Kerogen and Palynomorph Analyses of the Mid-Cretaceous Bahariya Formation and Abu Roash "G" Member, North Western Desert, Egypt

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ABSTRACT

Bahariya Formation and Abu Roash "G" Member sediments in the Razzak #7 well, North Western Desert, Egypt, contain abundant kerogen and fossil palynomorphs. In this study, we examined changes in these organic components and use them to interpret paleoenvironmental conditions and biostratigraphy. Terrestrial organic components dominate the Bahariya Formation and basal Abu Roash "G" Member, in particular degraded phytoclasts. Because the dinoflagellate cysts in these units are dominantly peridinioids such as *Subtilisphaera*, the sediments were likely deposited in nearshore, moderate to high-energy conditions. In contrast, amorphous organic matter and marine palynomorphs are more abundant in the upper part of the Abu Roash "G" Member, suggesting deeper depositional conditions. The overall palynomorph composition is typical of the mid-Cretaceous "African – South American" (ASA) Microfloral Province. There is a noticeable variation in the abundance of certain palynomorph taxa such as *Afropollis jardinus* and trilete spores, which are fewer toward the top of the Abu Roash "G" Member. This variation may be a reflection of prevailing changes in the wet/dry conditions and sea level rise.

INTRODUCTION

The search for exploitable hydrocarbon reserves in Egypt began in the early 1940s (Barakat et al., 1988) and led to the discovery of several oil and gas fields in the northern part of Western Desert. This region is approximately 250,000 km^2 (97,000 mi^2) and is characterized by simple surface geologic features contrary to its complicated subsurface image. The Razzak Oil Field was discovered in February 1972 and is among the many fields discovered in the early 1970s in the highly faulted Mesozoic sedimentary basins of the Western Desert. It is located 270 km (168 mi) northwest of Cairo and 60 km (37 mi) south of the Mediterranean Sea (Fig. 1). The subsurface Cretaceous sediments in the Razzak Basin are considered to be potential sources for oil and gas (Shahin et al., 1986). The siliciclastic strata of the lower Cenomanian Bahariya Formation are rich in palynomorphs and have been studied at several Western Desert localities (e.g., Urban et al., 1976; Saad, 1978; Sultan and Aly, 1986;

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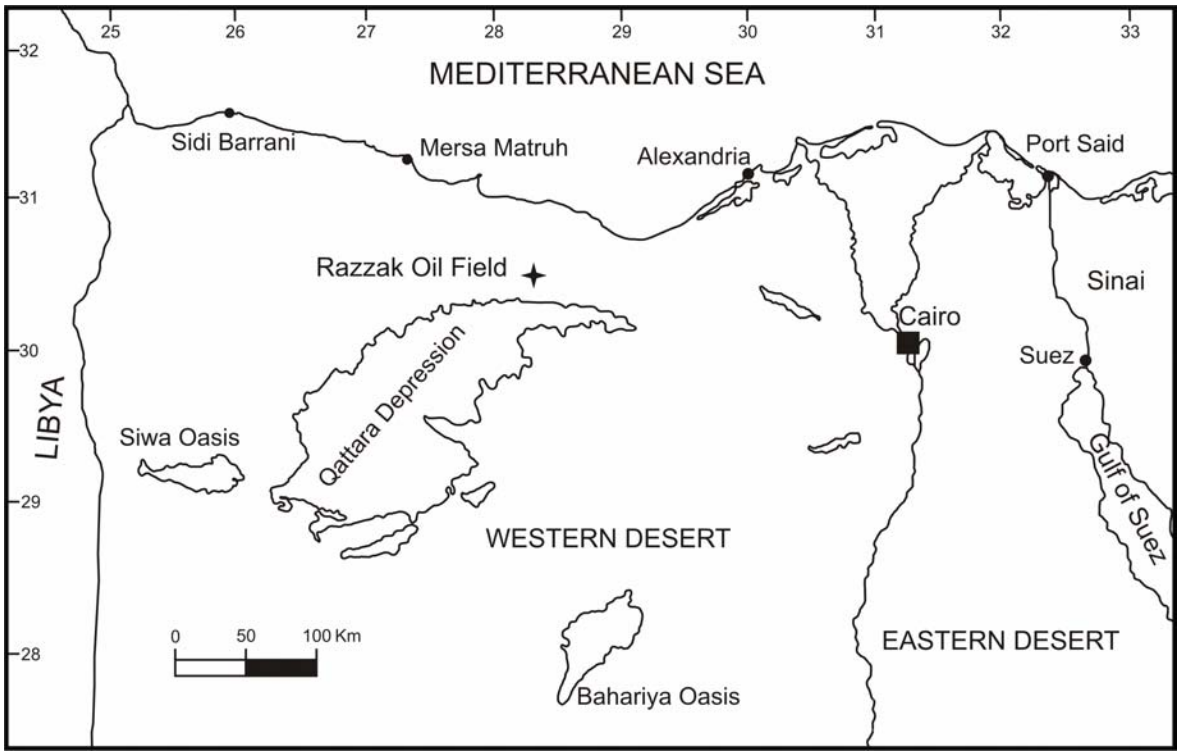

Figure 1. Location map of the Razzak Oil Field, Western Desert of Egypt.

Aboul Ela and Mahrous, 1992; El Beialy, 1993a, 1993b, 1995; Schrank and Ibrahim, 1995; Ibrahim, 1996, 2002). Fewer palynological studies have been undertaken for the Upper Cretaceous carbonate-rich Abu Roash and Khoman formations (El Beialy, 1994; Schrank and Ibrahim, 1995; Ibrahim et al., 2006), which have been dated using foraminifera (Abdel-Kireem and Ibrahim, 1987; Abdel-Kireem et al., 1993, 1995).

The Razzak #7 well encounters the Bahariya and Abu Roash formations (A-G members). This paper presents preliminary palynological data for the Bahariya Formation and basal Abu Roash "G" Member sediments only. The objectives of this study are to identify and document the microfloral range for pollen, spores and dinoflagellates, in addition to characterizing palynofacies from particulate organic matter (kerogen) components. Palynomorph information is used to refine biostratigraphy (palynostratigraphy) and is integrated with palynofacies to interpret paleoenvironmental conditions. A preliminary assessment of particulate organic matter types is also used to indicate the hydrocarbon potential of the sediments.

STRATIGRAPHIC SETTING

The sedimentary sequence in the North Western Desert ranges in age from Cambrian to Recent and is very thick, reaching more than 3 km (1.9 mi) (Abu El Naga, 1984; Barakat et al., 1987; Hantar, 1990). The Cenomanian to Santonian succession in the region is divided mainly into two lithostratigraphic units, the Bahariya Formation and the overlying Abu Roash Formation (Fig. 2).

Stromer (1914) and Said (1962) described the Bahariya Formation, which is variously called the Razzak Sand, Meleiha Shale, and Medeiwar Member of the Abu Subeiha Formation by prospecting hydrocarbon companies and researchers (El Gezeery and O'Connor, 1975). The formation is composed of variegated shales alternating with sandstones, siltstones and limestones. The shales are varicolored, thinly laminated, grayish green to green, calcareous and silty in part, and the siltstones and sandstones are grayish white to yellowish white, glauco-

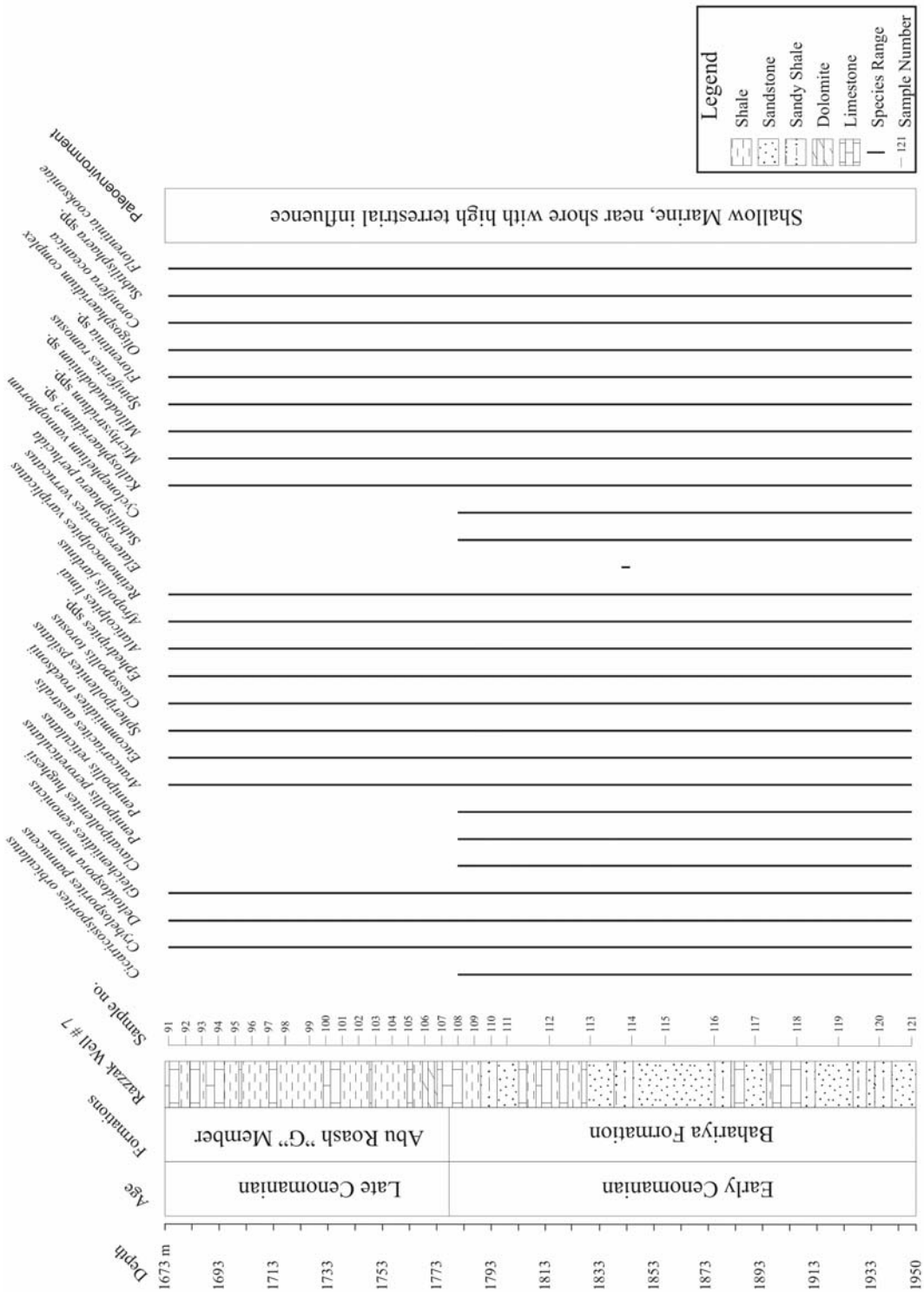

Figure 2. Lithologic log and vertical ranges of selected palynomorphs in the Razzak #7 well.

nitic and pyritic. These rocks represent a gradational fining upward sequence that is conformable with the overlying Abu Roash. Dated as early to middle Cenomanian (Hantar, 1990; Schrank and Ibrahim, 1995; Ibrahim, 2002), about 170 m (560 ft) of the Bahariya Formation is encountered in the Razzak #7 well (Fig. 2).

Norton (1967) and Robertson Research International et al. (1982) subdivided the Abu Roash Formation into seven informal members designated as A to G from top to bottom. Schlumberger (1995) later subdivided the formation into seven members equivalent to the A-G members as follows: A = Ghorab, B = Rammak, C = Abu Sennan, D = Meleiha, E = Miswag, F = Mansour, and G = Abyad. Members B, D, and F are relatively clean limestones and dolomites, while members A, C, E, and G are largely fine-grained clastics. Specifically, the Abu Roash "G" Member is composed of dark gray calcareous mudstone to pale gray calcareous shale. The Abu Roash Formation is conformable with the overlying Khoman Formation and has been dated as late Cenomanian to Santonian (Hantar, 1990; Schrank and Ibrahim, 1995; Abdel-Kireem et al., 1995). The Razzak #7 well drilled through approximately 555 m (1821 ft) of the Abu Roash Formation.

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METHODS

Thirty-one ditch cutting samples representing the Bahariya Formation and basal Abu Roash "G" Member were analyzed for this preliminary study using standard laboratory processing techniques (Traverse, 2007). Each sample was digested in hydrochloric and hydrofluoric acids to remove carbonates, silicates and fluorides from the sediments. This residue was then used to prepare a kerogen slide before further centrifuging in heavy liquid ($ZnBr_2$), screening through 10 µm sieves, and additional slide making. Slides were scanned using transmitted light microscopes for palynomorphs and particulate organic matter. However, palynomorphs have been studied in detail (minimum 200 grains per sieved slide) in ten representative samples so far. Selected palynomorph taxa, in particular those with biostratigraphic and paleoenvironmental value, are illustrated in Figures 3 and 4. For palynofacies analysis, 200 particulate organic matter particles (each with a minimum size of 5 µm) were point counted per kerogen slide for a subset of 13 samples; however, we have scanned all 31 kerogen samples as well as several others in the upper part of the Abu Roash "G" Member. These particulate organic matter components are shown in Figure 4, and percentage data are illustrated in Figure 5. Nikon polarizing microscopes and Nikon Q-Imaging MicroPublisher 3.3 RTV digital camera were used in this study. All slides are currently in housed in the palynological collection at Missouri University of Science and Technology.

PALYNOSTRATIGRAPHY

The Bahariya and basal Abu Roash "G" units in Razzak #7 well yield a rich, diverse and well-preserved palynomorph assemblage comprising terrestrially derived sporomorphs (spores, gymnosperm and angiosperm pollen), freshwater algae, and marine palynomorphs (dinoflagellates, acritarchs, and foraminiferal test linings). Sporomorphs dominate the overall palynomorph assemblage, accounting for approximately 60-65% of total counts. The vertical ranges within the studied section of a select group of biostratigraphically and paleoenviron-

(FACING PAGE) Figure 3. All specimens were photographed under 100X magnification. All names are followed by slide number (SN), England Finder reference (EF), and scale bar length. A, *Cicatricosisporites* sp., SN 121/1, EF S43/2, 22.5 µm. B, *Triplanosporites* sp., SN 121/1, EF U44/3, 24 µm. C, *Deltoidospora mesozoica* (Thiergart) Schuurman 1977, SN 115/1, EF G45/4, 22.5 µm. D, *Crybelosporites pannuceus* (Brenner) Srivastava 1977, SN 115/1, EF J47, 16.5 µm. E-F, *Stereisporites antiquasporites* (Wilson and Webster) Dettmann 1963, SN 108/1, EF U43/1, 16 µm. G, *Cicatricosisporites orbiculatus* Singh 1964, SN 115/1, EF N46/3, 30 µm. H, *Classopollis torosus* (Reissinger) Balme 1957, SN 121/1, EF R43, 30 µm. I, *Circulina parva* Brenner 1963, SN 115/1, EF J46, 30 µm. J, *Spheripollenites psilatus* Couper 1958, SN 108/1, EF P47/1, 15 µm. K, *Ephedripites* sp., SN 121/1, EF H39, 22.5 µm. L, *Alaticolpites limai* Regali et al. 1975, SN 121/1, EF P43/2, 30 µm. M, *Elaterosporites verrucatus* (Jardiné and Magloire) Jardiné 1967, SN 115/1, EF M46, ~17 µm. N, *Afropollis jardinus* (Brenner) Doyle, Jardiné, and Doerenkamp 1982, SN 115/1, EF L46/3, 30 µm. O, *Pennipollis peroreticulatus* (Brenner) Friis et al. 2000, SN 121/1, EF K40, 24 µm. P, *Tricolpites* sp., SN 115/1, EF N46/4, 26 µm.

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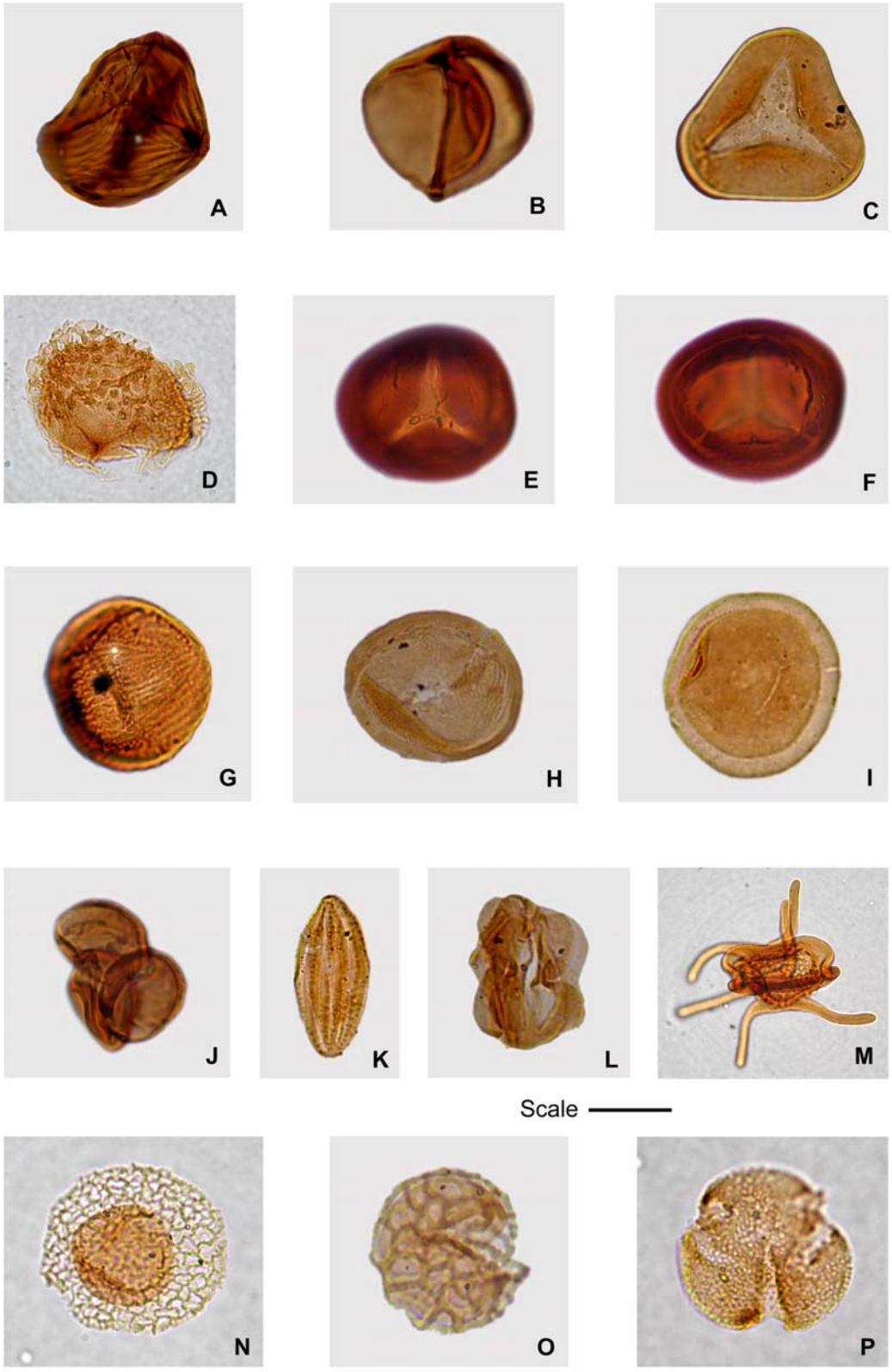

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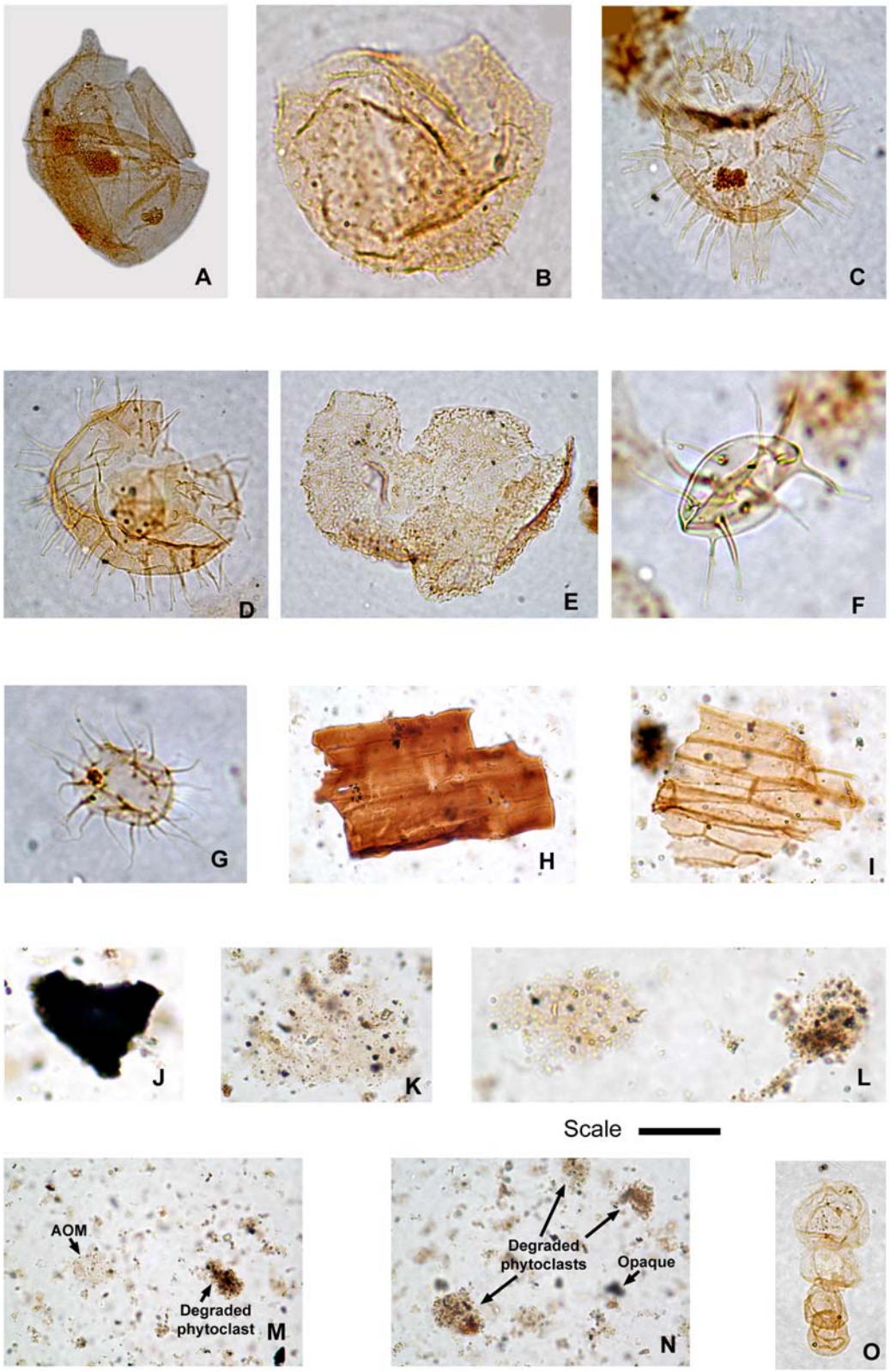

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(FACING PAGE) Figure 4. All specimens were photographed under 100X magnification. All names are followed by slide number (SN), England Finder reference (EF), and scale bar length. A, *Milloudodinium* sp., SN 108/1, EF H43/1, 15 µm. B, *Kallosphaeridium*? sp., SN 121/1, EF H39/2, 15 µm. C, *Coronifera oceanica*? Cookson and Eisenack emend. May 1980 , SN 108/1, EF H43, 19.5 µm. D, *Florentinia* sp., SN 108/1, EF O44, ~21 µm. E, *Cyclonephelium vannophorum* Davey 1969, SN 109/1, EF J48/3, 9 µm. F-G, *Micrhystridium* spp., SN 108/1, ~24.5 µm. H-I, Structured phytoclasts; H, SN 109/2kr, 7.5 µm; I, SN 109/2kr, 12 µm; and J, Opaque (black) debris, SN 109/2kr, 15 µm. K, Amorphous organic matter (AOM), SN 109/2kr, 10.5 µm. L, AOM (left) and degraded and comminuted phytoclasts (right), SN 109/2kr, 15 µm. M-N, General views showing different types of particulate organic matter, SN 109/2kr, 7.5 µm. O, Foraminiferal test lining (uniserial form), SN 115/1, EF M46/3, 9 µm.

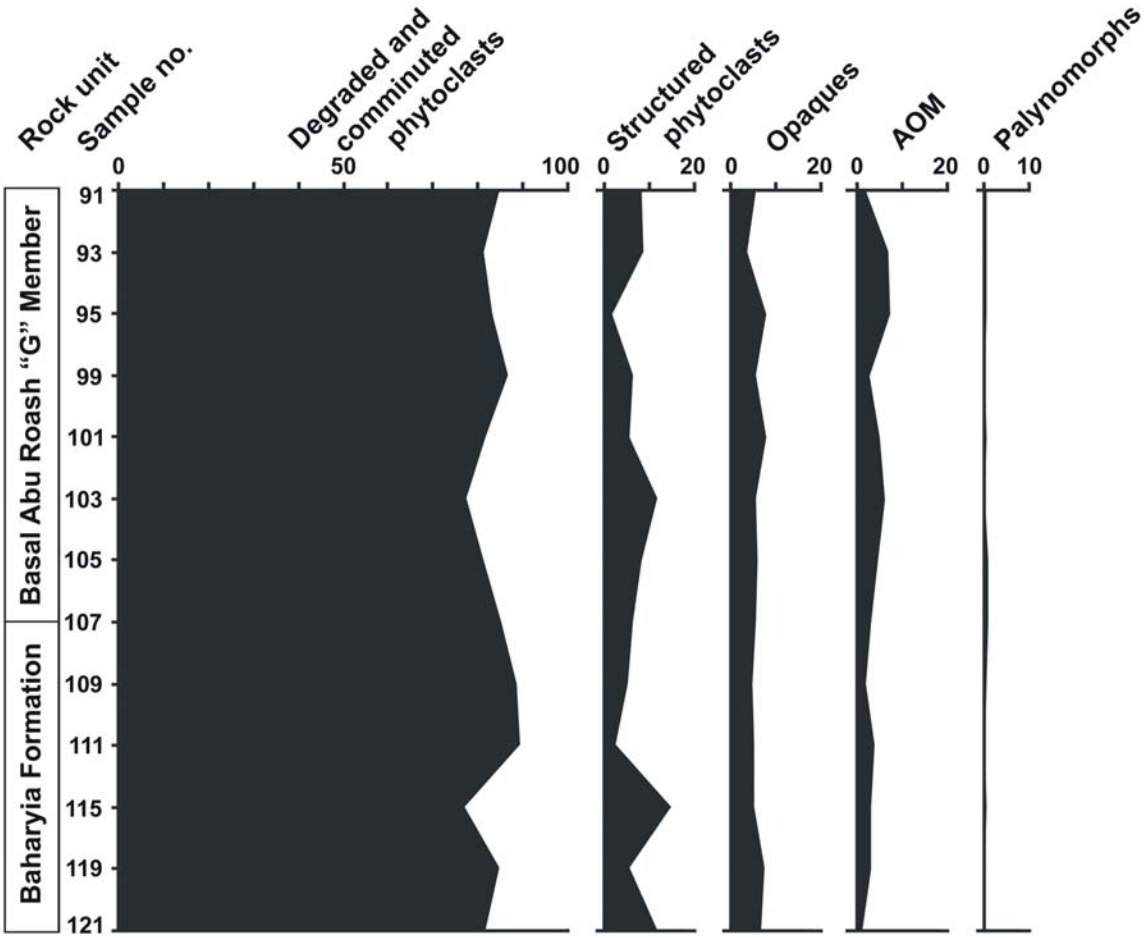

Figure 5. Percentage distribution of particulate organic matter in the sediments.

mentally significant taxa are shown in Figure 2; Figures 3 and 4 illustrate photomicrographs of some of these taxa. Most of the recorded palynomorphs are long ranging and were previously recorded from Jurassic and Cretaceous strata in Egypt and elsewhere (Palynodata, 2005). However, the co-occurrence and dominance of the well-known angiosperm pollen *Afropollis jardinus* with other sporomorph and dinoflagellate taxa, such as *Alaticolpites limai*, *Araucariacites australis*, *Cicatricosisporites orbiculatus*, *Classopollis torosus*, *Crybelosporites pannuceus*, *Deltoidospora* spp., *Elaterosporites verrucatus*, *Ephedripites* spp., *Gleichiniidites senonicus*, *Kallos-*

phaeridium?, and *Spheripollenites psilatus*, confirm the existence of the mid-Cretaceous "African – South American" (ASA) Microfloral Province proposed by Herngreen (1974). Herngreen et al. (1996) renamed this province as Albian-Cenomanian Elaterates Province.

Recovered dinoflagellates in the Bahariya Formation and basal Abu Roash "G" Member include *Coronifera oceanica*, *Cyclonephelium vannophorum*, *Florentinia cooksoniae*, *Palaeoperidinium cretaceum*, and *Subtilisphaera perlucida*, and these also confirm this age range. However, the presence of the spore species *Cicatricosisporites orbiculatus* and the dinoflagellate *Cyclonephelium vannophorum* indicates an age not younger than middle Cenomanian for the Bahariya Formation (Palynodata, 2005). No palynostratigraphic zones are proposed in this preliminary study.

PALYNOFACIES AND PALEOENVIRONMENTAL RECONSTRUCTION

Palynofacies analysis identified types of kerogen: palynomorphs, structured phytoclasts, degraded and comminuted phytoclasts, amorphous organic matter (AOM), and opaques (black debris). Unstructured and degraded phytoclasts account for 75-90% of the kerogen components in the sediments, followed by structured phytoclasts (2-12%), opaques (3-8%), AOM (1-7%), and palynomorphs (1% or less) (Fig. 5). We note here that the overwhelming amounts of degraded and comminuted phytoclasts cover up palynomorphs and other components on the slides. The presence of a diverse marine dinoflagellate assemblage in comparison to terrestrially derived sporomorphs in the sieved slides indicates a shallow marine depositional paleoenvironment in general for the studied sedimentary sequence. The majority of the dinoflagellates (e.g., *Coronifera* and *Kallosphaeridium*?) have short and thin processes, suggesting a near shore, moderate to high-energy paleoenvironment. This environment experienced a high input of phytoclasts. These results show that there is no discernible change in depositional environment for the Bahariya and basal Abu Roash "G" Member, which is in contrast to the lagoonal environment inferred for the latter unit by Hantar (1990). Differences in interpretation may be due to prevailing local conditions within the juxtaposed basins in the Western Desert.

The high abundance of *Afropollis* indicates an arid to semi arid warm climate (Herngreen et al., 1996; Ibrahim, 2002; Mahmoud and Moawad, 2002). However, the occurrence of fern spores, mainly produced by hygrophilous plants, associated with freshwater algae suggests the possibility of local or seasonal humid conditions (Schrank and Mahmoud, 2000). A quick slide scan of samples from the upper part of the Abu Roash "G" Member shows an increase in AOM and marine palynomorphs in comparison with samples from the lower Abu Roash "G" and Bahariya. This suggests a deepening in the marine environment upsection.

HYDROCARBON POTENTIAL

Oil was discovered in the Razzak Field in seven separate reservoirs (Jurassic – upper Cenomanian) in the structure on the northeast plunging anticlinal nose of one of a series of structural highs forming the Qattara Ridge (Ezzat and Dia El Din, 1974; El Ayouty, 1990). This structure is dissected by a number of faults, both parallel to the structure and perpendicular to it, mostly without large displacement. Oil was found in the Bahariya Formation sands; a less conspicuous pay is the Abu Roash "G" dolomite unit. Our palynofacies analysis shows that type III kerogen is overwhelmingly dominant in these units, confirming results by Ibrahim (2002) in the Abu Gharadig Basin. Type III kerogen is phytoclast-rich and is considered gas-prone (Tyson, 1995). Pending total organic carbon (TOC%) analysis of the sediments will likely confirm these findings. Qualitative analysis of palynomorph colors indicates that these sediments are mature. A more detailed analysis using the Pearson (1990) color scale will be undertaken later.

CONCLUDING REMARKS

This preliminary study of the Bahariya Formation and basal Abu Roash "G" Member in the Razzak #7 well has documented the presence of a rich, diverse and well-preserved palynomorph assemblage characteristic of the Albian-Cenomanian Elaterates province of Herngreen et al. (1996). The depositional environment for both of the

studied units was near shore, moderate to high energy with high terrestrial input. Palynofacies analysis indicates the dominance of gas-prone type III kerogen. Ongoing study of the Abu Roash "A-F" and upper "G" members will provide more robust data to enhance the interpretations made in this preliminary study.

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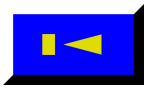


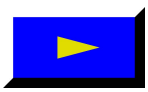

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