

## Chapter. 2

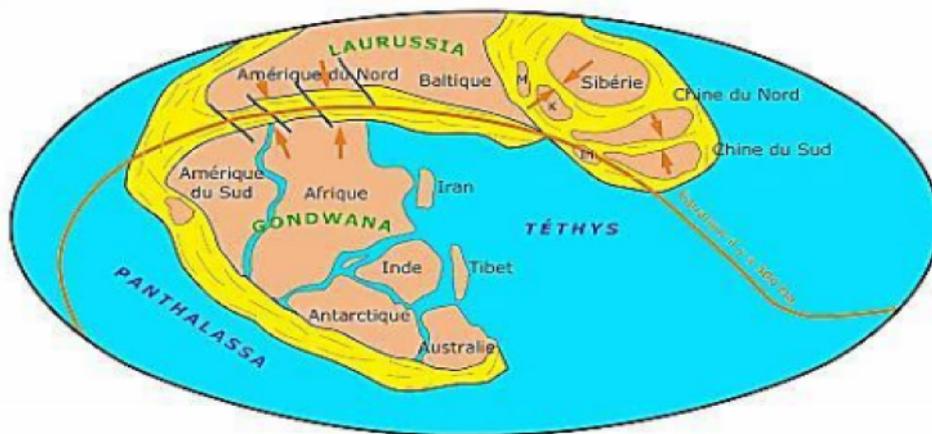
### The major sedimentary cycles of the folded Paleozoic basins of the Sahara

#### I. The Hercynian phase or Variscan Chain

##### Introduction

The Variscan or Hercynian orogeny is a Paleozoic orogenic cycle that began in the Devonian and ended with the Permian, forming the Variscan chain. It follows the Cadomian and Caledonian orogenic cycles.

It is the result of the collision of the Gondwana and Laurentia-Baltica continents to form the supercontinent Pangaea. It is responsible for the formation of the Variscan chain, clearly visible in Europe and North America; (Very little in Africa).



In the Cambrian, during a period of extension, the Iapetus Ocean opened between Laurentia and Baltica, then the Rheic Ocean between Baltica and Gondwana. From -350 Ma to -330 Ma, the collision between Gondwana and the Armorica microplate occurred, giving rise to the Variscan chain. Evidence of this collision is provided by ductile (sheath folds) and brittle deformations. The Variscan chain extends, discontinuously, over more than 5 000 kilometres from southern Spain to the Caucasus.

It extends over approximately 700 kilometres in width with a northern boundary that runs from southern Ireland to northern Germany and a southern boundary that stretches from southeastern Bohemia (Germany) to the Betic Cordillera.

This chain is characterised by the folding of primary terrains older than the Carboniferous and even the Permian.

#### 2. Characteristics:

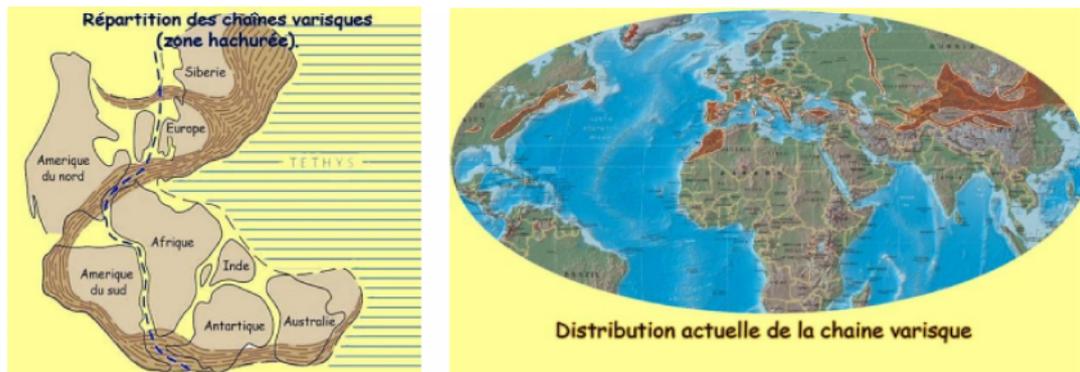
We can distinguish numerous tectonic phases:

- the Ardennes orogenic phase: beginning of the Lower Devonian (400 ma);
- the Breton phase, beginning of the Lower Carboniferous (360 ma);
- the Sudetic orogenic phase, beginning of the Carboniferous, (320 ma);

- the Erzgebirge orogenic phase, Upper Carboniferous (310 ma);
- the Asturian orogenic phase, late Carboniferous (300 ma);
- the Saalian orogenic phase, Lower Permian (270 ma);
- the Palatine orogenic phase, the most recent, end of the Permian (250 ma).

This chain is eroded, and the evidence that remains are the deep roots of the massifs.

We find numerous testimonies of it.



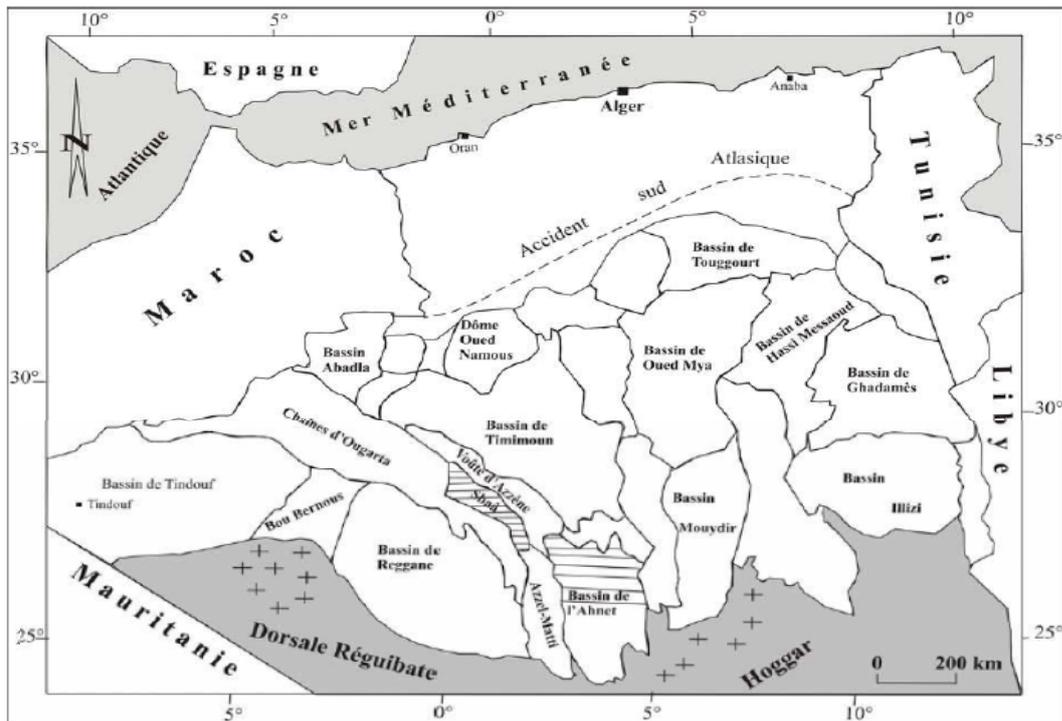
## II. The Saharan platform (Secondary - Tertiary).

The Saharan platform, located south of the South Atlas flexure, covers an area of 8 000 000 km<sup>2</sup>, spanning several countries in the northern part of the African continent. It has been a stable cratonic domain since the Paleozoic.

Very old terrains are found there, from the Proterozoic (1.8-2 Ga) emplaced during the Archean and during the Eburnean orogeny.

The different parts of the Saharan platform's basement are part of Gondwana. Among the witnesses of this ancient orogenic cycle (625-550 ma), we recognise the suture zone of the West African Pan-African chain, which corresponds to a collision chain (example of traces in the Ougarta Mountains (Bechar)).

We recognise in this platform several subsident zones that led to the development of significant sedimentary basins that developed between the shields. They are characterised by variable subsidences and deformations and are limited by moles. In the Algerian part of the platform, the most important basins are those of Illizi-Berkine in the East, Hassi Messaoud, Hassi R'mel, and Oued Mya in the centre, and Tindouf, Bechar, Reggane, Ahnet, Sbaâ, and Timimoun in the West. The Paleozoic series, discordant on the basement and forming the filling of these basins, have significant thicknesses often exceeding 8000 m. The thicknesses are highly variable, and sedimentary gaps have been identified. The Paleozoic sedimentary series, primarily detrital, were affected by the deformations of the Caledono-Variscan orogenic cycle.



The most important basins of the Saharan platform in Algeria.  
(SONATRACH Map, Exploration Division).

## II.1. Characteristics of the Saharan platform

### II.1.1. Paleogeographic overview.

The outcrops, core studies, and numerous works carried out on the Saharan platform allow us to provide an overview of the environment and palaeogeography of this study area:

- **In the Cambrian:** The deposits are attributed to a braided fluvial environment that allowed for the establishment of sandy outwash plains on the infra-Tassilian surface.
- **In the Ordovician:** The environment is marine, as the Tremadocian transgression lasted until the Caradocian. At the end of this period, the ice cap was established.
- **In the Silurian:** After the melting of the glaciers, a glacio-eustatic transgression marked this period of the Paleozoic. The end of the Silurian is marked by the Caledonian epeirogenic movements that led to the emergence of vast regions whose erosion constitutes the source of supply for the detrital series of the Lower Devonian.
- **The Lower Devonian sandstone:** It is linked to a meandering fluvial network.
- **The Lower Devonian argillaceous-arenaceous:** Marked by the beginning of a marine transgression that continues until the Upper Devonian.
- **In the Middle and Upper Devonian:** Sedimentation is essentially clayey with intercalations of fossiliferous carbonate levels, indicating the establishment of a marine environment at the end of the Devonian.

- **In the Carboniferous:** From the beginning of the Tournaisian, clayey-sandy sedimentation interspersed with levels of ferruginous oolites indicates a marine regression and the establishment of a transitional environment.

- **In the Mesozoic:** The sediments associated with this ensemble are of continental to lagoonal type. The respective establishment of a continental and then lagoon environment occurred throughout the Mesozoic.

- **The Cenozoic:** Marked by the resumption of detrital sedimentation indicating a widespread regression across the entire Saharan platform.

## II.2. The sedimentary basins.

The sedimentary basins of the Saharan platform correspond to large depressions filled with marine, fluvial, and lacustrine sediments that lie in discordance on the infra-Tassilian surface formed before the Cambrian. The substratum of this surface, whose structures are inherited from the Pan-African deformation, corresponds to a set of panels that remain mobile during the Paleozoic. This structural organisation contributes, among other things, to the remarkable variations in the thicknesses of Paleozoic sedimentary accumulations from one area to another on the Saharan platform. It is in this context that sedimentary basins develop, which are of intracratonic character. Among the large sedimentary basins in the western part of the Algerian Saharan platform, we recognise

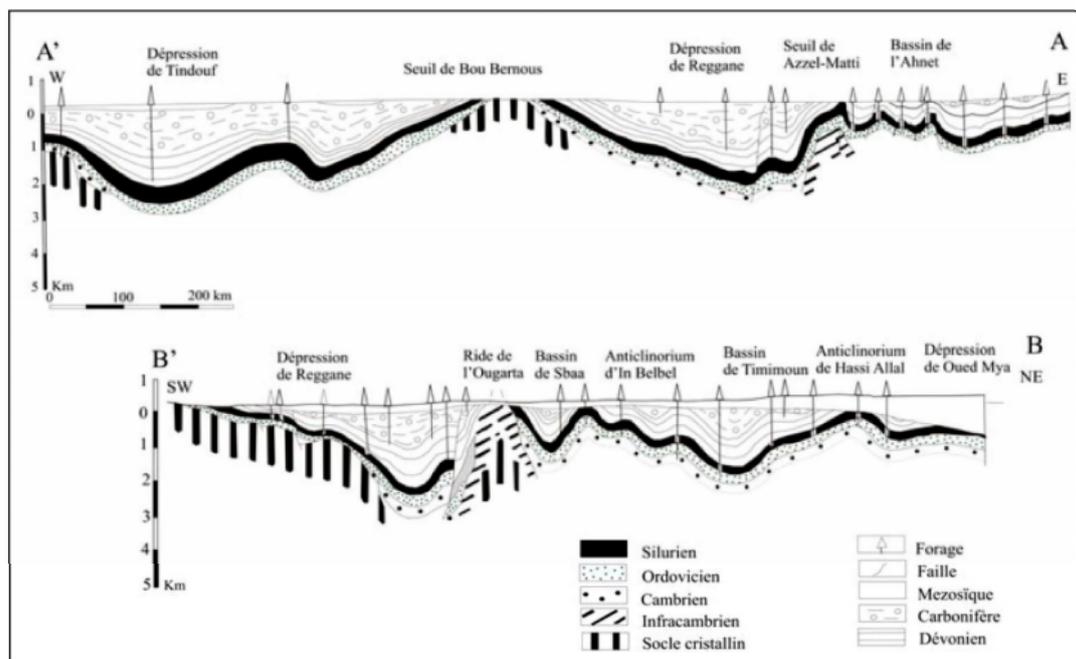


Fig.06: Coupe géologique du Sahara algérien (d'après SCHLUMBERGER 1979).

## II.3. The main structural elements of the Saharan platform.

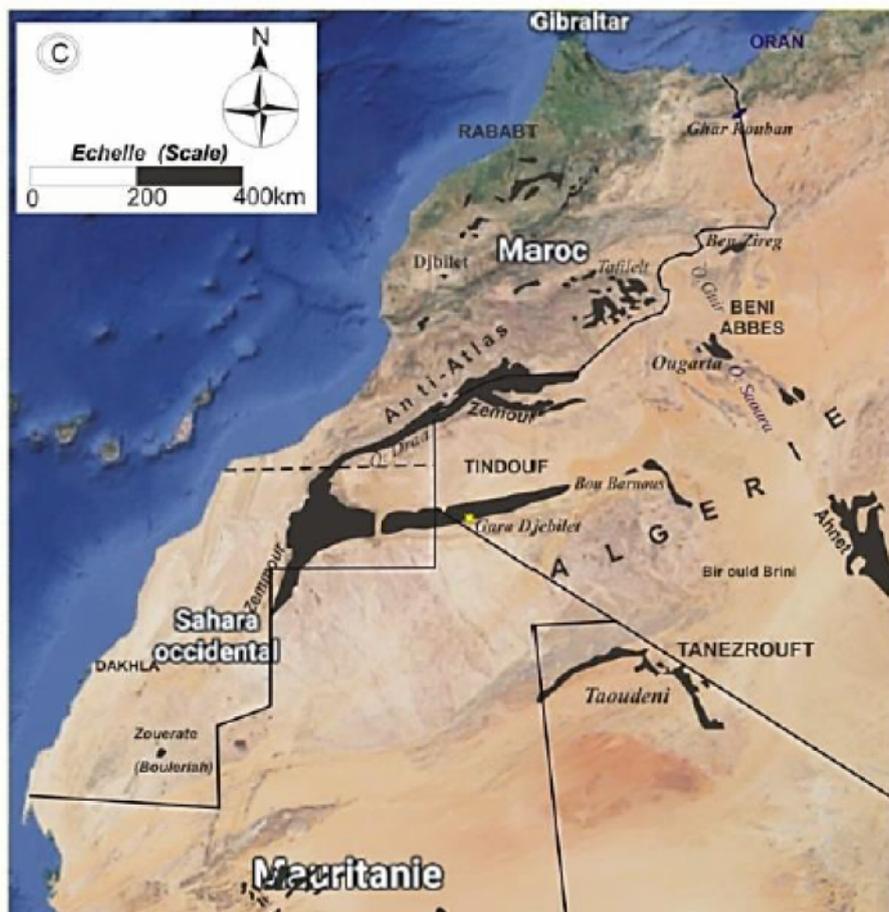
The Algerian Saharan platform is covered by ergs (masses of sand dunes) and regs (stony plateaus). Only the Ougarta Mountains present significant reliefs. Elsewhere, outcrops are found in the beds of wadis bordered by hamadas (plateaus).

The Saharan platform, which occupies a very large area of the northern part of the African continent, corresponds to one of the largest Precambrian platforms in the world. It is now made up of the association of several intracratonic basins of Paleozoic age.

## II.4. Examples of sedimentary basins of the Saharan platform.

### II.4.1. The Tindouf Basin

The city of Tindouf is located in the extreme Southwest of Algeria, at the extreme west of the desert region of Saoura. The city of Tindouf is approximately 2000 km Southwest of Algiers; the morphology of this region is characterised by the existence of an immense post-Silurian asymmetrical basin running from West-Southwest to East-Northeast. It extends over 540km in length and 250km in width with an area of more than 130 000km<sup>2</sup>. This basin is surrounded to the North by the Moroccan Anti-Atlas, to the South by the Reguibat Ridge, to the East by the Erg Chech Depression and the Ougarta Mountains, and to the West by the Aïoun Basin of the Mauritanides.



### II.4.2. Subdivision of the Tindouf basin:

The basin is subdivided into two sub-basins: The North syncline and the South Tindouf syncline, which offer contrasting terrains ranging from the Archean to the present.

The Tindouf Basin is a pericratonic basin, an asymmetrical syncline whose main outcrops of the first platform cover (Paleozoic) are located on its two flanks, North and South.

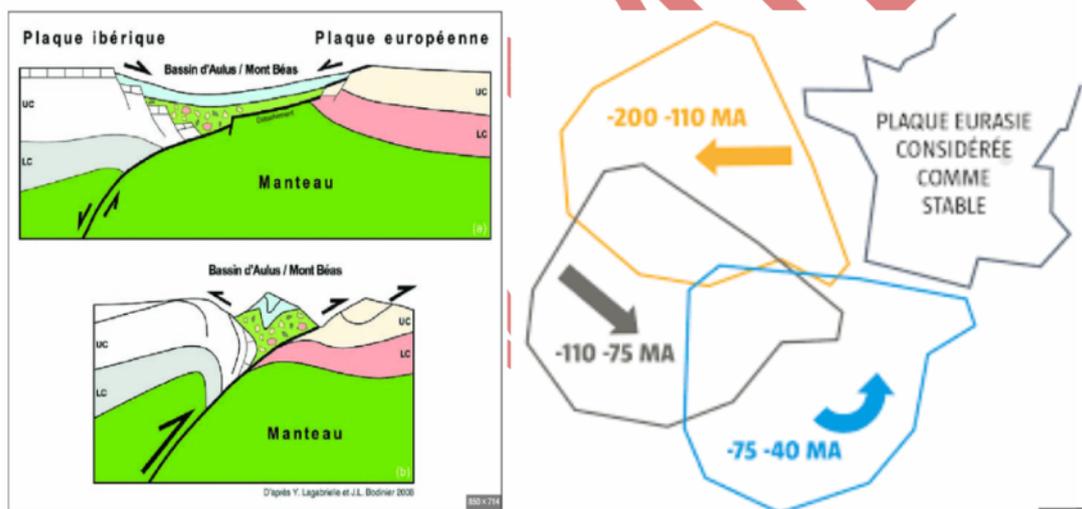


c. **Quaternary:** It includes regs, alluvium, scree, sebkhas, and especially ergs (sand dunes), which occupy a significant part of the region (Erg Iguidi).

### III. The late-Eocene orogenic phase (Atlasic phase)

The late-Eocene orogenic phase, or Atlasic phase, is a period of major compression that occurred at the end of the Eocene, between the Lutetian and the beginning of the Priabonian. It caused significant tectonization, manifested by NE-SW orientated folds and major faults, and is the origin of most of the current architecture of the Maghreb mountain ranges, such as the Atlas. This phase took place in a basin already pre-structured by previous faults; it is the "**Pyrenean phase**," It marks an essential step in the geological structuring of the Atlasic domain of Algeria, particularly in the Aurès, the Saharan Atlas, and the North Algerian Tell.

The "Pyrenean phase" is a period in geological history, during the Tertiary (mainly in the Eocene), characterised by the formation of the Pyrenean mountain range. It resulted from the collision between the Iberian plate and the European plate, a compression process that caused the shortening and uplift of the chain, notably the folding of sedimentary layers.



Several angular unconformities recorded by the Paleogene series characterise this phase. Indeed:

Outcropping in the **eastern Atlasic chain**, locally, the **Ypresian** (Eocene) exhibits angular unconformities over the **Cretaceous**, generally with low angles, with erosion of the **Paleocene** layers and reworking of the Cretaceous, due to tectonic movements.

#### The Ypresian phase:

The Ypresian is a chronostratigraphic interval, extending from 56 to 47.8 Ma, located at the base of the Eocene epoch. It takes its name from the city of Ypres in Belgium, where these strata were first studied. Ypresian deposits are marine, with abundant plastic clays serving as an impermeable substrate, promoting a high water table in the regions of Flanders and northern France. This stage also corresponds to the appearance of the first primates and equids.

## Tectonic characteristics of the orogenic phase

1. This is a major compressive phase responsible for the folding of sedimentary series and the appearance of strike-slip and overthrust structures.
2. The dominant compression directions are north-south to north-northeast/south-southwest, inherited from the geodynamics of the Late Cretaceous.
3. These constraints notably reversed old extensional faults, creating anticlines and synclines in the Tell and the Aurès (e.g., Djebel Amour, El Kantara).

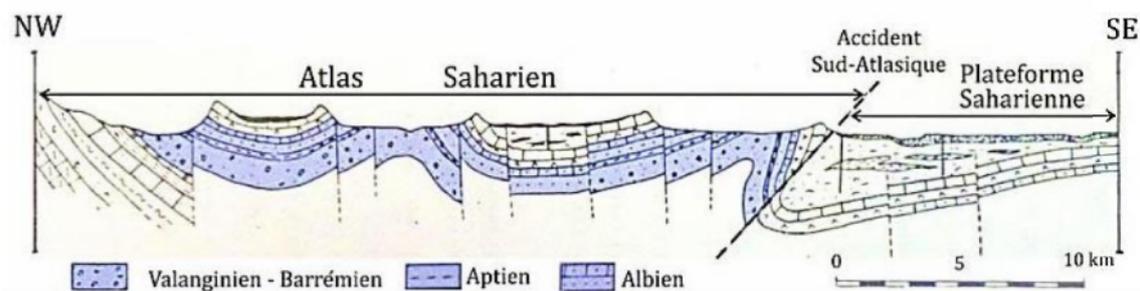
## The major late-Eocene phase: fracturing and associated structures

The major late-Eocene phase, also called the Atlasic phase, takes place during the Lutetian–Priabonian (approximately 47 to 34 Ma). It is characterised by significant fracturing and associated tectonic structures, which testify to an intense compressive phase on an already pre-structured basin.

### Fracturing and associated structures

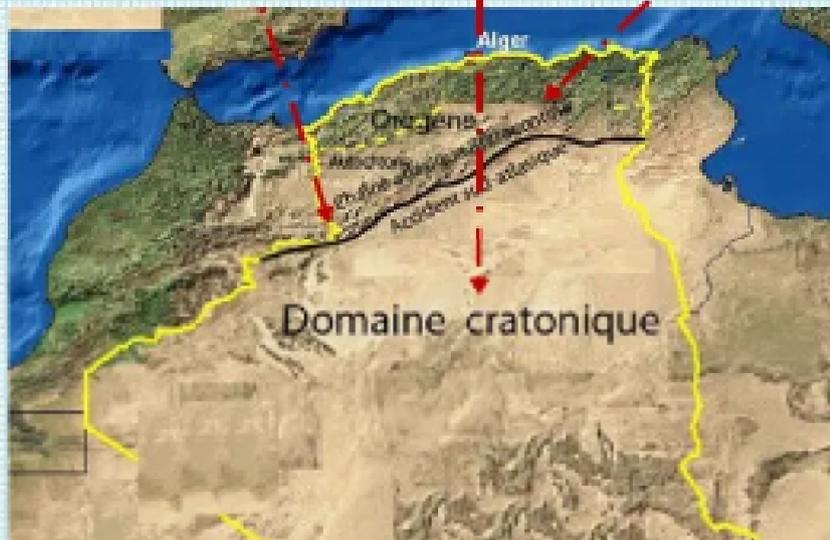
This phase is recorded by three major angular unconformities in the sedimentary series.

1. The fractures and faults are organised along several main directions: east-west, NNE-SSW, north-south, and NW-SE, following a pre-Paleogene structural heritage, mainly from the Jurassic-Cretaceous.
2. The compression generated inversion structures with typical folds, overlaps, and overlapping faults.
3. The fracturing led to significant karstification and erosion, facilitated by these fractures promoting stress dissipation and the movement of rock blocks.



Sur le plan structural, l'Algérie est subdivisée en deux unités tectoniques majeures séparées par la faille sud atlasique :

1. Domaine Cratonique      2. Domaine Orogénique



### **The period of relaxation Oligocene – Lower Miocene: the birth of the Numidian basin.**

The period of relaxation between the Late Oligocene and the Early Miocene saw the birth of the Numidian basin, characterised by the opening of this basin in a context of extension and dislocation, following a previous compressive phase. This period, ranging from the Aquitanian to the Lower Burdigalian, is marked by the deposition of Numidian flysch, sandstone and pelitic deposits, before their detachment and northward transport.

### **General geodynamic context**

The Oligocene–Early Miocene period (approximately 34 to 16 Ma) marks a stage of post-collisional tectonic relaxation in the North African margin of the Tethyan domain. After the compressive phases of the late Eocene (Atlasic phase), the Maghreb experienced an opening and lithospheric thinning responsible for the establishment of subsiding basins known as Numidian. This period coincides with the end of the subduction of the Maghrebian Tethys and the beginning of the opening of the western Mediterranean basin. It is therefore associated with extensional movements (normal faults) promoting the creation of deep sedimentation basins.

### **Birth and evolution of the Numidian basin**

#### **Formation of the basin**

During this relaxation phase, large perimediteranean basins developed, trapping thick series of sandy and clayey flysch: the Numidian flysch. These deposits, often turbiditic, can reach more than 2000 m in thickness, indicating rapid and prolonged subsidence.

## **Sedimentary characteristics of the Numidian**

The Numidian series generally rest unconformably on the carbonated Upper Eocene, with a marly transition, then a sandstone transition. We distinguish several facies according to age and location:

Numidian clayey-sandstone (Lower to Middle Oligocene)

Numidian sandstone-clayey (Upper Oligocene – Lower Miocene)

## **Subsequent tectonic evolution**

At the end of the Early Miocene, the Alpine orogenic phase caused a general shortening of the Maghrebide domain:

- Folds, overlaps, and imbricated scales with southeast vergence.
  - Ascent of calc-alkaline plutons in the internal units (La Galite, Nefza, Kabylie).
  - Progressive closure of the Numidian basins and uplift of the Maghrebide massifs.
- These deformations transform the extensional basins into imbricated orogenic zones, and prepare for the establishment of the post-nappe Neogene basins (Mitidja, Cheliff, Soummam, Constantine).