

The Great Features of Algerian Geology

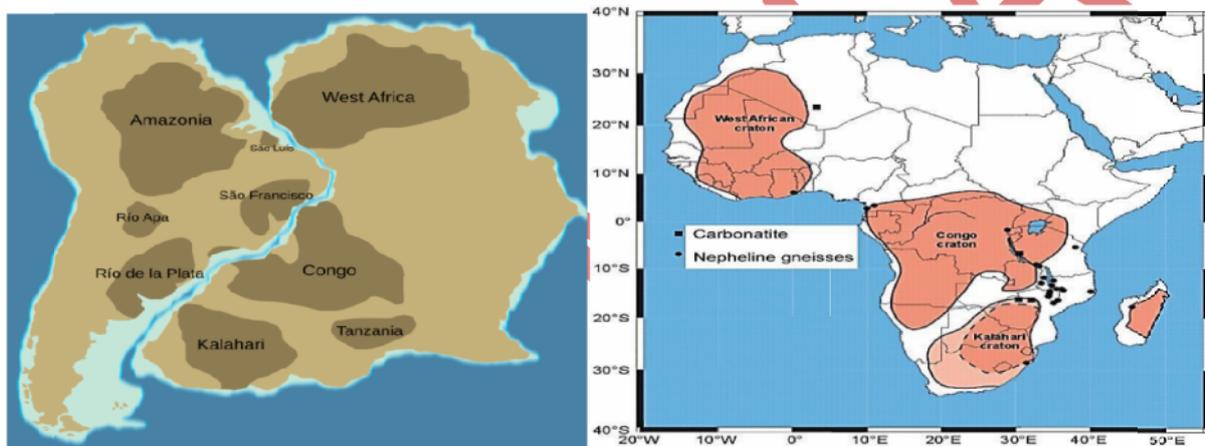
Chapter. 1

The geology of the Sahara (Precambrian and Paleozoic)

I. The WAC: West African Craton (The Réguibat Ridge)

1. Introduction

The West African Craton is one of the five main cratons of the Precambrian basement that form the African plate, alongside the Kalahari Craton, the Congo Craton, the Saharan Metacraton, and the Tanzanian Craton. It constitutes a vast geological region that extends from Morocco to the Gulf of Guinea, covering an area of approximately 4.5 million km². Its ancient substratum is partially covered by more recent sedimentary formations, such as the Taoudeni Basin.



2. List of the 5 African cratons

- **West African Craton:** extends from Morocco to the Gulf of Guinea and includes countries such as Algeria, Mali, Ghana, and Côte d'Ivoire.
- **Congo Craton:** covers the Congo Basin and several Central African countries.
- **Kalahari Craton:** located in the south, mainly covers Botswana, South Africa, and Namibia.
- **Tanzania Craton:** located in the African Great Lakes region.
- **Saharan Metacraton:** complex zone in the north of the continent, between the Sahara and the Sahel, potentially formed from assembled cratonic fragments.

3. Origin and geological evolution

The West African craton was formed by the fusion of three Archean cratons (Leo-Man-Ghana, Taoudeni, and Reguibat), between 2.1 and 2 billion years ago. It experienced two major orogenic events:

* the Liberian (-3.0 MA - 2.5 MA)

* the Eburnean (-2.5 MA - 1.8 MA) At the end of which the WAC definitively stabilised around 1.9 MA.

The roots of the craton extend up to 300 km into the lithospheric mantle, attesting to its tectonic stability since the Archean.

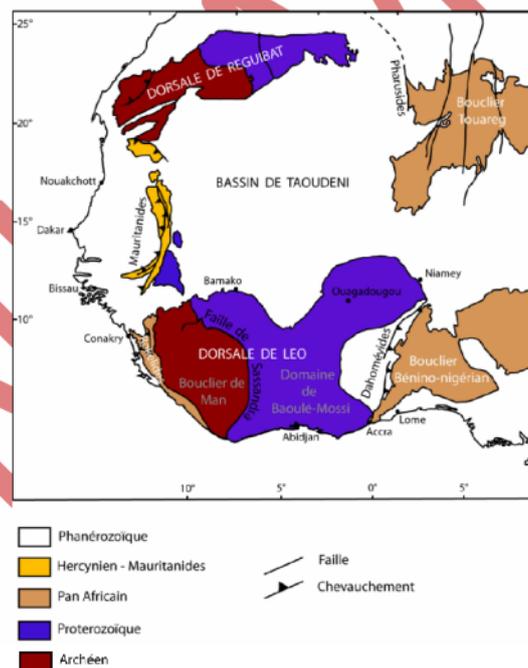
Two major orogenic episodes mark the ancient history of the WAC:

A/ The Taoudéni Basin

The Taoudéni Basin is a vast sedimentary geological formation located in West Africa, covering an area of approximately 1.5 million km² between Mauritania, Mali, and southwestern Burkina Faso.

B/ The Leo-Man-Ghana craton

The Leo-Man-Ghana craton, also known as the Man craton, is one of the three major Archean blocks that merged to form the West African Craton. Located south of the craton, it largely covers regions of Ghana, Ivory Coast, Sierra Leone, Liberia, Guinea, Burkina Faso, and Mali. This craton is mainly composed of Archean rocks, such as granulites, hypersthene gneisses, greenstone belts with peridotites, as well as ferruginous quartzites rich in haematite and magnetite. The rock masses of this craton include ancient metamorphic rocks, mainly dated between 2.9 and 2.5 billion years. These Archean areas exhibit very significant outcrops that bear witness to a complex geological history ensuring the deep lithospheric stability of the basement.



II. The basins of the Saharan-Algerian platform

Algeria includes four major regions from North to South:

- The Tell Atlas (or the Tell), consisting of steep reliefs and coastal plains, the richest of which are the Mitidja in the centre, the Chélif in the west, and the Seybouse in the east;
- The high plateaus, which are flat areas elevated above sea level;

- The Saharan Atlas, forming a long series of reliefs orientated NE-SW extending from the Moroccan border to that of Tunisia;

- The Sahara, which holds the majority of hydrocarbon resources, is a desert formed by vast expanses of dunes (Eastern Erg and Western Erg), rocky plains (Regs), and dotted with oases, which are as many urban centres such as the cities of El Oued, Ghardaïa, and Djanet...

The Eglab massif in the West and the Hoggar massif in the East practically form the southern boundary of the Algerian Sahara.

1. Structural aspects.

Algeria is divided into two major tectonic units separated by the South Atlasic flexure:

- ❖ The North of Algeria bearing the imprint of Alpine tectonics. It is delimited by the following elements:
 - To the South, the Saharan Atlas, a mountain range of alpine origin.
 - In the centre, platforms such as the Oran Meseta to the West and the Ain Regada mole to the East.
 - In the northern part, the Tell Atlas is a complex zone made up of nappes emplaced during the Lower Miocene. Late Neogene basins such as the Chélif and the Hodna were established on these nappes.
- ❖ The Saharan platform, which is the subject of this work, is relatively stable, with less pronounced tectonics. It is composed of a Precambrian basement covered by transgressive Phanerozoic sediments. Different tectonic elements delineate sedimentary basins in which the lithostratigraphy is more or less complete.

The major lineament of the country corresponds to the South Atlas flexure that separates alpine Algeria in the North from the Saharan platform in the South, mainly composed of Precambrian and Paleozoic terrains.

This platform has changed little since the end of the Paleozoic and corresponds to a relatively stable cratonic domain (Fabre, 1976; Coward and Ries, 2003).

2. Basins of the Western Province of the Saharan Platform

The province is essentially dry gas, it includes the following basins:

- the Ahnet basin;
- the Timimoune basin;
- the Béchar-Oued Namous basin;
- the Reggane basin;
- the Tindouf basin;
- the Taoudéni basin;
- and the Sbâa basin.

These basins cover an area of more than 650000 km². The first signs of oil were encountered in the Reggane and Tindouf basins at the beginning of exploration in 1950, and the first commercial quantity oil discovery was made in the early 1980s in the Carboniferous sandstone of Sbâa and the Upper Devonian.

A. Ahnet Gourara Basin

The Ahnet Gourara basin, located in the central-western part of southern Algeria, covers an area of 121164 km². In this part of the Saharan Platform, the first exploration drilling Berga-1 was carried out in 1953. This basin preserves a thick sedimentary series ranging from the Cambro-Ordovician to the Carboniferous.

B. Béchar Basin

The Béchar basin is located in the Northwest of the Saharan Platform. It is bounded to the North by the South Atlas Fault, to the South and Southwest by the Ougarta Range. It is separated from the Timimoune basin to the Southeast and East by the Beni-Abbès saddle, the Méharez vaults, and Oued Namous.

C. Reggane Basin

The Reggane basin is bordered to the North by the southern edge of the Ougarta range, which separates it from the Sbâa basin, to the West by the Krettamia-Bou Bernous saddle, to the East by the Azzel Matti saddle, and to the South by the crystalline massif of the Eglab. The basin covers an area of 140000 km².

The exploration of the Reggane basin began in the 1950s with fieldwork in geology, followed by large-scale seismic refraction campaigns in 1957, and gravimetric (aerosurface) surveys in 1969. Reflection seismic campaigns began in the 1970s.

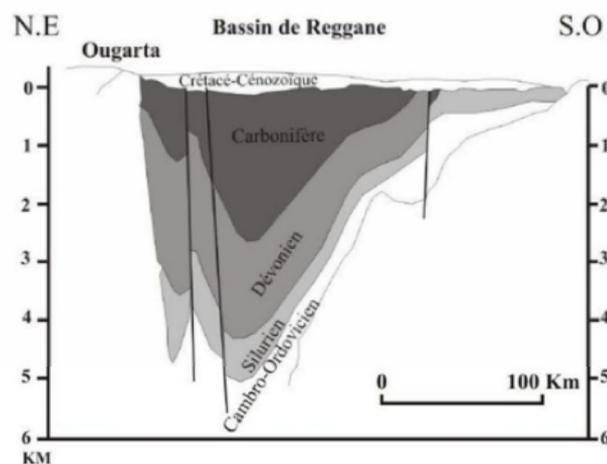


Fig. 2b : Coupe du bassin de Reggane

D. Tindouf Basin

The Tindouf basin is located at the extreme west of the Saharan Platform. This basin forms a vast depression orientated East-West, covering an area of over 130000 km². It is bounded to the East and Northeast by the Krettamia Bou Bernous saddle and the Ougarta

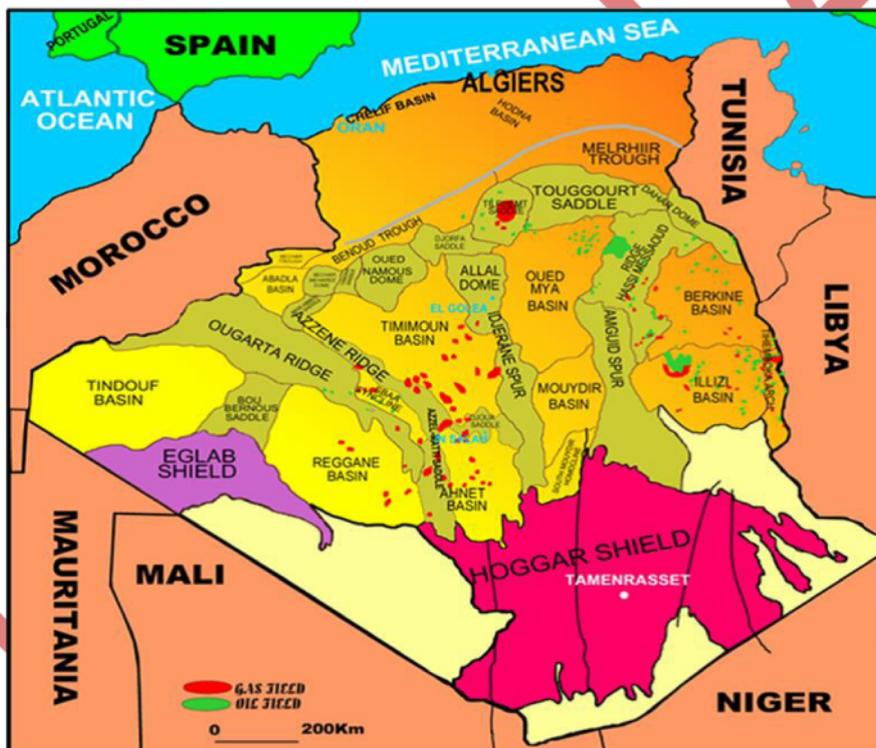
Mountains, to the West by the Algerian-Moroccan and Algerian-RASD borders, to the North by the Moroccan Anti-Atlas, and to the South by the Reguibat massif.

E. Taoudenni Basin

With an area of approximately 1 500 000 km², the Taoudenni Basin is the largest basin in West Africa. It is located on the southwestern borders of Algeria and also covers the northern parts of Mali and the eastern parts of Mauritania.

F. Sbâa Basin

The Sbâa basin or depression, located in the Southwest of the Algerian Sahara, covers an area of 32 683 km². It is bounded to the Southwest by the Ougarta ranges, to the South by the high zone of Bled El Mass, to the Northeast by the Timimoune basin, and to the East by the Ahnet basin and the Azzène arch. Exploration activity in the Sbâa basin dates back to 1954. Subsequently, an accumulation of oil in the Givetian highlighted the research.



Map of the sedimentary basins of the Saharan Platform

3. Main hydrocarbon deposits in Algeria

The most productive hydrocarbon basins remain those of Oued Mya, where the giant fields of Hassi Messaoud and Hassi R'mel are located, and Berkine, where the fields of Ourhoud and Hassi Berkine South are located.

As for the Southwest basins, they constitute a relatively important hub for gas exploration, as well as equally important development with the commissioning of gas fields in the In Salah region and the Adrar region.

More than 200 deposits are now recognised. The reservoirs are almost entirely sandstone and are mainly found in the Cambro-Ordovician, Siluro-Devonian, Carboniferous, and Triassic levels.

The hydrocarbons produced are largely supported by enhanced recovery operations, both through water injection and gas injection.

1/ Hassi Messaoud Field

The light oil field of Hassi Messaoud was discovered in 1956 by the MD1 drilling, which crossed the sandstone reservoirs of the Cambro-Ordovician at a depth of 3 337 meters. The deposit, measuring 40 x 40 km, is located in the Algerian Sahara, 800 km south of Algiers. The Hassi Messaoud deposit has an anticlinal dome structure, largely inherited from the Hercynian orogenic phase, which reached its peak at the end of the Paleozoic.

2/ Hassi Berkine South Field

The Hassi Berkine South (HBNS) field was discovered in January 1995 by the Sonatrach/Anadarko association through the drilling of the HBNS-1b well. It was put into operation in 1998.

The deposit is of Triassic age. It has an asymmetrical anticlinal structure with very little relief.

3/ Ourhoud Field

The Ourhoud field is located in the central part of the Berkine basin, 320 km southeast of Hassi Messaoud. It extends over three exploration blocks, 404a, 405, 406a. The deposit was discovered by the BKE-1 (Berkine East-1) well drilled in July 1994 by the Sonatrach and Anadarko association. The Ourhoud structure corresponds to a complex horst bounded to the east by a major regional fault with a vertical displacement ranging between 200 and 300 meters.

4/ Haoud Berkaoui Field

The Haoud Berkaoui field is located approximately 100 km west of Hassi Messaoud. It is part of Block 438c and, along with the Benkahla and Guellala structures, forms a major hub of the Oued Mya depression.

It was discovered in 1965 by the OK101 well and produces from the sandstones of the lower Triassic argillaceous-arenaceous series.

5/ Edjeleh Field

The Edjeleh field is located in Block 241, in the southeastern part of the Illizi basin, approximately 50 km southeast of In-Amenas. Located on the Tihemboka shoal, it covers an area of approximately 30 km². The deposit was discovered in 1956, then put into operation a few years later. The presence of hydrocarbons in this field was confirmed in six superimposed and distinct reservoir levels.

6/ Hassi R'mel Field

The Hassi R'mel field was discovered in 1956 and put into production in 1961. It is located in the Algerian Sahara, 550 km south of Algiers. It covers approximately 3500 km². The field is a condensate gas deposit with an oil ring on the eastern flank. The structure of Hassi R'mel is an elliptical anticline whose main axis is orientated NE-SW.

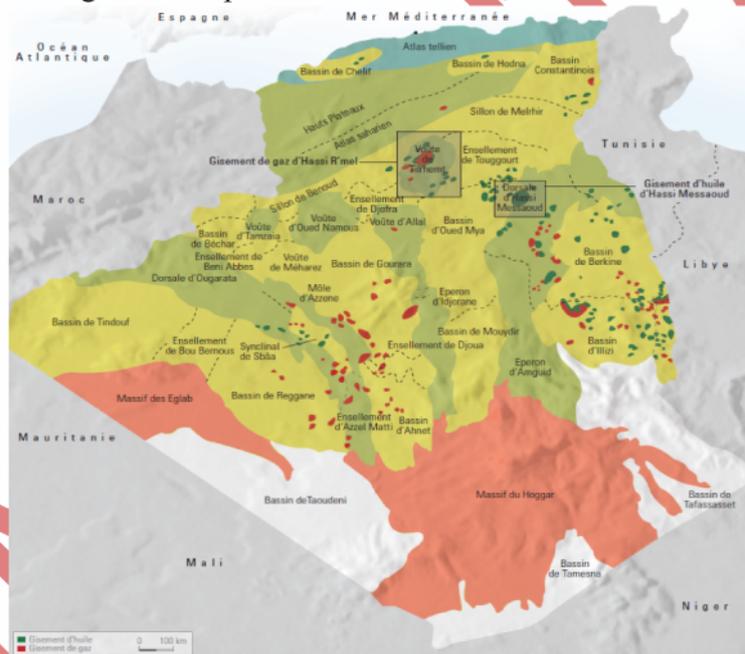
7/ Rhourde Nouss

The Rhourde Nouss (RN) region is located 230 km southeast of the Hassi Messaoud field. The first drilling was carried out in 1961. A series of reservoirs containing condensate gas was encountered from the 2,685-meter mark.

This region is characterised by the presence of 13 accumulations containing up to a dozen reservoirs.

8/ Krechba Deposit (In Salah)

The Krechba deposit is located in the northern part of the In Salah region. The field was discovered in 1957 by the drilling of KB1, which encountered the Tournaisian reservoirs of the Carboniferous and Siegenian–Gedinnian of the Lower Devonian at a depth of 1 700 to 3 350 meters. The various wells drilled have yielded gas flows in the three reservoirs. This field, along with those of Teg and Reg and, further south, those of the In Salah region (Hassi Moumen, Garet el Befinat, Gour Mahmoud, and the In Salah structure), forms a large gas complex exploited within the framework of the Sonatrach–BP–StatOil association. After processing, the produced gas is transported to Hassi R'mel, located 450 km north of Krechba.



The geological units of Algeria. Contribution of SONATRACH Exploration Division, Research and Development Centre.

The shields:

Three very ancient shields resulting from the structuring of the West African craton (Réguibat and Léo) and the Pan-African orogeny (Hoggar) characterise the northwestern part of the African continent.

The sedimentary basins are located in peripheral and intermediate positions between the Réguibat and Hoggar shields.

In Algeria, the Precambrian outcrops in two main regions: the Hoggar massif and the Réguibat ridge.

The Réguibat Ridge

The Réguibat Ridge (named after N. Menchikoff en 1949 : Reguibat crystalline country) is a vast geological structure outcropping in the north of the West African craton, occupying a strip more than 1500 km long and 300 to 400 km wide, mainly in Mauritania, southwestern Algeria, and, to a lesser extent, Morocco. Located between the sedimentary basins of Tindouf to the north and Taoudeni to the south. It extends from meridians 3° to 16° west and from parallels 20° to 27° north. It is bordered to the west by the Mauritanide chain and to the east by the mobile chain of Central Africa. It is a crystalline basement window, sometimes also called the "Réguibat crystalline country," formed by Precambrian terrains at the surface, in contrast to the sedimentary cover that dominates the neighbouring regions. The ridge is divided into two main domains:

- An Archean domain in the west and southwest, formed of granito-gneissic basement, greenstone belts, ferruginous quartzites, affected by catazonal metamorphism and locally cut by late granites (dated up to 2.6 Ga).
- A Birimian domain (Lower Proterozoic) to the east, rather weakly metamorphic, with iron-rich volcano-sedimentary belts and varied granitoids, more pronounced exposure in Algeria (Eglab, Yetti massifs).



The Touareg Shield

- The Touareg Shield Constitutes the mobile zone between the West African craton and the hypothetical East African craton, Extends from 1° to 11° East longitude (i.e., over 1000km) and from 20° to 27° North latitude (i.e., over 700km).
- The Touareg shield is composed of: the Hoggar in Algeria, the Adrar des Iforas in Mali, and the Air in Niger. They represent an orogenic segment of the trans-Saharan Pan-African folded chain, bounded to the East and West by two major Pan-African sutures.
- The Touareg shield is composed of terrains ranging in age from the Archean to the Neoproterozoic, dating the passage of three tectono-metamorphic events:
 - Archean event dated to 2860-3000 Ma (Peucat et al., 1996).
 - Eburnean event dated to 2000 Ma (Allègre et al., 1972; Latouche et al., 1974; Bertrand and Lassère, 1976; and many other authors).

- Pan-African event between 800 and 600 Ma (Caby et al., 1981).

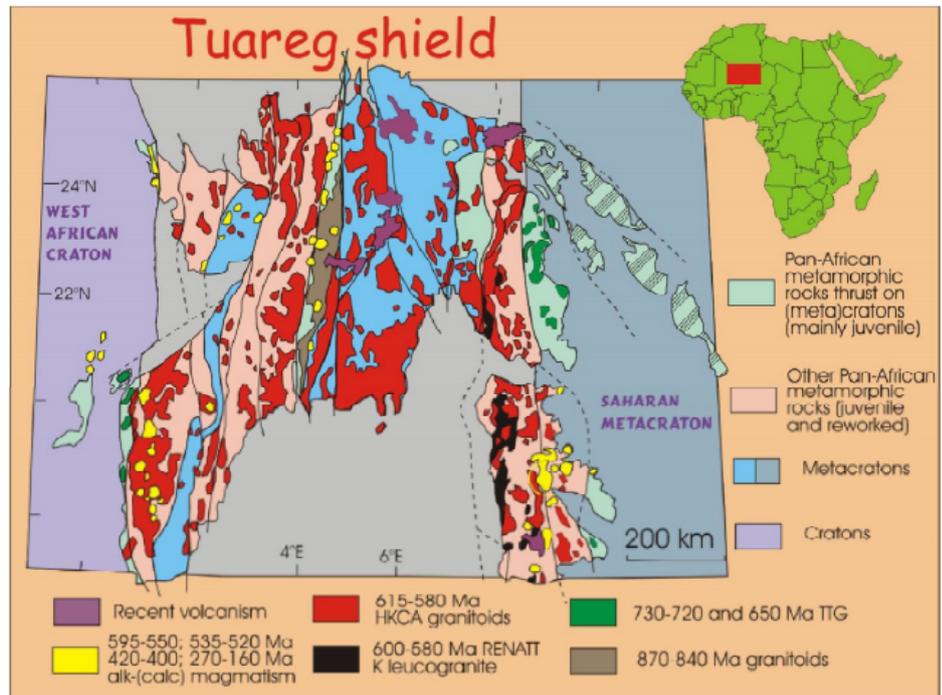
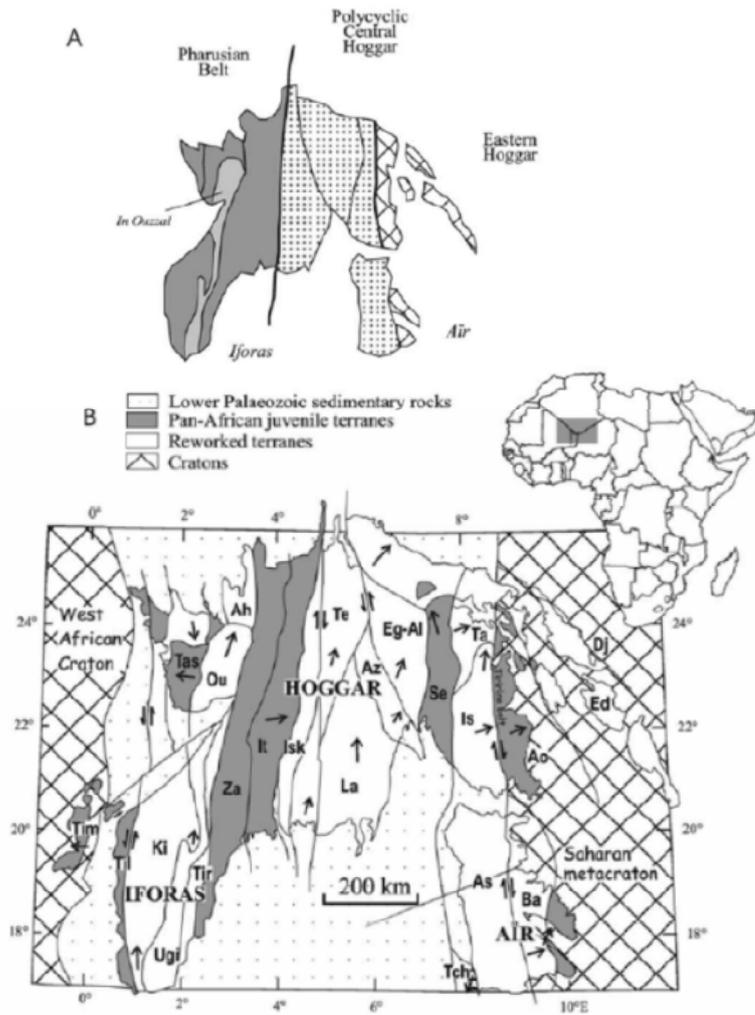


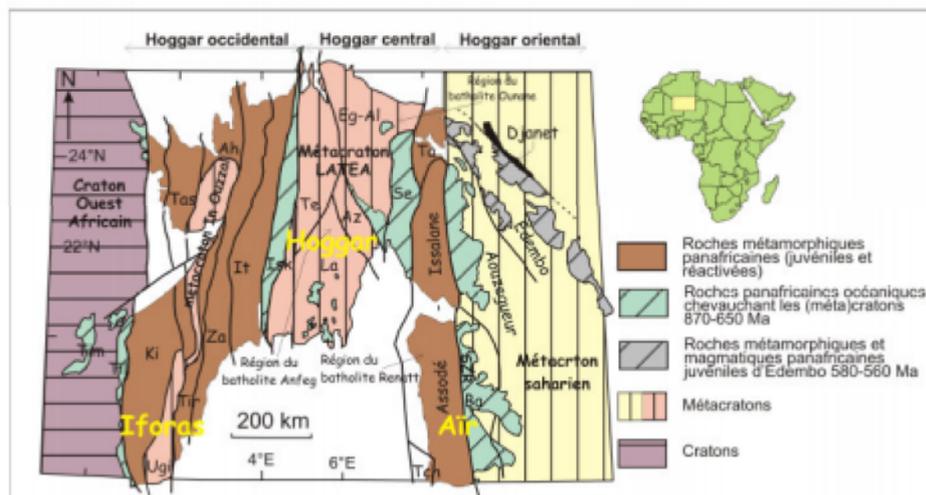
Fig.7.a. Carte Géologique Simplifiée du Bouclier Touareg

(Liégeois et al. 1998 ; Liégeois et al., 2008)

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Bouclier Touareg. (A) première subdivision (Bertrand et Caby, 1978);
(B) carte des terrains du Bouclier Touareg (de Black et al, 1994).
 Flèches remplies : mouvement des terrains



7.c. Bouclier de Touareg

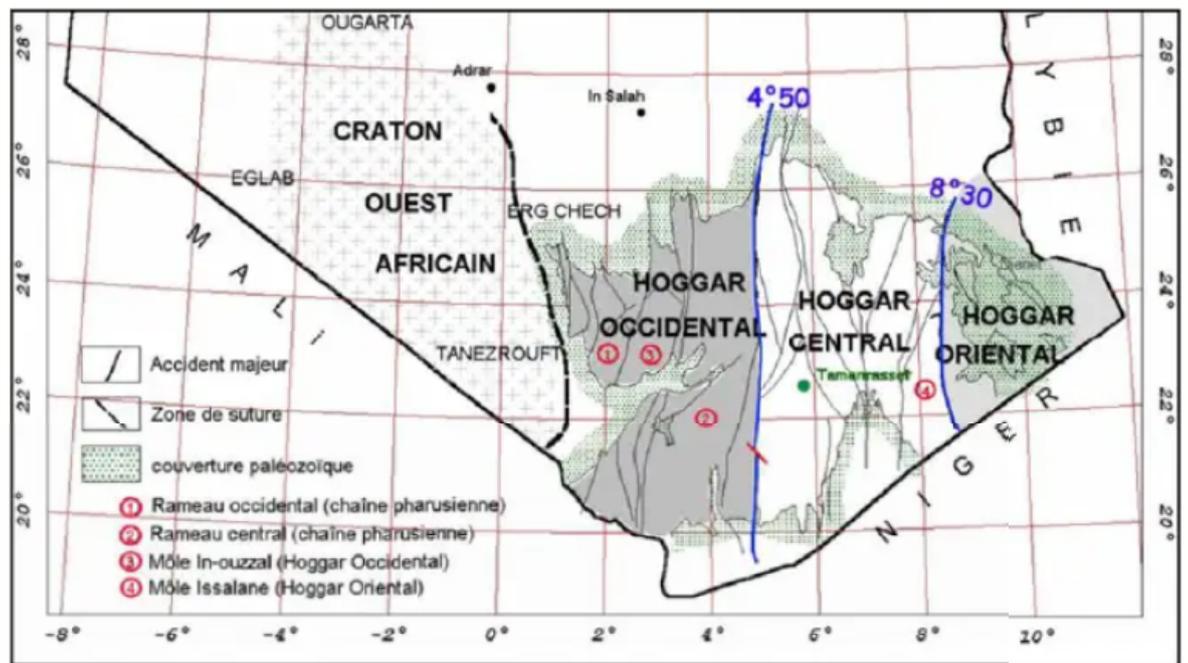
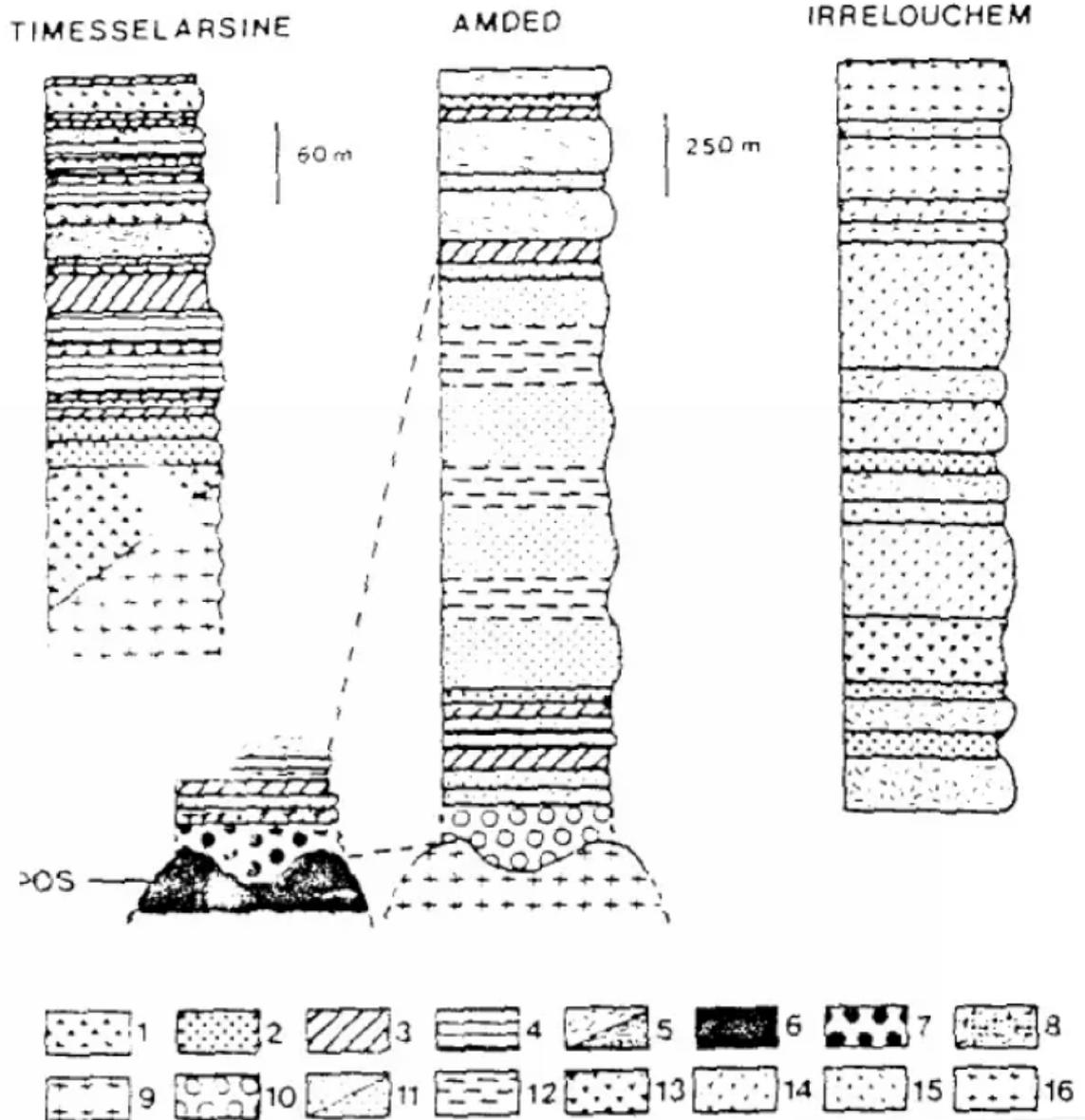


Figure I. 2: carte des principaux domaines structuraux du Hoggar (Caby et al., 1982)



Figurell.1: logs des formations du Pharusien I (formation de Timesslarine et SPOS: paléosuture océanique de Silet, et du PharusienII (Amded et Ighellouchem) ; 1. Brèches basiques, 2. Pyroclastites, 3. Chertes, 4. Calcaires, 5. Roches basiques massives ou en coussins, 6. SPOS, paléosuture de Silet, 7. Conglomérats ultramafique, 8. Grés d'origine ophiolitique, 9. Quartz-diorite, 10. Conglomérat, 11. Arkoses et grés, 12. Mudstones, 13. Brèches acides, 14. Andésites, 15. Rhyolites, 16. ignimbrites

The Yetti-Eglab Massif

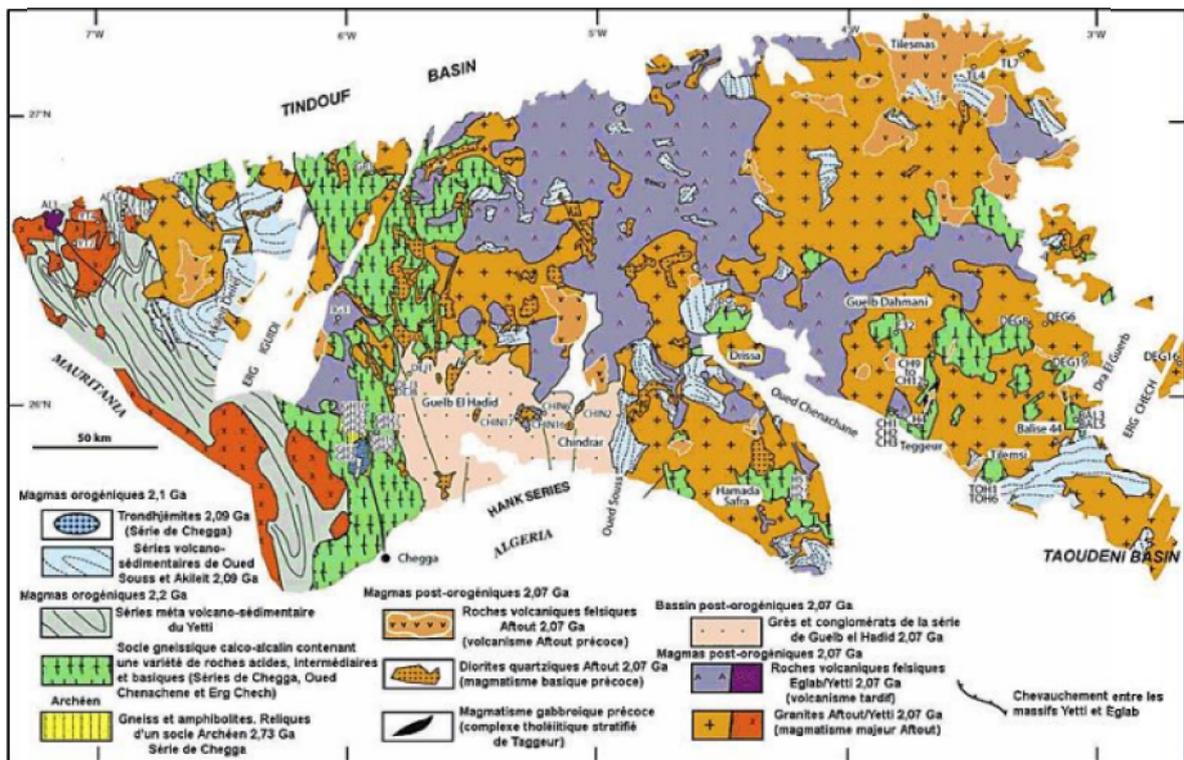
The Yetti-Eglab Massif is divided into two structural units: the Yetti domain to the West and the Eglab domain to the East. These two domains are separated by a tectonic contact affected by intense schistosity (mylonitic zone): the Yetti-Eglab junction (Sabaté, 1973).

- **The Eglab domain** is mainly composed of large post-tectonic granitic massifs (Aftout granites) and felsic volcanic rocks (Eglab Series). These rocks are not deformed or metamorphosed. They cut across or rest on folded volcano-sedimentary formations (Oued Souss Series) and older metamorphic rocks (Chegga Series and Chenachane-Erg Chech Groups).

(1) According to Gevin (1951) and Buffière et al. (1965), the Eglab, Aftout, and Oued Souss series belong to the **Upper Reguibat System (URS)**.

(2) The foliated and verticalised plutono-metamorphic formations (Chegga Series and Chenachane-Erg Chech groups) form the **Reguibat Basement System (RBS)** and appear as enclaves or windows within the SSR units.

- **The Yetti domain** is essentially composed of highly folded volcano-sedimentary series probably belonging to the Reguibat Basic System, intersected by granites belonging to the Reguibat Upper System. The Yetti massif constitutes an independent tectonic terrain that was initially separated from that of the Eglab before reuniting around 2 Ga, thus generating the Eburnean (or Birrimian) continental collision (Lefort et al., 2004).



IV. Geodynamics of the Yetti-Eglab Massif

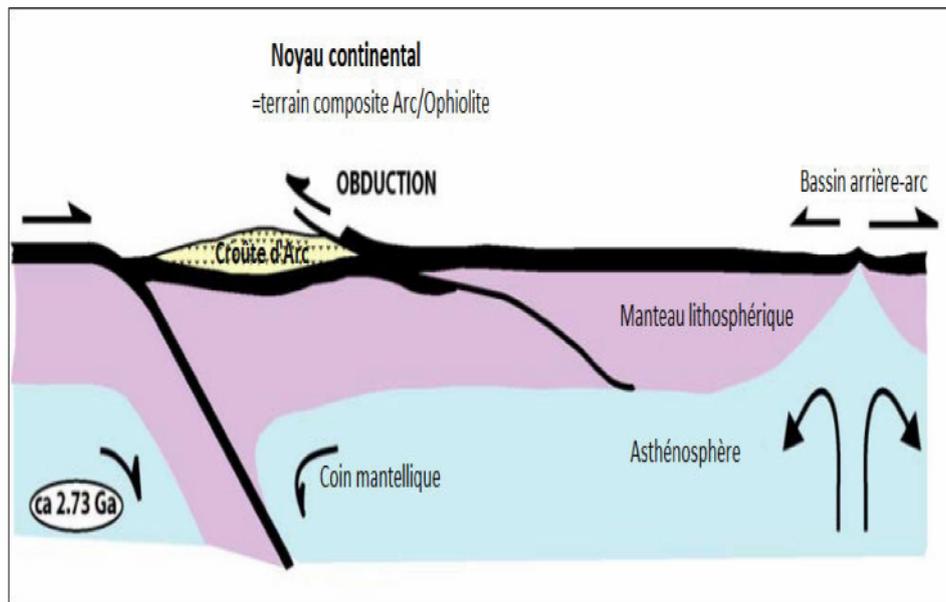
Two recent geodynamic models have been proposed to explain the establishment of the different structural units of the Yetti-Eglab massif. The model of Peucat et al. (2005) mentions four stages in the tectono-metamorphic and magmatic evolution of the Yetti-Eglab massif:

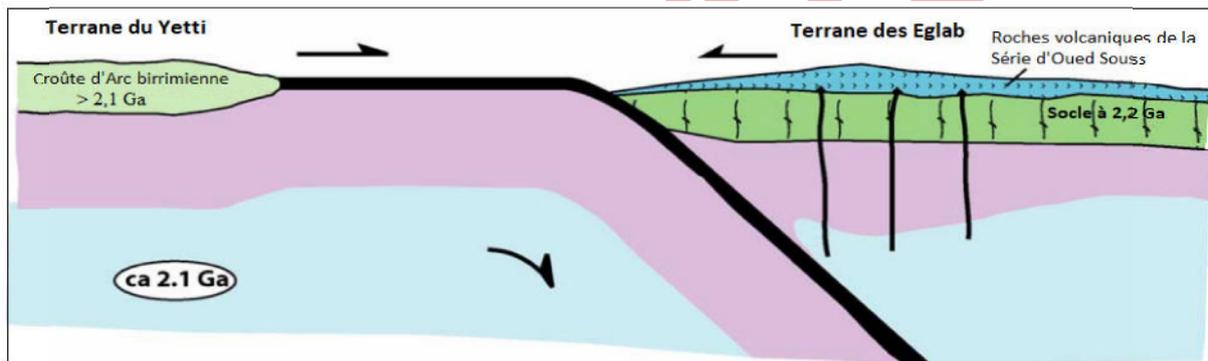
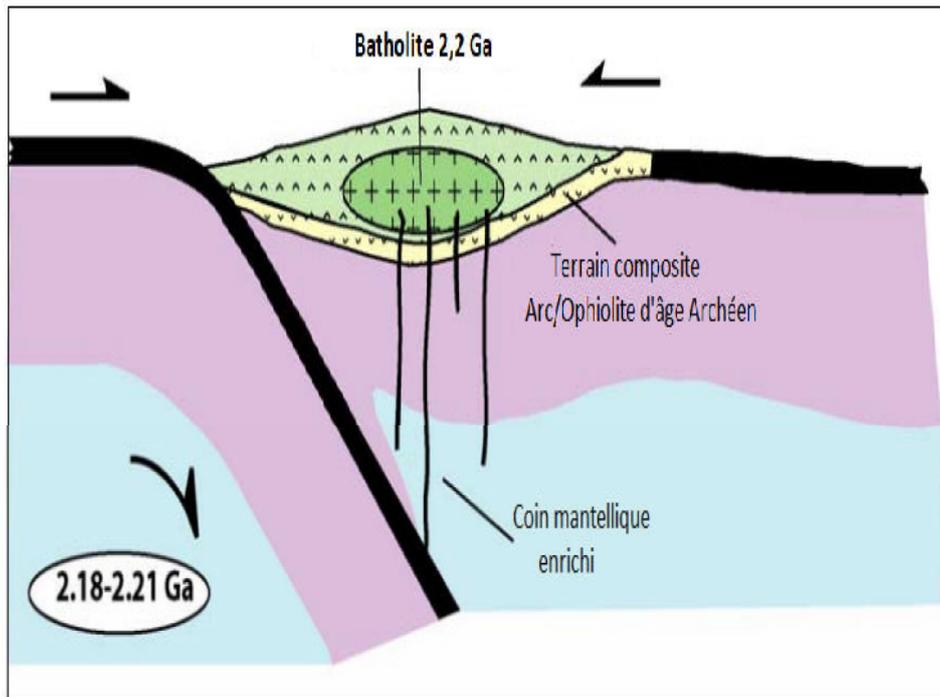
- the first takes place in the Archean, in relation to the existence of relics of oceanic crust dated to 2.7 Ga. This crust was probably obducted shortly after its formation on an Archean island arc, leading to the formation of a composite arc/ophiolite crust.

- the second stage corresponds to an orogenic activity that took place between 2.21 and 2.18 Ga and was characterised by the emplacement of a batholith in an active margin or a mature island arc. These magmatic formations were deformed and metamorphosed during this orogenic phase. A major uplift and erosion followed this phase, forming the basement on which the Oued Souss formations would be deposited.

-A second orogenic phase took place around 2.1 Ga and manifested itself by the emplacement on the 2.21 Ga basement of calc-alkaline volcanic rocks from the Oued Souss series.

The 2.21 Ga basement was then an active margin. Around 2.09 Ga, there was a collision between the Yetti terrane and the Eglab terrane. This collision is responsible for the deformation of the Oued Souss series. Syntectonic trondhjemites were also emplaced during this collision. The post-orogenic phase following the Eburnean collision is characterised by lithospheric delamination, uplift, and mantle upwelling, which led to the emplacement of the Aftout and Yetti plutons in an extensional context around 2.07 Ga, as well as the Eglab volcanism and the Guelb el Hadid continental basin.





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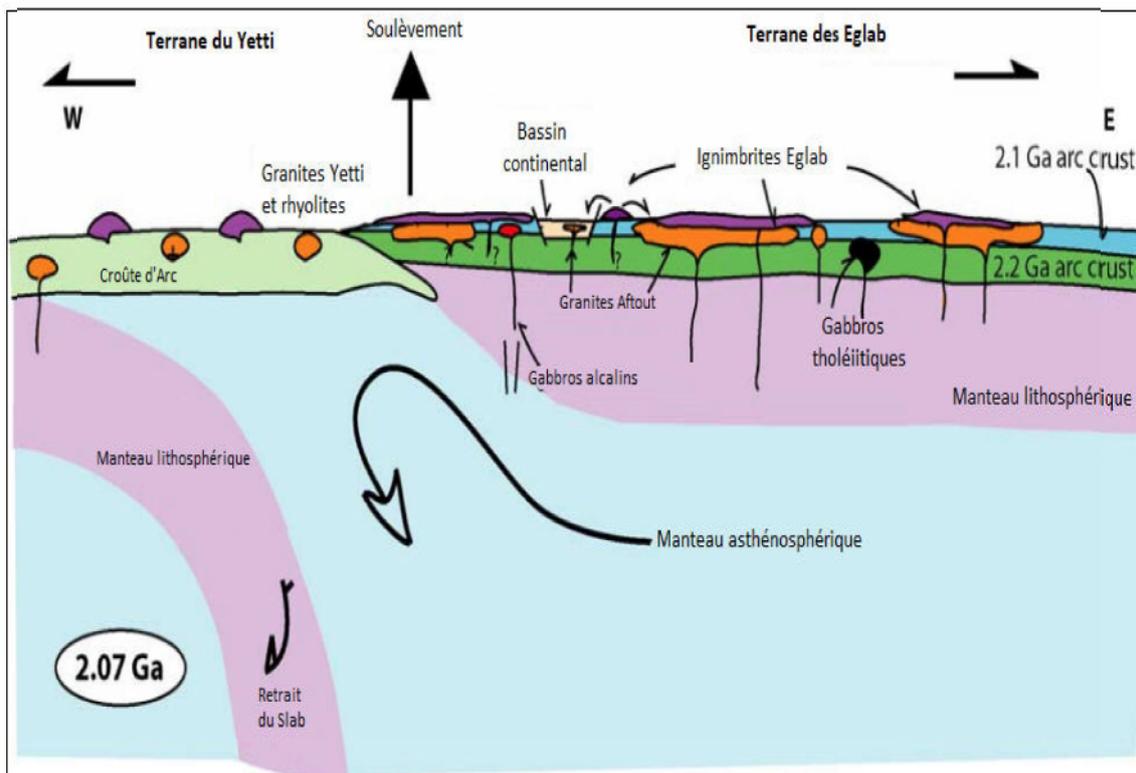
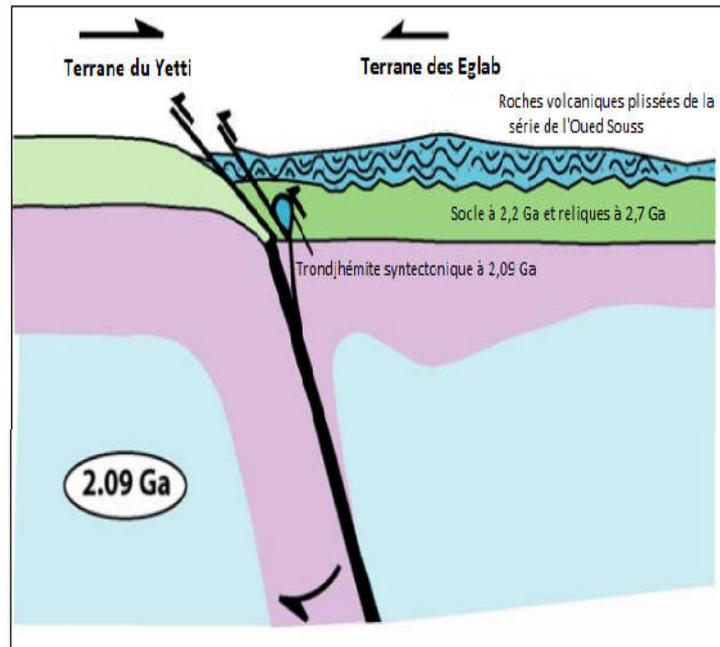
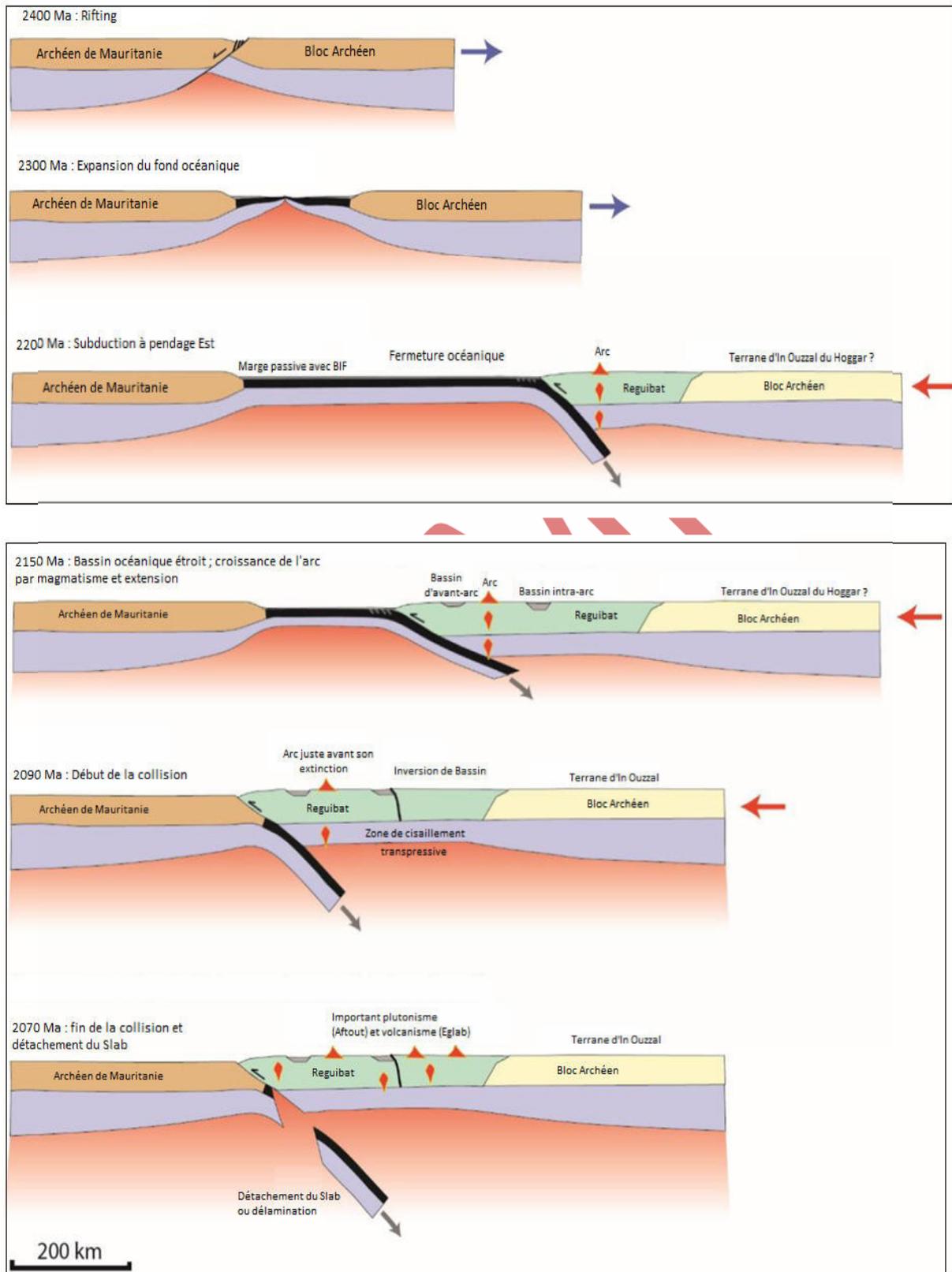
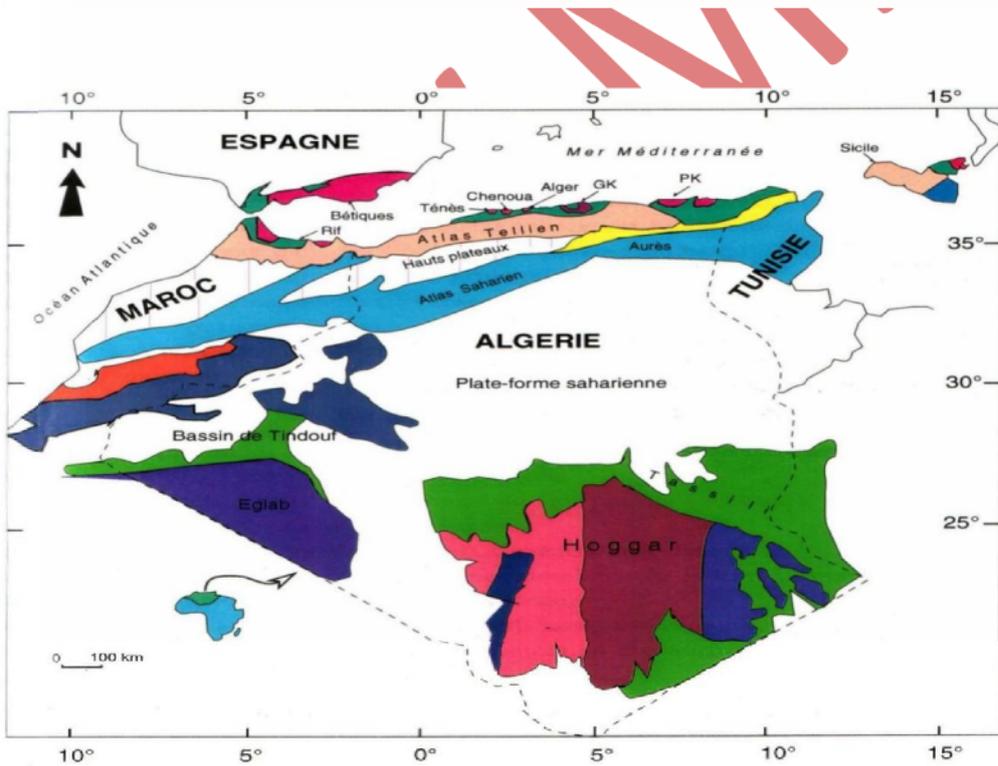
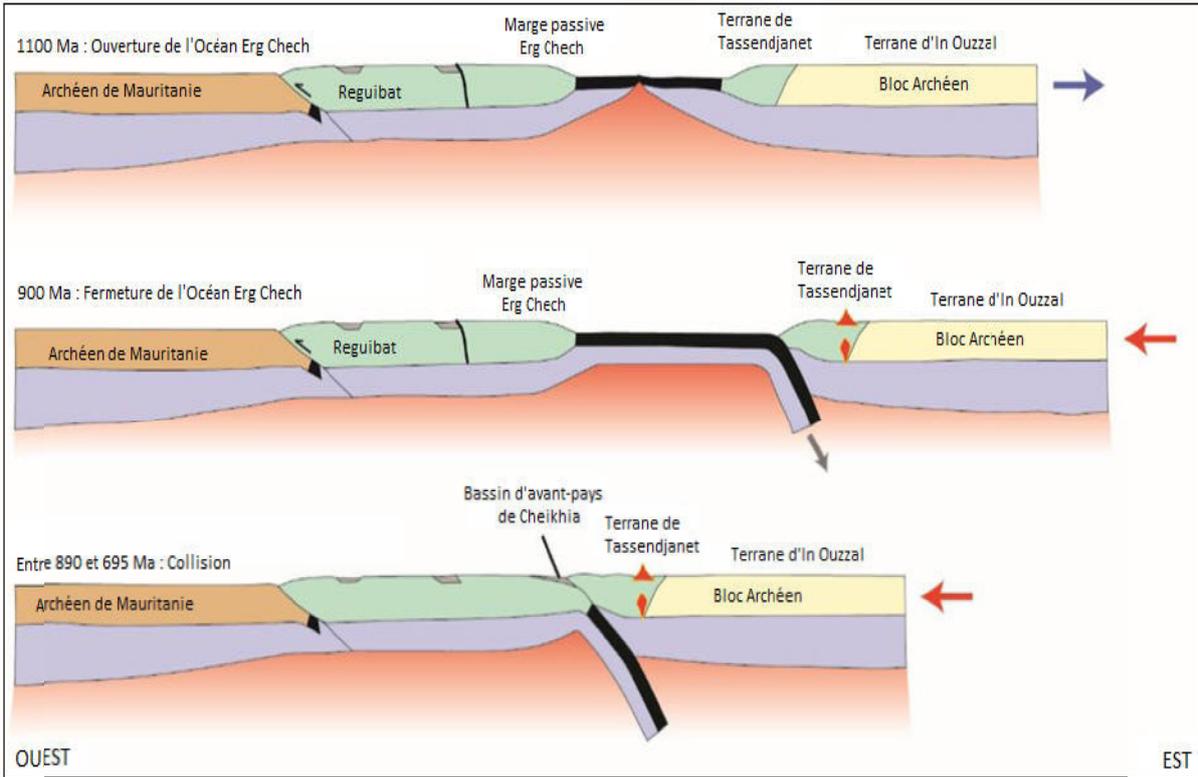


Figure: Geodynamic evolution of the Yetti-Eglab Massif, according to Peucat et al. (2005) A second model was proposed by Taylor et al. (2019) and differs from the previous model on two major points.

The first concerns the absence of an Archean continental nucleus in the Eglab massif, and the second concerns the non-existence of a suture zone between the Yetti and Eglab terranes, which challenges the existence of the Yetti terrane as an independent terrane from the Eglab before the Eburnean collision at 2.09 Ga. The different stages of this model are well illustrated in the figure. It should be noted that this model also highlights the geodynamic

evolution of the areas located east of the Eglab domain up to the Pan-African collision between 890 and 695 Ma.





- | | | | |
|---|------------------------------|---|--|
|  | Ougarta |  | Terrains récents |
|  | Tassili et bassin de Tindouf |  | Miocène moy-sup (synchro et post-nappe) |
|  | Hoggar oriental |  | Domaine interne (socle et dorsale) |
|  | Hoggar central |  | Flyschs maghrébins |
|  | Hoggar occidental |  | Nappes telliennes |
|  | Mole In Ouzzal |  | Avant pays pré-atlasique et Méséta |
|  | Socle éburnéen Eglab |  | Atlas saharien (haut et moyen Atlas marocain + Atlas tunisien) |
| | |  | Anti-atlas |
- Pk: Petite kabylie
Gk: Grande kabylie

D. BELHAI, 1996