

## ORGANIC PETROLOGY OF OIL SHALES IN QUSEIR-SAFAGA DISTRICT, EGYPT

By

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### بيترولوجية المواد العضوية ( الكيروجين ) لصخور الطفله البيتومينية في منطقة القصير - سفاجا

بمصر

خالد أحمد خالد

تمت دراسة المواد العضوية ( الكيروجين ) وجهدها في تكوين المواد الهيدروكربونية في صخور الطفله البيتومينية المتواجدة في قطاعات مناجم منطقة البحر الأحمر ( القصير - سفاجا ) وذلك باستخدام أسلوب الفحص الميكروسكوبي وأيضا نتائج التحليل العنصري لهذه المواد العضوية ( الكيروجين ) .

دلت الدراسة على أن كيروجين هذه الصخور يتبع النوع الأول ( I ) في منطقة سفاجا ويتغير بوضوح إلى النوع الثاني ( II ) في منطقتي الحمراوين والقصير وكلا النوعين ذات أصل بحري وبيئة ترسيب اختزالية .

ويتكون هذا الكيروجين بصفة أساسية من مجموعة الليبتينيت وخاصة النوع السابروييلي ، كما تم التعرف على أنواع الليبتينيت المنقولة من البيئة الأرضية مع بعض حبيبات الفيترينيت والانيرتينيت وكلها توجد بنسبة أقل .

تم استنتاج ان المواد العضوية لهذه الصخور تعتبر غير ناضجة وتقع في نطاق المرحلة البعيدة للترسيب ( الداياجينيسيز ) .

Key Words: Oil shale, Kerogen, Organic petrology, Egypt.

#### ABSTRACT

The kerogen and hydrocarbon-generating potential of oil shales from three mining districts in the Red Sea province of Egypt have been investigated using microscopy and elemental analysis.

The results reveal that, the kerogen type ranges from Type I for Safaga oil shales to Type II for both of Hamrawein and Quseir districts. The kerogen seems to be of marine origin and formed in reducing conditions. Kerogen concentrates are formed mainly of the autochthonous liptinite group (amorphous sapropelic organic matter and sapropelic structured phytoclasts). In addition, autochthonous and land derived vitrinites, as well as detrital inertinites are also present.

In general, the organic matter of all studied kerogen isolates is immature and lies within the diagenesis state of maturation regardless of the high vitrinite reflectance value of the Type II kerogen.

#### INTRODUCTION

Oil shale deposits occur in many countries of the World. An association of marine black shales with phosphorite is known in some countries of the Middle East including Jordan, Palestine and Syria. In Egypt, several oil shale beds of Cretaceous age have been recorded. Some of them are recorded in Quseir-Safaga district, particularly in phosphate mines in the Red Sea

province. The geochemistry of these beds has been little studied: (Troger, 1984; Abdel Rahman and Khaled, 1988; Khaled *et al*, 1989 and El-Kammar *et al*, 1990). Until now, the characteristics of the organic matter (kerogen) contained in these Egyptian oil shales have not yet been studied, therefore, the aim of this work is to characterise the kerogen isolated from these rocks using the elemental analysis and microscopic techniques (optical properties) in addition.

## GEOLOGY AND SAMPLING

Fresh oil shale samples were taken from almost all the phosphate mines within the studied area where these outcrop (Fig. 1). These sampled beds lie within Duwi (phosphate) Formation, dated by most authors as Campanian - Early Maastrichtian. Some samples were also collected from surface outcrops in the vicinity of mines.

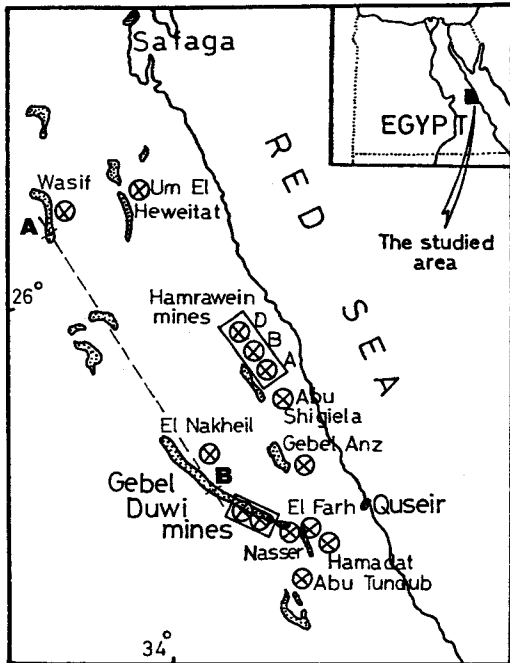


Fig. 1: Location map of studied mining areas. ⊗mine location, ⊕ outcrops of Campan.-Maestrich. rocks.

Stratigraphically, the Duwi Formation overlies the Quseir variegated shales and underlies the Dakhla Shales (Fig. 2). It consists of interbedded shales, marls and carbonates, including many phosphate horizons. Most sampled oil shales lie in the upper part of the formation, overlying phosphate beds and having vertical thickness up to 40 m.

## METHODS

Kerogens were isolated from 25 selected samples using a procedure modified from (Saxby, 1970 and Brass & William, 1973). Whole-rock and kerogen-particle pellets were prepared following the procedures of (Bostick and Alpern, 1977 and Bostick, 1979). Reflectance analysis was performed using a Zeiss reflected light microscope fitted with white (halogen) and fluorescent light (HBO) sources. Using the white-light reflectance measurements at 546 nm in oil ( $n = 1.518$  at  $24^{\circ}\text{C}$ ) at an effective magnification of 500X were made on a minimum of 20 particles per sample. The obtained readings were statistically treated and the average reflectance values ( $R_o$ , %) were then computed for each sample. Fluorescence observations were obtained using an ultraviolet excitation and an appropriate barrier filter. Photomicrographs were taken under reflected and under fluorescent light.

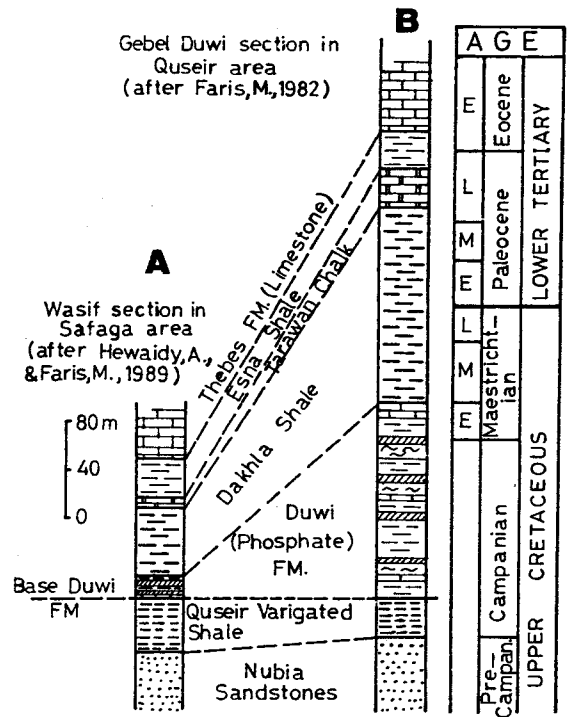


Fig. 2: Stratigraphic sections of sediments in Safaga and Quseir areas.

▨ Phosphate      ~ Marl

The total organic carbon content (TOC, %) and the elemental analysis of kerogens were carried out using a Leco CHN-600 and Leco SC132 elemental analysis instruments.

## RESULTS AND DISCUSSION

Several different approaches classifications for kerogens and their constituents have been introduced by many investigators. Based on the elemental analysis of the three elements: C, H and O, Tissot *et al.* (1974) have classified kerogens into Types I, II and III using van Krevelen's diagram, (1961). For optical description and classification of kerogen components many palynological and coal petrographic studies on optical microscopy have been carried out by, e.g. (Combaz, 1964; Staplin, 1969; Alpern, 1970; Hagemann, 1974; Ottenjann *et al.*, 1974; Teichmuller, 1974; Stach *et al.*, 1975; Raynaud & Robert, 1976; Bostick, 1979; Durand, 1980; Massoud & Kinghorn, 1985; Mukhopadhyay *et al.*, 1985a; Goodarzi, F. 1986a; Thompson & Dembicki, 1986; Senftle *et al.*, 1987 and Stasiuk, 1988).

In this work, the two basic categories of organic matter (sapropelic and humic) together with coal petrographic terms (liptinite, vitrinite and inertinite) are used to describe and identify macerals of the organic matter of the available kerogen concentrates. In addition, phytoclast groups of (Bostick, 1979) as well as those of (Massoud & Kinghorn, 1985) are used also to classify kerogen groups in the study.

The sedimentary organic matter in kerogens from oil shales of Quseir-Safaga district is composed of sapropelic phytoclasts mixed with some humic matter. The sapropelic material is mainly amorphous and structureless. It is distinguished in reflected light by light to dark-brown colour, and low to medium

semitranslucent under the transmitted light. They show a yellow to orange or pale brown intermediate fluorescence (LP in Plate Ia, b, c and d). Many large sapropelic phytoclasts of algae are recorded showing a light yellow colour under transmitted light. They have a brown colour under the reflected light, low to intermediate reflectance and exhibit an intermediate yellow to orange fluorescence. These phytoclasts are alginites, AG (Plates Ic, d, IIa, b, c, d and IIIc). Plate IIIa and b shows a liptinite phytoclast with an exinite margin and dark centre under UV excitation. Such phytoclasts seem to be sporinites. They show a pale to dark greyish colour under the white light and yellowish colour under the transmitted light. They exhibit a low reflectance and a weak orange fluorescence.

On the other hand, the humic organic matter (herbaceous) is not abundant and is mainly formed of vitrinite and inertinite maceral group. Vitrinite particles are found cloudy, greyish brown to light-grey in colour having low to intermediate reflectance and very low dark brown and pale dark yellowish brown fluorescence (Plate Ia and b). Meanwhile, inertinites are represented by white to yellowish white, fine to medium size particles with strong reflectance and very weak or no fluorescence. Plate (III d) shows a large redeposited grey vitrinite particle, VI (middle left) as well as a small size one (middle right); dispersed detrital white inertinite grains (left) of different sizes with strong reflectance; dark brown elongated alginite kerogen particles (top); and scattered small white cube form pyrite grains.

Based on the aforesaid petrographic results and following the classification of Bostick, (1979), the studied sapropelic organic matter belongs to the Liptinite phytoclast group, which includes: spores, pollens, plant cuticles and structured or coherent algal bodies. The Vitrinite group includes the low-grey structured or apparently unstructured woody tissues. The inertinite group consists of the greyish-white to yellowish white unstructured coal macerals.

Using the classification of Massoud & Kinghorn, (1985), the sapropelic organic matter of Quseir-Safaga oil shales consists of both Kerogenite (amorphous and structureless sapropelic material) group, which includes liptikerogenite phytoclasts (Bituminite coal maceral) of Types I and II Kerogen of oil and gas potential; and Liptinite "LP" group (structured sapropelic materials) which consists of autochthonous LP phytoclasts (alginite, sporinite, cutinite, and resinite coal maceral) and detrital LP (detrital fragments of the aforesaid macerals and liptodetrinite) of Type II kerogen of oil and gas potential. The rare humic organic matter is represented by both vitrinite "VT" group (structured humic or woody material), which includes autochthonous VT phytoclasts, and inertinite "IN" group, comprising detrital or unstructured "IN" particles. In addition to the organic matter, framboid and cube form small size pyrite grains are recorded almost in all the studied samples (Plates Ic, IIa, IIIa and d).

Analytical results of the whole oil-shale rock samples from the three areas and the associated kerogen concentrates are presented in Tables (1 and 2). Kerogen types based on their hydrogen/carbon (H/C) and Oxygen/carbon (O/C) atomic ratios are plotted on a van Krevelen's diagram shown in Fig. (3). The results indicate that, the studied oil shales, in general, have a total organic carbon content (TOC %) from 11.6 to 16.6% reflectance. These sapropelic materials are of yellow colour and Kerogens from Safaga region in the northern part of the studied area are characterized by a high hydrogen content (H/C, 1.53) and low oxygen content (O/X, 0.09). Therefore, these kerogens are Type I (Fig. 3). Additionally, their vitrinite reflectance ( $R_o$ , %) is 0.3%, and the thermal alteration index (TAI) 2. They are composed mainly of amorphous and palynomorphs sapropelic materials.

In the Hamrawein region, south of Safaga, the Kerogen concentrates are found to be of relatively low hydrogen content (H/C = 1.3) and mostly have the same oxygen content (O/C =

**Table 1**  
Geochemical characteristics of oil shales and kerogens, Quseir-Safaga district, Egypt.

Mining Area	Number of Studied Samples	Oil Shales			Kerogen		Atomic H/C	Ratios O/C	Type
		Kerogen %	TOC %	Elemental C	Analysis H	% O			
Safaga	7	21.8	16.6	76.	9.7	9.	1.53	0.09	I
Hamrawein	9	15.5	11.6	74.8	8.6	10.1	1.3	0.1	II
Quseir	9	19.6	13	65.7	6.8	17	1.24	0.19	II

**Table 2**  
Optical Assessment of Kerogens

Mining Area	Composition of insoluble organic matter			Kerogen Type	Thermal alteration index (TAI)	Average value of vitrinite reflectance ( $R_o$ , %)
	Amorphous	Palynomorphs	Humic			
Safaga	●	●	○	I	2.	0.3
Hamrawein	●	●	○	II	2.7	0.7
Quseir	●	●	○	II	2.5	0.5

● dominant (> 50%), ● common (20-50%), ○ minor (< 20%)

0.1) in comparison to Rabah kerogens. Their vitrinite reflectance value is markedly increased ( $R_o = 0.7\%$  and TAI is 2.7). These kerogens are mainly composed of amorphous sapropelic materials with less content of palynomorphs, humic and cuticles matter. Hamrawein kerogens are found to be of Type II (Fig. 3).

- △ H - Hamrawein kerogen (9 samples)
- Q - Quseir kerogen (9 samples)
- S - Safaga kerogen (7 samples)

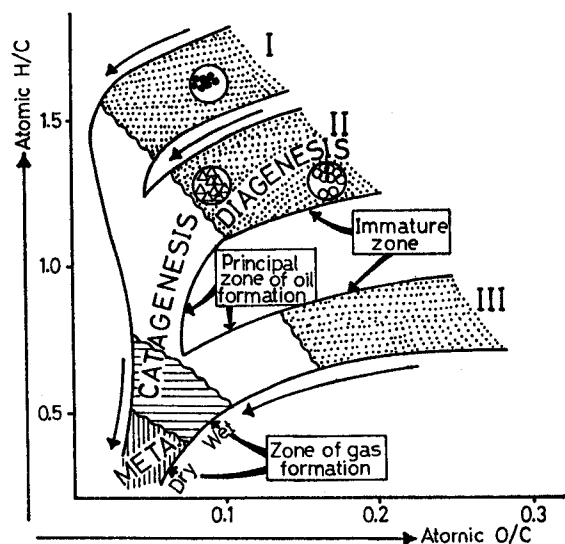


Fig. 3: The elemental composition and types of kerogens of the studied oil shales.

(General scheme of kerogen evolution presented on van Krevelen's diagram. After Tissot and Welte, 1978)

Principal products of kerogen evolution:

- ▨ CO<sub>2</sub>, H<sub>2</sub>O
- Oil
- ▨ Wet gas
- ▨ Dry gas

Furthermore in the southerly direction, kerogen concentrates of Quseir oil shales have almost the same hydrogen content ( $H/C = 1.24$ ) as that of Hamrawein shales, whereas they have the higher oxygen content ( $O/C = 0.19$ ) among the studied kerogens. The vitrinite reflectance value of Quseir kerogens is around 0.5, and TAI is 2.5. Here kerogens are also composed of amorphous sapropelic materials and minor content for other organic constituents. These kerogens are belonging to Type II too.

Fig. (3) indicates that, all the studied kerogen samples (either Type I or Type II) lie within the immature diagenesis stage although  $R_o$  values of Type II kerogens (0.5%) suggest the mature catagenesis stage of maturation. Some large liptinitic fragments (algal phytoclasts) are partly gelified as a result of the alteration by being in a source rock (Plates Ib, d, IIb, d and IIIb, c). In general, composition of components of these kerogens indicates that, they have a great generating potential for oil and gas as denoted by Tissot and Welte, 1978 and Bailey, (1981).

The liptinitic phytoclasts assemblage presented in the studied oil shales are suggested to be of shallow to open marine origin and reducing environmental conditions. This is proved by the presence of the marine warm water phytoplanktonic components and microforams as well as the abundance of pyrite grains. This conclusion mostly agrees with that of Mukhopadhyay *et al.* (1980) who stated that, amorphous kerogen (e.g. sapropelic kerogenite bituminite) is generally assumed to be composed of biodegraded phytoplanktonic, zooplanktonic and liptinite components. However, it is suggested here that, the studied oil shales were formed under anoxic conditions, where high algal input due to prolific planktonic growth in surface water results in an abundance of sapropelic organic material which became preserved under anaerobic conditions (Macauley *et al.* 1985).

In general, the aforesaid optical properties indicate that, the liptinitic sapropelic phytoclasts of the studied kerogen concentrates are mostly autochthonous. The rare vitrinite particles are mainly autochthonous vitrinites (Plate Ia and b) with minor contribution of parautochthonous (first cycle) vitrinite particles (Plate III d) which were denoted by Massoud and Kinghorn, (1985), as land-derived vitrinites which derived by water into marine sediments during the same cycle of deposition. In addition, few light grey cracked and weathered vitrinite fragments are also present (Plate III d) and could be considered as to be allochthonous oxidized vitrinites if matched to those of Stach *et al.* 1975 and Massoud and Kinghorn, (1985). Also, the detrital unstructured inertinites could be derived from land by water or by erosion of uplifted sediments. However, the organic petrology of samples examined from Quseir-Safaga district oil shales suggests that marine organisms (phytoplanktons and marine fauna) were the main contributors to the kerogen, and the terrestrial input was minor.

## CONCLUSIONS

The present results declare that, Kerogens of Quseir-Safaga environs are mainly composed of autochthonous liptinite group, including amorphous sapropelic organic matter and sapropelic structured phytoclasts. Humic organic matter is rarely recorded and represented by autochthonous (first cycle) vitrinite and inertinite groups with minor contribution of land-derived particles. It is also concluded that, Kerogens of Safaga oil shales belongs to Type I, meanwhile those from Hamrawein and Quseir regions seem to be of Type I and II. Both types were produced by marine organisms (algae) under reducing condition. All Kerogens are still immature, where they lie in the diagenesis stage of maturation. They could act as a fairly good gas and oil generating potential if they reach the principal zone of oil formation (catagenesis stage).

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### **PLATE I**

Ia: Light brown amorphous sapropelic liptinite masses (LP, right) and an autochthonous vitrinite fragment (VT, left). Polished surface, reflected white light, 500X, oil immersion. (Rabah mine oil shale, Safaga). Ib: Plate Ia under UV excitation showing a yellow fluorescence of the amorphous sapropelic masses and the weak pale yellowish brown fluorescence of the vitrinite fragment. Ic: A large liptinitic sapropelic algal (alginite, AG) phytoclast (top) and light to dark brown amorphous sapropelic liptinite masses (LP). Polished surface, reflected white light, 500X, oil immersion. (Nasser mine oil shales, Quseir). Id: Plate Ic under UV excitation showing the pale brown fluorescence of the amorphous masses (LP) and a yellow fluorescence of the liptinite algal phytoclast (AG).

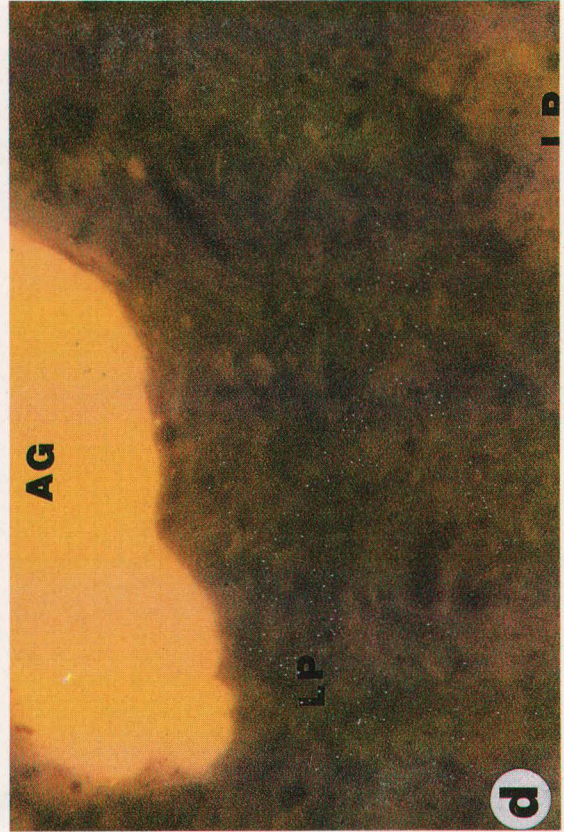
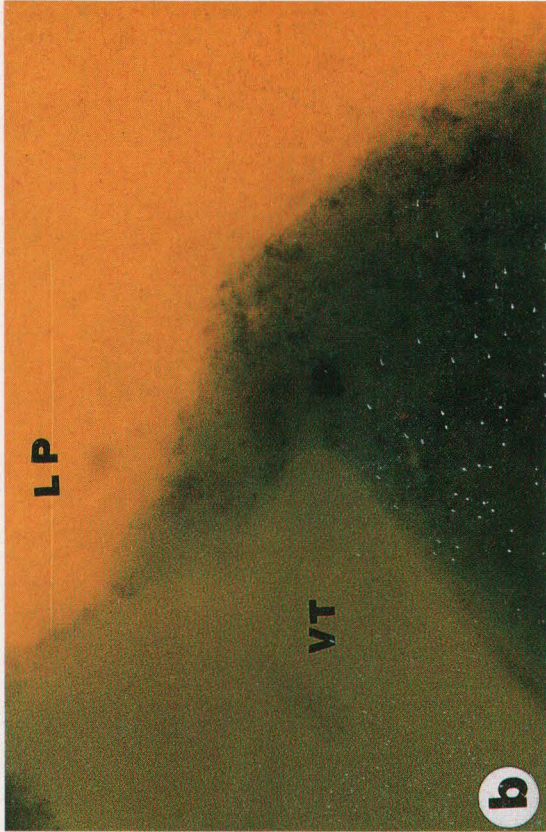
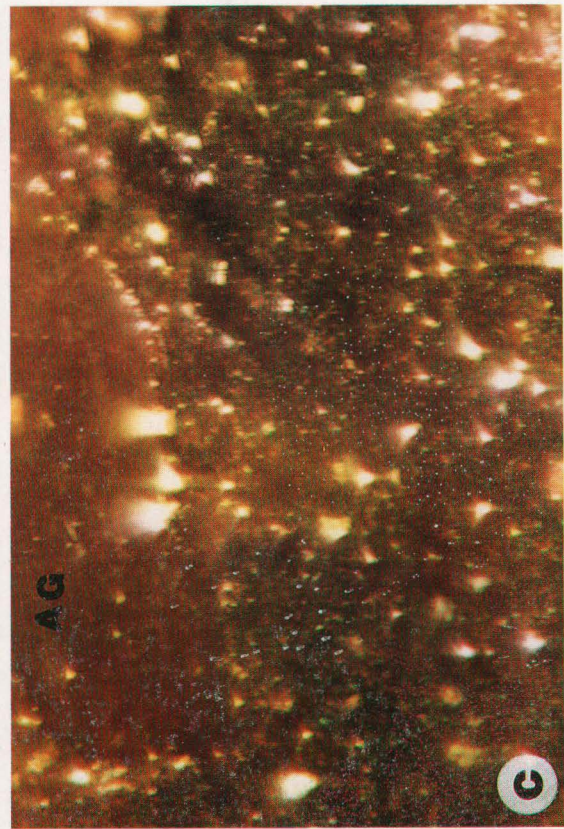
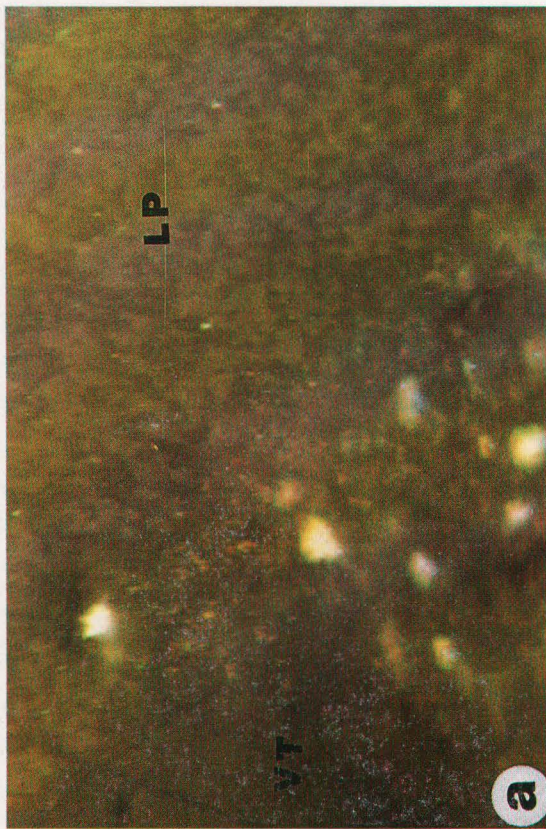
### **PLATE II**

Iia: A large liptinitic sapropelic algal fragment (AG) of light brown colour (middle) with pyrite inclusions (white grains). Polished surface, reflected light, oil immersion, 500X. (Nasser mine oil shales, Quseir). Iib: Plate Ib under UV excitation showing a yellowish orange fluorescence of the liptinite fragment (AG). Iic: A dark brown alginite phytoclast under reflected light. Polished surface, 500X, oil immersion. (Rabah mine oil shales, Safaga). Iid: Plate Iic under UV excitation showing the yellow intermediate fluorescence of the alginite phytoclast.

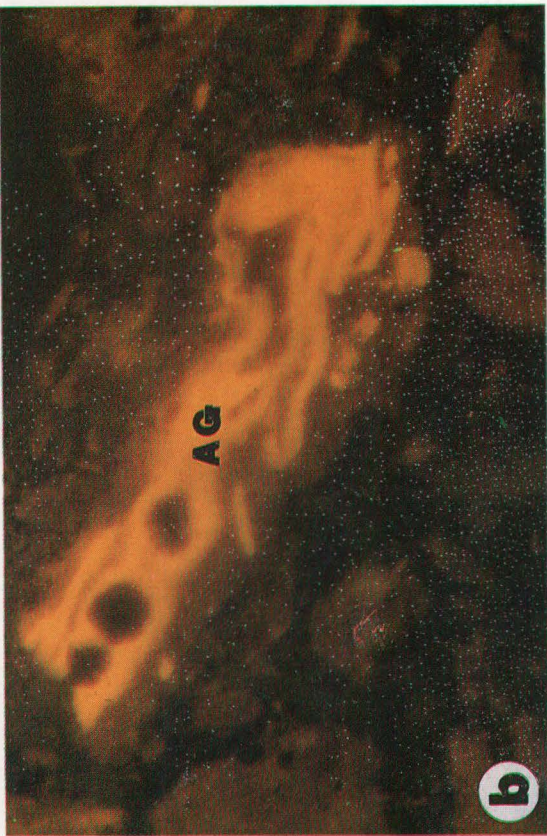
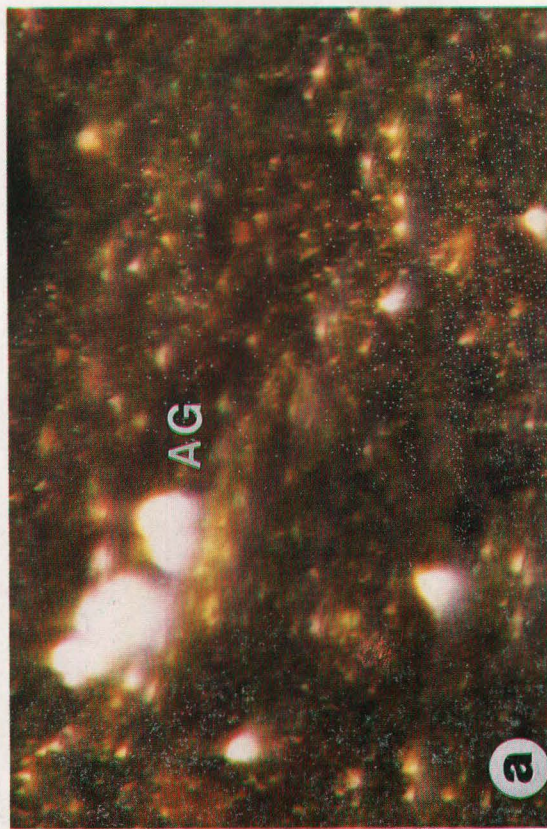
### **PLATE III**

IIIa: Many light to dark brown liptinite phytoclasts (sporinites, S) under the reflected white light. Polished surface, 500X oil immersion. (Hamrawein B mine oil shales, Hamrawein). IIIb: Plate IIIa under UV excitation showing the intermediate yellowish orange fluorescence of the sporinites (S). IIIc: A rounded liptinitic sapropelic algal phytoclast (alginite, AG) with yellow fluorescence and partly gelified periphery. Polished surface, under UV excitation, 500X, oil immersion. (Rabah mine oil shales, Safaga). IIId: A dark grey elongated alginite phytoclast (AG, top), a large light grey cracked and weathered and redeposited vitrinite (VT) fragment (left) and a small grey one (VT, middle right), and a yellowish white, strongly bright inertinite (IN) particles (top right and down left). Polished surface, reflected white light, 500X, oil immersion. (Hamrawein B mine oil shales, Hamrawein).

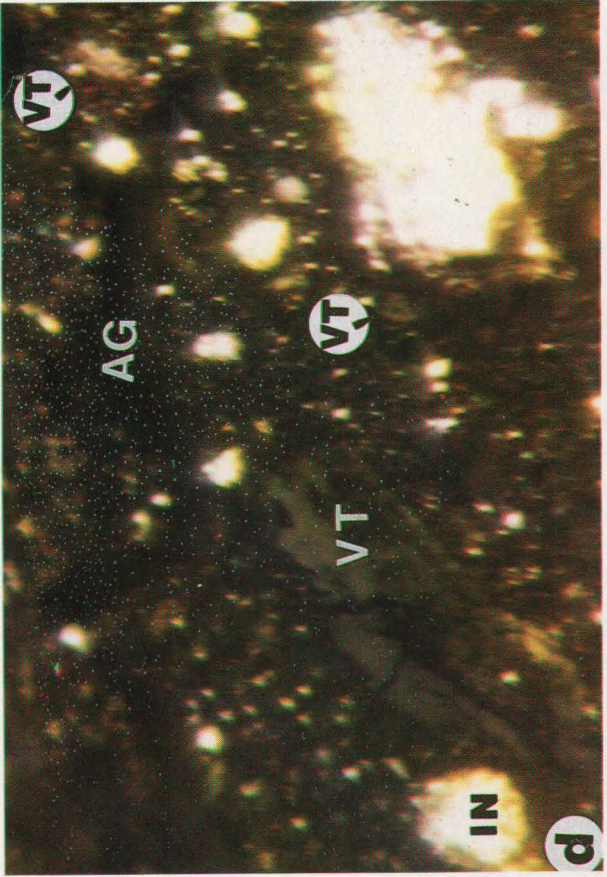
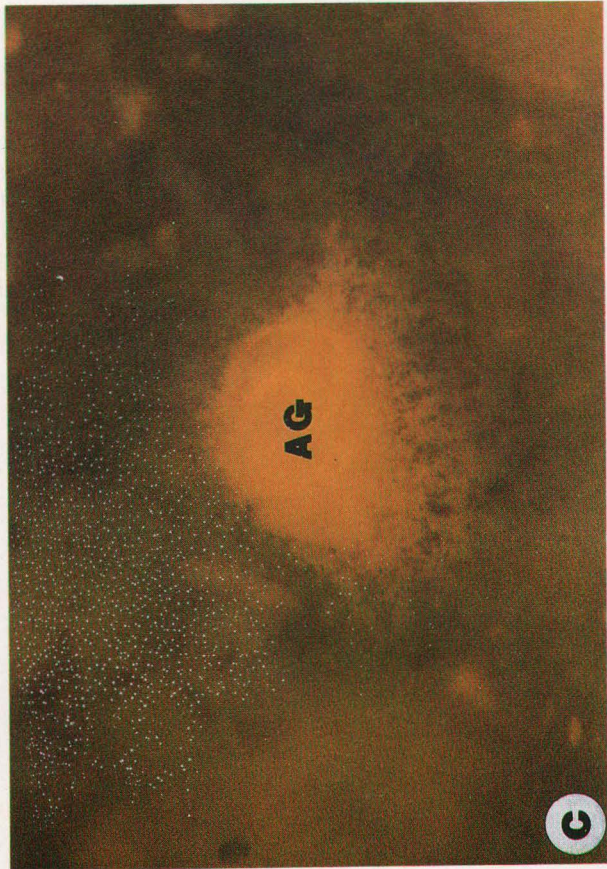
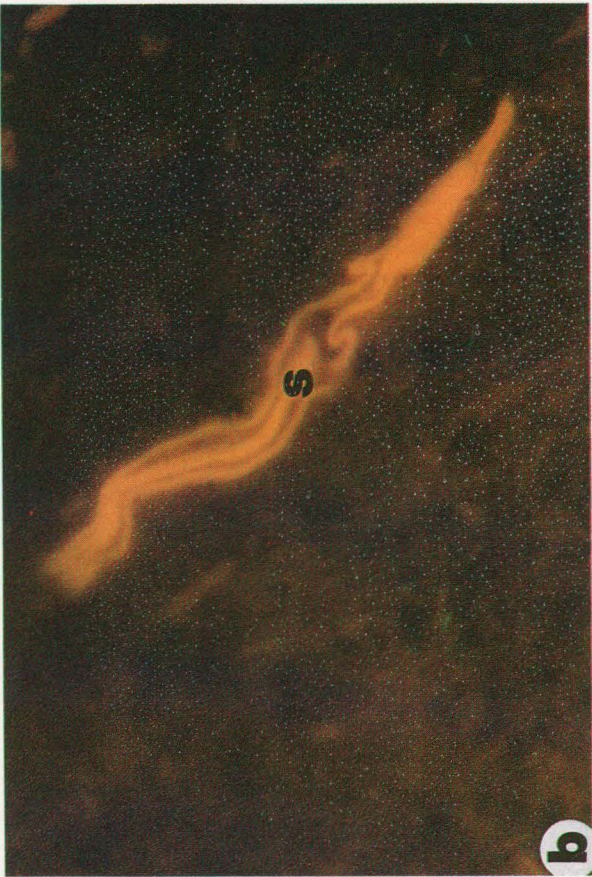
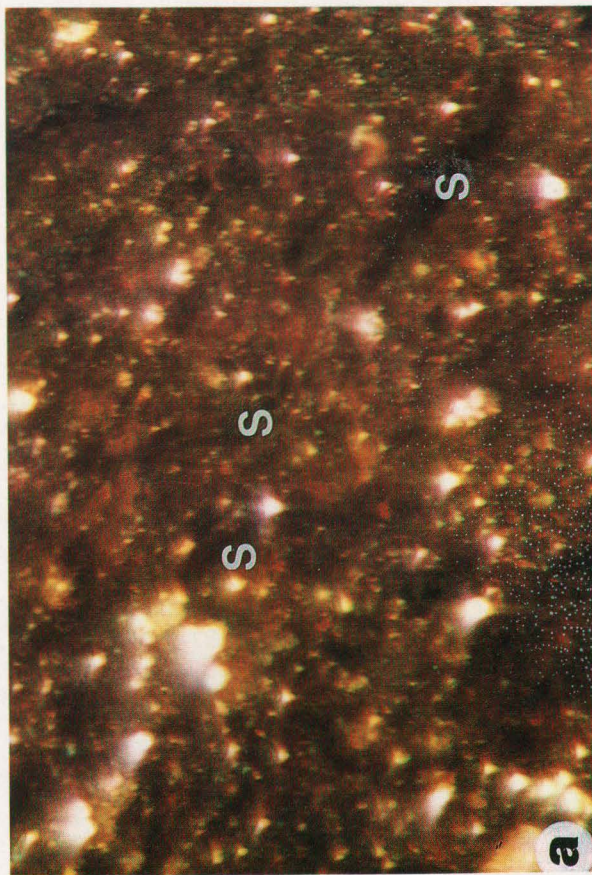
**PLATE I**



**PLATE II**



**PLATE III**





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