

Overview of the Triassic System in Syria: Lithostratigraphic and biostratigraphic correlations with neighboring areas

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ABSTRACT

Biostratigraphic data provide evidence of the presence of Triassic sedimentary successions in the main mountain belts in Syria. The study of the sedimentary successions in these chains and in the main deep wells lead to a new subdivision of the Triassic in Syria into four lithological units/formations: (1) The lower Habari Formation is clastic and Scythian to Early Anisian in age. (2) The overlying Abu Fayad Formation is generally carbonaceous, Late Anisian to Ladinian in age, and subdivided into three members. (3) The Hayan Formation is mainly evaporitic and Carnian – Norian in age. (4) The upper Safa Formation is generally carbonaceous, with some marl intercalations and thin evaporite beds, and Norian to ?Rhaetian in age. These lithological formations extend over the entire northern Arabian platform with very characteristic and distinguishable facies, rendering their correlation within Syria and to their equivalents in neighboring countries straightforward. Moreover, lateral facies changes in these formations enabled establishing a geological and paleogeographical evolution of Syria and the surrounding areas during the Triassic Period. This evolution revealed the presence of two NE-elongated Triassic paleostructures: Hamad Uplift in the south and Aleppo-Mardine High in the north, which separate the Palmyride Basin from the Rutbah Basin in the south, and the Palmyride Basin from the Ifrine Basin in the north, respectively.

INTRODUCTION

The first evidence for the occurrence of Triassic rocks in Syria was mentioned by Dubertret (1937) in exotic allochthonous blocks obducted within the ophiolitic complex onto northwest Syria. These scattered blocks are composed of compact grey sandy limestone becoming in places grey thinly laminated limestone, with *Halobia parcelltica* Kittl, *H. norica* Mojs, or *H. plicosa* Mojs, and *Daonella imperialis* Kittl. Further studies demonstrated the presence of Triassic rocks in Syria's major ranges in, for example, the Palmyrides (Mouty, 1976; BRGM, 1977, Mouty and Al-Maleh, 1983, 1997a), the Coastal Chain (Jibal As-Sahilyeh) (Mouty, 1997b) and the Mount Hermon (Anti-Lebanon) (Mouty and Zaninetti, 1998; Mouty, 2000) (Figure 1).

Oil and gas exploration wells penetrated Triassic formations in different parts of Syria providing valuable data, which enhanced the knowledge of this period. At least two lithological terminologies were used to describe the subsurface Triassic section. The first was formally defined in Syria, while the other was adopted from northern Iraq. Syrian petroleum geologists abandoned the Syrian terms in favor of Iraq's in order to establish better and easier correlations between lithostratigraphic formations, which usually lacked biostratigraphic markers. After the discovery of oil and gas in clastic reservoirs in the Euphrates Graben area during the 1980s, a specific terminology was established for that particular area by the petroleum operators (SPC, the Syrian Petroleum Company, AFPC with Shell and DEZPC with Elf and Total). There the entire Triassic section was named "Mulussa" with a local sequence definition between Mulussa A (Scythian) and Mulussa H (Rhaetian to Lower Jurassic) (Jamal et al., 2000). Figure 2 shows the established subdivisions of the Triassic successions of Syria, their age and their correlations with neighboring countries.

Later studies, carried out on the Triassic successions in Syria, demonstrated discrepancies between the Syrian petroleum geologists' reference chart and those defined in other countries, in particular Iraq. This led to confusion and occasionally to erroneous lithostratigraphic correlations (Bach Imam and

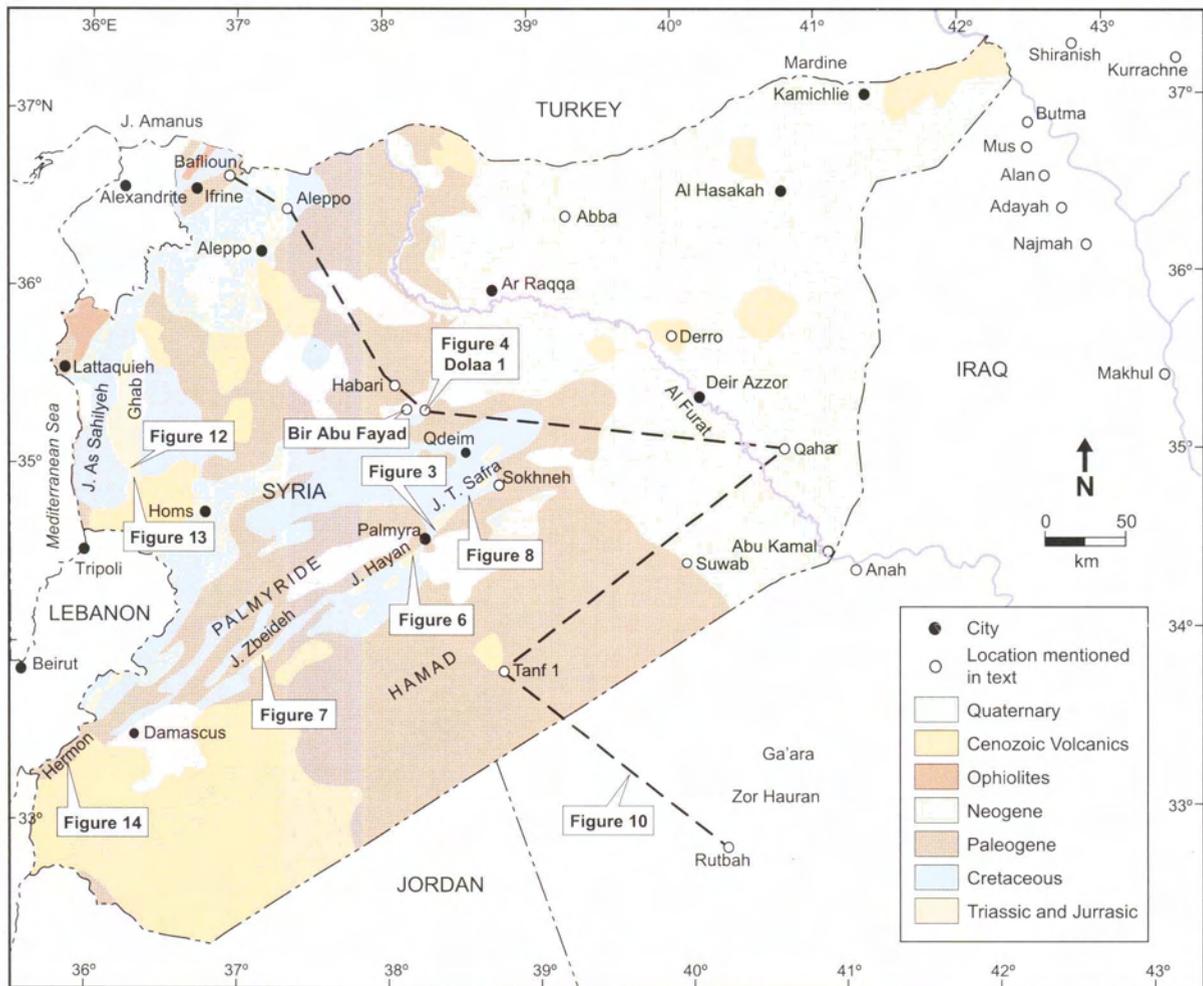


Figure 1: Schematic geological map of Syria (after Ponikarov, 1966) showing the type localities of Triassic formations in the region.

Sigal, 1985; Kammar, 1994). Moreover this left doubts on the validity of earlier correlations conducted by petroleum geologists between Syrian lithological units and Iraqi charts.

The first objective of this paper is to review all the subdivisions of Syrian Triassic successions made by different workers in order to establish a local stratigraphic subdivision based on numerous lithological, macro- and micropaleontologic criteria. The second objective is to correlate Triassic formations and lithological units within Syria and with those in neighboring countries, and to improve the understanding of the paleogeography of the northern Arabian Platform during the Triassic Period.

STRATIGRAPHY AND SUBDIVISIONS

Outcropping Triassic rocks in the cores of the major Syrian ranges do not show the entire Triassic section. Hence, studying complete Triassic successions is mainly based on subsurface data. The Palmyrides Belt is the most favorable area to establish a Triassic subdivision for all of Syria, due to the numerous borehole penetrations, and to the common exposure of Upper Triassic successions in the Palmyrides anticlines (Figure 3).

The first Triassic-penetrating reference well used in this study is Dolaa 1 drilled by SPC in 1948, about 78 km north of Palmyra (Syria) at 35°15'40"N and 38°20'09"E (rotary table elevation 491 m above sea level; Figure 1). There, for the first time, Dubertret and Daniel (1962) and Daniel (1963) described and subdivided the Triassic successions into five lithostratigraphic units. This subdivision differs from the

Locality Age	SYRIA					IRAQ			JORDAN	PALES-TINE																						
	Ancient	Syria Petroleum Company	Kammar (1994)	TOTAL Jamal et al. (2000)	This Study	South-west	North-west	North	W. Zarka	W. Ramon																						
Late and Mid Jurassic	Dolaa Group	I	Qamchuqa	Mulussa	Mulussa	Satih	Muhaiwir	Sargelu	Sargelu Sekhah-nian	Subehi	Mishor																					
Rhaetian												Sargelu Alan Mus Adayah Butma	C	H	Safa	Ubaid	Alan Mus Adayah Butma	Sarki	Zarqa	Shefayim												
Norian														G							Hayan	Zor Hauran	Balluti	Balluti	Mohilla							
														F												D	E	Hayan	Zor Hauran	Balluti	Balluti	Mohilla
														E																		
Carnian		D	C	Abu Fayad	Mulussa	Kurra-chine	Kurra-chine	Hisban	Saha-ronim																							
Ladinian		III								Kurrachine Dolomite	B	C	Kurra-chine	Kurra-chine	Hisban	Saha-ronim																
Anisian																	IV	B	B	Kurra-chine	Kurra-chine	Hisban	Saha-ronim									
Scythian		V	Amanus Shale	A	A	Habari	Gelikhana	Humrat Main	Zafir																							
										Late Permian	II	Amanus Sandstone	A	Qdeim	Ga'ara	Chia Zairi	Argov															
Doubayat Group	I	Amanus Shale	A	A	Habari	Beduh	Humrat Main	Zafir																								
									Late Permian	II	Amanus Sandstone	A	Qdeim	Ga'ara	Chia Zairi	Argov																

Figure 2: Correlation between formations and units in Syria and in neighboring countries. See Figure 1 for location.

Triassic subdivisions in Iraq, which was later adopted by Syrian petroleum geologists for describing almost all major wells in Syria. This difference is outstanding when comparing two very close wells in the middle of the Palmyride Basin, namely Dolaa 1 (drilled in 1948 by SPC, Figures 4 and 5) and Bir Abu Fayad well (drilled in 1988 by SPC), using all data cited by previous authors. The Dolaa 1 section is described according to the old Syrian Triassic subdivision (Dubertret and Daniel, 1962, Daniel, 1963), while Bir Abu Fayad well, just 15 km away to the west of Dolaa 1, was described by petroleum geologists according to the Iraqi Triassic subdivision (Kammar, 1994) (Figure 5).

Throughout this study, four lithological units are distinguished in the Syrian Triassic succession, particularly in the Palmyride Basin. They represent two major sedimentary cycles: (1) the first starts with a lower clastic unit, overlain by a calcareous carbonate one; and (2) the second is composed of an evaporitic unit overlain by an upper carbonate unit. Without specific mention in the following sections, all lithostratigraphic description refer to the well Dolaa 1.

Triassic Lower Clastic Unit: Habari Formation

This unit corresponds to Unit I of "Doubayat Group" in Dolaa 1 (Figure 4). According to Dubertret and Daniel (1962) it consists of 110 m (2,258–2,368 m below rotary table – RT) of thick black silty shale with fine grey limestone intercalations, becoming calcareous upwards. It bears the fauna assemblage *Halobia* sp., *Daonella moussoni* Sea, *Myophoria kefersteini* group, cf. *Mr. vulgaris* (Schlotheim), cf. *Hoernesia socialis* (Schlotheim), *Pseudomonotis* cf. *clarei* (Emmrich), *Gervillia angusta* (Goldfus), *Worthenia* sp.? *Estheria*, "Orthoceras sl, *Gonodus* sp., *Natiria gaillardoti* (Lefr), *Ceratites* cf. *trinodosus* Mojs, teeth of

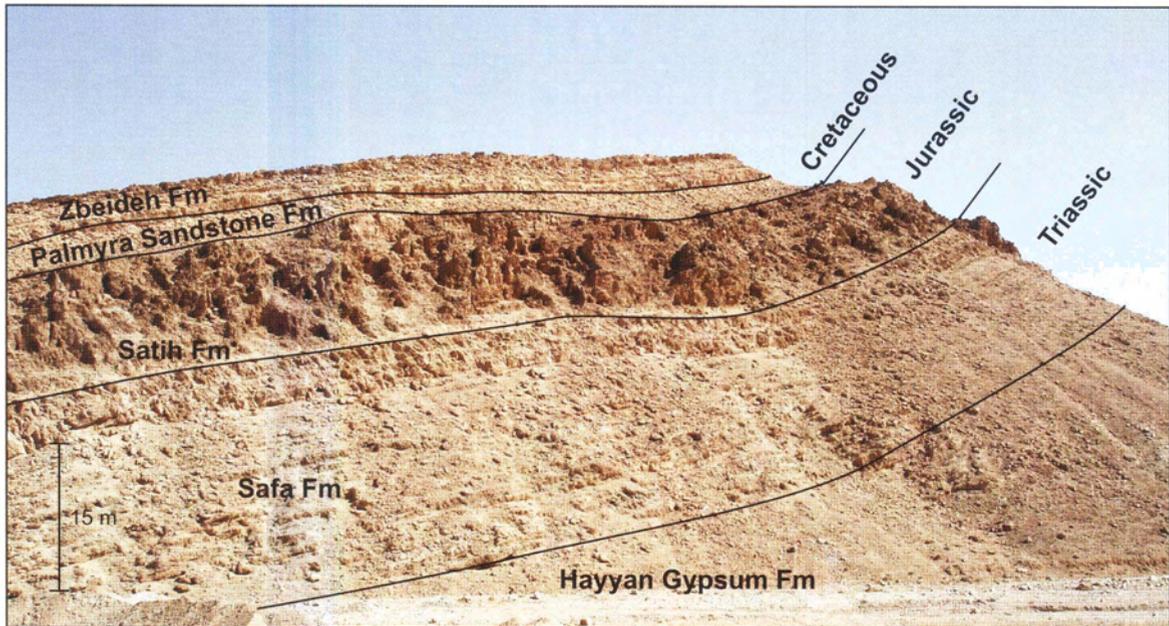


Figure 3: Outcrop of the Middle – Upper Triassic Hayan Gypsum Formation, Upper Triassic Safa Formation, Lower – Middle Jurassic Satih Formation, and Lower Cretaceous Palmyra Sandstone Formation and Zbeideh Formation in the Palmyrides area. Height of the cliff is 50 m, see Figure 1 for location.

?*Nothosaurus* (Hudson determination). Therefore, the Lower Clastic Unit could be dated Anisian and Early Triassic (Scythian).

Lithostratigraphic correlation of Dolaa 1 with Bir Abu Fayad (Figure 5) shows that petroleum geologists in Syria named this clastic unit “Amanus Shale Formation” as an equivalent to the upper part of the clastic successions in the Mount Amanus in the northeast of Alexandrite (Figure 1) described by Dubertret (1932, 1936) and named “Amanus Group” by Henson (1941). This name was initially used by the Syrian Petroleum Company (SPC) geologists for the beds they later called “Doubayat Group” in reference to Dolaa 1. Furthermore, the correlation between the section of the Mount Amanus and that of Dolaa 1 was subsequently over-ruled by the same authors (Dubertret and Daniel, 1962).

Because the correlation is confusing it is preferable to abandon misleading terms and refer to Unit I of “Doubayat Group” of Dolaa 1, as a stratotype of this clastic unit of Lower Triassic. The present authors suggest the term “Habari Formation” for this clastic unit, after the name of a small hill located 35 km northwest of Dolaa 1.

Petroleum geologists in Syria gave the underlying unit (Unit II of “Doubayat Group” in Dolaa 1) the term “Amanus Sand Formation” (Figure 5), which is composed of grey-reddish shale and micaceous sandstone and quartzite with rare thin slightly fossiliferous limestone beds dated as Permian. For the same reason as justified for the “Amanus Group”, we suggest naming this Permian unit the “Qdeim Formation”, after the name of a locality located 55 km northeast of Palmyra.

Triassic Carbonate Unit: Abu Fayad Formation

In Dolaa 1 (Figure 4), this 493 m thick unit (1,765–2,258 m below RT) is represented by three members and consists, according to Dubertret and Daniel (1962), from bottom upwards, of the following members:

Member A (Unit V of “Dolaa Group”, Figure 2) composed of 204 m (2,054–2,258 m below RT in Dolaa 1) dark grey limestone with some silicified microclastic intercalations. It contains the following fauna:

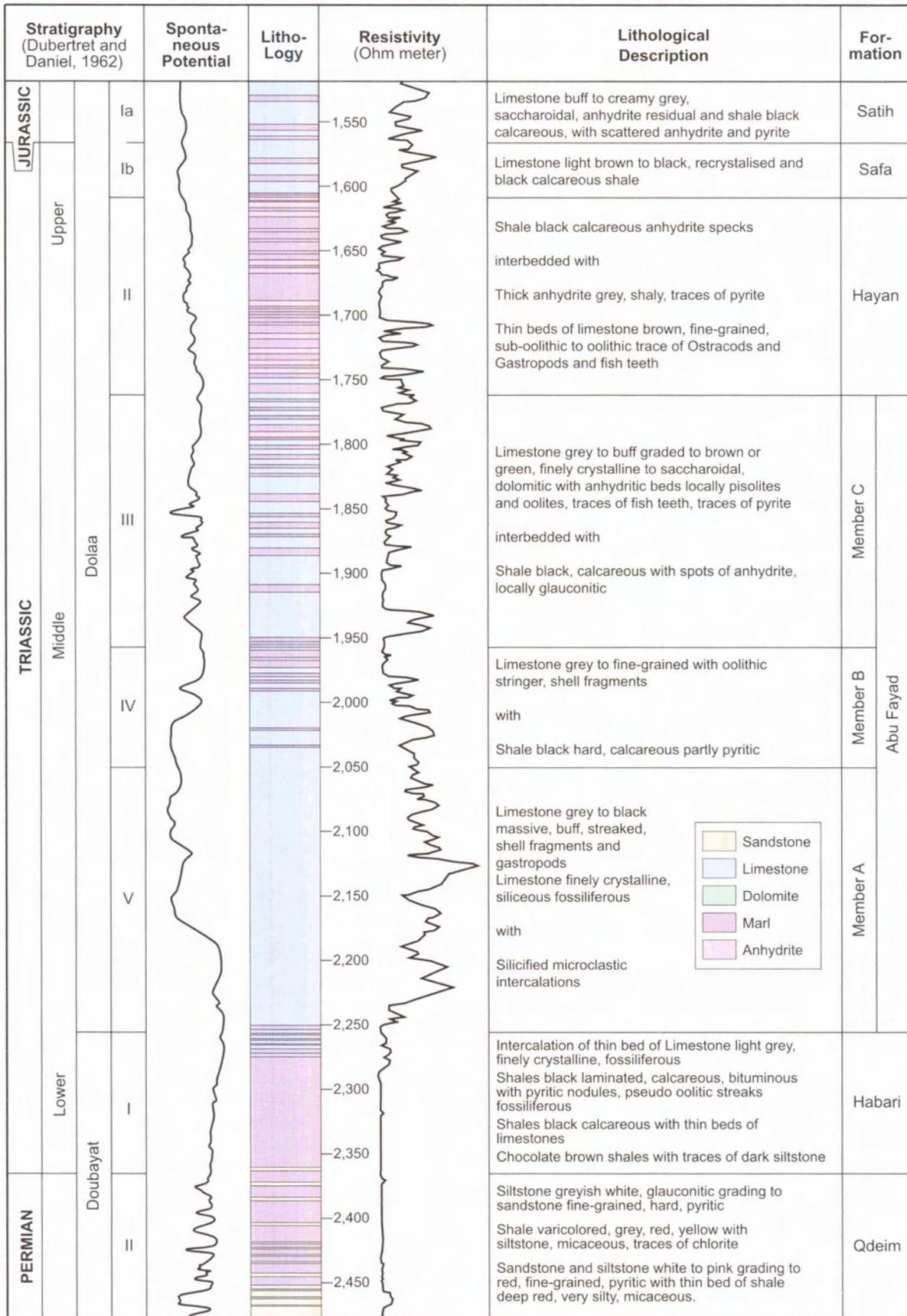


Figure 4: Dolaa 1 reference well: lithostratigraphy and proposed terminology. See Figure 1 for location.

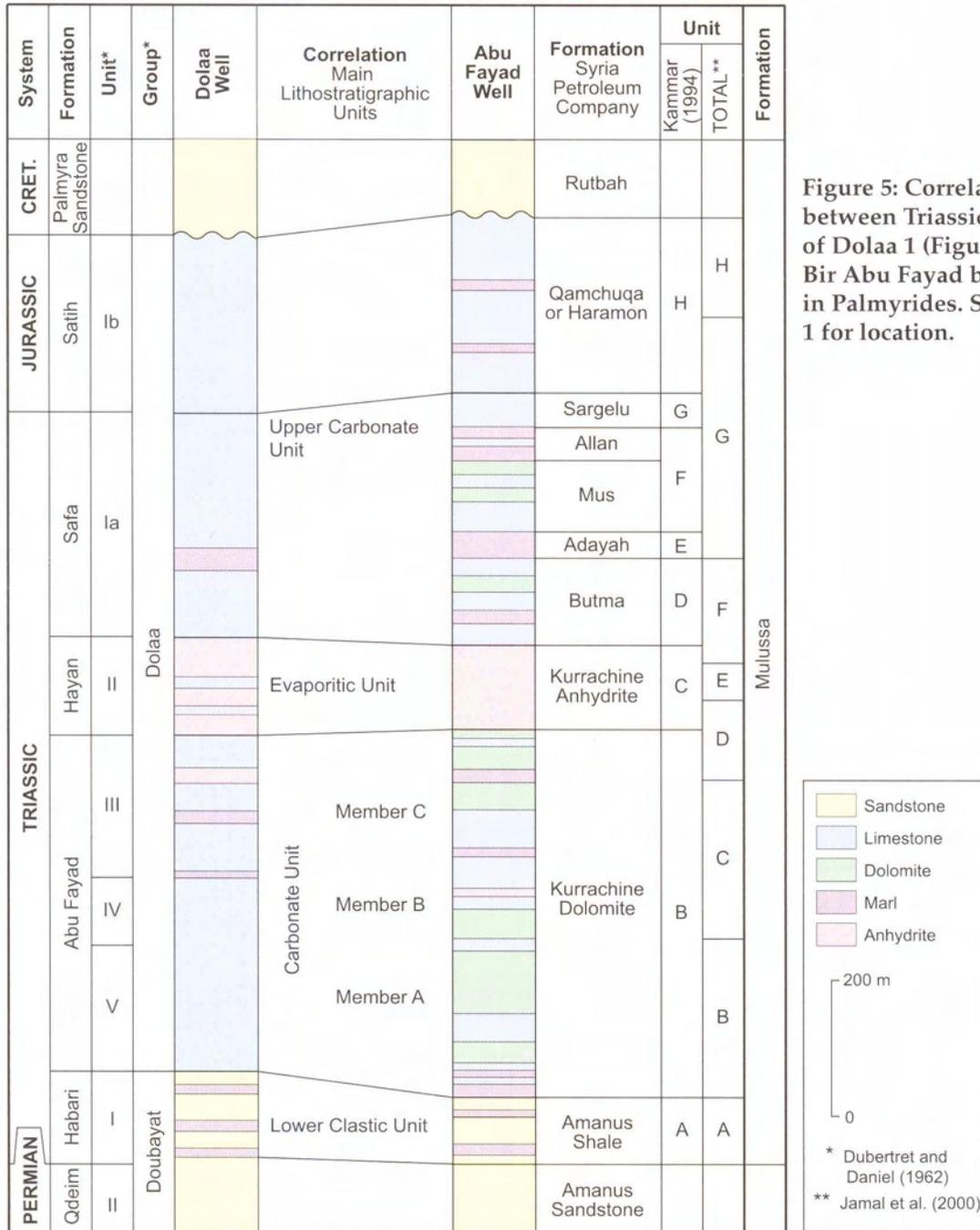


Figure 5: Correlation between Triassic sections of Dolaa 1 (Figure 4) and Bir Abu Fayad boreholes in Palmyrides. See Figure 1 for location.

Posidonia juv. cf *P. wengensis* group, *Posidonia wengensis* Wissman var. *cycloidalis* Kittl, *Daonella lomelli* Mojs, *Avicula globosa* Wissman (Hudson determination), indicating an Anisian age.

Member B (Unit IV of “Dolaa Group”, Figure 2) composed of 94 m (1,960-2,054 m below RT in Dolaa 1) grey, silty or oolitic or crystallized limestone, with hard black shale. It contains the following microfauna: *Trocholina* sp., often abundant, Radiolaria, small foraminifera, ?*Nodosaridae*, *Fronicularidae*; thus dated as Ladinian.

Member C (Unit III of “Dolaa Group”, Figure 2) is 195 m (1,765-1,960 m below RT in Dolaa 1) brown and grey dolomitized limestones, with rich in black dolomitic shale beds and occasional anhydrite beds or nodules in the middle part, oolitic limestone with *Lingula tenuissima* Bronniman, ostracoda and micoforaminifera. Accordingly, it is dated as Ladinian.

The correlation of Dolaa 1 with Bir Abu Fayad (Figure 5) shows that petroleum geologists termed this carbonate unit “Kurrachine Dolomite Formation”, as an equivalent to the lower part of “Kurrachina Formation” of Wetzel (1950) after the Kurrachina ridge (Amadia area), with its type locality in northern Iraq (Figure 1).

We believe the correlation with the “Kurrachina Formation” is not correct because this formation should be correlated only with the upper part of the “carbonate unit” (Member C), as described above. It is preferable in this case, to consider the above described unit in Dolaa 1, as the stratotype of this carbonate unit, and we suggest naming it the “Abu Fayad Formation”, after the locality “Bir Abu Fayad”, situated 15 km to the west of Dolaa 1.

Triassic Evaporitic Unit: Hayan Formation

This unit is represented in Dolaa 1 by Unit II of the Dolaa Group (Figure 4). It is composed from the bottom to the top, according to Dubertret and Daniel (1962), of 155 m (1.610–1.765 m below RT) thick black calcareous shale, alternating with thick anhydrite beds and some thin oolitic limestone beds, rich in ostracods, gastropods and fish teeth.

Correlation of the Dolaa 1 log with that of Bir Abu Fayad (Figure 5) shows that petroleum geologists termed this unit “Kurrachine Anhydrite Formation” as an equivalent to the upper part of “Kurrachina Formation” (Wetzel, 1950) of the Amadia area in northern Iraq, which seems to us unjustified, for the same reason given in the previous section.

Therefore, it is preferable to consider Unit II of Dolaa Group as the stratotype of this Evaporitic Unit, which crops out in the cores of some anticlines of the southern Palmyrides, composed mainly of 120-m-thick gypsum, anhydrite with laminated clayey marl horizons, termed by Henson (1938-1941) as “Hayan Gypsum Formation” after Hayan Mountain (5 km west of Palmyra), who mistakenly considered it as Albian in age (Dubertret, 1935) (Figure 6).

The evaporitic deposits were termed by Chenevart (1949) as “Assafir Formation”, after Assafir Mountain, northwest of Palmyra. Field investigations proved that the “Assafir Formation” is the same unit and that it was incorrectly considered as ?Aptian – ?Albian. Ponikarov (1966) determined the age of these deposits as Middle Jurassic (Bajocian). The Triassic age was confirmed by Mouty and Al Maleh (1983) who named it the “Hayan Gypsum Formation”. It was also dated as Triassic (Mouty, 1976, BRGM, 1977, Mouty and Al Maleh, 1983), according to rare important microflora detected in clayey horizons intercalated in this formation in the Hayan Mountain.

The authors propose to retain the term “Hayan Formation” given by Henson (1938-1941) for this evaporitic unit.

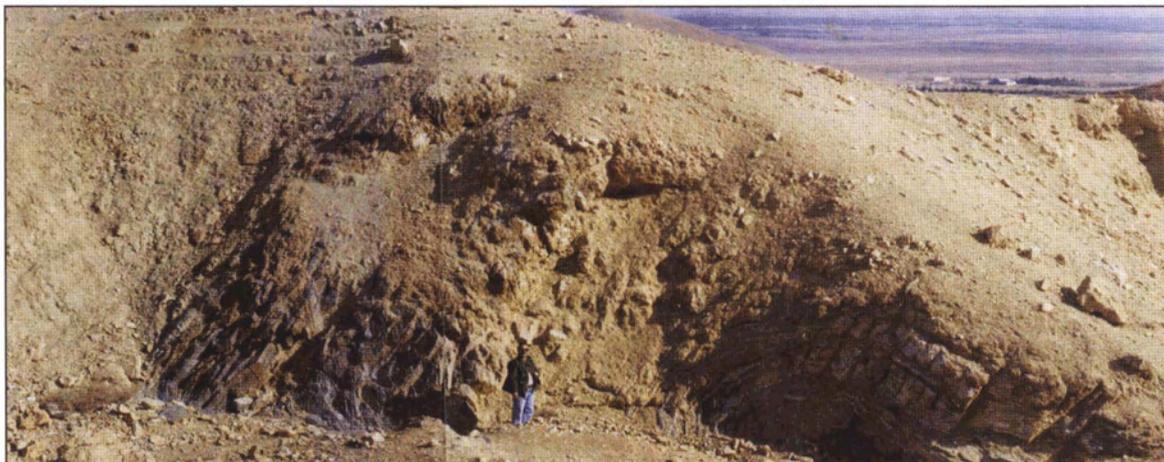


Figure 6: Outcrop of the Middle – Upper Triassic Hayan Gypsum Formation on the core of Hayan Mountain, Palmyrides Chain. See Figure 1 for location.

Triassic Upper Carbonate Unit: Safa Formation

This unit, mainly carbonate (45 m thick, 1,565–1,610 m/RT), is represented in Dolaa 1 by Unit I of Dolaa Group. It crops out in the main mountain chains in Syria; in particular in the core of some southern Palmyrides anticlines where it is mainly composed of limestone and dolomitic limestone (45 m thick). In the Zbeideh-Abu Zounnar mountains, near the Safa Mountain (c. 33°37'20"N, 37°00'30"E; Figure 1), the proposed Safa Formation and overlying Satih Formation can be distinguished (Figure 7).

The lower formation is composed of thin calcareous beds intercalated locally with thin marl and marly-gypsiferous at its base (Member A), and moderate to thick limestone and dolomitic limestones beds at the top (Member B) bearing characteristic Upper Triassic microfauna: *Aulotortus sinuosus* (Weynschenk), *Agathammina inconstans* (Michalik, Jenderjakova, Borza), *Galeanella* aff. *laticarinata* Al Shibani, *Lamelliconus procerus* (Liebus), *Trochammina alpina* (Kristan-Tollmann), *Nodosaria* sp., *Glomospirella rosetta* Zaninetti, Ciarapica, Cirilli, *Gandinella* aff. *falsofriedli* (Salaj, Borza, Samuel), *Ophthalmidium* spp., *Endothyra* aff. *obturata* Bronnimann, Zaninetti (Plate 1). Locally, for example in the Taniet As-Safra Mountain at the northeastern-most rims of the Palmyrides, some intercalating sandstone beds are encountered (Figure 8). This lower section of the Upper Carbonate Unit corresponds laterally to the upper section of the Mulussa Formation in the Euphrates Graben (Jamal et al., 2000); here a 100–200-m-thick continental clastic unit caps a regressive sequence and forms the lower most part of the prolific oil reservoir section in the Deir Ez Zor area.

Correlation of Dolaa 1 with Bir Abu Fayad (Figure 5) shows that petroleum geologists in Syria use for this Upper Triassic section names from a group of Iraqi formations: Butma, Adaiyah and Mus Limestone, Alan Anhydrite and Sargelu formations. It should be noted that these formations were defined in wells drilled within a small area in northwest Iraq, and do not crop out. Their age has not yet been proved by paleontological evidence, and their facies and thickness are variable (van Bellen et al., 1959–2005). This renders any correlation between these formations with lithostratigraphic units in Syria uncertain.

We propose to give to the lower section of this Upper Carbonate Unit the name of "Safa Formation", after its type locality Jabal As-Safa, located at the foot of Jabal Zbeideh, 80 km east-northeast of Damascus (Figures 1 and 7).

In the Palmyrides the Jurassic "Satih Formation" (Mouty, 1997a) concordantly overlies the lower carbonate sequence. It contains at its base abundant microfauna of which *Mayncina termieri* Hottinger, characteristic foraminifera of the Lower Jurassic, and at its top, *Amijiella amij* (Henson), a characteristic foraminifera of Middle Jurassic.

Correlation of Dolaa 1 with the Bir Abu Fayad well shows that petroleum geologists in Syria use for this Jurassic formation, either the term "Qamchuqa Formation" or "Haramoun Formation". The age of the Qamchuqa Formation, in its type locality in Iraq, is paleontologically determined as Lower Cretaceous. The Haramoun Formation, which is named after Hermon (Haramoun) Mountain,

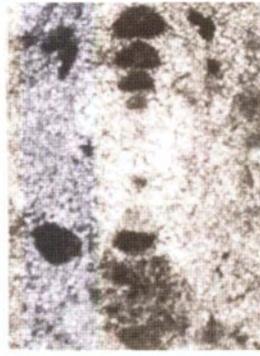
Plate 1 (facing page): Foraminifera fauna characteristics from the Triassic System in Syria.

- (1 to 3) *Aulotortus sinuosus* (Weynschenk) x60.
- (4) *Aulotortus* sp. aff. *A. friedli* (Kristan-Tollmann) x60.
- (5 to 8) *Agathammina inconstans* (Michalik, Jendrejakova and Borza), x90.
- (9 and 10) *Ophthalmidium* spp., x90.
- (11 and 12) *Lamelliconus procerus* (Els Hostalets), x60.
- (13) *Spiramphorella* ? sp., x60.
- (14) *Glomospirella rosetta* Zaninetti, Ciarapica and Cirilli, x60.
- (15 and 17) *Nodosaria* sp. (15 : x60, 17 : x45).
- (16) *Trochammina alpina* (Kristan-Tollmann), x90.
- (18) *Gandinella* sp. aff. *G. falsofriedli* (Salaj, Borza, Samuel), x90.
- (19 and 20) *Endothyra* sp. aff. *E. obturata* Bronnimann, Zaninetti, x60.

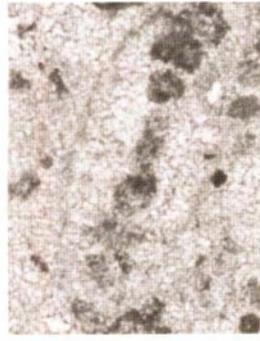
PLATE 1



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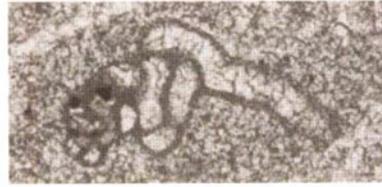
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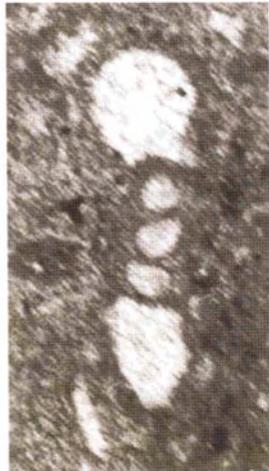
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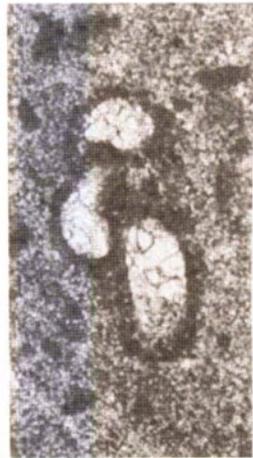
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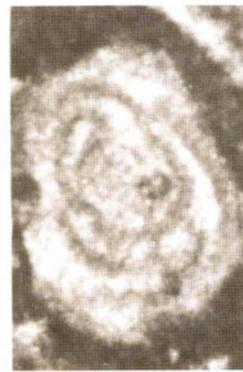
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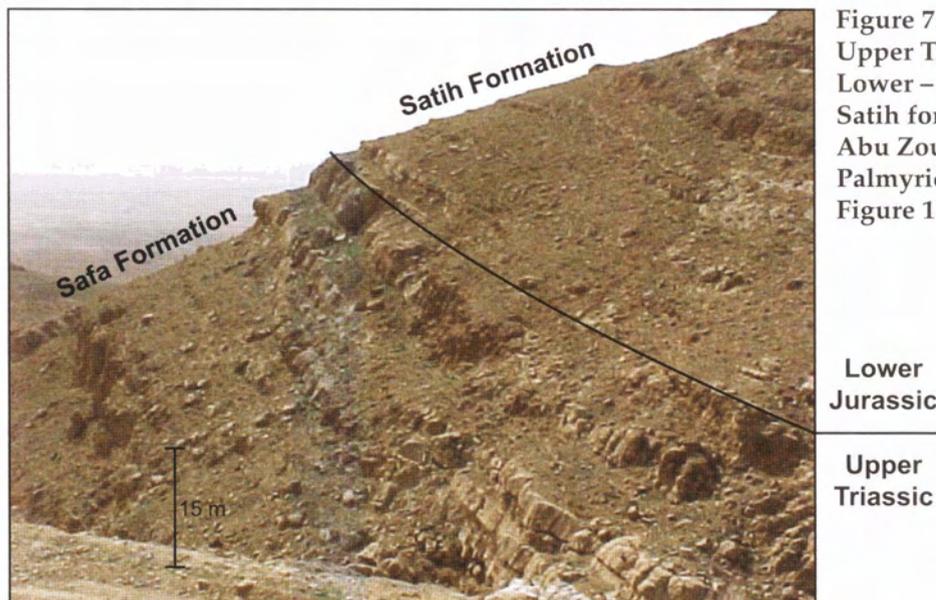


Figure 7: Outcrop of the Upper Triassic Safa and Lower – Middle Jurassic Satih formations, Jabal Abu Zounnar-Zbeideh, Palmyrides Chain. See Figure 1 for location.

stratigraphically misfits with Middle Jurassic “Hermon Limestone” Formation described by Dubertret in 1966. To avoid any misleading correlation by applying “Qamchuqa Formation” and “Haramoun Formation”, we suggest removing them from the Syrian nomenclature.

The contact between the two formations of the Upper Carbonate Unit – Satih Formation (Jurassic) and Safa Formation (Upper Triassic), clearly visible on the outcrops (Figures 3 and 7), is difficult to distinguish in wells sections.

CHRONOSTRATIGRAPHY

The present available publications for dating the Triassic successions in Syria are those of Dubertret (1937), Dubertret and Daniel (1962), Bach Imam et al. (1980, 1985) based on fauna; BRGM (1977), Mouty et al., Maleh (1983), Bach Imam and Sigal (1985), Kammar (1994) based on palynology; and complementary micropaleontology data gathered since then from the upper parts of Triassic successions, which crop out in the main mountainous chains in Syria (Mouty, 1997, 2000).

A review of different internal SPC (Kammar, 1994) and TOTAL unpublished reports on the palynologic contents of the Triassic succession encountered in a great number of Syrian wells allows distinguishing four assemblages of miospores having a chronostratigraphic significance (Figure 9).

Assemblage I: *Lunatisporites noviaulensis* - *Densoisporites nejburgii*

This assemblage appears in the Habari Formation (Figure 9). Palynologic analysis of some levels of this formation encountered in wells drilled in the Palmyride Basin (Kammar, 1994), and in other areas in Syria, revealed the presence of pollen forms indicative for Early to Middle Triassic (Scythian – Anisian) age. The most important of which to mention are *Lunatisporites noviaulensis* Leschik, which is considered as restricted to Scythian (Geiger and Hopping 1968) and *Densoisporites nejburgii* (Schulz), which is a good marker of Lower Anisian in Europe (Vissecher and Brugman 1981). The macrofauna already cited in Dolaa 1 and other wells in central Syria (*Pseudomonotis* cf. *clarei* (Emmrich), *Ceratites* cf. *trinodosus* (Mojs) indicates a Scythian – Anisian age for the Habari Formation.

Assemblage II: *Aratisporites saturni* - *Angustisulcites klausi*

This assemblage appears in the Abu Fayad Formation (Figure 9). The most important to mention is *Aratisporites saturni* (Thiergart), which is a good marker of Upper Anisian in Europe (Vissecher and



Figure 8: Outcrop of the Upper Triassic Safa Formation in the Thaniet As Safra Mountain. Two black sandstone beds occur within this formation. See Figure 1 for location.

Brugman 1981). The macrofauna already reported in Dolaa 1 and other wells drilled in central Syria (*Posidonia* juv. cf *P. wengensis* group, *Posidonia wengensis* Wissman var. *cycloidalis* Kittl, *Daonella lomelli* Mojs, *Avicula globosa* Wissman) indicates a Middle Triassic (Anisian – Ladinian) age for Abu Fayad Formation.

Assemblage III: *Paracirculina scurrilis* – *Protodiploxypinus gracilis*

This assemblage appears in the Hayan Formation (Figure 9). Palynologic analysis of some levels of this formation's outcrops in the Palmyride Basin and in northeast of the country, revealed the presence of pollen forms indicative for a Carnian – Norian age (Mouty et al. Maleh, 1983; Bash Imam et al., 1985; Kammar, 1994). The most important to mention is *Camosporites secatus* (Leschik), a good marker of Ladinian – Carnian in Europe (Visscher and Brugman 1981). Ostracods, specifically *Simeonella brotzenorum* Sohn, mentioned in the upper part of Hayan Formation, indicates a Late Triassic age for this formation.

Assemblage IV: *Vesicaspora schemeli* – *Samaropollenites speciosus*

This assemblage appears in the Safa Formation (Figure 9). Palynologic analysis of some levels of this formation in the Palmyride Basin and in the northeast of the country, revealed the presence of the characteristic forms of Upper Triassic pollen such as *Praecirculina granifer* Scheuring, *Samaropollenites speciosus* Goubin. Microfauna already reported in some outcrops in the Palmyrides, in particular *Aulotortus sinuosus*, *Galeanella laticarinata*, indicates a Norian – ?Rhaetian age for the Safa Formation.

CORRELATIONS AND PALEOGEOGRAPHY

Data derived from major deep wells in the Palmyride Basin and different areas of Syria show the same subdivision of Triassic successions, having in general the same characteristic facies, which enables an easy correlation of Triassic formations and lithological units within Syria and neighboring countries (Figure 2).

Habari Formation

In most wells within Syria, this formation is generally composed of black, pyrite-bearing silty shale with fine grey calcareous intercalations. The formation reaches its maximum thickness in the

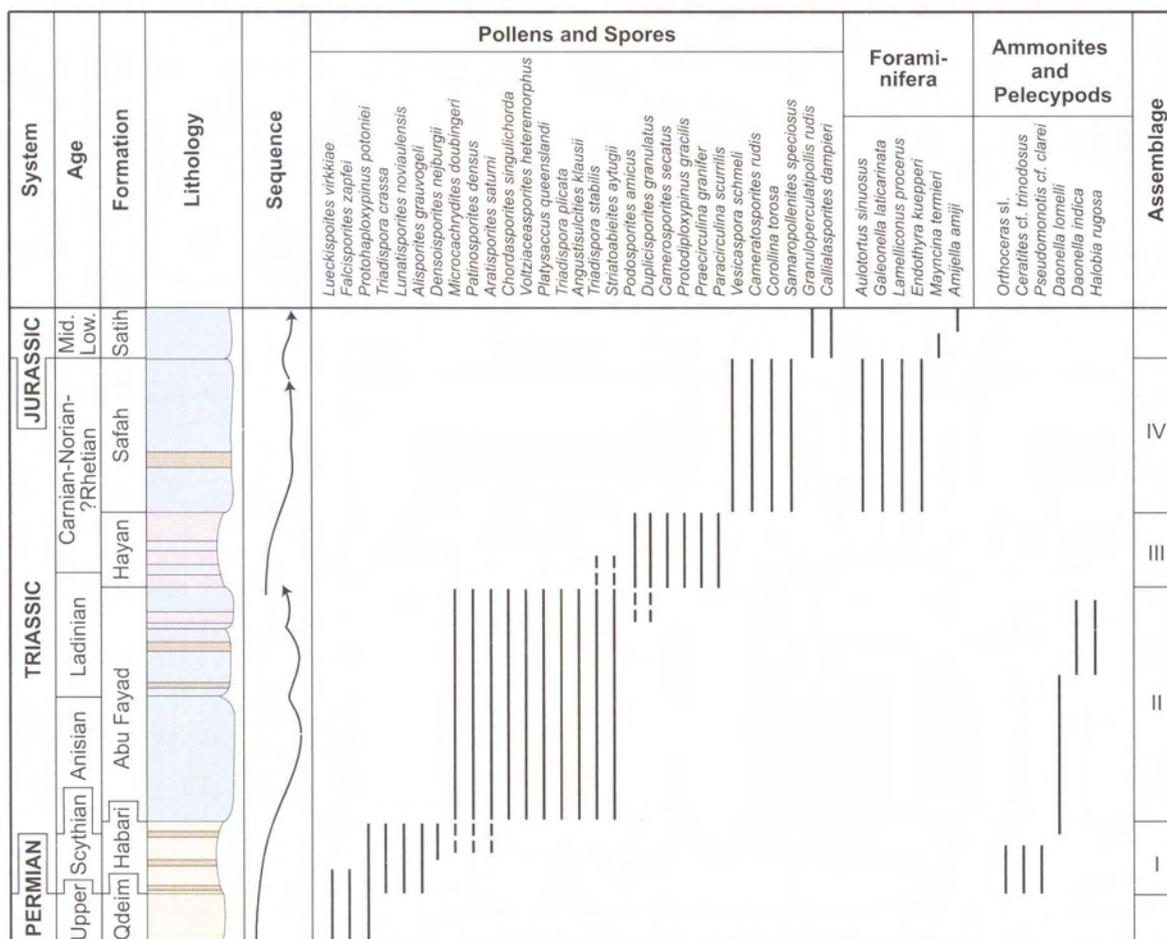


Figure 9: Stratigraphic distribution of main species (microflora, foraminifera, macrofauna) in the Triassic of Syria.

Palmyride (138 m) and in the Levantine basins (168 m), while it is missed in Aleppo Plateau and along the northern edge of the northern Arabian Platform (Kammar, 1994), in Hamad area (Caron et al., 2007; Caron et al., 2000; Brew et al., 2001; Al Bassam et al., 1983; Best et al., 1993), in the Euphrates Graben (Jamal et al., 2000) and in the Rutbah area (southwest of Iraq) (Buday, 1980) (Figure 10). This implies that the Triassic sea invasion was restricted to the Levantine zone and the Palmyride Basin along a NE-elongated bay (Figure 11).

The Habari Formation is correlated to the two Lower Triassic formations in northern Iraq (area of Amadia). The lower one is the "Mirga Mir Formation" which is composed, according to (Wetzel, 1950), of marly limestone, and shale with *Pseudomonotis (Claraia) clari* Emmrich, *P. (claraia) aurita* (Hauer), *Anadontophora fassaensis* Wissmann, *Myophoria ovata* Goldfuss, *Spirorbis valvata* Goldfuss, of Induan age. The upper is correlated to the "Beduh Formation" (Wetzel, 1950), which is composed of shale and marl with some intercalations of limestone and sandstone levels, with *Anadontophora fassaensis* Wissmann, *Myophoria praeorbicularis* Bitner, *M. balatonis* Frech, *Gervillia* sp.? *Palaeonella distincta* Bitner, *Nucula* sp., *Gonodon* sp., of Olenekian age. These two formations are missing in southwestern Iraq (Rutbah area) due to a stratigraphic hiatus (Buday, 1980) (Figure 2).

The Habari Formation is also correlative with the "Humrat Ma'in Formation" in Jordan, which according to Wetzel and Morton (1958) is composed of sandstone, shale, layered basalt, with rare marly limestone levels dated as Scythian, based on abundant fauna collected from different localities in this area (Figure 2).

It is also also correlative with a group of four formations of basal Triassic successions of Wadi Ramon in Negev (Palestine): Yamin and Zafir formations of the Negev Group (Weissbrod, 1969, 1976), and Raaf and Gevanim formations of Ramon Group (Zak, 1963, 1986). The ammonites in the Gevanim Formation belong to the "binodosus zone" of lower Anisien (Parnes and al., 1985). Thus, this correlation confirms an Anisian age of the upper part of Habari Formation, and a Scythian (Olenkian – Induan) age of the lower part of Habari Formation (Figure 9).

Abu Fayad Formation

In most of the wells, the three members of this formation are encountered, the lower member is composed of dolomicrite with shale intercalations; the middle one is composed of dolosparite and dolomicrosparite (wackestone); and the upper one is composed of dolomicrite and dolomicrosparite with thin anhydrite beds. The formation reaches its maximum thickness in the Palmyride (500 m, Best et al., 1993 and the Levantine Basin (> 600 m).

During the Triassic, the Abu Fayad Formation's sediments covered the Syrian platform, except the major part of Hamad area (Tanf and Swab wells), where Permian quartzite is overlain by Cretaceous sandstones (Best et al., 1993). Accordingly, the Hamad area was emergent at that time (Hamad Uplift, Caron and Mouty, 2007), surrounded by the Triassic sea, which deepened northwest (Palmyride Basin) and southeastwards (Rutbah Basin) (Figures 10 and 11).

While the lower member of Abu Fayad Formation extends over a vast area of the Aleppo Plateau region, the other two members are missing there (Kammar, 1994). Similarly, the Aleppo Plateau was emergent at that time as an uplifted area encircled by a broad Triassic sea, which deepened northwestwards (Ifrine Basin), and southeastwards (Palmyride Basin) (Figures 10 and 11).

The wells in the Euphrates Graben, bounded by the Hamad Uplift to the southwest and the Kleissiah Uplift to the northeast show dolomitic and argillaceous sandstone and siltstone in the Mulussa B Formation directly overlying the Carboniferous section (Jamal et al., 2000); this Triassic transgression is a lateral equivalent for the lower Member of Abu Fayad Formation. At the same location, the Mulussa C (Ladinian) corresponds to evaporitic units demonstrating restricted marine environment; it is disappearing in the southeastern extension of the Euphrates Graben, pointing out probable extension of the Hamad High (or the Kleissiah High, to the north) during the Middle Triassic.

The Abu Fayad Formation correlates with the two formations of Middle Triassic in northern Iraq (Amadia area): the lower one is the Gelikhana Formation (Wetzell, 1950), which consist of dolomite and of limestones with some shale and marls intercalations with *Lingula tenuissima* Bronniman, hence

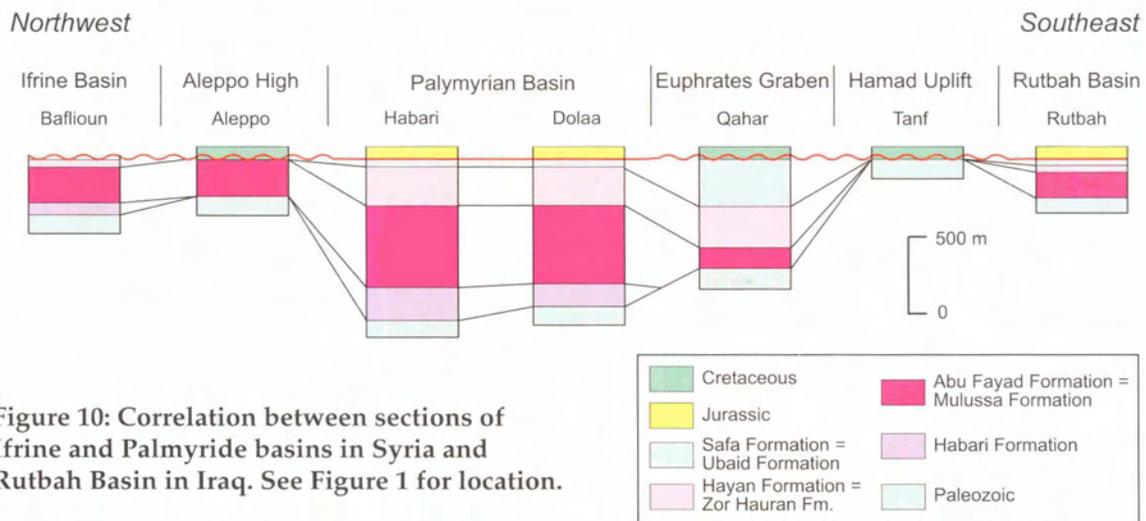


Figure 10: Correlation between sections of Ifrine and Palmyride basins in Syria and Rutbah Basin in Iraq. See Figure 1 for location.

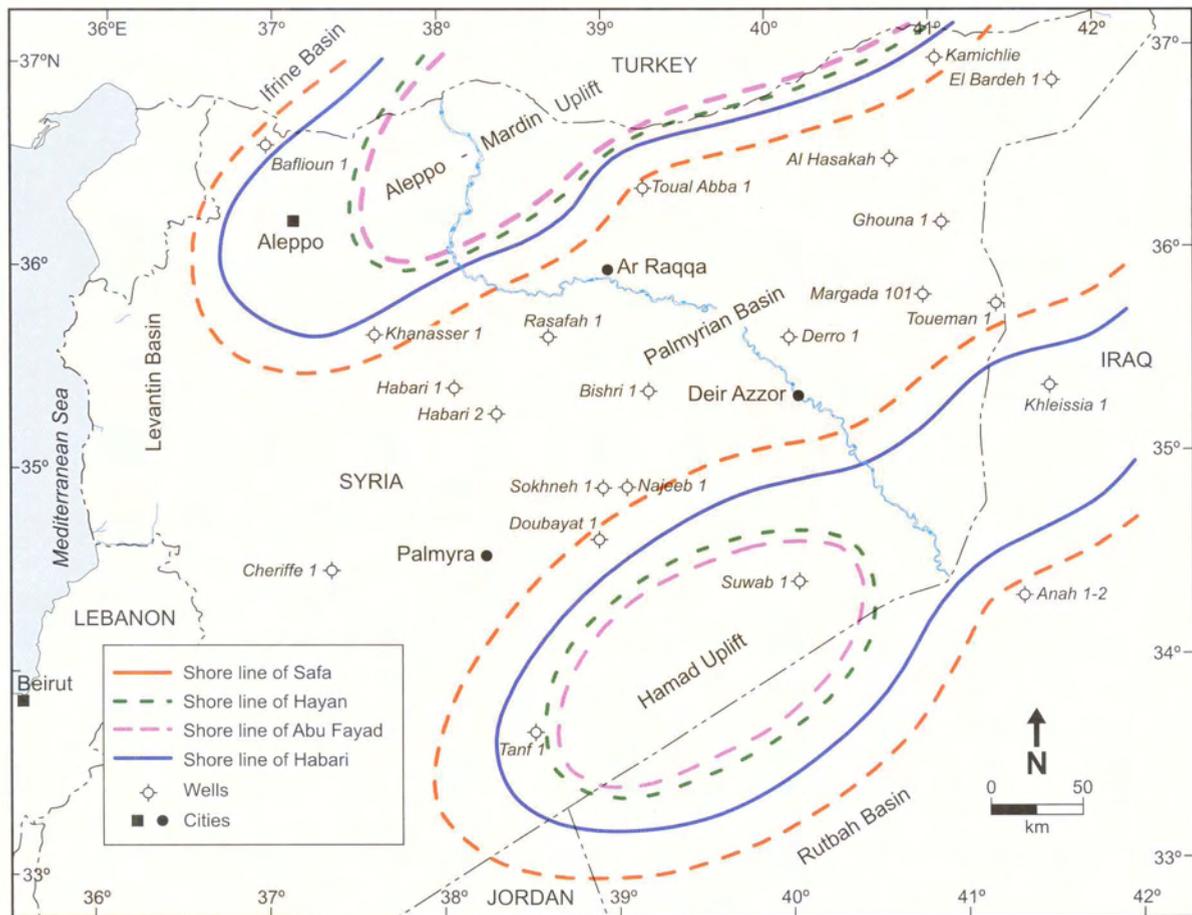


Figure 11: Schematic palaeogeographic map of Syria during the Triassic Period.

considered through correlation as Middle Triassic. The upper one is Kurrachina Formation (Wetzel, 1950), which is mainly composed of limestone with *Posidonia wengensis* Wissman, determined too as Middle Triassic (Figure 2).

The Abu Fayad Formation also correlates with the Mulussa Formation (Williamson and Picles, 1931) in southwestern Iraq (Rutbah area), which is composed, according to them of massive, oolitic/pseudoolithic limestones with *Pseudomonatis nigrigans* Stef, *Myophoria* aff. *postera* Moore, *M. kferesteini* (Munster), *Mytilus ministus* (Goldfuss), *Pteria* sp., *Gervillia* sp., *Problematica* spp., *Trocholina* spp., indicative for Middle Triassic age (Figure 2).

The Abu Fayad Formation correlates with the "Hisban Limestone Formation" (Wetzel and Morton 1958) in Jordan (Wadi Saiyala, the Dead Sea area), which is dominantly composed, according to them of limestone beds with some marly levels with *Paraceratites binodosus* Mojs, *Pseudocerithium* sp., *Nautilus* sp., *Encrinus* sp., giving it a Middle Triassic age (Figure 2).

The Abu Fayad Formation is correlable also with "Saharonim Formation" of Wadi Ramon in Negev (Zak, 1963, 1986), who subdivided it into four members (S1, S2, S3, S4), correlable with Ammonites zones (Parnes, 1986) (Figure 2).

Hayan Formation

The Hayan Formation in Syria reflects a regional shallow-water depositional period when widespread evaporites accumulated on the Arabian Platform during most of Late Triassic time. While the thickness of the formation reaches its maximum in the Palmyride (170–500 m) and Levantine Basins (150 m)

and the Euphrates Graben trend area, it drops to a minimum in Rutbah Basin (western Iraq) and in Ifrine Basin (northwest Syria), and is missing in the Hamad and Aleppo Uplifts (Aleppo-Mardine High) in south, southeastern and northern Syria respectively (Figures 10 and 11).

The Hayan Formation correlates with the "Baluti Shale Formation" (Wetzel, 1950) in the Chia Gara area in northern Iraq, composed, according to him of "dolomitic shale with thin dolomitic and pseudo-oolitic limestone intercalations with *Glomospira* sp.", indicating a restricted environment (Figure 2). The formation also correlates with the evaporitic successions of Zor Hauran Formation (Dunnington, 1951) in the Rutbah area (southwest Iraq), composed, according to him, of gypsiferous marls with marly limestone and oolitic limestone intercalations with *Lingula* sp., *Myophora* sp., *Archeodiscus* sp., *Glomospira* sp., thought to be of ?Rhaetian age (Figure 2).

The Hayan Formation correlates with the "Zarqa gypsiferous Formation" (Morton and Wetzel, 1959) in Jordan, which is mainly composed, according to them of gypsum, anhydrite, limestone intercalating beds with *Myophoria* sp., shales and ferruginous sandstone. This "Zarqa gypsiferous Formation" is dated as Upper Triassic according to its stratigraphic position overlying the Middle Triassic "Hisban Formation" (Figure 2).

The Hayan Formation correlates with the "Middle Gypsum and Dolomite Member" (m2) of "Mohilla Formation" (Zak, 1963) in Negev (Wadi Ramon), which was dated by conodonts and by the species of *Spiriferina* sp. and *Myophoria* sp. as Carnian (Figure 2).

Safa Formation

This formation was deposited during a gentle sea floor subsidence with local development of small depocenters as reflected either by clayey-gypsiferous sediments interbedded within relatively thick carbonate deposits in some areas, or by alternation of small lithological carbonate and clayey-gypsiferous units in some other areas.

The Safa Formation reaches its maximum thickness in the Palmyride and Levantine basins, it drops to its minimum in Rutbah Basin (western Iraq) and in the Ifrine Basin (northwest Syria), and is absent in the Hamad Uplift (south-southeast of Syria) and Aleppo Uplift in northern Syria (Aleppo-Mardine High) (Figures 10 and 11). The Euphrates area developed into an isolated 50–70-km-wide basin (paleogaben?) with a SE-elongation where the Mulussa F and G show a thick continental siliciclastic section (up to 300 m thick) sourced either from the Khleissia or the Hamad eroded highs (Jamal et al., 2000).

During the deposition of this formation, and apart from the Euphrates localized feature, the major paleogeographic domains did not undergo sudden important changes compared to their former status. Other factors, which usually control sedimentation, such as climate, subsidence and oceanic water contribution, influenced the deposition of small lithological sub-units having frequent lateral and area-dependant facies changes from anhydrites to carbonates or *vice-versa*. Nevertheless, carbonate dominates generally in the basin's center, while anhydrite dominates at the basin fringes. This makes lithological subdivision of this formation, hence precise large-scale correlations of its sub-units, a difficult and confusing task.

The "Safa Formation" correlates with the "Jweikhate Formation" (Mouty, 1997b) in the Coastal Chain of Syria (Figures 12 and 13), whose upper part crops out on the eastern side of the chain and mainly composed of dolomite and dolomitic limestone with *Gsollbergella spiriloculiformis* (Orvezne-Scheffer), *Ophthalmidium* sp., *Trochammia alpina* Kristian-Tollmann, *Planiinvoluta carinata* Leischner, *Galeanella* aff. *laticarenata* Al Shaibani, *Nodosaria* sp. (Mouty, 1997b). A thick bed of black clayey-silty marl, bearing lignite seams, in the middle part of this formation, delivered an abundant microflora, such as: *Samaropollenites speciosus*, *Patinasporites densus*, *Tymanicysta* sp., and several forms of Dinoflagellates.

A deep well in northern Ghab Depression, 10 km to the east of the Coastal Chain, encountered a volcanic level in the middle of this Upper Triassic formation (Syrian Petroleum Company, personal



Figure 12: Outcrop of the Upper Triassic “Jweikhate Formation”, Lower Jurassic “Treize Formation” and Middle Jurassic “Ouyoun Formation” in the Coastal Chain of northwest Syria). Height of the cliff is 100 m, see Figure 1 for location.



Figure 13: Outcrop of the Upper Triassic Jweikhate Formation in the Coastal Chain of northwest Syria. Height of the cliff is 50 m, see Figure 1 for location.

communication). This level is most probably coeval with that encountered in Toual Aaba well (54 km northeast of Raqqa) and more developed volcanism in the Euphrates Graben, where 50–100 m of weathered basalts and dolerites are described in several pluri-kilometric patches interbedded in the Mulussa F section (base of Safa Formation).

The “Safa Formation” also correlates with the “Rimeh Formation” of Hermon Mountain (Anti-Lebanon), whose upper part crops out in the core of this anticline (Figure 14), and is composed of black thin bedded micritic limestone, intercalated by greenish grey marl beds, some of which contains characteristic Upper Triassic microfauna, such as *Aulotortus sinuosus* (Weynschneken) (Mouty and Zanetti, 1998).

It also correlates with “Simalek Formation” of Kurd Dagh (north-northwest Syria) whose upper parts crops out in the core of the Simalek anticline and is composed of a thick successions of grey dolomite and dolomitic limestone underlying the calcareous successions of “Dodo Formation” with *Lithiotis* sp., characteristic Lower Jurassic Pelecypods (Mouty, 2000).

It correlates with the “Sarki Formation” in the Chia Gara area in northern Iraq which is composed of “massive dolomite beds, alternating with shale and yellowish marls with *Archaeodiscus* sp., *?Problematica* sp., *?Trocholina* sp., *Glomospira* sp.”. The formation underlies “Sehkanian Dolomite Formation” with Lower Jurassic (Lias) *Lithiotis* sp., which is overlain by Sargelu Formation, which is composed of limestone with Ammonites and Rhynchonellidae species characteristic for Middle Jurassic (Figure 2).

The Safa Formation correlates with a group of four formations in Mosul area in northwestern Iraq, bottom upwards: “Butma Formation”, “Adayah Anhydrite Formation”, “Mus Limestone Formation” and “Alan Anhydrite Formation” (Dunnington, 1953). These formations are composed, according to him, of an alternation of limestone, shale and anhydrite. They are dated by the authors (Sadooni and Alsharhan, 2004) as Jurassic. We believe that this dating is erroneous due to poor microfauna reported to be found in their type-localities in Iraq. The fossil contents of *Glomospira* sp., *Archaeodiscus* sp., *Problematica* sp., *Nodosaria* sp., tend to give them an Upper Triassic rather than Jurassic age, since, the presence of Nodosaridae was never reported in Near East Jurassic formations on one hand, while is frequent in Upper Triassic on the other hand. Moreover, the correlable levels of this group in NE Syria were dated by palynologic evidences as Upper Triassic (Bach Imam et al., 1980; Kammar, 1994) (Figure 2).



Figure 14: Outcrop of the Upper Triassic Rimeh Formation in the core of the Hermon major anticline, Anti-Lebanon belt. Width of foreground cliff is 300 m. See Figure 1 for location.

It is also correlates with “Ubaid Formation” in Rutbah area in southwest Iraq, which is composed of limestones with subordinate marl and marl-limestone intercalations with *Archaediscus* sp., *Problematica* sp. (Figure 2).

The formation correlates with the “Shefayim Formation” in Negev (Wadi Ramon), which is composed of dolomite and dolomitic limestone (Figure 2). The volcanism evidenced in this area is synchronous with the one described in the Syrian domain (Ghab Depression, Euphrates graben); it should be linked with first evidence of the Eastern Mediterranean opening in the area.

CONCLUSIONS

The present study on the Triassic of Syria led to the establishment of a new subdivision of four lithological units (formations), from base to top (Figures 2 and 4):

1. Habari Formation: lower clastic unit, Scythian – Early Anisian in age,
2. Abu Fayad Formation: carbonaceous unit, subdivided into three members: the lower two are free of evaporites and Late Anisian – Early Ladinian in age, and an upper evaporites-bearing member of Late Ladinian in age,
3. Hayan Formation: mainly evaporitic unit of Carnian – Norian age,
4. Safa Formation: top carbonaceous unit of Norian – Rhaetian age.

The Lower/Middle Triassic boundary is located within the upper part of Habari Formation, and the Middle/Upper Triassic boundary is located within the upper part of Abu Fayad Formation.

This accurate subdivision of the Triassic in Syria, based on characteristic facies, is valid over the northern Arabian platform. Thus, it allows easy correlations of Triassic formations and lithological units, not only in Syria, but also with their equivalents in neighboring countries. This led, in turn, to reconstructing the palaeogeographic evolution of the northern Arabian platform during Triassic time, which can be summed up in four periods:

1. the first is characterized by the creation of subsiding basins, which received clastic supply derived from the erosion of emerged zones to the south (Hamad Uplift in Syria and Iraq), and the north (Aleppo-Mardine High, Syria). These sediments were deposited in a very shallow-marine environment.
2. The second period is characterized by a shallow-marine environment due to a transgression that invaded most of the Syrian Platform, except the country’s southern part, which formed an emergent NE-elongated paleostructure: the Hamad Uplift.
3. The third period is characterized by evaporite sedimentation in subsiding basins. Tectonic movements were restricted to subsiding basins favoring evaporite sedimentation along the depocenters of the basins and clastic deposits in the Euphrates Graben area.
4. The final period is characterized by epineritic sedimentation under constant paleoclimatic conditions. Gradually towards the end of the Triassic, a carbonate sedimentary regime overwhelmingly dominated western Syria (Levantine basin) in particular.

Correlations with neighboring countries, based on deep wells data, indicate the presence since Late Anisian of two paleostructures parallel to the Palmyrides: Hamad Uplift to the south and Aleppo-Mardine High to the north, which separated the Palmyrides Basin from the Rutbah Basin to the south, and the Palmyrides Basin from the Ifrine Basin to the north (Figure 11). The formation of these two uplifts could have been due to the response of the Arabian Platform to the opening of Neo-Tethys Ocean.

Correlations with Wadi Ramon formations in Negev (Figures 1 and 2) precisely date the Triassic formations in Syria on the basis of ammonites zone.

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