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ABOUT THE PLATE TECTONIC PATTERN OF THE MIDDLE EAST

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ABSTRACT

The area of the Middle East and specially the Gulf of Suez, Gulf of Aqaba, Red Sea and Gulf of Aden are interesting from the tectonic point of view. The work presents the different theories formulated by many workers on this area, and gives new evidences and theory about the plate tectonics of the area under consideration based mainly upon the correlative studies of geographic continuity, petrography, geochemistry and structural trends.

The authors proposed the presence of three main tectonic plates, these are the African, Sinai (Levantine) and Arabian plates. The African plate tends to move in NW direction while the Arabian plate tends to move in NE direction. The dynamic resultant of these two (nearly perpendicular) trends was the separation of the Sinai plate. The geochronological events in the area were as follows: The presence of two major plates which are the African and Arabian, during the early Paleozoic, then the formation of the Gulf of Suez, which is dated back as Carboniferous or even older, then the opening of the Red Sea which actively take place during Eocene-Miocene period and finally the formation of the Gulf of Aqaba which is proposed to be formed mainly during Pliocene.

INTRODUCTION

Many theories had been proposed to explain the tectonic development of the Middle East. The geophysical data played the most important role and as a matter of fact sometimes, we get data which are not in harmony with the previous fixed data. The area of the Middle East is composed mainly of the African, Arabian, Levantine (Sinai) and Turkish plates. These plates were located south of the Paleozoic Tethys, as part of the northern margin of Gondwanaland.

The present work is an attempt to explain the plate tectonics of the African, Sinai and Arabian plates i.e. the plates surrounding the Egyptian area.

Sinai Peninsula plate is regarded by many investigators as the geographic and geologic extension of both the Eastern Desert of Egypt and the western part of the Saudi Arabia. However, this continuity is interrupted by the presence of the Suez and Aqaba Gulfs *(Fig. 3)*.

BALL [1911] concluded that, the Gulf of Suez ows its origin to erosion and secular oscillation rather than local subsidence by trough faulting. SWARTZ and ARDEN [1960] postulated that at the end of the lower Eocene the Sinai block moved towards the SE direction along NW-SE faults. SAID [1962] considers the Gulf of Suez as a rift valley. YOUSSEF [1968] arrived at a conclusion that the Gulfs of Suez and Aqaba have the trends of two complementary sets of wrench faults. MCKENZIE, *et al*,. [1970] visualized the Red Sea area with three tectonic plates: The Arabian, the Nubian and Sinai. The Arabian plate is moving in a NE direction, while the Nubian takes a westward direction. LE PICHON *et al.*, [1973] consider that, at the Gulf of

Suez there is a predicted right lateral strike slip with minor extension of about 30 kms. The Gulf of Suez is a north western branch of the Red Sea, which was subjected to an intense geological and geophysical researches, explaining that, the Red Sea is formed by a series of transcurrent faults [GIRDLER, 1966; ABDEL GAWAD, 1969], which are associated with the addition of new oceanic crust in the axial parts [PHILLIPS, 1970] and the drifting of Arabian to the NE direction [DAVIS and TRAMONTINI, 1970].

EL SOKKARY [1976], explain that, Sinai Peninsula underwent a rotational movement of 6° in an anticlockwise direction and over a distance of about 45 km during most probably Cretaceous Tertiary times in order to take the present day setting; while EL SHAZLY [1980], distinguished five NNW-SSE segments or old plates in the Egyptian Basement, these plates act alternatively as highs and lows.

The proposed theory and evidences

The purpose of this work is to present the pertinent geologic data, to consider it in relation to prior tectonic hypothesis and to deduce from it revised concepts of plate tectonics and evolution of this interesting region.

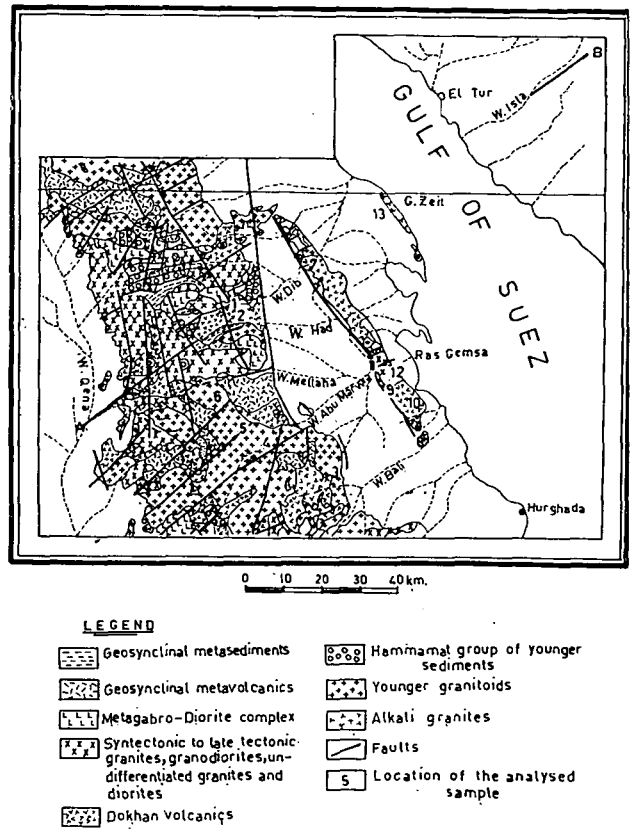

Fig. 1. Geologic map of main basement mass, Esh Mellaha and G. Zeit blocks [after EL RAMLY, 1972]

The correlation of the geographic position, petrography, structural trends and geochemistry of Esh Mellaha block comparable with the main basement mass lying to the west *(Fig. 1)*, shows a very close genetic similarity and both are controlled by deep-seated faults. Esh Mellaha block has about 80 km length and 5 km width. It is stretched in NNW-SSE direction.

The Esh Mellaha block is composed mainly of schists, metavolcanics, serpentinites, diorites, Dokhan volcanics, Hammamat mollasses and granites which are the same rock units outcropped in the opposite part of the main mass of the basement rocks (lie to west) [KABESH, *et al.*, 1970; FRANCIS, 1972].

Table 1 shows correlation of the geochemical analyses of some rocks sampled from the main mass of the basement rocks, Esh Mellaha block and Gabal Zeit (laying east of Esh Mellaha). The samples of rocks collected from each mass are very close in their petrographic composition and their geochemical analyses.

The detailed petrographic studies of the different rock units outcropping in the main basement mass, Esh Mellaha block and G. Zeit [SCHURMANN, 1966; KABESH *et al.*, 1970; FRANCIS, 1972; ABU EL-LEIL, 1980], reveal an addition evidence about their similarity and that they belong to one single mass (which later on drifted in separate blocks) and even belong to the same magmatic activity. We can summarize the main petrographic characteristics of the different rock units sampled from different blocks in the following from the oldest unit:

1. The metasediments are of low grade metamorphosed greywackey rocks, consist mainly of quartz and plagioclase feldspars in fine quartzo-feldspathic matrix having chlorite, biotite composition.
2. The Dokhan volcanics are ranging from intermediate to acidic rocks having the composition of andesite and rhyolite. The porphyrites predominate in all cases.
3. The granitic rocks are ranging from medium to coarse grained and from pale pink to red colour. They have the composition varying from granodiorites to leucocratic granites.

The close coincidence of the major Precambrian structural trends in the main mass of the basement rocks, Esh Mellaha, G. Zeit and the western part of Sinai Peninsula which are NNW-SSE in different blocks suggests the same opinion, that they form a single mass [EL RAMLY and SALLOUM, 1974; ABDALLAH and SALLOUM, 1978].

From the above mentioned data, the present authors came to the conclusion that, the main basement mass, Esh Mellaha block, G. Zeit and Sinai Peninsula were linked together during the Precambrian, and this Afro-Arabian plate would be moving north-north eastwards during the period 100—45 Ma in response of seafloor spreading in the south Atlantic and Indian oceans [SHELTON and GASS, 1979], in other words complex drifting was initiated in this area during mid-Triassic time and seas gradually invaded the subsiding block-faulted terrain.

The Esh Mellaha block was drifted from the main basement mass lying to the west, for a distance ranging from 10 kms in the northern part to about 25 kms in the southern part. Esh Mellaha block was twisted as a result of the drifting and so it is not parallel to the main mass of the basement complex but makes about 25° with its intersection. The resulting configuration is closely similar to the shape of the two coasts of the Gulf of Suez. In the first case the depressed area in between was filled by Meso-Cenozoic sediments, having thickness about 5 kms, which unconformably overlying the rocks of the basement complex. The oldest rock unit of this sedimentary sequence belong to the Carboniferous.

HAILWOOD and TARLING [1973] studied the Upper Devonian — Lower Carboni-

TABLE 1

Comparative average geochemical analyses

	Main mass of basement rocks						Esh El Mellaha Block						* G. Zeit
Contents / Sample No.	1	2	3	4	5	6	7	8	9	10	11	12	13
SiO_2	76.70	61.145	67.95	71.51	67.91	72.24	76.90	60.19	69.99	71.78	67.45	74.98	76.11
Al_2O_3	12.53	17.43	15.52	14.57	16.60	14.43	12.53	16.065	14.19	12.18	15.73	14.20	12.87
Fe_2O_3	1.67	4.00	1.83	2.55	1.86	1.17	1.59	4.29	1.42	1.55	2.39	0.93	0.96
FeO	0.37	1.19	1.94	0.43	1.69	1.34	0.25	1.49	0.55	0.78	1.88	0.61	0.74
MnO	0.01	0.155	0.04	0.04	0.07	0.24	0.01	0.135	0.06	0.08	—	—	—
MgO	0.19	2.26	0.27	0.67	1.13	0.29	0.18	2.675	0.45	1.04	1.31	0.34	0.60
CaO	0.67	3.80	2.81	1.23	1.87	0.85	0.81	4.00	3.99	1.73	1.72	1.38	0.33
Na_2O	4.56	2.875	4.67	4.41	4.33	3.32	4.39	3.67	5.07	4.73	4.34	3.60	4.18
K_2O	2.46	1.285	3.02	4.82	4.41	5.32	3.16	1.663	1.94	2.97	4.81	6.27	3.97
H_2O^+	0.15	1.97	1.11	0.18	0.10	0.46	0.31	2.06	0.78	1:16	0.29	0.47	—
H_2O^-	0.05	0.20	0.10	—	—	—	0.10	0.10	0.02	0.02	—	—	—
CO_2	0.16	2.39	—	—	—	—	0.37	1.91	—	—	—	—	—
TiO_2	0.22	1.34	0.55	0.10	0.10	0.10	0.14	0.895	0.51	0.68	trace	—	—
P_2O_5	0.05	0.275	0.32	—	—	—	0.05	0.30	0.41	0.17	trace	trace	—
Total	99.99	100.015	99.87	100.46	100.13	100.56	100.23	99.476	99.57	98.87	99.87	99.78	99.76

1 and 7 average geochemical analyses of keratophyre [after SCHURMANN, 1966]
2 and 8 average geochemical analyses of dark grey quartz porphyrite [after SCHURMANN, 1966]
3 and 9 average geochemical analyses of granodiorite [after SCHURMANN, 1966]
4 and 10 average geochemical analyses of pink leucocratic granites [4 after ABU EL-LEIL, 1980 and 10 after SCHURMANN, 1966]
5 and 11 average geochemical analyses of granodiorite-adamelite [5 after ABU EL-LEIL, 1980 and 11 after SCHURMANN, 1966]
6, 12 and 13 average geochemical analyses of coarse grained granites [6 after ABU EL-LEIL, 1980, 12 after KABESH *et al.*, 1970 and 13 after SCHURMANN, 1966]

* G. Zeit i e. G. = Gabal (arabic) = mountain

ferous pole positions and it has been indicated that during these periods Africa moved over the South Pole in a north westerly direction. During the Carboniferous, Sinai was linked to the Eastern Desert [EL SOKKARY, 1964; ANVAR and EL SOKKARY 1970; HUSSEIN, *et al.*, 1971].

DRAKE and GIRDLER [1964], deduced that Arabia suffered from an anticlockwise rotational movement relative to Africa by some 6° to 9°. It seems that drifting had occurred during Cretaceous and later times and was accompanied by the volcanic activity of the area [ANDREW, 1937; FARIS, *et al.*, 1953].

VAN DER PLOEG [1953] divided the Gulf of Suez into four structural provinces separated by three NNE-SSW fault zone *(Fig. 3)*. The provinces constitute two uplifted (I and III) and alternating with two depressed (II and IV). The Esh Mellaha and G. Zeit blocks lie within the uplifted province III.

VAN DER PLOEG's cross disturbances, SAID's shifting tectonic activity from west to east and the presence of seismicity at the mouth of the Gulf of Suez [FAIRHEAD and GIRDLER, 1971] all tend to suggest, that the disturbance represent a series of parallel strike slip faults along which active fracture zones tend to move progressively as an echelon taking a general eastwards direction.

The correlation of the geographic continuity, petrographic studies, geochemical analyses and structural trends of samples from the main basement complex, Esh Mellaha block, G. Zeit block and W. Araba block (Sinai), shows that they are strikingly similar.

The Red Sea indicates a strong positive gravity anomaly beneath a central deep trough some 50—70 kms wide, which indicates, that basic rocks occupy much of this narrow central zone [GIRDLER, 1958; GASS and GIBSON, 1969; ROBERTS, 1969]. So the Arabian sialic block has moved away from the African, the basic rocks in the fracture representing sub-sialic or oceanic crust. Such major structures with parallel sides have been called Rhombochasms [CAREY, 1958].

So, it is well known, that the Middle East region, particularly around the Egyptian territory is mainly controlled by the dynamics of three moving plates. The eastern Arabian plate is supposed to move in NE direction [DAVIS and TRAMONTINI, 1970]. The Western (African) plate is supposed to move in NW direction [HAILWOOD

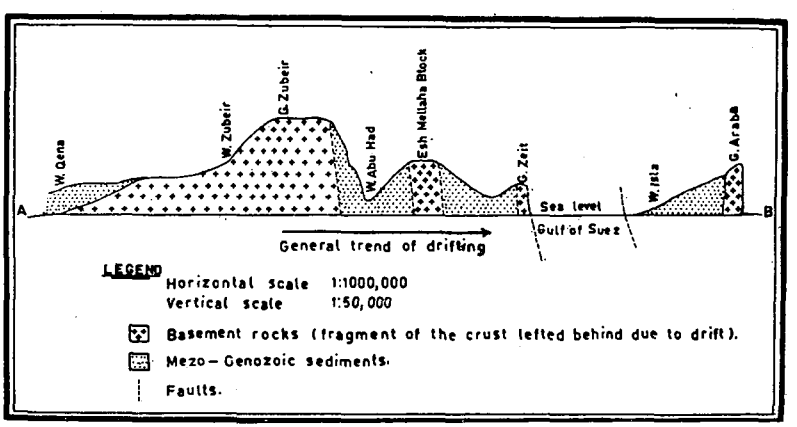

Fig. 2. Topographic profile along the area showing location of fault zones and the basement rocks

and TARLING, 1973]. Concerning the third Sinai (Levantine) plate, it was bounded by active system of transcurrent faults dominating along both the Gulf of Suez and Gulf of Aqaba (and extends further north up to the Dead Sea).

Admittedly, this region lies under the effect of three plates and the tectonics of the Middle East area will be explained on this basis.

During the early Paleozoic times were persisted only the African and Arabian plates. Sinai (Levantine) plate at these periods was behaving as a linked part to the Arabian plate. As stated above, the Arabian plate tend to move in NE direction, in the mean time, the African plate tend to move in NW direction.

The dynamic resultant of such nearly perpendicular trends is the splitting of the Sinai plate and the formation of NNW—SSE VAN DER PLOEG's transcurrent faults.

The supposed geochronological tectonic sequence of events in the area is as follows: the presence of two major African and Arabian plates during the early Paleozoic, then the formation of the Gulf of Suez, which is dated back as Carboniferous or even older as a result of sea floor-spreading. Then the opening of the Red Sea which actively took place during Eocene-Miocene period. Finally the formation of the Gulf of Aqaba which is proposed to be formed mainly during Pliocene and being still active.

It seems also, that Esh Mellaha block and G. Zeit block are fragments of crust which were left behind when the African and Arabian plates were drifted and separated as a result of sea floar spreading *(Fig. 2)*.

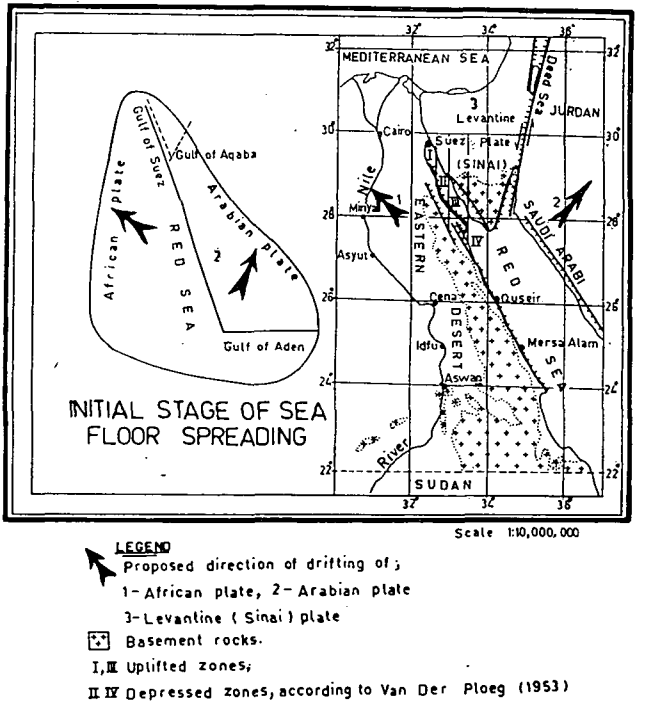

Fig. 3. Proposed plate tectonic map of the Middle East area

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