Organic petrology of Ora formation in Akkas field, western Iraq

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Abstract
Detailed petrological investigation of the organic matter has been performed using polished sections examined under incident light microscopy on the Lower Carboniferous Ora formation in Akkas field to characterize the nature and origin of the contained organic matter in the shale beds. Microscopical investigations reveal that the organic matter consists of mixed terrestrial and marine organic matter. Marine organic matter represented by alginite and bituminte; whereas terrestrial is represented predominantly by sporinite, and minor amounts of vitrinite.

Key words: Ora formation, liptinite, Akkas field, alginite

Introduction
The Akkas gas field is located in the western desert of Iraq near the border with Syria covering an area of 200 km^2 (77 mi^2) (Figure 1). Oil Exploration Company of Iraq (OEC) drilled six wells in this field between 1993 and 2002, targeting the Paleozoic hydrocarbon system. The penetrated successions in these wells range in age from Tertiary to Lower Paleozoic. Akkas-1 well is the deepest, with a total depth of 4238 m.

In Akkas-1well, Ora formation composed mainly of black fissile shale with intercalation of sandstone, siltstone and dolomite streaks with pyrite and gluconite [1]. Three lithofacies were identified in Ora formation by [2,3]; these are shale, sandstone, and dolostone. They also considered Ora formation represents the transition between the underlying fluvial- marine clastics of Kaista formation, and the overlying carbonate of the Harur formation. In Akkas-1 well, the shale unit characterize by high gamma-ray readings, and the pyrite, mica, and glauconite are common [2,3]. In the type locality, which located in Ora anticline in the northmost of Iraq close the border with Turkey, it consists of black micaceous and calcareous shale with olive green silty marl and lenses of detrital limestone, fine-grained sandstone occurs as intercalations through the succession; with thickness about 256 m. Lower part of the formation, which was part of Kaista formation, comprises of thin-bedded dark blue argillaceous limestones, with beds of silty shale and sandstone [4]. Details of the lithology of Ora formation are summarized in [1,2,3].

Ora formation present in most of the north and west central Iraq, and may be absent in the south and southwest Iraq due to erosion during the Late carboniferous, but the presence of Ora formation is unknown in east Iraq [4]. The Lower Carboniferous in Turkey is represented by Ziyarettepe Formation, which contains sandy and clayey limestones and organic matter-rich black shales which are the principal effective source rocks in the eastern Taurus region [5].

In type section and in the west (wells Akkas-1 and Khlesia-1), Ora formation is overlain conformably by Harur formation; the contact is gradational [1]. The age of Ora formation is Early Carboniferous (Tournaisian) in the type section [4,6], in Akkas -1 well [7], and Khlesia-1 well [8].

Ora formation in Akkas field was subjected for several studies, most of them focused on the sedimentology and sedimentary environment of the formation [2,3]; palaeontoloy and the age of the formation [7,8], but there are a few studies concerned with the nature of organic matter [9]. They concluded that the organic matter of the formation is terrigeneous origin; and mainly composed of woody fragments, chitin, pollens and spores. The present study focused on the nature and the origin of the organic matter using polished sections cut perpendicular to the bedding examined by high magnitude incident white light microscope provided with blue light excitation to test the fluorescence nature of the organic matter.

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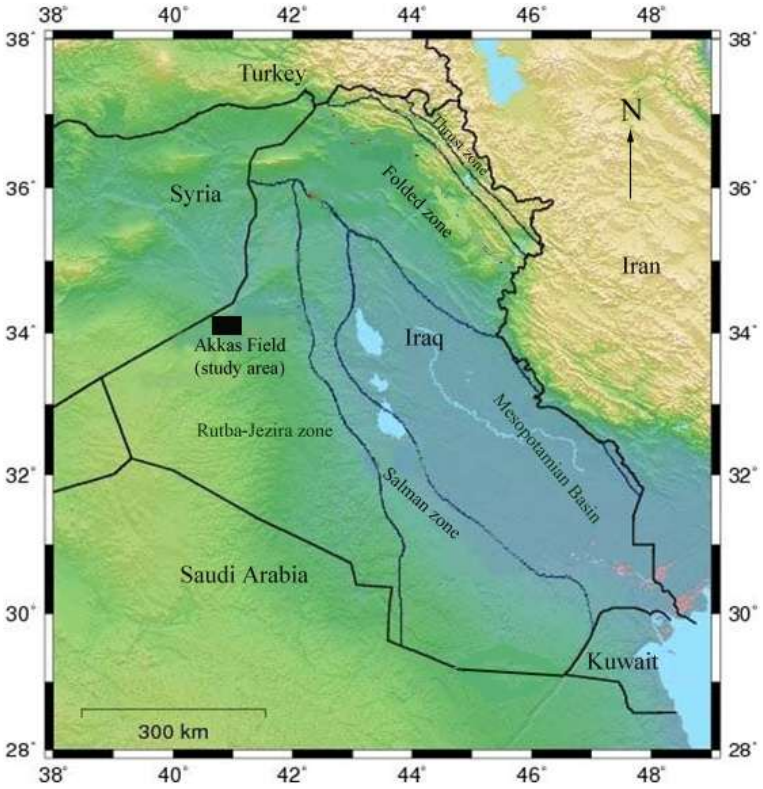

Figure 1. Map of Iraq showing the major tectonic zones and the study area

Materials and Methods

The cutting and core samples of the present study were provided by the North Oil Company (NOC)-Kirkuk. These samples are from two wells in Akkas field; these are Akkas-1 and Akkas-3. According to North Oil Company (NOC) final report; Ora/Kaista formation in Akkas-1 well are at depth interval of 1082-1464m; and in Akkas-3 well at depth interval 941-1377m. [1] considered Ora formation is at interval 1297-1402 m in Akkas-1 well. The available amounts of samples for analyses were limited, therefore, palynomorph slides, or kerogen concentrate, could not be made because these slides needs large amounts of rock sample, instead, polished sections were made for organic petrology study.

For this microscopic study, thirteen (13) samples of Ora formation from Akkas 1 and 3 wells (8 from Akkas-1 and 5 from Akkas-3) were selected (Table 1). Firstly, these samples were embedded in a mixture at rate of 10:3 of epoxy resin and hardener. Then they were hardened in oven at 37 ^{0}C for at least 12 hour [10]. Samples were ground and polished using automated Struers Tegra Pol 21 polishing machine.

The polished section were investigated using a Zeiss Axio Imager microscope for incident white light and incident light fluorescence mode exited by ultraviolet light at magnification of 400X. Diskus Fossil software was used for data processing.

(Table 1): Samples depth of the present study from Akkas-1 and 3 wells

Well	Depth (m)
Akkas-1	1300
Akkas-1	1312
Akkas-1	1320
Akkas-1	1335
Akkas-1	1350
Akkas-1	1367
Akkas-1	1382
Akkas-1	1400
Akkas-3	1225
Akkas-3	1233
Akkas-3	1240
Akkas-3	1243
Akkas-3	1250

Result and Discussion

The organic matter assemblages of the present study are not similar throughout the studied section, but the difference is not significant; generally, the lower part is organic-rich in comparison with the upper part. Some of the examined samples their organic matter could not be identified because of the low organic matter content; other samples have abundant organic matter. Organic matter of the studied samples of Ora formation is a mixture of both terrestrial and marine origin, but that of marine origin is the dominant represented by alginite and bituminite. Terrestrial organic matter represented by sporinite, small fragments of vitrinite, and some inertinite shows up as well. Most of the groundmass appears to be

mixture of lamalginite (small, elongated particles) and amorphinite. High amount of terrestrial organic matter, represented by sporinite from the land plants are also present, and most of them appear as ovoid shape. All these macerals occur as discrete, disseminated particles and not concentrated in organic-rich layers. Tasmanites (the spore of prasinophytes) is also present in some samples.

The following macerals were identified in the present study:

1- Liptinite:

Liptinites composed of relatively hydrogen-rich, translucent plant materials and bacterial degradation products; and transform to oil and gas if subjected to heating [10,11]. Liptinite include many maceral types (Table 2).

(Table 2): Maceral groups and their origin (after [11])

Maceral group	Maceral	Origin
Vitrinite	Telinite	Cellular structure of wood, leaf and root tissue
	Collinite	Structureless, infilling gel
	Vitrodetrinite	Unidentified cell fragments
Liptinite	Sporinite	Spore and pollen cases
	Cutinite	Waxy coating of leaves and stems
	Suberinite	Cork tissues
	Resinite	Resin bodies
	Alginite	Algal tests
	Liptodetrinite	Unidentified liptinite fragments
	Fluorinate	Lenses/layers, possibly plant essential oil
	Bituminite	Wisps or groundmass, from lipids
	Exudatinite	Veins of expelled bitumen-like material
Inertinite	Fusinite	Charred wood and leaf tissue
	Semifusinite	Partially charred wood and leaf tissue
	Macrinite	Charred gel material
	Micrinite	Charred liptinitic material
	Sclerotinite	Fungal remains
	inertodetrinite	unidentified inertinite fragments

The following liptinite macerals were recognized in the present study:

A- Alginite:

Alginite forming from algae which is particularly resistant and oil-rich. Two alginite-forming algae have been documented; these are *Botryococcus braunii*, which is planktonic green algae; and *Tasmanites*, which is single-celled green algae [10]. Alginite divided into two main types, alginite A and B; and alginite B subdivided into telalginite and lamalginite. In marine sediments, alginite represent the morphologically well preserved remains of marine plankton [12].

In the studied samples of Ora formation, the alginite are round shaped when observed in sections parallel to bedding plane. represented by lamalginite (alginite derived from small, unicellular or thin-walled, colonial planktonic or benthic algae with a distinctive lamellar form with little recognizable structure in sections perpendicular to bedding [10]). In the present study, it occurs as microlaminae of fine and very fine elongated grained material aligned parallel to bedding (Plate 1). *Tasmanites* is the main algae, which appears as disc shape with strong fluorescence (Plate 2). Tasmanite is a single-celled green algae; it is compressed to form a flat disc, is widespread alginite-forming oil algae; occur abundantly in the oil shales of Jurassic-Cretaceous of Alaska. Alginite was also recognized in Ordovician Khabour Formation and Silurian Akkas Formation in Iraq and represented primilarly by Tasmanite [13,14].

Alginite is was recognized in most of the studied samples, and in some samples it forms more than 70% of the organic matter. It is very abundant in the lower part of the formation in studied wells.

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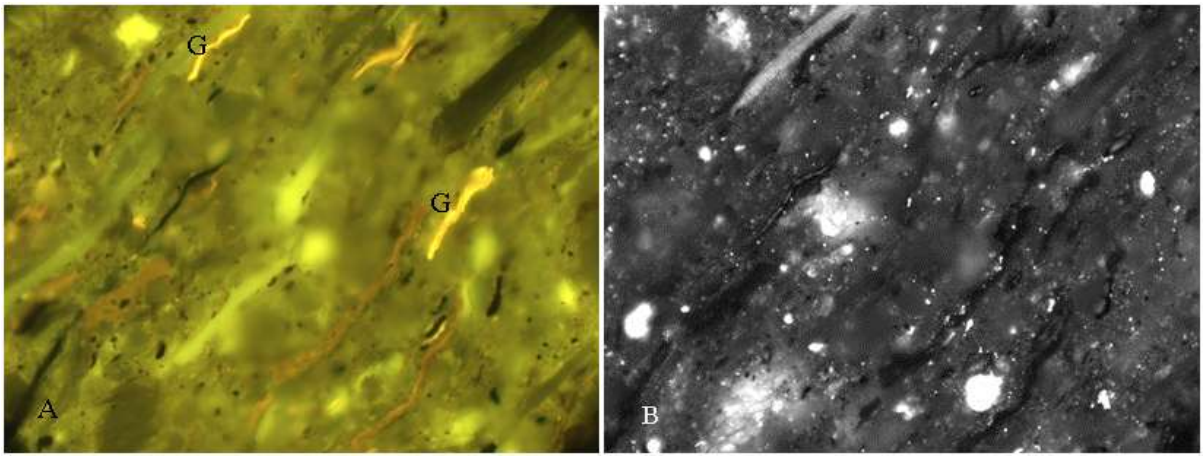

Plate (1) A: Brightly fluorescing lamina consisting of alginite particles (G). Incident light fluorescence mode. B: Same section as A but in an incident light. Akkas-1 well, 1382 m. Oil immersion, X400

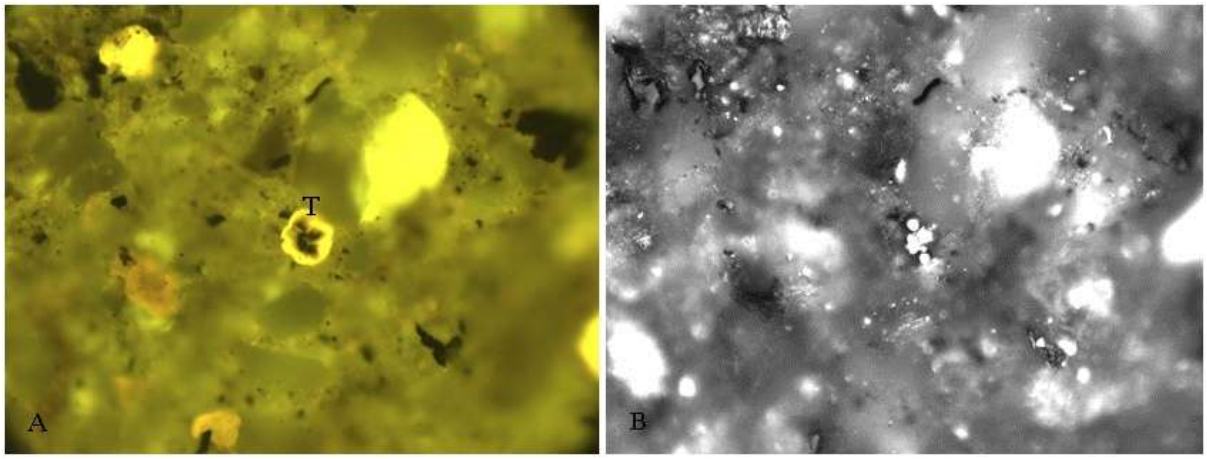

Plate 2: (A): Strongly yellow fluorescing *Tasmanite* alginite (T). Incident light fluorescence mode. B: Same section as A but in an incident light. Akkas-3 well, 1233 m. Oil immersion , X400

B- Bituminite:

Bituminite, or amorphous organic matter (AOM), was first described by [10] who assigned it to liptinite group. It differs from other macerals by lack of well-defined shape related to a biological precursor. It probably originates as bacterial decomposition products of algae and faunal plankton [10], or by the complete restructuring of the biopolymers through degradation and recondensation reactions [15].

In the present study, bituminite occur in most of the examined samples in low abundance relative to alginite; and occurs as irregular shape. Because of its low reflectance, it is less recognized in reflected light, but it is well recognized under fluorescent; which are weakly or brown fluorescing (Plate 3 and 4). Sometimes, in polished sections, it appears as matrix materials, which have no defined shape mixed with mineral grains. In most of the studied samples, the amorphous organic matter is associated with alginite (Plate 3), therefore, it is believed that the amorphous organic matter has been originated from alginite. The amorphous nature of the organic matter reflects significant microbial interaction at the water/sediment interface and within the sediments where reducing conditions have predominated. The good preservation of the these relatively unstable macerals (alginite and bituminite) support the conclusion that the position of the oxic/anoxic interface well above the sedimentary surface during the entire period of the deposition [16].

In most of oil shales, the organic matter consists essentially of mixture of alginate and bituminite [10]. In Lower Palaeozoic successions, bituminte and alginites are very common, where these macerals are of algae origin. Plants were began to colonize the land possibly in the Ordovician, but certainly by the Silurian [11]; before that time, the life was restricted to the marine environments and the algae was the dominant life form.

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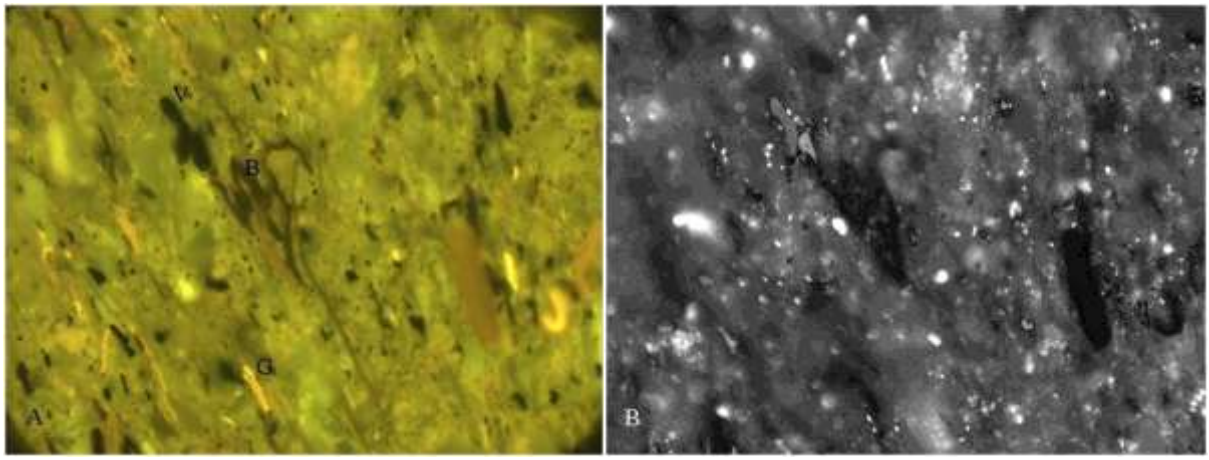

Plate 3: (A): Brown fluorescing bituminite (B) with yellow fluorescing alginite (G) and vitrinite (V). Incident light fluorescence mode. B: Same section as A but in an incident light. Akkas-3 well, 1243 m. Oil immersion, X400

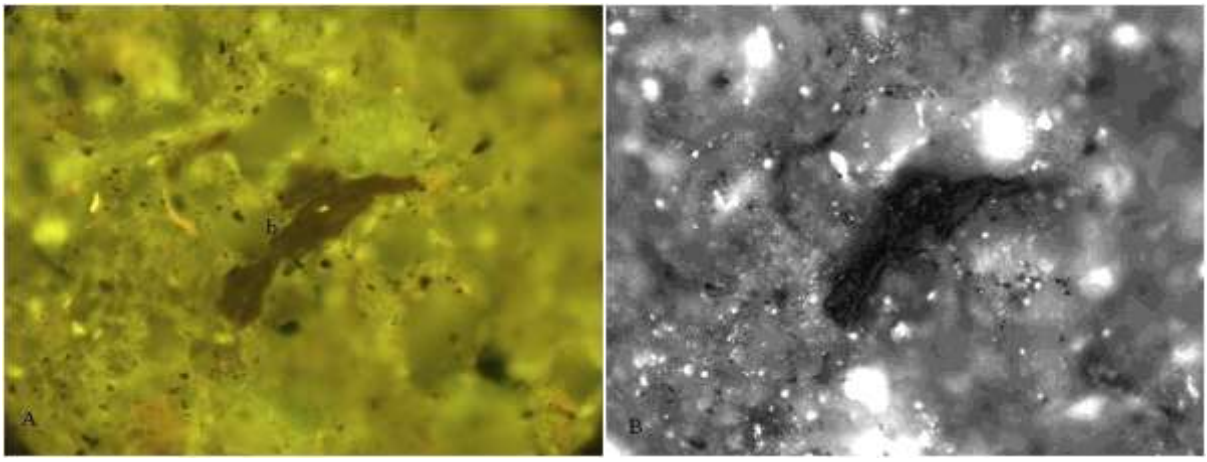

Plate 4. (A): Brown fluorescing unstructured organic matter (bituminte) (b). Incident light fluorescence mode. B: Same section as A but in an incident light. Akkas-3 well, 1240 m. Oil immersion, X400

C- Sporinite:

Sporinite; which belong to liptinite macerals, originates from the outer cell wall of spores and poll cell walls are composed of sporopollenin, which is a very resistant, highly polymerize linked, insoluble substance, consisting of oxidative polymers of carotenoids and carotenoid esters.

Sporinite was identified in most of the examined samples; because of they are translucent and its low reflectance, they are difficult to recognize under reflected light; but they are easily recognized under blue light excitation; where they are show yellow to orange fluorescence with ovoid to elongated shapes (Plate 5).

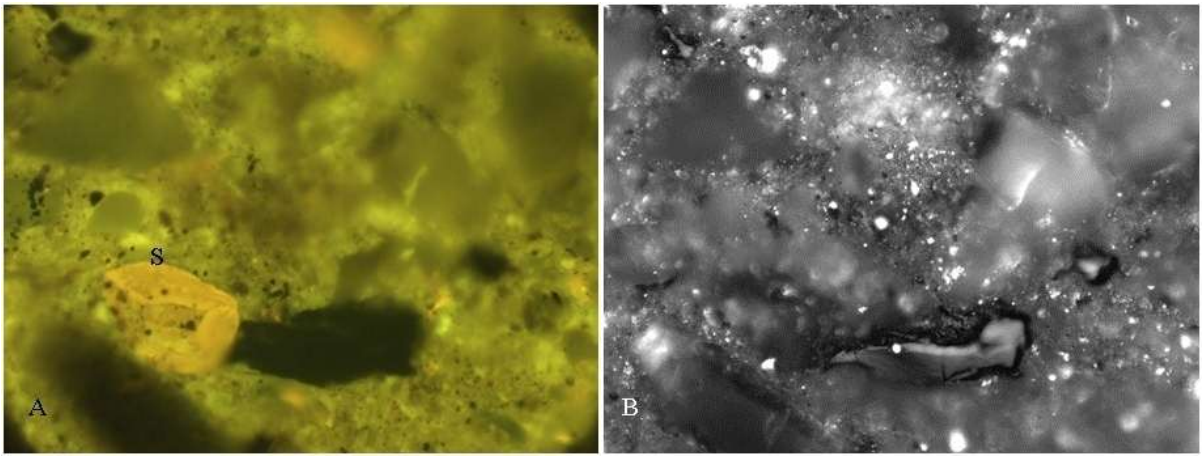

Plate 5. (A): Strongly yellow fluorescent sporinite (S). Incident light fluorescence mode. B: Same section as A but in an incident light. Akkas-1 well, 1320 m. Oil immersion, X400

2- Vitrinite and inertinite:

Vitrinites are coalification products of humic substances, which essentially originate from the lignin and celleluse of plant cell walls. Inertinites are derived from the same original plant substances as vitrinite and liptinite, but they have experienced different primary transformations.

These two macerals were identified in low abundance in some the studies samples. Vitrinite occurs as gray, small fragments under reflected light; and they show brown to black color under blue light (fluorescence) (Plate 3). Inertinite is similar to vitrinite but it appears as white, very small fragments with high reflectance under incident light; with no fluorescence.

The fluorescence colors of the organic matter of the present study samples are shiny, brown, orange, and non-fluorescent. Most of the organic matter from the Ora formation show strong fluorescence under blue light excitation such as alginite and sporinite (Plates 1, 2, 3 and 5). Some of them appear as amorphous fluorescence which often extends throughout the sample and displays no morphology which can be equated with any known maceral type, this fluorescence indicate they are oil prone character. It has been found out that most brightly fluorescing organic particles are hydrogen- rich immature liptinite, and that most weakly fluorescing particles are hydrogen poor [17]. This indicates that the organic matter of this part of Ora formtion has low level of thermal maturity. While in other examined samples there are some nonfluorescent maceral populations. The non-fluorescent of the amorphous organic matter is at least partly explained by extensive degradation of the original hydrogen-rich organic matter at the time of deposition, and/ or alternatively it could be related to present-day thermal maturities [18, 19], but the low level of thermal maturity reached by Ora Formation (as indicated by the fluorescence) excludes the possibility that fluorescent extinction could be due to thermal maturity.

Conclusions

The organic petrology of Ora formation in Akkas field concluded that the organic matter of the formation composed of mixed of terrigeneous and marine organic matter. Liptinite macerals (represented by alginite, bitumenite, and sporinite) are the main components of the organic matter; with minor amounts of vitrinite and inertinite. Liptinite macerals show yellow fluorescence under ultraviolet excitation, which indicate that they are immature and oil-prone.

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دراسة بتروغرافية عضوية لتكوين اورا في حقل عكاز، غرب العراق

محمد وكاع الخفاجي

قسم علوم الارض التطبيقية ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

الملخص

تم عمل دراسة تفصيلية للمواد العضوية في تكوين اورا (الكاربوني الاسفل) في حقل عكاز، باستعمال المقاطع المصقولة والتي تم فحصها باستخدام الضوء المنعكس للتعرف على طبيعة واصل المادة العضوية فيها. اظهرت الدراسة ان المادة العضوية في تكوين اورا تتكون من مزيج من المواد العضوية البحرية والقارية. تتمثل المواد العضوية البحرية بشكل رئيسي بالالجنابت والمواد العضوية غير المتبلورة، بينما تتمثل المواد العضوية القارية بشكل رئيسي بالسبورنايت، مع كمية قليلة من الفيترنايت.