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SPORE COLOUR INDEX AND ORGANIC THERMAL MATURATION STUDIES ON THE PLIOCENE SEDIMENTS OF THE EL QARA-2 BOREHOLE, NILE DELTA AREA, EGYPT

By

MOHAMED I.A. IBRAHIM
Department of Geology, Faculty of Science, University of Qatar, Doha, P.O. Box 2713, Qatar

دراسة معامل تغير لون الأبواغ والنضوج العضوي الحراري لرسوبيات البليوسين في بئر القرعه -٢ ، دلتا النيل - مصر

محمد إسماعيل إبراهيم

يختص هذا البحث بدراسة تغير لون الأبواغ ونضوجها الحراري والسحنة البالينولوجية لبعض العينات الاسطوانية الممثلة لمتكوني أبو ماضي وكفر الشيخ (البليوسين) في بئر القرعه - ٢ والذي يقع في شمال وسط دلتا النيل - مصر .

وقد تم استخدام تغير لون الأبواغ والسحنة البالينولوجية في استنتاج معامل التبدل الحراري ومن ثم النضوج العضوي الحراري وهذا بدوره ادي إلى تقسيم التتابع الطباقي إلى ثلاث سحنات عضوية حسب ارتباطها بتكوين الهيدروكربون والغاز الطبيعي كالتالي :

أ - السحنة العضوية غير الناضجة : تميز هذه السحنه الجزء العلوي من متكون كفر الشيخ وتصل إلى عمق ٢٠٠٠ متر ولون الأبواغ فيها أصفر فاتح إلى اصفر كهرماني، ورسوبيات هذه السحنة تفتقر للمواد الهيدروكربونية ودرجة التدرج الحراري تكون أقل من ٦٥° مئوية .

ب - السحنة العضوية الناضجة : تمثل هذه السحنة الجزء السفلي من متكون كفر الشيخ وتتراوح في عمقها من ٢٠٠٠ حتى ٣١٥٥ متر وتتميز بلون الأبواغ البني الفاتح إلى البني القهوائي . ورسوبيات هذه السحنة غنية بالمواد الهيدروكربونية والكروجين من النوع الثالث والذي قد يؤدي لتكوين قطرات الغاز الطبيعي خلال التدرج الحراري بين ٦٥° - ١٧٠° مئوية .

ج - السحنة العضوية المتحولة : وتمثل هذه السحنة متكون أبو ماضي وتتراوح في عمقها من ٣١٥٥ حتى ٣٥٠٠ متراً وهذه السحنة تتميز بلون بني داكن للأبواغ وهذا يعني أن معدل التدرج الحراري أعلى من ١٧٥° مئوية ، مما يؤدي إلى تحول هذه السحنة العضوية والهيدروكربونات بها إلى مواد كربونية .

Key Words: Nile Delta, Pliocene, Palynology, Spore Colour, Thermal Maturation, Source Rock.

ABSTRACT

Eight conventional core samples from the El Qara-2 well, situated in north central Nile Delta area, Egypt, have been palynologicaly investigated for determining the thermal maturity of the Pliocene Abu Madi and Kafr El Sheihk formations, based on the change in colour of pteridophytic spores.

A monotonous assemblage of miospores including *Baculatisporites scabridus, Ricciaesporites* sp., *Foveoisporites* sp., *Laevigatosporites major, Polypodiaceoisporites retirugatus, Leiotriletes cf. paramaximus, Polypodiidites usmensis,* and *Rugulatisporites* cf. *trophus* which suggests a ?Pliocene age.

Three organic facies could be recognized: a) Immature organic facies penetrate strata down to 2000 m and are characterized by the presence of pale yellow spores, b) Mature organic facies range in depth from 2000-3155 m within the Kafr El Sheihk Formation. These facies contain light brown spores, which could be considered as good source rocks for wet gas generation. c) Metamorphosed organic facies lie between 3155-3500 m within the Abu Madi Formation with spores altered to dark or opaque brown colour. This signifies a high-carbon content which produce mainly dry gas.

INTRODUCTION

All the hydrocarbon-bearing reservoirs so far found in the Nile Delta basin consist of sandstone bodies belonging mainly to the Pliocene and Miocene [1]. Studies concerning source rock potential in the Nile Delta are likewise limited. Deibis [2] suggested that the Pliocene Kafr El Sheikh Formation is the source of the gas in both the Abu Madi and Abu Qir gas fields. Maturation and source rock evaluation in northwestern and central parts of the Nile Delta area were studied by Abdel Fattah [3], Abu El-Ella [4] and Abdel Fattah et al. [5].

Few and limited palynological studies have been carried out on the Neogene sequence of the Nile Delta area. The first attempt has been done by Poumot & Bouroullec [6] on the Miocene-Pliocene sediments of nine offshore wells, north ot the Nile Delta, followed by the work of Saad et al. [7] on the Plio- Pleistocene sediments of the Abu Qir-2X well, and recently El Beialy [8, 9, 10 & 11] investigated dinocysts, miospores and other palynomorphs from different sites in the same area.

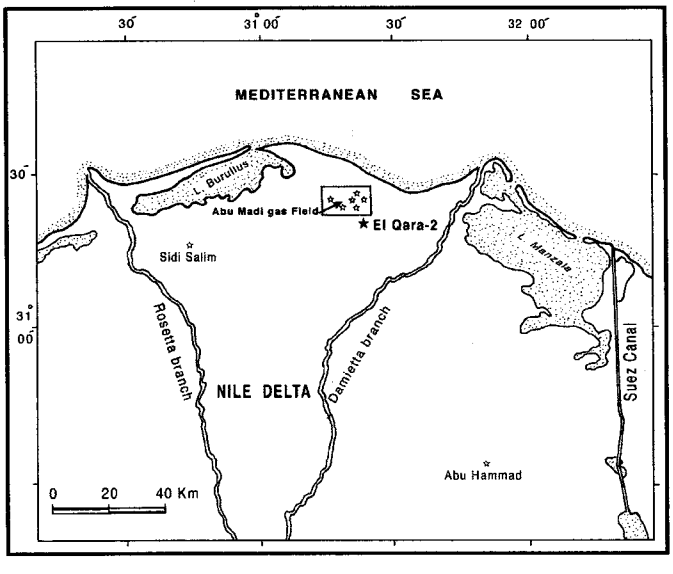


Figure 1: Sketch map showing the location of the El Qara-2 borehole.

The present study is based on the investigation of eight core samples collected from the Pliocene rock sequence penetrated by the El Qara-2 well, northern central Nile Delta (Figure 1). The location of the studied samples is shown in Figure 2.

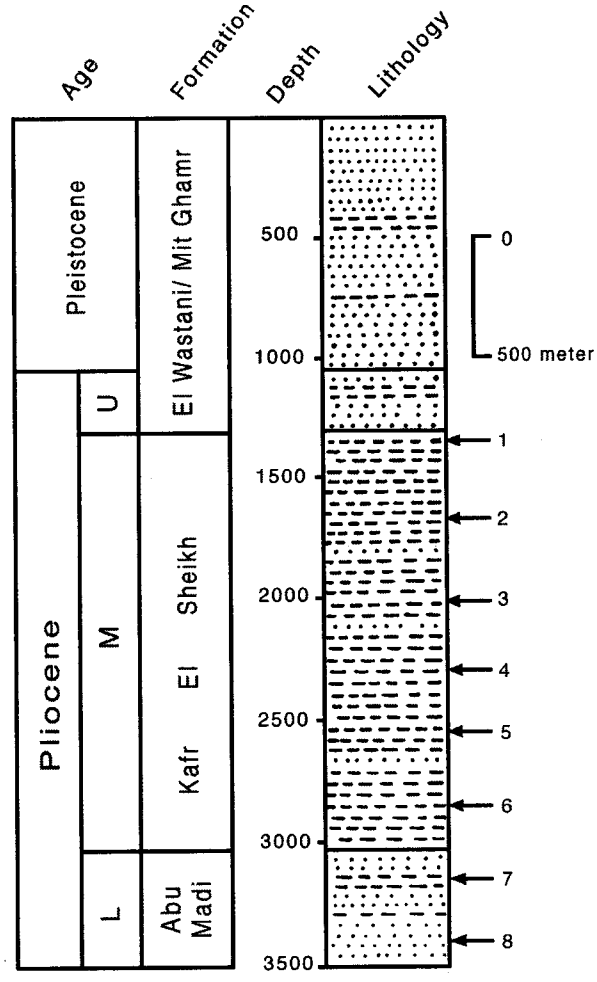


Figure 2: Lithostratigraphic columnar section of the El Qara-2 borehole. Ages and formations names are given by IEOC and Abdel Fattah et al. (1991). The location of samples is indicated by arrows.

STRATIGRAPHIC SETTING

Information on the stratigraphy of the Nile Delta area have been gathered by many workers such as Said [12], Rizzini et al. [13] and Harms & Wray [14]. The Neogene-Quaternary stratigraphy is relatively uniform over the whole Delta as detected from deep wells, and is formed by three sedimentary cycles. The most ancient one, comprises at least the Middle and Upper Miocene. It begins with a clayey sedimentation of a fairly deep sea or outer shelf (Sidi Salim Formation) and ends in the Messinian with the deposition of a fluvial-deltaic series (Qawasim Formation) and evaporites (anhydrites of the Rosetta Formation).

The second is the Pliocene-Quaternary cycle, which begins with the Lower Pliocene sandy Abu Madi Formation, followed upward by the clayey Kafr El Sheikh Formation, which shows open sea character [13]. This cycle ends with the deposition of the coastal and fluvial-deltaic sediments of the El Wastani and Mit Ghamr formations.

The final Holocene cycle is represented by a few metres of coastal and lagoonal sediments.

The Abu Madi Formation within the El Qara-2 well, comprises cores 7 and 8. These are composed of thick layers of sand, interbedded with thin shale strata, is believed to be of Lower Pliocene age as assummed by Rizzini et al. [13] based on the presence of *Sphaeroidinellopsis* sp. in the Qawasim-1 well. The Abu Madi Formation is the gas-producing horizon of the Nile Delta gas fields [1] and [2].

The Kafr El Sheikh Formation penetrated within the El Qara-2 well, is represented by six cores. No fauna were investigated in these samples due to insuffecient weight of samples. Therefore, the age of the Kafr El Sheikh Formation is believed to be of Lower to Middle Pliocene age based on the presence of *Globorotalia margaritae, G. puncticulata, G. aemiliana & G. crassaformis* as recorded from the Qawasim-1 well [13].

PALYNOLOGICAL ANALYSIS

The studied core samples were investigated for the pteridophytic spores and the associated sedimentary organic matter. The hydrochluoric and hydrofloric acids were used respectively to eliminate the calcareous and siliceous components of the rock samples. No heat effect nor treatment with any oxidizing agent during laboratory treatment were applied. The residues were concentrated for their palynomorph using zinc bromide solution for separation (sp. gr. 2.0). These palynomorphs and the kerogen are dispersed in cellosize and mounted in Canada Balsam.

Microscopic analysis indicates the presence of well preserved palynomorphs including spores, pollen and few badly preserved dinocysts. The pteridophytic spores are the only palynomorphs selected in this study (plate 1) for reconnaissance of the geothermal history of the Nile Delta sediments, although Bujak et al. [15] have pointed out the various categories of organic matter in sedimentary rocks do not all follow the same geothermal maturation course.

Important pteridophytic spores recorded in this study are: *Baculatisporites scabridus* Playford, *Camarozonosporites* sp. sensu Truswell *et al.* 1985, *Foveoisporites* sp. sensu Playford 1982, *Laevigatosporites major* Venkatachala & Bharadwaj, *Polypodiaceoisporites retirugatus* Muller, *Leiotriletes* cf. *paramaximus* Krutzsch, *Polypodiidites usmensis* (Van Der Hammen) Hekel, and *Rugulatisporites* cf. *trophus* Partridge.

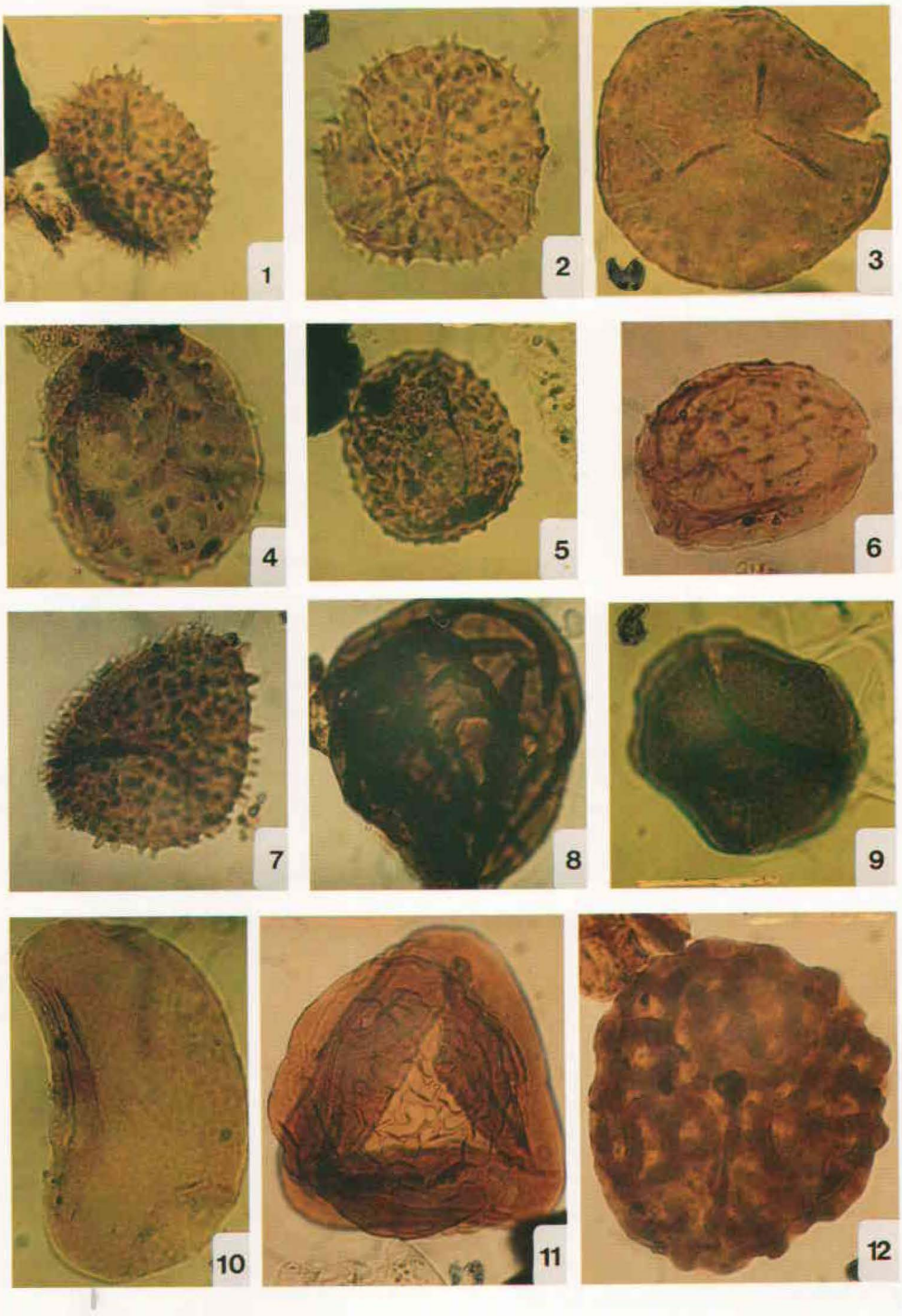
The above-mentioned spores were recorded from the Miocene deposits elsewhere and may extend upward to the Pliocene, especially the long ranging species *B. scabridus,* which is recorded in co-eval assemblages from South Australia [16] and Papua New Guinea [17]. *Polypodiaceoisporites retirugatus* is a Late Neogene spore from offshore SW Africa [18] and Pleistocene sediments worldwide. Therefore, a Pliocene age is most probable for this interval. El Beialy [10] and [11] gave a similar approach to the age of Abu Madi and Kafr El Sheikh formations from the Mit Ghamr-1 and Damanhour South-1 wells respectively, on the basis of dinocysts.

On the other hand, the total sedimentary organic matter encountered herein is represented by miospores, pollen, cuticles, vitrinite particles together with rare dinocysts. Such record are indicative of deltaic deposits as revealed from the models of Pocock et al. [19] and Tyson [20] and [21]. The Amorphous Organic Matter (AOM) are very small, thin rectangular or platy individual grains, usually light brown in transmitted light. A comparison with kerogen type D of Thompson & Dembeiki [22] may indicate the existence of possible hydrocarbons. The very low percentage of AOM and abundance of terrestrial exinitic and vitrinitic particles recorded herein could be correlated with kerogen type 3 of Tissot & Welte [23] which shows only gas, and Kerogen type III (gas prone) of Tyson [20] and [21].

ASSESSMENT OF THERMAL MATURATION

Staplin's hypothesis for the colour changes of palynomorphs [24] is considered herein to assess thermal maturity of the sedimentary organic matter. This hypothesis is based on the observed change in spore/pollen wall (exines) along the carbonization-coalification route. This can be observed by studying the colour in transmitted light. Fresh exines of modern plants are pale yellowish to almost colourless [25]. If exines are heated, e.g., by deep burial or proximity of the enclosing sedimets to a lava flow, the colour intensifies from yellow to orange to brown, dark brwon, and ultimately black [26, page 431].

The temperature alterations were tabulated by Staplin [27] with revision and correction by himself [28] into Thermal Alteration Indices (TAI) for colour of exinite, measured into five grades. These grades have a worldwide usage [29], [30], [31] and [32].



All magnifications x1000.

1, 2, 4, 7. *Baculatisporites scabridus Playford,* 1982.
1. Pale yellow.
2. Amber yellow.
4. Deep brown.
7. Very dark brown.

3. *Leiotriletes* cf. *paramaximus* Krutzsch, 1959. Light brown.
5. *Polypodiidites usmensis* (Van Der Hammen) Hekel, 1972. Dark brown
6. *Ricciaesporites* sp. Dark brown.
8. *Taxodiaceaepollenites* sp. Dark brown.
9. *Foveoisporites* sp. sensu Playford,1982. Dark brown.
10. Cf. *Laevigatosprites major* Venkatachala & Bharadwaj, 1964.
11. *Polypodiaceoisporites retirugatus* Muller,1968.
12. *Rugulatisporites* cf. *trophus* Partridge in Stover & Partridge, 1973.

The course of thermal maturity is acheived herein by selecting the ornamented spores *B. scabridus* (and related forms). It is clear that the colour is directly related to the numerical thermal alteration index (TAI) [28]. TAI is therefore, a scale based on both colour of spores/ pollen, which is herein applied, and also on vitrinite reflectance (R_o) [33]. There is no correlation with the latter.

Results of microscopical analysis for thermal alteration indices, using spore colouration, from the studied section are presented in Table (1) and the colour changes are shown in plate 1. According to these data, the suggested geothermal gradient (GG) [28] and the probable hydrocarbon facies have been detected and affixed in the same table.

Table 1

Assessment of Thermal Alteration Index (TAI) based on the colour of spores, geothermal gradient (GG) and thermal maturation level in the El Qara-2 borehole. TAI and GG values are based on Staplin's hypothesis (1969, 1977, 1982).

Age	Formation	Core No.	Depth (m)	Spore Colour	Figure in Plate (1)	TAI	Temperature °C	Thermal Maturation
Pliocene Middle	Kafr	1	1360	Pale yellow	1	1.5	40-45	Immature
		2	1690	Amber yellow	2	1.8		
	El	3	2025	Light brown	3	2.5	65	Mature
	Sheikh	4	2320	Deep brown	4	2.8		
		5	2550	Dark brown	5	3.0	~ 100	
		6	2863	Dark brown	6	3.0		
Early	Abu	7	3155	V. dark brown	7	3.5	~ 175	Metamorphosed
	Madi	8	3403	Opaque brown	8,9	3.8	~ 200	

An expected increase in maturation is recorded as older sediments are encountered as reported from the Abu Madi Formation of the El Qara-2 borehole. Accordingly, three categories of organic matter could be identified from top to bottom as follows:

1) Immature organic facies: These contain pale yellow pteridophytic spores which penetrate strata to depth 2000 m. Their presence indicates that the organic matter is immature, having no source potential for hydrocarbon.

2) Mature organic facies: Contain light brown spores, comprise deposits of the Kafr El Sheikh Formation from depth of about 2000 m down to depth of 3155 m. The organic matter is mature and may have source potential for wet gas (kerogen type 3 of Tissote & Welte [23]).

3) Metamorphosed organic facies: Spores are distinguished by their dark brown to opaque brown colour, encountered from the Abu Madi Formation between 3155 m down to depth of about 3500 m. As a result of heating, these deposits might be lost their ability to produce oil and might produce dry gas. Heating of the sediments of the Abu Madi Formation is suggested to be mainly the result of tectonic burial.

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