A new model for structural deformation in the palmyride fold belt, Syria

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Abstract

The Palmyride mountain chain is the main structure in central Syria. It represents an intracontinental NE-SW trending fold belt, within the northern part of the Arabian Plate. It is bounded by the Aleppo–Mardine uplift to the North–West and by the Hamad Uplift to the South-East.

This study is based mainly on numereous field geological observations. New informations are obtained about the tectonic behavior of the Palmyride fold belt. The main faults are generally normal. There is no surface geological evidence for thrusting within the Palmyrides, as suggested by the authors before.

The argument to be developed in this study is that the Palmyrides fold belt owe its existence to the lateral displacement of the Triassic gypsum, not to the lateral decollement of its overlying series, and consequently no shortening of 20 km as estimated by the authors before.

A simple model is proposed to explain the observed tectonic features. It is interpreted that this tectonic event induced a master transfer of the Triassic gypsum under the Arabian Plate movement toward the north and the northeast at the Neogene time.

Keywords: Tectonic, Dyapirism, Arabian Plate, Palmyrides, Syria

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نموذج جديد للتشوّه البنيوي في حزام الطي التدمري في سورية

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الملخص

السلسلة التدمرية هي البنية الجيولوجية الرئيسة في وسط سورية. وهي عبارة عن حزام طي ضمن قاري ذي اتجاه شمال شرق–جنوب غرب في الجزء الشمالي من الصفيحة العربية. يحدّ هذه السلسلة من الشمال الغربي نهوض حلب-ماردين، ومن الجنوب الشرقي نهوض الحماد.

تعتمد هذه الدراسة بصورة رئيسة على مشاهدات حقلية عديدة. كما تم الحصول على معلومات جديدة فيما يتعلق بتكتونيكية حزام الطي التدمري. الفوالق عادية بصورة عامة. لا دليل على وجود سطوح دثر جيولوجية في صلب السلسلة التدمرية، كما أشار إلى ذلك المؤلفون من قبل.

الدليل الذي تم إيضاحه في هذه الدراسة هو أن وجود حزام الطي التدمري يعود إلى الانتقال الجانبي للجص الترياسي، وليس الانزلاق الجانبي للزمر الرسوبية التي تعلو الجص الترياسي، وعليه ليس هناك تقصير في هذه الزمر الرسوبية قدّره المؤلفون من قبل بـ 20 كم.

اقتُرِح أنموذج بسيط لشرح المظاهر التكتونيكية المشاهدة. وهو يفسر تدخّل الحدث التكتونيكي في تهجير الجص الترياسي بتأثير حركة الصفيحة العربية نحو الشمال والشمال الشرقي خلال زمن النيوجين.

الكلمات المفتاحية: التكتونيك، الطي الملحي الثاقب (ديابير)، الصفيحة العربية، السلسلة التدمرية، سورية.

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INTRODUTION

The Palmyrides mountain chain is the main structure in central Syria. It has an average elevation of about 1500m. It represents a Neogene intracontinental NE-SW trending fold belt, within the northern part of the Arabian Plate. It is 400 km long and 100 km wide, bounded by the Aleppo- Mardine uplift to the North –West and by the Hamad Uplift to the South-East **(fig. 1).**

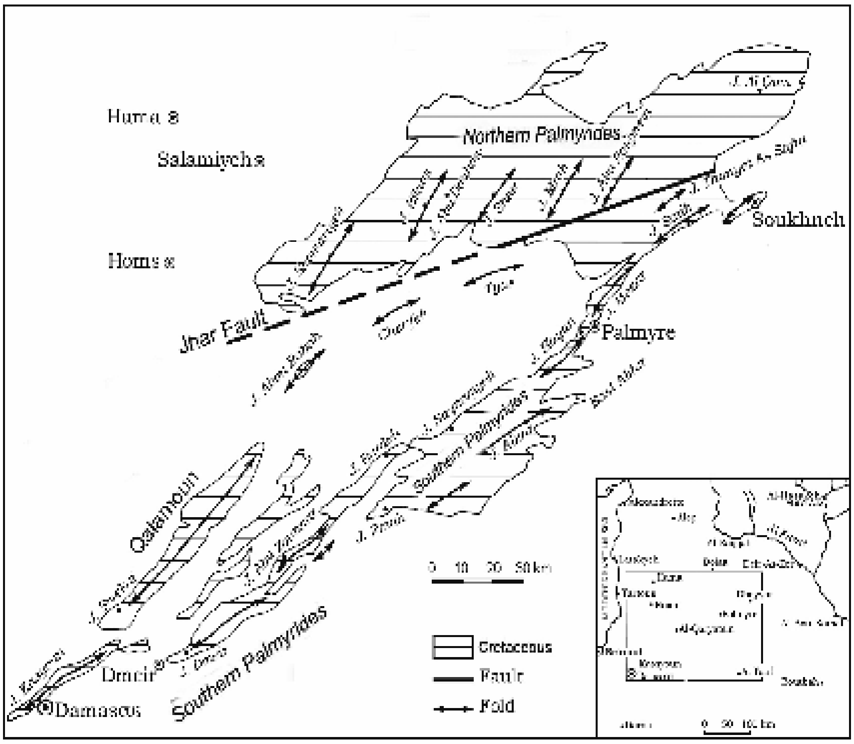

Fig. 1 - Strutural map of the Palmyrides fold belt.

The Palmyrides consists of two main areas, the southern Palmyrides and the northern Palmyrides, which are separated by the Ad Daww depression which is about 100 km long, 20 km wide and contains up to 11 km of Phanerozoic strata (Chaimov *et al.,* 1992; Seber *et al.,* 1993).

-The Southern Palmyrides is characterized by linear, asymmetric anticlines with southeast vergence and by very narrow synclines. The southeastern limbs dip steeply (70-80°) to SE, in contrast to the northwestern limbs, which dip gently (20-30º) to NW. Rocks exposed in the belt range in age from Triassic to Pliocene and Quaternary, the former exposed in the anticlinal cores, the latter preserved in synclines.

The northern Palmyrides is characterized by broad and relatively symmetric anticlines. This area contains mainly two blocks: the Bishri block to the east, a broad northeast plunging anticlinorium, and the Bilaas block to the west, which is characterized by NNE–SSW trending folds. The southern flank of this area is cut by Jhar Fault that strikes about N70E for a distance of nearly 200 km, but no more than 50 m of displacement as is shown across the outcropped Rmah Formation in the southern flank of Jabal Abu Roujmein at about 40 km NE from Palmyra.

It is generally accepted that the compressive stresses resulted from the movement of the Arabian Plate to the North played the main role in the Neogene tectonic of the Mesozoic Palmyride basin that was recognized as an aulacogen (Ponikarov, 1967). The evolution of this belt has been influenced by the tectonic activity of the neighboring plate boundaries, the Red Sea rift, and especially the closing of the Tethian oceanic basin (Ponikarov, 1967; Dubertret, 1966; Quennell, 1984; Lovelock, 1984; McBride *et al.,* 1990; Chaimov *et al.,* 1990; 1992, 1993; Al-Saad *et al.*, 1992, Best *et al.*, 1993; Searle, 1994; Salel *et al.,* 1994).

The presence of folded Pliocene implies that the belt is a very young feature. However, unconformities between the Oligocene and Miocene, and the Miocene and Pliocene suggest that there were several distinct tectonic phases in the evolution of the region.

Because of its great importance, the Palmyrides were the aim of numerous surface and subsurface geological studies. Different interpretations were proposed for the Palmyrides structures: normal faulting with uplift (Ponikarov *et al.*, 1966), salt diapirism (Omara, 1964; Khoury & Mouty, 1967), dextral transcurent motion (Quennel, 1984), sinistral transcurrent motion (Giannerini *et al.*, 1988), folding and thrusting (Chaimov *et al.*, 1990; 1992),

Based mainly on seismic data, most of the geologists interpret actually the Palmyrides chain as a thrust fold belt which has resulted by the decollement of the Mesozoic and Cenozoic series overlying the Triassic evaporites (Chaimov *et al.*, 1990; 1992; Salel *et al.*, 1993).

The present work represents a contribution to obtain new information about the tectonic behavior of the Palmyrides fold belt, in order to get better understanding of the tectonic evolution of the northern part of the Arabian Plate.

Data and Methodology

This article summarizes the results of geotectonic investigations in the Southern Palmyrides chain. Seven anticlines along this chain, from the SW to the NE, have been studied. The database for this transect includes detailed geological mapping of Syria (scale 1/200000) (Ponikarov, 1966). This mapping formed later the base of the new geological mapping (scale 1/50 000), which has been accomplished by the “General Establishment of Geology and Mineral Resources of Syria”.

The stratigraphy of the various units and formations in the Palmyrides chain has been studied in detail (Mouty, 1993, 1997; Mouty *et al.*, 1983, 2002). It is shown in the range chart **(fig. 2).**

The tectonic investigations of these anticlines consist of defining the beds contacts on both sides of the faults and the strike and dip of the faults planes.

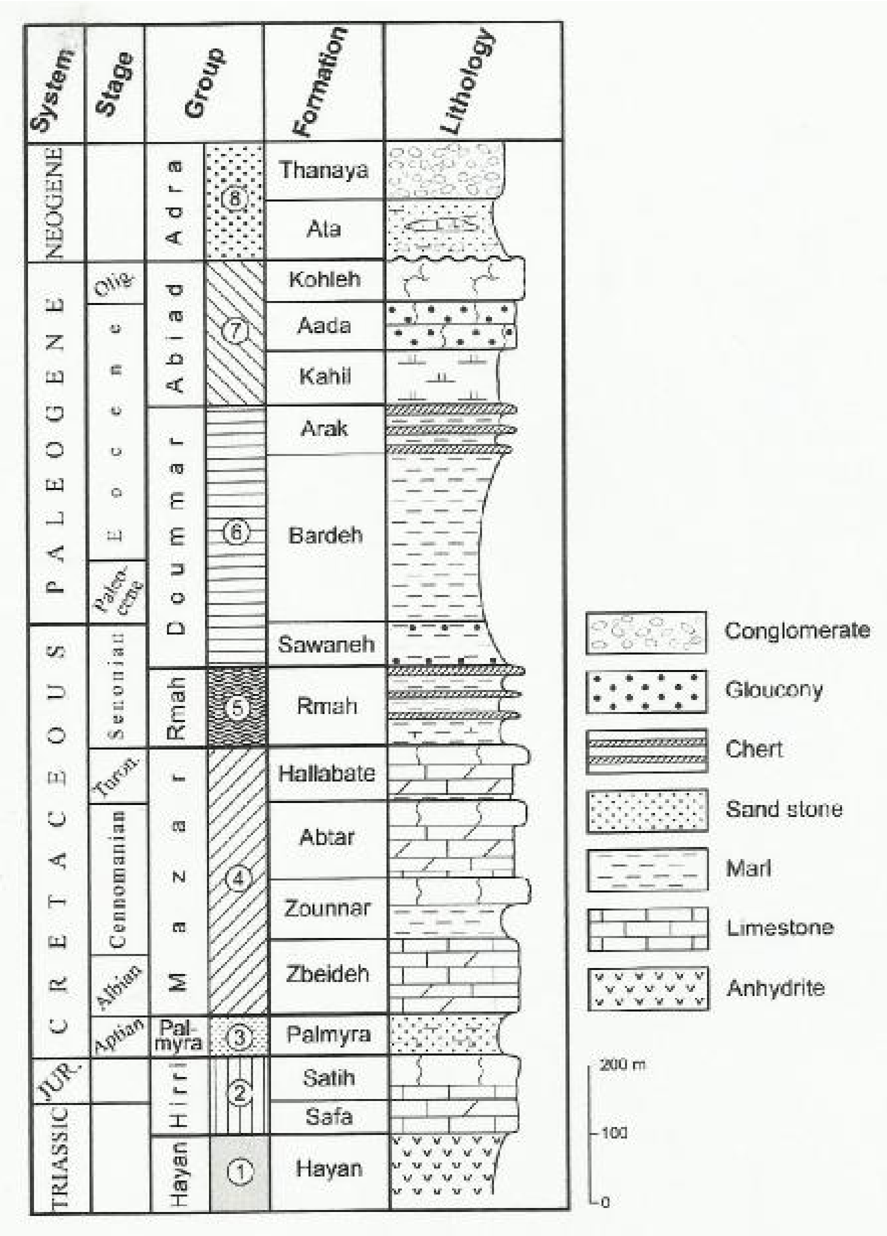

Fig. 2. Stratigraphic column of the Palmyrides Chain.

STRATIGRAPHY

The stratigraphy of the Palmyrides has been presented by the authors before (Dubertret, 1966; Ponikarov, 1967; Mouty, 1976, 1997, 2000; Mouty and Al Maleh,1983; Mouty et al. 2002; Caron and Mouty, 2007; Mouty and Gout, 2010). **Figure 2** show the stratigraphic colomn of the outcropped sedimentary serie. The oldest rocks exposed at the surface are the Triassic “Hayan Formation” (Mouty, 1976), composed of gypsiferous marls and gypsum horizons exposed in the core of some anticlines in the central part of the Southern Palmyrides. Calcareous and dolomitic limestone beds containing Pelecypods, Brachiopods, Crinoids…from the Lower and Middle Jurassic succession (Satih Formation) (Mouty, 1997) overlie the Triassic carbonate “Safa Formation” (Mouty and Gout, 2010). The Pre-Aptian to Aptian “Palmyra Formation” consists of ferrigenous quartzose sandstones, shales and argiliceous marls with locally altered volcanic rocks.

The Middle Cretaceous shelf carbonate deposition, consisting of the Mazar Group (Albian to Turonian), begins with the calcareous and dolomitic limestones of Zbeideh Formation (Albian to earliest Cenomanian), with a lower fossiliferous marly unit and an upper cliff-forming unit of dark gray, massive bedded dolomites of Abu Zounnar Formation (middle to late Cenomanian). The late Cenomanian Abtar Formation consists of a lower, well-stratified series of thin-bedded dolomitic limestones and an upper sequence of dark gray, massive bedded dolomites locally containing flint nodules. The Turonian Hallabat Formation is composed of a lower thin-bedded marly dolomitic limestones and an upper sequence of massive bedded limestones and dolomitic limestones (Mouty and Al Maleh, 1983, Mouty *et al.,* 2002).

The Upper Cretaceous, consisting of the Soukhneh Group (Coniacian to Maastrichtian) begins with thin-bedded cherts alternating with limestone nodular beds, clays and marls of Rmah Formation (Coniacian to lower Campanian). The late Campanian Sawaneh Formation consists of red to yellow clay with thick phosphatic beds at the base and phosphato-glauconitic bed at the top. The Bardeh Formation spans the Maastrichtian to early Lower Eocene and is composed of gray, white, and yellowish marls. The late Lower Eocene Arak Formation is composed of alternating marly limestones and thin chert beds (Mouty and Al Maleh, 1983).

The Abiad Group (Middle Eocene to Oligocene) consists of a lower recessive Kahil Formation of white chalky marls (Middle Eocene), a middle Aada Formation of massive bedded glauconitic marly to chalky limestones (Upper Eocene), and an upper cliff-forming Kohleh Formation nummulitic or recifal limestones, with locally sandy limestones or sandstones at the top (Late Eocene to Oligocene).

The thick continental Neogene deposition occurred into structurally controlled intramountane basins such as the Ad Daww depression.

Structure

The Palmyrides fold belt consists of two main regions :

- The Southern Palmyrides is characterized by a linear, asymmetric anticlines with southeast vergence.
- The northern Palmyrides is composed of broad and relatively symmetric anticlines with an East-Southeast vergence.
- The southern and northern parts of the Palmyrides are separated by the Ad Daww Neogene depression.
- The main data in the present work are obtained mainly from anticlines of the southern part of the Palmyrides. It includes field description and measurements of different tectonic structures with different scales of observation .
- The main anticlines of the southern Palmyride fold belt have been studied: (Jabal Kasyoun-Abu Al Ata, Jabal Zbeideh-Abu Zounnar, Jabal Al Rmah, Jabal Al Abtar, Jabal Hayan, Jabal Al Mazar) **(fig.1)**.

Jabal Kasyoun-Abu Al Ata (fig. 3)

This linear, asymmetric anticline is 45 km long and 2.5 km wide. It belongs to the extrem SW end of the southern part of the Palmyride fold belt. Stratigraphically, the section of this anticline starts in its core by the upper marine Cenomanian limstones (Dubertret, 1966). Its southeastern limb dip steeply (60-80º) to SE, in contrast to its northwestern limb which dips gently (20-30º) to NW.

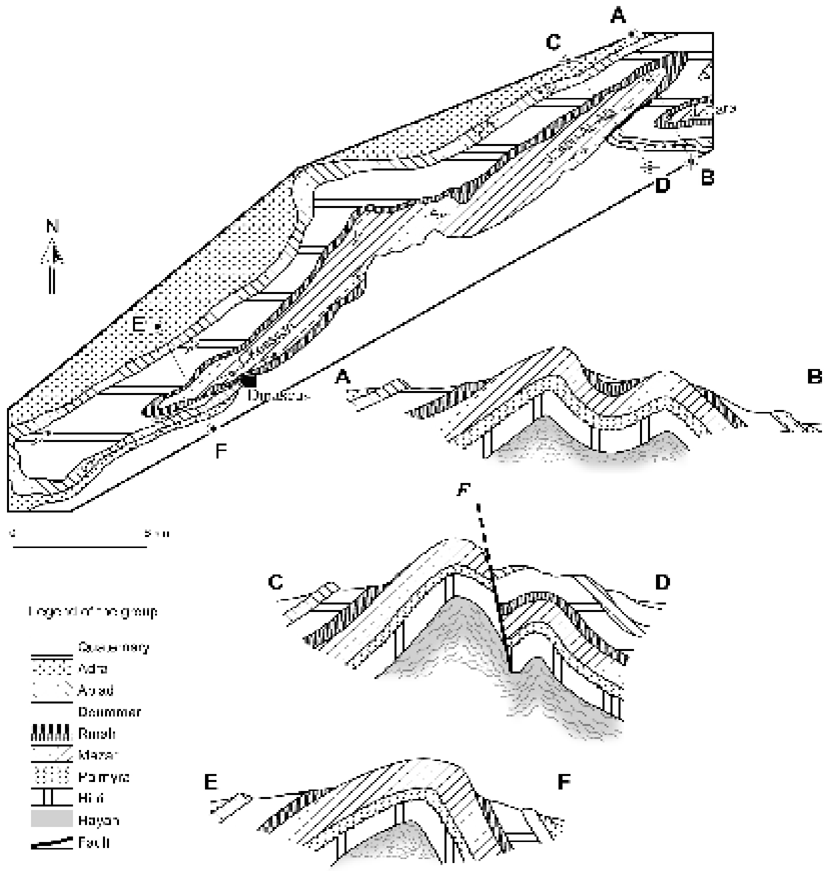

Fig. 3. Geological map of Jabal Kasyoun–Abu Al Ata with cross sections across the anticline structure.

The lithostratigraphic sequences with their biozones are confirmed from the Cenomanian to Paleogene. There is no surface geologic evidence for a fault along the southern margin of Jabal Kasyoun as mentioned by the authors before ((Ponikarov 1967), except in the NE extremity of the anticline, in Jabal Abu Al Ata, which appear like "whales back"**,** the axis of the anticline here goes up rapidly and is affected by a big longitudinal normal fault less than 1km long, along the maximum ascending of the anticline axis (from 900m at the top of Turonian bed to 1650m high).

This fault represents the contact of Jabal Abu Al Ata anticline with Jabal Al-Qata anticline. It is limited just along this contact, at the highest part of Jabal Abu Al Ata and disappears completely before the NE end of the Abu Al Ata anticline. No evidence of thrusting along this fault**.**

Jabal Zbeideh-Abu Zounnar (fig. 4)

The Zbeideh anticline lies 80 km to the northeast of Damascus. It is 23 km long and 2.5 km wide. Stratigraphically, the section of this anticline starts in its core by the upper marine Triassic limstones (Mouty, 1997). The general strike of this linear asymmetrical anticline is N60ºE. It is affected by a longitudinal normal fault which is represented by the ascending of the middle Triassic anhydrite (Hayan Gypsum) with 50m broad outcrup along the maximum rising of its axis.

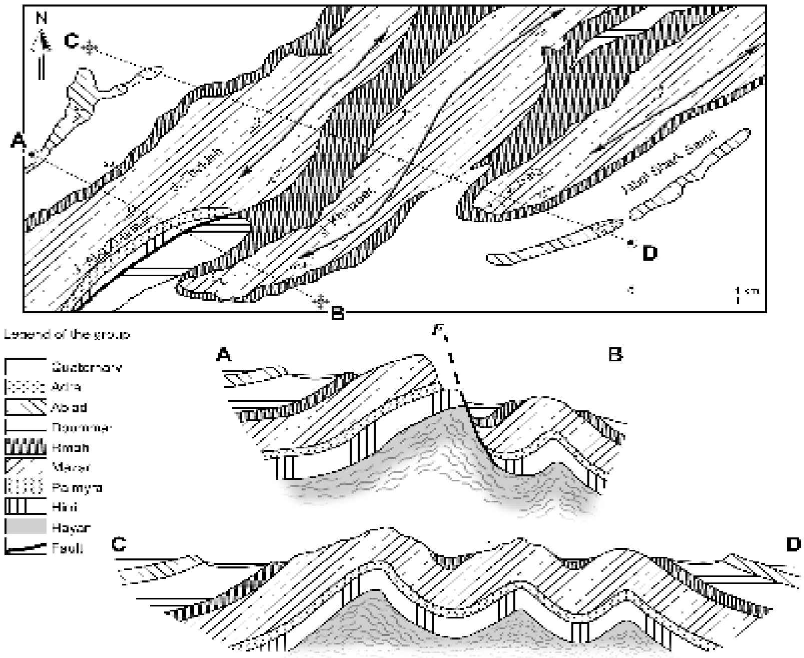

Fig.4. Geological map of Jabal Zbeideh-Abu Zounnar with cross sections across the anticline structure.

The displacement amplitude of this fault reachs its maximum just at the highest part of the core of the anticline, decreases gradually and disappears completely before the ends of the anticline **(fig.5)**. The fault plane as exposed on the Upper Triassic dolomitic limestone from one side where it is vertical and slickenside **(fig.6),** and on the Lower Eocene (Arak Fm.) from the other side where it is represented by local crumpling of the beds. These phenomina indicates that the fault is normal, and deny the hypothetic thrusting along this fault as mentioned by the authors before.

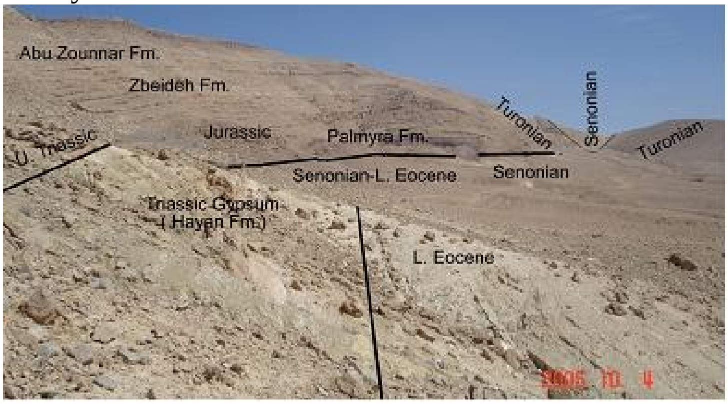

Fig. 5. Southeastern flank of Jabal Zbeideh-Abu Zounnar. (Triassic gypsum on outcrop).

Fig. 6. The vertical fault plane as exposed on the Upper Triassic dolomitic limestone in Abu Zunnar-Zbeideh anticline

Jabal Al Rmah (fig. 7)

The fold axis strikes N50ºE. The SE limb dips steeply. Whereas, its NW-limb dips gently to middle steep getting flatter towards the northwest. It is affected by a longitudinal normal fault along the highest part of its axis. This anticline is 10 km long and 2 km wide. It lies 110 km to the northeast of Damascus. Its core forms the Jabal AlRmah, which is in a shape of "back of whale". The section of this anticline starts in its core by the upper marine Triassic limestone (Mouty, 1997) to the Oligocene.

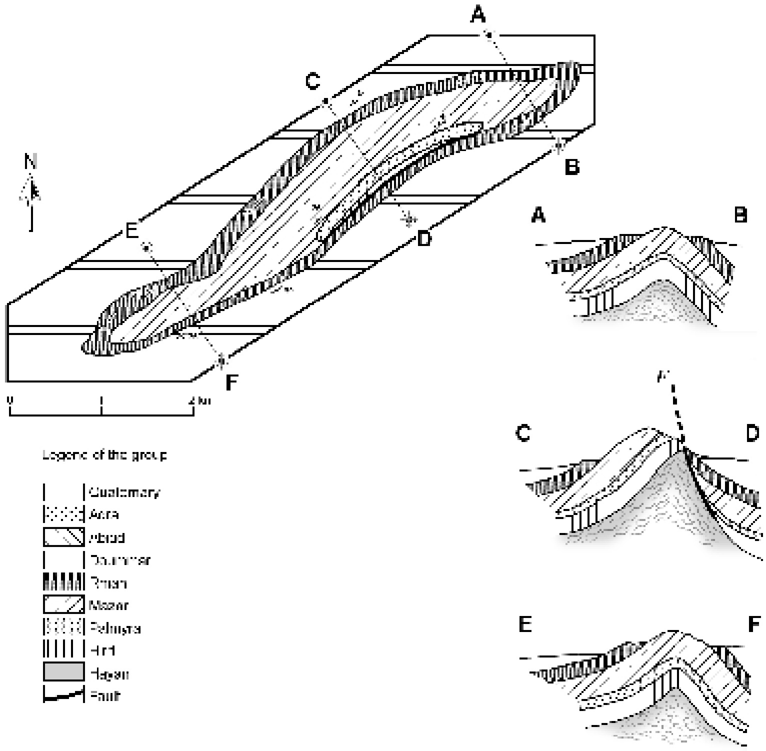

Fig. 7. Geological map of Jabal Al Rmah with cross sections across the anticline structure.

The displacement amplitude of this fault reaches its maximum just at the highest part of the core of the anticline, then decreases gradually and disappears completely before the ends of the anticline. No evidence of thrusting along this fault as mentioned by the authors before .

Jabal Al Abtar (fig. 8)

The Al Abtar anticline lies 20 km to the southwest of Palmyra. It is a linear asymmetrical anticline of about 60 km long and 2.5 km wide (depending on the outcrop of Mesozoic rocks). It is the southern flank of the Palmyrides chain. The fold axis strikes N56ºE. It is affected by a longitudinal normal fault wich is limited to the central part of the anticline just along a smoll distance of the highest part of the anticline not acceed 2-3 km., and disappears completely at the ends of this central part of the anticline.

There is no surface geologic evidence of thrusting along the southern margin of Al Abtar anticline, as mentioned by the authors before .

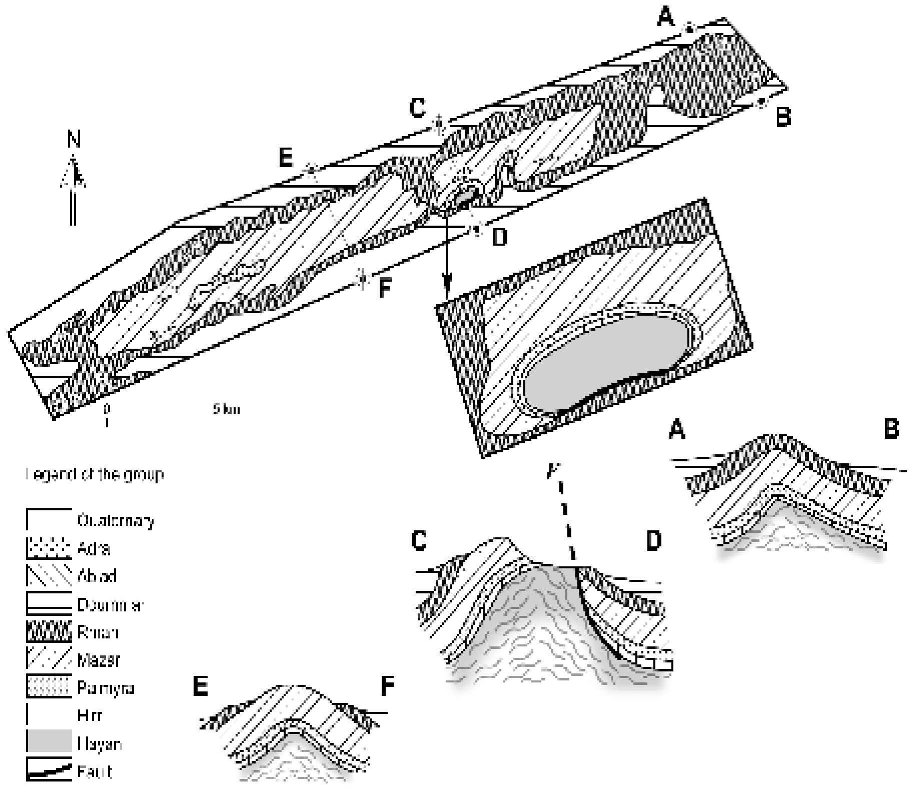

Fig. 8. Geological map of Jabal Al Abtar with cross sections across the anticline structure.

The stratigraphical section in Jabal Al Abtar starts from the Triassic gypsum and gypsiferous marl deposits in the core (Hayan Gypsum Formation), till the Upper Cretaceous (Rmah Formation) in the northwestern limb of the anticline (Mouty and Al Maleh 1983).

Jabal Hayan (fig. 9)

Hayan Mountain is located about 5 km to Southwest of Palmyra. It is about 13km. long and 2.5 km wide (depending on the outcrop of Mesozoic rocks). The fold axis strikes N40ºE. It is affected in its central part by NE-SW trending normal fault. It decreases gradually and disappears completely before the ends of the anticline

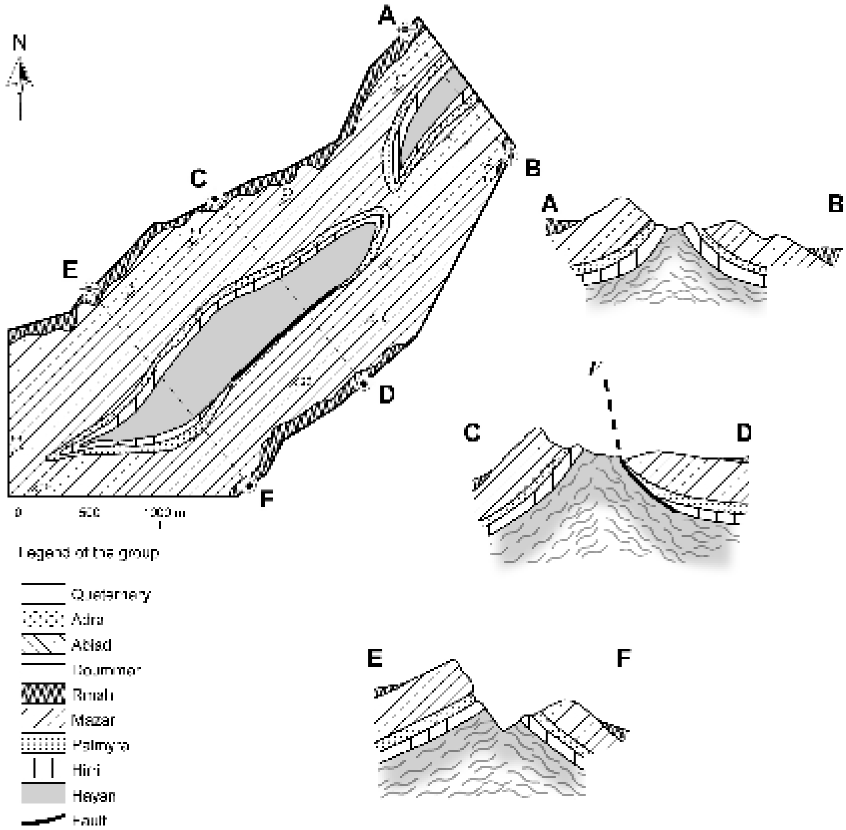

Fig. 9. Geological map of Jabal Hayan with cross sections across the anticline structure.

The displacement amplitude of this fault reachs its maximum just at the highest part of the core of the anticline, corresponding to the highest part of the axis. There is no surface geologic evidence for a thrust as mentioned by the authors before.

The stratigraphical section starts from the Triassic gypsum and gypsiferous marl deposits in the core till the Upper Cretaceous to Paleogene in the northwestern limb of the anticline (Mouty and Al Maleh 1983).

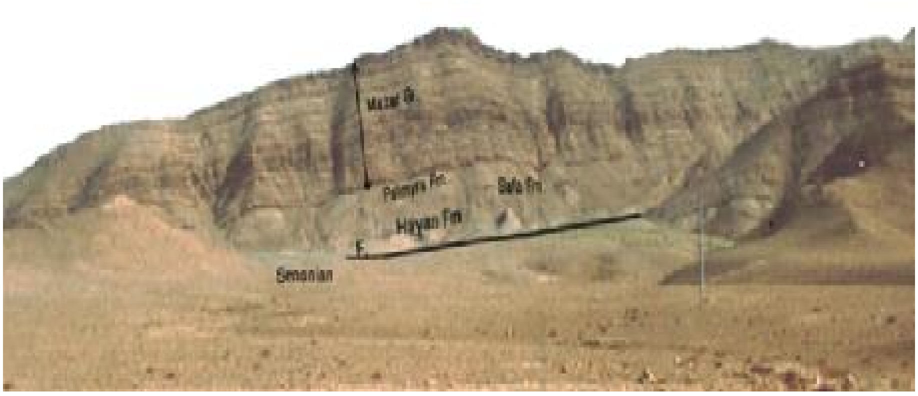

Fig. 9a. The fault in Jabal Hayan is along the maximum ascending of the fold axis of the anticline

Jabal Al Mazar (fig. 10)

In the Al Hirri anticline, one of the folds of Al Mazar Mountain is located in its southern part. It is affected by a longitudinal normal fault along the highest part of its axis, where its displacement amplitude reachs its maximum, then decreases gradually and disappears completely before the ends of the anticline. No evidence of thrusting along this fault .

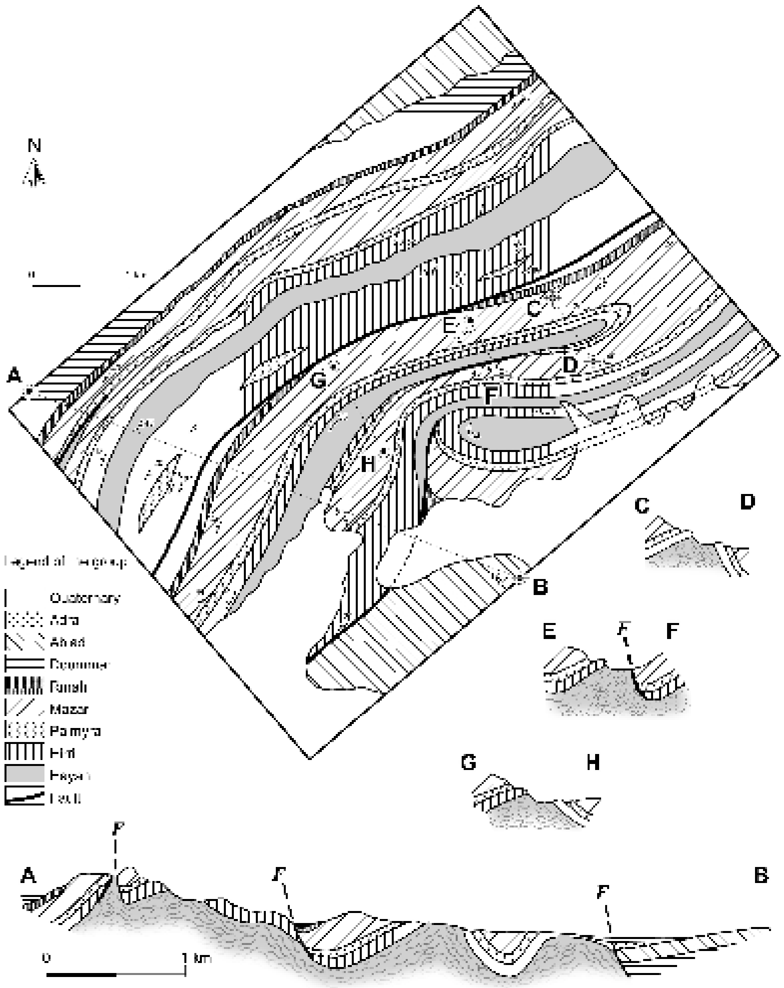

Fig. 10 - Geological map of Jabal Al Mazar with cross sections across the anticline structure.

DISCUSSION

Despite the strong complexity of certain structures in the Palmyrides, one does not meet any of the reverse folds nor the thrust faults, suggested until now by geologist (Chaimov *et al.*, 1990, 1992, 1993; McBride *et al.*, 1990; Salel, 1993; Salel and Seguret, 1994; Searle, 1994).

It is important to mention that the principal faults in the Palmyrides strike parallel to the core of the anticline. They are not beside the anticline flank. They are normal and limited along the highest parts of the anticline axis. Their vertical separation reachs its maximum in the highest point of the axis, then decreases gradually from this point and disappear completely at the end of the culminating parts of the anticline axis. These phenomena require a vertical pressure upwards to form the anticlines in the Palmyrides chain.

The seismic profiles show that the folding in the Palmyrides Chain affects the Triassic evaporites up to the Neogene stratigraphy. The Paleozoic sequence beneath the Triassic gypsum is not folded conformably with the disharmonically overlying Mesozoic rocks (Searle, 1994). This indicates that the deformation of the Palmyrides chain is related to the Triassic evaporitic beds.

Some geologists have interpreted the causes of the folding of Palmyrides Chain by diapiroic force of the Triassic evaporites (Khoury & Mouty, 1986), while the other geologists have interpret these causes by the decollement of the overlying beds of the Triassic evaporites (Chaimov et al. 1990, 1992; 1993; McBride et al.1990; Salel, 1993, Salel and Seguret, 1994; Searle, 1994), under the movement of the Arabian plate in time of the opening of the Red Sea and of its collision with the Anatolian Plate in the north

The diapiric hypothesis requires an upwards vertical pressure to overcome of the weight of the overlying beds on the Triassic evaporites. If this argument is valid for the saliferous domes, it is not valid to form a linear fold which exceeds more than 100 kilometers long as the Palmyrides chain. In fact, the diapirism never happen in isolation of a strong tectonic movement.

The decollement hypothesis requires the presence of thrust faults and a reverse folding. These phenomena are not recognized in the Palmyrides chain, where the overlying Triassic evaporites beds are largely exposed in numerous anticlines in the southern Palmyrides which do not show any indices of decollement .

Therefore, what are the origins of the pressures which have formed the Palmyrian fold belt?

A representative structure

A small representative structure outcrops in Jabal Al Balaas, in the Palmyrides Chain within the Hallabate Formation (Turonian) which contains a gypsum layer of 5 m in thickness. This structure is composed of small anticlines which are separated by small synclines **(fig.11)**. The gypsum bed is deformed: the cores of the small anticlines are full of gypsum, which is approximately absent under the adjacent small syncline. The surface of the underlying bed is flat.

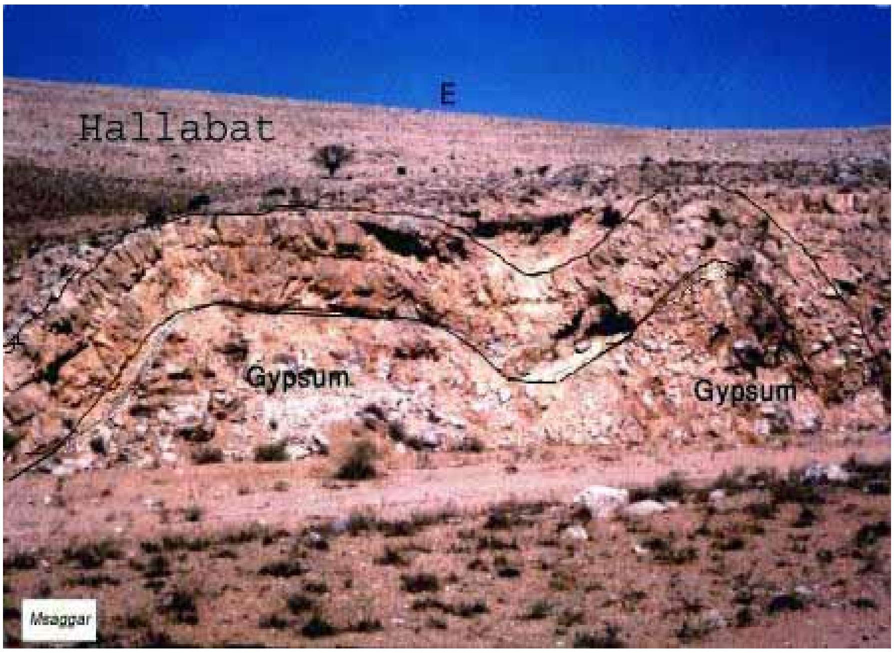

Fig. 11. Structure showings the accumulation of the gypsum forming an anticline structures.

This small structure allows to conclude that the gypsum which is characterized by its high elasticity was transfered from its original place and accumulated in another place, under the influence of a lateral pressure. The accumulation of the gypsum applied a pressure on the overlying beds to form an anticline. In the same time, these overlying beds dropped down to replace the gypsum, so forming a syncline.

This small structure which is formed by a thin layer of gypsum (5m) resembles the big folds in the Palmyrides where the thickness of the Triassic evaporite layers reach sometimes more than 400 m of halite, anhydrite, and shale. These deposits become more halitic in the central and southwest Palmyrides where more than 700 m of pure halite have beene found in Jubat and Faid wells" (Sawaf *et al.,* 2001). One of these most characteristic structures is represented by the Abou Rabah anticline in the Ad Daww depression. In the outcrop, this anticline is formed by the marly-limestone series of the Campanian. Deep drilling of this structure crossed mainly an important thickness of Triassic evaporitic sediments. Seismic profile in NW-SE direction cuts the Abou Rabah anticline (Chaimov *et al.*, 1992), where one can see a great difference in the thickness of the Triassic series which is thick in the core of the anticline and relatively thin or absent in the adjacent syncline **(fig. 12)**.

This allows to conclude that under the pressure resulting from the Arabian Plate movement toward the north, the Triassic evaporitic series in the Palmyrides was deformed and transfered from a place to accumulate in another place producing the rising of the overlying series towards the place where it was accumulated and the drop down of the overlying series towards the evacuated place. This interpretation differ from the overlap interpretation or the decollement interpretation.

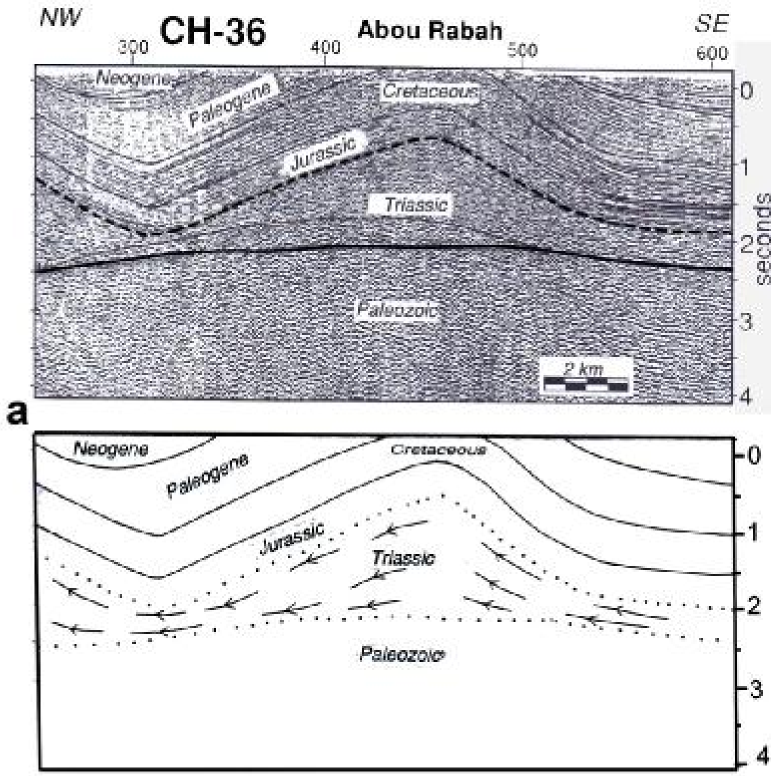

Fig.12. Seismic profile over Abu Rabah fold modified after Chaimov *et al.*, 1992), with balanced cross section, showing the anomalous thickness of the Triassic evaporates.

The seismic profiles in the Algero-Provencal Basin show clearly the difference in thickness of the Miocene evaporate, which corresponds to the anticlines and the synclines (Rouchy, 1986) **(fig.13)**. The seismic profiles in the Sao Paulo Plateau, SE of Brazil (Hudec *et al.*, 2004) **(fig.13a)** and in the Kwanza Basin, Angola, SW of Africa (Modica *et al.*, 2004), show clearly the accumulation of the Aptian salts and locally their thining, forming an anticline structures.This confirms the transfer interpretation of evaporites.

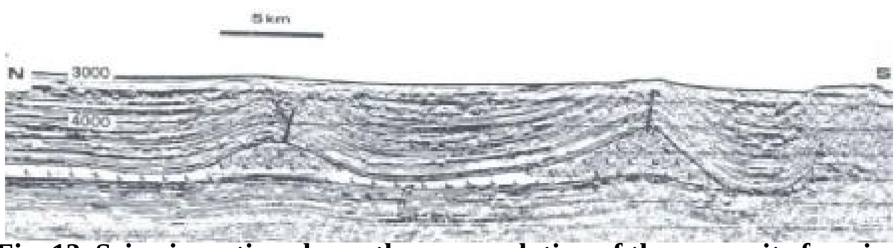

Fig. 13. Seismic section shows the accumulation of the evaporite forming an anticline structures in the northern part of Algero-provencal basin (L L L + evaporite).

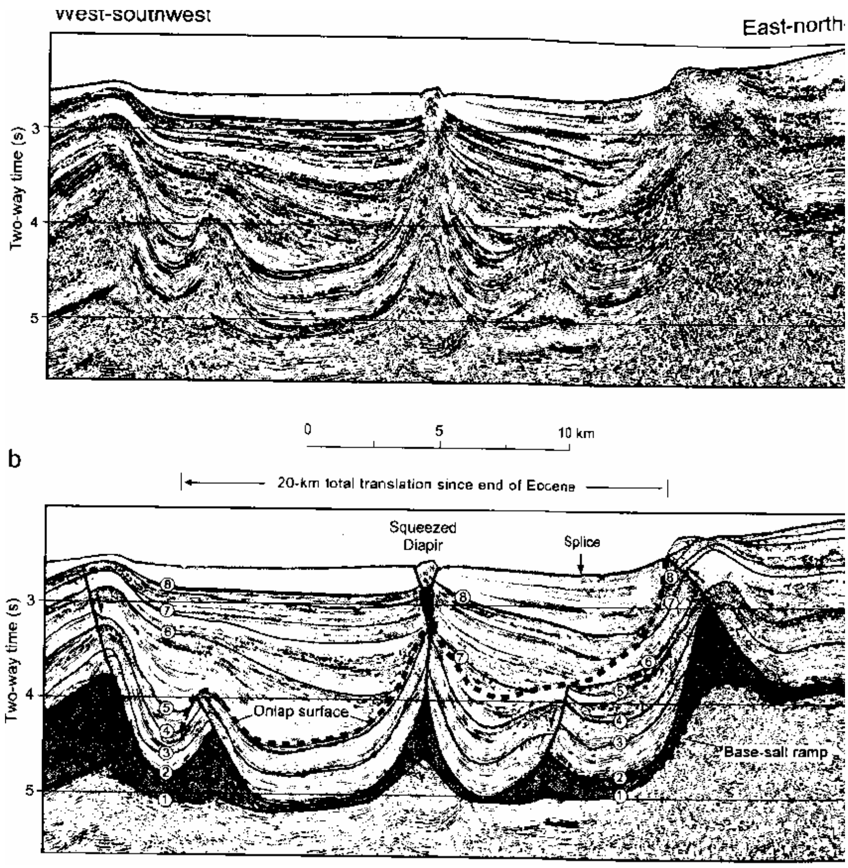

Fig. 13a. Seismic section shows the accumulation of the Aptian salts and locally their absence forming an anticline and horst structures in the Sao Paulo Plateau, SE of Brazil.

Modeling and shortening

For a better understanding the style of the Palmyrides fold belt formations, we establish a cinematic model which represents the different structures of this chain **(fig.14)**.

In this model, the Triassic evaporite bed (B) is surrounded by two dolomitic beds: an underlying bed (A) of Middle Triassic and an overlying bed (C) of Upper Triassic – Jurassic.

The simple folding in this model shows that the rise of the anticline (Vd) is equivalent to the drop down (Vd2) of the adjacent syncline The quantity of the gypsum accumulated in the core of the anticline is equivalent to the quantity of the gypsum transferred from the syncline zone.

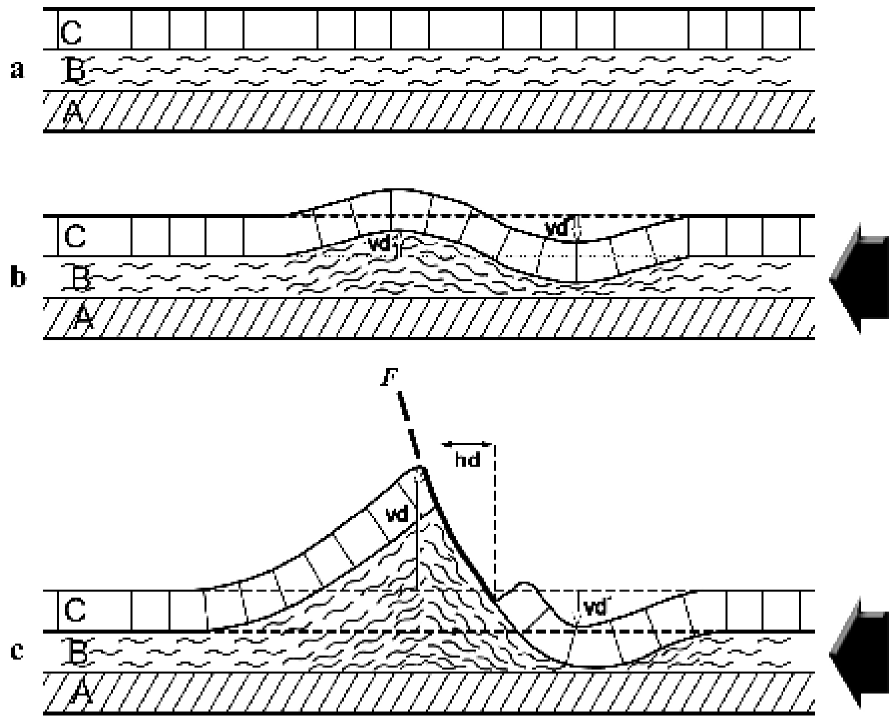

Fig. 14. Folding models showing the effect of the displacement of the gypsum and the restoration of the cross section without shortining.

The rate of ascending vd would be equivalent to the descending: ascending is thus compensated here by the descending. This state corresponds to the actual anticline structure of Jabal Abu Rabah and Cherifeh **(fig. 12)**.

In case that the gypsum accumulation is considerable, this exerts, at the place which it was accumulated, a strong vertical pressure giving a faulted structure in the overlying series. The adjacent syncline cannot reach the same value. The base of the syncline cannot exceed, in any case, the thickness of the gypsum bed. This state corresponds to the anticline structures in Palmyrides chain, in which the depth of the synclines are relatively smaller than the elevation of the anticlines.

The horizontal distance (hd) between the two lips of the fault would be equivalent to the distance which is suggested as shortening by the authors. Consequently, no decollement of the bed overlying the gypsum.

This modeling allows us to understand the deformation style of the genesis of the Palmyrides chain. It is clear, in this model, that the pressure direction which produced this deformation is from the side of the steep flanck of the anticline and of the low lip of the fault.

According to the assymetric anticline and to the fault aspects in the southern Palmyrides, this interpretation corresponds to the pressure caused by the Arabian Plate movement toward the N-NE forming the Palmyrian fold belt during the Neogene.

The pressure effect of the Bitlis suture in the north of the Arabian plate is clearly shown in the Jabal Abd Al Aziz, NE Syria. This anticline is cut in its core by a big normal fault. Opposite to the southern Palmyride, the low lip of Abd Al Aziz fault is in the northern flank of the anticline, which indicates the sense of the closing effect of the Bitlis suture producing this anticline **(Fig.15).**

In this sense, the steep sides of the anticlines facing S-SE in the southern Palmyrides chain, on the other hand, they are facing N in Jabal Abd Al Aziz (NE Syria) and Jabal Sinjar (NW Iraq).

The Mesozoic and Cenozoic sediments in the Palmyrides basin and the Jabal Abd Al Aziz area in NE Syria, were submitted to a compression between two pressures: the Arabian plate movement during the opening of the Red Sea in the south and the closing of the

Bitlis-Zagros suture in the north. It is normal to interprate, in this case, that the anticline structures in the central part of the Palmyrides chain are relatively quiet.

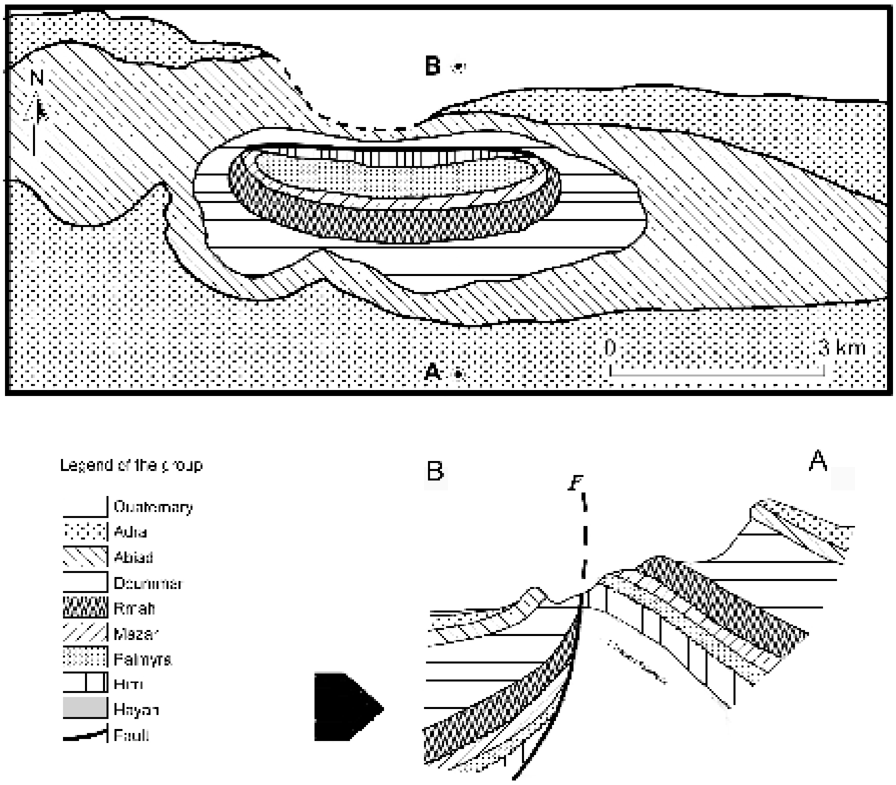

Fig. 15. Geological map of Jabal Abd al Aziz with cross sections across the anticline structure.

Timing of folding

Based mainly, on seismic reflection profiles, Chaimov et al. (1992) shows that the Palmyride trough was inverted from a trough to a fold-thrust belt in Late Cretaceous time and accelerated in the Neogene.

The lithostratigraphic sections represented by outcrops in the Palmyrides chain (Ponikarov, 1967; Ejel, Mouty&Maleh, 1983) show that the Maastrichtian - Lower to Middle Eocene series is composed of pelagic marls ("Palmyra Marl Group", Wellings, 1939). The pelagic sedimentation process did not cease at the boundary of the Cretaceous and Paleocene. Every where Paleogene deposits overlie conformably without interruption the Cretaceous beds. There is a gradual transition from the Maastrichtian to Paleocene rocks ((Soulidi-Kondratiev, 1966; Ponikarov, 1967).

The lower Paleocene deposits are present over most of the area with the exeption of some localities in the west of the area (Faradzhev, 1966).

Some breaks inside this serie, are limited in the northwestern part of the Palmyrides (Ash Shomaryeh area) (Ponikarov, 1966; Mouty & Al Maleh, 1983), without any disconformity and any horizon of detritic sediments, and without changes in the lithology of the sequence, with the exeption of the presence of some glauconitic pelagic marl horizons, which can not be considered as a marker of stratigraphic unconformity.

These breaks inside this pelagic marl sequence can not be interpreted by a tectonic movement (uplifting). On the other hand, they can be interpreted by the effect of submarine currents (Mouty & Al Maleh, 1983), which exsisted at that time in the area (Soulidi-Kondratiev, 1966).

The anormal contact which interpreted as overlap by Chaimov et al. (1990) on seismic profile of Abu Rabah anticline **(fig.12)** it represents, in my interpretation of this profile, the absence there of a regional seal by the evaporitic transfer.

According to the folding of the volcanic lava dated Miocene in the Palmyrides chain (Kasyoun, Al Rmah anticlines), (Mouty *et al.*, 1992), the timing of folding in the Palmyrides is Late or post Miocene.

Petroleum System In Palmyrides

The geologic evolution of Palmyrides region has created conditions most suitable for the preservation of hydrocarbon. A number of Triassic oil, gas and condensate discoveries have been made in the Palmyride Basin of Syria (Beydoun *et al.*, 1995).

The reservoir/ seal pattern was recognized within the Middle Triassic deposits in Palmyrides and neighbouring areas.The hydrocarbons were defined in the Abu Fayad Formation (Kurra Chine Dolomite Fm.) which is constituted of limestone, dolomitic limestone and dolomite, and sealed by the Hayan Formation (Kurra Chine Anhydrite Fm.) which is constituted of anhydrite and salt.

The traps which are developed in the Neogene are mostly structural in the form of folds or fault blocks (Brew et al.2001).

The anhydrite seals of the Triassic reservoirs of Syria have held considerable hydrocarbons in place; where these evaporites are absent or very thin, potential reservoirs in good structural traps have frequently proved barren or flushed (Beydoun *et al.,* 1995).

The transfer of the Triassic evaporites, according to our model, modified the distribution of this important cover of the hydrocarbons potential in the Palmyrides and neighbouring areas. In case of the complete transfer of this cover, the hydrocarbons became downgraded there and flushed by meteoritic water. That is the case, in general, of the faulted anticlines in the Palmyrides chain.

CONCLUSION

This study, which is mainly based on numereous field geological investigations, allows to conclude:

1-The Palmyrides fold belt is normal. The general aspect of its anticlines is like "whales back". The main faults are generally normal. They represent the maximum ascending of the anticlinal axis. There is no reverse folding and no surface geological evidence for thrusting faulting within this chain as mentioned by the authers (Chaimov *et al.;* 1990).

2-The Palmyrides chain owe its existence to the lateral displacement (transfer and accumulation) of the Triassic evaporites affected by compressive stresses resulted from the movement of the Arabian Plate to the north played the main role at the end of Cenozoic.

3-The absence of any indices of the decollement in the contact between the Triassic evaporites and their overlying beds which are largely exposed in numerous anticlines in the southern Palmyrides, denies the existence of the decollement supposed by authors (Lovelock, 1984; Chaimov *et al.;* 1990).

4-The absence of a deformation structure in Aleppo Plateau and in Hamad uplift is due probably to the absence of the Triassic evaporite in these areas.

5-The Jhar fault strikes about N70E for nearly 200 km. Its vertical and horizontal separation don't exceed 20-50m as measured in outcrop (Mouty, 1993), not more than 1 km as calculated by seismic reflection profiles (Chaimov *et al.,* 1992). This fault is probably contemporaneous with the Euphrate Graben (Cretaceous in age): the Upper Cretaceous and Paleogene sediments are highly thick to the north of this fault in the Palmyrian basin (Ponikarov *et al.*, 1967). It was lightly reactivated in the Neogene .

6-The evaporites with their characters of elasticity react everywhere in the same way under the effect of pressure. It is probably the case of the Triassic evaporites which were deposited on the Peri-Tethyian platforms and which have afterwards played the same role in the genesis of the folded chains (the Jura Mountain in France, the Atlas Mountain in Moroco, particularly the chains in the south of Tunisia).

7-The siliceous layers show under a pressure, similar phenomena like those of the evaporitic layers. The radiolarites beds in the ophiolitic complex, NW of Syria; shows the transfer of some thin radiolarite beds and their accumulation forming the core of a small anticline structure **(Fig.16)**.

Fig. 16. The radiolarites beds in the ophiolitic complex, NW of Syria; here forming the core of a small anticline structure indicates only the transfer of the beds.

8-Our modeling allows to understand the deformation style of the genesis of the Abd Al Aziz structure easely comparable with those in the southern Palmyrides,

9-The genesis of the folding may be, in general, the result of the evaporites displacement within sedimentary series under the plates movements.

10-Concerning the hydrocarbon prospection, it is important to mention that: a) the Triassic evaporites beds, as a principal cover in this domain, may be affected by some discontinuities which destroyed the hydrocarbon of the reservoire in the strong folded zones. B) The Triassic evaporites displacement has no effect on the underlying beds. In this case, the anticlinal structures situated below the Triassic evaporite beds are due, logically, to the effect of a Paleozoic evaporites displacement, as the Eocambrian anhydrite found in the northeast of the Arabian plate (Husseini, 1989).

Based on the detailed geological analysis, a new structural interpretation now suggest that the Palmyrides Chain is the result of the displacement of the Triassic evaporites under the Arabian Plate movement to the north and north-east. This interpretation differs from earlier interpretations which featured a decollement of Mesozoic and Cenozoic series overlying the Triassic evaporites (Lovelock,1984; Chaimov *et al.,* 1990, 1992, 1993).

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