



Petrographic, palynofacies and geochemical characteristics of organic matter in the Saouef Formation (NE Tunisia): Origin, paleoenvironment, and economic significance



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ABSTRACT

Saouef lignite layers and carbonaceous shales are studied in order to reconstruct the origin and depositional environment of organic matter (OM), as well as to evaluate their economic potential. The study is based on organic compositions, bulk geochemical parameters, biomarker data, and carbon isotope composition of OM ($\delta^{13}\text{C}$). Lignite samples, collected next to the Saouef village, were macroscopically identified as stratified matrix coal or as humic coal. Rock Eval pyrolysis and the palynofacies analysis indicate the predominance of Type-III-IV kerogen (OM). The depositional environment fluctuated between terrestrial environments with a low water table to the limnic environment. The OM is derived from higher land plant remains (e.g. wood, root, bark) from a mixed vegetation including conifers and angiosperms, and emerged macrophytes. The dominance of huminite over liptinite and intertinite maceral groups, along with the phytoclasts, confirms the woody origin of the OM. A high bacterial activity is evidenced by the abundance of hopanoids in the extractable OM as well as by the amorphous OM content. The high measured TOC values exceeding 20 wt% in some samples may give an economic value of the organic layers of Saouef Formation. However, a $T_{\text{max}} < 435\text{ }^\circ\text{C}$ and $R_{\text{f}} < 0.5\%$ induce the immaturity of the samples despite the presence of expelled bitumen in one sample.

1. Introduction

Lignite deposits in Tunisia occur in Cretaceous, Oligocene, and Miocene strata. However, only the Miocene lignites belonging to the Saouef Formation (Fm) are of greater geographical extension (Abbes, 1981, 1983). Saouef lignite layers were the object of several studies since 1922 in order to assess their economic utility as fossil fuels. Studies were resumed later by the SOREMIT (Société Mixte founded to establish a detailed study about lignite and coal resources) in 1939, and then by the National Mines Office in 1981. The studies revealed that the lignites of the Saouef Fm show a generally high ash yield (16%–70%; Freiberg, 1984) which restrict their utility as a combustible fossil fuel to the crises period.

The previous studies essentially were based on proximate analysis (moisture contents, ash and volatile matter yields, fixed carbon contents) and calorific values. Maceral composition, palynofacies and biomarker analyses are increasingly used for lignite/coal assessment and paleogeothermal reconstruction, as well as for the characterization of the peat-forming environment (Tyson, 1995; Batten, 1996; Taylor

et al., 1998; Kalaitzidis et al., 2004; Bechtel et al., 2005; Mendonça Filho et al., 2012; Suárez-Ruiz et al., 2012; Singh et al., 2017a,b,c; and many more). In the present study, the paleoecological (i.e. vegetation, climate) and paleoenvironmental conditions during deposition of the Saouef lignite layers in Tunisia, as well as their hydrocarbon potential, are evaluated first time by the combined petrographic, palynofacies and organic geochemical methods.

2. Geological setting

The Oligo-Miocene is characterized by a general extension expressed by a synsedimentary normal NW-SE faulting system (Philip et al., 1986) generating extensional basins (Rouvier, 1977). Thick continental to shallow marine silicoclastic sediments deposited during subsidence of the basins (Blondel, 1991; Bedir, 1995). The upper Miocene is marked by the rise of the Atlas orogeny in the Maghreb region due to the Africa-Europe collision causing the reversion of the extensional basins (Rouvier, 1977; Turki, 1985; Ben Ayed, 1986; Bedir, 1995). Tunisia was exposed to a NW-SE oriented compression during

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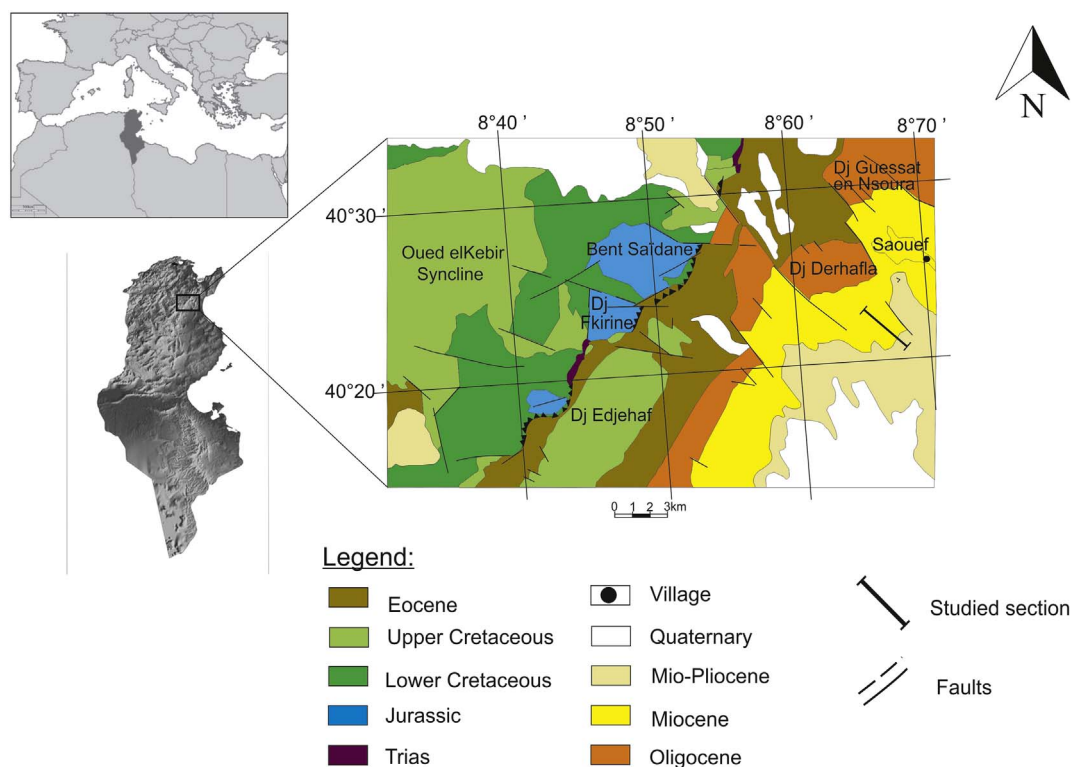


Fig. 1. Geographic location of the Saouef Syncline and the studied section (Freiberg, 1984, modified).

the Tortonian.

The Saouef Formation in the Saouef Syncline (Fig. 1) represents a regressive megasequence (Biely et al., 1972) resting directly on a transgressive shaly sequence known as Mahmoud Formation. The Saouef Fm contains alternating successions of fine sandstone and dark grey to brown clay with the presence of oysters and lignite layers, deposited in paralic basin. It was attributed by Hooyberghs (1977) to the Tortonian due to the presence of *Globorotalia acostaensis*. However, Bismuth (1984), Tayech (1984), and Mannai-Tayech et al. (1992, 1995) proposed a Serravallian-early Tortonian age. The important geographical extension and thickness of the Saouef Fm, reaching 2000 m thickness in Sahel areas, reflect the important subsidence during its deposition, during Oligo-Miocene (Blondel, 1991; Bedir, 1995). Based on the sequence analyses, the Saouef Fm is subdivided into units deposited during progradation and retrogradation, respectively. The subdivision was sometime a subject of controversy between authors, but it was an agreement that the lignite and carbonaceous deposit should be included in one unit (Abbes, 1983; Abbes, 1981; Mannai-Tayech, 2006, 2009; El Euch El Kondi, 2007; Ayadi, 2013; Moktar and Mannai-Tayech, 2014).

During this work, we are adapting the subdivision of Mannai-Tayech (2009) who divided the Saouef Fm into 4 units (Fig. 2): Unit I—first sandy deposits overlying on Mahmoud Clay, attributed also to the Beglia Fm by Abbes, 1981; Abbes, 1983. Unit II— is characterized by alternation between sandy bars with shale intervals. Unit III— the main subject of this work and characterized by the lignite and carbonaceous deposits within the alternation of sands and shales. This unit is further divided into 2 subunits: a and b, where in the Unit IIIa shales are dominating sands, and in the Unit IIIb sands are dominating shales. Unit IV— the last unit and is known as the shaly roof of the Saouef Fm, where this regressive Fm is sealed by a shaly interval.

The studied section (Fig. 3) has been taken from the Saouef Syncline (Fig. 1) where the Formation was defined for the first time. The syncline is located in the central north of Tunisia and oriented NE-SW. The Plio-Quaternary occupy the core of the syncline, which is inserted within the meridional termination of the Tunisian Dorsal to the west (presented in

this area by Bent Saidanen, Fkirine and Edjehaf mountains) and to the east by the Draa Souatir anticline, shown as Cretaceous domes in the geological map.

3. Materials and methods

The Miocene sedimentary OM was deposited mainly during the Serravallian-early Tortonian in the study area. The OM-bearing sediments include lignite layers and carbonaceous shales, are present mainly in the third unit of the Saouef Fm. The lithological section was next to the Saouef village (Fig. 1). The section covered the third unit of the sequence, and 17 samples were collected from the lignite and carbonaceous shale layers (Fig. 3). The samples were taken after digging of at least 20 cm to avoid the altered sediments and recent organic contaminations.

3.1. Carbon and sulphur analysis

Total carbon (TC) and sulphur (TS) contents of all the samples were determined on pulverized sample material (100–150 mg) using an Eltra Helios C/S Analyser. Samples were pretreated with 50% Hydrochloric acid to discard the inorganic carbon. 2 standards are loaded (coal standard for Sulphur content and calcite sample for carbon content) in order to calibrate the device. Then, Samples are loaded one by one into the combustion furnace. The programmed temperature starts from 1 °C a 1550 °C maximum. Samples are burnt in an oxygen atmosphere at 1550 °C. The combustion gasses (CO₂, H₂O, SO₂) coming from the furnace pass through a dust filter. The water vapor is chemically absorbed. CO₂ and SO₂ gas are detected in the additional infrared cells.

3.2. Rock Eval pyrolysis

Pyrolysis analysis (Espitalié et al., 1977) was performed on all samples using a Rock Eval 6 analyzer. Depending on the TOC content, 10 to 50 mg of each pulverized samples were heated gradually in an inert atmosphere.

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