dense and the biochemical activities in Urmia Lake watershed have flowed very weak. But due to increment of moisture amount and rainfall events in glacial period, the vegetation cover has been developed and
biochemical activities have been improved. The family of wooden plants and trees were abundant around the lake at that time.

3 Conclusions
The conducted studies on biostratigraphy evidences of old sediments of Urmia lake, illustrate that Urmia Lake bed rock was formed about 1.8 million years ago along with the volcanic activities in west part of Islami island, and was shaped with porous pyroclastic volcanic materials. After the formation, runoffs resulted from rainstorms and volcanic activities produced waters leads to accumulate lots of water in a wide area of Urmia Lake basin, also the impact of climatic factors in glacial period, caused sedimentary environment and the lake area changes during Pleistocene. As the evolution trend of Urmia Lake fluctuations is in long term retrograde mode. But the sequential changes of atmospheric factors leads to form the sedimentary alluvial, flood plains, intermediate areas, lakes and playas repeatedly during geomorphological history of Urmia Lake. The evidences detect two large desertification about 4,000 and 12,000 years ago in Urmia Lake. Consequently the impact of climatic factors on structural changes of lake water balance is completely obvious, as a result nowadays this lake is drying up completely due to global warming effects and human activities.

References
Amini A., 2009, The study on sedimentary deposition of Urmia lake in the margin of shahid kalantari high way, earth science journal, No: 74, PP 57-68
Barzegar F., and Sadighiya A., 1992, The investigation on shahid kalantari high way impact to sediments distribution and deposition disturbance with use remote sensing technique, Remote sensing center of Iran, Internal report
Djamali M., 2008, A late Pleistocene long pollen record from Lake Urmia, NW Iran, Quaternary Research 69. pp413-420 http://dx.doi.org/10.1016/j.yqres.2008.03.004
Javanmard K., 2001, The civil engineering structure impact on Urmia lake, The first conference on Urmia Lake, technical faculty of Urmia university, Urmia, Iran
Keltz K., and Shahrabi M., 1986, Holocene sedimentology of hypersaline Lake Urmia, northwestern Iran, Palaeogeography, Palaeoclimatology, Palaeoecology, Volume 54, Issues 1-4, 15 May 1986, Pages 105-130 http://dx.doi.org/10.1016/0031-0182(86)90120-3
Khoshravan H., 2014, The study on Urmia lake coasts morphology, Caspian Sea national research and study center, Internal report
Sivani B., 2000, The identification of natural environment of west Azarbaijan, environment organization of Iran. Internal report
Sabouri J., 2009, The study on fossils and sedimentary environment and chronostratigraphy of the sedimentary terrace in Gachbashi region of Urmia lake, internal report, geological survey of Iran
Tarhe No Andishan., 2003, Hydrolic and hydrodynamic study and environment investigation on Urmia lake at the parallel of shahid kalantari High way, Road and transportation ministry of Iran