Implication of Holocene Catastrophic Tectonic Activities on Archaeological sites at Mediterranean Shore North West Sinai Egypt

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Abstract: The civilizations from Pharaohs time, Greek-Roman to Islamic times had been destroyed by tectonic movements on Mediterranean shore line for several times at the Farama old city (Pelusium) west north Sinai. Field structural measurements, Satellite SPOT and ETM images and geologic maps helped for interpretation the tectonic movements and geneses of the recent geomorphological features. We attended the digging elaborations and excavation dug in archaeological sites that reached to 12 m depth at Farama, 3.8 km to the south of the recent Mediterranean. The published archeological time-data were considered. This archeological site subjected to regional events implicated on the civilizations due to tectonics. 1- Three main catastrophic cycles were happened at 1000BC, 33BC and 870 AD, partially deformed the civilizations. 2- In last decade, Mediterranean fluctuation; regression and transgression in four cycles in about 2 meters total thickness overlie the last civilizations. 3- Inside the excavated archaeological sites, there are young phases of Holocene faulting activities on F 1 affected on the declined civilizations. And sliding-down movements in NW trend which yield normal faults and fracture cutting the exposed building. Around the excavated archaeological sites, there are young phases of Holocene NE-SW faulting activities separates between Quaternary carbonate rocks and sabkhas, sand dunes with 6m down-throw to the NW. Normal E-W fault with down throw 4m to the north sculpt the topography controlling different sand dunes patterns and separates between them. New Quaternary faulting activities with northern down-throw separated between old marine ridge and down throwing the Quaternary silt which mixed by Mediterranean water

Key words: Tectonic, Archeological site, Mediterranean shore line, Holocene and Sinai.

INTRODUCTION

The study area is located in the northwestern Sinai, between Latitude 30° 45′ N in the south and the Mediterranean coast in the north and between Suez Canal in the west and Longitude 32° 42′ E in the east. Farama (Pelusium) was a city in the eastern extremes of Egypt's Nile Delta, 3.8 km to the south of the recent Mediterranean Tell el-Farama, include Balouza and other sites was in ancient times, with two branches of the Nile (Ostium Pelusiacaum) surrounding what was then Pelusium, the eastern gateway to Egypt. Alternative names include “Sena” and “Per-Amun” (Egyptian, Coptic: Paramoun meaning House or Temple of Amun), Pelousion (Greek), Sin (Chaldaic and Hebrew), Seyán (Aramaic), and Tell el-Farama (Egyptian Arabic). Pelusium was the easternmost major city of Lower Egypt, situated upon the easternmost bank of the Nile at the south-eastern border of Sahl el Tina (el Tina plain), the Ostium Pelusiacaum, to which it gave its name and this word is an Egyptian appellation. Peremoun (created by Amun) or Peromi, and its Greek a “city of the ooze” or mud Pelusium lay between the seaboard and the Deltaic marshes of the Delta, about 4.4km from the sea (Fig.1). The Ostium Pelusiacaum was choked by sand as early as the first century BC, and the coast-line has now advanced far beyond its ancient limits, so that the city, even in the third century AD, was at 6.8 km from the Mediterranean. The Pelusium’s fortress covers 20 acres, measuring about 200 by 400 meters. Its walls averaged about seven feet thick, and were set with 36 towers and three gates. However, the current fortress can only be dated to the late sixth century AD (Dunn 2006). The Farama city and neighbored Balouza village gathered both a geological tectonic site and an archaeological history site in an important place influenced with the earth tectonic movements and global climatic changes. Therefore, this article aim to understand how the geological history sculpted the recent geomorphological units and their implication on archaeological sites foreseen area for Egypt’s future. According to Shata (1992) the study area is classified as a coastal plain that is characterized by the earth tectonic movements and global climatic changes. Therefore, this article aim to understand how the geological history sculpted the recent geomorphological units and their implication on archaeological sites foreseen area for Egypt’s future. According to Shata (1992) the study area is classified as a coastal plain that is characterized by the earth tectonic movements and global climatic changes. Therefore, this article aim to understand how the geological history sculpted the recent geomorphological units and their implication on archaeological sites foreseen area for Egypt’s future. According to Shata (1992) the study area is classified as a coastal plain that is characterized by the earth tectonic movements and global climatic changes. Therefore, this article aim to understand how the geological history sculpted the recent geomorphological units and their implication on archaeological sites foreseen area for Egypt’s future. According to Shata (1992) the study area is classified as a coastal plain that is characterized by the earth tectonic movements and global climatic changes.
The Archaeological History:

Tell el-Farama, was in ancient times, called Peremun (= that which Amun created) the house or temple of Amun. The city was situated near to the easternmost arm of the Nile (or the Pelusiac arm) and the artificial north-south canal opened by Sesostris (Fig. 2). Pelusium provided the pilgrims with all the supplies necessary for the dangerous trip. Archaeologists launched the "North Sinai Salvage Project" in 1991; several works has been carried out at Pelusium, as well as Tell el-Makhzan and Kanais, which were probably parts of "greater Pelusium in ancient times. Two of the unearthed citadels go back to the Pharaonic age while the third belongs to the Persian age. The first citadel dates back to the age of the Hyksos (1603-1567 BC). Within the walls of the citadel there were found houses, store- houses, furnaces, and human remains, pottery from Cyprus and pottery from the age of the Hyksos. The second citadel dates back to the New Kingdom in the 18th and 19th dynasties. The citadel was built on the remains of a Hyksos citadel, following the war waged against them by Ahmos. The third citadel of the Persian age (341-332) was found to have no towers. Excavations unearthed pottery segments of the Persian age (Jakubiak, 2009). It was perhaps the most important fortress city along Egypt's ancient Horus Military road. However, during peaceful times, and during the Graeco-Roman era, it was also an important trading post, the king of Assyria, Sennacherib (720-715 BC), during the 25th Dynasty, intent on invading Egypt, approached Pelusium, but withdrew without a fight (Dunn 2006). The decisive battle which transferred the throne of the Pharaohs to Cambyses II of Persia, king of the Persians, was fought near Pelusium in 525 BC. However, according to legend, Pelusium fell without a fight, by the simple expedient of having the invading army drive cats (sacred to the local goddess "Bast") before them. As Cambyses advanced at once to Memphis, Pelusium probably surrendered itself immediately after the battle (Jakubiak, 2009). In 373 BC, Pharnazus
satrap of Phrygia, the city contained at the time a garrison of 5,000 Greek mercenaries under the command of Philopron. In 333 BC, Pelusium opened its gates to Alexander the Great, who placed a garrison in it under the command of one of those officers entitled Companions of the King. In 55 BC, again belonging to Egypt, Mark Antony, as cavalry general to the Roman proconsul Gabinius, defeated the Egyptian army, and made himself master of the city. In 48 BC, Pompey is murdered in Pelusium. In 31 BC, immediately after his victory at Actium, Augustus appeared before Pelusium, and was admitted by its governor Seleucus within its walls. In 501 AD, Pelusium suffered greatly from the Persian invasion of Egypt (Eutychius, Annal.). In 619 AD, Tell el Farama was attacked and conquered by a Persian army under Khuzran. In 640, Amr Ibn al-As (Muslim-Arab) had come to Egypt. The khallifs who ruled Pelusium following the crusades, then the harbor generally subjected to natural hazards, and from this epoch Pelusium, which had been long on the decline, now almost disappears from history.

Materials and Methodology:
Field work with Satellite SPOT and ETM images and available geologic and topographic maps helped for interpretation the structural movements to understand the geneses of the recent geomorphological features at Farama area. Deposition and erosion landforms are investigated. The author attended the digging elaborations and excavation dug in archaeological sites in years 2010 & 2011 and reached to 10m depth at 3.8 km south the recent Mediterranean shore line at the Farama old city (Pelusium) that arranged with other archaeological sites in E-W trend inside the target area. The published historical time-data are considered. We correlated the excavated and pits dug in archaeological sites with detailed topographic survey and elevations using (GPS and altimeter) of the sites and the surrounding substratum at the Mediterranean shore line. Field structural measurements done in the target site and construct a new structural map. A new geomorphological map prepared in the field with help of topographic and available geological maps as well as the Satellite SPOT images and digital elevation model.

Stratigraphy and Soil of the Study Area:
The study area, Sahl el Tina as a hole belongs to Quaternary age. From top to base, the sedimentary succession can be differentiated into recent beach deposits, alluvial conditions, marine, lacustrine, aeolian conditions and terraces of the deserted wadis (Said 1993).

The soils in Sahl el Tina is clay and silty loam level surface low-lying terrain and reached these soils have an Aquic moisture regime where the water table in many parts is closed to the surface. The parent material constitutes a matrix of Nile alluvium and lacustrine deposits sometimes mixed with aeolian sand deposits (Noaman et al 1987). Ali and Abd El Kawy (2007) studied soil profiles which reached to the water table level from 40 to 130 cm, only a profile closed to the study area reached to continuous many shells layer at 55 cm depth.

Fig. 2: a. The Pelusium Roman Theater after excavation and reconstructed on Tell el Farama in 2010 (eright).
Fig. 2: b. The cycles of deformations and civilization in the western side of Tell el Farama (left).
According to topography, Ali and Abd El Kawy (2007), classified the sand dunes in north Sinai (including the study area) into longitudinal dunes, low barchans, and high barchans and the sand sheets into lower and high topographic sand sheets level, but they not linked between their topographic classification and the structural geology. And they named the Sahl el Tina as lower terraces and high terraces. They divided the area into; marine, fluvo-marine and aeolian plains. The current search found their marine landform unites, lower terraces and lower dunes lay in the lower down throw of the major NE fault series; while, their aeolian landform lies in the high fault throw.

The inspection of litho-resistively cross sections by Ibrahim et al, (2004) reveals the presence of two main Quaternary aquifers. The first is the shallow sand aquifer (dune aquifer) and thickness ranging from 4.5 to 33m. Furthermore, this shallow aquifer is present in the form of a continuous layer in the south and disconnected in the north. The second is the deep sand aquifer that is represented by varying depth average 91m. This layer is interpreted as a coarse sand and gravel layer saturated with fresh water. There is a clayey unit spreads in the area and acts as an impermeable barrier between the shallow and deep aquifers with thickness increases towards the

**Geophysical Previous Mapping:**

Geophysical mapping of the area inside the northern limits of the Pelusium town, conducted from 2005 as part of a research project in the Polish concession, developed into a full-scale geophysical prospection project within the framework of a broader study aimed at reconstructing the urban layout of sites in the Nile Delta based on the results of geophysical research (Herbich et al 2009). The most intriguing structure in Pelusium (Tell el-Farama) discovered by the magnetic survey is a square building with round central chamber almost 35 m in diameter. The electrical resistivity survey has helped to clarify the plan of a number of Pelusium structures mapped by the magnetic method. An integrated approach to the prospection made it possible to identify the building material, whether red brick, mud brick or stone. In a number of cases, combined analyses of magnetic and resistivity images indicated which linear anomalies on the magnetic map reflected structures and which the spaces between structures (Herbich et al 2009).

A major NE-SW fault was defined by Neev (1975) as Pelusium Line in a model to explain the tectonic evolution of the Middle East and the Levantine Basin. It has been described as transcontinental sinistral shear. The Pelusium Line has been recently investigated by numerous workers (Stanley et al., 1996, Goodfriend and Stanley, 1999; Stanley et al., 2008 ) using different tools from deep and shallow geophysical studies to radio-carbon dating of certain shell types extracted from a series of cores. The semblages of radio-carbon dated core sections recovered at major ruins at coastal site on which an ancient port fortress by Stanley, et al (2008) whom stated that the late Holocene development of this margin surface is unusual in that it has been subject to important geologically recent uplift since the city's founding, in contrast to predominant subsidence and relative sea-level rise. Vertical tectonics resulted from displacement along the Pelusiac Line, a major structural feature several kilometers southeast of Pelusium. Pelusium, after approximately 800-850 AD, continued as a commercial center for an additional three to four centuries prior to its abandonment by the time of the Crusades. Submergence of the city on the delta margin by rise of relative sea level has been effectively countered by episodic fault-related uplift of this lower plain sector and continued sub-aerial exposure since Byzantine time. A geo-electrical survey was made by National Authority for Remote Sensing and Space Sciences, Egypt. (2011) across the Pelusium Line (Figure 3-a 6) as a part of the geotechnical studies (made for the sustainable development of the proposed Millennium City at East Port Said) revealed an observable lateral change (displacement) in one of the profiles that crosses the Pelusium Line, ERT-2 image (Fig. 3.5). The other two profiles show a distinctive change in depth (from ~ 15 in ERT-1 image to 34 meters in ERT-3 image) for the mid. resistant beds (1-10 ohm. m) that has been attributed to the presence of old coastal ridges (Figure 3-a) that are now buried under the exposed sand dunes. The physiographic units in Figure 3 are range from wet mud, sandy mud to sand as relics ends of sand dunes.

**RESULTS AND DISCUSSIONS**

**Structure:**

Tel el Farama is a northern neighbor to the Pelusium structural line which coincide on a regional NE-SW fault (named F 1 on Figure 4), it extended from about 9 km to the north east of Farama old city and reach to Qatara depression at about 60 km to the west of the Nile Delta (F 1 on Fig. 4), the Qatara depression may initiated as a result of fault series including this fault. This structural events affected by many faulting activities through the history coincide on F.1. Most probably it was the old Mediterranean shore line. Several evidences such as uplift and down-throw movements were found at the faults plane

Young active phases for NE-SW fault (F 1) with about 6m down throw affected on the configurations of the sand dunes systems in the area (Fig. 5). The altitude in uplifted area reach up to >20 asl to the SE of F1. There are patches of water bodies scattered in the land and patches of wet sabkhas at altitude 8 m scattered in the low land.

**Geophysics:**

Several evidences, among which the Neve fault (named F 1 on Figure 4) is the most important one, which initiated the uplift of the Pelusia town. This fault is clearly visible on the magnetic map and its throw is about 8 m. The throw of this fault is also observed in the electrical resistivity survey (ERT-2 image, Figure 3-6) as a part of a larger study aimed at reconstructing the urban layout of sites in the Nile Delta based on the results of geophysical research (Herbich et al 2009).

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Fig. 3: A geo-electrical survey made by National Authority for Remote Sensing and Space Sciences, Egypt. (2011) across the Pelusium line. The physiographic units ranges from wet mud (dark blue color), sandy mud (green color) to sand as relics ends of sand dunes (red and dark red colors).

On the hydrological map of Egypt which prepared by the Water Research Institute of Egypt (1999), it is found the water differentiation line separates between the saline water (Mediterranean seepage) and the extensive highly productive aquifers of underground water coincide with F1. Pelusium, line on structural map of Sinai prepared by Said (1990) also coincide with F 1. To the south of this fault, the Pleistocene rocks exposed on the geological map of Sinai (Egyptian geological Survey, 1992). This delineate the activity of this fault with northern down throw within the Quaternary.

This fault (F 1 on Fig.4) named by Hussein and Abd Allah (2001) as“Nile delta hinge zone” with northern downthrown subsurface fault. He draws it as nearly E-W. Keelye (1994) draw the fault as NE-SW and named it as”Trans African lineament “depositional tectonic phase 1 (in Mid-Cambrian to End-Devonian) With NW down throw which he named “the continental or non depression” It named by Neev (1975) as “Pelusium line” and “Nile delta Flexural zone”

In addition, this fault coincides with flexure zone by Kerdany and Cherif (1990) where they drew flexure zones in north Egypt. Cairo topographic map (1942) draw and postulated the Sahel Tina area as water area connected with the Mediterranean. North Sinai geological map (1992), Sahel el Tina Formation composed of mixture of black and white sands and silt and outcropped exposed in NE narrow belts separated by Al Qantra Formation composed of sand and grits with minor clay inter-bedding.

Inside the excavated archaeological sites, there are young phases of Holocene faulting activities on F 1 affected on the declined civilizations. Sliding-down movements in NW trend which yield normal faults and fracture cutting the exposed building
Around the excavated archaeological sites, there are young phases of Holocene faulting activities. A normal NE-SW fault separates between Quaternary carbonate rocks and sabkhas, sand dunes (and sheet) with 6m downthrow to the NW (Fig.6). Normal E-W fault with down throw 4m to the north sculpt the topography controlling different sand dunes patterns and separates between them (Fig.7). New Quaternary faulting activities with northern down-throw separated between old marine ridge (the strand lines) and down throwing the Quaternary silt which covered by Mediterranean water due to the lowering topography (Fig.8).

Fig. 4: General structural elements affected on the area plotted on Landsat TM image. F1 is the main fault with NW downthrown.

Geomorphology:
The recent landscape of Mediterranean coastal terrain in Egypt includes coastal landforms, structural landforms, and aeolian landforms. Figure 9 shows a new geomorphological map prepared in the field with help of topographic and geological available maps and the Satellite SPOT images. In the following, the interpreted geomorphological units and their significances discuss in brief.

Coastal Landforms:
Marine ridges (and strand lines):
The old Mediterranean E-W ridges altitudes of med. 1.8 m above sea level, these dry (old) marine ridges are wedged toward the west from 6 m width to 2m. They separate between several water bodies, wet lands, Tel el Farama and the Mediterranean Sea. Several strand lines (former shoreline) disturb the Sahl el Tina (including general depressions and separate between the land and the sea. These ridges strand lines composed mainly of clay, shale, sands and gravels beds inter-bedded by thin gypsum beds. These strand lines found in elongated shape, vary in topographic level from low in the inner zones (2 m a.s.l) to high in the outer (0.5 m a.s.l) indicating to the older Mediterranean water. The strand lines were well tied with the rise and fall in the older levels which happened very erratically with no regular pattern. Most probably these strand lines represent Mediterranean degradation phase. The strand line northeast of Farama city composed of siliceous carbonate loose conglomerate, myriads of carbonaceous root casts found on some ridges.

Salt and Water Bodies:
Salt bodies, exposed at 0.75 km from Mediterranean, extended in E-W trend with 8 km length and 3.5 km width. The shallow salt margins mixed with black mud, black sands and wet clay. Wide water bodies range from 0 to -6m thickness is formed due to Sahl el Tina subsidence under south the Mediterranean Sea. Some water bodies have red color due to high salinity (Fig.10).

Structural Landforms:
Sahl el Tina Depression:
Sahl el Tina plain is a structural depression covered by mud, salt, sands mixed with marine water (Figures 9 & 11). formerly was covered by Mediterranean water, it extended westward to the east of Nile Delta. This plain has the same altitude of Mediterranean but only separated by strand lines.
Fig. 5: Photograph shows sliding on Quaternary fault affected on the upper phase of civilization.

Fig. 6: (right and left). Photographs show sabkhas, sand dunes, and sand sheet are separated downthrown from Quaternary carbonate rocks by Quaternary fault.
Low Hills of Carbonate Rocks:

Low hills of Quaternary carbonate rocks exposed at 22 km south Mediterranean shore line. They form a NE-SW dissected chain with altitude reach up to 28 m above sea level. They are bale yellow hard rocks composed of carbonate minerals and marine valves. Their foot slopes covered by dry mobile sands (Figures 6 & 9). These layered carbonate rocks formed in marine sedimentary ecology in Pleistocene- Holocene time exposed facies looks like the Shagra Formation on Red Sea coast in Egypt. These carbonate rocks lie at the up-throw side of NE fault (F 1), where the altitude reach up to >20 asl to the SE of F1. There are patches of water bodies scattered in the land and patches of altitude 8 m scattered in the low land.

Aeolian Landforms, Sand Dunes and Sheets:

Sand dunes lies at 10 to 12 km to the south of Mediterranean shore line and arranged in different systems and thickness. The configurations of sand dune patterns are controlled by NE-SW faults with 6 meters NS down throw (Figures 7 & 9). This activity of a Quaternary fault represents the younger phase of NE-SW tectonic direction in this area. Sand sheets covered a wide area on the upper side of F1 and stretched to the east.

Civilizations and Catastrophic Implications:

Both the Sahl el Tina plain and the Mediterranean water level have more or less the same altitude. Only the Mediterranean separated from Sahl el Tina by strand lines (natural marine ridge, Fig. 9). The strand lines increases in its eastern part with marine deposits delineate to the Mediterranean Sea regression in Holocene cycles, while it decreases in its western part due to sea transgression because of the down-throw of F 1.

Old Nile Delta sedimentation had been deposited before Pharaoh Time, and then Pharaoh Era dominated for long time. catastrophic deformation process took place. From 1000BC to 720BC, the area covered (choked) by sands at the first Centenary of BC causing the Mediterranean Sea regression about 6 km to the north. The Pelusium's fortress can only be dated to the late sixth century AD (Herbich et al 2009), it arranged with other archeological sites in E-W trend. Graeco-Roman Era (Pelusium town and building with different materials) followed by deformation cycle from 33BC to 500 AD. Islamic Era refreshes the Pelusium town and constructs the Tell el Farama city on a relative elevated land and considered it as a huge trading center and travel. This followed by catastrophic deformation cycle from 870 AD to now.

In last decades, the archeological site has been declined by tectonic movements and covered by succession of Mediterranean transgression and regression four cycles with about 2 meters total thickness overlie the last civilization. This cover interactive between marine deposits and deformation cycles (Figures 13 and 14).

Evidences in recent decades, 1- the land subsidence gathered the Mediterranean and the terrain in one topographic altitude due to down throw movement. 2- In Sahl el Tina mud cracks movements, the mud fall to down after dry, this is opposite phenomena to the normal mud cracks (in other places) where the mud rise to up after dry (Fig. 12). 3- The historical events are recorded intercalated with periods of break. 4- The sea separated from lakes (water bodies) and sabkhas by natural marine ridge determine the older shore lines and delineate the regression cycles of the Mediterranean (Fig. 8).

From the above features, we can summarize the events passed on the Tel el Farama site (Pelusiuman) as on Figure 14 in the following:
Fig. 9: A new geomorphological map of the study area prepared in the field on the Satellite SPOT images (2011) with help of topographic and geological available maps.

Fig 10: Salt bodies at Sahl el Tina plain.

Fig 11: Sahl el Tina plain, mud, salt, sands covered and mixed with marine water.
**Fig. 12:** The mud (in mud cracks) is rising up in Sahl el Tina area (right photo), while in normal case the mud (in mud cracks) throw down in central Sinai (left photo).

**The Catastrophic Cycles and Implications on the Civilizations:**
In the excavated site, we found alternative between the civilizations and deformation cycles (Figures 2, 13 &14).
1. The old Nile Delta tributaries sedimentation before Pharaoh Time.
2. Pharaoh era.
3. Deformation cycle from 1000BC to 720BC. And the area covered (choked) by sands at the first Centenary of BC and the sea regressed about 6 km to the north.
4. Greco- Roman era.
5. Deformation cycle from 33BC to 500AD.
6. Islamic era.
7. Deformation cycle from 870 AD to now.

From geomorphological significances, the structural activities together with Holocene Mediterranean movements sculpted the geomorphological units. And now the recent geomorphological units integrated with structural active lines and elements to delineate the history of the area. In addition, the outcropped Pleistocene-Holocene carbonate rocks are geological evidences on the marine fluctuation through the Quaternary. And the old Mediterranean ridges with altitude 1.8 m above sea level separate between several water bodies, wet lands and Tel el Farama. These E-W dry marine ridges are events on the marine fluctuation through the Quaternary and on the land subsidence. The patterns configurations of mobile sand dunes are controlled by NE-SW faults with 6 meters NS down activities throw represents the younger phase of NE-SW tectonic direction in this area (Fig. 7).

**The Last Decades Terrain Declined:**
The wall of excavation pits in archeological sites illustrated the following succession from surface to down; 1- recent sediments 50 cm, 2-upper deformation cycle 65 cm, 3- marine sediments 35 cm, 4- lower deformation cycle 65 cm, Regenerated tectonic cycles calculated as each 400 years on NE-SW fault trends with about 3 meters NS down throw. Marine transgression and regression cycles had been followed up these tectonic movements. This succession covered the Farama old city after 870AD (i.e. from 1140 years) with about 2 meters total thickness in the excavation sites overlie the last civilizations.

The evidences from the field work on the subsidence of the archeological site and the neighbored Sahl el Tina east Nile delta (the area which restricted by major NE fault F 1 on Fig. 4) are; 1-We found the same altitudes for both the water in the sea and the lakes and sabkhas on the terrain. The measurements all the study area elucidated there is some land batches fall down under sea level to about 5m meters and filled with water.

**Recent Terrain Sliding and Subsidence:**
There are young phases of Holocene faulting activities on F 1 affected on the declined civilizations. On NE thrust fault, NW sliding-down movements yielded several small normal faults and fractures cutting the exposed building in the excavated archaeological sites (Fig. 4). This thrust fault is a one of fault swarms as steps of F 1.

In Sahl el Tina mud cracks movements, the mud fall to down after dry, this is opposite phenomena to the normal mud cracks (in other places) where the mud rise to up after dry (Fig. 12). The historical events are intercalated with periods of break (Figures 13,14 &15). The sea separated from lakes (water bodies) and sabkhas by natural marine ridge this reflect the older shore lines (Figures 9 and 11).

El Banna and Hereher (2009) stated that in area extends for 13.3 km east and west of the El Bardawil lake, the satellite TM images for 1986 and 2001, respectively. From these classified images, the land area on both
sides of El Bardawil is estimated as 7,827,970 m² in 1986 and 7,062,538 m² in 2001. The difference between the two dates indicates a net loss of landmass (erosion) of 765,431 m² in 15 years. The post classification change detection image reveals a total accretion of 310,219 m² with a rate of 20,681 m²/year, and a total erosion of 1,075,650 m² with a rate of 71,710 m²/year.

Fig. 13: The cycles of deformations from roman age era to Islamic era inside the excavation of archeological site.
Fig. 14: The cycles of deformations after hidden the Islamic era to the recent inside the excavated the archeological site marked on Fig. 10 by a box.

Fig. 15: Schematic diagram illustrates the sequences and direction of catastrophic events and phases on the Farama area in simple modeling of the locations and orientations of geological and historical events at Farama old city and locate the figures.

**Conclusion:**
This important archeological site subjected to major tectonic phases and climatic changes, three regional events implicated on the global civilizations. 1- Alternative cycles between the civilizations and the catastrophic movements. Three main catastrophic cycles were happened at 1000BC, 33BC and 870 AD and deformed
partially the civilizations. 2- In last decades, the terrain and civilizations had been declined in the historic succession. Mediterranean regression and transgression four cycles with about 2 meters total thickness overlies the last civilizations in the excavation sites. 3- Inside the excavated archaeological sites, there are young phases of Holocene faulting activities on F 1 affected on the declined civilizations. And sliding-down movements in NW trend which yield normal faults and fracture cutting the exposed building. Around the excavated archaeological sites, there are young phases of Holocene NE-SW faulting activities separates between Quaternary carbonate rocks and sabkhas, sand dunes with 6m down-throw to the NW. Normal E-W fault with down throw 4m to the north sculpt the topography controlling different sand dunes patterns and separates between them. New Quaternary faulting activities with northern down-throw separated between old marine ridge and down throwing the Quaternary silt which mixed by Mediterranean water.

We recommended that these tectonic movements should be in consideration when building on the area. The archaeological sites should be completely exposed and protected by surrounding cement walls.

REFERENCES


Water research institute, 1992. Hydrogeological map of Egypt ministry of public work and water resources of Egypt.