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Petrography, Quantification of the Finished Deformation: Case of Nagarwa – Walungu / South Kivu/ DRCongo

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ABSTRACT

From the petrographic point of view, we have 6 types of the rocks level in the sector of Nagarwa: siltites, conglomerates, sandstones, quartzites, shales and schists. The objects of this work were to determine the petrography and to quantify the finished deformation in structural domain. Microscopic observation of thin plates crafted from samples in PNAL and APL, highlights the transmitted light hétérogranulaire structure and equigranular; there is abundance of quartz grains mixed with opaque minerals and, incidentally, muscovite and clay phyllites. They occupy 80% of the total size of the rock. Their diameters range from 300 to 900 microns. Phyllites occupy less than 5% of the rock. Quartz crystals are recognizable by their low relief and a rolling extinction. In other cases it is observed muscovite and opaque reddish brown products due to oxidation. These are probably iron oxides and hydroxides. Sometimes they occupy more than 15% of the rock and have a size of 100 to 200 microns. The muscovite flakes show a bright color. Quartz grains essentially have sub rounded shapes, irregular and contiguous. Some phyllites are concentrated in the vacuolar areas.

The microscopic description of schists in NPAL and APL shows that Phyllites are often preferentially oriented and occupy 55% of the rock. Their diameter is about 50 microns. The phyllites length goes beyond 500 microns. A part from the phyllites, quartz grains are observed, although embedded in these abundant mass phyllites and occupy less than 10% of the rock. Their sizes range from 70 to 150 microns. The opaque minerals occupy 35% of the rock. In most cases the rock is mica schist. The shale are yellowish and reddish iron oxides in transmitted light appear in clusters in the rock. These clusters have a diameter of 850 microns and occupy about 15%. Biotite abounds. The flakes are elongated along the stratification plane and are long of about 450 microns and diameters of less than 50 microns. Quartz ghosts are detectable in the mass. They have a fine grain size and they occupy less than 15% of the rock. Sometimes observed blackish material, isotropic, organic aspect, aligned in parallel bands when it comes graphitic shales and they occupy 40% of the rock and are spaced approximately 200 microns. We observed four types of sandstone. The nature of the cement, the size of elements, the dominant mineralization and metamorphic grade allowed us to discriminate these sandstones.

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The quantification of finished deformation helped us to describe the preferred direction of the layers which is N156° E / 60° NE. Schistosity is subparallel to the bedding and has a preferential orientation of N135° E / 51° NE. Joints have a preferred direction of N67°E/42°NW. They are not abundant in the Nagarwa sector. We highlighted one family of joints. The maximum concentration of poles is 53.81%. Statistical of veins in Stereonet shows two families of veins with the front N10°E / 40°E and N50°/80°SE. However veins are rare in Nagarwa sector. The maximum pole of concentration is 41.03%. Flinn diagram gave us the state of the deformation using Flinn parameter. Ramsay diagram demonstrates the nature of spread values and shows a slight concentration values at Rs. The preferred orientation of the pebbles is N108°E / 50°WNW and deformation rate is less than 1 then, medium intensity.

Key words: petrography, finished deformation, transmitted light, metamorphic grade, phyllites, shales, quartzites, schists, sandstones, Flinn diagram, Ramsay diagram, and Stereonet.

1. INTRODUCTION

Located thirty miles southwest of the city of Bukavu, the Nagarwa sector is between latitudes 2°41’ 34’’S and 2° 44' 25"S and longitudes 28°51’ 09"E and 28°48' 07"E. Administratively, the area of Nagarwa is located in the South Kivu province specifically in Walungu territory, in the chiefdom community Ngweshe. We choose this topic to highlight the contribution of this work in the geological knowledge of Nagarwa sector. The Nagarwa sector had never been any study on its mining potential, nor on the quantification of the finite strain and even less in the geological mapping of its formations. In addition, through these contributions we could refine our knowledge and field methods. The overall objective of this work is to contribute to the geological knowledge of Nagarwa sector. This contribution is focused in two areas that are petrography and structural aspects.

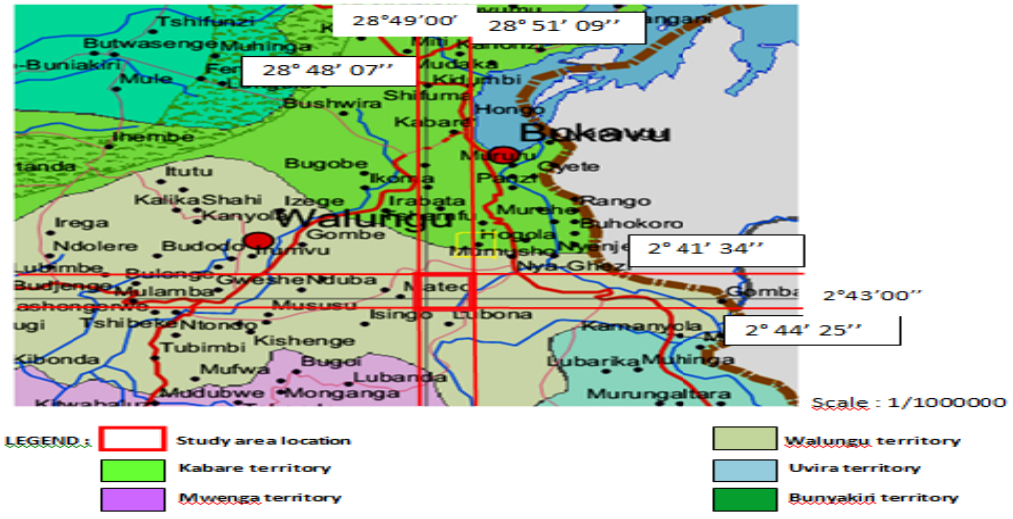

Figure 1: Administrative map of South Kivu (November 7, 2002 MONUSCO GIS UNIT).

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Figure 1 : Image satellitaire du secteur de Nagarwa (Google Earth)

Mushego hill Cibangere hill Nyidunga hill Nagarwa hill

Kasheke hill Rukube hill

Cardoen swamp Nshimbi swamp

C Cidasa river M Mughera river

1.1. Research Objectives

The main objects are:

- ✓ To determine the petrography of rocks in Nagarwa sector;
- ✓ And to quantify the finished deformation in the conglomerate outcrops in the study area.

2. MATERIALS AND METHODOLOGY

To achieve our goals, we adopted a methodology focused on four areas:

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Documentation: We conducted the literature review on the subject to be treated and the region concerned by our study;
Field works: six field trips were done, among the activities that were carried out on field is data collection: dip and strike of many outcrop have been taken, dip and strike of folds, joints, determination of fold axis, structural measures on pebbles (diameters and radius), geographic coordinates for mapping, etc.
Laboratory works: they include: the preparation of thin plates, polished sections of rocks and their microscopic studies were done at University of Lubumbashi;
The materials used are: Sylva type compass, Garmin GPS type, a geologist's hammer, a tape measure, the field book, a pencil, small bag for samples. Software such as Dips, Google Earth, Universalis 2009 and Arc GIS 9.3.

3. PETROGRAPHY ASPECTS

We observed the following rocks in the Nagarwa area:

- Conglomeratic facies rocks: conglomerate and breccia;
- The sandy facies rocks: sandstone, sandstone rich in iron, quartz sandstone, siltstone and quartzite sandstone;
- Quartzites;
- And Schist facies rocks: shales, schists and ferruginous shales.

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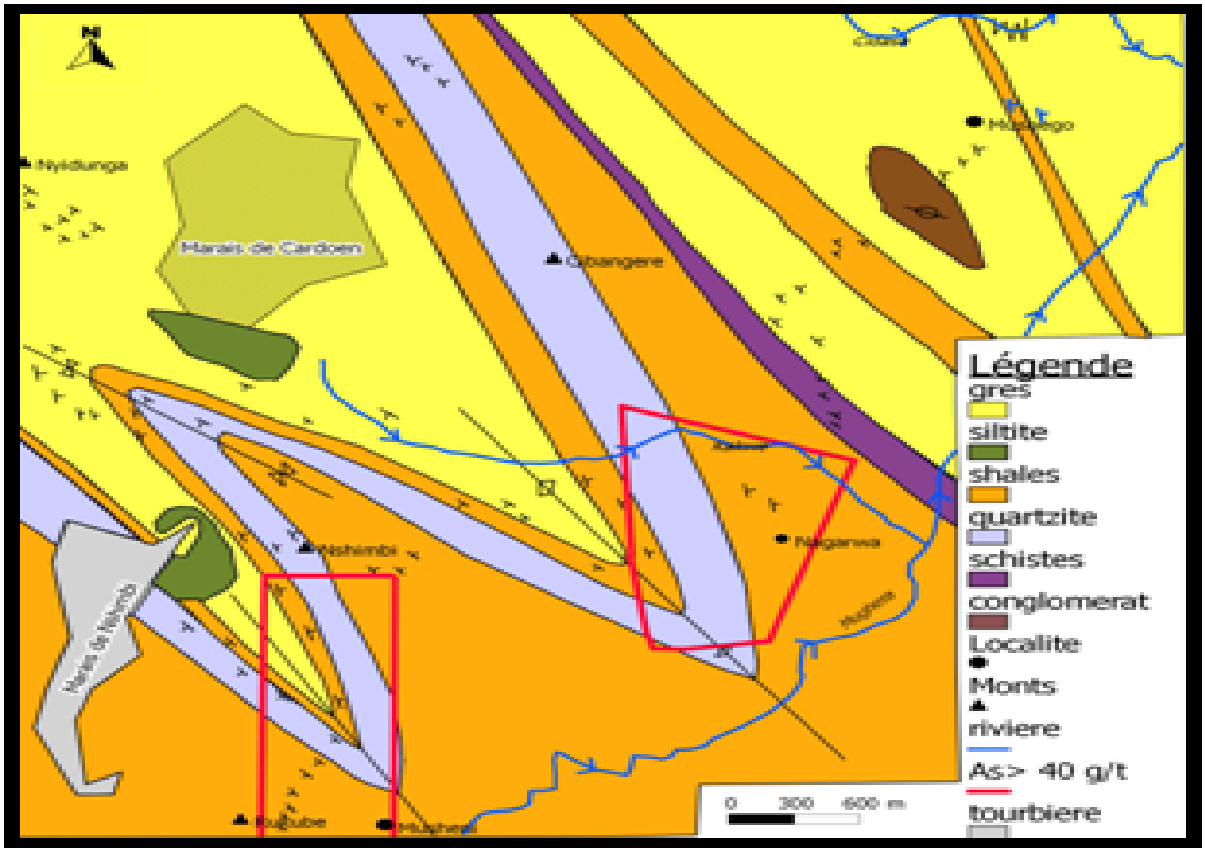

Figure 3: Geological map of study area

3.1. Macroscopic sample description

Macroscopic observation sometimes identifies formations red to reddish brown. The effects of advanced oxidation are evident. The color of the rock denotes an abundance of hematite. However, in most cases there is an abundance of quartz crystals juxtaposed consolidated with very few scattered strips of mica (muscovite). This is sericite. The particle size is fine; iron oxides are dispersed therein. The texture is compact.

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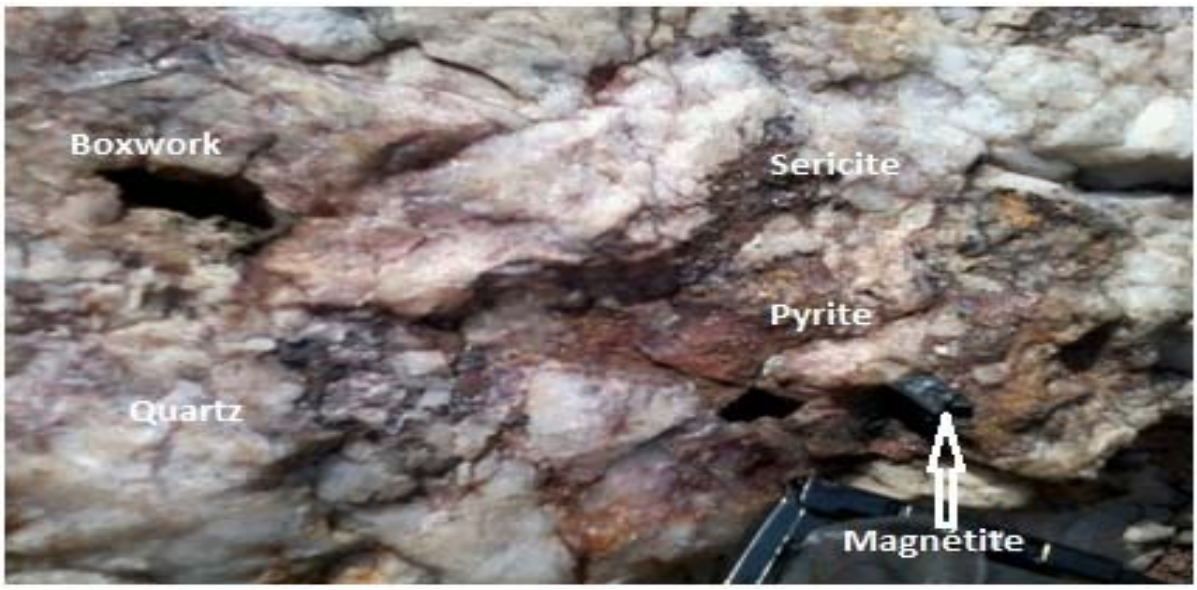

Figure 4:Scattered Hematite in quartzite with magnetite, sericite, pyrite and Boxworks

3.2. Microscopic description of Quartzite (Performed by Professor Makabu in the Laboratory of University of Lubumbashi)

Microscopic observation of thin plates crafted from samples in PNAL and APL, highlights the transmitted light hétérogranulaire structure and equigranular; the abundance of quartz grains there is intimately mixed with opaque minerals and, incidentally, muscovite and clay phyllites. They occupy 80% of the total size of the rock. Their diameters range from 300 to 900 microns. Phyllites occupy less than 5% of the rock. Sometimes the quartz grains have the same size and micas misdirected are rare. Quartz crystals are recognizable by their low relief and a rolling extinction. In other cases it is observed muscovite and opaque reddish brown products due to oxidation. These are probably iron oxides and hydroxides. Sometimes they occupy more than 15% of the rock and have a size of 100 to 200 microns. The muscovite flakes show a bright color. Quartz grains essentially have sub rounded shapes, irregular and contiguous. Some phyllites are concentrated in the vacuolar areas.

3.3. Microscopic description of Schists

The observations were made in NPAL and APL. In transmitted light of the mica flakes have a preferred orientation;

The observation of the transmitted light shows a preparation consisting essentially of phyllites rock. These are in order of decreasing abundance: muscovite, biotite and clay minerals purposes. Phyllites are often preferentially oriented and occupy 55% of the rock. Their diameter is about 50 microns. The phyllites length goes beyond 500 microns. Outside the quartz grains are observed phyllites, although embedded in this abundant mass phyllites and occupy less than 10% of the rock. They are almost equigranular, clear daylight or rolling polarized extinction. Their sizes

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range from 70 to 150 microns. Their cracks are sealed with opaque material glomeruli and sometimes brownish, probably metalliferous. There are a large proportion of opaque minerals or 35% of the rock. In most cases the rock is mica schist; Phyllites are elongated and their axes are parallel to each other as shown below by the microphotograph in figure 3.

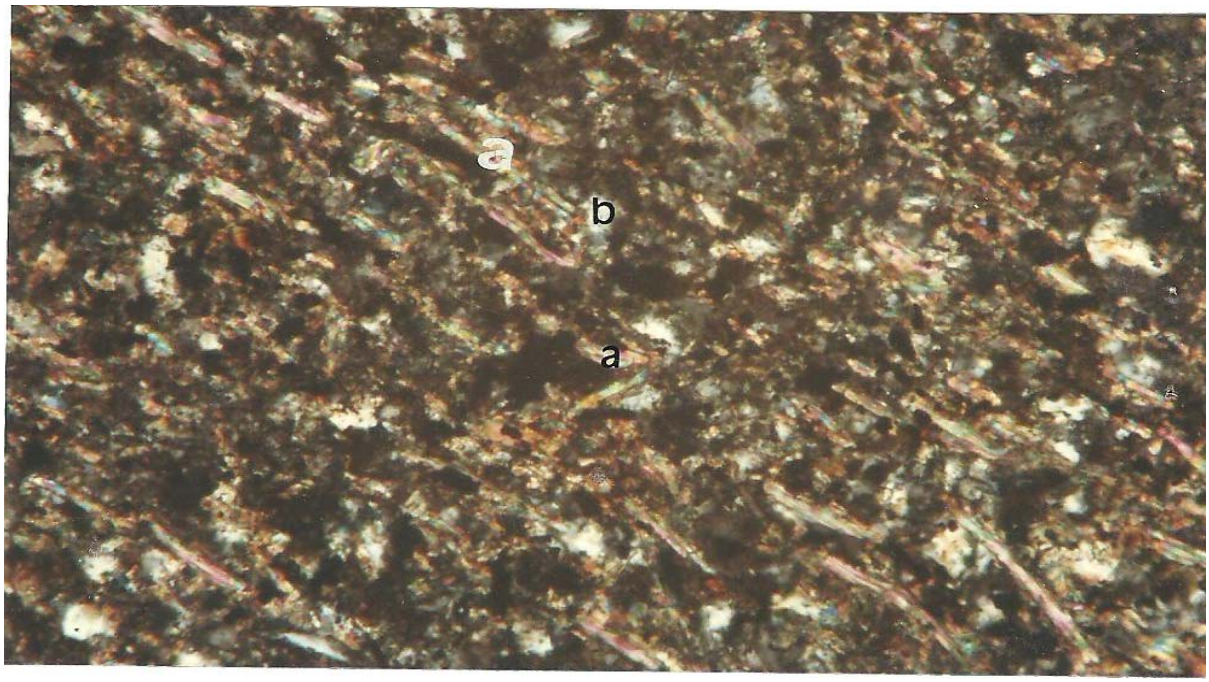

Figure 5: Thin plate of sample Y02, which shows the preferential orientation of phyllites
a: Quartz and b: Muscovite
Scale: 1/5

3.4. Microscopic description of Shale

Microscopic analysis shows that the shales are yellowish brown. Yellowish and reddish iron oxides in transmitted light appear in clusters in the rock. These clusters have a diameter of 850 microns and occupy about 15%. Biotite abounds. The flakes are elongated along the stratification plane and are long of about 450 microns and diameters of less than 50 microns. They are embedded in reddish plasmas. Quartz ghosts are detectable in the mass. They have a fine grain size. They occupy less than 15% of the rock. Sometimes observed blackish material, isotropic, organic aspect, aligned in parallel bands when it comes graphitic shales. They occupy 40% of the rock and are spaced approximately 200 microns. They abound in southern Nagarwa sector.

3.5. Macroscopic description of Sandstone

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We observed four types of sandstone. The nature of the cement, the size of elements, the dominant mineralization and metamorphic grade allowed us to discriminate these sandstones.

3.5.1. Sandstone: in these, the quartz grains are clearly individualized and can be detached by the nail. Touch is granular due to the presence of small quartz grains. The color is sometimes whitish gray. Texture is compact for small sandstone grains to porous for coarse sandstone elements. The particle size is variable, generally fine and sometimes coarse. The sandstones are sometimes jointed. The degree of cohesion is generally high and sometimes low. Some samples crumble at the slightest pressure of the fingers. The degree of impairment or weathering varies. As minerals include quartz and sericite. Outcrops are often in very hard benches and sometimes they are massive aspects; sandstones are folded and are preferentially oriented N156°E / 60°NE. Sandstone outcrops are found in all sector of Nagarwa especially in the northern part and northeastern where they abound. They are found in the entire Nagarwa sector starting from the Mont Rukube to Mushego Mount through the Nagarwa mount, Kakwe mount, Nyidunga mount and Lubanda - Karhongo mount.

3.5.2. Sandstone rich in quartz grains: in these rocks, the quartz fraction visible to the naked eye becomes predominant. The sandstone cement shrinks regarding to the quartz grains are abundant .The texture is compact, the size is small. The color is white. We found only one outcrop located at Nagarwa mount on its southeastern side and whose extension is approximately 1 meter. The coordinates of this outcrop are: 0702149 East Longitude and Latitude Southern 9699313 and whose altitude is 2068 m. another outcrop was observed at Cibangere mount in its North Slope.

3.5.3. Sandstone rich in iron: These rocks are grainy but have the distinction of being characterized by the predominance of iron oxides and ferruginous impurities whose presence is indicated by the different variations of colors. The reddish coloration indicates the presence of hematite, yellowish coloration indicates the presence of goethite and dark coloration indicates the presence of iron and magnetite that these types of samples have a high density and have the property of attract the magnet, irrefutable proof of their magnetic susceptibility.The degree of impairment varies. The particle size is fine and medium. Iron is present often well crystallized masses metal and black shine. Iron is often in the form of impregnation. They are sometimes jointed and also have joints. It was noted that the presence of boxwerks are cavities resulting from oxidation, the loss of iron crystals. These cavities are coated with a black coloring material for red through the yellow which is due to the alteration. The outcrops are often presented in layer or bed.They fall into two concentration poles. The first pole is localized on Nagarwa mount in the south, where outcrops are numerous and the second pole is localized further north towards Mushego. However, the whole area of Nagarwa is dotted or scattered by ironstone.

3.5.4. Quartz tic sandstone: They have the appearance of sandstone and quartzite. We distinguish the quartz grains in the sandstone rock cement and this aspect of the

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quartzite. These rocks have a compact texture and are hard to sampling hammer. The color is white but varies from gray. The weathering degree is low and the cohesion degree is high. They are often affected by tangles of quartz veinlets. Hematite is often present as well as disseminated iron abundance. Quartz tic sandstone outcrops are massive and are presented in benches oriented N130 ° E / 56 ° SW and N150 ° E / 60 ° NE. They are found further south of Nagarwa mount starting to Rukube mount through the Nshimbi and Kasheke Mountains.

3.6. Conglomerates:

We observed two types of conglomerates in our study area: the puddings and breccias.

- **Puddings:** they consist of ovoid members, elongated called pebbles which are held together by a matrix. The pebbles are quartzitic nature their dimension is between 1 and 20 cm. Cement is quartz. The color is gray. The grain size is coarse. The texture is conglomerate. They are very hard and sampling hammer is painful. Outcrops occur in large solid blocks far beyond the ground and are in prominence in vegetation;
- **Breccias:** They are constituted by angular elements, small fragments of sandstone kind. Cement is always ferruginous quartz. The size of the angular elements from a few millimeters to 7.5 cm. The color varies from white to gray. The texture is brecciated with coarse particle size. It is hard rock and weakly affected. They are located in Nagarwa mount. It is in the south-east of our area. Breccia outcrops are massive appearance. Its extension is very low.

3.7. Alluvial deposits

These alluvial deposits made pebbles, sands, silts and sometimes boulders. The rollers are quartzitic nature rounded and elongated. Their size ranges from a few millimeters to 25 centimeters for the largest roller. Color pebbles from white to yellow. These deposits present the sorting granular with larger elements at the base. The angular elements are boulders from the steep slopes.

These alluvial deposits are located in the Mughera marshes, along the river Mughera towards Mushego and along the river Cidasa especially when it is close to its point of affluence to Mughera River.

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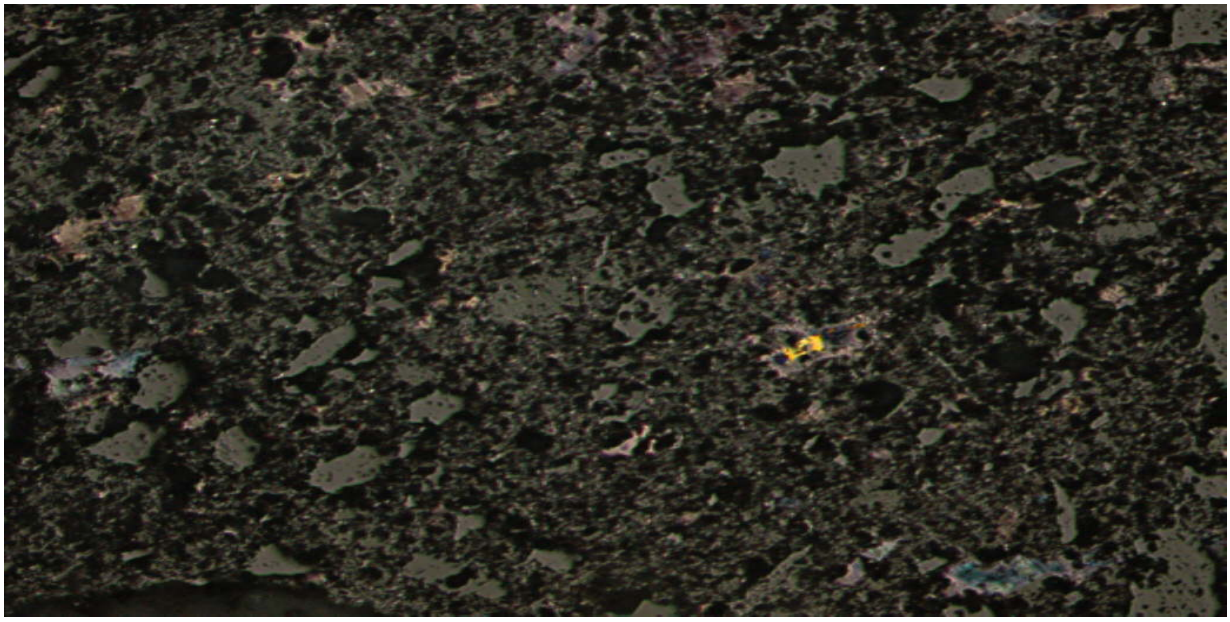

Figure 6: polished section Y02 with yellow crystal of chalcopyrite

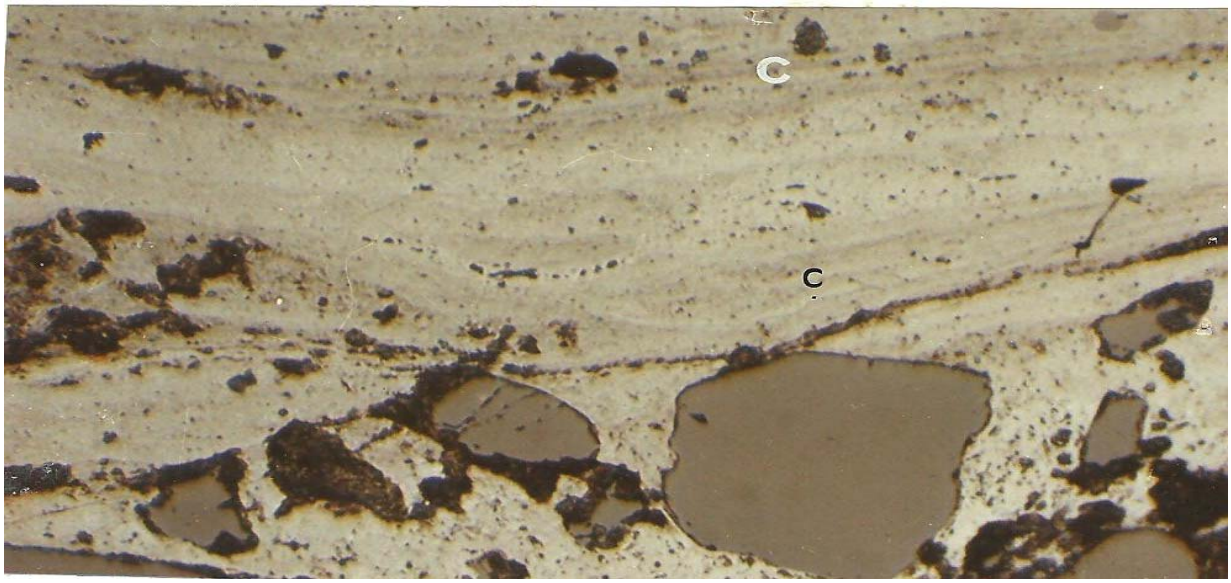

Figure 7: polished section Z07, with C: goethite

Rare hematite, goethite and pyrite are underlined with metallographic analysis

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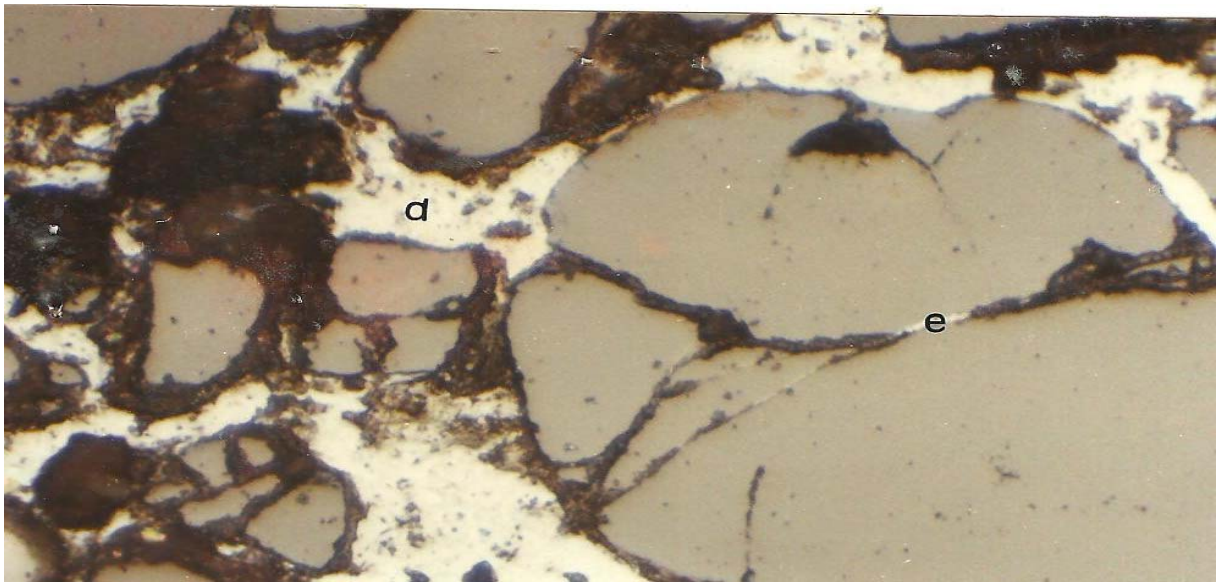
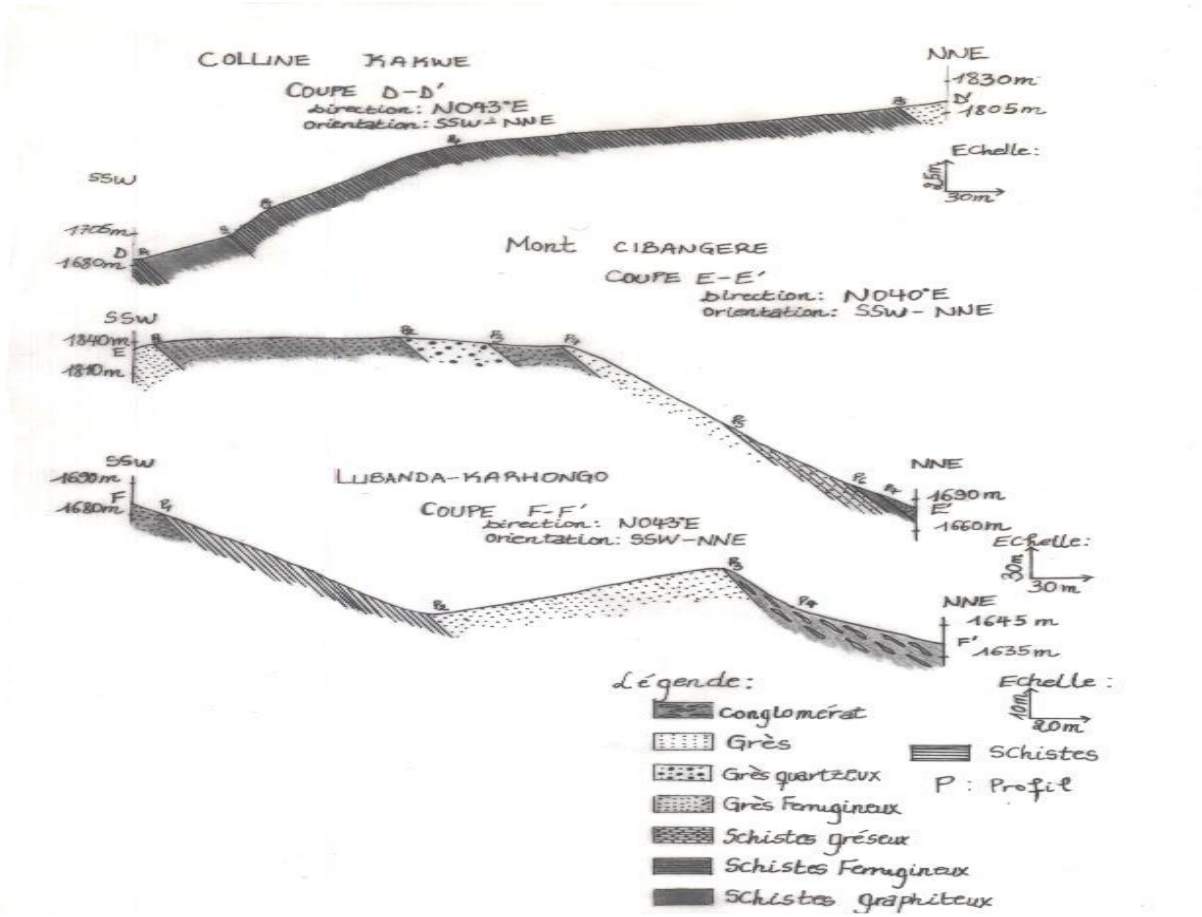


Figure 8: polished section A04, with d: hematite and e: pyrite



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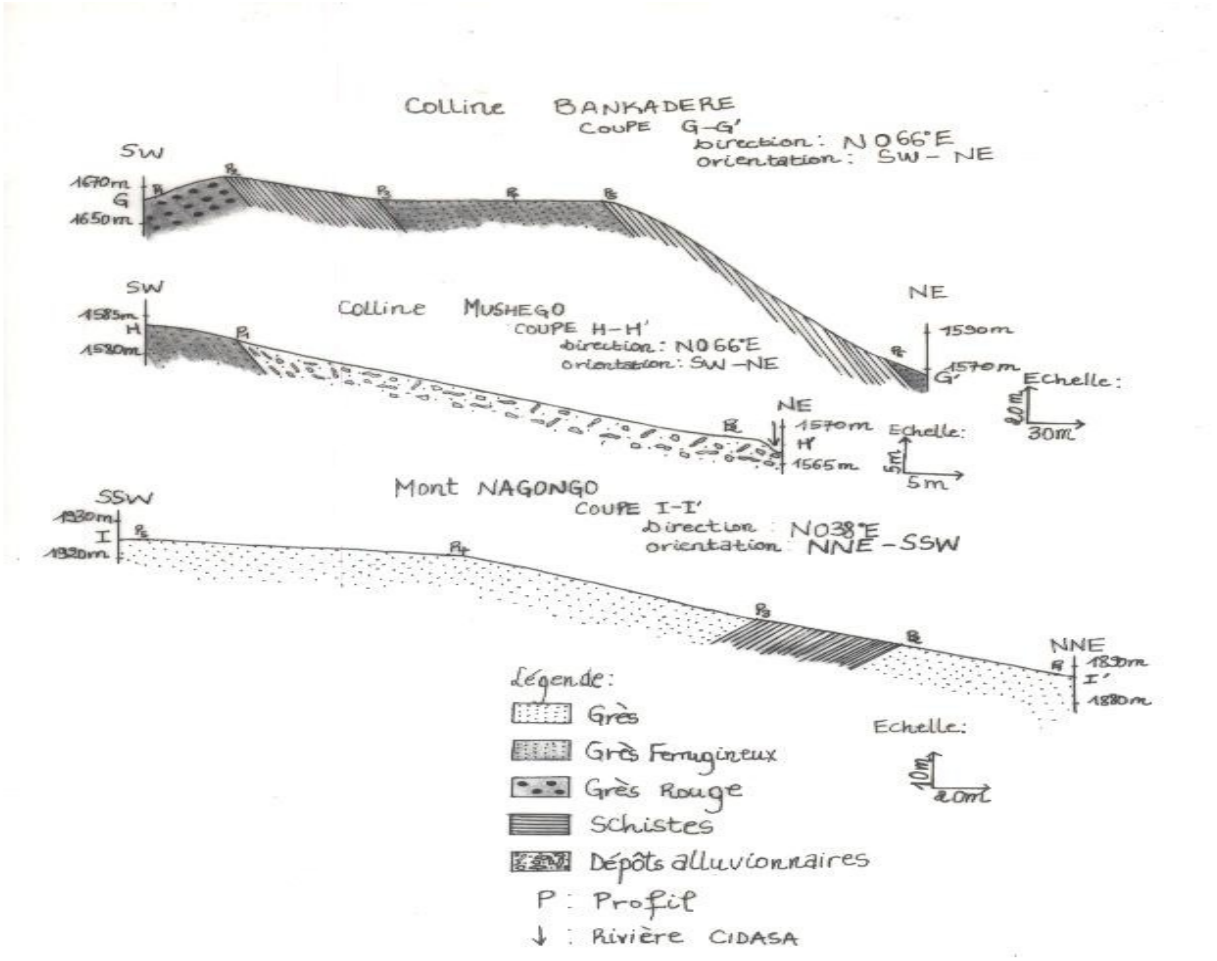

Figure 9: Geological cross section of Nagarwa sector

4. QUANTIFICATION OF FINISHED DEFORMATION

We identified several structural elements in the Nagarwa sector. We describe them and we spotted them geometrically. The planar structural elements have been described. These are: Stratification: The axial plane of major fold, the recorded schistosity S1, sinister thrust faults, joints and Veins.

Linear structural members have been described. These are: Lineation stretching and axes of the folds.

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Figure 10: Shear sinister affecting a quartz vein oriented N010°E / 40°E in a sandstone, 10 cm wide and 1.5 m length. Thrust faults amplitude is 7 cm (Nshimbi mount).

The preferred direction of the layers is N156° E / 60° NE. Schistosity is subparallel to the bedding and has a preferential orientation of N135° E / 51° NE. Schistosity affects shale.

4.1. Joints and veins

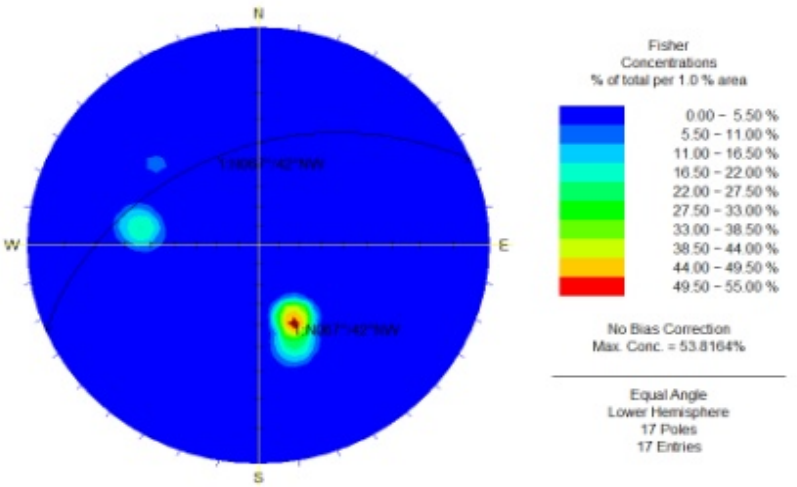

Figure 11: Statistical distribution of joints in Stereonet

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The joints have a preferred direction of N67°E and 42° to hang NW. They are not abundant in the Nagarwa sector. We highlighted one family of joints. The maximum concentration of poles is 53.81%.

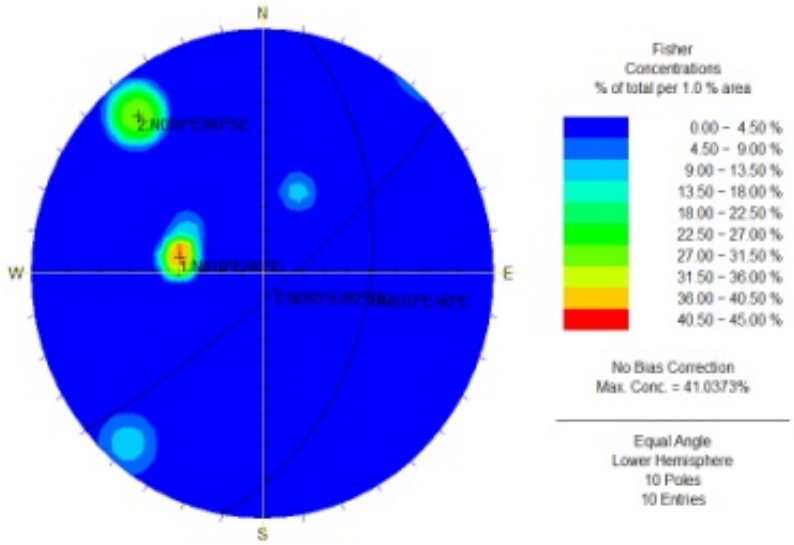

Figure 12: Statistical distribution of veins in Stereonet

We identified two families of veins with the front N10°E / 40°E and N50°/80°SE. However veins are rare in Nagarwa sector. The maximum pole of concentration is 41.03%.
We found the folding that affects the Nagarwa sector. Three fold axes were collected from the geometric tracking layers. There are two anticlines at Rukube mount and Nagarwa, a syncline at the foot of Nyidunga mount. Folding affects shales and sandstones.

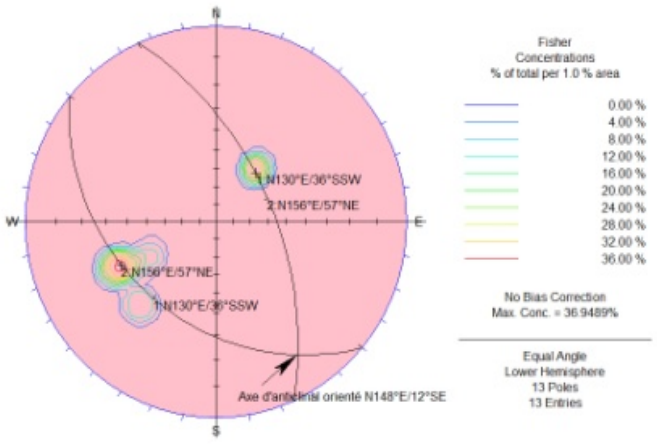

Figure 13: Determination of the fold axis of the Nagarwa anticline from the poles of the stratification planes

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At Nagarwa mount, dips are divergent and thus define an anticline. On the flanks, the layers have a direction of N156°E and 57° hang to the NE flank and the normal to the opposite side, they have a direction N130°E and 36° to hang from the SSW.

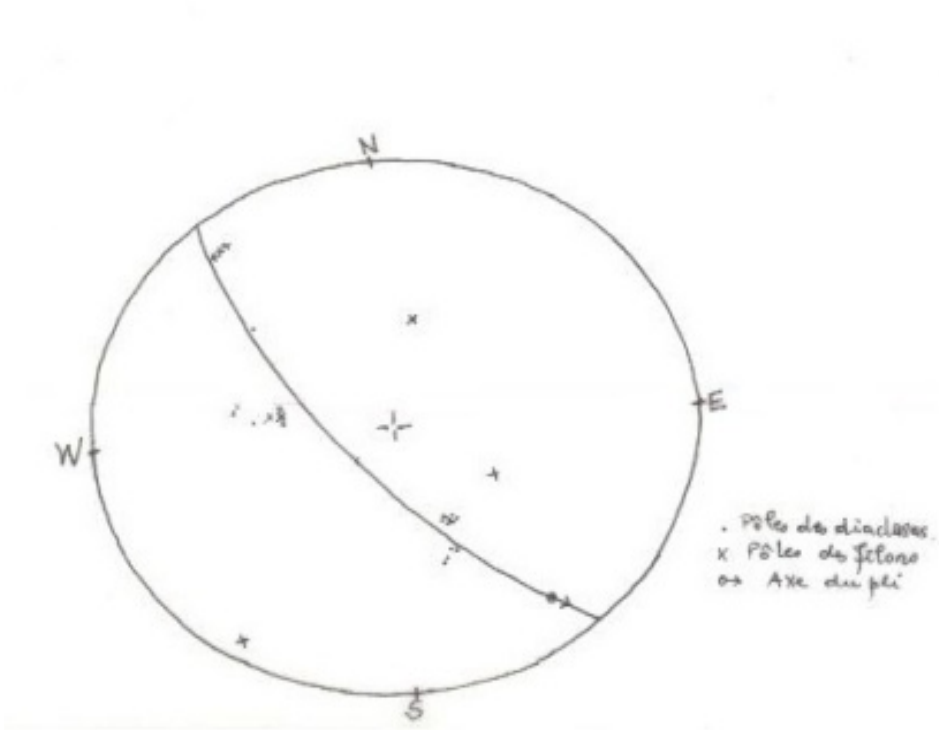

Figure 14: Position of the poles of the veins and joints regarding to axial plane of the major fold.

We see that the joints oriented N67° / 42° towards NW are related to folding because their poles fall to the axial plane. The veins in turn are not related to folding because their poles do not fall on the axial plane. It is the same for other joints.

4.2. Stretching lineation

It was observed at Lubanda - Karhongo in elongated rollers conglomerates. She has a preferential orientation of N110 ° E with a dip of 50 ° towards WNW. It was observed on the major axes of elliptical objects conglomerates.

4.3. Results on measures made on pebbles elongated

One site, Lubanda - Karhongo which presents the conglomerates with ovoid and elongated pebbles. It has therefore been the particularly object of measurements of the quantization distortion. We performed measurements only on elongated pebbles that are elliptical object in excellence. Unfortunately, these elongated pebbles are few compared to rounded pebbles.

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Figure 15: Elliptical objects (elongated pebbles) in conglomerate outcrop of Lubanda-Karhongo on the XZ plane

4.3.1. FLINN Diagram

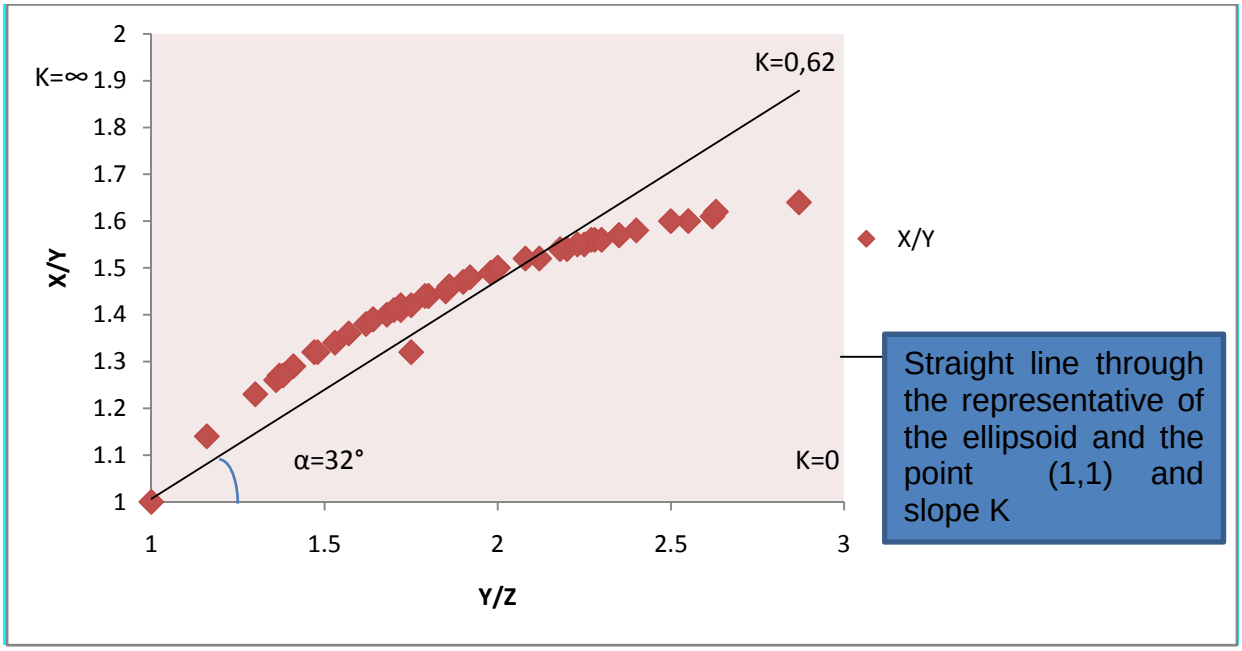

Figure 16: Flinn Diagram giving the state of the deformation using the Flinn parameter K

As α = 32°, K = tan α = tan 32° = 0.62: 0.62 to less than 1, the strain ellipsoid is flattened in the form of a wafer (pancake) and the deformation is triaxial flattening type.

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4.3.2. RAMSAY Diagram R_f/φ

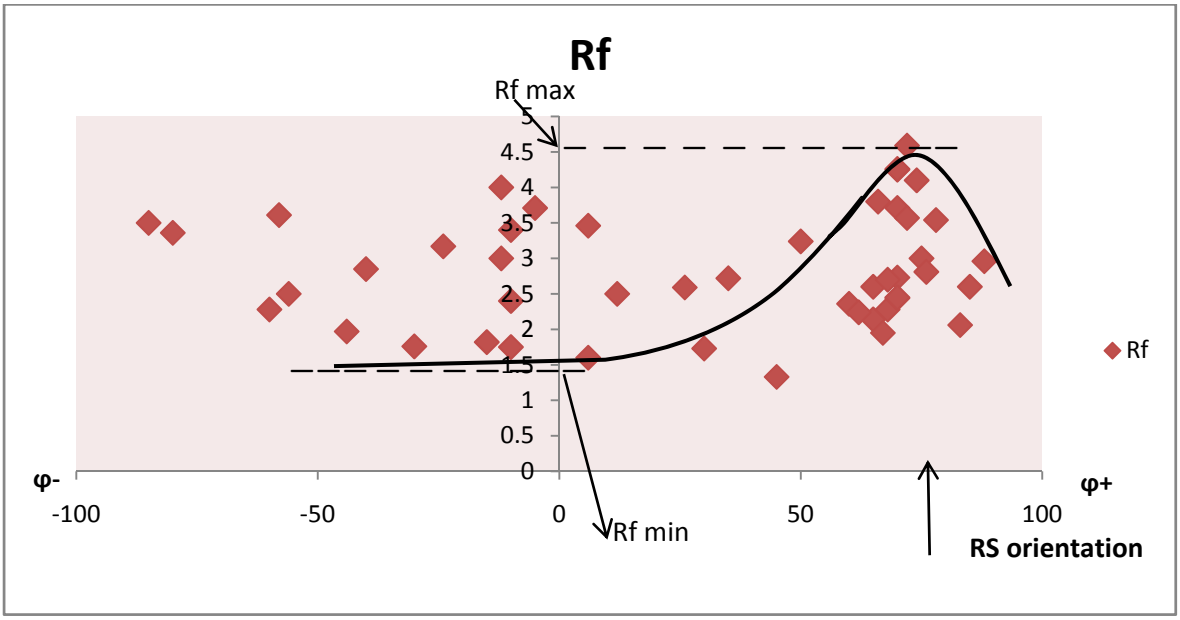

*Figure 17: Ramsay Diagram and corresponding **Rf/φ**curve*

The Rf/φ curve is a bell curve as shown in figure 12. It demonstrates the nature of spread values. But there is a slight concentration values at Rs. This reflects a mean deformation.

The preferred orientation of the pebbles is N108°E / 50°WNW. The maximum stress at the origin of these distortions is perpendicular to the preferred orientation that is to say N018°E in a NNE-SSW direction.

4.3.3. Deformation rate

The Rf/φ method allows also to determine the rate of the deformation of these rocks using the relationship: Deformation rate = $\frac{Rs-Ri}{Ri}$x100

For the site I, we have:

$R_{f\,max} = 4,59$ et $R_{f\,min} = 1,33$

$Rs=\sqrt{1,33_x4,59} = 2,47$

$Ri=\sqrt{\frac{4,59}{1,33}} = 1,85$

Deformation rate $=\frac{2,47-1,85}{1,85}$x100 = 33 %

The deformation rate is less than 1 with order of 1/3,the deformation is therefore medium intensity.

The rate of deformation has allowed us to detect that the deformation which affected the Nagarwa sector has medium intensity. The preferred orientation of the layers is subparallel to the

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schistosity plane. This indicates that the stretching lineation is related to the tectonic phase governing this cleavage. The pebbles were reoriented under the influence of tectonic stresses of D2 phase deformation that lead to crooked folds towards west. This study confirmed the medium intensity of the deformation at the tectonic phase D2.

Regionally, two major tectonic phases have been defined in the Kibaran. Phase D2 would generate stretching lineations including that of our study area. Deformation during this phase would be of medium intensity.From the geodynamic viewpoint, the tectonic phase D2 is related to the collision.

5. CONCLUSION

During this study, we realized that from the petrographic point of view, 6 types of the rocks have been identified in the sector of Nagarwa: siltites, conglomerates, sandstones,quartzites, shales and schists. In quartzite, the microscopic observation of thin plates crafted from samples in PNAL and APL, highlights the transmitted light hétérogranulaire structure and equigranular, there is abundance of quartz grains mixed with opaque minerals and, incidentally, muscovite and clay phyllites. They occupy 80% of the total size of the rock. Their diameters range from 300 to 900 microns. Phyllites occupy less than 5% of the rock. Muscovite and opaque reddish brown products due to oxidation have been observed and occupy more than 15% of the rock and have a size of 100 to 200 microns.

The microscopic description of schists in NPAL and APL shows that Phyllites are often preferentially oriented and occupy 55% of the rock. Their diameter is about 50 microns. The phyllites length goes beyond 500 microns. A part from the phyllites, quartz grains are observed, although embedded in these abundant mass phyllites and occupy less than 10% of the rock. Their sizes range from 70 to 150 microns. The opaque minerals occupy 35% of the rock. In most cases the rock is mica schist. The shale are yellowish and reddish iron oxides in transmitted light appear in clusters in the rock. These clusters have a diameter of 850 microns and occupy about 15%. Biotite abounds. The flakes are elongated along the stratification plane and are long of about 450 microns and diameters of less than 50 microns. Quartz ghosts are detectable in the mass. They have a fine grain size and they occupy less than 15% of the rock. Sometimes observed blackish material, isotropic, organic aspect, aligned in parallel bands when it comes graphitic shales and they occupy 40% of the rock and are spaced approximately 200 microns. We observed four types of sandstone. The nature of the cement, the size of elements, the dominant mineralization and metamorphic grade allowed us to discriminate these sandstones.

The quantification of finished deformation helped us to describe the preferred direction of the layers which is N156° E / 60° NE. Schistosity is subparallel to the bedding and has a preferential orientation of N135° E / 51° NE. Joints have a preferred direction of N67°E/42°NW. They are not abundant in the Nagarwa sector. We highlighted one family of joints. The maximum

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concentration of poles is 53.81%. Statistical of veins in Stereonet shows two families of veins with the front N10°E / 40°E and N50°/80°SE. However veins are rare in Nagarwa sector. The maximum pole of concentration is 41.03%. Flinn diagram gave us the state of the deformation using Flinn parameter. Ramsay diagram demonstrates the nature of spread values and shows a slight concentration values at Rs. The preferred orientation of the pebbles is N108°E / 50°WNW and deformation rate is less than 1 then, medium intensity.

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