American Journal of Sciences and Engineering Research
E-ISSN -2348 – 703X, Volume 4, Issue 5, 2021

Hydrogeological characterization of the Izegouande Permian aquifer (Tim Mersoï Basin, North Niger)

Tadewal Almoustapha Alfidja[1], Farida Boubé Dobi[2], Moussa Konaté[1]* and Ousmane Boureima[1].

[1]*Université Abdou Moumouni, Faculté des Sciences et Techniques, Département de Géologie Laboratoire Eaux Souterraines et Géoressources, BP 10662, Niamey, Niger*

[2]*Institut National Polytechnique Houphouët-Boigny (INPH-B), Laboratoire de Génie Civil, Géosciences et Sciences Géographiques, BP 1093, Yamoussoukro, Côte d'Ivoire*

Abstract: *In the Tim Mersoï basin, located in northern Niger, the increase in uranium mining activities and the demographic growth of Arlit and Akokan, which are induced cities, exert strong demands on groundwater resources. For the past decade, the Izegouande Permian aquifer, which contributes nearly 70% of drinking water supply in the mining areas, is one of the most vulnerable to anthropogenic activities. The main objective of this paper is to deepen the hydrogeological knowledge of the Izegouande aquifer. The methodology is based on the exploitation of borehole data by linear interpolation, associated with the mapping of water level contour and hydrodynamic parameters using ArcGis software. It appears from this work that to the east of the Arlit fault-flexure (east-flexure compartment), the Izegouande aquifer has a finer grain size and a smaller thickness, leading to limited exploitation possibilities (transmissivity ranging from 1.1 x 10^{-6} to 8 x 10^{-5} m²/s). While to the west-flexure compartment, the coarse grading associated with a high thickness favors higher productivity (transmissivity ranging from 1.87 x 10^{-4} to 3.83 x 10^{-3} m²/s). The sudden variations in thickness and facies of the Izegouande aquifer are closely linked to the synsedimentary play of the Arlit fault-flexure during the Permian. The high demands on the Izegouande aquifer caused a significant drawdown in the groundwater table, leading to a reversal of the groundwater flow direction (generally from north to south). The Arlit fault-flexure, which is a major crustal accident on a regional scale, long considered to be watertight, plays the role of a structural drain, influencing not only the exchanges between the Eastern and the Western-flexure compartments but also the drawdown of the groundwater level.*

Keywords: *Tim Mersoï basin, Arlit and Akokan, Permian aquifer, Izegouande formation, reversal of groundwater flow direction.*

I. INTRODUCTİON

The Arlit mining area, located in the Northern Niger, is an arid region with a cumulative rainfall of less than 150 mm per year [1]. The availability of surface water resources is highly dependent on climate change, which has become a major concern in recent decades [1]. In such context, groundwater is the main source of water supply, both for the population and mining activities [2]. In the Arlit area, the "*Société minière de l'Aïr*" (*SOMAIR:SR*) and the "*Compagnie Minière d'Akouta*" (*COMINAK:CK*) have been exploiting large uranium deposits for several decades [3 -13]. This region has important groundwater ressources [2] [7] [14] [15]. Water supply in the Arlit mining area was once provided by the Tarat Carboniferous aquifer [16-20]. The overexploitation of this aquifer, due to the development of mining activities and the resulting increase in the population of the induced cities, has led to a drastic drawdown of the groundwater level [16-21].

 Received- 23-08-2021, Accepted- 01-09-2021

In order to efficiently meet the drinking water needs of a growing population, new hydrogeological investigations have been carried out. The work focused on the Izegouande Permian formation [22-24]. Investigations on the hydrogeological characteristics of this aquifer, particularly in the western flexure, have given promising results regarding its productivity. It appears that the Izegouande Permian aquifer, which nevertheless has limited hydrogeological potential is intensively exploited (nearly 70%) for the supply of drinking water to the mining companies and a large part of the population of the Arlit region [22] [25 - 27]. However, the significant water withdrawals from this aquifer can lead, on one hand, to the depletion of the reserves and, on the other hand, to the degradation of the water quality. Thus, it is necessary to deepen the hydrogeological knowledge of this Izegouande aquifer, for rational and sustainable management of the water resources. It is within this framework that the present study is being carried out, the main objective of which is the geological and hydrodynamic characterization of the Izegouande aquifer.

II. MATERIALS AND METHODS

A. Presentation of the study area

The study area is located in the desert region, in the northern part of the Tim Mersoi basin, about 250 km northwest of Agadez. It is located between 18° and 19° 30' North latitude and 7° and 8° East longitude (**Fig.1**).

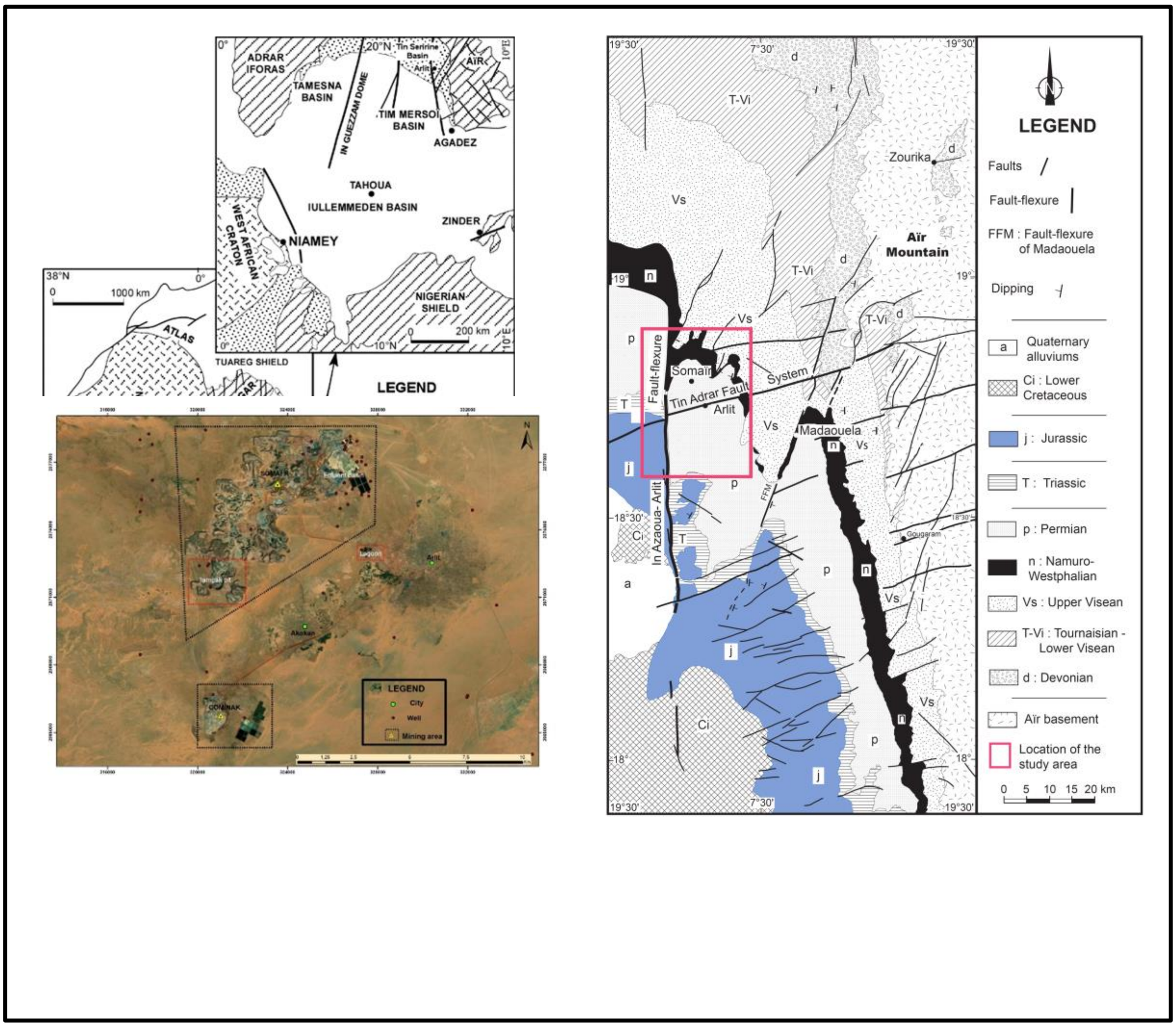

Figure 1: Location of the study area.

B. Methodology

The methodological approach implemented includes two stages:

- Processing of the borehole data by linear interpolation (Inverse Distance Weighted) using ArcGis 10.8 software. It should be noted that the data used concern boreholes which intersect the entire Izegouande formation. These data have made it possible not only to determine the top and bottom of the Izegouande aquifer, but also to specify its geometry.

- Mapping of water level contour and hydrodynamic parameters, using ArcGis software, made it possible to identify the characteristics of the Izegouande aquifer and to determine the groundwater flow direction. The method adopted was IDW linear interpolation. These maps were overlayed on the georeferenced and digitized structural map.

III. RESULTS AND DİSCUSSİON

C. Geometric characterization of the Izegouande Aquifer

In the Tim Mersoï basin, the N-S trending fault-flexure of Arlit, a major crustal fault on a regional scale, delimits two compartments: an elevated east-flexure compartment (where most of the uranium deposits are concentrated) and a lowered west-flexure compartment (where vertical rejection can reach 500 m). In this basin, the N-S Arlit and N70° Tin Adrar fault systems influence the distribution of the main thickening and thinning zones of the various sedimentary formations, in particular the Permian Izegouande one, which is the focus of this study.

1) Isobaths of Izegouande top

Analysis of the isobaths map of the Izegouande top reveals two distinct sectors from East to West, located on either side of the N-S Arlit fault-flexure (**Fig. 2**).

In the East flexure sector, the depths of the Izegouande top vary from 0 to 134 m, while in the western sector the depths are between 120 and 275 m. These variations in depths, associated with thickness variations of the Izegouande aquifer, on either side of the N-S Arlit fault-flexure, would be related to its normal synsedimentary activation during the Permian period (**Fig. 3**). The top of the Izegouande formation deepens towards the south, especially from the Tin Adrar fault (**Fig. 2**), and particularly in the area between the Mouron and Izegueram flexures (**Fig. 2**), where the depths of the Izegouande top exceed 40 m.

In the Cominak sector (CK), inside a graben bounded by the N70° trending Tin Adrar fault system, the top of the Izegouande formation is located between 30 and 40 m (**Fig. 2**). Further south, in another graben bounded by the N70° trending Aokare fault system (**Fig. 2**), the top of the Izegouande formation is deeper, reaching 134 m (**Fig. 2**). These observations highlight the control of the normal activation of the N70° fault system during Permian sedimentation.

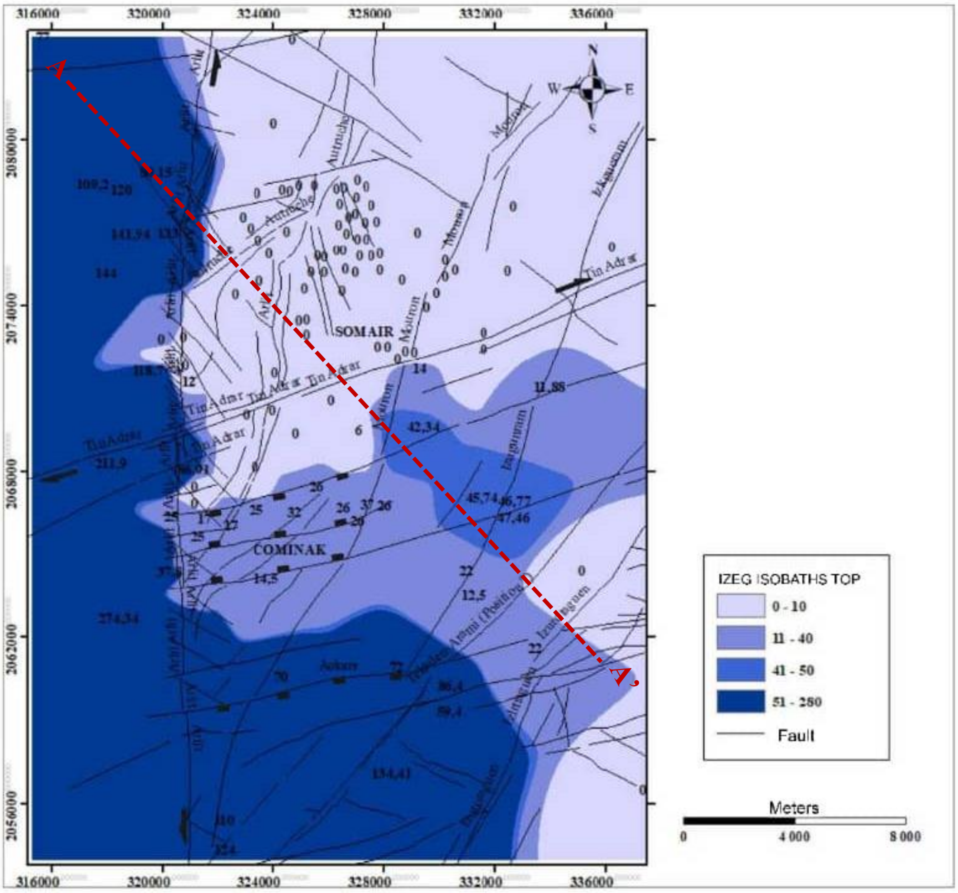

Figure 2: Isobaths map of the Izegouande top.

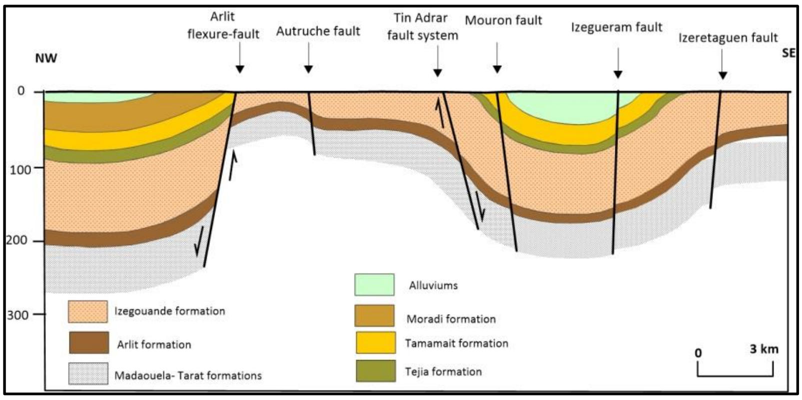

Figure 3: NW-SE cross-section (profile AA') of the study area (the thicknesses of the Arlit, Izegouande, Téjia, Tamamaït, and Moradi formations are deduced from previous work).

2) Isobaths of Izegouande bottom

The isobaths of the Izegouande aquifer's bottom (**Fig. 4**) show a comparable evolution to the Izegouande top one. Indeed, the Izegouande formation is relatively shallower to the East of the Arlit fault-flexure, with depths varying from 10 to 254 m, than to the West, where depths range from 140 and 393 m. These variations in depths, observed from East to West, are linked to the normal synsedimentary activation of the Arlit fault-flexure, which has favored a lowering of more than 100 m of the western flexure compartment. The deepening of the bottom is progressive in the eastern compartment, whereas in the west it occurs abruptly (**Figs. 3 and 7**). In the western compartment, the Arlit fault-flexure and to the North of the Tin Adrar fault system (**Fig. 4**), the depth of the Izegouande bottom is about 250 m, while to the south of the said fault system, the bottom depth is 300 m on average, i.e. a rejection of about 50 m (**Fig. 4**).

To the East of the Arlit fault-flexure, the depth of the Izegouande bottom is less than 100 m. To the North of the Tin Adrar fault system, the depths reached are less than 20 m in the Somair industrial area (**Figs. 3, 5, and 7**). The greatest depths (over 100 m) are observed in the Cominak (CK) sector (**Fig. 8**). Further South at the graben bounded by the Aokare fault system, the bottom of the Izegouande formation reaches depths of over 200 m (**Figs. 4 and 5**). We also observe a depression reaching depths of 150 m between the Mouron and Izegueram flexures (**Figs. 3 and 4**). These variations could be related to the influence of structuring during the establishment of the Izegouande formation.

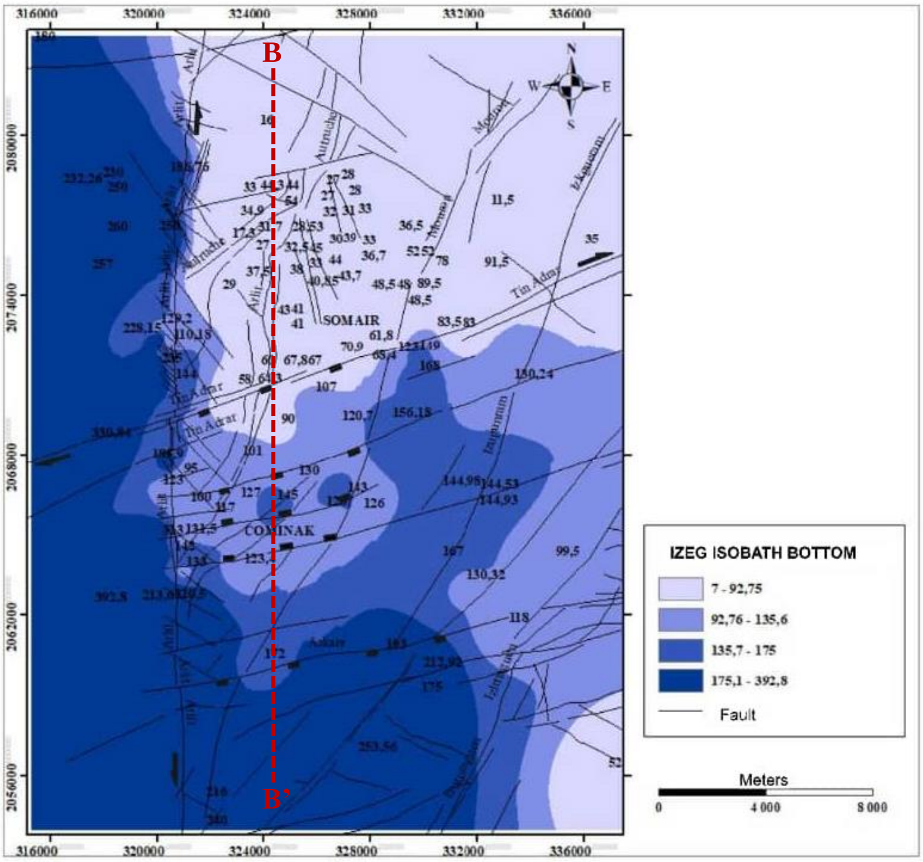

Figure 4: Isobaths map of the Izegouande bottom.

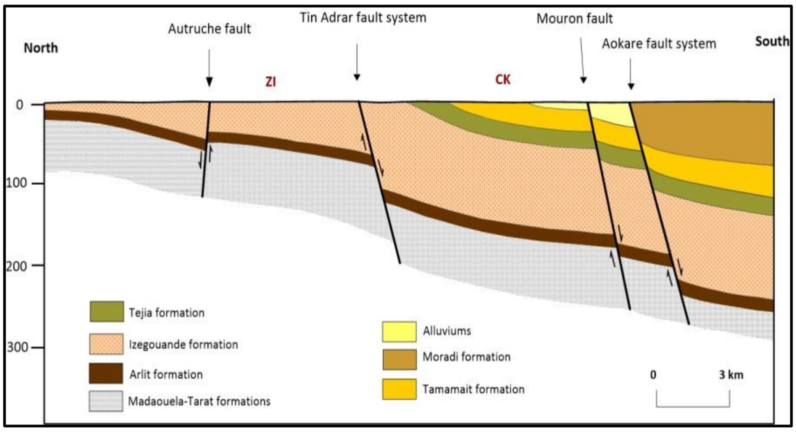

Figure 5: N-S cross-section (profile BB') of the study area (IZ: industrial zone, CK: Cominak).

3) Isopachs of Izegouande

Thickness variations of the Izegouande formation in the eastern compartment cannot be discussed, as the Izegouande formation is outcropping. However, in the contact zone between the Tin Adrar fault system and the Mouron fault. The maximum thicknesses of the Izegouande formation decrease from 70 to 30 m particularly near the Autruche Fault (**Figs. 3, 5 and 6**).

These observations highlight the presence of a dome structure (**Fig. 7**) between the Autruche and Mouron flexures, called "Autruche Dome". It should be noted that the lowest thicknesses were observed towards the contact zone with the Arlit fault-flexure (less than 20 m) (**Figs. 3, 6, and 7**).

In the Western compartment, the thickness of the Izegouande is beyond 100 m. These observations are in agreement with previous works [3] [4] [19] [26] [28], showing that the Izegouande deposits are characterized by important thickness variations related to the synsedimentary activation of the N-S (Arlit Fault-Flexure), N30° (Madaouela fault) and N70° (Tin Adrar fault system) accidents.

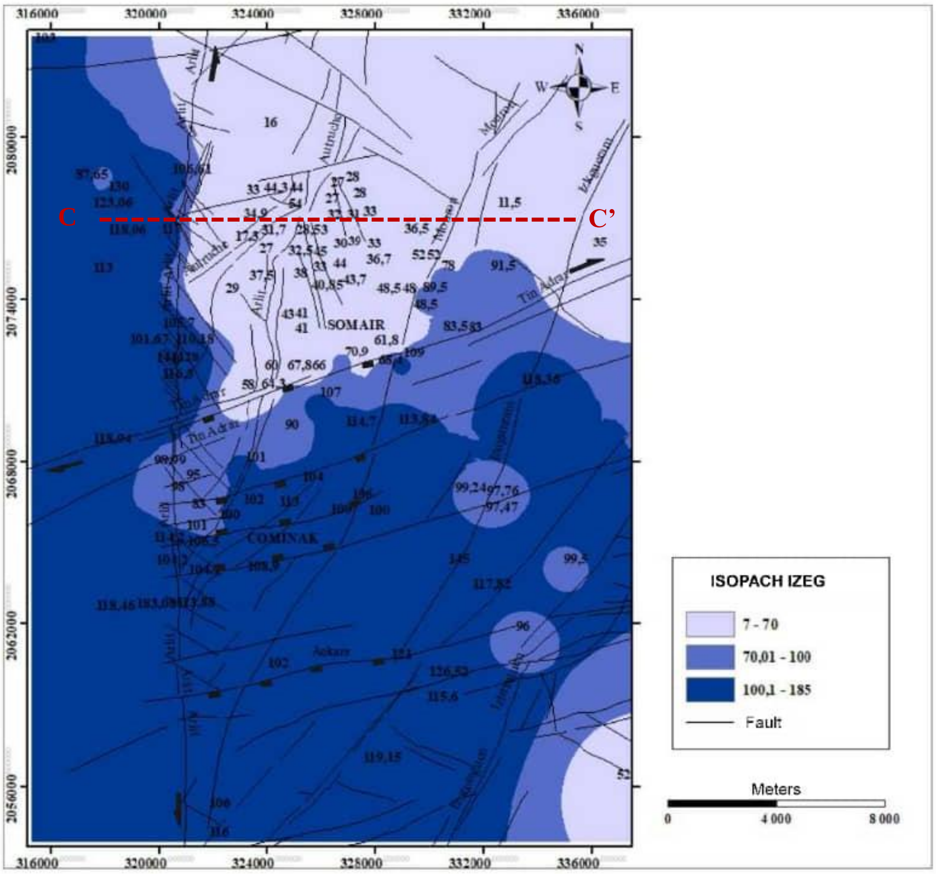

Figure 6: Isopach map of the Izegouande aquifer.

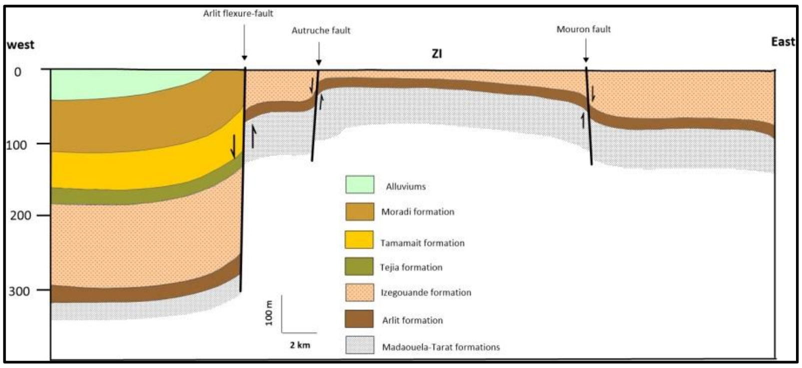

Figure 7: West-East cross-section (profile CC') of the study area.

D. Hydrodynamic characteristics of the Izegouande aquifer

1) Spatial repartition of the permeability coefficient

Analysis of the permeability spatial distribution map (Fig. 8) reveals that :

- To the South, the permeabilities are very low and vary from 1.80 x 10^{-8} to 8.44 x 10^{-6} m/s. These low values observed in this part could be attributed to the lithology of the aquifer associated with the low intensity of fracturing [11] [16] [22] [26] [31]. The lithology of the Izegouande formation is made up of feldspathic sandstone with carbonate cement sometimes, including lenses of mudstone. The highest permeabilities are found at the piezometers: AMIZ_0008_1 (6.89 x 10^{-6}) and Arli _2164_1 (6.40 x 10^{-6}). This can be justified by their location near secondary brittle faults (**Fig. 8**).

To the north, permeabilities are high. The values range from 4.22 x 10^{-6} and 1.89 x 10^{-5} m/s. The highest values are observed in the western flexure compartment, in particular at wells IZEG1 and IZEG2, where the aquifer formation is mainly made up of very coarse sandstones to conglomerate sandstones [16] [22] [23] [24] [26]. The high permeability observes in this part is justified by the variability of the lithology of the Izegouande formation, combined with the density of fracturing [8] [13] [19] [26] [30] [32] [33]. This heterogeneity of permeability is explained by: the lateral variation of facies, the presence of discontinuous clay layers, and the minor tectonic accidents that have locally affected the Izegouande formation [3] [4] [5] [6] [8] [14] [15] [16] [18] [19] [28] [30] [32] [33].

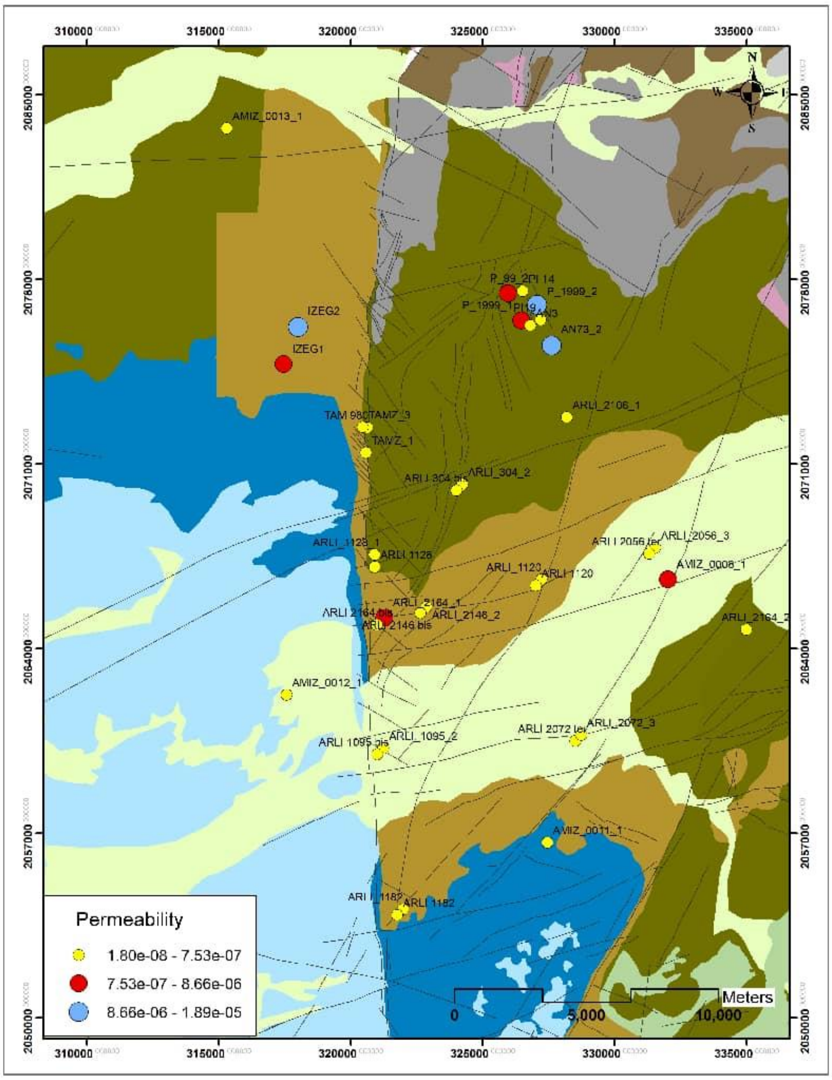

Figure 8: Map of spatial repartition of the permeability.

2) Spatial repartition of the transmissivity coefficient

The values of transmissivity determined for the Izegouande aquifer range from 1.10 x 10^{-6} to 3.82 x 10^{-3} m²/s with an average value of 3.40 x 10^{-4} m²/s (**Fig. 9**).

To the south, the transmissivities are low and homogeneous with values ranging from 1.10 x 10^{-6} to 4.24 x 10^{-4}m²/s. The lowest values are observed at the piezometers TAM980, TAMZ1, TAMZ3, Arli_3080_1, and ARLI_1095_2, which are located near the Arlit fault-flexure. The values range from 9.4 x 10^{-5} to 1.1 x 10^{-6} m²/s. The distribution of these transmissivity values is also linked to the fracture density and especially to the lithology of the aquifer. Sections of boreholes in this southern part have shown that the aquifer is essentially made up of very fine sandstones with carbonate cement, intercalated with clayey layers [16] [17] [18]. This explains the low productivity of the aquifer in this sector.

In the northern part, transmissivities increase from East to West as one approaches the Arlit fault-flexure. The values increase from 1.12 x 10^{-6} m²/s in the eastern compartment to 3.82 x 10^{-3}m²/s in the western flexure. This increase in transmissivity in this northern part is due to the variability of certain geological characteristics such as the lack of mudstone lenses and specially the density of fractures. The highest values can be observed in the Northwest (**Fig. 9**) with transmissivities of 8.51 x 10^{-4} to 3.82 x 10^{-3} m²/s. In this region, the aquifer grain size is coarser and the sedimentation is predominantly sandstone [23] [24], the transmissivity is good. However, low values are observed locally in the extreme northwestern part at piezometer AMIZ_0013_1.

These results show that this hydrodynamic parameter varies according to the lenticular structure of the Izegouande deposits and the position of the boreholes to the main structural axes.

Thus in the east-flexure compartment, the Izegouande aquifer is not very productive. On the other hand, in the west-flexure compartment, it is sufficiently productive to be exploited for drinking water supply (Izeg001, Izeg_002, Izeg_003, and Izeg_004).

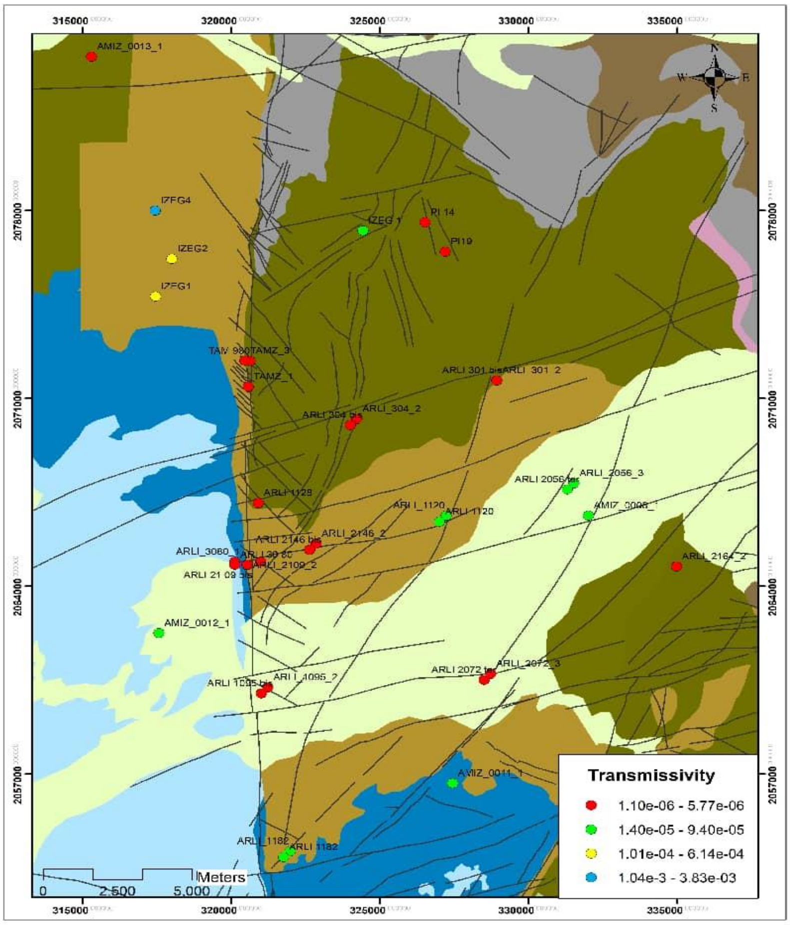

Figure 9: Map of spatial repartition of the transmissivity.

E. Izegouande groundwater flow direction analysis

Little information exists on the flow direction of the Izegouande water table before mining activities. A water-level contour map of regional flow is shown in Figure 10. It is based on data collected in 1968 [14]. Data only exist for the eastern compartment of the Arlit fault-flexure. In this compartment, the water table initially flowed from the South-Southeast to the North-Northwest, from contour line 410 m to 386 m, with a gradient of about 0.5‰ and significant local disturbances (**Fig. 10**).

To the south, near the MALA_997 piezometer, the contour lines show a regular spacing with a parallel trend, reflecting a constant hydraulic gradient. The current lines are divergent, which could correspond to a recharge zone (**Fig. 10**).

At the Arli_2064b and Arli_1120 piezometers, abrupt deformations of the induce divergent flow axes (**Fig. 10**). This divergence could be justified by the density of the fractures observed in this sector and the outcrop of the aquifer. These fractures could constitute structural drains that feed the water table in addition to the direct natural recharge in the outcropping parts [19] [30] [33].

In the north-northwestern part, the contour line get deformed and narrow near the Arlit fault flexure (**Fig. 10**). The current lines converge, which shows downward drainage between the Izegouande and the underlying Tarat nappe, via the Arlit fault flexure which then can be considered as a semi-tight boundary.

The Izegouande water table can therefore be considered as flowing from a recharge zone located in the south to an evaporation zone located in the north of the study area.

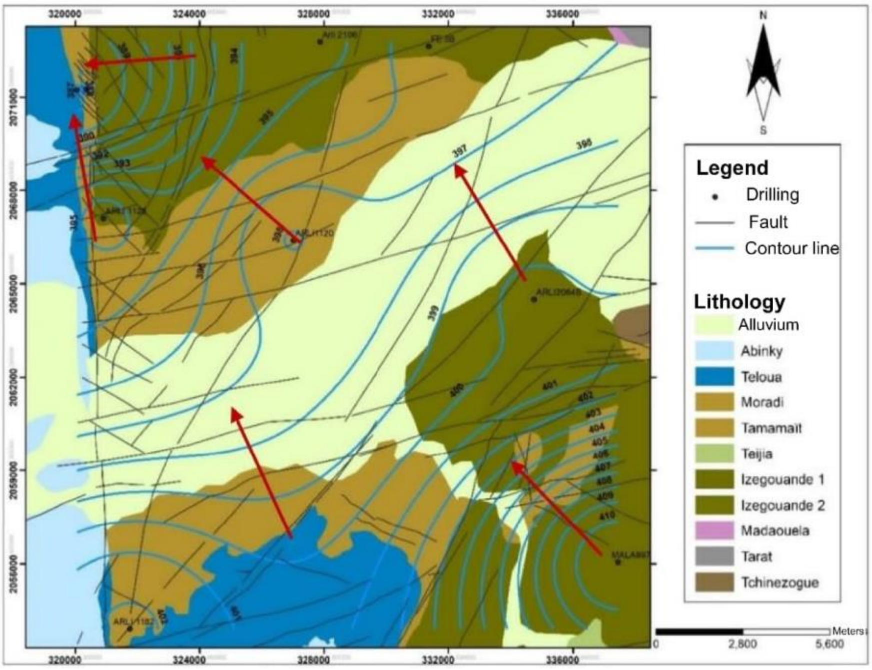

Figure 10: Groundwater level contour map of the Izegouande aquifer in 1968.

Currently, the overall flow of the Izegouande aquifer is quite complex with anomalies observed around the Somaïr industrial zone (ZI) and in the vicinity of the effluent ponds (**Fig. 11**). The general flow is from North-Northeast to South-Southwest towards the Cominak mine.

To the East of the Arlit flexure, the contour lines are strongly deformed and irregularly spaced (**Fig. 11**). The contour lines converge towards the Cominak mine with water levels measured around 330 to 340 m (i.e. about 50 m below the initial piezometric level [18]). To the East, at the outcrop and recharge areas, the Izegouande water table would have fallen by around 8 m. To the North, in the SOMAÏR sector, the contour lines are more distant and scattered, thus reflecting the drawdown of the water table in this sector.

In the area of the factory, the contour lines form a dome structure of about 8 m in height (from 392 to 400 m), with divergent flow axes (**Fig. 11**). This dome was likely created by water infiltration from the surface. Indeed, from the factory, most of the water flows towards the South-Southwest. Part of this water arrives as overflow on the Tamou pit (**Fig. 11**) and another part flows towards the Cominak mine with hydraulic gradients of 1‰ [18].

At the piezometers PI_12 and PI_13, to the Southwest of the Somaïr industrial zone, a second dome structure was identified in the area of the SOMAIR lagooning basins (**Fig. 11**). The groundwater level is around 400 m, whereas the regional level in the sector should be around 392 m. From the ponds, the water from Izegouande flows firstly to the west, towards the well of ARLI_248_3 and then to the south-southwest, towards the Cominak mine [18].

In the TAMGAK pit (**Fig. 11**), on the edge of the Arlit fault-flexure, the contour lines are narrow (strong hydraulic gradient, high water flow velocity), highlighting a depression with convergent flow axes (**Fig. 11**).

On the other hand, to the Northwest of the Arlit fault-flexure, the contour lines are condensed and show a tendency towards convergent flows (**Fig. 11**). This convergence characterizes a zone of exploitation of the water table corresponding to the pumping by wells intended for drinking water supply. In the central part, the contour lines are parallel and their spacing is almost regular on both sides of the Arlit fault-flexure. These results show that the Arlit fault-flexure does not constitute a watertight boundary in some locations.

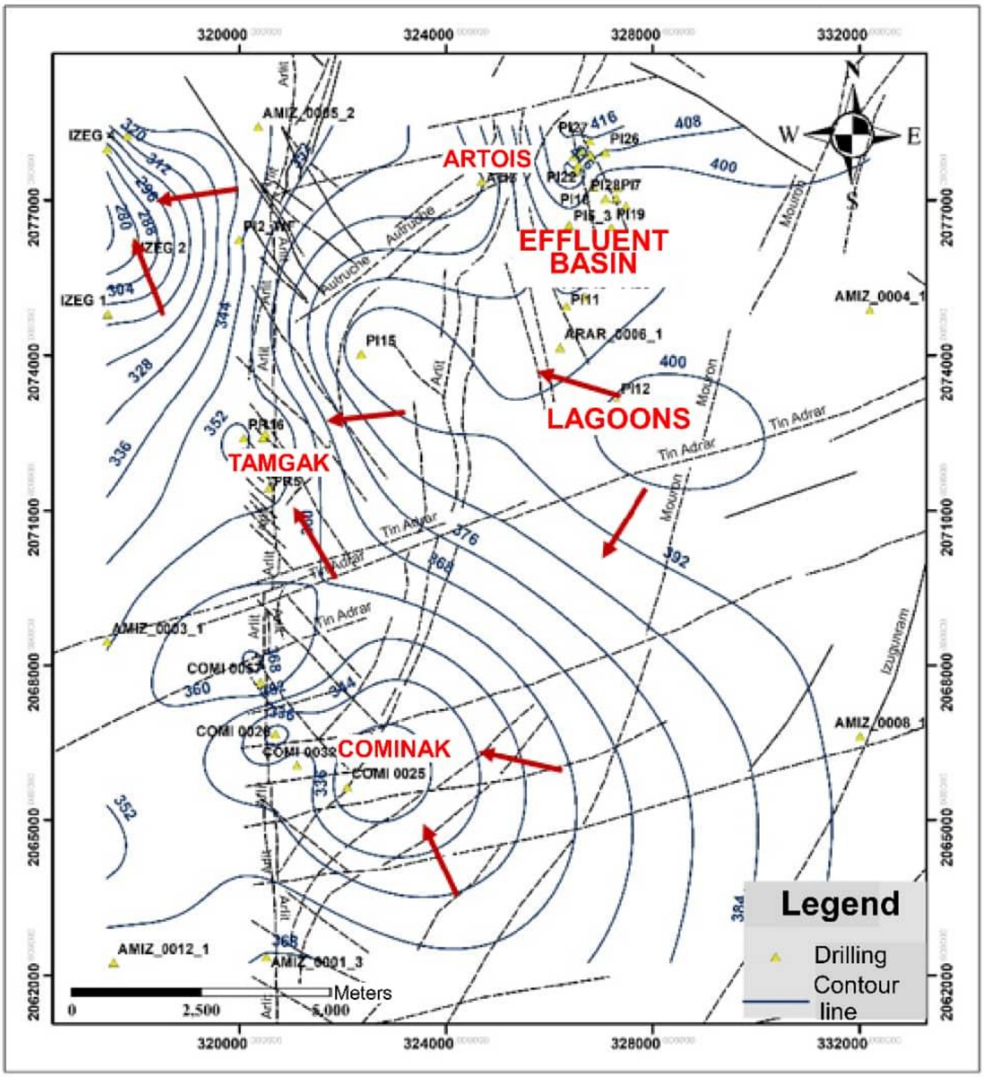

Figure 11: Groundwater level contour map of the Izegouande aquifer in 2020.

IV. CONCLUSION

In the Arlit mining area, fracture systems, such as the N-S Arlit fault-flexure and the N70° Tin Adrar fault system, control the geometry of the Izegouande aquifer (thickening and thinning zones). These variations in thickness, concomitantly to the Permian sedimentation, lead to variations in the depth of the top and bottom of the Izegouande formation. The Izegouande aquifer outcrops in the northern part of the study area and towards the East while it deepens to the South and the Western of the Arlit fault flexure.

The hydrodynamic parameters and their spatial distribution have shown that to the East of the Arlit fault-flexure, the Izegouande groundwater table has limited exploitation possibilities, due to its hydrodynamic characteristics. To the West, on the other hand, more interesting hydrodynamic characteristics are recorded, with the best ranges of values observed in the north, precisely in the northwestern part.

The Spatio-temporal analysis of the groundwater level contour shows that the strong anthropogenic solicitations (water supply for the population and dewatering) had a strong impact on the dynamics of the Izegouande groundwater table, inducing its lowering (7.15 to 54.72 m). This lowering of the water table influenced a reversal of the flow direction of the Izegouande water table. The flows that were from the Southeast to the Northwest at the start of mining activities in the 1970s have been marked since the beginning of the 2000s by a reversal of the flow direction (from the Northwest to the Southeast). The Arlit fault-flexure, which is a major crustal fault on a regional scale, long considered to be impermeable, actually constitutes a semi-tight limit. It ensures the connection between East and West flexure compartments of the Izegouande water table.

V. RÉFÉRENCES

1. Adamou, R., Ibrahim, B., Bonkaney, A. L., Seyni, A. A., Idrissa, M. (2021) Niger - Land, climate, energy, agriculture and development - A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security, ZEF Working Paper Series, ISSN 1864-6638, Center for Development Research, University of Bonn, 67p.
2. Ousmane, B. (2002) La gestion et l’exploitation des eaux souterraines au Niger, ISARM-AFRICA, Managing Shared Aquifer Resources in Africa- IHP-VI, SERIES ON GROUNDWATER No. 8, 129-133p.
3. Valsardieu, C. (1971) Cadre géologique et paléogéographique des minéralisations de charbon, du cuivre et d’uranium du de la région d'Agadès (République du Niger), Thèse de doctorat Université de Nice, 518 p.
4. Sempéré, T. (1981) Le contexte sédimentaire du gisement d'uranium d'Arlit (République du Niger), Mémoire Thèse, Ecole Nationale Supérieure des Mines de Paris, 374 p.
5. Forbes, P. (1983) Le gisement d’Uranium d’Akouta ; Sédimentologie - Pétrographie - Minéralogie – Géochimie, Rapport interne Centre de Recherches sur la Géologie de l’Uranium, 86p.
6. Diracca, A. (2005) Synthèse des travaux d'exploration au Niger (Géologie régionale, gisements, modèles génétiques, cibles), Rapport interne COGEMA, Réf. : CN/2005/R/11/AD, 213p.
7. COMINAK (2005) Etude de faisabilité AFASTO, Rapport interne, 287p.
8. Gerbeaud, O. (2006) Evolution Structurale du Bassin de Tim Mersoï : Déformations de la couverture sédimentaire, Relations avec la Localisation des gisements uranifères du secteur d’Arlit, Thèse unique, Université Paris Sud, 261 p.
9. Cavellec, S. (2006) Evolution diagenétique du bassin de Tim Mersoï et conséquences pour la genèse des minéralisations uranifères dans les formations carbonifères du Guezouman et du Tarat (district Arlit-Akokan, Niger), Thèse unique, Université Paris Sud XI, 450p.
10. Wagani, I. (2007) Potentialités uranifères des sources volcaniques envisageables pour la formation des minéralisations de la région d’arlit (Niger), Thèse unique, Université Paris Sud, 283p.
11. Mamane, M. M. (2016) Le système métallogénique des gisements d’uranium associés à la faille d’Arlit (Bassin de Tim Mersoï, Niger) : diagenèse, circulations des fluides et mécanismes d’enrichissement en métaux (U, Cu,V), Thèse Unique, Université de Lorraine, 390 p.
12. Bohari, A. D., Harouna, M. and Mosaad, A. (2018) Geochemistry of Sandstone Type Uranium Deposit in Tarat Formation from Tim-Mersoi Basin in Northern Niger (West Africa) : Implication on Provenance, Paleo-Redox and Tectonic Setting, Journal of Geoscience and Environment Protection, 185-225, http://www.scirp.org/journal/gep.
13. Abdoulwahid, S. (2020) Rôle des accidents N70° dans la mise en place des minéralisations uranifères du bassin de Tim Mersoï : cas du graben de DASA, bordure occidentale de l’Aïr (Nord Niger), Thèse unique, Université de Niamey, 150 p.

14. SCETAGRI (b) (1985) Nappes aquifères de la région d'Arlit, République du Niger, Synthèse hydrogéologique – Nappe de l'Izegouande, 119p.
15. Dodo, A. (1992) Etude des Circulations Profondes dans le Grand Bassin Sédimentaire du Niger : Identification des aquifères et compréhension de leurs fonctionnements, Thèse unique, Université de Neuchâtel, 165p.
16. COGEMA NIGER (2004) Synthèse hydrogéologique, la nappe du Tarat dans la region d'Arlit-Akokan, Rapport interne AMAN, 204p.
17. COGEMA NIGER (2004) Modélisation Hydrogéologique de la Nappe du Tarat, Rapport Ecole des Mines de Paris, 55p.
18. Seyni, K. et Lebeux, A. (2012) Synthèse hydrogéologique à la Zone Industrielle SOMAIR, Etat des lieux Avril 2012, Rapport interne AREVA NC, Réf. : 12/NIG/AMN/04/HYDRO, 54 p.
19. Illias, A., Babaye, M. S. A., Baraou, I. S., Ousmane, B., Adamou, R. (2019) Influence du système de fracturation sur le fonctionnement hydrodynamique de la nappe du Tarat, Bassin de Tim Mersoï, Nord Niger, Afrique SCIENCE, 15(4) (2019) 81 – 95,ISSN 1813-548X, http://www.afriquescience.net.
20. Dobi, F. B., Kouakou, E. K., Nazoumou, Y., Boko, B. A., Edimo, S. N., Maina, F. Z. and Konaté, M. (2021) Aquifer Depletion in the Arlit Mining Area (Tim Mersoï Basin, North Niger),Water 2021, 13, 1685, https://doi.org/10.3390/w13121685.
21. Dodo, A., and Zuppi, G. M. (1999) Variabilité climatique durant le Quaternaire dans la nappe du Tarat (Arlit, Niger), C. R. Acad. Sci. Paris, sciences de la terre et des planètes, 328, 371–379.
22. Goffin, M. (2004) Le réseau de piézomètres dans la ZI SOMAÏR nappes de l'Izegouande et du Tarat : Propositions de modifications des protocoles d'échantillonnage - Propositions de sites pour l'implantation de nouveaux piézomètres, Rapport interne SOMAIR, 19p.
23. Bottero, S. et Abdoulahi, A. (2005) Reconnaissance hydrogéologique des aquifères en Ouest accident d'Arlit (Tel 0001_1 et Izeg 0001_1), Rapport interne AREVA NC. Réf. : 06/NIG/AN/03,62 p.
24. Bottero, S. et Abdoulahi, A. (2006) Reconnaissance hydrogéologique des aquifères en Ouest accident d'Arlit et dans le secteur d'Akokan (Tarat 0001 et Izeg 0002), Rapport interne AREVA NC, 69 p.
25. AMAN (2014) Campagne d'arrêt des puits janvier – février 2014, Rapport de synthèse Akokan - Arlit, Suivi de la nappe du Tarat et du réseau de production en eau potable et en eau industrielle d' Arlit- Akokan, Rapport interne AREVA, 88 p.
26. Alfidja, A. T. (2016) Contribution à l'étude hydrodynamique et hydrochimique de la nappe d'Izegouande après une cinquantaine d'années d'exploitation uranifère dans la région d'Arlit (Niger), Mémoire de Master, Université de Niamey, 69 p.
27. Korgom, F. Y. (2019) Caractérisation hydrogéologique et hydrogéochimique des nappes souterraines de la Zone Minière d ' Arlit au Niger, Mémoire de Master, Université de Liège, 68 p.
28. Yahaya, M. (1992) Dynamique sédimentaire du Guézouman et des formations viséennes sous-jacentes en liaison avec la tectonique, le volcanisme et le climat, Mémoire Thèse Université de Bourgogne, 355 p.
29. Konaté, M., Denis, M., Yahaya, M., et Guiraud, M. (2007) Structuration Extensive Et Transtensive Au Dévono-Dinantien Du Bassin De Tim Mersoï (Bordure Occidentale De L'Aïr, Nord Niger), Annales de l'Université de Ouagadougou Série C, Vol. 005, 1-32.
30. Boko, B. A., Konaté, M., Adamou, R., Abdoulaye, A. (2017) Contribution du système de fracturation à la recharge des aquifères du bassin de Tim Mersoï (Nord Niger), REV. CAMES - Vol.05 Num.01. 2017 * ISSN 2424-7235.
31. Wattinne, A. (2008) Etude des circulations de fluides (diagenèse) autour de la faille d'arlit : projet Tamgak, Rapport interne AREVA NC, 60 p.
32. Adamou,R., Moumouni, A. A., Ikhiri, K., Ousmane, B., Abdoulaye, A. et Konaté, M. (2015) Etat des lieux sur les aquifères de la zone minière d'Arlit pour la période allant de 1968 à 2013 : hydrogéologie et hydrochimie, Expertise collégiale FAST-SOPAMIN, Collection Etudes Nigériennes, 156 p.
33. Boko, B. A., Konaté, M., Adamou, R., Abdoulaye, A. (2017) Influence du système de drainage sur la vulnérabilité à la pollution des aquifères du bassin de Tim Mersoï, Nord Niger, *Afrique* SCIENCE *13(4) (2017) 261 - 274* 261 ISSN 1813-548X, http://www.afriquescience.info.