

Sedimentology Diagenesis Stratigraphy and Paleontology of the Lower Cretaceous Rock Sequence in Lebanon*

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Abstract

The Neocomian-Barremian “Grès de Base” or Chouf Formation, the only main Formation to be properly studied in this time period in the region, interacts with two improperly studied underplaying and overlaying carbonate strata.

This study also aims to provide a detailed stratigraphic account of the entire Lower Cretaceous in Lebanon, by state of the art petrographic and mineralogic analyses of these rocks. It was demonstrated that the Chouf Formation was deposited in both aquatic and eolian environments. Still to be evidenced, are the strata cyclicity in the sandstone strata as well as the presence of shallow water carbonates in the Lower Cretaceous.

Lithostratigraphic and petrographic analyses revealed that the Neocomian-Barremian outcrops include distinct aquatic and eolian facies. These petrographic analyses described the organic rich layers in the aquatic dominated sandstone facies, but should also determine those found in the limestones

In the clastic beds, the kerogens resulted in corrosion and dissolution of the quartz grains increasing the porosity/permeability of the bulk rocks upon initial hydrocarbon migration and later on the telogenic flushing with meteoric waters. A similar case should be observed for the preserved bitumens in the carbonates.

Thus, this will enable us to study also the petroleum prospects of the Lower Cretaceous rock sequence as well as providing a proper sequence stratigraphic analysis of this period.

Foreword

In Lebanon, the entire Lower Cretaceous is reviewed ([Figure 1](#)). Generally, it was found to be a period of regressions at the base, gradually returning back to transgressive cycles (Walley, 1997). Ukla (1970) indicated that most, if not all of these formations thin out in a W-E direction.

The **first** sequence is the Upper-Tithonian to Mid-Berriasian Salima Formation (Fm). It generally comprises oölitic grainstones, which are often yellowish-ochre in color and compact (e.g. Dubertret, 1955, Tixier 1971-1972; Toland, 2000), as this period is known to be a hiatus. The Sulaiy Fm of Eastern Arabia is of similar age (e.g. Fayyad, 1966). The **second** sequence is the Neocomian-Barremian Chouf Fm ([Figure 1](#)). It comprises three main units of sandstone strata that have been analyzed in details. Globally, it is an immature sandstone with roughly 7% clay content of Wealden age (e.g. Wealden-sandstein – Fraas, 1878).

The **third** sequence is the Abeih (Jeita) Fm. It mainly contains costal carbonates showing pisolitic limestones with fossils at its base – showing the gradual transition from a more sandy to a more marine sedimentation ([Figure 1](#)) – to more oölitic, detrital, or subreefal carbonates that were dated to the Barremian based on the presence of *Charophytes* (Tixier, 1971-1972). The **fourth** sequence is the Mdairej (Jezzine) Fm ([Figure 1](#)). It is composed of white compact cliff-forming subreefal limestone beds traceable almost everywhere. It also shows orbitolinid fossils in its topmost strata, which appear steeped.

The **fifth** sequence is the Hammana Fm. It comprises alternations of marls and thinly bedded limestones showing abundant internal mussels as *Cardium*; *Orbitolina* (Sabbagh, 1961; Walley, 1997; Ferry, et al., 2007 – [Figure 1b](#)). Some recurrence of ferruginous sandstones and oölitic ferruginous concretions were reported in these strata. Above that begins, with a marked contrast, a succession of alternating greenish marl and limestone beds of 1–2m thick – displaying typically Albian fauna. They grade without break to the Cenomanian deep-water carbonates (e.g. Dubertret, 1955; Sabbagh, 1961; Saint Marc, 1970; Walley, 1997; and Ferry, et al., 2007).

Fossil studies were quite poor in the area, and proper studies in paleontology are lacking to this day. However some accounts were given by various authors, e.g. Sabbagh (1961), Basson and Edgell (1971), Smimova and Mroueh (1980), Saint Marc (1970), Walley (1997), and Noujaim-Clark and Boudagher-Fadel (2001). Hence, the purpose is to modernize and update all these data in order to provide a better sequence stratigraphic scheme for the Lower–Cretaceous, with proper hydrocarbon assessment. Hence, analyses of our strata with PetroMod will be conducted, as with the Tithonian-Valanginian Sulaiy Fm of Eastern Arabia (e.g. Al-Ameri and Al-Musawi, 2009).

Purpose of Research

Walley (2001) tectonic scheme presents the various deformations affecting the geologic sequences (Figure 2). Brew et al. (2001) mainly focuses on the tectonics and structures of Syria. The Syrian Arc Deformation, (related to the Palmyrides Basin) and the Dead Sea Fault System (DSFS) are the main causes of tectonic activity in the region.

The lithostratigraphic and petrographic analyses carried out by Bellos (in press) revealed that the Chouf Formation includes five distinct facies. Using XRD analysis the different mineral constituents were segregated and utilized to interpret the reservoir potential, as below:

- Clay rich strata (or clays) are very poor reservoirs or even seals.
- Carbonates (with clays) are also poor, in spite of the presence of mouldic porosity and/or unconnected pores, as they theoretically do not transmit fluid.
- Immature sands and greywacke are also poor to very poor reservoirs. Bulk mineralogy shows the presence of 5-15% to more than 15% clay content, respectively (and might include chlorites, glauconites (indicator of marine setting) and/ or other indicators of maturity such as feldspars, like in the case of arkose).
- Submature sands show some reservoir properties. Bulk mineralogy studies show the presence of some clay and they also tend to act as poor reservoirs.
- Arenites are technically good reservoirs/aquifers with high theoretical porosity (e.g. Tabet, 1978; Abbud, 1985; Hamzeh, 2000). Bulk mineralogic studies point out low to very low clay content.

This data can be very useful in attempting to answer the current questions about the petroleum prospects of Lebanon, namely characterizing our potential reservoir rocks, (e.g. as found by al-Haddad (2007) in the case of the type I/II asphalts of the Chekka Fm), that can be achieved by correlation with other Mesozoic reservoirs (e.g. Levant, Egypt, Arabia, Persia, etc...). The Nubian, Ruthabah and Hathira Fm's are such examples (e.g. Beydoun and Habib, 1995).

Interpretations and Discussions

The Chouf Sandstone is one of the key units of Lebanese Geology. It is represented by the presence of clays, iron oxides, amber, plant remnants and maybe volcanics in its lower/ upper parts (e.g. Dubertret (1955), Tixier (1971-1972), Nissenbaum and Horowitz (1992), Ferry (2007), and Bellos (in press)). Evidence of flooding or marine influence can be evidenced by clay draping as well as liesegangen (e.g. Pothero and Schwab, 1996), and glauconitic horizons.

The Chouf Fm is dated to the Hauterivian/Wealden age (e.g. Bellos (in press) where mostly arenites have been deposited, sandwiched between 2 clay rich strata and some limestones, hence acting as an aquitard, due to the amounts of sands and clays. However water is still stored and transmitted, but not to satisfy exploration demands (e.g. Tabet, 1978; Abbud, 1985; Hamzeh, 2000).

The paragenesis and burial history of the Chouf-Abeih Fm's are shown in [Figures 3-5](#). The resulting pyrolysis results point out that the metamorphosed bitumens transformed to plant type kerogens (see [Figures 3-5](#)). Bellos (in press) demonstrated that the pyrolysis of the Chouf Fm data reveal that the Lower Cretaceous bitumen – containing lignite (of low HI and high TOC values) – were improperly matured to kerogens, with temperatures barely reaching the oil-window.

Therefore, the Salima, Chouf and Abeih Fm's need more study (and will possibly be discussed in a research paper). Establishing good contacts and proper sequence stratigraphy will be a good start. With that, proper dating, and detailed hydrocarbon studies should follow. Thus, in the current study, 1) establishing ground contacts for the Salima-Chouf and Abeih Fm's, 2) detailed sequence stratigraphy, 3) dating and paleontologic identification, and 4) proper hydrocarbon potential should be assessed. It is also expected, provided the available means permit, to study these basins in details with petroleum software, such as PetroMod and others, depending feasibility.

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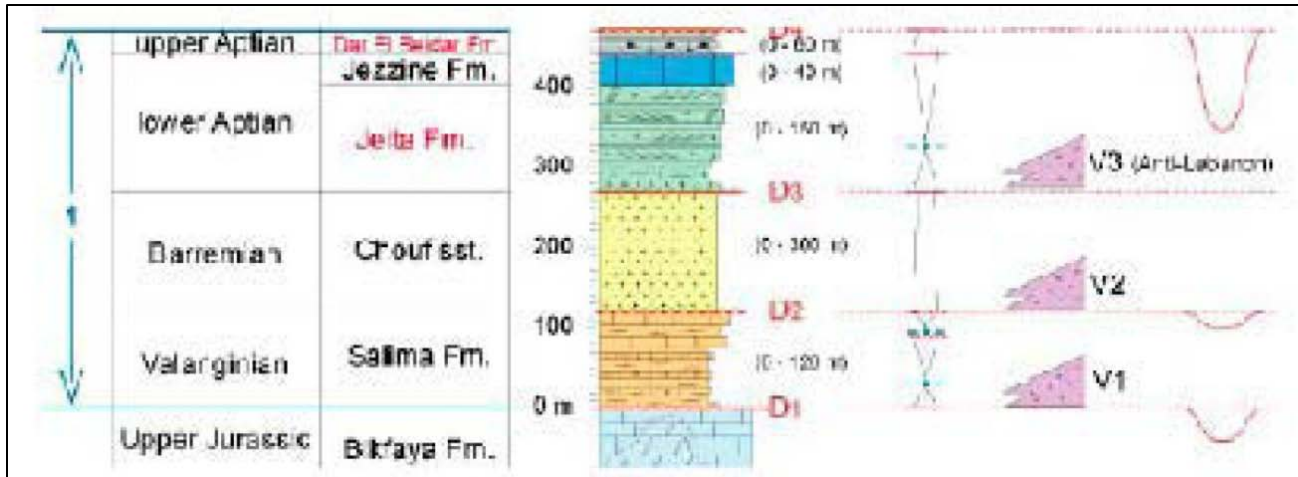


Figure 1 A. Revised Stratigraphy of the Lower-Cretaceous of Lebanon.

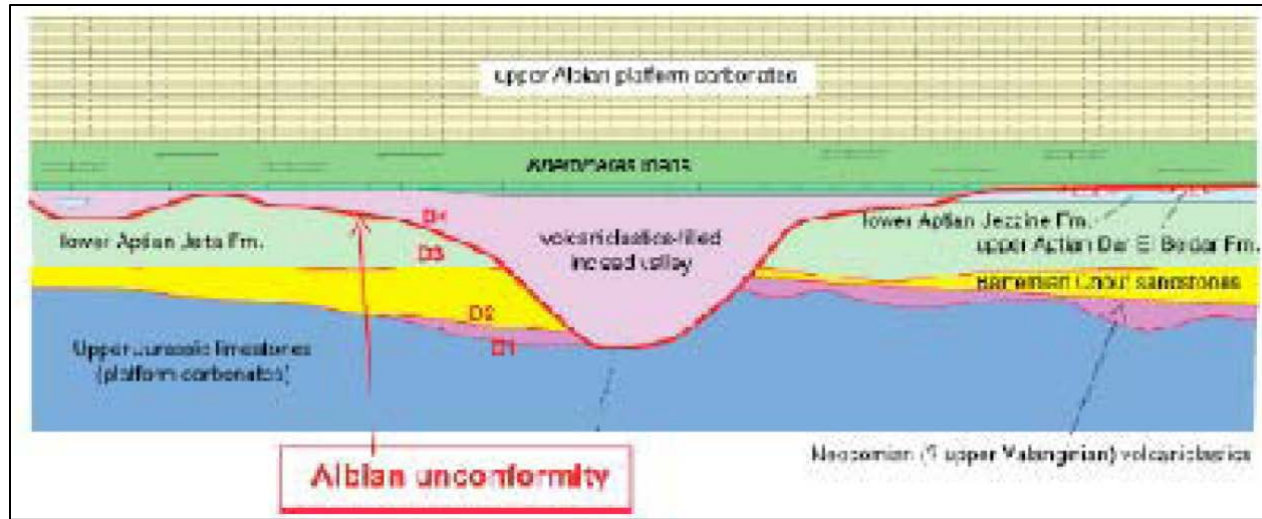


Figure 1 B. Albian incised valley at Beit Monzer, near Ehden, in northern Lebanon showing disconformities (D1-4). Only the lower Cretaceous beds are affected; the Knemiceras marls (upper Hammana Fm) and the upper Albian platform carbonates (Sannine Fm?) rest conformably over everything.

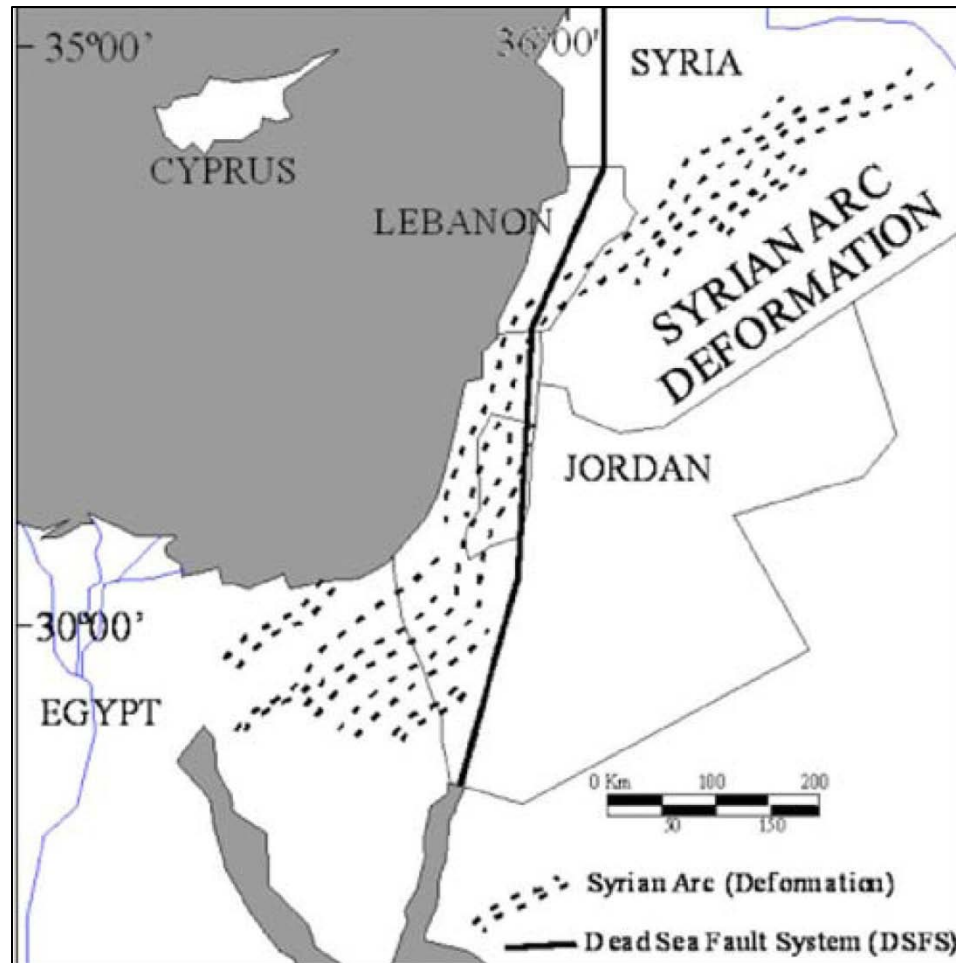


Figure 2: Simplified map showing the two major tectonic features that affect the Levantine margin: The Syrian Arc Deformation (Mid Eocene) and the Dead Sea Fault System (DSFS Miocene). Map modified from Walley (2001).

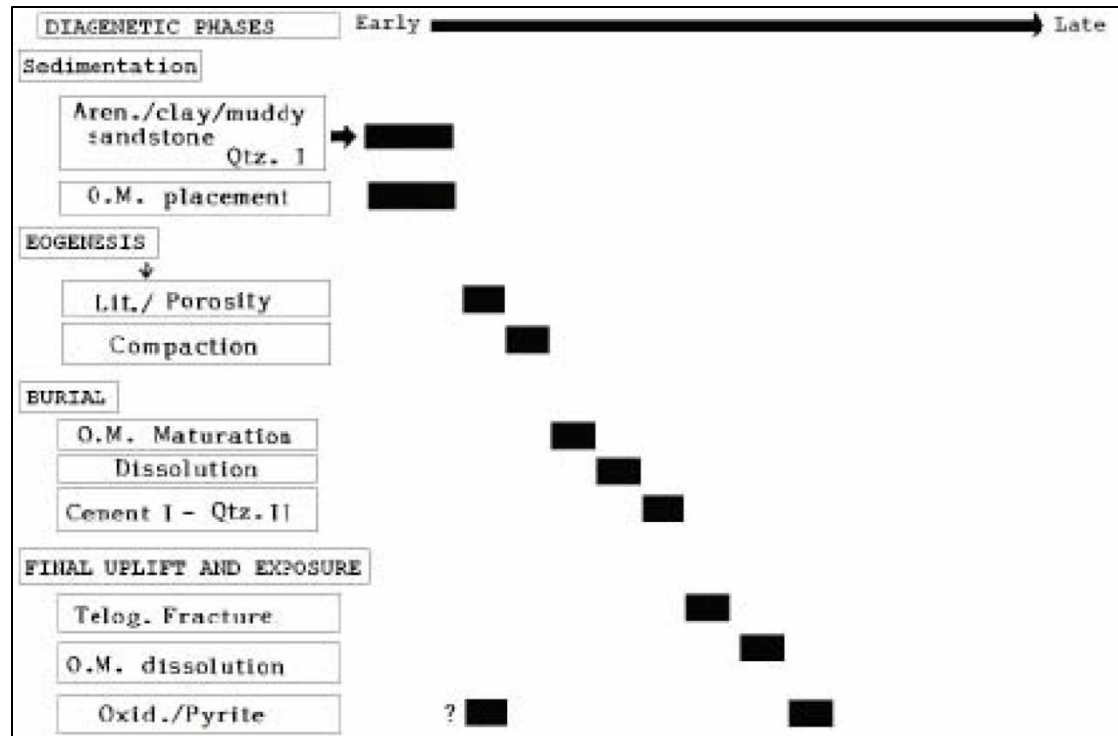


Figure 3: Sequence of diagenetic phases for the sandstone facies exposed in Lebanon (cf. Bellos, in press). Aren. = arenite, O.M. = organic matter, Qtz. = quartz, Lit. = lithification, Telog. = telogenesis, and Oxid. = oxidation.

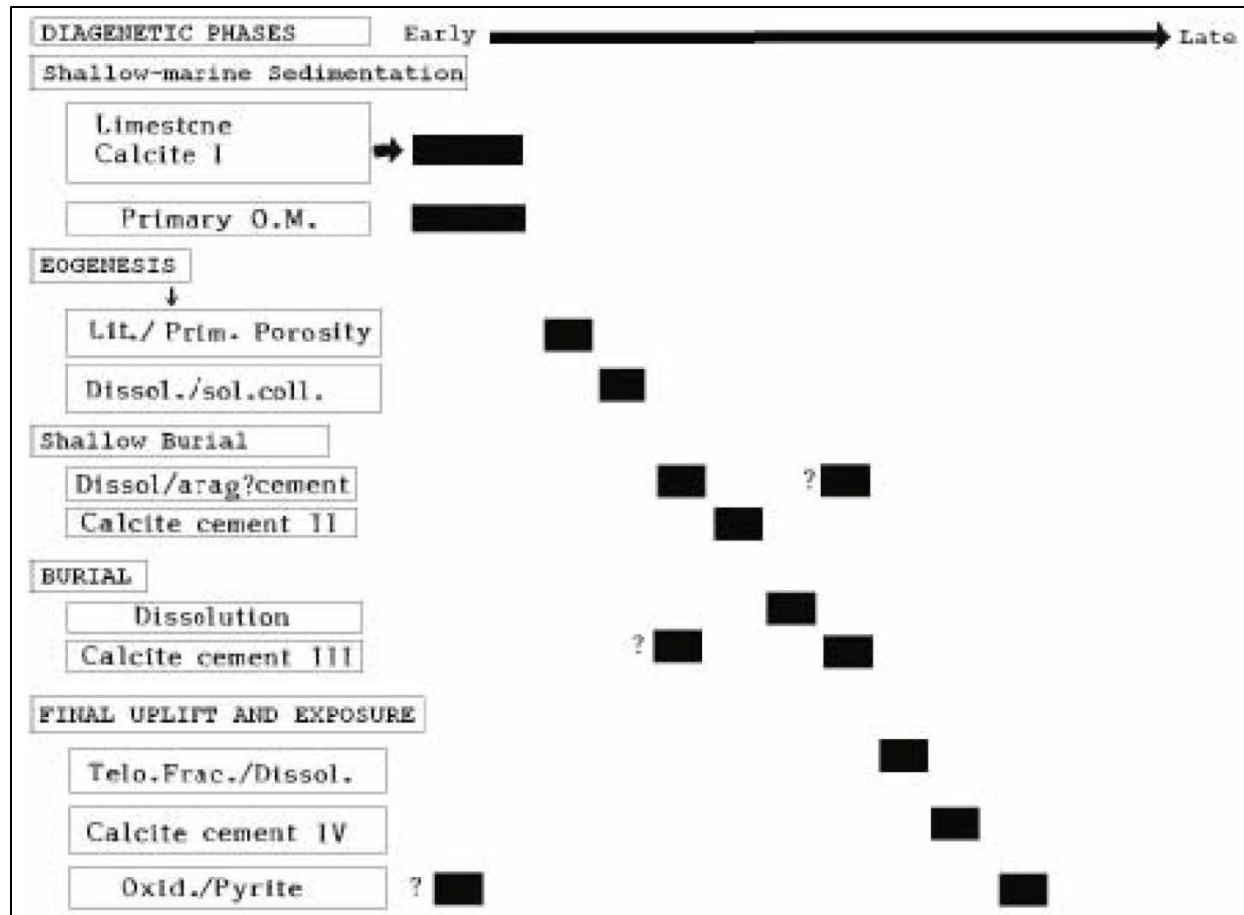


Figure 4. Sequence of diagenetic phases for the limestone facies exposed in Lebanon (cf. Bellos, in press). O.M. = organic matter, Prim. = primary, Dissol. = dissolution, sol. coll. = solution collapse, arag. = aragonite, Telo. = telogenesis, and Oxid. = oxidation.

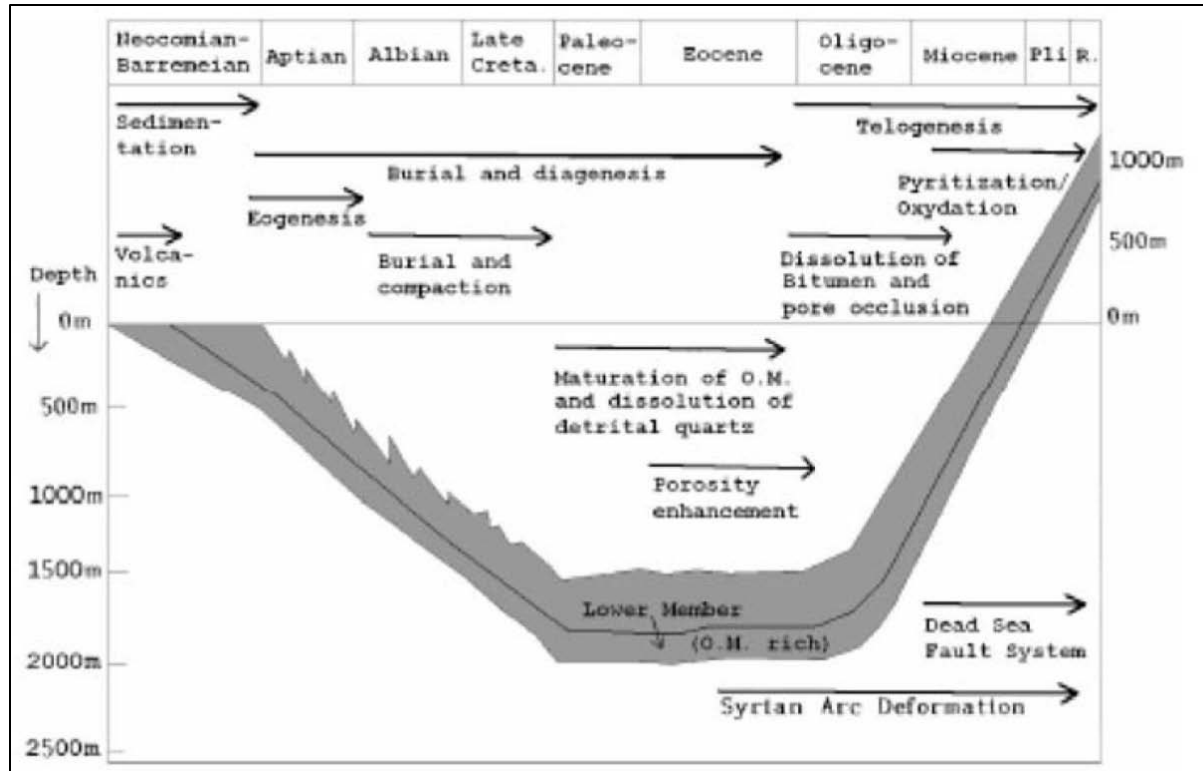


Figure 5: Burial curve with recorded diagenetic history of the Chouf Fm (Bellos, in press). Note the recorded burial estimation is estimated at 188 m, thickness is 300 m, and the resulting curve is uncorrected for compaction (Creta. = Cretaceous, Pli. = Pliocene, T. = Recent, and O.M. = Organic Matter). Based on this, the pyrolysis results in Bellos (in press) were estimated, and will be further exposed herein.