Sea level rise in Alexandria during the Late Holocene : archaeological evidences

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The Mediterranean Sea as such is regarded as a natural historical museum in which the eventual history of various civilization is displayed. Most of the submerged ruins are Hellenistic quays, harbours, village, statues, shipwrecks and other artifacts.

Since its construction in 332 B.C, Alexandria became one of the main centres of Hellenistic civilization. The sea level has greatly changed in Alexandria than during the Ptolemis and Roman times (Breccia,1922). Alexandria was also subsided (2-3 m) during this period, this was observed in the necropolis along the coastal area. Direct evidences for the subsidence of the earth's crust accompanied by the rise of sea are the submerged Roman ruins in the Eastern and Western Harbours of Alexandria and in Abu Qir Bay (Jondet, 1916; Tousson, 1934; Morcos, 1985).

Several observations were made on the coastal stretch of Alexandria on emerged and submerged coastal structures, excavated pools & necropolis to derive the original sea level following the method of Flemming (1969).

Table 1. Ancient sites in Alexandria, with age in millenia, relative displacemnt in m, average rate of displacement.

Name	Age (millenia)	Depth (m)	Depth/age (m/millenium)
Pharos (lighthouse)	2.3	2	0.86
Timonium	2.0	4	2.0
Antirrhodes	2.0	2	1.0
Cape Lochias	2.0	2	1.0
Hercules T.	2.2	4	1.8
Isis T.	2.0	3	1.5
St. Chyr Ch.	2.0	3	1.5

The ancient sites in Alexandria with approximate age in millenia and relative displacement in meters are shown in Table 1. A vertical movement on the coast of Alexandria is of 1-2 m/millenium downwards. Although, no concrete relation was found between age and depth of sites, a relative vertical displacement higher than the effect of the rise of sea level is obvious. Therefore, the eustatic factor is accompanied by a tectonic factor in Alexandria. Tectonic factor accompanied by the warping of the Nile Delta resulted the subsidence of the coastal area. Broadus et al (1986) found that the rate of subsidence of the Nile Delta is in the order of 5-6 m every few thousand years. As sea level rises the wedge of salt water that underlies the delta fresh ground water is forced further inland. This ground water seriously affect most of the coastal antiquity sites along Alexandria.

A prospective scenario assumes a 1 m rise in relative sea level over the next 100 year in the delta of Egypt; this can be thought of as a 50 cm rise in eustatic sea level combined with 50 cm increase in local subsidence (Hoffman et al., 1983). This rise would affect at least 15 % of Egypt's current gross domestic product (Broadus et al., 1986).

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Application of factor analysis to the geochemical data of Alexandria shelf sediments

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Introduction:

The shelf of Alexandria encompasses two depositional sedimentary environments (El-Sayed, 1979); this area has well-defined geochemical and mineralogical provinces (El-Sayed, 1981). This paper discusses the application of the Factor Analysis (F.A) to the geochemical data of 40 bottom sediment samples collected from the inner shelf of Alexandria (Fig. 1) and representing the different sediment constituents.

Methods:

Powdered samples were totally digested by a mixture of strong acids; quantitative chemical analysis was carried out in an AAS for the determination of major elements and some trace metals.

The raw geochemical data were classified objectively using F.A. The F.A starts by the construction of a correlation coefficient matrix, then the extraction of eigenvectors and eigenvalues. The final step is the varimax rotation technique to achieve a simple structure to the rotation of the factor matrix.

Results and discussion:

The average concentrations of the geochemical parameters are as follows: 19.46 % SiO_2, 11.76 % Al_2O_3, 31.03 % CaO, 5.72 % MgO, 1.12 % Fe_2O_3, 0.14 % TiO_2, 0.53 % NaO, 0.14 % K_2O, 0.05 % MnO, 66 ppm Cu and 52 ppm Ni.

The rotated factor matrix is shown in Table 1, while the plot of the first two factor is presented in Fig. 2. Results of the F.A reveal that three factors account for 70 % of the initial information. Factor 1 accounts for 33.7 % of the total variance and characterizes the association of Ca-Mg and Na and the inverse association of Fe-Mn. It is mostly a carbonate factor which define the skeletal and non-skeletal carbonates in the area and the chemical interaction between iron and manganese. Factor 2 accounts for 19 % of the total variance and describes an alumino-silicate association which strongly reflects the terrigenous and relict origin of most of the sediments. Factor 3 which accounts only for 17.4 % of the total variance defines a K-Fe-Mn association. This factor reflects the feldspar-clay mineral association which is largely contributed through terrigenous agencies.

The F.A provides a powerful approach to the interpretation of wild geochemical data in a rapid and explicit way; it also enable the identification of the different sources and association of elements in the inner shelf of Alexandria.

Fig.(1)

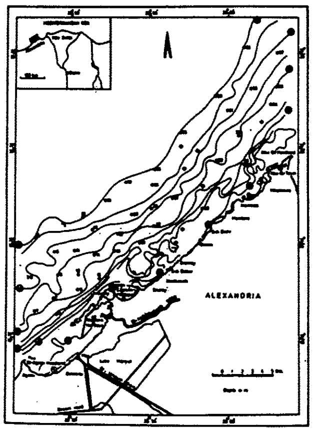


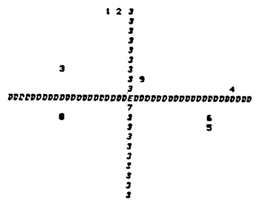
Table (1)

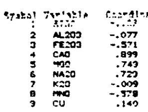
Rotated Factor Matrix:

	FACTOR 1	FACTOR 2	FACTOR 3
SIO2	-.12278	.90868	-.08192
AL2O3	-.07720	.91775	.24054
FE2O3	-.57140	.25954	.63831
CAO	.89874	.07616	-.14955
MGO	.74901	-.23907	.01714
NA2O	.72950	-.11705	.319[illegible]
K2O	-.00902	-.04598	.91769
MNO	-.57845	-.16719	.50349
CU	.14041	.20418	.34925

Fig.(2)

Horizontal Factor 1 Vertical Factor 2





Symbol	Variable	Coordinates	
1	[illegible]	[illegible]	[illegible]
2	AL2O3	-.077	.919
3	FE2O3	-.571	.260
4	CAO	.899	.076
5	MGO	.749	-.239
6	NA2O	.729	-.117
7	K2O	-.009	-.046
8	MNO	-.578	-.167
9	CU	.140	.204

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