World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Characterization of the deformation of the Jurassic-Cretaceous deposits of the Toulouk sector (Tim Mersoï basin, North Niger), relation with the uranium mineralizations

Sani Abdoulwahid [1, *], Souley Idi Baraou [2], Konaté. Moussa [2], Alassane Ibrahim Maman Bachir [3] and Peter Wollenberg [4]

[1] *Department of Geology, University of Agadez, Niger.*
[2] *Department of Geology, University Abdou Moumouni of Niamey-Niger.*
[3] *Department of Fossil Energy, University of Agadez, Niger.*
[4] *Global Atomic Corporation, Canada.*

World Journal of Advanced Research and Reviews, 2024, 21(02), 1415–1429

Publication history: Received on 16 January 2024; revised on 16 February 2024; accepted on 19 February 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.2.0515

Abstract

The Toulouk sector, located in the Tim Mersoï basin, is a particular area due to the presence of a Horst structure within the vast expanses of the Irhazer mudstones. This structure has shown sub-surface uranium mineralization. This raises the problem of understanding the deformation of this sector as well as the mechanisms that favoured the establishment of these mineralizations. Thus, the approach implemented consisted in:

- Filed work, analysis of satellite imagery data, cartographic and logging data,
- A correlation of geological and logging data,

This approach allowed the establishment of a local lithostratigraphic framework and the visualization of the uranium distribution and copper mineralization in this sector. It appears from this work that the Toulouk sector would be subjected to an extensive synsedimentary phase that would have favored a structuring in horst and half-graben. The latter would have favored the development of several tectonic structures. These served as drains for the mineralizing fluids.

Keywords: Toulouk sector; Synsedimentary structuration; Uranium mineralization; Horst and half-graben; Hydrothermal fluids flows

1. Introduction

The Paleo-Mesozoic Tim Mersoi Basin, located on the western edge of the Aïr, corresponds to a northward branch of the Iullemmeden synclise [1]. It is a basin that is well known for its uranium mineralization. In this basin, south of Imouraren, a regional scale antiform structure called the In Adrar Assaouas dome (Fig. 1) has been the subject of numerous exploration campaigns. It appears from this work that the sandstone formations that characterize the axis of the dome progressively evolve towards clayey facies to the west, whereas towards the east, abrupt changes from these sandstone facies to clay are observed. Authors such as: [2], [3], [4], [5] have assimilated the Jurassic to Cretaceous age sandstone and clay deposits to the Tchirezrine II and Assaouas formations. According to [2], [4], [5] the sandstone deposits contain analcime intercalations. In this sector, important uranium and copper showings have been reported (CEA reports 1963, 1971; [7]). Similarly, the work of [3], in his report of the prospecting campaign, Azelik mission (1957-1958), revealed the presence of numerous copper and uranium showings, related to the N60°-N80°, N90°-N100°,

* Corresponding author: Sani Abdoulwahid

and N170 °-N180 ° structures. It should also be noted that phosphate and copper mineralization has been described in this same region by [8]. The problem arises as to the continuity of these mineralizations under the clay covers on both sides of the axis of the dome of In Adrar-Assaouas. Thus, the objective of this work is to investigate the distribution of these uranium and copper mineralizations under the thick clay covers of the Irhazer to the west of the Horst.

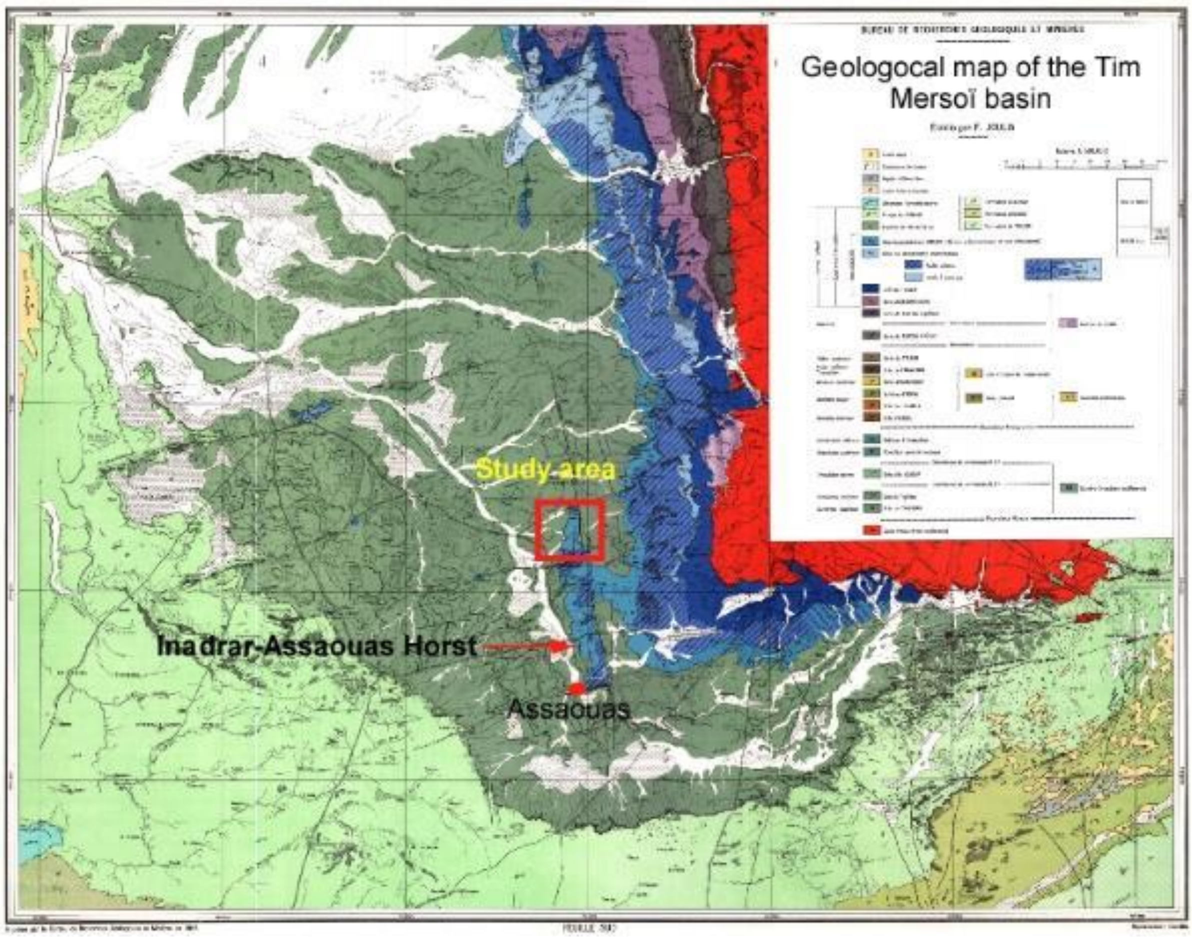

Figure 1 Geological map of the Tim Mersoï basin in Niger, showing the location of the study area [9].

2. Methodological approach

The methodological approach adopted in this study consisted of:

- Field work and analysis of previous work associated with satellite image analysis and fracture analysis based on the drilling core study of the study area. This step allowed to realize the geological map of the Toulouk sector.
- Tectonic-sedimentary analysis based on the exploitation of core drilling data, destructive drilling data and logs. Data from some boreholes were used to perform a correlative interpretation in order to define the structural model of the Toulouk sector. Thus, perpendicular sections oriented along the axis of the dome were made in order to visualize the lateral and vertical distribution of facies,
- And finally the analysis of the spatial distribution of the mineralization based on the correlation of the logging data.

3. General context

3.1. Study Area

The dome of In Adrar-Assaouas is located in the Tim Mersoï basin south of Imouraren and north of Agadez. It straddles the departments of Tchirozérine and In Gall. It extends from southeast of Assaouas to Teguidan Tagaït (Fig. 1). The study area concerns the northern part of the Inadrar-Assaouas horst (Fig. 1) located in the Toulouk permit (held by GPB Niger minerals).

3.2. Geological setting

The Tim Mersoï basin corresponds to a northward branch of the Iullemmeden Syncline. It extends into Algeria where it is called the Tin Séririne syncline [1] (Fig. 2). It is bounded to the east by the Aïr Massif and to the west by the In Guezzam ridge which separates it from the Tamesna basin in Mali (Fig. 2).

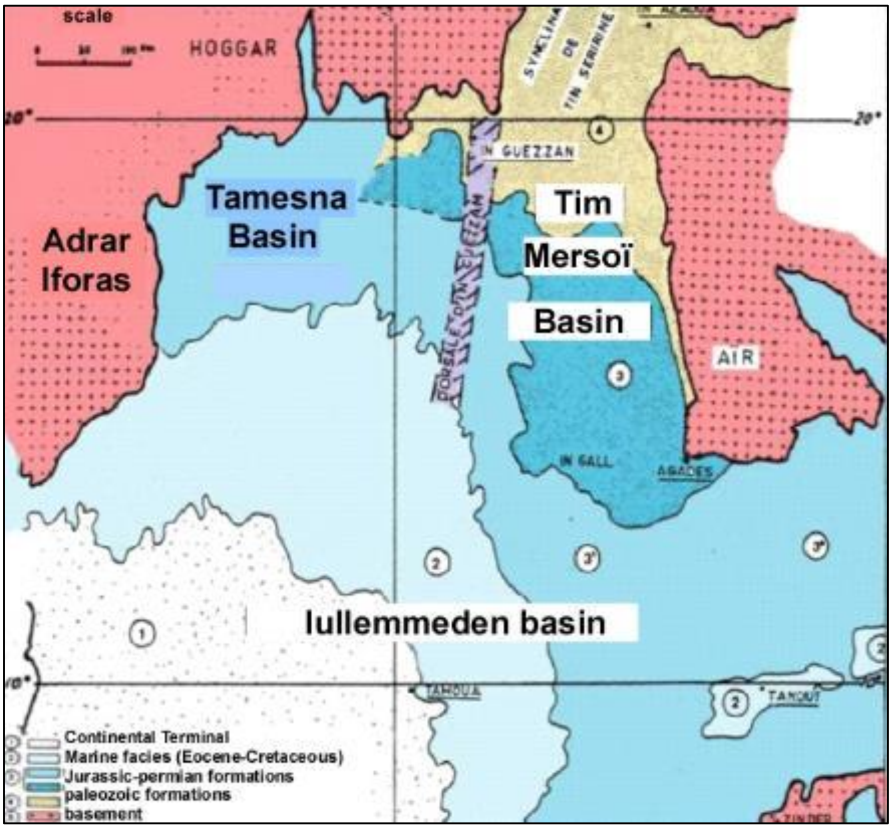

Figure 2 Location of the Tim Mersoï basin in its regional geological context [8].

The Tim Mersoï basin corresponds to a vast intracratonic depression along the western edge of the Aïr. Its sedimentary filling has a maximum thickness of about 1500 m with an estimated area of 114,000 km^2 [5]. The sedimentary series of the basin rest unconformably on the rejuvenated Precambrian and Pan-African basement. The age of these sedimentary series ranges from Devonian (Teragrass sandstone) to Early Cretaceous (Tegama sandstone) (Fig. 3).

Along the western edge of the Aïr, the sedimentary series present successive stratigraphic dips from north to south (Fig. 3), reflecting the displacement of sedimentation areas. This arrangement of the layers in bevels reflects the influence of tectonics on sedimentation [9].

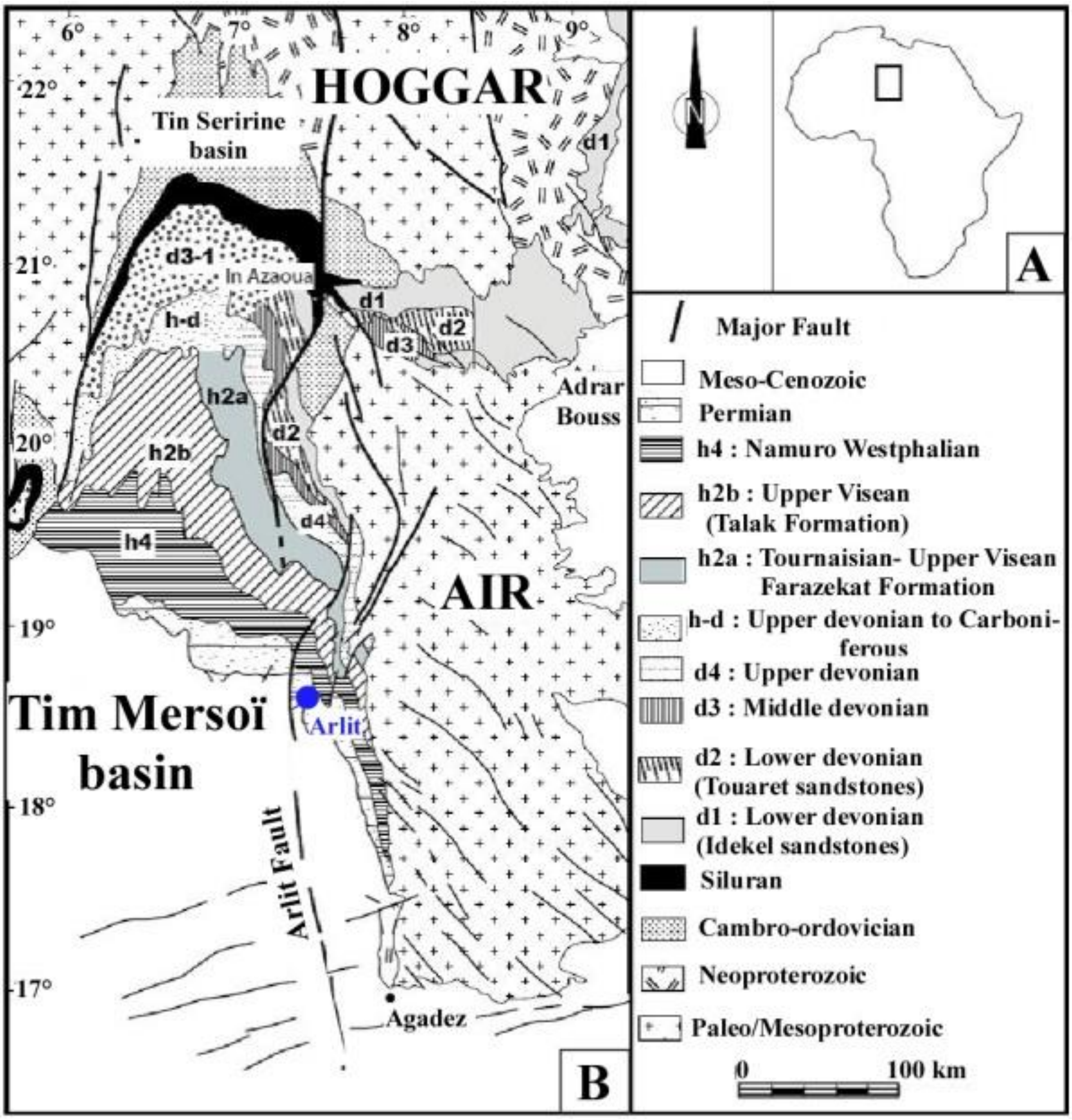

Figure 3 A- Location of the Tim Mersoi basin in Africa. B - Synthetic geological map of the Tim Mersoï / Tin Séririne basin [10].

The different paleo-environments of deposition of the Tim Mersoï basin are described as follows:

- The Teradah series (Fig. 4) consisting, from the oldest to the most recent of :
- The Teragh formation (100 m thick, Lower Viséan), consisting of clay, varves and sandstone, with esker structures, moraines, witnesses of the fluvio-glacial environment of the deposits [5], [8].
- The Talak Formation (about 200 m thick, Upper Viséen), is made up of shales with marine fauna and flora [9]. It is characterized by thin intercalations of fine sandstones and the presence of gypsiferous and phosphate levels at the top [11].
- The Akokan unit (about 20 m thick, Upper Viséan) is characterized by silty-muddy facies resting on the underlying Talak clays [12].
- The Tagora series (Fig. 4), comprising mega-sequences of sandstone and clay, which contain the deposits of the Arlit area (Guézouman, Tchinézogue, Tarat, Madaouéla). Its maximum strength reaches 500 m. The age of the sediments varies from Viséen (Guézouman, Tchinézogue, Tarat) to Upper Carboniferous (Madaouéla). The sedimentation is of platform to fluvio-deltaic type.

- The Izégouandane series, comprising the Izégouande, Téjia, Tamamaït and Moradi formations (Fig. 4), is formed of arkose of fluvial origin and palustrine to lacustrine clay. A Permian age has been attributed to this series whose thickness reaches 800 m.
- The Agadez Sandstone Group (Fig. 4), formed of arkosic to conglomeratic sandstones, fluvial to fluvio-lacustrine, with a thickness of 400 m. It includes the Aguélal, Goufat, Wagadi and part of Dabla series. The formations are of triassic to lower cretaceous age. The formations of this group are particularly rich in analcime [13], [14] and contain significant uranium mineralization.
- The Irhazer Group (Lower Cretaceous), consisting of argillites about 300 m thick, deposited in a palustro-lacustrine environment.
- The Tegama series (Fig. 4), with a maximum thickness of 700 m, consists of fluvial sandstone deposits of Lower Cretaceous age, which extend to the south of the Iullemmeden basin.

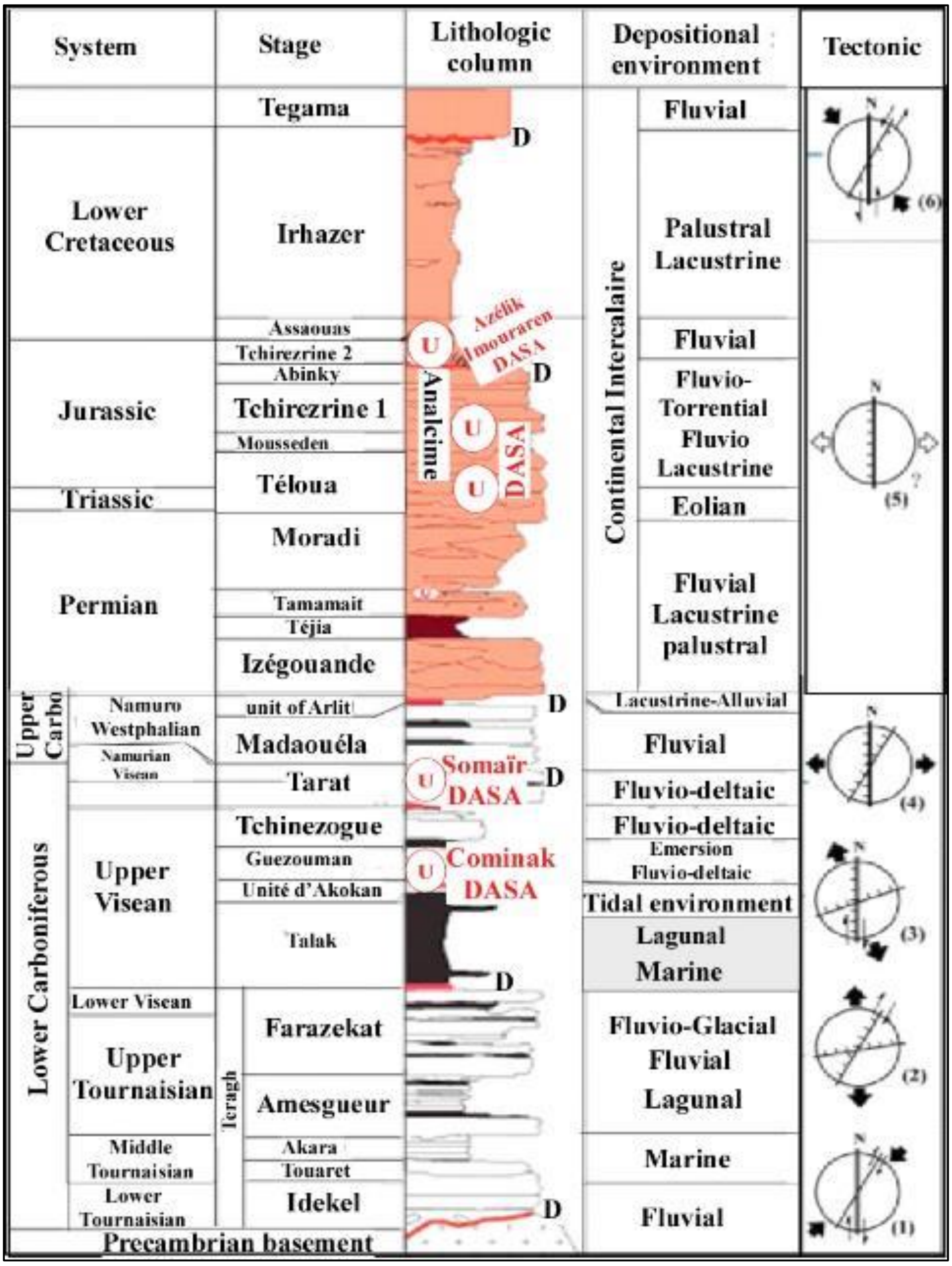

Figure 4 Lithostratigraphic column of the Tim Mersoï basin formations (from [11], modified).

The polyphasic evolution of the Tim Mersoï basin is marked by soft and brittle accidents. The repercussion of the underlying basement faults is reflected in the basin by synclines and anticlines, often faulted. Their axes are oriented in the same way as the main tectonic directions. [15] reports that the reactivation of structures in fault and flexure zones induces several styles of deformation depending on the rheology of the overlying materials. In particular, he distinguishes:

- Syn-sedimentary or early deformations for non-lithified sediments;
- Syn- to pre-compaction deformations for poorly consolidated sandstones;
- And post-compaction deformations for consolidated sandstones.

Three major accidents were distinguished :

- N-S accidents (Fig. 5), represented by the In Azaoua-Arlit Fault Flexure. This is a major crustal accident on a regional scale. The faults of this family correspond to ancient late-Pan-African rifts, whose replay in the sedimentary cover, depending on the time, is expressed as a fault, flexure or flexure-fault [11], [16].
- N30° faults (Fig. 5): they are expressed in the basement and in the cover in the form of flexure. These faults are spaced about 20 km apart. The most important are the Madaouéla fault-flexure (Arlit sector) and the Adrar-Emoles fault-flexure (DASA sector) [11], [16], [17].

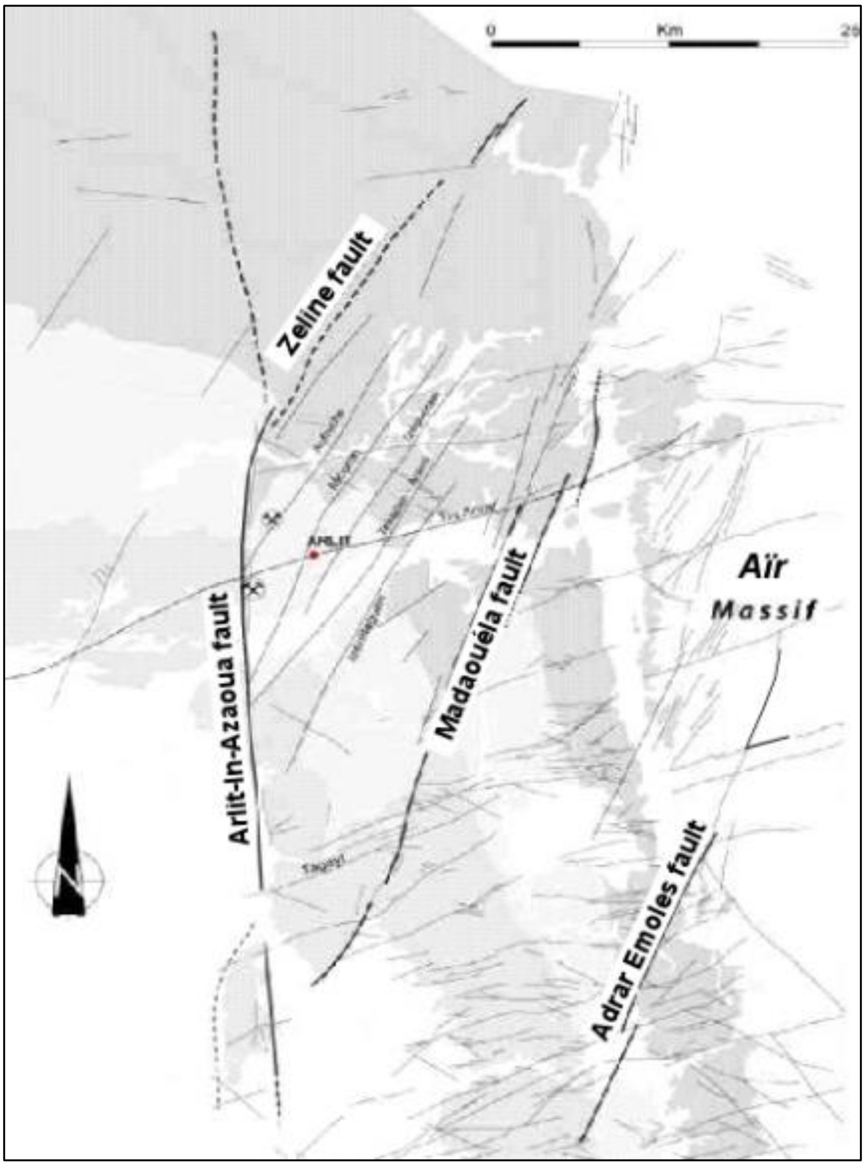

Figure 5 Structural map of the Tim Mersoï basin [10].

- The N130-N140° structures and their N70-N80° conjugates (Fig. 5). The N130-N140°E faults constitute the main network of faults in the Aïr Massif and, according to [10], are of late Pan-African origin. The N70-N80°E faults, combined with the previous faults, appear in the southern half of the Tim Mersoï basin [16]. According to [17], the

N70-N80°E and N130-N140°E fault systems would have controlled the sedimentation of the basin during the Carboniferous. At the map scale, the N70° system structures play a dampening role on the operation of N30° trending flexures [10], [18].

Uranium mineralization in the Tim Mersoï Basin is thought to be hosted in sandstone formations of all series from the Carboniferous to the Lower Cretaceous [18], [19]. It would be directly or indirectly linked to the different volcanic episodes reported by many authors such as [12], [15], [19], [20], [21]. In the setting of this mineralization, [19], [22], [23] emphasized the circulation of fluids and note that the same mineralizing fluid can be at the origin of post-diagenetic mineralization in Carboniferous and Jurassic formations. Uranium mineralization in the Tim Mersoï Basin is thought to be hosted in sandstone formations of all series from the Carboniferous to the Lower Cretaceous [18], [19]. It would be directly or indirectly linked to the different volcanic episodes reported by many authors such as [12], [15], [19] and [20]. In the setting of this mineralization, [22], [23], [24] emphasized the circulation of fluids and note that the same mineralizing fluid can be at the origin of post-diagenetic mineralization in Carboniferous and Jurassic formations.

4. Results

4.1. Sedimentological analysis

The sedimentological analysis of the study area was carried out on the data of cores and destructive drillings as well as on outcrops. For this analysis the emphasis was put on the northern part of the dome, corresponding to the part most investigated during the mapping work. The identified formations were represented in figure 6. This allowed us to propose a lithostratigraphic column of the study area (Fig. 7). Furthermore, fieldwork and the analysis of previous data have enabled us to update the geological map of the Toulouk area (Fig. 8).

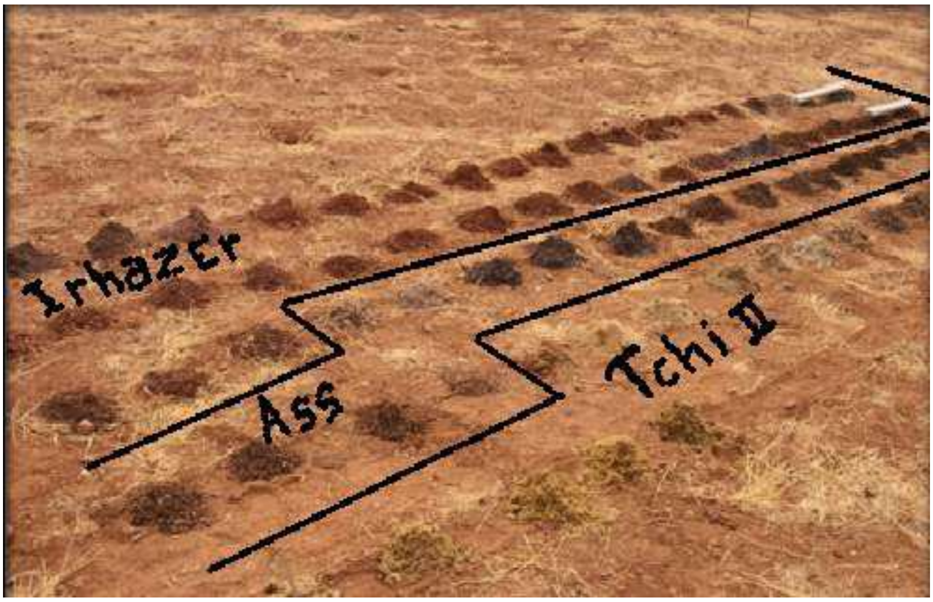

Figure 6 Cuttings assemblage giving the lithostratigraphic succession of the study area.

It is from top to bottom, following the progression of the drilling tool of the following formations:

- The Irhazer formation (Figs. 6 and 7), of Lower Cretaceous age, consists mainly of argillites, silty argillites, more or less carbonated. This brown to reddish formation contains intercalations of fine clayey sandstone. On the cores, this formation sometimes shows horizontal to subhorizontal bedding and includes a diversity of fossils: lamellibranchs, fish bones and scales. This type of facies characterizes a shallow, lacustrine-type environment. This interpretation is in agreement with the observations of [8] who maintains that in the Cretaceous an immense lake called Irhazer was at the origin of the setting of the argillites of the same name. The Irhazer mudstones are locally overlain by recent alluvial or conglomeratic deposits remaining from the Tegama Formation. The contact with the underlying formation is not clear because of the similarity of the two facies.

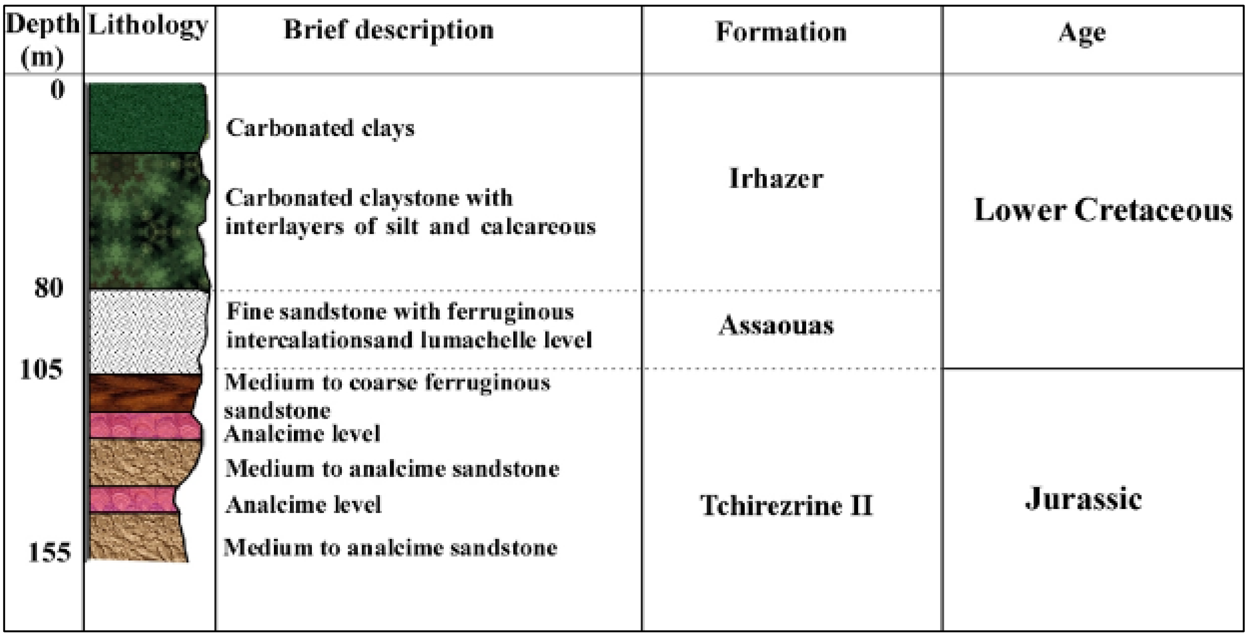

Figure 7 Synthetic lithostratigraphic column of the study area.

- The Assaouas formation (Figs. 6 and 7). It includes very fine clayey and calcareous sandstones that give it a character very close to the Irhazer. This lithofacies is described in several previous works [7], [8] as a transitional facies between the Tchirezrine II and the Irhazer. The Assaouas formation is distinguished from the Tchirezrine II sandstone by the following particular features: fine calcareous sandstone with sound slab flow, multiple wrinkles, shell level (lumachelle level) and a darker coloration.

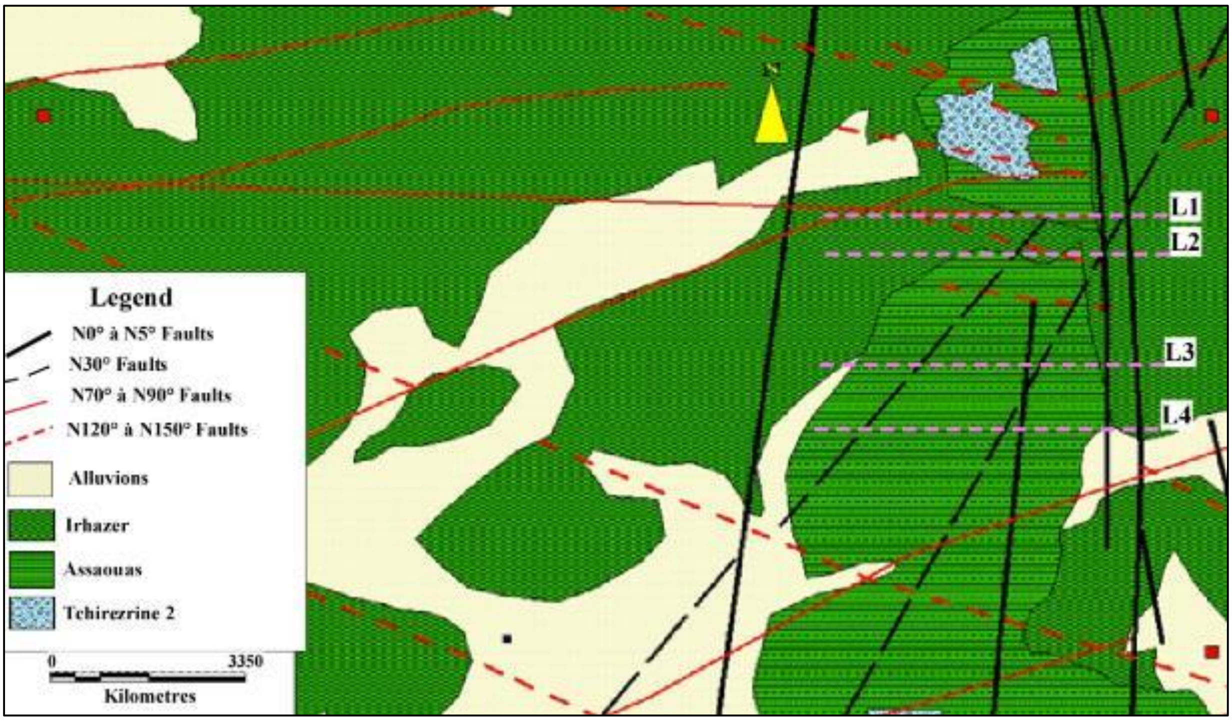

Figure 8 Geological map of the Toulouk sector showing the layout of the tectonic-sedimentary analysis sections of the study area (L1, L2, L3 and L4).

- The Tchirezrine II formation (Figs. 6 and 7), dated to the Jurassic, includes: medium to coarse arkosic sandstones with microconglomeratic levels, two or three levels of analcime sandstone or clay and analcimolite interbeds. The presence of silicified wood in the studed area is evidence of a Jurassic wet environment. The size of the quartz and feldspar minerals as well as their angular shape indicates a weak transport.

4.2. Tectonic-sedimentary analysis

Four lines of deep boreholes (Fig. 6) are located orthogonal to the axis of the orthogonal to the axis of the dome. An airborne geophysical survey map geophysical survey map is used as a support to justify the location of the drill holes of the holes in relation to the surface anomaly.

It should be noted that the different logs were interpreted according to the variation in geophysical resistivity parameters and the gamma radiometric reading. The results of the chemical analyses (essentially for their uranium content) were used to calibrate certain stratigraphic levels. Thus, three layers (A, B and C) were identified (Fig. 9).

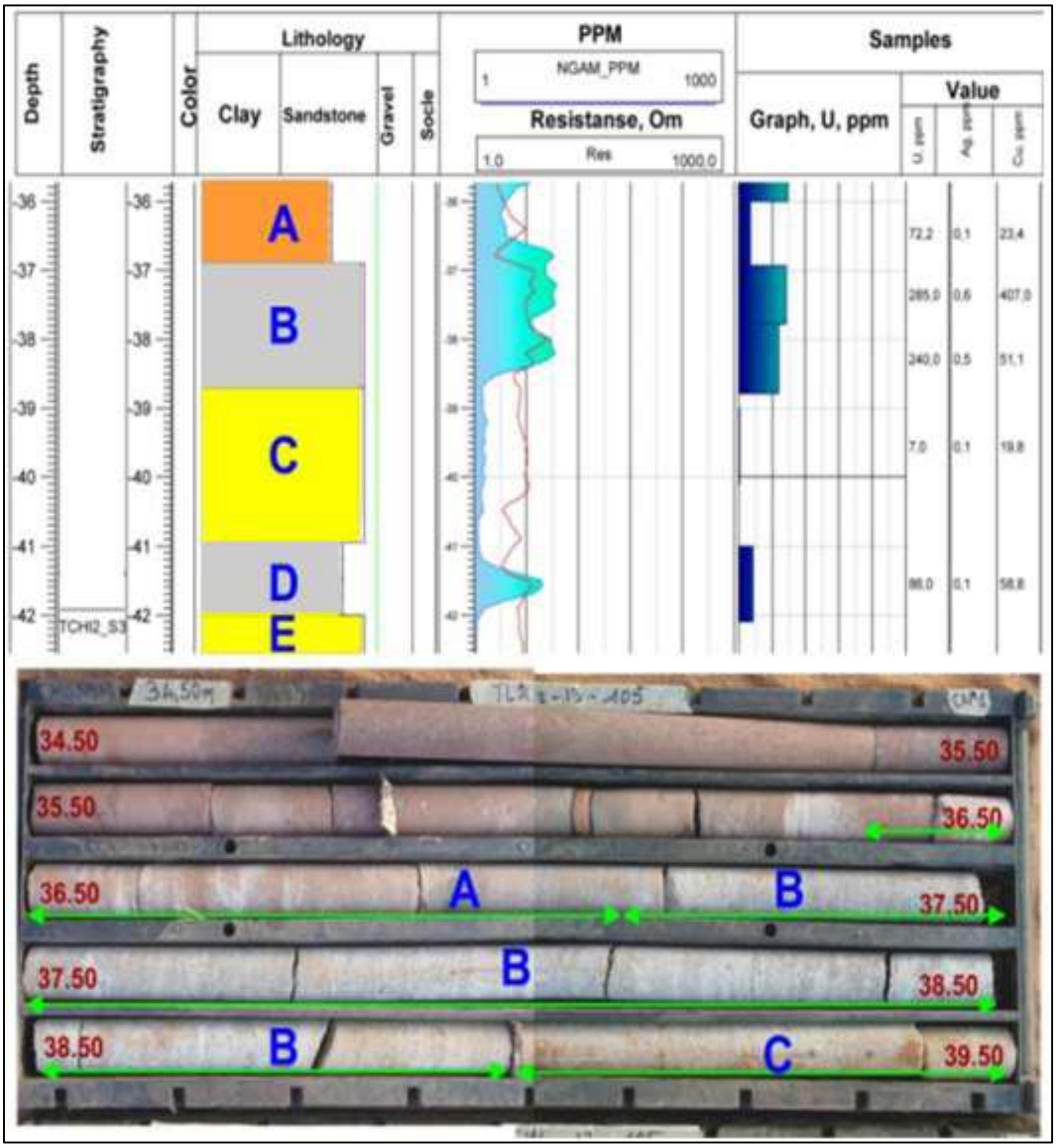

Figure 9 Correlation between lithology, logging and chemical analysis results.

Layer A (Fig. 9), which consists mainly of reddish analcime sandstone, shows a weak radiometric response. It is surmounted by a layer richer in analcime showing a stronger radiometric response. Here, radiocoring allowed us to locate the level of mineralization down to 34.20 m. Layers B and C (Fig. 9) represent sandstones of similar grain size but different compositions. The variation in lithofacies lies in the nature of the cement that probably trapped the uranium (U) in B.

4.2.1. Analysis of the first line (Location, Figure 8)

This section comprises 8 holes (Fig. 10), 3 of which (F03, F07 and F22) are very deep. The analysis of this section shows:

- A variation in the thickness of the Irhazer formation. The latter increases towards the eastern flanks and especially to the southwest of the dome. The powers of the Aswan, Chirezrine II and Abinky remain very little variable outside the large beds of the paleochannels.

- The Lower Carboniferous (Talak observed at F03) rests in major unconformity on the basement. The latter consists of leptynite in the study area.

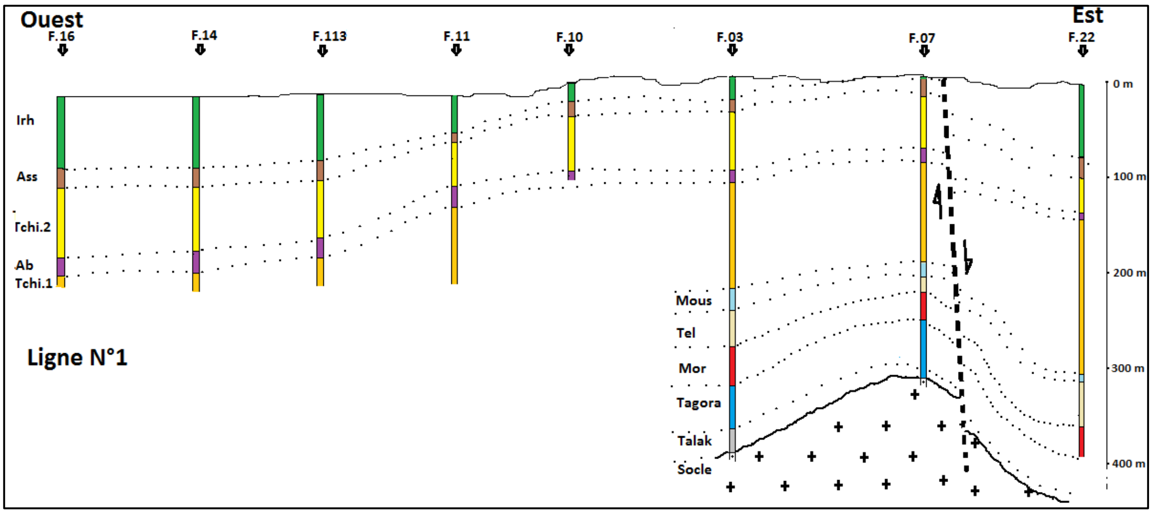

Figure 10 Correlation of line 1 soundings.

4.2.2. Analysis of the second line (location Figure 8)

At the level of this section 7 boreholes were concerned (Fig. 11). It was observed:

- As for the previous section, a variation in thickness of the Irhazer formation,
- A thickening of the Tchi2 formation in holes F23 and F44,
- Contrary to the previous section, here it is the Moradi formation that rests on the basement.

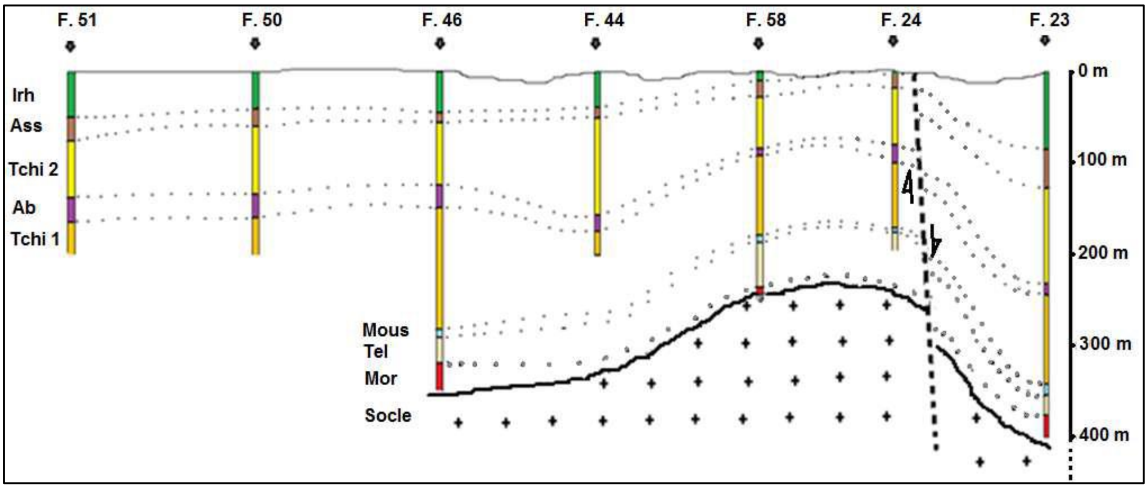

Figure 11 Correlation of line 2 soundings.

4.2.3. Analysis of the third line (location figure 8)

For this section five (5) boreholes were concerned (Fig. 12). The correlation carried out shows:

- A thickening of the Irhazer and Tchi2 especially at the level of hole F121 where the Irhazer reaches 100 m.
- Contrary to the previous sections, here it is the Teloua Formation that lies unconformably on the basement.

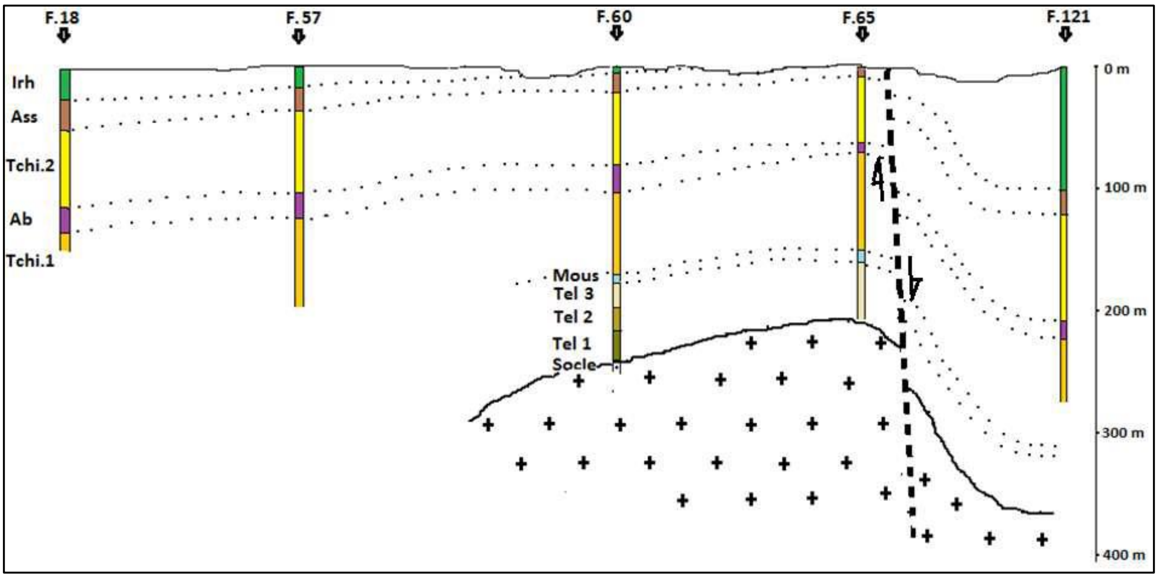

Figure 12 Correlation of line 3 soundings.

4.2.4. Analysis of the 4th line (location figure 8)

Here 7 holes (Fig. 13) were analyzed and show :

- Of all the drill holes analyzed none reached the basement,

- Thickening of the Irhazer and Tchi2 formations, especially in holes F122, F138 and F152,

- Thickening of the Tchi1 formation in borehole F122.

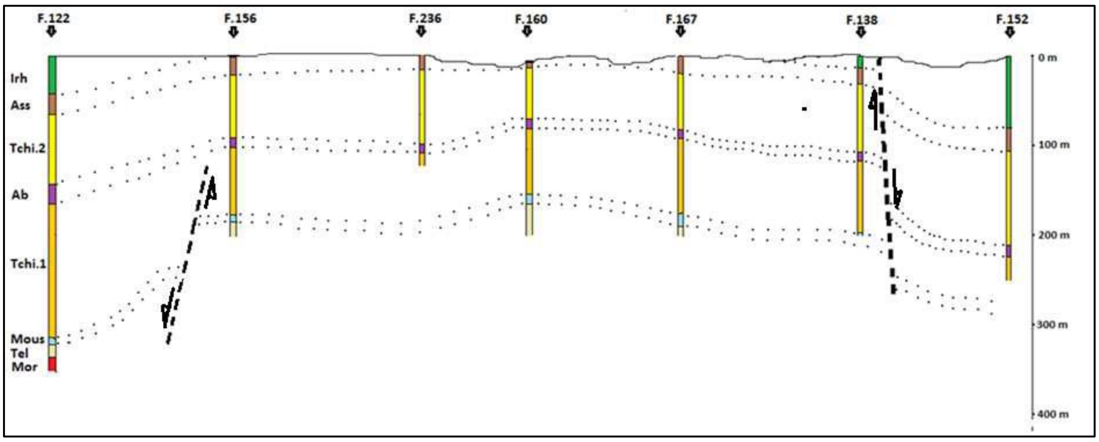

Figure 13 Correlation of line 4 surveys.

4.3. Analysis of the distribution of the mineralization

Prior to any drilling activity, the uranium mineralization should have been mapped. This was made possible by the use of a portable spectrometer (GF instrument and RS 230). In the study area, the host levels are characterized by the following lithofacies

- Very fine calcareous sandstones of the Assaouas formation with intercalations of clayey and/or ferruginous sandstones. The cement is sometimes ferrugino-analcimeous with occurrence of malachite.

- Conglomerates with analcime nodules most often marking the contact between the Assaouas and Tchirezrine 2 formations. The highest uranium contents were detected in the conglomeratic levels containing larger pebbles.
- The medium to coarse sandstones of the Tchirezrine 2 formation contain silicified tree trunks of metric to plurimetric size, up to 50 cm in diameter (Fig. 9). High radiometric values have been detected in these deposits.
- The fine sandstones of the Assaouas Formation contain malachite often associated with native copper.
- In this area, several factors seem to be responsible for the accumulation and distribution of uranium mineralization:

- The meandering aspect of the paleochannels, linked to the paleo-topography, would have influenced the orientation of the mineralized bodies. Correlations of geological drilling hole data show lateral and vertical variations in facies reflecting this meandering aspect of the paleochannels.
- High uranium grades are always associated with the presence of analcime in the Tchirezrine 2 sandstone, especially at the top of this formation. At the same time, copper mineralization has been identified in the calcite-bearing wrinkled sandstone of the Assaouas.
- The circulation of fluids in the fracture network and in the faults would have favored the concentration and accumulation of the uranium mineralization. This fluid circulation would have favored the formation of a ferruginous cement sometimes calcitic in the medium to coarse sandstones rich in analcime of the Tchirezrine 2 formation.

5. Discussions

In order to better characterize the deformation and uranium mineralization in this sector, the various data were reconciled. The exploitation of the drilling data allowed correlations to be made on either side of the axis of the dome. The results of this work were compared with those of the other sectors of the Tim Mersoï basin.

5.1. From the tectonic-sedimentary point of view

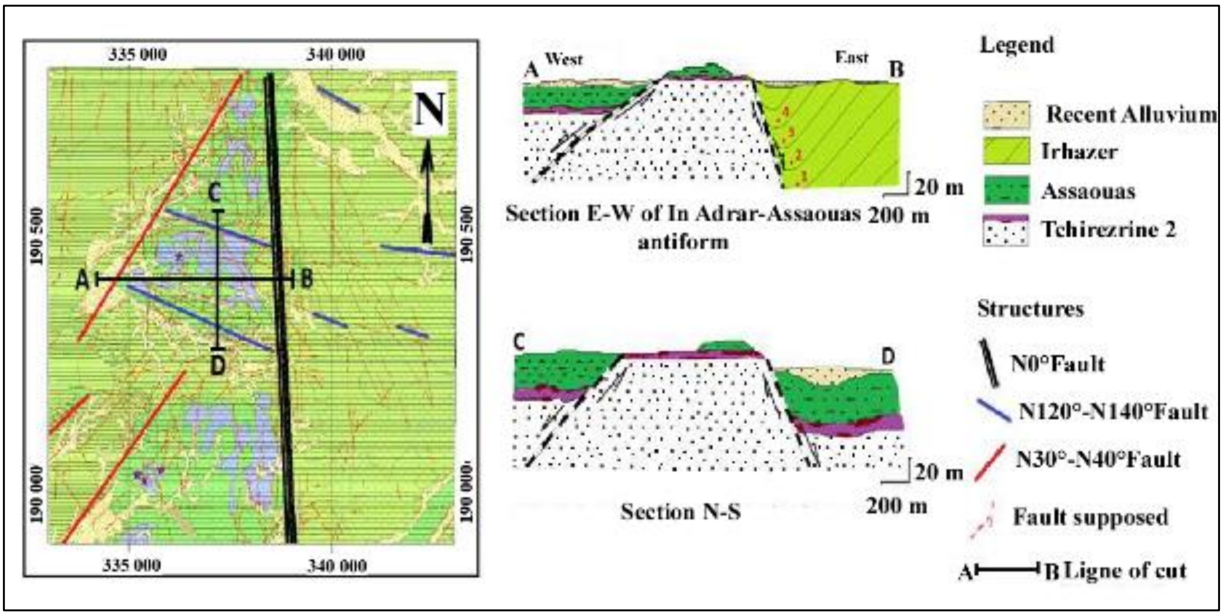

Figure 14 Structural model of the Toulouk sector, showing two orthogonal sections of the Maraliche Horst.

Important variations in thickness and facies for the Irhazer, Assaouas and Tchirezrine2 formations (Jurassic to Lower Cretaceous) have been highlighted. These variations in thickness and facies are organized along several tectonic directions: N0°, N30°, N80° and N140°. This would have favored a dome and half-graben structuring. This observation is in agreement with the work of [18], [19] who had highlighted during the same period (Jurassic to Lower Cretaceous) important variations in thickness and facies in the DASA sector for the same formations. Contrary to the Toulouk sector, where the structuring had favored the formation of a dome, at DASA, this structuring, in connection with the play of the N70° accidents would have favored the formation of a graben. At Toulouk, bevels in the layers have been demonstrated: (1) For the Tchirezrine 2 and Abinky formations, strong reductions in thickness (from 150 m to 50 m) from the center of the basin to the axis of the dome have been demonstrated; (2) For the Assaouas formation, the beveling of the layers is much more pronounced in the contact zone with the Aïr Massif. This horst and half-graben geometry is associated with a synsedimentary structuring of the Toulouk sector (Fig. 14).

At the level of section AB (Fig. 14), vertical and lateral migration of deposits towards the eastern boundary fault of the dome has been demonstrated. The horst observed in the northern part of the dome and the size of the discharge (50 m to more) reflect an extensive to extensive strike-slip regime as reported by [11] and [16] for the Tim Mersoï basin and [19] for the DASA area.

Also, folding in association with thickness variations have been demonstrated in this Toulouk sector. At the level of several deep boreholes, ductile levels were observed, mostly consisting of argillite and/or analcimolites sealing tectonic structures. These ductile levels are folded and show variable thicknesses depending on whether the borehole is located on the axis of the dome or on the flanks. These folds have been linked to the Late Cretaceous compressive phase by [11], [12], [19], [21], [24], [25], [27].

5.2. Uranium mineralization

In the Toulouk sector, uranium mineralization is most often disseminated either in the grey analcimeous sandstone of Tchi2 or in the clayey sandstone of Assaouas. The mineralized sandstones of Tchi2 are also rich in organic matter and often in pyrite. It should also be noted that this mineralization is often associated with malachite. In the Tim Mersoï Basin, several authors ([15], [26] and [27] for the Imouraren deposit, [15] for the Tim Mersoï Basin deposits, [18],[19],[24] for the DASA deposit) had shown that Jurassic mineralization (contained in the Tchi2 sandstones) is associated with levels of sandstones rich in organic matter, pyrite or analcime.

As for the distribution of mineralization, the combination of drilling hole data, logging and spectrometric surveys has allowed us to establish a model for the Toulouk sector (Fig. 15).

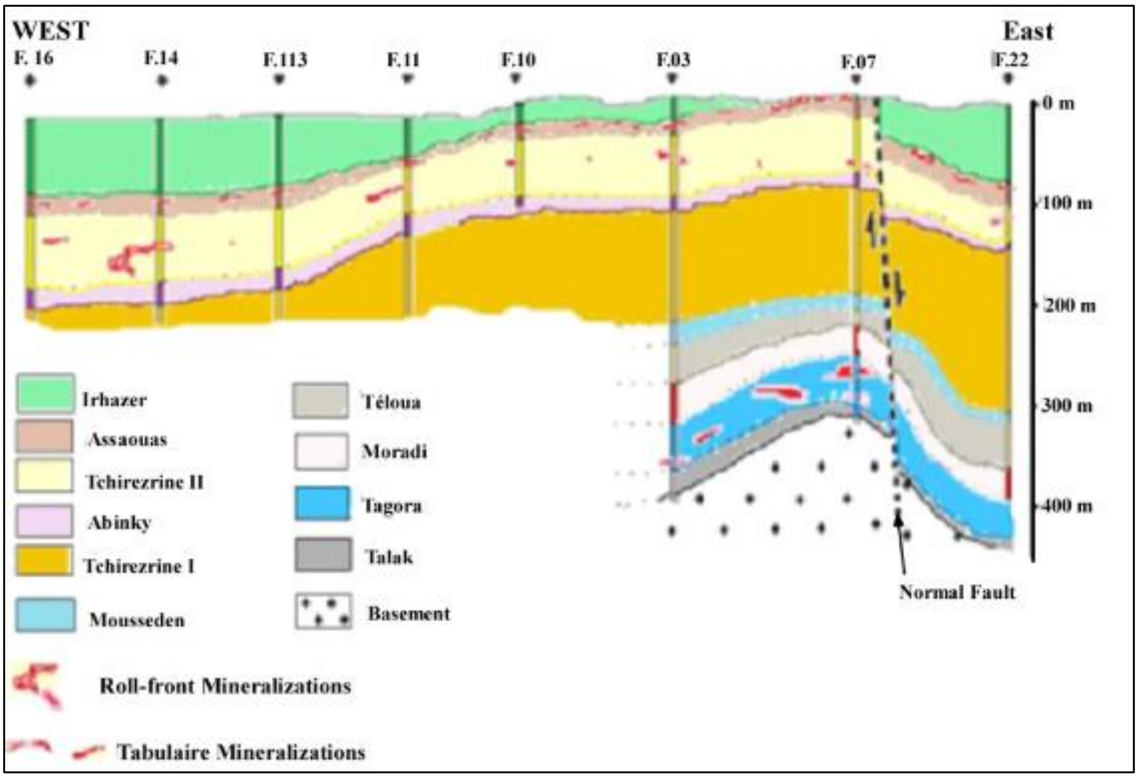

Figure 15 Distribution model of uranium mineralization in the Toulouk sector.

It should be noted that a horst and graben structuring has been highlighted for the Toulouk sector. This structuring, associated with synsedimentary folding has favored the formation of hydrothermal fluid circulation zones. This structuring has greatly shaped the paleochannels which are very favorable places for the concentration of mineralization. This observation has already been mentioned [12] for the Arlit sector and [18] for the DASA sector. Form [15] these folds would have played a topographic role by creating high zones and depression zones favorable to fluid circulation. [18], [23] and [27] have shown that the relationship between uranium and organic matter results in an interaction from the formation of the mineralized complex, transport to the reduction and precipitation of uranium.

6. Conclusion

The correlations of the Jurassic-Cretaceous formations on both sides of the axis of the dome of In Adrar-Assaouas, consisted essentially in the acquisition and exploitation of cartographic data, borehole data and logging data. This allowed to highlight:

- Variations in thickness (lateral and vertical) and facies of sedimentary layers. These variations reflect the effects of extensive and compressive synsedimentary tectonics. The latter is responsible for the structuring of the basin into horsts and grabens,
- The structuring thus highlighted would be associated with a primary concentration of uranium.
- Uranium mineralization is related to sediments rich in organic matter, pyrite and/or analcime, often in association with Cu.

This work shows that the factors that favored the development of uranium mineralization in the Toulouk sector are: the sedimentological factor, the paleogeographical factor, and especially the structural factor, which played a major role during the reactivation of the Pan-African faults. The multiple faults and late fracturing would have facilitated the circulation of hydrothermal fluids which would have been enriched in their course before ensuring accumulation in favorable environments (paleochannels rich in organic matter, pyrite and/or analcime).

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] MOUSSA, Y. Sedimentary dynamics of the Guézouman and underlying target formations in relation to tectonics, volcanism and climate, PhD these, 1992, Bourgogne University, 341p.

[2] Joulia. The primary series to the N and NW of the Aïr (central Sahara). Discordances observed. - Bull. Soc. geol. Fr., 1959, p.192-196.

[3] Imreh L. Azelik Mission, prospecting campaign report, 1958, 37 p.

[4] Tauzin P. Geological setting of uranium deposits on the eastern edge of the Tim Mersoï sedimentary basin (Niger), 1981, 40 p.

[5] Elhamet, M.O. Geological and petrographic analysis of the Tarat Formation in the Somaïr pits (Upper Palaeozoic). An experimental palaeoclimatic interpretation in the early Carboniferous glacial period (Arlit region - northern Niger). [Ph.D. thesis], 1983, Dijon University de Dijon (France) and Niamey University (Niger), 279 p.

[6] CEA. Internal report, 1963, 1971.

[7] Cogema. Internal report. 1977.

[8] Valsardieu C. Geological and palaeogeographical study of the Tim Mersoï basin, Agadès region (Republic of Niger). PhD thesis, 1971, Nice University, 518p.

[9] Joulia F. Geological map of the western sedimentary edge of the Aïr at 1:500,000 scale. Published by BRGM, 1963, Orléans, France.

[10] Greigert J. et Pougnet R. Attempt to describe the geological formations of the Republic of Niger, 1967,

[11] Gerbeaud, O. Structural evolution of the Tim Mersoï Basin: Deformations of the sedimentary cover, Relations with the location of uranium deposits in the Arlit sector (Niger). PhD thesis, 2006, Paris-South University UFR scientific of Orsay, 270 pages.

[12] Forbes, P. Influence of sedimentary and tectonic structures, regional alkaline volcanism and diagenetic-hydrothermal fluids on the formation of U-Zr- Zn-V-Mo mineralisation at Akouta (Niger): PhD thesis published by the Uranium Geology Research Centre (CREGU), 1989, Nancy, v. 17, 376 p.

[13] Pacquet A. Analcimes and diagenetic clays in the sedimentary formations of the Agadès region (Republic of Niger) [Ph.D. thesis], 1968, Strasbourg University, 258 p.

[14] Abdoulaye A., Konaté M., Harouna M., Moussa Y., Paolo R. and Gemma T. P. X-ray diffraction characterization of analcimes from the Tim Mersoï basin (northern Niger), 2007, doi:10.1016/j.crci.2007.02.002.

[15] Mamane M. M. he metallogenic system of uranium deposits associated with the Arlit fault (Tim Mersoï Basin, Niger): diagenesis, fluid circulation and metal (U, Cu, V) enrichment mechanisms.PhD thesis, 2016, Lorraine University, 402 pages.

[16] Konaté, M., Denis, M., Yahaya, M., and Guiraud, M. Extensive Devono-Dinantian structuring of the Tim Mersoï basin (Western edge of the Aïr, northern Niger). Published in: University of Ouagadougou, Annals, Series C, 2007, v. 005, 32 p.

[17] Wright, Li. Study of the Anou Araren-Solomi coalfield, Phase 1: Data study; Aïr coal, Coal Mines of France with British Mining Consultants Ud. 1980, 21- 41-51 pp.

[18] Sani, A., Konaté, M., Karimou, D. H. and Wollenberg, P. Polyphasic tectonic history of the N70° DASA Graben (northern, Niger). Global Journal of Earth and Environmental Science, 2020, Volume 5(3), Pages 58-72.https://doi.org/10.31248/GJEES2020.075.

[19] Sani A. The effect of N70° faults in the emplacement of uranium mineralisation in the Tim Mersoï basin: the case of the DASA graben, western edge of the Aïr (northern Niger). PhD thesis, 2020, Abdou Moumouni University, Niamey, Niger.

[20] Sempéré T. The sedimentary context of the Arlit uranium deposit (Republic of Niger), 1981, 375 p.

[21] Wagani I. Uranium potential of volcanic sources considered for the formation of mineralisation in the Arlit region (Niger). Thesis, 2007, University of Paris XI, Orsay, 283p.

[22] Salze D., Belcourt O and Harouna M. The first stage in the formation of the uranium deposit of Arlit, Niger: Role of a new non-continental organic matter, 2018, https://doi.org/10.1016/j.oregeorev.2018.09.021. 0169-1368/ Elsevier.

[23] Salze D. Study of interactions between uranium and organic compounds in hydrothermal systems, (PhD thesis), 2008, Université Henri Poincaré (Nancy1), 301p.

[24] Sani A., Souley B. I., Laouli I. K., Konaté M. The Tim Mersoï Basin in Niger, a Basin with Unusual Uranium Bearing Potential. Research Journal of Engineering Sciences, 2023, Vol. 12(3), 15-23.

[25] Guiraud, R. Boureïma, O., and Robert, J. P. Evidence of shortening deformations in the Mesozoic of the Aïr periphery (Niger). Proceedings of the French Academy of Sciences, Paris., 1981, 282 (II): 753-756.

[26] Billon S. Clay minerals in the Imouraren uranium deposit (Tim Mersoï Basin, Niger): implications on the genesis of the deposit and on the optimisation of ore treatment processes. Thesis Earth solids and surface envelopes. Poitiers: University of Poitiers, 2014. http://theses.univ-poitiers.fr.

[27] Mamane M. M., Cathelineau M., Deloule E., Schimtt R. et Brouand M. Cenozoic oxidation episodes in West Africa at the origin of the in situ supergene mineral redistribution of the primary uranium ore bodies (Imouraren deposit, Tim Mersoï. Basin, Northern Niger), 2019, Mineralium deposita. https://doi.org/10.1007/s00126-019-00945-w.