Verification of the Persian Gulf Sea level changes in Holocene through sedimentary core obtained from sea floor of Bushehr neighboring area

Razyeh Lak*, Ali Mohammadi, Reza Behbahani and Majid Moeini

Marine geology department, Geological Survey of Iran
E-mail address: Lak_ir@yahoo.com or r_lak@gsi.ir

Abstract
The Persian Gulf is a sedimentary epicontinental and marginal basin located in a dry climate. The climate, morphology, hydrology, current, waves and tide specifications determine its sediments' types. To study the paleoceanography of the Persian Gulf, a core having the length of 15m from shallow water close to the coastal areas of Bushehr in form of an undisturbed sample was prepared. After cutting the sample, macroscopic verifications, photography, and description of cores, 50 subsamples were prepared and granulometry and ICP analyses implemented. Results obtained by granulometry and percentage of particles, plus outcomes of chemical analysis and microscopic observations indicate that there is a positive correlation between calcium value and particle sizes. It means when Ca value increases, the percentage of sand also increases. In comparison with sedimentary facies, Ca value is similar to coastal and continental facies. When facies are marine, particle sizes decrease, but the values of Al, Mg, Na and K increase. In fact, rising of the Sea level is along with decrement of particle sizes, and increment of clay minerals, like Al, Si, K & Mg. But Ca value is increased by decrement of sea water level and increment of particle sizes. Therefore, when seawater level is high, the minimum of Sea level conditions occurred in 204, 396, 516 and 673 centimeters from the surface. The Maximum of Sea levels has been seen in 280, 510,593 and from 714 to 140 centimeters below the surface.

Keywords: *Holocene, Sea level change, Persian Gulf, Cores,*

Introduction
The Persian Gulf is a back arc basin and marginal sea, and its average depth is about 35m. Its area is about 226000sqkm having the maximum depth of 104m (Purser, 1976). The Persian Gulf floor is unstable from tectonics point of view and has a sharp slope on the Iranian side. It is stable in the Arabian shield, has a mild slope and does not have continental shelf. In the northern part, its source of fresh water is Shatt-ol-Arab or Arvand Rood (originating from the Tigris and Euphrates Rivers in Iraq) and certain small rivers along the Iranian coasts. The arid climate of this region is intensively impressed by oceanographic and sedimentary processes of the Persian Gulf (Emery, 1956; Pilky and Noble, 1966; Khalaf et al., 1979; Evans, 1988). A surficial current produced an oceanic water entry cycle clockwise along the Iranian coastline (Hartman et al., 1971). Water salinity varies from 36.6% at the beginning point of the Hormoz Strait to 40.6% at the end part in the northwestern area (Swift & Bower 2006).

The recent sediments of the Persian Gulf are riverine clastic, biogenic and aeolian deposits (Lak, 2010). Riverine clastic deposits originate from Shatt-ol-Arab certain small rivers of the northern coats. Shatt-ol-Arab flooding has a small role in sediment supply because most of them are trapped in the delta area, and only a small amount of them (about 10%) reaches the

Persian Gulf (Emery, 1956; Milliman and Meade, 1983; Al-Bakri and El-Sayed, 1991). Aeolian deposits mainly originate from southwestern winds (Purser, 1973; Evan, 1988). Dusty storms bring relatively high amount of fine-grain clastic materials from coastal plains, northern deserts, northwestern part (Iraq) and Arabian deserts to the Persian Gulf (Sugden, 1963; Khalaf et al., 1979; Al-Bakri et al., 1984).

This region located between the Zagros Mountains in northeast and Arabian Platform in the southwest having a 990km length and 370km width (Kampf & Sadrinasab 2006). After the Gulf of Mexico and the Hudson Bay, the Persian Gulf is the third biggest gulf in the world. This gulf connects the Hormoz Strait and Oman Sea to the Arabian Sea in the east. It also ends in the Arvand Rood Delta that is the result of merging of the Tigris, Euphrates and Karoon Rivers. Since plenty of relatively comprehensive environment and organic geochemistry studies of Holocene sediments were carried out by various scientists, such as Kirkham, 1997; Al-Ghadban et al., 1996 & 1998; Whittle et al., 1998 & Al-Sharhan and Kendel, 2003), therefore, it seems compulsory to implement studies respecting these subjects in northern coasts (Iranian part) of the Persian Gulf. The study area located in shallow water close to the coastal areas of Bushehr city north of the Persian Gulf (figure 1).

Methodology

In this research, an undisturbed core having a length of 15m and 5 diameter was prepared by drilling device. 23 cores having 60cm dimensions were prepared in polika (PVC) pipes, after numbering and marking the upper part of layers, two ends of samples were protected and transferred to marine geology laboratory of applied geology research center in Karaj. Cores were longitudinally cut to two parts by core-cutting device. The facies characteristics, such as sediments' grain sizes, color, fossils' contents, organic matters and their contact were severely considered, and possibly sedimentary environment of each facies was determined. Cores' photos were taken by a Canon 12 megapixel digital camera. Then, 1cm slabs of some parts of core that did not have coarse grains were prepared. X-ray images of slabs were provided by radiography device. 50 sub-samples were produced from cores (figure 2). The properties of sub-samples vary by facies changes. Prepared samples were verified by granulometry, ICP and organic matters determination analysis. granulometry of particles having diameters of more than 63µ done with wet sieve shaker and particles with diameters of less than 63µ carried out by Laser Particle Sizer device by Germany Fritsch Company. Some samples were crushed and powdered to determine the percentage of their major and trace elements. They were analyzed by ICP-OES Variant model. Employed standards were specific to marine sediments for analyzing the samples.

Results and discussion

Facies' descriptions, sediments' granulometry results and ICP were inserted in Excel and Log Plot data sheets. These results plus digital photos, radiography and facies' descritions were merged, and then stratigraphical column and seawater fluctuations for Holocene were designed. Table 1 show 12 facies from surface to 15 meters below seabed with environment, lithology, description and total organic carbon contain. Besides, along the length of core, granolometery result, percentage variations of elements such as iron, aluminum, Calcium, Magnesium and etc. were plotted in form of graph (figure 3,4 & 5).

12 Facies were determined along the core indicating, riverine, coastal, intertidal, lagoonal and open sea environments. Meanwhile, 5 sedimentary types, including clayey silt, silty clay, sandy mud, gravelly mud plus gravelly and muddy were determined.

Verification of sedimentary environment indicates that calcium values decrease in lagoonal and marine environments, and increase in intertidal, coastal and riverine environments. The graph of elements' percentage variations is completely in harmony with sedimentary facies. When water level is high and development of lagoonal and marine environment occurs at the site of core preparation, calcium value decreases, but Si, Fe, Mg, K and Al values increase. These variations are along with other specifications of facies, including availability of foraminifers, grey color, percentage increment of organic matter and evidence, such as fenestral fabric. When the seawater level goes down, the conditions are vice versa. It means that calcium percentage increased, but Fe, Si, Al and Mg elements' percentage increased. when Ca value increases, the percentage of sand also increases. When facies are marine, particle sizes decrease, but the values of Al, Mg, Na and K increase. In fact, rising of the Sea level is along with decrement of particle sizes, and increment of clay minerals, like Al, Si, K & Mg. But Ca value is increased by decrement of sea level and increment of particle sizes.

Sediments color varies from cream and yellow colors towards brown. Fossil contents intensively decreased, and often these contents are exclusive to bivalves that only one of the valves is available. When these changes are very clear in the sedimentary environment, the above-mentioned elements are observed on the peak of related graphs.

Vertical sequence of the Persian Gulf are; facies, including shell fragments, benthic foraminfers, fenestral fabric, bioturbation, variation of the sedimentary particle size, sediment types, etc. These are the evidence that assist us to reconstruct the sedimentary environment of the Persian Gulf sediments (Tables 1). With regard to these studies, it is possible to realize that the studied core in the Bushehr Province introduces 12 facies indicating riverine, coastal, intertidal, lagoonal and marine environments.

Conclusion

Results obtained by granulometry and percentage of particles, plus outcomes of chemical analysis and microscopic observations indicate that there is a positive correlation between calcium value and particle sizes. It means when Ca value increases, the percentage of sand also increases. In comparison with sedimentary facies, Ca value is similar to coastal and continental facies. When facies are marine, particle sizes decrease, but the values of Al, Mg, Na and K increase. In fact, rising of the Sea level is along with decrement of particle sizes, and increment of clay minerals, like Al, Si, K & Mg. But Ca value is increased by decrement of sea level and increment of particle sizes. Therefore, when seawater level is high, the minimum of Sea level conditions occurred in 204, 396, 516 and 673 centimeters from the surface. The Maximum of Sea levels has been seen in 280, 510,593 and from 714 to 140 centimeters below the surface.

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Table 1: Core description, lithology and facies

FACIES	ENVIRONMENT	LITHOLOGY	DESCRIPTION	(TOC %)	Depth (cm)
1	Fluvial	gM	Yellowish gravelly mud without shell	0.03	0-55
2	Coastline	gmS	Grayish yellow gravelly muddy sand with a few shells	0.05	55-135
3	Intertidal	cZ	Yellowish clayey silt with minor limy pebel and fenestral fabric, without shell	0.03	135-215
4	Intertidal	cZ	Grayish clayey silt with fenestral fabric	no data	215-240
5	lagoon	cZ	Thin interbeded grayish bioturbated clayey silt and organic laminae with sparse gas bubbles	0.04	240-290
6	lagoon	cZ	Grayish clayey silt with dark gray sand lenses and a few shells	no data	290-372
7	Open marine or Barrier	sM	Grayish sandy mud with shells	no data	372-385
6	lagoon	cZ	The same as facies 6	0.07	385-430
8	Shallow marine	sM	Grayish yellow sandy mud with benthic shells	no data	430-512
9	Marine	cZ	Grayish yellow clayey silt with fenestral fabric, deeper than facies 8	0.05	512-520
8	Shallow marine	sM	The same as facies 8	no data	520-578
9	Marine	cZ	The same as facies 9	0.06	578-660
10	Marine	zC-cZ	Grayish silty clay to clayey silt with a lot of forams, coarsening up ward, bioturbation at top	0.08	660-718
11	Marine	cZ	Interbeded grayish yellow clayey silt and organic laminae with gas bubbles and benthic shells(Gastropoda and Pelecypoda)	0.07	718-990
12	Marine	zC	Interbeded light to dark gryaish silty clay and organic laminae, richer than facies 11	no data	990-1000
11	Marine	cZ	The same as facies 11	0.07	1000-1200
12	Marine	zC	The same as facies 12	0.11	1200-1240
11	Marine	cZ	The same as facies 11	0.09	1240-1500

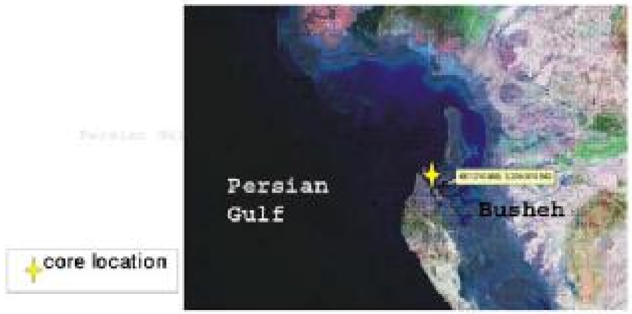

Figure 1: Location of the Bushehr core, shallow water of the Persian Gulf

Figure 2: Core cutting, Preparation of sub samples and determination of facies

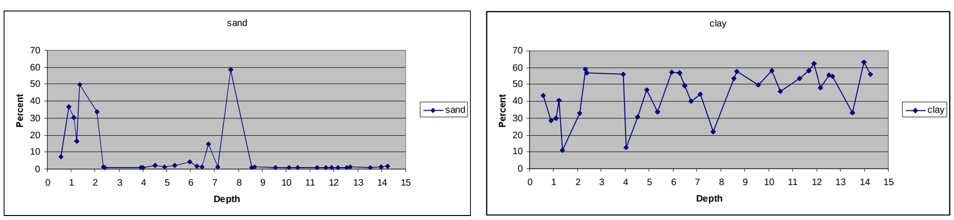

Figure 3: Clay and silt percentages graphs from the surface to 15 meters below the Seabed

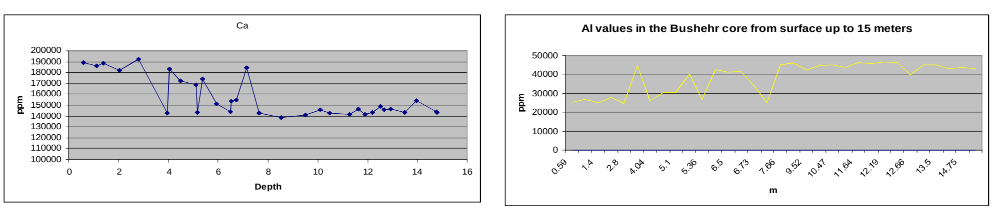

Figure 4: Value of Calcium & Aluminum changes from the surface to 15 meters below the Seabed. Sea level changes according to the Aluminum curve.

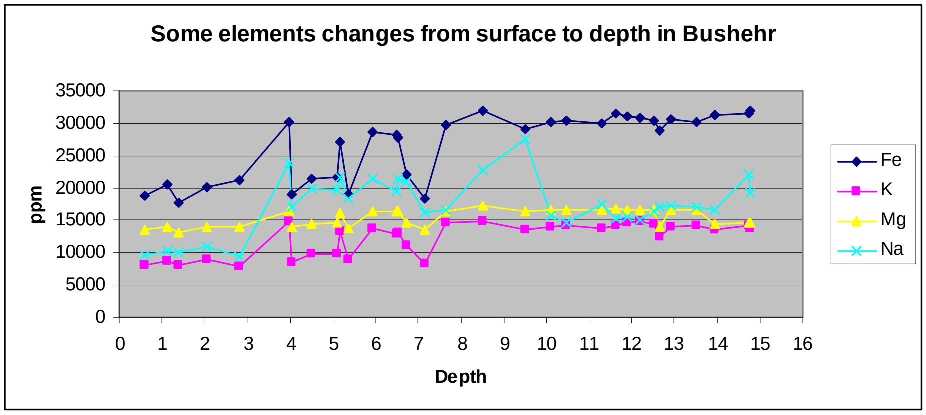

Figure 5 : Na, Mg, K and Fe value changes from the surface to 15 meters below the Seabed.