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Faciological Sectioning and Mapping of Intra-Tarat Mineralization Systems in the Taossa Sector of SOMAIR (Tim Mersoï Basin, North-West Niger)

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ABSTRACT

This work focuses on the sedimentological study of the Taossa deposit (Tim Mersoï Basin), one of the ore deposits belonging to the concession area of SOMAÏR (Société des Mines de l'Aïr). The Tarat Carboniferous formation hosts numerous uranium deposits, including the Taossa deposit. The study of this deposit led to the proposal of a new division based on intra-Tarat facies characteristics. The Tarat formation has thus been subdivided into five units (instead of four). These are, from bottom to top: U1, U2, U3G, U4a and U4b. Each of these units is distinguished from the others by its specific facies pattern. Thus, the U1 unit consists of coarse to very coarse microconglomeratic sandstones, the U2 unit consists of argillites or alternating argillites-fine sandstones, U3G sub-unit consists of coarse to very coarse sandstones at its base. U4 is subdivided into 2 sub-units (U4a and U4b). U4a encompasses the summit part of Unit U3 and the fine sandstone base of Unit 4, and U4b consists of Tarat-Madaouéla argillite or clay-silt alternations in the Taossa area. The advantage of this division is that it could facilitate ore categorization during the mining phase. Isohypsic and isopaque

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maps of the various intra-Tarat units have also been produced. They show that the Tarat sediments were deposited in a fluvio-deltaic environment. Geological modeling suggests that uranium mineralization at the Taossa deposit is concentrated along the flanks of anticlines and synclines, which are sites of preferential accumulation of organic matter and sulfides, reputed to be reducing and fixing agents for uranium.

Keywords: Faciological Sectioning; Intra-Tarat Mineralization; Taossa Deposit; Tim Mersoï Basin; SOMAÏR

1. Introduction

The Tim Mersoï basin, located on the western edge of the Aïr granite massif, is a world-famous uranium province^[1,2]. The deposits are hosted in sandstone formations^[3,4]. Mineralizations are spatially associated with fault zones, major tectonic lineaments and small grabens^[5–7]. Appearing at different geological periods, these mineralizations range from the end of the Viséan to the terminal Carboniferous, then from the Jurassic to the Cretaceous with a probable remobilization in the Tertiary^[8,9]. In terms of reserves, Niger is one of the leading countries in the world^[9]. In the center and periphery system^[10], Niger is a peripheral country and maintains a comfortable seventh place as a global uranium producer and second in Africa after Namibia^[8]. Today, apart from the DASA site, which is in the development phase of the mining complex, the Société Minière de l'Aïr (SOMAÏR) is the only company that exploits uranium in Niger. The Akouta mining company (Cominak) has just closed its facilities in 2021^[11]. SOMAÏR has until now only exploited deposits in Arlit with relatively high grades, such as Tamgak, Taza, Tarkiza, Tamou, Ariege, Arlette and Artois^[12,13]. The Artois deposit, divided into several sectors (Grand Artois, Artois Nord and Artois Sud), is the only deposit currently being exploited. In an effort to increase its reserves, SOMAÏR is returning to carrying out development work in sectors previously considered to be weakly mineralized^[8].

Given the depletion of current resources at the SOMAÏR open-pit mine, the main challenge facing this national company today is, of course, the development of low-grade uranium deposits that are economically viable. Indeed, during various exploration efforts over the years of operation, a number of deposits were identified and classified as unprofitable. However, current challenges and rising uranium prices have led to the consideration of a rational exploitation of these deposits. With the aim of ensuring economically viable mining, studies have been undertaken to better under-

stand the geology of these deposits. This study provides a detailed geological analysis of the Taossa deposit, one of the most significant targets in the Tim Mersoï Basin, located within the Tarat Formation. With this in mind, since 2011, this sector of Taossa has been the focus of large-scale work carried out by SOMAÏR, whose activities had slowed following the drop in uranium prices. However, with the rise in uranium prices since 2022, this sector is now the subject of a series of large-scale sedimentological and structural studies focusing on the main sedimentary systems of the deposits. The objective of this article is to gain a better understanding of the mechanisms of concentration and/or preconcentration of uranium mineralization in the Taossa area. Based on geological data, the aim is to propose a new facies-based subdivision of the Tarat Formation. More specifically, the aim is (i) to identify and characterize the distinctive features of the sedimentary systems and (ii) to propose a new intra-Tarat stratigraphic division, with the primary goal of optimizing ore extraction and processing techniques in the Taossa sector.

This study presents the results of a sedimentological analysis incorporating field data, logging data, gamma-ray data, and mapping data and proposes a new review of the facies classification of the Tarat Formation. To this end, the article is divided into three (3) main sections: (i) the section on materials and methodology, (ii) the section presenting the results, and (iii) the section discussing the results.

2. Geological Framework of the SOMAÏR Deposits

Most of the deposits exploited by SOMAÏR are located some seven kilometers west of the town of Arlit (**Figure 1**). Born following the discovery of uranium in 1958^[14], Arlit is located 245 km north-northwest of Agadez and approximately 1,215 km from Niamey (the capital of Niger) (**Figure 1**)^[15]. On the western edge of the Aïr crystalline

massif and at the northeastern end of the Tim Mersoï Basin, the parallels 18°35' and 18°43' and the meridians 7°15' and 7°20'.

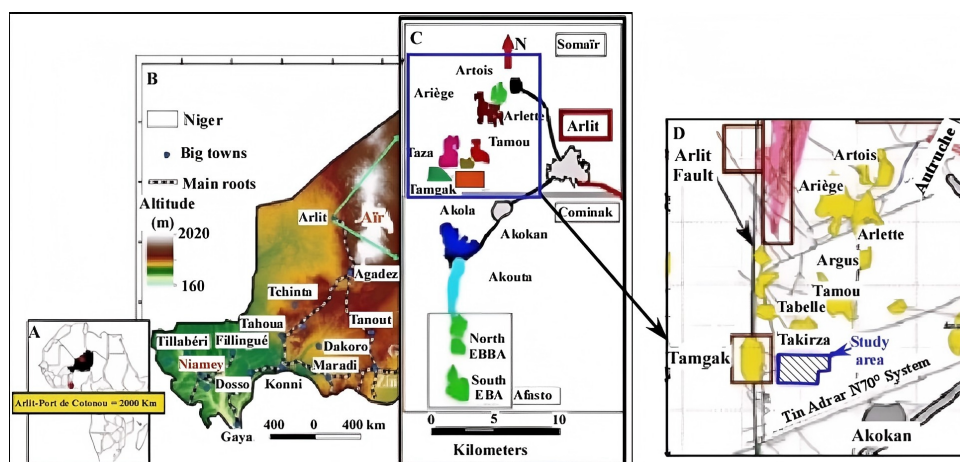


Figure 1. Geographical location of the Arlit region and the study area^[15].

The surveys carried out within the Tim Mersoï Basin have made it possible to divide it into six (6) sedimentary series and/or groups. These are the Têrada, Tagora and Izé-gouandane series, as well as the Agadez and Irhazer groups, which are locally surmounted by the Tégama series^[8]. The host formation (the Tarat) of the uranium mineralizations exploited by SOMAÏR was identified at the level of the Tagora series (Carboniferous: Viséan-Westphalian)^[15]. Resting unconformably on the argillites and sandstones of the Tchinzogue, the Tarat Formation (10–100 m)^[16] constitutes the basal part of the uppermost sequence of the Tagora series. It is composed mainly of argillaceous sandstones and reduced coarse sandstones rich in organic matter^[8].

On the vertical plane, a sequence of deposits with fluvio-deltaic characteristics emerges, with frequent ravine surfaces and synsedimentary games of brittle tectonic accidents that control the direction and the power of the Tarat sandstone deposits^[17,18]. From the wall to the roof, the Tarat formation is composed of four sedimentological units, namely: (i) Unit U1: Coarse to very coarse kaolin sandstones, light gray or whitish in color; (ii) Unit U2: Medium to coarse sandstones with clayey layers, light to dark gray in color; (iii) Unit U3: Composed of medium to fine sandstones, light gray in color; and (iv) Unit U4: Composed of clayey-silty sandstones, light to dark gray in color.

The deposits exploited by SOMAÏR are known to be a combination of tabular and tectono-lithological deposits^[19]. Thus, the distribution of mineralization within the units varies

considerably^[16,20]. Impermeable clay levels are commonly located above or below the mineralized zones^[16,21]. According to Valsardieu^[22], the Tarat is highly silicified with a porosity that decreases as one approaches the In Azouza-Arlit flexure-fault. The latter represents, on a regional scale, a major N–S-oriented accident system^[21], in addition to having a normal play that lowered the western compartment by an average of 200 m^[4,21,23]. For Konaté et al.^[5], such a system would be reactivated in dextral strike-slip in the terminal Viséan, while Cuney, Guiraud et al., and Salze^[21,24,25] stated that it would be sinistral in the Cretaceous.

Among others, satellite faults (Madaouela fault: 30° N and 40° N) exert a control on the orientation of the paleochannels in the Tarat^[21]. Also, the 70° N–80° N beam of Tin Adrar, which acted as a normal fault in the Viséan^[5,21] or as a left-lateral strike-slip fault^[5], exerts a control on the spatio-temporal distribution of the deposits. In this regard, Salze et al., Billon et al., and Abd Elmola et al.^[26–28] confirmed that all the Tarat deposits are located to the north of the said beam.

3. Materials and Methods

3.1. Materiels

The data used in this study include, in particular: reports from exploration campaigns in the study area and drilling data from the study zone; logging data, including

lithological and logging sections, as well as measured mineralization data and structural data collected in the field. The tools used primarily consist of drilling equipment, logging equipment, and computer software (modeling software).

3.2. Methods

The methodological approach implemented in this study includes:

- The sedimentological analysis consisted of describing the cuttings and outcrops, as well as the log data. This made it possible to propose a new facies subdivision of the Tarat Formation. This sedimentological analysis focused on the description of cuttings and outcrops (mine faces). The sedimentological logs were generated using WellCAD software, and these logs were correlated using diagrammatic logs;
- The tectonic-sedimentary analysis made it possible to study the relationships between tectonics and sedimentation in the Taossa area, in particular the vertical and lateral changes of facies. This made it possible to identify the causes of facies changes. For the tectonosedimentary analysis, borehole sections were used. Two EW sections located in the NE and SW parts of the deposit were used. The selection of these sections was guided by the orientation of the major geological structures and, in particular, by the uranium mineralization;

- To better understand the sedimentary filling of the Taossa deposit, contour and isopach maps were produced. These maps are an excellent tool for understanding erosion and deposition processes in a sedimentary basin. The analysis of the isohypse and isopach maps was used for the analysis of the sedimentary systems in the study area. This made it possible to propose a model for the deposition of the Tarat formation for the said area.

It should be noted that to carry out this study, a number of software programs were used: Wellcad, Surfer, and MapInfo.

4. Results

Provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

4.1. Sedimentological Analysis

In the study area, sedimentological analysis was carried out on both faces and boreholes. Analysis of the facies enabled us to propose a vertical sequence of facies (**Figure 2**) in the area where the deposit was discovered. The various formations identified include, from base to top: the Tarat, Arlit, and Izégouande (**Figure 2**).

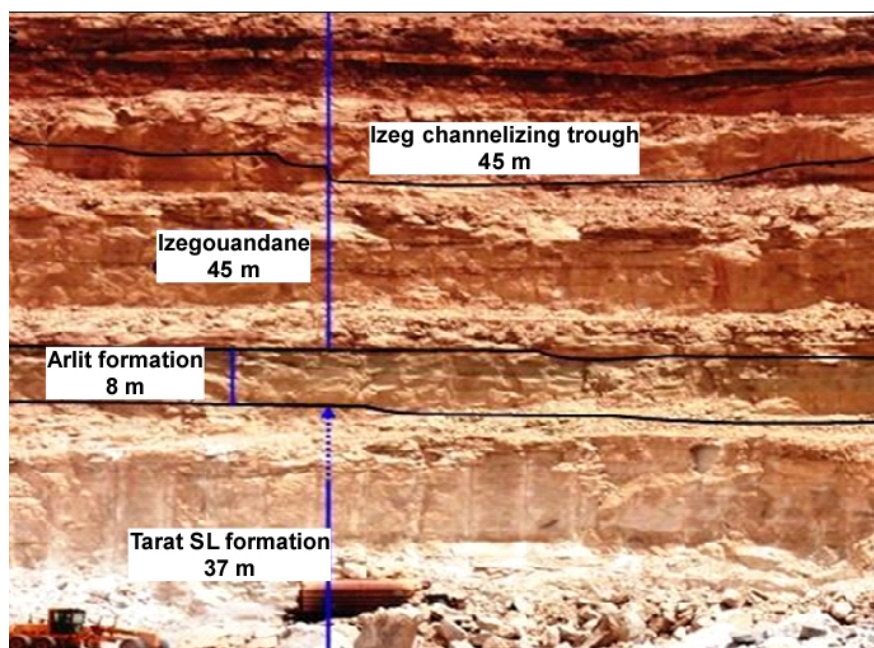


Figure 2. Parement in the Taossa open pit.

Most of the boreholes drilled were destructive. They show the vertical succession of different lithofacies in the study area. Four formations were identified. These are, from base to summit: the Tchinezogue Terminal Unit (UT), the Tarat, the Arlit and the Izéguande (Figure 3). Thus, on the basis of facies characteristics, an intra-Tarat division has been drawn up. This breakdown incorporates information

derived from the description of facings and cuttings, and from data analysis (Figure 4).

Compilation of cuttings and logging data has enabled us to produce a lithostratigraphic log for the Taossa area (Figure 5). Analysis of the log (Figure 5) shows that uranium mineralization is located in unit U1 (Tarat base unit).

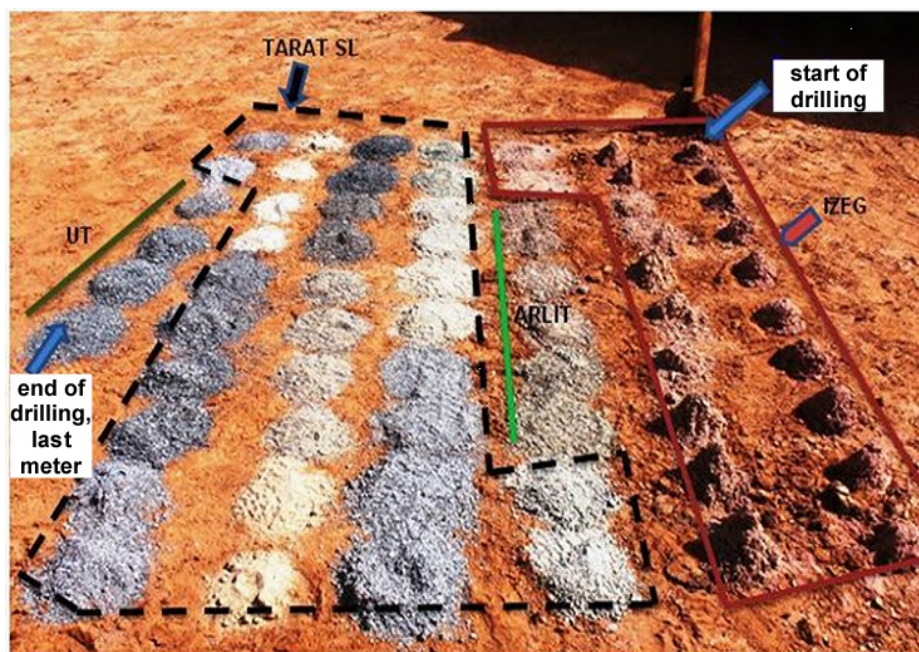


Figure 3. Layout of cuttings highlighting the lithological succession in the Taossa deposit.

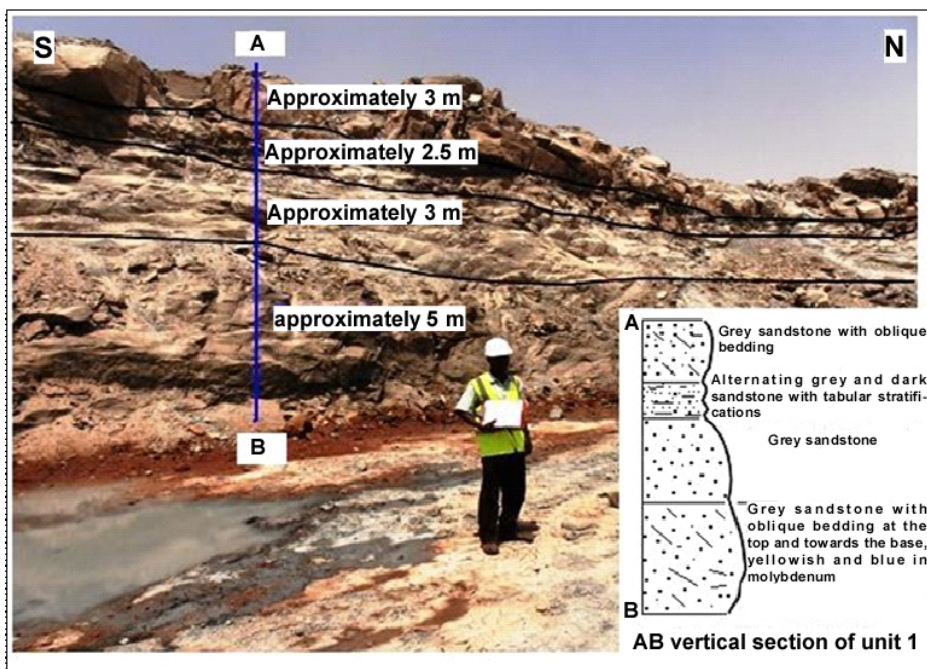


Figure 4. Survey of a face at the Taossa deposit.

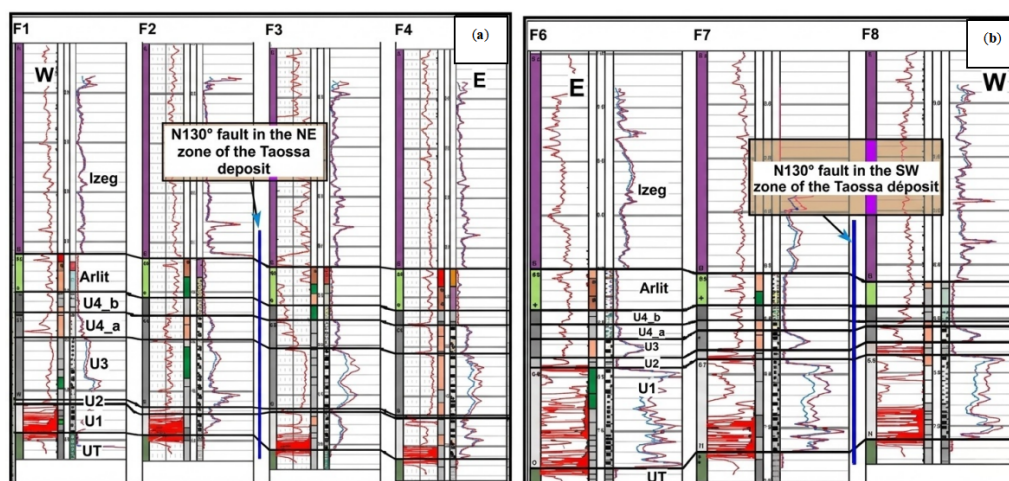


Figure 5. Lithostratigraphic correlations of the Taossa deposit: (a) NE zone; (b) SW zone.

Note: The 130° N fault transition zone, shown in blue color.

4.2. Tectono-Sedimentary Analysis

Like most deposits in the SOMAÏR area, the Taossa deposit lies to the east of the Arlit fault-flexure. Structurally, the Taossa deposit is characterized by 130° N brittle faults, which divide the area into high zones (anticlines) and low zones (synclines). The various geological sections show that the deepest boreholes are located in the eastern zone (**Figure 5**). On the other hand, the shallowest boreholes are located in the extreme west of the deposit. The cross-sections (**Figure 5**) also show that the play of the two main 130° N faults did not produce significant discharges, but would have resulted in lateral and vertical variations in the facies of certain stratigraphic units. This points to synsedimentary tectonics. For example, Unit 2 thins to the east of the 130° N fault, while Unit 1 thickens (**Figure 5a**). Also, Arlit and U4 are more developed to the east of the 130° N fault, whereas they become thinner to the west of this structure (**Figure 5b**).

❖ Analysis and Evolution of Intra-Tarat Facies

Facies can be defined as all the lithological and palaeontological characteristics of a member, formation or group of sedimentary deposits at a given location. For the purposes of this study, petrographic characteristics were examined, including grain size, shape and binding phase.

❖ Causes of Facial Change

In general, the causes of facies change are multiple and multiform in nature, due to the diversity of factors influencing sedimentation during the filling of a given depositional environment. Indeed, it is undoubtedly very important to

highlight two main causes in the context of this work:

Transgressions and regressions are obvious causes of facies change. In the case of a transgression, it is possible to encounter fine, then medium, and finally coarse material on the same horizontal, moving toward the continent, while the opposite phenomenon is observed in the case of a regression;

Syn-sedimentary tectonics induce lateral variations in facies on the same horizontal plane on either side of the tectonic structure (syn-sedimentary faults). In the specific case of the Taossa Sector, 130° N structures have had an influence on sedimentation.

❖ Characterization of Lateral and Vertical Facies Change

Vertical facies change is a logical evolution of a sequence in a normal sedimentary system. From bottom to top, a normal sedimentary series should contain the following terms: pebbles and gravel, sand, clay, carbonate and evaporite. Evaporites are usually excluded. For a tectonic sequence, vertical variations are represented by tectonic jerks. The most frequently encountered terms are coarse sandstone detritus at the base and then at the top, fine to clayey detritus and finally carbonate. Lateral variations are most often characterized by abrupt changes in lithology on the same horizontal plane and for the same depositional episode. In the Taossa deposit, lateral facies changes go hand in hand with vertical variations.

❖ New Intra-Tarat Division

The Tarat is the formation that hosts all the deposits in

the SOMAÏR domain, including the Taoussa deposit, which is the subject of this study. Once the reserves have been estimated and an effective and efficient feasibility study carried out, each deposit whose economic profitability has been justified is ready for exploitation. To optimize production during this phase, ores are classified not only by grade but also by host lithology (M6 clay or M4 sandstone, for example). The lithology of ores can also be used to budget the plant, which will lead to a request for a category of ore with a well-defined lithology that can satisfy its technical capacities in a given

time. Sandstones, for example, cause less financial impact than clays, which consume far more chemical reagents and are considered penalizing factors to some extent.

Taking into account all these characteristics, which are not only technical and financial but also geological, a new intra-Tarat division has been proposed, focusing on the resistivity and NGRS probe signals of the different lithofacies described on the geological logs. This breakdown shows, from bottom to top, the vertical succession of the following units in the Tarat of the Taoussa deposit (**Figure 6**).

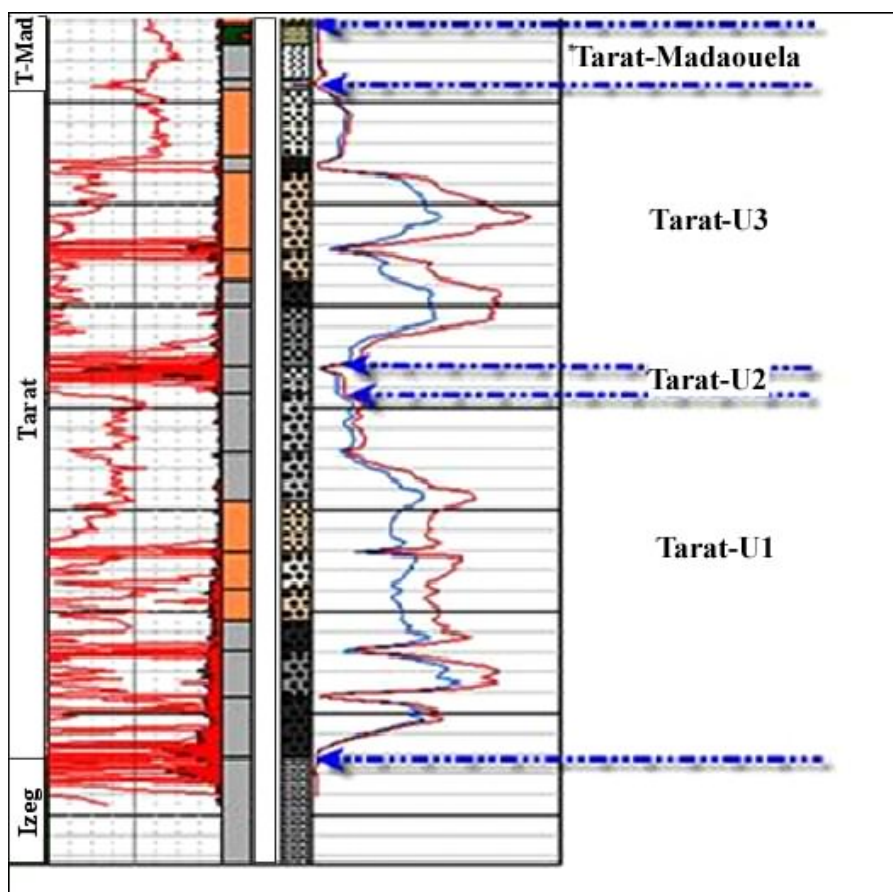


Figure 6. New intra-Tarat division of the Taoussa deposit.

The Tarat U1 unit consists of coarse to very coarse microconglomeratic sandstones. The U1 facies can be considered unitary at the mine and the whole can benefit from the same technical treatment process when mineralized;

The U2 unit at Tarat consists of argillites or alternating argillites-fine sandstones. The U2 facies can be considered clayey at the mine and requires the same technical processing considerations when mineralized;

Unit 3 has a U3G sub-unit consisting of coarse to very

coarse sandstones at its base. This lithology is classified in the same category as U1 at mine level;

Tarat U4 has been subdivided into two sub-units, U4a and U4b:

Unit U4a encompasses the summit part of Unit U3 and the fine sandstone base of Unit 4 in certain parts of the deposit. It therefore consists of fine to medium sandstones with clay fractions. When U4a is mineralized, it is classified in the mine as a coarse clay mineral;

Unit U4b consists of Tarat-Madaouéla argillite or clay-silt alternations in the Taossa area. The lithology of U4b can be considered identical to that of U2 for the mine;

The latitudes and thicknesses of all these units are used to produce isohypsic and isopach maps to study depositional systems.

Using the resistivity and natural gamma ray (NGRS) signals, all five of these clearly distinguishable intra-Tarat units (**Figure 6**) were identified, and the dimensions were determined using WellCAD cross-sections. Thicknesses and elevations were determined and used to map the sedimentary systems.

4.3. Cartography of Sedimentary Systems

The main sedimentary systems found at the Taossa deposit are mainly channels. By definition, these correspond to a set of trough morphologies that offer the particularity of being represented in a variety of variants. They are the preferred location for sediment flow and deposition. To study the paleogeographic behavior of these sedimentary systems during the deposition of the intra-Tarat units, isohypsic and isopach maps were produced for the various Tarat units in the study area.

4.3.1. Analysis of Isohypes Maps

By definition, isohypses are curves of equal elevation of geological formations. For this study, the elevations of all intra-Tarat units resulting from the proposed new division were used. The isohypses maps (5 figures in this subsection) were produced using MapInfo software. Analysis of the isohypses maps shows:

The isohypsis map of the Tarat U1 unit (**Figure 7**) shows that the south-western part of the Taossa Sector was elevated, while the eastern and south-eastern parts corresponded to subsided areas. The sedimentary input was NW to SE.

The isohypsum map of Tarat Unit U2 (**Figure 8**) shows that the direction and orientation of the channel axis did not change significantly at the start of deposition of Tarat Unit U2. The flow diverged, defining a meandering morphology (**Figure 8**). Thus, the south-west quadrant representing the convex bank of the meandering channel would be the preferred zone for deposition of this unit.

The U3G isohypses show that the eastern part of the sector is the low-altitude zone, while the elevated part corresponds to the southwestern strip of the sector (**Figure 9**). Sedimentary inputs are directed east and northeast, in line with flow directions (**Figure 9**).

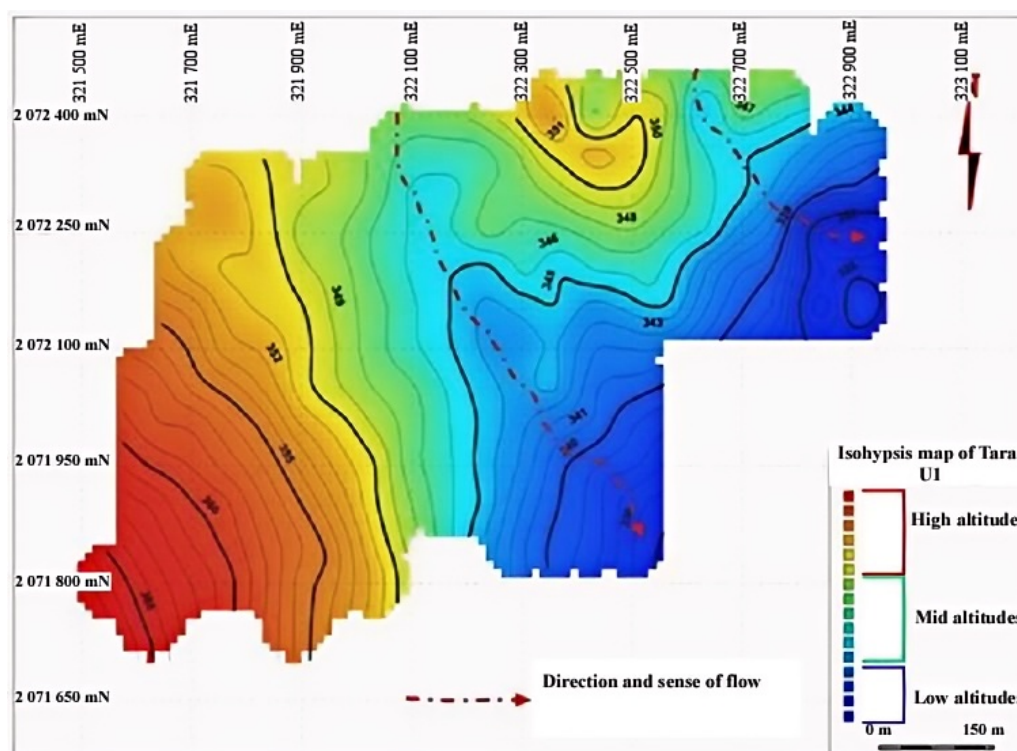


Figure 7. Isohyps map of Tarat unit U1 of the Taossa deposit.

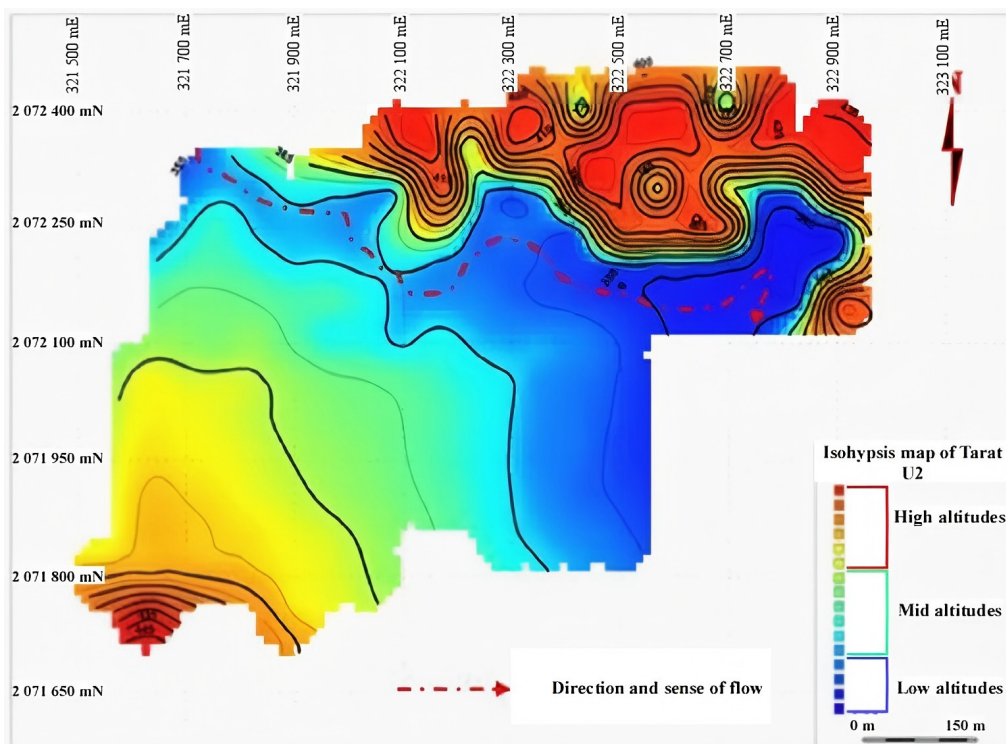


Figure 8. Isohyps map of Tarat unit U2 of the Taossa deposit.

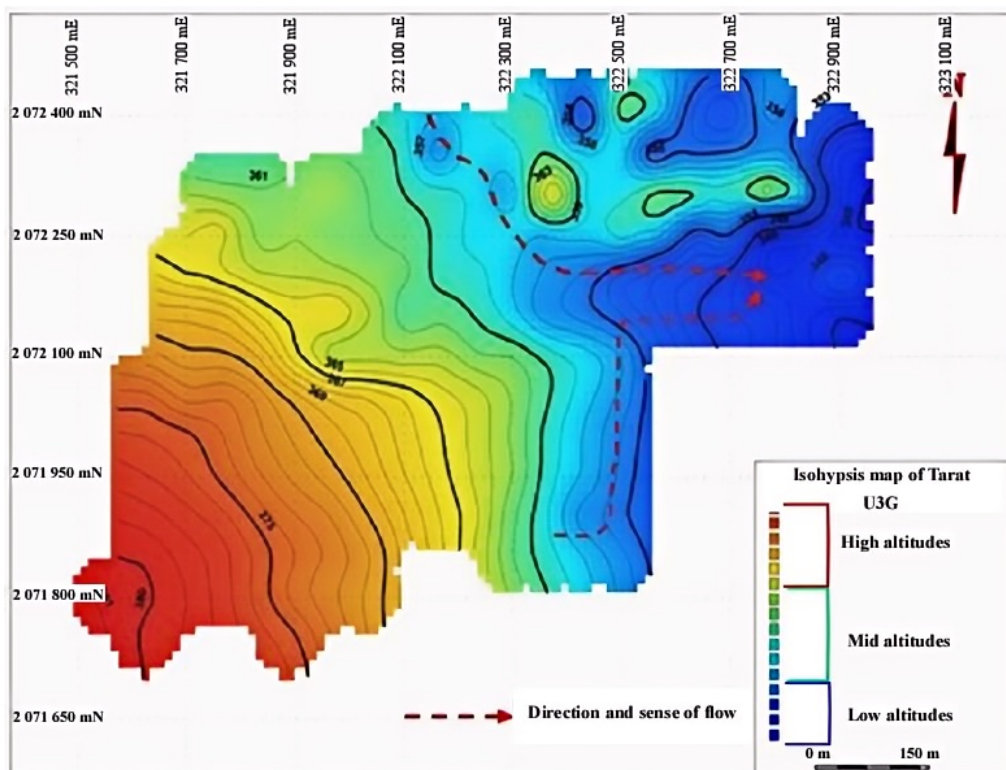


Figure 9. Isohyps map of Tarat unit U3G of the Taossa deposit.

The isohypse map of unit U4a (**Figure 10**) shows that high altitudes are located in the southwestern part, while low altitudes are located in the eastern and southeastern part. The flow direction is NW–SE.

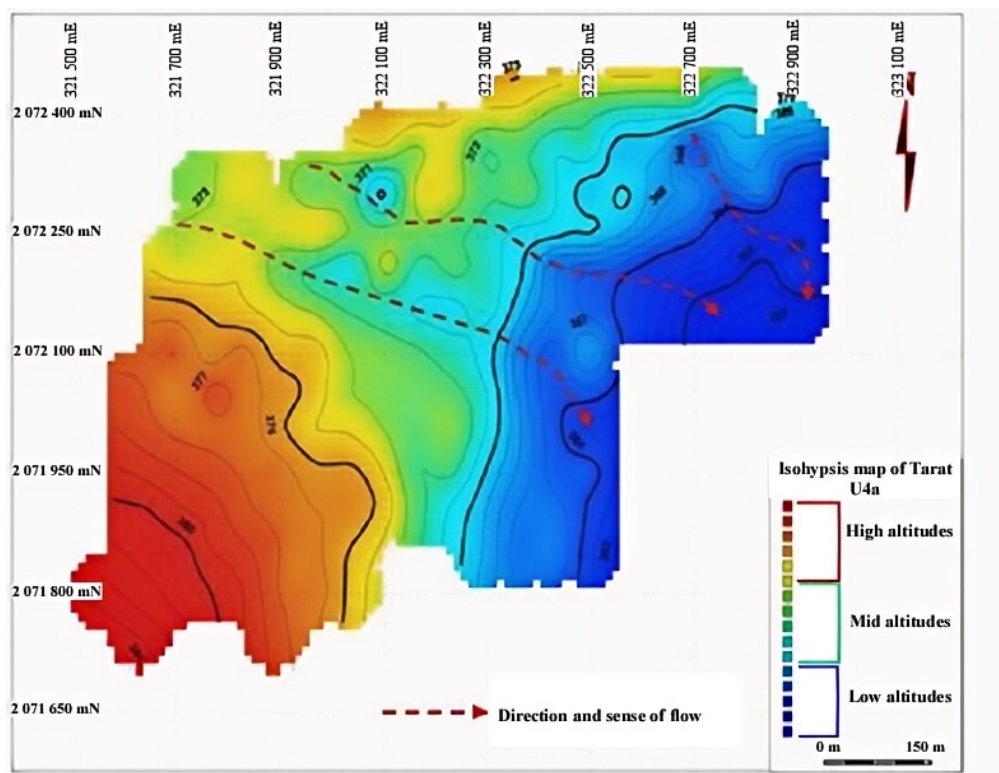


Figure 10. Isohypsis map of Tarat unit U4a of the Taossa deposit.

The isohypses of Unit U4b (Figure 11) show that the flow is oriented toward the east, i.e., toward the subsided zone. In contrast, the uplifted zone has remained almost untouched since the deposition of Unit U3G.

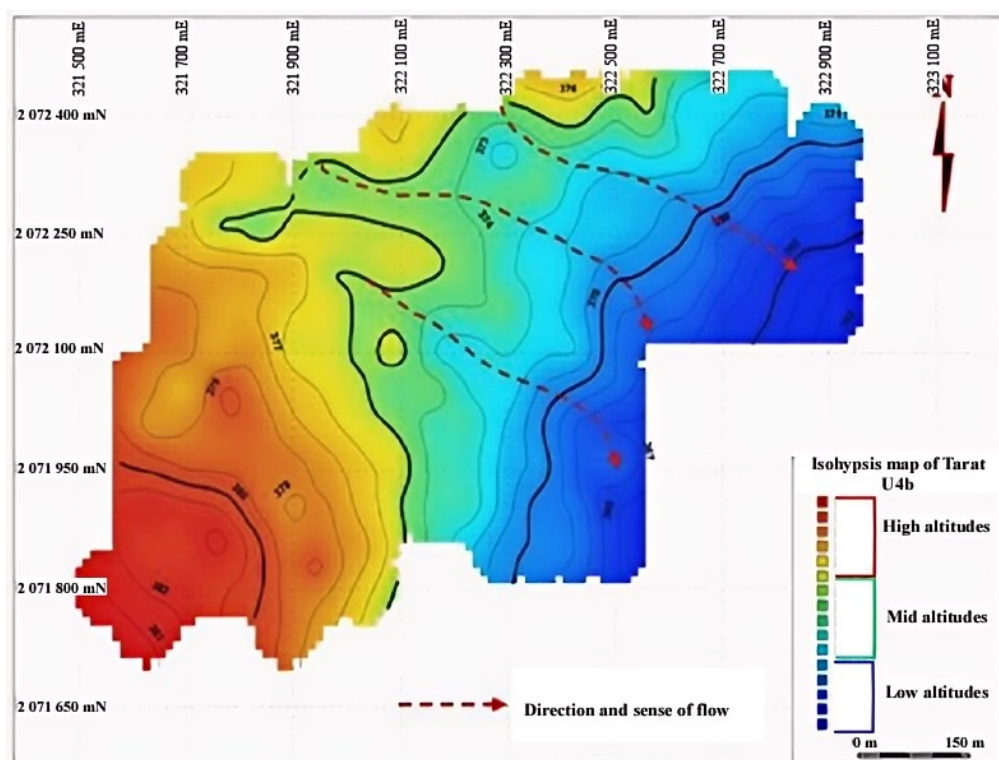


Figure 11. Isohypsis map of Tarat unit U4b of the Taossa deposit.

4.3.2. Analysis of Isopaque Maps

By definition, isopachs are curves of equal thickness for the geological formations studied. To produce the isopaque maps of the Taossa deposit (**Figure 12**), we used the data on which the intra-Tarat division was based. MapInfo and Surfer software were used. Analysis of the isopach maps shows:

For the Tarat unit U1, sediment thickness is closely associated with channel depth. Low thicknesses are observed in the upstream part of the channels (**Figure 12a**).

Unit U2 is thinner in the eastern part of the deposit. It is more developed in the western and south-western part of the area (**Figure 12b**).

For Unit U3G, the thickness is more developed to the north and northeast (**Figure 12c**).

The paleo-surface of the U4a deposit (**Figure 12d**) is very similar to that of the preceding U3G, as the low-lying areas of both units (U4a and U3G) are in the same position. The same applies to the non-deposit zone, which is located in the south and south-western part. The trend is for the U4a deposits to develop eastwards and north-eastwards (**Figure 12d**).

For Unit U4b, the axial zone of the deposit, running east-west, is the depositional zone with the greatest observed strength. In the extreme southern and northern parts, however, thicknesses are low (**Figure 12e**).

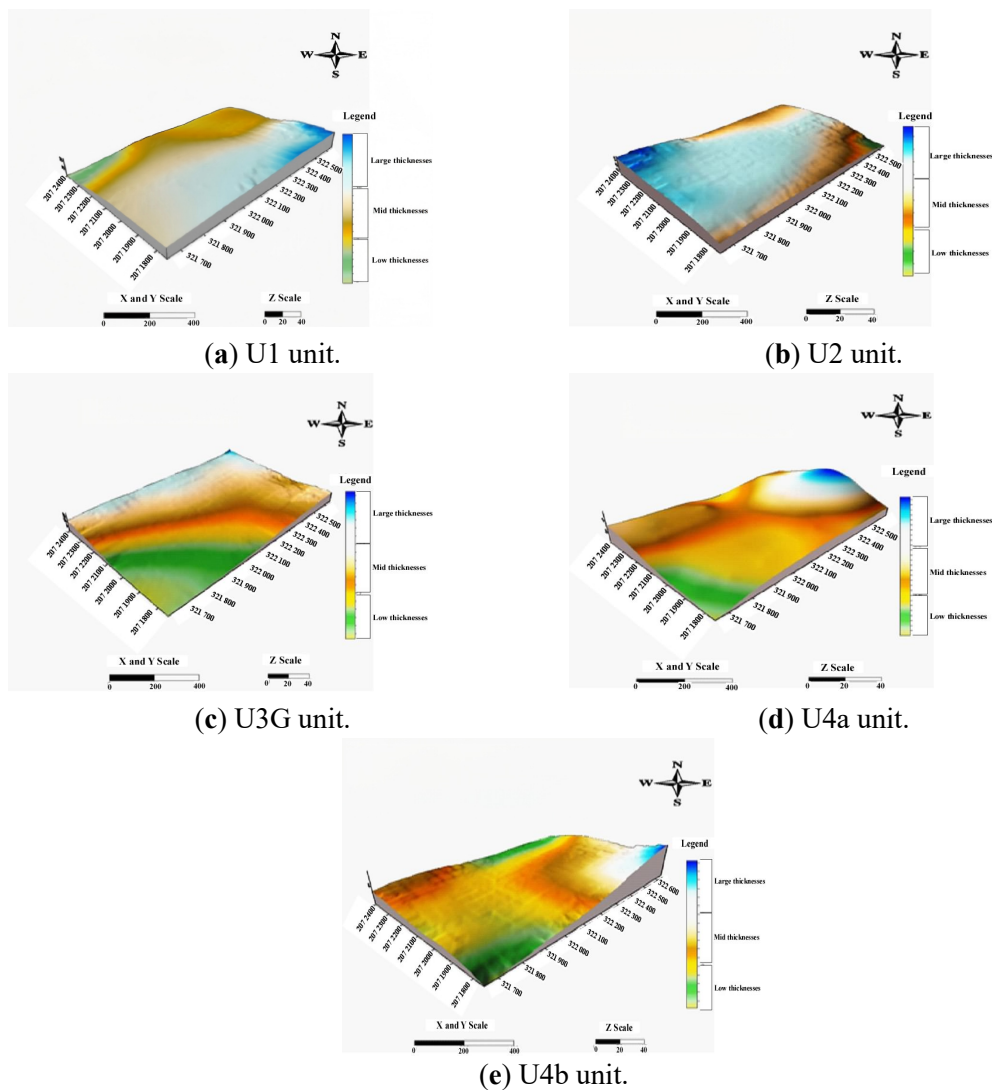


Figure 12. Isopaque maps of intra-Tarat units of the Taossa deposit.

4.3.3. Modeling the Tarat Depositional Systems of the Taossa Deposit

To produce the geological model of the Taossa deposit (**Figure 13**), the various isopach maps of the different Tarat units were compiled. It should be noted that the background

color used is that adopted from the stratigraphy during logging.

The 3D block analysis reveals an N–S-trending synclinal zone along the axis of the deposit, while the SE and N–W-trending parts correspond to anticlines.

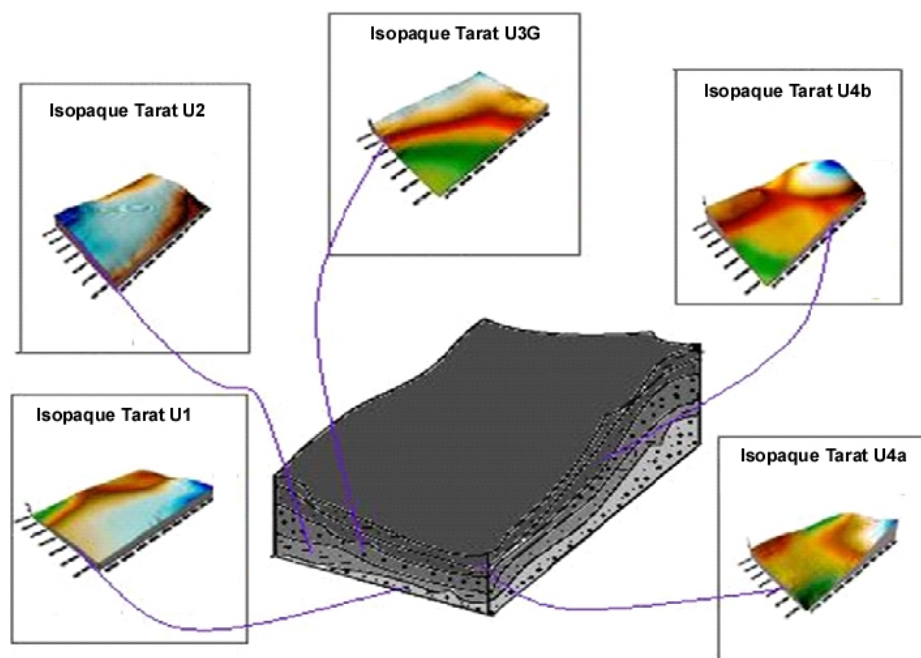


Figure 13. A typical depositional succession model for the intra-Tarat units derived from the proposed new division.

The analysis of the sediments of the various Tarat units has shown that this formation is made up of coarse to very coarse sandstones at the base, with fine sediments (argillites or argilo-siltite interlayers) towards the top. In addition to these characteristics observed on cores and in the field, flat, oblique, and criss-cross stratification have been observed. The intra-Tarat units, deposited in a fluvio-deltaic environment, display various morphologies of sedimentary bodies. Analysis of the isohypsis maps illustrating the morphology of the paleosurfaces of deposition of the lithostratigraphic units shows that the main NW–SE direction of sediment transport has not changed significantly from one unit to the next. On the other hand, the orientation of the flow generally changes. Channel geometry also changes from one unit to another. Indeed, the isohypses of units U1 and U3G show that their channels are flat (non-straightened flanks), whereas the channel of U2 has a straightened flank and a strong sinuosity (meandering channel in the direction of its orientation). For U4b, the channels are flat with 3 different beds that eventually merge downstream.

4.3.4. Morphology of the Taossa Deposit

A 3D model block (**Figure 14**) was produced to map the distribution of mineralization in the Taossa deposit. This block diagram shows that mineralization is generally located on the flanks of anticlines and synclines, which are favored zones for the accumulation of organic matter and sulfides, which are reputed to be essential substances for uranium fixation.

The main results highlight the continental origin of the Tarat deposits in the Taossa reservoir. Overall, sedimentation is characterized by lateral spatio-temporal variations. Deposits of this formation are enriched by the dismantling of organic-rich soils derived from abundant Carboniferous vegetation. The sedimentation context and the notable presence of organic material favor the development of a reduced environment. The grano-decay of the intra-Tarat sequences shows a fluvial influence. The subdivision of this formation has resulted in five intra-Tarat units: U1, U2, U3G, U4a, and U4b.

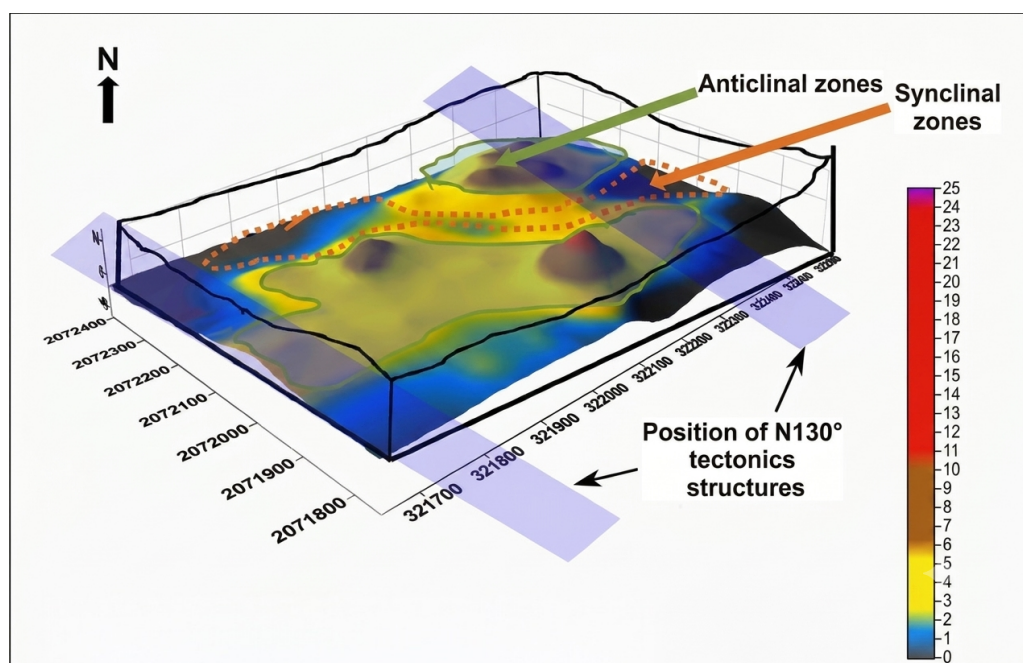


Figure 14. Reservoir morphology at the Taossa deposit.

All these units would have developed in fluvio-deltaic channels. One of the characteristics of flow in a channel is that any narrowing of the channel produces an increase in water velocity, and consequently in bank and bottom erosion. However, any flow is initiated over a narrow zone of influence with a relatively high initial velocity, and consequently causes erosion and gullyng of the underlying layers. This is precisely the case for the U2 paleo-surface (**Figure 12**). Channel widening, on the other hand, is accompanied by a reduction in velocity, which favors sedimentation. This is the case for the channels of U1, U3G, U4a and U4b, whose flanks are not straightened and whose depositional thickness is greater in their downstream parts (**Figure 12**), probably corresponding to deltaic plain-type subenvironments. When currents reach a floodplain, velocity decreases upstream and downstream, favoring the deposition of fine elements and clays on coarse sediments that have benefited from the high transport energy. These conditions are typical of U3G and U4a, two units that follow each other in a normal sedimentary cycle.

The paleo-surface of U1 (**Figure 12a**) shows that the base of the Tarat is erosive on the UT, with two distinct zones marked by high relief in the southwest and a depressed zone in the southeast of the deposit, where most of the sediments in this unit are concentrated in a NW–SE channel system. But this unit will be gullied in the axial part corresponding to the minor bed of the meandering channel deposited by

the U2 (**Figure 12b**). This is why the U2 is so powerful in this axial zone and in the convex zone of the channel. The deposition of U4b probably took place on a deltaic plain where the channels meet (**Figure 12e**).

The area is structured into synclinal and anticlinal zones, corresponding to elevated and subsided areas. It should be noted that this structuring is corollary to that of the two synsedimentary 130° N tectonic structures in the Taossa deposit (**Figure 13**). The combined influence of these structures undoubtedly played a decisive role in the formation of the Taossa deposit.

4.3.5. Synthetic Log of the Taossa Deposit

The synthetic log of the Taossa deposit (**Figure 15**) includes:

- ❖ Formation age column;
- ❖ Series and stratigraphic units column;
- ❖ Lithology and resistivity column;
- ❖ The facies summary column;
- ❖ and the depositional environment column.

This log type of the Taossa deposit contains only the formations crossed by the boreholes, notably from the Izé-gouande to the first meters of the Tchinezogue Terminal Unit, where the boreholes stopped (**Figure 15**). The average thicknesses of the formations in the area are used to analyze the sedimentary filling of the Taossa deposit.

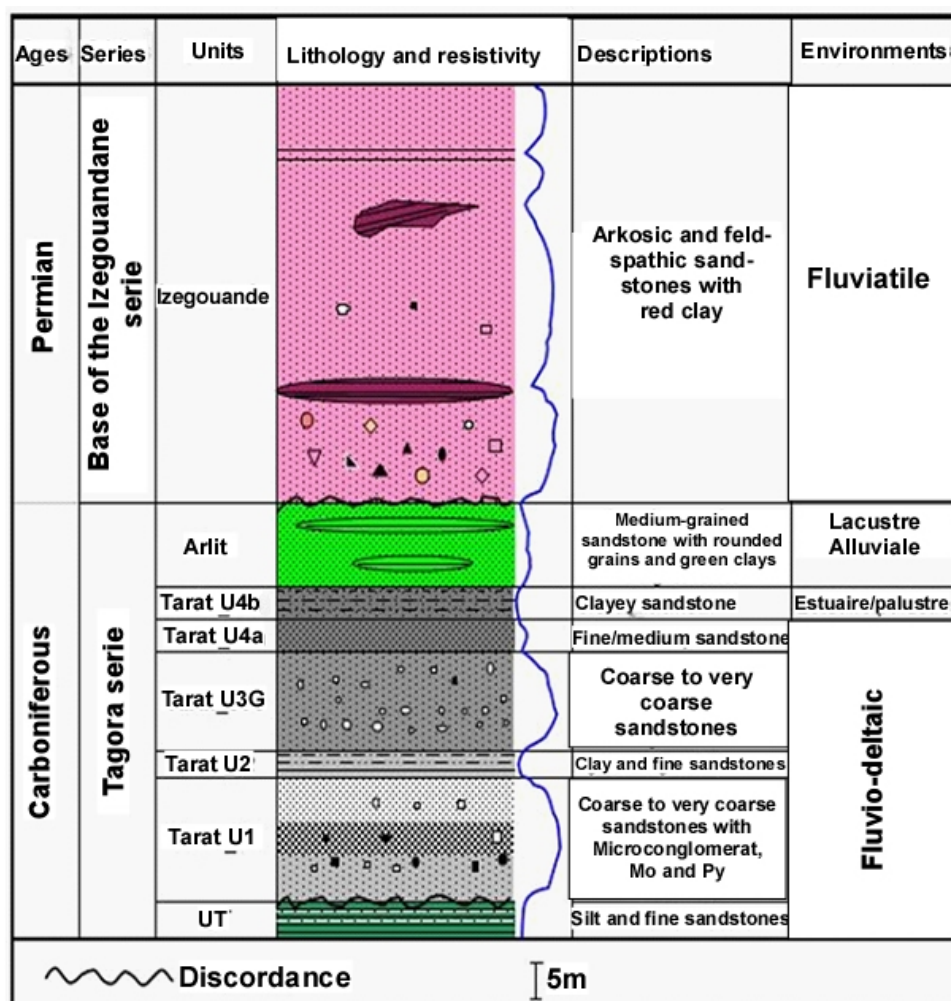


Figure 15. Synthetic log of the Taossa deposit, incorporating the new stratigraphic division.

According to the petrographic features of the main units of this Tarat of the Taossa deposit, it consists of:

- **U1:** coarse-grained sandstone. These units mostly consist of coarse-grained sandstone; grains are mostly detrital quartz, feldspar, with organic matter and pyrite.
- **U2:** Mudstone and fine-grained sandstone, mostly laminated, gray to dark in color.
- **U3G:** coarse to very coarse-grained sandstone. This unit consists mostly of sandstone with an abundance of quartz grains of various sizes, angular to sub-angular grains with lithic rock, organic matter, and pyrite.
- **U4a:** medium-grained sandstone. These units consist of medium-grained sandstone and mostly consist of quartz, followed by feldspar and rock fragments (mudstone and siltstone).
- **U4b:** Clayey sandstone. It consists of siltstone/silty-muddy sandstone with abundant mudstone layers.

4.3.6. Relationship between Uranium and Sedimentary Systems

Two (2) well-cut sections were cut to study the distribution of mineralization at the Taossa deposit (**Figures 16 and 17**). These sections revealed lateral and vertical variations in the facies of the various Tarat units. U4b is more developed than U4a in the synclinal zone, while in the anticlinal zone, their thicknesses are identical in some places. The cross-sections above (**Figures 16 and 17**) show the position of the syncline to the extreme east and the anticline to the west, whose flank is visible. The strongest radiometric accumulations are located on the flanks (**Figures 16 and 17**). The mineralized zones are located in the NW zone (**Figures 16 and 17**) of the Taossa deposit, corresponding to the thickening zones of the U1. Examination of cuttings and core samples has shown that these levels correspond to zones of high organic matter and/or sulfide accumulation. This allowed uranium fixation.

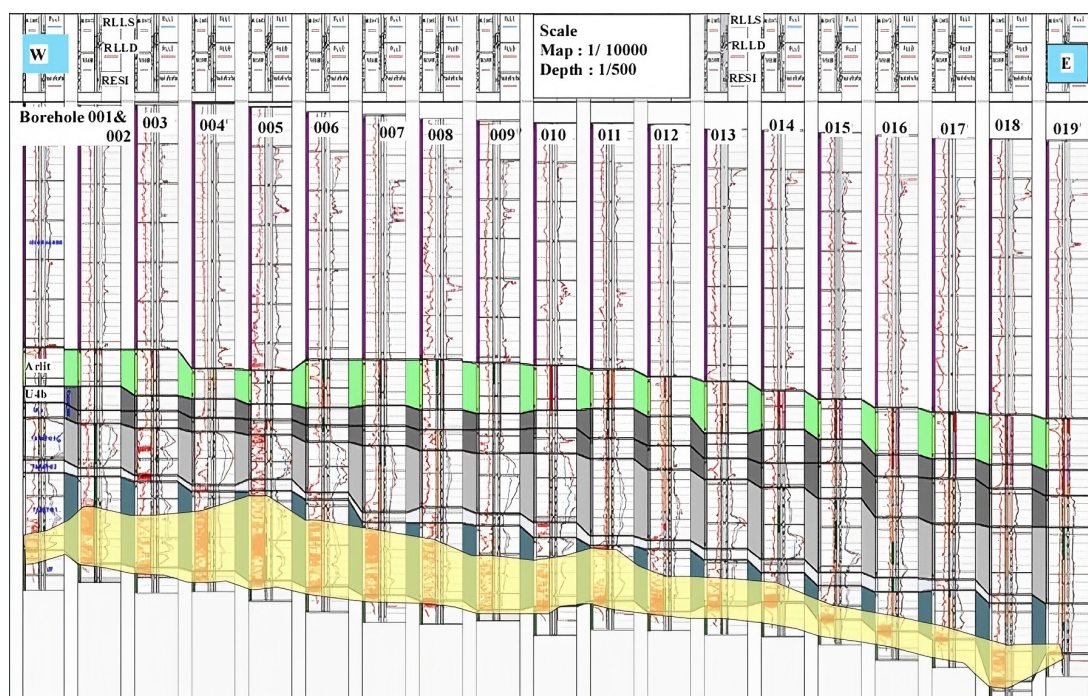


Figure 16. Wellcad E-W sections in the central zone of the Taossa deposit showing the distribution of uranium mineralization.

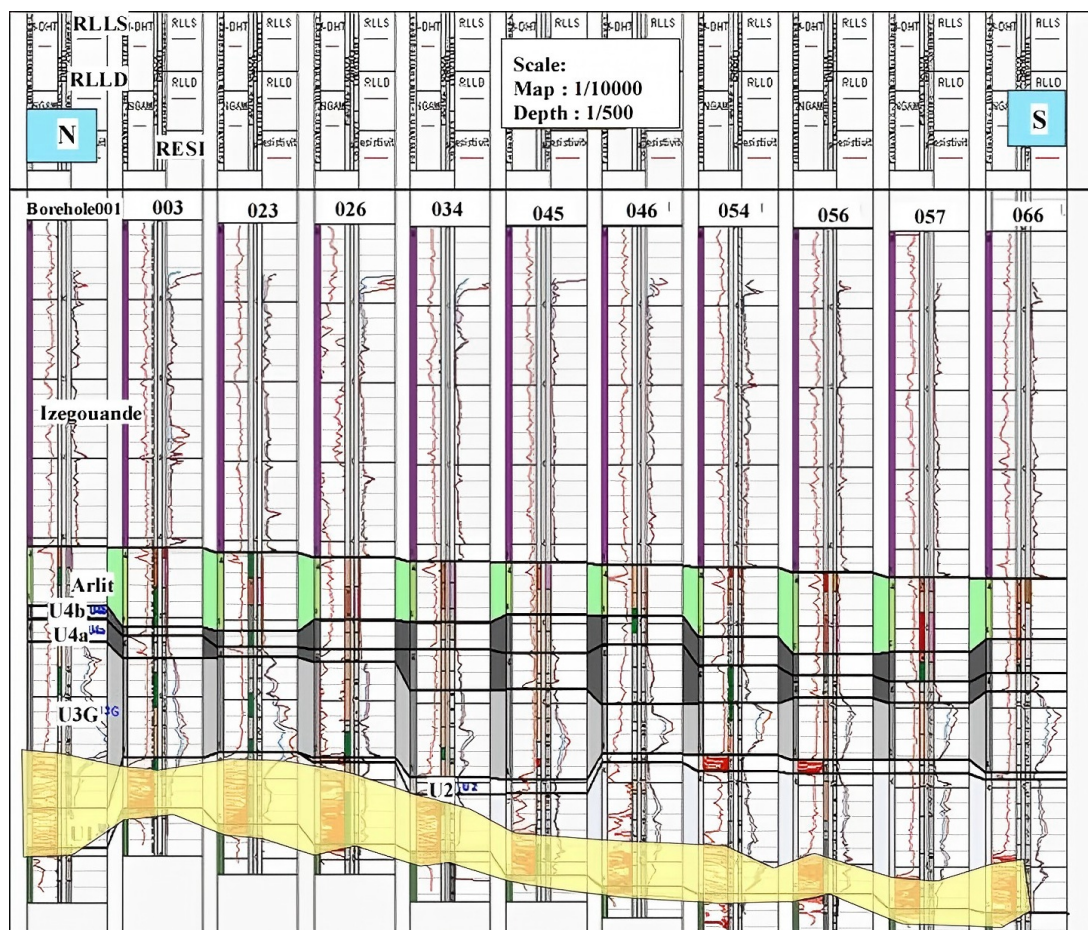


Figure 17. Wellcad N-S sections in the central zone of the Taossa deposit showing the distribution of uranium mineralization.

5. Discussion

The Taossa deposit, like the other deposits exploited by Somaïr, is also located in the Tarat formation. The latter, belonging to the Tagora series, consists of very fine to coarse sandstones, microconglomerates at the base, and black mudstones deposited in an estuarine environment. The new intra-Tarat division carried out as part of this work highlights five (5) units, U1, U2, U3G, U4a and U4b, unlike the usual divisions carried out in the Arlit sector, where either three (3) or four (4) units are frequently highlighted^[16,29,30] at the Tamou and Tamari deposits, respectively. Mineralization at the deposit studied is located in the lower part of the Tarat, whereas at Somaïr's other prospects, it is found in the upper part of the Tarat^[31]. In the Dajy area^[7,32,33], it has also been shown that mineralization in the Tarat formation is located in the lower part. The latter corresponds to the organic-rich part of the coarse to medium sandstones. Structurally, 130° N faults have been shown to play an important role in both the sedimentation process and the distribution of uranium mineralization. These tectonic structures would have favored the compartmentalization of the Taossa area into high and low zones, creating favorable zones for the accumulation of organic matter and sulfides.

The present work has shown that uranium mineralization in the Taossa deposit occurs mainly on the flanks of anticlinal and synclinal structures, where medium- to coarse-grained sandstones rich in organic matter have been emplaced. This suggests that tectonic structures played a role in the development of mineralization. These observations are in line with the work of Sani, Mamane Mamadou et al., Oumarou, Sani et al., and Huang et al.^[7,32–35]. Subsequently, the circulation of mineralizing fluids would have favored the mobilization and deposition of uranium in zones favorable for its fixation. These observations are in line with those of Sani et al., Huang et al., Mamane et al., Billon, and Ding et al.^[34–38], according to whom mineralization is always associated with levels rich in pyrite and organic matter. According to Mamane Mamadou et al., Oumarou, Billon, and Ding et al.^[32,33,37,38], this organic matter comes from the accumulation of plant debris, which is considered a reducing agent for uranium. According to Oumarou^[33], uranium mineralization at the Arlit deposit is substantially in the form of uraninite with minor amounts of U-Mo or U-Ti-(V) oxides.

According to this author, the most probable source of uranium in the basin is linked to the intense activity within the Aïr crystalline rocks for the northern deposits (Arlit and Akouta) and the volcanism of the annular complexes of Nigeria for Imouraren further south. Niger's uranium deposits as a whole are classified as hydrothermal diagenetic uranium deposits (tabular or tectonic-lithological subtype) according to Valsardieu^[22], as their distribution is linked to the activity of the Arlit Fault and local lithological factors. Tectonic movements are thought to have controlled the distribution of uranium mineralization around the Arlit Fault on a larger scale. This created the paleotopography, which in turn determines the main directions of fluid flow and the slope of the permeable sandstone channels^[4]. According to this last author^[4] there is an oxidation front (rolling front) at Akouta deposit.

In roll-front deposits, organic matter plays a major role in uranium mineralization^[39–44]. In the Dongsheng deposit (China) and other regions, redox fronts were observed between a uranium-rich fluid and an organic fluid (oil, gas (methane)). Contact between these fluids is thought to have led to uranium precipitation^[45–49]. The tectonic structures present in the basement and their extension into the sedimentary part of the basin are now fairly well understood^[33,50,51]. According to Cuney^[21], who described their role in determining fluid flow as well as in the architecture and location of deposits at the mining district scale, it is primarily the N–S, 30° N, and 70–80° N structures that are considered good indicators at the regional scale. The same observation was made by Jébrak and Marcoux^[8] in the Dajy area. In the Taossa deposit, 130° N tectonic structures are the most common. These structures are believed to have played an important role in the tectonic development of this area and even in the formation of the uranium mineralization.

In uranium deposits hosted by sandstones in the Bayingobi and Dongsheng Basins in China and in the Tim Mersoï basin in Niger, the geology is controlled by faults, which are thought to have played an important role in the migration of hydrothermal and reducing gases or oil, providing the reductant required for the formation of U minerals^[48–50,52].

Also, in the Ordos Basin (China), the formation of the tabular deposit has been attributed to the prolonged and stable interaction between oxidizing, slightly alkaline, uranium-bearing meteoric precipitation and acidic organic fluid mi-

grating toward the discharge zone. This interaction is believed to have triggered sequential adsorption-reduction processes, which occur due to a drop in pH and the presence of reducing agents. These processes are responsible for uranium mineralization at the interface where the two fluids interact^[53].

6. Conclusions

The Taossa deposit is one of SOMAÏR's uranium deposits. The formation hosting the mineralization is the Tarat, about 24 m thick and located at a depth of around 79 m over the entire study area. The aim of this sedimentological study was not only to establish a new intra-Tarat stratigraphic division, but also to determine the depositional environments of this formation. The study revealed that Tarat sedimentation took place in a fluvio-deltaic environment. Five sedimentary units were distinguished in the Tarat Formation, from bottom to top: U1, U2, U3G, U4a and U4b. Analysis of the isohypsic and isopaque maps of all these units has shown that they were all deposited by a fluvio-deltaic system transporting sediments rich in organic matter, whose diagenesis conditions favored the development of a reduced environment. The basic idea behind this intra-Tarat stratigraphic division lies in the segregation of clay facies, particularly in the U2, U4b and U1, U3G and U4a units, to facilitate ore sorting during the deposit mining phase. An overview of the morphology of the deposit shows that there is a relationship between the direction of the anticlinal and synclinal structures and that of the 130° N tectonic faults.

The subsidence zone lies between these structures, and mineralization is essentially localized on the flanks of the domes, which constitute a confined environment that preserves organic matter. This proves that these synsedimentary structures played a decisive role in the sedimentation of the Tarat and the emplacement of the Taossa mineralization.

Author Contributions

Conceptualization, methodology, validation, A.S.; formal analysis, A.S., K.D.H. and A.K.A.A.; investigation, A.S. and K.D.H.; data curation, A.S.; writing—original draft preparation, A.S., K.D.H. and M.K.; writing—review and editing, A.S., K.D.H. and M.K.; visualization, A.K.A.A.; supervision, M.K. All authors have read and agreed to the

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AI Use Statement

The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.

Abbreviations

SOMAÏR	Société des Mines de l'Aïr.
U	Unit.
DASA	Dajy Surface Anomaly.
UT	Unité Terminale.

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