

## Coastal sedimentary morphology of Urmia Lake

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**Abstract** The main goal of the research is to analyze the morphological condition of Urmia lake coasts. By the study of topographic maps, satellite images and field research, the various types of coasts were identified: mud flats, salt marshes, sandy or cliffed coasts, and islands. Moreover the interpretation of seismic profiles, has led to recognize so important morphological features in the lake bed, such as: erosive channels, colos, mud volcanoes, the raised sandy masses and under water mounts. The main results illustrate the variable morphological behavior of Urmia Lake in different parts of the lake.

**Keywords** Morphology; Urmia lake; Sediments; Coasts

### Introduction

The morphologic structure of coastal area of seas and lakes depends on different parameters: the geological and tectonic nature, the water level fluctuations, waves, boundary currents, climate conditions, and type of deposition sites and sediments (Khoshnavan 2007). As a result, the zoning of coastal areas are conducted on the base of production mechanisms and origins of sedimentary materials and internal - external effective forces in transferring the sedimentary cells (Horikawa 1988). The morphodynamic behaviors and reactions of coastal areas are depending on coastal morphological features, the condition of sedimentary basin and hydrodynamic forces (Horikawa 1988). On the base of mentioned factors, different sedimentary environments have been shaped such as: sandy beaches, mud flats, cliffed or graveled coasts, and sandy dunes (Horikawa 1988). The principal question in current study is to identify the morphological units of coastal areas and Urmia lake bed. In this regard, the results of previous researches have illustrated that the topographic type of Urmia Lake bed and beaches is not normal (Khoshnavan 2014). As the spatial distribution of heights up to coastal line in different parts is not similar and also the lake bed depth increases along south to north. The primary bathymetry studies on Urmia Lake, have

illustrated that various sedimentary structures have been shaped by hydrodynamic forces in different parts of lake bed (Keltz and Shahrabi 1986). Besides, the obtained results from evaluation of sub bottom sediments have confirmed the existence of various sedimentary facies such as detrio clastic, chemicals, biochemical and organic materials in sedimentary sequences of upper Pleistocene in Urmia Lake. Moreover, it has been approved that the origin of 25 to 40 percent of detrio clastic sediments in the lake, belongs to runoffs and winds, and 60-75 percent of other sediments have chemical and biochemical origins (Amini 2009). In current study all geomorphological coastal and lake bed types in Urmia lake basin will be identified and zoned by the help of scientific evidences such as: topographic maps, hydrography curves, geophysical profiles and field research.

### 1 Study area

Lake Urmia is the largest lake in the Middle East and the second largest salt lake on earth. It is located lat 37° to 38.5° N, long 45° to 46° E. The Urmia Lake with the area over 5000 square kilometers is one of the most considerable morphotectonic structures in Iran plateau. The length of the lake is 125 km and its width is estimated 15 to 50 km, and also the average width is

40 km (Figure 1). The area of the lake is variable due to water level, and presently because of wide drought effects, the average depth is about 1.5 meters (Khoshnavan 2014). Diverse topographical features around the lake, which involve high mountainous regions with cliffed structures up to low hill slopes and also mud flats, give special sight to the region (Seivani 1990). As the mountainous regions around the lake with elevated mountain tops and thin soil profiles, mostly have no vegetation cover. Some of the important heights overlooking the lake are Islami peninsula in east, Zambil Mountain in west, the rocky hillsides of Govarchinghaleh region in northwest, also central and southern mountains in lake located in southern Islands (Figure 2). There are hill slopes in west coastal parts of Urmia Lake which are spread along north-west and south-east directions, and their plain and sub mountains slopes are relatively high. The expanse of lake coastal parts adjacent to mentioned areas are quite limited. In some western parts of Urmia Lake, the heights of mountains reach over 3,000 meters. Sahand volcano with 2,500 meters height from the sea is located at the eastern part of Urmia Lake. The evaluation of bed slope and the distribution of bathymetry shows that the lake is divided

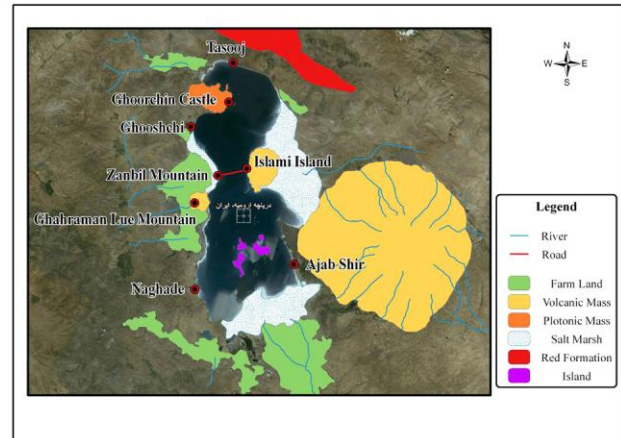


Figure 2 The morphological units map of study area

to deep and subsiding northern parts and also shallow southern parts. The slope of lake bed in western parts is more than eastern parts.

## 2 Materials and methods

Identification and zoning of morphological features of Urmia Lake is conducted on the base of several considerable criteria such as: topographic condition, the distance between heights and shoreline, the hydrograph of bed, the hydraulic regime of rivers leading to the lake, the development of erosive processes and weathering condition, development of erosional channels, the performance of faults and other tectonic structures, instability of lake bed in subsiding areas and raised bottoms in the regions surrounding the islands, the volcanic spring in the bed and finally the improvement of sedimentary morphological processes. Furthermore by overlapping the spatial information of mentioned factors in each of the lake coasts, the morphological zones may be identified. In the first instance, by the use of geographic information system (GIS), and topographic points of the site and using layer to raster tool was surveyed the digital elevation maps (DEMs) and the elevation distribution, the slope and aspect of the Urmia lake watershed have been investigated (Figure 1). Then shallow areas with very gentle slopes were distinguished from deep steep areas by analyzing the bathymetry situation of the lake through its width and length. Afterwards, shapes and types of different coastal regions of Urmia Lake were identified by studying Landsat-8 satellite images and also the images interpretation has been verified due to field research, along 7 transects in coastal area

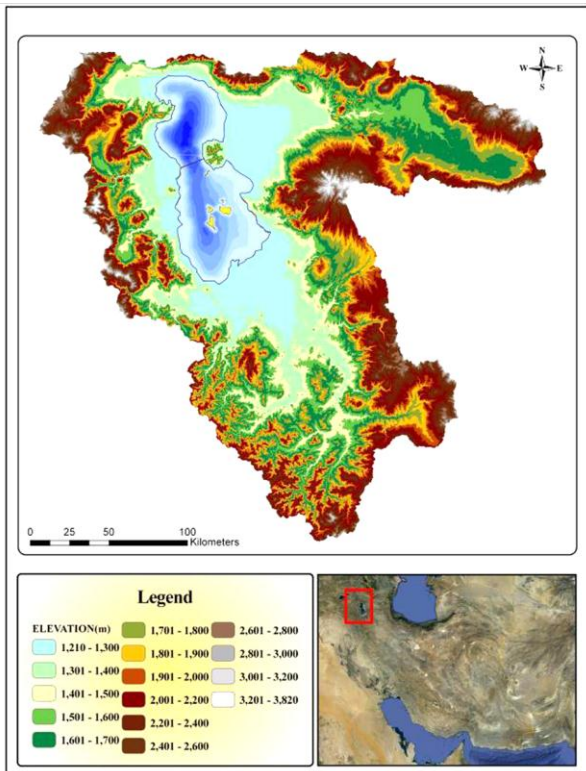


Figure 1 physiographic schematic Figure of Urmia Lake basin

(Ghahramanloo elevations, Zanbil mountain, Govarchinghaleh, Tasooj, Islami Island, Ajabshir and Naghadeh), and the morphological features have been identified and classified (Figure 2). In addition, the lithostratigraphic units and morphological features of lake sub bottom have been analyzed by exploitation of conducted geophysical studies on the lake bed, such as shallow seismic methods up to 10 m depth (Keltz and Shahrabi 1986) and high resolution seismic methods up to 1000 meters depth (Tarh No Andishan company 2003).

### 2.1 Morphological features of Urmia Lake coastal parts

The most important components of Urmia lake morphological structure are as follows: the volcanic mountains (Sahand, Islami, Zanbil and Ghahramanloo), Ultramafic acidic rocks in northwest of the lake, Cretaceous and Miocene sedimentary layers in Misho mountains and finally flat mire zones and salt tongues (Figure 2). The morphological structure of coastal land forms surrounding the lake, varies from low slope mud flats in southeast and southern parts to steep cliffed coasts in islands and northwest and western parts. The Urmia lake coasts consist of different sedimentary environments such as: alluvial fans, river deltas, wetlands, salt marshes, and erosive channels. The gained observations from field studies have illustrated that the coastal regions overlook the northwest side of Urmia Lake, from Ghalghachi up to Govarchinghaleh, are cliffed coasts (Figure 3). The effects of hydrodynamic forces, dissolution of salts and variable water levels of the lake during the past times, have caused erosion and weathering of calcareous sand stone masses, and also improvement of erosive processes, in some parts of watershed, has led to form rocky beaches and erosive bays (Figure 3). The northern beaches structure of Urmia Lake, from Salmas to Tasooj region is red alluvial formation playas which have shaped alluvial terraces in the marginal parts of lake due to runoffs and past floods (Figure 4). The bottom slope of mentioned region is so gentle and fine sandy materials with calcareous pellet particles cover the lake bed (Figure 4). The salt thickness in aforementioned area is inconsiderable. The field studies have proven the dominance of mud flats with playa sedimentation system around Islami Island, also the most part of deposits in current coastal line margins in mentioned region, consist of thick salt

sedimentations along with black sludge containing heavy minerals with volcanic origins. Moreover the upper Pleistocene belonged sedimentary terraces have been observed in Gamichi region which is overlooking the southern part of Islami Island (Figure 5). The structural interactions between volcanic masses of Sahand and Urmia lake coastal line along Maragheh – Azarshahr path, have shaped cliffed coasts in eastern and southeast parts of Urmia Lake. The southern parts of Urmia Lake are mostly mud flats yielded from alluvial sedimentation of Zarrinehrood and Siminehrood rivers, and the western sides of lake are narrow coasts with almost steep slopes along with several erosive channels. There are conic volcanic mountains in Ghahramanloo region, which upper



Figure 3 The mud flat and erosive terrace with alluvial sediments in coastal parts of Tasooj



Figure 4 the erosion cliffed coasts in northwest of Urmia Lake (Govarchin Ghaleh region)





Figure 5 the sedimentary terrace belonged to upper Pleistocene located in 6 km of Urmia northeast (Ghahramanloo region)

Pleistocene sedimentary terraces have been formed at their southern margins (Figure 5). As a result on the base of field studies the most important geological types of Urmia lake coastal areas are as follows: the erosive river sedimentary terraces, the vertical erosional cliffs, the sedimentary terraces produced due to water level fluctuations of Urmia Lake, erosional channels, cliffed and sandy coasts, mud flats and salt marshes. The Urmia lake coastal areas are divided in to several classes in aspect of morphological structure: very low slope and raised mud flats of eastern and southern parts (Islami island – Miandoab), the steep cliffed rocky coasts of northwest (Ghalghachi – GovarchinGhaleh) and southeast (Ajabshir–Maragheh), sandy alluvial beaches in subsiding central north parts (ShahidKalantari causeway), raised zones of central south parts (islands) with detrio clastic, carbonate and salt materials. Also, various sedimentary environments have been shaped at the above morphological units such as: river estuaries (Aji Chai river: the eastern part, Siminehrood and Zarrinehrood rivers: southern parts), wetlands and marginal marshes (containing brackish to fresh water) mostly located in southeast and southwest parts, lake (central part up to northeast), playas (the overlooking coastal to southern region of Ajichai estuary and Tasoojcoastal area) and salt marshes (the Ajichai estuary and western part of Islami island).

## 2.2 The morphology of Urmia lake bed

The obtained results from interpretation of shallow geophysical seismic profiles of bed, have shown that the variability of morphological structures differs in various parts (Keltz and Shahrabi 1986). The mentioned studies have also confirmed the existence

of special sedimentary structures in the northern part of Urmia Lake in the form of raised domes of carbonate muds with 4 meters long, 3 meters wide and 3 meters high (Keltz and Shahrabi 1986). There have seen the sedimentary structures such as ripple marks and somewhere erosive features, on the above domes. Furthermore the results have shown that there are raised sedimentary features in sub bottom sedimentary sequences in northern part along the causeway structure axis, with the origin of mud volcanoes and colos. Moreover the erosional channels have been formed in central part of Lake Bottom near western rivers of the watershed. These morphological features have been created due to intensive floods events of the past and their effects on the lake bed. Furthermore under water mounts and Island roots have been observed in southern parts of the lake (Keltz and Shahrabi 1986). The morphological sub bottom features of mentioned area are the underwater mountain series which have caused to form islands in some parts that they are existed from water. The evaluation of high resolution seismic deep profiles (Tarh No Andishan company 2003) results shows that the Urmia lake bed rock with a combination of Pyroclastic rocks, has a thickness about 750 meters. The mentioned sedimentary layers have been displaced due to lots of vertical faults. There are geotechnical destabilizer morphological features in the lake sub bottom, which have caused topographical changes of lake bed, such as: deep colos, subsided marshy sinkholes with sticky clay sediments, and mud volcanoes. Consequently, the different morphological structures are identified on the base of seismic studies: the thin raised sandy features in northern part of Urmia Lake, mud volcanoes, colos resulted from high pressure volcanic flows, erosional channels and under water mounts.

## 3 Discussion

The obtained results from historical geologic studies of Urmia lake have shown that the water level fluctuations, the performance of hydrodynamic erosive forces, rivers and runoffs resulted from floods and finally the climatic processes (wind, evaporation, rainfall) had significantly affected the morphological evolution of Urmia Lake (Khoshhravan 2014). As the development of sedimentary and erosion processes in watershed have caused the formation of various sedimentary environments and different morphological

zones (Khoshnavan 2014). The remained erosional sedimentary terraces in river estuaries have illustrated the alluvial sedimentary transport in to the Urmia Lake, which have caused the morphological changes of coastal parts and lake bed, under the effect of climate conditions and catastrophic floods (Figure 4). The aforementioned features are mostly observed in northern parts of the lake overlooking the southern hill sides of Misho mountains along the Salmas – Tasooj path and also in southwest of the Urmia Lake in an area between Naghadeh and Oshnavieh. So it can be inferred that the vulnerability of Urmia Lake coastal parts to erosional risks due to catastrophic floods, are considerable in mentioned regions. The residual sedimentary terraces from past water level fluctuations of Urmia Lake, in western and eastern parts illustrate the vast area of the lake during upper Pleistocene (35,000 years ago). The water level has experienced gradual drop from that time onwards and has reached to the 45 meters level higher than its current situation (Sabouri 2009). Consequently the descending order of water zones area of Urmia plain during upper Pleistocene and Holocene is an undeniable fact. The natural factors such as global warming along with evaporation increment and runoff reduction and the series of human activities have intensified the reducing trend of Urmia Lake water level during the last 15 years (Khoshnavan 2014). The active sedimentation processes with huge deposition loads in Zarrinehrood and Siminehrood estuaries, in southern part and the coastal areas surrounding the Ajichai river estuary in eastern part, have caused the blockage and displacement of estuaries and led to form mud flats and salt marshes containing black sludge and very fine sticky mud. The various types of coasts have been shaped around Urmia Lake such as: cliffed coasts, gravel or sandy beaches, salt marshes, mud flats and river estuaries, and it is worthy to mentioned that the effect of water level reduction is quite different on each of them, so the salt have deposited in different thicknesses in coastal line. As the thickest salt sedimentations are observed around cliffed coasts and the thinnest ones are shaped in mud flats or sludge marshes. The distinction between northern and southern parts of Urmia Lake is clarified by subsided northern zone and raised under water elevations of southern part. This issue illustrates the distinct behavior of Urmia Lake bed in different parts. As, the

thickness of deposited sedimentary layers on lake bed rock is increasing along south to north and east to west directions (Tarh No Andishan company 2003). More over the type of morphological features of bed illustrates some sedimentary instabilities in causeway surroundings, in the form of mud volcanoes and sinkholes. The mentioned sedimentary features may create serious problems for engineering structures. The raised under water mounts in southern parts of Urmia Lake are an index of compressional effected sub bottom sedimentations due to tectonic forces which have led to shape lots of islands in central and southern parts of the lake. Furthermore the gradual bed subsidence in northern side of the lake has created the deeper basin, consequently the deep water flows had possibility to build raised sandy features. The occurrence of catastrophic floods in geological history of west part of the lake, has led to shape vast erosional channels, as this morphological feature is a nice guide to determine the vulnerability level of coastal parts.

#### **4 Conclusion**

The morphological structure variability of Urmia Lake is so great. The most frequent morphological features of Urmia Lake coastal area are as follows: Islands, mud and salty flats, salt marshes, cliffed coasts, sandy beaches and Playas. There are various types of sediments have been deposited in different parts of Urmia Lake which the most important ones are: the sludge containing organic matters, the sands containing heavy minerals, the clays with fine carbonate materials, aragonite pellets and finally gravel materials produced from the erosion of large rocks along with the evaporative salt and gypsum sediments. The most considerable factors of creation and development of Urmia Lake morphological features are as follows: the geological and geodynamic factors (epirogenic activities), the water level fluctuations in lake, catastrophic floods events, human interventions and finally the behavioral changes of rivers hydraulic flows and runoffs. The global warming along with rainfall reduction in northwest of Middle East, in recent decades, have led to increase the evaporation amount and cumulative reduction of Urmia Lake water level and other lakes of our country. In this regard, some of the engineering practices intensify the challenges, because of their structural conflict with spatial and temporal essence of natural features, so it is really required to optimize the management of current and future problems hereof.

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