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RESEARCH ARTICLE

INFLUENCE OF THE ARLIT FLEXURE FAULT ON THE GEOMETRY OF THE TARAT AQUIFER: ARLIT SECTOR, TIM MERSOÏ BASIN, WESTERN OF THE AIR MASSIF (NORTH, NIGER)

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Abstract

Since 1968, the Tarat aquifer has ensured the need for industrial water and the supply of water to the population (AEP), since the installation of the city of Arlit. The high pressure exerted on this aquifer has caused a continuous decline in the level of this aquifer considered as fossil. The present study aims to provide a better knowledge of the geometry of the Tarat aquifer. A methodological approach based on the analysis and processing of data from mining boreholes and logging revealed that the Tarat aquifer compartmentalized into two zones: a collapsed area east of the Arlit fault, and another raised to the west associated with significant variations in the thickness of the water table in the Arlit area.

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Introduction:-

The region of Arlit, western edge of the Air massif is a semi-arid region. Thus, most of the water resources in this area are represented by groundwater. In addition, this area has a significant uranium potential exploited by two companies, one of which has been closed since 2020. The exploitation of this uranium potential has resulted in an excessive pumping of the Tarat aquifer which has dried up in places (Boko et al., 2017; Illias et al., 2019; Alhassane et al., 2021). The increase in uranium production in recent years (from 2620 tonnes in 2010 to 3065 tonnes in 2012), followed by a strong demographic explosion in the city of Arlit and the treatment of gold in recent years has resulted in an increase in the demand for drinking water and also for industrial needs. This high demand for this aquifer, first through the supply of water to the population, then mining activities, and finally that of the treatment of the Gold coming from Tchibarakatène causes a considerable drop in the piezometry of the water table since its exploitation (Dodo et Zuppi 1999 ; Illias et al., 2021).

Because this aquifer is considered non-renewable, its sustainability depends directly on the amount of water withdrawn for all uses.

Moreover with the exhaustion of the uranium reserve of the COMINAK, the population of Arlit turned to a new activity in particular irrigated agriculture. Thus, today there are in the city large agricultural fields working in irrigation from boreholes capturing both the Izegouande aquifer, and that of Tarat.

As a result, in this arid area, the life and future of these populations depend heavily on this groundwater. Thus, a rigorous and rational management of groundwater this aquifer is necessary and it is imperative to conduct a study

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through a hydrogeological knowledge of this fossil aquifer. It is in this context that the present study aims to characterize the geometry of the Tarat aquifer in the Arlit sector.

Materials and Methods:-

Location of the study area

The Arlit region is located northeast of Niger more precisely between longitudes 7°15' and 7°30' east and latitudes 18°15' and 19°00' north, with an average altitude of 400 m, limited to the east by the crystalline basement of the Air massif (fig.1). This region receives on average annual average heights of rainfall ranging from 120 mm in the Air massif (1000-2022 m Altitude) to 40 mm in the plains (Dodo et Zuppi 1999), with an average annual evaporation of about 4100 mm (Gallaire et al., 1995; Dodo et Zuppi 1999; Illias et al., 2019).

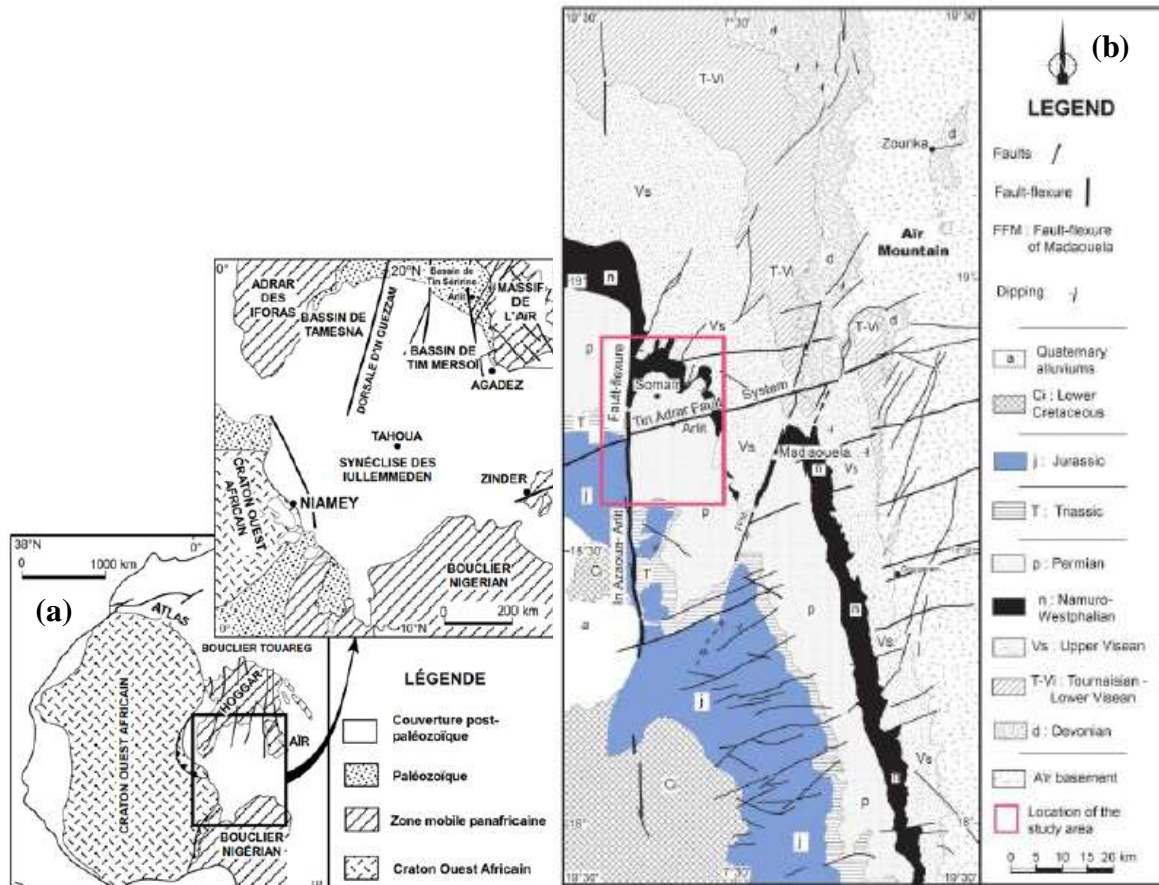


Figure 1:- (a) Location of Tim Mersoï du basin and Iullemedensyneclise (Valsardieu, 1971 ; Wright et al., 1993, modified) and (b) Geological map of Tim Mersoï basin a long of occidental edge of Air Massif (Konaté et al., 2007)

Geological context

The Tim Mersoï basin is the northeastern extension of the Iullemedensyneclise (Valsardieu et Dars 1971; Fabre 1988; Coquel, Lang, et Yahaya 1995; Konaté et al., 2007). It is limited to the east by the Air massif, to the north by the Hoggar massif, and to the west by the In Guezzam ridge. It extends to Algeria where it takes the name of basin of Tin Serririne (Coquel, Lang, et Yahaya 1995) (fig. 2). The oldest sedimentary series are of Cambro-Ordovician age (Jouliia, 1959) and part of the basin contains a sedimentary cover with ages ranging from the Devonian (Terag sandstone) to the Early Cretaceous (Tegama group). Four major fault families are recognized in the Tim Mersoï basin. These are $N0^\circ$ fault system known as the Arlit fault, the Madaouéla $N30^\circ$ fault system, the Tin Adrar beam $N70^\circ - N80^\circ$ and the $N130^\circ - N140^\circ$ faults. (Konaté et al., 2007). The lithostratigraphic column of the Tim Mersoï basin (fig. 3) comprises two sequences: (i) a lower sequence represented by the grey carboniferous formations (Farazekat, Talak, Guézouman, Tchinezogue, Tarat, Madaouéla and Arlit) and (ii) a summit sequence corresponding to red formations of Permian age (Izégouande, Tejia Tamamat, Moradi) to Jurassic (Téloua) (Jouliia, 1959; Cazoulat 1985; Yahaya et Lang 2000; Pagel et al., 2005).

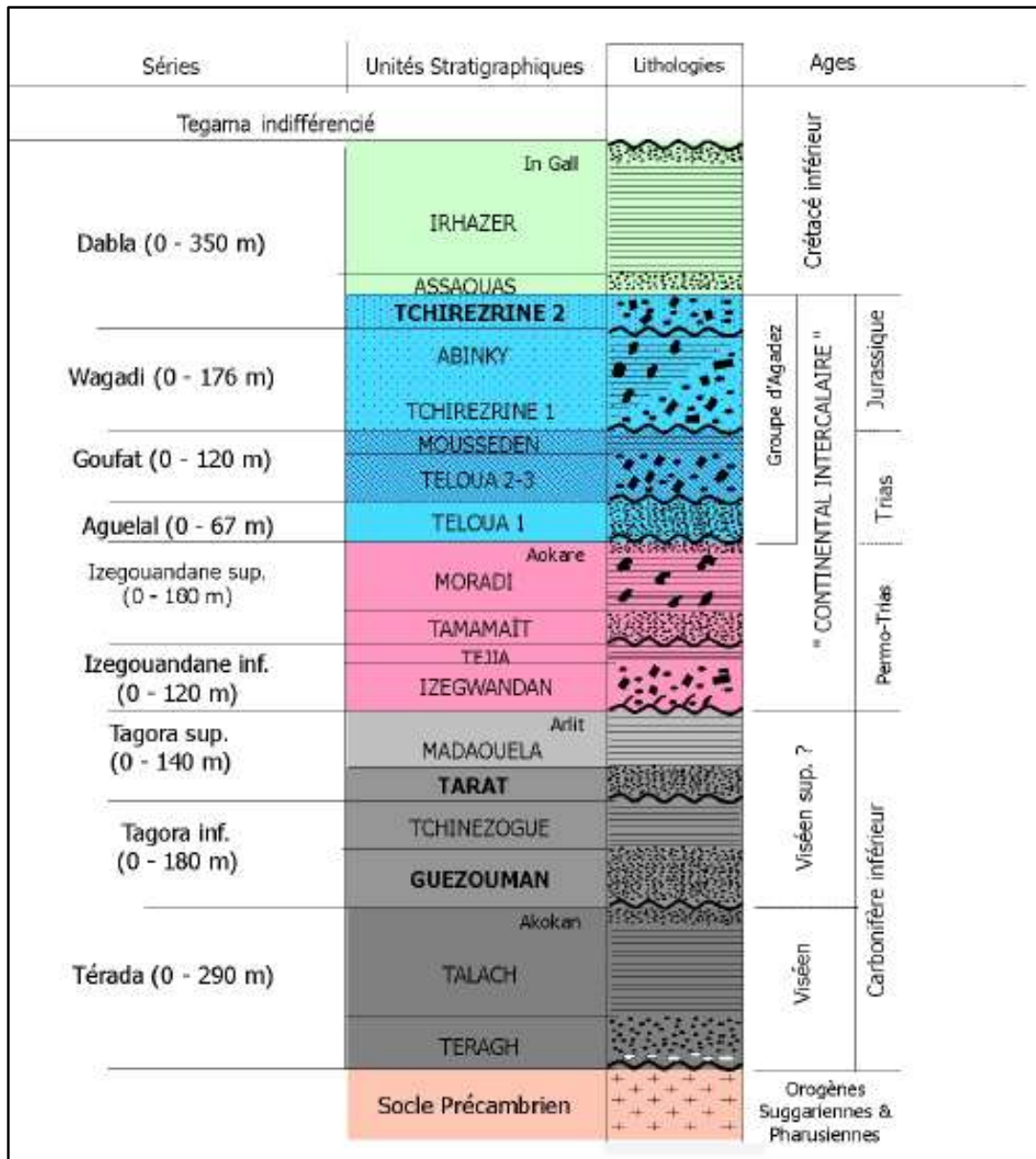


Figure 2.- Simplified lithostratigraphic column of the geological series of the Tim Mersoï basin (Cazoulat 1985,modified).

Hydrogeological context

Several hydrogeological studies conducted in the Arlit region have shown the presence of four permeable horizons constituting an aquifer system comprising from the bottom to the top the following aquifers: Guézouman aquifer, Tarat , Izégouande and Téloua(Dodo et Zuppi 1999;Illias et al., 2019;Illias et al., 2021;Alfidja et al., 2021;Dobi et al., 2021).

Guezouman aquifer

Contained in the sandstone levels of the Guézouman, host formation of uranium deposits exploited by COMINAK (Bigotte et Obelliane 1968), the Guézouman tablecloth is characterized by significant lateral variations in thickness(Abd Elmola et al., 2020).The wall of the aquifer is represented by the Talak clays, while its roof corresponds to the Tchinezogue formation, (very fine sandstone) (Moussa, 1992;Dodo et Zuppi 1999;Gerbeaud, 2006).The Guézouman has a thickness varying from 30 and 70 meters for an average value of 40 meters.

Transmissivities are also low, ranging from $1.5 \cdot 10^{-6}$ to $1.8 \cdot 10^{-4}$ m²/s. Storage coefficients are homogeneous values around $4.5 \cdot 10^{-5}$.

Tarat aquifer

The Tarat aquifer is contained in coarse sandstone by means of the Tarat formation (Dodo et Zuppi 1999 ; Cavellec, 2006), host deposit of uranium mineralization exploited by SOMAÏR. The wall of the aquifer corresponds to the Tchinezogue formation (very fine sandstone) while its roof is represented by the arkosic sandstones of the Izegouande. The thickness of the aquifer is subject to very important variations due to both tectonic structures and the mode of sedimentation related to the energy of the deposit medium (Boko et al., 2017 ; Illias et al., 2019). Transmissivities vary between $7.4 \cdot 10^{-5}$ and $1.1 \cdot 10^{-3}$ m²/s, and storage coefficients are around 10^{-5} .

Izegouande aquifer

The reservoir consists of arkosic sandstones, coarse at levels and with micro conglomerate past (Moussa 1992;Yahaya et Lang 2000).The wall of the aquifer consists of the Arlit unit. The Izegouande aquifer is free-water to the east of the Arlit fault, while to the west of the fault, it is captive and surmounted by the Moradi, Tamamaïte and Téjia formations. Transmissivity are also low and range from $1 \cdot 10^{-4}$ to $7.8 \cdot 10^{-5}$ m²/s.

Téloua aquifer

The Teloua aquifer consists of coarse sandstone with micro-conglomerates is free-water and only outcrops west of the Arlit fault floret. The wall of the aquifer is formed by the arkosic red sandstones of the Izegouande.

Methodology:-

The methodological approach is based on the determination of the roof and wall dimensions of the Tarat aquifer based on data from development surveys (elevation and wall dimensions of the Tarat). These holes intersect the Tarat formation over its entire thickness. The producing part is in the medium and coarse sandstones with micro-conglomerates of units U3 and U1on all its thickness up to its base (formation of Tchinezogue).

Data from logs (resistivity, Spontaneous Polarization) carried out on all the soundings were used to accurately determine the different stratigraphic limits of the crossed formations.

The data was processed using the Surfer.11 software. The method of interpolation by kreging was chosen and it made it possible to establish maps: equal thicknesses (isopaques), equal depths (isobaths), and equal altitudes (isohypsis) of the aquifer.The organigram chart (fig.3) summarizes the various operations carried out.

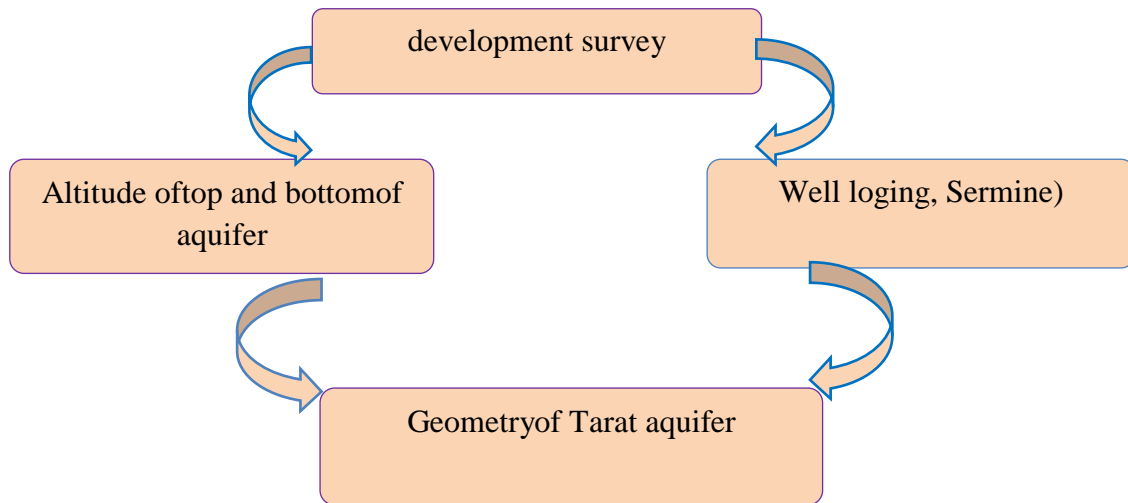


Figure 3:- Organigram chart of the various operations.

Results:-

Isobaths map

The observation of the maps (fig. 4 a and b) isobaths (curves of equal depths of the Tarat wall) (fig. 4a and 9b) shows two distinct areas from east to west. A western zone where the wall is deeper with depths of around 800 m with hollows of 850 m.

To the east the wall of Tarat is shallower and the depths vary from 250 to 50m.

In the North, the depths are of the order of 500 to 50 m showing that the wall of Tarat goes up to the North. At the extreme North-East the depth of the wall goes up to 0m indicating that the Tarat outcrops on this part.

In the South, the Tarat wall is much deeper, it can reach 850 m while in the Southeast the depth is less, it is of the order of 250m. This shows that the geometry of the Tarat aquifer is highly affected by tectonic accidents.

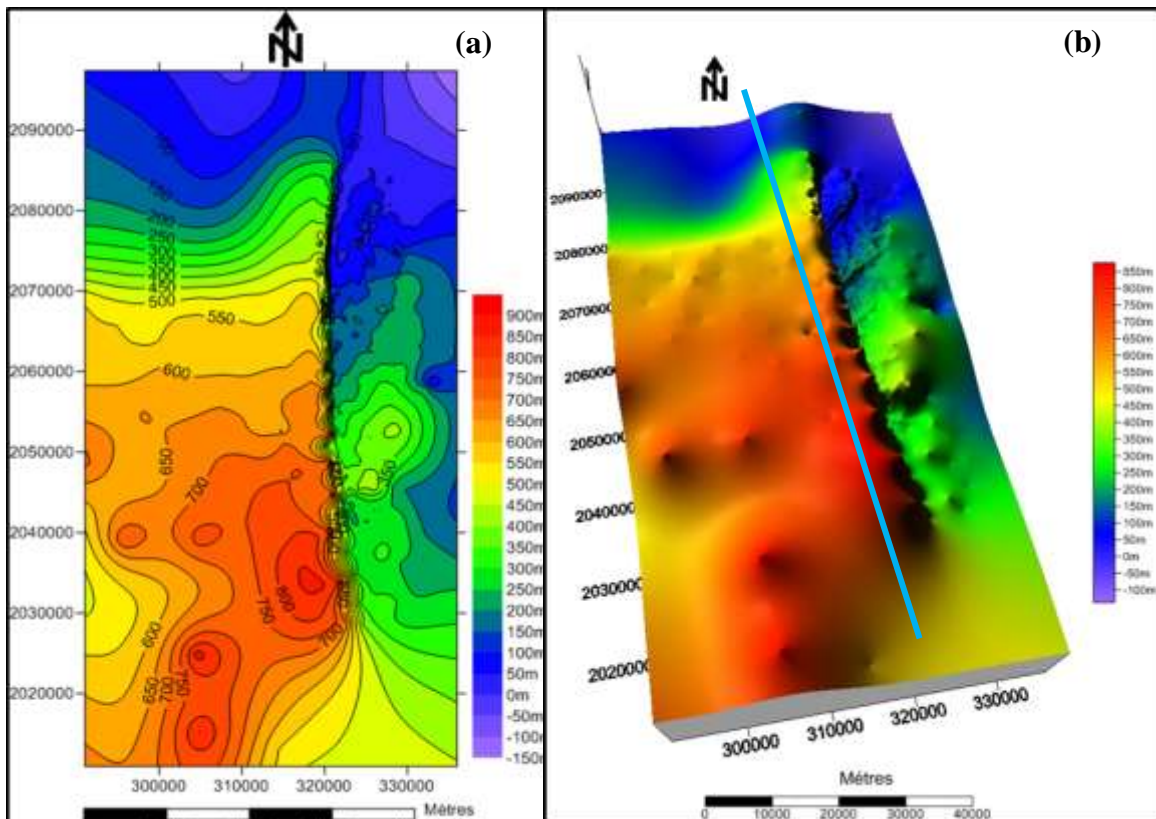


Figure 4:- Maps 2D (a) and 3D (b) of Tarat aquifer isobaths.

Isohypsismap

The analysis of the maps (2D and 3D) of the isohypsismap (curves of equal altitudes of the Tarat roof) of the roof of the Tarat aquifer (fig. 5) reveals the same observations as the isobath maps.

Thus, two sectors are distinguished: a western sector where the altitudes vary from 100 to -450 m and an eastern sector with altitudes from 50 to 250m. Ce shows a difference in altitude of the roof of the aquifer from West to East. The abrupt change in the altitudes of the roof of the aquifer observed from East to West would be explained by the Arlit fault play materialized by a black line (fig. 5 3D map (d)).

In the North, the altitude of the aquifer roof varies from -100 to 550 m at the extreme North-East where the Tarat outcrops. In the South, the altitude varies from 50 to -550 in the Southwest where the roof of the Tarat deepens.

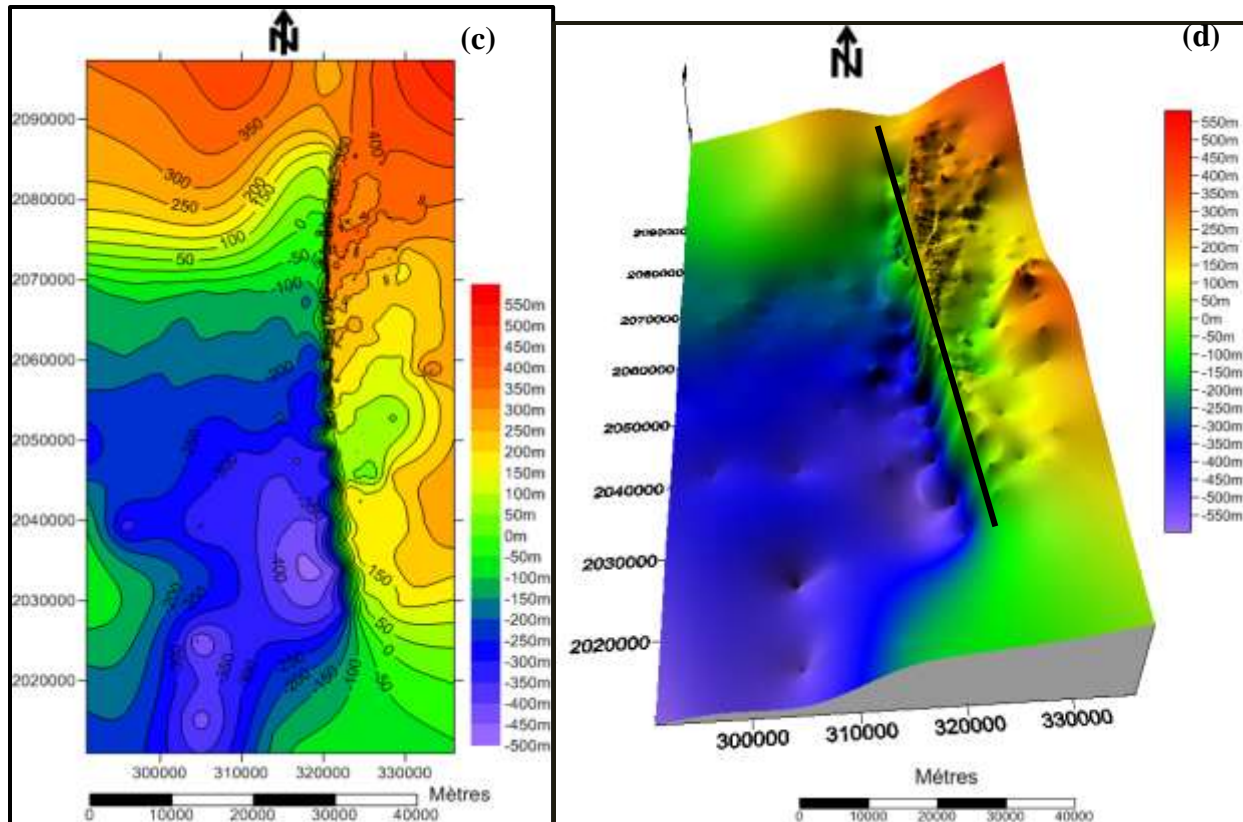


Figure 5:- Maps 2D (c) et 3D (d) of Tarat aquifer isohypses.

Isopaquemap

Analysis of the isopaque charts (e and f) (curves of equal Tarat thicknesses) (Fig. 6) shows the same observations as the isobath and isohypsis charts (fig.4 and 5). However, on isopaque charts these disturbances are more noticeable.

In the center, on either side of the flexure fault materialized by the gray line (fig.6 f) are visible two zones: a western zone where it is observed a maximum thickness of the order of 150 m. This thickness decreases while going towards the South-West with values ranging from 60 to 20 m.

In the eastern zone, the thickness is 30 to 20 m or even 50 m to the southeast. On this eastern part, it is observed abrupt variations in the thickness of the aquifer which is 90 to 20 m with peak to the North and the eastern approaches of the Arlit flexure. This shows that the Tarat is thicker to the west.

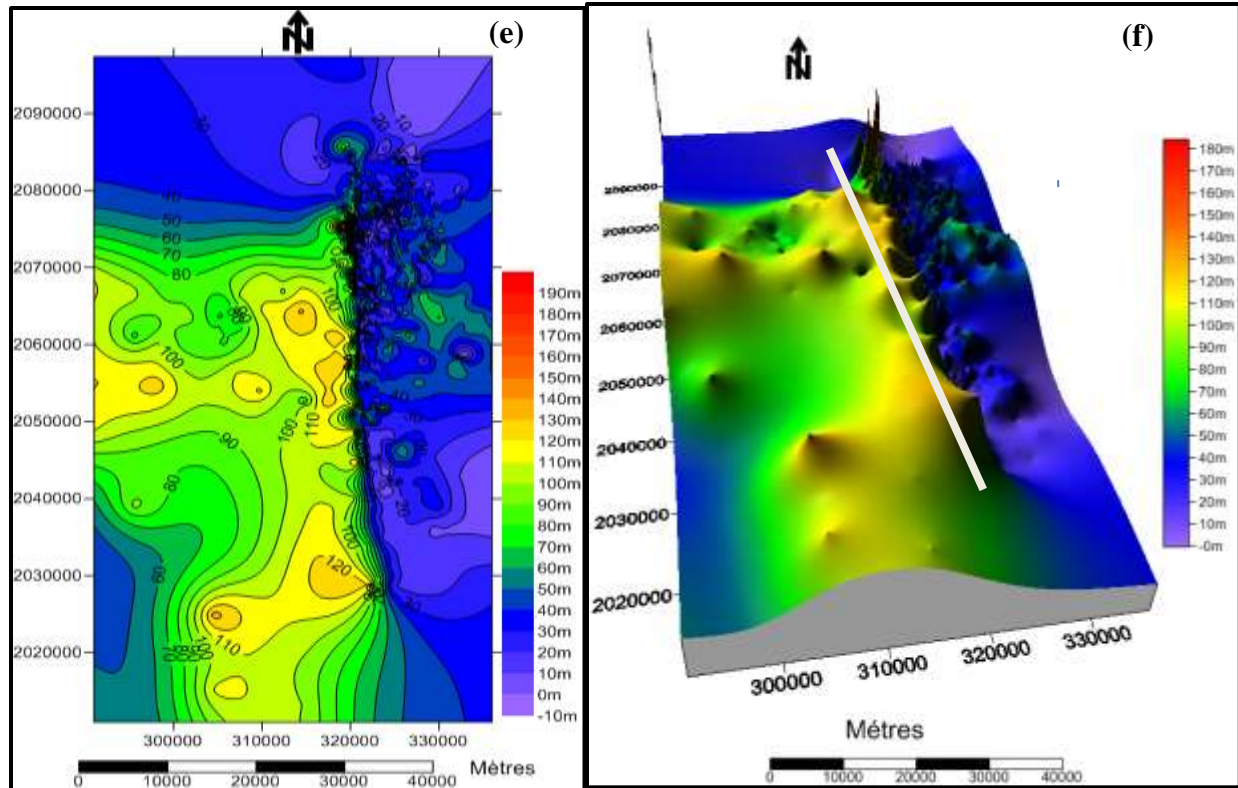


Figure 6:- Cartes 2D (e) et 3D(f) des isopaques du Tarat.

Discussions:-

This variation of depths from West (800m) to East (50m) is due to the effect of the flexure Arlit fault materialized by the blue line (fig. 4b) showing that the aquifer of Tarat is deeper in the West of the flexure than in the East.

Also on the eastern part, abrupt variations of the depths are observed which would be explained by the presence of secondary accidents (Mouron's flexure, Austrian flexure etc.) which were mainly expressed in this part (Gaultier, 1972).

From field surveys and stratigraphy data, the realization of two cross-sections at the Madaouela flexure allowed to estimate a flexure amplitude of about 200 to 300 m in the Carboniferous-Permian age series (Gerbeaud 2006).

The total vertical discharge of the flexure fault can reach 200 meters in the Arlit area. In the area of the Tin Adrar beam oriented N70° a vertical discharge of approximately 60 m was estimated (Bottero, 2004).

The modelling of the Tarat aquifer in the Arlit region (Bottero, 2004) shows that the direction and speed of the flow of the aquifer vary according to the geometry of the aquifer, particularly from one structural compartment to another as a function of the dominant lithology.

Flexures affecting the aquifers of the Tim Mersoï basin are linked to a succession of tectonic events during the evolution of the basin (Gauthier, 1972; Hirlemann and Robert, 1980). Since the hydrodynamic properties of tectonic structures vary in the longitudinal direction with the geometry of the tectonic structures, they are not waterproof along their entire length (Boko et al. 2017; Illias et al. 2019). Flexures behave as generally permeable structures and as a result, aquifers are fragmented according to structural compartments.

Also, (Garnier in 2003), showed that the deposits are located in edge of domes corresponding to the ascents of the roof of the Tchinezogue and on a regional scale, the deposits are on a thin area of the Tarat. This confirms what has already been observed by previous work that the sedimentation of the Tarat is characterized by significant thickness

variations related to the syn-sedimentary games of accidents N0°, N30° and N70° (Yahaya et Lang 2000; Gerbeaud 2006; Salze, 2008).

The thickness variations of the series between the West compartment and the East compartment are due to steering accidents N30° with a syn-sedimentary play during the deposit of the Tarat (Valsardieu, 1971, Gauthier, 1972).

A tight mesh (50 m) of drilling carried out south of Arlit made it possible to highlight spectacular variations in thickness (from 2 to 15 meters) over small distances and these variations of thickness correspond to paleo valleys, all are oriented N70° (Hirlemann, 1980).

Conclusion:-

The Tarat aquifer consists mainly of medium to coarse sandstone locally micro-conglomerates with intercalations of clay levels. The analysis of isobath, isohypsis and isopaque curves shows that the Tarat aquifer has a complex geometry especially on its eastern part. The latter is characterized by abrupt variations in depths, altitudes and thicknesses related to secondary accidents that occurred mainly in this part of the Arlit sector. In addition, the aquifer outcrops to the north as it deepens to the south. Analysis of isopaque, isohypsis and isobath charts also shows that the East compartment is high while the West compartment is low.

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