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ORIGINAL PAPER

Paleo-Tsunami deposits on the Red Sea beach, Egypt

El-Sayed Mohamed Salem

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Abstract The characteristics of the recent tsunami deposits threw light on some sources of deposition on the beach of the Red Sea. The studied area is delineated by latitudes 25°6′ N and 25°9′ N and longitudes 34°50′ E and 34°53′ E; it covers an elongate area of about 12 km^2 along the Red Sea coast, North Marsa Alam City (4 km). The area is bounded by Wadi Asalay to the north and Wadi Sifayn from the south. For evaluation of the area, a lot of information allows us to interpret the conditions prevailing during deposition of the sediments especially at the coast. To achieve the target, five wells were drilled to study core samples, well logging measurements, and 69 vertical electrical sounding stations were carried out. The studied area and adjacent areas were geologically surveyed to note geological features related to Paleo-earthquakes. From geological and geophysical studies, the dominant rock types at the western portions of the studied area are sandstone, sandy clay, clay, clayey sandstone, and gravels; at the middle portion of the studied area, the rocks are hard, but the eastern side of the area, especially at the beach of the Red Sea, several cycles of depositions of coral reefs occurred with intercalations of clastic deposits such as clay, sand, sandstone, conglomerate, gravels, pebbles, and a lot of fossils and shell fragments. The rocks are characterized by heterogeneous properties and ill-sorted. The area includes large numbers of faults due to highly tectonism of the area. The results indicated that the area has lateral variation of sediments. The carbonate rocks at the beach contain clastic fragments, and carbonate blocks are included within clastic rocks. With increasing the distance from the beach to the west, the sediments are less heterogeneous. The beach of the Red Sea was subjected to Paleo-tsunami waves due to highly Paleo-seismic activity inside the Red Sea and left their signature in geological column especially at the beach. The observation of some geological features such as Paleo-liquefaction and landslides indicate that the area subjected to strong earthquakes related to rifting of the Red Sea.

Keywords Paleo-earthqukes · Tsunami waves · Liquefaction · Landslide

E.-S. M. Salem (✉)
Egyptian Geological Survey,
Cairo, Egypt
e-mail: Sayedsalem2000@hotmail.com

Introduction

Bosworth and Taviani (1996) studied Quaternary coral reefs south of the Gulf of Suez relative to sea level changes. They found sands and sandy clay; gravels are deposited during uplift of coral reefs along the Red Sea coast. Purser et al. (1993) described a variety of deformational structures for Neogene sediments in NW Red Sea coast as a result of multiple earthquake shocks. They summarized types of deformations as liquefied soft sands, plastic folding, and fissuration of slightly consolidated mud, sands, and gravels and brecciation of lithified sediments. Plaziat and Ahmed (1993) studied the deformations in Pliocene sequence north of Marsa Alam city, between Wadi Egla and Wadi Samh, due to major earthquakes. They concluded that the deformation structures consist of slumping, local brecciation, and a faulted bed between non-affected beds. The present is the key to the past. On Nov. 22nd, 1995 Nuwaybi quake struck Aqaba region; the mainshock parameters are origin time 04:15:11.5 GMT, M_S=7.2, lat. 28.77° N, long. 34.709° E, depth, 8.04 its location within the Gulf of Aqaba. Basta et al. (1996) mentioned that a tsunami of 3 to 4 m in height hit Nuwaybi harbor at Gulf of Aqaba. Serious damage was observed in the harbor's platform. Recent fractures (7 and 8 in Fig. 6) are observed offshore and inshore in some places at the Gulf of Aqaba. Tsunami destroyed the Bedouin dwellings (Abel Aziz et al. 2007). Maamoun et al. (1984) studied Shadwan earthquake which occurred March 31, 1969 in the mouth of the Gulf of Suez. They stated that landslides, earth slumps, and rock falls were observed at Shedwan Island itself. Fissures and secondary cracks in soil were observed south of Shedwan; at the tip of Sinai (Ras Mohamed), there are large fractures due to Shedwan earthquake which extend from sea to land, as shown in 6 of Fig. 6. The sea became suddenly stormy; the effects of the earthquake reaches Marsa Alam at the south and Port Said city which is located on the north of Egypt. The forgoing observations indicate how the recent activity of two small arms of the Red Sea affect the adjacent areas and left damage effects, so the Paleo-earthquakes within the Red Sea which relate to rifting of the Red Sea were more serious and left signatures on the geological column.

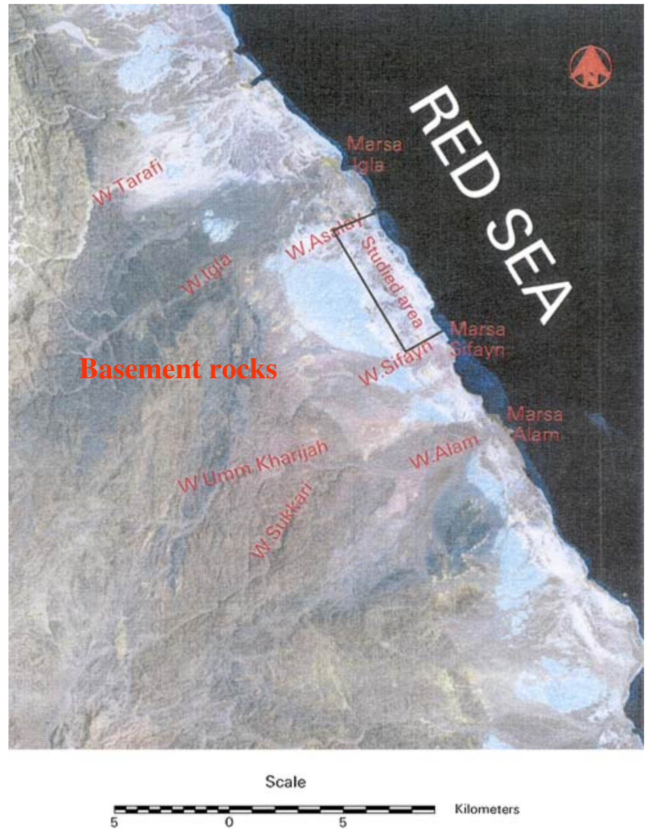


Fig. 1 *1* Landsat (TM image) of the studied area and adjacent areas (Salem 2000)

Stratigraphy

The area under consideration (Fig. 1) has been studied by many authors. The rock units exposed in the area (Fig. 2) from base to top (Akkad and Dardir 1966) are:

1. *Abu Dabbab Formation* has limited extension in the area under investigation. It is exposed at some small parts at the western portion, with the beds dipping to the east. It represents an evaporite series, deposited under arid climatic conditions, intercalated with detrital materials. It underlies Samh Formation. The age of this formation is Middle Miocene.
2. *Samh Formation* forms the core of anticline folds or a part of monoclinic in the studied area. This formation which covers a large area occupies the western portion of the studied area. The beds of this formation are soft and medium compact, forming the slopes of escarpments. Samh Formation is made up of marl, sandstone, clay limestone, and conglomerate. The age of this formation is Mio-Pliocene.
3. *Gaber Formation* occupies the middle and west of the northern portion of the studied area. It is characterized by high hills at the middle of the area. It conformably overlies Samh Formation. It has hard rocks which resist weathering actions; it is considered as flanks of folds either anticline or syncline in the area. The estimated age of this formation is Pliocene. Gaber Formation is represented by sandstone, marl, conglomerate, and oolitic limestone.
4. *Shagra Formation* conformably overlies the Gaber formation. It is characterized by hard coralline bed at the base and is more calcareous and fossilifereous than Gaber Formation. It is distributed parallel to the Red Sea coast. The extension of its outcrops depends on the structure, deposition of younger sediments, and weathering elements. The age of the formation is Pliocene. The formation consists of sandstone, marle, clay band, conglomerate, and reefal limestone (hard, crystalline, fossilifereous, porous, and sometimes contains gravels, cavernous full of other materials).

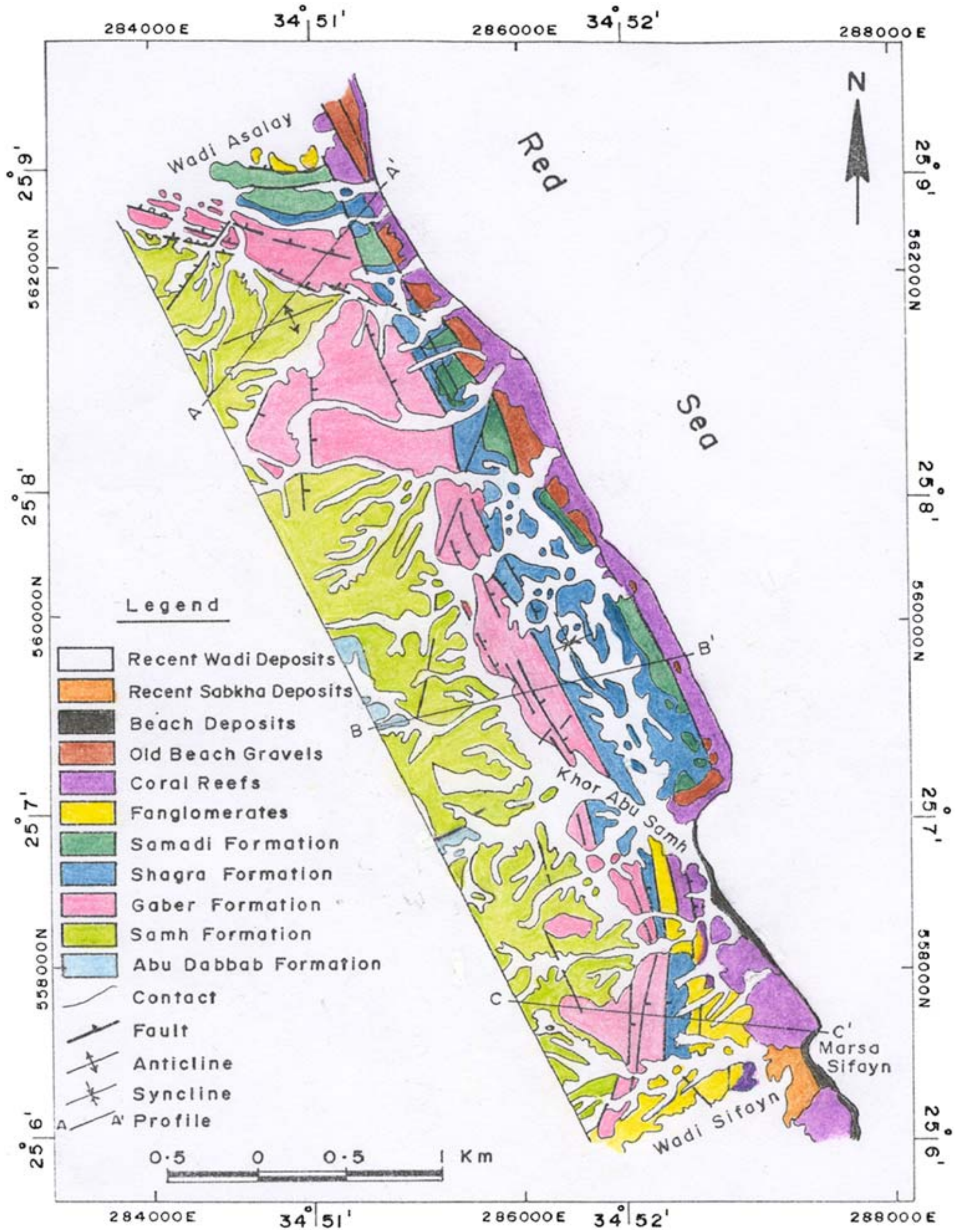


Fig. 2 Geological map of the concerned area (EGSMA 1998)

5. *Samadi Formation* is considered to be the upper part of Shagara Formation (Akkad and Dardir 1966). Its thickness ranges from 21 to 32 m. The type locality existed at Marsa Samadi, south of Marsa Alam. The formation has limited distribution in the detailed studied area. This formation is characterized by low hardness, so the erosion factors affect it greatly. The age is Pliocene–Pleistocene. It consists mainly of gravels with small intercalation of sandstone and limestone.

6. *Fanglomerat, Sabkha, and Wadi deposits* are represented by rock fragments, sands, sandstone, gravel, and clay. At the last, coral reef rocks consist of reefal limestone with calcareous sandy silt pockets. Cross-section along three profiles are located in the map as shown in Fig. 2, illustrating the relationship among different formations and topography (Fig. 3). The following table was prepared to summarize the lithological characteristics of the formations according to Issawi et al. (1999):

Formation	Lithology	The lithological characteristics
Abu Dabbab	Thick massive gypsum beds with thin intercalations of marl, limestone and sandstone.	The presence of marine incursions in the north of the study area, while at the south, gypsum with no or very thin marine bands and circulation of sea water associated with arid conditions were prevailing. Reefs developed offshore resulted in the creation of lagoons separated from the sea except through narrow inlets.
Samh	Marl, sandstone, shale, and rare limestone bands.	Igneous and metamorphic pebbles, subangular quartz and feldspar grains, 0.02 to 0.06 mm in size are included in sandstone, interformational conglomerates of common occurrence, the arkosic sandstone which predominate at the southern part of the Samh area represent a rapid burial in a subsiding fault trough.
Gaber	Sandstone, fossiliferous marl, oolitic limestone and conglomerate	The sandstone is arkosic and partly calcareous including angular to subangular quartz and feldspar grains. The conglomerate is formed of subrounded to rounded igneous and metamorphic pebbles and cobbles. High energy environment. Tidal bars. The frequent presence of rhodophytes and corals indicates relatively open marine conditions.
Shagra	Sandstone, marl, reefal limestone, calcareous grits, conglomerate and gravel beds	The sandstone is fine to coarse-grained, ill-sorted and granitic pebbles embedded in a matrix of faint brown iron-stained calcite; the Shagra is mostly interbedded conglomerates and sandstones with minor limestone bands. The lithotope consists of poorly sorted angular to subangular gravels and boulders derived mainly from the Precambrian basement hills and reworked Neogene carbonate clasts floating in a sandy matrix.

Topography

Several topographic features characterize the concerned area, such as plains, plateaus, hills, escarpments, and wadis (Fig. 4). The highest altitude reaches about 59 m above sea level. Generally, the area is characterized by great varieties of topographic features; accordingly, it is easy for the geologist to note the geological features related to Paleo-earthquakes from the outcrops of the formations without trenches.

Structure

The area was affected by high level of tectonism relating to the Red Sea rift. Accordingly, the structural pattern is represented by several faults with predominant trend of NNW–SSE and anticlinal and synclinal folds, as shown in Fig. 5. In spite of the studied area having a small area, it includes many structural elements (faults and folds).

Drilled wells

Several wells were drilled (Fig. 4) in the area under investigation to achieve several targets such as identification of lithology (Tables 1, 2, 3, 4 and 5; Salem 2000), clarifying the physical properties of rocks and study of the properties of core samples. The results indicated rapid variation of sedimentation cycles at the beach of Red Sea. The beds include high quantities of fossils and shell fragments, cavernous rapid deposition and poor sorting, in addition to the occurrence of Paleo-liquefaction phenomenon of Pliocene in well no. 2 (western side of the map) at a depth of 48 m from the surface, as shown in 1 of Fig. 6. Also, at the same region, Paleo-landslides were observed at several sites. All the mentioned criteria indicate Marsa Alam region and adjacent areas near the Red Sea coast subjected to very seismic activity due to rifting of the Red Sea. The sources of Paleo-earthquakes were not far from the concerned area, and some of them originated from the bottom of the sea; the opportunity to originate tsunami waves was available several times to deposit Paleo-tsunami deposits (the characteristics of the deposits near the Red Sea beach are the same facies of recent tsunami deposits). Observed liquefaction shows the epicenter near the studied area. The question is: does a liquefaction phenomenon indicate tsunami deposits at any area? The answer is no. The liquefaction indicates that an earthquake struck the area.

Geophysical study

The electric method in the present study is represented by vertical electrical sounding using Schlumberger configuration. The electric method depends on electrical properties of rocks which are related to the lithology. The resistivity contrast between the subsurface layers reflects the geological boundaries; in turn, it gives the subsurface lithology.

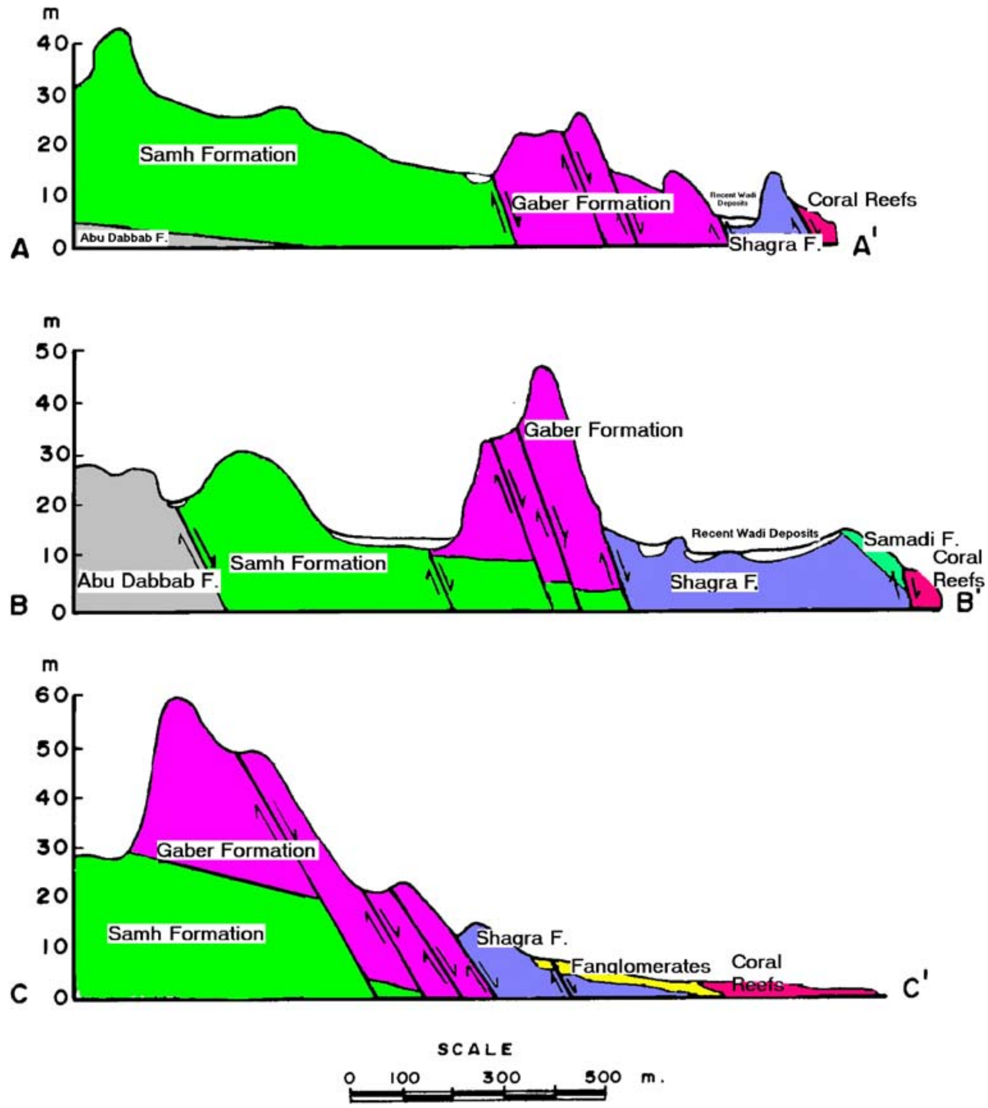


Fig. 3 Cross-section along three profiles, their locations in foregoing map

Four geo-electric cross-sections were constructed along the concerned area: these are A-A\, B-B\, C-C\, and D-D\, as shown in Fig. 7. The first geo-electric cross-section (A-A\) consists of four units: the surface unit (3.7–1,234 Ω m) which corresponds to alluvium and wadi deposits. The second unit (1.0–30 Ω m) corresponds to clay and clayey sandstone. The third unit (1.5–4.4 Ω m) corresponds to clay, sandy clay clayey sandstone, marl, and gypsum intercalations. The fourth unit (39–90 Ω m) corresponds to gypsum layers. The second geo-electric cross-section (B-B\) covers Gaber outcrops; it includes four units. The surface unit (1.8–771 Ω m) corresponds to sandstone, conglomerate, and limestone. The second unit (4.0–17 Ω m) corresponds to sandstone, limestone, and marl. The third unit (0.5–16 Ω m) corresponds to clay, sandy clay, sandstone, clayey sandstone, and limestone. The fourth (22.6–53 Ωm) corresponds to gypsum layers. The third geo-electric cross-section (C-C\) covers coral reefs and the Shagara Formation. This section is characterized by an abundance of limestone with lateral variation as a result of the intercalation of clay and sand. The fourth geo-electric cross-section (D-D\) is located at Red Sea beach. It is characterized by gravels at some locations and limestone with lateral variations as a result of the intercalation of clay and sand or occurrence of clastic rocks which contain carbonate rocks. The carbonate rocks have low density and high porosity due to the occurrence of fossils and shell fragments; they are characterized by heterogeneous properties and the thicknesses of rocks are highly varied. The geo-electric cross-sections are complicated (a lot of faults, rapid sedimentation, and the variation of thicknesses).

Salem (2000) stated from interpretations of different geophysical methods (magnetic, electric, seismic, and well logging measurements) several cycles of uplifting and

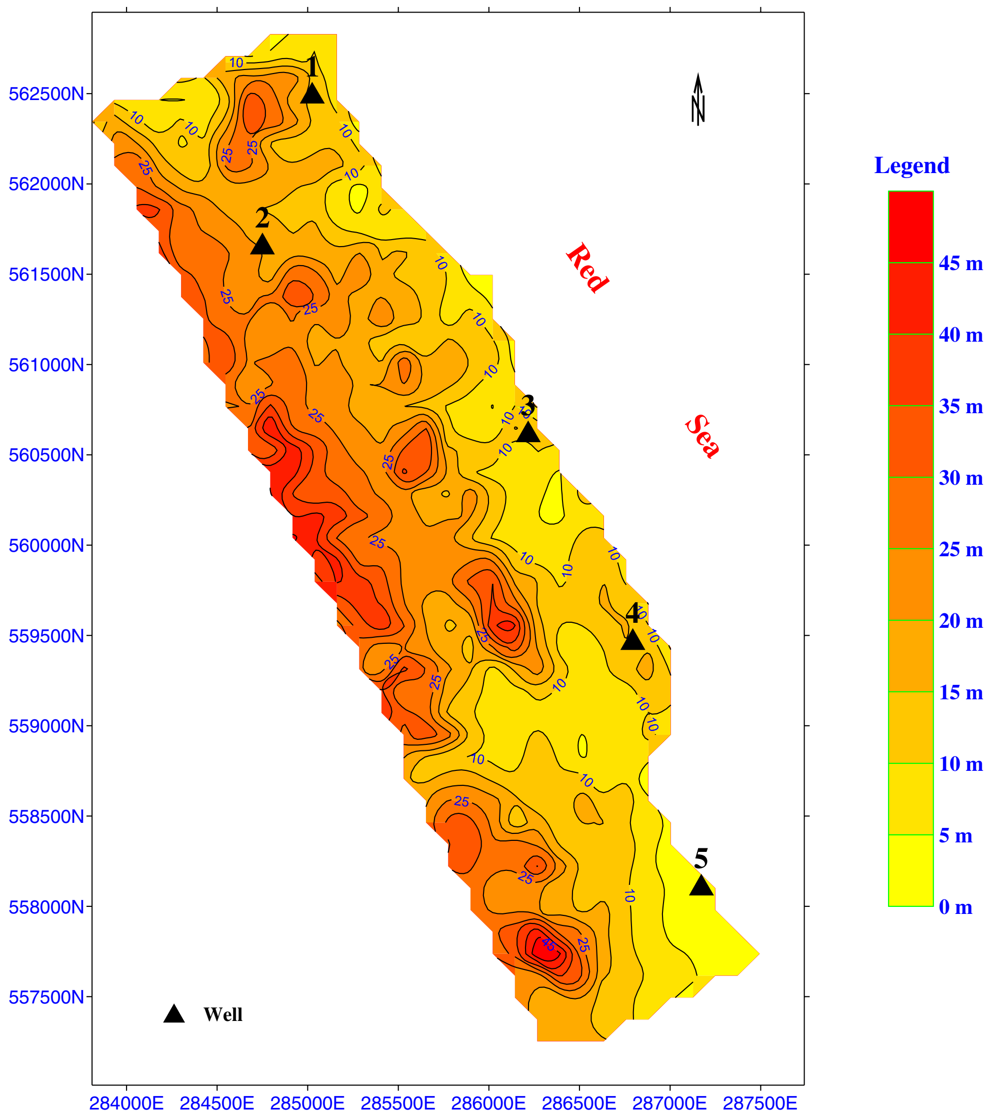


Fig. 4 Topographic map and wells of the studied area

subsidence of coral reefs of Red Sea beach at the Marsa Alam area. These uplifting cycles did not occur for all the area, but some parts subjected to subsidence and others were uplifting. Carbonate rocks interrupted several times to deposit clastic deposits. The rocks in the Marsa Alam area are characterized by heterogeneous properties, and the carbonate rocks have low density because these rocks contain fossils and clay intercalations and are characterized by lateral variation. Generally, the rocks at the concerned area have high secondary porosity and low compressive strength. The failure occurred at the weakness points during compressive and tensile tests such as at the lateral variations of lithology and joints. The depositional signatures indicate that tsunami tidal waves struck the area. Dawson and Stewart (2007) summarized generic diagnostic criteria of offshore palaeo-tsunami deposits from different sources (Table 6; Ballance et al. 1981; Takashimizu and Masuda 2000; Massari and D'Alessandro 2000; Cantalamessa

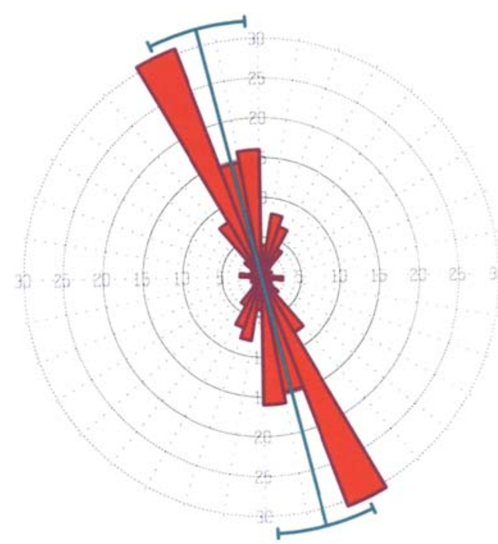
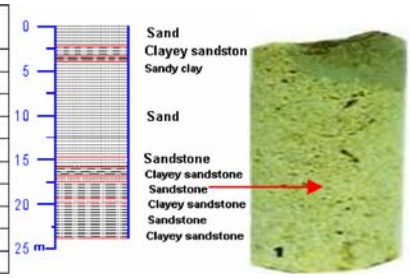


Fig. 5 Rose diagram representing major and minor fault trends (Salem 2000)

Table 1 The depth and thickness of rocks for well no. 1

Rock type	Depth (m) from	Depth (m) to	Thickness (m)
Sand	0	2.3	2.3
Clayey sandstone	2.3	3.4	1.1
Sandy clay	3.4	4.15	0.75
Sand	4.15	14.75	10.6
Sandstone	14.75	15.9	1.15
Clayey sandstone	15.9	16.9	1.0
Sandstone	16.9	17.5	0.6
Clayey sandstone	17.5	19.5	2.0
Sandstone	19.5	20	0.5
Clayey sandstone	20	24	4.0



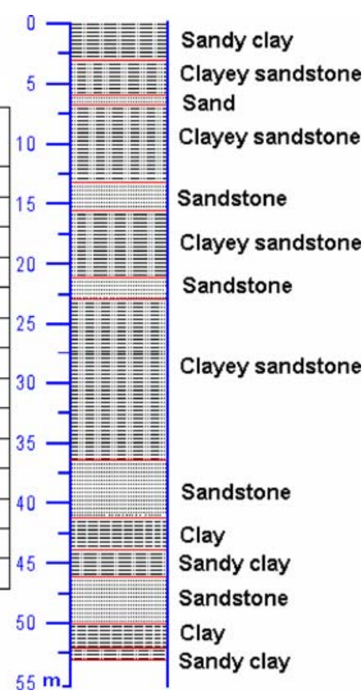
and Di Celma 2005; Le Roux and Vargas 2005; Fujino et al. 2006; D. R. Tappin, personal communication). They stated "Unusually coarse sediment compared with the overlying and underlying deposit. The bed includes many exotic fragments (e.g., plants, coconuts, beach rock, corals) from beach environment, which are absent from the overlying and underlying deposits. Admixture of clasts—poorly sorted angular clasts mixed with well-rounded beach pebbles and beach sands Indicates erosion from shoreface and emergent coastal environments (beach, talus slopes at cliff bases, nearby alluvial fans etc.) A liquefied zone below or in the lower part includes rip-up clasts, injection and deformation structures indicates very high dynamic pressures from vibration and rapid deposition. Irregular undulating erosional base, and flatish top (tempestites mainly have mostly sharp, flat-ish bases and irregular upper surfaces). Erosion by strong currents in the early upflow stage results in irregular infilling of a scoured substrate (rather than irregular aggradation under combined-flow conditions typical of storms), Condensed mud or organic bed in the upper part Deposition from water with a high mud content and with large amount of organic debris washed. Good–excellent preservation of fossils indicates rapid deposition and minimal reworking".

Paleo-geological features

In general, soil liquefactions and landslides are natural phenomena related to earthquakes; they are fossils of

Table 2 The depth and thickness of rocks for well no. 2

Rock type	Depth (m) from	Depth (m) to	Thickness (m)
Sandy clay	0	3.2	3.2
Clayey sandstone	3.2	6.0	2.8
Sand	6.0	6.7	0.7
Clayey sandstone	6.7	13.5	6.8
Sandstone	13.5	15.7	2.2
Clayey sandstone	15.7	21.2	5.5
Sandstone	21.2	23.0	1.8
Clayey sandstone	23.0	36.6	13.6
Sandstone	36.6	41.3	4.7
Clay	41.3	43.8	2.5
Sandy clay	43.8	46.1	2.3
Sandstone	46.1	50.0	3.9
Clay	50.0	52.0	2.0
Sandy clay	52.0	53.0	1.0



Paleo-earthquakes. Recently, Salem et al. (2003), as a trial, estimated the maximum distance to liquefaction sites at Nuwaybi region due to Aqaba earthquake 1995 (near the beach where the conditions are suitable) to range from 35 to 45 km with magnitude m_b=6.1, while the maximum distance due to Dashour earthquake 1992 is nearly 25 with m_b=5.8, so Paleo-liquefaction phenomena were observed near the beach of Red Sea (1 and 2 in Fig. 6) to note that an earthquake which hit the area either originated from the land or the bottom of the sea. During the field trips, it was found that the landslide phenomenon has occurred as a result of the change from unequilibrium case to attain an equilibrium one due to earthquakes because earthquakes play an important role in triggering landslides. Identification of Paleo-landslide north Marsa Alam (3–5 in Fig. 6) was carried out by certain criteria such as remains of formations (5 in Fig. 6), dipping of strata, and lithology. The occurrences of these features indicate that the area is characterized by high Paleo-seismic activity.

Conclusions

Flash flood and tsunami waves were two factors of deposition on the beach of the Red Sea. The first ran from the west (basement mountains where high topography) to the east through ancient wadis and the second originated from the bottom of the sea directed to the west. The lithological characteristics of recent tsunami deposits were similar to the lithological characteristics of sedimentary rocks at some parts of the beach of the Red Sea, such as lateral variation of sediments (interpreted electrical survey and core samples). The sedimentary rocks are characterized by heterogeneous properties and are ill-sorted, there are

Table 3 The depth and thickness of rocks for well no. 3

Rock type	Depth (m) From	to	Thickness (m)
Conglomerate	0	3.0	3
Sand	3.0	3.6	0.6
Sandy clay	3.6	11.8	8.2
Limestone	11.8	12.3	0.5
Sandstone	12.3	16	3.7
clayey limestone	16	19.4	3.4
Limestone	19.4	23.2	3.8
clayey limestone	23.2	25	1.8
Limestone	25	26.1	1.1
clayey limestone	26.1	29.1	3
Sandstone	29.1	30.3	1.2
clayey limestone	30.3	31.9	1.6
Clayey sandstone	31.9	33.5	1.6
clayey limestone	33.5	37.8	4.3
sandy clay	37.8	39.2	1.4
Clay	39.2	40.3	1.1
Limestone	40.3	42.6	2.3
sandy clay	42.6	44.4	1.8
Clay	44.4	45.2	0.8
clayey sandstone	45.2	46.2	1
Sandstone	46.2	50	3.8
Limestone	50	51.4	1.4

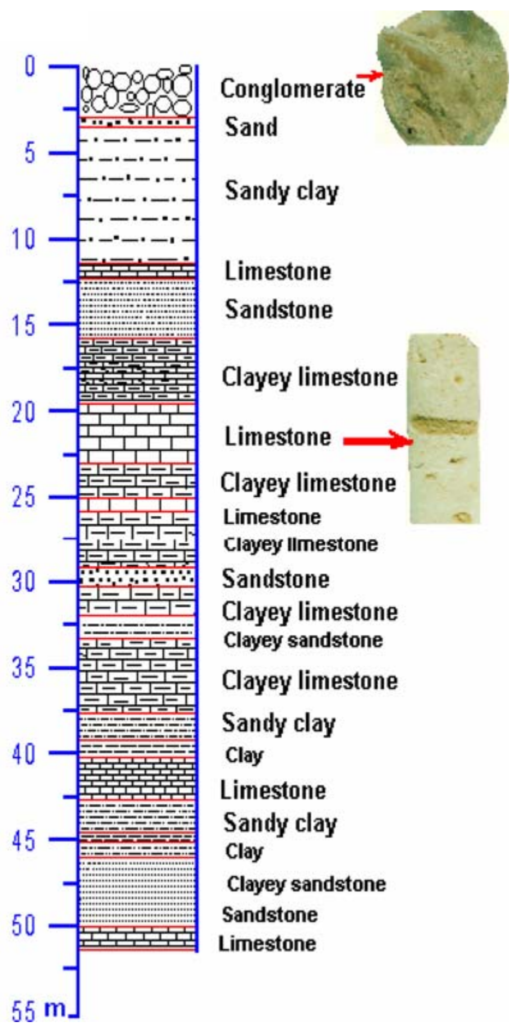


Table 4 The depth and thickness of rocks for well no. 4

Rock type	Depth (m) from	Depth (m) to	Thickness (m)
Gravels, pebbles and sand	0	1.3	1.3
Moderately hard fossiliferous Limestone	1.3	2.7	1.4
Sandy clay with pebbly sand	2.7	5.3	2.6
Reefoidal limestone	5.3	12.7	7.4
Beach sands with shell fragments	12.7	13.3	0.6
Clayey sandstone	13.3	15.1	1.8
Sandstone	15.1	17.3	2.2
Sandy clayey limestone, highly fossils, cavernous, low specific gravity	17.3	20.6	3.3
Sandy clay	20.6	22.8	2.2
Clay	22.8	23.8	1.0
Sandy clay	23.8	25.5	1.7
Clay	25.5	26.2	0.7
Sandstone	26.2	27.7	1.5
Sandy clay, moderately hard , shell fragments	27.7	32	4.3
Sandstone	32	33.3	1.3
Sandy clay	33.3	35.7	2.4
Sandstone	35.7	38.8	3.1
Sandy clay	38.8	43.5	4.7
Sandstone	43.5	45	1.5
Sandy, clayey limestone	45	46.2	1.2
Sandy clay	46.2	53.5	7.3
Sandstone	53.5	58.2	4.7
Clayey sandstone	58.2	61.8	3.6

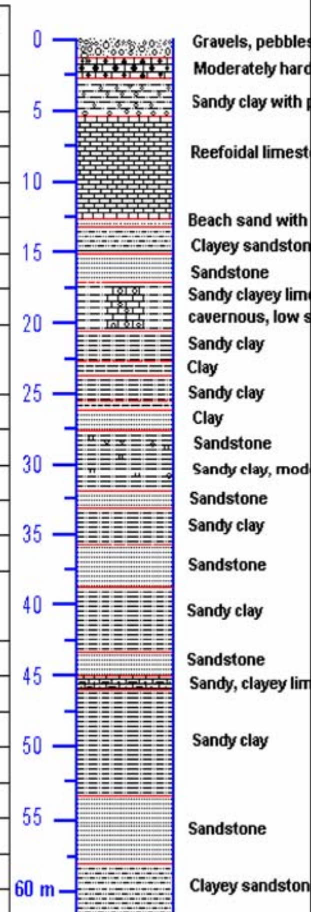
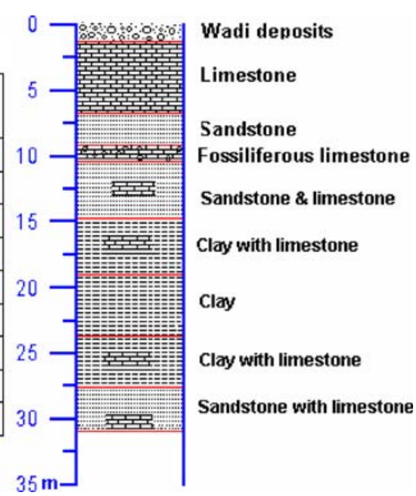


Table 5 The depth and thickness of rocks for well no. 5

Rock type	Depth (m) from	Depth (m) to	Thickness (m)
Wadi deposits	0	1.4	1.4
Limestone	1.4	6.8	5.4
Sandstone	6.8	9.2	2.4
Fossiliferous limestone	9.2	10.3	1.1
Sandstone & limestone	10.3	14.9	4.6
Clay with limestone	14.9	19.1	4.2
Clay	19.1	23.9	4.8
Clay with limestone	23.9	27.8	3.9
Sandstone with limestone	27.8	31.0	3.2



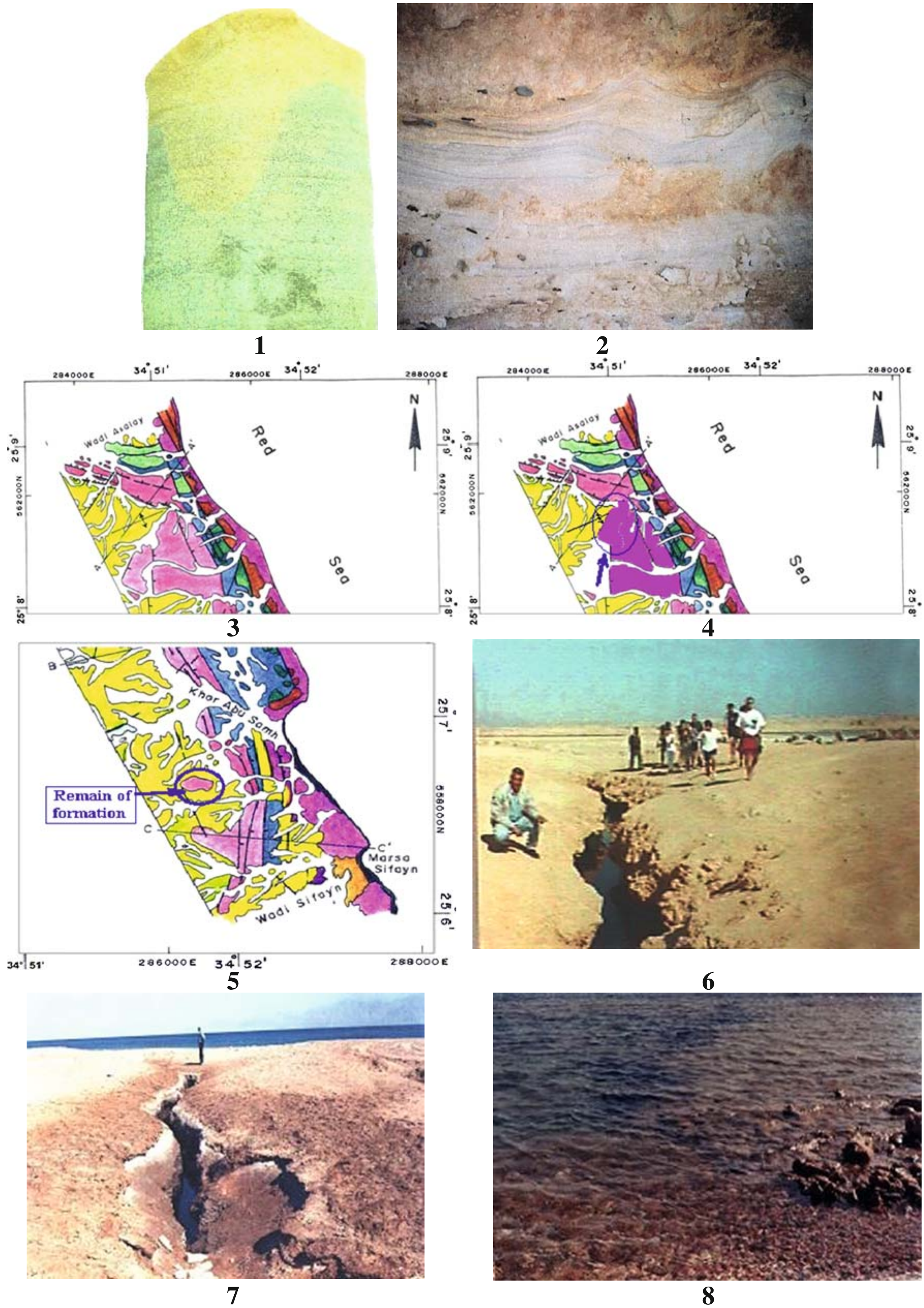
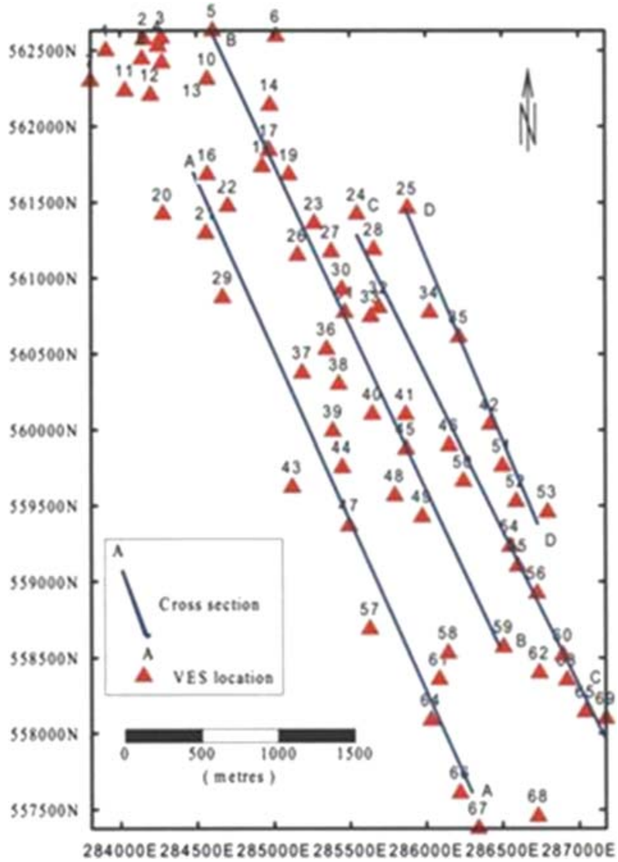


Fig. 6 *1* Subsurface Paleo-liquefaction phenomenon at depth 48 m from the top of the well no. 2 at North Marsa Alam area. *2* Surface Paleo-liquefaction at the beach at South Marsa Alam area. *3* Block of oolitic limestone (Gaber Formation) slid at the Marsa Alam area. *4* Restored block before sliding. *5* Paleo-landslide evidence representing by remain patches of Gaber formation within Samh Formation (Gaber Formation overlies Samh Formation). *6* Fracture due to Shedwan earthquake, 1969 at Ras Mohamed (tip of Sinai). *7* and *8* Fractures due to Aqaba quake

Fig. 7 *1* Location map of geo-electric cross-sections (Salem 2000). *2* Geo-electric cross-section along profile D-D\. *3* Geo-electric cross-section along profile C-C\. *4* Geo-electric cross-section along profile B-B\. *5* Geo-electric cross-section along profile A-A\



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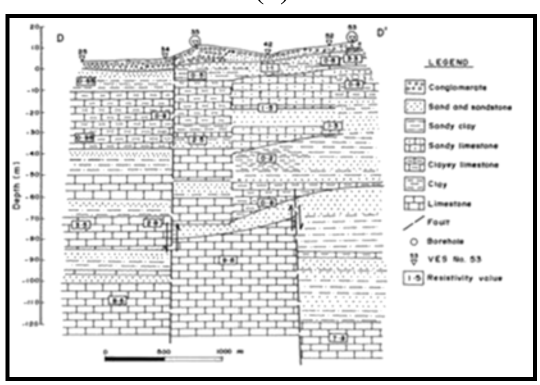

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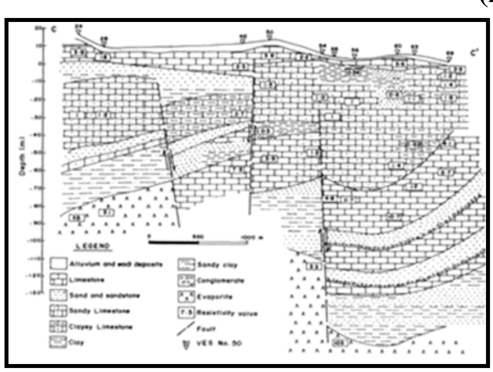

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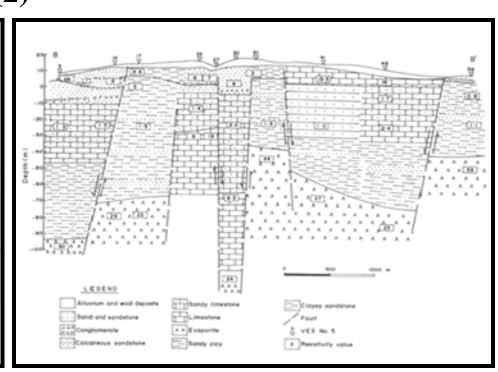

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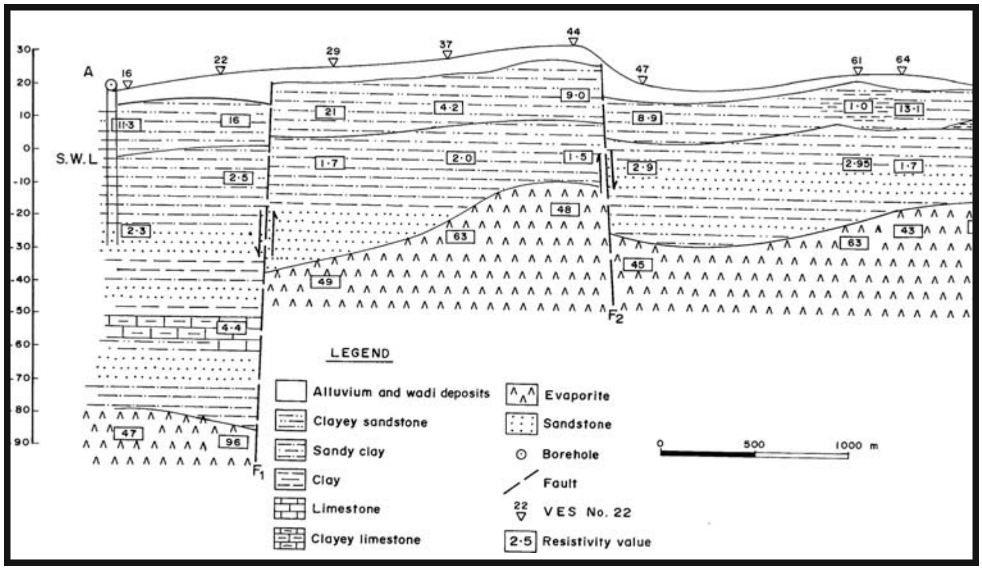

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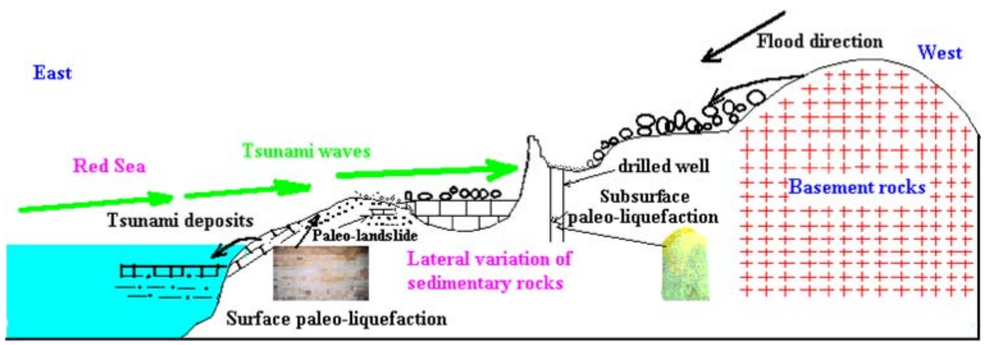

Fig. 8 Rapid variation of sedimentation cycles with different thicknesses at the beach of Red Sea in addition to Paleo-geological features

Table 6 Criteria of Paleo-tsunami deposits after Dawson and Stewart (2007)

Characteristics	Interpretation	Source
Unusually coarse sediment compared with the overlying and underlying deposit	i.e., The bed is an 'event horizon'	1, 4
The bed includes many exotic fragments (e.g., plants coconuts, beach rock, corals) from beach environment, which are absent from the overlying and underlying deposits	An unusual influx from a subaerial source	2, 6
Admixture of clasts—poorly sorted angular clasts mixed with well-rounded beach pebbles and beach sands	Indicates erosion from shoreface and emergent coastal environments (beach, talus slopes at cliff bases, nearby alluvial fans, etc.)	4
A liquefied zone below or in the lower part includes rip-up clasts, injection and deformation structures	Indicates very high dynamic pressures from vibration and rapid deposition	2, 5
Irregular undulating erosional base, and flatish top (tempestites mainly have mostly sharp, flatish bases and irregular upper surfaces)	Erosion by strong currents in the early upflow stage results in irregular infilling of a scoured substrate (rather than irregular aggradation under combined-flow conditions typical of stroms)	6
Inversely-directed imbrications: Paleo-currents alternate between landward and seaward directions	A long period of oscillatory current reversals	2, 3, 6
Cross-stratification includes mud drapes	Deposition from calm conditions during long-period oscillatory flows	2
Bed geometry should be more sheet'-like [rather than the typical pinch-and swell (hummock-and-swale) of tempestites]	Widespread runout (rather than substrate mobilization by short-period storm waves)	7

Table 6 (continued)

Characteristics	Interpretation	Source
Inverse- to normally graded coarse-grained, clast-supported basal 'carpet'	Initial deposition via basal traction flow followed by late-stage settling of coarser material from a laminar, inversely graded debris flow	4
Condensed mud or organic bed in the upper part	Deposition from water with a high mud content and with large amount of organic debris washed from the land	6
Scour-and-grading structure	Stagnant and brisk flow velocities alternated repeatedly	6
Antidune-like deposits (?)	Deposited from relatively thin but high velocity backwash flows	7
Multiple upward-fining units	Transport energy decreases with time during deposition of the tsunamiite-multiple units reflect successive waves	4
Bioturbation is absent in the bed, although this is common in the overlying and underlying deposits	Rapid deposition from strong currents	2
Good–excellent preservation of fossils	Indicates rapid deposition and minimal reworking by later stroms, longshore currents and other processes	6

occurrences of fossils and shell fragments, low values of the thicknesses of sediments, clastic rocks which contain carbonate rocks, and sometimes the last are included within clastic rocks (core samples). The observation of Paleo-geological features (Paleo-liquefaction phenomena) in the area shows that the area suffered from Paleo-seismic activity, its sources from the land and the sea.

The following model (Fig. 8) shows tsunami waves, accordingly, tsunami deposits at the beach of the Red Sea, flood direction and its deposits from the west to east, geological features related to earthquakes as indication of severe Paleo-seismic activity starting from Miocene. There are geological features reserved in geological record such as subsurface Paleo-liquefaction at the west (Samh Formation), Paleo-landslide at the middle (Gaber Formation), and surface Paleo-liquefaction (Pleistocene) at the east.

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