Natural hazards mapping of mega waves on the NW coast of Egypt

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Abstract: **Some boulder fields were deposited by the sea waves during winter storms or by paleo tsunami mega waves and most of these boulders were uprooted from the marine platform and distributed within 90 m of the shoreline, are found up to 4 m above present mean sea level.**

The objective of this work is defining systematic characterisation of the high-energy depositional contexts working by storms or paleo tsunami deposit, and to reconstruct the history of mega block deposition along the study area, depends upon extensive field surveying and geomorphic mapping by using GIS and GPS techniques as well as statistical analysis of boulders in order to determine both extreme events using the significant wave height and period of maximum observed storms and historical tsunamis along the study area, as well as geomorphic hazard mapping and samples dating.

The results show that both possible processes (storm and tsunami waves) can deposit these boulders, it attested at Alexandria for example by the archaeological excavations and historical sources. Tsunami waves and storms cause the displacement of huge boulders from sea bottom and submersible marine terraces (platforms) to the beach due to its major power and ability of carving and graving it is also capable of pulling other boulders from the land and redeposit it on the beach or coastline.

1. INTRODUCTION

The study area forms a belt about 20 Km deep, which extends for about 500 Km of the NW coast of Egypt on The Mediterranean Sea between Alexandria City and El Sallum town near the borders with Libya “Fig.1”.

The objective of this work is defining systematic characterisation of the high-energy depositional contexts working both on the type of storm or paleo tsunami deposit and the different geomorphological contexts, and to reconstruct the history of mega block deposition along the study area, using chronostratigraphy methodology, it will aid in evaluating the risk of submersion in an area that is affected by storms and tsunamis. The consequences on the occupation of the coastline are important, such as the destruction of Alexandria’s ancient lighthouse, as well as dating of mega blocks characteristic of high-energy events (storms or tsunamis) using fixed marine bioconstructions, to evaluate sedimentological impacts and natural hazards associated with these events (submersion, coastal mobility, erosion, high-energy impacts).

Figure 1. Location map of the study area

2. SETTING

2.1. Geology

The coastal plain of the study area is consists of three Pleistocene calcareous ridges parallel to the coast and separated by flat-bottomed depressions. The ridges sediments are composed of well sorted medium grained aragonic ooids sands. The cliffs of the Middle Miocene table run parallel to the coast. A discontinuous series of dunes develops at a distance varying from the coast to 2 Km deep. There are some saline depressions and sabkhas in the lower part of the plain, some with outlets to the sea. The escarpment of the plateau is deeply cut by wadis.

2.2. Geomorphology

The previous geomorphologic studies of the northwest coastal plain of Marsa Matruh area as a part of the northwest coastal plain of Egypt show that the origin of the extended calcareous ridges could be grouped under three environmental conditions as follows:

- Continental environment (Hilmy, 1951).
- Marine environment (Anwar et al.,1981).
- Maine/ continental environment (El-Shazly et al., 1964 ; Selim, 1974 & Torab, 1984).

But sea waves were able to erode the first calcareous ridge in some parts of the study area and therefore the second ridge found on the coastline directly and affected by coastal erosion at the moment.

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2.3. Climate

Average annual wind directions graph “Fig. 2” indicates that most wind blow toward the NW coast of Egypt from NW & NNW directions. Offshore wind speed at 50 m a.g.l. of Egypt “Fig.3” show that The NW coast of Egypt is lies in the most offshore wind speed in the Mediterranean region, its speed range between 6-7 m/s (determined by meso scale modelling, Wind atlas of Egypt, by Mortensen, et al., 2006).

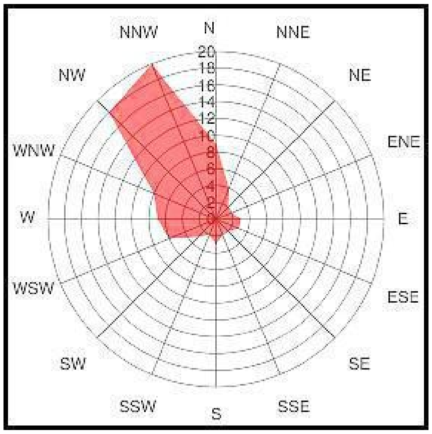

Figure 2. Average annual wind directions in Marsa Matruh city between 2001/2011

(Data source: www.windfinder.com)

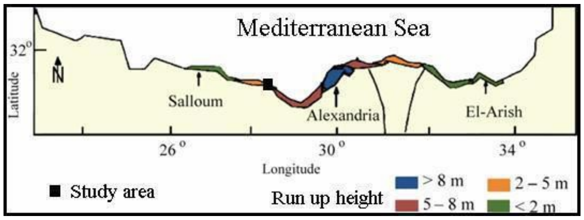

Figure 3. Run up height along the Egyptian Mediterranean sea coast (After: Hamouda, 2006)

3. METHODS

This paper depends upon detailed geomorphological field surveying, 578 boulders have been measured in eight selected sites of the study area, the boulders measurements were chosen on 11 elongated sectors “Tab.1& Fig.4”.

TABLE.1. LOCATION OF SELECTED FIELD WORK SITE

Site#	Sector#	Location	Coordinates	
			Lat. (N)	**Long. (E)**
1	1.A	El Fyrouz Beach	31°22`01"	27°16`12"
2	2.A	Andalusia Beach	31°22`08"	27°17`49"
	2.B			
3	3.A	Alam El Rom Beach	31°22`18"	27°19`22"
	3.B			
	3.C			
4	4.A	Mina Hasheesh Beach	31°22`22"	27°19`46"
5	5.A	Ras El-Hekma west	31°13`43"	27°51`49"
6	6.A	Ras El-Hekma east	31°13`39"	27°52`27"
7	7.A	Ras Hossan	31°05`37"	28°06`32"
8	8.A	El-Dabaa	31°04`33"	28°28`24"

Each sector started from the coast line to the end of boulder field, including coordinates, the three boulders axis (a, b &c), elevation from coastline of the mean sea level and distance between each boulder and coastline by use GPS and tape. The boulders volume and weight have been calculated using the volumetric method as $2.2 g/cm^3$.

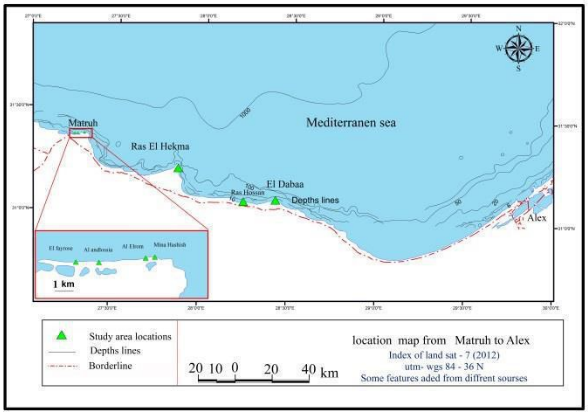

Figure 4. Location of selected field work sites

4.RESULTS

4.1. Distribution and dimensions of accumulated mega boulders:

The measured dimensions of accumulated boulders “Tab.2” and the field observation show that most boulders are rectangular, with sharp, broken edges, most blocks consist of limestone and sandstone fragments up to $14m^3$ in volume and 43 ton in weigh, some of these blocks were observed by local people to have moved after strong winter storms. it shows that maximum mean size of accumulated boulder appears on site # 3c (Volume 2.25 m^3), and the maximum mean weight is 2.57 ton at the same site and also the maximum number of the boulder deposited on the site # 3.C (90 boulders), but the maximum mean distance between the coastline and the end of boulder field is (54.93 m) in site # 1.A .

TABLE 2. AVERAGE DIMENSIONS OF ACCUMULATED BOULDERS

S#	Bn	Average dimensions of boulders			D	L	V	W
		a(m)	**b(m)**	**c(m)**				
1.A	57	1.51	1.14	0.51	54.93	0.96	1.02	2.08
2.A	13	1.82	1.61	0.65	26.95	1	2.15	4.58
2.B	85	1.07	0.79	0.36	39.69	3.41	0.41	0.17
3.A	90	1.34	0.94	0.42	29.92	3.43	1.01	2.57
3.B	23	1.42	1.01	1.7	28.2	0	0.65	1.04
3.C	38	1.63	1.21	.47	21.63	3.60	2.25	7.96
4.A	81	1.22	0.94	0.41	9.49	1.2	0.56	0.89
5.A	38	1.45	0.97	0.40	10.67	0.95	0.74	1.46
6.A	55	1.36	0.97	0.33	14.46	.37	0.51	0.84
7.A	51	0.85	0.59	0.26	7.04	1.33	0.16	0.18
8.A	47	0.87	0.58	0.17	19.1	1	0.13	0.19
Oa	52.54	1.31	0.98	0.51	23.81	2.02	1.56	2.11

(After: Dalal, 2013)
S#: Sector #
Bn: Boulders number
D: Distance (m)
L: Level (m)
V: Volume (m^3)
W: Weight (t)
Oa: Overall average

4.2. Topographic profiles and geomorphological maps:

Eight topographic profiles have been surveyed and geomorphological maps on the selected sites; it shows the accumulated boulders morphology on beaches and coastal platforms as the following: it seems as random shape deposition at Alam El Rom and semi parallel to the coastline “Fig.5&6”.

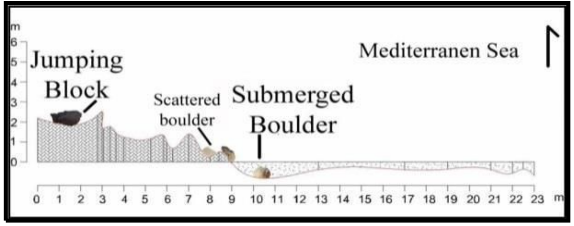

Figure5. Example of topographic beach profiles for site # 1.A

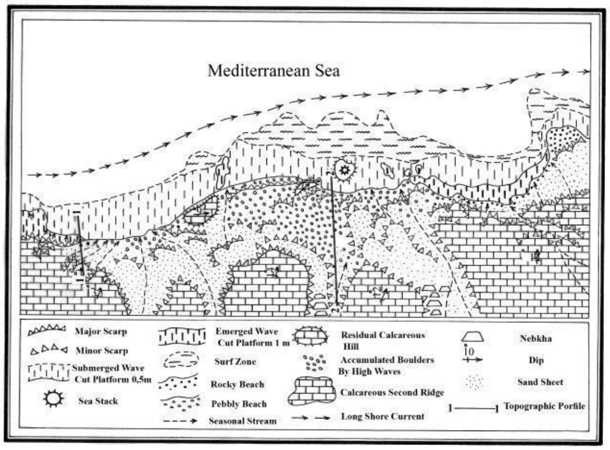

Figure.6: Geomorphological map for site #3 at Alam El Rom Beach

4.3. Boulders accumulation positions on the beaches

Boulders accumulation can be classified as many types such as the following example positions on the beaches depending upon field investigation:

4.3.1. Boulders accumulated horizontally on the coastal platforms by strong waves, and it always advance horizontally near the coastline « Fig.7».

4.3.2. Vertically accumulated boulders on the beach or settling vertically upon earlier boulders .

4.3.3. Buried boulders under aeolian sands on the back shore inside aeolian accummulated sands.

4.3.4. Crammed boulders inside high coastal notches (2-3 meters above sea level), as a result of high waves energy « Fig.8 ».

4.3.5. Sequential deposited rocks by powerful waves flowing consecutively

Figure7. Horizontally boulder deposits on site # 3 at Alam El-Rom

Figure8. Crammed boulders inside high coastal notches on site # 3

4.4. Estimation of storms and tsunami waves heights

Some equations have been used to estimate storms and tsunami wave heights depending upon boulders dimensions, volume, weight, moving distance on the platform (Williams D.& Halls, A., 2004) & (Pignatelli, C.et al., 2009) “Table 3”, the first equation show that the minimum storms wave height is more than 10 m on sector 2.A and 6 m on sector 3B&C, and tsunami waves height about 2.7m (Sector 2.A) and 1.6 (Sector 1.A.,3.B&C).

TABLE 3. ESTIMATED HEIGHT OF STORMS AND TSUNAMI WAVES.

Sector #	**Boulder #**	**Estimated minimum wave height (m)**			
Equation		**Williams D.& Halls, A., 2004**		**Pignatelli, C.et al., 2009**	
Wave type		**HS(m)**	**HT(m)**	**HS(m)**	**HS(m)**
1.A	57	6.292	1.573	2.696	0.614
2.A	13	10.786	2.696	7.191	1.797
2.B	85	4.943	1.234	2.696	2.696
3.A	90	5.393	1.348	2.696	0.647
3.B	23	6.292	1.573	3.595	0.898
3.C	38	6.292	1.573	3.595	0.898
4.A	81	2.696	0.674	2.696	0.674
5A	38	5.842	1.460	2.696	0.674
6.A	55	5.393	1.348	2.696	0.667
7.A	51	4.044	1.011	2.39	0.449
8.A	47	3.146	0.786	1.779	0.440
OA	**52.54**	**5.556**	**1.388**	**3.156**	**0.;952**

(After: Dalal,2013)
HS: Storms wave height
Ht:Tsunami wave height
OA: Overall average

4.5. *Boulders shells dating*

Two samples of seashells were collected from accummulated boulders on site # 3B & 3C at Alam El-Rom has been dated. The results shows that the first sample was displaced from 60 years ago, as a result of an earthquake centered at the bottom of Mediterranean sea near the southern coasts of Cyprus Island near Limassol city, this earthquake took place on 10-9 1953 and caused tsunami waves that damaged about 135village and killed40 persons and 1000 others were became homeless(Guidoboni et al., 1994). The second sample back to 960 ±35 BP (1018 to 1088 AD) as evedence of other tsunami occurred in the eastern portion of The Mediterranean Sea “Table 4”.

TABLE 4. DATING OF SEASHELLS WERE COLLECTED FROM SITE #3 AT ALAM EL-ROM

Sh #	**S #**	**Dimensions of boulders**			**D**	**V**	**W**	**Dating BP**
		A (m)	**B (m)**	**C (m)**				
1	3B	1.45	0.7	0.45	32.70	0.46	0.66	60 ± 4
2	3B	2.15	1	0.50	27.20	1.08	2.31	960 ±35

Sh#: Shell Sample number
S#: Sector number
D: Distance between boulder & coastline (m)
V: Volume (m^3)
W : Weight (ton)

4.6. *Geomorphological Hazard map*

The geomorphological hazard map « Fig.8 » has been produced for the study area using hazard index depending upon the following factors :

1. Coastline shape.
2. Angle of wave direction to the coastline.
3. Beach profile Slope.
4. Hardness of beach rocks.
5. Sea water depth.
6. Estimation of mega boulders accumulation by storms and tsunami.

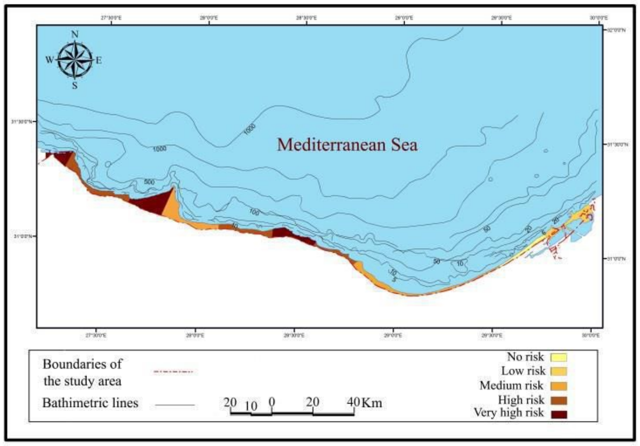

Figure8. Geomorphological hazard map of the study area.

5. CONCLUSION

The results show that both possible processes (storm and tsunami waves) can deposit these boulders, specially the NW coast of Egypt has recorded a number of seismic or tsunami events during the Holocene (tsunamis of 23 AD, 365 AD, 746 AD, 881 AD, 1202 AD, 1303 AD, 1870 AD and 1908 AD attested at Alexandria for example by the archaeological excavations and historical sources.

Tsunami waves and storms cause the displacement of huge boulders from sea bottom and submersible marine terraces (platforms) to the beach due to its major power and ability of carving and graving it is also capable of pulling other boulders from the land and redeposit it on the beach or coastline. The geomorphological hazard map of the study area shows that Alam El Rom and the western coast of Ras El-Hekma, then El Dabaa and El Fyrouz areas east of Mersa Matruh City of about 10 65, 135 and 2 km, is the most affected portions by hazards by estimated tsunami catastrophic in the NW coast of Egypt, and currently more affected recent storms depending on the results of the results of this study.

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1. REFERENCES

1. Anwar,Y.M., M.A. El Askary, and S.M. Nasr (1981), Petrography and origin of the oolitic carbonate sediments of Arab' Bay, western part of the continental shelf of Egypt, N. *JB.Geol*. Palaont Mh.,2: 65-75.
2. Dalal,N., (2013), The Catastrophic Geomorphology of Some Chosen Parts of NW Coast Between Alexandria and Marsa Matruh in Egypt and Eastern Sicily, Italy, *MA. Degree Thesis*, Damanhour University, Egypt.
3. El Shazly, M.M., A.A. Shata and E.M. Farag, (1964), Lithology of the Neogene and Post-Neogene sediments in Marsa Matruh area.*J.Geol.,*UAR,Ciaro, 8:21-45.
4. Guidoboni E., A. Comastri, G. Traina, (1994), *Catalogue of Ancient Earthquakes in the Mediterranean Area up to the 10th Century*, Roma .
5. Hamouda.A,Z,(2006), Numerical computations of 1303 tsunamigenic propagation towards Alexandria, Egyptian Coast. *Journal of African Earth Sciences* 44 (2006) 37–44.
6. Hilmy, M.E., (1951), Beach sands of the Mediterranean coast of Egypt, *Jour. Sed. Petrology*, 21: 109-120.
7. Mortensen,N., Said,U.,Badger,J.,(2006), Wind Atlas for Egypt, Proceedings of the *2006 European Wind Energy Conference and Exhibition*, Athens, Greece, February 27 to March 2.
8. Pignatelli,C., Sansò,P ., Mastronuzzi.G.,(2009), Evaluation of tsunami flooding using geomorphologic evidence, *Marine Geology* 260 (2009) 6–18.
9. Selim, A.A., (1974), Origin and lithification of the Pleistocene carbonates of the Salum area, western Coastal plain of Egypt, *Jour. Sed. Petrology*, 44: 70-78.
10. Torab, M. (1984), Geomorphology of Um El Rakham aea, west of Marsa Matruh City, *MA. Degree Thesis*, Alexandria University, Egypt.
11. William,D,M., Hall,M,A.,(2004), Cliff-top megaclast deposits of Ireland, a record of extreme waves in the North Atlantic—storms or tsunamis, *Marine Geology* 206 (2004) 101–117.