Qatar Univ. Sci. Bull. (1983), 3: 217 - 231

CONTRIBUTION TO THE SEDIMENTOLOGY OF THE BAHARIYA FORMATION OF GEBEL EL-DIST, BAHARIYA OASIS, WESTERN DESERT, EGYPT

By

M. E. HILMY, M. M. ABU-ZEID AND N. SAAD

Department of Geology, Faculty of Science, Ain-Shams University, Cairo

Key Words: Claystone, Cretaceous (Bahariya Formation), Delatic environment, Egypt-Bahariya Oasis (Gebel El-Dist), Fluviatile environment, Heavy minerals, Standstone, Sedimentology; Siltstone.

ABSTRACT

Combined microscopic, grain-size and heavy-mineral analyses were carried out on the Bahariya Formation at Gebel El-Dist (type section), Bahariya Oasis. These studies revealed that the formation is composed of moderately poorly-sorted silty sandstones and sandy siltstones with few intercalations of sandstones, siltstones and clayey siltstones. The heavy-mineral suite is composed of (in order of decreasing abundance): opaques, zircon, rutile, staurolite, tourmaline, kyanite, garnet and biotite. Seven heavy-mineral zones are delineated in the El-Dist section. Comparison of these zones with those recognized in another occurrence of the Bahariya Formation revealed that they have a wide areal distribution.

The Bahariya Formation was deposited mainly in fluviatile and deltaic environments, with low energy. The sediments were inherited from an igneous rock with minor contribution from metamorphic and sedimentary lithologies. The provenance remained almost unchanged during the deposition of the formation.

INTRODUCTION

Gebel El-Dist, which lies near the northern scarp of the Bahariya Oasis (Figure 1), is considered to be the type section of the Bahariya Formation (Lower Cenomanian). The latter represents the oldest exposed rocks in the area and is unconformably covered by Eocene limestones and dolostones.

Lithologically, the Bahariya Formation is composed of claystones, siltstones and sandstones. It contains ironstone bands, iron oxide concretions, gypsum, glauconite, mica, chlorite and coal fragments. Coprolites and vertebrate and invertebrate fossils are reported. Microstructures as cross-lamination and colour-banding are common, especially at the base of the formation. Fig. 2 presents the stratigraphic columnar section measured at G. El-Dist.

Ball and Beadnell (1903) were the first to measure the section of G. El-Dist. Stromer (1914) described the vertebrate and invertebrate fossils and named the formation "Baharijestufe". The paleo-environmental studies carried out on the Bahariya Formation were mainly based on the fossil content and the gross lithologic characters (Ball and Beadnell, 1903; Stromer, 1914; Lebling, 1919; El-Akkad and Issawi, 1963 and Said and Issawi, 1964). These studies indicated deposition under fluvio-marine conditions. Soliman *et al.* (1970), on the other hand, suggested deposition in a prodeltaic, partly restricted, and reducing environment.

The present wotk aims at interpreting the depositional environment and provenance of the rocks of the Bahariya Formation by investigating some sedimentological aspects which have not been dealt with before. This was achieved by carrying out combined microscopic studies and grain-size analysis which were also used for the textural classification and nomenclature of the investigated rocks. Characterization of provenance was aided by the determination of the relative abundance of the heavy minerals which were also used to subdivide the succession into heavy mineral zones. The regional significance of these zones was assessed by comparing with the zones delineated in the Bahariya Formation in the Naqb Ghorabi section, thirty kilometers to the NE of the El-Dist section.

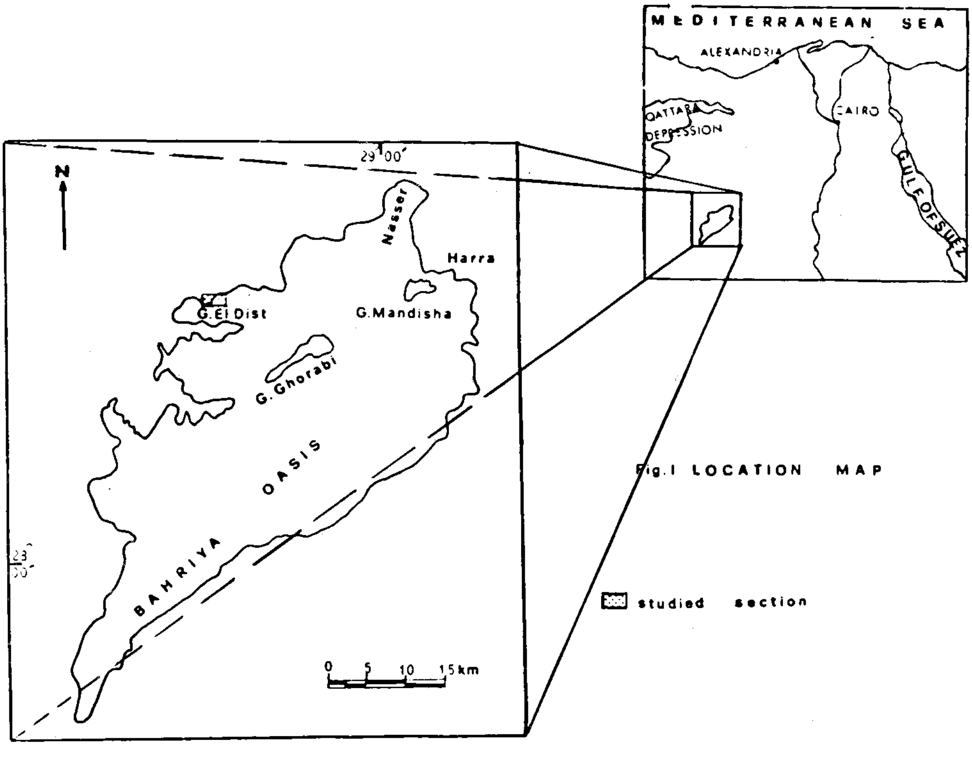

Figure 1. Location Map

PROCEDURES

Mechanical analysis was carried out on a number of samples selected on the basis of thin-section description in order to represent the various rock types in the succession. The preparation of samples for size-analysis (disaggregation and dispersal) was carried out according to the procedure recommended by Ingram (1971). The sand fraction was separated by screening; the silt and clay fractions were analysed by the pipette method as adopted by Galehouse (1971). The heavy minerals were separated and their percentages, based on the number of grains, were determined. The nonopaque suite of the minerals, which is most useful in genetic interpretations, was recalculated to a total of 100% by omitting opaque grains.

RESULTS AND DISCUSSION

A - Petrography

1. This-section description

The succession of the Bahariya Formation is composed of alternating beds and bands of sandstones, siltstones and claystones. The sandstones range from quartz arenites to wackes; with the former predominant. They are fine to medium-grained and mostly moderately poorly -sorted. The quartz grains, which form most of the rock, are subangular to subrounded; frequently exhibiting wavey extinction. The feldspar is principally potassic and, to a much lesser extent, oligoclase and andesine. Very few weathered feldspar grains are observed. Fine-grained detritus in the form of microcrystalline rock fragements of diverse compositions (micaceous, siliceous, chloritic) and origins (igneous, metamorphic, sedimentary) are observed in parts. Syndepositional clay matrix occurs as clay-sized particles, as well as silt-sized clay aggregates and sand-sized pellets. This type of clay matrix has generally been considered to typify fluvial and turbidite environments having low energy expenditure (Blatt *et al*, 1972). Clays in the form of thin laminae (e.g. clay flasers) formed as a result of variation in competency of the depositional medium are also found in parts of the succession. Iron oxides occur as grain-coatings, fluccules, concretions, scattered minute spots and as irregular patches impregnating the groundmass in parts. The ironstone bands are mainly hematitic and contain a few very fine quartz grains. Pyritic crystals and glauconite are found especially at the base of the formation.

2. Grain-size analysis

The obtained grain-size data were used to contruct cumulative curves from which statistical size parameters were determined using the equations given by Folk and Ward (1957). Table (1) presents the size data, together with the calculated parameters, from which the following general characteristics are revealed:

i. The mean size of the sediments shows a remarkable variation throughout the succession. The average mean size is 4.326 Ø.

ii. The sediments are generally moderately poorly-sorted.

iii. Most of the curves of distribution are coarse- to strongly coarse-skewed. Five samples (19, 55, 58, 67 and 71) have near-symmetrical curves.

iv. Most of the samples have platykuritic curves, except for samples 5, 39, 43 and 67 which have leptokuritic curves and samples 7 and 21 with mesokurtic curves.

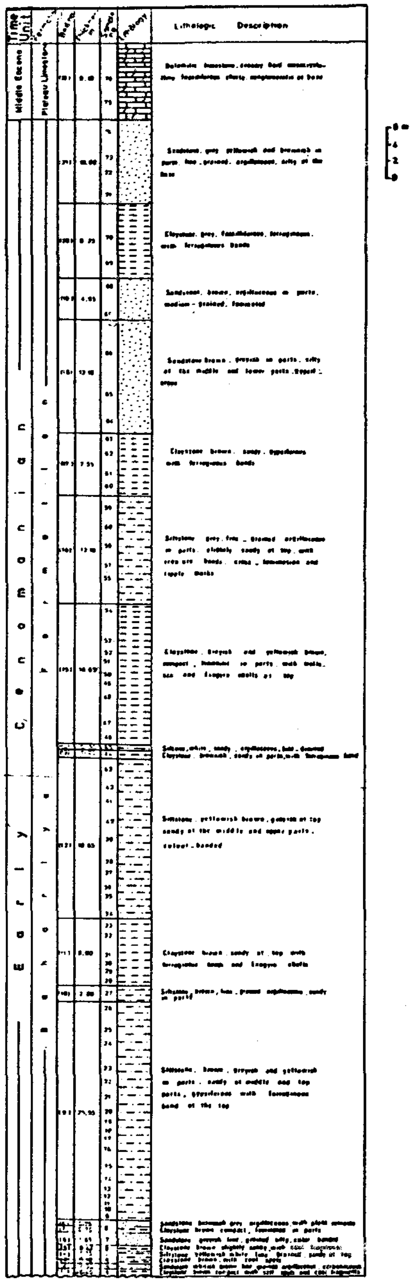

Figure 2. Stratigraphic Columnar Section of Gebel El-Dist.

Table 1
Statistical Grain-Size Parameters of Samples from the Bahariya Formation.

Sample	$\varnothing_5$	$\varnothing_{16}$	$\varnothing_{25}$	$\varnothing_{50}$	$\varnothing_{75}$	$\varnothing_{84}$	$\varnothing_{95}$	M_Z	O_I	SK_I	K_G
D_5	1.70	2.00	2.40	3.00	3.80	4.60	6.30	3.20	1.35	0.33	1.35
D_7	2.00	2.30	2.60	3.40	4.50	5.20	6.50	3.63	1.40	0.52	0.97
D_{15}	2.70	3.00	3.60	4.70	6.10	6.80	7.40	4.80	1.66	0.12	0.77
D_{19}	2.40	3.00	3.40	4.70	5.80	6.50	7.30	4.70	1.62	0.05	0.84
D_{21}	2.30	3.00	3.50	4.20	5.20	6.10	6.80	4.40	1.46	0.18	1.08
D_{34}	2.50	3.00	3.20	4.20	5.70	6.30	7.00	4.50	1.51	0.21	0.74
D_{39}	3.00	3.80	4.20	4.80	5.70	6.30	7.20	4.96	1.27	0.18	1.15
D_{43}	2.10	2.50	2.90	3.30	4.60	5.60	7.00	3.80	1.52	0.50	1.18
D_{55}	3.00	3.80	4.40	5.20	6.40	6.80	7.20	5.26	1.39	0.01	0.86
D_{58}	1.80	3.00	3.60	4.80	6.00	6.60	7.00	4.80	1.62	0.07	0.89
D_{65}	2.80	3.50	3.90	4.80	6.00	6.70	6.90	5.00	1.42	0.10	0.80
D_{67}	0.40	1.40	1.80	2.40	3.00	3.20	5.60	2.30	1.24	0.05	1.77
D_{71}	2.80	3.20	3.50	4.80	6.20	6.80	7.00	4.90	1.54	0.08	0.64

Textural classification of the Bahariya Formation

The nomenclature schemes for the textural classification of fine-grained sediments adopted by Trefethen (1950) and Picard (1971) are used in this study to classify the investigated samples according to their mechanical composition. Figures 3 and 4 show that most of the samples are texturally classified as sandy siltstones and silty sandstones. Samples 39, 55, and 67, on the other hand, are classified as siltstone, clayey siltstone and sandstone respectively.

Environmental interpretation of grain-size data

Several ways of approach proposed by previous workers are followed in the present work to interpret the depositional environment of the Bahariya Formation using grain-size data. However, these approaches are cautiously applied due to the fact that the original grain-size distribution in the rock could have been diagnetically changed by various processes (e.g. pelletization by organisms, degradation of larger framework elements, recrystallization, etc).

The discriminant functions of Sahu (Sahu, 1964) were claculated for the rocks under investigation (Table 2). However, these functions were successfully interpreted in only about 40% of the samples for which a deltaic environment of deposition is clearly indicated. For the other 60% of the samples, however, no specific environment is definitely revealed.

Plots of various combinations of four statistical parameters (Mz σ_I, Sk_I and K_G) have been used by previous workers. However, many investigators agree that skewness appears to be the parameter most sensitive to the environment of depostion (Friedman, 1961 and 1967; Passega, 1957 and 1964; Mason and Folk; 1958; Moiola and Weiser, 1968).

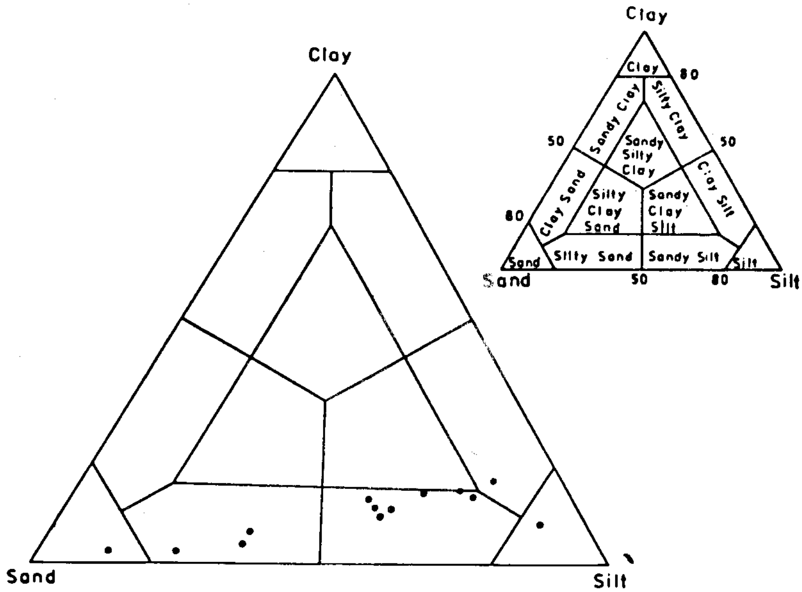

Figure 4. Ternary Diagram showing the mechanical composition of El-Dist samples.

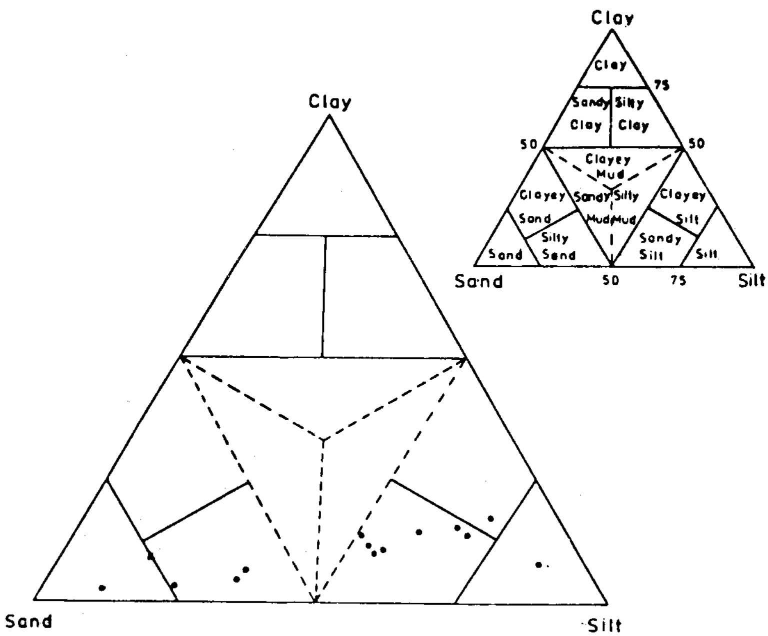

Figure 3. Ternary Diagram showing the mechanical composition of El-Dist samples.

Table 2
Discriminant Functions of Sahu as Calculated for the Bahariya Formation.

Sample No.	Y_1	Y_2	Y_3	Y_4
D_5	−1.156	200.802	−16.603	10.941
D_7	−3.759	212.976	−18.633	10.464
d_{15}	−4.782	272.625	−23.321	7.236
D_{19}	−4.547	262.467	−21.854	7.116
D_{21}	−4.823	232.184	−18.247	9.243
D_{34}	−5.752	237.759	−19.684	7.658
D_{39}	−8.524	208.162	−12.748	10.227
D_{43}	−2.374	242.186	−21.546	11.422
D_{55}	−8.963	225.388	−15.433	7.635
D_{58}	−4.790	265.319	−21.921	7.583
D_{65}	−8.097	227.377	−16.689	7.702
D_{67}	2.890	170.695	−12.973	10.744
D_{71}	−6.882	245.829	−19.739	6.505

A plot of skewness versus standard deviation was proposed by Friedman (1961 and 1967) and Moiola and Weiser (1968) in an attempt to distinguish between beach and river sands. The use of this plot in the present work (Figure 5) reveals that all samples of the Bahariya Formation plot on the 'river' side of the diagram. The same result was also achieved when a plot of mean size versus standard deviation was used (Figure 6). The latter was proposed by Moiola and Weiser (1968) to distinguish between river, beach and dune sediments.

A plot of skewness versus kurtosis was proposed and successfully used by Mason and Folk (1960) to identify the sediments of the beach, the aeolian flat and the inland dune environments. Using this plot for the Bahariya samples (Figure 7) reveales that only two of the them fall in the areas of aeolian flat and dune environments, while the rest of the samples are different from those characteristic for the environment dealt with by Masn and Folk.

The use of the C-M diagram presented by Passega (1957 and 1964) shows that there is a distinct grouping of data points of the Bahariya Formation in an area very close to the fields of 'bed load' and 'turbidity currents' (Figure 8.)

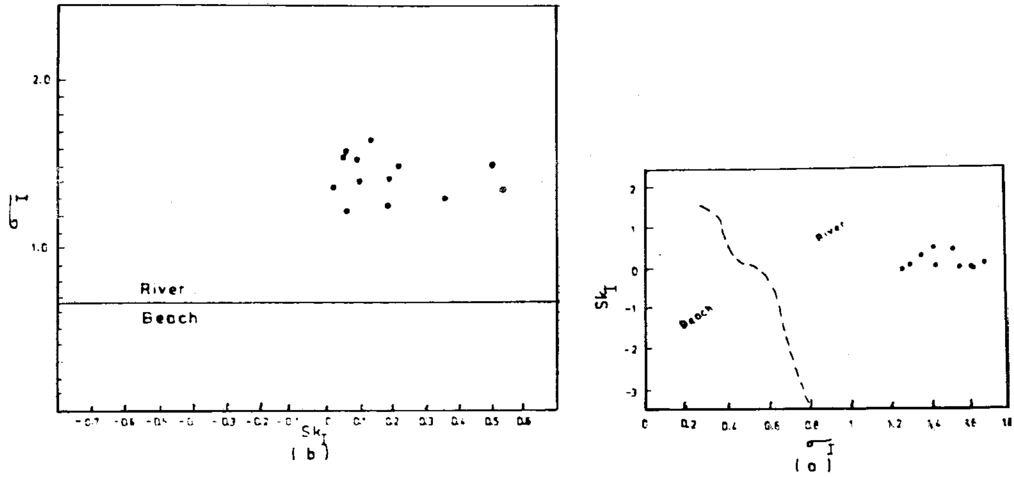

Figure 5. Plot of Skewness versus standard deviation for samples of the Bahariya Formation.

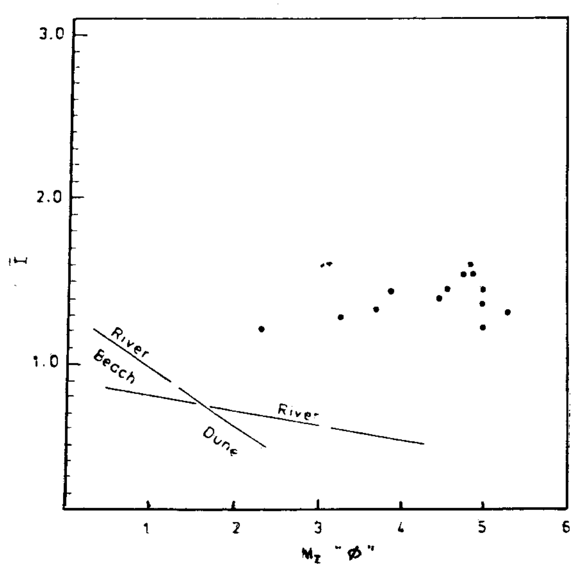

Figure 6. Plot of mean size versus standard deviation for samples of the Bahariya Formation.

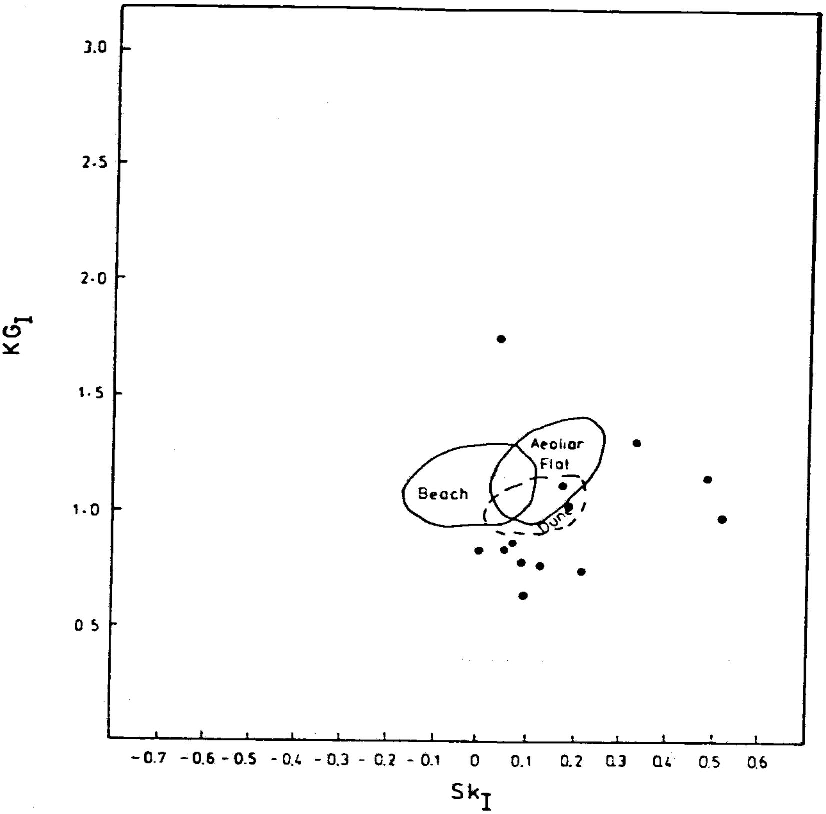

Figure 7. Plot of skewness versus kurtosis for samples of the Bahariya Formation.

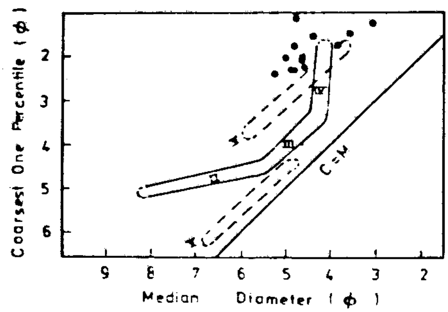

Figure 8. Plot of samples of the Bahariya Formation on C-M pattern.

Based on the results of microscopic studies and mechanical analysis, it can be concluded that the succession of the Bahariya Formation represents a cyclic sedimentation of sandstones and siltstones with a few intercalations of claystones. The environment of deposition was predominantly fluviatile with a considerable contribution from deltaic and, to a much lesser extent, terrestrial and marine environments. They were mostly tectonically stable and the conditions that prevailed were reducing, especially during deposition of the lower part of the succession

B - Heavy-Mineral Analysis

The heavy-mineral assemblage identified in the Bahariya Formation of the El-Dist section is composed of (in order of decreasing abundance): opaque minerals, zircon, rutile, staurolite, tourmaline, and kyanite. Garnet and biotite occur in minor amounts in the middle and top parts of the formation. The minerals of the assemblage range form ultrastable to semistable (Hubert, 1971). Most of the grains are subangular to subrounded; a few are well-rounded. Evidence of intrastratal solution is lacking which makes it possible to interpret the source lithology.

The gross mineralogy of the heavy-mineral assemblage remains unchanged throughout the succession. However, the variation in the percentage distribution of the major components and the appearance or disappearance of some of the minor species (e.g. garnet and biotite) made it possible to subdivide the succession into seven heavy-mineral zones (Figures 9 and 10). The study of these zones revealed that, for each zone, the light and heavy-mineral assemblage have similar degrees of mineralogical maturity.

The nature of the heavy-mineral assemblage together with the other petrographic characteristics of the Bahariya Formation strongly suggest that the principal source rock was an igneous rock with a minor contribution from metamorphic and sedimentary lithologies. The latter is indicated by the presence of well-rounded heavy-mineral grains and the rarity of the unstable and semistable mineral species (Hubert, 1971). Moreover, the provenance remained unchanged during the deposition of the formation as indicated by the unchanging nature of the heavy-mineral assemblage throughout the succession. The appearance of some minor species in parts of the succession can be explained by the progressive denudation and unroofing of new parts in the source rock having slightly different composition.

The areal distribution of the heavy-mineral zones recognized in the El-Dist section was investigated in an attempt to elucidate the paleoenvironmental conditions under which the Bahariya Formation was deposited. This was achieved by comparing these zones with the corresponding ones in the Naqb Ghorabi section which lies at about 30 km to the NE of the El-Dist section. Five heavy-mineral zones were delineated in the Bahariya Formation in Naqb Ghorabi section (Figure 11). The study of these zones reveled that the gross mineralogy of the heavy-mineral assemblage and the change in the relative abundance of the major mineral species with time are similar to those in the El-Dist section. The lower three zones in the Naqb Ghorabi section are almost identical with the corresponding ones in El-Dist section except for the absence or zircon and kyanite which are found in minor amounts in zone III in the El-Dist section. Slight differences between the top zones in both sections are represented by the absence of biotite in Naqb Ghorabi and the remarkable rounding of the more stable survivors.

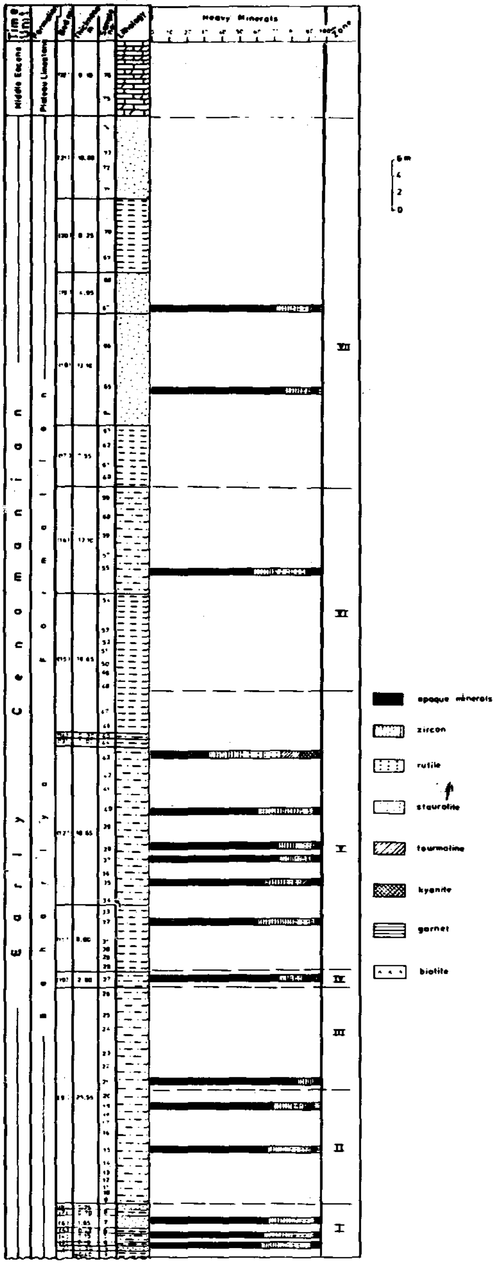

Figure 9. Distribution of heavy-minerals in Gebel El-Dist.

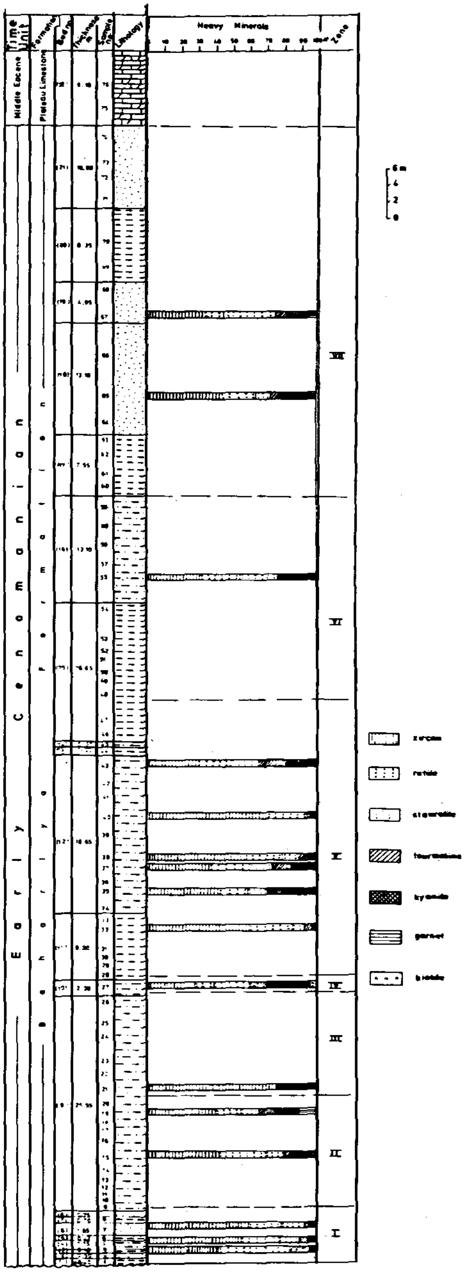

Figure 10. Distribution of transparent heavy-minerals in Gebel El-Dist.

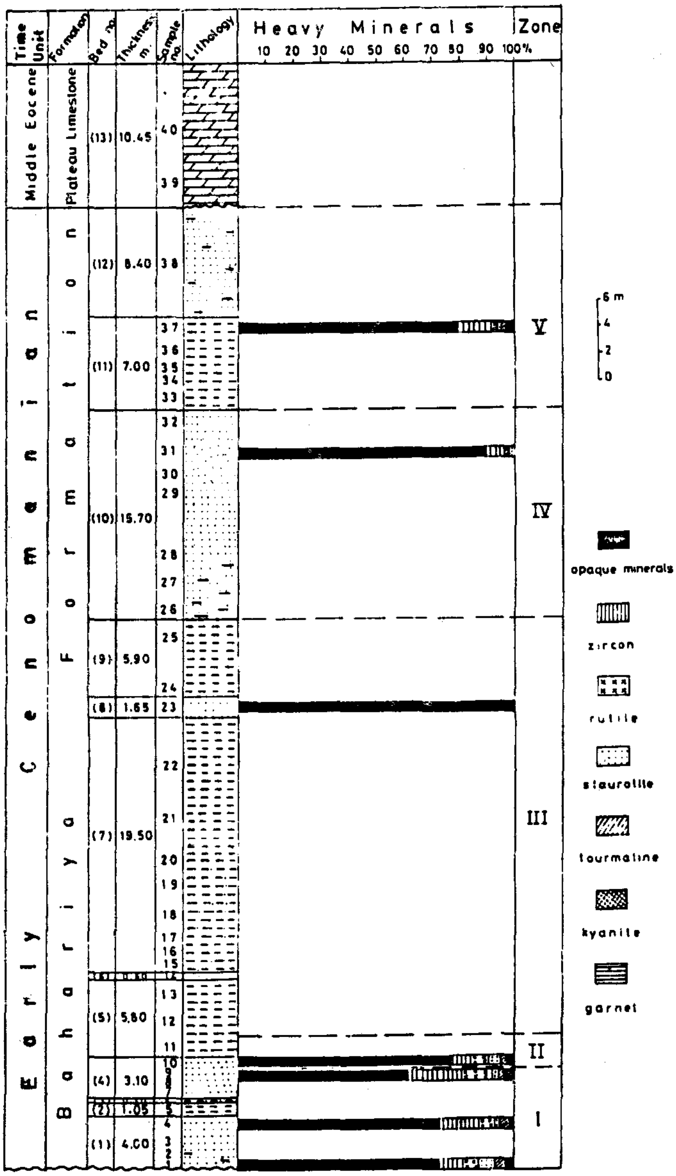

Figure 11. Distribution of heavy-minerals in the Naqb Ghorab; Section.

The foregoing discussion of the results obtained clearly reveals that heavy-mineral zonation established in the El-Dist section is of wide distribution. Sediments of the Bahariya Formation in both the El-Dist and Naqb Ghorabi sections were derived from the same source rock. Minor differences in the nature of the heavy-mineral assemblages can be attributed to differences in the paleogeography and paleocurrents due to differences in location of the two sections within the basin of deposition and with respect to the source rock. The absence of the semistable mineral biotite in the Naqb Ghobari section and the remarkable rounding of the more stable survivors may be attributed to transportation of the grains for longer distances.

ACKNOWLEDGEMENT

The authors wish to thank Dr. M. A. Boukhary and Dr. A. M. Strugo (Department of geology, Faculty of Science, Ain-Shams University, Cairo) for their help in collecting the samples used in this study.

REFERENCES

Ball, J., and **H.J.L. Beadnell, 1903.** Bahariya Oasis, its topography and geology. Egypt. Surv. Dept., Cairo.

Blatt, H., G. Middleton and **R. Murray, 1972.** Origin of sedimetary rocks. Englewood Cliffs, N.J., Prentice-Hall, 634 pp.

El-Akkad, S., and **B. Issawi, 1963.** Geology and iron ore deposits of the Bahariya Oasis. Geol. Surv. Egypt, Cairo, Paper no. 18, 300 pp.

Folk, R.L., and **W. C. Ward, 1957.** Brazos River bar, a study on the significance of grain-size parameters. J. Sed. Petrology, V. 27, P 3-27.

Friedman, G.M. 1961. Distinction between dune, beach and rive sands from their textural characteristics. J. Sed. Petrology, V. 28, p. 151-163.

Friedman, G.M. 1967. Dynamic processes and statistical parameters for size frequency distribution of beach and river sands. J. Sed. Petrology, V. 37, p. 327-354.

Galehouse, J.S. 1971 Sedimentation analysis. In: Procedures in sedimentary petrology. Graver, R.E., editor, Wiley Intersciences.

Hubert, J.F. 1971. Analysis of heavy-mineral assemblages. In: Procedures in sedimentary petrology. Carver R.E. edition, Wiley Intersciences.

Ingram, R.L. 1971. Sieve analysis. In: Procedures in sedimentary petrology. Carver, R.E., editor, Wiley Intersciences.

Labeling, C. 1919. Ergebnisse der Forschungseisen, E. Sromer: in der Baharija Oase und anderen Gegended Aegyptens, Abh. Bayer. Wiss. Math. Naturw., V. 29, p. 1-44.

Mason,, C.C., and R.L. Folk, 1958. Differentiation of beach, dune and aeolian flat environments by size analysis. Mustang Island, Texas. J. Sed. Petrology, V. 28. p. 211-226.

Moiola, R.J., and D. Weiser, 1968. Textural parameters: an evaluation. J. Sed. Petrology, V. 38, p. 45-53.

Passega, R. 1957. Texture as a characteristic of clastic deposition. Bull. Am. Assoc. Petrol. Geol., V. 41, p. 1952-1984.

Passega, R. 1964. Grain size representation by CM patterns as a geological tool. J. Sed. Petrology, V. 34, p. 830-847.

Picard, M.D. 1971. Classification of fine-grained sedimentary rocks. J. Sed. Petrology, V. 41, p. 179-195.

Sahu, B.K. 1946a. Depositional mechanisms from the size analysis of clastic sediments. J. Sed. Petrology, V. 34, p. 73-83.

Sahu, B.K. 1964b. Significance of the size distribution statistics in the interpretation of depositional environments. Res. Bull. Panjab Univ. (n.s.), V. 15, P.213-219.

Said, R. and B. Issawi, 1964. Geology of Northern Plateau, Bahariya Oasis, Egypt. Geol. Surv. Egypt, Cairo, Paper no. 29, 41 pp.

Soliman, S.M., M.I. Faris and O. El-Badry, 1970. Lithostratigraphy of the Cretaceous Formations in the Bahariya Oasis, Western Desert, Egypt (UAR). 7th Arab Petroleum Congr., Kuwait, Paper no. 59 (B-3), p. 1-30.

Stromer, E. 1914. Die Topographie und eologie der Strecke Gharaq-Baharija nebst Ausfuhrungen ueber dieegeologische Geschichte Aegyptens. Abh. bayer. Akad Wissench., Math-Naturw., Kl-11, p. 1-78.

Trefethen, J.M. 1950. Classification of sediments. Am. J. Sci., V. 248, p. 55-62.

دراسات على الخصائص الترسيبية لصخور تكوين البحرية بجبل الدست ـ الصحراء الغربية ـ مصـــر

محمد عز الدين حلمي ، محمد محمود أبو زيد ، نعيمـة ســعد

يشتمل هذا البحث على عدد من الدراسات والتحاليل التي أجريت على عينات من صخور تكوين البحرية بجبل الدست بالواحات البحرية بشمال الصحراء الغربية المصرية (قطاع مميز) ، وقد أوضحت هذه الدراسات أن هذا التكوين يشتمل أساساً على صخور رملية غرينية وصخور غرينية رملية رديئة الفرز نوعاً بالاضافة إلى طبقات رقيقة متبادلة من الصخور الرملية والصخور الغرينية وكذا صخور طينية غرينية .

وتتراوح الصخور الرملية بين الـ Quartz Arenites والـ Wackes ، ومن ناحية أخرى فان محتوى المعادن الثقيلة لصخور تكوين البحرية يتضمن المعادن التالية : معادن معتمة ، زركون ، روتيل ، ستوروريلايت ، تورمالين ، كيانيت ، جارنت ، بيوتيت ، وقد أمكن تحديد سبعة نطاقات في تكوين البحرية طبقاً لمحتواها من المعادن الثقيلة ، وبمقارنة هذه النطاقات مع مثيلاتها في تواجدات أخرى لنفس التكوين اتضح أنها تتميز بتوزيع جغرافي شاسع .

ودلت نتائج هذه الدرسات على أن صخور تكوين البحرية قد ترسبت أساساً في بيئات نهرية ودلتائية تميزت في الغالب بطاقة حركية ضعيفة ، ومن ناحية أخرى فان هذه الصخور أستمدت في الغالب من صخور نارية مع مساهمة بسيطة نسبياً من الصخور المتحولة والرسوبية ، ويعتقد أن هذه الصخور لم تتغير في طبيعتها خلال ترسيب تكوين البحرية .