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Article

Palynofacies analysis and hydrocarbons assessments on some subsurface Middle Jurassic rocks of northern Western Desert, Egypt

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Abstract

The current study's palynofacies analysis and visual microscopic inspections of some subsurface Middle Jurassic rocks from Egypt's northern Western Desert revealed that not all the investigated rock units are suitable source rocks for hydrocarbons; some are gas-prone rocks, while others are oil-prone rocks. However, assessments of the hydrocarbon potentiality of the studied rock unit, which is represented by the Khatatba Formation in the Fadda-1 well, can be classified as overmature gas-prone source rocks, as well as reconstruct plant cover and infer palaeoclimate conditions. The high frequency of *Deltoidospora* and *Cicatricosisporites* spores suggests locally pteridophyte-dominated lowlands vegetation near/at the well site. Conifer flora is assumed to exist in somewhat dry hinterlands due to the presence of saccate (*Araucaria cites* and *Balmeiopsis*) pollen grains. In addition, due to the presence of drought resistant *Cassopolis* pollen grain, a regional warm and relatively dry palaeoclimate is thought to have prevailed, with a local humid condition developing around the well site.

Keywords
Palynofacies, Northwestern Desert, Egypt, Paleoclimate, Hydrocarbon potential

1. Introduction

Palynology has a wide range of applications in the earth and natural sciences. It may be used to calculate the thermal maturation of sedimentary organic matter and the hydrocarbon potential of source rocks. Most of the successful gas finds in the Western Desert have come from several stratigraphic strata in the Jurassic period. Several half-graben-like basins with intervening platforms with basin and range geometry were produced during an early rifting phase in the Jurassic and Early Cretaceous. In the northern basins of the Western Desert, thick wedges of the Jurassic section were deposited, including probable source rocks. The faults that form the rift's boundaries are aligned E-W, ENE-WSW, and WNW-ESE. Some basins were also confined locally by NNE-SSW-oriented faults (Said, 1990). Palynofacies analysis can also be employed in maturation and source rock studies. (Batten, 1981; Tyson, 1993; Tyson, 1995) Tyson (1993) introduced the word Kerogen to characterize the scattered particle organic matter of sedimentary rocks that is insoluble in hydrochloric (HCl) and hydrofluoric (HF) acids in a purely palynological sense. In this research, we may investigate the thermal maturation of the Fadda-1 well of potential source rocks using

spore/pollen coloration, i.e., thermal alteration index (TAI), and other measurements such as vitrinite reflectance (Ro), which is important in evaluating sediments and their potential as oil and/or gas source rocks.

2. Geological setting

The Western Desert's sedimentary column is thick, with successions ranging from the pre-Cambrian basement complex to the Holocene. The thickness of the sedimentary section is approximately 4267 m, with the sequence reaching its highest thickness in the Abu Gharadige Basin (8-9 km deep) and 3 to 6 km to the north. (Hantar, 1990; Said, 1990) classified the Western Desert's sedimentary sequence into three major cycles that indicate transgressive/regressive stages in its geological history. The lower clastic division of the Paleozoic-Jurassic and lower Cretaceous sequences represents the first cycle. The second sedimentary cycle is the middle calcareous division of the Cenomanian-Eocene carbonates, while the upper clastic division, which includes post-Eocene sediments, is the third. (Notron, 1967) made the first attempt to identify Jurassic sediments in the northern Western Desert. Gebel Maghara in Sinai has the thickest and most complete Jurassic exposure (2000 m thick), ranging in age from Bajocian to Kimmeridgian. (Said, 1990) The Khatatba Formation is the Jurassic rock unit examined in the current work. (Issawi et al., 1999) It is made up of alternating shale and sandstone strata with occasional limestone streaks that get thicker and more frequent near the formation's top. The formation conformably underlies the Masajid Formation (Said, 1990). The Khatatba Formation's clastics change upward to a more carbonate section of the Masajid Formation. A palynologically-based, Bajocian to Callovian age (Omran et al., 1990). In the Fadda-1 well, it attains a 439 m (1440 ft) thick at a depth from 4267 to 4706 m (14000-15440 ft). Hantar (1990) classified this formation as being formed in low-energy shallow marine environments based on its lithology, fossil content, and age.

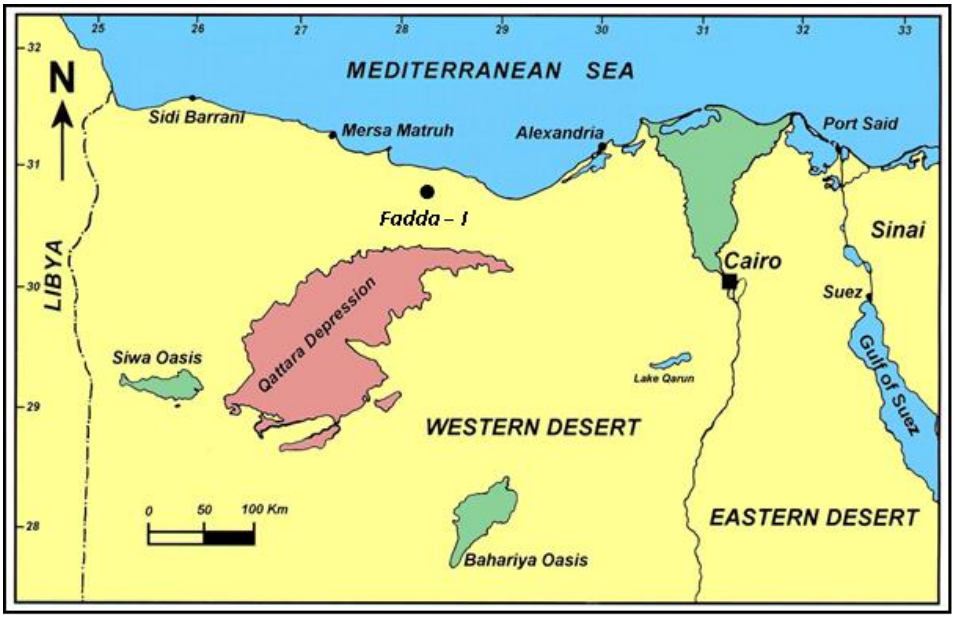

Figure 1. Sketch map of Egypt showing the location of the Fadda-I well. (After Abdel Kireem et al., 1993).

3. Material and methods

The current study is based on the collection of twenty ditch cutting samples from the middle Jurassic in the Fadda-1 well, Matruh Basin, northern Western Desert Egypt (Figure 1). The ditched samples were prepared using normal (HCl-HF treatment) palynological techniques, without the use of oxidation or ultrasonic treatments, nylon sieves were used to sieve the palynological residue with a mesh size of 10 µm. Some spores were chosen to remark on thermal maturity by comparing their colors with conventional charts. (e.g., Pearson, 1984); an approximate estimate of vitrinite reflectance might also be obtained using this type of chart. Three to five slides were scanned

for each sample to discover any unusual palynomorphs, which are significant in determining the age of the analyzed rock units. Identify the organic debris contents and their degree of preservation (i.e., palynofacies analysis) that may be employed in kerogen analyses, paleoenvironmental interpretations, and hydrocarbon assessments.

4. Results and discussions

The palynofacies analysis may be used in maturation and source rocks studies. (Batten, 1981; Tyson, 1993; Tyson, 1995) The name kerogen became popular, and different authors defined it differently. Authors referred to the organic components as "organic matter" (e.g., Lorente & Van Bergen, 1990), "palynodebris" (e.g., Van der Zwan, 1990; Boulter, 1994), or "kerogen" (e.g., Tyson, 1995), with the latter being the most often used term today. Tyson's (1995) approach for visual palynofacies analysis and kerogen type identification is employed in this work because it is simplistic, with microscopy being the sole instrument to be used with regular palynological slides with no further preparation. Furthermore, it is a method for investigating the qualitative properties of kerogen components. Pearson's (1984) color chart was utilized to calculate the numerical thermal alteration index (TAI), theoretical vitrinite reflectance, and other parameters (Ro %). The organic thermal maturity of the investigated periods in the wells was assessed using Batten's (1980) palynomorph scale. The main observable alteration in spore/pollen exines during the carbonization-coalification process is a change in a transmitted light color. Fresh exines range in color from light yellowish to virtually colorless. When heated (for example, by deep burial or proximity of adjacent sediments to a lava flow), the color of these exines changes from yellow to orange to brown, dark brown, and finally black. (Traverse, 1988). Measurements of pollen and spore color change (thermal alteration index) and vitrinite reflectance are used to assess regional thermal maturation.

4.1. The Fadda-1 borehole

In general, the examined succession in the Fadda-I well (14000-15440 ft 4267-4706 m) displays a notable increase in color intensity with increasing depth. Although the color rating may fluctuate within the same slide, the mean rank is used. Ternary Liptinite-Vitrinite-Inertinite (LVI) kerogen plots (Figure 2) and TAI values vary from 3+ to 4-, corresponding to 1.2-2.0 % vitrinite reflectance (Figure 3). The percentage frequency of each particulate organic matter element has changed based on the change in percentage frequency (i.e., palynomorphs, Phyto clasts, AOM).

The Khatatba Formation indicates one palynofacies type, that generates the kerogen type III and IV (gas prone material), which depends on AOM and Phyto clasts but in the case of the increase of opaques clearly in different levels through these facies which indicate kerogen type IV which depends on opaques inert material, it has overmature palynomorphs with dark brown color range. This is corresponding to 3+ to 4- TAI and theoretical estimate of vitrinite reflectance 1.2-2.0 %.

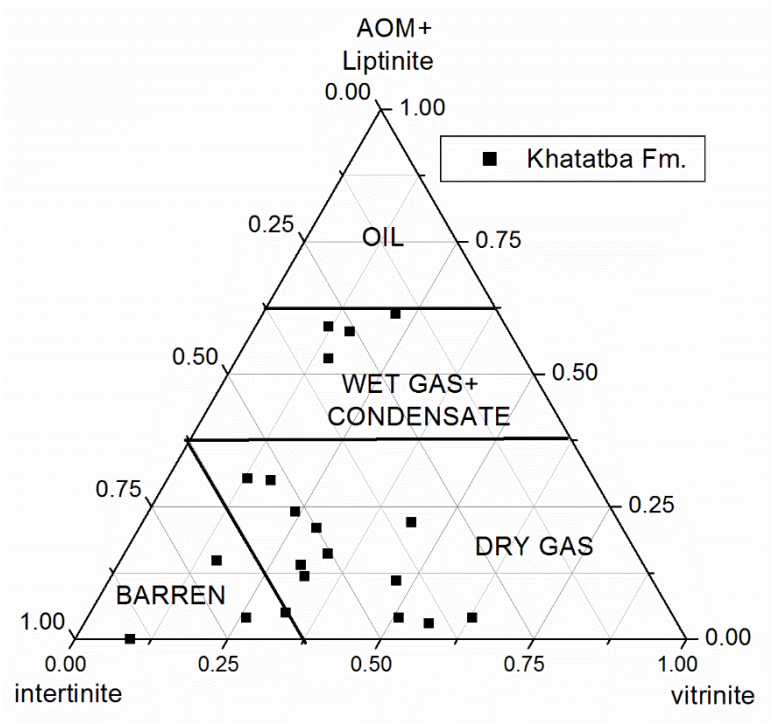

Figure 2. Ternary Liptinite -Vitrinite -Inertinite (LVI) kerogen plots (after Dow, 1982) of the Khatatba Formation in the Fadda-1 borehole.

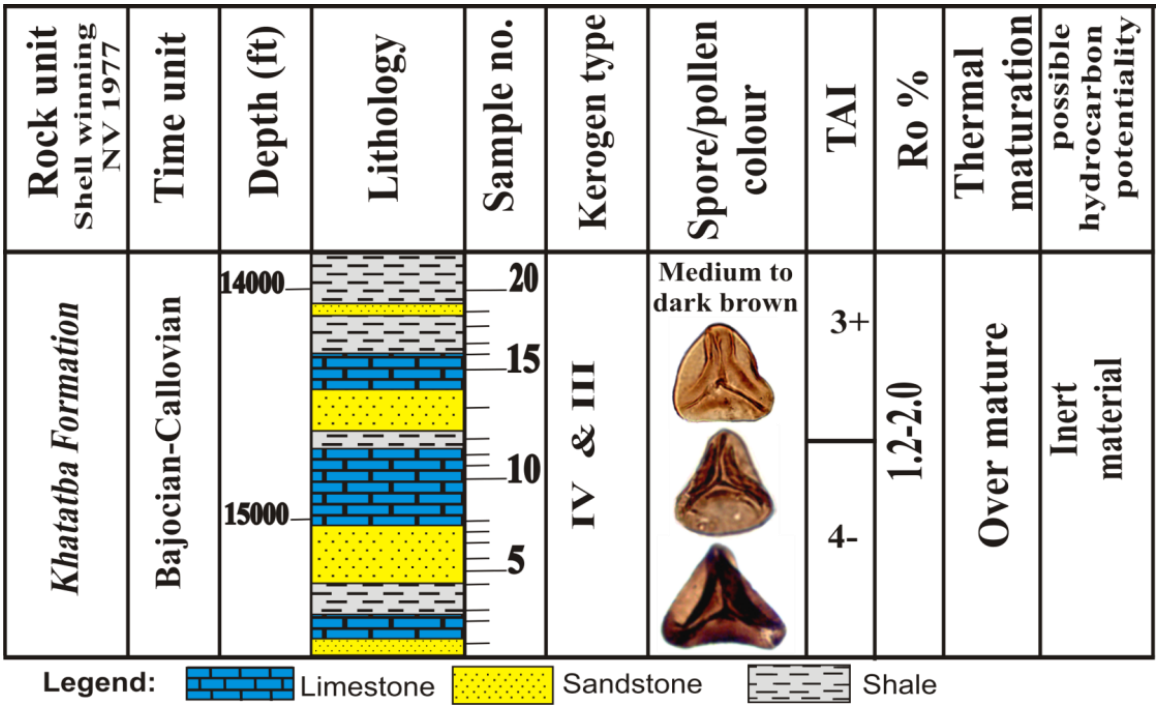

Figure 3. Kerogen type, spore/pollen color, TAI, Vitrinite reflectance (Ro %), Thermal maturation, and source rock potentiality of the Khatatba Formation in the Fadda-1 borehole

5. Palaeovegetational cover and palaeoclimate

The examination of terrestrial palynomorphs recovered from Fadda-1 well samples shows a subtropical to tropical plant cover close to the research region. Pteridophytes reflect the amount of fern spores (e.g., *Deltoidospora*) and Schizaeaceans (*Cicatricosisporites*) palynomorphs in most of the samples analyzed from the Khatatba Formation probably signifies on wet lowlands, local pteridophyte vegetation. (Playford, 1971; Schrank & Mahmoud, 1998)

Changes in sedimentation rates profoundly influence differences in the percentage frequency of terrestrial palynomorphs (i.e., transgression-regression), Because these fern spores display taxonomic stability throughout all analyzed sections, they are regarded as more essential than any other ecological parameter on land (Deaf, 2009). The prevalence of araucariacean pollen recommends the presence of conifer forests in relatively arid hinterlands. (Schrank & Mahmoud, 1998; Schrank 2001; Mahmoud & Moawad, 2002)

The presence of the drought resistant Cheriolepidiacean conifer pollen grain *Classopolis*, which grows in hot subtropical latitudes. (e.g., Doyle, 1999), indicates that the borehole is in a hot and typically dry environment (Doyle 1999; Watson, 1988). Based on lower *Classopollis* frequencies than found in the palaeosubtropics, Doyle et al. (1982), Schrank (1990), and Brenner (1996) postulated that the African palaeotropics considerably wetter paleoclimates (e.g., Egypt and Sudan). However, the existence of fern spores, which are predominantly generated by hygrophilous plants, shows that locally or seasonally humid conditions may exist (Schrank & Mahmoud, 1998), as a result, a regional warm and semi-arid palaeoclimate is predicted to prevail during sediment deposition, with a local humid condition developing next to or at the well site (Zobaa, et al., 2013).

6. Conclusions

The current study focuses on the palynological investigations of 20 ditch samples taken from the subsurface stratigraphic Middle Jurassic Fadda-1 well in Egypt's northern Western Desert. The organic thermal maturation and source rock potential are investigated by examining the exines color of thin-walled palynomorphs using Pearson's (1984) color chart to indicate the thermal alteration index (TAI) and vitrinite reflectance (Ro %) in terms of organic thermal maturity. The presence of considerable numbers of opaques and phytoclasts associated with extremely mature to overmature palynomorphs of medium to the dark brown color in the Fadda-1 well indicates that the Khatatba Formation is an overmature gas-prone source rock in the study area (Fadda-1 borehole). Hydrocarbon evaluation will need more research. Local pteridophyte vegetation near the borehole and conifers in comparatively dry hinterlands are expected to flourish in a warm and dry regional palaeoclimate.

Acknowledgments

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الملخص العربي

تحاليل بالينولوجية وهيدروكربونية على بعض صخور التحت سطحية للجوراسي الأوسط بشمال الصحراء الغربية- مصر

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اهتمت الدراسة الحالية بتقدير النضج الحرارى و استنتاج الصخور المصدرية لتوليد خام البترول و الغاز الطبيعى فى التتابع محل الدراسة وتعتمد هذه الدراسة على فحص الكيروجن ودراسة التغير فى لون أحافير الأبواغ السرخسية الملساء و يعتبر دراسة متكون الخطاطبة بمصر من الرسوبيات الفقيرة أو النادرة في محتواها الأحفوري وقد أوضحت الدراسة الحالية أن متكون الخطاطبة فى بئر فضة التابع لحوض مطروح والذى ينتمى الى العمر الباجوسى/ الكالوفي يحتوى على نوع من الصخور المصدرية كاملة النضج الحرارى وتعتبر هذه النتائج احتمالية لأن تقدير النضج الحرارى لا يعتمد فقط على الوصف البصر للون أحافير الأبواغ و لكن يعتمد أيضا على التحليل الكيميائى و عمل مقارنة بين الوصف البصرى و المعلومات الكيميائية. ولقد ساهمت النسب المئوية للأنواع المختلفة لبعض أنواع الأبواغ وحبوب معراة البذور وحبوب مغطاة البذور بالإضافة الى بعض السوطيات الدوارة وبعض أنواع طحالب المياه العذبة والتى لها مدلول بيئى جيد فى التعرف على البيئات الترسيبية والظروف المناخية التى سادت أثناء ترسيب هذه الصخور بالشرق والغرب. حيث لوحظ تسجيل نسب عالية من أبواغ الخنشاريات (fern spores) والتى تعكس تواجد غطاء من النباتات التريدية النامية فى أماكن رطبه، مما يؤكد سيادة المناخ الرطب أثناء ترسيب صخور هذه الفترة. بالإضافة لوجود الأر وكاريا arucariacean والتى تمثل تمثيلا جيدا مما يدل على انتشارها على هيئة غابات وذلك فى المناطق الجافة نسبيا والمحيطة بالأراضى الرطبة التى تنمو عليها السراخس ويدل ذلك ويؤكد على المناخ الرطب بالإضافة الى الغطاء النباتى الخنشارى والذي يؤكد أيضا المناخ الرطب.