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RESEARCH ARTICLE

AUTOMATIC ETCHECOPAR MICROTECTONIC ANALYSIS OF THE DAJY SECTOR (AGADEZ REGION, NORTHERN NIGER)

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Abstract

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This study, based on microtectonic analysis using Echecopar's automatic method combined with field work in the Dajy sector, highlighted that the direction of minimum stress σ_3 is not homogeneous in this study area. It was thus highlighted :

1. An extensive tensors linked to a direction of σ_3 of approximately N90° ;
2. An extensive tensors linked to a subhorizontal σ_3 direction N120° E to N160° E,
3. An extensive tensors with σ_3 directions parallel or subparallel to the N70° E faults. This category of tensors appears to be associated with strike slip fault (Fig. 6).
4. And an average N156° extension for the Jurassic series.

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Introduction:-

The Dajy area belongs to the large Tim Mersoï sedimentary basin (Fig. 1). This basin, well known for its uranium mineralization, is characterized by major tectonic faults, the dynamics of which, if understood, could lead to the discovery of valuable uranium showings. In fact, deformation studies in the Tim Mersoï basin are quite disparate, as they are carried out in different sectors in connection with uranium exploration permits. The Dajy sector, the subject of this study, located to the north of the Agadez region, has been the focus of major exploration campaigns. In recent campaigns, several geological outcrops have revealed fault mirrors with striations that are therefore suitable for microtectonic analysis. In order to better understand the dynamics of tectonic movements in this area, we undertook this study using the Etchecopar automatic method. The aim of this study is to :

- determine the various paleostress tensors;
- determine the phase(s) of deformation ;
- and specify the geodynamic context of the deformations.

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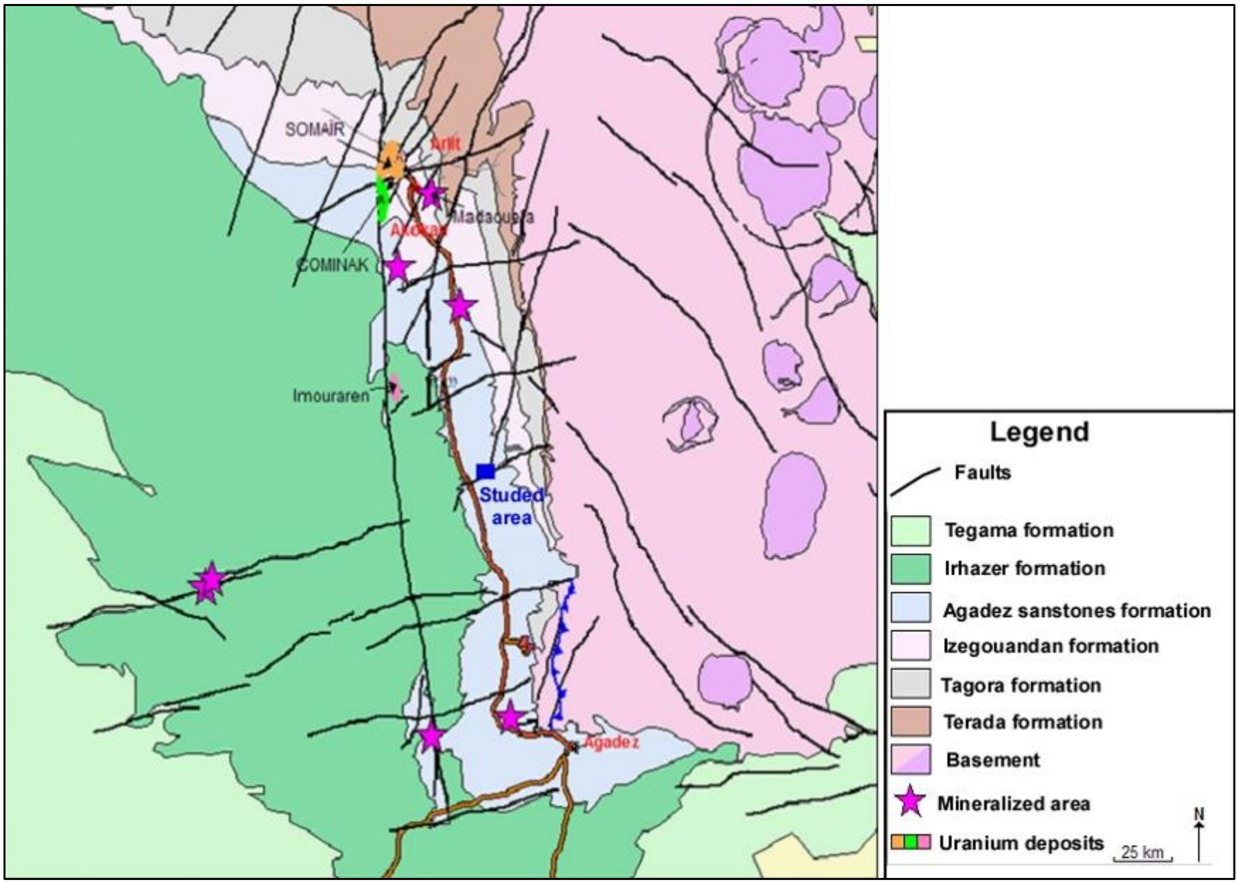

Figure 1:- Geological map of the Tim Mersoï basin showing the location of the study area (Areva, 2006, Modified).

Methodological Approach:-

The methodological approach used in this study is Etchecopar's (1984) automatic method. This method provides a better understanding of the dynamics of tectonic movements by carrying out a microtectonic analysis of brittle deformations. It should be noted that this microtectonic analysis of brittle deformations follows on from field work and presents two approaches:

1. The first involves a kinematic and statistical study of deformation. This enables us to draw up deformation trajectory maps based on microstructures (diaclases, tension cracks and stylolites).
2. The second, more dynamic approach, consists in deriving stress magnitudes from the analysis of brittle deformations (striated microfacial planes). This second approach assumes that there is a relationship between stress directions and microstructure orientations (striated microfacial planes, cracks, stylolites).

Building a data file:

Measurements were taken along the fault planes observed in the field. The creation of a data file depends on the types of microstructures that can be observed and measured in the field. Surveys consist in measuring

a) Azimuth and dip of microfault planes;
b) Pitch and plunge sector of striations;
c) The azimuth of any striations;
d) Direction of movement;
e) A reference number is assigned to each striated microfaille plane measured.

The measurements thus obtained are used to create a data file which, after input and conversion into an ASCII file, can be used by the various data processing programs ("FAILLE", "ARTO" and "EBENS"). The table below shows an example of a data file.

Table 1: Microtectonic analysis data file (Dajy 1 station). Fault plane Azimuth, dip, geographic sector (N= north), pitch and geographic sector of striation plunge (N= north), Nature of fault (N= Normal, I= Inverse, D=Dextre and S= senestre), Reference number of measured microfault plane (001).

Fault_Plan Direction	Bend/Sector	Pitch and sector_Strie	Fault_Nature	Measure_Ref
70	46N	75N	N	1
70	52N	65N	N	2
73	55N	75N	N	3
75	45N	72N	N	4
68	55N	70N	N	5
75	47N	65N	N	6
76	40N	50N	N	7
88	74N	55N	N	8
90	75N	50N	N	9
72	55N	45W	N	10
76	48N	60N	N	11
78	25N	55N	N	12
74	20N	55N	N	13

Etchecopar's (1981) automatic method or successive approximation method

This method is based on Bott's principle.

Bott's principle:

To interpret the dynamics of striated fault planes, it is assumed that a stripe has the direction of tangential stress resolved on the plane (Anderson (1951), cited by Etchecopar (1984)).

According to Bott, the orientation of a striae on a fault plane depends on 4 parameters:

1. The three orientation parameters of the principal stress trihedron (σ_1, σ_2, σ_3),
2. The value of the ratio $R = (\sigma_2 - \sigma_3)/(\sigma_1, -\sigma_3)$

The position of the stress trihedron (σ_1, σ_2, σ_3) is expressed by the Euler angles (Ψ, θ, φ, R) to define the stress tensor.

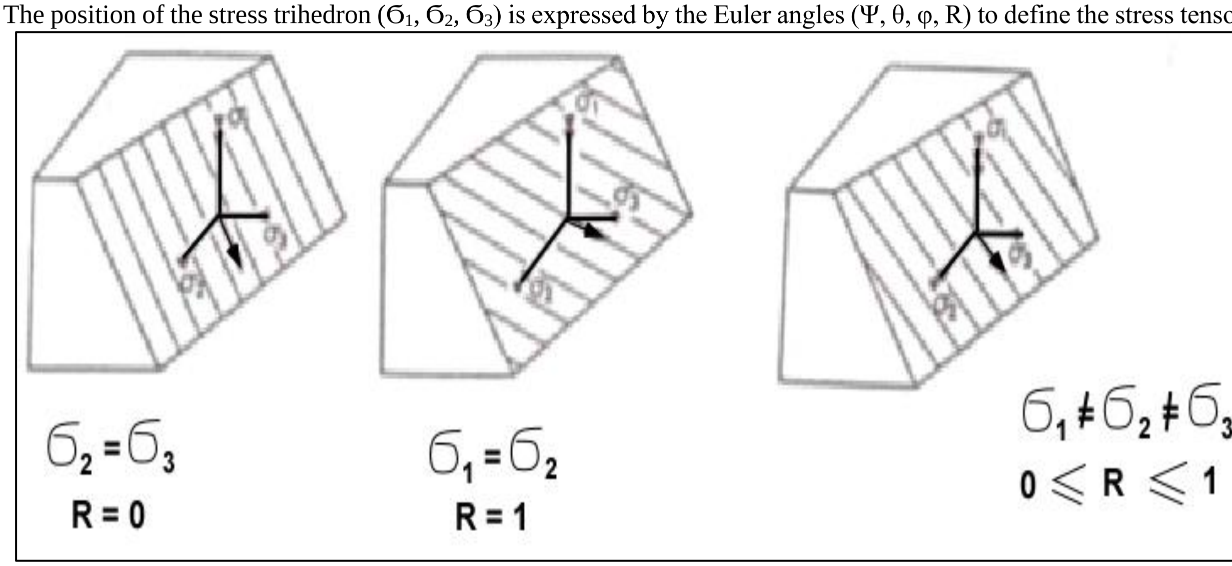

Figure 2:- Illustration of Bott's principle of variation in tangential stress as a function of the ratio tangential stress as a function of the ratio $R = (\sigma_2-\sigma_3)/(\sigma_1-\sigma_3)$ (Konaté, 1996, modified)

The Etchecopar method is implemented using the "Faille" program. Three statistical parameters enable all possible combinations to be made to calculate a tensor. These parameters are :
- The percentage (N1/N) of data taken into account;
- The number of random draws (between 100 and 200) to fix the starting tensor;
- The odd number (between 100 and 400) used to vary the random draw.

Principle for determining the N1 population of striae corresponding to Tensor T1
The following criteria are used to determine the tensor:
- The histogram of deviations between real (measured) and calculated striae, to visualize the quality of the results;
- Average deviation: this is the sum of deviations between actual and calculated striae. A low mean deviation (2 to 3) indicates that not all striae compatible with the calculated mean tensor have been taken into account, while a high mean deviation (>10) implies that the result obtained is far from the correct solution;
- The representation of striated planes on the Morh circle is based on a breaking criterion. The representation on the Morh circle indicates the reliability of the proposed solution.

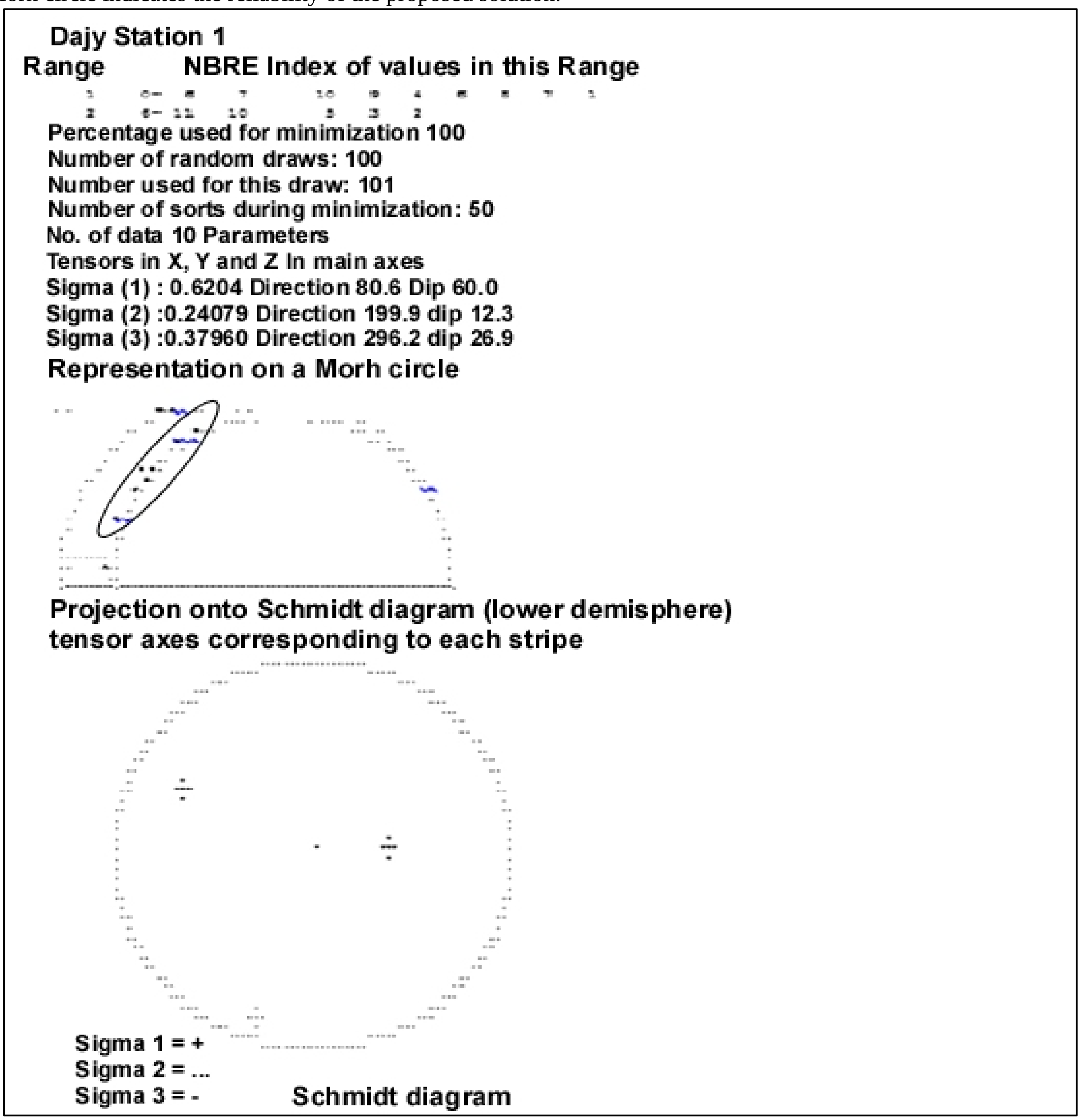

Figure 3: Principle of tensor determination and representation of stress states on the Morh circle.

Geological setting of the study area:-

The geological setting of the Dajy area is part of the general geological context of the Tim Mersoï basin. All the sedimentary series described in this basin are represented in the Dajy area. Studies of the core and destructive drilling carried out as part of the exploration campaigns have revealed a complex stratigraphy with significant variations in thickness from one hole to the next. In the Dajy area, the outcropping formations are Jurassic and Cretaceous. From a tectonic point of view, the main faults identified (Fig. 4) are :

- faults N65-70° ;
- faults N20-30° ;
- faults N95-105° ;
- and faults N130-150°.

Results of Dajy data processing using Etchecopar's automatic method:-

The figure below shows the main faults in the study area, together with the location of the various microtectonic measurement stations.

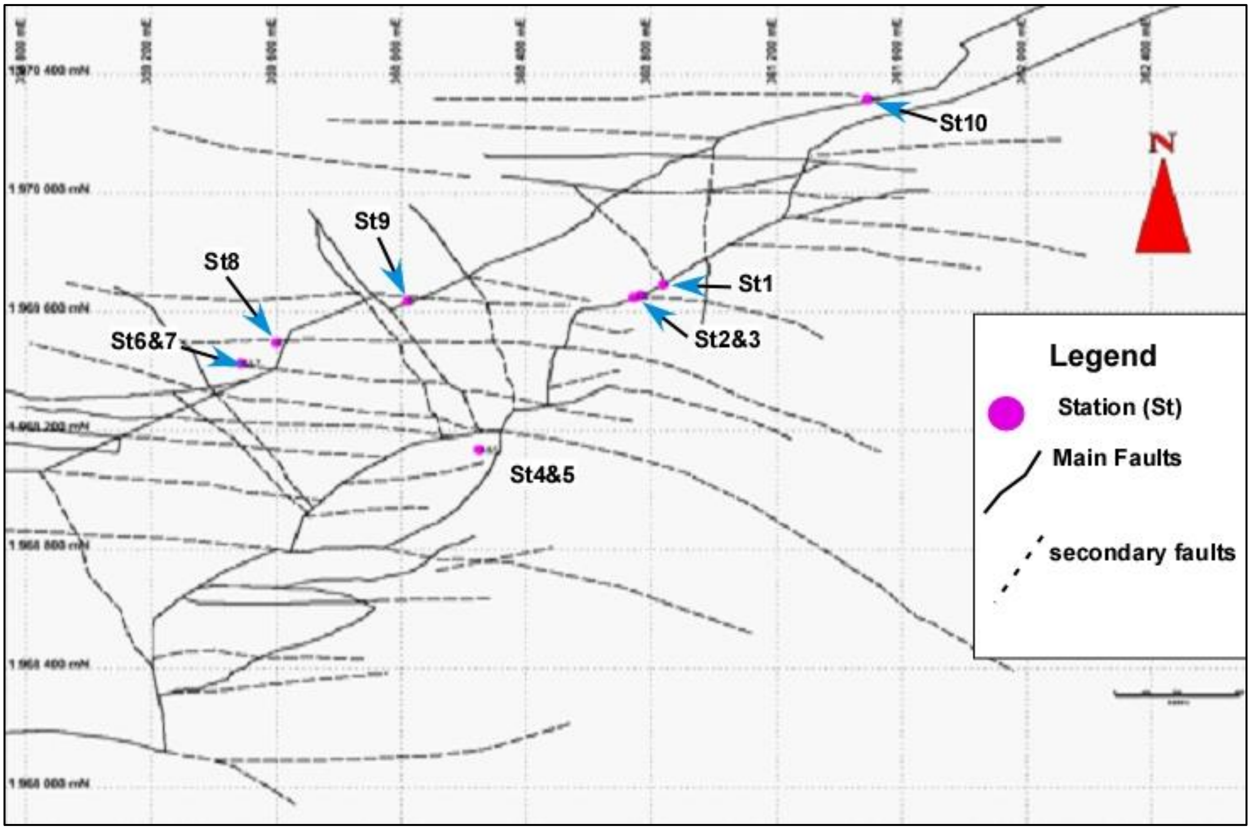

Figure 4:- Structural map of the Dajy area, showing the location of the various measurement stations.

Based on geological outcrop observations, the various stations for microtectonic analysis were selected. Various fault planes were observed at the selected outcrops. These show brittle and semi-ductile faults. Both normal and strike-slip faults were observed (Fig. 5).

Based on measurements taken at the various microtectonic analysis stations selected, the Etchecopar (1984) method was applied to obtain the results shown in table 2.

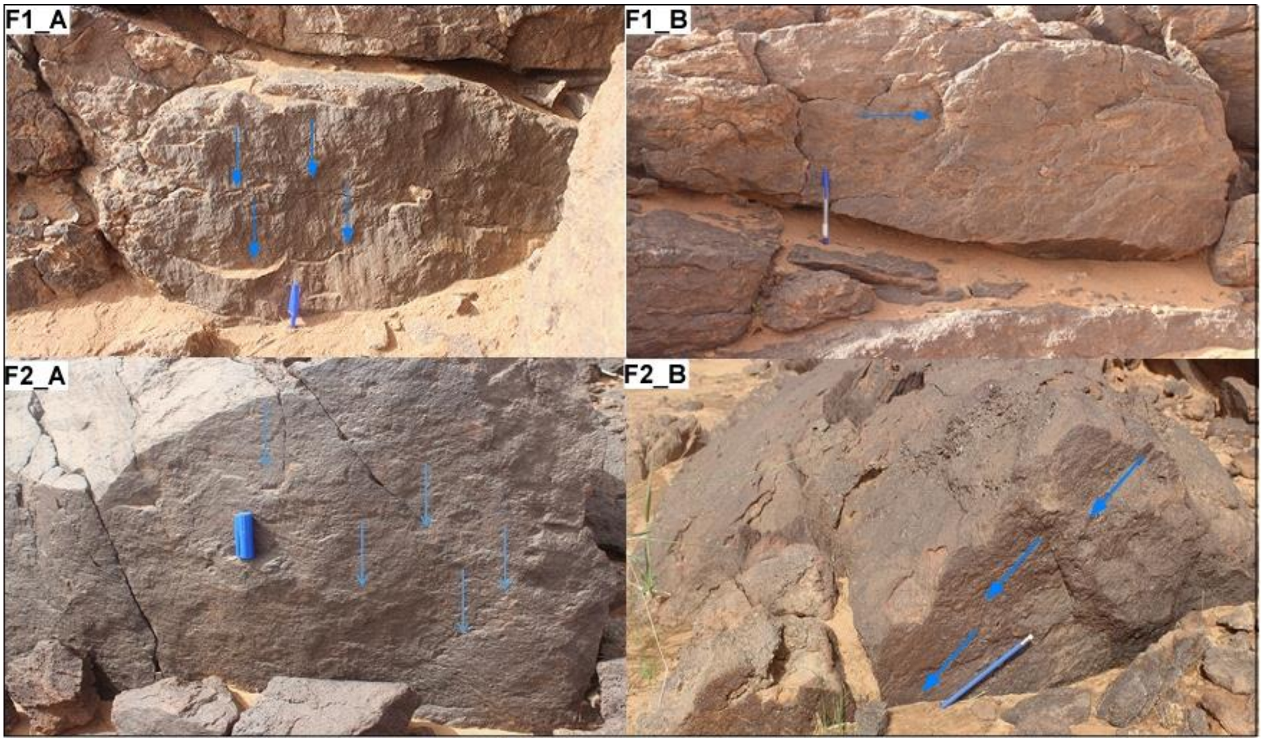

Figure 5:- Microphotographs of outcrops in the Dajy sector showing tectonic structures. F1_A = N70° fault mirror (showing striations and tectoglyphs) dipping 75°N, F1_B = N70° strike-slip fault mirror (sinister strike-slip), F2_A = current ripples picked up by synsedimentary play of N70° fault, F2_B = N150° fault mirror dipping 78°W (with southeast striations).

The results of data processing at the various stations (Jurassic series) are shown in Table 2. These stations are characterized by normal fault planes, revealing extensive tensors.

Table N°2:- Extensive-type tensors: Dir= Direction, Pend= Dip, D= Distensive.

Station no.	**Ϭ1**		**Ϭ2**		**Ϭ3**		**R report**	**Type of associateddeformations**
	Dir	Pend	Dir	Pend	Dir	Pend		
1	73.8	75.8	166.5	0.7	256.7	14.1	0.26	D
2	87.6	60	179.9	12.3	263.2	26.9	0.14	D
3	87.9	58.4	178.9	13.5	268.9	27.9	0.16	D
4	171.6	78.2	271.9	2.1	2.3	11.6	0.38	D
5	320.7	86.0	127.0	3.9	217.1	0.9	0.83	D
6	334.2	55.8	77.7	9.0	173.6	32.7	0.65	D
7	231.7	47.2	0.9	30.3	108.2	27.1	0.99	D
8	244.3	44.3	35.7	42.0	138.4	14.8	0.32	D
9	234.9	67.9	357.2	12.2	91.3	18.1	0.03	D
10	225.6	89.1	135.6	0.9	45.6	0.4	0.39	D

The direction of minimum stress Ϭ3 is not homogeneous in this study area. It is possible to distinguish:

- ✓ on the one hand, extensive tensors linked to a direction of $Ϭ_3$ of approximately N90° (Fig. 6);
- ✓ on the one hand, extensive tensors linked to a subhorizontal $Ϭ_3$ direction N120° E to N160° E (Fig. 6);
- ✓ on the other hand, extensive tensors with $Ϭ_3$ directions parallel or subparallel to the N70° E faults. This category of tensors appears to be associated with strike slip fault (Fig. 6).

- ✓ an average N156° extension for the Jurassic series.

The extensive Jurassic episode (N156° E on average) determined in this work is corroborated by the extensive East-West elongation tectonics highlighted by the work of Gerbeaux (2006), relating to the deformation phase affecting the Permo-Cretaceous period (Figs. 6 and 7).

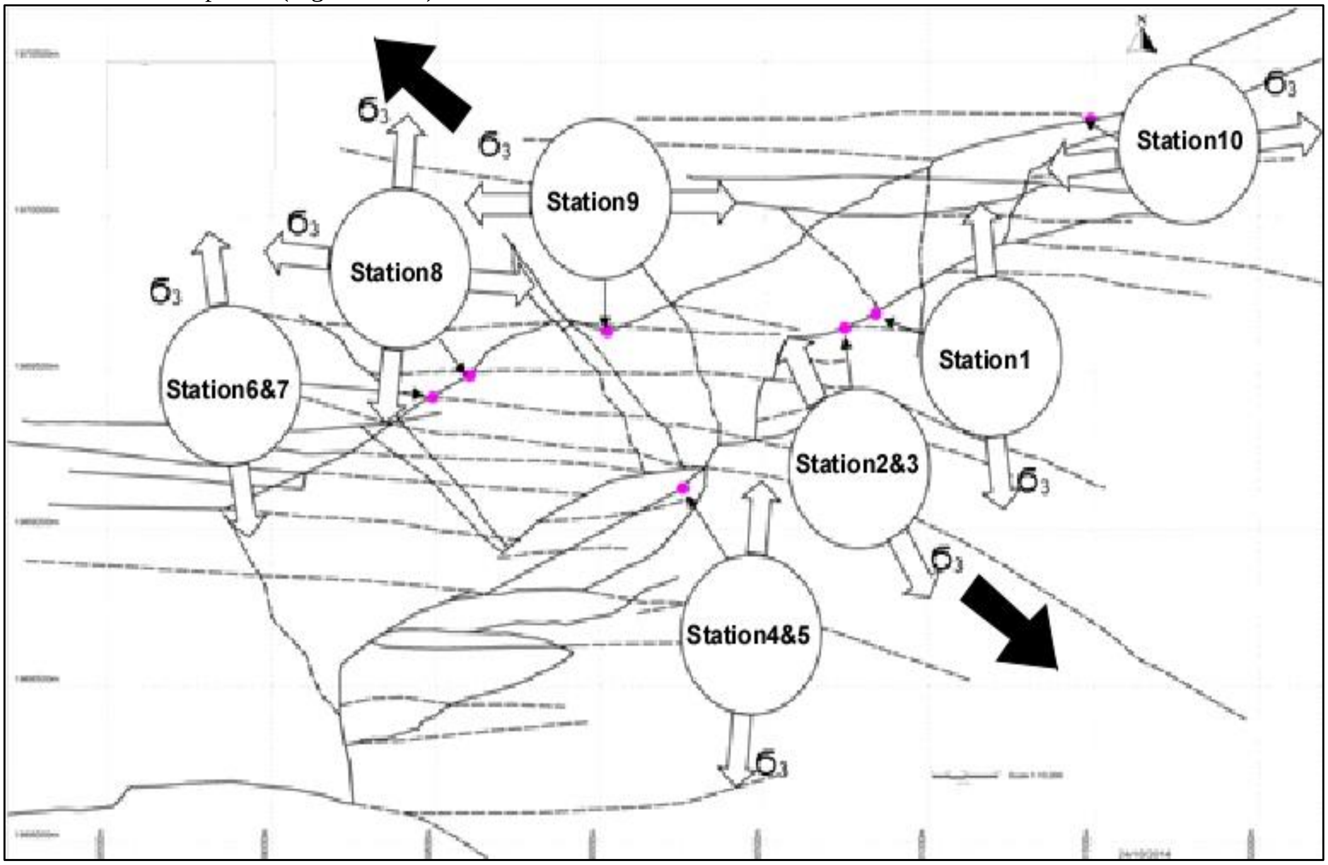

Figure 6:- Structural map of the Dajy area, showing a mean direction of extension N156° for the Jurassic series. The main cartographic works carried out were used by Gerbeaud to give the chronology of the various tectonic episodes recorded in the Tim Mersoï basin (Fig. 7).

Based on previous work, it has been possible to provide a chronology of the various tectonic events that have affected the basin. These tectonic events are as follows (1): NE-SW shortening, leading to dextral sliding of the NS faults. This shortening occurs mainly in the Upper Pan-African, and continues into the Lower Paleozoic (Djouadi et al., 1997, Paquette et al., 1998); (2) :approximately NS extension in the Upper Devonian - Lower Carboniferous, leading to extensive to transtensive reactivation of N30° and N70° trending faults; (3) : NNW-SSE extension in the Viséen (Valsardieu, 1971, Yahaya and Lang, 2000), resulting in the creation of N70°-trending tectonic-sedimentary structures in the Guézouman; (4): major extensive stage approximately EW during deposition of the Tarat and Madaouéla; (5): succession of extensive phases on the Arlit fault between the Lower Permian and the Cretaceous (N156° extension highlighted in the Dajy_Present study area); (6): major NW-SE compressive stage in the Upper Cretaceous, leading to the reactivation of the Arlit NS fault as a sinister strike-slip, and the formation of flexures on N30°-trending faults.

Conclusion:-

This study, based on microtectonic analysis using the method of Etchecopar (1984), has enabled us to highlight an extensive N156° episode for the Jurassic period in the Dajy sector. It has also been shown that the direction of minimum stress is not homogeneous in this sector (N70° to N90°, N120° to N150°). The N70° direction, corresponding to the direction of the major faults, would be linked to the senestral strike slip faults thus identified.

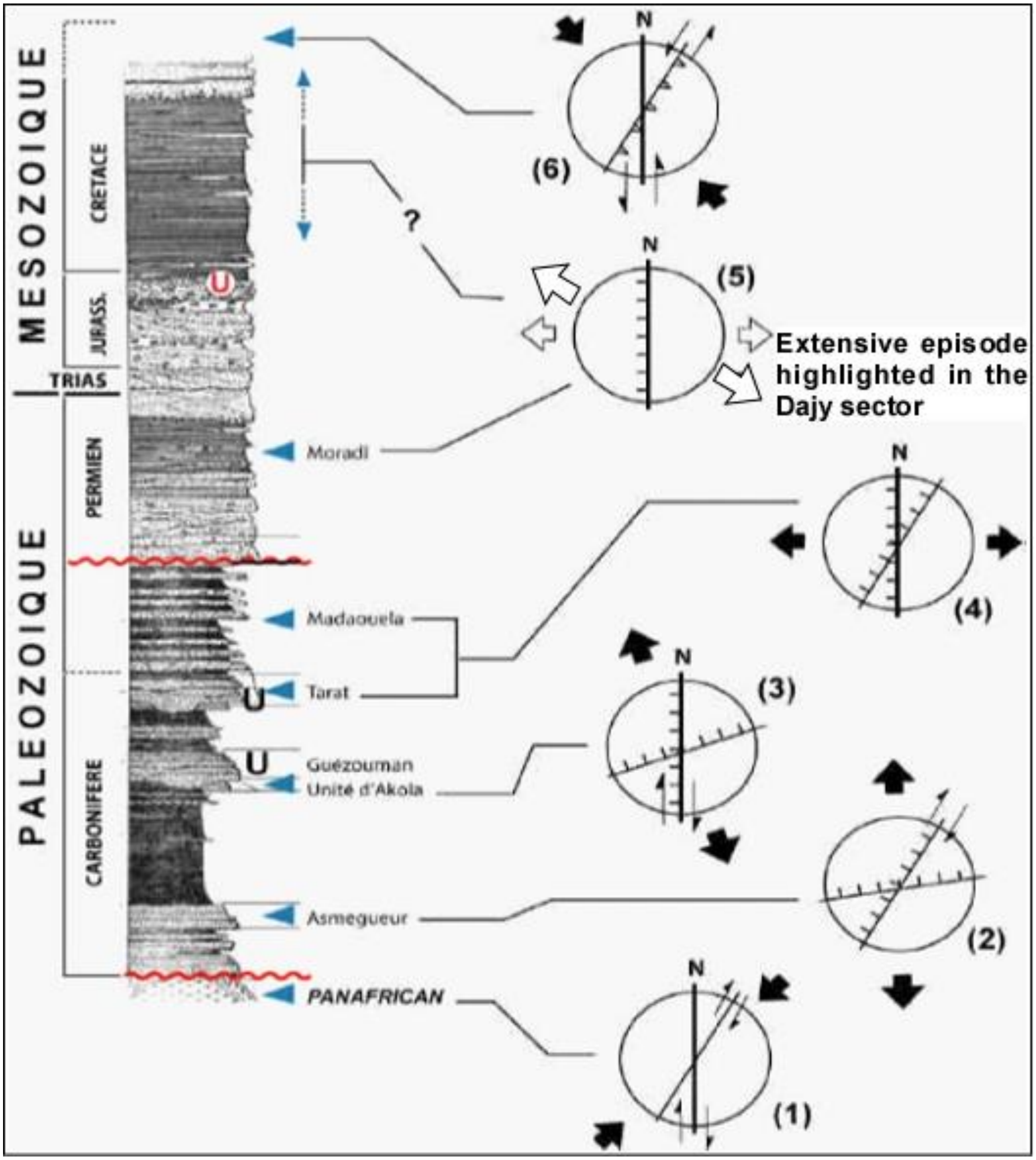

Figure 7:- Chronological representation of the main tectonic episodes recorded in the sedimentary cover of the Tim Mersoï Basin (Gerbeaud, 2006, Modified).

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