J. Basic. Appl. Sci. Res., 2(1)289-297, 2012
© 2012, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Holocene Sedimentation Rate in Gorgan Bay and Adjacent Coasts in Southeast of Caspian Sea

Arash Amini[1*], Reza Moussavi Harami[1], Hamid Lahijani[2], Asaddollah Mahboubi[1]

[1]Department of Geology, Faculty of Sciences, Ferdowsi University of Mashhad, Mashhad, Iran
[2]Iranian National Institute for Oceanography, Tehran, Iran

ABSTRACT

Many radiometric data including ^{14}C and ^{210}Pb were collected from shallow and deep cores in 10 sites of Gorgan bay and adjacent Coasts in southeast of Caspian sea, north of Iran. These data were classified to Early Holocene (Lower Newcaspian) and Late Holocene (Upper Newcaspian) and their sedimentation rate were measured. After the normality test of gathered data, IDW (Inverse Distance Weighting) was chosen as interpolation method and sedimentation rate maps were produced. Average of 2.06 mm/year sedimentation rate in Early Holocene (Lower Newcaspian) and 5.08 mm/year in Late Holocene (Upper Newcaspian) of Gorgan bay were calculated. Our findings indicate that sedimentation rate increases from east to west of Gorgan bay in both Early and Late Holocene.

KEY WORDS: Sedimentation rate, sedimentation pattern, Gorgan bay.

INTRODUCTION

The Bay of Gorgan is located in SE of Caspian Sea in northern Iran. Gorgan bay is formed during the Newcaspian /Holocene period (Svitoch and Yanina, 2006) by a sandy spit which is named Miankaleh coastal barrier system. It covers an area of about 400 Km^2 (Karbassi and Amirnezhad, 2004) and the maximum length and depth are 70 Km and 5m respectively (Fig. 1). It seems that the eco-system of Gorgan Bay is influenced by both water intrusion from the Caspian Sea and to a lesser extent by fresh river water.

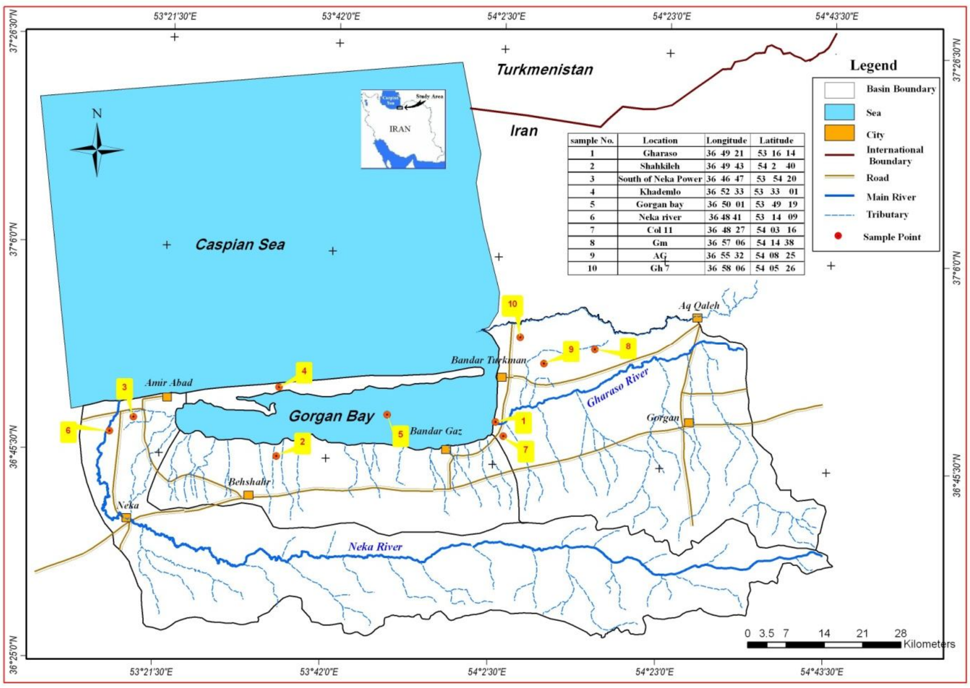

Fig1: Location of Gorgan bay and adjacent Coasts and sampling locations

Water discharges from Caspian sea through Ashoradeh and Bandar-Turkman water pathway is about 35 m^3 per second and total discharge of rivers around the Gorgan bay catchments reaches to 500 m^3 per second. Average daily evaporation is about 5.5 mm per day (Sharbati et al, 2010; Lahijani et al, 2002). Totally, about 3.5 million tons of sediments from Gharaso and other rivers enter into Gorgan Bay per year (Afshin, 1994).

***Corresponding Author:** Arash Amini , Department of Geology ,Faculty of sciences, Ferdowsi University of Mashhad , Mashhad, Iran, E-mail:arash88amini @yahoo.com

Average of total organic carbon (TOC) in Gorgan bay sediments is about 29 % weigh (Lahijani et al, 2002), while average of $CaCO_3$ is 36%.Texturally, sediments consist of fine to coarse sand, sandy mud and mud (Fig. 2) .

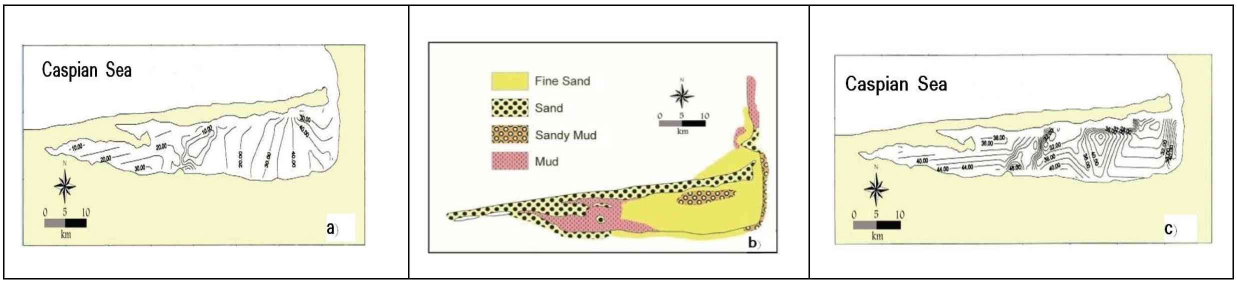

Fig 2: Distribution of TOC persent (a), Sedimentary texture (b) and $CaCO_3$ in Gorgan bay (Lahijani et al., 2002)

Gorgan metamorphic complexes including schist, phyllite and slate and Jurassic shale, sandstone and marl as well as Cretaceous limestones formed major rock units in the catchment area in the upstream that supply sediments to Gorgan bay.Geological and sedimentological evidences show that the south Caspian Sea basin has very high sedimentation rate up to 1000 m/MA since the Middle Pliocene (Lerche et al.; Nadirov, Bagirov, & Tagiyev, 1997).

Ownegh (2010) discusses the shape of paleo-Gorgan bay and believes that the Gorgan Bay had a distinct long narrow shape which has occurred at -15 m below sea level in about 700 BC.

The aim of this study is to determine the sedimentation rate in Gorgan bay and neighboring coastal area by means of radiocarbon dating of cores data and comparing the study area with Anzali and Amirkola lagoons in western parts of the Caspian Sea. Also the hypothesis is that whether the high sedimentation rate of Middle Pliocene in the Caspian Sea continued through Holocene period or not? We believe that this study can help in a better understanding of sedimentation rate in the Caspian Sea.

MATERIALS AND METHODS

Quaternary sedimentation rate can be measured by 2 major methods including:

1 – Use of macro or microfossil index in a column sections or cores in which foraminifera, ostracode, diatom and nano fossils play the main role. This method is relatively cheap but requires professional specialist in order to recognize fossil family and species.

2 – Use of radiometric techniques in a column sections or cores. Isotopes of 5 common elements are used to determine sedimentation rate at marine environments (Table 1). These methods are relatively expensive but can be done easily and fast. In this study, we used radiometric data in 10 sites (Cores) around and inside of the Gorgan bay (Fig. 1).

Table 1 - Radiometric techniques that used in order to estimate sedimentation rate in many bays and seas of the world

Radiometric techniques	Case study - References	Usage in this study
^{14}C	(Venice lagoon-Italy - Serandrei-Barbero ., et al , 2006) (San fransisco bay- USA- van Geen., et al, 1999) (Azov sea-Ukrain - Matishov ., et al, 2009) (Caspian Sea – Azerbaijan- Kuprin., et al, 2003)	+
^{210}Pb	(Sellafield –scotland- Teasdale., et al , 2011) (Biscay bay – France- Dubrulle et al , 2011) (Hudson Bay- Canada - Kuzyk., et al , 2009) (Manila Bay- Philippine-Maria., et al , 2009)	+
^{137}Cs	(Sellafield –scotland- Teasdale., et al , 2011) (Hudson Bay- Canada - Kuzyk., et al , 2009)	_
^{7}Be	(St. Lawrence-USA- Cooper ., et al , 2002)	_
^{234}Th	(Biscay bay – France- Dubrulle et al , 2011)	_

At the first step Early Holocene and Late Holocene sedimentation rates were calculated by means of 14 C and 210 Pb radiometric data in each of 10 cores. All data calculated by 14 C except site 5 that was measured by 210 Pb.

Samples of site 1 were shown with Lab No. poz 38786 and 38787. Site 2 samples were identified with Lab No. poz 38792 and 38790. Site 3 samples were recognized with Lab No. poz 38789. Site 4 samples were known with Lab No. 38788.

Data which is related to cores 1 to 4 were analyzed in Poznan Radiocarbon Laboratory, Poznan, Poland. Data of cores 5 to 10 are used from published data of Karbassi and Amirnezhad (2004), Lahijani et al. (2009) and Abdollahi (2007).

The second step was analyzing the Early Holocene and Late Holocene sedimentation rate data, in terms of normality. Based on this analysis, data is fitted to the normal distribution.

The third step was testing the data by the Kriging Method for interpolation. But the results were not satisfactory because the number of sample was very limited therefore IDW (Inverse Distance Weighting) was chosen as the interpolation method and maps were produced by using this method.

RESULTS

The sedimentation rate and the sediment sources may not remain constant through time. Thus, different zones may differ in the sediment supply because of changes in the sedimentation rate or type of sedimentary materials. During the Early Holocene (Lower Newcaspian) in the Gorgan bay, sedimentation rate ranges from 0.52 to 8.6 mm/year with an average of 2.06 mm/year (Table2). While during the Late Holocene (Upper Newcaspian), sedimentation rate ranges from 0.59 to 28.1 mm/year with an average of 5.08 mm/year. Regardless of Upper Newcaspian data of site 2, average of 2.52 mm/year is calculated.

Table 2 - Sedimentation rates in Upper and Lower Newcaspian in Gorgan bay and neighboring regions .

Sampling Site (References)	Period	Depth (Cm)	Date (Year)	Sedimentation Rate (mm/ year)
1 (This study)	Upper Newcaspian	199	2225	0.89
	Lower Newcaspian –Upper Khvalyn	1136	21450	0.52
2 (This study)	Upper Newcaspian	290	103	28.1
	Lower Newcaspian –Upper Khvalyn	1661	18040	0.92
3 (This study)	Upper Newcaspian	1917	2225	8.6
4 (This study)	Upper Newcaspian	52	880	0.59
5 (Karbassi and Amirnezhad, 2004)	Upper Newcaspian	70	500	1.4
6 (Lahijani et al., 2009)	Upper Newcaspian	520	2400	2.1
7 (Abdollahi, 2007)	Upper Newcaspian	200	2380	0.84
8 (Abdollahi, 2007)	Upper Newcaspian	300	650	4.6
	Lower Newcaspian	800	5990	1.3
	Lower Newcaspian	1400	8990	1.5
9 (Abdollahi, 2007)	Upper Newcaspian	180	2303	0.78
		450	3669	1.2
10 (Abdollahi, 2007)	Upper Newcaspian	280	956	2.9

Sedimentation rate pattern during the lower Newcaspian (Early Holocene) toward the east and north of Gorgan bay is relatively low (Fig. 3) but toward the west and near Neka river, sedimentation rate increases.

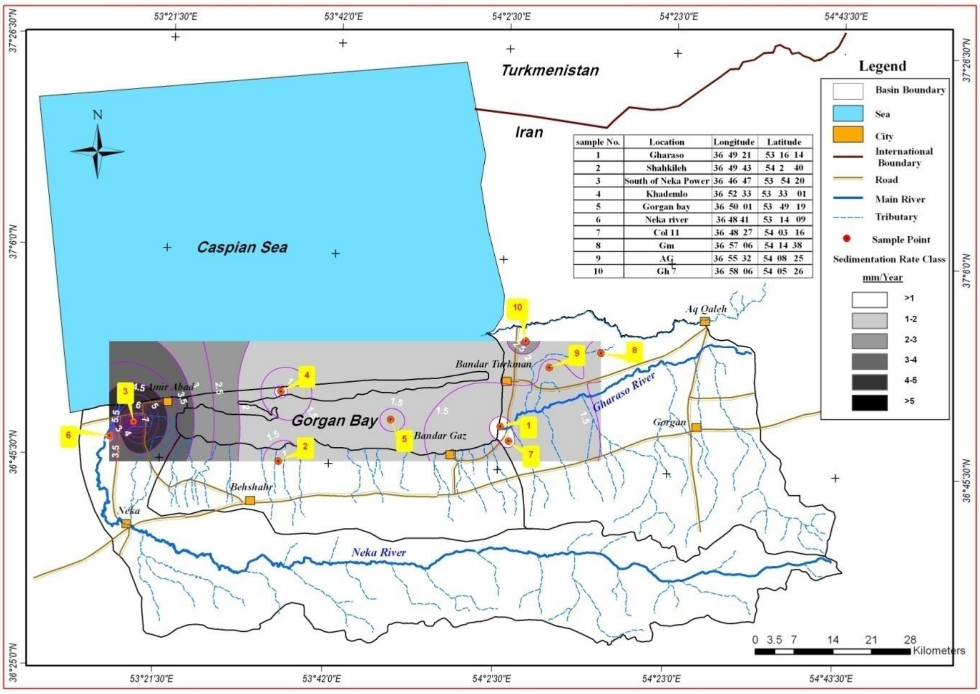

Fig 3: Sedimentation rate pattern in Lower Newcaspian (Early Holocene) of Gorgan bay

Sedimentation rate pattern in upper Newcaspian (Late Holocene) in the east and center of Gorgan bay is low (Fig. 4), however toward the south and west, sedimentation rate increases and anomaly in sedimentation rate is found.

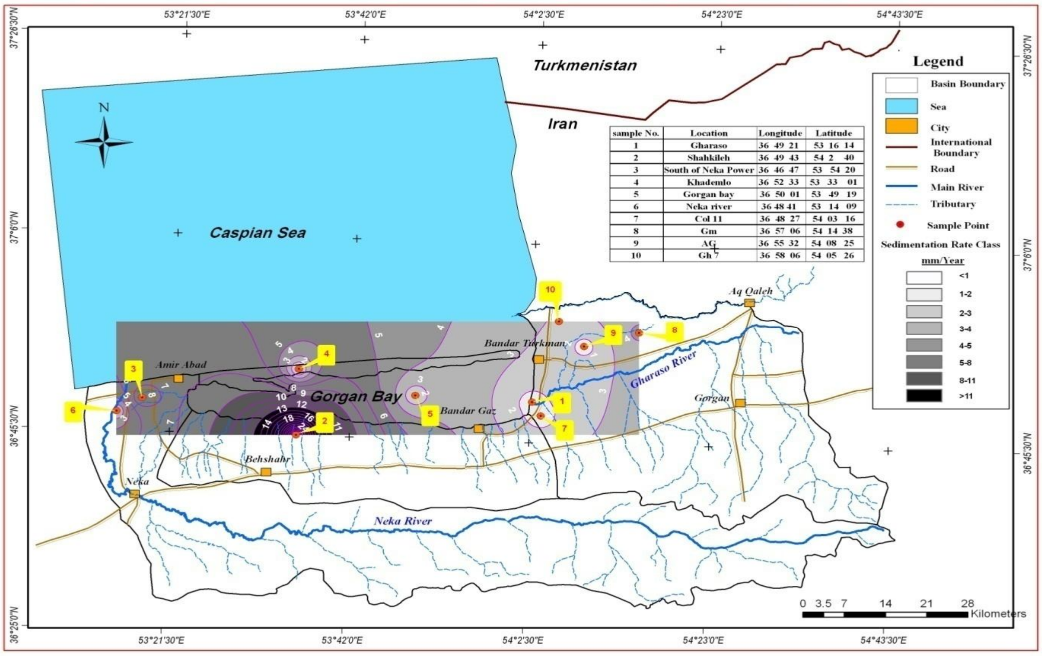

Fig 4: Sedimentation rate pattern in upper Newcaspian (Late Holocene) of Gorgan bay

DISCUSSION

Parkinson et al. (1994) classified sedimentation or accumulation rates to 'historical' (1–100 years) and 'geological' (hundreds to millions of years). Cahoon et al. (1995) defines vertical sedimentation or accumulation to the sum of sediment deposition and erosion, and plant production and decomposition. The differences between vertical accumulation and under water surface elevation changes is commonly defined as 'shallow subsidence' that depends on negative subsidence of direct surface rise due to vegetation roots pushing sediments upward or positive subsidence such as compaction, dissolution, or decomposition (Thomas and Ridd, 2004) . Usually deep subsidence is related to tectonic movements in a long time. In Gorgan bay, we focused on historical sedimentation rate but in a short historical rate (Holocene = 10000 year) shallow subsidence was not regarded comparing to deep subsidence in a long time. This scale is more reliable and acceptable because during the Late Holocene (Upper Newcaspian), composition, dissolution and decomposition occur in a limited time and space.

On the other hand, Gharibreza et al (2004), on the basis of surface sediment analysis, believed that Gorgan bay sedimentary facies have 3 different sources including: Miankaleh coastal barrier system which is formed by effects of wind and beach processes containing sandy sediments in north of the study area (sampling sites 3 and 4) and in the second group, sediment supplies from rivers (Sampling site 1, 6 and 7). Turbidite and flood deposits in south of Gorgan bay is caused by high slope and provide the 3rd group of sediments to Gorgan bay (sampling site 2). Mechanisms of sediment supplies influence the sedimentation rates. So, high sedimentation rate in Shahkileh (site 2) is probably related to turbidite and flood deposits. Comparison of 3 long profiles in the study area from Alburz Mountain in the south of Gorgan bay (Fig.5) shows that Shahkileh has high slope related to Gharaso (site 1) and south of Neka power station site (site 3). Existence of 3 gravel horizons (175-200 cm), (224-252cm) and (815-840 cm) in the core of site 2 confirms a high sedimentation rate because this site is located near a paleochannel and is fed by flood and turbidite deposits. 4 gravel particles from level 185 cm (S5-185) found in Shahklileh site (Fig. 5), show low roundness which indicates that particles do not have enough time for rounding.

Gorgan bay sedimentation rate patterns have been compared with 3 regions, including Aral Sea in the Caspian Sea, Black Sea and Azov Sea, and are summarized and presented in Table 3 and Figure 5:

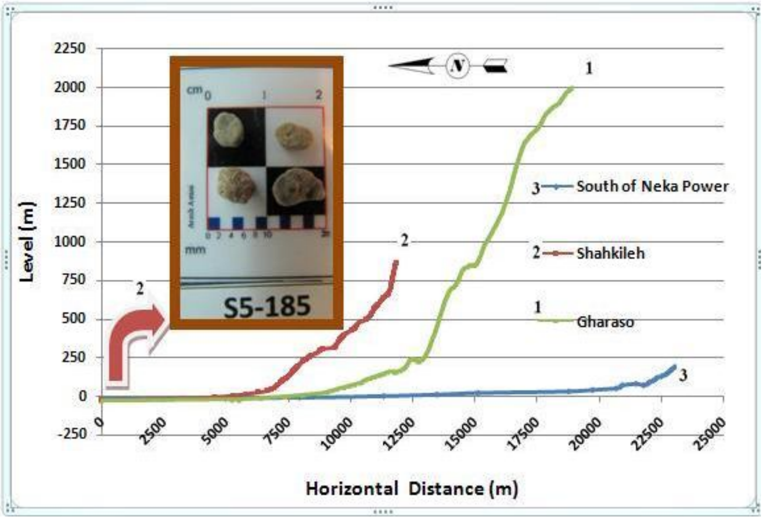

Fig 5: Comparison of 3 length profile of study area from Alburz mountain (South) with Gorgan Bay (North). Cores located at the end of each profile. Gravel size material is observed in different layer such as S5-185.

1–Sedimentation rate in the sea such as Aral Sea in east of Caspian Sea (Core 15 and 86), Black sea (Core 1462 and 1474) And Azov sea (Core 43 and 79)
2- Similar bay and lagoons in Iranian Caspian Sea coast (Anzali and Amirkola cores)
3- Sedimentation rate of South and middle Caspian Sea (G5-04, Gs19, Gs20 and SR12 cores)

In addition to south and central Caspian Sea, studies of other regions help us to understand similarities and differences between our study areas with these regions. Aral Sea, Azov and black sea are similar to south Caspian Sea geologically and they were connected to each other during the pre-Holocene time and even Aral Sea was connected to Caspian Sea for a short period during Holocene time with hydrologic exchanges (Rubanov, 1991). Distribution of sedimentation rate data in these 3 regions (Table 3 and Fig.6) indicates that sedimentation rate in Anzali and Amirkola lagoons, with limited water circulation, vary between 0.6 and 5 mm/year (Dash line in Fig. 3). Holocene sedimentation rate in the Aral and Azov with average of 0.54 mm/year is similar to each other but Black sea with average of 1.36 mm/year is different from Aral and Azov Sea.

Sedimentation rate pattern in southern and central areas in the Caspian Sea (Rectangular area in Fig. 3) indicates low to very low rate in these regions. Samples from cores number G5-04 (Kurpin et al., 2003) in the eastern part of the southern Caspian deep-sea depression from the depths of 405 m and SR-12 at the depth of 830 m show that the sedimentation rate was really low therefore this basin was starved during the Holocene period. On the other hand, Lahijani et al (2010) believed that dating of the near shore cores in Iranian coastal area demonstrates high rate of sedimentation that changes between 10 and 25 mm/y. They interpreted that this high sedimentation rate can be related to high sediment supply, both by river and coastal and sea drifts.

Table 3- Sedimentation rates in 3regions: South and middle Caspian sea, Aral –Azov-Black sea and Iranian Caspian Lagoons.

Region	Core Number	References	Depth (Cm)	Date (Year)	Sedimentation Rate (mm/ year)
South and Middle Caspian sea	GS-04	Kuprin et al (2003)	30	6230	0.05
	GS-04		65	9050	0.07
	GS-19		65	6100	0.11
	GS-19		390	8860	0.44
	SR-12		9	4970	0.02
	SR-12		100	8980	0.11
	GS-20	Boomer et al (2005)	425	8300	0.51
	GS-20		536	9960	0.54
Aral- Azov- Black Sea	Aral-Core 86	Callonnec et al (2005)	125	1510	0.82
	Aral-Core 86		375	7030	0.53
	Aral-Core 15		50	970	0.51
	Aral-Core 15		310	7500	0.41
	Black sea - Core 1474	Degens and Ross (1972)	365	3090	1.9
	Black sea - Core 1474		600	7090	0.85
	Black sea - Core 1462		500	3450	1.4
	Black sea - Core 1462		890	6650	1.3
	Azof sea– Core 43	Matishov et al(2009)	99	1800	0.55
	Azof sea– Core 79		76	1900	0.4
Iranian Caspian Lagoons	Anzali (14C)	Zareh Khosh eghbal and Ghazban (2010)	24	400	0.6
	Anzali-HCGA05 (210 Pb)	Vahabi-Moghaddam et al (2006)	155	310	5
	Amirkola-HCGL02	Leroy et al (2011)	37.5	150	2.5

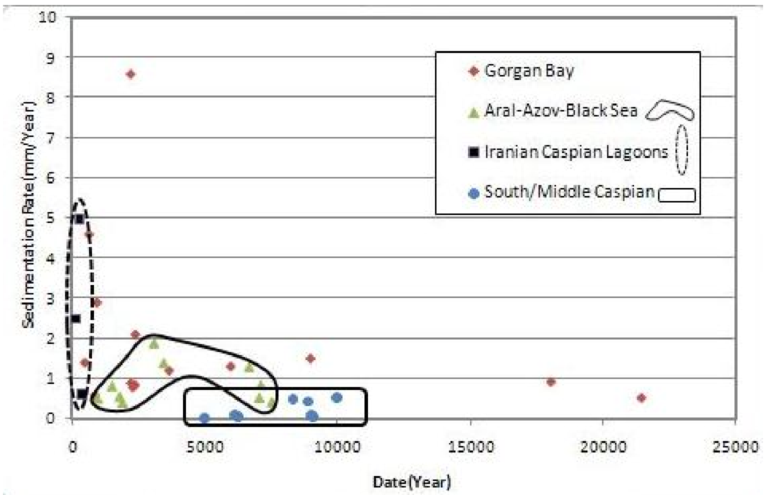

Fig 6: Comparison of the distribution trend of sedimentation rate in Gorgan bay, Iranian Caspian lagoons in the south and center of Caspian sea, Aral, Azov and Black sea.

It seems that a Holocene sea level change is one of the most important factors that has affected the Gorgan bay sedimentation pattern. Model of sea level changes in Gorgan bay is reconstructed according to Rychagov (1997) (Fig.7). On the basis of our data, Paleoshoreline fluctuated from level of -38 to level of -20 meters in 5 major transgressive and regressive phases. Horizontally, during the Holocene period, the shoreline in the Gorgan bay shifted at least about 15 Km to the west, 21.5 Km in the centre and 28.5 Km in east of Gorgan bay. These rapid changes cause a shift in the mouth of rivers and change the sedimentation rate pattern. On the other hand, rapid sea level changes cause morphological changes of Miankaleh coastal barrier system and sinking or uprising some parts of them. These processes possibly influence water circulation and TOC of Gorgan bay. Huc (1988) believed that in similar hydraulic conditions, organic matter is preferentially deposited with fine-grained mud and sedimentation rate co-varies with total organic carbon content in fine-grained bottom sediments. Probably variations in TOC within the Holocene sediments of the Gorgan bay can control sedimentation rate although the relationship between sedimentation rate and TOC is complicated by various other factors, such as lithology, water depth, distance from shore, and types of organic matter (Pelet, 1987).

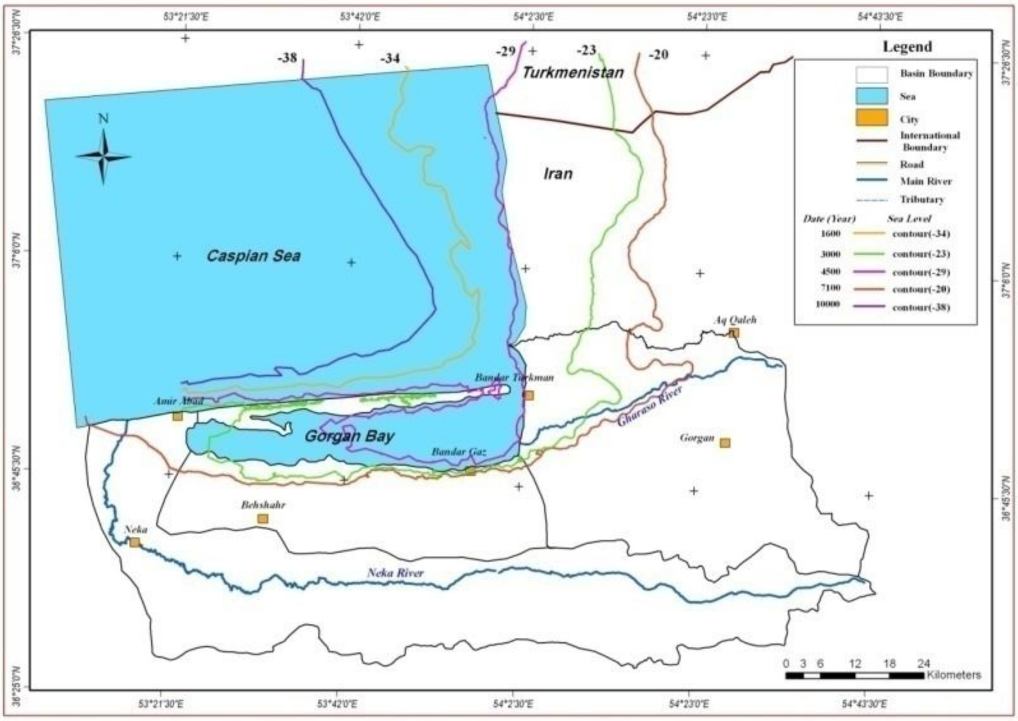

Fig 7: Holocene sea level changes and paleoshoreline in Gorgan Bay

CONCLUSIONS

Sedimentation rate in Gorgan bay is controlled by many known factors, such as watershed basin physiography, sediment supply, sediment texture, sea level changes and probably unknown factors likes TOC changes and shallow subsidence. Effects of these factors, apart from shallow subsidence rate in Holocene, have been used to estimate the sedimentation rate and distribution pattern in the Gorgan Bay.

Isotopic analysis of ^{14}C and ^{210}Pb shows that the average sedimentation rate was about 2.06 mm/year during lower than Newcaspian and 5.08 mm/year during the upper Newcaspian.

The results of our study shows that the short length rivers which enter the Gorgan bay with high slope can be produced gravelly horizon; therefore sedimentation rate was relatively high as an anomaly (sampling site 2) by both flood and turbidite during the high discharge into the region.

Sedimentation rate is also largely controlled by rapid sea level changes (level 38 to 20) during the Holocene and sedimentation rate in both lower and upper Newcaspian sediments increased from east to west in Gorgan bay.

Acknowledgements

This work was supported by the National Oceanographic Institution of Iran. We acknowledge the Geology Department at Ferdowsi University of Mashhad for their logistic support in this study.

REFERENCES

Abdollahi, Ata. (2007) The dynamics of the Caspian Sea during Holocene along Iranian coasts, Port and Ship Organization Department of Coastal Engeneering, Internal report, 63 p.

Afshin, E. (1994) Iran rivers, Vol 2, Energy ministry, Jamab, 251p. (In Persian)

Boomer, I., Grafenstein, U.V., Guichard,F.O and Bieda ,S.(2005) Modern and Holocene sublittoral ostracod assemblages (Crustacea) from the Caspian Sea: A unique brackish,deep-water environment, Palaeogeography, Palaeoclimatology, Palaeoecology 225 ,173– 186.

Cahoon, D.R., Reed, D.J.,Day Jr., J.W. (1995) Estimating shallow subsidence in microtidal salt marshes of the southeastern United States: Kaye and Barghoorn revisited. Mar. Geol. 128, 1 –9.

Callonnec,L.L ., Person, A., Renard,M ., René Létolle,R ., Nebout,N., Ben Khelifa, L ., Rubanov ,I. (2005) Preliminary data on chemical changes in the Aral Sea during low-level periods from the last 9000 years , C. R. Geoscience: 337, 1035–1044.

Cooper, L.W., Grebmeier, J.M., Larsen, I.L., Egorov, V.G., Theodorakis, C., Kelly, H.P., Lovvorn, J.R. (2002) Seasonal variation in sedimentation of organic materials in the St. Lawrence Island Polynya region, Bering Sea. Mar. Ecol., Prog. Ser. 226,13–26.

Degens, E .T and Ross. D . A. (1972) Choronology of the black sea over the last 25000 year, Chemical Geology, 10; 1-16.

Dubrulle, C., Jouanneau,J.M , Lesueur,P., Bourillet,J.F ., Weber,O. (2007) Nature and rates of fine-sedimentation on a mid-shelf:''La Grande Vasie` re'' (Bay of Biscay, France), Continental Shelf Research ,27, 2099–2115.

Gharibreza, M, R , Rahimipour , H and Motamed , M. (2004) Sedimentology, Sediment transport and Sedimentation Mechanism in Gorgan Bay ,Watershed research Inistitue, Internal report (In Persian)

Huc, A.Y. (1988) Aspects of depositional processes of organic matter in sedimentary basins.Organic Geochemistry, 13, 263–72.

Karbassi, A.R and Amirnezhad, R. (2004) Geochemistry of heavy metals and sedimentation rate in a bay adjacent to the Caspian Sea, International Journal of Environmental Science & Technology,Vol. 1, No. 3, pp. 191-198.

Kuprin , P.N ., Ferronsky , V.I ., Popovchak, V,P ., Shlykov, V. G., Zolotaya, L. A. and Kalisheva , M. V. (2003) Bottom Sediments of the Caspian Sea as an Indicator of Changes in Its Water Regime, Water Resources, Vol. 30, No. 2, 2003, pp. 136–153.

Kuzyk,Z.A., Macdonald,R.W., Johannessen,S.C., Gobeil ,C ., Stern, G.A . (2009) Towards a sediment and organic carbon budget for Hudson Bay, Marine Geology, 264 , 190–208.

Lahijani, H., Haeri, O., Sharifi, A. (2002) Sedimentology and mineralogy of Gorgan bay sediments. Research Report, Iranian National Center for Oceanography, 61pp.

Lahijani, H.A.K., Rahimpour-Bonab, H., Tavakoli, V., Hosseindoost, M. (2009) Evidence for late Holocene highstands in Central Guilan–East Mazanderan, South Caspian coast, Iran. Quaternary International, 197, 55–71.

Lahijani, H., Leroy, S.A.G., Naderi Beni, M .,Haghani, S., Shahkarami,S , Abbassian , H .,Tavakoli ,V , M. Hossenidost ., M ., Habibi , P ., Yeganeh , S and. ZandiI ,Z . (2010) Controls on sediment Distribution Pattern in the South Caspian Sea, Iran, Proceeding of the International Conference the Caspian region : Environmental Consequences of the Climate Ghange , Moscow State University, 350 p.

Leroy,S.A.G., Lahijani, H.A.K., Djamali,M., Naqinezhad,A., Moghadam,M.V., Arpe, K., Shah-Hosseini, M., Hosseindoust, M., Miller,C.S., Tavakoli,V ., Habibi, P ., Naderi Beni , M. (2011) Late Little Ice Age palaeoenvironmental records from the Anzali and Amirkola Lagoons (south Caspian Sea): Vegetation and sea level changes , Palaeogeography, Palaeoclimatology, Palaeoecology ,302 ,415–434.

Maria,E.J .S., Siringan,F.P., Bulos, A.D., Sombrito , E,Z. (2009) Estimating sediment accumulation rates in Manila Bay, a marine pollution hot spot in the Seas of East Asia , Marine Pollution Bulletin, 59 , 164–174.

Matishov, G.G ., Kovaleva,G,V and Pol'shin V,V.(2009) New Data on the Sedimentation Rate in the Sea of Azov in the Late Holocene, Doklady Earth Sciences, Vol. 429, No. 8, pp. 1369–1372.

Nadirov,R.S ., Bagirov , E .,Tagiyev, M ., Lerche ,I. (1997) Flexural plate subsidence, sedimentation rates, and structural development of the super-deep South Caspian Basin ,Marine and Petroleum Geology, Vol. 14, No. 4, pp. 383- 400.

Ownegh, M. (2010) Cyclic Development of the Qara-Su river Drinage Network in response to Caspian sea level Fluctions in late Quaternary, Proceeding of the International Conference the Caspian region: Environmental Consequences of the Climate Ghange , Moscow State University, 350 p.

Parkinson, R.W., DeLaune, R.D., White, J.R. (1994) Holocene sea level rise and the fate of mangrove forests within the wider Caribbean region. J. Coast. Res. 10, 1077–1086.

Pelet, R. (1987) A model of organic sedimentation on present-day continental margins. In: Marine Petroleum Source Rocks (J. Brooks and A. J. Fleet, eds.), Geological Society of London, pp. 167–80.

Rubanov, I.V. (1991) Salt accumulation in the Aral Basin. In: Sevastyanov,D.V. (Ed.), History of Lakes Sevan, Issyk-Kul, Balkhash, Zaisan and Aral. Moscow, pp. 231-234, (In Russian). Russian Academy of Sciences.

Rychagov, G.I. (1997) Holocene oscillations of the Caspian Sea, and forecasts based on palaeogeographical reconstructions. Quaternary Internationa , 41/42, 167–172.

Serandrei-Barbero,R., Albani,A., Donnici, S ., Rizzetto,F.(2006) Past and recent sedimentation rates in the Lagoon of Venice (Northern Italy), Estuarine, Coastal and Shelf Science, 69 ,255-269.

Sharbati, S., Hosseni, S., Taghizadeh, V ., Imanpour, M and Gorgin, S. (2010)Two dimentional modeling in Gorgan Bay Currents influence by sea level changes and wind pattern changes , proceeding of first conference of Caspian sea ecology. NRCES(2010) Sari.Iran.

Svitoch, A. A. and Yanina T. A. (2006) Holocene Marine Sediments on the Iranian Coast of the Caspian Sea, Doklady Earth Sciences, 2006, Vol. 410, No. 7, pp. 1166–1169

Teasdale, P.A Collins, P.E.F., Firth, C.R., Cundy , A,B. (2011) Recent estuarine sedimentation rates from shallow inter-tidal environments in western Scotland: implications for future sea-level trends and coastal wetland development , Quaternary Science Reviews, 30 ,109 -129.

Thomas , S ., Ridd ,P.V. (2004) Review of methods to measure short time scale sediment accumulation, Marine Geology , 207, pp95– 114.

Vahabi-Moghaddam, M., Vahabi-Asil, F., Lahijani, H., Amidi, J., Hafezi, S., Attarilar, A. (2006) South Caspian sediment dating using 210pb technique, In: Fourth International Conference dating Caspian Sea-level change, Aktau, Kazakhstan, p. 111(Abstract book).

Van Geen, A., Valette-Silver,N.J., Luoma,S.N ., Fuller,C.C., Baskaran,M., Tera,F ., Klein, J. (1999) Constraints on the sedimentation history of San Francisco Bay from ^{14}C and ^{10}Be, Marine Chemistry,64, 29–38.

Zareh khosh eghbal, M and Ghazban, F. (2010) Determine of sedimentation rate of Anzali Lagoon by ^{14}C , 4th sediment and erosion national congress. (In Persian)