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Geographical, Geological and Hydrogeophysical Survey of the Causse of El Hajeb-Ifrane (Morocco)

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ABSTRACT

In this work, we will present the main features of the regional environment of the El Hajeb-Ifrane Causse, namely the geographical, geological and hydrogeophysical contexts that prevail in their diversity between the Middle Atlasic Causse of El Hajeb -Ifrane and the plain of Saiss through the transition zone.

The presentation of these contexts is synthetic and reveals the essential elements of knowledge related to the objective of this work. Numerous references, including the main research works inspired by Morocco's water resources and other doctoral thesis carried out in the same area, can be consulted for more details.

Keywords: Causse of El Hajeb-Ifrane, Geography, Geology, Hydrogeophysical.

1- INTRODUCTION

The limestone plateau of the Causse El Hajeb-Ifrane is part of a large structural unit of the sub-tabular Middle Atlas; it is characterized by rugged limestone formations, which allow the circulation of large quantities of water, which is part of the underground flows which feed the resurgences of the city of El Hajeb (Ain Khadem, Ain Aghbal. The main flow directions are generally oriented to the north and north-west (Amraoui, 2005).
This work is in addition to previous scientific work that guided us to study the study area from a geographic, geological and hydrogeophysical point of view.

Some research work has been carried out on the rivers (Chahlaoui, 1996, Karrouch, 2011, etc.), other authors have been interested in the study of the water table and especially the hydrogeological and geophysical side (Essahlaoui 2000, Amraoui 2005, etc.).

2- GEOGRAPHIC CONTEXT

The study area located in the central north of Morocco (Figure 1), covers an area of about 4000 km², it is subdivided into two parts:

The Causse of El Hajeb-Ifrane, which is part of the Middle Atlas Causse, is bounded on the north by the plain of Saiss. The southern limit is the ridge line on the left bank of the Oum-er-Rbia watershed in Khenifra. The western limit is marked by the abrupt interruption of the Causse which dominates primary grounds of the meseta (cliff of Ito, Azrou and Ain-Leuh). In the East, the boundary is also marked by the Causse cliffs overlooking the buttonhole of primary lands of Bsabis. (Bentayeb and Leclerc, 1977).

The piedmont area of the Middle Atlas Causse, bounded on the north by the plain of Saïss proper, on the east by Oued Sebou, on the west by the Causse of Agourai and on the south by central Morocco.

The study area concerns a territory straddling two closely linked zones, the Middle Atlas Causse of El Hajeb-Ifrane in the South and the Saiss Basin in the North. These two areas are marked by a diversified relief, in the upstream part, there is a karst limestone plateau, which extends along the Causse, but downstream these limestone formations sink under other tertiary formations and plio- quaternary species such as sands, lacustrine limestone and marl (Bentayeb and Leclerc, 1977).

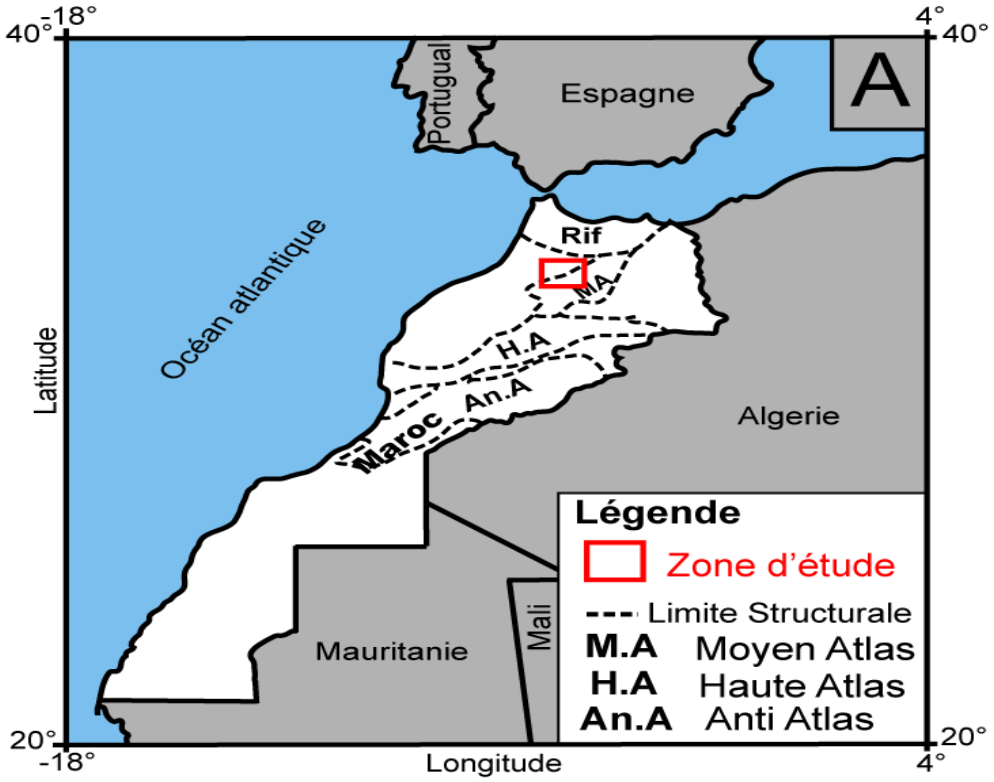

Figure 1: Location of the study area (Causse of El Hajeb-Ifrane).

3- GEOLOGY CONTEXT

3.1 The middle atlas's Causse

The term Middle Atlas Causse is reserved for tabular regions located directly to the north and northwest of the north-mid-Atlas accident that separates them from the pleated Middle Atlas located to the east (Colo, 1961).

The Causse is limited to the West by the primary lands of the Wadi Beht basin (Moroccan primary Meseta) and to the northwest by those of Tazzeka on which it rests. To the north, the limit is determined by the Tertiary and Quaternary terraces of the South-Rifain corridor under which it is bogged down in a vast dissymmetrical depression, interrupted on its northern flank in contact with the Rif and the Prif (Colo, 1961 Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975).

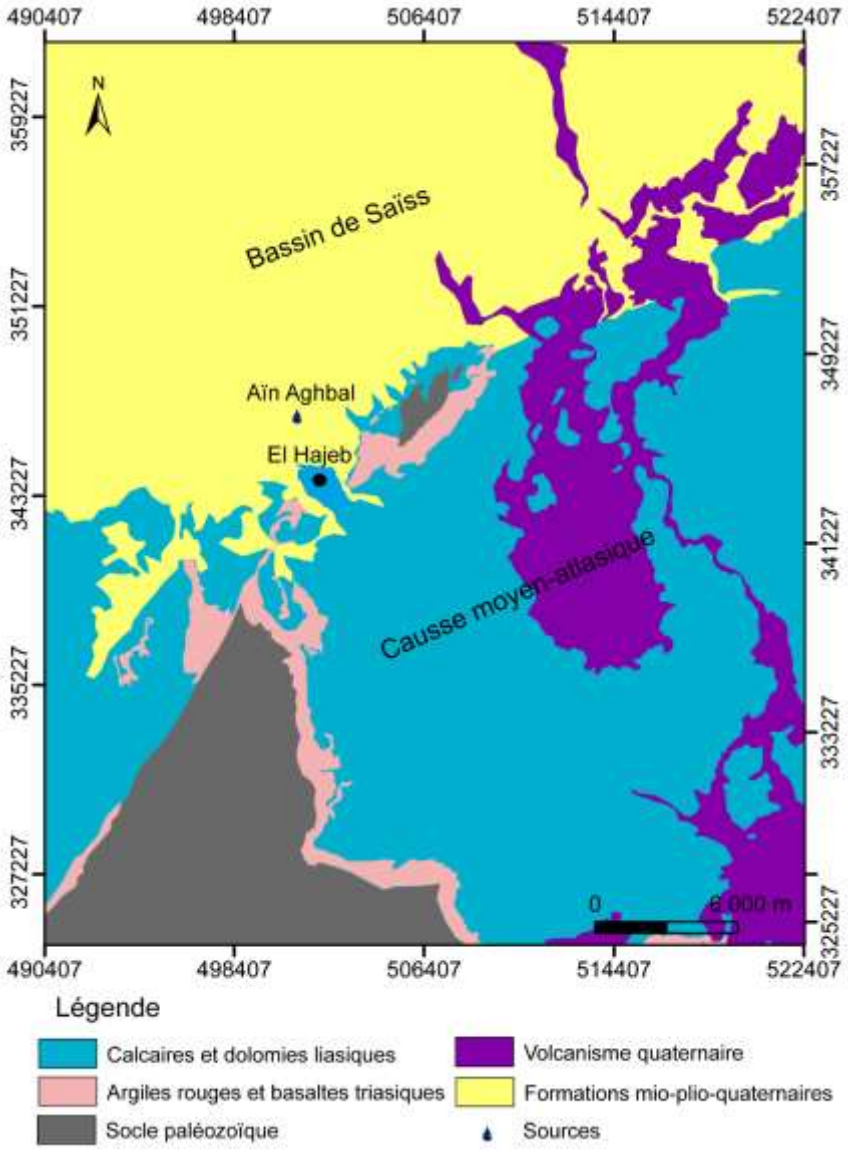

Figure 2: Extracted from the geological map of the study area (El Hajeb, 1 / 100,000)

3.1.1- lithostratigraphy

Permo-Triassic

It consists of a series of marls and red clays, sometimes purplish, gypsiferous, saliferous, within which are interspersed doleritic basalt flows, the Permo-Triassic rests unconformably on the post-Hercynian surface (Figure 3). This series is flush with the base of the liasic cover, in favor of the buttonholes and on the periphery of the Causse. It stakes the north-middle Atlas accident which can mask it locally (Chamayou, Leclerc, 1975).

Towards the North, the Permo-Trias is inapparent because it sinks with the Causse under the tertiary cover of the South-Rifain corridor.

In general, the Permo-Triassic series has everywhere the same composition and the same characters and one finds from bottom to top:

- a basic detrital level including conglomerates, pelits and sandstones;

- a red pelitic series passed greenish or purplish. These pelits are impregnated everywhere with salt and gypsum;
- a basaltic series (dolerites) interspersed within the red pelitic series, but their stratigraphic relationship is very variable. The thickness of these basalts can reach 150 m (Causse of El-Hajeb).

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Lower and middle lias

The lower Lias represents the formation of dolomites and limestones which constitute the main material of the Causse. In the northern section, Liassic sedimentation would begin in the Hettangian, represented by marl or dolomitic marl and dolomite levels of low importance (1 to 5 m), flush at various points at the foot of the western border between El-Hajeb and Ben-Smime. Above these levels, the lower Lias is represented by a dolomitic series about 150 m thick (Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975).

Upper Lias and Dogger

The Toarcian is a radical change in sedimentation and marly facies are becoming very important. However, the upper Lias and Dogger sediments are much less represented than the Dolomitic and Limestone series of the lower and middle lias.

From the Upper Toarcian begins to develop a marl-limestone series that continues throughout the Aalenian and Lower Bajocian. The upper lias and the Dogger are absent at the Middle Atlas Causse.

While the middle Bajocian has a distinctly marly facies (Boulemane marls), the upper Bajocian is represented by a series of more or less dolomitic limestones known by the "cornice limestones" (Colo, 1961 Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975).

Cretaceous

Cretaceous deposits are generally characterized by limestone and marly alternations of Cenomanian and Turonian. These facies become marly during the Senonian. However, the Cretaceous is represented only in the syncline of Bekrit-Timahdite (Pleated Middle Atlas).

Tertiary

The Oligocene, Miocene and Pliocene do not seem to be represented in the Causse of the Middle Atlas. Only one outcrop of the Mio-Pliocene continental north of Guigou's Almis (Bentayeb and Leclerc, 1977).

Quaternary

- Volcanic flows :

The thickness of these basaltic flows has been recognized both by geophysics (Benslimane, 2005) and by drilling. On the plateau of Timahdite, in the vicinity of the big craters (Jbel Hebri, Chedifat and Bouahsine in the valley of Oued Guigou). The castings reach thicknesses of the order of 150 to 200 m. This thickness decreases towards the periphery of the plateau to reach a few tens of meters. In the valley of the wadi Tigrigra to Azrou West, the casting reaches 90 m, but is reduced towards the West to a thickness of 3.5 m at the threshold of Sidi-Mokhfi (Colo, 1961 Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975).

-Sedimentary formations

The main quaternary formations have accumulated at the bottom of closed or semi-closed bowls. These are deposits of dayas, resulting from the on-site decomposition of limestone and dolomite and peripheral runoff. These deposits, mainly clay, can reach high thicknesses.

Another very common quaternary formation is that of the travertine deposits found in the emergence of each major source of Lias or marking the location of ancient emergences that are now extinct or displaced. These travertine deposits are not only quaternary but may be older (Bentayeb and Leclerc, 1977).

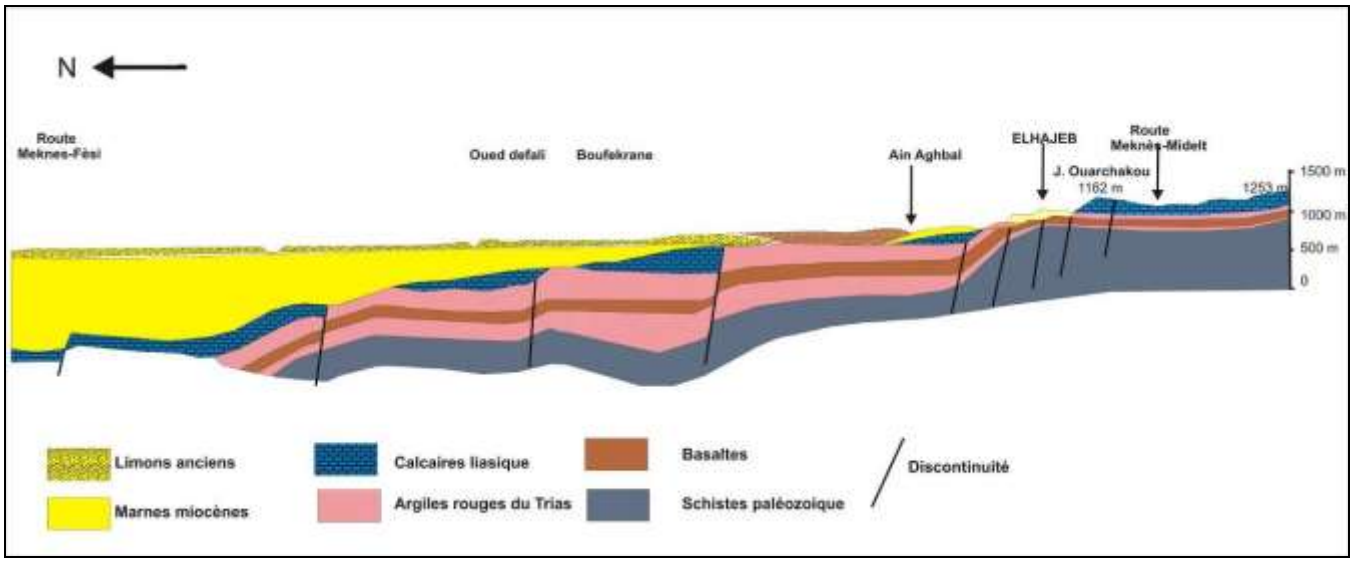

Figure 3: Schematic geological section of the Saïss plain and the Causse-plaine pass

(Geological map of El Hajeb 1/100.000)

3.2- Plain of Saïss

The Meknes-Fes basin is part of the "Sudrifain corridor" which extends from the Rharb plain to the west and to the Touahar pass to the east. Between the two great structural units which form the northern and southern limits of the basin a marine transgression deposited in the Miocene a very powerful marly series, followed at the Plio-Villafranchien and the Quaternary by continental deposits. The two main structural units of the Prerif and the Middle Atlas directly influence the current structure of the basin: the Middle Atlas extends under the basin and corresponds to the pre-Neogene substratum whose accidents have replayed by favoring the main directional flexures SW-NE (Figure 4) (Piquet, 1972).

The pre-Neogene substratum is formed mainly by calcareous and dolomitic Lias, Triassic variegated clays or Primary schists, depending on the extent of erosion and sedimentation deficiencies. The Lias of the Middle Atlas Causse progressively sinks under the basin of Meknes-Fes, towards the North. It is affected by flaws and flexures.

The Primary is only exposed south of the Meknes plateau between El-Hajeb and Agouraï, in the form of brown, purplish flyschs, interspersed with sandstone-pelitic beds. The known Triassic outcrop on the southwestern edge of the basin consists of gypsiferous clays and doleritic basalts, which may exceed 700 m. The lower and middle Lias, with a power of about 200m, are composed of dolomites, limestones and dolomitic limestones. Indurate marly and marl-limestone series constitute the upper Lias but are often absent at depth, mainly towards the South (Colo, 1961 Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975).

The Miocene series begins with sandstone limestones in the west and molasses south of Burdugal age then continues with blue marl and ends with sandstones and marl blue Tortonian age. The Miocene can reach a power of 1000 m in the region of Fes; it ends with a sandy-sandy facies (30 to 50 m) called "Sahelian" and reported to the Pliocene (Figure 4).

In the Pliocene and Villafranchian lakes lacustrine limestones, pudding and tawny sands forming the three facies of deposits of the lake basin of Meknes-Fez. In the plain of Saïss limestones and marl-limestones (chalk) lacustrine, of a power of 60 to 100 m rest directly on the blue mares of Tortonien or on sandstone marl of the Sahelian. In the eastern part they pass laterally to puddings; on the Meknes plateau, their average thickness is 20 m and they cover the fawn sands, or they intersect in the fluvial deposits (sands and pudding) (Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975)

The Quaternary is represented by various deposits: alluvial cones and scree at the foot of the Causse means-Atlas, travertines of El-Hajeb, Sefrou, the medina of Fes, limestone and calcareous crusts, marsh deposits (in particular in the region of Douyet) and basaltic flows on the border and on the Middle Atlas Causse (Colo, 1961 Bentayeb and Leclerc, 1977, Chamayou and Combe, 1975).

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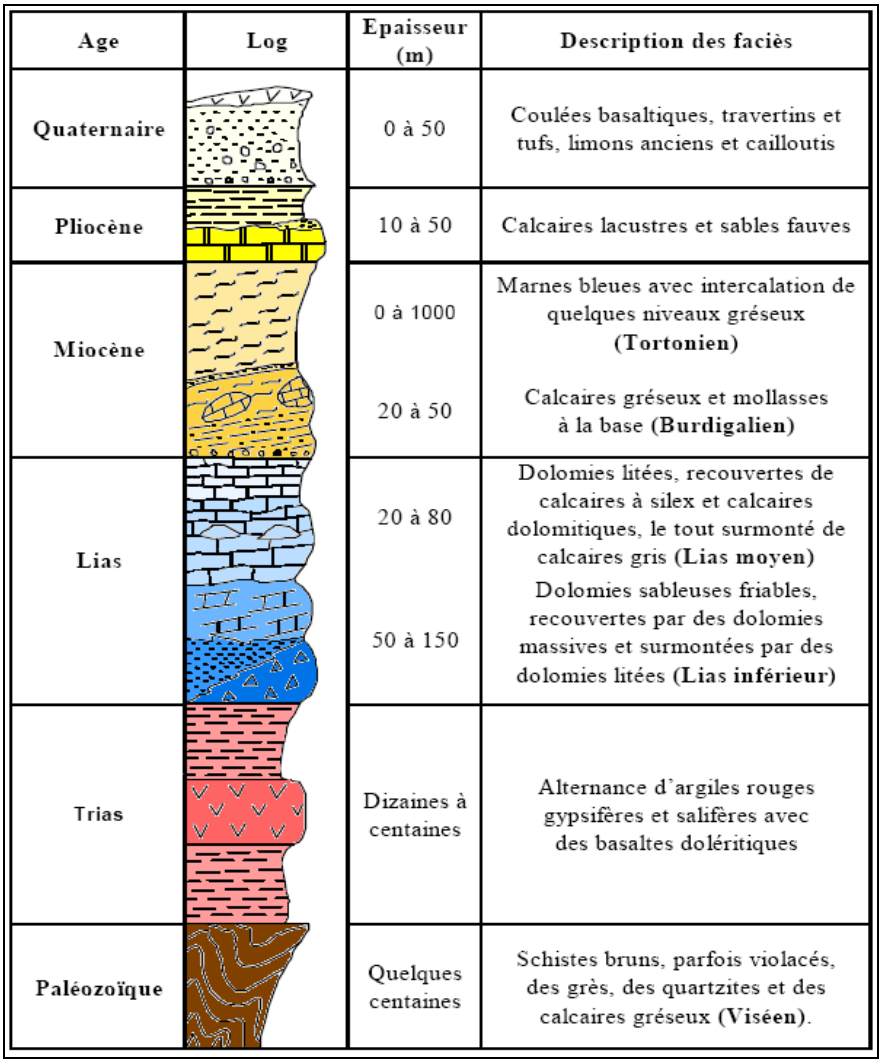

Age	Log	Epaisseur (m)	Description des faciès
Quaternaire		0 à 50	Coulées basaltiques, travertins et tufs, limons anciens et cailloutis
Pliocène		10 à 50	Calcaires lacustres et sables fauves
Miocène		0 à 1000 20 à 50	Marnes bleues avec intercalation de quelques niveaux gréseux **(Tortonien)** Calcaires gréseux et mollasses à la base **(Burdigalien)**
Lias		20 à 80 50 à 150	Dolomies litées, recouvertes de calcaires à silex et calcaires dolomitiques, le tout surmonté de calcaires gris **(Lias moyen)** Dolomies sableuses friables, recouvertes par des dolomies massives et surmontées par des dolomies litées **(Lias inférieur)**
Trias		Dizaines à centaines	Alternance d'argiles rouges gypsifères et salifères avec des basaltes doléritiques
Paléozoïque		Quelques centaines	Schistes bruns, parfois violacés, des grès, des quartzites et des calcaires gréseux **(Viséen)**.

Figure 4: synthetic log of Saïss basin (Amraoui, 2005)

4- HYDROGEOHPYSICAL CONTEXT

4.1 Hydrology context

4.1.1- The Causse of El Hajeb-Ifrane

Given the karst nature characterizing the Middle Atlas Causse, the hydrographic network is less developed. The map shown in Figure 5 illustrates the major streams in the study area that are most often on a temporary basis. These wadis originate either at the Causse (wadi Tizguit in particular), or from emergences located at the edge of the Causse (Wadi Aghbal, originating from the source of Ain Aghbal). The main flow direction of these streams is from SSE to NNW and the average slope is 2 to 3%.

4.1.2- Plain of Saïss

The hydrographic network is poorly developed in the southern part of the Saïss Basin where part of our study area is located. It is represented by some wadis such as wadi Defali, wadi Bougnaou, wadi Boufekrane, these wadis are born from the Karstique Causse. The flow direction of these wadis is generally SSW towards the NNE near the Causse and becomes SSE towards the NNW north of the basin (BOUIKBANE, 2015).

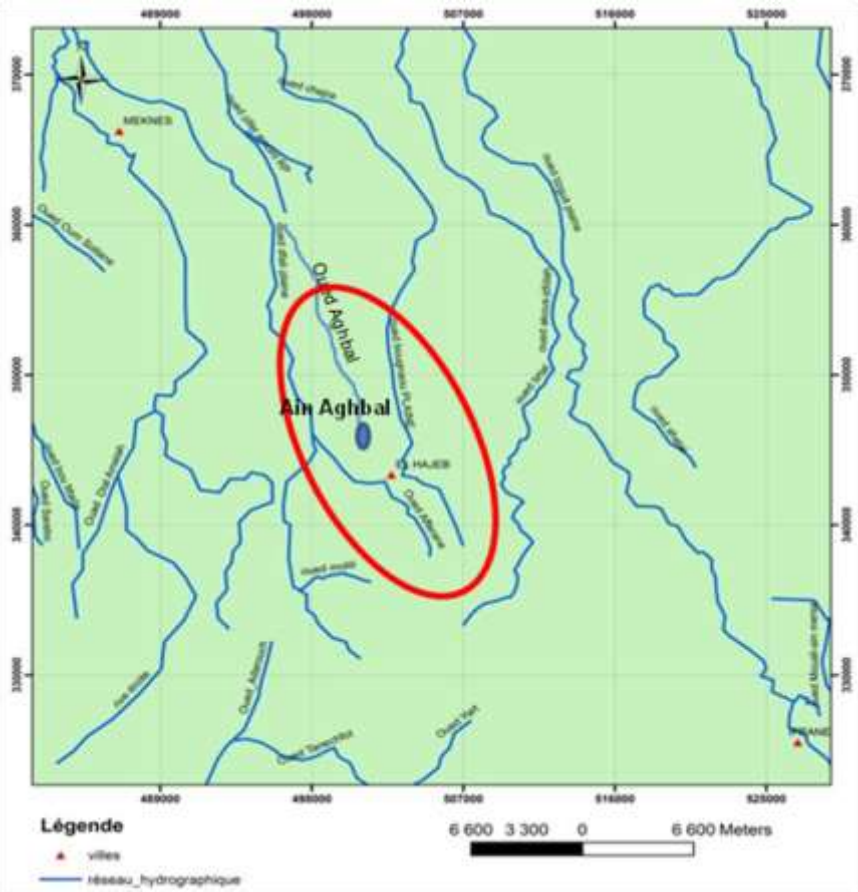

Figure 5: Map of the main Oued at the edge of the Saïss Basin and Middle Atlas Causse (BOUIKBANE, 2015)

4.2- Hydrogeological context

4.2.1- The Causse of El Hajeb-Ifrane

The only source of the Causse underground water supply is meteoric (rain or snow). A very high proportion of precipitation infiltrates the limestone karst and reappears mainly on the outskirts of the Tabular Middle Atlas. The main outlets of the underground waters of the Middle Atlas limestones are thus peripheral and in addition of various natures: emergences of border in contact with the Lias and its Triassic substratum (Aïoun-Ras-El-Ma, Sidi-Rached, Oum-er -Rbia, ...), sources of flexure at the flooding of the Causse under the South Rifain furrow (Aïoun-Ribaa, Bittit ...), emergences within peripheral aquifers such as lake limestones (Aïoun-Akkous, Cheggag, ...), releases with the water table of Saïss detectable only by the study of the balance of this aquifer, drainage by the Sebou Oued of the underground waters of the basins of Sefrou and Annoceur-Bsabis, drainage by the flows quaternary basalts of the Tigrigra wadi valley from the waters of the Ras-El-Ma and Aîn-Leuh basins (Figure 6) (Combe, 1975, Bentayeb and Leclercl, 1975, Tabyaoui et al, 2005 and Sefroui and al, 2013).

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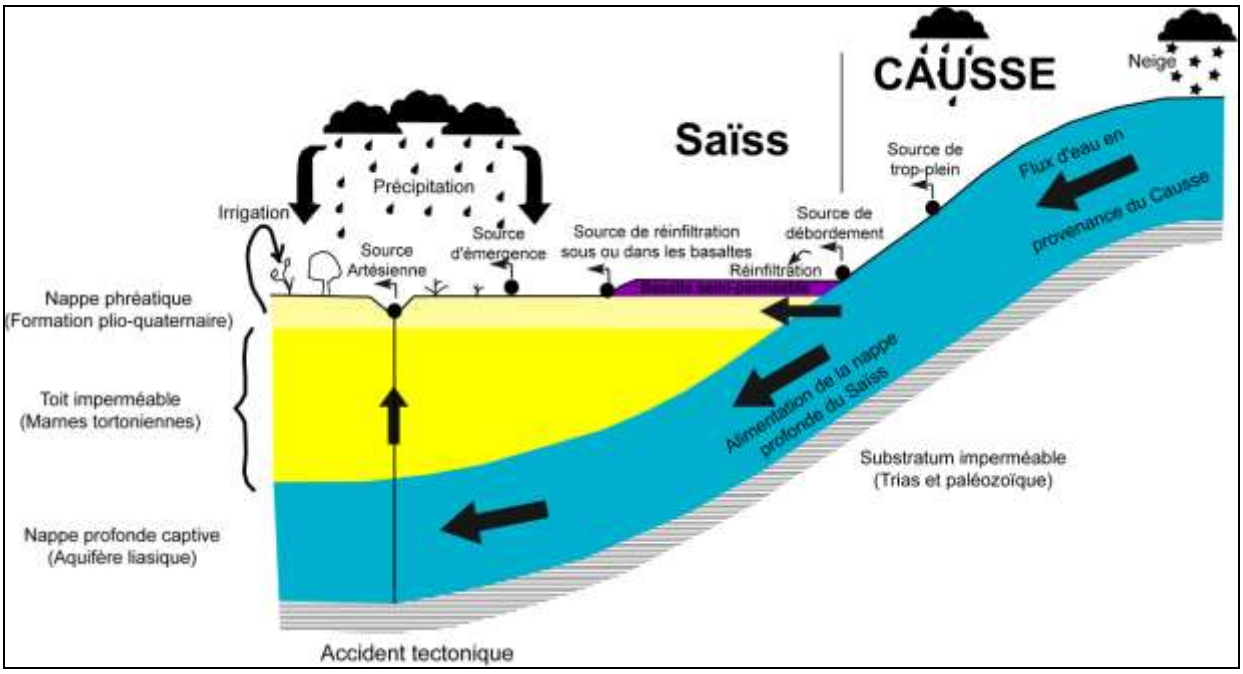

Figure 6: Schematic section of feeding the aquifer nappes by the Middle Atlas Causse

4.2.2- Plain of Saiss

In this region, there are two major aquifer reservoirs (Figure 6):

- A free water table circulating in the Plio-Villafranchian formations (sands, lacustrine limestones and sandstones);

- A deep sheet which circulates mainly in limestone formations of the Lias.

The Lias is calcaro-dolomitic and covers the Permo-Triassic substratum. This formation represents the main reservoir of water in the region, it forms a captive aquifer, artesian, which springs in certain sectors.

The Miocene separates the two aquiferous entities, it is essentially marno-sandstone and covers the Lias. It is found in almost the entire basin.

The analysis of the piezometry of the Lias aquifer shows that it can be subdivided into several hydraulic units (Margat, 1960, Amraoui, 2005):

- The western part between Meknes and Oued Kell constitutes a unit, characterized by a weak hydraulic gradient, separated from the rest of the zone not a major fault of direction N-S, whose flow is from the SE to the NW;

- The panel of Haj Kaddour, it is limited to the West by a major fault N-S; and to the east by a region marked by the absence of the Lias, the flow is mainly towards the NNE;

At the central part of the basin, the flow is mainly towards the North and North-East.

4.2- Geophysical context

The first electrical prospecting studies were carried out in the Saïss basin in 1937 by the african geophysical company de (AGC), on behalf of the Directorate of Research and Water Planning (DRPE) to meet needs. Other geophysical measurements were carried out by the seismic reflection campaign (ONAREP 1985) and allowed to establish several interpretative maps including the isohypse map of the Paleozoic and Triassic roofs. Geoelectric sections at the Saïss basin scale were developed by AGC in 1989 (Figure 7). Sectoral studies were carried out in the early 2000s (Essahaloui, 2000) in particular in the southern part of the basin to follow the limestone roof of the Lias and map the heterogeneities of the plio-quaternary facies.

Since 2000, several geophysical studies have been carried out by the Department of Geology of the Faculty of Sciences of Meknes in the framework of projects of end of studies of DESS, specialized Masters or PhD.

South of the basin and in contact with Plaine-Causse, the vertical electrical soundings carried out by the AGC were widely spaced (2km) and could not illustrate in detail the relation between the Causse and the plain necessary to understand the

transfer of the underground flows (Figure 7). So we wish to carry out geophysical studies with precision and high resolution in the southern part of the Saïss basin, and in particular in the piedmont area of the Causse d'El Hajeb in order to specify the fracturing network, which vehicles the groundwater and subsurface of the Causse to the plain of Saiss.

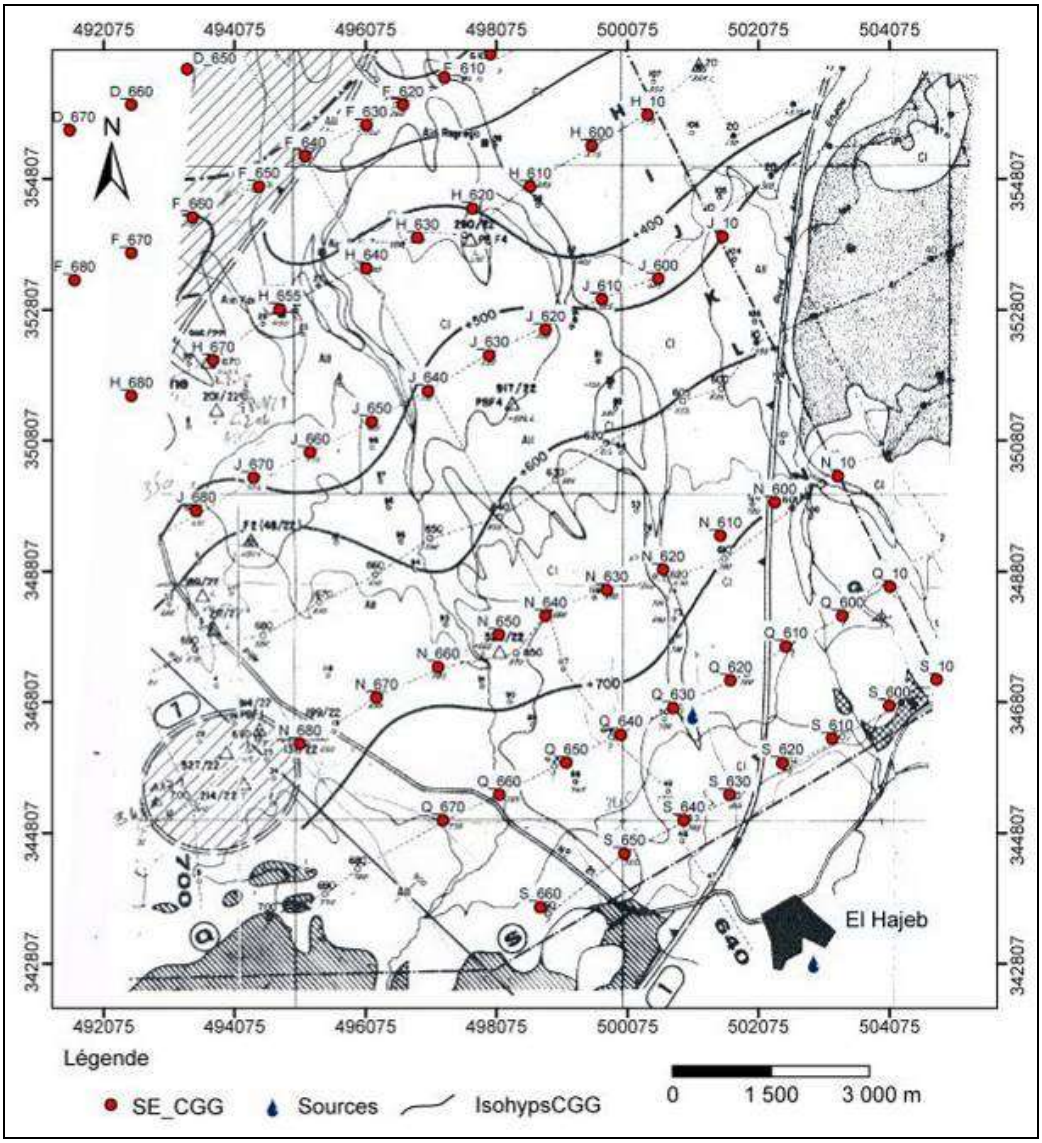

Figure 7: Situation Map of Electrical Measurement Profiles Conducted by AGC at the study area level (AGC, 1985)

5- CONCLUSION

The study area seems to be much diversified morphologically and geologically by going from the Middle Atlas Causse, known by its tabular limestone formations with more or less reliefs, towards the plain of Saïss constituting a synclinal depression passing through the piedmont, what is the transition zone in the form of an embankment connecting the Causse to the plain.

From a hydrogeological point of view, the Causse average-atlas is rich in limestone karst formations, the latter form a very important aquifer due to intense fracturing constituting favorable locations for infiltration of surface water. The northern part of the study area (Saïss basin) comprises two hydrogeological reservoirs, one superficial flowing in the plio-quaternary formations (tawny sands, lacustrine limestone, sandstone) and the other deep in the limestone formations of the Lias, and constitutes the main aquifer in the basin of Saïss.

The various geophysical studies carried out have generally shown the existence of major discontinuities in the basin as well as the presence of areas where Lias limestones are absent.

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BIBLIOGRAPHIC REFERENCE

1. **Tabyaoui F.Z., Sahbi H., Elouazzani A. & Chadli K., (2005).** Contribution of hydrogeochemistry to groundwater characterization of the plio-quaternary aquifer of the Meknes plateau. 3rd International Conference of Environmental Geosciences. June 2005.
2. **FASSI O. (1999).** The surface formations of Saïss de Fes and Meknes from geological times to current use of soils. Thesis 527p. Notes and Mem. Serv. Geol. No. 389. Rabat, Morocco.
3. **AFRICAN GEOPHYSICAL COMPANY (AGC), (1988).** Geophysical synthesis of basins of Fez-Meknes and Boudnib-Errachidia. UNDP / DTCD project. MOR 86/004. DRPE report. (Unpublished).
4. **Bentyeb et Leclerc r. (1977).** The middle atlasic causse, in water resources of Morocco. Volume 3, atlantic and southern atlasic domains, notes and memoirs, geological service, n ° 231, pp.37-66.
5. **Chamyou J., Combe M., Gentier B., Leclerc C., (1975).** The Meknes-Fes basin, Morocco water resources, Volume 2, plains and basins of Atlantic Morocco, Notes and Memories of **the geological service, Rabat, Morocco, pp. 41-71**
6. **Margat J., (1960).** Hydrogeological map of the Fes-Meknes basin at 1 / 100,000. Rabat: Edition of the Office of Irrigation.