Volume n° 5 - from P37 to P54

Field Trip Guide Book - P52

32nd INTERNATIONAL GEOLOGICAL CONGRESS

BIOSTRATIGRAPHY, SEDIMENTOLOGY AND TECTONO-EUSTATIC EVENTS OF THE LOWER AND MIDDLE JURASSIC OF THE KSOUR MOUNTAINS (WESTERN SAHARIAN ATLAS, SOUTHERN ALGERIA)

Leaders: L. Mekahli, S. Elmi

Associate Leader: M. Benhamou

Florence - Italy
August 20-28, 2004

Post-Congress

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Front Cover:
Outcrop of Zerga (Sfissifa area)

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General setting

The Ksour mountains close to the Moroccan border offer a great choice of scenic outcrops exposing good examples of intervening controls of the sedimentation: local tectonics, slope deposits (breccias, megabreccias, turbidites), break-up of the initial (Liassic) carbonate platforms, differentiation of tectonically-controlled small subbasins (Toarcian-Aalenian) changing upwards to a siliciclastic turbiditic environment. Evolution to prograding Bajocian reefs was very steep and fast; upward a paralic environment developed up to the progradation of a Late Jurassic delta. The outcrops visited will also allow collection of Tethyian ammonites and brachiopods. On the way to the south, the excursion will visit the Jurassic site of Saïda and observe its structural features. The return trip will end with the recently discovered sauropod site of Sfissifa, and a general survey of the Tlemcen mountains.

Cultural and general interest: Oran historic site, prehistoric rupestrian carvings, old Berber palaces (ksour), pre-saharian oasis, eolian dunes, scenic Aïn Ouarka hot springs and salt deposits, pre-saharian sabkhas, the old mosque of Tlemcen -- a historic city and religious center, Mansourah Almoravid (Andalousian) ruins.

General information: 5 days. The departure and arrival points are in Oran. Travel by bus; the degree of physical effort is medium. Temperature: 30-40°C.

Introduction

The northern part of the African plate is represented by the Sahara platform (Figure 1). This large desert ends westward on the Atlantic shore. To the east, it is limited by the Red Sea, but it extends to the Arabian plate. To the north-east, the Sahara reaches the Mediterranean, while its western part is limited by the Berberids to the North by a remarkable structural line, 2000 km long, between Agadir (Morocco) to the west and Gabes (Tunisia) to the east.

The Berberids (Figure 2) are orientated east-west. They encompass several structural units around a resistant mole (the domain of High-Plains). In the visited area, the following units are distinguisheable from north to south: the Tell – Rif belonging to the Maghrebid part of the Alpine Belt, the slightly deformed Tlemcenian domain, the more stable High Plains (the so-called Oran Meseta) and the Atlasic domains. In the latter, the Saharan Atlas constitutes the palaeostructural and palaeogeographic articulation between the Moroccan High Atlas and the central Algerian Aurès. In its Ksour segment the Atlas domain is trended SW-NE whereas its orientation is roughly west-east in the High Atlas and NW – SE in the Aurès.

The first and last days of the trips will be partly devoted to a transect through the Tlemcen to the Atlas domains. This allows us to observe the main characteristics of the Tlemcenian structure and Jurassic succession: great strike-slip faults segmenting the SW – NE trend of the structure (Saïda, stop 1 of day 1); late break up of the initial carbonate platform (Late Pliensbachian) and late development of the siliciclastic turbidites (Callovian); large development of the Late Jurassic carbonate platform (stop 16 of day 5; Figure 8).

In the Ksour Mountains (the Atlas domain), the major feature is its diachronous history compared to the Tlemcen Domain: early development of the initial carbonate platform, probably as early as the Rhaetian-Hettangian in the most subsiding subbasin (Aïn Ouarka, Chemarikh). The marine Lower Hettangian has been proved by the first known occurrence of a Hettangian ammonite in the Maghreb, south of the Rif. The Sinemurian is well dated by rich ammonite faunas. The subsiding subbasins became hemipelagic during the Sinemurian, with radiolarian limestones and with several biostratigraphical markers. Along the northern marginal subbasin (Aïn Ben Khelil) and its border (Djebel Reha), the first drowning occurred slightly later. Regional peak deepenings happened during the Late Pliensbachian, the Early Toarcian, and at the beginning of the Late Bajocian. The return to a platform environment began diachronously, from the Late Bajocian (in the SW) to the Early Bathonian (in the NE).

The Ksour Mountains are part of the folded Saharian Atlas; long and tight anticlines offer good exposures of the Jurassic. It must be stressed that the folded range is larger than the Atlas Jurassic trough. The main stratigraphic characteristics are:

- early installation of the initial carbonate platform, probably as early as the Early Hettangian (inside the *Chemarikh Dolomites*) or, even, the Rhaetian (*Tiout Bridge Formation,* Bassoullet, 1971, 1973); at the

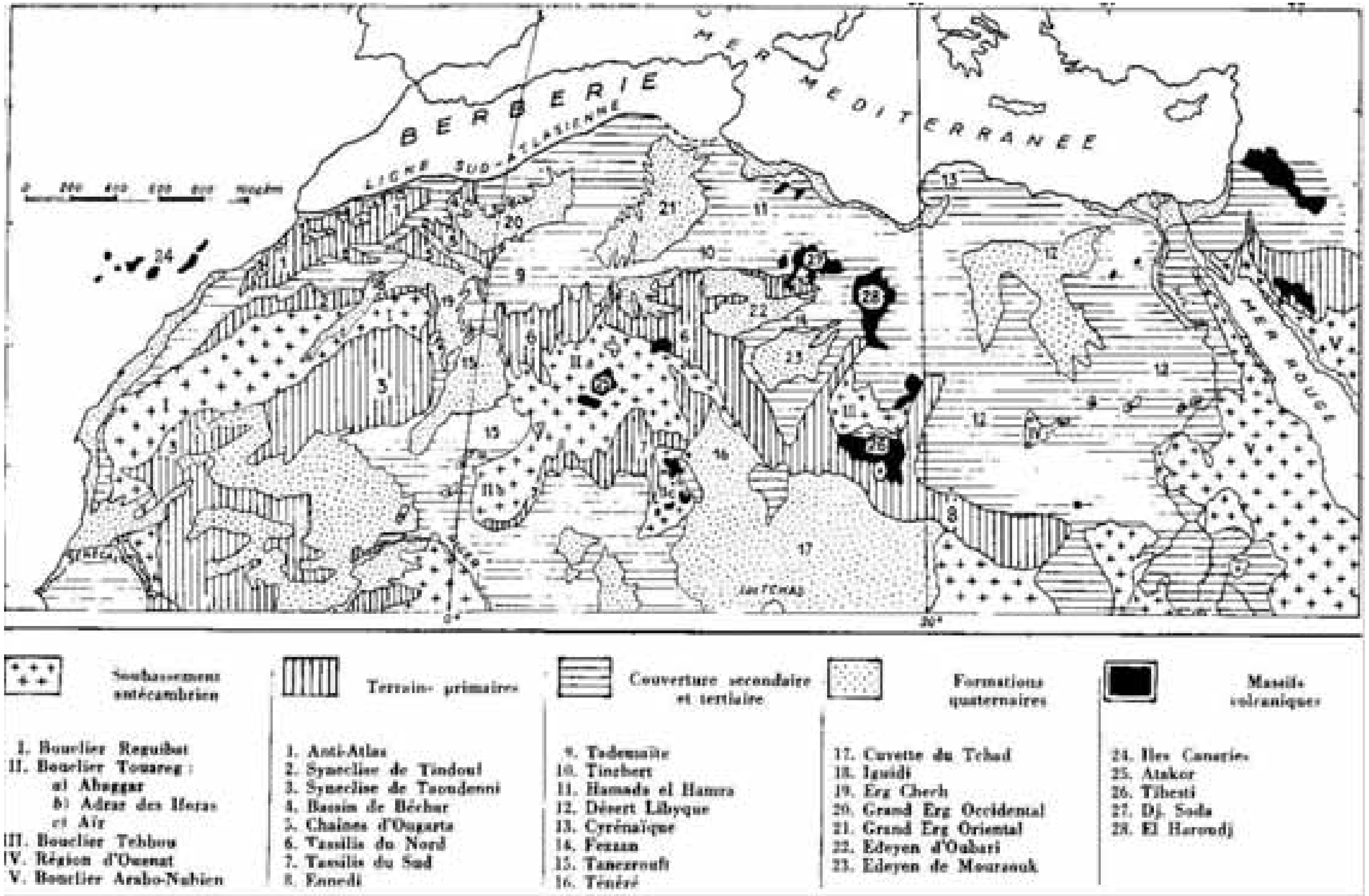


Figure 1 - The Maghreb system and its position on the northern margin of Africa (Menchikoff, 1947)

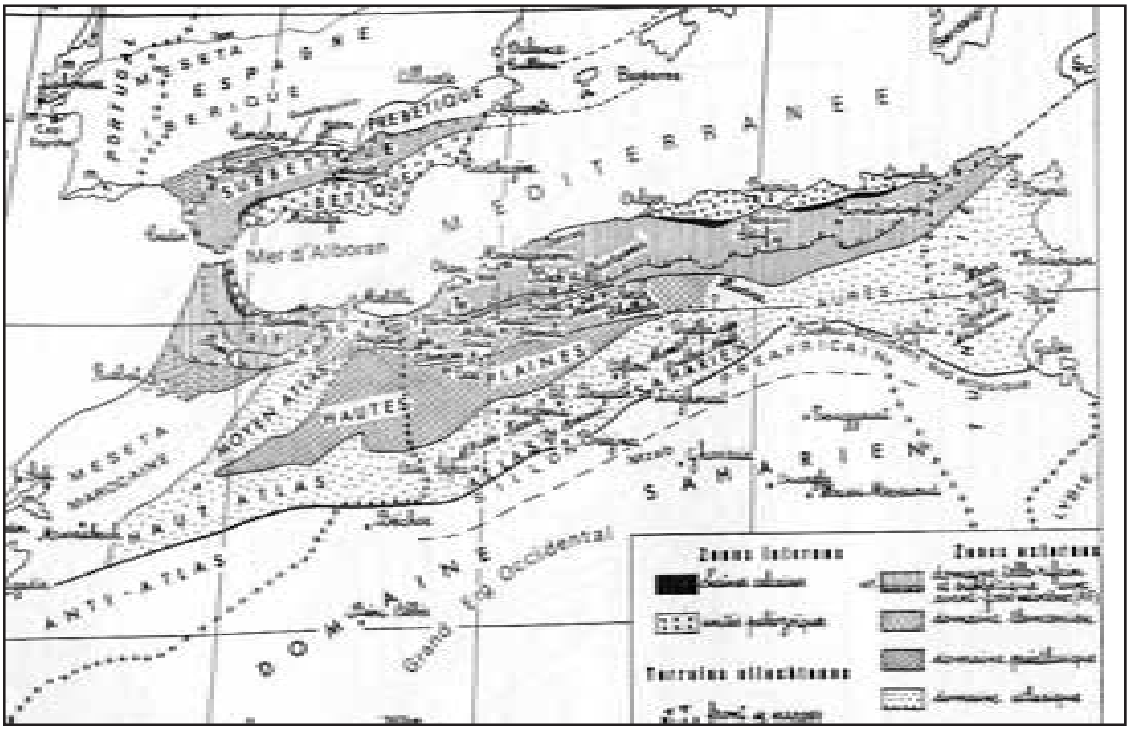


Figure 2 - Structural map of the western Mediterranean and the studied areas (Benest, 1985)

top, some episodic deepening can be documented by poorly-preserved Hettangian (and possibly lowermost Sinemurian) brachiopods and ammonites, indicative of the first “maximum flooding” (or, more accurately, main deepenings);
- early deepening with pelagic facies appearing during the Early Sinemurian (Semicostatum Zone); in the Southern Aïn Ouarka “umbilicus” (losangic or circular subbasin), the radiolarias occurred as early as this age (lower member of the *Aïn Ouarka Pelagic Limestones)* (Bassoullet, 1973); in the westernly Figuig umbilicus, radiolarias seem to appear slightly later, at the beginning of the Late Sinemurian (Elmi 1996);
- basinal facies ranging up to the beginning of the Late Bajocian, when quartzose turbidites were interbedded within basinal marls *(Teniet el Klakh Fm);*
- quartzose sedimentation became progressively dominant during the Late Bajocian; the return to (Fig.1) carbonate platform conditions was diachronous and emphasized by the development of built-up reefs at the lower part of the *Tifkirt Formation,* while Arabian ammonites arrived on the adjacent platforms. This basin to platform inversion occurred during the middle part of the Niortense Zone (Bou Lerfahd near Aïn Ouarka; Djebel Sfissifa; Djebel Guettaï, for instance) with the exception of the Median Shoal (Souiga-Melah) and of the neighbouring El Harchaïa anticline, where siliciclastic turbidites and/or calciturbidites persisted until the end of the Early Bathonian.
- no carbonate platform during the Late Jurassic; the area is invaded by the deltaic and prodeltaic sediments of the *Ksour Sandstones Group* (Bassoullet, 1973; Delfaud, 1975; Elmi, 1978).

From the north to the south, the Ksour are composed of several zones characterized by their different sedimentary and geodynamic history, as documented by the comparison of the synthetic profiles summarized on Figure 3.

Regional geologic setting

The detailed part of our field trip is mainly devoted to the Aïn Ouarka area, but we shall give an overall view of the different sectors of the Ksour mountains (Figure 4). From north to south: a/ The Aïn Ben Khellil area (northeastern border, northern transitional slope to

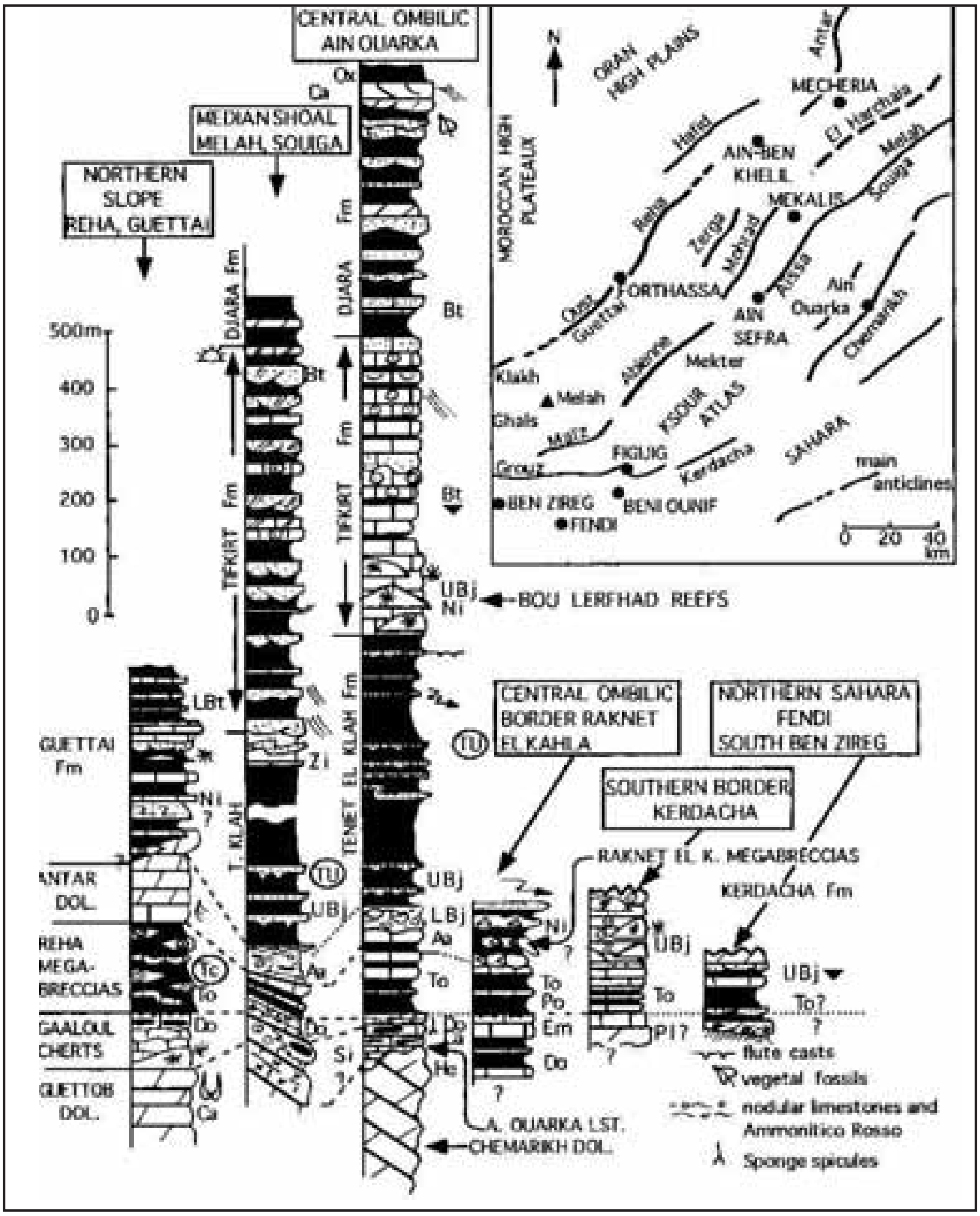


Figure 3 - Comparison of the stratigraphic profiles through the Saharian Atlas (Ksour mountains) from the northeastern marginal folds to the Sahara (South of Ben Zireg, between Bechar and Figuig). Each log is a synthesis of several measured sections. Abbreviations of stages, zones and facies symbols: He= Hettangian, Si = Sinemurian, Ca= Carixian, Do= Domerian, To= Toarcian, Aa= Aalenian, LBj= Lower Bajocien, UBj= Upper Bajocian, Bt= Bathonian, LBt= Lower Bathonian, Pl= Planorbis. Em= Emaciatum, Po= Polymorphum, Ni= Niortense, Zi= Zigzag, Tc= calciturbidites, TU= Quartzose turbidites. From Elmi et al., 1998.

Figure 4 - Field trip itinerary

the High Plains, and Aïn Ben Khelil subbasin), b/ the Melah-Souiga (or Mekalis) median shoal, c/ the Aïn Ouarka subbasin or central umbilicus, d/ the southern border (Kerdacha).

a - The Aïn Ben Khellil area
The northeastern border
This border, with the Hafid and Antar anticlines, belongs to the palaeogeographic domain of the High Plains. The basal *Guettob Moulay Mohamed Carbonates* (exposed c.30 m) may be equivalent to the *Koudiat el Beia Fm* (Sinemurian?) dated to the Late Sinemurian. Above, Bassoullet (1968, 1973) has recorded *Orbitopsella dubari* Hottinger, *Planisepta compressa* (Hottinger) *sensu* Septfontaine 1984, 1985, quoted as *Labyrinthina recoarensis* (Cati), and abundant *Palaeodasycladus mediterraneus* Pia from the *Oulad Amor Formation* (35 to 85m). These can be attributed to the Lower Pliensbachian (Carixian) through comparison with similar beds (especially in the Moroccan Middle Atlas) and by the occurrence of the brachiopod *Hesperithyris renierii* (Catullo) var. *sinuosa* or *minor* DUBAR. The

Toarcian *Jebel Nador Fm* is represented by thick purple marls, bioclastic limestones and dolomites (60 to 120m). The Middle Jurassic shallow carbonates *(Antar Dolomites Fm)* and the overlying sandstones have not been accurately dated.

The northern transitional slope

The Ksour Mountains are limited to the north-west by a trend of anticlines bordering directly on the High Plains (Dj. Guettaï, Reha, Guettob Moulay Mohamed). The Lower Jurassic outcrops especially at the foot of the Dj. Reha.

It consists of three formations. At the base, the *Guettob Moulay Mohamed Carbonates Fm* has a thickness of more than 150 m. It begins with a *Massive Dolomites Member,* changing upwards into a *Lithiotis Limestones Member*, rich in large shell bivalves, randomly disposed and containing corals at several levels. These are overlain by the *Gaaloul Cherty Formation* (95-100m). This consists of grey cherty limestones in decimetric beds separated by thin marls. The surface of the beds are locally covered by varied bioclasts and oolites. These beds document an outer platform environment. Their top is a rubefied hard ground bearing belemnite rostrums, indicating a condensed episode. The age ranges from the Carixian (*Tropidoceras* sp., in the lower part) to the Late Domerian (with *Emaciaticeras* sp. and *Tauromeniceras*) at the top. The main part is dated to the Middle Domerian: *Reynesoceras* gr. *indunense* (Meneghini), *Prodactylioceras sp., Arieticeras* sp.

Above that, the *Reha Formation* (150 m) is a thick, cyclic sequence:

- alternating marls-limestones beginning at the top of the Domerian (*Tauromeniceras* sp.) and ranging onto the Early Toarcian. *Paltarpites* sp. and *Dactylioceras (Eodactylites*) gr. *mirabile* FUCINI, indicate the lower Mirabile Subzone of the Polymorphum Zone; higher, *Dactylioceras (Orthodactylites)* sp. marks, probably, the top of the same zone;
- marls bearing a pyritic ammonite fauna of the Bifrons Zone; the Gradata Zone is badly documented at the top by loose ammonites: *Pseudogrammoceras subregale* Pinna and "*Podagrosites*" gr. *aratum* (Buckman) associated with *Audaxlytoceras dorcadis* (Meneghini). These marls have accumulated along a slope, indicating the presence of a narrow oolitic barrier limiting the Atlas open sea from the High Plains sabkha (Cornet *et al*., 1953; Bassoullet, 1973; Mekahli, 1998). Toarcian marls containing dwarf or miniature ammonites indicate a tendency towards the isolation of the area in a relatively deep marine environment. It is the local indication of the Toarcian anoxic event.

This general instability can be compared to similar conditions which are known during the Early-Middle Toarcian as evidenced along the northern ridges of the Moroccan Central High Atlas (Talghemt Pass) or along the faults limiting the Figuig Atlas and the Western (Higher) Sahara. This marked Toarcian deepening led to the differentiation of small subbasins (umbilicus) along the bordering faults. The return to a platform setting was rapid, with the deposition of *Zoophycos* limestones, passing vertically and laterally to shallow carbonates (*Antar Dolomites Formation)*. During the Late Bajocian, oolitic bodies and reefs prograded from the SW and the west *(Guettaï Formation)* over alternating marls and neritic limestones, yielding the now classical *Ermoceras* fauna (Arkell & Lucas, 1953; Alméras *et al*., 1994).

The Aïn Ben Khelil subbasin

This succession is known from wells (see Kazi Tani, 1986 ; Aït Ouali, 1991; Aït Ouali and Delfaud, 1995) and Toarcian outcrops (Ras el Guenatis). The Toarcian facies (alternating marls and micritic limestones) seems to indicate that the sea bottom was then less deep than at the foot of the Reha slope. This is consistent with the data given by the ammonites *(Furloceras* of the Gradata Zone), which have a "normal" size. The area was not invaded by the Bajocian reefs and the deposition of siliciclastic turbidites continued until the Early Bathonian, particularly in the famed locality of El Harchaïa (Flamand, 1911), where the alternating sandstones-marls is rhythmically interrupted by allodapic oolites and by bioclastic limestones (Elmi & Alméras, 1985), rich in ammonites, brachiopods and bivalves. It is the type locality of *Oraniceras hamyanense* Flamand. The abundance of *Ctenostreon* (= *Pina*) *palati* Flamand is noteworthy (Bassoullet, 1973). These beds can be considered as a marginal facies of the *Teniet el Klakh Fm.*

b - The Melah-Souiga (or Mekalis) median shoal

The initial platform carbonates (the *Souiga Dolomites Fm*) indicate a tidal to intertidal dominated environment. However, their upper part yields a rich rhynchonellid fauna, similar to that of the Ouarsenis, where it has been collected below the Middle Carixian *Tropidoceras* (Benhamou, 1996). It is associated with

Zeilleria hierlazica (Oppel), which appeared only during the Sinemurian. Above these, calcareous red nodular or pseudonodular (bioturbated) limestones occur (calcareous Rosso Ammonitico: micritic pink limestones in decimetric beds separated by thin marly layers) at the base of the Domerian *Aouinet es Siah Fm*. The upper part of the formation consists of cherty limestones. The Toarcian is represented by the marl-dominated lower part of the *Aïn Beida Fm* overlain by the Aalenian *Zoophycos* limestones (Dj. Souiga) changing upward to a marly Rosso Ammonitico (Melah), (Figure 5a).

The dynamic role of this region seems to have changed during the Aalenian-Bathonian; there are no Bajocian carbonate platforms nor reefs. Distal turbidites occurred during the Early Bathonian; these are associated with slumps and brachiopod-rich limestones (top of the *Teniet el Klakh Fm)* which are younger than in the Guettaï and in the Aïn Ouarka areas.

In the Aïn Beida section of Djebel Melah, the *Teniet el Klah Fm* begins with a turbiditic bed showing flute-casts and containing rare ammonites *(Leptosphinctes)* from the Late Bajocian (Figure 5b). Channelized sandstones have appeared after the Early Bathonian Note that the limit between the *Teniet el Klakh Fm* and the *Tifkirt Fm* is now placed under the first channelized sandstones, instead of being defined on biostratigraphic data (Bassoullet, 1973; Elmi, 1978). The type locality of these two formations is situated across the pass separating the Djebel Souiga and the Djebel Tifkirt.

c - The Aïn Ouarka subbasin or central "umbilicus"

This was the most strongly subsiding area of the Ksour, where the thickness of the sedimentary accumulation depended largely on pull apart dynamics up to the Late Bajocian (Bassoullet, 1973; Mekahli, 1998; Mekahli & Elmi, 1997). The Jurassic succession begins with the initial platform carbonates of the *Chemarikh Dolomites Formation* documenting a shallow, protected, subtidal environment, with indication of a reef-barrier (Aït Ouali, 1991). Near the top, some brachiopods, including *Zeilleria perforata* (Piette) (= *Terebratula psilonoti* quendstedt), indicate the first open sea influences. They occur under the first occurrence of an ammonite (Mekahli, 1998). It is a poorly preserved but significant specimen of *Caloceras* gr. *pirondi* (Reynes) that suggests that a seaway has been temporarily opened through the Eastern Atlas Ranges. It also indicates that the first important Jurassic deepening took place as early as the Early Hettangian.

The *Chemarikh Dolomites* were tilted and eroded before the onlap of the following *Aïn Ouarka Pelagic Limestones.* These limestones consist of pelagic micrites bearing radiolarias and *Diotis.* Their deposition began during the Early Sinemurian. On the northwestern side of Djebel Chemarikh, this relatively thick unit (120 to 160m) shows a succession of seven members (A to G) (See Figure 6).

Member A- Deep platform limestones onlapping the truncated *Chemarikh Dolomites* (Figure 5c).

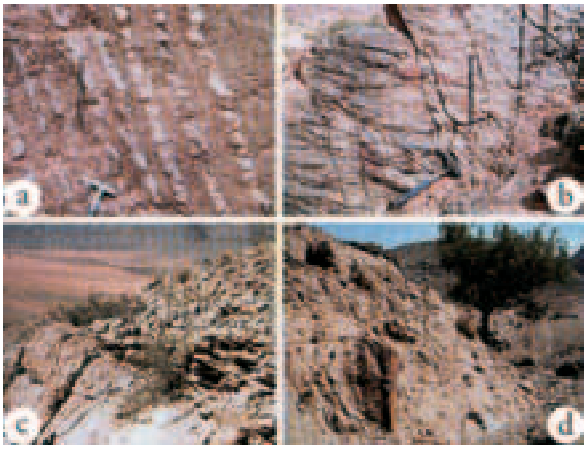


Figure 5a - Marly Rosso Ammonitico. Local facies in the Mellah. Aalenian-Lower Bajocian. Aïn Beïda, eastern slope of Djebel Mellah (Naâma wilaya).
Figure 5b - Lower surface of a turbidite sandstone bed, bearing flute casts and ammonites (**Leptosphinctes **sp.). Base of the Teniet el Klakh Formation (Niortense zone, Upper Bazocian). Same locality as Figure 5a.
Figure 5c - Onlap of the Lower Sinemurian Aïn Ouarka Formation (decimetric beds) on the truncated massive strata of the Chemarikh Dolomite Formation (Hettangian). NW slope of Djebel Chemarikh, Aïn Ouarka (Naâma).
Figure 5d - Raknet el Kahla megabreccia (breccia n° 5). Vertical dip. Heterometric blocks of platform carbonates are reworked into marls of the same facies as the Teniet el Klakh Formation. One** Ermoceras **has been collected in these reworked elements. The blocks in the foreground measure more than 1 m. These features illustrate a sedimentation occurring at the foot of a scarp. Raknet el Kahla, northeast of Aïn Ouarka (Naâma W.) From Elmi et al., 1998.

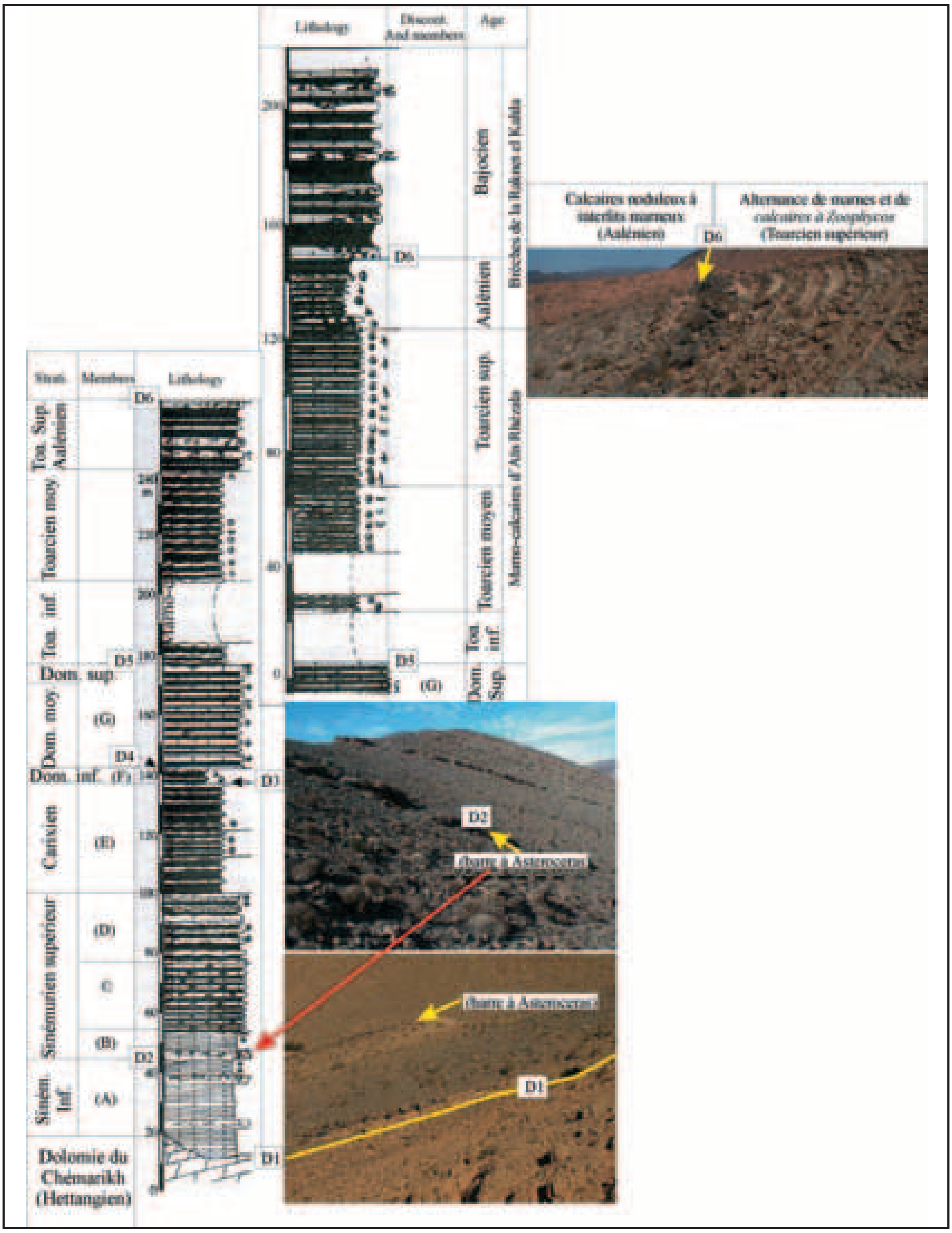


Figure 6 - Stratigraphic profiles of the Chemarikh (outcrop C/CK in the Aïn Ouarka area)

These consist of micrites with silty quartz, scarce bioclasts and Foraminifera, including Nodosariids and *Involutina liassica* Jones, an association commonly found in basinal or slope facies. The composition of the ammonite fauna, discovered by Bassoullet (1966, 1973), indicates that it may be correlated with the Semicostatum Zone. This has been completed by recent field sampling: *Arnioceras geometricum* (Oppel), *A. miserabile* Fucini, *A.* cf. *speciosum* Fucini, *A*. cf. *flavum* Buckman. This fauna may range into the Turneri Zone, and globally it can be compared with the Rejectum interval, defined by Dommergues *et al.* (1994) in the Central Apennines and by El Hariri *et al*. (1996) in the High Atlas of Beni Mellal. The Chemarikh data (Central Aïn Ouarka Umbilicus on Figure 4) allows for a better definition of the biostratigraphic range of this interval (or "biohorizon"). It does not range up into the Upper Sinemurian since it is overlain by *Asteroceras* -bearing limestones.

Member B- Wavy bedded, grumelous and bioturbed limestones (1-3m, disappearing toward the north-east, near the crest of the palaeorelief; Kazi Tani, 1986; Aït Ouali, 1991). It has yielded a rich fauna of the Obtusum Zone with large and well preserved *Asteroceras* (Elmi et al., 1998; Figure 19-22). They bear a strong affinity with the Lombardian fauna illustrated by Parona (1896): *Asteroceras stellare* (Sowerby) *in* Parona, *A.* cf. and aff. *confusum* Spath, *A. meridionale*, *A. varians* Parona, *A. margarita* Parona (which may be slightly younger than the rest of the fauna), *Arnioceras* cf. *arnouldi* (Dumortier). *Epophioceras* sp. (cf. *E*. sp. *in* Dommergues *et al.* (1994) comes from the nearby locality of M'zimer on the southeastern edge of the Djebel Chemarikh. The *Asteroceras* beds are overlain by 5 m of sublithographic limestones containing *Gleviceras* gr. *doris* (Reynes) (Oxynotum Zone). They may rest directly on the truncated *Chemarikh Dolomites* (Figure 5c).

Member C- Radiolarias-rich cherty limestones. Ammonites become rare, but several levels of the Raricostatum Zone are present:
- a lower level with *Plesechioceras* cf. *delicatum* (Buckman) and badlly preserved Oxynoticeratids;
- a level with Schlotheimiids: *Angulaticeras gr. dumortieri* (Fucini);
- an upper level with *Paltechioceras* nov. sp. (showing a relatively narrow umbilicus for the genus and straight ribbing; it is close to *P. boehmi in* Pallini (*non* Hug);

Member D- Wavy, bedded limestones and marls. The upper part is a coquina with thin-shelled bivalves (*"Diotis" janus* Meneghini; (Bassoullet, 1973). Small ammonites: *Galaticeras* cf. *aegoceroides* (Gemmellaro) from the Carixian.

Member E- The marls become progressively frequent. The Demonense Zone (Middle Carixian) is documented by the appearance of *Tropidoceras calliplocum* (Gemmellaro). The Late Carixian (corresponding to the Davoei Zone) is evidenced near the top, where *Protogrammoceras* appears with *P.* gr. *dilectum-pseudodilectum* (Fucini) and *P.* gr. *volubile-pantanelii* (Fucini).

Member F- Marly Rosso Ammonitico This member contains a rich fauna of the Celebratum and Algovianum Zones, with abundant large macroconch *Reynesoceras* (including *Aveyroniceras).*

Member G- Green marls and limestones, stacked into a upward stratodecreasing sequence. They begin in the Algovianum Zone, and the top is dated to the Emaciatum Zone. One specimen of *Pleuroceras solare* (Phillips) has been collected. This is one of the rare occurrences of this northern ammonite at the foot of the Saharian margin. To the north-east (Raknet el Kahla), the facies changes to micritic limestones containing several levels rich in *Taurومeniceras* (Elisa Subzone).

Upward, the *Aïn Rhezala Formation* is a thick, marl-dominated unit, changing to micritic limestones at the top. All the Toarcian zones have been evidenced. The lower Gemma Subzone of the Gradata zone is particularly fossiliferous. The succession of the first *Pseudogrammoceras* is well illustrated. *P. subregale* PINNA and *P. pinnai* Rivas are abundant in the Alticarinatus Subzone (Upper Gradata Zone). On the other hand, the micritic limestones of the Aalenian and of the Lower Bajocian, interrupted by some inputs of reworked material (oolites and lenticular breccias) *(Raknet el Kahla Megabreccias),* have yielded only a few ammonites: *Leioceras (Cypholioceras)* cf. *comptum* (Reinecke) (Opalinum Zone, Bifidatum = Comptum Subzone), *Staufenia (=Ancolioceras) opalinoides* (Mayer) (Murchisonae Zone, Haugi = Opalinoides Subzone), *Ludwigella* cf. *arcitenens* (Buckman) and *Euaptetoceras* sp. (Concavum

Zone). Calciturbidites, slumping and megabreccias become frequent.
Siliciclastic turbidites were widespread at the beginning of the Niortense Zone (Upper Bajocian), and the first sandstones mark the beginning of the *Teniet el Klakh Formation,* which documents a particularity high subsidence ratio (thickness up to 300 m for the lower part of the zone). A rapid and clear shallowing occurred at the end of this zone, preceeding the progradation of the *Bou Lerfahd Reefs and Limestones* within the neritic limestones, marls and sandstones of the *Tifkirt Formation* (500 m thick) which begins, here, at the top of the Niortense Zone and ranges up to the Lower Bathonian. This evolution suggests a tectonic interruption of the basinal conditions, leading to progradation of the carbonate and siliciclastic platforms (final or senile homogeneization stage). This dynamic inversion from a general deepening to a shallowing regime is interrupted by oscillatory parasequences. This inversion seems due to a major tectonic event (Elmi, 1978) with a change from the umbilicus (extension) stage to the depocenter (sag) stage; after this event the sedimentation rate kept pace with subsidence, even when this latter was intensified by more global controls (eustacy).

The reefs are exposed along the road (see Figures of stop 7 a, b). The maximum thickness is 14m. The base (4m) consists in stratified beds of fossiliferous bioclastic limestones: bivalves (*Isognomon, Lopha*), solitary corals (*Montlivaltia* ?), crinoids (*Pentacrinus*), bryozoa, calcisponges and rare Foraminifera (Lenticulinids). The central part is a reef constructed by massive coral colonies (*Isastrea, Thamnastrea*, stylinids) cemented by bioclastic micrite. Associated fauna are: bivalves (*Isognomon, Lopha*), crinoïds (*Pentacrinus*), bryozoa, algae (*Solenopora*) and stromatopores. The reefs are capped by onlapping,bedded biomicrites. The coral are phaceloid (branchiate) corals (stylinids), associated with ostreids, serpulids, bryozoas and calcisponges. A ferruginous hard-ground is developed at the top of the coral build-up. This data, and the progradation of the *Bajocian Bou Lerfahd Reefs,* allow us to surmise that a polygonal tilted block was differentiated along the Djebel Chemarikh in the median part of the Aïn Ouarka Subbasin. It must have risen from the SW to the NE,; supporting evidence can be found from the sedimentary perturbations shown by the Liassic formations. This block was limited by steep slopes. The present Aïn Ouarka N90 fault and Triassic outcrop underline the northern limit of this palaeostructure.
Upward, the *Tifkirt Formation* consists of a succession of alternating sandstones and clays or marls, interrupted by 4 oolitic levels. The last occurs 60m above the reefs and has yielded a rich brachiopod fauna indicating a Late Bajocian age (see Figure of Stop 7).
Tectonically controlled slopes are evident from the existence of the *Raknet el Kahla Megabreccias,* which have been deposited diachronously from the Early Aalenian to the Early Niortense Zone. They are transitional to the Saharian border, but some are transverse to the general trend. Thus, a south-western sector (Chemarikh), with thicker, deeper and more argillaceous deposits, can be separated from a north-eastern one (Raknet el Kahla) where megabreccias are more frequent and thicker (some blocks exceed 1 m) (Figure 5d). These megabreccias range from the Early Toarcian (*Eodactylites)* to the end of the Early Bajocian [*Emileia* cf. *brocchi* (Sowerby), *Otoites* cf. *sauzei* (d'Orbigny)]. The Lower Toarcian is noteworthy due to the presence of a "niveau chocolat" (brown, chocolate- coloured layer) which is a thin calciturbidite. Similar, coeval beds are known in the Middle Atlas (Colo, 1962) and in the Lusitanian Basin of Portugal (Duarte, 1994). The breccias contain limestones (with bioclasts, corals and brachiopods) reworked from the adjacent platforms and, also, resedimented "arabic ammonites" (*Ermoceras),* known to have been restricted to the epineritic shallow platform surrounding the Northern Gondwanian Margin.

From the Bathonian upward, the sedimentation became progressively dominated by coarser and more important siliciclastics in a prodeltaic environment. The beginning of coarse channelized sandstones within the *Tifkirt Formation* is diachronous: late Niortense Zone (Late Bajocian) in the southwestern Aïn Ouarka , post-Zigzag Zone (Early Bathonian) along the median shoal, post-Gracilis Zone (Early Callovian) eastward in the eastern Ksour (El Bayadh). These can be even earlier on the borders of the atlasic furrow (beginning of the Late Bajocian in the northern Djebel Guettaï, and probably in the western end of the Ksour, near Beni Ounif and Figuig).

Upward, the *Djara Formation* consists of alternating sandstones, clays and dolomites. The sandstones are laminated. The carbonates are locally oolitic (Aïn Ouarka where the formation reaches a thickness of 450m). The environment is a shallow marine platform fed by strong sandy supplies in front of a delta (the "Ksour delta"). Shore bars may have isolated lagoons in which green or red clays were deposited. This formation is poorly dated (topmost Bathonian to Oxfordian in the Aïn Ouarka sector; mainly Oxfordian eastward).

The carbonates disappear after the sedimentation of the *Djara Formation*. The *Aïssa Formation* is a thick accumulation (450 to 500m) of massive sandstones, separated by grey, red or multi-coloured clays. Sedimentary features indicate an environment of fluvial littoral plain: oblique, wavy, cross-bedded laminations, overturns, and lingoïd ripples. This formation is considered to be of Latest Oxfordian to Early Kimmeridgian, on the grounds of sequential correlations with the Tlemcenian Domain (Benest, 1985).

The subsequent *Tiloula Formation* is probably Latest Jurassic – Earliest Cretaceous in age. It is a succession of sequences made up of multicoloured clays (grey-greenish, purple), channelized and pebbly sandstones and dolomites (with stromatolites, birdeyes, and halite). In the Aïn Sefra area, this formation has a thickness of 500 to 650 m, but it is often hidden by Quarternary deposits.
Upward, the *Tiout Formation* is a coarsely detritic unit (pebbly sandstones, mud cracks, slides, and channels), accumulated in varied environments of a fluvio-deltaic plain. It is tentatively considered to be Lower Cretaceous to Albian.

The Late Cretaceous transgression is indicated by clays and gypsum (*Mdaouer Formation*; 100 to 150 m thick in the Aïn Sefra sector) and by carbonates and marls (130m) yielding cenomanian ammonites (*Vascoceras*).

d- The southern border (Kerdacha)
There are no Jurassic outcrops south of Aïn Ouarka. The transition is known only to the west in the Djebel Kerdacha, where the Liassic to Bajocian deposits show evidence of shallow platform conditions. However, a distinct deepening occurred probably during the Late Pliensbachian (sponge-spicules) and the Toarcian. Southward, a subsiding basin extended onto the Lower Sahara, but the environment remained always margino-littoral and sabkhaïc (see Busson, 1967).

Field trip itinerary (see Figure 5 & 7)

DAY 1

- Meeting of the participants in Oran; registration at Oran University (Es Senia), near the airport. Departure

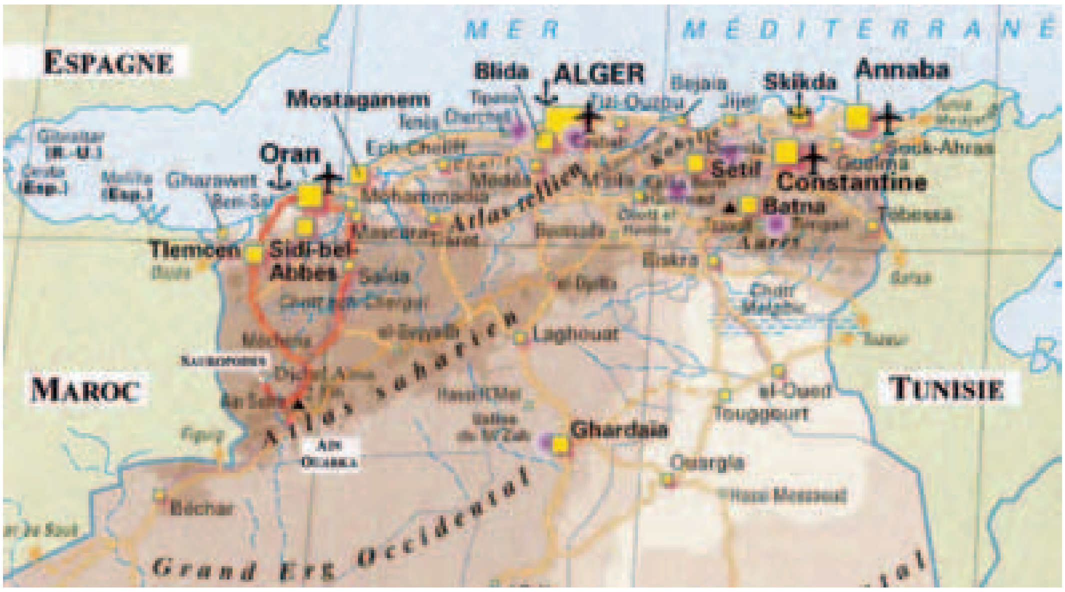
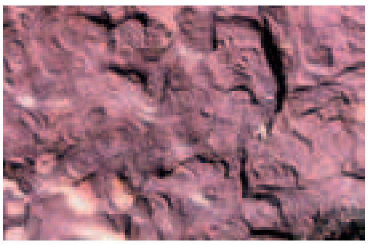


Figure 7 - Field trip itinerary (Oran, Mohammadia, Mascara, Saïda, Mecheria, Aïn Sefra, Aïn Ouarka, Aïn Sefra, Sfissifa, Aïn Sefra, Mecheria, Tlemcen, Oran).

for the city of Aïn Sefra. Participants arriving in Oran on 08/29 must make separate bookings.
- Air conditioned bus.
- Lunch in the field; dinner in hotel.
- Accommodations in double and single rooms at the Mekther hotel in Aïn Sefra.
- Between Oran and Mohammadia to the east, the road follows the Miocene depression (flexural basin of the Alpine belt). After that, the direction of the route remains roughly north - south. Between Mohammadia and Mascara, largely denuded bad lands occur on the Cretaceous and Paleogene deposits belonging to the Tellian outer nappes. The overthrust's southern limit is crossed just before Mascara, where another Neogene basin has been differentiated. South of Mascara, the itinerary reaches the Saïda Mounts belonging to the Tlemcenian domain, where the Upper Jurassic forms two cliffs (lower Tlemcen Dolomite and upper Terni Dolomite) separated by a marly slope (Raouraï marly Limestones).

Stop A:

On the way to the south, the excursion will visit the Jurassic site of Saïda and observe its structural features along a major SSW – NNE strike slip fault between the callovo-oxfordian siliciclastic turbidites and marls and Middle Jurassic tidal dolomites. (see Figure 8). South of Saïda , the Middle Jurassic carbonates form a large plateau interrupted by the depression of the Chott ech Chergui. The recent evaporitic sediments are swept by the wind and accumulated in gypsum eolian dunes. This is a recent subsiding area developed on the site of the Oran High Plains. The Atlas' north-eastern border is crossed at Mecheria, where the Djebel Antar is composed of Middle Jurassic dolomites.



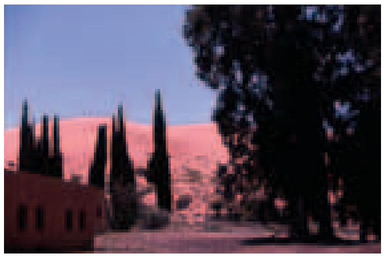
Days two, three & four

- Breakfast in hotel; lunch during excursion; dinner in hotel.
- Accommodations in double and single rooms at the Mekther hotel in Aïn Sefra.

DAY 2

Stop 1:

Eolian dunes in Aïn Sefra



Stop 1 - Eolian dune (Aïn Sefra).

Stop 2:

The old town of Aïn Sefra (Aïn Sefra ksour) and its geologic setting; to the north: narrow anticlines (Dj. Aïssa, for instance) separated by large synclines. To the south, on the contrary, the dunes are resting on Djebel Mekter, a massive and multifolded anticline separated from the northern structures by a main fault running roughly from west to east (the Aïn Sefra fault).

Stop 2 - Old palaces (ksour) in the neighbourhood of Aïn Sefra.

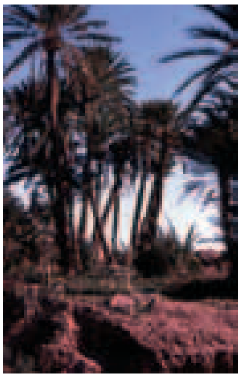
Stop 3:

Tiout bridge outcrop [dinosauroids traces (Rhaetian (?) *Grallator*) have been discovered in the past (Bassoullet, 1973]. Rhythmic tidalites crop out in tectonically complex conditions along the Aïn Sefra fault, which is underlined by Triassic basalts and marls. The Cretaceous sandstones of the Tiout Formation are widespread. To have a more general view of the tectonic contacts and of the stratigraphy , this stop will be completed by a view of the SW end of the Djara anticline (Ahmar Rhedda, near Aïn

Stop 3 - Outcrop near Tiout bridge.

el Hadjar, along the road to Bechar): the core of the anticline is marked by Triassic tectonically piercing through the Upper Jurassic sandstones of the *Djara Formation* (see, also, illustration of stop 12b).

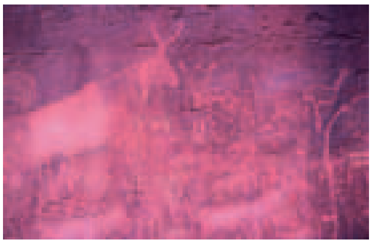
Stop 4:
Pre-saharian oasis of Tiout.



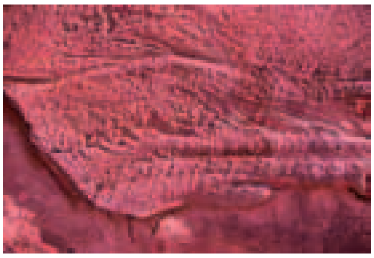
Stop 4 - Pre-saharian oasis of Tiout.

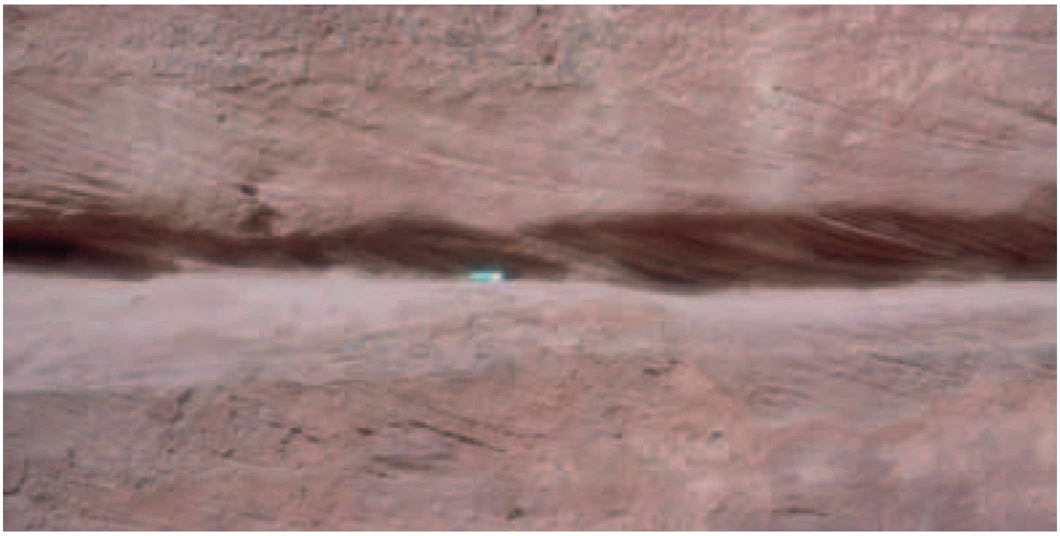
Stop 5:
Prehistoric rupestrian carvings on the Tiout Formation coarse sandstones (Tiout, Aïn Sefra).

Stop 5a - Prehistoric rupestrian carvings at Tiout.



Stop 5b and c - crossstratification in the sandstones of the Tiout Formation (Lower Cretaceous) (Tiout, Aïn Sefra).





Stop 5b and c - crossstratification in the sandstones of the Tiout Formation (Lower Cretaceous) (Tiout, Aïn Sefra).

DAY 3

The Aïn Ouarka area.

Stop 6:

Arrival at Aïn Ouarka and its scenic landscape.

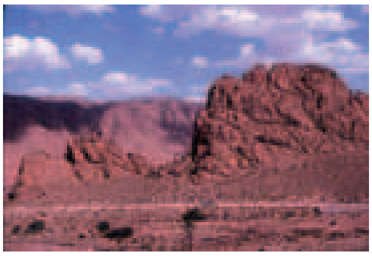
Stop 6 - Arrival at Aïn Ouarka (Aïn Rhezala).
Bajocian reefs (the Bou Lerfahd reefs).
Tifkirt Upper Bajocian to Bathonian on the left (west),
Lower Liassic dolomites on the right (east).
In the background: Dj. Djeraouine
(the Djara and Aïssa Formations).

Stop 7:

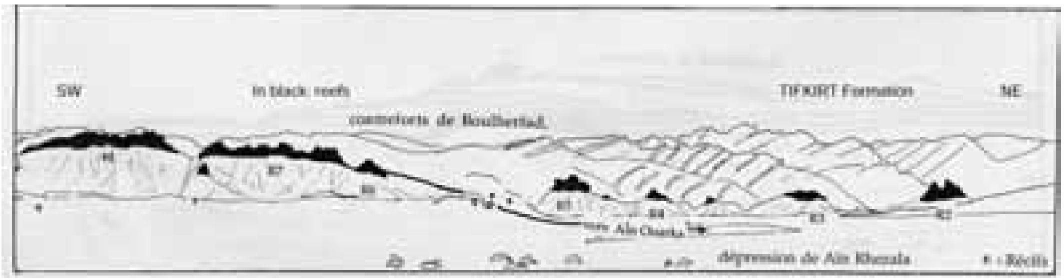
The Bou Lerfahd reefs.

Stop 8:

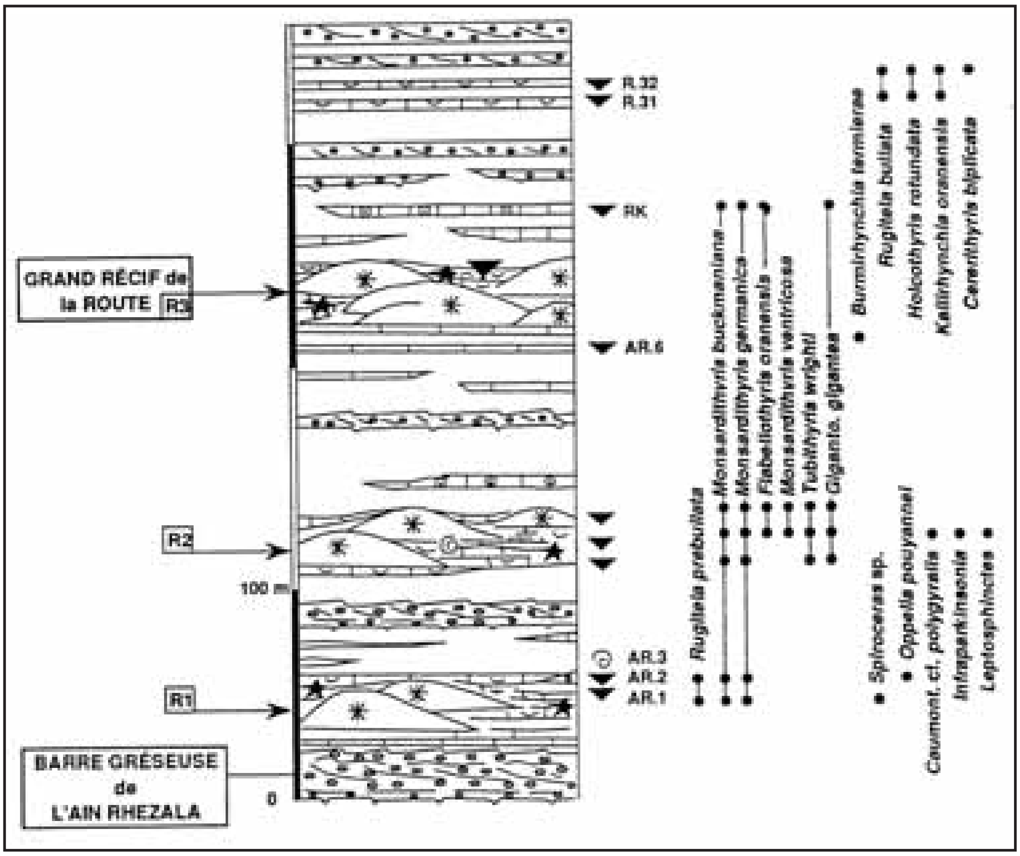
Detailed study of the Djebel Chemarikh succession, from the Lower Liassic to the Bajocian.



Stop 7a - Main reef (R3).
In the background: Djebel Chemarikh..



Stop 7c - Sketch of the reefs. View from the west.



Stop 7b - Biostratigraphy and summarized log of the Upper Bajocian to Lower Bathonian .

Stop 9:
The Aïn Ouarka hot springs in their tectonic setting.

Stop 10:
Recent salt deposits.

Stop 11:
Outcrop profile of Raknet el Kahla.

Stop 12:
Raknet el Kahla: Pliensbachian to Bajocian detailed section, illustrating the sedimentary and tectonic instability (breccias, slumps, and lateral dichronism).
- On the return route: transgressive limestones of the Cenomanian-Turonian resting unconformably on the Jurassic.

DAY 4

Sfissifa.

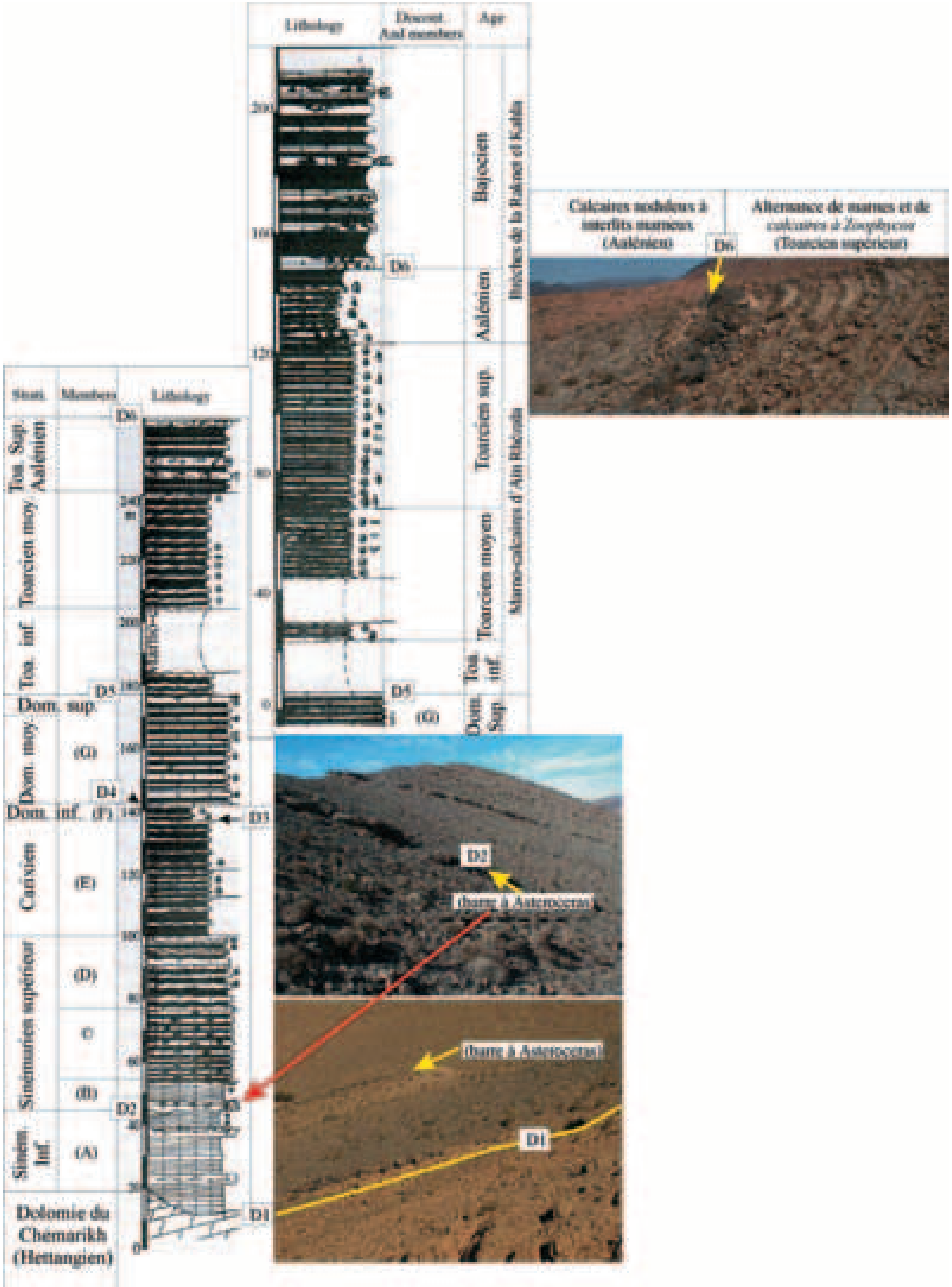
Stop 13 - Stop 14:
Old Berber palaces (ksour) in Sfissifa, and the Middle Jurassic outcrop profile of Djebel Zerga.

Stop 15:
The new sauropod site of Sfissifa

DAY 5

- Breakfast in hotel; lunch during the trip; dinner in hotel.
- Dinner, accommodations in double and single rooms in hotel in Oran.

Stop 16:
General survey of the Tlemcen mountains (Fig. 8).



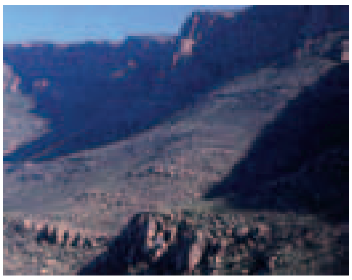
Stop 8 - Stratigraphic profiles of the Chemarikh (outcrop C/CK in the Aïn Ouarka area)

Stop 9 - Pre-saharian sabkhas and hot springs (the Aïn Ouarka area)

Stop 10a - Caravan along the Imperial trail. In the background: NE end of the Aïn Ouarka anticline (the Tifkirt to Djara Formations). Bajocian reefs behind the alluvial terrace.

Stop 10b - Caravan in front of theTriassic clays and basalts. Dj. Chemarikh in the background.

Stop 16b - The Upper Jurassic carbonates [final Jurassic platform near Beni Snouss (Khemis)]. Lower cliff: Tlemcen Dolomites; median slope: Raouraï marly limestones; upper cliff: Terni Dolomites.

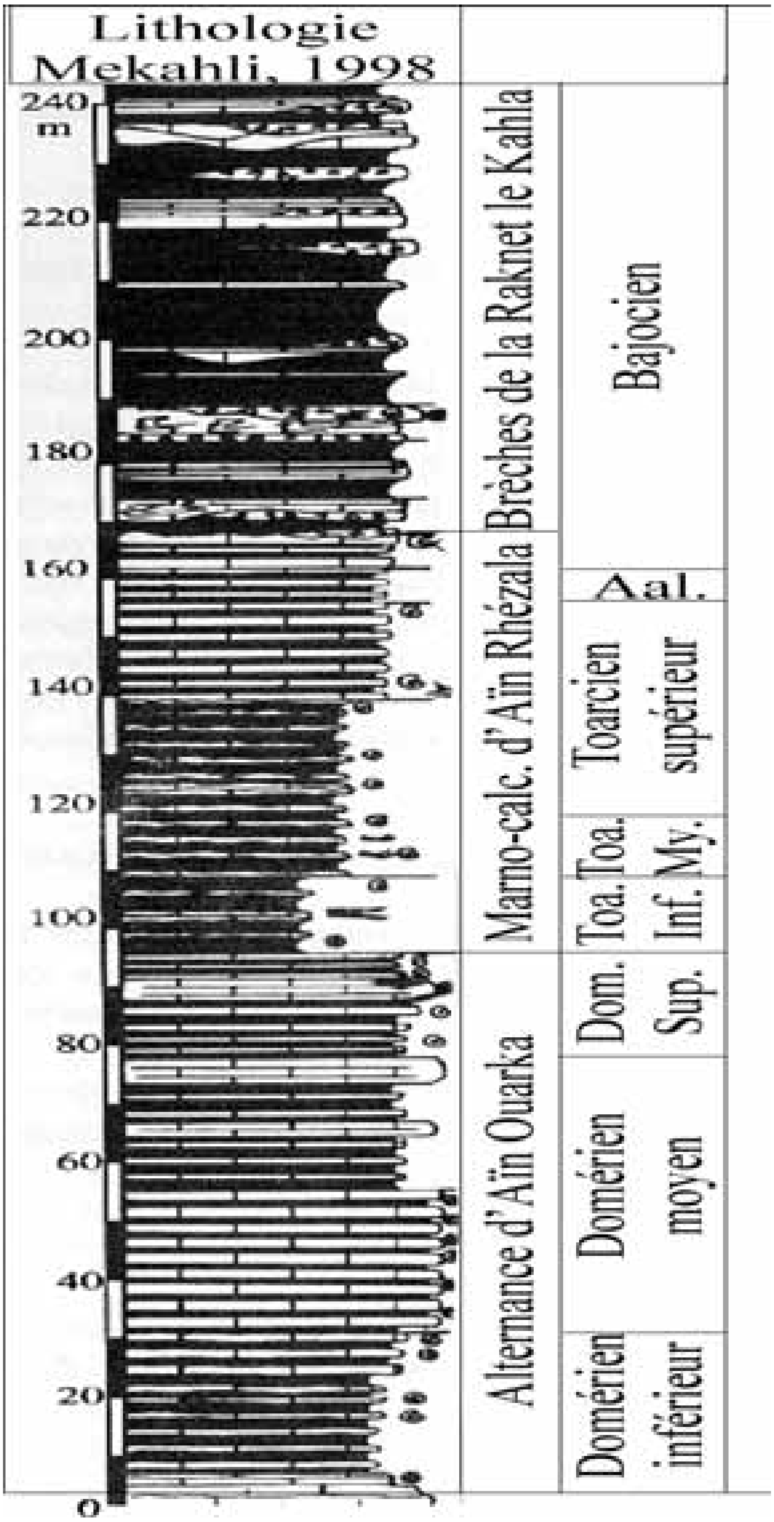


Stop 16a - Tlemcen (Rhar Roubane Mounts) Sandstones and clays from the Bou medine Formation (Oxfordian – Kimmerigian) overlain by the carbonates of the Tlemcen Formation. (Near the village of El Fahs).

Stop 11a/b - Outcrop profile of Raknet el Kahla. (NE Aïn Ouarka area).

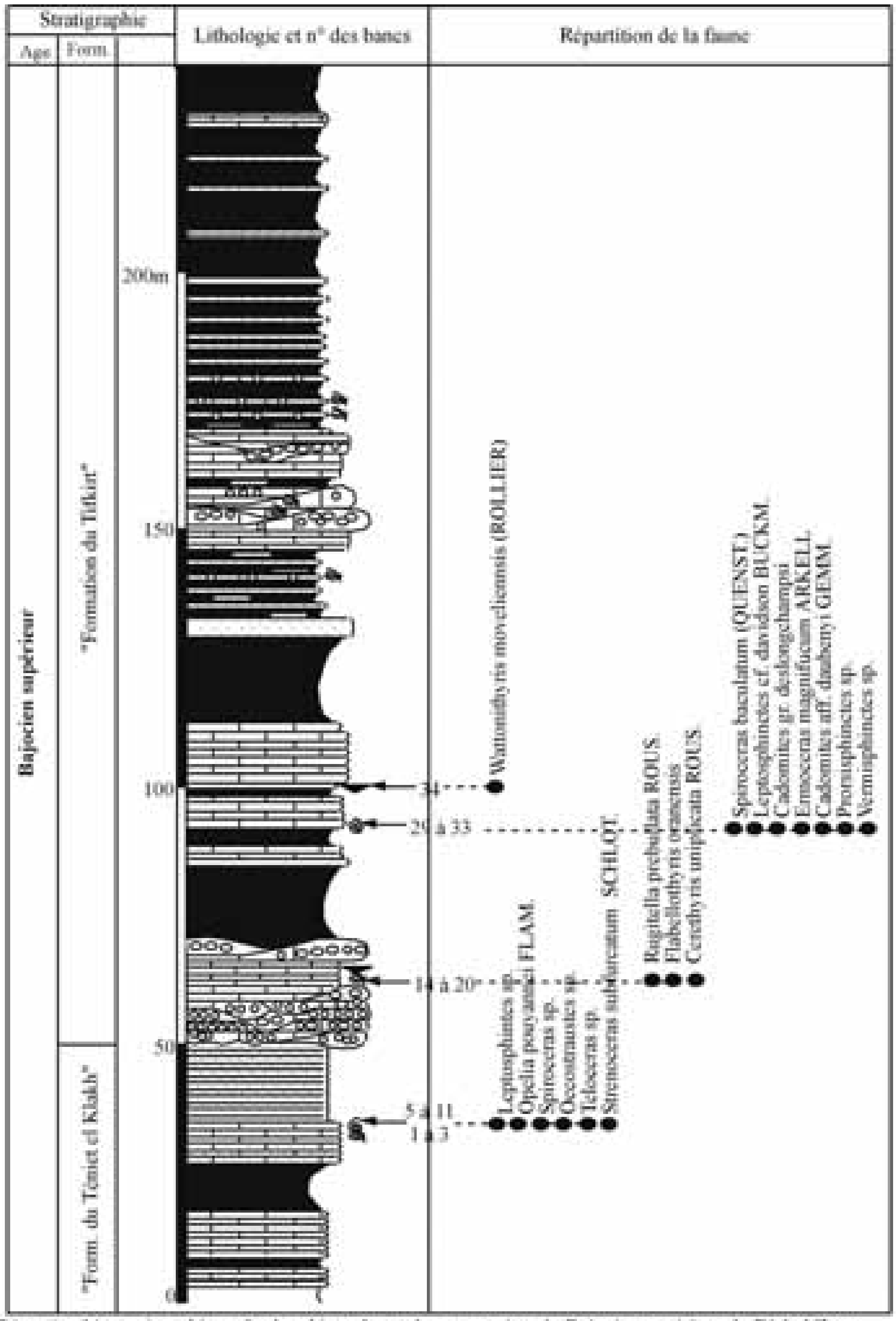
Stop 13 - Outcrop of Zerga (Sfissifa area)

Stop 15 - Sauropod site near Sfissifa



Stop 12 - Stratigraphic profile of Raknet el Kahla.

Volume n° 5 - from P37 to P54



Répartion biostratigraphique des brachiopodes et des ammonites du Bajocien supérieur du Djebel Zerga de Sfissifa (Mekahli, 1989, inédit).

1: ammonites ; 2: bélemnites ; 3: bioclastes ; 4: bioturbation ; 5: bivalves ; 6: brachiopodes ; 7: crinoïdes; 8: débris de végétaux; 9: entroques ; 10: fissures ; 11: madréporaires ; 12: oolithes ; 13: rhizocorallium ; 14: ripple marks ; 15: slumps ; 16: calcaires ; 17: dolomies ; 18: grès ; 19: marnes ; 20: silts et argiles.

Stop 14 - General survey of Zerga stratigraphy (Sfissifa area)

Stop 17:
The old mosque and the historic city of Tlemcen

Stop 18:
The mansourah almoravid (andalousian) ruins.

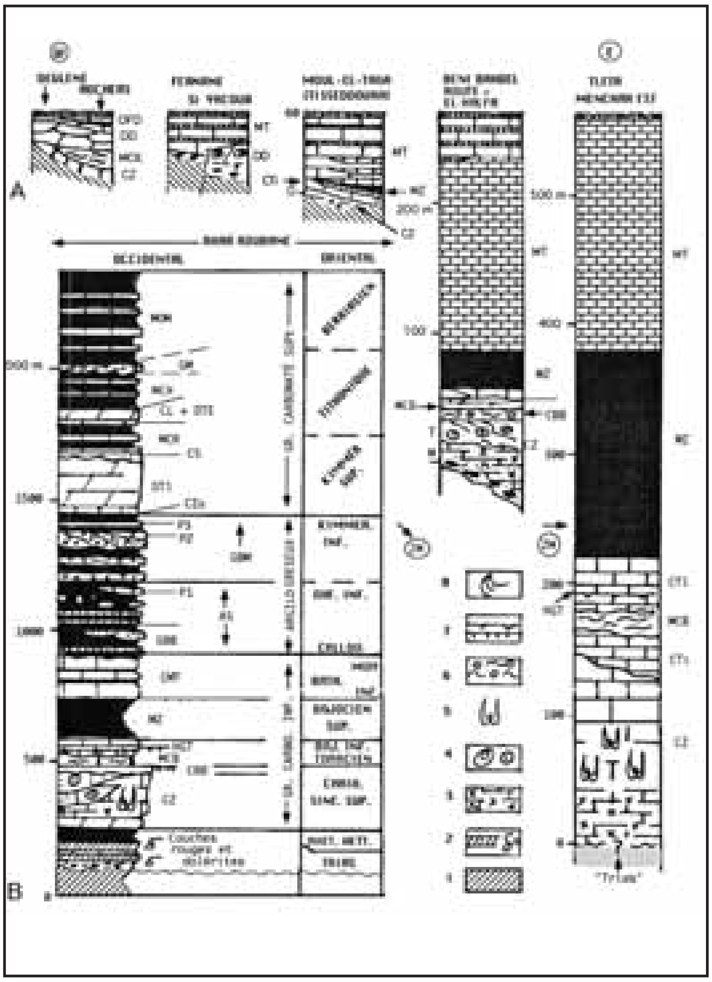


Figure 8 - Stratigraphic profiles of the Jurassic in the Rhar Roubane Mountains in the Tlemcen Domain). (Elmi, 1996 b) A- Variations of the Lower carbonate Group along the Rhar Roubane Horst. CCB = Beni Bahdel pseudonodular limestones (Domerian); CTi = Tisseddoûra limestones (Domerian); CTl = Tleta limestones (Aalenian – Lower Bajocian); CZ = Zaïlou limestones (Sinemurian – Carixian); DD = Deglène Dolomite (Aalenian – Bajocian); HGT = Tmetoceras hard ground: MCB = Bayada limestones (Toarcian); MCK = Khorchef marly limestones (Toarcian); MT = Moul el Taga limestones (Lower – Middle Bathonian) ; MZ = Zahra marls (Upper Bajocian); OFD = Deglène ferruginous oolite (Lower – Middle Bathonian); ZM = mobile zones. B – Overview of the Jurassic sequence in the Béni Bahdel area. AS = Saïda clays; CL = Lato limestones; CS = Stah limestones; Cza = Zarifet limestones; DTE = Terni dolomites; GBB = Bou Beker Sandstones; GBM = Boumedine sandstones; GM = Merchiche sanstones; MCH = Hariga marly limestones; MCR = Raouraï marly – limestones; MOM = Ouled Mimoun marly limestones; P1 to P3 transgressive carbonates within the Boumedine sandstones.

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