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Stratigraphy of the Upper Cretaceous–Lower Paleogene Successions at Esh El-Mellaha Area, Gulf of Suez, Egypt: New contribution

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Abstract: Detailed field and lithostratigraphic studies are carried out on the Upper Cretaceous–Lower Paleogene section at Esh El-Mellaha area, Gulf of Suez, Egypt. The section is located at Wadi Dib west of Gebel Zeit. The fieldwork led to recognize four lithostratigraphic units, which are arranged in stratigraphic order as follows: the Sudr, Dib, Esna and Thebes formations. The Sudr Formation is here differentiated into two distinctive informal new rock units, argillaceous bedded limestone unit (at base) and calcareous shale unit (at top). The Dib Formation is here proposed for the first time as a new rock unit. It consists of carbonate rocks (bioclastic limestone) embracing reworked gravelly and pebbly extra-clasts and broken exhumed mega-fossils (e.g. gastropods and bivalves). This formation is equivalent to the upper part of the Dakhla Formation at different geographic neighborhoods of Egypt. Chronostratigraphically, the Sudr Formation is here assigned to the Maastrichtian Stage according to the occurrence of *Gansserina gansseri* and *Pseudoguembelina palpebra* index fossils. The Dib Formation is assigned to the Lower Paleocene (Danian Stage) according to the occurrence of *Praemurica uncinata* and *Morozovella angulata* index fossils. The Esna (shale) and Thebes (limestone) formations are assigned to the Lower Eocene (Ypresian Stage) according to the occurrence of *Acarinina sabyaensis* and *Morozovella formosa* index fossils. The Dib Formation is bounded by two regional unconformities surfaces (erosional surfaces) due to the impact of two tectonic events (I and II). which were related to the Syrian Arc Orogeny. The Tectonic Event I was recorded at the Sudr/Dib formations boundary and coincide with the Cretaceous/Paleocene (K/Pg) boundary. The Tectonic Event II was recorded at the Dib/Esna formations boundary nearly at the end of the Danian age. This event is characterized by the occurrences of paleosol zone and led to the missing of Tarawan Formation. Moreover, there is a tectonic event more (III) at the Esna/Thebes formational boundary. It is evidenced by the missing of the upper part of Esna Formation (Abu Had Member). These tectonic events are related to the Syrian Arc orogeny.

Keywords: Upper Cretaceous – Lower Paleogene – Dib Formation – Esh El-Mellaha – Tectonic Event.

1. Introduction

The Upper Cretaceous–Lower Paleogene strata are well represented all over the Egyptian geographic provenances. They consist of thick sequences of siliciclastic and carbonate facies. During this geologic interval, Egypt was located at the southern Tethys margin, and was subjected to intensive tectonics coinciding with the sea-level changes that impact the deposition of the sediments. [**1-10**] These authors believed that the Syrian Arc Orogeny was the main influential tectonic event during this time. The impact of this tectonic event varies from one place to another with major effects in the northern parts of Egypt than the southern parts. Esh El-Mellaha area is one of the most regions that was subjected to intensive tectonics in Egypt. [**1**], [**6-7**]

Several geological and stratigraphical studies were carried on the Upper Cretaceous-Lower Paleogene rocks in Egypt. [**2**], [**9**], [**11-20**] Nevertheless, there are many stratigraphic problems that still as a matter of controversy such as the complete or partially missing of some rock units, the lateral and vertical facies change, and their relationship with sedimentary basin evolution in the study area. In the study area, one of the major significant problems is the classification or sub-division of the rock units. For example, the Upper Cretaceous (Maastrichtian)-Lower paleogene (Ypresian) successions in the study area (Esh El-Mellaha) were subdivided by the specialized stratigraphic workers

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into three rock units (formations), Sudr (at base), Esna (at middle) and Thebes (at top)). [1],[21-23] These works ignored the reasons of missing of the Dakhla and Tarawan formations which are well represented in the neighborhoods regions such as, Wadi Tarfa and Wadi Dakhla north of the study area and Safaga and Qusier south of the study area. [1],[6] The intent of the present study is to solve this problem. It introduces detailed field and laboratory studies to differentiate the stratigraphic rock units and their vertical relationships

2. Materials, Methods and Depository

Forty (40) representative samples were carefully collected, covering the Upper Cretaceous (Maastrichtian) – Lower Paleogene (Ypresian) sequence from the four stratigraphic units at Wadi Dib in Esh El-Mellaha area, Gulf of Suez, Egypt. Wadi Dib is located at latitude 27° 45′ 21″ N and longitude 33° 14′ 33″ E (Fig. 1). This section is well measured and described. Thin sections were made for some hard rocks, to define the lithology and determine the depositional environment. The samples interval vary, which was closed at the change in the types of rocks especially at rock units vertical changes. About 100 grams from each sample were disaggregated in water with drops of dilute hydrogen peroxide (H_2O_2). Afterward, the samples were washed through a 63µm sieve and the obtained residues were dried. This technique was repeated until clean surface textures of the foraminiferal tests were recovered. Dilutesodium bicarbonate may be used to obtain a clear surface of the foraminiferal test. Constant split from the dried residue was investigated qualitatively and quantitatively under the binocular stereomicroscope. The planktonic and benthonic foraminiferal species were picked out, identified, counted, mounted in micro slides, and housed in the collections of Mr. Ibrahim El-Mohandes at Department of Geology, Faculty of Science, Sohag University, Sohag, Egypt.

Fig.1: location map

3. Lithostratigraphy

The detailed field survey of the Upper Cretaceous–Lower Paleogewne rocks at Wadi Dib in Esh El-Mellaha area led to identifying four rock units arranged from base to top as follows: the Sudr, Dib (new), Esna and Thebes formations fig (2-3)

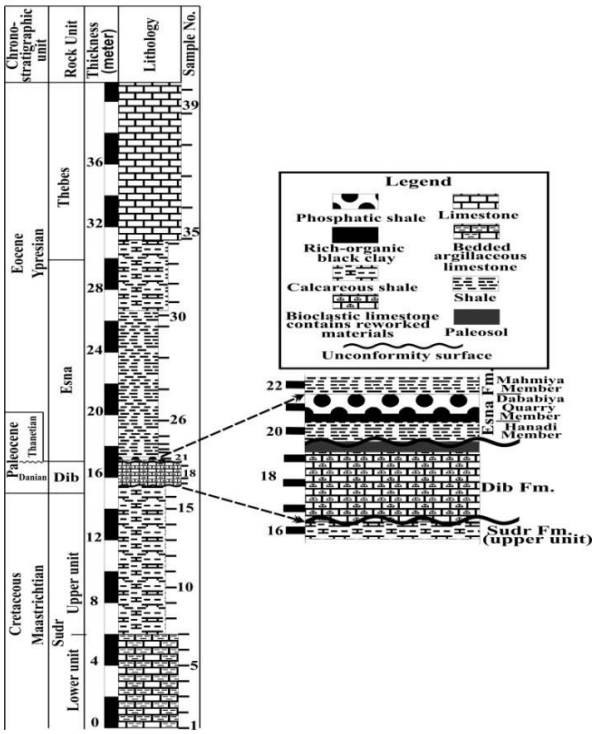

Fig.2: lithostratigraphy of Wadi Dib section.

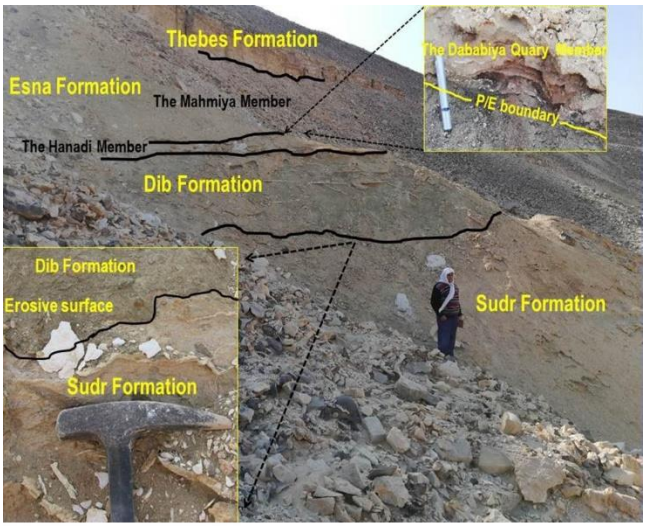

Fig.3: field photo shows the different rock units at Wadi Dib.

3.1. The Sudr Formation

Ghorab proposed the name of Sudr Formation to describe the chalky limestone rocks in west-central Sinai, Egypt. [24] In the present study (Esh El-Mellaha area), the exposed Sudr Formation attains ~15m thick and consists of bedded argillaceous limestone (at base) and calcareous shale (at top). Based on the fieldworks, the Sudr Formation is here subdivided into two informal new distinctive units, as follows:

3.1.1. The bedded argillaceous limestone unit (New)

Name: From the description of the sequence at the study section.

Type section: Wadi Dib. The upper part of this unit is only described because the lower part is unexposed (Fig. 3).

Lithology: This unit consists of well bedded argillaceous limestone (Fig. 4). This limestone is characterized by the occurrence of some pectenids shells of *Pecten farafrensis* species. These shells are scattered throughout the beds of the strata of this unit.

Boundaries: The bedded argillaceous limestone unit represents the lower part of the Sudr Formation at the study section. The complete thickness of this unit cannot be evaluated at the study area, because the basal part of it is unexposed, so the upper part is only described. Thus, the lower boundary of this unit is not defined. The upper boundary represents the base of the upper calcareous shale unit (New, the present study).

Thickness and distribution: The exposed thickness of the lower bedded argillaceous limestoneis ~6 meters at the study section. It is well distributed in Esh El-Mellaha area and extended laterally southwards to Wadi Mellaha and northwards to the end of Esh El-Mellaha area (Fig. 1).

Regional correlation: The exposed part of the lower argillaceous limestone unit is equivalent to the lower part of the Dakhla Formation, due to the presence of the same foraminiferal faunal content of the early Maastrichtian age such as; *Gansserina gansseri* and *Rugoglobigerina hexacamerata*. These index planktonic foraminiferal species were recorded within the lower part of the Dakhla Formation. [2] At the same time, the unexposed part of this unit may be equivalent to the Duwi Formation of the Campanian age southward at the Safaga and Quesier areas.

Biostratigraphic characterization and age: Based on the planktonic foraminiferal index fossils, the bedded argillaceous limestone belongs to early Maastrichtian.

Genetic interpretation: The lower bedded argillaceous limestone represents the basal part of the Sudr Formation which was deposited in open marine conditions of an outer neritic paleoenvironmental condition that contains a high diversity of planktonic and benthonic foraminiferal species.

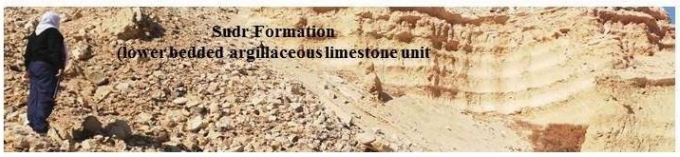

Fig.4: filed photo shows the lower bedded argillaceous limestone unit of Sudr Formation.

3.1.2. The upper calcareous shale unit (New)

Name: From the description of the sequence at the study section.

Type section: The upper part of the Sudr Formation at Wadi Dib (Fig. 3).

Lithology: This unit consists of brownish calcareous shale. The rocks of this unit are characterized by the occurrence of rich *Pecten farafransis* shells (Fig. 5).

Boundaries: The lower boundary is the lower bedded argillaceous limestone unit, while the upper boundary is the base of the Dib Formation (New, the present study).

Thickness and distribution: The thickness of the upper calcareous shale unit ~9 meters at the present study section. It is well distributed and covering the upper part of the Sudr Formation throughout Esh El-Mellaha area that extended southwards to Wadi Mellaha and northwards to the end of Esh El-Mellaha area (Fig. 1).

Regional correlation: The upper calcareous shale unit is equivalent to the middle part of the Dakhla Formation at different geographic neighborhoods of Egypt, due to the presence of the same foraminiferal faunal content of the late Maastrichtian age such as; *Pseudoguembelina haraensis* and *Pseudoguembelina palpebra*. These index planktonic foraminiferal species were recorded within the middle part of the Dakhla Formation. [2]

Biostratigraphic characterization and age: Based on the occurrence of *Pseudoguembelina haraensis* and *Pseudoguembelina palpebra* planktonic foraminiferal index fossils, the upper calcareous shale unit is assigned to the late Maastrichtian age.

Genetic interpretation: The upper calcareous shale unit represents the upper part of the Sudr Formation that contains a high diversity of the foraminiferal species. Generally, it was deposited in the open marine setting of an outer neritic paleoenvironmental conditions.

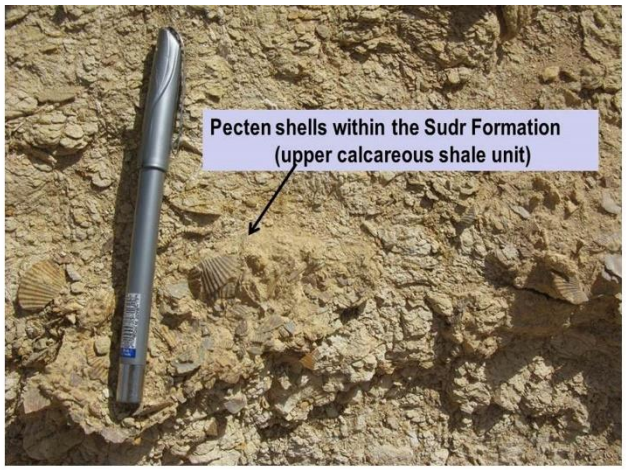

Fig.5: filed photo shows the pecten farafransis shells within the upper calcareous shale unit of Sudr Formation.

3.2. The Dib Formation (New)

Name: From the name of the study area (Wadi Dib), Esh El-Mellaha area, Gulf of Suez, Egypt.

Type section: Wadi Dib section, Esh El-Mellaha area, Gulf of Suez, Egypt at latitude 27° 45′ 21″ N and longitude 33° 14′ 33″ E.

Lithology: The Dib Formation consists of glauconitic bio-clastic limestone (Fig. 3). It contains embracing reworked gravelly and pebbly extra-clasts and broken exhumed mega-fossils (e.g. gastropods and bivalves. The lower boundary of this formation is marked by the occurrence of irregular surface which represents the Cretaceous/Paleogene (K/Pg) boundary. Moreover, the upper boundary of the formation is marked by the occurrence of unconformity surface between the Dib and Esna formations. This unconformity surface is characterized by the occurrence of paleosol layer (Figs. 6&7).

Boundaries: The lower and upper boundaries of the Dib Formation are characterized by the occurrence of two erosional surfaces between the Sudr and Esna formations respectively.

Thickness and distribution: The thickness of the Dib Formation is ~ **1.25** meter at the study section.

Regional correlation: The Dib Formation is equivalent to the upper part of the Dakhla Formation. It is well distributed in Esh El-Mellaha area (Fig. 1).

Biostratigraphic characterization and age: The Dib Formation is assigned here to the Danian age due to the presence of the planktonic foraminiferal species such as; *Praemurica uncinata* and *Morozovella angulata*. These index planktonic foraminiferal species were recorded within the upper part of the Dakhla Formation at many localities in Egypt. [1],[6],[25]

Genetic interpretation: The Dib Formation is deposited in a middle to outer neritic paleoenvironmental condition. It contains fresh Danian foraminiferal species with some reworked megafossils of Cretaceous Period.

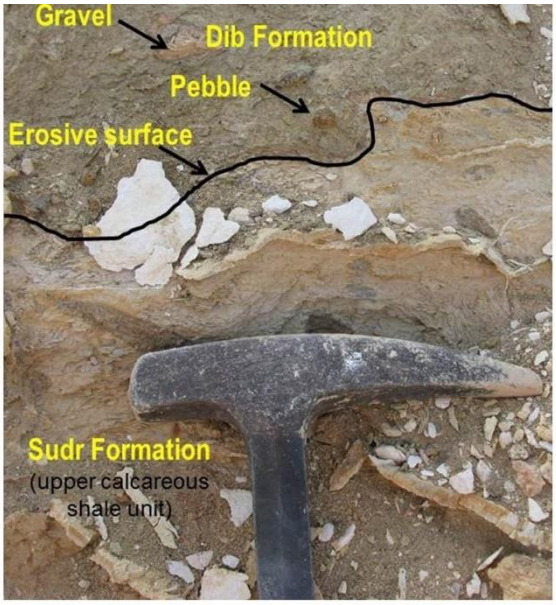

Fig.6: filed photo shows the unconformity surface (erosive surface) between the Sudr Formation (upper calcareous shale unit) and Dib Formation, which contains gravels and pebbles.

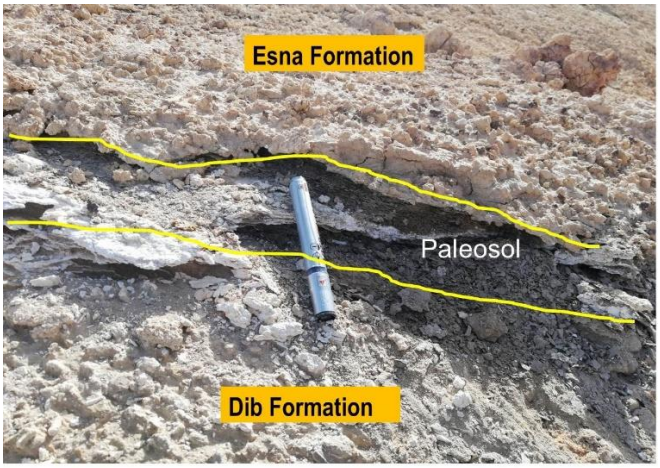

Fig.7: filed photo shows the unconformity surface (paleosol surface) between the Dib Formation and Esna Formation.

3.3. The Esna Formation

The Esna Formation is uncomfortably rest on the Dib Formation, due to the missing of the Tarawan Formation. It is marked by the occurrence of paleosol. The Esna Formation was firstly introduced by Beadnell to define the shale between the Duwi Formation (Phosphate) at the base and Thebes Formation (Limestone) at the top. [26] Said emended Beadnell's nomenclature and subdivision and referred the Esna Formation only to the interval between the Tarawan Formation (Chalky limestone) and the Thebes Formation (Limestone). [27] Said (op. cit) erected the Dakhla Formation for the shales underlying Tarawan Formation (Chalky limestone). Aubry *et al*. used the definition of Said at the GSSP, and subdivided the Esna Formation into four members arranged from base to top as follows, the Hanadi, Dababiya Quarry, Mahmiya and Abu Had. [27-28] At Wadi Dib (this study), the Esna Formation can be subdivided only into three members: Hanadi, Dababiya Quarry and Mahmiya, because the Abu Had is not represented either due to non-depositional or erosion. The Hanadi and the Dababiya Quarry members are represented by very thin thickness ~ 15cm and 25cm respectively. The Mahmiya Member measures about 14 meter thick.

3.4. The Thebes Formation

The name of Thebes Formation was firstly introduced by Said to describe about 290 meters thick limestone section with many flint bands that overlies the Esna Formation at Gabal Gurnah, in the western side of the Nile facing Luxor. [29] At Wadi Dib section, the Thebes Formation consists of thick succession of massive limestone papery at the base with flint nodules (Fig. 8). The basal part is only measured of the Thebes Formation (~ 8 meters thick) at the present study.

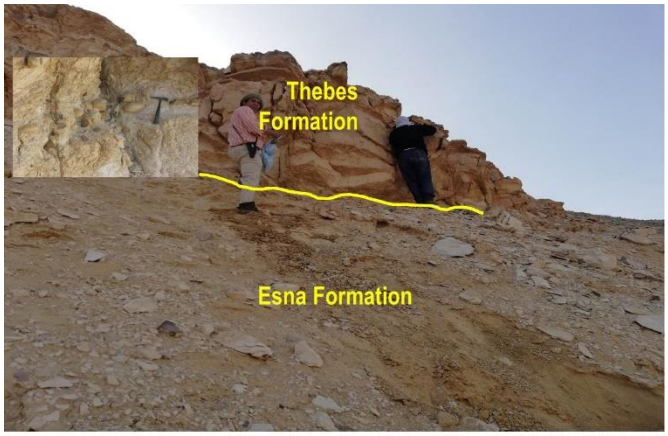

Fig.8: filed photo shows the sharp contact between the Esna and Thebes formations. The Thebes Formation contains flint nodules.

4 Discussion and Conclusion

The present study represents detailed field and lithostratigraphyical studies at Wadi Dib, Esh El-Mellaha area, Gulf of Suez, Egypt. Lithostratigraphically, four rock units are identified; the Sudr, Dib, Esna and Thebes formations. The Sudr Formation is here subdivided into two distinctive informal new rock units, argillaceous bedded limestone unit (at base) and calcareous shale unit (at top). Moreover, the Dib Formation is here proposed for the first time as a new rock unit. It consists of carbonate rocks formed from bioclastic limestone. The Dib formation is equivalent to the upper part of the Dakhla Formation at different geographic neighborhoods of Egypt. Depending on the planktonic foraminiferal index fossils, the Sudr and Dib formations are assigned to the Maastrichtian and the Danian stages. Also, the Esna (shale) and Thebes (limestone) formations are assigned to the lower Eocene (Ypresian Stage).

Esh El-Mellaha area is subjected to three tectonic events (I, II and III) which are related to the Syrian Arc orogeny. These tectonic events are evidenced by field and lithostratigraphic criteria. The tectonic Event I led to a major uplift of the sedimentary basin during the K/Pg boundary. This event is documented by the presence of an irregular (erosive) surface between the Sudr and Dib formational boundary. Also, the Dib Formation is characterized by the occurrence of glauconite sediments and pebbly to gravelly extra-clasts. The tectonic Event II is evidenced by the presence of an irregular (erosive) surface (paleosol layer) at the Dib/Esna formational boundary. This event led to the missing of the Tarawan Formation due to the formation of an aerial paleohigh. The tectonic Event III is matched at the Esna/Thebes formational boundary within the Ypresian stage. This event is supported by the missing of Abu Had member.

5 References

[1] Obaidalla, N., A., Planktonic foraminiferal bio-stratigraphy and faunal turover events during the Late Cretaceous-Early Tertiary along the Red Sea Coast, Egypt. Journal of African Earth Sciences, **31(Oct-Nov)**, 571–595, 2000. https://doi.org/10.1016/S0899-5362(00)80008-1

[2] Obaidalla, N., A., El Ayyat, A., M., & Kassab, A., Biostratigraphical and sedimentological studies on the Upper Cretaceous/Paleogene sequence, Western Desert, Egypt. Assiut University Journal of Geology, **35(Jan),** 141–207, 2006.

[3] Obaidalla, N., A., Abdel-Maksoud, N., A., Hosny, A., M., & Mahfouz, K., H., Nature of the Paleocene/Eocene (P/E) boundary in Sinai, Egypt. Journal of African Earth Sciences, **136(Dec),** 44–60, 2017. https://doi.org/10.1016/j.jafrearsci.2017.01.036

[4] Obaidalla, N., A., Mahfouz, K., H., Soliman, M., F., & Moghawry, A., Stratigraphical studies on the Matulla/Sudr formational boundary, western Sinai, Egypt. Assiut University Journal of Geology, **47(Dec),** 23–40, 2018.

[5] Mahfouz, K., H., Stratigraphic studies on the Paleocene-Eocene succession of the Sinai, Egypt. (Unpubl. PhD thesis), Assiut University, Assiut, Egypt, 263 p, 2013.

[6] El Ayyat, M., A., & Obaidalla, A., N., Stratigraphy, sedimentology and tectonic evolution of the Upper Cretaceous/Paleogene succession in north Eastern Desert, Egypt. Journal of African Earth Sciences, **81(May),** 35–59, 2013. https://doi.org/10.1016/j.jafrearsci.2013.01.007

[7] El Ayyat, M., A., & Obaidalla, N., A., The impact of the Syrian Arc Orogeny on the Early Paleogene rocks, western shoulder of the Gulf of Suez, Egypt. Palaeogeography, Palaeoclimatology, Palaeoecology, **454(Jul),** 30–53, 2016. https://doi.org/10.1016/j.palaeo.2016.04.011

[8] Metwally, A., A., & Mahfouz, K., H., The Paleocene/Eocene (P/E) boundary along the eastern plateau of Kharga–Baris oases, Western Desert, Egypt. Journal of African Earth Sciences, **147(Nov),** 569–584,2018. https://doi.org/10.1016/j.jafrearsci.2018.07.013

[9] Faris, M., Obaidalla, N., A., Metwally, A., A., Salman, A., & Zaky, A., S., Late Cretaceous-Early Paleogene tectonic events at Farafra-Abu Minqar Stretch, Western Desert, Egypt: results from calcareous plankton. Arabian Journal of Geosciences, **11(Aug),** 1–18, 2018. https://doi.org/10.1007/s12517-018-3787-9

[10]Mahfouz, K., H., & Metwally, A., A., Maastrichtian–Paleocene successions at Kharga–Dakhla stretch, Western Desert, Egypt: Paleoenvironmental and basin evolution interpretations. Journal of African Earth Sciences, **162(Feb),** 103731, 2020. https://doi.org/10.1016/j.jafrearsci.2019.103731

[11] Said, R., & Kerdany, M., T., The Geology and Micropaleontology of Farafra Oasis, Egypt. Micropaleontology, **7(Jul),** 317-336, 1961.

[12] Barthel, K.,W., Herrmann-Degen, W., & Falkner, G., Late Cretaceous and Early Tertiary stratigraphy in the Great Sand Sea and its SE margins (Farafa and Dakhla Oases), SW desert, Egypt. Mitteilungen der Bayerischen Staatssammlung für Palaontologie und Historische Geologie **21(Des),** 141–182, 1981.

[13] Khalifa, M., A., & Zaghloul, E., A., Stratigraphy and depositional history of the Upper Cretaceous-Paleocene sequence in Abu Minqar-Farafra stretch, Western Desert, Egypt. Annals of Geological Survey Egypt, **XV**, 275–285, 1985.

[14] Strougo, A., The Velascoensis event: a significant episode of tectonic activity in the Egyptian Paleogene, Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, **173**, 253–269, 1986.

[15] Obaidalla, N., A., and Kassab, A., S., Biostratigraphy of the Khoman Formation, Bahariya Oasis, Western Desert, Egypt. An approach to the K/T boundary. Egyptian journal of geology, **44 (2)**, 443 453, 2000.

[16] El-Azabi, M., H., & El-Araby, A., Depositional cycles, an approach to the sequence stratigraphy of the Dakhla Formation, west Dakhla-Farafra stretch, Western Desert, Egypt. Journal of African Earth Sciences, **30(May),** 971–996, 2000. https://doi.org/10.1016/S0899-5362(00)00064-6

[17] Tantawy, A., A., Keller, G., Adatte, T., Stinnesbeck, W., Kassab, A., and Schulte, P., Maastrichtian to Paleocene depositional environment of the Dakhla Formation, Western Desert, Egypt: sedimentology, mineralogy, and integrated micro- and macrofossil biostratigraphies. Cretaceous Research, **22(Dec),** 795–827, 2001. https://doi.org/10.1006/cres.2001.0291

[18] Keheila, E., A., & Kassab, A., Stratigraphy and sedimentation-tectonics of the Campanian-Thanetian succession in north Wadi Qena and southern Galala, Eastern Desert, Egypt: Evidence for major and regional erosive unconformities. Bulletin Faculty of Science, Assiut University, Assiut, Egypt, **30 (1-F),** 73–109, 2001.

[19] El Younsy, A., R., M., & Khalil, M., Diagenesis and diagenetic processes in view of Sequence Stratigraphy for the Upper Cretaceous-lower Eocene sequence, Farafra oasis, Western Desert, Egypt. 5th International Conference on Geology of Africa, Assiut, Egypt, **I**, 519–538, 2005.

[20] Obaidalla, N., A., El-Sheikh, I., Mahfouz, K., H., Salman, A., M., Soliman, M., F., & Abdel-Aleem, F., M., Upper Cretaceous–lower Paleocene subsurface sequence, Farafra Oasis, Western Desert, Egypt: stratigraphical and paleoenvironmental inferences. Arabian Journal of Geosciences, (In press), 2020. https://doi.org/10.1007/s12517-020-05812-x

[21] Chereif, O., H., & Ismail, A., A., Late Senonian-Tertiary planktonic foraminiferal biostratigraphy and tectonism of the Esh El-Mellaha and Ghrmoul areas, Egypt. Middle East Research Center, Ain Shams University, Earth Science Series **5**,146-159, 1991.

[22] Ismail, A., A., Late Cretaceous-Early Eocene benthic

foraminifera from Esh El-Mellaha area, Egypt. Revue de Paleobiologi, Geneve, **31(Jul),**15-50, 2012.

[23] Hewaidy, A., A., Farouk, S., & El-Balkiemy F., A., Foraminiferal biostratigraphy, stages boundaries and Paleoecology of the uppermost Maastrichtian-Lower Eocene succession at Esh El-Mellaha Area, North Eastern Desert, Egypt. Journal of Amirican Science, **13(May),** 73-113, 2017b. http://www.jofamericanscience.org

[24] Ghorab, M., A., Abnormal stratigraphic features in Ras Gharib oil field.-3rdArab Petroleum Congress, Alexandria, 10p, 1961.

[25] Obaidalla, N., A., El-Dawy, M., H., & Kassab, A., S., Biostratigraphy and paleoenvironment of the Danian/Selandian (D/S) transition in the Southern Tethys: A case study from north Eastern Desert, Egypt. Journal of Afrcian Earth Sciences, **53(Jan),** 1–15, 2009. https://doi.org/10.1016/j.jafrearsci.2008.07.004

[26] Beadnell, H., J., L., The relation of the Eocene and Cretaceous systems in the Esna - 569Aswan Reach of the Nile Valley. Quart Journal of Geological Society, London, **51,** 667-570, 1905.

[27] Said, R., The geology of Egypt. Amsterdam: Elsevier, 377 p, 1962.

[28] Aubry, M-P, Ouda, Kh., Dupuis, C., Berggren, W., Van Couvering, J., A., and the Members of the Working Group on the Paleocene/Eocene Boundary, Ali J., A., Brinkhuis, H., Gingerich, P., H., Heilmann-Clausen, C., Hooker, J., Kent, D., V., King, C., Knox, R.. W., O., B., Laga, P., Molina, E., Schmitz, B.. Steurbaut, E., Ward, D., R., Global Standard Stratotype-section and Point (GSSP) for the base of the Eocene Series in Dababiya section (Egypt). Episodes, **30 (Dec),** 271- 286, 2007. https://doi.org/10.18814/epiiugs/2007/v30i4/003

[29] Said, R., Planktonic foraminifera from the Thebes Formation, Luxor, Egypt. Micropaleontology, **6 (3),** 277-286, 1960.