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Lithostratigraphy of Senonian phosphorite deposits in the Palmyridean region and their general sedimentological and paleogeographic framework

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Abstract-- Phosphorite deposits in the Palmyrides Mountain Chain form a major portion of an Upper Campanian lithostratigraphic unit termed the Sawwaneh Formation which has a thickness that varies between 17 and 317 m. This region is subdivided into two lithologically differentiated zones, the northern ranges and the southern ranges. The Hamad Uplift, which bounds the Palmyridean Basin on the south, controlled phosphorite deposition. In the central part of the northern rim of the uplift only reduced phosphorite sedimentation occurred. The sedimentary milieus were enriched in phosphorus and plankton due to a regional paleogeographic evolution marked by the Senonian transgression and upwelling onto the Arabian platform.

Key words: phosphorite, Palmyrides Mountain Chain, Sawwaneh Formation, Palmyridean Basin, Hamad Uplift, Senonian transgression, Syria.

INTRODUCTION

Phosphorite deposits are encountered in some areas in Syria. The highest concentrations of phosphorites are located in the Palmyrides Mountain Chain, particularly in its southern central part where they have been mined in two mines for years.
Most of the studies that were carried out by Cayeux [1], Russian Technoexport Mission [2,3], Atfeh [4], Al Issa [5] and Abbas [6] on the phosphorite deposits focused mainly on the mineralogical and geochemical characteristics of the deposits exploited in the operating mines; in contrast, the lithologic and sedimentological characteristics were only restrictively and briefly reviewed. Accordingly, a clear perspective on the general paleogeographic framework of the phosphorite deposits and on their genesis has been lacking.
This study aims to specify the lithologic, paleontologic, petrographic and sedimentological characteristics of the phosphorite-bearing Senonian rocks in the Palmyrides Mountain Chain. We have constructed geologic cross-sections across the entire chain in order to delineate the paleogeographic framework within which the phosphorite deposits were formed.

LITHOSTRATIGRAPHY

The Palmyrides Mountain Chain, located in central Syria, is composed of a NE—SW elongated group, 350 km long, of mountains covering an area of 30,000 km^2. The Chain is segmented by a vast Neogene—Quaternary depression into northern ranges and southern ranges. The sedimentary series exposed in the Palmyrides Mountain Chain, which has ages ranging from the Upper Triassic up to Neogene, consists of several lithologic units (Figure 1); among these, the Soukhneh Group is characterized by its significant phosphorite deposits. This unit is composed mainly of two rock types: calcareous rocks and siliceous rocks. The first type is dominated by limestone, marly limestone, limy marl and marl with characteristic limy concretionary structures of few centimeters up to 2 m size. The siliceous rocks are

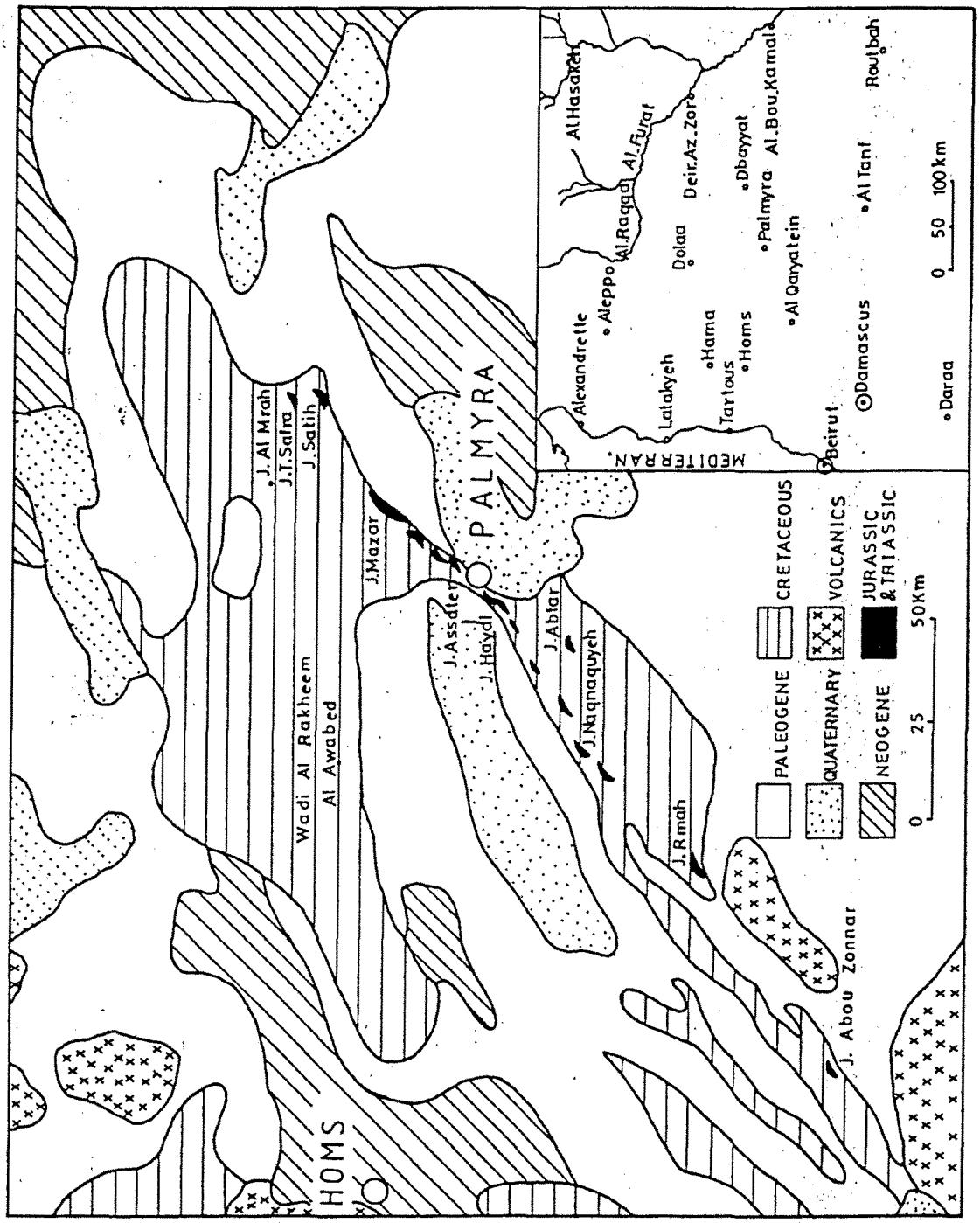
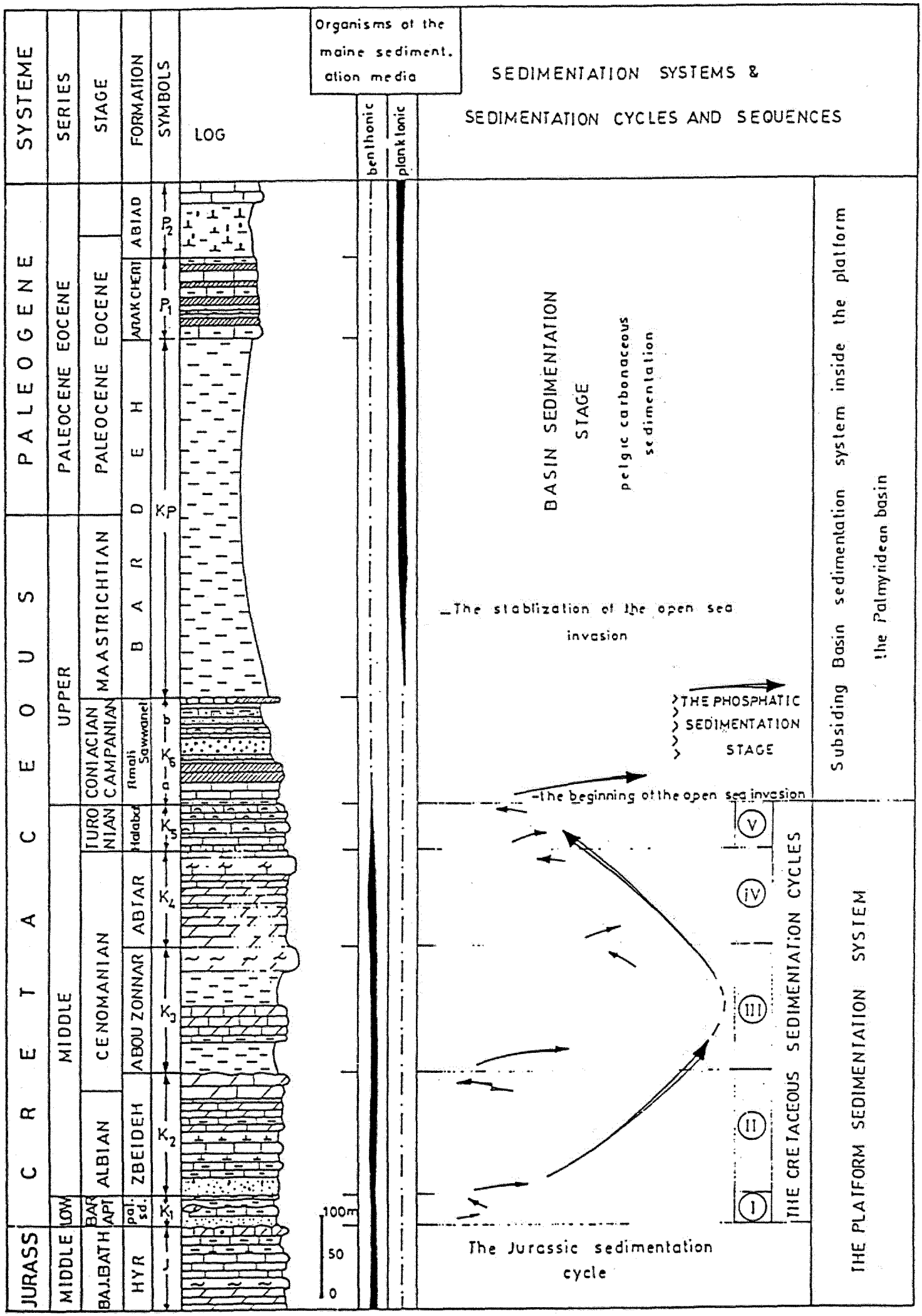


Figure 1. Simplified geological map of the Palmyrides Mountain Chain in central Syria.

composed generally of thin layered chert horizons or chert lenses and nodules. The Soukhneh Group is divided into two lithologic units: the Rmah Formation and the "Sawwaneh Formation" (Figure 3).

Rmah Formation

The lower part of the formation is composed of marly limestone and limy marl intercalated by thin limestone beds and concretions as well as by chert lenses and nodules. The upper part is composed mainly of marly limestone with concretionary structures distinguished by intercalating thin chert beds. The formation has an average thickness of 60—280 m,



General lithostratigraphic column and units in the Palmyrides Mountain Chain

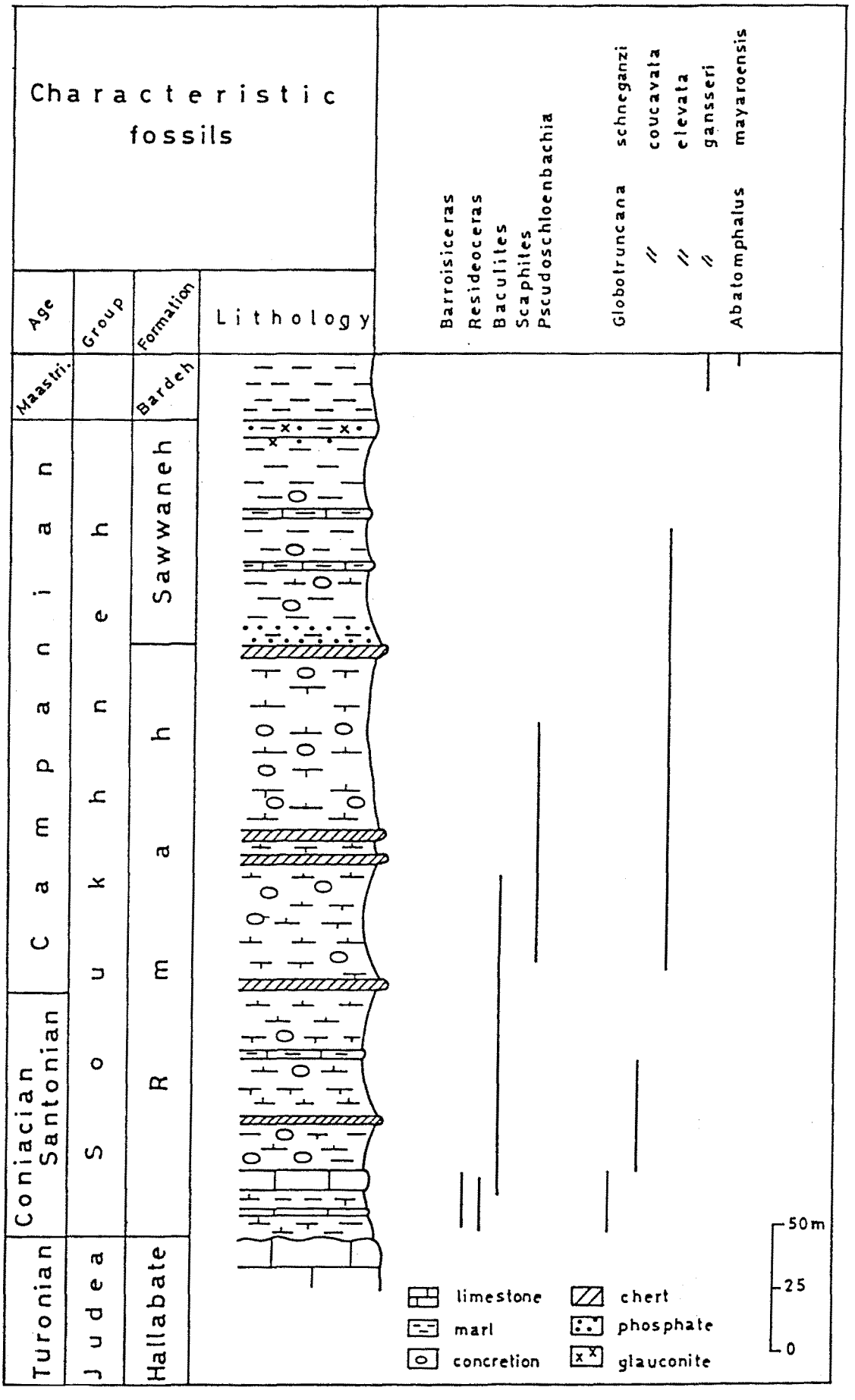


Figure 3. Stratigraphic section of the Senonian rocks in the Palmyrides Mountain Chain.

increasing northwards where it consists of a deeper water facies with a high content of ammonites, pelecypods and pelagic foraminifers. Toward the west and southwest the formation changes into a deep-water facies marl devoid of concretionary structures and is terminated by a cliff-forming chert horizon. According to the guide fossils present, the formation is given an age of Coniacian—Early Campanian (Figure 2).

Sawwaneh Formation

The basal part of the formation is marly limestone and limy marl intercalated with phosphorite beds varying in thickness and reaching a maximum of 10—12 m in the central southern range. The upper part of the formation is composed mainly of reddish yellow clayey marl intercalated with thin marly limestone beds with concretionary structures; this part of the unit is known as the"Erek Marl" and is overlain by a glauconite and phosphorite-bearing marl known as the "Tantour Marl". The latter marl is replaced locally by a siliceous horizon.

The thickness of the Sawwaneh Formation ranges from 17 m to 317 m. Generally, its thickness increases considerably northwards without significant facies changes, suggesting subsidence and deepening of the basin toward the north. The thick phosphorite horizons in the central part of the chain thin westwards and vanish totally below the overlying Erek Marl and Tantour Marl at the chain's westernmost extremities. Based on the occurrence of the microscopic pelagic fossils *Globotruncana calcarata* and *Globotruncana elevata*, the formation is assigned to the Upper Campanian.

The first listed fossil, defining the well-known *Globotruncana calcarata* zone, is characteristic for the Upper Campanian; its presence is restricted to the southwest extremity of the chain near Damascus. The second listed fossil, which is characteristic for Campanian in general, is present in the Sawwaneh Formation over the entire chain. Accordingly, the main phosphorites deposits in the Palmyrides Mountain Chain are assigned a Campanian age (Figure 3).

PETROGRAPHY

The macro- and microscopic facies of the Soukhneh Group show significant vertical and lateral variations. Among the main microscopic facies encountered are as follows:

In the limestone and marly limestone: Micrite and clayey biomicrite with pyrite, organic matter, clay minerals (sepiolite, attapulgite) and variable content of planktonic and benthonic foraminifers (the top horizons of mudstone and clay wackestone are rich in planktonic foraminifers).

Biomicrite—coquinoid microsparite with pelecypods of variable size.

Clayey glauconitic phosphatic biomicrite.

Laminated micrite with echinoids.

Organic biocalcarenite.

Biosparite with debris of mollusca, echinoids and benthonic foraminifers.

Biopelmicrosparite.

In the siliceous rocks: Siliceous lutite with micro- to cryptocrystalline quartz and chalcedony. It contains inclusions of micrite, microsparite, dolomicrite and fine planktonic foraminifers.

In the phosphorite rocks and phosphatic limestones; A wide spectrum of facies is encountered. The facies vary from biomicrite—microsparite with a small content of phosphatic grains to friable phosphatic arenite. The phosphatic components are generally granular with grain sizes of 0.05 to 0.5 mm; occasionally, the phosphate grains are millimetric and rarely centimetric to decimetric in size (remnants of vertebrae), and they form 10 to 80% of the rock. Some phosphatic rocks contain conglomerate-like chert pebbles and large shell horizons. The petrography of the phosphatic components reveals different kinds of phosphatic grains [7-9]; among these are phosphatic pellets, coated phosphatic grains composed of two or three aggregated grains, grains with non-phosphatic nuclei, irregular grains, coprolite grains resulting from the epigenesis of organic matter, grains with inclusions of non-organic, organic

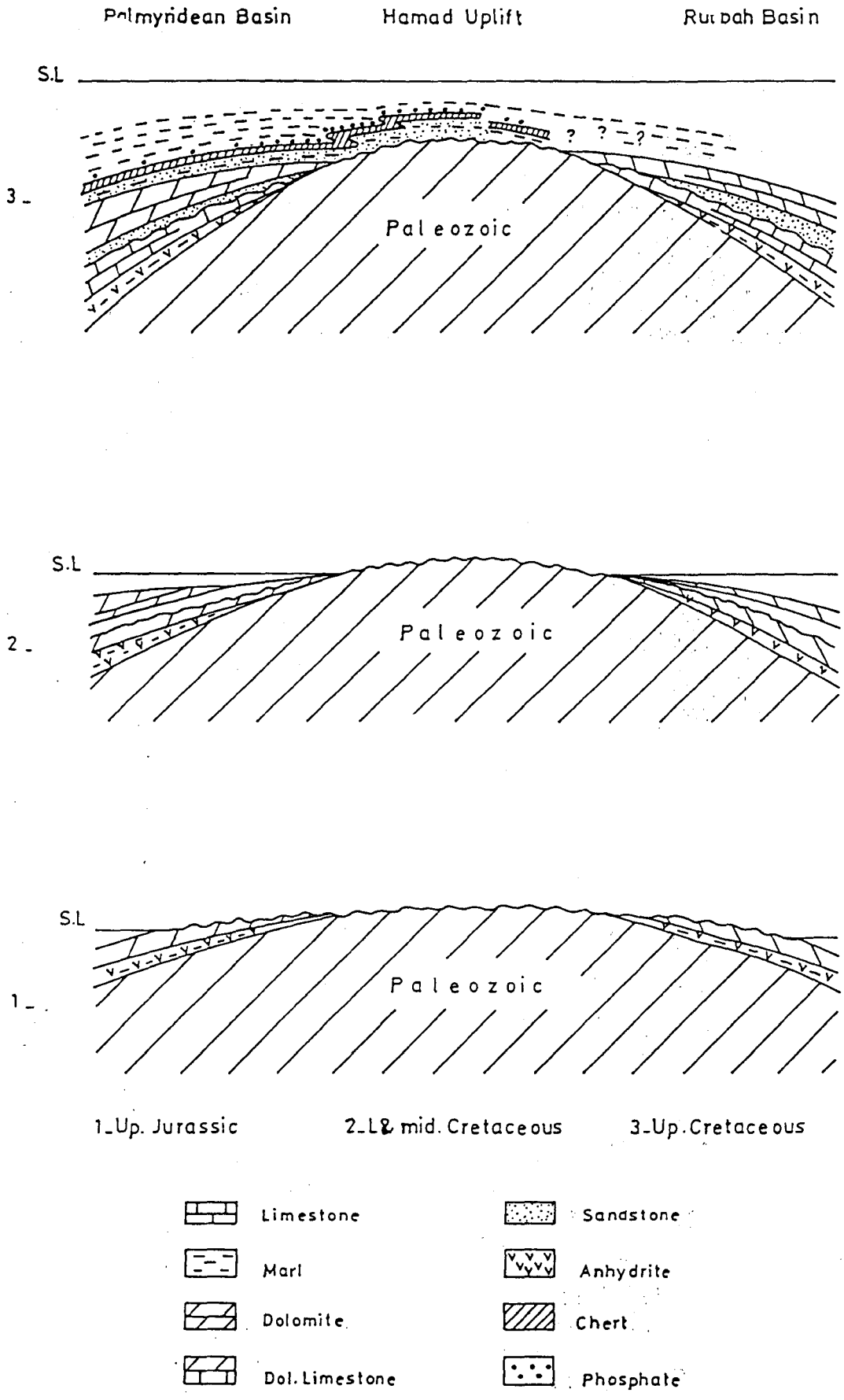


Figure 4. Lateral sedimentologic and paleogeographic effects of the Hamad Uplift from the Late Jurassic till the end of the Cretaceous.

and mineral substances, fish scales, teeth and vertebrae, irregularly-shaped and reworked grains. Phosphate beds may contain some limy and cherty clasts along with phosphatic grains which in turn contain organic matter in variable amounts.

SEDIMENTOLOGICAL AND PALEOGEOGRAPHIC FRAMEWORK OF THE FORMATION OF PHOSPHORITE DEPOSITS

During the deposition of the Soukhneh Group in the Palmyrides an important change in the sedimentary conditions throughout the entire region took place. For the first time since the onset of the Cretaceous, marine waters rich in planktonic foraminifers flooded the platform. Accordingly, the Hamad Uplift , which had remained emergent since the beginning of the Mesozoic, was submerged for the first time in its history by the Senonian sea. This submergence was modified by local features such as the Hamad Uplift which controlled phosphorite sedimentation in Senonian time [7-10] (Figure 4).

During the formation of the Rmah Chert Formation the Palmyridean region was initially shallow, in general, with lateral variations of sea floor morphology. The region was slightly but variably effected by the Senonian transgression. Consequently, it is marked by diversified sediments. Hence, the calcareous, siliceous and phosphatic limestones have vertical and lateral variations in structures and organic matter content. The calcareous sediments with clastic quartz at the base of this formation, encountered in the central part of the southern range of the Palmyrides, mark the onset of the Senonian transgression onto the Palmyridean region in general and the Hamad Uplift in particular. Unstable conditions during the phosphorite deposition were behind the presence of phosphatic limestone within this formation. The dominance of siliceous sedimentation at the end of the formation of the Rmah Chert Formation throughout the entire Palmyrides indicates general subsidence and paleoceanographic conditions suitable for silica abundance in the waters of the Palmyridean Sedimentary Basin. In part at least, this might be related to submarine acidic volcanism on the northern Arabian platform which enriched the sedimentary milieus by a regional silica supply. More likely, however, it reflects increased upwelling and higher biosiliceous productivity [11]. Such milieus in the northern range of the Palmyrides were deeper and more pelagic, for instance, at Jabal Al Mrah.

During the deposition of the Sawwaneh Formation, the entire southern range of the Palmyrides was characterized by the sedimentation of phosphorite around the rim of the Hamad Uplift. This structure was elongated to the south of the Palmyridean Basin between the localities of Bardeh and Soukhneh. The phosphorite sedimentation was concentrated most markedly in the central part of the northern rim of the mentioned uplift. The presence of associated calcareous and siliceous sediments confirms lateral variations in sedimentary conditions in the Palmyridean Basin. The marginal rim of the rising Hamad Uplift formed submarine highs which were especially suitable sites for phosphate sedimentation and concentration. Among the additional factors contributing to this sedimentation was the enrichment of phosphorus from the P-rich deep water on the northern edge of the Arabian Platform by currents which upwelled onto this extensive platform. The warming up of the platformal water on one hand, and the abundance of nutrients on the other, caused a proliferation of plankton which assimilated, stored and concentrated a large amount of phosphorus. After the deposition of the plankton, a huge amount of phosphorus dissolved and became concentrated in the sea-floor sediments, The contribution of the bacterial activity in such environments in the deposition of phosphorite is a possibility. Such environments existed in the central northern rim of the Hamad Uplift, in particular at variable depths ranging from few meters to fifty meters at maximum. The differences in the prevailing physico-chemical and energy conditions in these environments led to successive phosphatic, calcareous and siliceous deposits. The amount of planktonic and benthonic foraminifers in the sediments deposited varied considerably according to the prevailing conditions resulting from the Senonian transgression. Generally, the depth of the Palmyridean Basin increased from the central northern rim of the Hamad Uplift outwards, but the depths increased more rapidly northwards. Consequently, the northern range of the Palmyrides has experienced steady subsidence and deepening since the deposition of the Rmah Chert Formation and accordingly pelagic calcareous sedimentation, almost devoid of phosphorite, prevailed.

The reviewed paleogeographic and sedimentological characteristics confirm that the Palmyridean Basin started differentiating and continued developing throughout Coniacian—Santonian—Campanian time. This basin was bounded on the south by the Hamad Uplift where phosphorite sedimentation prevailed. The deep and subsiding central part of the basin, located in the northern range of the Palmyrides, was characterized by a steady deposition of pelagic calcareous sediments.

The presence of this paleogeographic structure (Hamad Uplift) is confirmed by the variations in thicknesses of the Soukhneh Group measured in sections across the entire Palmyrides and by the typical reduction in phosphorites located around the rising rim of the Hamad Uplift.

Phosphorite deposition diminished gradually towards the northern areas of the Palmyridean Basin where it was replaced by monotonous and thick calcareous sediments. Local phosphorite deposition at the northern margin of the Palmyridean Basin (Al Awabed, Wadi Al Rakheem) was most likely related to sea floor rises attached to the southern rim of the Aleppo Uplift; i.e. a distinctive paleogeographic structure bounded the Palmyridean Basin to the north.

The remarkable thickness of the marly, pelagic Bardeh Group (Cretaceous—Paleogene), which overlies the Soukhneh Group, gives evidence for the belief that the Palmyridean Basin continued subsiding, deepening and developing a differentiated shape during Late Cretaceous—Paleogene time span.

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REFERENCES

1. L. Cayeux. Contribution sur les phosphates Senoniens de Syrie, *C. R. Acad. Sci.* 200, 1553-1555 (1935).
2. Russian Technoexport Mission. *The geological map of Syria. Scale 1/1,000,000: Explanatory notes.* (Technoexport, U.S.S.R). Ministry of Industry - Syria (1966).
3. Russian Technoexport Mission. *The geological map of Syria. Scale 1/200,000: Explanatory notes, Sheet: XIV, XV, XVI, XX, XXII.* (Technoexport, U.S.S.R). Ministry of Industry - Syria (1966).
4. S. Atfeh. *The phosphate deposits in Syria.* Ph.D. Thesis, University of London, London (1967).
5. M. Al Issa. *The geological structure and the composition of phosphatic deposits in Palmyridean Basin.* Ph.D. Thesis, Institute of Geological Research, University of Moscow, Moscow (1972).
6. M. Abbas. *Geochimie de l'uranium des phosphorites des Palmyrides centrales, Syrie.* These d'Etat, Institut de Geologie, Universite de Strasbourg, Strasbourg (1987).
7. A.Kh. Al Maleh. Les depots phosphates du Senonien en Syrie et les conditions paleo-geographiques de leur genese. In: *27em Intern. Geol. Cong. Volume 11.* p.92. Moscow (1984).
8. A.Kh. Al Maleh. The general characteristics of Cretaceous sedimentation in the northern part of the Arabian Platform (the Syrian Platform). In: *8th IAS Regional Meeting of Sedimentology.* pp.34-35. Tunis (1987).
9. A.Kh. Al Maleh. The geology of the phosphatic deposits in Syria (Senonian and Palaeogene). In: *10th International Field Workshop and Symposium.* pp.xx-xx. Tunis (1987).
10. A.Kh. Al Maleh and M. Mouty. The sedimentary and paleogeographic evolution of the Palmyridean region during Cretaceous. In: *Proceedings 3rd Jordan Geological Conference.* pp.213-244 (1988).
11. Z. Reiss. Assemblages from a Senonian high-productivity sea, *Révue de Paleobiologie,* Vol. Spéc. no.2, 323-332 (1988).