Source Rock Potential of the Organic Rich Turonian – Upper Campanian Carbonates of Northern Lebanon
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Abstract
Upper Cretaceous chalks, marls, and shales are arguably the most prolific petroleum source rocks in the eastern Mediterranean region. 209 core samples from the Turonian – Upper Campanian rock succession in north Lebanon were collected and analyzed for their organic matter (OM) content, quality, and maturity. The total organic carbon (TOC) measurements revealed a very good source rock potential for a 150 m interval within the Upper Santonian – Upper Campanian, with an average of 2% TOC. High HI values (average 707 mg/g TOC) characterize these source rocks as type I kerogen and reflect a very good preservation of the organic matter. Tmax values (average 421°C) match the other maturity parameters such as vitrinite reflectance (average 0.35%), and all point towards immature organic matter. The equivalent Upper Cretaceous in the offshore Levant basin has enough overburden to have reached maturity. However, the accurate extrapolation of the organic matter quality and quantity to the offshore is yet a challenge with the data at hand.

Introduction
Recent gas discoveries in the eastern Mediterranean brought back the attention towards this region and triggered a new phase of exploration, making out of the Levant Basin a new frontier hydrocarbon province. Substantial questions are still unanswered concerning the types and distribution of source rocks. The Upper Cretaceous chalks, marls, and shales are among the best petroleum source rock candidates potentially charging reservoirs in the Levant Basin and Margin (Gardosh et al., 2006; Inan et al., 2010; Nader, 2011).

The elevated organic matter content in the Upper Cretaceous succession is attributed to an increase in primary productivity induced by an extensive coastal upwelling that operated during the Late Cretaceous along the SE Tethys margin (Almogi-Labin et al., 1993, 2012; Ashckenazi-Polivoda et al., 2010, 2011; Schneider-Mor et al., 2011). A pre-existing anticlinal-synclinal basin architecture resulting from the early pulses of the Syrian Arc compression lead to a considerable variation in the thickness, organic matter content, and lithofacies of the Upper Cretaceous rock succession (Bein et al., 1990; Almogi-Labin et al., 2012). Hence, quantifying those variations and characterizing the various organofacies exposed onshore, is vital for reconstructing the contemporaneous paleogeographic setting, and anticipating the distribution of these major source rocks within the Levant Basin and Margin.

Material and methods
In this study 209 core samples from the Turonian – Upper Campanian rock succession in north Lebanon (Fig. 1) were collected and analyzed for their organic matter (OM) content, quality, and maturity. This work provides a contribution to the relatively scarce geochemical information available for the eastern Mediterranean and discusses its implication on future petroleum exploration.

Total organic carbon (TOC) content was measured for all the samples using a liquiT OC II analyzer. Rock-Eval pyrolysis (Espitalie et al., 1977) was performed on a selection of 33 representative samples from the upper Santonian — upper Campanian, having TOC>1%,
using a Rock-Eval II instrument of DELSI INC. Vitrinite reflectance measurement was performed on 10 samples. GC-MS analysis was performed on 9 samples.

**Results**

The TOC content of the studied section varies from almost null up to 5% with an average of 1.5% (Fig. 2). The highest TOC values are observed in the mid-lower Campanian (Fig. 2). The Rock-Eval data revealed a high hydrogen index (HI) with an average of 707 mg/gTOC (Fig. 3), a low Tmax with an average of 421°C, and a very low production index with an average of 0.026. Vitrinite reflectance measurement showed an average VRr of 0.35%.

Organic geochemical analysis revealed a clear dominance of short chain (nC_{15}—nC_{19}) relative to long chain n-alkanes (nC_{27}—nC_{31}) (Fig. 4). The C_{27}, C_{28}, and C_{29} regular steranes distribution is similar in all samples (Fig. 5) and has an average of 42% C_{27}, 25% C_{28}, and 33% C_{29}.

**Discussion**

The relatively high TOC content observed within the upper Santonian — upper Campanian interval indicates a high organic matter input, burial, and preservation. The cyclicity in the TOC content might be due to variations in the OM primary productivity which in turn was triggered by terrestrial-derived nutrients and/or by fluctuation in upwelling intensity (Ashkenazi-Polivoda et al., 2010, 2011; Almogi-Labin et al., 2012; Schneider-Mor et al., 2012). In both cases, increased primary productivity will have enhanced oxygen consumption in the deeper part of the water and thus controlled oxygen content of the water column and at the sea floor, leading to excellent preservation of the organic matter.

The upper Santonian — mid upper Campanian 150 m succession proved to have an average of 2% TOC, which renders it as a very good petroleum source rock in terms of organic content. The high HI values classify the kerogen as oil prone type I (Fig. 3) (Langford, F.F. & Blanc-Valleron, M.-M., 1990) and reflect the excellent preservation of the marine organic matter.

The n-alkanes distribution pattern (Fig. 4) shows a dominance of short chained (<C_{20}) n-alkanes, typical for algae/phytoplankton derived organic matter. The marine, algal/phytoplanktonic source of organic matter is also attested in the C_{27} — C_{29} regular steranes distribution (Fig. 5), which also shows no change in the organofacies throughout the studied section.

The examined maturity parameters in this study reflect the thermal immaturity of this source rock. The Tmax values derived from the Rock-Eval analyses clearly show that the inspected rock succession has not reached the oil window. The vitrinite reflectance measurements, even though conducted on a very limited number of vitrinite macerals due to the scarcity of terrestrial particles, still clearly reflect the immaturity of the organic matter which is not enough for petroleum generation and expulsion. However, seismic lines show a deeper burial of this Upper Cretaceous succession towards the offshore.

**Conclusions**

The investigated section includes a high amount of algal/phytoplanktonic marine-derived organic matter and shows no change in the organofacies throughout the whole studied interval. The high HI values classify the kerogen as oil prone type I, and reflect the excellent preservation of the organic matter as a result of reducing bottom waters. The upper Santonian — mid upper Campanian high organic content renders this rock succession as a very good petroleum source rock.

In terms of maturity, this source rock has not reached the oil window and did not generate any hydrocarbon. However, the equivalent Upper Cretaceous in the offshore Levant basin has enough overburden to have reached maturity. However, the accurate extrapolation of the
organic matter quality and quantity to the offshore is yet a challenge with the data at hand. Hence, a more detailed understanding of the depositional conditions is needed for this section as well as analogous Upper Cretaceous sections in the eastern Mediterranean region.

*Fig. 1:* Simplified geologic map of Lebanon showing the location of investigated section (square). The map is modified after Dubertret (1955).
Fig. 2: Total organic carbon values for the Turonian — upper Campanian rock succession in Chekka, northern Lebanon.
Fig. 3: $S_2$ vs. TOC Rock-Eval data for a selection of samples from the Turonian — upper Campanian rock succession of Chekka, northern Lebanon.

Fig. 4: A typical aliphatic fraction total ion chromatogram for a lower Campanian representative sample.
Fig. 5: Regular steranes ternary diagram of a selection of samples from the upper Santonian — upper Campanian.
References


