SEDIMETOLOGICAL STUDY OF THE CARBONIFEROUS LOWER IN AIT TAMLIL BOUTONNIERE

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Abstract

The basin of the lower Carboniferous of Aït Tamlil is located in the western extremity of the Moroccan Central High Atlas (districtof Azilal) (Figure 1). We present in this study the sedimentary evolution of the lower Carboniferous of Aït Tamlil inlier (Central High Atlas), through a multidisciplinary study that involves petrographic, lithostratigraphic and sedimentary environment analysis of the basin deposits (slope deposits, fluvial deposits, fan turbidites). The study revealed that intrinsic factors to the system (lithology of the basin) and extrinsic (tectonic) share the control of this evolution according to the weight of each factor spreading of the platform towards the center of the basin. This basin is formed by four large upper Visean formations and constituted mostly of East-West oriented autochthonous and allochthonous Paleozoic series, as well as siliciclastic and carbonate sedimentary deposits. These formations are distributed as follows: Jbel Imgant, Tizi n'Toutfi, Jbel Abberonech and Iguer complex n'Igherm. Normal sedimentation is continuous in the Aït Tamlil basin and had lasted for deposition phases of jbel Imgant turbidite series and its equivalent platform of Jbel Abberonech, chaotic series of Tizi n'Tnoutfi and that of Iguer n'Igherm can take place on a very short time. The interpretation of these sediments intervenes in the paleogeographic reconstruction of the region.

Keywords: Morocco, Central High Atlas, Aït Tamlil Basin, Sedimentation, Paleogeography

Introduction

The Aït Tamlil inlier is an isolated outcrop of Paleozoic lands in the west boundary of the Central Hight Atlas surrounded by distinctly discordant Mesozoic lands on the Paleozoic. This outcrop is composed by autochthonous and allochthonous series dated at Ordovician, Silurian, Devonian and Carboniferous. The set is shaped as a halo elongated East-West and bounded by East-West oriented accident but with N70 Atlasic faults.

In detail, the basin is affected by many brittle and ductile accidents (Proust, 1973). Aït Tamlil Basin is lower Carboniferous age, especially the entire upper Visean.

The progress of the Carboniferous sedimentary phenomena at Ait Tamlil basin can be related to the nearest basins with same age as the Skoura basin to the south, the Ourika basin towards the West and also the of Western Jebilet basin to the Northwest.

In fact, the Lower Carboniferous outcrops are widespread in Morocco, mainly in the mesetien area (Izart and Beauchamp, 1987). They represent large marine turbidite basins and platform dominated by storm deposits.

At basin-wide, the upper Visean sea has been affected by a transgression followed by a decrease during the Hercynian orogeny (Beauchamp, 1984).

During the upper Visean, Moroccan Central Meseta is marked by a tectonic and sedimentary instability during the formation of several basins especially in the central and Central-Eastern Meseta (Bamoumen et al, 2008).

Aït Tamlil Basin is a material of choice for the sedimentological study in the context of a basin structured by active faults probably with extensions of the South Atlas fault. This basin is filled by mega-slump sedimentary. As result, the basin is filled by deep turbiditic sediments, followed by siliciclastic detrital sediments of deltaic platform and associated with channelized fluvial sediments.

The upper Visean of Ait Tamlil basin lay down directly on the Devonian already deformed. The unconformity surface is observed at 18 km in the East of Aït Tamlil (Jenny and al., 1980). We detected other stations: in front of the forest survey house, at the Douar Ignouria and at the Douar Tassa.

The upper Visean lands in the Aït Tamlil basin are represented by a set of sandstone-pelitic sequences described by Jenny and al. (1980). Their sedimentological study distinguishes several formations. These formations will be described from the South to the North as follows: The formation of

the Jbel Imgant, the Tizi n'Tnoutfi complex, the Jbel Abberonech and the Iguer n'Igherm complex (Figure 1).

The objective of this work is to present a description of these series, to reconstruct their depositional models and trace the paleogeographic evolution of the basin during the Upper Visean.

Aït Tamlil Basin is a very interesting case of its kind, which summarizes sedimentation phenomena largely controlled by local and regional tectonics in an active environment. This basin is localized near the old South Atlasic deep faults, which can control clearly the opening and closing of the basin. The small size of this basin suggests that it is opened in the context of pull- apart basin between major north and south faults and other NE- SW oriented faults. The synsedimentary deformation and chaotic sedimentation as well as different levels of conglomerates are aspects of this active tectonics, which escorted the establishment of turbidite series of this basin.

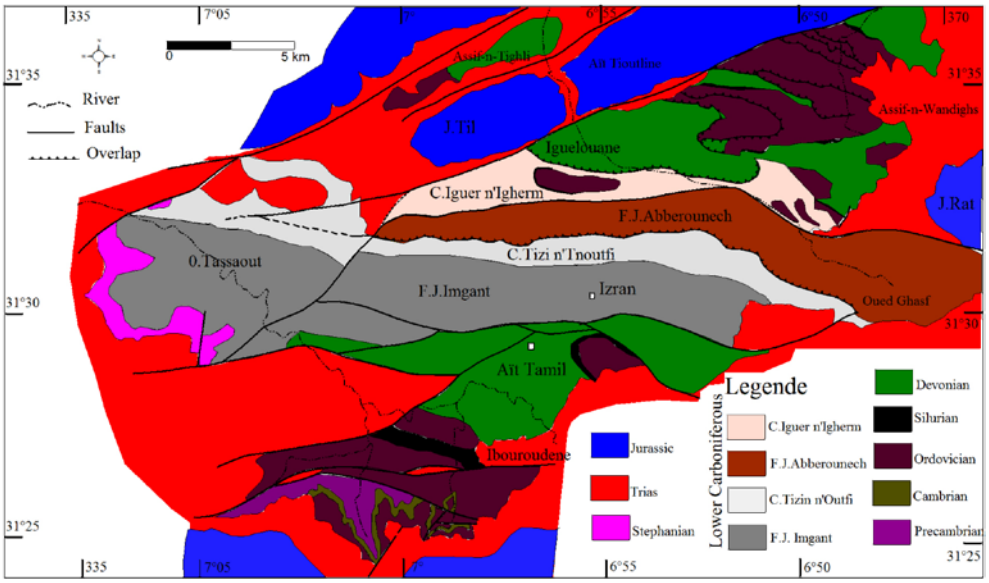

Figure 1. Geological map of Aït Tamlil (Jenny and Le Marrec, 1980)

Location of the study area

The basin present the easternmost Paleozoic outcrop of the old massif of the High Atlas (Proust, 1973) at the eastern part of the Fatouaka area located in the Azilal province at 57 km to the south of the Demnate on the road to Ouarzazate. This Paleozoic inlier outcrops within four geological maps of Azilal, Skoura, Telouat and Demnate (at 1/100 000 scale) and four topographic maps of Demnate Tifni, Aït Tamlil and Telouat (at 1/50 000 scale). But three-quarters of the basin are represented in the geological map

of Azilal at 1/100 000 scale as well as the topographic map of Tifni at 1/50 000 scale. This is an area surrounding 230 square kilometres (Jenny, 1988).

Geological overview of the study area

The upper Visean basin at the Ait Tamlil Basin is part of the Eastern Central Meseta (Piqué and Michard, 1981, 1989; Piqué and al, 1993). It is located at the eastern of the ancient massif of the High Atlas of Marrakech (Proust, 1973). It corresponds to the Paleozoic strata exposed in a halo of Permo-Triassic sandstones (Jenny and LeMarrec, 1983) and is characterized by length of 30 km and width of 7 km. It is presented by autochthonous and allochthonous land, the south is separated by Devonian greenish siltstones, which filling the east-west fault, whereas in the north by the Mesozoic deposits.

The major faults that structure the Aït Tamlil basin are Atlas N70 dominant with divergence to the Northwest. The tectono-sedimentary formations recognized (Jenny and LeMarrec, 1981; Proust, 1973) are:

• The Jbel Imgant formation considered as the only autochthonous formation of the inlier, which rests directly on the Devonian shale deformed by an angular unconformity. This succession is limited at the uppermost part by a contact fault with the complex of Tizi n'Tnoutfi.

• The Tizi n'Tnoutfi complex, oriented east-west, is headed by a contact overlapping of Jbel Abberonech formation.

• The sliding slick of the Jbel Abberonech shows an east-west sliding sole. These formations are covered by the Iguer n'Igherm complex, which composed by Ordovician and Silurian mega-olistolithe.

Lithostratigraphy

Aït Tamlil Basin is widely present in the axial part of the Central High Atlas of Demnate. The area is constituted by an old base, which is formed by sediments from the Precambrian to the Lower Carboniferous oriented East-West and covered by the Mesozoic sediments. Structurally, the faults are oriented northwest facing southeast with overlapping accidents to the East-North-East (Jenny, 1980; Jenny, 1988).

- The Precambrian

It consist of basic eruptive outcrops, sericite shales and quartzites topped with large angular unconformity by the Cambrian rhyolites.

- The Cambrian

It is presented by olive green solid sandstone, fine sandstone and breccia with mica.

- The Ordovician

It consist of gray micaceous sandstone (psammites) with flaser bedding structures and bioturbated quartzites.

- The Silurian

It is presented by black chert rocks and black shales sometimes altered with cream color and graptolites and also the calcareous-marl rust alternations with casts of fossils (crinoids mainly S.Willsfret).

- The Devonian

It consists of limestone above bio-clastic sandy limestone named by Lévêque (1961) as Tassaout limestone dated by tentaculites. Greenish micaceous siltstones with tentaculites is overcomed by Tassaout limestone.

- Carboniferous

It is characterized by the upper Visean, which is divided into four successions from bottom to top. Jbel Imgant succession affected to the upper Visean (cf6γ-v3bγ) or (V3b) (Roch, 1939), Jbel Abberonech succession dated as (cf6γ-v3bγ) or (V3b), Tizi n'Tnoutfi d'Iguer n'Igherm complex and Ait Tamlil slick.

Sedimentology of successions

During the Carboniferous an upheaval has occurred in the nature of the deposits, thereby, carbonate deposits pass to detrital deposits because of the destruction of Precambrian and lower to medium Paleozoic relief filling the basins (Soualhine and al, 2003).

Jenny and LeMarrec (1980) subdivided the Lower Carboniferous Basin of Ait Tamlil according to lithology into four formations from South to North:

- Jbel Imgant formation corresponding to alternating rhythmic turbidite series intercalated with disorganized zones.
- Tizi n Tnoutfi complex formation characterized by chaotic zones.
- Jbel Abberonech formation corresponding to alternating pelitic sandstones and black shale, it is recorded under sliding slick.
- Iguer n'Igherm complex formation corresponding to decametric olistolithes with different age and lithology.

A- The Jbel Imgant Formation

Cross-section on the road Aït Tamlil – Demnate

This section is characterized by series exceeding 950 m of thickness formed by an alternating siliciclastic with limestone base, lateral thickness variations are common (Figure 2).

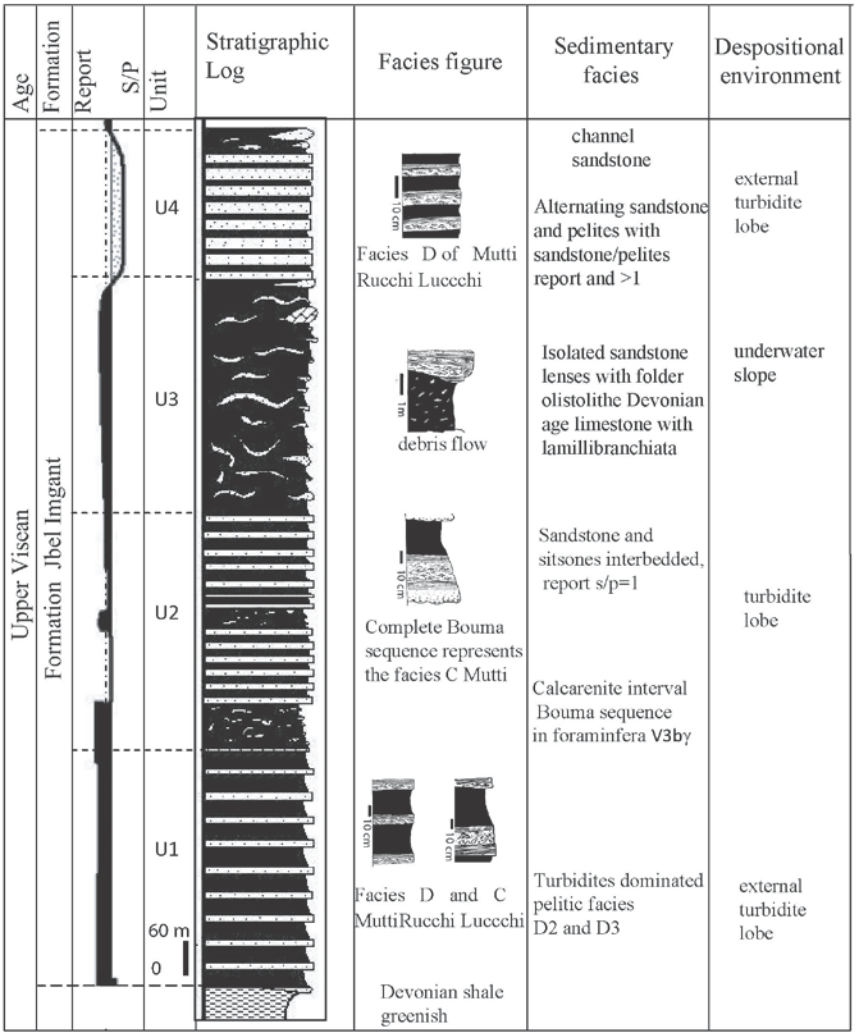

Figure 2. Lithostratigraphic column formation of Jbel Imgant

Four units characterizing the Aït Tamlil section are, from the base to the summit:

The first unit consists of calcarenites and pelites with pelitic dominance. All leads to several strato-decreasing mesosequences. Bouma sequence appears to be complete in the base and truncated at the summit. This unit shows a conglomeratic bed with rounded elements of 4 to 8 cm. The paleo-currents are measured from flute-casts and groove-casts present at the base of the turbidite layers. The overlapping wrinkles and micro-wrinkles in the sequence of the section are also considered. Convolutes bedding are present at some levels and usually show a pronounced spill. The convolute bedding, flute-casts and groove-casts shows current dominance from South to the North. Microscopically, the sandy limestone interval at the base of

sequence shows presence of the foraminifera (Endothyridès and Tetrataxis) and bioclasts (crinoids, bryozoans, brachiopods...), the quartz are rounded and associated with oolites (with foraminifera nucleus).

Generally the most dominant facies in this unit are D facies associated with C facies of Mutti E and Ricci Lucchi F (1975).

This unit of 250 m thickness marked by disorganized levels ranging from 20 to 30 m, with blocks of facies and gravel packed in a pelitic matrix. The sandy pelitic deposits show turbidites with equal ratio G/P (1/1) and bioturbated bases with groove-casts.

The mega-olistostrome unit 240 m thick characterized by a regional extension shows the syn-sedimentary deposits sliding in large-scale with an evident of hydro-plastic deformation. The slumps sides and their level of sliding indicate generally directions of layers from South to North. Some levels of slumps show a vertical sequential organization evolved between deformed beds and transition of debris-flow with conglomeratic elements. The average thickness of these levels is multi metric. The overlying beds are continuous and intact with regular base dominated by sandstone.

The third unit (250 m thickn) characterized by classic turbiditic deposits and microconglomeratic bases with bioclastic elements, exceptionally a conglomeratic level with centimetric pebbles, it shows an abundance of sedimentary Precambrian rhyolites and greenish shales probably from Devonian, the set constitute a limestone matrix. The appearance of a massive calcarenite isolated from turbiditic mass can be interpreted as an olistolithe originatingfrom the platform.

The last unit (220 m thick) begins with a succession of classic turbidite sequence Tcde from 30 to 40 cm with a dominance of sandstone and many structures as overlapping wrinkles, convolute, based beds are bioturbated with sometimes current marks. This unit ends with a dominance of black shell with multi metric lenticular sandstone microconglomeratic bodies with a pluri-decametric extension. Laterally, this level can be related to a channelized succession dominating the top of this unit.

Cross-section between Tassa and Targa N'Aït Mellal

The series (2000 m thick) are formed by alternations of siliciclastic with conglomerate base. The lateral thickness variations are common. At 15 km in the west of the Jbel Imgant the units are similar to those of the first. It begins at the bottom by conglomerate series with 3 meter thickness and centrimetric shale flattened to rounded elements (Figure 3).

- The first unit is characterized by conventional turbidite series with alternating of complete Bouma sequences and sometimes truncated at the base showing localized folding. This unit shows similar sedimentary characteristics to that of the first unit in the previous cross-section.

- The second unit consists of packed turbidite sequences in black shales. The process of the turbidite sediments corresponds to mega-sliding giving disorganized sedimentary structures. This unit is marked by the synsedimentary phenomena.

- The third unit shows alternation of classical turbidite sequences predominantly sandstone with the presence of some decametric levels disorganized. The sandstone thicknesses at the base on the unit are thicker than the top part. Sedimentary structures are marked at the base of sandstone beds as flute-cast (picture) indicating a current with South to North direction.

- The fourth unit consists of homogenous shales. An Olistolithe of calcarenitic bed 20 m thick and 40 meters wide marks a clear change of an exogenous body in this serie.

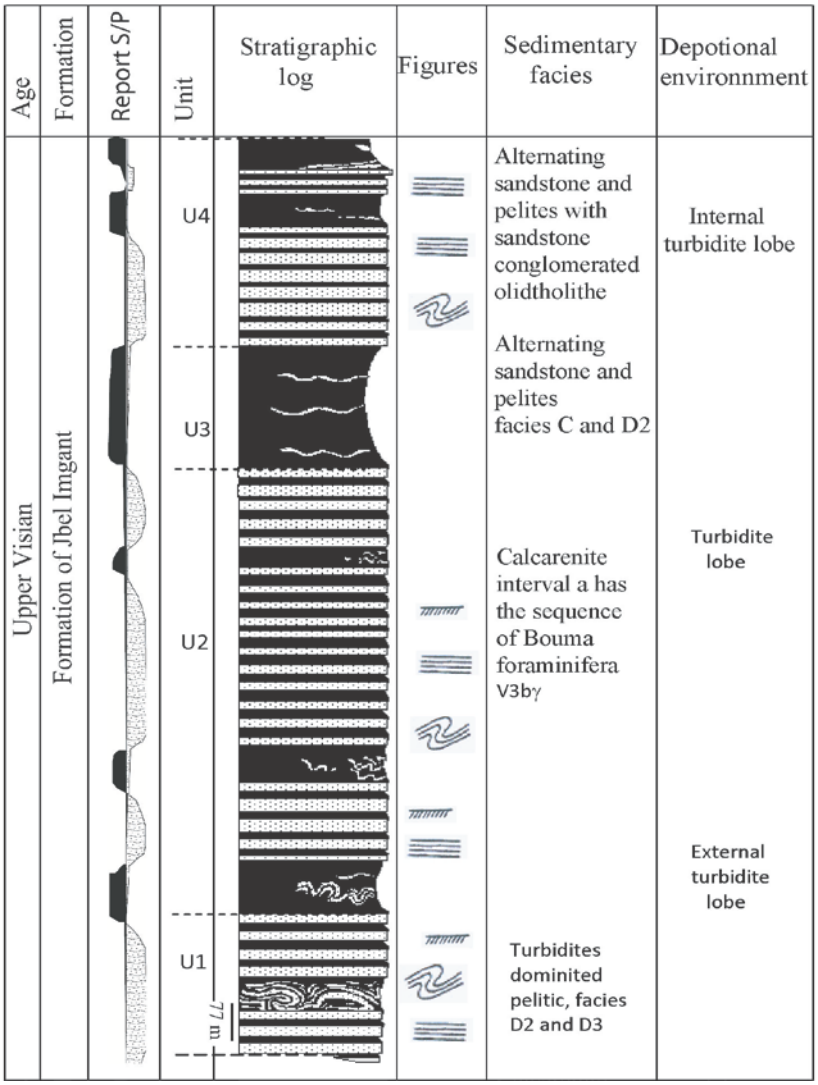

Figure 3. Lithostratigraphic column formation of jbel Imgant TASSA

Tizi n'Tnoutfi complex

Tizi n'Tnoutfi complex (450 m thickness) outcrops at the northern part of the Jbel Imgant succession. It's a chaotic formation where sporadically encounter olistolithic blocks with Devonian material packed in a soft matrix of upper Visean age. These olistolithes have been interpreted as lenses of varying size (Jenny and Le Marrec, 1980).

This complex is bordered by the Jbel Imgant succession with concordance contact and progressive transition between these successions at the South. This complex also is surmounted by the Jbel Abberonech succession at the North and by the Jbel Rat at the East. Tizi n'Tnoutfi complex consists of pelites and black shales. The base starts with alternation of black shale and pelites that organized as convoluted and slumps. The sandy pelitic olistolithe blocks are lenticular, sometimes pleated and deformed. These structures are due to a lateral facies variation since these blocks disorganized and are not of the same level, then our section of the complex is estimated (Figure 4).

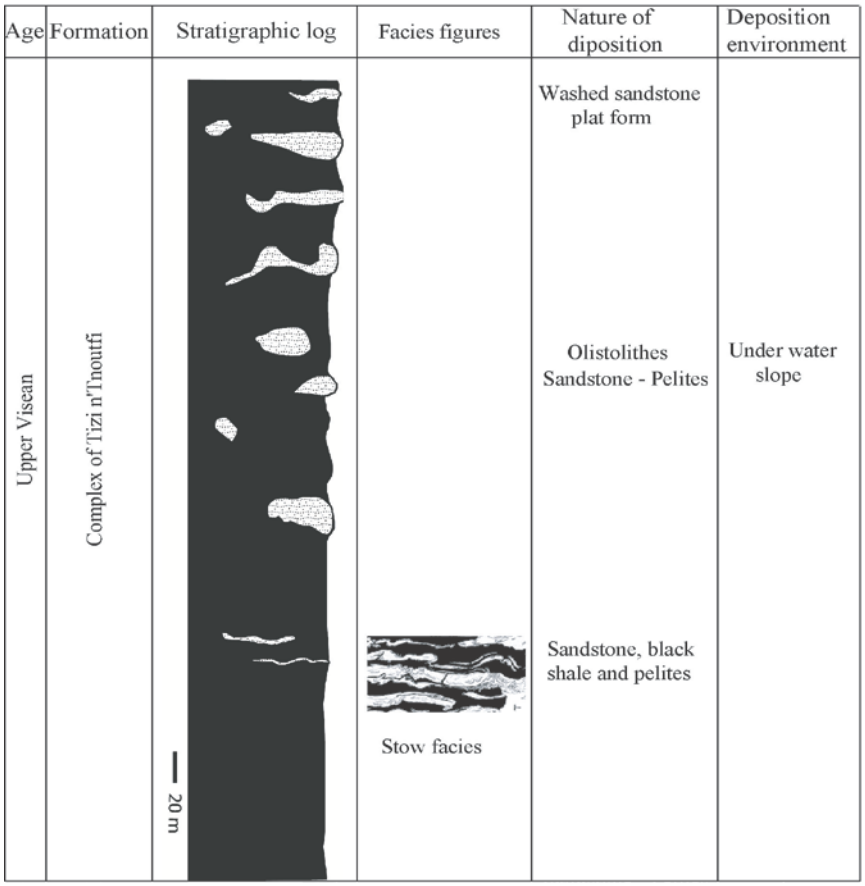

Figure 4. lithostratigraphic column of upper Visean Complex Tizi n'tnoutfi the buttonhole of Aït Tamlil

The Devonian facie is characterized by alternation of pelites with interbedded yellowish sandstones (5 to 30 cm thick). The laminar sedimentary and diagenetic structures are present in some beds of the sandstone. On the road, 100 meters before the Cole Tizi (intersection of three old roads) a lenticular olistolithic folded, which consists of alternation of sandstones and pelites. In the thin sections, these sandstones are sometimes quartzitic, but this time the sedimentary structures observed are in the form of desiccation cracks. These desiccation cracks are surmounted by a zone of shale-pelitic overcome by alternating sandstones and pelites. The fossils marks are presents at the top of the sandstone beds and indicate that the block is reversed.

C- The Jbel Abberonech Formation

The formation of Jbel Abberonech of upper Visean age outcrops along the old Ait Tamlil track, with an estimated 1,000 m thickness. It has been defined by Jenny and Le Marrec (1980) between the Tizi n'Tnoutfi complex at south and the Iguer n'Igherm complex at the North with an E-W orientation. It is repeated by flaking and constitutes a slick sliding. The deposits exposed along this succession are formed essentially of alternation of sandstones and pelites with dominance of sandstones and also some disorganized areas (of megaslumps), a conglomeratic sandy limestone bed and black azoic shale levels. We also note the presence of fossil remains indeterminate plants in pelites. The set is organized in a sequential evolution and consists of four units (Figure 5):

- The first unit (150 m thickn) consist of silico- clastic deposits organized as graded sequences. It begins with a 2 m micro-conglomeratic channel formed by alternation of sandstone and microconglomerates. The conglomerate shows in microscopic a variation of elements with volcanic and metamorphic origin. The quartz grains show rounded shapes dominant. This conglomerate followed by a succession of sandy- pelitic series with dominance of sandstone. The sandstone beds are 5 to 20 cm thick. The base of these beds has a high rate of quartz particularly rounded (Figure 6) reflecting a log transit from the source due to the grain size of quartz (100 to 200 micron). These sandstones are surmounted by conglomeratic with rollers flattened with around 3 m thick followed by descending grano-conglomeratic beds (40 cm thick) with limestone elements, iron gravel and pelitic elements associated with sandy levels.

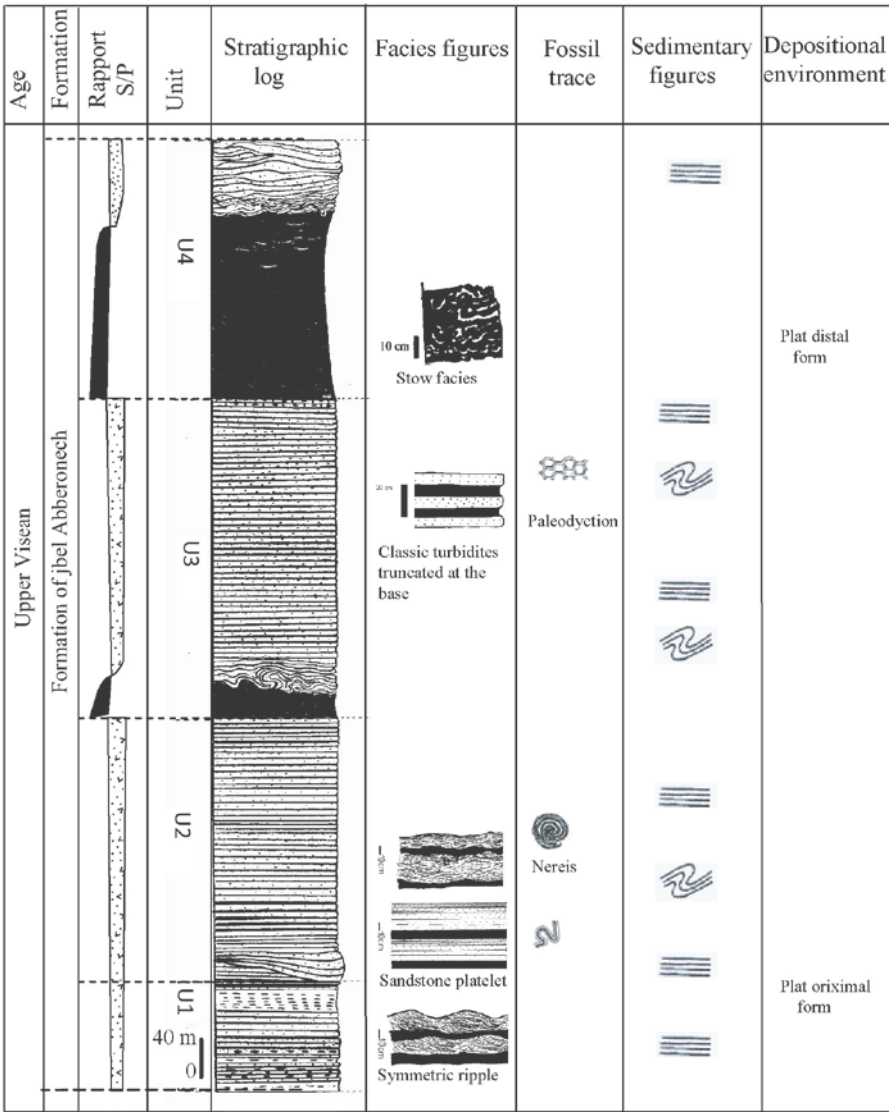

Figure 5. Lithostratigraphic column formation Jbel Abberonech

All successions are surmounted by alternation of sandstones and pelites. This unit is characterized by four facies:

+ Microconglomerates facies with bioclastic elements macroscopically, but microscopically this facies is characterized by the presence of foraminifera, crinoids and bryozoans.

+ Conglomeratic facies: This facies is characterized by flattened elements from different types (limestone, pelites, and iron gravel) (Figure 7). Morphometric analyzes of 100 gravels indicated the platform proximal deposit located at distal part of river.

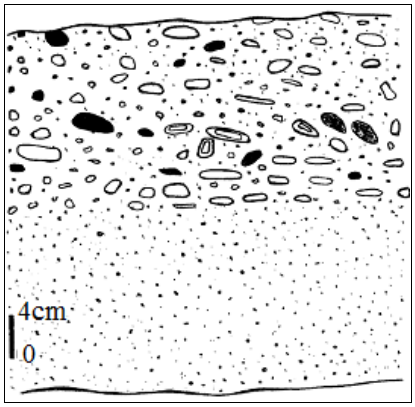

Figure 6. Grading curve of sand at unit 1 of formation of Jbel Abberonech

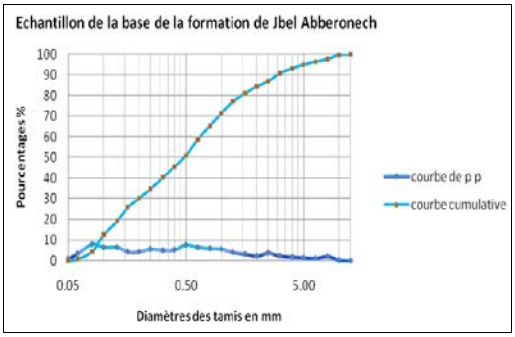

Figure 7. Grano-grawin conglomerate bench polygenic

+ Sandy pelitic facies is formed in sandstone beds with fine laminations plates (low biogenic production) and crisscross form as symmetrical ripples with length of 22 cm. This type of ripples is formed by wave action. These symmetrical ripples occurred typically in marine environments just below the base of wave action related to good weather. The ripple-laminated sandstone shows a gradual transition to the planar and the top of sandstone become criss-cross.

+ Sandy facies: grain size analyses show elements of quartz very rounded, shiny, sometimes dulled with different origin: granitic, quartzite, volcanic elements or silica elements and pelites elements more or less flattened. 2.5 < So <3 sediment normally classified; Sk <1 for negative asymmetry, classification is maximum to the side of high grain size indicate a turbulent sedimentation and agitated torrential deposits or coastal belts. The projection of the data on the Friedman diagram shows long transport and fluvial marine depositional environment (Figure 8).

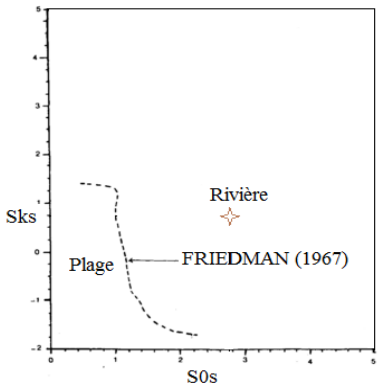

Figure 8. Diagram Sks/SOs

- The second unit begins with a lenticular sandstone channel (around 40 to 100 m in length) surmounted by alternation of sandstones series and pelites (200 m thickness). This unit is characterized by rhythmic sequences dominated by sandstones (5 to 40 cm thickness) with presence of bioturbation at the base and a high percentage (80 %) relative to pelites. In some places, sandstone beds are plan at the top and characterized also by parallel laminations bench on bench and platelets, criss-cross laminations with symmetrical ripples with wave length of 22 cm. This succession constitutes repetitive meso- sequences corresponding to megasequence. Analysis of 20 sequences shows the sandstone/pelites ratio is superior to 1. The presence of series with parallel laminations platelet and criss-cross laminations with ripples in the sandstone beds and non-gradual transition from sandstone to pelites indicate that deposition was in the intermediate platform.

- The third unit begins with azoic black shales (20 m thickness) surmounted by an alternation of sandy pelitic series formed at the top of laid down folds with bend axis sliding bed to bed. This serie represent a megaslump overcome by sandy pelitic series with dominance of sandstone (present around 90% in the unit). The fossil marks are present in these beds as paleodictyon and nereis that are deep facies present in deep sediments. These facies indicate a deeper environment sedimentation deposit. This unit characterized by calm deposit at the base and agitated at the top.

- The fourth unit (150 m thick) begins with a conglomeratic sandy limestone bed (2 m) followed by a succession dominated by pelitic facies, which covered two thirds of the entire unit and characterized by the presence of isolated lenticular sandstones. These successions are surmounted by sandstone series folded and slipped on pelites creating megaslumps. While in the top of the unit these series becomes normal with positive stratification (contact between the Jbel Abberonech succession and Iguer n´Igherm complex).

D- Iguer n'Igherm complex

The Iguer nIgherm complex is limited at the south by the Jbel Abberonech succession and Mesozoic and lower Paleozoic succession at the north. This complex is characterized by the presence of centimeteric to kilometeric Ordovician and Silurian olistolithes deposits. These olistolithes are packed in siliciclastic sediments of pelitic Nature (Figure: 9). The thickness of this complex is estimated around 400 meters because the base contact is affected by Jbel Rat fault at the south of the complex and the upper limit is surmounted by the scales of Devonian flysch and Ordovician psammites (Jenny, 1988).

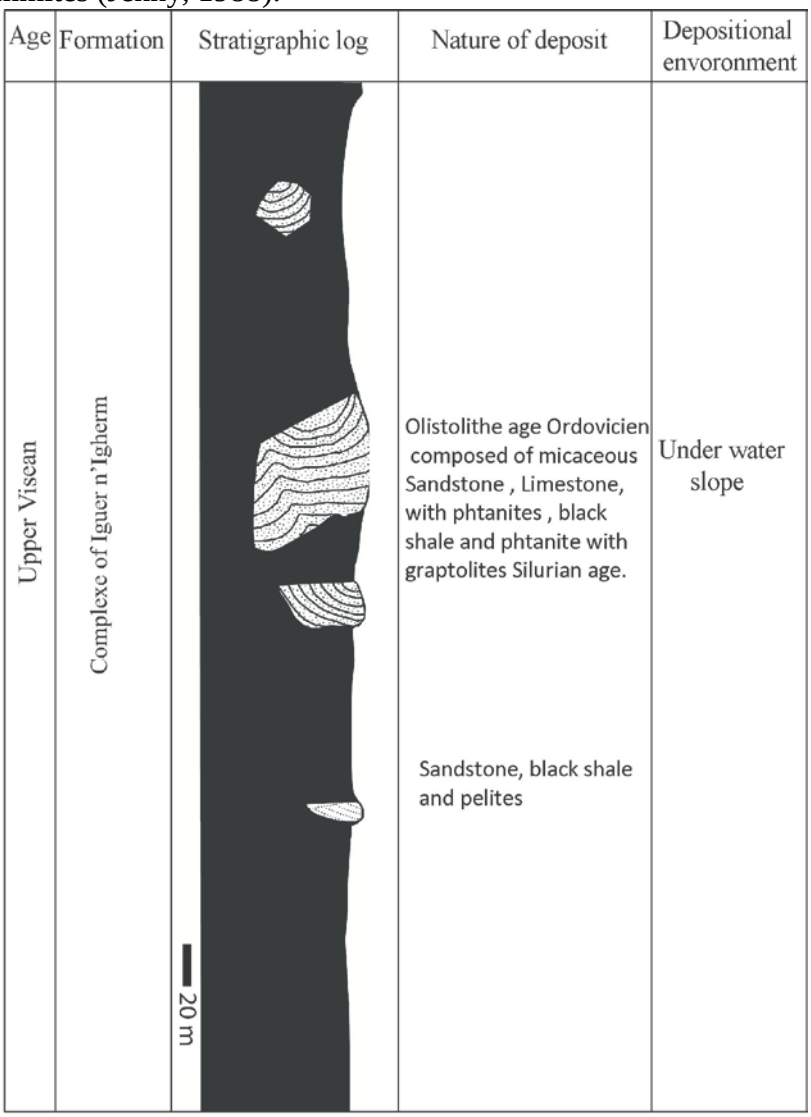

Figure 9. Lithostratigraphic colomn of Iguer n'Igherm complex

Interpretation and Conclusion

The fundamental characteristics of the Visean series at the Aït Tamlil inlier are:

- An abundance of channels of different sizes in the Jbel Imgant and Abberonech successions indicating an installation of a continental slope interspersed with canyons and depressions carved into the continental slope.

- The abundance of soft rollers in the coarse sediments indicating a remobilization of deposits through erosion phases probably due to tectonic events affecting the margin of the basin.

- The synsedimentary slides materialized by different slumps with different scale, debris flow in large thickness and the convolved levels shows a fast sedimentation on an unstable slope.

- The coarse facies are sandstone and associated to synsedimentary slide levels and debris flow related with visible synsedimentary faults shows a strong subsidence that generates a significant progressive unconformity in the Visean series.

- The occurrence of a chaotic level generalized in the basin, which correspond to the Tizi n'Tnoutfi complex, marks the beginning of a period of continental margins uplift of the basin. This uplift finished by the implementation of the Jbel Abberonech series, which is part of the platform of the Ait Tamlil basin. The implementation of these allochthonous successions has beneficiated of a large olistrostrome plastic behavior of the Tizi n'Tnoutfi to slide to the deep basin after the detachment of its origin to the platform.

The Phases that have marked the Ait Tamlil basin evolution are summarized as follows (Figure 10).

- The opening of the basin in a local extensional context following a compressive tectonic phase responsible of deformation marking the Devonian series. The unconformity of the lower Visean on the deformed Devonian is visible in several places.

- The deep sedimentation is marked by turbidite lobes arranged on the continental slope sheared by channels that derive coarse materials sometimes. This phase is also marked with a strong subsidence that could be causing frequent synsedimentary landslides at every level of the Imgant series. The installation of a large platform with calcareous deposits indicates a calm phases deposits escorted by filling of subsidence basin on a 2000 meter thick of turbidite deposits.

The mega- sliding at the Tizi n'Tnoutfi complex with the Visean sediments and Devonian blocks mark a chaotic sedimentation phase triggered by tectonic events with high magnitude. These tectonic events are marked by reverse fault responsible of uplift of the platform borders and the basin borders.

This phase is the origin of the allochthonous aspect of the Abberonech series, which is part of the Visean syngenetic platform of the Imgant series. This allochthonous serie (100 m thickness) is characterized by plastic materials of the Tizi n'Tnoutfi series, which are sliding from South to North of the Visean basin.

The Iguer n'Igherm complex marks a phase of filling by the Ordovician exotic materials, Silurian and Devonian coming from the northern part of the Visean basin. The thrust-faulting during the compressive phase are the origin of the multi-dimensions of blocks at several levels in this series of 400 m thick.

In a general overview, the Skoura basin can present the coastal margin of the deep basin of the Aït Tamlil. In fact, the coastal and deltaic series described in this basin (Izart. 1991) matchs with the margin of the deep basin, which extends to the north.

The normal sedimentation is continuous in the Aït Tamlil basin, it does had lasted during the deposition phases of the Imgant turbidite series, and their equivalent of the platform of the Jbel Abberonech succession. The chaotic series of the Tizi n'Tnoutfi and Iguer Igherm can occur on a very short time.

The secondary cover lying with an angular unconformity on the Ait Tamlil inlier covers even more details on some contact between the successions especially the exact size of the Iguer n´Igherm complex. The northern border of the basin consists of the Ordovician, Silurian and Devonian layers. The base which is connected with the extension of the Visean basins and their closure especially as the layers slides of oriental Jebilet (Figure 10.)

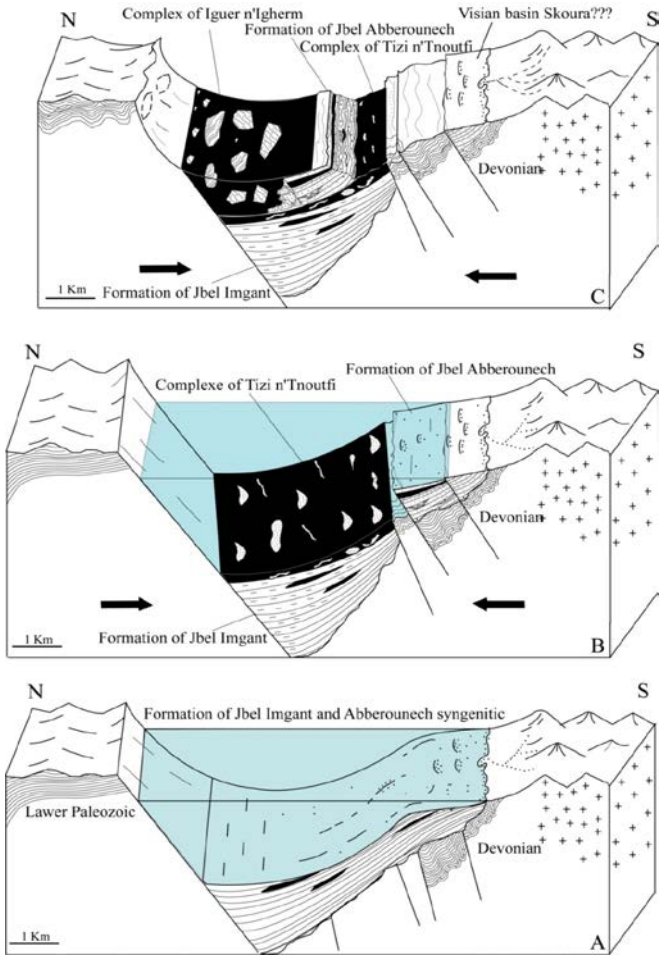

Figure 10: Evolution of basin upper Visean age of Aït Tamlil

A- Phase of formation and Jbel Imgant Abberonech syngenetic,
B- Phase of the complex of Tizi n'Tnoutfi,
C- The end phase of filling.

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