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Abstract:

In eastern Gilan the recent coastal terraces, organizing a zone with 2 to 8 km width, which are related to the tectonic movements of the Astara Fault. The Astara Fault with N-S trend is a mountain bordering fault, separating Talesh mountains in the west from south Caspian coast in the east. It seems that the processes of forming new terraces are accompanied with some hiatus in sedimentary system, which it is possible to see them as a discontinues fossiliferous horizons.

In the eastern coast, no rivers enter to the sea, hence there is not deltaic deposits in this part. In principle, in the eastern part, from the mouth of the Atrak River towards north, the Caspian Sea attached to the expanded extra-ordinary heat of the Turkmenistan low-lands, which is not inhabitable. Turkman sahra, is an alluvial peneplain, that stream-beds of Atrak, Gorgan and Qarasu rivers are flowing in these alluviums. In all coastal parts of the Caspian, marine terraces, can be seen, which is indicator of sea-level rise in the past.

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Quaternary stratigraphy of Bandar-e-Anzali Quadrangle map, Scale: 1:250,000

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2023

Quaternary stratigraphy of Bandar-e-Anzali Quadrangle map, Scale: 1,250,000

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1-1- Introduction

Stratigraphical sequences, are those lithofacies that the absolute age of their upper and lower borders (even not precisely) are known. One of the most differences between the Quaternary sequence, with other systems is that we know exactly the age of the upper border of Quaternary system. It is worth to mention that except the upper border of Quaternary system, none of stratigraphic horizons are known precisely. Within the recent sediments in different stratigraphical horizons, one can find the evidences of climate variations, such as soil stratigraphic horizons, glacial and interglacial deposits, lake and evaporate deposits, transgression and regression of the sea level, tropical and cold region fossils, variation of oxygen isotope in the skin of organisms, quantitative and qualitative variations of flora, etc.

The main goal of this study is to investigate the effective agents of the sedimentological discontinuities of the studied area. In the course of this research, the scope of sedimentological studies, is to understand the textural and structural characteristics of alluvial deposits (river deposits), and stratigraphy or the stratified sequences in the coastal zone.

following softwares used in this research:

- Global Mapper
- Arc GIS
- Corel Draw and Sedlog

1-2- Caspian Sea

The Caspian Sea, with a north- south trend, and length of about 1204 km, and mean width of 204 km, surrounded by Iran and five other countries. The recent total area of the Caspian Sea, is about 438,000 km^2, with water volume of 80,000 km^3, and mean depth of 180 m. The widest part of the Caspian Sea is located in north Astara to north of Hosseinqoly Gulf. The area under study, covers the southwestern parts of the Caspian, including Bandar Anzali, Masuleh, Rezvan Shahr, north of Astara, and parts of Khalkhal and Kivi.

2- Morphology

2-1- Morphology of the Caspian

The cut bank of the Caspian, sometimes in the frame of embayment's, with regards to their location and situation, and different properties, have a specific role in sea-level fluctuations. In General, the embayment's of the eastern coasts, due to the specific heat of the Turkmenistan desert and extra ordinary evaporation, to compare with western coasts are more effective for sea-level fall.

In the eastern coast, no rivers enter to the sea, hence there is not deltaic deposits in this part. In principle, in the eastern part, from the mouth of the Atrak River towards north, the Caspian Sea attached to the expanded extra-ordinary heat of the Turkmenistan low-lands, which is not inhabitable. Turkman sahra, is an alluvial peneplain, that stream-beds of Atrak, Gorgan and Qarasu rivers are flowing in this alluviums. In all coastal parts of the Caspian, marine terraces, can be seen, which is indicator of sea-level rise in the past.

There are few cut banks in the southern coasts, which might be due the high depth of water. The estuary rivers, that entering to the sea from the south, did not create any important change in the southern coast. It is worth to mention that the southern plain of the Caspian was covered by sea, and results are Neogence and Quaternary brackish deposits, which mostly covered by vegetation. Sea-floor surveying in the southern part of the Caspian by NIOC, indicating a worthy development of mentioned deposits with remarkable thickness.

With the view of depth, the Caspian Sea can be divided to three parts:

Northern part with 6.2 m depth

Middle part with 176 m depth

Southern part with 325 m depth

Generally, the Caspian experienced several sea-level fluctuations, more due to glacial and interglacial periods, from upper Pliocene to Quaternary. It can be said that the sea-level was about 75 m higher than today, in early Quaternary.

Morphological subdivisions of the South Caspian Coast

According to Paluska (1977), morphologically south Caspian coast can be divided into 7 units:

1- Coast between Astara and Poonel

In eastern Gilan the recent coastal terraces, organizing a zone with 2 to 8 km width, which are related to the tectonic movements of the Astara Fault. The Astara Fault with N-S trend is a mountain bordering fault, separating Talesh mountains in the west from south Caspian coast in the east (Figure 1). It seems that the processes of forming new terraces are accompanied with some hiatus in sedimentary system, which it is possible to see them as a discontinues fossiliferous horizons (Figure 2, Figure 3 & Figure 4).

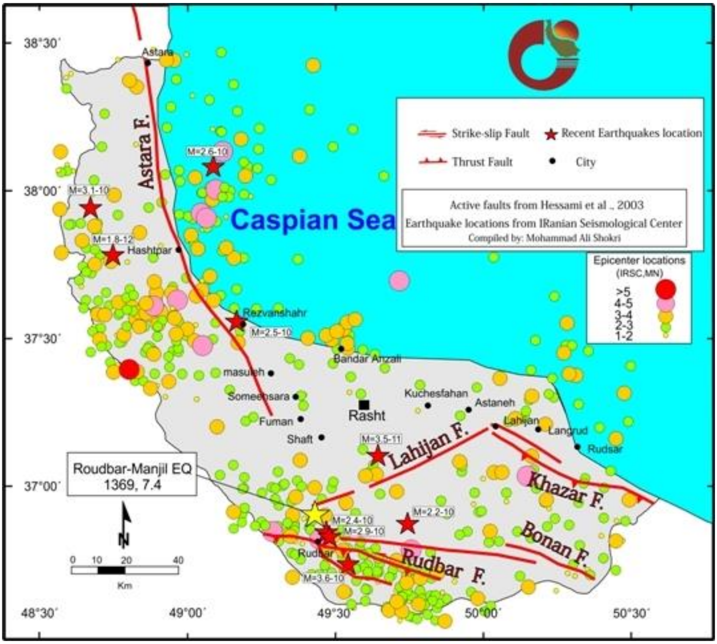

Figure 1: The Astara Fault with N-S trend is a mountain bordering fault, separating Talesh mountains in the west from south Caspian coast in the east

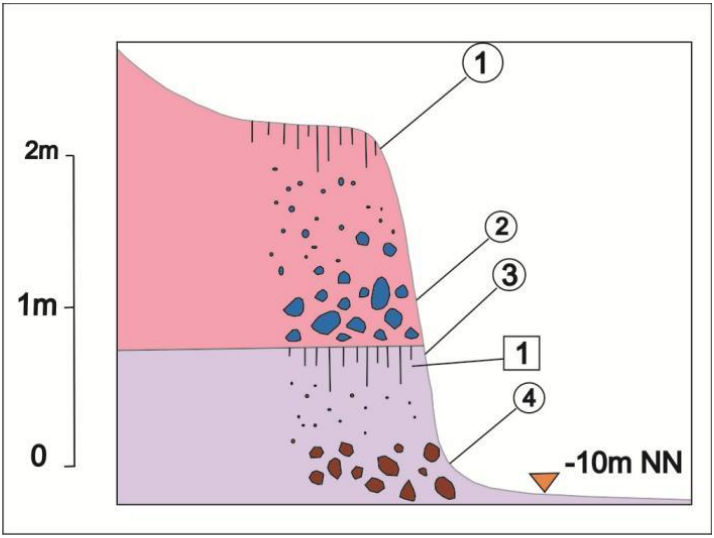

Figure 2: Trench on Lisar-Borsara road. Fluvial alluvial deposits with layers of fossil soils (Paluska, 1977).

1) The surface soil horizon of the present time. 2) wall deposits without layering in the upper parts of sand deposits. 3) Fossil soil horizons, and brown weathered sandy silts. 4) Same as section 2.

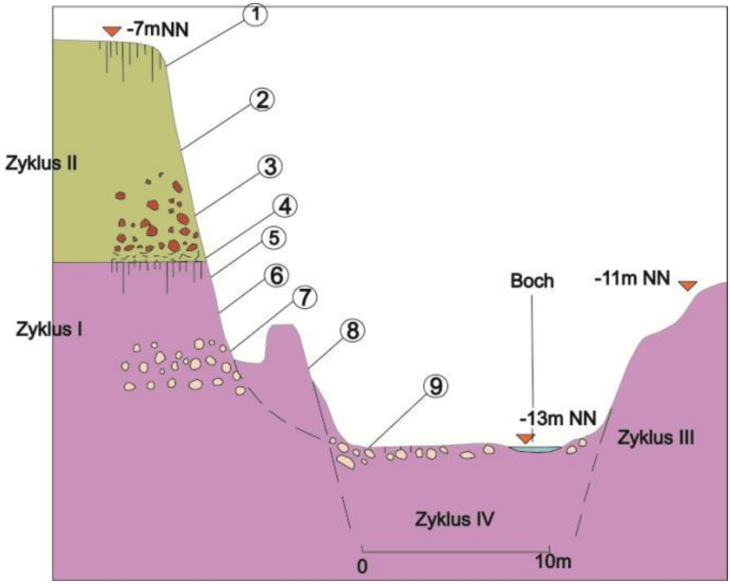

Figure 3: Outcrop in Asalem, which was formed in the deposits of a river incision, a total of 4 sedimentary cycles (river line, along with the fossil soil horizon) (Paluska, 1977).

1) The present time surface soil horizon. 2) Fine to medium-grained sand without layering, in the upper part silty. 3) Sand pebbles, fragments up to 8 cm in size. 4) Fine-grained silty sands with thin layering. 5) The horizon of decomposed fossil soil up to a depth of 40 cm. 6) fine- to medium-grained sands without layering. 7) Sandy gravel and well-sorted gravel. 8) artificial cut wall (by road construction). 9) debris and large blocks of the river instream-bed.

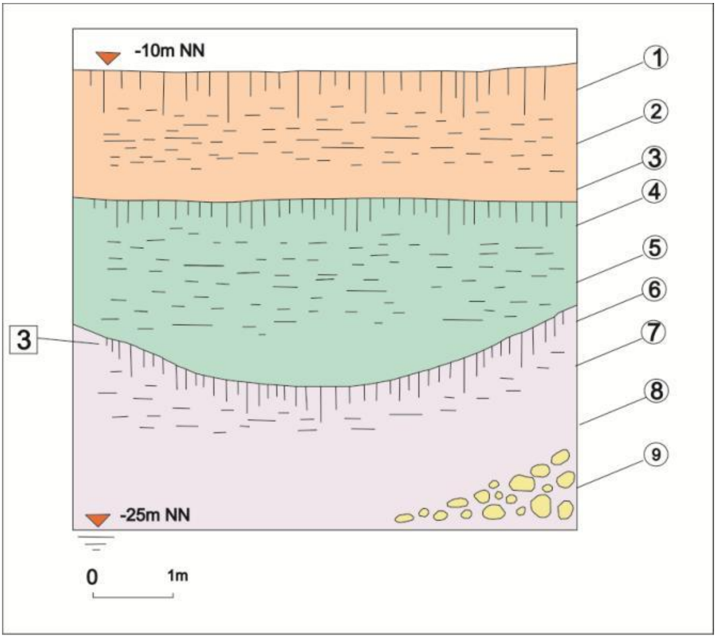

Figure 4: Outcrop in Lamir area, the cut that the river created in the deposits of three successive sedimentary cycles (fluvial-alluvial) with horizons of fossil soils (Paluska, 1977).

1) The present time surface soils. 2) Silty sandstones. 3) Untextured sand. 4) Fossil soil horizons, soil plant horizons (humus) with the structure of coarse-grained materials. 5) Sandy silts in lower part silty sand. 6) Fossil soil horizon very rich in soil plants along with shells fragments (sample no. 3). 7) Sandy silts. 8) Well-sorted medium-grained sands without layering. 9) Medium to coarse grained pebbles.

2- Coast between Poonel and Langroud

This part of the Caspian coast, consists of deluvial- fluvial deposits. Sandy boulders, sometimes greater than 80 cm, transported in the river cannels (Figure 5 & Figure 6) (Paluska,1977). An exceptional event, is 5 m marine deposits 20 to 25 m above sea-level in Astaneh profile. The reason for erasing Caspian Sea-level in the past, is the present location of Rasht city, which is 20 km far from the coast. In historical documents, mentioned that Rasht was a harbor, and in 19th century was an active center for carry on business transaction between Volga area and Abbasian Caliphs (Paluska,1977).

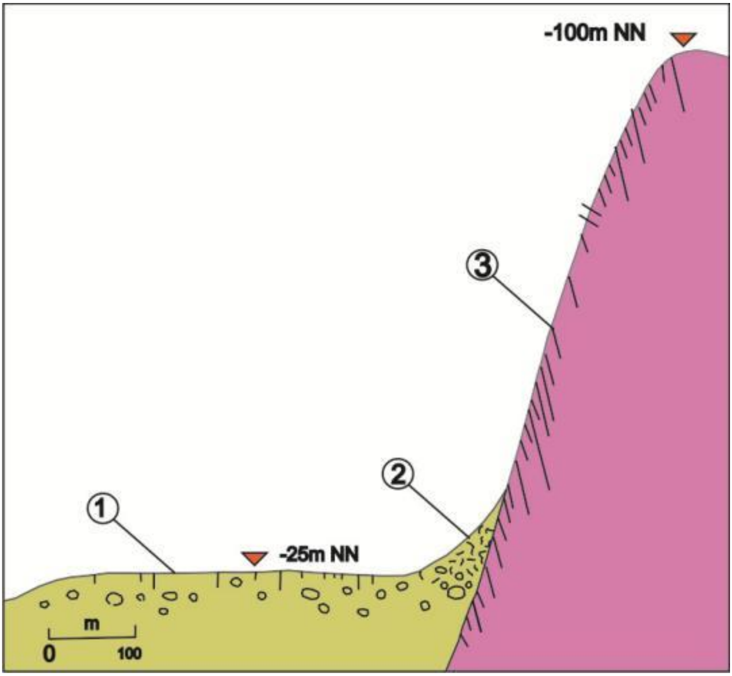

Figure 5: Masal area, cross section of a mountainous river showing floodplain deposits (Paluska, 1977)

1) Sandy pebbles. 2) slightly silty unconsolidated deposits. 3) Pre-Quaternary hard rocks.

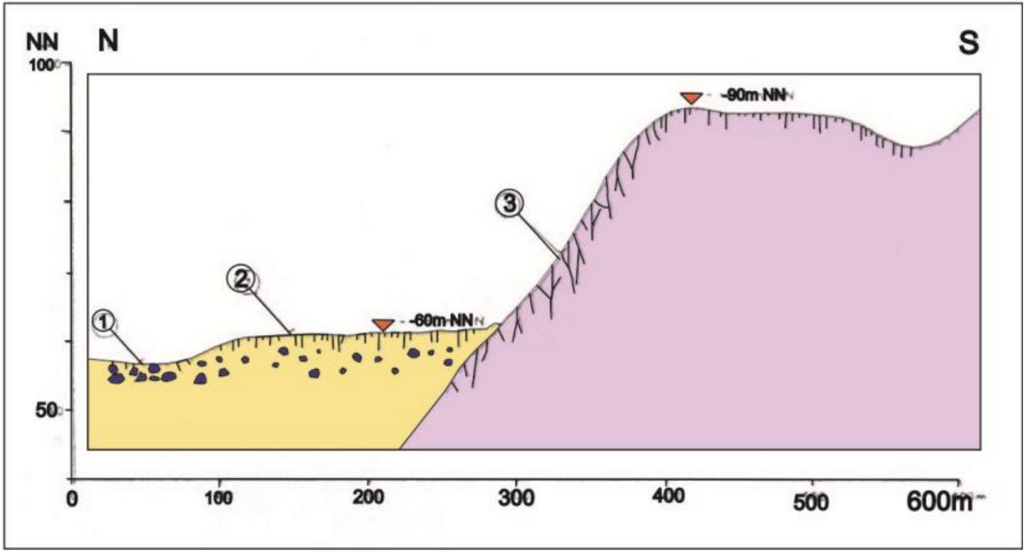

Figure 6: Gasht area section in a mountainous river (Paluska, 1977).

1) Old river bed with deposits of coarse pebbles with blocks up to 50 cm in size. 2) sandy pebbles and sand. 3) Pre-Quaternary hard rocks (porous clastic limestones).

3- Littoral section between Langroud and Alamdeh

From Langeroud southeastwards, towards Galandroud river head, the littoral width is about 5 km, and morphology is similar to Astara-Poonel section. A sequence of deposits can be seen in an exposure near Sisangan (Figure 7). In this outcrop, deposits consist of cross-bedded, poorly sorted of sand and silt. The effect of Quaternary tectonic in young sediments, also can be seen in one of the small tributary of Ramsar river (Figure 8). Another example of similar deformed deposits, are crop out, at the beginning of Chalus- Tehran road.

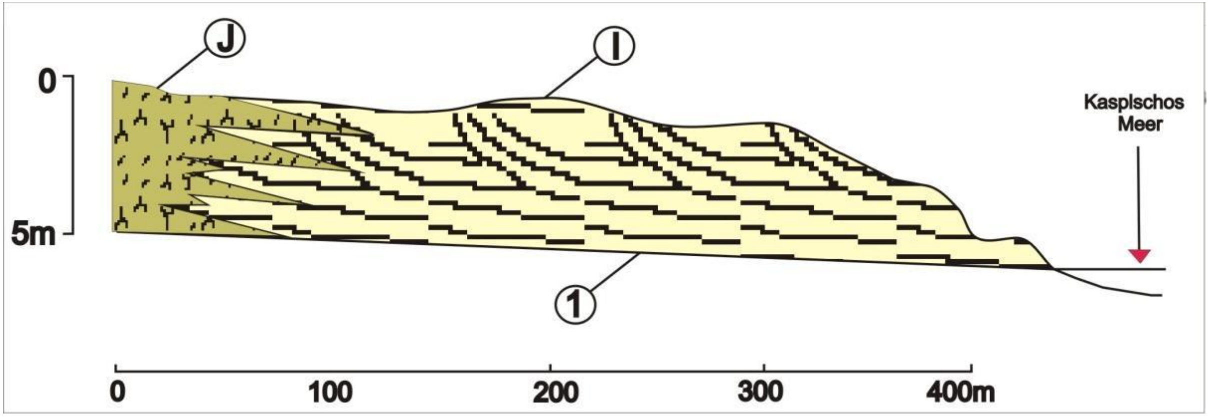

Figure 7: Sisangan outcrop: a cut of a river in wall (Paluska, 1977)

1) The mixed deposits of sand and cobble with cross-beding. 2) Fine-grained sands with alluvial deposits in the upper part of the section. 3) alternation of fluvial (sand) and alluvial (often silt) layers with multiple layers of fossil soil horizon.

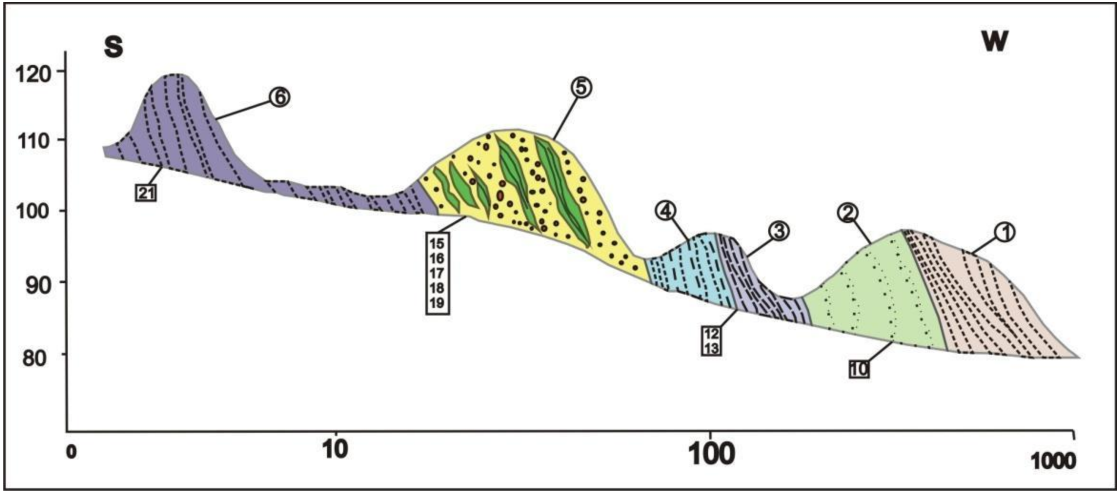

Figure 8: Outcrop in the Galanrud River south of Alamdeh (Paloska, 1977).

1) Thin layer silty-marl, unconsolidated, along with many molluscs. 2) alternating layers of sand and sandy gravel (sample no. 10). 3) Silt and marl (samples 12 and 13) with thin layering, unconsolidated, with medium to coarse grained sand interlayers. 4) Alternating of silty sand and silty marl and sandy sand layers. 5) faulted and tectonized eroded layers with silt, marl, sand, and shelly layers. 6) Thin layers of consolidated silty marl (sample 21).

4- Littoral section between Alamdeh and Neka

This is one of the most important littoral zone, with abundant Quaternary deposits, spreading eastwards to Babol, Qaemshahr and Sari. From the structural point of view, is similar to Rasht. Deposits mainly can be seen in rivers alluvial fans (such as Haraz and Talar rivers). Peneplanes with 50 to 100 m altitudes, are juxtaposed to the thrusted hillock of the Alborz Mountains (Paluska, 1977), due to the Neogen- early Quaternary tectonic movements (Figure 9).

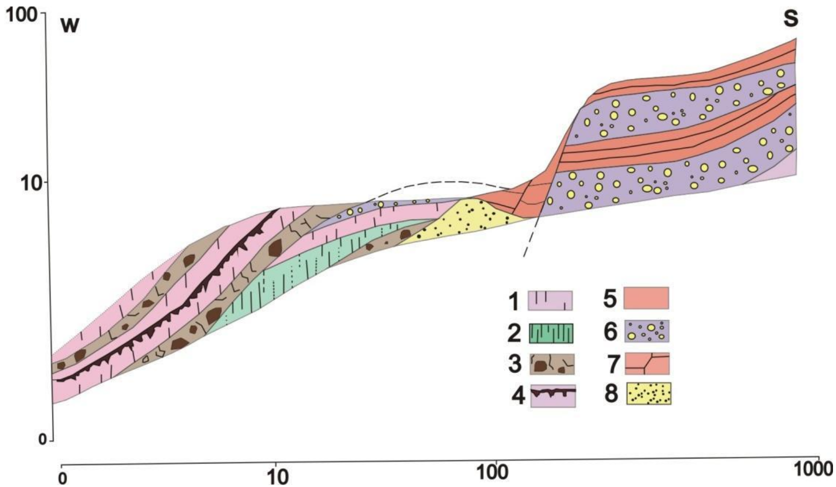

Figure 9: Outcrop of Talar River, south of Qaem Shahr (Shahi): on the road side, a section of alternating sand layers with pieces of conglomerate inside it (Paluska, 1977).

1) Upper layers consists of more fossil soils including brown soils and soft sands. 2) Sandy loess horizons, in some parts with abundant fossil fragments. 3) Brownish fossil soil horizon. 4) Limestone resulting from dissolution and redeposition. 5) Fine grain sand with silt. 6) Conglomerate, sand and rubble. 7) Faulting. 8) Soil mass or debris.

Sussli (1976) reported the presence of Miocene-Pliocene deposits in north Amol road, which gradually transform to Aghchagilian epoch.

In addition to mentioned deposits, the aeolion facies with fossiliferous soil horizons are also can be seen in this lithoral zone (Figure 10).

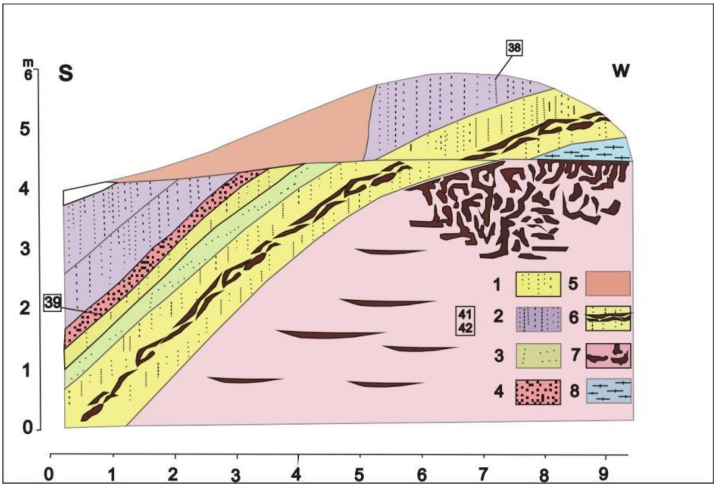

Figure 10: Neka outcrop, south of Ghaem Shahr-Neka road (Paluska, 1977).

1) Surface soils and fossiliferous soils, brownish loess and sandy loess. 2) sandy loess and, in some parts with fossils. 3) Fossiliferous, weathered brown soil. 4) Thin-layer fine-grained silty sands. 5) Fossiliferous sand. 6) Limestone, resulted from dissolution and redeposition in loess (concretion). 7) Calcareous concretions in sand (travertine). 8) Tuff sedimentary layers, pale green, clay silts without bedding based on lithology.

5- Littoral zone between Naka and Bandar-e-Torkaman

This littoral zone, display several geo-archeological sites in this area. One of the most attractive feature in this zone, is great lagoon and Gorgan embayment. It seems that the Neka-Behshahr zones are sources of gravelly materials for construction in this vicinity. The gravelly materials are made of very fine to very coarse grain components (Figure 11).

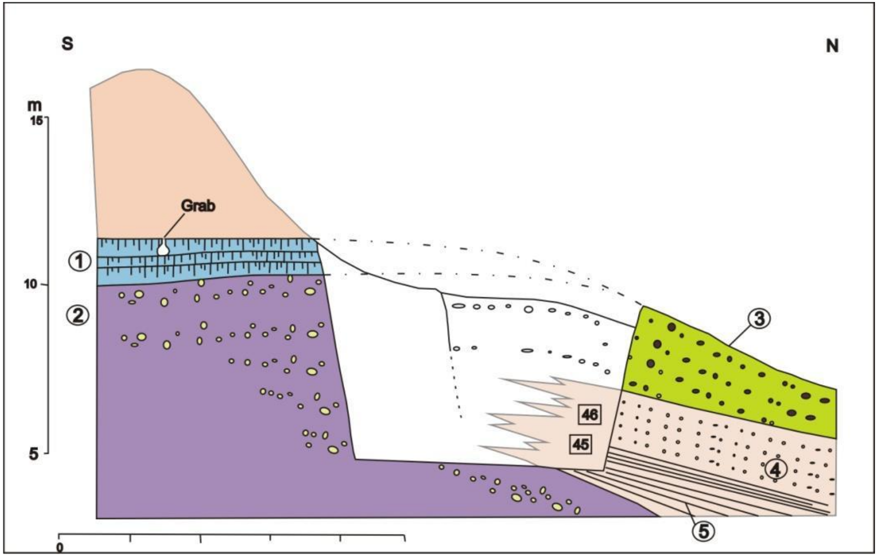

Figure 11: Outcrop near Neka, south of Ghaemshahr-Neka road (Paluska, 1977).

1) Alternating layers of sand and loess with layers of fossils. 2) Sandy gravels and sandy layers with a slight slope to the north. 3) The layers of sand and gravel. The layers have a gentle slope towards the north. 4) Silty sand in the lower part of thin layer silty clay (samples 45 and 46).

Ehlerz (1971), noticed that the dip of sediment layers is opposite to the river flow, and concluded that this is the result of erosional process of ancient rocks.

Another interesting feature in this littoral zone, are caves in Jurassic limestone's. Three of caves that investigated by archeologists with remains of Neolithic artifacts are: Belt, Hutu and Seven. In the slope of caves, only alluvial sediments can be seen, and no marine deposits found there. To compare with European common subdivisions, it is possible to correlate them with the European late glacial periods of Khavalin- Neo Caspian transform zone.

6- Littoral zone in the Gorgan bayhead

From Bandar-e-Torkaman towards east, a 100 km low-land starts from Gonbad-e-Kavous to Gorgan bayhead. Most parts of this area covered by aeolian (loess) deposits. Also, from Gorgan head river and far distances, alluvial terraces developed that constitutes the agricultural land. Thompson (1938) and Ehlerz (1971), reported three terraces from zero to 45 m heigh, but we are not agree with this interpretation. Instead we believe that river sedimentation occurred at least 5 to 6 meters in upper part. Therefore, sedimentation accomplished in its stream bed in Gorgan plain, without a major climatic change. An interesting section can be seen in a river cut with several fossiliferous horizons in Agh Qala (Figure 12).

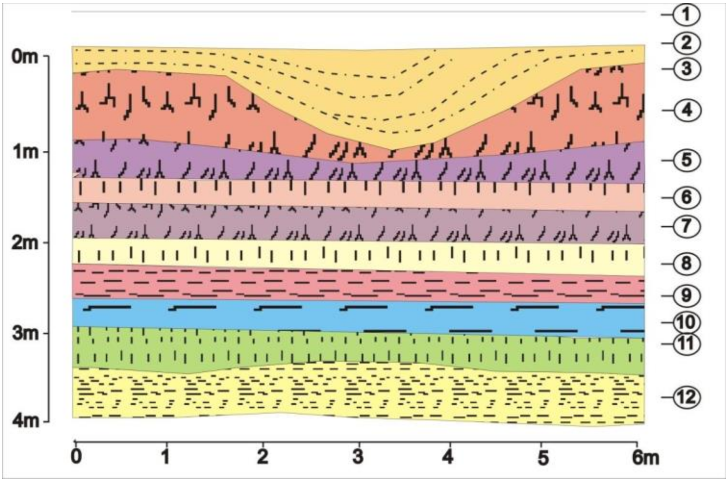

Figure 12: Outcrop in Agh Qala (former Pehboi Dej), in Gorgan rud deposits (Paluska, 1977).

1) Surface soils. 2) Fine-grained thin layer silty sands in the bottom shell fragments. 3) Brown fossiliferous soil. 4) Loamy clays. 5) Brown fossiliferous soils with sedimentary origin. 6) Silty sandy. 7) Thin layer silt. 8) Fine-grained silty-sand. 9) Silty clays with the shell fragments. 10) Silty sandy.

The marine facies, that deposited in recent times, are limited to the Gorgan bayhead area that mostly covered by continental deposits. On the other hand, development of aeolian materials along the coast, together with the equivalent age of early to middle Holocene for these sediments, enable us to call them Gorgan epoch. There are about 300 pre-historical mound in this area, but most of them are covered by desert steppes of Turkmenistan or vegetation. Aren (1936,

1945) estimated about 40,000 people inhabited here, during the ancient copper period. It is worth to mention that only three of pre-historical mounds were investigated, i.e. Shah Tappeh (Aren, 1935, 1945), Yaren Tappeh (Crawford,1963) and Toorang Tapeh (Vasayesh, 1967).

7- Littoral zone of Turkmenistan

This zone developed in the vast area in north of Gorgan depression. The Iranian part of this zone is covered mostly by sandy losses. In the desert parts which called wadi, there are many mud cracks.

There is another important about the existence of the Gorgan bayhead. In this manner, it is vital importance, whether or not, that the young, low depth sea, is transgressed towards the Turkmenistan coastal zone? Answer to this question needs more research (Paluska, 1977).

3- STRATIGRAPHY

3-1- Introduction

Quaternary system with 1.65 to 2.4 million years old, is youngest and shortest system of the earth's history, and consists of Pleistocene and Holocene epochs. The Pleistocene is the major part of the

Quaternary system, and is defined by the glaciated periods. The age of the Holocene is about 10,000 yrs, and defined the newest history of the earth.

The Quaternary system, based on the climate change, can be divided to cold and warm ages and glaciated periods. The Quaternary time scale is very short for a phylogenic evolution of index fossils. The intense climate variations are helpful for subdivision of Quaternary epoch as follows:

- Accumulation of gravelly materials due to cold weather conditions.
- Moraines and gravelly materials due to ablation.
- Deposition of losses in cold periods.
- Marine and lake deposits resulted in warm and cold periods.
- Vegetative cover of warm and cold periods.
- Erosional process in warm conditions and loess forming.
- Paleo-glacial curves, based on the oxygen isotope variations of the foraminifera.
- The presence of foraminifera in abyssal-zones.

3-2- Pliocene-Quaternary Stratigraphy of the South Caspian Basin

- **Pliocene**

The development of Pliocene deposits can be seen in Gorgan plain, Mazandaran and Gilan, and consists of Cheleken (lower-middle Pliocene) and Aghchehgil (upper Pliocene) epochs.

- **Cheleken Deposits**

The Cheleken consists of thick clay, marl, sandstone and brownish red conglomerate in the Gorgan plain.

In Iran this deposits are called continental series and part of it is equivalent to the same sediments in Azerbaijan Republic. Fossil remains, except a few fresh water Ostracods are rare.

In the vicinity of Alamdeh, Chelenken deposits mostly overlain unconformably, yellow Sarmation sediments, but in exploration oil wells, cover the Cretaceous deposits. Data about Cheleken in Bandar-e-Anzali, is exclusive and doubtful.

- **Aghchagylin Deposits**

This epoch in type-section consists mainly of limestone and marl, sandy marl, and grey to white sandstone, that overlain conformably lower Pliocene sediments.

The thickness of Aghchagyl in Gorgan plain wells with littoral facies are reported about 380 m to 720 m respectively.

In Mazadaran (10 km east of Amol), and Gilan (in Ghazian) these deposits found in depths of 1485 m and in the range of 1370-1570 m respectively.

- **Quaternary**

Deposits of the Quaternary system consists of loess, alluvial terraces, alluvial fan and sand dunes. An entire deposits of the Quaternary system found in oil wells of the Gorgan plain, Mazandaran and Gilan plains.

- **Stratigraphy and Geographical Development of Quaternary Deposits**

The Quaternary system in Caspian basin can be divided in to the following stages:

- **APSHERONIA DEPOSITS**

The name of Apsheron derived from the Apsheron peninsula which is located west part of the Khazar in republic of Azerbaijan. It consists of thick sequences of sand, marl and remains of lamellibranchia shells. In Iran, the Apsheron system consists of blue and green color marls, thin grain sand with intercalation of gravels, and partly thin layers of volcanic ashes. The thickness of this stage in Iran varies from 450 m to more than 800 m.

- **POST BAKUVIAN DEPOSITS**

Generally, marine deposits in coastal Gilan, Mazandaran and Gorgan, starts with 160-600 m thick Bakuvian stage, followed by 300-450 m thick old Caspian deposits, which indicating a severe subsidence in the Caspian Basin during Neogene and Quaternary.

The thickness of post Bakuvian deposits in Gonbad-e-Qabus, Gorgan, Mazandaran plain, Gilan plain, and north Bandar-e-Anzali (main Khazar well No.1), are about 185 m, 300 m, 375 m, 130 m, and 420 m respectively. While, the thickness of post Bakuvian deposits, northeast of Neka, is about 390 m, indicating a thickness increase from east to west.

- **KHAZARIAN STAGE**

This stage consists of clay, thin unconsolidated blue color clay layer with shell fragments. These deposits in Iran, are lower parts of the Ancient Khazar, but Russian scientists, believed that the Bakuvian stage, constitute the lower part of the Ancient Khazarian deposits.

- **KHVALINSKIAN STAGE**

In Iran, Vatan and Yasini (1969), found similar deposits, settled in the upper part of the Ancient Khazarian, and below the unconsolidated Holocene Neo-Caspian sediments, which is consist of a 45 m very soft and unconsolidated clay, with abundant bivalves and gastropods shells (Mousavi Rouhbakhsh, 1997).

- **NEO-CASPIAN DEPOSITS**

This stage consists of 45 m of grey to blue color clay with thin layers of unconsolidated fine grain sands with abundant shell fragments. The Neo-Caspian deposits, in addition to exploration wells, can also be seen between Mahmood Abad – Amol, and near Gorgan plain.

Quaternary sedimentary environment in Bandar-e-Anzali quadrangle

Quaternary sedimentary environments in studied area are as follows:

Deluvial facies

Proluvial facies

Fluvial facies

Alluvial facies

Coastal facies

Terrestrial facies

Volcanic facies

Biological analysis of Quaternary deposits based on the Caspian Sea-level fluctuations

Sedimentation of Neo-Caspian epoch started approximately 13,000 years ago, with a rate of 3 mm/yr. Reported thickness of this epoch, varies from 30 m to 45 m (Khazar No.1 exploratory well) up to 160 m in Anzali coastal zone (well No.1) (Ghazian).

The beginning of sedimentation of Neo-Caspian epoch was almost contemporaneous with Wurm IV glaciation period, and at this time sea-level of the Caspian was about 7-9 m below the global sea-level (currently the Caspian Sea-level is 25.6 m below the global sea-level).

The fauna of the Neo-Caspian epoch is the same as the fauna of to-day. The Quaternary brackish sediments, which investigated more in Mazandaran exploratory oil well No.1 (1 km north of Amol) are as follows:

Aremarkable thickness of loess deposits developed in north Neka valley, between Neka and Gorgan, as well as in the vicinity of Gorgan city, which is mostly related to the cold and dry climate of the late Wurm. Following sea regression in early Quaternary (base of the Apsheronian), the size of Caspian reduced, and its connection with the neighboring basins: The Black Sea Azof was cut off, so Caspian basin became a closed lake. Subsequently, due to the entering fresh water its salinity decreased. Therefore, due to the environmental change and hydrochemical variation of Caspian basin in Apsheronian epoch, most of the faunas were no longer able to live and became extinct (such as Bivaler Avicalaria, Moha), but some of the faunal adopted the new environment and continued to living (such as Clessiniolla Apsheronia). Follow up transgression of the Caspian during Lower Bakuvian, Upper Bakuvian and Lower Khovalinskin, again connected to the neighboring brackish basins (Black Sea, Azof and Aral). While in the Middle Bakuvian and Neo-Caspian, the connection of the South Caspian Basin with the surrounding basins is cut off (Mousavi Rouhbakhsh, 1997).

Under the condition of climate changes in the glacial and interglacial periods, the sedimentary condition of the southern Caspian Sea, in the Upper Apsheronian, Middle Bakuvian changed to a continental environment and due to the increased temperature continental red clays (rich in iron oxides) deposited. Due to the rapid regression of the sea, and increase in concentration of CO_3Ca, oolitic sediments deposited in shallow parts of the sea and presence of salt and gypsum indicates a hot and dry climate in this periods. But in the Lower Apsheronian and Lower Bakuvian, due to the Gunz-Mindle glaciation Caspian basin suffered a cold and dry climate (Mousavi Rouhbakhsh, 1997). Ammonata tepida, in one of the fresh water fauna in this stage.

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