II CENTRAL & NORTH ATLANTIC CONJUGATE MARGINS CONFERENCE

LISBON 2010

FIELD-TRIP GUIDEBOOK

AGADIR BASIN (Morocco)

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Impressão: Impressões e Soluções, Laboratório de imagem, LDA.
Design Gráfico: Claudia Magno
Lisboa, Outubro 2010
Tiragem: 30 ex.
ISBN: 978-989-96923-2-9

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FIELD TRIP PROGRAMME

Day 0

Meeting in Agadir Airport and departure to the Riad Mogador hotel.
Briefing on the geology of the field trip area.

Night in the Riad Mogador hotel.

Day 1

Argana Valley

Reconnaissance of a typical and complete Atlantic Triassic synrift sequence.

Stop 1-1: Ikakern location. Contact Permian/Palaeozoic and alluvial fan basal sequence (T-1 and T-2 members).

Stop 1-2: Timezguidewene location. Breaded stream T-3 member on the Paleozoic (reactivation of synrift faults) and meandering system T-4 member.

Stop 1-3: Argana town. Unconformable contact between flood plain T-5 and meandering T-6 members (reactivation of the synrift faults) and flood plain T-7.

Stop 1-4: Abdelmoumen dam: T-6 Aeolian deposits.

Stop 1-5: Amskroud town: Short stops to appreciate the Alpine deformation style at the Southern Atlas fault zone at the outcrop and on seismic lines.

Night in Agadir at the Riad Mogador Hotel.

Day 2

Agadir-Imouzer Ida Outanane-Agadir

Stop 2-0: Oued Tamassint; SCP Log n° 22.
(If possible because of access to the section).

Stop 2-1: Tizgui. Outcrops of the Lower Lias Tizgui formation along the SouthWestern flanks of the Anklout anticline.

Stop 2-2: Timoulay, Aït Chehrid and Tizi n'Tinkitti. Section of Dogger red beds set on the Lias limestone, up to half way to Tizi n'Tinketti the road cuts in the following succession as logged by Ambroggi (Fig. 5).

Stop 2-3: Imouzzer Ida-ou-Tanane, Tidlli and Tamarout. General view of previous section the North-Western flank of the Immozzer anticline.

Night in Agadir at the Riad Mogador Hotel.

Day 3

Agadir – Essaouira

Reconnaissance of the Jurassic and Cretaceous facies and depositional environments.

Stop 3-1: Cap Ghir light-house; Kimmeridgian and Oxfordian Reefal build ups and facies as well as expression of the Atlasic (Alpine) structuring.

Stop 3-2: Southern flank of Jebel Amsiten anticline; tectonic style of the Atlasic deformation at the outcrop and on seismic data.

Stop 3-3: core of Jebel Amsiten "Arich Ouzla" salt pan; salt percement and onlaping deposits.

Stop 3-4: Jebel Tidsi salt diaper; as seen at the outcrop and imaged by seismic. Role of the salt tectonics in the sediments distribution during the Mesozoic and the Atlasic inversion as seen on the seismic.

Night in Essaouira at the Riad Mogador Hotel.

Day 4

Essaouira– Agadir Via Chichaoua

Fig. 1 - Itinerary of the field trip and location of the domains of the western High Atlas.

Fig. 2 - Location of the second day field trip stops in the Argana Valley (1/100 000 Geological Map, after Tixseron, 1974).

DAY 1

2nd October 2010

Argana Valley

Day 1: Visit to the Argana Valley

Introduction

The aim of this first day field trip is to examine the Triassic red beds of the Argana valley.

The outstanding scenery of the outcrops and the excellent exhibition of the entire succession allow understanding the development of Atlantic rift basins and consequently modeling the covalent subcropping basins, particularly the adjacent Essaouira and Haha basins, which are subjects to hydrocarbon exploration and production.

Geological setting

The Argana valley is located at the Southwestern corner of the Essaouira-Agadir Mesozoic basin, approximately 100 km southwest of the Meskala gas and condensate field (Fig. 1). This physiographic depression extends 85 km along a NNE-SSW trend with a maximum width of 25 km at the southern end of the valley (Fig. 2).It is composed by four adjacent sub-basins separated by East-West trending strike-slip faults.

The Permian and Triassic red beds of the valley were brought to the surface in relation with the Alpine compressional tectonic event and the inversion of the western High Atlas during the Tertiary.

The sedimentary section consists of 2.500 to 5.000 m of very coarse alluvial conglomerates at the bottom and grade upward into fine grained red-brown sandstones and shale. Laterally and westwards the upper shale passes to salt.

The basal terms set unconformably on the Paleozoic of the hercynian Central massif and the whole basin is dipping to the West in half graben-like which is likely bounded by a master normal fault facing East. This fault is presently hidden by the Jurassic and Cretaceous strata, but can be inferred from the gravity and magnetic data.

A subdivision into lithologic units named T-1 through to T-8 was established by Tixeront in 1971. A more comprehensive and modern sedimentological study carried out by Roy H. Brown in 1979, Tourani (1997) and Hofman *et al. (*2000), led to a subdivision of the lithologic units into the following informal formations and members (Fig. 3).

Ikakaern Formation (0 to 1500m) - Permian

This formation comprises Driss River conglomerates and Tourbiain conglomerate members which correspond to the Tixeront T-1 and T-2 respectivaly.

In the eastern side of the valley, at the Ikakaern location, T-1 sets unconformably on the Paleozoic of the Massif Central. T-2 generaly overlies T-1 but these tow members interfinger in the basin.

The depositional system of the Ikakaern formation is interpreted to be alluvial fan grading laterally and upward into distal braided stream.

Timezgadouine Formation (1000 to 2010m) - Triassic Carnian

It includes Tanameurt Volcanoclastic member (T-3), Agalegal sandstone member (T-4) and Irohalene mudstone member (T-5).

Near to Timezgadouine location the t-3 member sets unconformably on the underlying units and on the Paleozoic.

Sedimentologic studies established that the T-3, T-4 and T-5 members correspond respectively to braided stream channels deposits, meandering system deposits and flood plain deposits.

Bigoudine Formation (300-1450m) – Carnian - Norian

The Bigoudine formation encompasses Tadarart sandstone member (T-6), Sidi Mansour mudstone member (T-7) and Hasseine mudstone member (T-8).

At Ait Youssi location, few hundred meters east of the Argana village, T-6 rests with an angular unconformity on T-5.

Argana Basalt 60-140m) – Noprian - Sinemurian

Tholeitic lava flows are interbedded with playa to lacustrine mudstones.

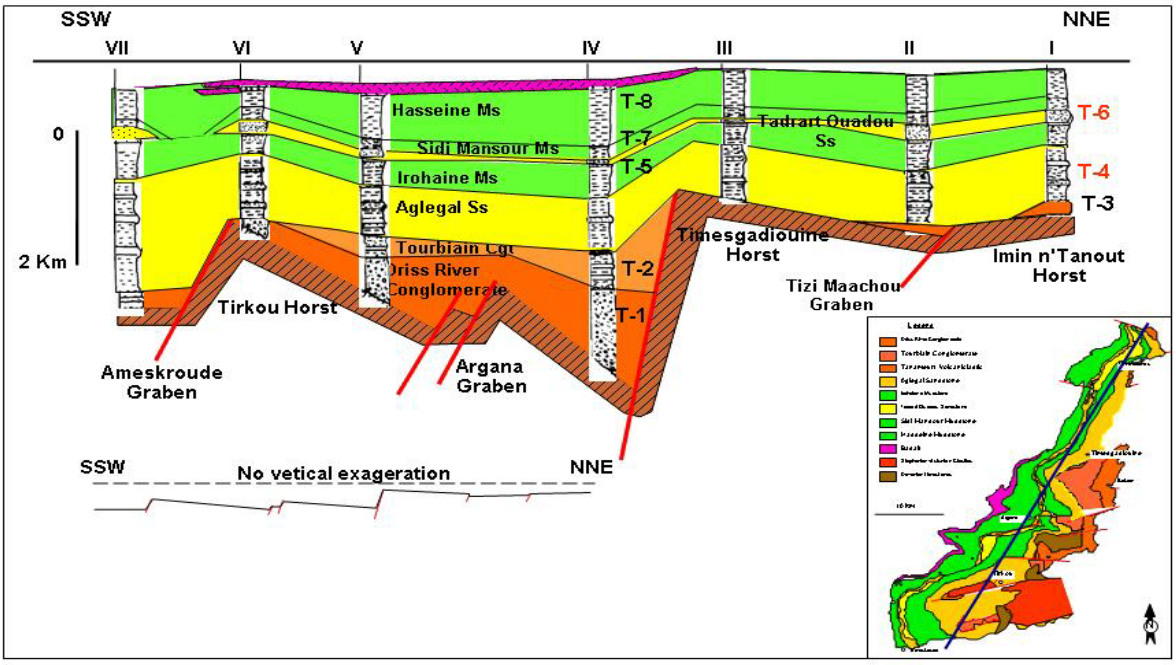
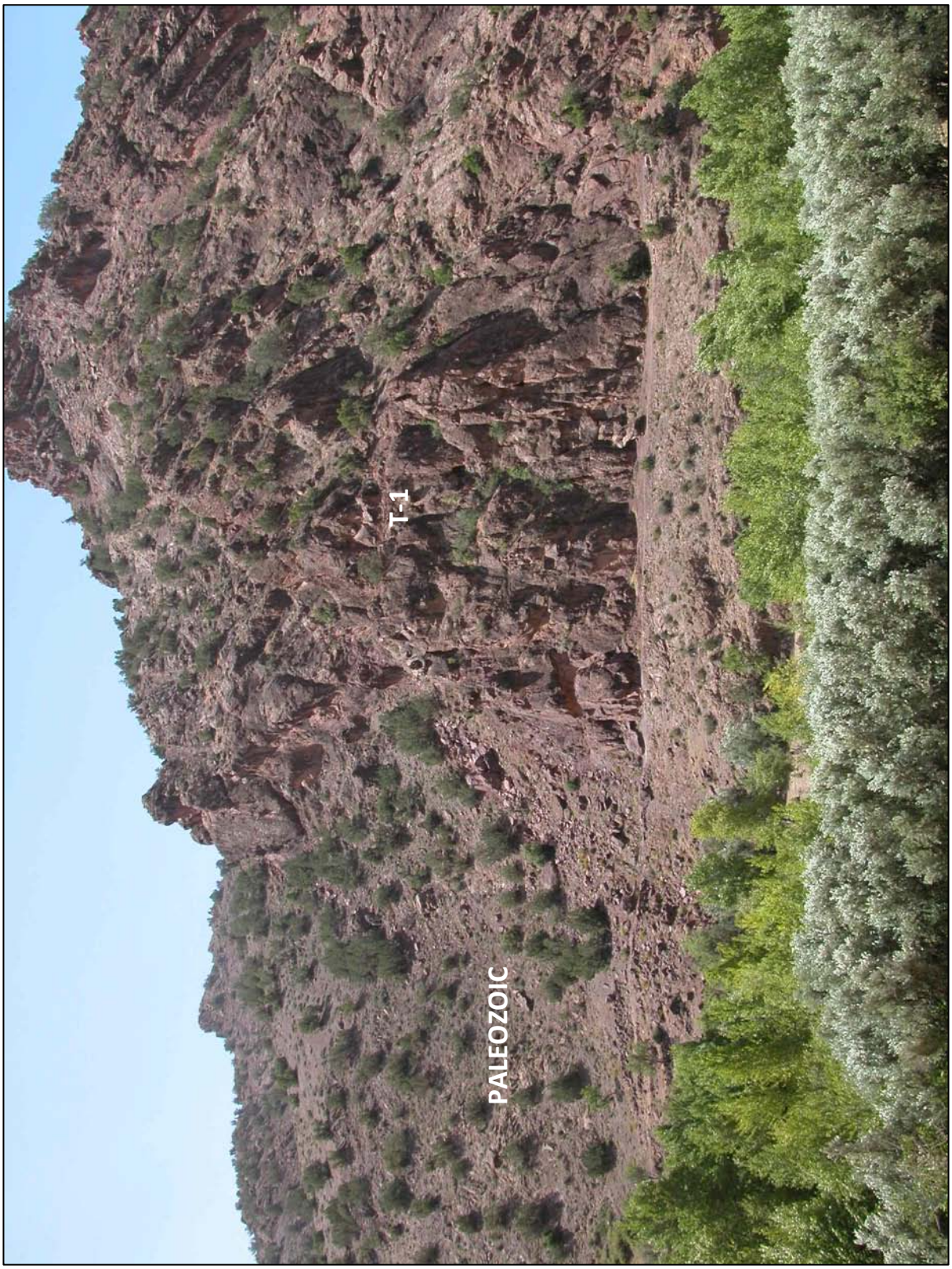


Fig. 3 - NNE-SSW section across the Argana valley showing the geometry and the thickness changes of the different formations (Modified from Tixeron, 1974).



Stop 1-1 - Ikakern location. Contact between the Permian/Palaeozoic basement and alluvial fan basal sequence (T-1 and T- 2 **m**embers).

Stop n° 1-1 - Ikakern

At this stop, located on the eastern side of the Argana Valley, the Permian Ikakern formation overlies unconformably the basement (Paléozoic).

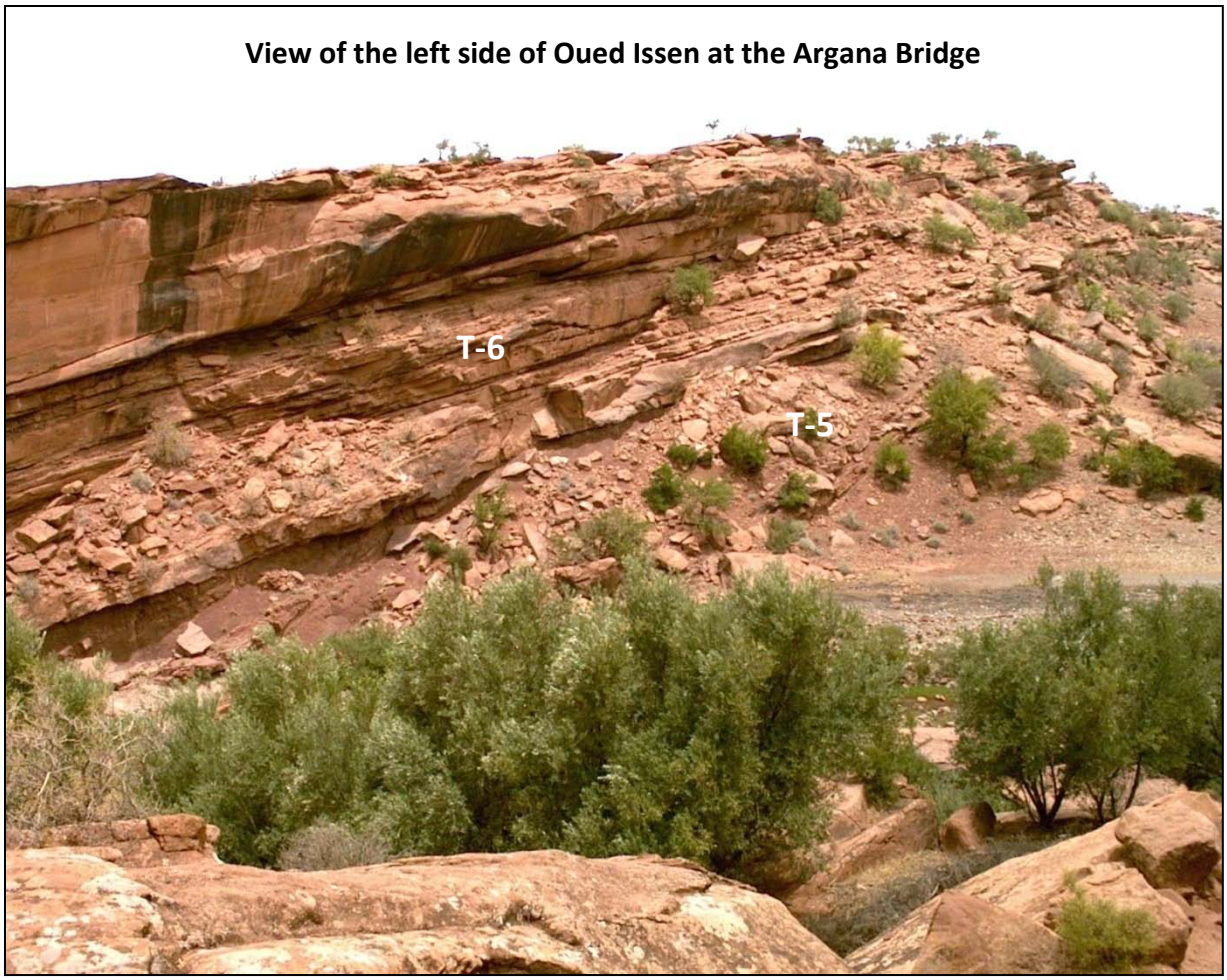
The Ikakern formation consists of T-1 and T-2 members which are formed by coarse grained and badly sorted conglomerates deposited in alluvial fans systems.

Stop 1-2: Sidi M'barek ou M'barek. Contact of T-3 on Palaeozoic

Stop n° 1-2 - Sidi M'barek ou M'barek (Timezguidewene)

At this stop, the braided stream and deposits Volcanoclastic of Tanameurt member (T-3) sets unconformably on the basement. This area corresponds likely to paleohigh bloc in the interior of the Argana basin during deposition of T-1 and T-2 members.

T-3 is then overlain by T-4 meandering system deposits and T-5 flood plain deposits.



Stop 1-3: Argana (Oued Issen bridge). T-6/T-5.

Stop n° 1-3 - Argana

The stop is located in the Argana sub-basin, few hundred meters to the East of the Argana village. The small bridge on the Oued Issene (river) is based on T-6 member and from there we can see the contact with T-7.

On the left side of the river, the T-6 member sets unconformably on T-5. Tilting of T-5 and likely the underlying formations is due to reactivation of rift fault. This resulted in the creation of accommodation space where coarse sediments were deposited.

The basal contact is erosional and the immediate deposits are conglomerates with well rounded pebbles and mud flakes. Several fluvial point bar sequences can be distinguished at this multistory channel fill separated by thin shale intervals of the flood plain. Generally these shale intervals are eroded by the overlying channel.

The whole sequence is fining upward and passes to sandstones with scores, trough as well as planar cross beds. It terminates with a thin section of decimeter thick aeolian sandstone beds.

The right side of the river offers a nice view of the lateral accretion of meandering fluvial point bar, overlain by a massive sand body of channel fill.

T-6 is overlain by mudstone dominated cyclic lacustrine or playa lake deposits of T-7. The lowermost part of T-7 is marked by highly bioturbated mudstone and siltstone base which indicate the influence of marine or lake environment. Several green grey (likely silver mineralized) shale beds were interpreted by some authors as maximum flooding surfaces at the top of brown chocolate shale of the transgressive sequences.

Stop 1-4: View of the T-6 sandstone at the Abderrahman Addakhil dam on Oued Issen.

<u>Stop n° 1-4 - Abderrahman Addakhil dam</u>

The stop is located in the Argana sub-basin, on a secondary tar road to the city of Taroudant in the Souss plain.

From the junction to the stop location, the road follows the contact between T-6 and T-7. As for the Argana Bridge, in the previous stop, the Abderrahman Addakhil dam is also based on T-6 sand bars.

At the site of the dam, outcrops the thickest section of the T-6 member. Unlike in the Argana stop 2-3 and the Amezri location, the T-6 seems to be dominated by Aeolian doposits. The

sandstone is very fine grained, well rounded, well sorted and shows steep through cross laminations.

The channels above the Aeolian section look thinner with flat base and separated by thicker shale intervals of the flood plains indicting lack of accommodation space.

The Amezri outcrop is located in the Tizi Maachou sub-basin which was the less subsiding and had therefore accumulated the thinnest Triassic section compared to the Argana sub-basins.

Here, the multistory channel fill character of the T-6 sandstone as well as the internal architecture and sedimentary structures of the individual sand bodies are well illustrated.

At least four individual point bar sequences of a fluvial meandering system can be distinguished. These are separated by flat basal surfaces and very thin shale horizons of the flood plains.

Stop n° 1-5 Amskroud

Stop 1-5: Amskroud; Style of alpine deformation affecting the Upper Lias carbonates at the southern front of the western High Atlas.

DAY 2

3rd October 2010

Agadir - Imouzer Ida Outanane - Agadir

Day 2: Visit to the Westen High Atlas

Introduction

The aim of this first day field trip is to examine some of the prominent geological aspects that mark the Moroccan Atlantic margin between Essaouira and Agadir. The complete Mesozoic section is exposed in this area due inversion of the Atlas golf.

Generel Stratigraphy: Triassic - Jurassic (fig. 4)

The area between Essaouira (Mogador) in the north and Agadir in the south has been called by various authors "The Haha Trough", "The Occidental High Atlas", "The Western High Atlas and "The Atlantic Atlas" (fig.1). It is bordered to the south by the Tertiary Souss Trough and to the north by the Palaeozoic and Triassic Doukkala Basin.

The stratigraphic chart of the area was primarily established by E. Roch (1930), based on macrofossils. Later R. Ambroggi (1963) and D. Ager (1974) improved the stratigraphic data base using microfossils. Adams, Ager and Harding (1980) have concentrated their work on the sedimentology of the area and the present text is based mainly on their publication.

1. Triassic Argana Red Beds Formation

The Triassic sediments are mainly exposed in the eastern part of the "Atlantic Atlas" in the **Argana** Valley. The section averaging 3000 m in thickness consists of conglomerates at the base and grades upward into finer grain sandstones, shale and terminates with salt or gypsum. The lower part of the section is interpreted by Tixeront (1973) and Jones (1980) as alluvial fans, the upper part as fluvial to deltaic deposits. The sequence is capped by basaltic lava flows.

Palynological age dating of middle Carnian (Upper Trias) has been reported by several authors for the upper parts of the section.

2. Early and Mid-Jurassic

2.1. Pre-Aalenian Formations

I_{4-6} Arich Ouzla Formation and I_{7} - Amsitten Sandstone Formation

The oldest Jurassic rocks are dolomites and dolomitic limestones cropping out in a belt around a diapir in the Jebel Amsitten. Presumably because of the aspect of the outcrop this

unit has been called the “Amsitten Reef" although the scarce fossils (brachipods and forams) do not indicate a reefal environment. For this reason it is renamed Arich Ouzla Formation. This is followed by a sequence of clastics, red sandstones, breccias and conglomerates called the Amsitten Sandstone formation. The Arich Ouzla Formation is probably Sinemurian and the Amsitten Sandstone Formation may partly be Toarcian.

2.2. Tamarout Limestone Formation

l_8-j_1 - Aalenian (lower Bajocian)

l_7 - Toarcian (?)

Equivalent of "Dolomies d'Anklout" on the geological map (F. Duffaud).

This formation consists mainly of pale coloured, often white, limestone, marls and dolomites, with colites and pelletal limestones. In the east of the district there are algal-mats and gypsum beds; the formation is thickest on the southern side of the Anklout anticline (300 m). The age dating of these beds is based on some small brachipods (Zeilleria anglica & Terebratula whitackeri) found by Ambroggi (1963). According to D. V. Ager, these forms cannot be regarded as of any stratigraphical value, but suggests, on the basis of the accompanying bivalve fauna, an age ranging from the upper Lias to the beginning of the middle Jurassic.

(Aalenian = Lower Bajocian in Great Britain).

The stunted nature of this fauna suggests some unusual factor in the environment, perhaps abnormal salinity. R. Jordan in Germany, has postulated massive oil and salt pollution of the sea in Toarcian times and this may be the cause of unsuitable bottom conditions.

2.3. Ameskroud Red Beds Formation

Dogger (Bajocian - Bathonian) = Grés rouges d'Ameskhoud on the geological map J_{1-2}

This formation is widely developed, though because of its soft nature it is not very well exposed. It is best seen along the main road to Imouzzer near Aït Chehrid (Tizi Tinketti).

The formation (250 - 300 m) consists mainly of red clastics with a general decrease in grain size upwards.

To the west there are dolomitized limestones and marls – sometimes recrystallized. Rhynchonellids have been found in the top part of the sequence, with trace of fossil "Thallassinoides”, which probably indicates a high energy shallow marine environment, close to the intertidal zone.

It appears that this formation is composed of detrital material derived from the central Palaeozoic Massif to the east and deposited principally by rivers although it is probable that much of the fine-grained material was windblown, with evidence of marine conditions not far to the west.

3. Middle and Upper Jurassic

3.1. Ouanamane Formation

J_4 – Callovian - Lower Oxfordian

J_3 - Callovian

Marnes d'Anklout + Calcaires d'Anklout + Dolomies de l'Amsittene on the geological map.

Details of the sequence: (In the Ida-ou-Tanane district)

- Marl and Shale member J_4

- Somalirhynchia limestone member J_3

- Iggin'Tarhazout oolite member $J_{3\text{-}3}$

- Transition dolomite member J_3

a) Transition dolomite member is mainly made of thin laminated dolomites, probably of algal mat origin, with flat pebble conglomerates. It would appear therefore that the Transition Dolomite member represents the brief establishment of intertidal/supratidal conditions prior to the main transgression.

In the Imouzzer anticline where this basal member is thickest (16 m), nodular marly dolomites interbedded with grey-green clays rest on a two-metre thick bed of cross-bedded sandstone with a burrowed top.

The member thinks south-westward to reach 8 m on the Imouzzer road at Aït Chehrid (Tizi Tinketty) location.

b) Iggi n'Tarhazout Oolite Member consists of 33 m of burrowed oolitic and intraclastic limestones. It is 10 to 25 m thick in the Immouzzer anticline. Eastwards, the section is almost completely dolomitized, but the original oolitic or intraclastic nature of the rock is clear.

The formation is diverse, but the most constant faunal elements are echinoderms and echinoderm fragments (Pygurus marmonti, Pseudodiadem inequale, Collyrites elliptical, Ambroggi, 1963). Trichite, which is a large bivalve with a thick shell of prismatic calcite typical of transgressive Jurassic floors, is common especially near the base.

It seems probable that the Iggi n'Tarhazout Oolite Member represents an oolite shoal of an early Callovian transgression.

c) Somalirhynchia Limestone Member is one of the strange features of this area, on account of to its fauna. The sediment consists of alternation of fossiliferous, bioturbated limestones and marls (thickness increasing from 8 m in the east to 42 m in the west, at Aït Chehrid). Occasionally the top surfaces of limestones are encrusted with oysters, serpulids .The presence of cement fringe, the occurrence of abundant pedunculate brachipods which would have needed affirm substratum for attachment, suggests that this member was deposited slowly in a shallow subtidal marine environment (to a depth of 30 m) with occasional halts in sedimentation .The slowness is outlined by the relative abundance of the fauna.

This fauna consists of bivalves (Pholadomya, Pleuromya, Pecten, Ostrea, Lopha), one echinoderm (Collyrites acuta), but mainly with very numerous brachiopods of East African origin: Biemithyris bovingtoni Muir-Wood, Somalirhynchia weiri Muir-wood, Stalmorynchia trilobata Zieten, occurring in the hard limestones as lens like accumulations. Such fauna, unknown in Europe, is reported from Ethiopia, Somaliland and Saudi Arabia, but a similar fauna has also been reported from the Southern Algerian Atlas; these facts suggest the possibility of a current, from the East to West at this time around the North of African cration.

d) Marl and Shale Member, the top member of the Ouanamane Formation, consists of unfossiliferous white marls with rare nodular limestones (with shelly debris) and southwards, shelly limestones in the basal part and poorly bedded shelly limestones with a sparse fauna at the top; the thickness growing from 15 m north of the Imouzzer anticline to 54 m south of the Anklout anticline. As ammonites are absent eastwards, Ambroggi assumed a retreat of the sea westwards.

The Ouanamane Formation represents the gradual establishment of marine conditions across the area, the beds thickening and becoming more marine towards the west: this suggests that the transgression came from approximately a westerly direction.

3.2. Lalla Oujja Formation

J_{5a} **- Part of Rauracian**

Equivalent of: British Corallian

Portuguese Lusitanian

Now considered the middle part of Oxfordian (Luxembourg emendation 1962)

"Reservoir de Sid Rhalem" - oil producing - assumed to be "reefs"

The Lalla Oujja Formation is one of the most interesting formations of this area, but its understanding is complicated by the difficulties of the lateral correlations, and the ambiguity of the general stratigraphical nomenclature.

The formation consists of hard, red dolomites, thickest (70 m) around Aït Chehrid (Tizi n'Tiketti), but only 10 m in the south rim of the anticline.

In places, for example, along the road down to the waterfall below the village of Imouzzer Ida-ou-Tnane, compound corals and large algal growths are seen in life position and local patch reefs are developed. However, where ever it is the most massive, the formation is always completely dolomitized (original organic build-ups are masked). In many places, especially in the western part of the area, large masses can be seen with overlying outward dipping bedded limestones reflecting the morphology of the massive units. This confirms the original reefal nature of these beds.

Where not completely dolmitized, the bedding is visible, and the strata are bioturbated, with skeletal debris of algae, corals and a few bivalves, echinoderms and foraminifera. The beds may represent accumulated debris forming from and between reefs.

In the eastern part of the area, the top of the formation consists of sandy, parallel laminated beds passing upward into a cross-bedded unit (alternations of more or less sandy material with shelly layers and nerineid gastropods. Current directions seem to be bimodal with a west northwest - east southeast trend.

It seems that the same formation is present at Cape Rhir, near the coast, below the lighthouse. But there are some doubts about the correlation so that some authors (R. Ambroggi, F. Duffaud) believe that these beds at Cape Rhir to be younger ("Rauracian-Sequanian") than those of the Anklout-Imouzzer area ("Argovian" of D. V. Ager). The doubt is accentuated by the use of much of the old stratigraphic nomenclature.

3.3. Iggui-El-Behar Formation

"Sequanian" - "Rauracian"; upper part of Oxfordian J_{5b}

= Calcaires du Hadid on geological maps (F. Duffaud)

Because of lack of fossils, this formation is noted J_3 (Middle & Upper Jurassic), in the south of the Ankelout anticline (Assif n'Talmot).

3.4. Imouzzer Formation

Lower Kimmeridgian - J_{6a} (from Imouzzer Ida-ou-Tanane = Ida-ou-Tanane Falls)

"Marnes rouges d'Imouzzer" (F. Duffaud, S. C. P) on geological maps.

"Marnes chocolat" (R. Ambroggi, 1963)

This formation is characterized by the appearance of soft, dark red-brown mudstones and pale greenish beds of the same nature, sandstones and limestone also occur. In the east of the area, red beds dominate the sequence and limestones are rare.

In the east, this formation is about 120 m thick, but in the west the formation is thinner and limestone is more common.

The limestone are generally micritic and often shelly, the fauna is mainly of bivalves : especially common are oysters which in some banks make up over half the rock; laminated limestone of algal mat origin occur at some horizons and there are some poorly sorted bands of ooliths and intraclasts with intraformational conglomerates.

These rocks were probably deposited in a marginal environment; in the west marine influences dominated in the bottom part of the formation, while in the east only occasional marine beds occur with poor faunas. Some banks, such as those with abundant oysters, are characteristic of abnormal salinities. The upper part of the formation is essentially continental throughout. Though the exact environment in which beds were deposited is not certain, it may have been a large lake with occasional marine incursions.

3.5. Tismeroura Formation

Transition beds - **Portlandian (Purbeckian) - Upper Kimmeridgian**

- Anhydrite de l'Ihchech J_{7a}

- Calcaires dolomitiques and l'Ihchech J_{6b} On geological maps (F. Duffaud)

A complete section of the Tismeroura Formation is seen in the Aït Mansour syncline, East of Imouzzer, where there are 330 m of fine grained greyish and brownish limestones and marls. Some dark red mudstones occur, intercalated with limestones near the base of the sequence. Westwards, several beds rich in oysters occur: these are bioturbated and slightly dolomitized. In the strata above these oyster beds, algal laminated limestones are recorded. The whole formation shows similarities with the British Purbeck beds, with monospecific oyster beds indicative of abnormal salinities and algal mats.

The depositional environment would appear to range from restricted subtidal (shelly banks) to intertidal and superatidal (algal limestones and evaporitic beds). The formation of such a thickness of marginal deposits suggests that subsidence was gradual and keeping peace with deposition. This would tend to indicate that the faults which were active during the Triassic and Early Jurassic producing differential subsidence were not active at this time.

This formation is attributed (Ambroggi, 1963) to late kimmeridgian and Portlandian (in the French stratigraphical sense, which would include the English "Purbeckian"). One cannot but atribute the similarities with the British succession to coincidence, though they presumably both record the general regression of shelf seas at the end of Jurassic times.

3.6. Tarhrat Formation

Portlandian - Berriasian $J_{7b\text{-}n1}$ (Jurassic - Cretaceous) transition beds

Timesiline limestone on geological maps (F. Duffaud)

The name of this formation is taken from the gorge of Assif n'Tarhrat, on the Agadir-Imouzzer road. At the base there are 6.5 m of soft crumbly limestone and marls packed with the oysters Aetostrea, Ostrea and Lopha; above these beds about 5 m of yellow siltstone is found which forms a good marker horizon, and the highest beds are pale grey, medium grained massive limestones; at the top the limestones contain quartz pebbles up to 1.5 cm in diameter.

The slight diversification of fauna compared with the formation below probably denotes the incoming of a more marine environment, this is the youngest formation seen in the area and would seem to record the invitation of the early Cretaceous transgression. The bivalve Aetostrea is of early Cretaceous age and is seen at several higher horizons on the coast north of Agadir.

Jurassic Paleogeography

It is most interesting to compare the Jurassic stratigraphical record in Western Morocco with the Jurassic succession in the Middle and High Atlas: these two troughs were separated by a ridge, the Central Hercynian Massif ridge, separating two basins, the Western Atlantic Basin, and the Eastern Basin (Middle and High Atlas) oriented towards the ancestral Tethys, the present Mediterranean Sea. Apparently, there was no E-W connection through this ridge, and the only possibility of communication was through the northern part of Morocco, below the Rif thrust belt, and by the Sierra Nevada-Gibraltar area. Some red beds which could be Jurassic have been described from the north margin of the High Atlas (Ferrandini, 1984) and the northern side of Jebilet (Lavill, 1983).

The troughs of the High and Middle Atlas were mainly filled by sediments during the Lower and Middle Jurassic: the final red beds sealing the deposits of these two trenches date from the Bathonian, perhaps Callovian times.

At the same time, the Western Moroccan Basin, only opened slightly during the Lower Jurassic, appears to have been infilled by sediments since the Upper Liassic times, but it

continued during the middle and especially Upper Jurassic: as if the subsidising areas have changed from eastern to western Morocco during the upper part of the Middle Jurassic, around the axis of the Central Hercynian ridge.

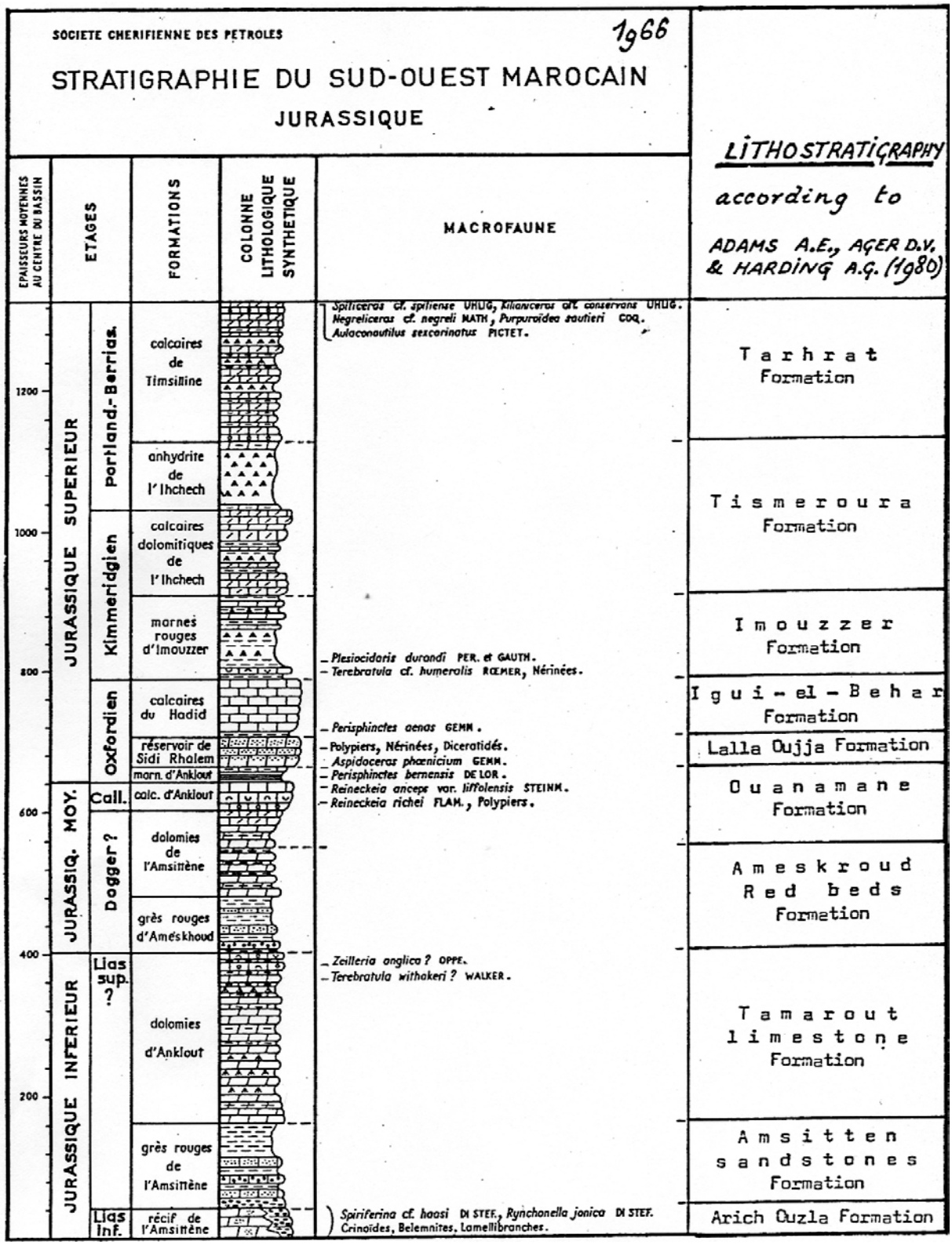


Fig. 4 - Jurassic Stratigraphic column of southwest Morocco Atlantic basins. (After Adams *et al.*, 1980).

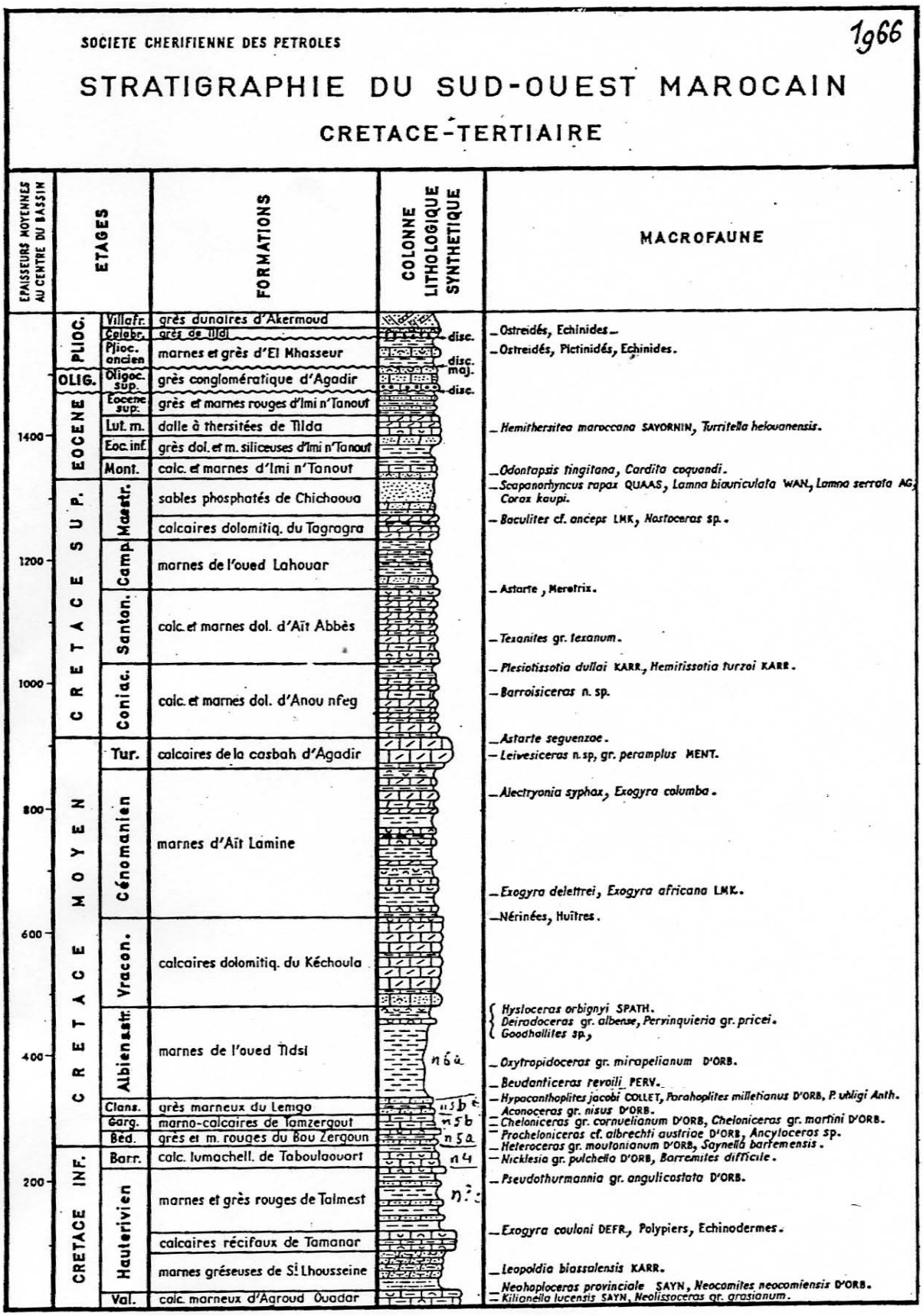


Fig. 5 - Cretaceous and Tertiary Stratigraphic column of west Morocco Atlantic basins (After Adams *et al.*, 1980).

Stop 2-0: Oued Tamassint; SCP Log n° 22

(If possible because of access to the section)

The section is exposed on the Western termination of the L'Gouz anticline.

It exhibits from top to bottom:

- Lias: Dolomite and gypsum

- Upper Lias: Limestone and marls

- Dogger: Red beds; conglomerate, sand/sandstone and shale

- Callovian: Limestone and dolomite

Stop 2-1: Tizgui

This stop is situated on the main road from Agadir to Imouzzer n'Ida-Outanane on the Southern flank of Anklout anticline.

The Lower Lias Tizgui formation crops out along the flanks of the Anklout bold anticline and exhibits lateral variations in thickness and facies. At the SouthWest of the Tizgui locality, this formation is 200 m thick and consists of:

- Red conglomerate and sandstone (5 to 10 m exposed);
- Poudingues and breccias (5 m) with Palaeozoic pebbles and boulders;
- Red shale and sandstone (80 m);
- Alternating shale and sandstone.

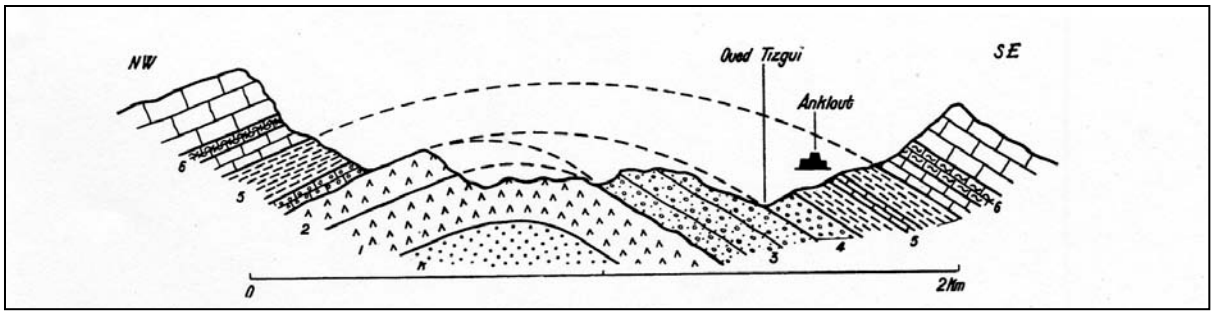


Fig. 6 - Section across the Anklout anticline showing Tiassic/Lias boundary and lateral thickness changes on short distances. Up.Lias: 6. Grey dolomitic limestone; Low. Lias: 5. Red salt shale, 4: conglomerate and sandy limestone, breccias ets; 3: red conglomerate and sandstone; Triassic/Lias boundary: 2 fresh basalt lava flows; 1: weathered lava flows (Ambroggi; 1963).

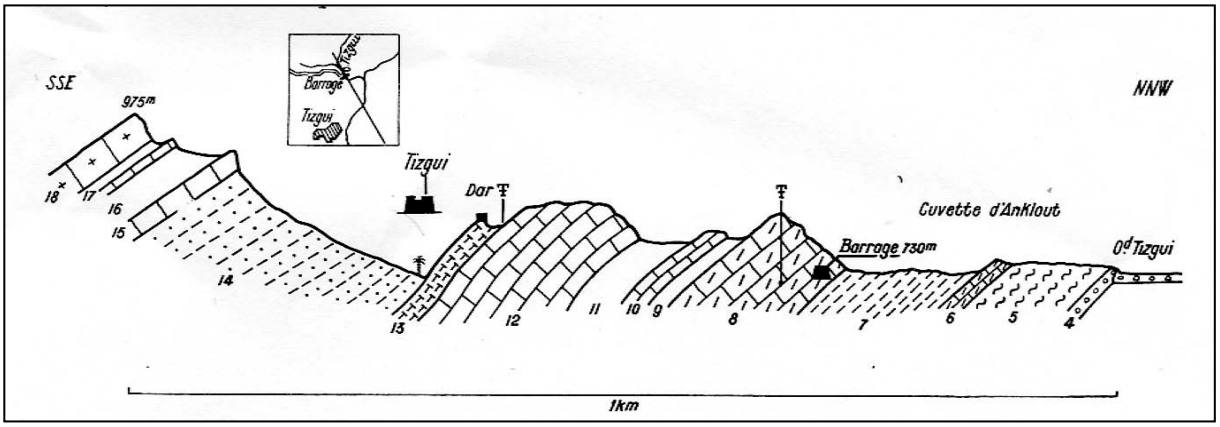


Fig. 7 - Section of Upper Lias to mid Upper Jurassic at the Tizgui locality (Southern flank of the Anklout anticline).
4-7: Lower Lias; 8-13: Upper Lias; 14: Dogger; 15: Callovian; 16: Oxfordian; 17: Argovian; 18: Rauracian - Sequanian; Q: Quaternary alluviums (Ambroggi; 1963).

Stop 2-2: Timoulay, Aït Chehrid and Tizi n'Tinkitti

From Timoulay village (Douar), where the Dogger red beds set on the Lias limestone, up to half way to Tizi n'Tinketti the road cuts in the following succession as logged by Ambroggi (Fig. 7):

- Grey conglomerate with Paleozoic pebbles alternating with red sandstones and shale (180 m);
- Marls and limestone (2 m);
- Yellow limestone with marine Fauna (calcite recrystallized rhynchonelles) (2 m);
- Green and red shale with breccias alternating with limestone (6m);
- Soft red-brown shale (40 m);
- Red sandstone with quite coarse quartz pebbles (3 m);
- Red-brown shale (6-8 m);
- Fine grain sandstone (1 m);
- Red-brown shale (4 m);
- Fine grain sandstone (2 m);
- Red and green shale (4 m).

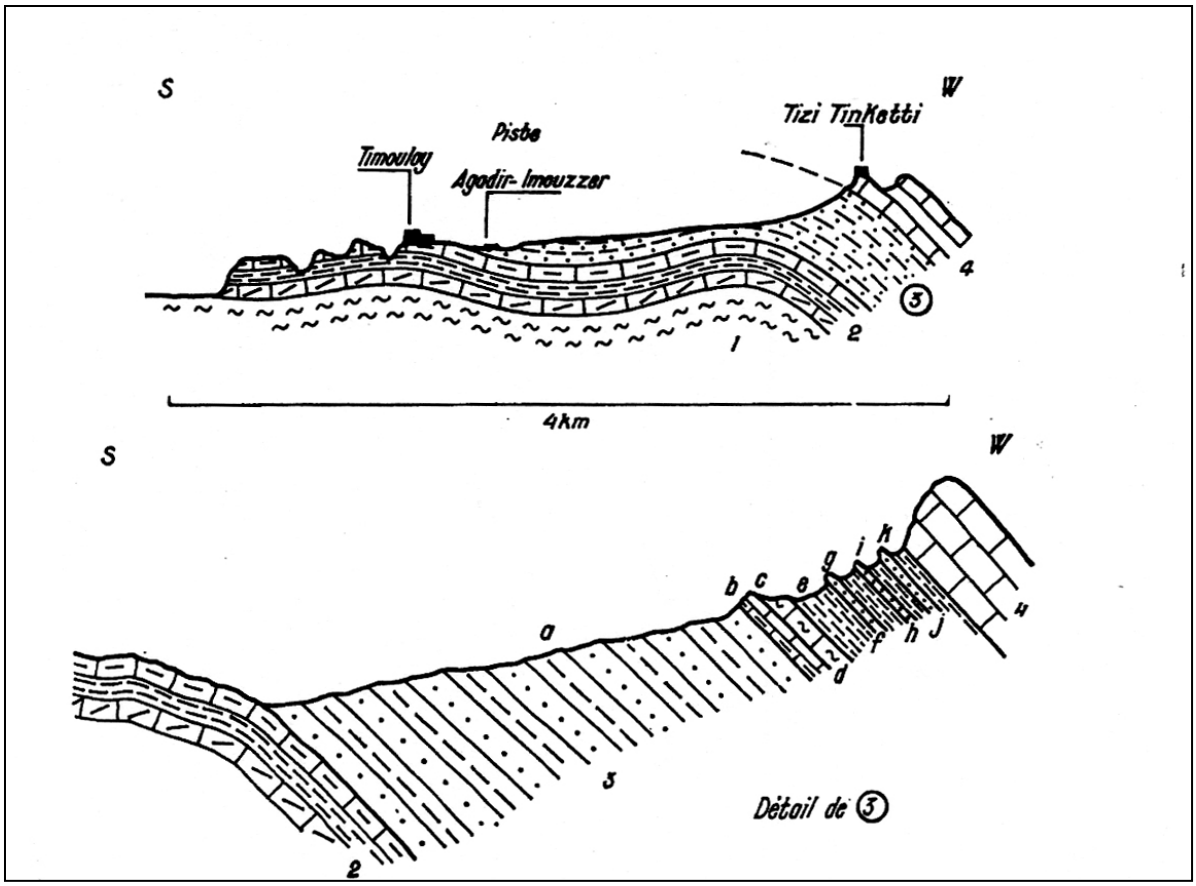


Fig. 8 - Cross sections in Timoulay-Tizi Tinkitti region. 1: Lower Lias; 2: Upper Lias; 3: Dogger; 4: Callovian. (Ambroggi; 1963).

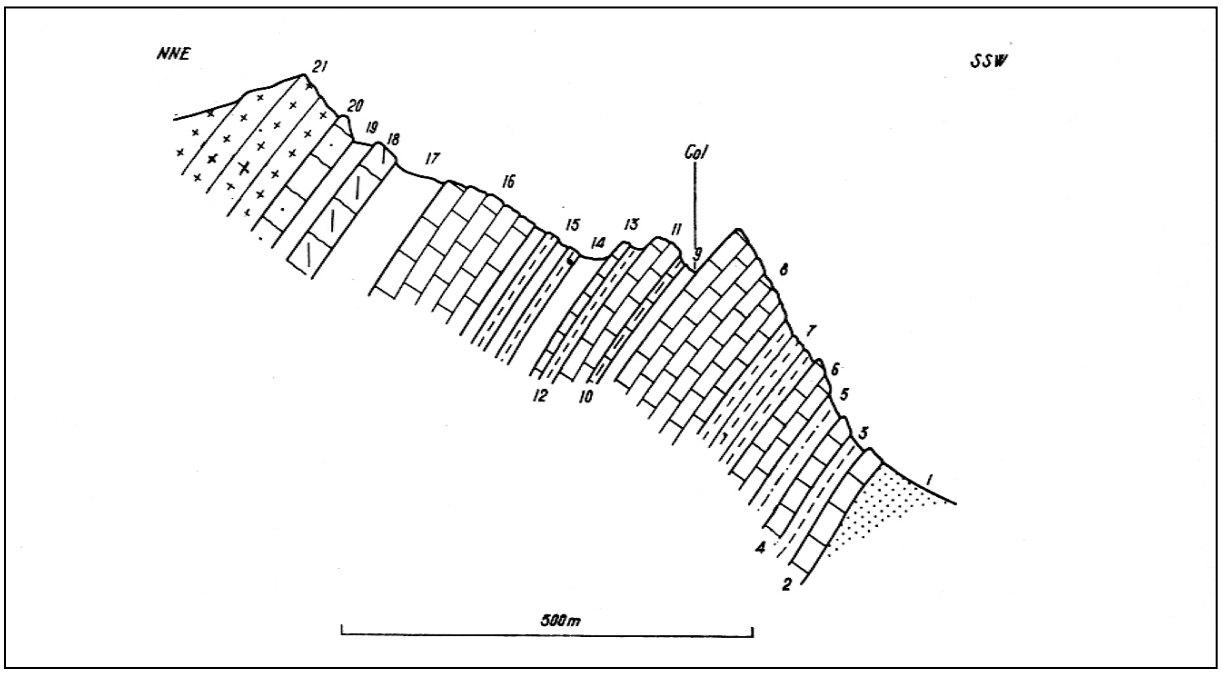


Fig. 9 - Callovian and Oxfordian section at Tizi n'Tinkitti. 1: Dogger; 2-8: Callovian; 9-15: Oxfordian; 16-17: Argovian; 18-20: Rauracian; 21: Rauracian-Sequanian. Level number 1 corresponds to number 3 on the Timoulay section (Ambroggi; 1963).

The road continues up to Tizi Tinketti (Tinketti gap) through carbonates of Upper most Dogger and Upper Jurassic (Fig. 8 and 9):

Callovian (Ouanamane Formation): Transitional dolomite member

2: Dolomitic limestones (2 m);
3: Green marls (2 m);
4: Yellow limestones with calcite moulds (1 m);
5: marls (3 m);
6: Igui mn Tarhazoute member dark grey limestones, with brachiopode sections and oysters (Alectryona), Trichites, some ammonites casts (3 m);
7: Somalirhynchia Member = Grey limestones, marls with brachiopods and ammonites (Peltoceras sp) casts (3 m);
8: Black limestones with Trichites, Ostrea gregaria, "Rhynchonella ampla " Douville.

Oxfordian

9: Yellow marls and grey limestones with brachiopods and Pecten subfibrosus (4 m);
10: Grey limestones with marls (1 m);
11: dark grey limestones with numerous fossils, as:

- corals, oysters (Ostrea gregaria)
- Pecten subfibrosus
- Arcomytilus pectinatus
- Brachiopods: Rhynchonella ampla;
- Somalirhynchia; Rhynchonella bilobata sp.; Terebratula sp.;

12: Yellow marls and limestones with marls. Marls and shales member;
13: Grey limestone with brachiopods (1 m);
14: Green marls (5 m);
15: Shaly limestones and green marls in alternation, with numerous brachiopods (8 m).

" Argovian" = Lalla Oujja Formation

16: Bioclastic light grey limestone with corals, crinoids, echnoids, brachiopods and scarce ammonite moulds (10.5 m);
17: Yellow or grey marls;
18: Dark grey limestone 4 m from where Gentil (1905) is reported to have found:

- Perisphinctes chavattensis
- (= Arisphinctes vorda ARKELL which is Upper Oxfordian, sensu lato)
- "Rauracian" = Igui-el-Behar formation;

19: Marls and yellow-green shaly limestone (3 m);
20: Brown biodetritic limestone (4 m).

"Sequanian"

21: "Reefoid" dolomite, with voids and abundant fauna of corals, crinoids, spines of echinoids (20 m)

- Megalontids (Ager, 1974);

22: Light grey or yellow lithographic limestones, in O.2 to 0.4 m layers 18 – 20 m.

Kimmeridgian = <u>Imouzzer Formation</u>

23: red marls with <u>Arcomytilus pectinatus.</u>

The stop at Aït Chehrid (Tizi n'Timekti, Southern side of the road to Imouzzer) is made to observe vuggy dolostone of the Lalla-Oujja Formation - approximately level 16 of the section by Ambroggi, attributed to "Argonian-Rauracian", on the basis of Arisphinctes. But there are some doubts about the exact correlations, with only a few ammonites of bad preservation, and not precisely located (old survey of Gentil in 1905).

About such vuggy dolomites of Lalla Oujja Formation, Adam, Ager and Harding write: "where most massive, the formation is nearly always completely dolomitized and develops deep karstic weathering. These massive developments probably represent original organic buildups".

Such dolomites, with vugs and voids, are common in some parts of Jurassic outcrops of Morocco, especially on the external rim of platform facies, where reefs can grow. They have received the name of "dolomies zebrees" in North-Eastern Morocco, they are the same as the "franciscan facies" in Alpujarrids of Southern Spain*. Dolomies zebrees" has also been applied to a bounded dolomite found in the Leadville district of Colorado. "The origin of this unusual textural alteration begins with the formation of incipient fractures along or subparallel to the original bedding" (C. Shreiber). Another explanation is sedimentological, i.e. they are original structures from the time of deposition. In any case, this rock is good as "reservoir" and is frequently associated in Morocco with lead-concentrations (district South

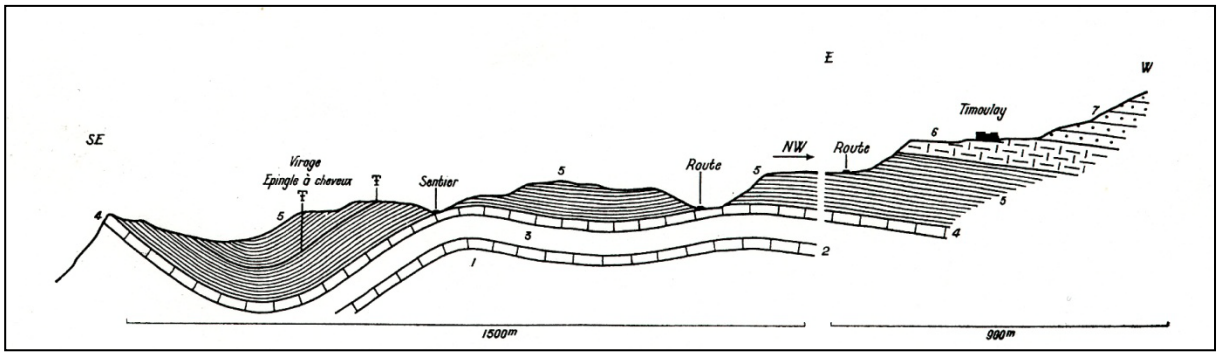


Fig. 10 - Cross section showing the Upper Lias and Dogger formations in Timoulay area. 1-6: Upper Lias; 7: Dogger (Ambroggi; 1963).

of Oujda, North-East Morocco: Zellidja and Touissite mines).

Stop 2-3: Imouzzer Ida-ou-Tanane, Tidlli and Tamarout

On the North-Western flank of the Immozzer anticline and starting from its axes, the following succession crops out:

- Upper Lias: yellow Limestone and dolomite and grey marls
- Dogger: poorly consolidated red sandstone and shale. The sandstone intervals pass laterally into conglomerates (250 - 300 m)
- Callovian: Grey-green and fossilliferous limestone and dolomite

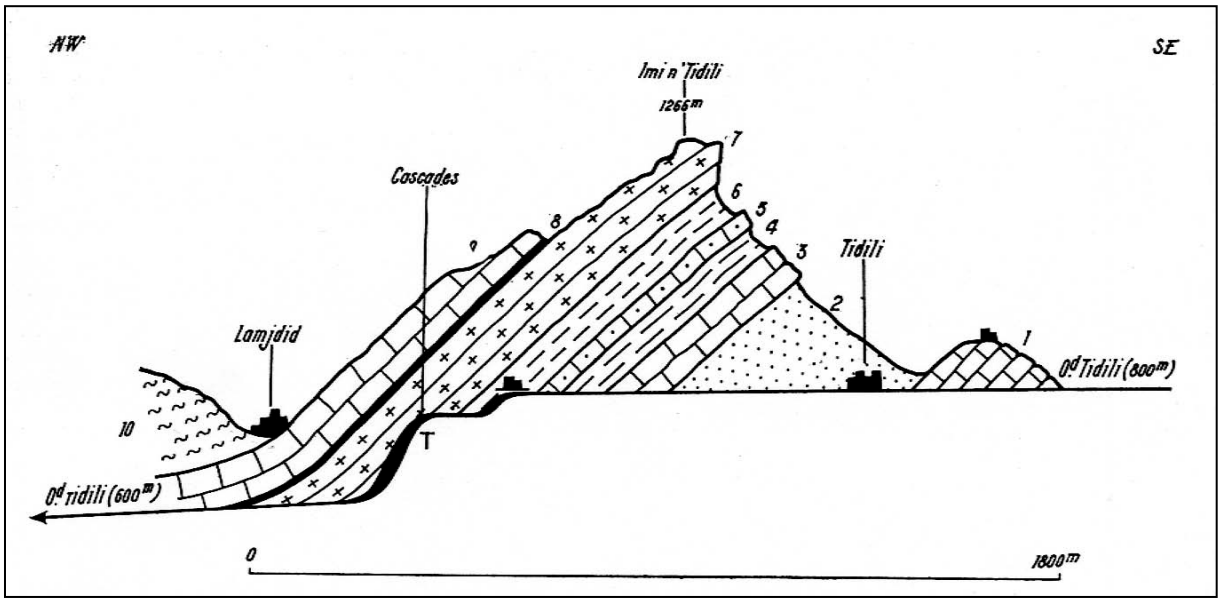


Fig. 11 - Jurassic section at Imin n'Tidili location. 1: Upper Lias; 2: Dogger; 3: Callovian; 4: Oxfordian; 5-6: Argovian; 7-9: Rauracian - Sequanian; 10: Lower Kiméridgian (chocolate marls); T: Travertine.(Ambroggi; 1963).

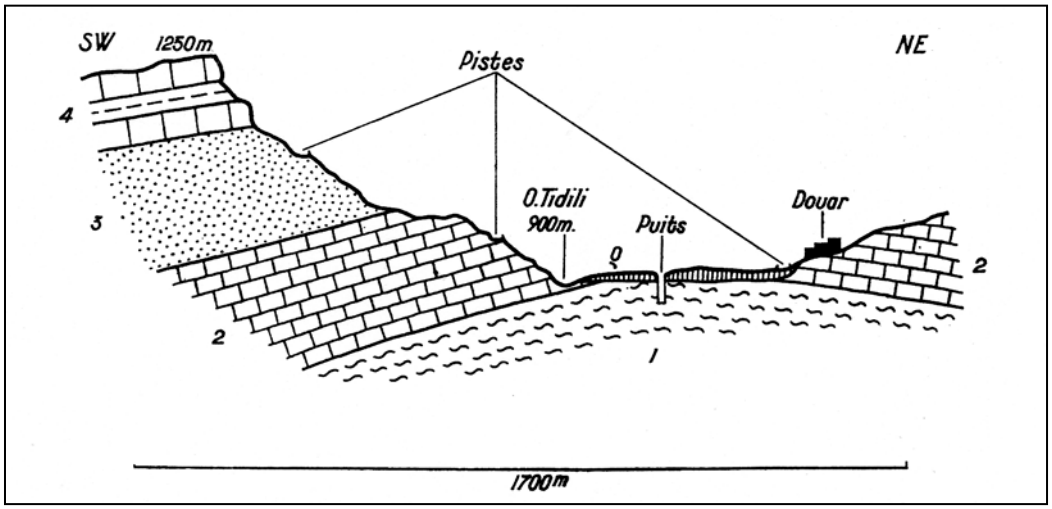


Fig. 12 - Lias section in the Tidili gorge 1: Lower Lias; 2: Upper Lias; 3: Dogger; 4: Upper Jurassic. (Ambroggi, 1963).

DAY 3

4th October 2010

Agadir – Essaouira

Day 3: Agadir – Essaouira

Stop n° 3-1: CAP GHIR –Oxfordian "Reef" (Fig. 13, 14 & 15)

The section in the Cap Ghir area is as follows (according to Ambroggi,1963):

J5 a: "Argovian ": Lalla Ourjja Formation

1. Hard grey bioclastic limestone, with Peltoceras ,Ostrea ,Nerinea and echinid in a cliff along the seashore ,on the southern side of the cape (5-6 m);
2. Green marls (2 m);
3. Bioclastic limestones with algae and Peltroceras sp. (equivalent of levels with some Perisphinctes aeneas Gemm, found a few kilometres to the East, at Tiguert, which is in the Peltoceras (Gregoryceras) transversaruim zone of the Middle Oxfordian of western Tethys);
4. Green and red marls and thin layers of grey limestones, with oysters and fossil tortoise – These levels are attributed to the Argovian (Middle Oxfordian).

J5b : Rauracian – Sequanian : Igui el-Behar Formation

5. Along the western seashore, in the intertidal zone, dipping westwards, some grey and hard limestones with Diceras (early Rudist) gastropods and corals .These layers have been quoted as the Cap Ghir "Reef".

The age of such sequence is attributed to the Rauracian –Sequanian substages of the Swiss chronology.

The Kimmeridgian section starts from 6 to 17

J_{6a}: equivalent of the Imouzzer Formation

7, 9 and 11 = lilestones banks with Nerinea binodosa, N.subelegans and other gastropods;
15 and 17 = limestones with some corals.

6_b and J_{7a}: Tismeroura Formation

From beds 18 to 28, the section is attributed to the Portlandian

19-20. are red marls with gypsum, which could be probably attributed to the Purbeck facies. The other limestone's show oysters, Trichites, nerinied gastropods, algae, and some corals in bed 19.

The fauna of the level 5 is dominated by the abundance of the earliest genus of rudists Diceras .Among them are also numerous gastropods (Nirinia, Ptygmattis, Petroceras, Fusus, Pleurotomaria) and abundant corals. These corals can be of great size and importance, but are isolated, generally broken and not found in situ.

The first rudist Diceras appears in the Rauracian substage. Its origin can be traced to in the Protodiceras or Megalodon of the Middle Liassic. These forms are known in the reef banks of the Ziz valley (eastern High Atlas) and the comparison between the Oxfordian banks of Cap Ghir and the middle Lias pavements of the Eastern High Atlas are very striking; but is it possible to speak about reef in these to occurrences?

Problems are as follows:

1. The exact position of such pavement in the stratigraphic record of Cap Ghir: the very gentle folding somewhat confuses the strtigrapy;

2. The ambiguities of the old stratigraphical classification of the Central European Oxfordian, ie: Argovian Rauracian, Sequanian, not well defined in the standard stratigraphical classification: The emendation of the Luxembourg Jurassic Collquiums 1 and 11 have rejected these subtages .

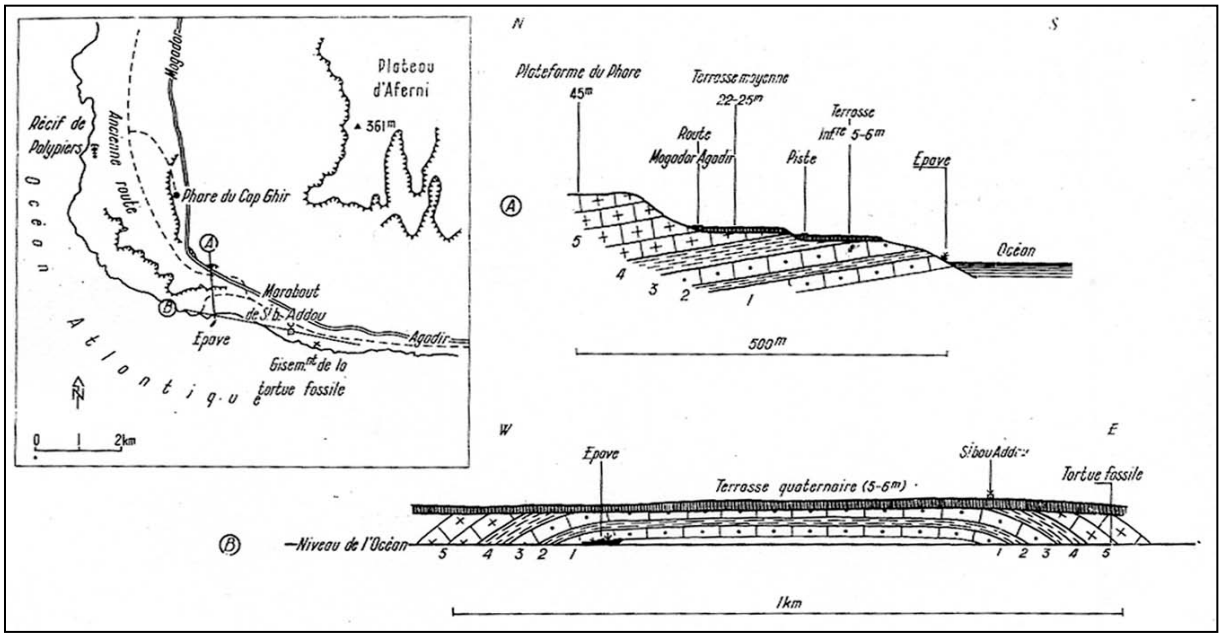


Fig. 13 - Cap Ghir Argovian section. Locations of the cross section are given on the index map. 1-4: Argovian; 5: Rauracian – Sequanian. (After Ambroggi, 1963).

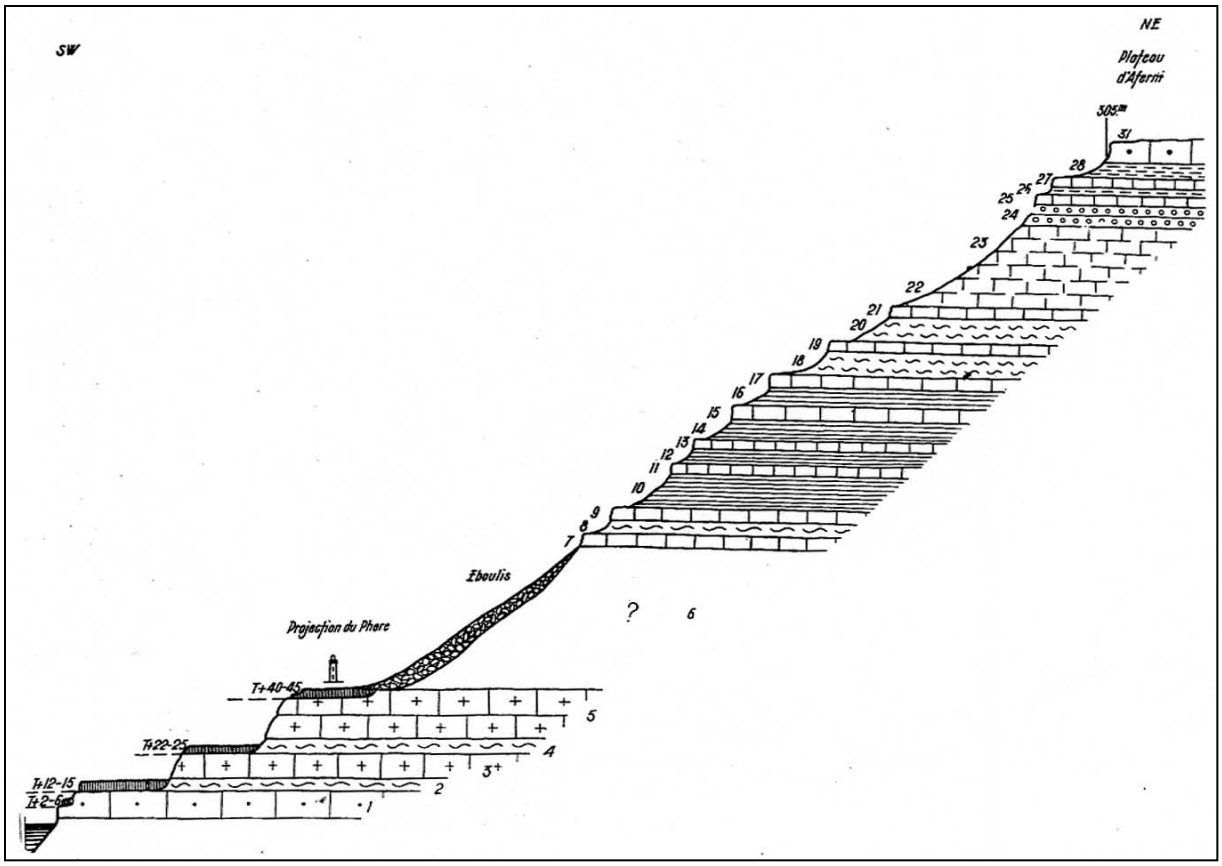


Fig. 14 - Typical section of the Upper Kimmeridgian at Cap Ghir light house locality. 1-4: Argovian; 5: Rauracian – Sequanian; 6: Lower Kimmiridgian; 7-17: Upper Kimmiridgian; 18-28: Lower Portlandian; 31: Pliocene. (After Ambroggi, 1963).

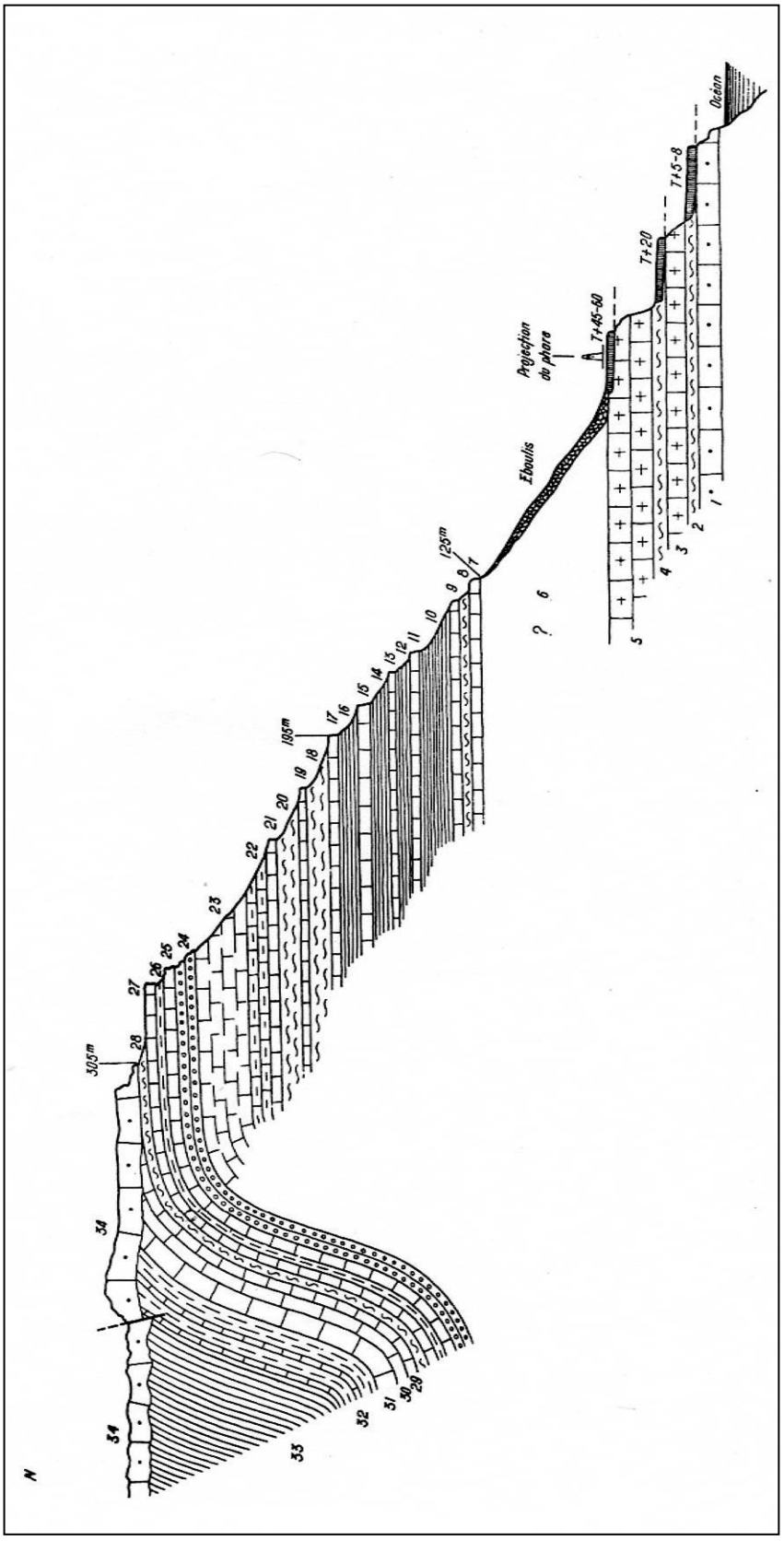
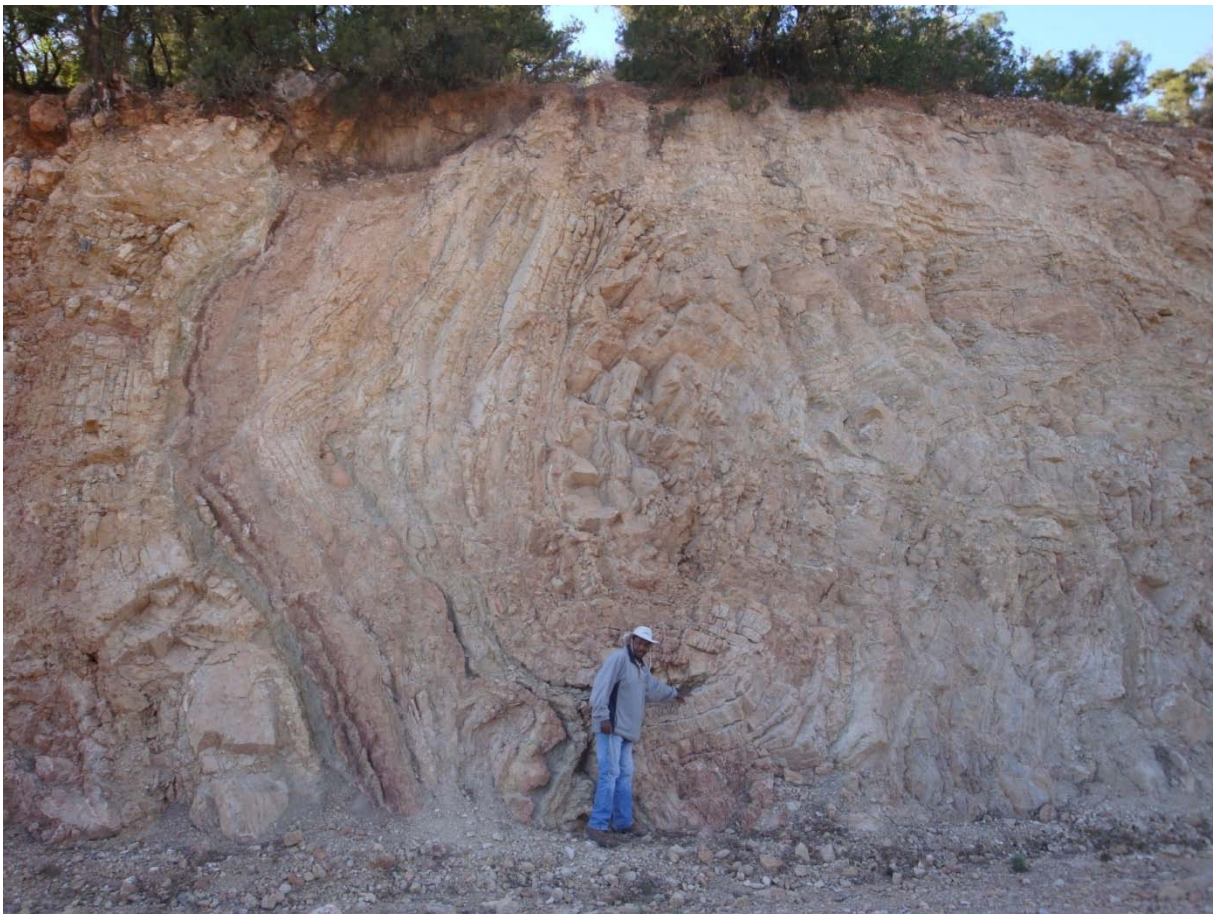


Fig. 15 - Portlandian section at Cap Ghir light house locality (western side). 1-4: Argovian; 5: Rauracian – Sequanian; 6: Lower Kimmiridgian? 7-17: Upper Kimmiridgian; 18-27: Lower Portlandian; 28-33: Upper Portlandian; 34: Pliocene; T: Quaternary marine terraces. (After Ambroggi, 1963).

Stop n° 3-2 : Alpine tectonic style at Jbel Lamsiten on the northern front of the Western High Atlas fold belt.

Jebel Amsitene is a huge ENE-WSW trending altasic anticline that affects the Jurassic and Cretaceous strata.

For a long time, this anticline was believed, by surface geologist, to be a hanging anticline related to a north verging atlasic master reverse which has inverted the Mesozoic western High Atlas gulf.



Stop 3-2: Southern flank of Jebel Amsiten anticline; tectonic style of the Atlasic Deformation and disharmony within the Jurassic strata.

Stop n° 3-3 : JEBEL AMSITTEN; Arich Ouzla diaper (NE Birdj Id-ou-Moulid)

The Jebel Amsitten is a huge (20 Km long) and regular anticline, with a WSW-ENE strike (Atlasic trend). According to the geological map, it does not seem to have important faults in the axial direction (but such faults have been quoted on sections by Ambroggi, 1952). On the southern side of the anticline, and in the southern side of the road cut, a little "patch-reef" occurs, in a sequence that seems to indicate passage beds between the Oxfordian and Kimmeridgian.

The heart of Jebel Amsitten (Arich Ouzla) is a diapiric outcrop of Triassic with salt exposures. The salt pan is surrounded by a cliff formed mainly by dolomitic rocks with small vugs and known in the Moroccan geological literature as the "recif de l'Amsittene" ("Amsitten reef") (F. Duffaud, the S.C.P.).

In fact, there is nothing recalling in any way the elements of a reef. In a few places, where the limestone is not dolomitized, the following fossils have been found (Duffaud, 1960): Sperifirina, Rhynchonella jonica, Terebratula, Zeillera, Chlamystextorius, Entolium disciforme and crinoids.

A few kilometres west of Arich Ouzla there the **Ida-Ouazza salt-pan** which is an outcrop of Triassic rocks where salt is being extracted at numerous localities.

The rim on the southern side shows, below the Amsitten Sandstone Formation, a cliff of dark limestones (a few meters thick) with some fossils: crinoids and bivalves, at several places some debris of shells appears belonging to the Megalodontidae, Protodiceratidae, etc. But they are not in situ and seem to have been smoothed, corroded and displaced: they are not forming a "back-reef", but they are the proof that this type of facies is perhaps not very far away.

Some other small outcrops of such carbonate rocks are known north of Jebel Amsitten, in relation with the diapir of Oued Tidsi, and NE of Essaouira, in the core of Jebel Kourati, along the Triassic beds.

The well ESS-1 (10 Km NE of the town of Essaouira) has shown, below the equivalent of the so-called "Amsitten reef" about 630 m of carbonate rocks, first limestones and biodetrita limestones (346 m), and bioclastic dolostones (284 m). At the top of this formation some fragments of ammonites (*Arieticeras* sp., which is a genus especially abundant in the Middle-Domerian of the Tethys), have been found, also some brachiopods, and a Pecten, P. cf nogliriensis, which is also of middle Lias age.

The well ESW-1, 18 km W offshore of Essaouira, has shown a similar formation.

Therefore the following conclusions can be drawn:

- The thickness of such Liasic carbonate rocks, in some places, can reach 600 m;
- Nothing comparable appears in the cliff above the Argana red beds of Trias, where Upper Lias is directly transgressive on basaltic rocks of the Triassic;
- Middle and lower Liassic deposits are well developed around the town of Essaouira, and more to the west, offshore.

Stop 3-3: Arich Ouazza salt-pan; Triassic-Lias salt diapir. Along the diaper rim crops out the Lias dolomite of the Arich Ouzla formation (Amstene "reefs").

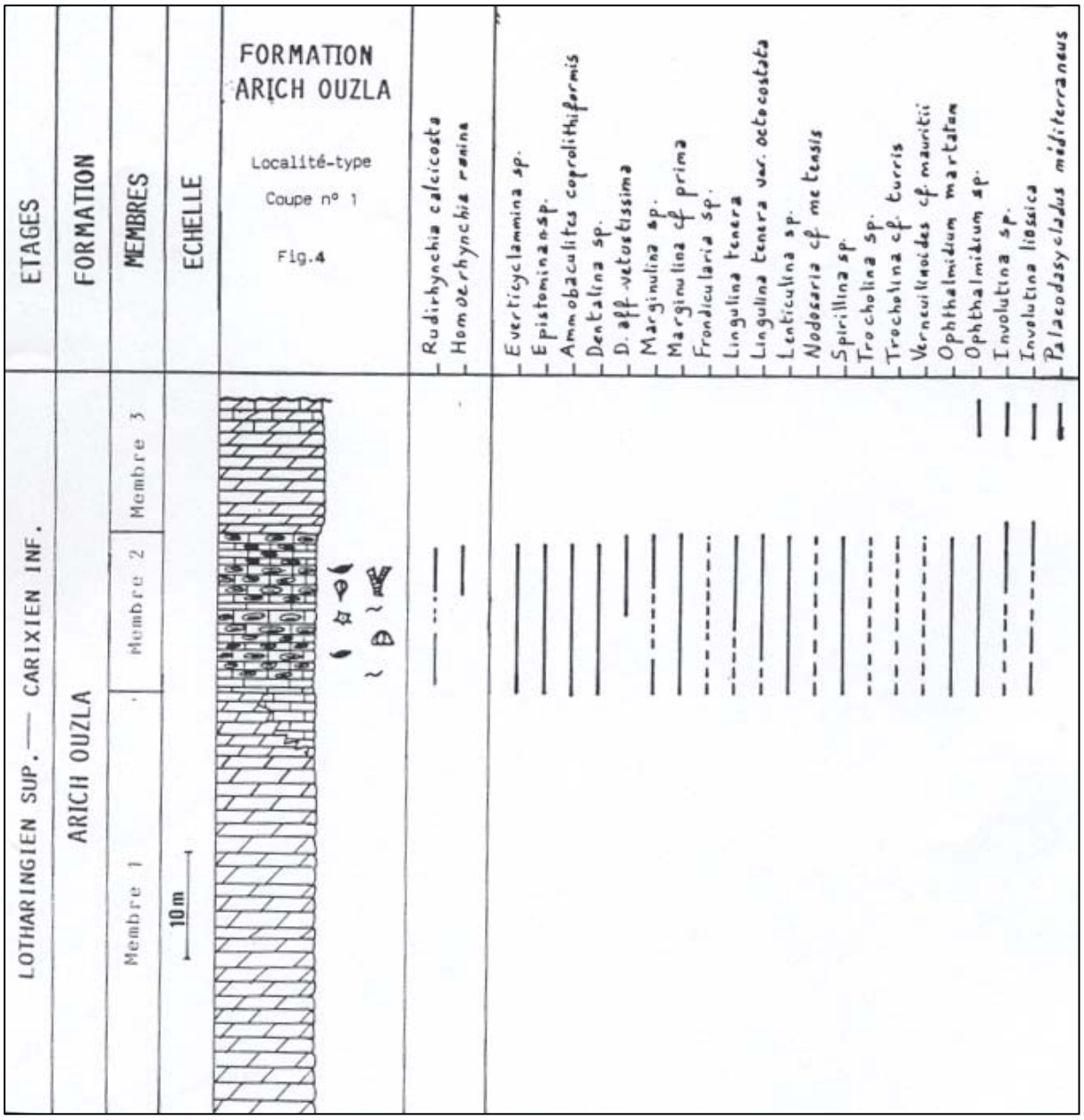


Fig. 16 - Lithostratigraphic and biostratigraphic log of the Arich Ouzla Formation (Bouaouda 1987).

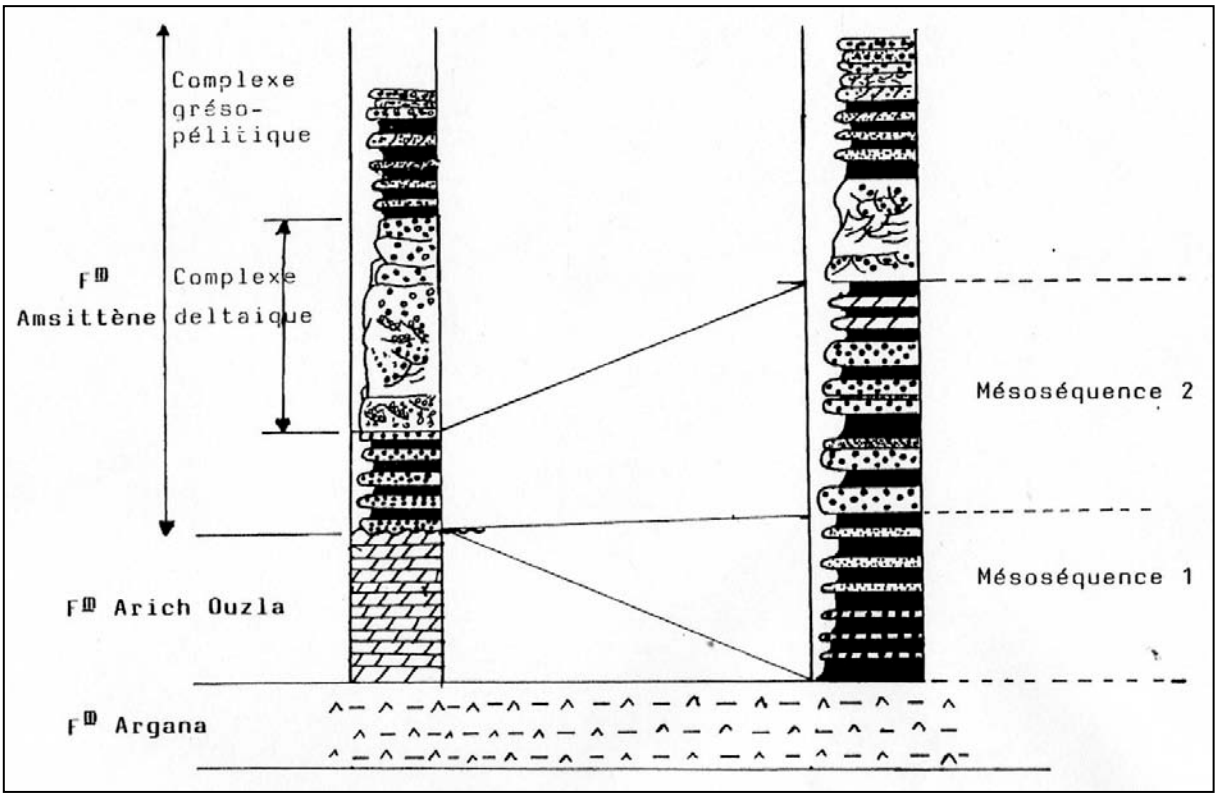


Fig. 17 - Fluvio-deltaic sequence of the Amsittene formation at Arich Ouzla locality (After Benaoud 1987).

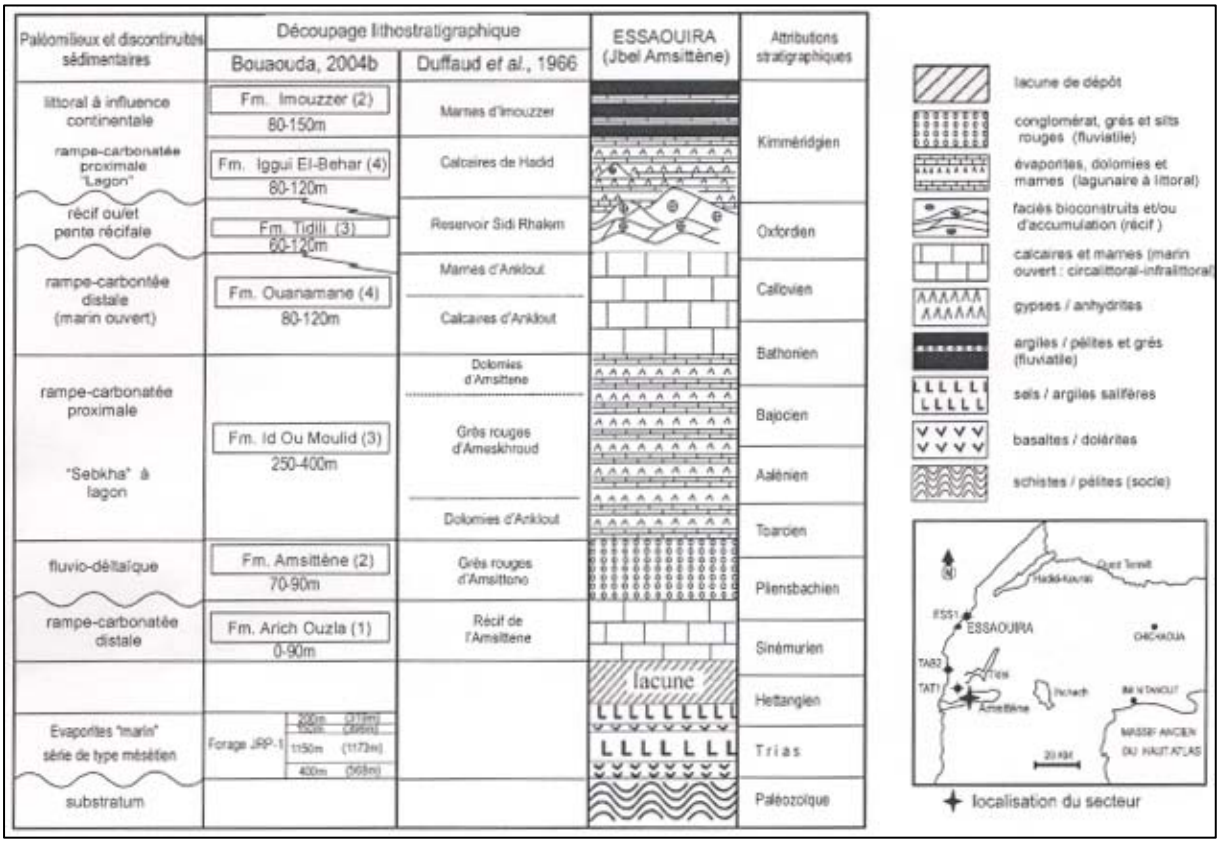


Fig. 18 - Synthetic lithostratigraphic column of the Triassic-Jurassic interval in the Essaouira basin (Bouaouda 2004).

Stop n° 3.4 : OUED TIDSI DIAPIR

The road from Essaouira towards the South just before Smimou, is running along the southern outcrop of the Oued Tidsi diapir (interpreted by Roch in 1930), where the first layers of early Cretaceous are directly covering the red beds of the Triassic intrusion.

The Oued Tidsi diapir is a good example of the Diapir Province of Western Morocco: the Jebel Amsistten but also the Jebel Hadid and Kourati, north of Essaouira, can also be interpreted as compressional - diapiric - folds onshore. Even the town of Essaouira is located directly above such diapiric structure, masked only by recent cover and sand dunes.

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