Chapter II: Algeria within the Context of the Western Mediterranean.

Example of a Paleozoic Series (Primary)
THE OUGARTA CHAIN

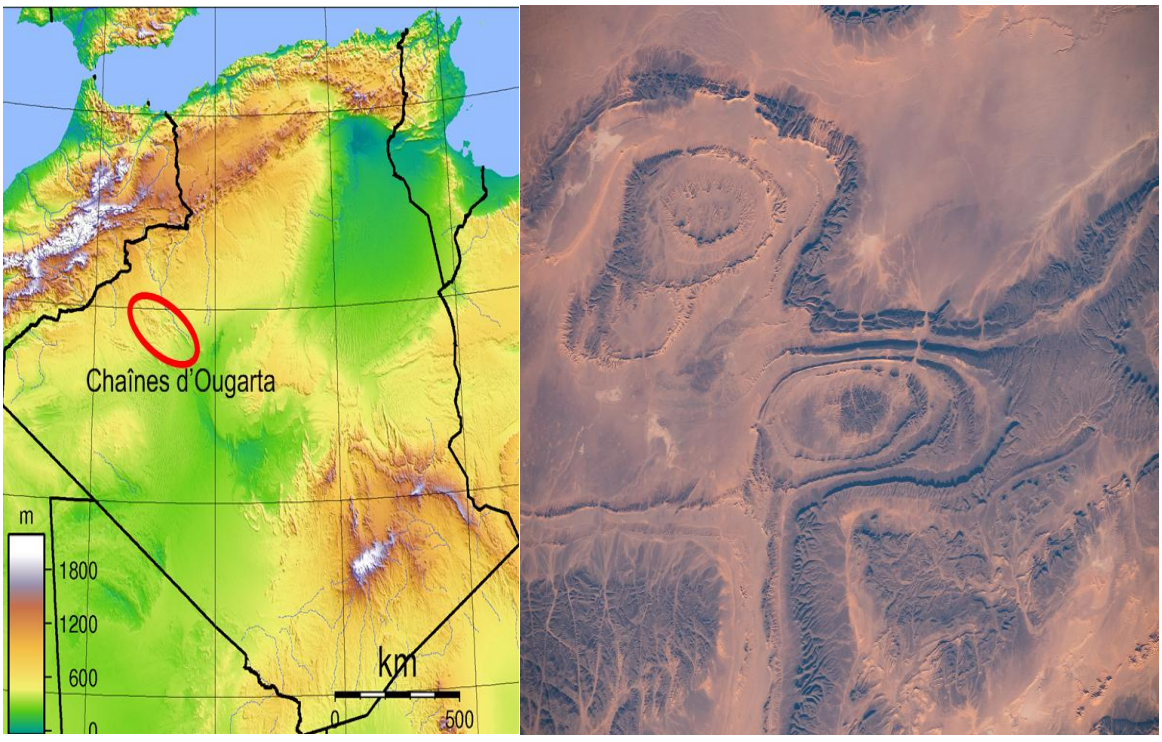
I. GEOGRAPHICAL FRAMEWORK: Situation of the Ouargla Mountain Range

The Ougarta mountain range is located in the northwest of the Algerian Sahara, in the heart of the Saoura region. It is located approximately 1,000 km south of Oran and 250 km south of Béchar.

Structure of the massif
This mountain range comprises two parallel bands orientated northwest/southeast, separated by the Erg Er Raoui:

• In the northeast, the Saoura range (the Ougarta Mountains proper).
• In the southeast, the Daoura range (Daoura Mountains, Kehal Tabelbala, Djebel Ben Tadjine).

Dimensions and role
With a length of 450 km and a width of 200 km, these belts ensure the geological transition between the Moroccan Anti-Atlas in the northwest and the Tuareg Shield in the southeast.



The Ouargla Mountains are delineated by reliefs and desert basins characteristic of the Algerian western Sahara. This structure makes it a well-defined massif within the arid landscape.

Geographical boundaries

- North: The Hamada of Guir, hard rocky plateau.
- South: Erg Chech, vast field of dunes.
- West: The Hamada of Draa, another desert plateau.
- Northwest: The Kem Kem Mountains.
- Southwest: The Erg Chech (continuation).
- Northeast: The Great Western Erg.

Educational interest

These boundaries perfectly illustrate the compartmentalisation of the Algerian Sahara into hamadas (eroded plateaus), ergs (dunes), and residual massifs, typical of Hercynian domains.

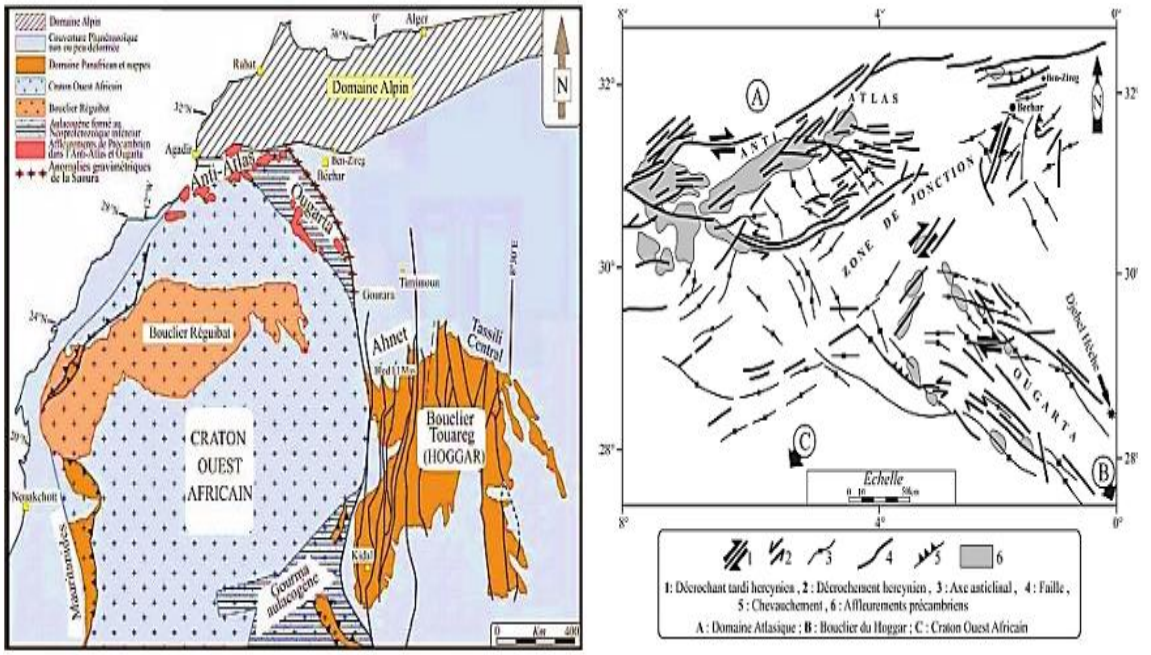
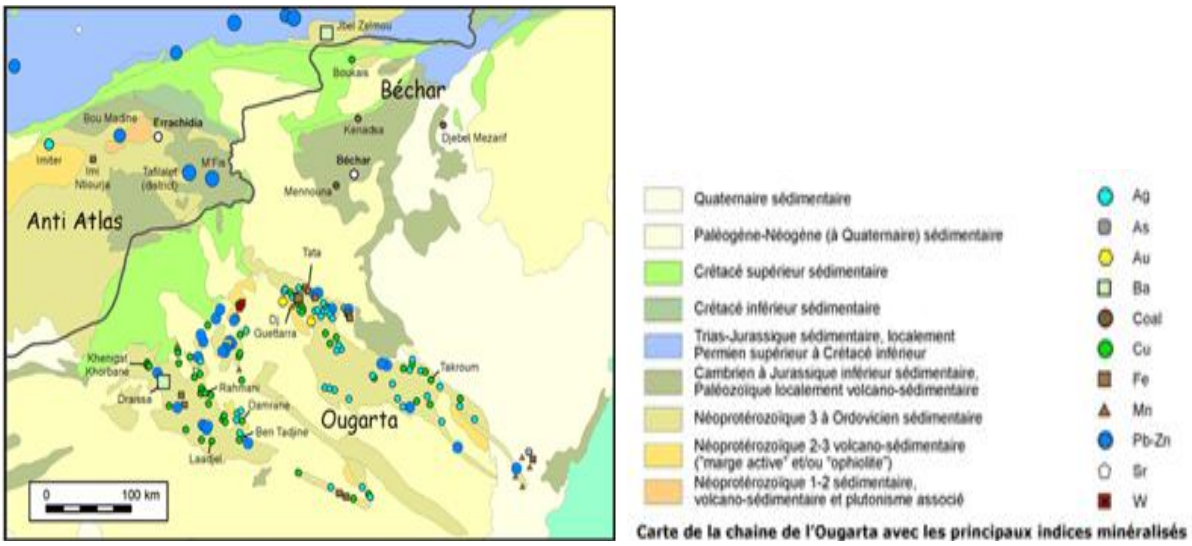
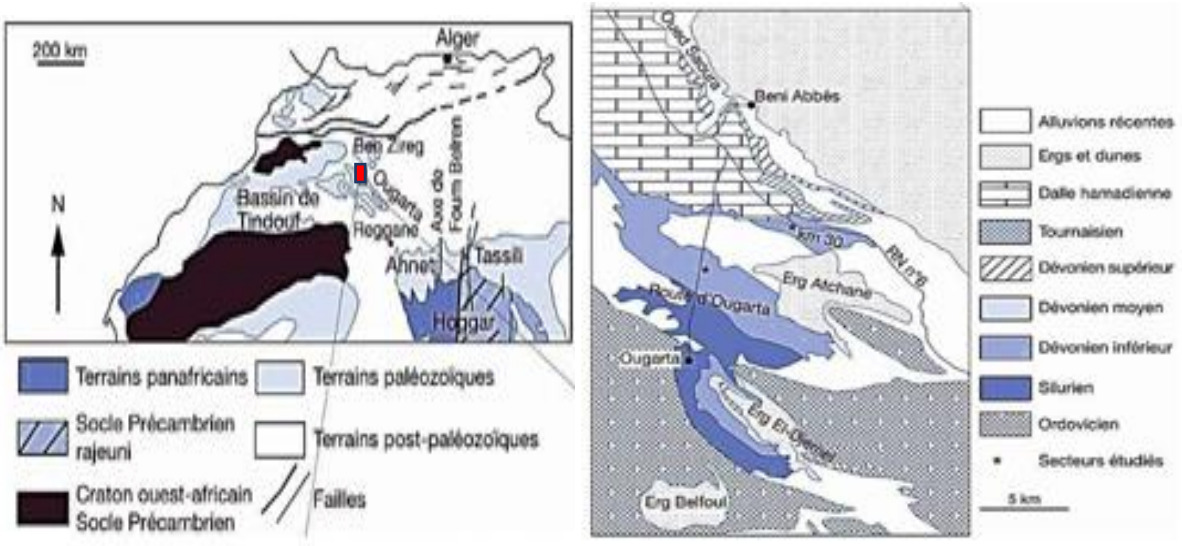


Figure : Schéma structural montrant le raccordement de la chaîne d'Ougarta avec l'Anti Atlas (Choubert, 1963 pour l'Anti-Atlas ; Donzeau & Zellouf, 1973 pour l'Ougarta ; Pareyn, 1961 pour le bassin de Béchar) (Modifié)



Carte de la chaine de l'Ougarta avec les principaux indices minéralisés



II. STRATIGRAPHIC SERIES:

A- The Precambrian

In the Ougarta, the earliest sedimentary records are volcanic deposits (Rhyolites) and volcanosedimentary deposits, in concordance with the Ougarta sandstones, but in some cases, they are separated by a well-marked angular unconformity.

1. The Pre-Paleozoic Substratum:

On the scale of West Africa, the series constituting the pre-Paleozoic substratum show significant variations in thickness and facies. They are little or not deformed and exhibit low-temperature epizonal metamorphism.

This substratum, in the Ougarta mountain range, is very poorly represented. With the exception of the outcrops of Sebkha El Mellah and Damrane at Ben Tadjine, it is covered everywhere else by Quaternary formations.

1.1. The flysch series:

In the Ben Tadjine region, this series consists of an alternation of centimeter-thick layers of quartzites and reddish clays.

1.2. The volcanic series:

The substratum of the Paleozoic sedimentary formations also includes a volcanic complex in buttonholes throughout the chain. Their orientation roughly corresponds to that of the chain. This volcanic substratum is composed of two formations: an andesitic and basaltic formation topped by a rhyolitic and ignimbritic formation.

1.3. The base conglomerate or Ben Tadjine:

These are coarse detrital sediments, essentially conglomerates, between the substratum, volcanic or volcaniclastic, and the first Cambrian sandstone sedimentary deposits with oblique stratifications.

The sources of contributions are varied. One is certainly local since a high percentage of rhyolites and ignimbrites is found. The other, which provided the granite pebbles, would be located to the west. The particularity of this conglomerate in this region is its stratigraphic position following the volcanic episode. Moreover, the volcanites are reworked in situ, yielding heterometric elements of rhyolites or ignimbrites rounded in a sandstone matrix.

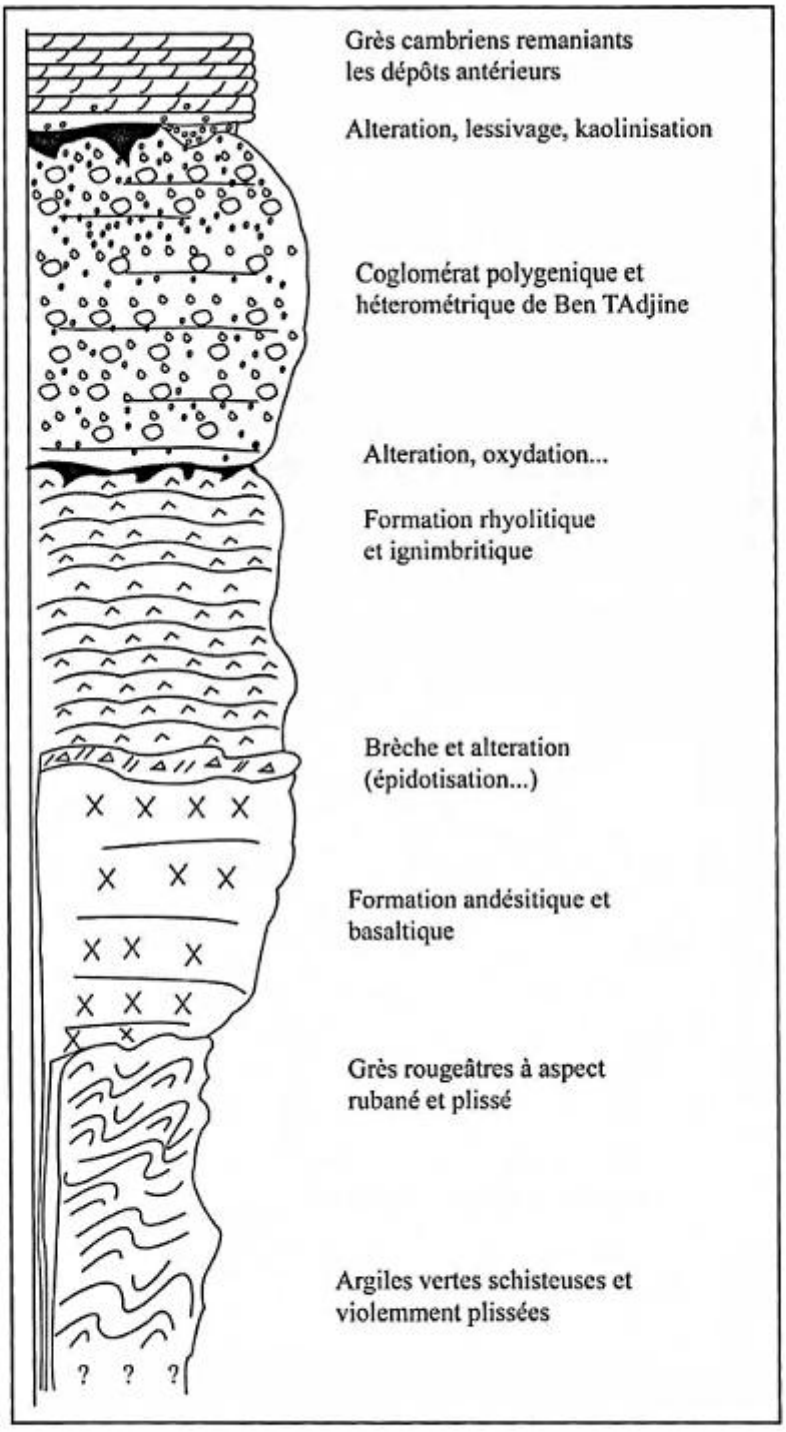


Fig.III.16. Colonne litho stratigraphique et chronologie relative des principales unités stratigraphiques du substratum antépaléozoïque de la chaîne d'Ougarta. Les épaisseurs sont inconnues

(in : R. HAMDIDOUCHE, 2009)

B. The Paleozoic Cover (primary):

Based on sequential criteria, the importance and significance of the discontinuities, two major sedimentary cycles are distinguished in the Paleozoic filling of the Ougarta "basin":

- a detrital cycle of grès-quartzite attributed to the Cambrian-Ordovician;

- a marine cycle of the Silurian-Devonian;
- separated by a major discontinuity, the Taconic phase, combined with a climatic event: the glaciation at the end of the Ordovician.

1. The Cambro-Ordovician cycle:

This first cycle, or Ougarta Sandstone of the authors, has long been attributed to the Cambro-Ordovician due to the rarity of fossils and its position beneath the dated Silurian.

1.1. The Cambrian:

The Cambrian of the Ougarta range is becoming relatively well known. Two formations with a total thickness of approximately 500 meters can be distinguished:

*** a basal formation or "Arkoses of Sebkhet El Mellah"** deposited in a braided fluvial environment, in discordance on a structured substratum that it reworks. - light arkosic sandstones with current ripples, oblique stratifications subsequently testify to a coastal environment or at least a certain marine influence.

The end of this formation is marked by significant ferruginization affecting banks rich in tigillites;

*** The second formation, or Quartzites of Ain En Nechéa,** is significantly more developed. It is composed of two members: a lower member that is clayey-silty and then sandy.
It is likely a vast and subsiding coastal environment with an epicontinental sea sensitive to eustatic fluctuations.

1.2. The Ordovician:

The Ordovician of the Ougarta chain has also been known for a long time. It is distinguished by:
- a clayey-sandy formation at the base. Its clayey member provided a fauna rich in Brachiopods, Trilobites, and small fossiliferous limestone blocks.

The Ordovician is crowned by a formation known as Djebel Serraf. It rests through a ravinement surface on the underlying formation. It begins with a ferruginous conglomerate layer topped by sandstones. Its summit is represented by glacial deposits.

The sequential analysis thus shows three regressive clayey-sandy formations.

In summary:
The sedimentation, primarily detrital from the Cambrian to the Ordovician and the absence of carbonates, suggests a relatively cold climate.
These last ones all show that during this long period, the Gondwana continent migrated south following the fragmentation and dislocation of Rodinia at the end of the Precambrian.
The organization of the sedimentary fill allows us to conclude that throughout this period, the general trend was towards opening.

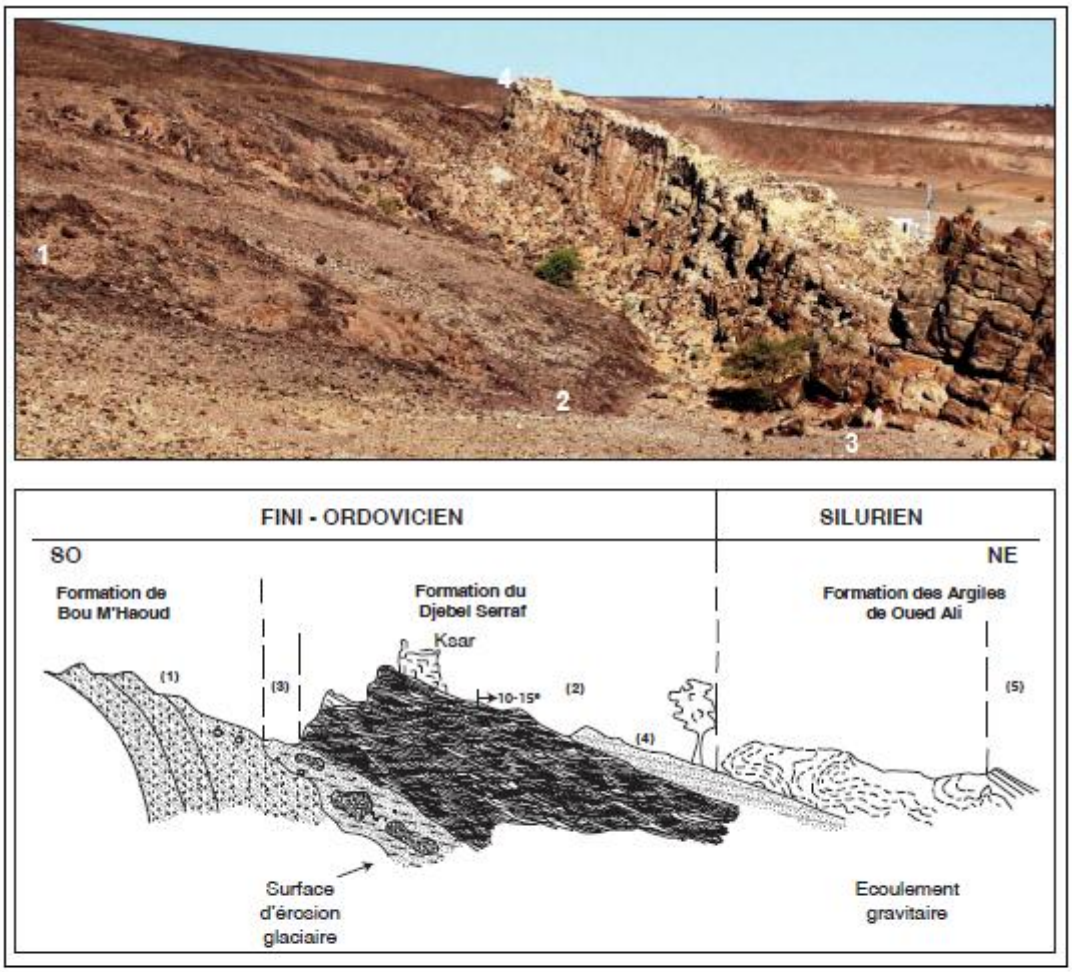


Fig. 4- Ksar d'Ougarta. La fin de l'Ordovicien. **(1)** Formation de Bou M'Haoud se terminant par une surface d'érosion glaciaire. **(2)** En discordance progressive, la Formation du Djebel Serraf avec **(3)** les Argiles Microconglomératiques très réduites et **(4)** les Grès d'Ougarta. Au second plan dans la plaine, en avant des reliefs, **(5)** le Silurien.

Ougarta Ksar. The end of the Ordovician. (1) Bou M'Haoud Formation ending by a surface of glacial erosion. (2) In progressive discordance, the Djebel Serraf Formation with (3) the very reduced "Argiles Microconglomératiques" and (4) the "Grès d'Ougarta". In the background of the plain, in front of the reliefs, (5) the Silurian.

2. The Silurian-Devonian cycle:
This cycle is significantly more imposing with its 3000 m compared to the previous one, which was reduced to a few 1000 m.

***The Ordovician-Silurian transition:**
It represents a tectonic phase in a glacial context. Along the Ordovician reliefs, deformations and organisations at different scales are observed...

2.1. The Silurian: The Silurian of the Ougarta chain has already been well studied. The contact and transition between the Ordovician and Silurian are clear in at least two places:

Ougarta village and about twenty kilometres southwest at the place called El Kseib.

The continuation is observed about ten kilometres to the east, at the site known as Draa Oued Ali.

In the village of Ougarta, the wadi near the Old Ksar shows the base of the Silurian, with twenty to thirty meters of silts and highly deformed clays resulting from gravitational flow and monoclinal black clays.

The sequence includes, in order, sandstones with ferruginous nodules, variegated clays, and coarse sandstones. Beyond that, black clays begin. It is worth noting some levels of limestone with Orthoceras, rare small-sized Phacops, and Lamellibranchs.

In the southwest, at El Kseib, the Ordovician-Silurian transition shows some tectonic peculiarities. The latest Ordovician beds show, in addition to evidence of glacial sedimentation, signs of synsedimentary tectonics.

It is possible to distinguish three sedimentary episodes in the Silurian series.

- The first episode corresponds to the transition from the Ordovician to the Silurian with a gap of approximately 2 million years.
- The second period is characterised by clayey and silty deposits with levels, quite spaced apart, of fossiliferous limestones rich in Orthoceras and fragments of Trilobites.

This period is controlled by episodes of slowdown in detrital inputs and favourable climatic conditions.

- The last stage of sedimentary evolution is the progressive return of detrital sediments, probably linked to Caledonian epirogenic activity.

In summary: The Silurian is a regressive mega-sequence, and the coarsest sediments are found in the south in the Tibesti.

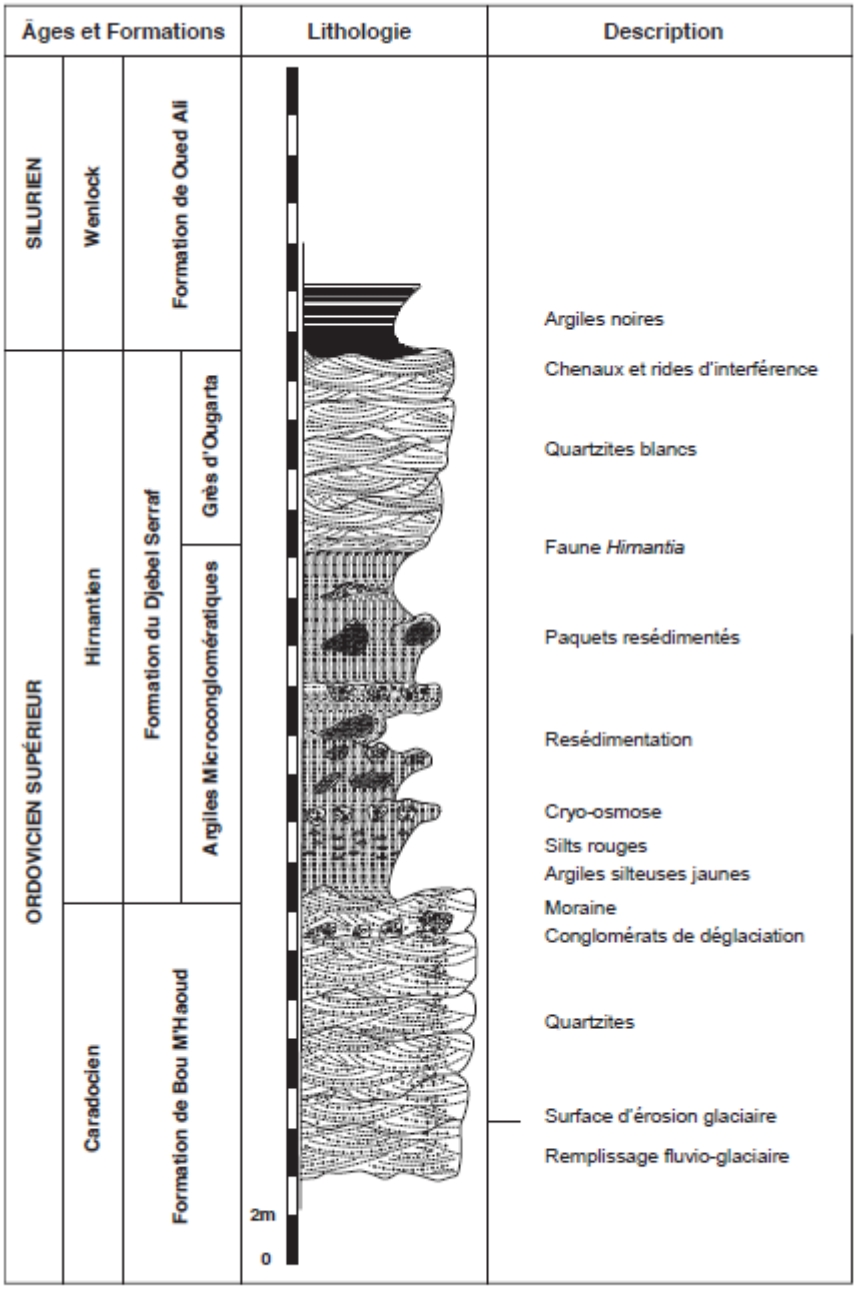


Fig. 5- El Kseib. Lithostratigraphie et évolution au passage Ordovicien-Silurien

El Kseib. Lithostratigraphy and evolution at the Ordovician-Silurian passage

2.2. The Devonian

The Devonian of Ougarta is essentially marine and approximately 2500 meters thick. The sedimentation there is continuous and can, therefore, constitute a reference series. The Silurian-Devonian transition is very subtle. Indeed, the similarities between the facies of the terminal Silurian and the base of the Devonian do not allow for a clear boundary to be drawn.

The typical section of the Devonian of Ougarta can be observed in Oued Ali, where the entirety of the Silurian and the transition zone to the Devonian outcrop.

The Devonian cycle is subdivided into three series named after the localities where they are best exposed.

• The Dkhissa series:
It is subdivided into three formations:

- the lower argillaceous-sandy formation of Zeimlet:

- the gréso calcareous formation:

- The upper carbonate formation:

• The clay-limestone series of Teferguenit:

It is composed of two formations.

- the lower clayey sandstone formation:

- the upper clayey carbonate formation:

• The Marhouma series:
It is subdivided into two formations.
- the Tamertasset clay formation:

- the Marhouma sandstone formation:

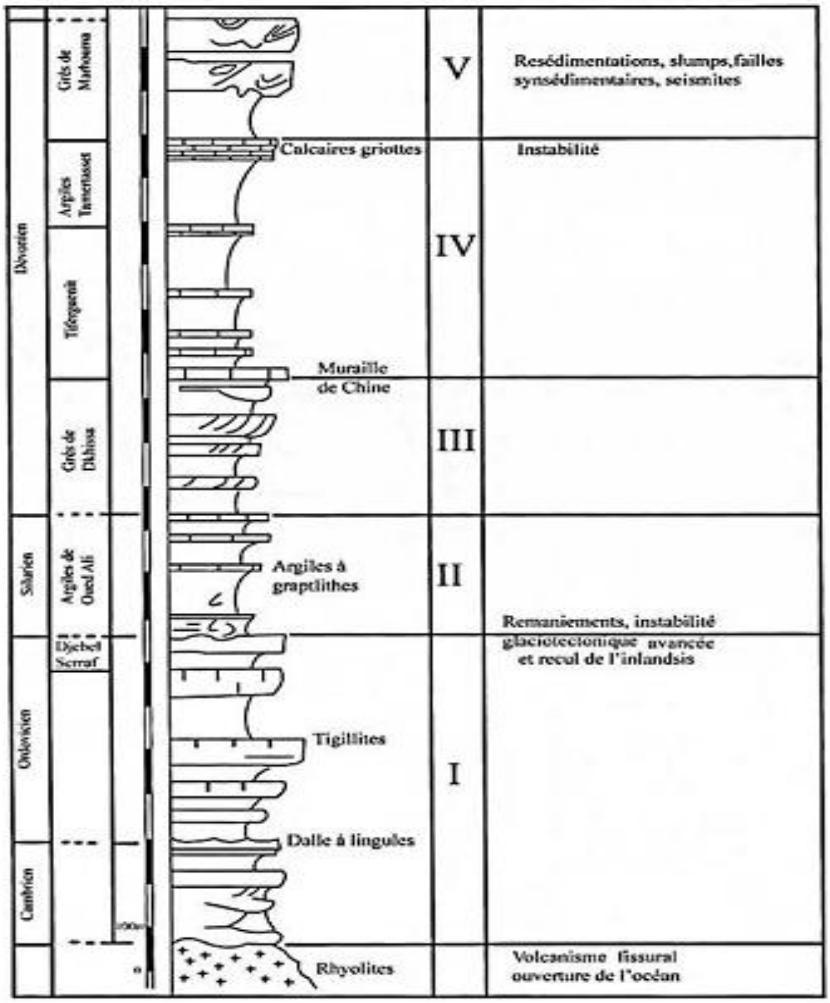


Fig.IV.1. Le découpage en série de la couverture paléozoïque de la chaîne d'Ougarta (d'après A. Nedjari 2003)

(in : R. Hamdidouche, 2009)

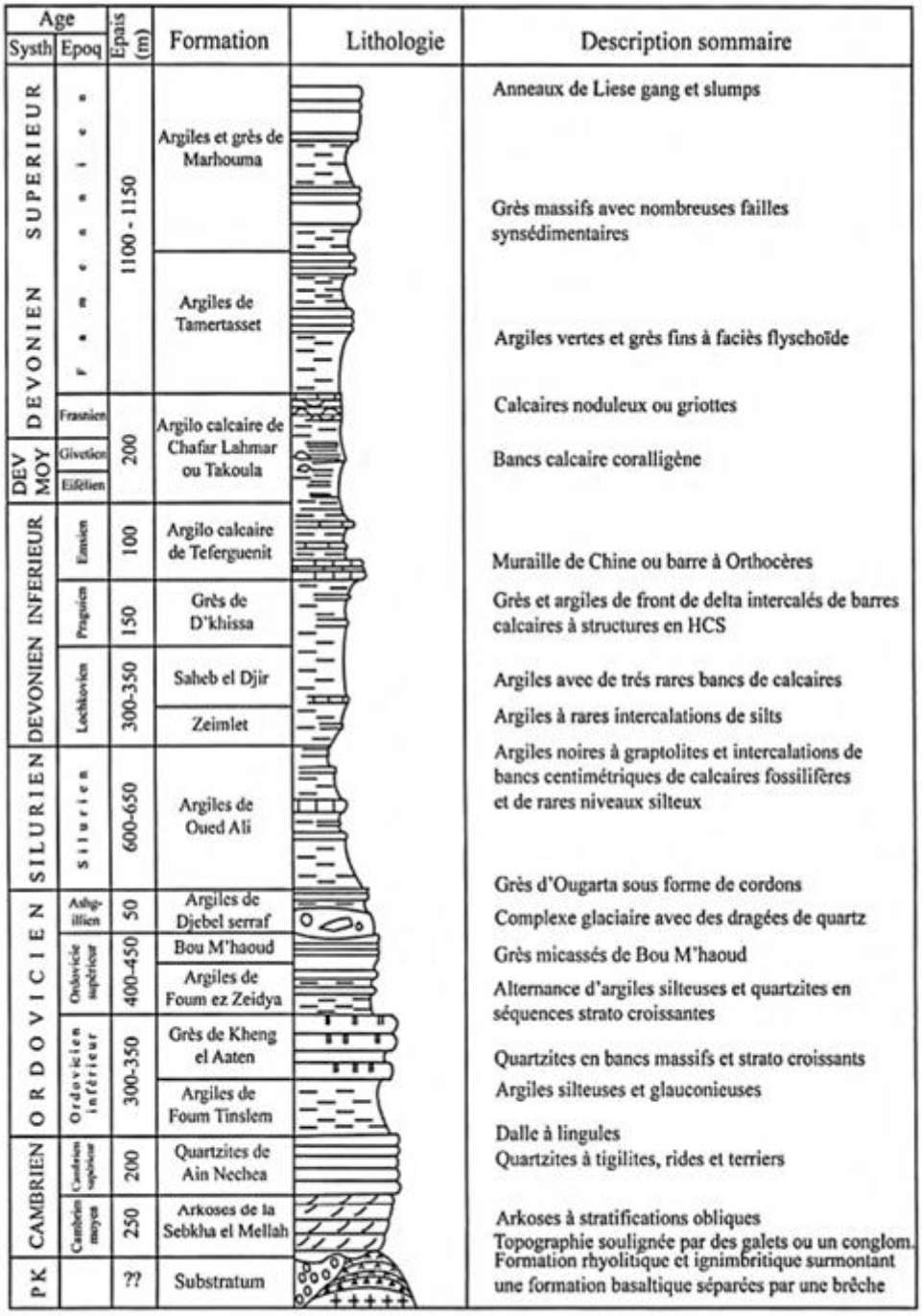


Fig. II. 15. Colonne litho stratigraphique synthétique du Paléozoïque des Monts d'Ougarta

(in : R. Hamdidouche, 2009)

III. TECTONICS:

The Ougarta range is a series of elongated folds running NW-SE, forming two beams separated by the Er Raoui erg.

To the east, the Saoura cluster is composed from south to north by the succession of the structures of Sebkhet El Mellah, Dj. Grezim, Dj. Djoub Etir, Dj. Ben Lechhab, Couiga, Dj Beraber, Koudiet El Megada, Dj Berga Siada, Dj. Ghnouma, Dj. Zeghamra, Dj. Boukbeisset, Dj. Bet Touaris, and Draa El Kelba.

To the west, the Daoura cluster includes Kahal Tabelbela and Dj. Ben Tadjine. The structural analysis was carried out by Donzeau (1971), based on field data and satellite imagery from Hervouet and Duée (1996). Donzeau (1971) had distinguished a number of the following tectonic elements and studied their mutual relationships to define a chronological framework for the deformations of the Ougartian structure.

1. Tectogenesis Model M. Donzeau (1983):

Based on the characteristics of the "Anti Atlas - Ougarta arc," which include: interleaved folds, basement blocks uplifted by several thousand meters; faults, low metamorphism; significant lithostatic load; a very low shortening rate (14%), proposes two hypotheses to account for these particularities. Tectonics interpreted classically as the result of two successive phases of deformation:

- a NE-SW compression is the oldest, while the E-W phase due to a N-S compression became distinct later.

- a WNW-ESE compression would be responsible for the dextral offsets along the NE-oriented fractures.

2. Another point of view:
Two tectonic styles and an important remark.

-The first style affects the Cambrian-Ordovician series. It is characterised by folds with a large radius of curvature arranged in a staggered pattern. It is a series of synclines and anticlines with short flanks and, generally, a gentle dip.

-The second affects and is observed in the Silurian-Devonian series. It is characterised by tight, fluted, boudinaged folds with boudins whose axes are orientated in various directions.

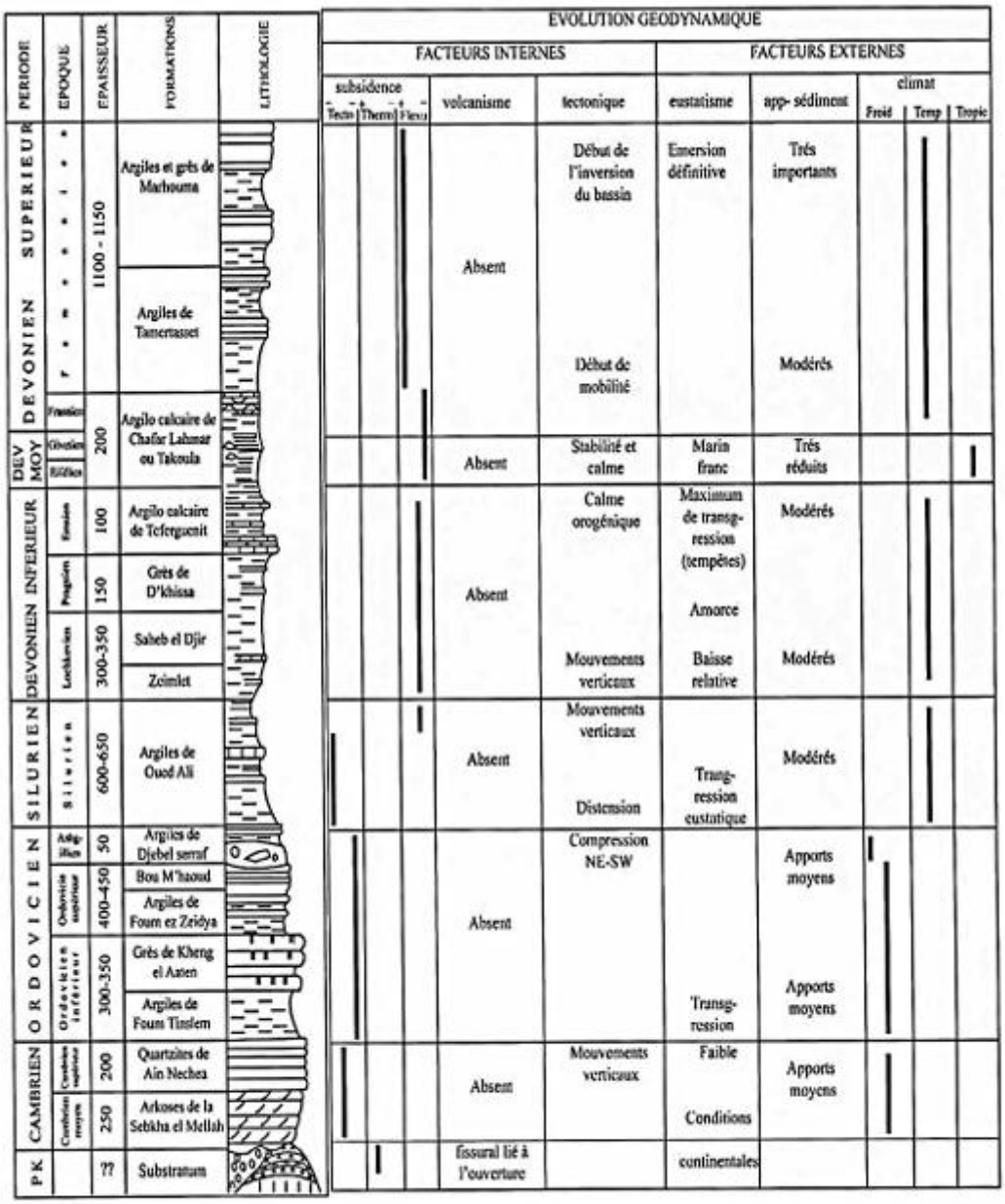


Tableau récapitulatif des principales caractéristiques géodynamiques du bassin de l'Ougarta.

(in : R. Hamdidouche, 2009)