

Mısır ve bilhassa Kızıldenizin jeolojik tarihçesi

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özet: Mısır'daki strüktür durumunun kompleks olması, teressüplerin başka başka havzalara ait bulunması muhtelif jeolojik katlardaki sahraların litolojik karakterlerini hulasaten vermediği güç yapmaktadır. Mısır'da 1897 denberi Mısır Jeoloji Enstitüsü tarafından bir çok işler görülmüş olmakla beraber Mesozoik ve daha genç sahalaların dakik hartaları petrol kumpanyaları tarafından yapılan faaliyetle başlar. Bu hususda bilhassa son on sene zarfında büyük terakkiler kaydedilmişse de maalesef bu malûmatın çoğu kumpanyaların arşivlerinde mahfuz bulunmaktadır. Bu konuşmada verilen bilgi 1937 -1940 ve 1947 -1949 senelerinde yapılan şahsi incelemelerle Mısır'da çalışan bir çok jeoloğlarla* yaptığım şahsî temaslara istinad etmektedir.

Mısır'da arazinin büyük bir kısmı yaşları Karboniferden eski olan sahalarla örtülüdür. Sina yarımadasının cenubu, Süveyş Körfezinin batısı, yaşları kesin olarak bilinmeyen gnays, metamorfik şist ve granit entrüziyonları 2000 metreye kadar yükselen dağları kaplarlar. Granit ve şistlerin üzerinde diskordansla kaim bir Karbonifer seksiyonu bulunmaktadır. Cenup batı Libya'da *Graptolit* ihtiva eden ve Silüre izafe edilen şeyi ve sleyt tabakaları bulunmuştur. Karbonifer en iyi Süveyş Körfezinin batısında ve doğusunda inkişaf etmiş bulunmaktadır. Nubia Formasyonu fosil ihtiva etmeyen kaim ve az sertleşmiş beyaz, pembe renkte bir gre serisi olup Karboniferden eski sahalaları örter. Bu kumtaşlarının yaşı Karboniferden Kampaniyene kadar değişmektedir,

Mısır Jeoloji Enstitüsü tarafından 1945 de Sina doğusunda Ortatriasa ait sahalalar bulunduğu gibi daha evvelce gene Sina'da iyice inkişaf etmiş bir Jurasik Seksiyonu bulunmuştur, Kretase umumiyetle Altkretase olarak boz veya kırmızı renkte demirli, bazen glaukonitli, ve kil ara tabakaları ihtiva eden 300

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metre veya daha kalın bir kumtaşı serisiyle başlar. Senomanien,, Turonien ve Senonien daha ziyade\ kalker fasiyesinde- ztülur etmektedir. Bununla beraber Ras Garib'de kumlu, Mili, ji-psli Senomanien bulunduğu gibi Nilin sağ' cenahında Asuan'ın kuzeyinde Sénonien, Nubia kumtaşları olarak görülmekte Te oolitik ...kısımlarında demir cevheri ihtiva etmektedir.

' Kretaseden Eosene geçiş; yakın doğu memleketlerinde⁴ umumiyetle olduğu gibi tranzisyon iledir, Ūstsenonien ile¹ Alt-eosene ait sahralar taktirde., petrol göstermeleri dolayısıfe hususî bir ehemmiyeti haizdir. Âlteosenle Lütésiye arasında bölgenin en mühim diskordansı bulun maktadır. Bu diskordans bazen, büyük Nümmülitler ihtiva eden konglomera ile* kendini göstermekte ve bu konglomera ise Süveyşin doğusunda bulınan petrol'sahalarında olduğu gibi petrol hazne taşlarını teşkil etmektedir. Mevzii bazı şakulî arz hareketleri neticesi olarak bazı bölgeler devamlı erozyona tabi olmuş ve. ancak Ūstmiosende su seviyesinin altında kalabilmiştir. Oligosen Siveyş Kanalının doğusunda ve Süveyş -Kahire' arasında kumtaşı,. konglomera, kuvarsit^ breş olarak ve Süveyş'in batı sahilinden Cebel Zeifte deniz teressübü olarak bulunmaktadır. Oligosen, Eosen t stünde bir diskordansla bulunmaktadır.

Neojene girildiği vakit Miosen denizinin müteaddit kollarla ayrılmış olması,.ve ayrı ayrı müstakil havzalar teşkil etmesi dolayısıle sahralar arasında mukayese güçleşir. Böylece.. Miosen stratigrafisi (a) Batı çölü Mioseni, (b) Kahire - Süveyş bölgesi Mioseni, (c) Süveyş körfezi doğu sahili Mioseni olarak iç grupta :mütâlea edilmiştir,

Pliosen umumiyetle daha yaşlı tabakalar üzerinde bir diskordansla bulunmaktadır, Pliosen teressüpleri (a) Süveyş bölgesi, Batı çölü Plioseni, ve (c) Nil vadisi Plioseni olarak üç bölümde ele alınmıştır.

Pleistosen alttaki tabakaları diskordansla örter. Pleistosen sedimentasyonu : (a) Süveyş -Körfezi çevresi, (b) Akdeniz sahili Pleistoseni, (c) Nil vadisi Pleistoseni, (d) Fayın çöküntüsü Pleistoseni, (e) Sina çölü Pleistoseni, (f) Karga ve.Kurkur vadileri "Pleistoseni, olarak altı " muhtelif bölgedeki tekevvünü gösterilerek izah edilmiştir.

Kızıl Deniz çöküntüsü hakkında son elli sene zarfında bir çok neşriyat yapılmıştır. Süveyş Körfezi çöküntüsü Alteosen'de başlamış olmakla beraber Kızıl Denizin pek eski zamanlardan beri bir kırıklık zonu olarak mevcut olması muhtemeldir. Süveyş bölgesinin 25° arz dairesinden Akdenize kadar Mesozoik ve Alteosen, devirlerinde su altında olduğu ve transgresyonun Akdenizden başlayarak Cenuba doğru ilerlediği bilinmektedir. Senoniende deniz 25 inci arz dairesine kadar ilerlemiş bulunuyordu. Alteosen sonlarında . Süveyş çevresinde yükselmeler ve bu hareketlerle birlikte şakulî faylanmalar husule geldi. Bu hâdisenin neticesi olarak vukua gelen aşınma yüzünden Ortaeosen tortulları eski sahralar üzerine diskordanslı bir temasla teressüp etti.

Orteeoseni müteakip tekrar ve muhtemelen daha mühim iltivalanma ve yükselme vukua geldi. Üsteosen denizi bu iltivalı satıh üz%rine teressüplerini braktı. Bazı bloklar deniz seviyesinin üstünde kaldılar. Böylece erozyon bütün Tersiyeri aşındırdığı gibi bazen 'bu aşınma granitlere kadar nüfuz etti. Oligosen içindeki alçalmalar kaim Miosen teressüplerinin bazı yerlerde doğrudan doğruya granitler üzerinde olmasına imkân verdi. Öte yandan Kızıl Denizin çökmesi kısa fasılalarla Miosen, Pliosen ve Pleistosen'de devam etti. Kahire-Süveyş bölgesinde 40 metre kadar kalın olan karasal Oligosen üstünde bulunan bazalt akıntılarının kafi surette Altmiosen olarak tesbit edilen sahraların altında bir diskordansla uzandıkları görülmektedir.

Süveyş Körfezinin teşekkülünden evvel bölgede bir umumî yükselme vaki olduğu ve bunun neticesi olarak derinlerde birleşen tansiyon fayları husule geldiği ve bu hareketlerin en çok Sina yarımadasında faal olduğu ve tansiyon faylariyle yırtma faylarının müştereken Süveyş Körfezi çöküntüsünü meydana getirdikleri kabul edilebilir.

The Geological History of Egypt and of The Red sea in particular

S. W. TROMP

1) Introduction '•

The geological history of Egypt is a very complex but most fascinating story which starts at least 1000 million years ago in the Pre-Cambrian. In order to give the complete history it would be necessary to discuss both the macro-stratigraphical and the micro-paleontological conditions in Egypt. However, in view of the limited time available, I shall have to restrict myself to the macrostratigraphy only and in particular to the lithological aspects of Egyptian stratigraphy.

Due to the complicated tectonic structure of Egypt and the sedimentation in different, often separated basins, it is extremely difficult, if not impossible, to give a brief summary of the lithological characteristics of the different geological periods in Egypt. Since 1897 considerable reconnaissance work has been done by the Geological Survey in Egypt (1, 2, 3, 4, 8), but very accurate detail surface mapping in Mesozoic and younger beds started much later, in combination with extensive drilling for oil by the Standard Oil Co. of Egypt, Anglo-Egyptian Oilfields (Royal Dutch Shell) and the Socony Vacuum Oil Co. Their studies increased our knowledge about the post-Paleozoic rocks tremendously, in particular during the last 10 years. But unfortunately most of these latter data are kept secret by the different oil companies. The summary given here represents therefore only a compilation of facts known from published data, personal observations during 1937-1940 and 1947-1949 and finally verbal informations received from a great number of oil geologists of the Socony Vacuum Oil Co., Anglo Egyptian Oilfields (Shell) and the Standard Oil Of Egypt. Still this compilation gives far from a complete picture of the present geological knowledge of Egypt.

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2) *Stratigraphy of the Pre-Carboniferous* 8

In Egypt an extensive area is covered by old rocks of unknown age, of which we know only that they are pre-Carboniferous in age. For this reason it seems preferable to indicate this area as Pre-Carboniferous only. Little is known of the stratigraphy of these Pre-Carboniferous beds (8, 10). They are outcropping in the southern part of the Sinai Peninsula (south of latitude 29°) east of Abu Zenima and along the western border of the Gulf of Suez (south of latitude 28° 45'). This section is composed of gneisses, schists and extensive granite intrusions of unknown age. The latter group is found for example on the west coast of the Gulf of Suez as mostly reddish coloured quartz-felspar granite ranges, representing a 50-70 km wide batholithic Pre-Cambrian intrusion, forming high maintains many over 2000 m. Apart from granites, also dioritic intrusions have been found in the lower hills of the same area. The granites sometimes contain enclaves of older sediments.

Both the granites and schists are unconformably overlain by a thick carboniferous section. These relations can be studied for example between Abu Zenima (E. coast of the Gulf of Suez) and the more eastwards situated manganese mines of Umm Bogma. The schists in this region are intruded by enormous granite batholiths which are covered by Carboniferous sandstones, the most remarkable feature being the contact plane between sandstones and granites, which is completely flat surface, not covered by a basal conglomerate of granite boulders, as we would expect.

Also different types of volcanic rocks occur in the Pre-Carboniferous section, such as the rhyolitic lavas and tuffs, dolerites in the Dokhan and Esh Range, including the famous imperial porphyry used for Egyptian statues, and still found in some of the historic monuments of Istanbul, etc.

The exact age of these different Pre-Carboniferous lithologic units is difficult to determine. HUME and his collaborators pointed out that all the above mentioned rocks probably are pre-Silurian, as beds with clearly marked Silurian fossils were»

found in the Ahagger regions of the Central Sahara and present no such metamorphosed characters. However, the **pre-Cambrian** age of the crystalline series in Egypt is particularly suggested by the stratigraphy of other neighbouring countries,

1) During the last war a publication appeared from **BEHBEND** who compiled different geological observations in Lybia made by **DESIÖ** and other Italian geologists. West of the Egyptian border a series of schists and gneisses occur which are intruded by granites containing gneisses and sandstone enclaves. Their age is uncertain. In 1938 **DESIÖ** discovered in a younger sandstone series lower and middle Devonian limestone intercalations, containing *C. honet es*, *S. piri fer*, etc. In SW Lybia a narrow zone of shales and slates occurs with upper Silurian **Graptolites**, but also sandstones with lower Silurian fossils have been reported. For these reasons at least part of the schists is considered to be pre-Silurian, the more so as near **Tschad**, further south, the schists seem to be covered by **pre-Cambrian** sediments*

2) **BLANKENHORN** discovered in 1910-near the SE corner of the Dead Sea large masses of granites, quartz porphyries and diorites resembling those of Sinai, which near wadi Sarmirj are overlain unconformably by red sandstones, covered by 14 m of red and green **marls**, followed by 51 m. of dolomites and limestones containing at nearby localities middle Cambrian *Trilobites* and *Hgalithe*. Later studies by **WYLLIE**, **CAMPBELL** and **LEES** indicated similar middle Cambrian beds in Jordan.

8) The lithologie, similarity between the pre - Cambrian (or basal Cambrian) volcanic series of Telbesmi in 8* E. Turkey, west of Mardin, the volcanic series of the Dead Sea, **Tangan-yika**, etc, and the Hammamat-Bokhan series of Egypt suggests a similar age for these Egyptian formations,

4) **BARTHÖUX** discovered in 1922 microscopic organisms in the green breccias of the **Hammamat**-schists^ which he described as Holothurian fragments* The organisms are half a millimeter long, 0- 1 mm wide and are in the shape of a *cornucopia*, the interior being spongy. **EVANS** found **smi-**

lar organisms in the pre-Cambrian Nama beds of south Africa, which are common in the Cambrian of N. America, Siberia, Australia, etc. but seem to occur also in the pre-Cambrian of Canada.

Although the greatest part of the Egyptian schists series seems to be pre-Cambrian in age, we should keep in mind that part of the pre-Carboniferous section in Egypt (e. g. the Gattarian intrusions) may be Cambrian or younger in age.

HUME compiled a great number of data on the relative age of the igneous and metamorphic pre - Carboniferous rocks of Egypt, Sinai and the N. Sudan which, except for a few alterations as a result of recent studies by ANDREW and SCHÜR-MANN, are still, accepted by most geologists who have studied the region. The stratigraphy of the pre - Cambrian of Egypt could be classified as follows.

I a) *Ereter schist and gneiss complex* : The oldest series of Egypt exposed in Wadi Ereier and composed of intensely crushed schists, micagneiss and igneous rocks.

b) *Sikait Magnesium series of Hume or Baramia series of Schurmann* They comprise Beryll-mica schists, Talc-, Graphite- and Chlorite schists and dolomites. The schists partly derived from sandstones, partly from argillaceous sediments.

c) *Haimur or lower paraschist series* ; The most typical occurrence being near Wadi Haimur. It consists of green epidotic calcareous schists, alternating with white marble bands. Both the Sikait and Haimur schists are intruded by *Serpentines*, e. g. at Baramia, which in places are rich in *Chromium ores*.

II a) *Shait series*: Plutonic intrusions of hornblende granites and diorites (partly changed into gneiss). Many of the *Auriferous quartzveins* in Egypt seem to be connected with these intrusions.

b) *Shadh or middle paraschist series* • particularly developed near Bir Shadli. They are composed of purple schists alternating with dolerite flows and a system of fine grained diorite sils.

III" a) *Dûkhan-or Fer ani series*: a volcanic series exposed in the Bokhaxi and Esh range, being contemporaneous or older than the Hammamat series, It consists of porphyrite, diabase qtiar» teporphyrite and quarteporphyry flows and tuff beds.

SCHURMANN considers the Shadli and Dokhan series as on© **unit**, both underlying the Hammamat series (see **below**), the main difference between. Shadli and Hammamat series being the abundance of dolerites in the Shadli series, which seem to be absent in the Dokhan and Hammamat series.

The famous ^Imperial **Prophyry**», in Pharaonic times quar» ried at Mons Prophyritus, belongs also to this Dokhan series. It is found in most antiquity sites along the Mediterranean, also in Istanbul for example,

b) *Hammamat series or upper paraschists* : they occur e. g. near Wadi Hammamat and are composed of reddish brown (sometimes greenish) conglomeratic greywacke^ felspathic quartzites and black to greengreen, brecciated schists (also known as breccia verde **d'Egitto**) intercalated with acidic and slightly basic tuff-beds and andesitic lava flows. The conglomerates contain **ace.** to ANDREW and SCHURMANN pebbles of the Dokhan and older series, which should indicate a post Dokhan age.

The «breccia verde» was used in Pharaonic times for sarcophagi and Egyptian statues and can be found in many antiquity •sites along the Mediterranean. Both the Dokhan and Hammamat series are probably the *Main periods of copper ore deposition* in Egypt. At the end of the Hammamat period probably a new period of strong volcanic activity started with quartz porphyry and quartz porphyrite flows, known as post *Hammamat volcanic series of Hume*. This whole section resembles the Cambrian volcanic series of Telbesmi in 3* E» Turkey and the Cambrian volcanic section- near the Dead Sea.

IV) *Oattanan intrusions* : Probably pre-Oarboniferous crystalline series ; probably the following succession of extrusions and intrusions took place:

a) Ultrabasic rocks (gabbros_f peridotites^ serpentines^ etc.) as fringe around a batholithic diorite nucleus (oldest Gattarian intrusions).

- b) Diorite intrusions (*Second Cataract type*).
- c) Biotite- and Hornblende granites and granodiorites (*Aswan type*), the latter being responsible for some of the *Auriferous veins* in Egypt.
- d) Red granite intrusions and pegmatites (*Central range type*) • *Period of tin, molybdenum and tungsten ore deposits* in quartz veins.
- e) Dykes- of felsite and porphyry.
- f) Dykes of dolerite (youngest Gattarian extrusions).

The classifications given above is based on a great number of short fieldtrips^x in very large areas and it should be kept in mind therefore! that this classification is still rather hypothetical. Unless a detailed map of the whole pre - Carboniferous area of Egypt is prepared by a great number of experienced geologists, we shall not be able to establish a detailed stratigraphy of this pre-Carboniferous section, the more so as it is of no interest to the oil companies who up till now did most of the detailed mapping in Egypt

3) *Stratigraphy of the Carboniferous*

Carboniferous rocks can be studied best in the Wadi Araba area (W. coast of the Gulf of Suez) and E. of Abu Zenima (E. coast of the Gulf of Suez) in the Umm Bogma area near the manganese mines. Interesting sections have been found also in the sub-surface sections of the Ras Gharib oilfields (W. coast of the Gulf of Suez).

1) *Wadi Araba section* : in Wadi Araba and along the east slope of the northern Qalala Plateau carboniferous beds were discovered in 1883 by SCHWEINFURTH. They were studied more in detail by Prof. J. WALTHER in 1887. From top to bottom the section consists of the following beds :

abt 400 m : middle Eocene limestones; at base large erosional unconformity.

240 m: upper Senonian (Maestrichtian and Campanian.)
chalky marls

- abt. 90 m: marly limestone and marl with sandstone intercalations and L. Senonian *Ammonites*
- 115450 m: Turonian limestone
- 155490 m Cenomanian marls and limestones
- 250 m: non fossiliferous reddish *Nubian sandstone* (probably Carboniferous in age)
- 2 m' bed with siliceous trees (*Aräucarioxylon*)
- 60 m: sandstones and marls
- 1 m hard blue-grey Carboniferous limestone with many *Crinoid* stems, *Zaphreniis*, *Spin fera*, *Rhgmchonella*, *Productidae*, *Bellerophon*^ *Fenestella*, etc»
- 40 m: marl and sandstone

The term *Nubian sandstone* is given to a thick monotonous nonfossiliferous sandstone series? either white or brownish in colour ? usually. loosely cemented and easily weathering into loose sand, consisting mainly of quartz and a few other minerals; which is overlying the Pre-Carboniferous granites and schists. Their age varies between Carboniferous and Campanian, but as a rule further north towards the Mediterranean the Cretaceous sandstones change gradually into marine argillaceous-, chalky- or limestone deposits,

2) *Umm Bogma section*« a very interesting section is outcropping along the road in, Wadi Baba leading up to the Umm Bogma manganese mines, ^which can be summarized as follows from top to bottom :

- abt 150 m : white or brownish sandstones with clay intercalations and prints of *Lepidodendtons*»
- abt 40 in: 'hard dolomites or soft grey limestones with *Corals*^ *Crinoids*, *Brachiopods* and Fish - teeth, They are overlying the deeper beds with a slight unconformity;
- 40 cm.-f e w m : black or reddish shales, locally with green copper- and ferrous salts. The thickness varies from place to place;- the thinner the shale, the thicker the overlying limestones;

1*2 — 6 m *Manganèse ore*, probably, originating sedimentary by dissolution of manganese salts of contemporaneous, or older basic intrusions (the thicker the covering shale, the thinner the ore deposits);

10 m white solid sandstone;

105 m alternation of white Nubian sandstones, green shales and red micaceous sandstones, the number of shales is increasing upwards. The basal sandstones ovtrly with an arkose or Nubian sandstone (but without a basal conglomerate) a completely flat fossil peneplain, the top of a Pre-Carboniferous granitic batholith. This suggests^x a nonfluviate and non-marine deposition propbly of aeolic, origin.

Abbut 8 cm, SSE of Umm Bogma, at Gebel Maghara, almost| at the same stratigraphic level as the manganese ores of UmiÅ Bogma, 'turquoise deposits occur. The detail section consists from top to bottom of the following beds ;

60 m. : sandstones

Two horizontal ferruginous seams, abt 2 1/2 m, apart; turquoise occurring at this level as Joint-filling or as concretionary nodules;

Lower sandstone series of Umm Bogma«

8) *Subsurface section at Ras Gharib* : under the Miocene evaporite series (see later) a carboniferous section occurs which can be summarized as follows (from top to bottom) :

abt, 80 m, : black clay-slates with small *Brachiopods* and *Conodonts* (discussed in article on "Th9 micro™ stratigraphy of Egypt,, ;

80 m* : alternation of white Nubian sandstones and black clay-slates, the number of clay - slates intercalations increasing upwards;

at least 100 m. : white Nubian sandstones with clay intercalations and prints of *Lepidodendrons*, which are

Important reservoir horizons in the Ras Gharip oilfield, • •

4) *Stratigraphy of the Triassic:*

Up till now nowhere in Egypt Permian beds have been found with certainty, But M, Triassic beds were discovered in 1945 by the Geological Survey of Egypt (in particular by Dr, GALL AL HAFEZ AWED) at Gebel Araifel-Naga in N.E. Sinai, They were described later in detail by Mr, EICHER from the Standard Oil Co, of Egypt It seems that a few years earlier this locality was discovered by the oil geologists of the Shell Oil Co., but no data were published on it. The section of Araifel-Naga consists from top to bottom of the following beds :

Thick section of L. Cretaceous Nubian sandstone[^] overlain by marine U. Cretaceous and Eocene beds, and directly underlain by the following Triassic beds :

80 m. : Grey to brown limestone with greenish and multi-coloured shale intercalations;

6,5 m. : Shaly marl with *Progonoceratites*, *Mgophoria laevigata** *Avicula* sp_M *Ostreâ mantis*, *Pseudoplacunoides*, etc,;

abt. 70 m. : Grey to brown limestones with one 4 m, thick sandstone intercalation and a few shaly intercalations, Also in these beds *Myophoria*, *Ceratites* and other Triassic macro-fossils were found,

This Triassic section is also interesting because some of the shales contain *Conodonis*, micro-fossils up till now mainly known from Palaeozoic beds,

5) *Stratigraphy of the Jurassic:*

One of the best exposed (more than 1200 m* thick) Jurassic •Sections was found in N. Sinai in Gebel Moghara and was described by MOON, SADEK and others round 1920. The author measured a standard section in 1937 (17) for the Socony Vacuum Oil Co*, which-can be summarized as follows from top to bottom :

a) *Upper Jurassic*: About 300 m«

120 m. : Light grey limestones with flint and chert beds and
•ferruginous *Corals*;

60 m. : Light grey chalky limestones;

100 m.: Grey limestones, in lower part with yellow - brown
marl intercalations,

b) *Middle Jurassic*: About 550 m.

200 m. : Alternation of grey limestones and yellow-brown
marls and marly limestones ;

80 m* : Dark brown ferruginous calcareous sandstones;

140 m.: Alternation of grey limestones and brown marls
with *Rhynchonellas*, *Terebratulas*, *Echinotds* and
Algae nodules ;

110 m. : Alternation of grey limestones, brown marls and
% brown, calcareous sandstones; at base a 5 -10 m.
Vthick clay bed.

c) *Lower Jurassic** 400 m.

200 m.: Brown ferruginous calcareous sandstones
with à few marl and limestone intercalations,
with *Rhynchonellas*, . Plant-fragments and
: *Algae* nodules; at base a .thin clay horizon; .

More' than 120 m, : Grey limestones with a single marl interca-
lation*

: - This marine facies of the Jurassic is only known near the
.Mediterranean, probably north of latitude 29°. Further south
Jhe Jurassic is developed in a Nubian sandstone facies,

6) *Stratigraphy of the Cretaceous* :

i a) *Lower Cretaceous*: It is usually developed as brow»,
|reddish or purple strongly ferruginous, sometimes glauconitie
|sandstones with clay intercalations. The thickness varies COR-
fsiderably but is mostly more than 800 m.

I b) *Cenomanian CÜ. Cretaceous*): A section of abi 150 m,
phickness consisting of an alternation of limestones or dolomit

tes, multicoloured ferruginous sandstones (often greenish glauconitic) and marls (often brownish); in lower section many gypsiferous clay intercalations occur. In certain areas (e. g. W. of Ras Gharib) the clay and sandstone content may dominate, in other areas (e. g. near Sudr) the limestone facies. In south Egypt (S. of 27° 15' lat.) the Cenomanian is developed in a Nubian sandstone facies, often calcareous in its upper zones. In N. Sinai often two facies are found in the same structure: On the flanks the dolomitic facies, in the centre an alternation of limestone, sandstone and marls, which indicate sedimentation during folding.

Common fossils of the Cenomanian are : *Orbitoltna*, *Rudistae* (*Preradiolites*, *Hippurites*), *Ogsters* (*O. olisiponensis*, *O. flabellaia*, etc.), *Neolobites*, etc.

vc) *Turonian*: in the N. Part of Egypt (N. of Gebel Zeit) it is usually developed as a cliff-forming section. In the S. part of the Red Sea district (e.g. in Wadi Melaha) it is developed in a Nubian sandstone facies, which changes further north, near Ras Gharib, into 80 m. of light grey marly limestones with few clay intercalations; on the E. side of the Gulf of Suez near Ras Matarma a 200 m. section of limestones with few marly limestone intercalations is developed. Further north in Sinai it consists, of 160 m. chalky limestones or even dolomites (flank facies), in upper part alternating with marly limestones. *Rudistae* and *Echinoids* (*Hemiasters*) are common.

North of Cairo in the Abu Roash structure a Turonian section is developed which consists of a number of well developed units which from top to bottom can be described as follows :

45 m. *Flint series i* white chalky marly limestones with many flint intercalations ;

20 m. *Nerinea beds'* 160 m. : limestone either composed of a *Biradiolite* reef (on R flank of structure) or a *Nerinea-Acteonella* bed (in the centre); in places thick *Coral* masses;

4 m. ; very gypsiferous clay

130 m. *Chalky limestone series* : white chalky limestones.

Several phenomena in the Abu Roach and N. Sinai structures, such as faciès changes with respect to the present-day structural axis, indicate local structural movements in Egypt at the end of the Turonian.

d) *Senonian* : in N. Egypt 100 - 200 m. • of light grey, [dark grey or brownish marly limestones occur; in S. Egypt (S. of Bas Gharib) the uppermost Senonian (Maestrichtian) is composed of 40 m. of white chalky marls, underlain by 20-40 m. of brownish grey marls and clays with several thin *Phosphate beds* (Campanian) which cover a Cretaceous Nubian sandstone series (composed of sandstones with few shale intercalations), usually calcareous near the top. These phosphate horizons, which sometimes are rich in *Reptile bones*²⁾ (so-called "Bone Beds,") and Fish-teeth, may reach considerable thicknesses and are exploited by the phosphate" companies in Safaga and Quseir on the W side of the Gulf of Suez.

ÎÎ^ the L. Senonian (Santonian) *Echinobrissus*, *Ostrea costei* and *PHcaiuia* often are abundant, in th Campanian *Bxogyra*, *overwegi*, *Pecten farafrensis* and *Gryphoea vesicularis* are common, also a few *Cephalopods* have been found.

An interesting, about 90 m. thick, Senonian Nubian sandstone section occurs E. of the Nile, 4 km, north of Aswan (N# of Wadi Abu Agag). It consists from top to bottom of the following section :

15 HL : sandstone, grits, quartzites, etc, ;•

10 m. : clay

8 m. : sandstone :

0.1 m. : oolitic *Iron ore*, further east developed into two bands,* each abt. 2 M. thick, separated by ferruginous sandstone;

6 m. ; refractory (fire) clay;

2 m. : sandstone ripple marks;

5 m. : two bands of oolitic iron ore, abt, 1 m. each alternating with ferruginous sandstone:

2) It is interesting to note • that, in accordance with other countries^ the first mammalian bones were found in Egypt in Eocene (LL Eocene) times«

10 m. : sandstone with ferruginous concretions;

10 m.: laminated clay;

20 m, : sandstone, kaolinised at base; covering irregular erosional surface;

Granites and schists.

These oolitic ores may be used in the future for a industry in Egypte, the electricity for the electric furnaces being supplied by a new hydro-electric plant which at present is constructed near the Aswan dam.

The Senonian age of the Nubian sandstone is indicated by the presence of the following fossils: *Inoceramus balli*, *I. cripsi*, fresh water shells of the genera *Unio*, *Mutella* and *Spathi* and plant-remains. These fossils, together with the great lateral variation of the beds and their cross-bedding, suggest very shallow water conditons during their formation. Also the oolitic structure of the iron ore indicates shallow coastal conditions, the weve action allowing the gradual growth of the oolites floating in colloidal solutions rich in iron oxide.

7) *Stratigraphy of the Eocene;*

r.) *Lower Eocene* > (In Egyptian literature often indicated as Yprosiian, Suessionian or Lybyan): The transition of Cretaceous and Eocene in Egypt and in the Near East in general is a gradual one and the exact boundary can not be established on a lithological or heavy mineral basis. Only a micro-faunal analysis (and perhaps also a drilling-speed analysis) enables us to establish this boundary within a meter (17, 18, 23). This transition zone of marls and marly limestones in Egypt is known as *Esna Shales* or *Danian* in the older Egyptian literature, a stratigraphic name which has proved to be superfluous in the Near East (23).

In S Egypt the marly basal Eocene section is only a few meters thick and is covered by at least 200 m. of creamish-white limestones, very rich in large flint nodules. Further north (near Ras Gharib) the whole Lower Eocene section is becoming more argillaceous and chalky (particularly in N E Sinai).

The L. Eocene is rather unfossiliferous: small Nummulites have been found {*N. variolarius*, *N. curuispira*}; *Operculina*.

libyca, small *Gastropods* (*Tarniella aegyptica*), *Conoclypeus*, etc.

Hundreds of dry distillation tests of field samples have revealed that oil drops were obtained after dry distillation only from L. Eocene and U. Senonian chalky beds (see also later U. Eocene). The Miocene, with a single exception, always gave a negative test. ***This suggests that the main source rocks of Egyptian oil are found in the Senonian and L. Eocene*** (see also U. Eocene).

b) *Middle Eocene*: (In Egyptian literature often indicated as Lower Moqattam, Parisian or Lutetian): At the top of the L. Eocene usually a big unconformity occurs which is probably the most important hiatus of the Near East, from Turkey up to Egypt and which is caused by regional uplifts which at the end of the L. Eocene created the initial faults of the Red Sea and Dead* Sea graben zones. Due to this regional uplift in Egypt higher blocks were deeply eroded during the end of the L. Eocene and basal M. Eocene and were covered unconformably by the Nummulitic limestones (e. g. *Nummulites gizehensis*) of the M. Eocene. In some fold blocks the erosion went as far as the Cretaceous (e. g. in Abu Roash) and as a result the Eocene limestones covered directly Senonian or older beds. In certain places (e. g. near Hammam Faraun or Wadi Dara) the hiatus probably is absent or very small. They were the deeper basins of the L. Eocene sea which remained below sea level during this period of regional uplift. In those areas also the thickest M. Eocene deposits seem to occur. At those places where a big unconformity is developed often a thick basal conglomerate with large Nummulites can be found, which can act as an oil reservoir horizon (e. g. on the E. side of the Gulf of Suez).

Due to local block movements in the Red Sea graben during the M. Eocene (and later) certain areas were continuously eroded and were covered for the first time in U. Miocene time only. However in the deeper basins between these blocks, marine sedimentation continued through the Mi and TL Eocene and Pliocene,

Thick M. Eocene sections have been described from the Nile delta area, the Moqattam Hills near Cairo and the Nile Val-

ley which seem to indicate a deeper water fades in N Egypt (limestones and chalks) than in S Egypt (many argillaceous intercalations in a limestone section'.

In the F A YUM AREA, 80 km. S W of Cairo, a well-developed section is outcropping. which was classified by BEAD-NELL (from top to bottom) into 3 units : Birket el Qarun series, Ravine beds and Wadi Rayan series of which the Birket el Qarun- and the upper part of the Ravine beds proved to be upper Eocene during the most recent surveys of the oil companies.

1) *Lower ravine beds* '• abt. 30 — 40 m. thick also known as *Oahannam beds*«

Top 10 m : hard light yellow limestone partly marly and sandy in places with *Nummulites gizehensis* ;

7 m : ochreous yellow and grey clays and marls with, gypsum,

3 m : hard yellow very gypsiferous shaly marl ;

10 m : yellow marly clays, brown clays, sandy glauconitic yellow and black clays with much gypsum and *Seuglodon* remains.

2) *Wadi Rayan series*'- abt 180 m. of siliceous limestones, marls and some clay intercalations ; fossils : *Nummulites gize** *hetisi* *Sy Fascioides*, *Carolin placunoides*, small Seurchins (*Porocidaris*, *Rhabdocidaris*), etc.

c) *Upper Eocene* (In Egyptian literature often indicated as Upper Moqattam, Priabonian or Bartonian): this section can be studied best on the E. coast of the Gulf of Suez near Hammam Faraun, in Wadi Tayiba, near Cairo (E. of Maadi) and in the Fay urn area. *

Wadi Tfiyiba-Hammam Faraun section :

40 m. : *Tanka beds* : white marly limestones, near top often reddish below a covering dolerite flow (so-called Lower Red Beds);

- 105 m. : *Oypsiferous maris* : in upper part dark brown saliferous marls, lower section grey or greenish gypsiferous maris;
- 20 m, : *Green bees* : brownish and greenish sandy marls, marly limestones and limestones;
- 65 mu : *Cardita series*: whitish weathering. Light brown chalky marls and marly limestones with many chert intercalations; •
- 160 m. : *Chalky limestone series*: white weathering light brown chalky marly limestone chalky marls, in lower part often pinkish; at base a thin conglomerate.

This lowest unit, of ten gives after dry distillation small oil drops which indicate⁵ that *also the U. Eocene may be a potential source i^ck for oil* particularly on the E. side of the Gulf of Suez. Y

Wadi Dara section •

A thick Eocene section, (the age of which being established by the lack of *Globigerinoides* and *Orbulina* and presence of small *Oiirnelinas* in an extremely richly developed marly section, flooded with *Globigerinidae*; see also my article on "*The micro*stratigraphy of Egypt*", was encountered on the W. side of the Gulf of Suez, N. of Gebel Zeit in the Wadi Dara (Socony Vacuum)-well. It consists of more than 400 m, of grey marls. with several thick clay intercalations,

Maadi Section :

South of Cairo (E. of Maadi) a 70-80 in, thick Ü. Eocene section occurs which is considerably broken up by faults. The section is overlying M. Eocene Nummulitic limestones of the Moqattam Hills, U. Eoeen consists of the following beds :

Top max, 7 m* : thick-bedded (50 cm or more) sandy limestone with a 40 cm' thick white sand intercalation;- the limestone is for the greatest part non-fossiliferous but in places rich in small *Echinoids* and large *Oysters* (Upper Echinoid zone);

- 15 m. : light grey and greenish - grey, often yellow, brown weathered, gypsiferous sandy clay, partly clayey sandstone, with limonite concretions; **abt.** 3 m. from top of this unit a 1 m. zone full of large *Oysters* (Upper *Carolia* Bed) ;
- 1 m. : brownish weathering **creamish-white** limestone full of shell fragments;
- 10 m. : very sandy, very gypsiferous clay,, yellow-brown weathering, in upper part full of *Oysters* (*O. fraasi*);
- ' . 1 m. : white limestone full of *Ecknoids* and **Oyster** fragments (Lower **Echinoid** zone);
- 4 m. : Yellow-brown slightly sandy marl;
- 2 m. : hard limestone with *Carolia*. (Lower *Carolia* Bed);
- 1,5 m. : yellow-brown sandy marl;
- 8-10 m. : dark brown gypsiferous shale with small *Oysr. ters*;
- Bottom 26 m. : • brownish weathering light grey and creamish-white gypsiferous marly limestone and argillaceous limestone.

It is rather certain that a hiatus exists in th Cairo area at the base of the U. Eocene, although it is usually more a disconformity than a real unconformity.

The following fossils are most common in the Maadi section; large *Oysters i Carolia pjacunoides*), smaller *Oysters* (*Os* trea fraasi*), *Echinolampas*, *Plicatula polymorpha*., *Nummulites beaumonti*; it is interesting to note that the *Nummulites* are practically missing above the base of the U. Eocene section.

Fayum section:

BEADNELL described a 175 m. thick U. Eocene section from the Fayum area as *Qasr el Sagha* — or *Carolia series*, which consists of an alternation of very fossiliferous limestones and purple or grey clays, with ferruginous sandstones particularly in the upper beds. Locally lignite horizons occur, near

the base gypsiferous clays are common, The section is rich in *Oysters* (see Maadi section) and *Tarritellas* and contains a famous *Vertebrate* fauna which was discovered round 1879 by SCHWEINFURTH. The following U. Eocene *Mammalia* and *Reptiles* were found: *Zeuglodon*, *Pterosphenus*, *Eosiren*, *Moeritherium*, *Stereogenys*-, *Tomisloma?* etc., which were described by ANDREWS a* o. The occurrence of land-animal skeletons together with *Crocodile* and *Turtle* remains and the abundance of plant-impressions and even lignites, indicate very shallow water conditions near an old shore-line.

We mentioned above that recent studies by the oil companies have revealed that also deeper beds in the Fayum area belong to the upper Eocene, They were described by BEARNELL as Birk el Qarun series and Upper Ravine beds, which are difficult to differentiate from the higher Qasr el Sagha series.

§ *el arun series*: abt 50 m. ochrous coloured sandstones and clays with sandy limestones overlying the Upper Ravine beds ; few concretionary sandstones weathering into large globular masses. Fossils : *Nummulites fraasi*, *N-beaumont* *Operculina discoidea*, *Plicatula polymorpha*, *Turritella pharaonica*, *Zeuglodon*, *Cardila*- and *Cardium*, *sp* etc«

Upper Ravine beds: abt. 40 m. yellow sandstones alternating with yellow brown and greyish gypsiferous clays, marls and marly limestones, containing small *Nummulites* and *Oysters*.

The whole upper Eocene unit on the Fayum area is indicated at present as *Qarun sagha series*, In a section 22 km W. of Qaret Gahannem this Qarun-sagha series is abt 210 m. thick. It is composed of two units :

1) a lower unit of abt 112 m, composed of calcareous sandstones/ in the upper part with few sandy clay intercalations and at the top a thick white sandy limestone; the section is rich in *Nummulites eoniortus-striatus*, *Carolia*, *Ostrea kerunia* and *Turritella*;

-2) upper unit of abt 100 m* of brownish ferruginous sandstones with few clay intercalations containing *Ostrea kerunia*, *Turritella* and *Carolia* but no *Nummulites*; at the top *Zeuglodon* remains occur.

The varying thickness of the Qarun-Sagha series and other similar phenomena (which are omitted for lack of space) indicate structural movements during sedimentation which started probably at the end of the M. Eocene.

8) *Stratigraphy of the Oligocène*

On the *E. border of the Gulf of Suez* a 50 m. thick section occurs known as *Upper red beds*. It consists of a basal conglomerate, overlying the upper Eocene Tanka beds, which is covered by abt. 40 m. reddish sandy marls, calcareous sandstones and sandy limestones which in their turn usually are covered by a conglomerate which is overlain by a thick (up to 40 m.) dolerite bed. This dolerite bed usually is covered again by a conglomerate, which in its turn is covered by Miocene (probably lower-) beds.

On the *W. border of the Gulf of Suez* a 100 m. thick marine section, composed of grey clays and marls, was encountered in the Wadi Dara (Socony Vacuum) well, N. of Gebel Zeit.

Oligocène is outcropping also in large areas *between Cairo and Suez*. It is characterized by at least 40 m. thick ochrous, brown, reddish or black silicified sandstones or quartzites, loosely cemented white or yellow brown weathering sandstones (resembling ordinary Nubian sandstones), hard breccias, conglomerates, etc. The sandstones often show pronounced cross-beddings and in many places they are rich in silicified wood. Trunks of up to 16 m. length have been found, belonging to the genera *Araucarioxylon*, *Palmyloxylon*, *Nicolia*, *Laurinoxylon*, *Acacioxylon*, etc. The trees probably are not in place because the bark seems always to be absent, there are no branches or roots and they are always in horizontal position. They were probably drifted into an estuary together with the sandy deposits which are partly aeolic or fluvial in origin. As these beds are overlain by thick (up to 18 m. basalt flows, which are unconformably covered by Lower Miocene beds and as the Oligocène sands are covering unconformably the upper Eocene beds, this usually non-fossiliferous sandy section is definitely Oligocène in age.

Near these IL Oligocène basal flows often very hard Siliceous sandstones, chalcedony and extremely hard-cemented conglomerates occur. These phenomena and the reddish and ochreous colouring of the Oligocène is probably due to the hydrothermal action which followed the late Oligocène volcanic activity. It is very likely that part of the silicification of the fossil trees is due to these solutions, which may explain their greater abundance and better preservation near these volcanic centres. It was found that the volcanic activity was completed before the L*. Miocene beds were deposited. The silicified sandstones and conglomerates gave rise in recent times to denuded necks and isolated hills such as Gebel Ahmar near Cairo and «Rennebaum's volcano» on the top of Gebel Moqattam, etc. The Oligocène is unconformably covered by the Miocene which we shall discuss later on.

The sands of the Oligocène and the many flint pebbles probably derived from the Eocene limestone ridges, which after being folded and faulted came above sealevel in pre-oligocene times and were denuded in places as far down as the Pre-Oretaceous Nubian sandstones.

Further eastwards the gritty sections change into a limestone facies: e, g, near Gebel Genefe, S* of Bitter Lake, about 100 m. of m. Miocene limestones are developed rich in *Meterostegina* and *Lithothamnium* the limestones in places being gritty and intercalated with marls. This section is underlain by about 19 m. of sandy limestones, gypsiferous clays and marls which belong probably to the L. Miocene,

Miocene of the Gulf of Suez area :

The Miocene transgression did not start in all parts of the Gulf of Suez at the same time. High blocks such as Gebel Zeit, Shadwan Island and oil structures such as Giftun Kebir, Sherm el Arab, Dishet el Baba, Eas Gharib, etc., were only covered completely in XL Miocene times. In other structures this took place in M. or L. Miocene times. The tL Miocene is therefore a rather uniform unit with thicknesses, fluctuating usually between 90 and 120 m. only, whereas the I, and L. Miocene, due to these overlap conditions, vary considerably in thickness. This is even more so as also between the L. and M. Eocene

local block movements seem to have taken place creating small erosional hiatuses.

The pre-Miocene erosional hiatus usually is considerable and may reach even the basement, in other words in the most extreme case granite blocks are covered directly by U. Miocene beds. Up to the basal U. Miocene open sea conditions prevailed and as a result, during the M. Miocene, marls were deposited often flooded with a planktonic *Qlobigerina* fauna (see later). Only in the deepest basins of the Gulf of Suez, e. g. in the Jemsah and Towila area, the influx of fresh water was insufficient to compensate the evaporation and as a result in lower and middle Miocene times thick saliferous deposits were formed also known in Egyptian geology as *Lagoonal series* or *Euanonte series*.

At the beginning of the U. Miocene the whole Red Sea basin was probably closed off and everywhere, except in the area N. of Suez, a solid saliferous section was deposited of abt. 100 to 120 m. thickness. In the Gharib and Sherm el Arab — Hurghada area this section is abruptly covered by sandstones and grits which suggests a sudden increased erosion of the granite mountains bordering the Gulf of Suez. This, together with the sudden absence of evaporite deposits in the higher beds (except in the deeper parts of the basins, e. g. near Abu Shaar, Jemsah, Wadi Dara, etc.), suggests a reopening of the Red Sea basin as a result of new tectonic movements.

An interesting *Oligocène section* occurs S. of Cairo in the Fayum area and was described by BEADNELL as *Fluvio-Marine series* or *Gebel el Qatrani beds*. It consists of abt. 280 m. of variegated (red and yellow) sands, sandstones and grits alternating with clay or marl; the limestones practically disappear in contrast with the Qasr el Sagha series. In the upper part a probably contemporaneous horizontal sheet of basalt was formed. Few fossil beds occur with *Melania*, *Potamides*, *Lucina*, etc. indicating an estuarine or fluvio-marine origin. Also enormous quantities of large silicified trees (without branches or roots) together with numerous remains of land-animals, crocodiles, tortoises and turtles have been found, indicating deposits of large rivers in a very shallow sea near a coastline comparable with large swampy delta regions in present-day tropical countries.

The most important Vertebrata discovered in this section are : *Arsinoitherium*, *Palaeomastodon*, *Moeritherium*, *Megalohyrax*, *Saghatherium*, *Pterodon*, etc.

It is interesting that this fluvio-marine facies continues in the Miocene and Pliocene of the Western desert, only the facies boundary moved gradually northward; in the Fayum this facies appears in the U. Eocene, abt. 70 km. N. a similar facies appears in the L. Miocene, near Wadi Natrun in the Pliocene. In other words the Large Delta area of N. Egypt was gradually filled up after the M. Eocene.

In 1938 ANDREW and CUVILLIÈRE discovered marine Oligocene limestone near Borg el Arab, W. of lake Mariut, which contains *Nummulites intermedius* and *Lepidocyclina dilatata*.

The Oligocene usually covers the Eocene with a pronounced unconformity or disconformity, except in the Fayum area where a gradual transition seems to have taken place. In the Cairo-gfuez area a considerable erosional hiatus exists but the whole U. Eocene has not been completely removed in this area,

9) *Stratigraphy of the Miocene :*

As soon as we enter into the Neogene it becomes extremely difficult to correlate beds of different areas as the Miocene sea was split up in a great number of smaller basins with different facies conditions. It is therefore almost impossible to characterize the Miocene development in a few pages, the more so as the correlations are not yet definitely established and even amongst the different oil geologists of Egypt considerable difference of opinion exists concerning the Miocene classification. We shall try to give a brief summary of the many facies developments of the Miocene, our classification being based on personal observations in the field, on our regional lithological subsurface correlations of a great number of wells drilled in Egypt by the different oil companies and on micro-faunal studies of these sub-surface sections and of different surface sections (see my article on "The microstratigraphy of Egypt,, , and 17, 20, 21)

Miocene of the Western Desert ;

From Cairo westward a rapidly broadening Miocene zone occurs which covers unconformably the pre-Miocene beds. This

zone which can be followed through the Lybian desert and further on into Cyrenaica forms a plateau rising southwards up to 200 m. and more. The Miocene consists of abt. 400 m. of marine deposits composed of sandstones, limestones and clays. The lowest beds are fluvio-marine or continental as remains of *Mäsiodons* and other extinct land-animals have been found. The Miocene contains also the following marine fauna: *Scutella Zitteli*, *Ostrea uirleti*, *Clpeaster* sp* *Bchinoiampas*, etc,

. *Miocene of the Cairo-Suez Area :*

The Miocene is overlapping with a pronounced unconformity the Oligocène sandy series, which is often covered by a thick Oligocène' basalt flow, in its turn being covered by conglomerates and grits. This large erosional hiatus is also indicated by the above mentioned silicified Oligocène plugs, which are surrounded irregularly by Miocene beds. Due to these overlap conditions the different Miocene sections are difficult to correlate in detail. BARRON has given the following general Miocene section for the western part of the Cairo - Suez basin, which consists of abt. 79 m. of the following beds«

- Top abt, 14 m₈ : hard white or yellow, often gritty limestones, rich in *Pecten* sp., *Echinolampas*, *Osirea uirleti*, etc./ with a thin marl intercalation near the base;
- 10 m. : calcareous grits changing northward into *Lithothamnium* limestones;
- 1 m. : *Lithothamnium* limestone;
- f, Miocene 11 m. : cross-bedded calcareous sandstone; - -
- 5,5 m» : marly sandstone with *Pecten*, *Turritella* sp., etc,
- 10 m. : calcareous sandstone with flint pebbles changing further north into limestones;
- 1 m. : Conglomerate and grit becoming sandy and calcareous further north,
- L* Miocene 10 m. : marly grits rich in *Pecten*, *Lueina*, *Cardium*.; *Turritella* sp, •

- II* Miocene 1,5 m. : hard **fossiliferous** ferruginous grit.
 10 m. : fossiliferous sandy marl and marly **sands...**
 5 m. : alternation, of **gypsiferous**. marls and **hard**,
 often **ferruginous**, limestone,

- *West' coast of the Gulf of Suez***

Lower Miocene: Max* **350-400 m.** thick either composed of grey marls intercalated with thick clay and anhydrite (or gypsum) deposits (e. g. near **Wadi Dara**) which may increase to such an extent **that** a completely **saliferous** section is developed (e. g. at **Towiiia Island**), or **an** alternation of dark grey carbonaceous **shaly** clays and sandstones (or sands) is **developed**, in the upper part rich in marls (e. g. **Hurghada** and further south). In **this** latter **facies**, being the *oil-producing horizon in Hurghada*, near the top often a so-called *flint conglomerate* **occurs/overlying** purple coloured marls; both **facts**, together with t&e varying thickness of the covering *Globigerina* marl series, indicate a small **erosionâl** period at the end of the **L. Miocene** as a **result** of local' block movements. The L, Miocene usually directly covers the **pre-Carboniferous** granite ridges.

Middle Miocene: Max« 400 m* thick greenish grey *Globigerina. mari series*, near the base often with limestone or dolomite intercalations particularly if the marls are directly overlapping basement rocks. The limestones are important *oil reservoir horizons*, e, g® **in Jemsa**, but particularly in the new oilfields on the E* side of the Gulf of Suez, the source rocks **overthere** being probably U. Eocene (see above). In surface sections *Aturia atari* and *Carchârodon* are common fossils. **In** the deeper basins often anhydrite (or gypsum) intercalations occur which may increase to such **an** extent that a completely saliferous section is developed either composed of anhydrite or rocksalt or an alternation of, both (e. g. near Wadi Dara and at Towiia), **In** certain shallow areas (e* g. **Habashi**) clays are replacing the marls. At the top of the M. Miocene (in Abu **Shaar** arid. Dishet **el Daba**) a thick (tip to 40 m.) **conglomerate** occurs mainly composed of enormous granite boulders.

Upper Miocene ; **abt.** 100 » 120 m. of solid * anhydrite, gypsum or **rocksalt** (in the deepest parts of the basins), sometimes

with few thin clay or marl intercalations. In the southern part of the Gulf of Suez, near the -W. border of the graben faults, the basal section is sandy developed (e. g. **Dishet el Daba**); N₉ of Suez (**at.Habashi**) slightly calcareous clays, with few gypsum nodules occur, indicating the northern end of the saliferous basin. In the above mentioned structures (**Giftum Kebir**, **Sherm el Arab**, etc.) the upper part of the U. Miocene solid anhydrite series is directly overlying the granite ridges with a relatively thin basal reef limestone or dolomite,

East coast of the Gulf of Suez:

Lower Miocene : thickness varies in places at least 250 m. thick. Either developed as grey or blueish green shaly clays with thin grit intercalations (usually in surface sections) or as **gypsiferous *Qlobigerina*** marls with limestone intercalations (usually in subsurface sections) overlying M. Eocene or Cretaceous (marine or Nubian sandstone faciès), often with basal conglomerate composed of **limestone-, flint-, and dolerite** pebbles. This unconformity represents an *important oil reservoir horizon* on the E. coast of the Gulf of Suez (e. g. in the **pre-Miocene** beds and the basal L. Miocene beds act as important oil reservoir horizons on the E. coast of the Gulf of Suez, *The source rocks probably being upper Eocene in age.*

Middle Miocene: more than 800 m. thick, either composed of ***Globigena*** marls with gypsum intercalations (in deep subsurface sections) or developed as a grit-marl series (usually in surface marl intercalations (containing ***Aturia aturi***, ***Cârcharodon***) and an upper shaly marl section (dark green and black). A general tendency seems to prevail (similar to the M. Miocene of the W. coast of the Gulf of Suez) that the thicker the ***Globigerina*** marl series is developed, in other words the deeper **the local block structures**, the less limestone intercalations (usually beach- or **detrital** limestones) occur in the M. Miocene. The greatest development of limestone can be expected if the marls are directly overlying the pre-Miocene beds, an important observation in connection with the **accumulation** of oil. In the Ras Matarma oilfield and **near-** the old faultscarps in the **Sudr oilfield**, the basal- M₉ Miocene (or top L. Miocene) is composed of **abt. 170 m*** of oil sands, conglomerates, gritty algae limestones,

shales, etc., which probably can be compared in age with the (*Flint conglomerate*) (at the top of the L. Miocene) of the W. coast of the Gulf of Suez. Near Wadi Feiran, in sub-surface sections, the M. Miocene -*Globigerina* marls seem to cover directly the granite basement, which is outcropping further south in the Abu Durba Mountains. The transition between marls and granite is formed by abt. 20 m, of fine oilproducing sand underlain by 18 m. of shale.

Upper Miocene-' abt. 120 m. of solid anhydrite or gypsum, known by the oilgeologists as *First gypsum bed* or *Loner lagoonal* or *Lower eoaporite series*. It is remarkable that thick rocksalt sections, such as occur on the W. side of the Gulf of Suez, have not been encountered yet.

All three sections (IL, M. and L. Miocene) seem to change laterally into gritty sandstones, conglomerates and clays towards the E. border of the faults.

10) Stratigraphy of the Pliocene:

The Pliocene usually is unconformably covering the lower beds. Different Pliocene areas are known in Egypt, the most important ones being the following :

Gulf of Suez area. :

E. Coast of Gulf of Suez : the previously mentioned lower lagoonal series is covered by the so-called *Upper lagoonal* or *evaponte series* (abt. 570 m.) which is subdivided by different geologists in a number of units which locally can be recognised relatively easily in sub-surface sections, but which are extremely difficult to map in surface sections. Those units are from bottom to top :

a) *Lower intergypseous marls with second gypsum beds* (abt. 120 m.): Composed of yellowish foraminiferal marls rich in *Globigerinidae* often with a gypsum intercalation, near the top often changing to greenish gypsiferous clays.

b) *3rd gypsum bed* (abt. 170 m.) : gypsum.

c) *Upper intergypseous marls* (abt. 60 m.): composed of white marls and yellow or greenish gypsiferous clays.

d) *4th gypsum bed* (abt. 75 in.) : alternation of gypsum and marls.

e) *Marl bed* (abt 60 in") : Yellowish marls sometimes with sandstone at the base.

f) *Nullipora rock* (abt« 75 in.): White limestone with abundance, of *Lit hoi ha m ni urn*.

g) *5th gypsum bed* (abt. 10 m.) : Gypsum alternating with creamish marls.

This upper lagoonal series may change into reef limestones and grit near the E* border of the Red Sea graben. But also for other reasons given above this classification has only local significance., À great number of oil geologists still consider this section as Miocene^ but for different reasons there seems to be little doubt that the Upper Lagoonal series is a Pliocene section,

W. coast of the Gulf of Suez : Three different faciès are known ;

a) *Sands lone fades t* It is particularly developed S.- of Hurghadä and in the Ras Gharib area and consists of more than 400 m. of usually calcareous sandstones and grits with marl and clay intercalations and a few limestone beds; *Laganum depressum* is the most common fossil in the upper part of this section. The section always is unconformably covered by Pleistocene beds, which explains the great variety in thickness of these sections,

b) *Argillaceous fades*: In certain areas near the border of the Red . Sea graben and above the deep subsurface structures (e. g. G if tün Kebir, Ras Gharib well no. 2) a thick argillaceous section occurs mainly composed of clays? marls and gypsum intercalations, in the upper part usually sandy developed. The thickness may vary between 400 and more than 800 m. depending on the erosional hiatus at the base of the Pleistocene.

c) *Evaporite fades*: In the deeper parts of the Pliocene basin the U. Miocene saliferous deposition continued throughout the Pliocene, As a result an up. to 700 m. thick section was deposited either composed of gypsum with clay intercalations, rock-salt or a combination of both« Usually rock-salt is

.developed only in the L, Pliocene. In certain places e. g. **Hurg-hàda**, Jemsa₃, Abu Shaar **etc.**, **diatomaceous** earth was encountered. Usually the erosional hiatus at the base of the Pleistocene is very small or even missing.

At the base of these three different faciès usually a thin **marl** section occurs, known as the *interglacial maris*, which is extremely rich in *Globigerinidae*, the ratios between the different genera being different from the M. Miocene' (*ilobigerina* marl series).

In the Gulf of Suez area at the base of the Pliocene grit series probably no erosional hiatus exists, which is indicated e- g. by the equal thickness of the underlying solid anhydrite unit. The grits and argillaceous deposits were **probably** washed into a shallow sea from the neighbouring Red Sea **Mountains**, the sudden **increased** erosion during the L. Pliocene probably being due to the structural movements«

Pliocene of the western desert:

L. Pliocene sands and gypsiferous clays /were found at the Wadi **Natron** depression, containing bones of *Hippopotamus*, *Elephants*, *Giraffes*, *Antilopes*, *Crocodiles*, *Fishes*, etc. At Deir el Rizo on the Bir Hammam - Moghara road **quartzites** have been found with Pliocene *Cardium*, *Cgtherea* and *Lucina* sp.; of Siwa Oasis fresh water limestones occur of probably Pliocene age.

; *Pliocene of the Nile valley* %

At the base of the **Moqattan** Hills near the Nile and S. of the Gizeh pyramids on the Saqara road, sands and loosely cemented sandstones occur with Pliocene *Oysters (Ostrea cuculiflata)*, *Peeiens*, *Clgpeasters*, etc,

I > In the present Nile valley from Beni Suef southwards | Miocene conglomerates and sands occur, but north of Beni | fiief limestones, sands and clays have been found containing | Corals, marine shells and seurchins, indicating a sea arm which | extended during Pliocene time up the Nile valley* The depth | to which Pliocene can be found in the Nile valley of abt **60-70** | ix above **sealevel**. The presence of marine Pliocene in the pre-

sent-day Nile valley and' the above mentioned origin of the XL Eocene and Oligocène deposits in the Fayum area indicate that the Nile valley was developed in its initial stages in pre-Pliocene times, probably at the end of the Oligocène during the general rise of S-Egypt

11) Stratigraphy of the Pleistocene.

The Pleistocene usually overlies the deeper beds with a considerable erosional hiatus and is differently developed in the different parts of Egypt

Pleistocene of the Gulf of Suez area :

In surface sections along the Red Sea and the Gulf of Suez a number of raised coral reefs and sea beaches can be observed, often at great heights above sealevel. Between Safaga and Quseir reefs have been found at 25 m, 72 m, 90 m, 114 m, 156 m, 168 m, and 238 m above sea-level, the lowest ones occurring close to the sea, the higher ones standing back 4-7 km BALL pointed out that these reefs may date back to Miocene time; only those near the present sea-shore are probably formed in Pleistocene times (probably U. Pleistocene) and it is due to these most recent regional uplifts that the Isthmus of Suez was finally uncovered,

iii sub-surface sections the L. Pleistocene is either developed as a section of at least 200 m of pebbly sandstones alternating with clays (or marls) or as an evaporite series of at least 850 m thickness composed of gypsum with clay intercalations. The latter facies is restricted to the areas with a saliferous development of the Pliocene, The U. Pleistocene is developed as gritty or pebbly, often calcareous sandstones with clay (or marl) intercalations or as coral reef limestones (e. g. at Gif tun Kebir), These sub-surface sections combined with the surface observations indicate a further deepening of the Red Sea graben in Pleistocene times in a regionally rising continent.

Pleistocene of the mediterranean coasts :

W. of Alexandria a ridge occurs, abt. 20 m above sea-level composed of very calcareous sandstones and oolitic limestones.

The base of this section (at least in a well 3 km 3^*-E_e of Hersa Matruh) lies 48 m below sea-level. A few km inland another ridge occurs, the area between both ridges being occupied by salt-lagoons and marshes with loamy ground. These ridges are fossil dunes which, must have been formed as a result either of a subsiding coastline or of a gradually rising Mediterranean sea-level. BALL has given an excellent summary of the youngest history of the Mediterranean coast. For different reasons (1 p. 56-67) he came to the conclusion that the following processes must have taken place :

a) From the M. Pliocene till U1 Pleistocene (abt. 20,000 years B. G_n so-called Middle Palaeolithic or Mousterian cultural period of Sandford) the coastal area was gradually rising above sea-level due to continental uplift, creating a number of continental uplift, creating a number of Nile terraces, the highest being at a level of 180 m (the coastline in the M. Pliocene being only 15 km N of Cairo), the lowest at 18 above present-Mediterranean levels

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b) During the early Recent (abt. 10,000 B. C, so-called late-Palaeolithic or Sebilian cultural period) the variations in sea-level seem to be caused by actual subsidence of the level of E. Mediterranean itself during periods of temporary severance of its connection with the ocean.

c) During the Middle-Recent (Neolithic period) slow continental subsidence took place in the Nile Delta area with a rate of 14 cm per century, which seems to continue at the present day. This explains the submerged Pleistocene fossil dunes of Alexandria, the submerged ancient building in the sea near Alexandria and presence of rock-cut catacombs in Alexandria (dating from 150 A. D.) below present subsoil waterlevel.

Pleistocene of the Nile valley.

As stated above, in the Nile valley a number of gravel and sandterraces occur which were created by a rising continent and continuous deepening of the Nile channel in the marine Pliocene deposits. Similar gravel deposits were deposited as a delta in the Pleistocene sea, at the time only 30-50 m North of Cairo. They were covered in recent times by Nile mud deposits,

usually abt. 9 m in thickness, the gravel series being known as *sub deltaic deposits*.

Pleistocene of the Fay urn Depression:

This enormous depression with a surface of abt. 12,000 sq. km lies abt. 80 km South of Cairo. At its lowest place a lake occurs (Birket el Qarum) the bottom of which lies 45 m below sea-level. This depression was probably formed by wind-erosion in late Pliocene or early Pleistocene times because no Pliocene has been found in the centre of the depression. The origin of the depression in a over 700 m thick 2-3° N. dipping Eocene section was possible :

- 1) because of a dome-shaped structure in the S. part of the Fayum which originated probably at the end of the M. Eocene;:
- 2) because of the presence of thick beds of soft arenaceous and argillaceous strata in hard Eocene limestones (see above);
- 3) because very likely faults are present in the Nile valley E. of Fayum which may be partly responsible for the W. part of the Nile being lower than the E. side.

In U. Pleistocene times the barrier between the Nile valley and the Fayum depression was broken up and the depression was filled up with a large lake (Lake Moeris). Thick lacustrine deposits, rich in fresh-water shells, fish-bones, remains of hippopotamus, crocodiles, turtles, etc., composed of gravels and sands, were formed in this lake. They are covering at present extensive peripheral parts of the Fayum depression as a series of terraces with pre-historic dwelling places, the highest being 44 m above sea-level. The level of Lake Moeris, being in free communication with the Nile, fluctuated considerably in U. Pleistocene times, gradually the connecting channel was filled up and the lake-level was lowered gradually by evaporation. In the 12 th dynasty King Amenemhat I re-established the free connection with the Nile; the lake acted as a result as a flood regulator. However, in the time of Ptolemy II the connection was not existing any more. A well drilled at Madinet el Fayum in 1898 passed through 5 m of Nile mud, 1,5 m mixed mud and sand, and 12 m of sand and gravel and finally the Eocene. The presence of an abundance of tamarisk stumps in the

youngest lake terraces indicates a difference in climate in pre-historic times.

Pleistocene wadi deposits of Sinai, Eastern- and Western desert :

In the deserts E. of the Nile and in Sinai deep erosional gullies were formed in Pleistocene times, in the W. desert however, very few distinct drainage channels occur, indicating arid conditions in that area at least during the last 20,000 years. The study of pre-historic implements in a wadi gravel terraces indicate, according to Dr. SANDFORD, that the large wadis in the E. desert were flowing streams prior to the close of the IL Pleistocene (Mousterian or M. Palaeolithic).

' Pleistocene of the Kharga and Kurkur oasis :

Calcareous tufa are covering the escarpment of Kharga Oasis. In one place they cover M. Pleistocene (Palaeolithic) implements which indicate an XL Pleistocene or Recent origin. These fresh-water tufa, precipitated from Ca CO_3 solutions and the presence of tree-remnants in them indicate a more humid climate than at present (see above Fayum depression). Also at Kurkur Oasis similar deposits occur which are deposited after the formation of the depression.

XI - Recent:

During the discussion of the Pleistocene we mentioned several times the Recent deposits, the most interesting ones being the up to 30 m high, hundreds of km long, dune-ridges of the W. desert, which in the central part of the Libyan Desert are moving southwards, the northern ends being supplied with disintegrated sandstone material of the northern scarp of the Qattara- and other depressions, which similar to the other great depressions of the Western desert were formed in Pleistocene times by wind erosion of pre-existing tectonic structures.

XII — The age and origin of the Red Sea Graben :

During the last 50 years a great number of publications appeared on the tectonic origin of the Red Sea Graben zone and its continuation towards East Africa and Turkey (9). A careful

study of these publications indicates however that only very few were based on actual field observations and many of these observations were only made during short reconnaissance trips. If all geophysical and geological surface and subsurface data known at present to the main oil exploration companies of Egypt (Royal Dutch Shell, Standard Oil Co. of Egypt and Socony Vacuum Oil Co.) could be published, no doubt a very accurate tectonic history of the greatest part of the Gulf of Suez could be written. Still the facts already on hand enable us to give a rather accurate analysis of this regional faulted zone.

Age of the Graben Zone:

We mentioned already that the Gulf of Suez Graben was formed initially at the end of the L. Eocene, but the fault movements continued at least till Pleistocene times. Some of the arguments favouring this statement are the following:

1) The Gulf of Suez, with a NW — SE direction cuts almost perpendicularly the NE — SW folding trends of N. Sinai. The difference in facies between flank and centre of some of these Sinai structures (e. g. Gehel Naghara) in the Cenomanian and Turonian beds indicate that these folding lines probably existed already in Cretaceous times. The Wadi Acaba structure on the W. coast of the Gulf of Suez indicates that the direction of the Gulf of Suez is the youngest one and has cut the Cretaceous direction.

2) Up to the basal M. Eocene there is little difference in facies between both sides of the Gulf of Suez,

3) The important regional unconformity at the base of the M. Eocene most areas between Egypt and Turkey, causing the direct deposition of M. Eocene limestones on basal Eocene or even Cretaceous beds indicates major tectonic movements in this part of the world at the closure of the L. Eocene.

4) There is a large erosional hiatus at the base of the Miocene in the Gulf of Suez indicating strong tectonical movement followed by a long period of erosion in pre-Miocene time.

All these different facts indicate that the Red Sea Graben originated in pre-Miocene and most probably in basal M. Eo-

cene time. This graben did not subside however as one block during the Neogene, but differential block-movement took place,

4) In Wadi Dara (W. side of Gulf of Suez), in a deep oil well drilled by the Socony Vacuum Oil Co., a continuous section was encountered containing Pliocene, the whole Miocene, Oligocène and U. Eocene, (well was abandoned at this stratigraphic level). Both Oligocène and U. Eocene were developed in a marine facies, their ages being established by microfaunal analysis. The presence of marine Oligocène and U. Eocene in the deeper parts of the Gulf of Suez Graben, whereas this section is missing in the regions directly west of the Graben fault (Eocene being present in those areas) indicates that this depression was formed in pre-U. Eocene and probably in M. Eocene times. Also the presence of basal Eocene in subsurface sections (e. g. W. of Ras Gharib) both in the graben itself and outside of it and of M. Eocene (unconformably overlying Cretaceous beds at the edge of the Graben fault) indicates a basal M. Eocene age for the first large structural movements in this area.

During the Miocene transgression the deepest parts of the graben were covered first but some of the higher eroded peaks of the graben blocks were covered for the first time only in U. Miocene times. These overlap conditions, which can be seen on the surface (e. g. in Gebel Zeit) and in subsurface sections of the different oil structures in the Gulf of Suez area, are another clear indication that the graben structures existed in pre-Miocene times.

Although the first definite subsidence and block-faulting in the Gulf of Suez must have taken place in the basal M. Eocene, it seems probable that the Red Sea Graben zone may have existed as a zone of weakness in much older periods; Facies researches on hand suggest that facies boundaries in the Cretaceous deviate considerably from the E - W direction which may be due to a pre-existing topography. Also the regional extension of these different graben zones in this part of the world suggests an older age. It should be kept in mind however that no positive evidence is available for this assumption at least not in Egyptian territory.

Structural history of the Graben zone

The actual tectonic history of the Gulf of Suez area is less simple than may appear from the above mentioned facts. We mentioned previously that from 25° N. latitude till the Méditerranéan the whole of Egypt subsided during the Mesozoic and L. Eocene. The subsidence started in the North and took place with greater speed than in the South. As a result, during the Jurassic, continental deposits (Nubian sandstones) were formed in S-Egypt, whereas at the same time marine sediments were deposited further north. In the U. Senonian practically the whole of Egypt, at least as far south as 25° latitude, was covered by the sea. At the end of the L. Eocene reversed movements took place. A regional updoming occurred accompanied by considerable block-folding along old (probably pre-Cretaceous) fault-zones with, at least partly, NE-SW direction. These block-movements created large dome-shaped structures, such as G. Maghara and G. Yelleg in N.E. Sinai, Abu Eoash (W. of Cairo) etc (22). Erosion removed the L. Eocene and uppermost Cretaceous in the high uplifted parts, and as a result during the following period of regional subsidence M. Eocene limestones were deposited on older beds with a considerable hiatus. In the deeper, less upfolded, parts of Egypt sedimentation continued and as a result no hiatus exists or only a very small one. The M. Eocene transgression was followed by a second period of regional updoming (probably more important even than the previous one) which was accompanied by local cross undulations. From this period onwards great parts of S. Egypt stayed more or less permanently above sea-level. Only north of the 28° latitude subsidence continued during the U. Eocene, the sediments being deposited on a tectonically undulated surface. In the Gulf of Suez graben faults brought the M. Eocene far below sea-level again, this is indicated for example in the sub-surface-sections of the oil structure near Eas Matarma (E. side of the Gulf of Suez), where a thick Miocene section is overlapping M. Eocene limestones which form the crest of the eroded pre-Miocene blocks.

Several of the blocks, that subsided in the Gulf of Suez depression remained above sea-level or moved temporarily upwards as a result of local anti-thetic block movements. Erosion

removed the Tertiary and older beds from the crest of those blocks, often as far down as the pre-Cambrian granites. Further subsidence during Oligocène times enabled Miocene beds to cover directly these granite peaks. Whereas in the Red Sea graben zone subsidence continued throughout the Miocene, Pliocene and Pleistocene, only temporarily interrupted by local uplifts as a result of tilted block - movements in the graben, Egypt as a whole was rising continuously, this is indicated by different facts ;

1) The fluvio-marine faciès of the U. Eocene was gradually moving northwards during the Miocene and younger periods (1) in other words the continental conditions, prevailing in II. Eocene times south of latitude 28° N, gradually appeared further north and large' rivers from the south filled up the large basin north of Fay urn.

2) Thick marine Pleistocene beds were encountered in Sub-surf alp sections along the Gulf of Suez, whereas at the edge of the Graben Pleistocene and older uplifted terraces can be found.

3) The sudden change in facies of the Pliocene (sandstones, grits, boulder deposits, etc.), after the deposition of abt. 120 m of solid anhydrite, gypsum or rock-salt during the U. Miocene, as a result of the closure of the Gulf of Suez and Red Sea both in the north and south, indicates a reopening of this basin, probably accompanied by vertical uplifts of the bordering areas followed by a sudden increased erosional activity.

Mechanism of the Red Sea Graben faults

Three outstanding phenomena must be taken into consideration in any theory on the origin of the Red Sea Graben zone :

1) Sinai, N. Egypt and the Gulf of Suez formed one large updoming area, the movements of which started at the end of the L.Eocene, but becoming very large at the end of the M. Eocene. Since this period the rising movements continued more or less regularly throughout the whole Tertiary.

2) Since the M. Eocene a NW-SE zone crosses this updoming area, the so-called Red Sea Graben zone, which subsided

more or less continuously during the whole Tertiary and Pleistocene*

8) Large basalt extrusions took place at different localities in Egypt, the age of which in several cases could be established to be definitely IL Oligocène and pre-L. Miocene*

a) In the Cairo-Suez area a more than 40 m thick fluviomarine Oligocène section is outcropping, this covers unconformably a definitely XL Eocene section, *At the top of the Oligocène sandstones^ etc, a (up to 18 m) thick basalt flow occurs, These basalt flows are unconformably covered by definitely L. Miocene marine deposits. No traces of volcanic activity are found in the L. Miocene, In other words these basalt flows represent a relatively short, well-marked period of volcanic activity,

b) The same conditions can be found N. and NW of Fayum indicating a similar U. Oligocène age,

c) Also the basalt extrusions N. of the North Qalala Plateau, abt 45 km W. of Bir Odeib, indicate the same field relations as in the Cairo-Suez area,

d) Near Hammam Faraun (E. side of the Gulf of Suez) and further south near Abu Zenima an interesting surface section is exposed near the edge of the graben faults. The upper Eocene Tanka beds are covered unconformably by a basal conglomerate which is overlain by 40 m of reddish sandy marls, calcareous sandstones and sandy limestones, which in their turn are covered by a conglomerate which is overlain by a thick (up to 40 m) dolerite bed. This dolerite bed is usually covered again by a conglomerate which is overlain by sandy Lower Miocene marine deposits. In other words a condition similar to the Cairo-Suez region. Near Hammam Faraun in the neighbourhood of the edge faults of the graben a hot water spring occurs,

e) In Ras Lagia, north of Hammam Faraun, the Socony Vacuum Oil Co. encountered in an oil-exploration well between 2300 and 2500 feet the same dolerite sill which further south is outcropping on top of the U. Eocene,

There is no reason to assume that the other basalt outcrops in Egypt are different in age. Some are definitely postTMUpper

Eocene, others post-M* Eocene, but lack of marine Miocene deposits prevent us of dating them more accurately.

If we consider these different facts, there seems to be little doubt that the formation of the Gulf of Suez was preceded by a regional updoming® This regional fold 'was due either to a regional buckling phenomenon' as a result of two opposing, mainly N-S directed geotectonic forces in the African continent or to the **HELMHOLTZ** mechanism (12,13), in other words to a frictional undulation fold created by the movements of the sial crust with respect to the sima. In both cases the movements or forces may be related to the upfolding of the Tethysbelt in the Mediterranean zone, which at least as far as Turkey, has on the whole an EW trend. This is supported by the fact that also in Turkey the main period of upfolding started at the end of the M! Eocene,

We have deçionsrated in . 1941 that due to the upfolding of the jM|ps by NS forces in the more rigid regions north of Switzerland two shearing - fault systems can be expected: a SE - NW system^ known as the *Hercynian - Thuringian* or *Saxonian fault system* and a SW - NE system, known as *Varisdan - Erzgebirge fault system*® These fault systems can be created artificially also in tectonic experiments (13,16).

It seems probable that a similar fault pattern was developed also in the more rigid areas south of the Balkans and of the Anatolian orogenic belt after the upfolding started in the basal M. Eocene, **Updoming** itself creates a system of stretch-faults converging downwards« As the updoming in Egypt seems to have been strongest in Sinai and the areas E of the present Nile Valley, we could expect the -greatest stretch-faults in these areas« A combination of both phenomena, shearing - fault patterns and stretch-faulting may have been the main cause of the formation of the Gulf of Suez depression.

The extensive basalt extrusions in the Oligocène of Egypt and also during later periods on the W coast of Arabia, along the graben-faults of Ethiopia^ along the Dead Sea graben zone • (e. g. W and N of Lake Tiberias .and in Syria) indicate that these originally superficial Eocene fault-systems in the M. East must have reached the sima layer during the Oligocène and

later periods as a result of further updoming during the XL Eocene. The updoming created a further relief in pressure and enabled the sima to become an active fluid which could extrude. Where two major opposing fault-systems were present very likely the mechanism of St. T ABER (11) became important because the sial blocks were floating in a liquefied sima layer. Blocks bordered by faults which were converging downwards became graben zones, those bordered by diverging faults became horsts. As the fault-systems were not completely symmetrical, in reality tilted block movements must have taken place and as a result parts of the horst nearest to the graben became the topographically highest points. As a result of later erosion the pre-Cambrian basement was exposed on these highest edges, whereas further away from the graben faults younger formations can be found.

Further updoming and stretching created a fault pattern as was clearly shown by OLOOS in a series of most elucidating experiments (5,6,7). As a result of these stretch-phenomena both *Synthetic graben faults* (i.e. faults having the same tendency as the main edge-faults and increasing the general downthrow in the graben) and *Antithetic faults* (i. e. faults counteracting the movements along the main faults) are formed«

Particularly in the region near Hammam Faraun and also further south splendid examples of these fault-patterns can be seen.

We fully realize that this synthesis of the origin of the Red Sea graben is not complete. Many facts could not be given as they are company secrets and several problems have not been solved yet. We have tried to compile only the main facts which may give a clue to the origin of the Red Sea graben a zone which probably was not formed either by compression or stretch, but by a complicated interaction of different fold and fault mechanisms.

This bring us to the end of the summary of "The Geological History of Egypt,, . I have tried to give a very brief summary of the vast literature concerning the geology of Egypt and of the different opinions of the oil-geologists in Egypt and I have naturally stressed those opinions which I consider to be

the most probable ones. A complete discussion of the Stratigraphy of Egypt would require a great number of Papers in order to give all the arguments which support our brief statements. Those interested in this evidence are referred to my article on "The Micro-Stratigraphy of Egypt,, to be published in the near future in the U. S. A.

We should keep in mind, however, that many of the stratigraphic problems discussed, still await further field studies before a definite solution can be given. Still we are inclined to believe that the picture given above is approximately correct and does not require fundamental changes in the near future.

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