UPPER CRETACEOUS FORAMINIFERA OF WESTERN SINAI (1)

BY

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1.—Abstract

The foraminiferal content of two Cretaceous sections from Western Sinai, namely Raha Scarp or Sudr section and Gebel Qabeliat or Tor section, was studied. The samples upon which this study was made were provided by the Anglo-Egyptian Oilfields Ltd. to which the author expresses his deepest gratitude. The study resulted in :—

1. The identification and description of 200 species and varieties, among which 30 species and 4 varieties seem to be new.

2. Establishing detailed statistical data for the relative distribution of the foraminifera in the two sections.

3. Finding strong faunal relations between the two sections and correlating the equivalent formations.

4. Zoning the two sections.

5. Comparing the foraminifera of the two sections with that of other more or less contemporaneous horizons in Egypt, also in Palestine, Central Europe, Sweden, France, the Gulf Coastal Region of U.S.A., California, Mexico, and Trinidad.

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(1) The following represents only the stratigraphical results achieved from studying the Upper Cretaceous foraminifera of Western Sinai. Parts including the systematic study of the fauna and the figures of the species, which form the major part of this study, will appear in the near future.

6. Assigning ages to the different formations represented in the two sections.

7. Emphasising the idea of dropping the use of such lithological terms as chalk and Esna shales as time indices.

2.—Introduction

Cretaceous rocks occupy about two-fifths of the surface of Egypt. They are largely developed in the southern and south-western part of the country, and also cover considerable areas in the north and north-east. They mostly belong to the upper divisions of the system. In the Western Desert they conformably overlie the Nubian sandstone in the south and south-west, and appear also in the north as in Abu-Roash. In the Eastern Desert they occur between the Nubian sandstone on the east and the Nummulitic limestone to the west. They appear also in the north as in Galala Plateau, Gebel Ataqa, etc. In Sinai they form the greater part of the northern, central, and western portions lying over the Nubian sandstone and the Jurassic and overlain by the Eocene. The facies varies from the typical chalk to alternate bands of chalk, marls, Nubian sandstone, dolomite and limestone.

3.—Sections and Their Location

1. *Raha Scarp Section* (Sudr Section):

(a) *Location:*

The lower part of the section was sampled from a locality lying N.W. of Bir Hinaik and having the co-ordinates: Longitude 32° 58′ 08″ E., Latitude 29° 44′ 37″ N. The upper part was sampled from another locality having the co-ordinates: Longitude: 32° 59′ 50″ E., Latitude 29° 46′ 28″ N. and lying 4½ kms. N.E of the first locality (see accompanying map).

(b) *Lithology:*

The succession as inferred from the Company's lithological log (Plate I) and from the author's study of the samples provided, may be summarised as follows:—

Top Eocene:	1. Limestone boulders containing Nummulites, Operculinas, Discocyclinas ?, Alveolinas, and Gasteropods, overlying unconformably the Esna shales.	
Esna shales:	2. Shales with flint at the base and top.	15ms.
	3. Bedded chalk with flint	4·5ms.
	4. Seliferous gypsiferous shales with iron concretions	13ms.
Cretaceous chalk:		
Bedded Chalk:	5. White bedded chalk	84·5ms.
Massive Chalk:	6. White massive chalk	5·5ms.
	7. Grey shales with pinkish marly chalk intercalations...	7·5ms.
	8. Thick section of hard chalk with Oysters and flint near the base.	152ms.
	9. Greyish brown seliferous shales.	9ms.
	10. White marly chalk	9ms.
	11. White hard chalk with echinoids.	9ms.
	12. White creamish pinkish limestone.	2·5ms.
Santonian:	13. Shales and sandy shales with marls and limestone intercalations.	

II.—*Gebel Qabeliat Section* (Tor Section):

(a) *Location:*

The section was taken at the southern end of Gebel Qabeliat and has the co-ordinates: Longitude: 33° 32′ 21″ E. and Latitude: 28° 20′ 48″ N. Gebel Qabeliat lies about 14 kms. N.W. of El Tor and forms the head of Gebel El Araba range (see accompanying map).

(b) *Lithology:*

As can be deduced from the Company's general lithological column of Gebel Qabeliat (Plate 3), the lithological log of the section (Plate 2), and from the author's own study of the samples provided, the section consists of the following formations from top to base:

Alluvium:	1. Sands and gravels.	
Miocene:	2. Shales with lenticular dolomitic intercalations with a boulder bed at the base unconformably overlying the Eocene	210ms.
Eocene:	3. Limestones with flints with a 30ms. thick bed of marls near the top ...	330ms.
Esna shales:	4. Marls	30·5ms.
	5. White gypsiferous seliferous limestones	4ms.
	6. Yellowish marls, in places gypsiferous and seliferous.	63·5ms.
	7. Conglomerate containing limestone pebbles cemented by a marly matrix.	2·5ms.
Cretaceous chalk:		
Bedded Chalk:	8. White creamish bedded chalk with flint	27ms.
Massive Chalk:	9. Hard white, sometimes pinkish chalk	21·4ms.
	10. Creamish marl	2·5ms.
	11. Pinkish chalk	4ms.
Santonian-Cenomanian:	12. Sandy marls with thin limestone intercalations.	310ms.
Nubian sandstone:	13. Sandstones with shales at the top	695ms.
Igneous Basement.		

4.—Laboratory Procedure

Samples from the base of the Cretaceous chalk to the top of the Globotruncana-Gümbelina zone (*see* Henson [1938] and Nakkady [1950 and 1951]) were collected from both sections at a 2 metres interval. From the 126 samples provided from the Raha Scarp section, only 34 representative samples were selected; 32 from the Cretaceous chalk and 2 from the Esna shales. From Gebel Qabeliat section 61 samples were provided; 27 samples from the Cretaceous chalk and 34 samples from the Esna shales. All the Cretaceous chalk samples as well as 23 Esna shales samples were studied, making a total of 84 representative samples from the two sections. Other samples were referred to for checking and comparison.

I.—*Disintegration and Washing:*

In the case of marls, shales, and soft chalk samples, an ample quantity of each sample was soaked overnight in water in a medium-sized enamel bowl. After decanting the muddy fluid and washing for several times, a few spoonfuls of sodium carbonate were added and the residue was boiled for several hours. The process of decanting and washing was repeated again and again until all the mud was washed out. Part of the residue was then transferred to a porcelain dish and reboiled with water and one tablespoonful of sodium carbonate for one hour, reboiling being followed by repeated decanting and washing until the supernatant water was clear. The residue in the dish which was almost nothing but a concentrate of foraminifera was dried in an oven and left to cool.

The hard chalk and limestone samples were at first crushed in a bronze mortar and then boiled with water and a few spoonfuls of sodium carbonate for a few hours. After decanting and washing for several times, the residue was dried in an oven and left to cool.

II.—*Sieving and Sorting*

The dried and cooled residue was passed through a set of sieves of 30, 60, 90, and 120 meshes to the inch, and then each crop was stored in a small glass tube with a label indicating the locality as well as sample, and mesh numbers.

III.—*Microscopic Examination:*

From each sample 0·4 gm. (0·1 gm. from each sieve) were studied. The picking of the foraminifera was done by a very fine 00 sable brush.

5.—The Foraminiferal Fauna

I.—*Previous Related Work:*

Previous works which have a bearing on the subject of the present study will be briefly reviewed. It is worth mentioning that not much work has been done on the Cretaceous of Egypt since the pioneering work of Ehrenberg in 1838.

(a) *Ehrenberg* (1838) attempted by means of foraminifera to correlate the limestone of Upper Egypt and Arabia with the white chalk of Europe. He figured the foraminiferal assemblage found in the chalk and marls of many localities, but his figures are hardly of any use for identification and comparison.

In 1854 he reported a large number of foraminiferal species from Upper, Middle, and Lower Egypt. From the 10 samples he examined from Theben (Upper Egypt), he figured and sometimes briefly described a large number of foraminifera. His figures are, however, very poor.

(b) *Wanner* (1902) reported 5 species, of which one was new, from the Upper Cretaceous of the Western Desert.

(c) *Henson* (1938) in his very interesting and valuable work on the stratigraphical correlation by small foraminifera in Palestine and the adjoining countries distinguished Upper Cretaceous marls, chalks, and shales from lithologically similar material of

Tertiary age "by the presence of species and genera that do not survive the Cretaceous in the region concerned; among these the most distinctive are Globotruncana (Rosalina), large and ornamented species of Gümbelina, Pseudotextularia, Bolivinoides, Bolivina incrassata Reuss, Gaudryina rugosa (d'Orb)". Of the species which are characteristic of the Cretaceous and extend into the Tertiary he mentioned: Anomalina ammonoides (Reuss) and Globigerina cretacea d'Orbigny and its near allies. He adds, "Globigerinidae other than these compressed forms are, as a rule, relatively rare and poorly developed in the Upper Cretaceous of Palestine and surrounding regions; Globorotalia, except G. stuarti (de Lapperent), is common only in the highest horizons".

(d) *Tromp* (1941) by quantitative, generic, microfaunal determinations in the Middle East countries; Turkey, Syria, Iran, Irak, and Egypt, tried to draw correlation conclusions.

In 1949 he published a paper on the value of Globigerinidae ratios in stratigraphy, stating that Globigerinidae can be of great value for differentiating between the Senonian and Eocene and between the Lower, Middle, and Upper Miocene. By accurate quantitative analyses of the occurrence of Globigerina and Globigerinella in many Cretaceous successions of Egypt, Sinai, and Southern Turkey (Arabian facies), he showed that the ratios of their relative abundance can serve to determine the boundaries between the Santonian, Campanian, Maestrichtian, and Basal Eocene stages.

In the same year he published another paper on the determination of the Cretaceous-Eocene boundary by means of quantitative, generic, microfaunal determinations and the concept Danian in the Near East. He discussed in this paper the diversity in opinion concerning the classification of the Upper Cretaceous and Basal Eocene and gave evidence to show that the Cretaceous-Eocene boundary can be established in the Middle East very accurately by using his method of quantitative generic analyses. He states that the boundary cuts through the so-called Danian and makes this term superfluous, at least in the Middle East.

He adds that in other countries also, further evidence suggests that the term is useless as an accurate stratigraphic unit and therefore should be abandoned. As to the nature of the contact between the Cretaceous and the Eocene, he denies the presence of an erosional hiatus.

(e) *Faris* (1947) in his report on the Cretaceous-Eocene contact in the Taramsa-Tukh area, regarded the Upper Esna shales (bed No. 5) as of Danian age, and the Lower Esna shales (bed No. 2) as of Maestrichtian age, the boundary between the two being uncertain due to the lack of fossils in the intervening beds. From the microfaunal examination of the upper Esna shales and the lower Esna shales he proved the existence of a strong affinity between the Danian shales and the basal Eocene limestone.

(f) *Cuvillier* (1949) comments on this work of Faris saying that the presence of Globorotalia cf. velascoensis Cushman in the Danian is very surprising and that, with the exception of Rzehakina, the forms which Faris reported from his Lower Eocene bed are known to be characteristic for the Upper Cretaceous rather than for the Ypresian.

Nevertheless on the basis of a study of his material from Kourkour, Gebel Gournah, and Kharga, he accepts the view of continuous sedimentation between the Cretaceous and Eocene.

(g) *The author* (1949) studied the micro-stratigraphy of the Pre-Tertiary surface and sub-surface sections of Abu-Roash, the establishment of the age boundaries between the different units being based on the quantitative, generic, microfaunal study of the area.

(h) *Nakkady* (1949 and 1950) studied the foraminifera of the Esna shales of the following 5 localities in Egypt; Gebel Duwi, Mellaha, Abu Durba, Danili, and Luxor. He identified, described, and photographed 168 species and varieties of which 19 species and 17 varieties were considered new. He correlated the Esna shales of Egypt with Upper Cretaceous formations from

Central Europe, Palestine, the Gulf Coastal Region of U.S.A., Mexico, and France, and with Palaeocene to Eocene formations of the Gulf Coastal Region of U.S.A. and Trinidad. He assumed a Mesozoic-Cenozoic conformity in those areas where the Esna shales intervene between Upper Cretaceous and Lower Eocene.

In 1951 he published a very interesting and valuable paper on zoning the Mesozoic-Cenozoic transition of Egypt by the use of the two members of the family Globorotaliidae, Globorotalia and Globotruncana. He considered the chalk and the overlying Esna shales as two phases of continuous sedimentation representing the last sequence of deposition at the close of the Mesozoic and the advent of the Tertiary. He distinguished the following three zones in this continuous sequence of sedimentation:

1. *Globotruncana zone:* Characterised by different species of Globotruncana together with typical Maestrichtian species. He assigned a Meastrichtian age to this zone.

2. *Globorotalia zone:* Characterised by Globorotalias of the strongly keeled type (colligera, simulatilis, velascoensis) together with Globigerina linaperta, Eponides lotus, Eponides umbonata, Loxostomum applinae, etc. He considered the age of this zone to be Danian to Palaeocene.

3. *Buffer zone:* Characterised by the complete absence or extreme scarcity of both Globorotalias and Globotruncanas. This zone is underlain by the Globotruncana zone and overlain by the Globorotalia zone. The forms which flourish in this zone are Globigerina bulloides, Anomalina pseudoacuta, Anomalina umbonifera, Gaudryina pyramidata, etc. The age of this zone is Danian.

As the relative extension of the zones is irrespective of the rock facies, he proposes the dropping of the use of such lithological terms as chalk and Esna shales and the use of the zone terms.

I.—*Omara* (1951) divided the Upper Cretaceous of Nezzazat on the basis of the quantitative generic study of the microfauna of the different formations into Senonian, Turonian, and Cenomanian. The Senonian is represented from base to top by Santonian shales and Campanian and Maestrichtian chalks. That part of the Esna shales which still contains Globotruncanas and Gümbelinas (larger than 0·3mm.) were still also attributed to the Maestrichtian. He takes the disappearance of Globotruncanas and large Gümbelinas to mark the beginning of the Lower Eocene. He assumed perfect conformity between the Cretaceous and the Eocene in the area.

II.—*Classification and Nomenclature:*

To facilitate comparison with the very many works done on the Cretaceous in America and Europe, the system of classification followed in this study is that of Cushman. The generic nomenclature is after Glaessner (1944) and Cushman (1948).

III.—*New Species and Varieties:*

Of the 200 species and varieties identified from the two studied sections, the following 30 species and 4 varieties seem to be new :—

Clavulina qabeliatensis.

Robulus defrawii.

  faragi.

  ibrahimi.

  torensis, (written as R. trompi in plate 5).

Lenticulina qabeliatensis.

Nodosaria qabeliatensis.

Entosolenia qabeliatensis.

Angulogerina ghorabi.

Valvulineria qabeliatensis.

Gyroidina qabeliatensis.

Rotalia qabeliatensis.

  sudrensis.

Alabamina sudrensis.

Globigerina qabeliatensis.

Globotruncana ansarii.
- esnehensis.
- pooleyi
- pseudofornicata.
- qabeliatensis.
- quadrata.
- quadrata var. plata.
- sudrensis.
- sudrensis var. parallela.
- torensis.

Anomalina qabeliatensis.
- sudrensis.
- torensis.

Cibicides abudurbensis Nakkady. var limbata.
- esnehensis.
- pseudoekblomi.
- qabeliatensis.
- qabeliatensis var. convexa.
- trompi, (written as C. torensis in plate 5).

The holotypes of these new species and varieties are deposited in the geological museum, Mining Department, Faculty of Engineering, Cairo University, Giza, Egypt.

6.—Faunal Distribution

1.—*Sudr Section :* (See plate 4)

143 species and varieties were identified from this section. Exclusive to the Massive Chalk which forms the base of the section are 59 species and varieties, the most important of which are Ammobaculites junceus, A. taylorensis, Gümbelina globulosa, Loxostomum cushmani, Globigerina qabeliatensis, Globotruncana torensis, and Anomalina sudrensis.

The basal part of the Massive Chalk is dominated mainly by the Globigerinidae, the Rotaliidae, and the Globorotaliidae and to a lesser degree by the Heterohelicidae and the Buliminidae.

Overlying the basal part of the Massive Chalk there comes a portion in which the fauna is largely dominated by the Globigerinidae and to a much lesser degree by the Heterohelicidae. In general the fauna is much less developed here than in the basal part, most of the species either disappearing or being represented by a smaller number of specimens. Two species of the Lituolidae flourish only at the base of this part and disappear upwards. The arenaceous foraminifera which in the basal part were represented by a few members of the Verneuilinidae and the Trochamminidae are represented here by the Textulariidae, the Lituolidae and the Verneuilinidae.

Overlying this comes a thick section in which the fauna becomes represented by a large number of species and in which the Globigerinidae become much less developed than in the previous two parts. The fauna of this section is mainly formed by the Rotaliidae, the Anomalinidae, the Heterohelicidae, and the Globorotaliidae. Globotruncana sudrensis var. parallela, G. torensis, and G. ventricosa which form the major part of the Massive Chalk and which together with the other Globotruncana species almost disappear in the overlying part appear again, but in this case they have the same distribution as the other Globotruncana species. The Heterohelicidae are represented by Gümbelina striata only, while the Rotaliidae are formed mostly by Gyroidina girardana, G. nitida, and G. qabeliatensis. Anomalina pseudoacuta, A. scorbiculata, and Cibicides multifaria are the Anomalinidae which predominate in this part of the Massive Chalk. The arenaceous foraminifera and the Lagenidae which are more or less poorly represented in the previously described two parts are here represented by a large number of species which, however, occur as single to frequent forms. The Buliminidae are, as a whole, less developed than in the previously mentioned two parts.

The upper part of the Massive Chalk is characterised by the reflooding of the Globigerinidae, the better development of the

Buliminidae and the relative impoverishment of the fauna in the Globorotaliidae, the Anomalinidae, the Rotaliidae, and the arenaceous foraminiferal families.

Exclusive to the Bedded Chalk are 11 species and varieties. In the lower part of the Bedded Chalk, the Globigerinidae suffer a diminution once again, the Rotaliidae become better developed and the arenaceous foraminifera, the Lagenidae, and the Buliminidae become less developed than in the upper part of the Massive Chalk.

In the upper part of the Bedded Chalk the fauna, including the Rotaliidae, becomes very poor and scanty and is mainly represented by Gümbelina striata and Eponides umbonata.

Overlying the Bedded Chalk and forming the upper part of the section is the Esna shales in which 10 species appear for the first time and of which, as already mentioned, only 2 samples were studied. In the lower sample the fauna is dominated mainly by the Heterohelicidae, the Rotaliidae, and the Buliminidae, and to a much lesser degree by the Valvulinidae and the Textulariidae. The Globorotaliidae are only represented by single to rare specimens of Globotruncana aegyptiaca, G. esnehensis, and G. gansseri. In the upper sample most of the species disappear or become represented by single or rare specimens and the fauna is almost completely formed by Gümbelina striata.

II.—*Qabeliat Section:* (See plate 5)

From this section 154 species and varieties were identified. The section starts from the base with the Massive Chalk from which the author identified 78 species and varieties, of which 22) species and varieties do not occur elsewhere in other parts of the section. Spiroplectammina dentata, S. laevis var. cretosa, Gaudryina laevigata, G. quadrans, Robulus torensis, Nonionella austinana, and Globotruncana ventricosa are the most important species which are confined to the Massive Chalk.

The lower part of the Massive Chalk is dominated mainly by members of the families Globigerinidae, Anomalinidae, and

Heterohelicidae and to a lesser degree by members of the families Verneuilinidae, Lagenidae, Buliminidae, Rotaliidae, Allomorphinidae, and Globorotaliidae. The Globigerinidae are represented by Globigerina cretacea, G. qabeliatensis, G. pseudotriloba, G. quadrata, and Globigerinella aspera. Anomalina pseudoacuta, A. qabeliatensis, Cibicides abudurbensis, and C. multifaria constitute the greater part of the Anomalinidae present in this part of the section. The family Heterohelicidae is represented mainly by Gümbelina globulosa and G. striata. The Verneuilinidae constitute the greater part of the arenaceous fauna and are represented mainly by Gaudryinalae vigata and G. rugosa. Robulus torensis, R. faragi, Lenticulina ovalis, and Nodosaria zippei are the best developed representatives of the Lagenidae. Bulimina prolixa and Neobulimina canadensis form the majority of the Buliminidae fauna, while Gavelinella moniliformis and Gyroidina qabeliatensis are the best developed Rotaliidae. Allomorphina cretacea is the only representative of the Polymorphinidae. The Globorotaliidae are represented to a large extent by Globotruncana aegyptiaca, G. caliciformis, and G. torensis.

Towards the top of the Massive Chalk all the forms become represented only by single or rare specimens, and this declination continues and becomes more serious in the overlying Bedded Chalk, in which all the forms disappear except Gaudryina (Pseudogaudryina) pyramidata, G. rugosa, Eggerella inflata, Dorothia pontoni, Globigerina cretacea, G. pseudotriloba, G. quadrata, and Globigerinella aspera. The extreme hardness of the rocks in the Bedded Chalk probably accounts for this scarcity of the fauna rather than the occurrence of a palaeontologic break as the same species reappear again with similar frequency at the base of the Esna shales which immediately overlies the Bedded Chalk.

In the Esna shales the fauna becomes once again well developed, and it is on the whole better developed than that of the Massive Chalk. The families which were previously mentioned to be well developed in the Massive Chalk are better developed here, being represented by a greater number of genera and species. Of the 133 species and varieties identified from the studied part of the Esna shales 76 species and varieties make their first appearance.

In the lower half of the studied part of the Esna shales, the fauna is dominated mainly by members of the families Globorotaliide, Globigerinidae, Heterohelicidae, Buliminidae, Anomalinidae, and Rotaliidae. A new element is added to the Heterohelicidae, namely Gümbelina striata var. deformis which, however, occurs only as a rare to frequent species. Many new species of the Buliminidae appear for the first time, while others which have already appeared in the Massive Chalk become better developed in this part of the Esna shales. On the other hand, Bulimina prolixa and Neobulimina canadensis which formed the greater part of the Buliminidae fauna in the Massive Chalk are represented only by single or rare specimens. Similarly Gavelinella moniliformis and Gyroidina qabeliatensis become less developed than in the lower half of the Esna shales, while new species of the Rotaliidae make their first appearance and the place of the two already mentioned species is taken by Valvulineria umbilicatula and Gyroidina girardana. Globigerinella aspera is much less developed than in the Massive Chalk. The family Globorotaliidae, as represented by the genus Globotruncana, is much better developed than in the Massive Chalk, being represented mainly by Globotruncana aegyptiaca, G. aegyptiaca var. duwi, G. aegyptiaca var. 1, G. caliciformis, G. esnehensis, and G. ansarii. Of the Anomalinidae, the genus Anomalina is better developed in this part of the Esna shales than in the Massive Chalk, while the reverse is the case with the genus Cibicides.

In the upper half of the Esna shales, another change of the fauna is perceptible. The Verneuilinidae which are well developed in the Massive Chalk and much less so in the lower half of the Esna shales become better developed here and are represented by Verneuilina cretacea, Gaudryina (Pseudogaudryina) pyramidata and Clavulinoides trilatera var. plummerae. As compared with the Massive Chalk. the Lagenidae here as well as in the underlying part of the Esna shales, are represented by a large number of genera and species which are, however, only represented by a few number of specimens. The species Gümbelina striata var. deformis is well developed here occurring as a flood form. As regards the Buliminidae, there is a marked decrease in the frequency of most of the species. The place of Valvulineria umbilicatula and Gyroidina girardana in the lower half of the Esna shales is here occupied by these two members together with Gyroidina globosa, G. qabeliatensis, and Eponides umbonata. New species of Globotruncana become predominant, namely G. gansseri and G. pseudofornicata. The Anomalinidae are represented mainly by Cibicides abudurbensis var. limbata and Cibicides esnehensis. The genus Anomalina is much less developed than in the lower half. Anomalina qabeliatensis, however, which is well developed in the lower part of the Massive Chalk and which is completely absent from the rest of the section, floods suddenly near the top of the studied part of the Esna shales.

7.—Zoning

By a consideration of the relative distribution charts of the foraminifera in both sections, a number of zones could be picked out. The significance of these zones for regional correlation in Egypt will be verified by further studies of other Upper Cretaceous localities.

I.—*Sudr Section:*

This section was found to be divisible into 8 zones. Starting from the base, these zones are :—

1. *Zone of Globotruncana ventricosa and G. sudrensis:*

This zone extends from the base and includes samples Bo. 1157 and Bo. 1161 and is characterised by the two species Globotruncana ventricosa and G. sudrensis which are almost flooding in this part of the section, and which disappear for some time with the end of the zone. The Heterohelicidae and the

Globigerinidae are the main elements of the fauna in this zone. The species which flood in this zone are Gümbelina striata, Valvulineria umbilicatula, Globigerina cretacea, G. qabeliatensis, G. quadrata, Globigerinella aspera, and Globotruncana sudrensis var. parallela.

2. *Zone of Bolivina monilifera :*

At the top of zone No. 1, the species Bolivina monilifera appears as a flooding form and is confined to this zone. All the Globotruncana species are absent, while the four species of the Globigerinidae, which flooded in the previous zone, remain as such. Eponides concinna, Gyroidina, nitida, Valvulineria umbilicatula, Discorbis pseudoscopos, and Gümbelina striata also flood this zone.

3. *Zone of Ammobaculites junceus and A. taylorensis :*

This zone follows on top of zone No. 2, and is characterised by the presence of Ammobaculites junceus and A. taylorensis which do not occur elsewhere in the section. In this zone the Rotaliidae and the Heterohelicidae are much less developed, and the fauna is largely made of the already mentioned two species of the Lituolidae.

4. *Zone of Trochammina diagonis :*

The appearance and disappearance of the species, Trochammina diagonis mark this zone. This species, together with Dorothia pontoni, which is represented by rare specimens, form almost exclusively the fauna of this zone.

5. *Zone of Bulimina ovulum var. triangularis :*

This zone is marked by the first appearance of Bulimina ovulum var. triangularis and includes samples Bo. 1177 and Bo. 1181. In this zone, the fauna is better developed than in the underlying two zones. The same species of Globigerinidae and Heterohelicidae develop once again.

6. *Zone of Anomalina sudrensis:*

The appearance of Anomalina sudrensis marks the beginning of this zone and it is in fact the most conspicuous species in it. This zone includes samples Bo. 1185 to Bo. 1197. Globigerinidae and Heterohelicidae flourish at the base of this zone and disappear completely towards the end.

7. *Zone of Globotruncana aegyptiaca and G. ansarii:*

This zone lies on top of zone No. 6 and includes samples Bo. 1201 to Bo. 1249. It is characterised by the first appearance of both Globotruncana aegyptiaca, and G. ansarii. Gümbelina striata, Gyroidina girardana, G. nitida, G. qabeliatensis, Anomalina sudrensis, A. pseudoacuta, and Cibicides multifaria are the major elements of the fauna in this zone. Arenaceous foraminifera, Lagenidae, and Globorotaliidae are represented by a large number of species which occur as rare to frequent forms.

8. *Zone of Bolivina incrassata:*

This last zone extends to the top of the studied part of the section and is distinguished by the first appearance of the well-known Cretaceous species, Bolivina incrassata. Heterohelicidae, Rotaliidae, Anomalinidae, and Globigerinidae are the major elements of the fauna throughout the zone, while the rest of the families are represented only by rare specimens. The Globorotaliidae are only present in the lower part of the zone and disappear completely in the upper part except for the single occurrences of Globotruncana contusa, G. esnehensis, and G. gansseri. Verneuilina cretacea, Gümbelina striata, Eouvigerina aegyptiaca, Buliminella carseyae, Loxostomum plaitum, L. trinitatensis, Gavelinella moniliformis, Gyroidina beisseli, Stensiöina esnehensis, Rotalia rigida, and Anomalina insecta flood near the top of the zone.

II.—*Qabeliat Section:*

In this section 6 zones could be detected which form base to top run as follows:

1. *Zone of Bolivina cretosa:*

This zone lies at the base of the Massive Chalk, and includes samples Bo. 1740 to Bo. 1741. It is characterised by the presence of the species Bolivina cretosa which does not occur elsewhere in the section. Other less conspicuous elements in this zone are Gümbelina globulosa, Bulimina prolixa, Gavelinella moniliformis, Gyroidina qabeliatensis, Globigerina cretacea, G. quadrata, and Anomalina pseudoacuta. The Globorotaliidae are only represented by a single specimen of Globotruncana esnehensis. The arenaceous foraminifera are mainly represented by Textulariidae, and Verneuilinidae.

2. *Zone of Globotruncana ventricosa:*

This zone overlies the Bolivina cretosa zone, and is better developed than it. It includes samples Bo. 1742 to Bo. 1749 (about 16 ms.). The species Globotruncana ventricosa which was absent in zone No. 1 appears here for the first time and disappears with the end of this zone. Other species of Globotruncana are also well developed in this zone, but they are not as valuable as Globotruncana ventricosa because they have a much larger vertical extension. In this zone, the family Globigerinidae is well developed and the fauna is dominated by its members together with Globotruncana aegyptiaca, Allomorphina cretacea, Gümbelina globulosa, Cibicides abudurbensis, and C. multifaria. Gaudryina rugosa, Robulus torensis, Lenticulina qabeliatensis, Nodosaria zippei, Nonionella austinana, Bulimina prolixa, Neobulimina canadensis, Gavelinella moniliformis, Gyroidina qabeliatensis, Globotruncana caliciformis, G. esnehensis, and Anomalina pseudoacuta are well developed at the base of the zone, and become much less so, or even disappear towards the top. New elements are added to the arenaceous foraminifera namely the rare occurrences of a few members of the family Valvulinidae.

3. *Zone of Pseudogaudryinella capitosa:*

In zone No. 2, the species Pseudogaudryinella capitosa was present, but it did not disappear with the end of the zone and persisted till sample Bo. 1752. Although this species occurs as a rare form, yet as the fauna is on the whole very poor, and as this species attains a large size and is easily identified, it can be, therefore, considered as the characteristic species of this zone. A few species of the genera Textularia, Gaudryina, Clavulina, Robulus, Bolivina, Allomorphina, Globigerina, Anomalina, and Cibicides which occur mostly only as rare forms, are the only elements of the fauna in this zone.

4. *Zone of Gaudryina (Pseudogaudryina) pyramidata:*

Overlying zone No. 3, and extending from the upper part of the Massive Chalk throughout the whole length of the Bedded Chalk, and ending at the beginning of the Esna shales, is a zone at the base of which Gaudryina (Pseudogaudryina) pyramidata appears for the first time. This zone has a very poor fauna which is poorer than that of zone No. 3. Most of the species have disappeared completely, and Gaudryina (Pseudogaudryina) pyramidata is the most conspicuous species.

5. *Zone of Globotruncana contusa:*

This zone extends from the base of the Esna shales up to sample Bo. 1781. Globotruncana contusa, G. torensis, and G. quadrata appeared for the first time at the base of the Esna shales, but this zone was named after Globotruncana contusa because it is numerically better represented than the other two species, and because of its universal occurrence in other Upper Cretaceous countries. Other elements of the fauna which flood in this zone are Anomalina pseudoacuta, Globotruncana aegyptiaca, G. aegyptiaca var. duwi, G. ansarii, Globigerina cretacea, G. quadrata, Bulimina kickapooensis, Gümbelina striata, and G. globulosa. Bulimina reussi, and Valvulineria qabeliatensis appear just before the end of this zone.

6. *Zone of Globotruncana gansseri:*

This zone is marked by the first appearance of Globotruncana gansseri, which continues to the top of the studied part of the Esna shales, and disappears together with the other species of the genus Globotruncana, (as the Esna shales samples were studied to the end of the Globotruncana zone of Nakkady (1951) which marks the upper limit of the occurrences of Globotruncana species). This zone is distinguished from the underlying zone by the better development of the Textulariidae, the Verneuilinidae, the Rotaliidae, and the Anomalinidae. Gümbelina striata var. deformis, which was a single to frequent species in zone No. 5, is here a flooding and conspicuous form.

8.—Micropalaeontological Stratigraphical Correlation

I.—*Biozonal Correlation of Sudr and Qabeliat Sections:*

Considering the foraminifera present in the two sections, the following statistical data could be deduced :

97 species common to the two sections.

52 species common to the Massive Chalk of both sections.

8 species common to the Bedded Chalk of both sections.

40 species common to the Esna shales of both sections.

7 species common between the Massive Chalk of Sudr and the Bedded Chalk of Qabeliat.

30 species common between the Massive Chalk of Sudr and the Esna shales of Qabeliat.

35 species common between the Massive Chalk of Qabeliat and the Bedded Chalk of Sudr.

26 species common between the Massive Chalk of Qabeliat and the Esna shales of Sudr.

4 species common between the Bedded Chalk of Qabeliat and the Esna shales of Sudr.

59 species common between the Bedded Chalk of Sudr and the Esna shales of Qabeliat.

Comparing the relative distribution charts of both sections, the most striking differences which will leap to the eye are the extreme scarcity of the fauna in the Bedded Chalk of Qabeliat, and the relatively smaller frequency of the foraminifera in Sudr. The Massive Chalk which is 28 ms. thick in Qabeliat attains a thickness of 149·5 ms. in Sudr. The almost unfossiliferous Bedded Chalk of Qabeliat is 27 ms. thick, while the corresponding formation in Sudr attains a thickness of 85 ms.. In Sudr the part of the Esna shales which lies in the Globotruncana-Gümbelina zone is 13 ms. thick, while the same formation is much better developed in Qabeliat, and attains a thickness of 76 ms.

Regarding the arenaceous foraminifera, the family Lituolidae, which flourishes in the Ammobaculites junceus A. taylorensis zone of Sudr, is totally absent from the Qabeliat section. On the whole, the arenaceous foraminifera are more developed in the lower part of the Massive Chalk and the Esna shales of Qabeliat than at Sudr, while in the Bedded Chalk the reverse is the case. In other places in both sections they have nearly the same distribution.

Nodosaria affinis, and Vaginulina taylorana which are confined to the Massive Chalk of Sudr, appear at Qabeliat higher up in the section, namely in the Esna shales. Pseudoglandulina pygmaea, which occurs throughout the section at Sudr, is confined to the Massive Chalk at Qabeliat. Saracenaria triangularis has a wider range at Qabeliat than at Sudr. In the former section, it occurs in both the Massive Chalk, and the Esna shales, while in the latter section, it is confined to the Massive Chalk. Frondicularia lanceolata, which occurs at Sudr in the Massive Chalk, and the Bedded Chalk, is limited in Qabeliat to the Esna shales only.

The family Polymorphinidae is absent from the Sudr section.

Gümbelina globulosa is confined to the Massive Chalk at Sudr, while in Qabeliat it is present in both the Massive Chalk and the Esna shales. Gümbelina striata var. deformis, occurring only in the Esna shales of Qabeliat as a flooding form, is present throughout the whole section in Sudr.

Bulimina aspera occurs at Sudr in the Massive Chalk while at Qabeliat it is present in the Esna shales.

Gavelinella moniliformis, which is a flooding form in Qabeliat Massive Chalk and Esna shales, is confined to the Esna shales in Sudr.

Gyroidina nitida which is well developed at Sudr is represented by a few specimens in the Esna shales of Qabeliat.

Pullenia reussi occurs throughout the section in Sudr, and is confined to the Esna shales in Qabeliat.

At Qabeliat, Globotruncana contusa is confined to the Esna shales, while at Sudr it occurs in both the Massive Chalk, and the Bedded Chalk. At Sudr, Globotruncana esnehensis occurs in the upper part of the section, while at Qabeliat, it does not extend beyond the Massive Chalk. Globotruncana globigerinoides, G. quadrata, G. torensis, and G. pseudofornicata are present in the basal part of the section at Sudr, and in the upper part at Qabeliat. Globotruncana ventricosa is confined to the lower part of the Massive Chalk at Qabeliat, but is found in both Massive and Bedded Chalk at Sudr.

It was difficult to correlate the zones of the two sections together, but in this respect there are many striking similarities to be observed :

1. The Globotruncana ventricosa zone of Sudr can be approximately correlated with the same zone in Qabeliat. Besides, both zones contain an assemblage of similar forms which are flooding or abundant, these being Globigerina cretacea, Gümbelina striata, Globotruncana quadrata, and Globigerina qabeliatensis.

2. Zones Nos. 2, 3, 4, 5, and 6 of Sudr are not present in Qabeliat, and with one single exception, the index species to these zones are not present in Qabeliat.

3. When the Globotruncana aegyptiaca-ansarii zone of Sudr is traced in Qabeliat, it will be found that the two species, which were chosen as index to the zone, are also flooding in Qabeliat from shortly after the base of the Globotruncana zone till near the top of the Globotruncana gansseri zone.

The author did not feel easy at making such a broad zone in Qabeliat, although it may be useful for comparing the two sections because:

(*a*) Correlation between the two sections, based on such a zone, will not be correct, because the overlying and underlying zones are different.

(*b*) The easiness with which narrower zones with good index markers express themselves quite well in Qabeliat, and which are thus of a more valuable stratigraphic importance. If in the future studies of other Upper Cretaceous sections the Globotruncana aegyptiaca-ansarii zone could prove to be of regional value for correlation, then this zone would cover in Qabeliat the greater part of the Globotruncana ventricosa zone, the Pseudogaudryinella capitosa zone, the Gaudryina (Pseudogaudryina) pyramidata zone, the Globotruncana contusa zone, and the greater part of the Globotruncana gansseri zone.

II.—*Correlation with other Upper Cretaceous Sections in Egypt:*

From the uppermost Cretaceous chalk and Esna shales of Egypt, Nakkady (1949) reported a number of species, a large part of which is present in the two studied sections, as can be seen in the following:

Locality	Number of species common with the two studied sections	
	Cretaceous chalk	Esna shales
Duwi	30	45
Mellaha	26	30
Abu Durba . . .	19	55
Danili	11	44
Luxor	—	31

III.—*Correlation with more or less Contemporaneous Horizons outside Egypt:*

1. *Senonian of Palestine:*

There are 13 species common between the Senonian of Palestine and the foraminifera of the two sections.

Owing to the absence of equivalents to the symbols in the legend given in the very condensed and interesting work of Henson (1938), it is difficult to compare exactly the relative distribution of the very important species given by him with that of the forms of the present study. Nevertheless the two results agree well with each other as regards the predominance of Globotruncana with the other less important characteristic Cretaceous genera and species as Pseudotextularia, Bolivinoids, and Bolivina incrassata.

2. *Kreideformation of Central Europe:*

Reuss's work on the Cretaceous of Bohemia includes important Cretaceous index species, of which 16 species were found in the material of the present study.

3. *Upper Cretaceous of Sweden:*

14 of the species found in the two sections are reported from the lower Senonian of Sweden, while only one species from the Upper Senonian of Sweden has been found in the Bedded Chalk, and the Esna shales of Sudr.

4. *Upper Cretaceous of the Paris Basin:*

Of the 200 species reported from the two sections, 19 species have been found in the Upper Cretaceous of the Paris basin, as expressed in the works of d'Orbigny, and Pierre Marie.

5. *Upper Cretaceous of the Gulf Coastal Region of U.S.A.:*

Considering the foraminifera identified from the two sections, and the foraminifera reported from the Upper Cretaceous Austin, Taylor, and Navarro beds of many localities in the Gulf Coastal region of America, the following interesting statistical data could by campiled:

The Massive Chalk of Sudr has 24 species common with the Austin, 38 species common with the Taylor, and 28 species common with the Navarro.

The Bedded Chalk of Sudr has 9 species common with the Austin, 14 species common wth the Taylor, and 20 species common with the Navarro.

The studied part of the Esna shales of Sudr has 4 species common with the Austin, 10 species common with the Taylor, and 9 species common with the Navarro.

The Massive Chalk of Qabeliat has 13 species common with the Austin, 31 species common with the Taylor, and 21 species common with the Navarro.

The Bedded Chalk of Qabeliat has one species common with the Taylor, and another one common with the Navarro.

The Esna shales of the same section has 17 species common with the Austin, 34 species common with the Taylor, and 40 species common with the Navarro.

6. *Upper Cretaceous of California:*

15 species have been found to be common between the two studied sections, and the Upper Cretaceous of California.

7. *Upper Cretaceous of Mexico:*

36 species are common between the Upper Cretaceous of Mexico and the two sections.

8.—*Upper Cretaceous of Trinidad:*

The Upper Cretaceous of Trinidad has 20 species common with the two studied sections.

9.—Discussion and Conclusions

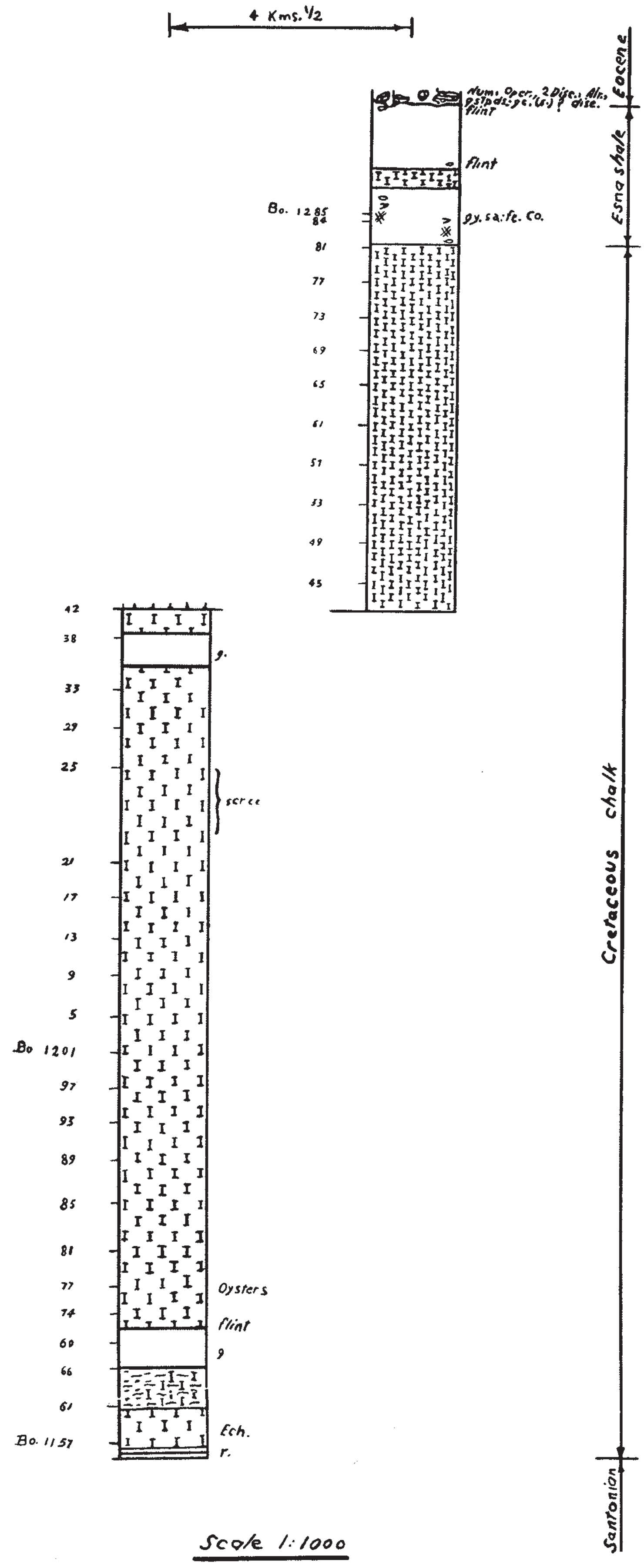
I. The Massive Chalk of both sections contains 7 index Taylor species, and 2 index Navarro species, thus showing a greater affinity to the Taylor.

II. The Bedded Chalk of both sections shows a greater affinity to the Navarro as it contains 7 index Navarro species.

Plate 1

COMPOSITE LOG OF

RAHA SCARP	RAHA SCARP
N W OF BIR HENAIK	EAST OF S.H.744
(WADI SUDR)	(WADI SUDR)
(383 ms.)	(515 ms.)
29° 44' 37" N	29° 46' 28" N
32° 58' 08" E	32° 59' 50" E



Scale 1:1000

Plate 2.

LITHOLOGIC LOG OF SECTION AT SOUTHERN END OF GEBEL QABELIAT

(TOR AREA)

Co-ordinates: 33° 32′ E (Approx)
28° 22′ N (")

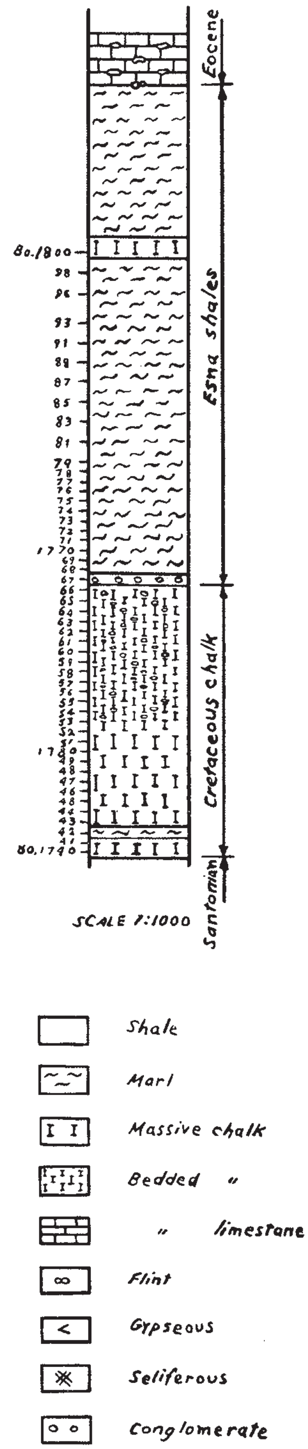
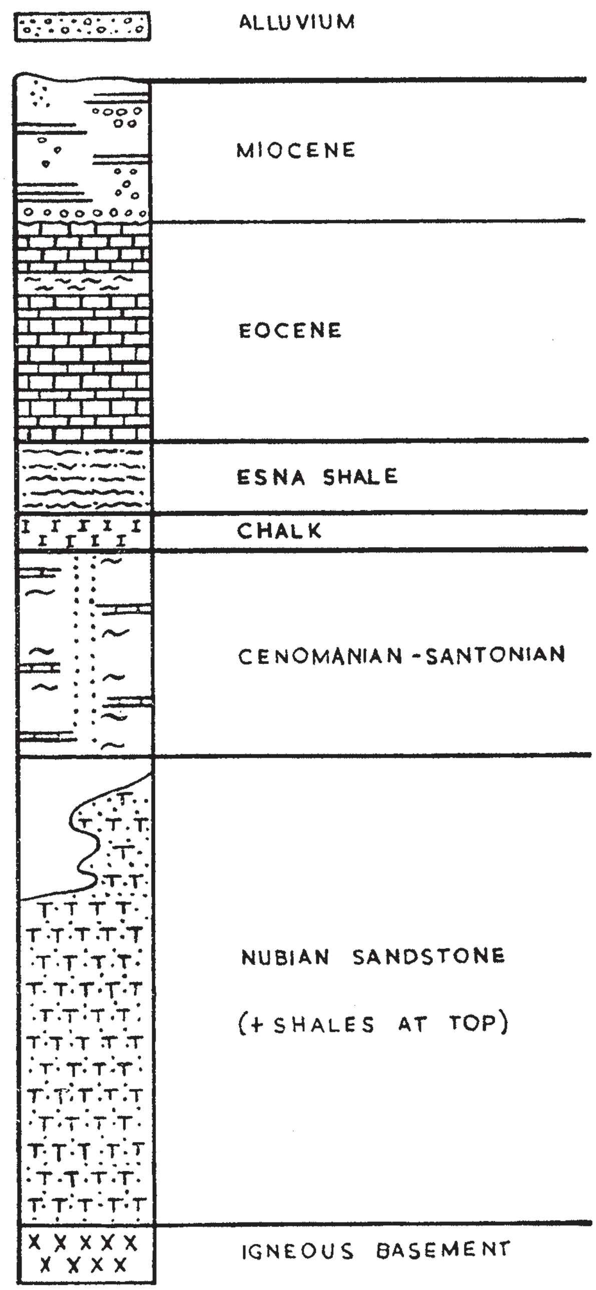


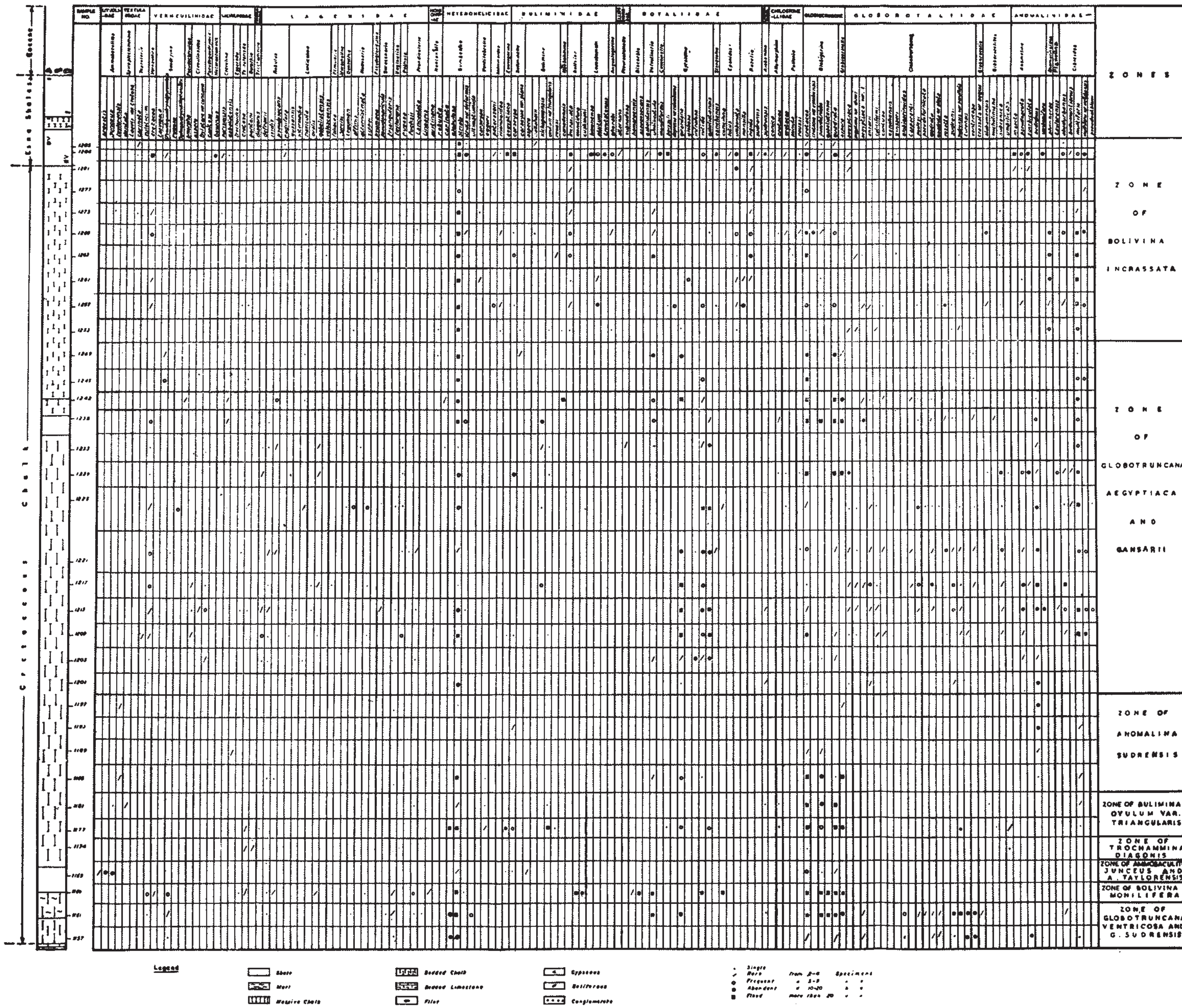
Plate 3

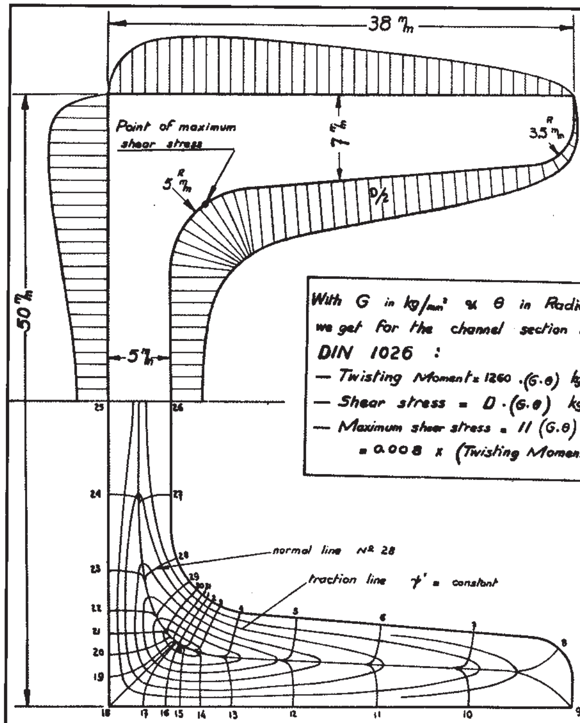
GENERAL LITHOLOGICAL COLUMN
G. QABELIAT



SCALE : 1/10,000

RELATIVE DISTRIBUTION CHART OF THE FORAMINIFERA IN SUDR SECTION



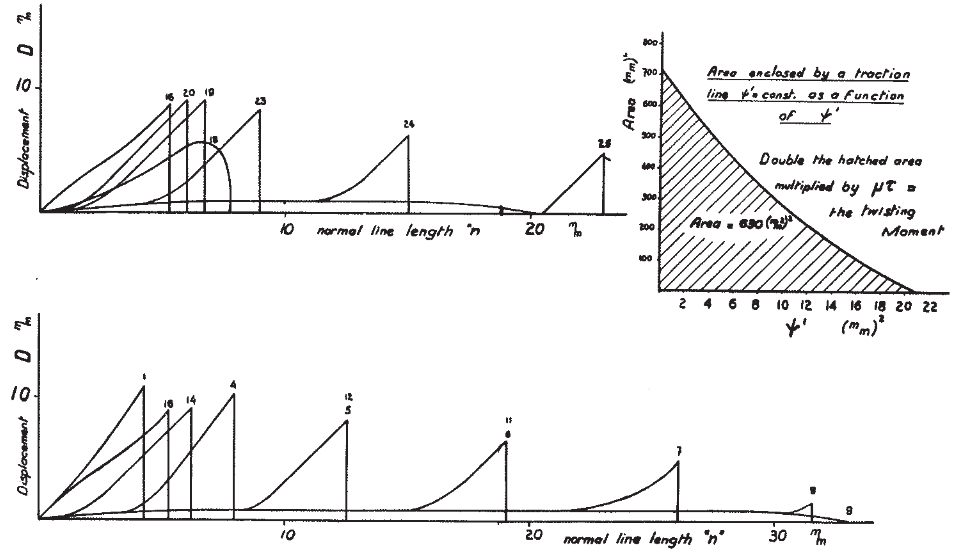


With G in kg/mm² & θ in Radians/mm we get for the channel section № 5 DIN 1026 :

— Twisting Moment = 1260 · (G·θ) kg.mm.

— Shear stress = D · (G·θ) kg/mm²

— Maximum shear stress = 11 (G·θ) kg/mm² = 0.008 × (Twisting Moment) kg/mm²



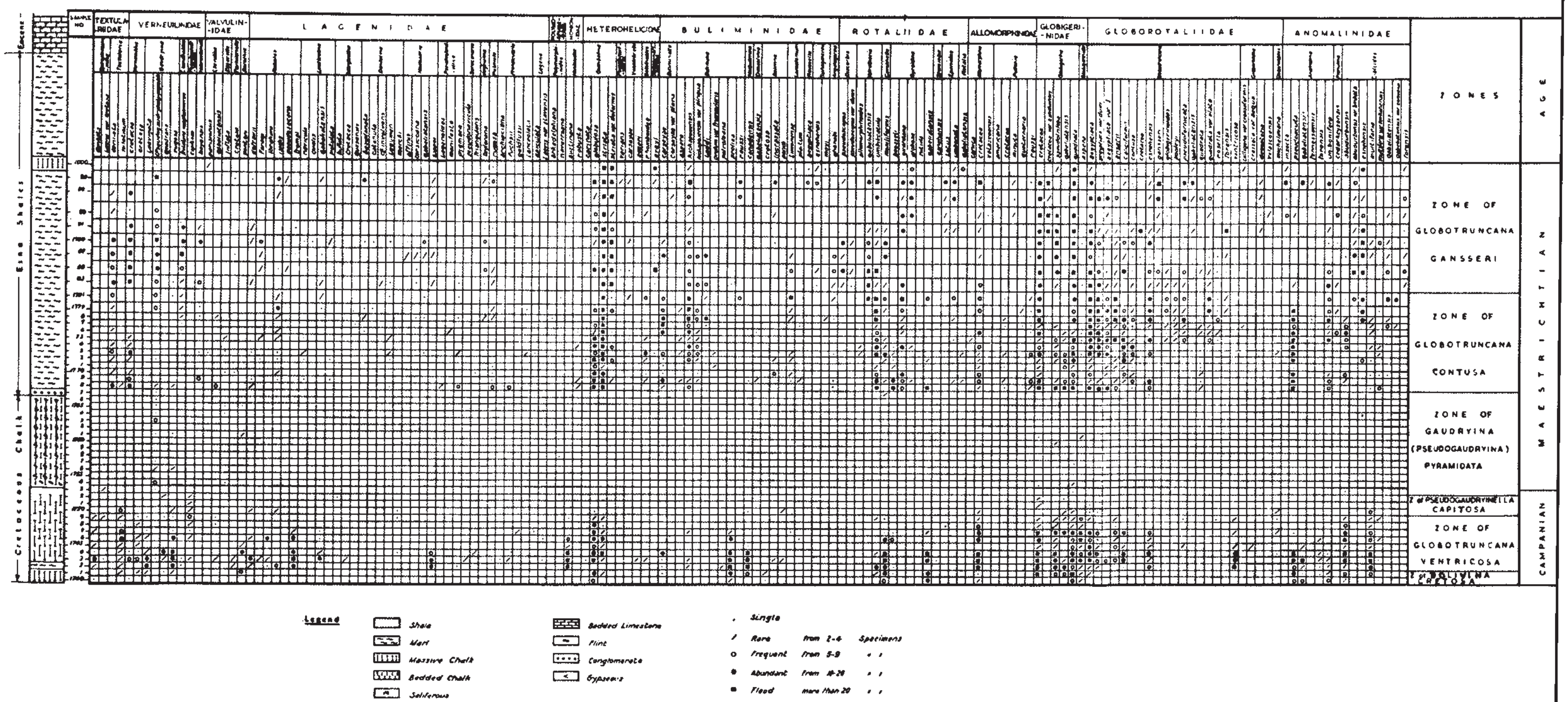
Differential Equation : $\frac{\partial D}{\partial n} + \frac{D}{\rho} = 2$

Suplementary Equation : $\int_{K}^{\text{Boundary}} D \cdot dn$ = constant.

Graphical Solution of
The Torsion Problem

Plate 5

RELATIVE DISTRIBUTION CHART OF
THE FORAMINIFERA
IN
GEBEL QABELIAT SECTION



III. The Esna shales of both sections can be correlated with the Navarro as it contains 9 index Navarro species and only 2 index Taylor species.

IV. As already mentioned in a joint publication by Nakkady and the author, (Congrès Géologique International, XIX Session, Alger, 1952, in press), the genus Globotruncana was of help in assigning ages for the formations of the two sections. Quoting the above-mentioned reference, the following observations were noticed in the two sections :

" 1. *Sudr Section :*

Globotruncana sudrensis, an affiliated form of the group lapperenti, floods the base of the section. Globotruncana lapperenti itself, together with another affiliated form, G. ansarii, appear higher up in the section. The presence of these affiliated forms, which have in common strongly curved, almost U-shaped ventral sutures, and overlapping chambers, is a possible indication of a Campanian age to the base, and middle part of the section.

Few specimens of Globotruncana gansseri appearing near the top of the section may be a possible indication of a Maestrichtian age.

2. *Qabeliat Section :*

The Globotruncana ventricosa zone found near the base of the section contains G. ventricosa, G. ansarii, and G. caliciformis. This assemblage possibly suggests an Upper Campanian age.

At the base of the Esna shales typical Maestrichtian species as G. contusa start to appear. G. calicifromis also floods this part of the section.

Further up in the section in the upper half of the Esna shales Globotruncana gansseri appears and continues to the end of the section suggesting a Maestrichtian age to this part of the formation ".

V. As already mentioned, the Mesozoic-Cenozoic transition of Egypt was zoned by the use of members of the family Globorotaliidae into a lower Globotruncana zone, a middle Buffer zone and an upper Globorotalia zone. The Globotruncana zone, which is characterised by different species of Globotruncana together with other typical Maestrichtian species, was attributed to the

Maestrichtian. On the same basis the Esna shales of both sections can as well be attributed to the Maestrichtian.

Judging from the above considerations and discussion, the following conclusions could be regarded, for the time being, as tentative :—

1. The age of the Massive Chalk at Sudr can be regarded as Campanian, that of the Bedded Chalk and the Esna shales as Maestrichtian.

2. Similarly the Massive Chalk of Qabeliat is of Campanian age, the Bedded Chalk as compared with that of Sudr is of an early Maestrichtian age (?), and at last the Esna shales is of a later Maestrichtian age.

3. The idea of dropping the use of such lithological terms as Chalk and Esna shales as time indices, receives further support from the present study, as the chalk occurs here partly in the Campanian, and partly in the Maestrichtian. It can be formed also in the Danian, or in the Palaeocene. Thus it loses its value, for long held, to be typically Danian.

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