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Origin and Environment of Deposition of Lebanon Basal Sandstones

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ABSTRACT

Lebanon Sandstones were deposited during the Lower Cretaceous. They consist of sequences of thick and regular sandy beds alternating with thinner shaly beds. Their cross-bedding pattern belongs mainly to the tabular-planar type. Marine fossils are mostly absent while plant fossils are moderately represented, expecially in lignite veins and shaly beds.

Sedimentary structures observed on fresh sections suggest fluvio-deltaic and flood plain environment of deposition. Mineral associations and paleogeographical considerations indicate a strong relationship between them and the «Nubian Sandstones» in Jordan.

RÉSUMÉ

Le grès de base du Liban a été déposé au Crétacé Inférieur. Il est constitué par une succession de lits gréseux, réguliers et épais alternant avec des lits argileux plus minces. Leur interstratification s'apparente principalement au type tabulaire-planaire. Les fossiles marins sont pratiquement absents alors que les plantes fossiles sont modérément représentées, particulièrement dans les veines de lignite et dans les lits argileux.

Les structures sédimentaires, observées sur des sections fraîches indiquent que le milieu de déposition était de type fluvio-deltaïque et plaine submergée. Les paragenèses minérales ainsi que des considérations paléogéographiques témoignent d'une parenté probable entre eux et les «Grès Nubiens» de la Jordanie.

1. Introduction

Lebanon Basal Cretaceous Sandstones were called "Grès du Liban" and later "Grès de base" by DUBERTRET (1929-1963). They are interesting for economical, geological and environmental reasons. Also they probably have close relationship with Nubian Sandstones in Jordan and Palestine.

These sandstones are present in more than half of Lebanon subsurface and their outcrops cover about 1/20 of the territory. Their thickness varies from a few metres

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to 280 metres, reaching the maximum in Central Lebanon. Field measurements and observations were carried on 30 sections especially in quarries and along newly constructed roads. Primary sedimentary structures, position of petrified wood, distribution of amber and disposition of concretions were studied in order to determine the directions of paleocurrents and the physical characteristics of the basin of deposition.

Mineralogical composition and sedimentological characters of 200 samples were established by the means of microscopy, X-ray diffraction and heavy minerals analysis.

2. Stratigraphy

As early as 1833, BOTTA had described Lebanon Basal Sandstones as an independant formation. FRAAS (1878) and ZUMOFFEN (1926) both gave accurate stratigraphical descriptions. DUBERTRET (1929-1963) completed by far the most extensive geological work on this subject.

In Lebanon these sandstones are sandwiched between sediments of Upper Jurassic and Aptian age. They overly unconformably Jurassic limestones but as their upper limit is not always evident, it was fixed by DUBERTRET (1955) as corresponding arbitrarily to the appearance of first datable marine fossils. BISCHOFF (1963) extended their upper limit to the Hauterivian - Barremian and ascribed them mostly to the Neocomian. However, DUBERTRET denied them the equivalency of a stage and reported them as a transgression facies over the Jurassic.

In fact, fossils are rare in Lebanon sandstones. They are confined to certain marly horizons. Rare fish teeth, Gastropods and Ostracods fragments were encountered in a few places, but plant fossils are more common. Most sections contain lignite veins with a thickness of 10 to 40 cm and exceptionally of one meter. Petrified wood and leaf impressions often accompany lignite veins. The species *Weichselia*, *Credneria* and *Pleuropholis* were cited by BLANKENHORN (1927). Oxidized, brown to black amber is interstratified at many levels and in different locations.

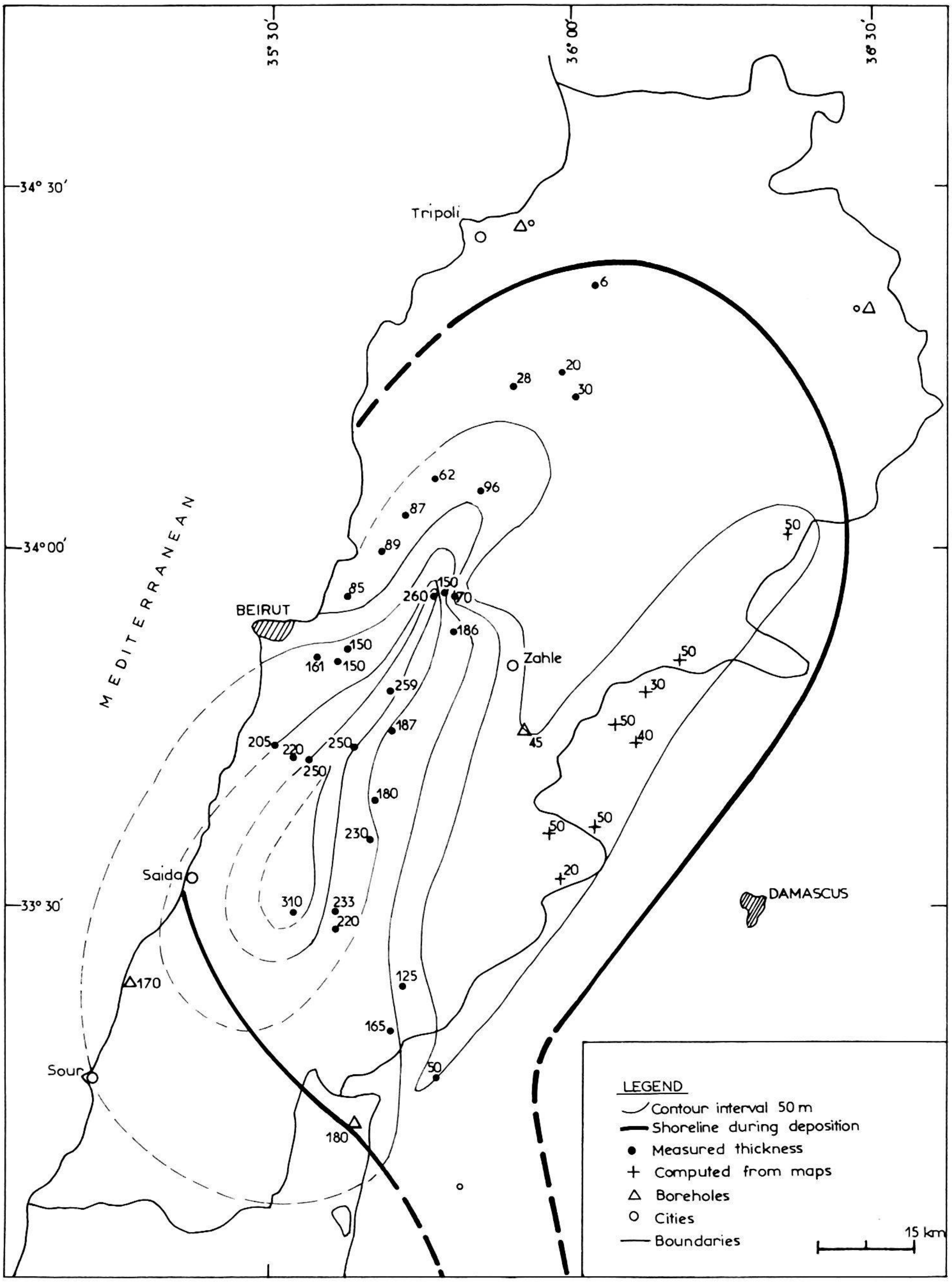
Basaltic intercalations are found in many sections. Basal Sandstones were deposited in the East and SE, later than they were in the West of Lebanon (DUBERTRET 1951).

3. Thickness and areal extension (see Textfig.)

Lebanon Sandstones exhibit a general semi-lenticular shape with a maximum thickness of about 280 m in Central Lebanon. They tend to disappear to the North and probably also to the West. They grade into shales in Syria. They become calcareous and argillaceous to the SW.

A continuity exists with the Basal Cretaceous Sandstones in Jordan and NE Palestine.

Cretaceous Sandstones are calcareous and shaly in North and Central Palestine (KARCZ 1965). In Jordan and SE Palestine, Nubian facies predominates and extends from Cretaceous through Lower Mesozoic and Lower Paleozoic (BENDER 1968; WETZEL & MORTON 1959). In Western and Central Syria, Basal Cretaceous becomes marly and locally ferruginous (WOLFART 1967; DANIEL 1963).



Isopach map of the Basal Cretaceous Sandstones.

4. Sedimentology

Lebanon Sandstones are made up of the following lithologies and types of beds:

1. White pure sandstone beds consisting of fine and subangular quartz grains. They constitute 5 to 10% of the total thickness of the formation.
2. Red sandstone beds with grains mainly medium to coarse in size and subrounded to rounded. Hematite is responsible for the red stain. 20 to 30% of total.
3. Yellow-orange sandstone beds with limonite and clay matrix. Variable size and grain roundness; 30 to 40% of total.
4. Clayey sandstones, grey or yellowish; 10 to 20% of total.
5. Grey shales, containing occasionally pyrite grains; 10 to 30% of total.
6. Lignite beds with an average thickness of 10 to 40 cm and a lateral extension up to 100 metres.

Quartz grains are generally well sorted, fine to medium in size, subangular to subrounded and mostly frosted. They are often coated with limonite, hematite or clay minerals. Some quartz grains include many rutile needles. Sutured and interlocked grains are frequent while undulatory ones are rare.

Kaolinite and to a lesser extent, montmorillonite constitute the predominant clay minerals. Illite, montmorillonite-illite and chlorite are irregularly represented.

The principal heavy minerals are tourmaline (blue and pink), zircon (yellow-orange) and rutile.

Opaque minerals consist of hematite, goethite, lepidocrocite, magnetite and pyrite. They are mostly of detrital origin.

5. Primary sedimentary structures

Lebanon Sandstones consist notably of an alternation of regularly stratified beds of variable thickness ranging from thin to massive. As a rule, lateral extension of beds is proportional to their thickness, though sandstone beds are mostly massive and shaly beds commonly thin.

6. Environment of deposition

6.1 Implication of the fossils

Almost total absence of marine fossils in Lebanon Sandstones points to their non-marine origin. Frequent and random interstratification in the sandstones of amber, whose specific gravity is close to that of water, indicates that the water level was most often corresponding to the level of the sediment at the time of deposition.

The presence of *Weichselia* species in lignite and shaly beds is an indication of the existence of local dunes. Rare Pelecypods, Ostracods and Charophyta oogonia remnants in some clayey levels are undeniable signs of the proximity to the sea. Limited transgressions could have been caused by local subsidence or by oscillation of the bottom of the sedimentary basin.

6.2 *Sedimentological implications*

Tabular-planar cross-strata are characteristic of deposition in shallow and relatively stagnant water. The non-rythmic alternation of beds of sandstones, clayey sandstones and shales is indicative of an irregularly repeated fluctuation of water level at the time of deposition.

The absence of topset deposits and the horizontal regularity of the strata suggest an erosional activity between two cycles of deposition.

Great thickness of beds and considerable lateral extent of the stratification are largely accepted as the signs of a flood plain sedimentation, while wedge and trough bedding attest to the original existence of local channels.

On the other hand, the thickness of beds is proportional to the hydrodynamic energy prevailing at the time of deposition. Consequently, shaly beds show a wider extension than equally thick sandy beds.

Cross-bedding is frequent and belongs chiefly to the planar-tabular type. Most foresets have an average dip of between 15° and 30°. The same values were found in Palestine (KARCZ 1965) and Jordan (WETZEL & MORTON 1959). Thickness of individual sets varies from 5 to 30 cm. Grains are relatively well sorted within each bed and sets show mostly uniform distribution and rarely graded bedding.

Wedge and trough types of cross-bedding are locally present. About 500 measurements of foreset azimuths (200 by the author in 1974 and 300 by KANAAN in 1966) indicate a general Westerly direction of the paleocurrents. This direction is supported by the E–W alignment of the petrified wood, as observed in several areas in Central Lebanon.

7. Similarity with "Nubian Sandstones"

Lebanon Sandstones exhibit nearly all the characters of "Nubian Sandstones":

1. Lower Cretaceous age at least in part. Though "Nubian Sandstones" of Jordan may range down in age to the Lower Paleozoic, Cambrian to Cretaceous (McKEE 1962; POMEYROL 1968).
2. Regular horizontal stratification with great lateral extent of beds.
3. Alternation of relatively well segregated beds of sandstones and shales.
4. Predominantly planar-tabular cross-bedding.
5. Relatively good sorting, fine to medium grain size and iron oxides or kaolinite coating of the quartz grains.
6. Nature and relative abundance of the heavy minerals: tourmaline, zircon, rutile.
7. Scarcity of marine fossils and moderate abundance of fossil plants.
8. Mainly continental, fluvio-deltaic, lagoonal and estuarine sites of deposition.

8. Source of sediments

At the end of the Jurassic, parts of Central and North Lebanon and Western Syria became emergent areas undergoing active erosion. Jurassic deposits are mainly calcareous and marly and could not provide sandy sediments. During Lower

Cretaceous time, the nearest possible sources for sandy materials were the Arabian "high" to the SE and Deir-ez-Zour "high" to the NE.

Dei-ez-Zour "high" was separated from the Lebanese basin by a marine depression directed to the NW, and passing through Aleppo region (WOLFART 1967). Consequently the Lebanon Sandstones could not have derived from that area.

As evidenced by sedimentary primary structures, the direction of the currents was NW in Jordan and westerly in Lebanon.

Furthermore a continuity exists between Lebanon Sandstones and "Nubian Sandstones" in South Jordan coupled with a close similarity in mineralogy and facies (BENDER 1968). Moreover, the heavy minerals association is indicative of a Precambrian acidic igneous and pegmatitic source rock environment.

All these facts point to the Arabian Shield as probably having constituted the major source for Lebanon Sandstones.

9. Conclusion

Lebanon Sandstones are composed of mature and reworked sand. Mineralogical characters and directions of the paleocurrents tempt relating them to the "Nubian Sandstones" of Jordan.

They were mostly deposited in a fluvio-deltaic environment transformed non-rhythmically into a submerged plain by flooding due to intermittent subsidence and heavy rainfall. With the decrease of the level and energy of water, coarse sand settled down first and was simultaneously reworked and sorted.

Later decantation of suspended clay formed argillaceous sandstones and shaly beds. Small depressions persisted for longer time as stagnant swamps, where organic matter was accumulated and later transformed into lignite. Progressive subsidence shifted eastwards according to the sheme of "delta switching" of MOORE (1958) and GOODLET (1959). A critical point was reached when deposition failed to compensate for subsidence. The result was a general transgression that caused the deposition of the more marly and calcareous Aptian and Albian sediments.

Subsidence is attested to by the contemporaneous tectonic activity suggested by frequent but locally limited volcanic extrusions.

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