

The major stages of the Jurassic evolution of a basin intraplate: example Middle Atlas (Morocco)

BENJELLOUN Faiza¹, ANJJAR Ahmed²

Abstract— The central Middle Atlas is framed by the north and south atlasic average accidents who put it in contact with the *causse* and the plateau of Douira-Anjil. To follow the Jurassic evolution of this part of the Central Middle Atlas. Several geological sections are made; they were closely sampled and allowed us to follow the spatiotemporal evolution of the facies of Lias and Dogger. The Jurassic Evolution of the Central Middle Atlas was carried out in five stages that are within the Domerian-Bathonian interval. The first stage goes back to the Domerian where the structuring of the Middle Atlas follows the dislocation of the liasic carbonate platform. The result is the individualization of a basin organized in wrinkles and depocentres, surrounded by stable zones, and a magmatic activity, which manifests itself by the introduction of successive sub-volcanic intrusions essentially at the level of the wrinkles. The second stage (Terminal Domerian and Lower-Medium Toarcian) is a phase of siltation. As for the third stage (middle-upper Toarcian and Aalenian), it is characterized by the establishment of a prograding carbonate platform. The fourth stage (lower Bajocian) corresponds to the second phase of siltation. During the fifth stage (Upper Bajocian and Lower Bathonian) a reef carbonate platform develops, draping detritic and evaporite sediments. The Jurassic basin of the Middle Atlas had a very brief life span: sketched at Sinemurian and individualized at the Domerian-Toarcian, it heals in the Bathonian -? Callovian. Its structural-sedimentary evolution can be described in terms of stability - mobility - filling and senescence.

Index Terms— Geodynamic Evolution, Jurassic, Major stages, Middle Atlas, Morocco, Sedimentology, Tectonics.

1 INTRODUCTION

THE Jurassic evolution of the Middle Atlas which is governed by various factors and complex. It took place in five stages that fall within the Domerian - Bathonian time interval.

The structuration of the Middle Atlas is carried out following the dislocation of the liasic platform, resulting in the individualization of a basin organized in wrinkles and depocentres with asymmetrical margins that surround stable areas. These structural and paleogeographic frameworks are permanent during the filling of the basin, nevertheless they have undergone some readjustments.

2 MATERIALS AND METHODS

Geographical and Geological Framework

The Middle Atlas is an element of the sub-domain of atlasic chains. It is delimited by: the plain of Saïs and the front of the tableland Rifaine in the North, the Guercif basin in the North-East, the depressions of Moulouya in the East and the South, Central Morocco in the West.

The Middle Atlas is composed by the juxtaposition of two structural domains: the subtabular *causse* and the pleated Middle Atlas (Fig.1). These domains are separated by the major lineament that emphasizes the zone of passage of the North-Atlas atlas accident [1].

The formations that make up the Middle Atlas are from the oldest to the most recent [2]:

- The Paleozoic formations that outcrop in the Tazekka massif and the buttonholes of El Hajeb, Bsabis, Kandar, El Menzel, Kerrouchen;
- The triassic-liasic formations outcrop around the Paleozoic terrains, especially in the Tazekka massif and the El Kbab - Kerrouchen region. These formations are also exposed along major accidents;
- The formations of the Lower and Middle Jurassic constituting the main part of the Middle Atlas chain;
- Cretaceous formations confined in the center of the chain;
- The Miocene flush in the NW part of the chain,
- Plio-Quaternary highly developed near major accidents and on the periphery of the chain (Fig. 1).

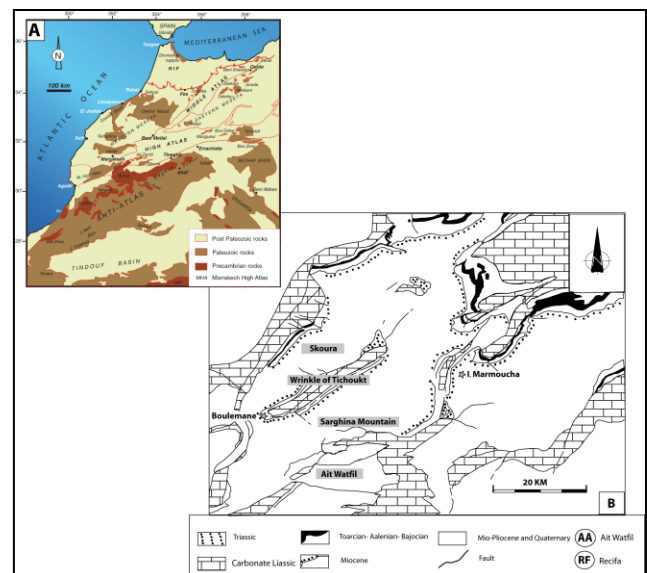


Fig. 1. Location of the study area. A- Position of the Middle Atlas with respect to the different structural domains of Morocco. B- Simplified geo-

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logical map of the studied region.

3 RESULTS AND DISCUSSION

3.1 Tectono-sedimentary evolution

The Jurassic studies of the Middle Atlas basin show that the deposits thicken by becoming more and more marine from SW to NE.

These sediments have undergone a significant synsedimentary deformation which attests to the mobility of the substratum.

Indeed, the reactivation of the structural framework, individualized since the Domerien and organized in wrinkles and depocentres, guided the successive paleogeographies while controlling the distribution of the various sedimentary bodies.

Sedimentary succession

In the Lias and Dogger deposits of the Middle Atlas, several formations or mesosequences are distinguished, they are delimited by sedimentary discontinuities of regional extension whose materialization changes from one region to another.

The sedimentary phases :

On the lithostratigraphic level, the Middle Atlas Jurassic deposits can be grouped into three phases: a carbonate phase which has been repeated three times in time; a marly phase which has reproduced, for its part, twice a phase, which is composed essentially of evaporites, silicico-clastites and terrigenous detritics. Although we note a deepening of the deposit environments, going from SW to NE, these three phases are identifiable.

The carbonated phase: the establishment of liasic, toarc-aaleno-Bajocian and Bajocian platforms marks it.

- The lower middle Lias is characterized by the stability of the substratum (rare or absent detritism), the homogeneity of facies (carbonates) and the generalization of tidal environments. It is a biostatic period that has favored this long development of carbonates, in average energy under a tropical climate.

- From the Middle to Upper Toarcian to the Lower Bajocian (Laeviuscula zone) [3]-[4], in the central Middle Atlas, a prograding carbonate platform develops. It is characterized by the frequency of oolitic cords from encrinitic flats, nodular facies and marl-limestones to Zoophycos.

- From the lower Bajocian (Humphriesianum zone) to the Lower Bathonian, the Bajocian carbonate platform is established, which is represented in the central Middle Atlas by the limestone cornice [5]-[6]. These are tidal deposits where the facies are frequent. They are relayed to the SW by dolomitic and calcareo-dolomitic sediments, while towards the NE, they lose their neritic and marly charm.

The marly phase: It is represented by two powerful marly masses that translate the installation of very subservient mudflats, one to the Toarcian and the other to the Bajocian.

- The Toarcian mudflat (lower and middle Toarcian) is a receptacle of Bechyne marls. This first phase terrigenous is fed by a massive arrival of fine colloids, especially illite and chlorite. It shows a rhexistasia and reflects a relative cooling of the climate that is favored by the extension of the seaspaces. We then witness a spreading of the vases and the erasure by sub-

mersion of the thresholds.

- The Bajocian mudflat (Lower Bajocian), More Subsidiary, is occupied by the marls of Boulemane. This formation, very powerful, took place during the transgressive maximum of the Sauzei zone. It allowed the siltation and flooding of wrinkles.

The composite phase: It starts from the Bathonian to the lower Cretaceous is marked by a mosaic of deposits where, in addition to carbonates and marls, the following facies trilogy: silicico-clastites, evaporites and terrigenous detritics. These varied sediments are confined in very subsidence gutters framed by the major active wrinkles.

These incessant changes in the sedimentary regime are guided by the internal and external factors of the sedimentary receptacle and neighboring regions (Fig. 2).

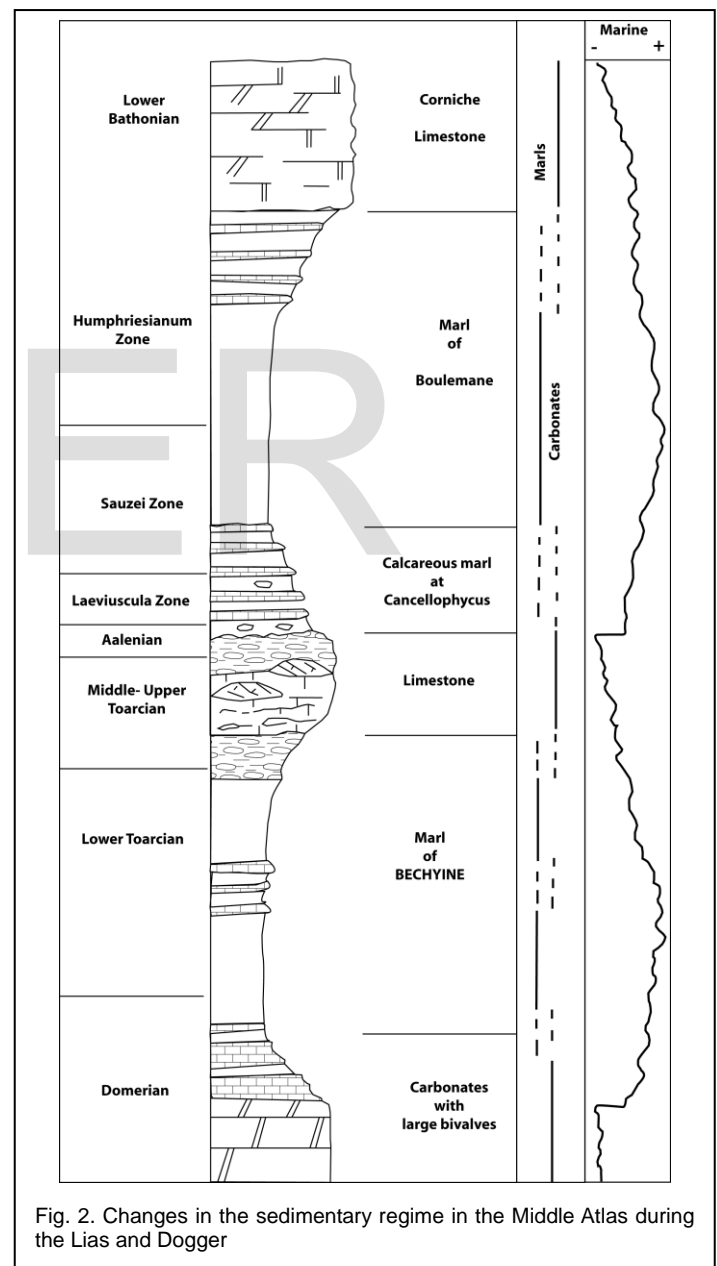


Fig. 2. Changes in the sedimentary regime in the Middle Atlas during the Lias and Dogger

3.2 Proposed model

To interpret the evolution of the Middle Atlas basin during the

Jurassic, we propose for each episode a model of overdischarge basin in multiple distensive and compressive relays of senestres recesses ENE and NE.

From Toarcian to Bajocian (Fig. 3-A): during this period, the configuration of the middle Atlas basin resembles a megaflower [7]. The opening of this one would be linked to a sinister EW detachment. In detail, the Middle Atlas is formed by an assembly of large depocentres delimited by anticline wrinkled [8].

NE-SW wrinkles are marked by senestral recesses, it is the major wrinkles N75 which are active following a reorientation of the constraints during the filling. These induced the formation of EW wrinkles and controlled the placement of subvolcanic intrusions. The combination of these different structures gives depocenters lozenge shapes. From the Toarcian to the Bajocian, the evolution of the main structures of the Middle Atlas is thus dominated by the association of structures in compression and distension.

From the Bajocian to the Upper Jurassic (Fig. 3-B): At the scale of the Middle Atlas, there are radical changes in paleogeography: in the central Middle Atlas are formed more or less confined environments. They are separated from the NE's open marine environments by a system of thresholds. These palaeogeographic changes are accompanied by a reactivation of N45 directional wrinkles during senescence. This results in the migration of subsidence areas and the tectonic confinement of depocenters. Then lagoonal environments of sebkha type are formed.

The evolution of the main structures of the Middle Atlas during the Bathonian is also dominated by an association of distensive and compressive structures [13].

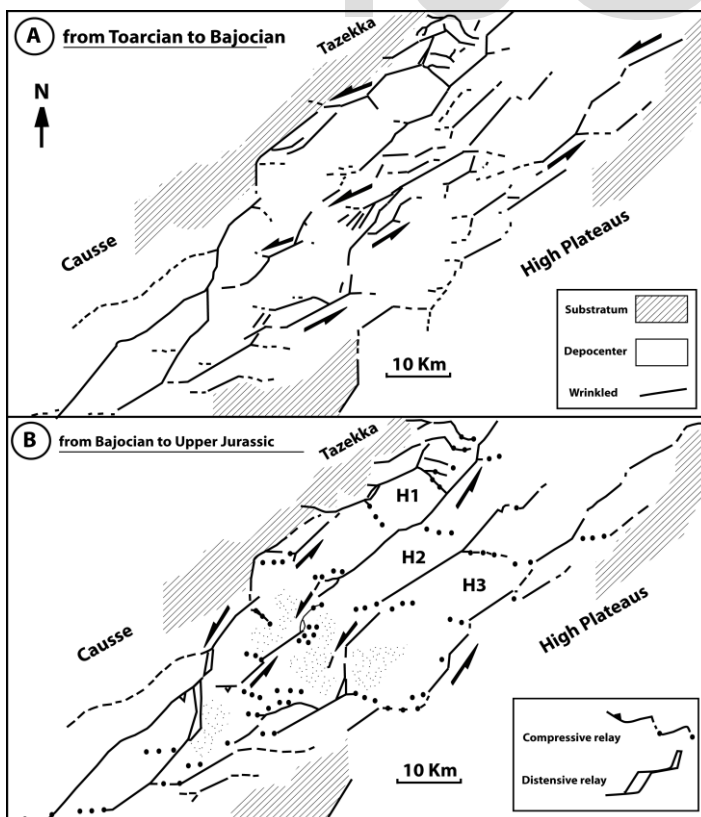


Fig. 3. Model of evolution on strike of the Middle Atlas basin after [12], modified slightly by [13] H1, H2, H3 shoals and palaeoseuil.

The Jurassic basin of the Middle Atlas is a basin on strike, sketched in Sinemurian and individualized in the lower Domérien-Toarcien, to heal from the Bathonian to the lower Cretaceous [8] -[12]. Its geometry, very complex is characterized by three types of structures: the depocentres, major N45 and N70 oriented wrinkles as well as the associated structures. The reactivation of wrinkles during periods of filling and senescence of this basin is diachronous [8]-[11]: the activity of certain wrinkles is amortized or even stopped, while others continue to act as zones high [14].

3.3 The stages of evolution of the Middle Atlas

The Jurassic basin of the Middle Atlas had a very short life span (about 40 Ma): sketched at Sinemurian and individualized in the Domerian-Toarcian and it heals in the Bathonian -? Callovian. Its structural-sedimentary evolution can be described in terms of stability, mobility, filling and senescence (Fig.4).

The stability period is established from the lower Lias to the middle Lias, it is characterized by the development of a carbonated platform, whose deposits are organized into a mega-opening sequence [15]-[16]. This biostatic period favored the development of tidal carbon facies in medium energy and in a dry tropical climate. However, in the north-eastern part of the Middle Atlas, the beginnings of instability and the arrival of faunas borealis (Amaltheidae) announce the destruction of peri-mesogean carbonate platforms and therefore the draft of the average atlas basin.

The period of mobilities manifested from the Domerian to the Lower-middle Toarcian (Bifrons Zone). It is marked by "a tectonic crisis". Indeed, the liasic carbonated platform is dislocated by a compressive tectonic episode induced by recesses. It then follows the individualization of the middle atlas basin, organized into wrinkles and depocentres. This new structural and paleogeographic framework, with high zones and areas of sedimentary accumulation, is permanent during the filling and senescence of the basin.

The period of filling is from the Middle to Upper Toarcian and Aalenian (Zone to Concavum, Discites, Laeviuscula, Sauzei and Humphriesianum) [17] in favor of an essentially carbonated syntectonic sedimentation, which are arranged in regressive mesosequences, of Klupfelian type. This sedimentation marks a rhexistasia and a softening of the climate. The uplift of anticline wrinkles, the development of associated distensive and compressive structures, the establishment of subvolcanic intrusions, the subsidence and filling of depocenters are synchronous. They are compatible with a game in sinister recess major accidents that punctuate wrinkles. This evolution is amortized and favors the installation of the Bajocian carbonate platform.

The senescence of the basin begins in the Bathonian, the dislocation of the Bajocian platform is consecutive of an intense activity of the wrinkles. At the same time, increased subsidence of depocenters results in tectonic confinement. Then the series of filling includes, in addition to the carbonates, continental evaporites and contributions silico-clastics whose sequential arrangement differs from one depocentre to another. Finally, the sea withdraws from the Middle Atlas Jurassic basin filled, to be confined to its north-eastern part.

The main structures of the Middle Atlas (wrinkles, depocentres and associated structures) are contemporary with the last three stages of evolution. Their interpretation is made by comparison with analog and mathematical models. The structures in compression and distension are interpreted as resulting from multiple compressive and distensive relays. A Jurassic evolution model on strike is finally proposed for the Middle Atlas basin.

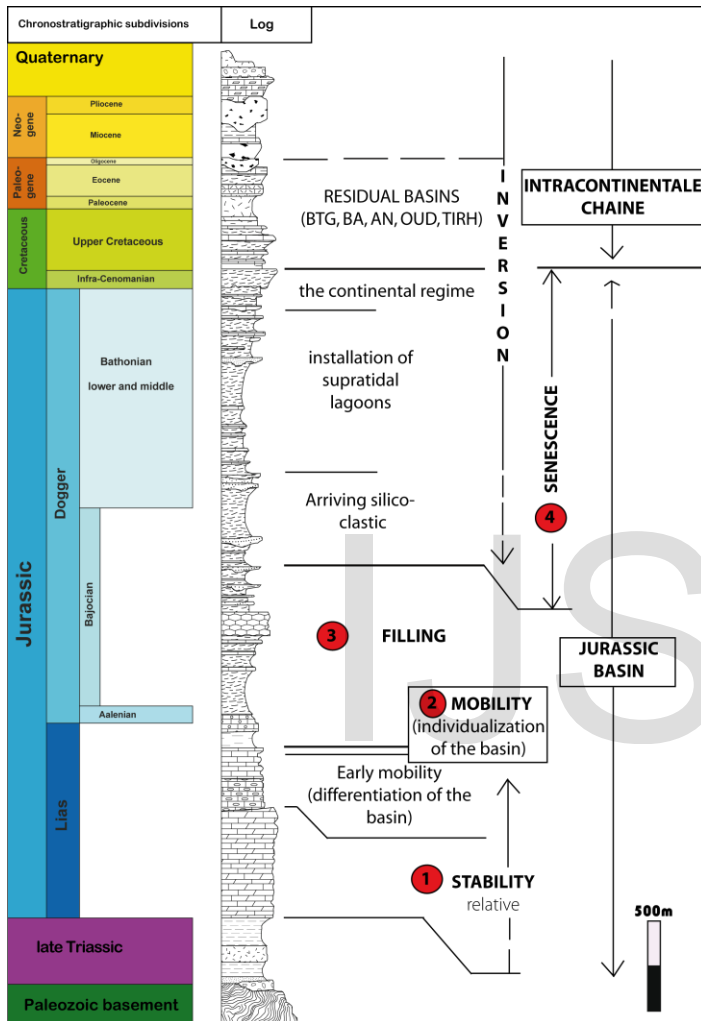


Fig. 4. The different stages of the Meso-Cenozoic geodynamic evolution of the Middle Atlas [3] BTG BouAnguer, Timahdit, Guigou - BA: Baqrit- AN: Ain Nokra- OUD: Oudiksou- TIRH: Tirhboula.

4 CONCLUSION

The Middle Atlas has been spared by Triassic attempts at opening, its structural and sedimentary evolution from the Jurassic to the Present occurred in two stages:

- Intraplaque basin during the Jurassic;
- Intracontinental chain whose structuration, as a morphological element, began in the Late Cretaceous.

This meso-Cenozoic evolution of the Middle Atlas is a consequence of the opening of the central Atlantic and the kinematics of American, African and Iberian plates, they can be sum-

marized [18] as follows:

- At the right of the central Atlantic, future continental margins and neighboring regions are affected by preliminary distensions (Permian Lias) is the phase of rifting.
- The beginning of the oceanization (opening of the central Atlantic) is dated -189 Ma, Africa is separated from North America, moves along a large sinistral detachment compared to Iberia still in solidarity with the new big bank of land [19].
- From the lower Cretaceous period between the great New Earth Bank and Iberia, the latter is then driven by Africa in its movement towards the East. The result is an uplift of the Atlas domain which appears as a shoal with regard to Cretaceous and Tertiary transgressions [20].
- As early as the Campanian, the Atlas strings were slowly structured, which were controlled by the remobilization of late Hercynian accidents during the early stages of the opening of the central Atlantic, and then during continental convergence in the Western Mediterranean.

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