

Using of Ground Penetrating Radar (GPR) and Sediment Cores As Method Interpretation of Sedimentary Environments the Estuaries of Northern West Oman Sea

¹Ahrari Roudi, M., ²R. Moussavi-Harami, ³R. Lak, ²A. Mahboubi and ⁴A. Motamed

¹Department of Geology, Science and Research Branch, Islamic Azad University, Tehran, Iran

²Faculty of Science, Ferdowsi University, Mashhad, Iran

³Research Institute, Geological Survey, Iran

⁴Islamic Azad University, Tehran, Iran

Abstract: The study area on the North West Coast of Oman Sea in Shoor and Parak estuaries is located within the city limits Chabahar. The GPR and seismic profiles in order to prepare and investigate the effects of subsurface and all is done. Identification of shallow subsurface structures material and thickness of the different are due to the contrast in electrical properties such as electrical conductivity and can pass including targets that are GPR detection methods are available. In this study the GPR profiles were taken with Mala GPR model. In order to calibrate the seismic data with characteristics facies obtained using a Euger involves two cores to lengths of 4.35 and 5 m were prepared. The data from these two methods were compared and the conclusions. The study showed that the cores are composed of two sedimentary facies. The first facies set includes mud with brown color and gravelly sandy mud facies with brownish cream color that the sedimentary environment is supratidal and the second facies set consists of muddy sand, gravelly mud and slightly gravelly sandy mud with gray color that specificities are related to depositional environment intertidal. Profile of the Shoor estuary defines four distinct facies that they are consistent with the core facies show up the upper facies set in the environment are supratidal and in the northeast of the South West on their thickness increases. The lower facies set environments intertidal formed that of the northeast toward the South West their thickness is unchanged. Profile of the Parak estuary defines two distinct facies that they are consistent with the core facies show up the upper facies set in the environment are supratidal that of the northeast toward the South West their thickness increases. The lower facies environments intertidal formed that of the northeast toward the South West their thickness does not change much. Since, the profile GPR No. 73 and 74 was nearer to the sea and influence the saltwater sea on penetration depth GPR is higher, detection of subsurface structures is less effective and two layers of subsurface has been identified in the parak estuary, but in Shoor estuary (the profile GPR No. 71 and 72), high distance from the sea and influence the saltwater sea on penetration depth GPR is less and detection of subsurface structures is better that has leading to the identification of four layers of subsurface. On the other hand comparison of sediment cores and GPR profiles with curve changes in global sea levels show that During two-Interval from time 2100 to 2800 years ago and so from time 4900 to 5800 years ago, increased sedimentation and sedimentation rates higher than average (0.1 mm per year) respectively. Finally, using GPR profile and cores, sea level changes in coastal environments can be revealed. These changes indicate that the two sedimentary cycles includes of a rise and fall sea level locally in the North West estuaries of Oman Sea in connection with the tectonic situation in the region.

Keywords: Core, electrical conductivity, parak, penetrating radar, shoor

INTRODUCTION

An estuary is a semi-enclosed coastal body of water having a free connection with the open sea and containing a measurable quantity of sea water (Cameron and Pritchard, 1963). Estuaries form a transition zone between river environments and ocean environments and are

subject to both marine influences, such as tides, waves and the influx of saline water; and river influences, such as flows of fresh water and sediment. The inflow of both seawater and freshwater provide high levels of nutrients in both the water column and sediment, making estuaries among the most productive natural habitats in the world (McLusky and Elliott, 2004). Most modern-day estuaries

were formed during the Holocene epoch by the flooding of river-eroded or glacially-scoured valleys when sea level began to rise about 10,000-12,000 years ago (Wolanski, 2007). GPR is penetrating radar studies of the Earth. This is one of the high-resolution geophysical methods that are used in order to identify the subsurface layers and the detection of underground structures in shallow areas. In this method, the high-frequency electromagnetic waves (5.12 to 2300 MHz) used for detection of subsurface structures (Neal, 2003; Tamura *et al.*, 2008; Miettinen *et al.*, 2009; Carpentier *et al.*, 2011). Hence, the division of Geophysics, usually in the field of electromagnetic methods is classified. The electromagnetic waves within the earth and the way data processing and interpretation of seismic reflection method, this method has many similarities. This method has many applications including those that can be used to determine the thickness of soil horizons and the depth of water table levels, detecting Porosity and permeability (air-filled cavities), buried channels and tunnels, to become the contaminated area to map, detection of buried objects in archaeological studies, check out the subsurface layers of the earth and etc. (Bristow and Jol, 2003; Lee *et al.*, 2005; Das *et al.*, 2006; Garcia *et al.*, 2004; Carling *et al.*, 2006). However, despite the high potential of this method, due to its limited penetration depth, this study is used in the shallow subsurface (less than 50-40 m). The rapid expansion of these studies is to provide very clear images of the surface. In studies such as Identify subsurface sediments, stratigraphy, geometry of mass of sand, compliance and understanding of sedimentary structures (Bristow and Jol, 2003; Bennett *et al.*, 2009; Benedetto and Pensa, 2007). GPR method as a convenient, fast and low cost to identify and separate the subsurface layers, identification of sedimentary facies and their changes, the detection of shallow subsurface anomalies such as porosity and cavities under the surface has been used within the estuaries of Shoor and Parak located in the North west coast of Oman. According to the cores of sedimentary and Identification of facies, relative sea level changes are well known (Woodroffe and Horton, 2005; Miettinen *et al.*, 2007; Rolett *et al.*, 2011; Railsback *et al.*, 2011). As the spatial position of estuaries and other parameters for example the volume of water, distance from the sea, vegetation, human interference and development, the sediments of estuaries are slightly different (Carling *et al.*, 2006; Bourrouilh-Le Jan, 2007). The morphology of the northern coast of Oman by tectonic processes plio-Pleistocene formed, although erosion and sedimentation processes has effected of surface modifications (Kassler, 1973). On the other hand, the lower sea level to about 120 m during the last period of glacial Pleistocene and Maximum (LGM) about 18 to 21 thousand years ago, it was found that exposure to the northern coast of Oman and they dug channels and rivers

in their range (Kassler, 1973; Weijermars, 1999). But after the last glacial period, sea level will advance to the basin about 4 to 6 thousand years ago to its maximum approximately 1 to 3 m above its current level of receipts Al- Asfour, 1978; Felber *et al.*, 1978; Lambeck, 1996; Uchupi *et al.*, 1996). The purpose of this research is the identification of shallow subsurface layers and matches them with data from sediment cores, relative sea level changes and identification in the sedimentary cycle in this area.

Geographical location of study area and operation of the GPR profile:

The study area is located in the Makran coast. Makran coastal escarpments, in south east of Iran are one of the largest accretionary prisms in the world. Oceanic lithosphere in the Arabian plate is moving north and is subducted under Lut plate and Afghan-Helmand block. The rates of both Arabic and Makran coast in the measurements geodetic is measured between Muscat and Oman 1.9 cm in years, While the current rate of shrinkage in the Makran coast and Chababar area is measured about 8 mm in years (Vernant *et al.*, 2004; Dolati, 2010). Sediments set of Related to the intermediate environment are in the study area and the oldest unit is deposits of the supratidal. These sediments (A set of fine sediment includes silt and clay particles) that were sediments between intertidal due to going back to sea (falling sea level) are located above the supratidal zone. Intertidal deposits in Oman coastal composed of mud sediment, silt and sand with a tissue adhesive and Includes asymmetrical current ripple, bioturbation and symmetrical current ripple and brands are the wave of especially in coastal estuaries and the coastal strip are a lot of expansion.

The operation of GPR was performed in the northern coast of Oman Sea in estuaries shoor and Parak (Fig. 1). The use of GPR has been prepared to the seismic profiles and all the side effects of both natural and artificial surface.

In two regions of coastal or the estuaries shoor and Parak, using the model GPR Mala (Fig. 2) in the direction perpendicular to the sea shore of the basin upstream four profiles were conducted and survey operations (Profiles 71, 72, 73 and 74, respectively in Fig. 1).

Profiles of 71 assorted in estuary Parak began from geographical coordinates N 25° 26' 34" and E 60° 33' 59" and with 920 m of navigation was ended the operation of GPR in coastal sand dunes on the geographical location of N 25° 26' 20" and E 60° 33' 22". Profiles of 72 in estuary Parak began from appropriate geographical coordinates N 25° 26' 22" and E 60° 33' 20" and Profiles parallel to the first 144 m and was ended the area at the point N 25° 26' 17" and E 60° 33' 19". Profiles of 73 assorted in estuary shoor began from geographical coordinates N 25° 25' 38"

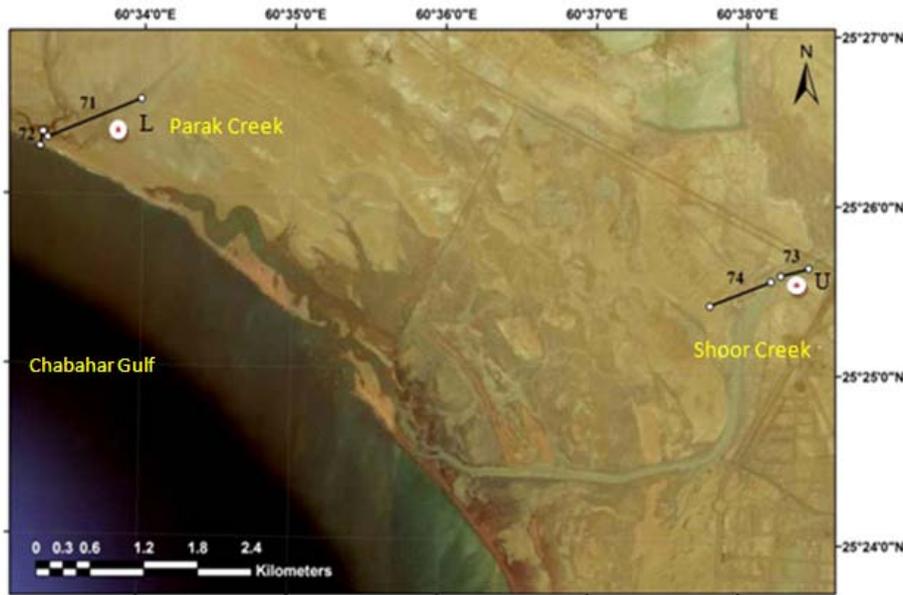


Fig. 1: Location of study, the GPR profiles is shown a segment and cores as a colored circle



Fig. 2: View of the GPR device model Mala Geoscience-3 Step charger (right) and Core-consuming manual Euger (left)

and E 60° 38' 26" and with the 300 m survey in the direction perpendicular and crossed of the channel was ended in location N 25° 25' 35" and E 60° 38' 15". The operation continued with enthusiasm worthy of 74 profiles. The profile at a point with geographical coordinates N 25° 25' 33" and E 60° 38' 11" was ended with a scroll 630 m and parallel to the profiles of the point

N 25° 25' 24" & E 60° 37' 47". Finally the total GPR harvest operation was 1,994 m. Required to explain, the high level of groundwater in these regions (about 3-2 m below ground level). Areas to be selected in the places that are not severe topography GPR data obtained so far have not been affected by errors caused by this factor. GPR data of four profiles in selected, after harvesting, were used processing and interpretation. In order to calibrate the seismic data obtained, two cores were prepared with lengths 4.35 and 5 m. sediment core L with geographic location N 25° 26' 21" and E 60° 33' 51" in parak estuary and sediment cores U and geographic location N 25° 25' 34" and E 60° 38' 19" in shoor estuary have been produced (Fig. 1).

MATERIALS AND METHODS OF THE STUDY

Methods the study included library studies and study check prior work, Field studies, laboratory studies that data have been combined. In the first part of the study, the location profiles have been recorded with GPS models Garmin-Olathe, Ks, USA. The profile of the GPR took and then, two sediment cores was performed with the length L of 5 m in the estuary Park and the length U 35.4 m in shoor estuary by the machine manually (Euger) (Fig. 3). In the study of sediment cores, the core were described by Visual Studies in desert and others characteristics such as shape, color, sedimentary structures. In order to the breakdown of sedimentary facies, selection of sample is done and they were prepared to sedimentology laboratories in Geological Survey of Iran. 65 samples aggregated. At this stage, about 200 g of

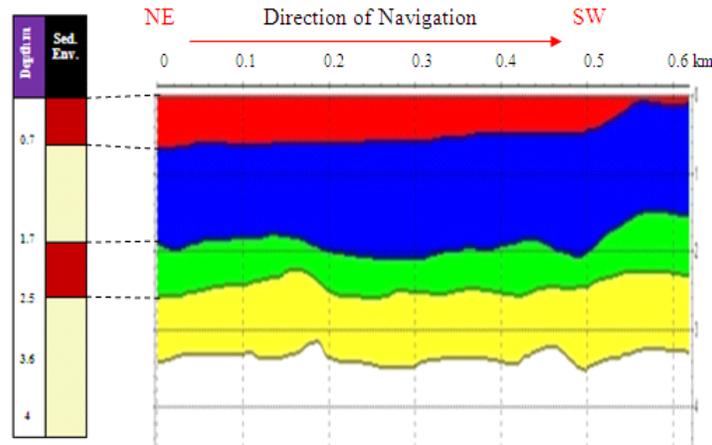


Fig. 4: Adaptation of the GPR profile with core facies No. U, Shoor estuary

facies to a depth of 3.6 m indicates that the environment is Intertidal. The slightly gravelly sandy mud sediment facies is with a little green with shell debris abundant. Reduce the amount of gravel that the components of skeletal fossils are marine, signs of rising sea levels and the environmental conditions are Intertidal. Facies 5: In this facies from depth of 4.25 m to a depth of 4.35 m appears and deposits of mud with greenish gray colors and the environment is Intertidal.

The combined results obtained from GPR data and sedimentary cores (Fig. 4), the GPR profiles and their compliance in estuary shoor, it was related that the change of sedimentary facies and depositional environment is with changes in particle size. In the GPR profiles of 73 and 74, subsurface layer 1 of with sedimentary unit 1 sediment core, subsurface layer 2 with sedimentary unit 2, subsurface layers 3 are consistent with sedimentary unit 3 and subsurface layer 4 with sedimentary unit 4. Since the waves with particles of sand and gravel abrasion damage to the beach from erosion of coastal outcrops of the above areas, can be attributed (Caldas *et al.*, 2006); Sorrel *et al.*, 2010 Therefore It seems Increased thickness of the layers identified shallow (subsurface layer 1) in the catchment area downstream in GPR profiles due to particles of sand and gravel is the wind the surface and near to shore that the longitudinal and transverse spread of relatively abundant. Therefore, this facies which gradually turn related to the environment Supratidal, intertidal, Supratidal and is intertidal and the two sedimentary cycles include a Raise and lower the water levels locally in the northern Oman Sea are.

Core L: Length of the core 5 m that was prepared in Parak estuary (Fig. 5) and four sedimentary facies from surface to deep consist of:

- Facies 1:** From the surface to a depth of 60 cm of muddy sediments is very sticky and greenish cream color reagent containing evaporating deposit is supratidal environment.
- Facies 2:** This facies is expanding from 60 cm to the depth of 90 cm. This facies consists of sandy mud sediments grayish cream color and abundant skeletal debris represents an increase in sea level and is intertidal environment.
- Facies 3:** From 90 cm to 1.5 m of the depth and from 3.85 to 4.85 m of a depth of sediment facies with muddy sand with small gravel is spread. The sedimentary facies is skeletal debris containing, grayish green colors and lamination thin. Histological features of this facies and field evidence indicate sea levels and environmental conditions is supratidal.
- Facies 4:** The facies from 1.5 to 3.85 m of depth and a depth of 4.85 to 5 m is expanding. The sedimentary deposits of this facies are slightly gravelly sandy mud with a little green to greenish-gray, skeletal debris and organic material. Increase the amount of mud and marine fossils, evidence of rising sea levels and environmental conditions is intertidal.

The combined results obtained from GPR data and sedimentary cores and their compliance with the GPR profile in Shoor estuary (Fig. 6) it was related that Changes in sedimentary facies and depositional environment is associated with changes in particle size. In the GPR profiles of 71 and 72, subsurface layer 1 from surface to a depth of 1.5 m with facies 1, 2 and 3 supratidal environment is consistent. Also the subsurface layer 2 in these profiles with sedimentary units 3 are correlated environmental intertidal.

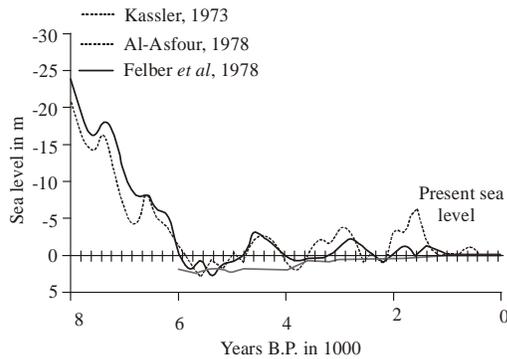


Fig. 7: Sea level curve in global scale (Uchupi *et al.*, 1996)

sedimentary sequence on the work that previously took approximately equivalent age (Gharibreza and Motamed, 2004) and age sediments was estimated at about 6,000 years ago. On the other hand comparison of sediment cores and GPR profiles with curve changes in global sea levels show that during two-Interval from time 2100 to 2800 years ago and so from time 4900 to 5800 years ago, increased sedimentation and sedimentation rates higher than average (0.1 mm/year), respectively (Fig. 7).

One of the important results of this study is that, in Parak estuary due to close to the shore line of and influence sea saline waters and also decrease depth of effect the penetration wave, subsurface layers were identified 2 layers but in shoar estuary due to away from the coastline and influence river waters, depth of effect the penetration wave is increased and 4 layers were identified. Results of the adaptation of seismic data and sedimentary facies indicate that Changing the particle size, type and depositional environment is related to sediments particle size in the subsurface layers.

Identify subsurface layers and interpretation of GPR profiles: Data processing performed on these four profiles is:

Profile 73: In this profile, there are four layers subsurface (Fig. 8). The thickness of subsurface layer 1 about 1.4 m, thickness of subsurface layer 2 about 70 cm, thickness of subsurface layer 3 about 40 cm and thickness of subsurface layer 4 about has about 84 cm. Also, in the GPR profiles, subsurface layer 1 with layers 1 and 2 sediment cores, subsurface layer 2 with layer 3 sediment cores and subsurface layers 3 and 4 are consistent with layer 4 in sediment cores. in the withdrawals from the beginning towards the coastline, the thickness subsurface layer 1 is almost uniform, the thickness subsurface layer 2, first increases and then decreases, the thickness subsurface layer 3, first decreases and then increases

again decreases and thickness subsurface layer 4, first increases and then decreases again increases. Thickness changes due to local sea level change that have been deposited tidal sediments. Colored lines between the layers and layers of red and blue areas show consideration. Depth of effect the penetration wave in these profiles of 3.6 m is not higher.

Profile 74: In this profile, there are four layers subsurface (Fig. 9). The thickness of subsurface layer 1 about 70 cm, thickness of subsurface layer 2 about 1.2 m, thickness of subsurface layer 3 about 70 cm and thickness of subsurface layer 4 about 80 cm. Also, in the GPR profiles, subsurface layer 1 with layers 1 and 2 sediment cores, subsurface layer 2 with layer 3 sediment cores and subsurface layers 3 and 4 are consistent with layer 4 in sediment cores. Therefore, in the withdrawals from the beginning to the end, the thickness of first layer up to 530 m area approximately uniform and then sharply decreases. This reduction in thickness due to relative sea level change and water underground. From The first line toward the sea the thickness subsurface layer 2 increases. At first the thickness subsurface layer 3 decreases and then increases and the thickness subsurface layer 4 increases and so then decreases again increases. Thickness changes due to local sea level change that have been deposited tidal sediments. Colored lines between the layers and layers of red and blue areas show consideration. Depth of effect the penetration wave in these profiles of 3.5 m is not higher.

Profile 71: In this profile, there are two layers subsurface (Fig. 10). Thickness of the first subsurface layer 1 about 4.1 m and thickness in the subsurface layer 2 is about 78 cm and from the top of point start move towards the sea, the layers thickness increased. The subsurface layer 1 in the profile 71 and 72 from the surface to a depth of 90 cm with facie 1 in supratidal environment and from depth of 90 cm to 1 m of depth is identical with facies 2 intertidal environment. So, the subsurface layer 2 in the GPR profiles with the sedimentary units 3 are related to environmental supratidal. Increased thickness of layers due to expansion of the surface sediments of sand dunes in coast. Colored lines are indicated contacts between the layers and red and blue areas. Depth of effect the penetration wave in these profiles of 2.5 m is not higher.

Profile 72: In this profile, there are two layers subsurface (Fig. 11) and thickness of the first subsurface layer 1 about 4.1 m and thickness in the subsurface layer 2 is about 78 cm and from the top of point start move towards the sea, the layer 1 thickness increased and an increase in the subsurface layer 2 initially increases and then

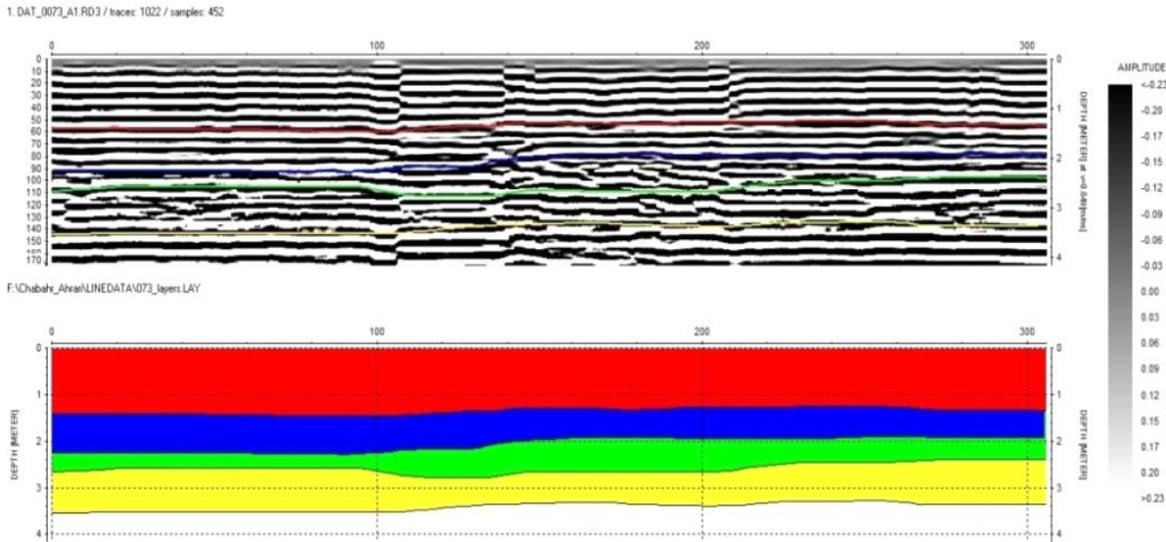


Fig. 8: Profiles 73 and image processing

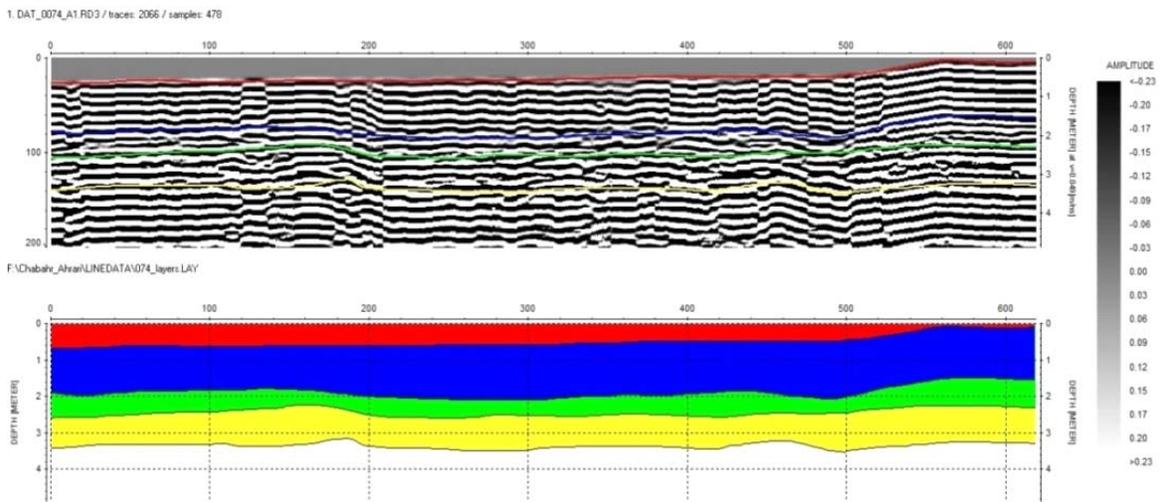


Fig. 9: Profiles 74 and image processing

decreases. In this core, a subsurface layer of the profile 71 and 72 of the surface to a depth of 90 cm with a depth of 90 cm of facies 1 and supratidal environment to a depth of 1 m is consistent with facies 2 intertidal environments. So, the subsurface layer 2 in the GPR profiles with the sedimentary units 3 are related to environmental supratidal. Increasing the thickness of layers due to sand dunes and wind deposits have been developed in the downstream. Colored lines between the layers and layers of red and blue areas show consideration. Depth of effect the penetration wave in these profiles of 2.6 m is not higher.

Since, the profile GPR No. 73 and 74 was nearer to the sea and influence the saltwater sea on GPR data.

Thus, detection of subsurface structures is less effective and two layers of subsurface has been identified in the Parak estuary and so in Shoor estuary (the profile GPR No. 71 and 72), high distance from the sea and influence the saltwater sea is less and detection of subsurface structures is stronger that has leading to the identification of four layers of subsurface. As can be seen, Differences in sediment type, grain size and amount of clay in the subsurface structures, creates contrast in electrical properties, including differences in the size of the electric permittivity of free space are the main reason for classification theirs in different layers.

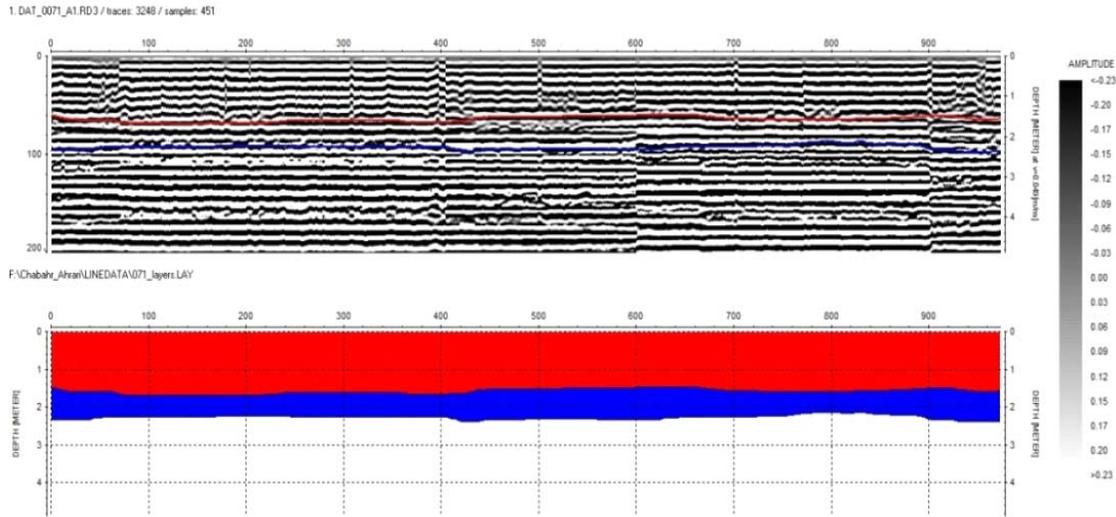


Fig. 10: Profile 71 and its image processing

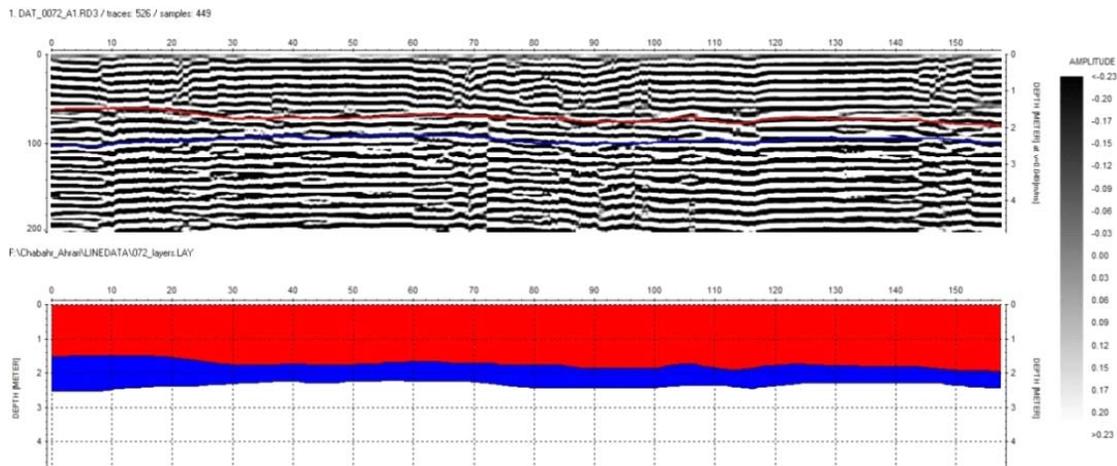


Fig. 11: Profiles 72 and its image processing section

CONCLUSION

- In the study area sediments set of Related to the intermediate environment are and the oldest unit is deposits of the supratidal.
- Sedimentary facies include slightly gravely sandy mud, gravely mud, gravely sandy mud, muddy sand and sandy mud.
- The combined results obtained from GPR data and sedimentary cores, the GPR profiles and their compliance in estuary Shoor and Parak, it was related that the change of sedimentary facies and depositional environment is with changes in particle size.
- In profiles 71 and 72, there are two layers subsurface. Thickness of the first subsurface layer 1 about 4.1 m and thickness in the subsurface layer 2 is about 78 cm and from the top of point start move towards the

sea, the layers thickness increased. The subsurface layer 1 in the profile 71 and 72 from the surface to a depth of 90 cm with facie 1 in supratidal environment and from depth of 90 cm to 1 m of depth is identical with facies 2 intertidal environment. So, the subsurface layer 2 in the GPR profiles with the sedimentary units 3 are related to environmental supratidal.

- In profiles 73 and 74, there are four layers subsurface. The thickness of subsurface layer 1 about 1.4 m, thickness of subsurface layer 2 about 70 cm, thickness of subsurface layer 3 about 40 cm and thickness of subsurface layer 4 about has about 84 cm. Also, in the GPR profiles, subsurface layer 1 with layers 1 and 2 sediment cores, subsurface layer 2 with layer 3 sediment cores and subsurface layers 3 and 4 are consistent with layer 4 in sediment cores.

in the withdrawals from the beginning towards the coastline, the thickness subsurface layer 1 is almost uniform, the thickness subsurface layer 2, first increases and then decreases, the thickness subsurface layer 3, first decreases and then increases again decreases and thickness subsurface layer 4, first increases and then decreases again increases.

- The profile GPR No. 73 and 74 was nearer to the sea and influence the saltwater sea on GPR data. Thus, detection of subsurface structures is less effective and two layers of subsurface has been identified in the Parak estuary and so in Shoor estuary (the profile GPR No. 71 and 72), high distance from the sea and influence the saltwater sea is less and detection of subsurface structures is stronger that has leading to the identification of four layers of subsurface.
- Thickness changes due to local sea level change that have been deposited tidal sediments. In the other hand, in Parak estuary due to close to the shore line of and influence sea saline waters and also decrease depth of effect the penetration wave, subsurface layers Were identified 2 layers but in shoor estuary due to away from the coastline and influence river waters, depth of effect the penetration wave is increased and 4 layers Were identified. Of course, in Parak estuary in near sea, increased thickness of layers due to expansion of the surface sediments of sand dunes in coast. These facies which gradually turn related to the environment Supratidal, intertidal, Supratidal and is intertidal and the two sedimentary cycles include a Raise and lower the water levels locally in the northern Oman Sea are.
- Comparison of sediment cores and GPR profiles with curve changes in global sea levels show that during two-Interval from time 2100 to 2800 years ago and so from time 4900 to 5800 years ago, increased sedimentation and sedimentation rates higher than average (0.1 mm/year), respectively
- Results of the adaptation of seismic data and sedimentary facies indicate that Changing the particle size, type and depositional environment is related to sediments particle size in the subsurface layers.
- Depth of effect the penetration wave in GPR profiles of 3.6 m in shoor estuary and 2.6 m in Parak estuary is not higher.
- Differences in sediment type, grain size and amount of clay in the subsurface structures, creates contrast in electrical properties, including differences in the size of the electric permittivity of free space are the main reason for classification theirs in different layers.
- The morphology of the northern coast of Oman by tectonic processes Plio-Pleistocene formed, although erosion and sedimentation processes has effected of surface modifications. On the other hand, the lower sea level to about 120 m during the last period of

glacial Pleistocene and Maximum (LGM) about 18 to 21 thousand years ago, it was found that exposure to the northern coast of Oman and they dug channels and rivers in their range, but after the last glacial period, sea level will advance to the basin about 4 to 6 thousand years ago to its maximum approximately 1 to 3 m above its current level of receipts

REFERENCES

- Al- Asfour, T.A., 1978. The Marine Terraces of the Bay of Kuwait. In: Brice, W.C., (Ed.), the Environmental History of the Near and Middle East Since the Last Ice Age, Academic Press Inc., Ltd., London, pp: 249-260.
- Benedetto, A. and S. Pensa, 2007. Indirect diagnosis of pavement structural damages using surface GPR reflection techniques. *J. Appl. Geophys.*, 62(2): 107-123.
- Bennett, M.R., N.J. Cassidy and J. Pile, 2009. Internal structure of a barrier beach as revealed by ground penetrating radar (GPR): Chesil beach. *Geomorphology*, 104: 218-229.
- Bristow, C.S. and H.M. Jol, 2003. Ground Penetrating Radar in Sediments. Published by the Geological Society, London, pp: 339.
- Bourrouilh-Le Jan, F.G., 2007. Very high energy sedimentation (supratidal hurricane deposits) and Mid-Holocene highstand on carbonate platforms andros, Bahamas: An alternative view. *Sediment. Geol.*, 199: 29-49.
- Caldas, L.H.O., K. Statterger and H. Vital, 2006. Holocene sea-level history: Evidence from coastal sediments of the northern Rio Grande do Norte coast, NE Brazil. *Mar. Geol.*, 228: 39-53.
- Cameron, W.M. and D.W. Pritchard, 1963. Estuaries. In: Hill, M.N., (Ed.), the Sea. Wiley J. and Sons, New York, 2: 306-324.
- Carling, P.A., A. Radecki-Pawlik, J.J. Williams, B. Rumble, L. Meshkova, P. Bell and R. Breakspear, 2006. The morphodynamics and internal structure of intertidal fine-gravel dunes: Hills Flats, Severn Estuary, UK. *Sediment. Geol.*, 183: 159-179.
- Carpentier, S.F.A., A.G. Green, J.A. Doetsch, C. Dorn, A.E. Kaiser, F. Campbell, H. Horstmeyer and M. Finnemore, 2011. Recent deformation of Quaternary sediments as inferred from GPR images and shallow P-wave velocity tomograms: Northwest Canterbury Plains, New Zealand. *J. Appl. Geophys.*, 72: 1-14.
- Das, B.K., A.S. AL-Mikhlaifi and P. Kaur, 2006. Geochemistry of Mansar Lake sediment, Jammu, India: Implication for source-area weathering, provenance and tectonic setting. *J. Asian Earth Sci.*, 26: 649-668.
- Dolati, A., 2010. Stratigraphy, Structural geology and low-temperature thermochronology across the Makran accretionary wedge in Iran, Swiss Institute of Technology Zurich. Diss ETH, No. 19151, pp: 165.

- Felber, H., H. H. Zl, V. Maurin, H. Moser, W. Rauert and J.G. Z l, 1978. Sea Level Fluctuations during the Quaternary Period. In: Al-Sayyari, S.S., J.G. Z l, (Eds.), Quaternary Period in Saudi Arabia. Springer, New York, pp: 50-57.
- Folk, R.L., 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Co., Austin Texas, pp: 182.
- Gharibreza, M.R. and A. Motamed, 2004. Late quaternary Paleoshorelines and Sedimentary Sequences of Chabahar Bay. 32nd International Geological Congress, Italy, Florence, pp: 15.
- Garcia, D., C. Ravenne, B. Marechal and J. Moutte, 2004. Geochemical variability induced by entrainment sorting: Quantified signals for provenance analysis. *Sediment. Geol.*, 171: 113-128.
- Kassler, P., 1973. Geomorphic Evolution of the Persian Gulf. In: B.H. Pursur (Ed.), the Persian Gulf. Holocene Carbonate Sedimentation and Diagenesis in a Shallow Epicontinental Sea, Springer, New York, pp: 11-32.
- Lambeck, K., 1996. Shoreline reconstructions for the Persian Gulf since the last glacial maximum. *Earth Planet. Sci. Lett* 142, pp: 43-57.
- Lee, S.H., H.J. Lee, H.R. Jo, J.J. Bahk and Y.S. Chu, 2005. Complex sedimentation of the Holocene mud deposits in a ria-type coastal area, eastern Korea Strait. *Mar. Geol.*, 214: 389-409.
- McLusky, D.S. and M. Elliott., 2004. The Estuarine Ecosystem; ecology, threats and management, 3rd Edn. OUP, Oxford. pp. 216.
- Mc Lusky, D.S. and M.Elliott, 2004. The stuarine Ecosystem, Ecology, Threats and Mangement. 3rd Edn., Oxford University Press, Oxford, pp: 216.
- Miettinen, A., H. Jansson, T. Alenius and G. Hagg , 2007. Late Holocene sea-level changes along the southern coast of Finland. *Baltic Sea. Mar. Geol.*, 242: 27-38.
- Neal, A., 2003. Ground-Penetrating Radar and its use in sediment logy: Principle, problem and progress: *Earth-science. Reviews*, 66: 261-330.
- Railsback, L.B., F. Liang, J.R. Vidal Romani, A. Grandal-d Anglade, M.V. Rodriguez, L.S. Fidalgo, D.F. Mosquera, H. Cheng and R. L. Edwards, 2011. Petrographic and isotopic evidence for Holocene long-term climate change and shorter-term environmental shifts from a stalagmite from the Serra do Courel of northwestern Spain and implications for climatic history across Europe and the Mediterranean. *Palaeogeogr. Palaeocli.*, 305: 172-184.
- Rolett, B.V., Z. Zheng and Y. Yue, 2011. Holocene sea-level change and the emergence of Neolithic seafaring in the Fuzhou Basin (Fujian, China). *Quaternary Sci. Rev.*, 30: 788-797.
- Sorrel, S., J. Schleich, S. Scott, O. Malley, E. Trace, F. Boede, U. Ostertag and P. Radgen, 2010. Barriers to Energy Efficiency in Public and Private Organizations. SPRU, Science and Technology Policy Research, University of Sussex, Brighton.
- Tamura, T., F. Murakami, F. Nanayama, K. Watanabe and Y. Saito, 2008. Ground-penetrating radar profiles of Holocene raised-beach deposits in the Kujukuri strand plain, Pacific coast of eastern Japan. *Mar. Geol.*, 248: 11-27.
- Tucker, M.E., 1988. Techniques in Sedimentology, In: Tucker, M.E. (Ed.), Blackwells, Oxford, pp: 394.
- Uchupi, E., S.A. Swift and D.A. Ross, 1996. Gas venting and late Quaternary sedimentation in the Persian (Arabian) Gulf. *Mar. Geol.*, 129: 237-269.
- Vernant, P.H., F. Nilforoushan, D. Hatzfeld, M.R. Abbasi, C. Vigny, F. Masson, H. Nankali, J. Matinod, A. Ashtian and J. Chery, 2004. Present day crustal deformation and plate kinematics in the Middle East constrained by GPS mesurments in Iran and Northern Oman. *Geophys. J. Int.*, 157(1): 381-398.
- Weijermars, R., 1999. Quaternary evolution of Dawahat Zulum (Half Moon Bay) region of eastern province, Saudi Arabia. *Geo. Arabia*, 4: 71-90.
- Woodroffe, S.A. and B.P. Horton, 2005. Holocene sea-level changes in the Indo-Pacific. *J. Asian Earth Sci.*, 25: 29-43.
- Wolanski, E., 2007. Estuarine Ecohydrology. Amsterdam, The Netherlands, Else vier, pp: 157, ISBN: 978-0-444-53066-0.
- Wolanski, E., 2007. Estuarine Ecohydrology. Amsterdam, The Netherlands, Else vier. ISBN: