PETROGRAPHIC AND STRUCTURAL STUDY OF THE PRECAMBRIAN FORMATIONS IN THE ZOUBOU-DOLKO AREA SOUTH-EAST OF FITRI-LAKE (CHAD).

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ABSTRACT

Precambrian formations in the Zoubou-dolko area south-east of fitri-lake in Chad was conducted for the first time to learn the different lithological formations. To achieved the objective, six (6) days of field campaign from 30 March to 05 April 2024 was organised. The result show that, the Petrography area made up of two lithological groups: a magmatics rocks (fractured granites, dolerites and ultrabasic rocks crossed by quartz veins,) and metamorphic rocks, represented by metadiorites, garnet micaschists, pyrite schists and green schists, meta-andesites and marbles. The Precambrian rocks are covered by sediment and microconglomerate in the fitri-lake, and intruded by dolerite dyke. The presence of garnet within these rocks provides valuable insights into the thermodynamic evolution and history of the Earth's crust. The Zoubou-dolko tectonic present three deformational phases; D1, D2, D3. The D_1 is materialized by S_1 foliation, is transposed by the deformation phase and is observed in metamorphic rocks. It is characterized in meta-andesite and highlighted in straight lines that are parallel to each other, phase D_2 is marked by the schistosity S_2 by the cutting in sheet direction NE-SW and with dips of NE, NNE, SE directions that lie on the schist; and lineation L_2 are observed in the meta-andesite in the form of quartz mineral stretches with their direction of extension 15SW.

The P_2 recumbent folds observed in the shale are symmetrical, with axial planes and dip in a N-E direction. These folds result from the transposition of the S_1 foliation by the second phase of D_2 deformation. The P_2 overturned folds observed in the shale, on the other hand, are the result of deformation of the S_1 foliation plane. These folds are asymmetrical with predominant directions N04E, N25E, N40E, N72E and dip towards the south with an oblique axial plane. The metamorphism associated with this phase is equilibrated in greenschist facies conditions. These schists have undergone ductile high-temperature formation, i.e. intense metamorphism.

Phase D_3 is characterised by the enlargement of the sealed vein joints and faults in the outcrop with different mean directions N45E, N70E, N80E, N50E, N60E. The link between the hydrographic network and fracturing has been demonstrated in several localities.

***Key words**: Central African Pan-African Belt, Petrography, Structural, Deformation Phase, Lake Fitri/Chad.*

I INTRODUCTION

The Precambrian basement formations outcropping in Chad lie between the Nigerian domain to the west, the Congo craton to the south and extends into the Sahara metacraton to the east [1]. Chad lies in the middle of a domain called the Central African Pan-African Belt (CPAC), [2]. In Chad, the Pan-African formations outcrop in the north in the Tibesti, in the east in the Ouaddaï, in the centre in the Massif Central (Guéra), in the south-west in the Mayo Kebbi and in the far south in Yadé ou Baibokoum] ([3] [4]) [1]. The Recently knowledge of geology of Iro Lake region results from the collision of differents african craton [5], [6].

This massif has geological affinities with the Guéra massif and the southern part of the Ouaddaï massif. Consisting of a series of rocks formed during the Pan-African orogeny around the end of the Precambrian (700-520 Ma). The chain is divided into three domains [7]. The Yaoundé domain, or southern domain, the central domain, or Adamaoua-Yadé, and the northern domain. It results from the collision between the São Francisco-Congo craton, the West African craton and the Saharan metacraton, between 900 and 550 Ma ([8] [9] [4] [7] [10]). The Pan-African lithologies previously identified as Late Neoproterozoic [6] are known to span from Cameroon through Chad to the Central African Republic before reaching the Republic of Congo and North East of Nigeria [7] and forming a huge part of the Central African Orogenic Belt (CAOB). The Chad domain lies between the Congo craton to the south, the West African craton to the west and the Eastern Sahara metacraton to the north [4]. These formations are divided into two domains according to their composition. The gravimetric feature highlighted in central Chad, to the east of Lake Fitri [11] corresponds to the boundary between the two domains [12]. The geological map available for this region shows poorly defined metamorphic and magmatic rocks. The available lineament map is not in detail. The lithological formations of Batha, have been subject of very few petrographic and geochemical studies, are the subject of these recent studies by [13], showing that the results obtained and the work carried out by [6]in the Mayo-Kebbi region show similarities in these facies, which are probably a southern extension of the country. The massif in the south-eastern part of Lake Fitri. The relationships between the different lithological types and the deformation structures affecting the magmatic and metamorphic formations remain unclear.

In this paper, we describe and discuss a variety Petrographic and structural carried out in the Lac Fitri area made up of two lithological groups of deformation-related microstructures observed in different formations.

2. Geological setting

In Chad, Precambrian formations outcrop between the Eastern Nigerian domain at in the west, the Congo Craton in the south and the Saharan metacraton in the east. The formations of the Proterozoic correspond to crystallophyllian rocks and granitoids which outcrop essentially on the periphery of the Chadian basin in the Tibesti to the north. hey occur at from Niger to Libya [14] in Ouaddaï in the east and in the central massif in Guéra, in Mayo-Kebbi in the south-west and in the extreme south in the

Baibokoum or Yadé region. The Precambrian formations constituting these massifs were affected by the Pan-African orogeny (700 to 520 Ma). Now Chad is part of a stable block. Its geological history since the beginning of Paleozoic is marked by the deposition of sedimentary platform formations over most of the territory. Paleozoic sediments accumulate in the north and east of the country following the latest pan-African tectonic shift. The posterior tectonics and the surrection of Tibesti and Ouaddaï limit sedimentation in the Erdis and Djado basin, which occupy northern Chad and adjacent regions [15][16][17][18]. The main cartographic unit is a large batholith, consistent with the host rocks, which are made up of micaschists, quartzites and gneisses, crossed by granites. According to [2] [19]; [20]), the Chad region was tectonically stable after the Pan-African Orogeny, and sedimentary formations accumulated over most of its territory during the Palaeozoic. [21] conclude that magmatism was structurally controlled by Pan-African suture zones that were reactivated during the opening of the central Atlantic Ocean.

Local geological shows that the south-western section of the Lac-Fitri department is essentially made up of magmatic rocks and metamorphic rocks. These rocks include marbles, granites, dolerites, schists, micaschists, ultrabasics, meta-andesites and metadiorites. They have a massive structure and a gritty, granolepidoblastic structure. These rocks form chaotic hills with blocks of varying dimensions. They also outcrop in the form of slabs and boulders.

3 LOCATION OF THE STUDY AREA

The Batha region is located in the centre of the country (Figure.1). It covers an area of 88,800 km². The Batha had a population of 527,031 in 2009, representing 4.7% of the national population. In 2012, the total population is estimated at 561,177, (22), with density of 6 inhabitants per km² and the annual growth rate is estimated at 3.84%.

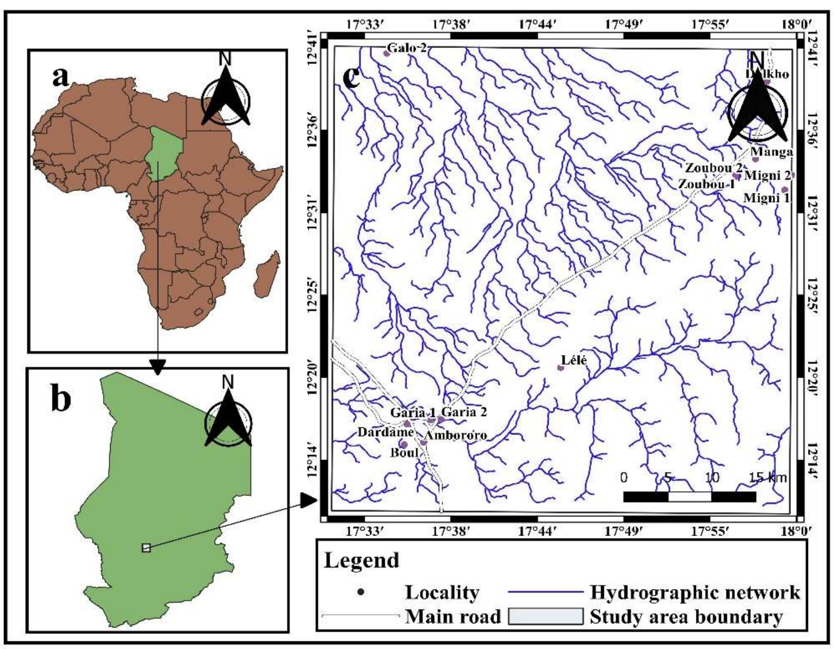


Figure.1. Location map of study area.

4. Material and Methods

Geological mapping and attitude of the main structural elements (i.e., foliations and lineations) were acquired with a traditional approach, integrated. The dataset was handled through the open-source software QGIS 2.18 for producing maps; Structural data were processed using GéoRose and Stéreonet plotted in the lower hemisphere Wulff projection. During the field survey, 20 specimens of magmatic and metamorphic rocks were collected. In this paper, we deal with a set of Twelve (12) thin sections over the entire samples collection, were produced in the thin section laboratory of the Earth Sciences Department in the Yaoundé 1 University of (Cameroon) (Figure 2). Geria (08 samples), Zoubou (12 samples). Samples were collected in different parts of the intrusions (close to the contact with the host rocks, in the central part and intermediate positions) to observe possible variations. We acquired high-resolution images by using the electric Olympus microscope connected to a Dell computer on which the XIMEA, both hosted at the Department of Geological in faculty of Applied and Exact Sciences in N'Djamena University (Chad).

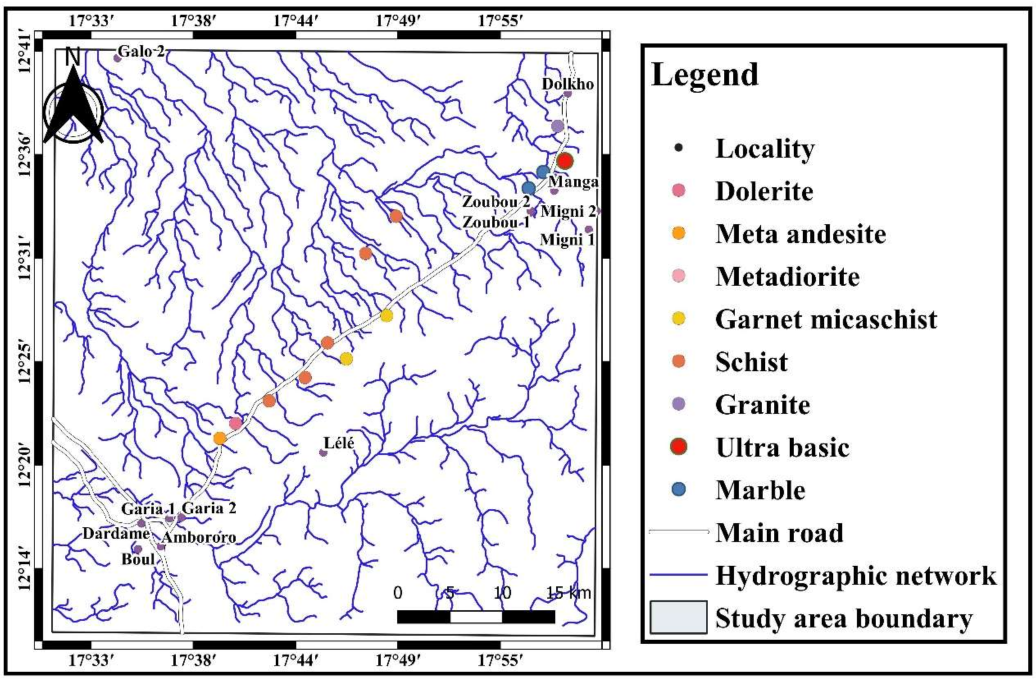


Figure. 2: Sampling Map

5. RESULTS AND DISCUSSION

5. 1.RESULTS PETROGRAPHIC

The petrographic study shows that the south-western section of the Lac-Fitri department is essentially made up of magmatic rocks (granites, dolerites ultrabasics) and metamorphic rocks represented by: marbles, schists, micaschists, meta-andesites and metadiorites. These rocks have chaotic form hills with blocks of varying dimensions. They also outcrop in the form of slabs and boulders. They have a massive structure and a gritty, granolepidoblastic texture.

Granites: outcrop in blocks and slabs in the Dolko village, with centimetric to metric size in a NE direction near the Zoubou village. The rock has a pinkish weathering patina running N90E. They are fractured granite with basic enclaves, quartz vein and with different direction N59E, N52E, N39E as showing in (Figure.3.a and b).

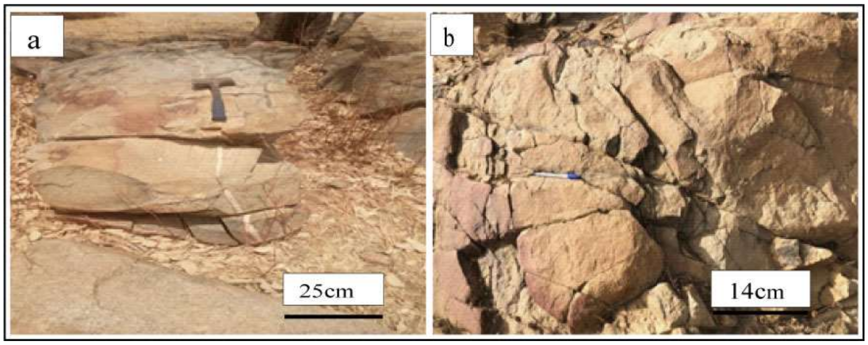


Figure: 3 a) Outcrop in blocks and slabs of pinkish granites showing the quartz vein; b) Granites with fractures

Dolerites : outcrop in blocks and balls in the Zoubou village, with centimetric to metric size in a NE direction. The rock has a grey and slightly reddish alteration patina and dips slightly as showing in (Figure.4.a and b).

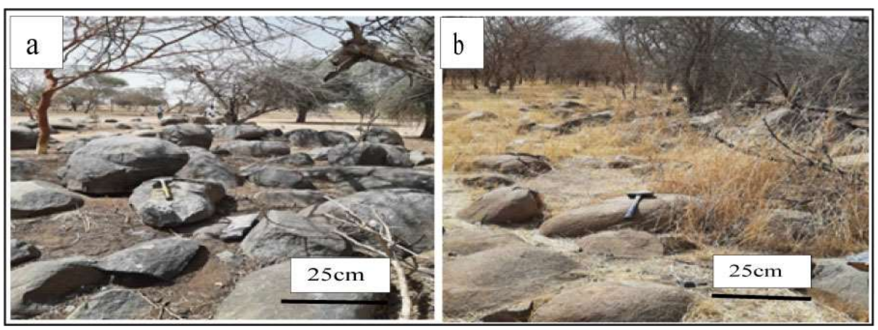


Figure: 4. a) Outcrops of blocks and balls of dolerite with grey weathering crust containing quartz; b) Dolerite with reddish weathering crust

Metamorphic rocks

- **The marbles**

Schistose marbles outcrop in blocks and slabs in the village of Zoubou with dimensions centimetric to metric in a NE direction and are almost affected by contact metamorphism of low degree under modified stress of the rock formation.

Some bedded marbles are covered by shale and sedimentary rocks as showing in (Fig.5.a) and the schistose marble has a light bedding running N180E (Fig.5.b.c). The rock has a with coloured weathering patina as showing in (Fig.5.d).

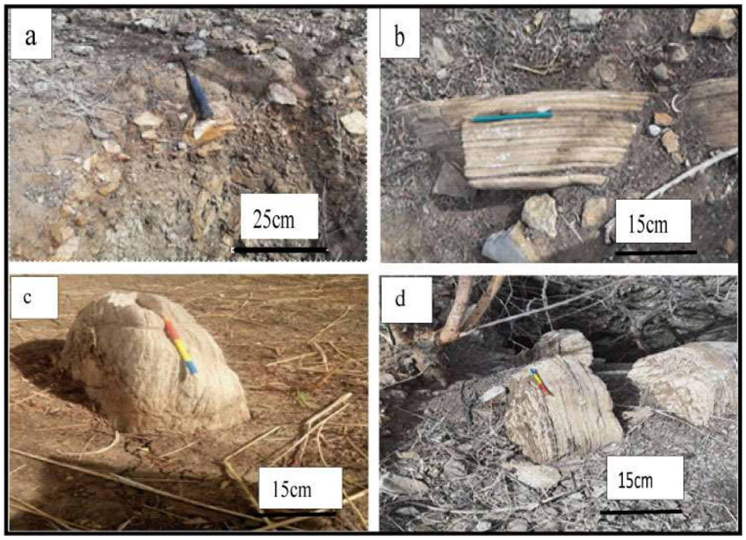


Figure: 5. a) Outcrop of slabs and blocks of marble covered by shale and sedimentary rocks; b) Marble showing bedding and certain minerals such as quartz; c) Marble with well-aligned bedding; d) Marble covered by shale.

- **Garnet micaschists**

Garnet micaschists outcrop in slabs in the village of Zoubou with a dimension of centimetric to metric. They are in the form of small-grained whitish rocks; quartz, garnet and biotite can be seen in them, with garnet dominating as showing in (Fig 6.a and b). And a schistosity observation containing reddish minerals with coarse grains and average direction N45E and vertical dip with minerals which are pyrites or magnetite, the presence of the mineral which is garnet indicates a deformation by intense metamorphism which affected the zone (Fig 6.c). the rock shows alternating light beds. At the fracture, the minerals observed are quartz and micas (Fig.6.d).

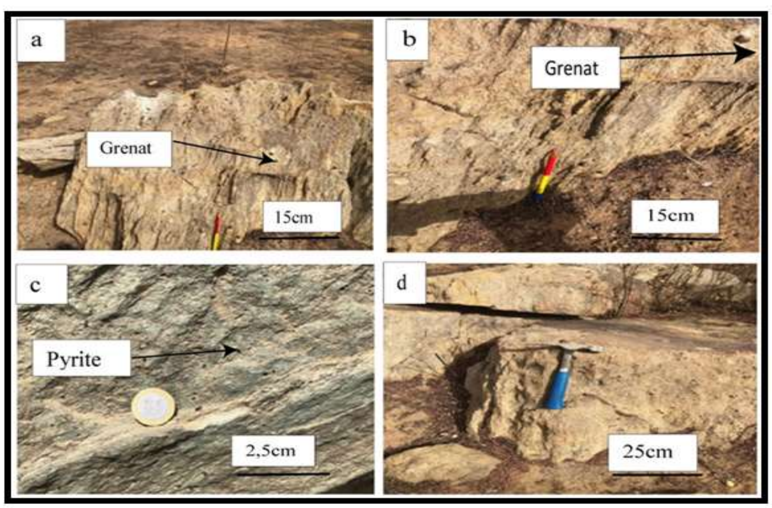


Figure.6: a) Outcrop of garnet micaschist in blocks and slabs; b) Garnet micaschist; c) Green schist with pyrite; d) Garnet micaschist in slabs.

Microscopically, the rock has a lepidoblastic texture (Fig.7.a). It is made up of the following minerals: Biotite, garnet, quartz and opaque minerals.

Garnet is automorphic and xenomorphic and has an elongated shape with a size of 0.1 to 1 mm and a greyish polarisation hue. It accounts for 60% of the rock's minerals and is associated with quartz and opaque minerals.

Biotite, yellowish-brown in colour, about 10µm to 0.5mm wide. It accounts for 25% of minerals in the rock, and is associated with garnet, quartz and opaque minerals. Quartz, which also accounts for 10%, is automorphic and xenomorphic with a size of 0.1 to 2 mm, associated with garnet and opaque minerals (Fig.7.b). Opaque minerals represent 5%, black in colour in LPA and LPNA, varying in size from 0.1 to 1.5 mm.

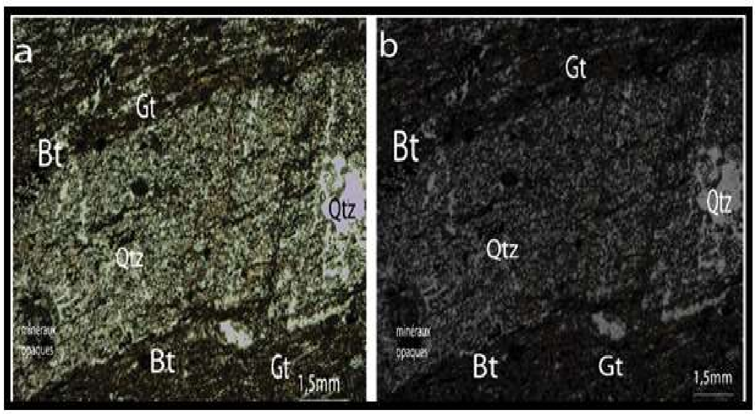


Figure.7. Microphotograph of garnet mica schist: a) foliated texture, quartz and garnet (LPA); garnet and opaque minerals (LPNA).

- **The schists**

The schists outcrop in slabs in the village of Zoubou with a metric dimension following the NE direction. These schists have undergone ductile high-temperature formation, i.e. intense metamorphism. These visible beds in the schists define a clear schistosity in foliation which can be deformed into micro-folds (Fig 8a; 8b). This foliation shows a N-E direction Shear criteria can be observed at all scales in the rock and indicates the N-W direction of movement. Folds are clearly visible and some with alternating quartz beds and a shallow dip (Fig 8.c and 8.d).

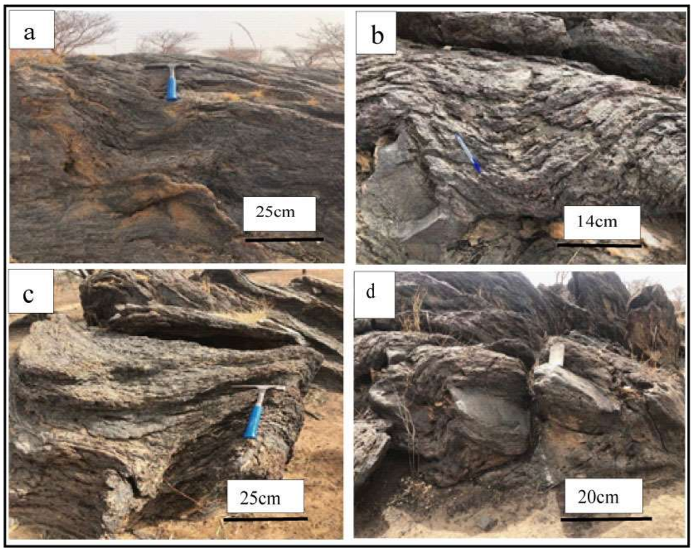


Figure 19: a) Outcrop of slab schist with folds; b) Schist showing well-formed folds with amphibole; c) Schist with recumbent folds; d) Schist with recumbent folds separated by the fault.

Microscopically, the rock has a grainy, sheeted texture (Fig 9a). It consists of chlorite, garnet, quartz and opaque minerals (Fig 9b).

Chlorite is xenomorphic and accounts for 45% of the rock's minerals. Its size is less than 1mm, and it results from the destabilisation of biotite.

Biotite is xenomorphic with its size varying between 0.2 to 1mm.

Quartz, which accounts for 15% of the minerals in the rock, is automorphic and xenomorphic, ranging in size from 0.1 to 4 mm, and has a rolling extinction in LPA and LPNA. Opaque minerals vary in size from 0.1 to 2.5 mm, with a size of 5% of the minerals in the rock. They keep their black colour in LPA and LPNA.

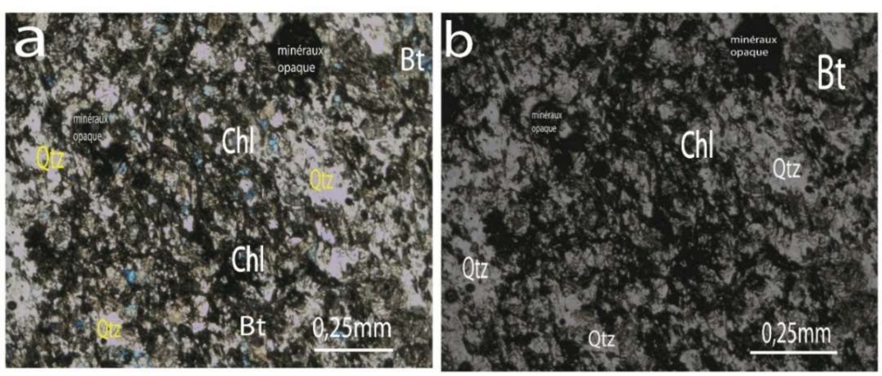


Figure.9: Microphotograph of shales: a) grainy texture with quartz (LPA), b) opaque minerals (LPNA).

- **The meta-andesites**

The meta-andesites outcrop in slabs and blocks; and a distance of about 9 km from the village of Zoubou with a metric dimension following the NE direction. Observation shows that, the meta-andesites are oriented W-E and have a very smooth and round pebble and oval shape (**Fig.10.** and **b**) which explains that there is the presence of the time and can also make a long displacement, with different direction and dip to the S-E. Macroscopic observation shows that the rock is composed of minerals such as quartz vein and even the presence of the enclave (Fig.10.c and .d).

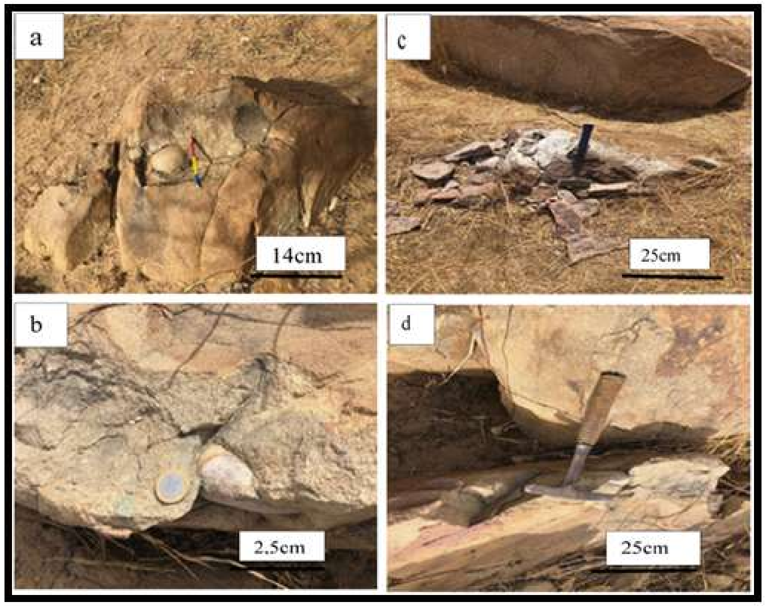


Figure. 10: a) Boulder and slab outcrop of meta-andesite with round pebble; b) Meta-andesite showing pebble intrusion with oval shape; c) Meta-andesite with enclaves; d) Meta-andesite with clear enclave.

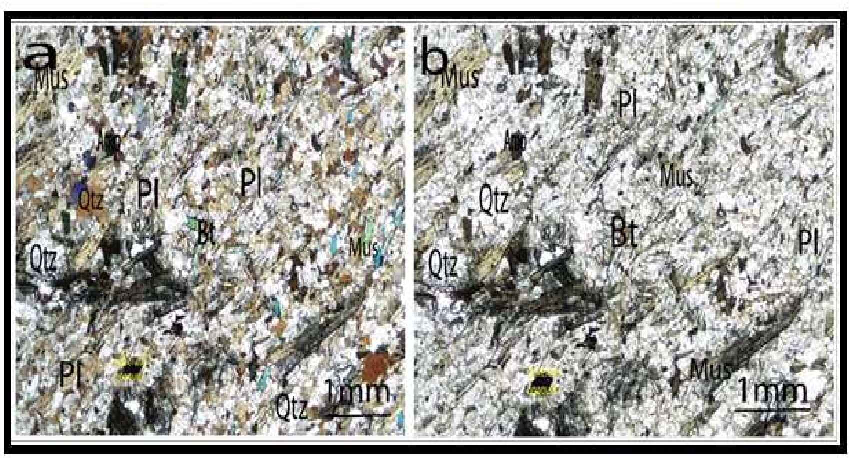


Figure.11: Microphotograph of meta-andesites: a) foliated and granulepidoblastic texture, muscovite, quartz (LPA); b) opaque minerals and quartz (LPNA).

- **The metadiorites**

The metadiorites outcrop in slabs under the village of Zoubou with centimetric dimensions and metric along the N-E direction. It has a greyish patina of alteration.

Macroscopic observation shows that the rock consists of quartz veins (Fig.12.a; 12.b).

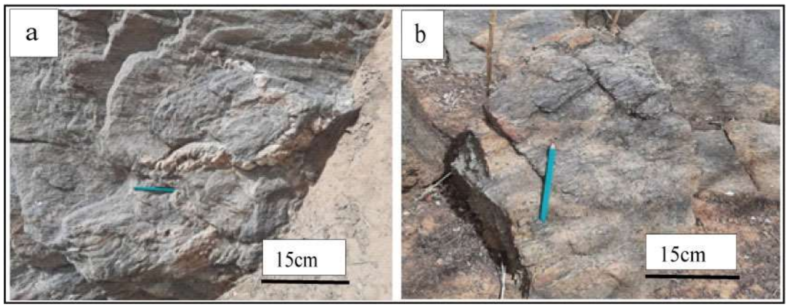


Figure.12: a) Metadiorite with quartz vein intrusion.; b) Slab outcrop of metadiorites

Microscopic observation shows a granolepidoblastic texture (Fig 13a). It consists of plagioclase, clinopyroxene, muscovite, quartz and opaque minerals.

Plagioclase is automorphic to subautomorphic and accounts for 40% of the minerals in the rock. They occur as elongated crystals with sizes ranging from 0.2 to 1mm. It is associated with clinopyroxene and opaque minerals. Clinopyroxene, which accounts for 25% of the minerals in the rock, is automorphic and subautomorphic and ranges in size from 0.2 to 1 mm, with a green and yellow colour in polarisation. It is associated with opaque minerals and quartz (Fig 13b).

Muscovite accounts for 19% of the rock's minerals. It forms flakes and has a green colouration These flakes are 0.1 mm in size.

Quartz accounts for 15% of the minerals in the rock, and forms xenomorphic crystals, with a size that varies between around 0.1 and 1 mm. They retain their colour polarisation by rolling in LPA or LPNA. They are most commonly associated with opaque minerals. opaque minerals, present 1% of the minerals of the rock, its black colour does not change in LPA and LPNA.

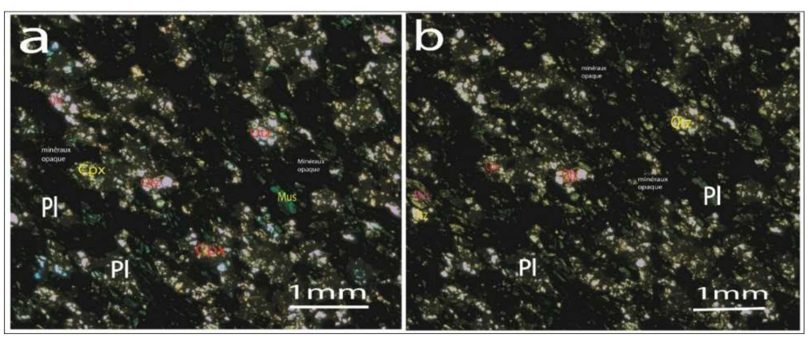


Figure.13: Microphotograph of metadiorites: a) granolepidoblastic texture, quartz, muscovite, clinopyroxene (LPA); b) opaque minerals, quartz, muscovite (LPNA).

5. 2. STRUCTURAL RESULTS

Linear segments were studied on the watercourses extracted from the STRM image in order to show their flow direction in the study area, and a linear segment map was produced. In fact, 99 measurements of the direction of the linear segments of the watercourses were carried out.

The distribution rosette of these linear segments is shown in Figure (9a). It can be seen from that the rivers in the area flow in a major direction N60E and in a secondary direction N10E. The number of fracture directions measured in the field is 79, and was used to create the fracture rosette (Fig 9b). This fracturing rosette shows a major direction N60E and a secondary direction N05E. By comparing these directions with the direction of the linear segments of the watercourses, we were able to understand the flow of the watercourses in the study area. There is a coincidence between the major flow directions of the watercourses (N60E) and those of the fractures (N60E). There is also a 5° coincidence between the secondary flow directions of the N10E streams and the N05E fractures. This suggests that the flow of water in the Fitri region is largely imposed by the fracturing of the basement rocks.

Geomorphologically, the Lake Fitri region has several morphological features including elongated hills and sandy plains. The hydrographic network is of the dendritic type, with the main watercourses fed during the rainy season. Analysis of linear segments of these watercourses and fracturing directions show that water flow in the Lake Fitri region is largely imposed by rainwater.

The link between the hydrographic network and fracturing has been demonstrated in several localities in the Adamaoua yadé-Baibokoum domain ([23][24][25].

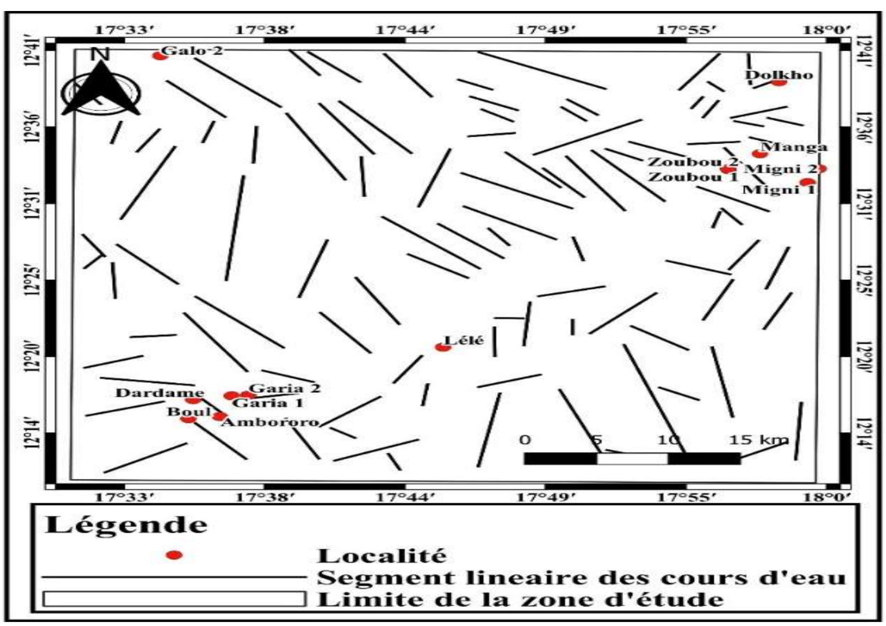


Figure 14. Map of linear segments of watercourses in the study area

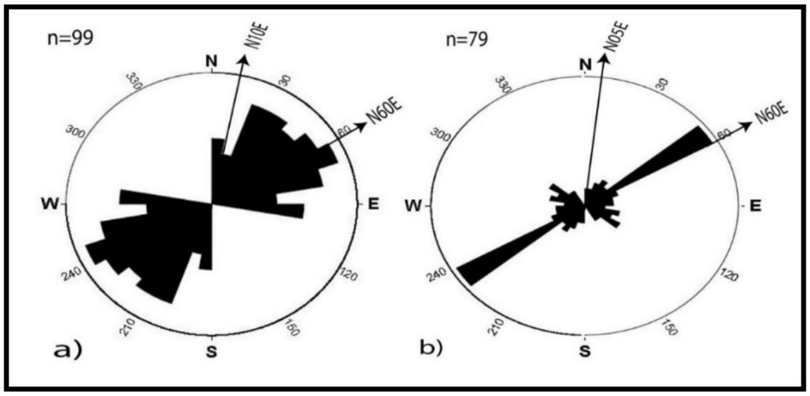


Figure. 15: a) Distribution pattern of linear segments of watercourses; b) Distribution pattern of fractures in the bedrock

The study area has three orographic groups: a group of sandy plains at altitudes below 300 m; a group of flat, elongated hills at altitudes between 450 and 600 m; and a group of hills at altitudes above 700 m, the highest point of which is 750 m. This group is characterised by hills with pointed tops and medium to steep slopes. The hydrographic network in the study area is of the dendritic type and is represented by temporary watercourses fed during the rainy season. A comparison of some of the directions of the rosettes suggests that in the department of Lac-Fitri, the flow directions of the streams are dependent on the fracturing that has affected the bedrock.

I. THE D1 DEFORMATION

The first phase of D1 deformation is characterised by S1 foliation transposed by the second phase of D2 deformation.

- **S1 FOLIATION**

S1 foliation is a deformation structure observed in meta-andesites.The S1 foliation is shown in a straight line (Fig16.a). They are marked by alternating light beds composed mainly of feldspars and quartz and light and dark beds of amphibole and biotite (Fig16.b).

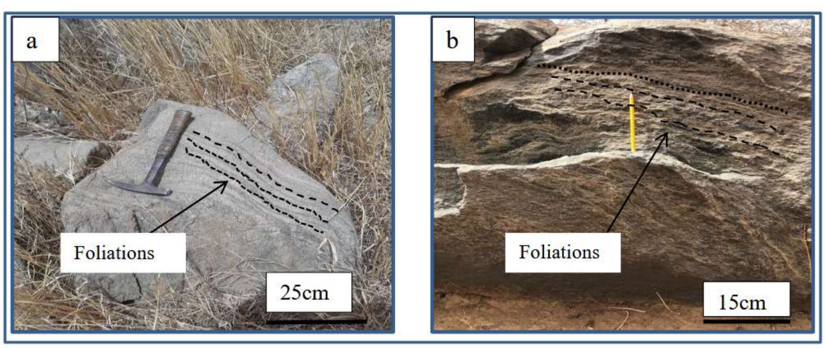


Figure 16 : a) S1 foliation forming a straight, clear line in the meta-andesite; b) meta-andesite with slightly dark amphibole and biotite feldspars and quartz.

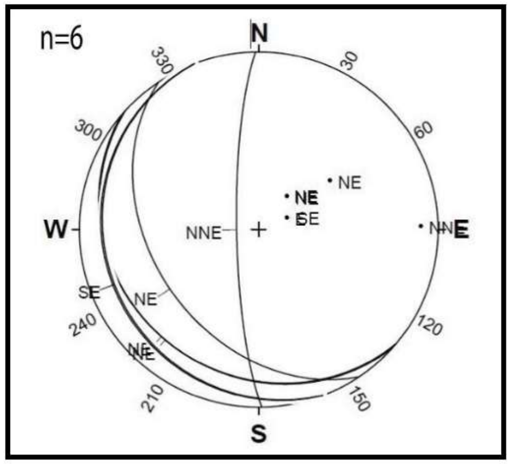


Figure 17: Stereogram of foliation in the study area.

II. **D2 DEFORMATION**

The second phase of D2 deformation is made up of S2 schistosity, L2 lineation and P2 folds.

- **SCHISTOSITY S2**

The schistosity S2 planes are highlighted in the schists in the village of Zoubou. This schistosity is marked by the sheeting of the rocks (Fig18.a). Schistosity S2 in the study area is recorded by the selective orientation of amphibole and quartz minerals, characterising penetrative deformation.

The schistosity planes identified in the Zoubou schists are generally N-E trending and dip 60°, 85°. In the village of Zoubou, foliations have been identified in the meta-andesites with axial planes whose folds P2 are the result of N-S bending.

The schistosity is marked by the preferential orientation of feldspar minerals and associated with a bedding direction of N57E, N110E, N130E, N158E, N90E, N70E, N73E, N180E,N15E, N68E; and with alternating light beds of feldspar and quartz and dark beds composed mainly of biotite and amphibole (Fig18.b).

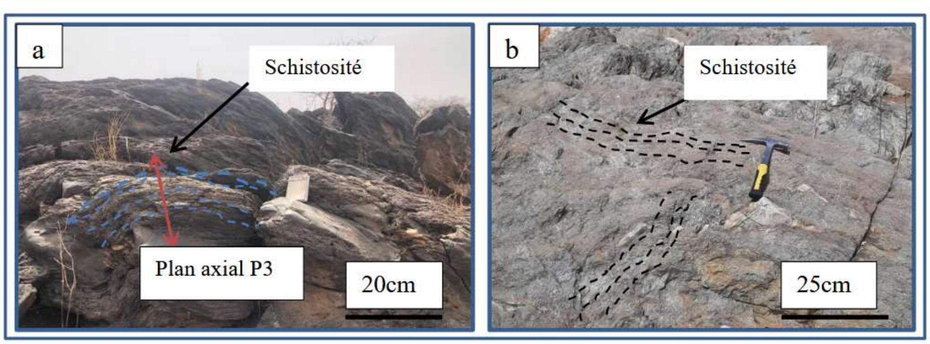


Figure 18: a) East-dipping S2 schistosity in the Zoubou greenschist with folds; b) Subhorizontal S2 schistosity in the Zoubou greenschist with alternating light beds of feldspars and quartz.

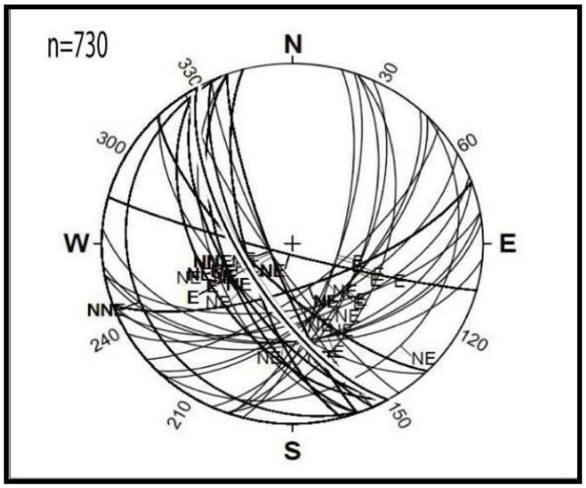


Figure 19: Stereogram of S2 schistosity in the study area.

- **L2 LINEATION**

L2 mineral lineation and stretching is evident in the deformed meta-andesites in the Zoubou village. This lineation is marked by the alignment and stretching of N65E feldspar and quartz minerals (Fig20.a). These lineations dip to the north and then to the east with shallow dips of N04° (Fig20.b).

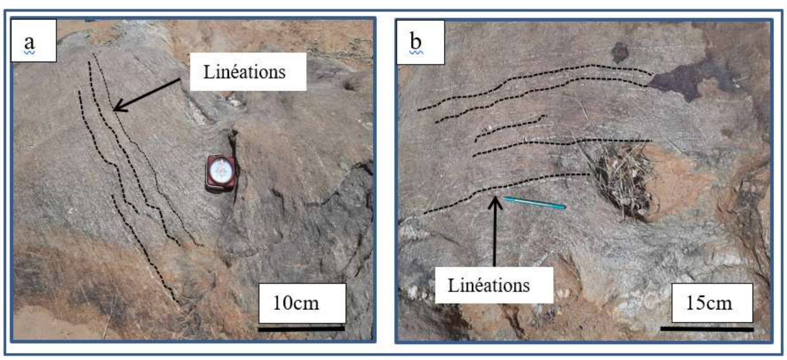


Figure 20: a) L2 lineation in deformed meta-andesites in the village of Zoubou with quartz vein stretching vertically; b) L2 lineation in meta-andesites with quartz vein stretching horizontally.

- **FOLDS**

Folded folds are found in the shale in the village of Zoubou. They are symmetrical; converge towards the N40E and have a subhorizontal plane well marked by a shallow dip N20° to the NE and N40° to the E and strong N60°NE, N80°SE trending N15E, N70E, N80E and has an axial plane trending N96E, N120E (Fig21.a). These folds result from the transposition of the S1 foliation by the second phase of D2 deformation (Fig21.b).

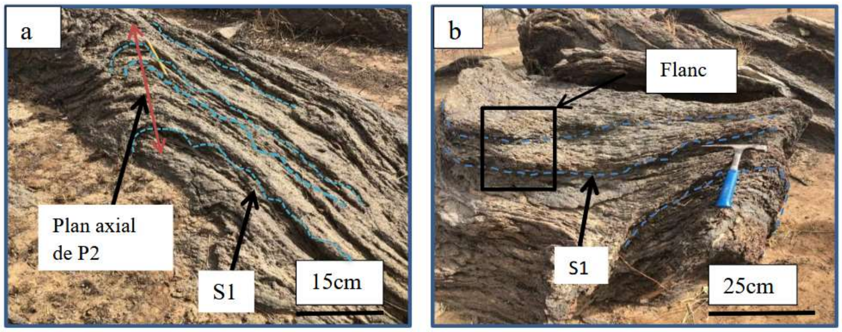


Figure 21. a) North-facing P2 shale folds in the village of Zoubou; b) South-facing shale folds.

- **SLOPED FOLDS**

The sloped folds P2 have been identified in the village of Zoubou; these outcrops are shales. The result from deformation of the S1 foliation plane (Fig.22.a).

They are asymmetrical folds (with long and short flanks) with a N40E angle of divergence and dip towards the south.

They have oblique axial planes N160E, N45E at the level of the fold hinges and with flank directions N04E, N72E, N25E (Fig.22.b).

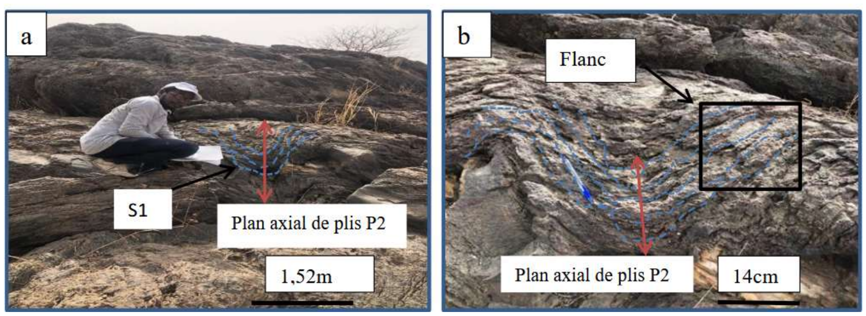


Figure 22 a) Folds overturned in the Zoubou shales with long and short flanks; b) Folds overturned in the shales with a dip towards the South with an oblique axial plane at the level of fold hinge

- **vein joints**

Vein joints are fracture planes in the micaschist which have been sealed by magmatic fluid to form the quartz vein N45E, N147E, N156E, N60E, N180E (Fig23. a) The veins observed on the outcrop are quartz veins. These veins are whitish in colour and strike N70E, N155E, N145E, N150E and N154E (Fig23.b).

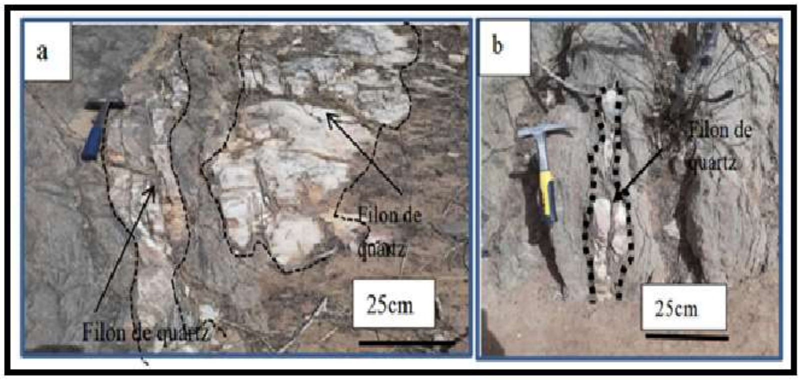


Figure 23 a) Slab outcrop of micaschists with clear quartz vein clogged; b) Micaschists with quartz vein.

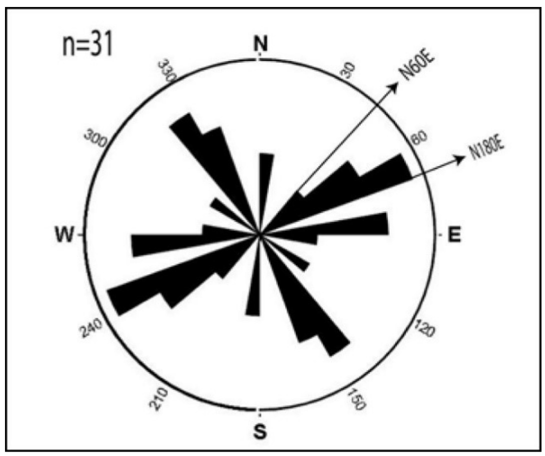


Figure.24. Rosette showing the direction of the quartz vein in the micaschists.

- **FAULT**

The fault forms a set of fracturing networks that highlight the brittle tectonics of the third phase of D3 deformation, fracturing with the intrusion of quartz veins in the directions N14E, N30E, N72E, N59E, N50E, N55E, N141E, N102E, N105E (Fig25.a).

This fracturing affects all the magmatic petrographic types in our study area with different fracture directions N47E, N100E, N130E, N14E, N60E (Fig25.b).

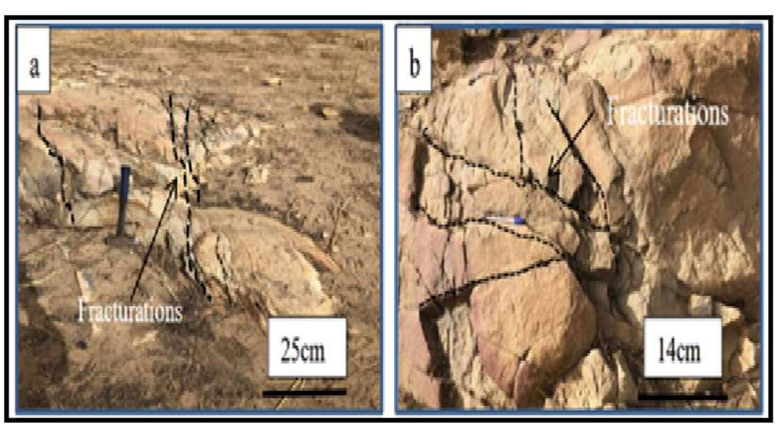
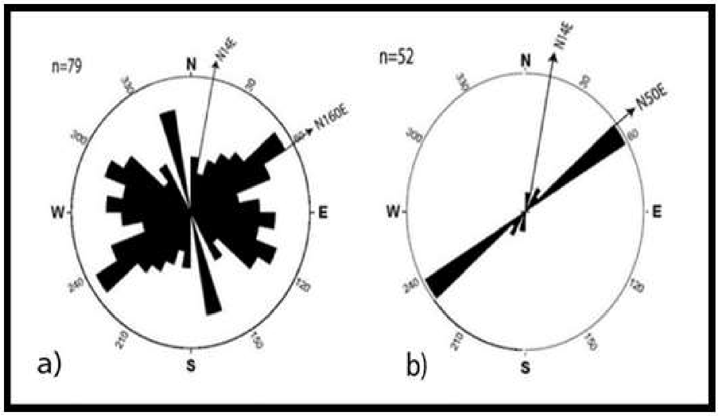


Figure.25: a) Fracturing pattern in the Zoubou area; b) Fracturing pattern in the Dolko area



5. DISCUSSION

5.1. Petrography

The magmatic rocks represented in our study area are: granites, dolerites and ultrabasics. Granites have a grainy texture with minerals such as quartz and micas; dolerites have a grainy and micro-grained texture consisting mainly of minerals such as micas and biotite, and some quartz veins; and microscopic observations show a granoblastic texture with a mineralogical assemblage of plagioclase, clinopyroxene, muscovite, quartz and opaque minerals; the ultrabasics have a gritty texture made up of quartz minerals, and microscopic observations show a porphyroid texture with an assemblage of minerals such as plagioclase, clinopyroxene, pyroxene, quartz and opaque minerals. These observations characterise magmatic deformation [26] [27].

Within metamorphic rocks, garnet often coexists with a diverse array of minerals, reflecting the complex interactions that shape metamorphic environments. Common mineral assemblages featuring garnet include schists, gneisses, and amphibolites, each representing distinct metamorphic facies characterized by specific temperature and pressure conditions. The presence of garnet within these rocks provides valuable insights into the thermodynamic evolution and history of the Earth's crust. The microstructures observed in schists and quartzite units described above have been used to understand the deformation events in the Zoubou-dolko area south-east of fitri-lake area. This has indicated that the relationship between the growth of metamorphic minerals and different deformation events is important, with several studies reporting the correlation between intensity of deformation and the metamorphic grade [28] [29]. Under the microscope, metamorphic minerals are generally arranged along the S1 foliation. However, we also have observed fractures and shear planes that are at an acute angle to the S1 foliation also containing muscovite and chlorite. These structures are probably conjugate structures related to the D 1 event.

The multiple mineral assemblages in pelites associated with S 1, as observed petrographically, are:

Bt + MsðSerÞ + Chl þ Ab + Qtz Pyrðserictic schistÞ

Bt + Ms þ Chl + Ab þ Qtz þ And —
Pyr ðchloritic schistÞ

Ms + Chl þ Ab + Cal þ Qtz ðcalcareous schistÞ

Ms + Chl þ Ab + Qtz + Tlc + Tr ðtalc schistÞ

Other minerals, such as zoesite and lawsonite, can be observed in the facies. Greenschist facies metavolcanic rocks are characterised by the assemblage albite–actinolite–chlorite–epidote (–pyrite–quartz) formed at low pressures.

5.2. Structuraly

The various structural elements penetrative (schistosities, foliations, lineations and folds) and the non penetrative structural elements (fracturing), identified in the different lithological types are : the foliation with straight lines with alternating light and dark beds, the schistosities, present in sheet is recorded by the selective orientation of amphibole minerals and quartz characterising a penetrative deformation, with axial plane whose folds P2 resulting from a bending N-S direction ; the lineation is marked by the alignment and stretching of the quartz vein, which extends northwards and southwards the folds are symmetrical with a vergence towards the N40E and have well-marked subhorizontal planes with a shallow dip and different directions.

The folds are the result of the transposition of the S_1 foliation by the second phase of deformation D_2; they are also asymmetrical folds with long and short flanks and an axial plane oblique; the vein joints, the veins observed on the outcrop are quartz veins; the fault, it forms a set of fracturing networks that highlight the brittle tectonics of the third phase of deformation D_3; with all the structural elements we have realised rosettes of different directions. As for the rosette of the linear directions of the watercourses produced from the values of the lineaments in the study area, a major direction N60E, and a secondary direction N10E were determined. All these directions are similar to those of the Pan-African faults recognised by [30] that affected the Pan-African chain in Central Africa.

The major N60E direction of the linear stream segments coincides with the directions obtained in the northern sector of the Kenga massif [31] and to the N-W of Bitkine [32] Finally, the structural and petrographic data collected by this study are summarised in the geological map presented in Figure 12.

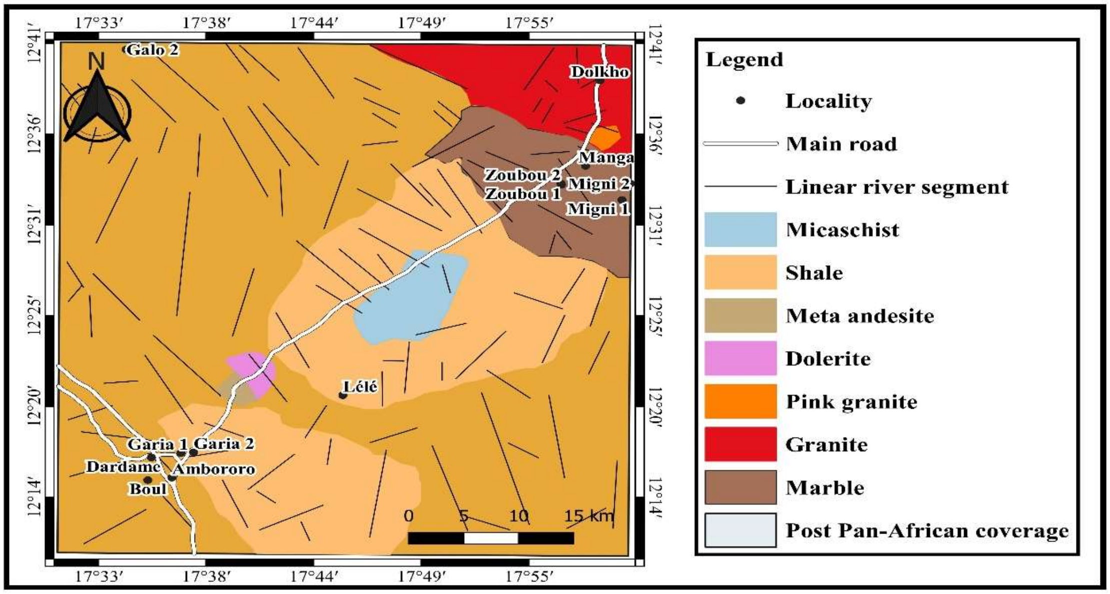


Figure. Geological and structural map of the study area.

7 . CONCLUSIONS

The petrographically two groups lithological formations are distinguised: magmatic formations (granites, dolerites and ultrabasics) and metamorphic represented by marbles covered by schists, micaschists with garnet, green schists, meta-andesites and metadiorites, which also outcrop in slabs and blocks.

Linear segments were studied on the watercourses extracted from the STRM image in order to show their flow direction in the study area, and a linear segment map was produced. This suggests that the flow of water in the Fitri region is largely imposed by the fracturing of the basement rocks.

Structuraly three phases of deformation has been identify. The first is specified by a foliation S_1 highlighted is straight line, they are marked by the alternation of light and dark beds. The second phase is marked by schistosity cutting in sheet; the lineation is characterized by alignment and stretching of minerals.

These lineations plunge towards the North and the other towards the East, with weak dips N10E, N12E, N15E, N20E; and the folds lying they are symmetrical towards the N-E with of plane subhorizontal well marked with of dip weak and strong of direction N-E and with axial plane. the recumbent folds result from the deformation of the S_1 foliation plane, they are asymmetrical and dip towards the South, they have an oblique axial plane at the level of the charnel houses. The third phase is materialised by the development of vein joints which have been clogged by magmatic liquid and the fault forms a set of fracturing networks.

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