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Petrographic Characterization of Geological Settings in the Locality of Mabuku in the Territory of Beni, DRC

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Abstract: The geology of the DRC has already been studied on regional plans, on the scale of a province or territory. But these studies are too synthetic and they do not consider the variations of petrographic facies that can occur at the scale of a locality or a village. Thus, to overcome this possibility, the present study aims to make a petrographic characterization of the rocks of the locality of Mabuku in the territory of Beni. To achieve this, we proceeded by a microscopic analysis of 10 field samples (selected on the basis of the variability of the petrographic characteristics of the rocks). Analyzes of these samples at the petrographic laboratory of the University of Nairobi in Kenya at the LPA and LPNA revealed that the lithology of the Mabuku locality consists of orthogneiss, schists, dolerite and diorite intrusions, quartzites , laterite and sandstones. However, there are four dominant formations. These are the orthogneiss found to the north; schist, dominant in the eastern part; doleritic intrusions in the northwest part; and the sandstones which are distributed along a SW-NE diagonal. Nevertheless, important gaps remain to be completed from the geochemical and metallogenic point of view in the locality of Mabuku.

Keywords: geological setting, petrography, Mabuku

INTRODUCTION

The geological context of the Democratic Republic of Congo is extremely varied (Lepersonne, 1949; BRGM, 1976; Mugisho & Shushano, 2013; Bulangalire & Kulimushi , 2015; Bibentyo et al., 2015). It is characterized from west to east by the Atlantic coastal fringe, the central basin, and a zone of the East African Rift (BRGM, 1976; Fernandez, 2015).

Indeed, the geology of this eastern part has already been the subject of in-depth petrographic studies at the regional level. These researches shows that the eastern DRC is characterized by two major structural units separated by an unconformity: the cover formations (Phanerozoic terrains), not metamorphosed, generally fossiliferous and of an age between the Upper Carboniferous and the Holocene; and the basement (Precambrian), metamorphic and folded formations forming an uninterrupted ring around the Congo Basin (Cahen, 1952; Pasteels, 1961; Villeneuve, 1980; Kokonyangi et al., 2006; Fernandez, 2015; Bibentyo et al., 2015).

The basement formations found in this eastern part of the country are grouped according to their age into three groups, in particular: 1°. the lower Precambrian formations, called the Kibalian, outcrop to the north (Lavreau & Ledent, 1975; Villeneuve, 1980; Pearce et al., 1984; Vicat & Vellutini, 1987; Chorowicz et al., 1988; Pouclet et al., 2016; Boniface & Tsujimori, 2021; Kabete et al., 2021); 2°. Middle Proterozoic formations, called the Kibarian (or Burundian) are found unconformably on the Kibalian in the Kivu region (François, 1995; Brinckmann et al., 2001; Vicat et al., 2001; Villeneuve & Chorowicz, 2004; Dabo & Aïfa, 2013; Cito etal al., 2015; Bibentyo et al., 2015; Ilombe et al., 2017) ; 3°. Upper Proterozoic formations called the Katangian, which is found in the southern part of Katanga (Okitaudji, 1992; François, 1995; Dewaele et al., 2006; Mambwe et al., 2017; Yantambwe & Cailteux, 2019; Basson et al., 2022).

For Villeneuve (1980), these Kibarian (or Burundian) formations can be separated into three subgroups: the Nya-Ngezie group, younger than 1200 Ma intruded by tin granites and pegmatites of 986Ma age; the upper Burundian group intruded by granites of 1380 Ma age; and finally the Lower Burundian group, characterized by formations older than 1600 Ma (Villeneuve, 1980; Villeneuve & Chorowicz, 2004; Villeneuve et al., 2022).

Referring to the cover formations, the tectonic rift in the east of Congo is occupied by Cenozoic formations, and is the site of recent volcanism (Thorpe & Smith, 1974; Chorowicz et al., 1988; Mavonga, 2007; Master et al., 2013; Simon et al., 2013; Pouclet et al., 2016; Mambwe et al., 2017; Rooney, 2020; Schneider & Hinderer, 2021).

All of these works are based on regional aspects, on the scale of a province or territory, and are too synthetic. They do not consider variations in petrographic facies that can occur at the scale of a locality or of a village. Thus, to overcome this possibility, the present study proposes to make a petrographic characterization of the rocks of the locality of Mabuku in the territory of Beni. Thanks to microscopic analyzes (thin sections) of the few rock samples taken from this locality. These samples are selected on the basis of the variability of the petrographic facies of the geological formations outcropping in this locality and are representative.

Regional geology of the territory of BENI, in North KIVU province

The geological settings in the region of Kivu can be divided into three main groups (Figure 1), of very unequal size (Lepersonne, 1949; BRGM, 1976; Dewaele et al., 2006; Fernandez-Alonso et al., 2012; Fernandez, 2015): 1) Precambrian basement (Kibalian, Kibarian or Burundian, Ruzizian, Bilati and Luhule-Mobisio group formations): They constitute the ancient base of Kivu characterized by: dark graphitic schists, phyllites, quartzites, sandstone schists, sandstone, arkose and conglomerates. Not forgetting amphibolic rocks, itabirites and granites (Denaeyer & Petitjean, 1951; Cahen, 1952; Safianikoff, 1952; Cahen et al., 1966; Geirsson et al., 2017); 2) Karroo system (Lukuga series) of Upper Carboniferous age. The rocks of this system appear only in the form of isolated beaches lining the bottom of a few valleys. These are notably amphiboloschists of sedimentary origin, dolerites, diabases, hornblende gabbros, granites, syenites and alaskites (Villeneuve, 1980; François, 1995; Buyse et al., 2020; Odhipio et al., 2020; Villeneuve et al., 2022); 3) Recent formations of the Tertiary, are the sediments with age varying from upper Pliocene, Pleistocene and Holocene. They include often considerable and very varied deposits: fluvial and lacustrine alluvium, terrestrial deposits, volcanic edifices and flows, ashes, tuffs, and finally, travertines and peats (Lepersonne, 1949; Cahen, 1952; Cahen et al., 1966; BRGM, 1976; Delvaux et al., 2017; Ilombe et al., 2017).

METHODS

The achievement of the objectives pursued by this work was made possible through a number of processes including documentation, fieldwork, laboratory analysis, data processing and analysis. Some of the rocks studied and sampled during our field campaign outcrop in riverbeds, others on road embankments, on the summits and sides of various hills.

This research campaign allowed us not only to directly observe the outcrops, to take the samples, but also to describe in situ, in a macroscopic way, outcrops and samples. The sampling was done on rocks in place using the geologist's hammer. We have georeferenced the outcrops and the sampling stations using GPS. The geographical coordinates were taken in UTM. A number was assigned to each sample. And a total of 10 samples were taken for laboratory analysis. This number of samples is chosen according to the variability of the petrographic characteristics of the rocks outcropping in the locality of Mabuku (Figure 2). Thus, each type of rock is represented by a sample.

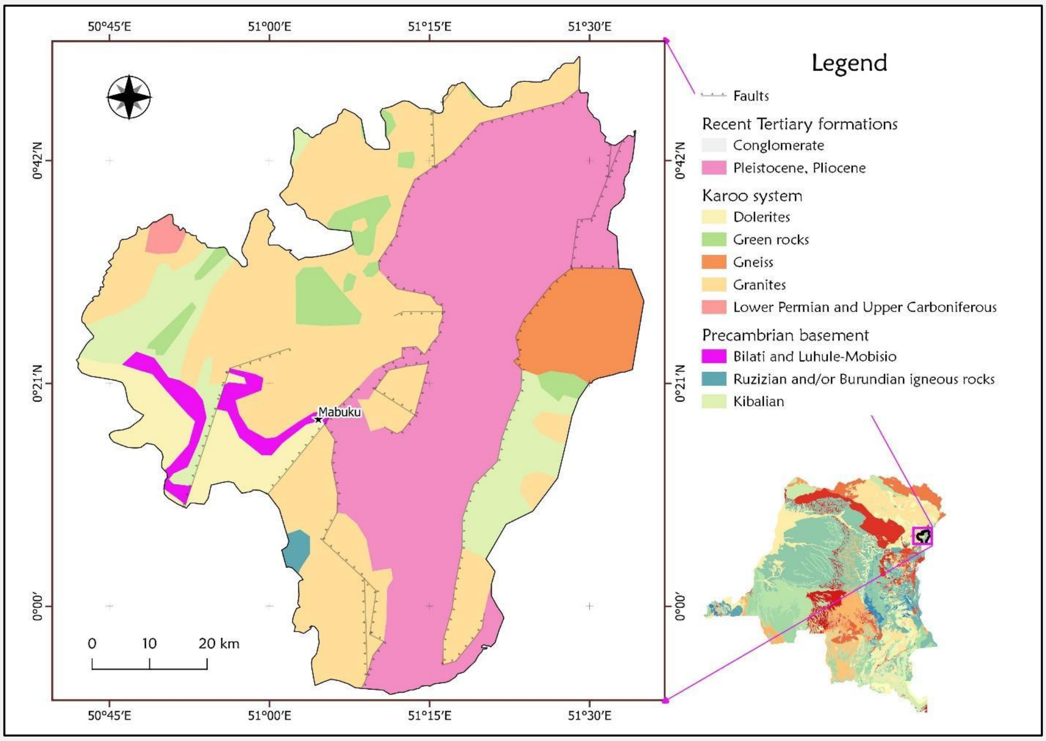


Figure 1. An extract from the geological map of the DRC, as adapted to the context of the territory of BENI. (Source: Fernandez & Dewaele, 2015)

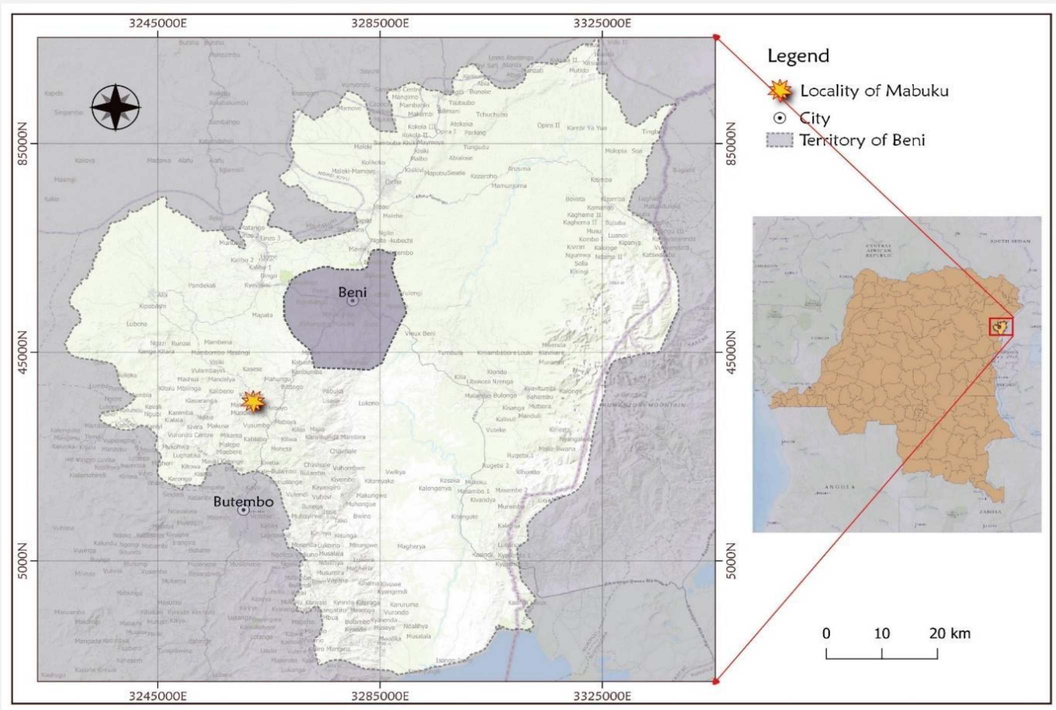


Figure 2. Location of the locality of Mabuku

The macroscopic description of the rock samples consisted in determining their visible characteristics such as: texture, main minerals, grain size, color, hardness (Salpeteur et al., 1992; Kokonyangi et al., 2006; Perdial, 2010; Bibentyo et al., 2015; Kawa et al., 2020; Benjamin, 2022).

This macroscopic description was followed by the confection of thin sections for petrographic analysis by the laboratory of the University of Nairobi in Kenya. This analysis made it possible to identify the presence of some minerals respectively by means of the analyzed polarized light microscope (LPA) and in unanalyzed or natural polarized light (LPNA), as well as their description.

RESULTS

Macroscopic description of samples

The macroscopic description of the samples (taken from outcropping rocks in the locality of Mabuku) shows the presence in Mabuku of orthogneiss, schist, sandstone, quartzite, dolerite, diorite and laterite (Table 1).

Thin sections and microscopic description of samples

The microscopic petrographic analyzes of samples in analyzed polarized light, LPA and in unanalyzed polarized light, LPNA (Figure 3 to 12) shows that the geological settings in the locality of Mabuku, are represented by orthogneiss (banded orthogneiss), sandstone (sandstone shale, micaceous sandstone, and ferruginous cement sandstone), schist, dolerite, microdiorite, metaquartzite, and laterite (pisolithic ferruginous cuirass).

The microscopic petrographic analyzes of samples in analyzed polarized light, LPA and in unanalyzed polarized light, LPNA (Figure 3 to 12) shows that the geological settings in the locality of Mabuku, are represented by orthogneiss (banded orthogneiss), sandstone (sandstone shale, micaceous sandstone, and ferruginous cement sandstone), schist, dolerite, microdiorite, metaquartzite, and laterite (pisolithic ferruginous cuirass).

Sample KM01

On the microscopic level and in transmitted light, the preparation is full of many white crystals with low relief. By turning the object holder stage, we detect a timid rolling extinction. These are quartz crystals that give the analyzed formation an equigranular structure. Oriented crystals of feldspars and pyroxenes are observed in the mass. The grains are stuck together and their boundaries are less clear. In places and in the fractures affecting this formation, opaque reddish-brown products due to oxidation are detected. These are probably iron oxy-hydroxides. The rock is banded orthogneiss (Figure 3).

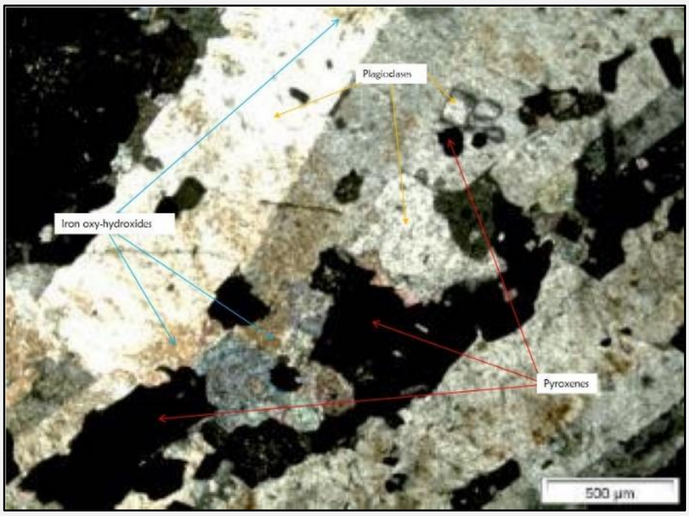
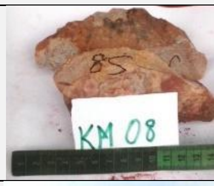


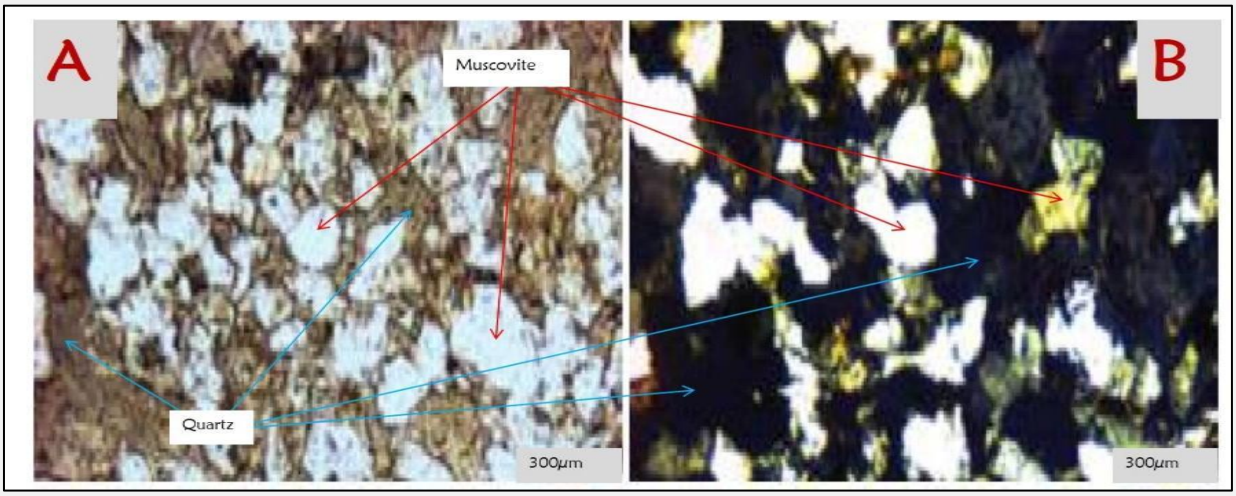
Figure 3. Banded Orthogneiss unanalyzed polarized light (LPNA)

Table 1. Macroscopic description of samples

No	Coordinates (UTM)	Petrographic Description	Sample No.
1	Lat.: 38820 Long.: 756112 Alt.: 1107	A sample of light olive color, grainy texture, massive structure, and made up of the minerals of quartz, feldspar and micas. The rock would be an *orthogneiss*.	
2	Lat.: 38468 Long.: 756282 Alt.: 1282	This sample has partial chlorite alteration. It presents millimetric veins of quartz which are parallel to the schistosity. It would be a sample of *schist*.	Sample KM04
3	Lat.: 38560 Long.: 757861 Alt.: 1510	A medium-grained specimen with quartz minerals and partial alteration of limonite. This rock would be a *sandstone*.	
4	Lat.: 38622 Long.: 754244 Alt. : 1363	Sample of massive light gray colour, with an aphanitic texture but containing a few grains of quartz. The rock would be a *quartzite*.	
5	Lat.: 38391 Long.: 755236 Alt.: 1194	Sample of Greyish coloration, with a massive structure, grainy, partially oxidized. There is zonal alteration of limonite and hematite. The rock would be a *Dolerite*.	
6	Lat.: 39209 Long.: 754796 Alt.: 1227	A sample of light olive color, with a massive structure, micrograined, partially oxidized. Presence of limonite and red blood cells. The rock would be a *dolerite*.	Sample KM20
7	Lat.: 36262 Long.: 756336 Alt.: 1325	Specimen of greyish colour, massive, micrograined, containing minerals of quartz, pyrite, kaolinite, hematite and limonite. The rock would be a *quartzite*.	
8	Lat.: 34291 Long.: 755501 Alt.: 1359	Sample having a medium olive color, massive, micrograined containing voids, partially oxidized to hematite. The rock would be a *diorite*.	Sample KM37
9	Lat.: 35194 Long.: 753635 Alt.: 1539	Light brown pink sample, stratiform, moderately grainy, containing quartz, hematite and limonite minerals. The rock would be *sandstone*.	
10	Lat.: 35664 Long.: 755200 Alt.: 1380	Sample of brown and massive coloration, containing quartz and limonite. The rock is partially oxidized and would be *laterite*.	Sample KM44

Sample KM04

This sample was named as a sandstone. At the LPNA, its mineralogical composition has been described as follows: quartz with low relief (limpid appearance) and muscovite with fine and regular cleavage (colorless and limpid). While at LPA, we described it as containing quartz minerals with low birefringence (first order gray) and high birefringence muscovite, second order gray (Figure 4).



(a) (b)

Figure 4. (a) A sandstone in unanalyzed polarized light (LPNA) and (b) analyzed polarized light (LPA).

Sample KM08

A metamorphic rock with a lepidoblastic texture. This rock is strongly foliated, because it consists of thick beds of brown minerals in the form of lamellae which are lamellae of biotite. These biotite beds are intercalated with quartz eyelets. It has been identified as a sandstone shale. Through these two minerals, crystals whose pleochroism goes from brown to blue-green, present two families of cleavage making between them an angle of 90° in LPNA. Their relief is average. It is an amphibole. In LPA, these crystals polarize in the vivid blue-green hues of the third order and present for some a simple twin. Their angle of extinction is oblique. In this rock (Figure 5), we have identified the following minerals: biotite, quartz and amphibole.

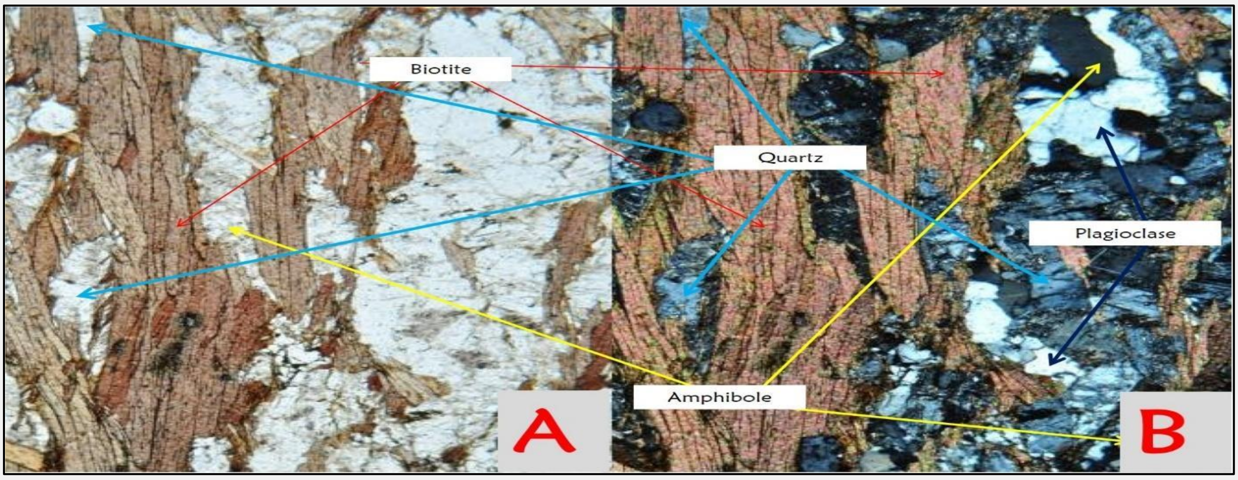


Figure 5. (a) A sandstone shale with unanalyzed polarized light (LPNA) and (b) with analyzed polarized ligh (LPA). Schale not respected.

Sample KM10

Microscopic observation in transmitted light of the blade made in a pegmatite indicates that the rock is made up of: a) Biotite: crystals with a slightly greenish hue joined together, with no pleochroism; b) Quartz: scattered sub-automorphic crystals, with heterogeneous grain size presenting a rolling extinction; c) Orthoclase: mineral in large areas, colorless and with low relief, simply twinned; Opaque minerals. It is identified as a schist (Figure 6).

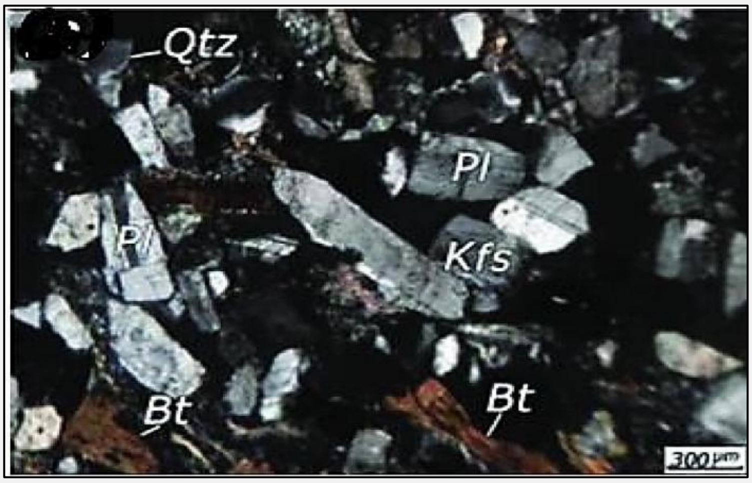


Figure 6. A schist with analyzed polarized light (LPA).

Sample KM16

Equigranular quartz grains, with unoriented muscovites, and plagioclases are less visible. The quartz crystals present in some places, a rolling extinction. Muscovite flakes display vivid color. The rock is essentially made up of sub-rounded, irregular and contiguous grains of quartz (99%). The texture is iso-granular (same size). This fissured one is clogged by opaque minerals. The rock is an oxidized micaceous sandstone (Figure 7).

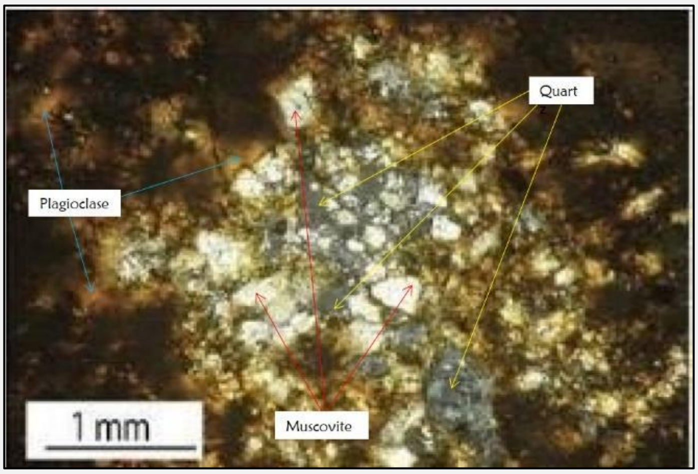
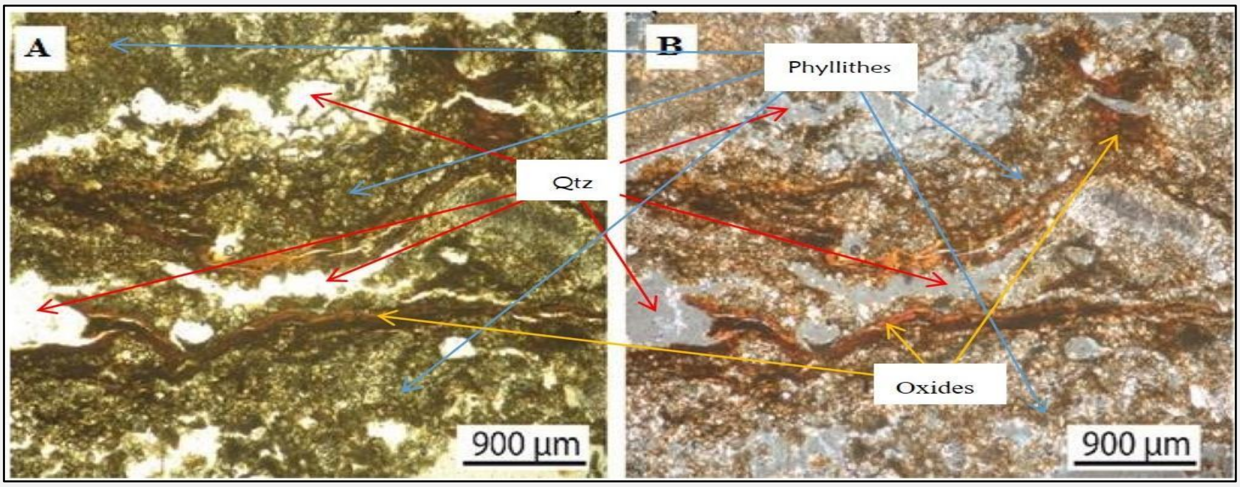


Figure 7. An oxidized micaceous sandstone to the analyzed polarized light (LPA).

Sample KM20

Siliceous rock, because it consists entirely of angular to sub-angular quartz crystals. This mineral is white clear in unanalyzed polarized light (LPNA) and it does not contain any trace of cleavage within it. In analyzed polarized light (LPA), quartz polarizes in the first order gray hues.

Through the small quartz crystals are scattered polygonal crystals of an opaque mineral with metallic reflections, which reveal their red color in reflected light, undoubtedly iron oxide. This rock is an altered dolerite with micro fractures filled with quartz (Figure 8).



(a) (b)

Figure 8. (a) Weathered dolerite to unanalyzed polarized light (LPNA) and (b) the same sample but to the analyzed polarized light (LPA).

Sample KM22

This blade is made up of the following minerals: Firstly biotite (it appears in the form of sub-elongated automorphic crystals, brown in color and showing a strong paleochroism in dark browns to greenish browns). The relief is medium. Note that this biotite is undergoing alteration, thus developing traces of chlorite. In LPA (b), these crystals have slightly shimmering, non-iridescent hues. The birefringence is attenuated by the phenomenon of chloritization. Secondly quartz crystals: colorless, xenomorphic, with low relief. In LPNA (a), these crystals exhibit rolling extinction and polarize in light gray hues. They polarize in bright to bluish hues with a black appearance. And presence of opaque minerals, dominated by iron oxides. It is an altered Microdiorite (Figure 9).

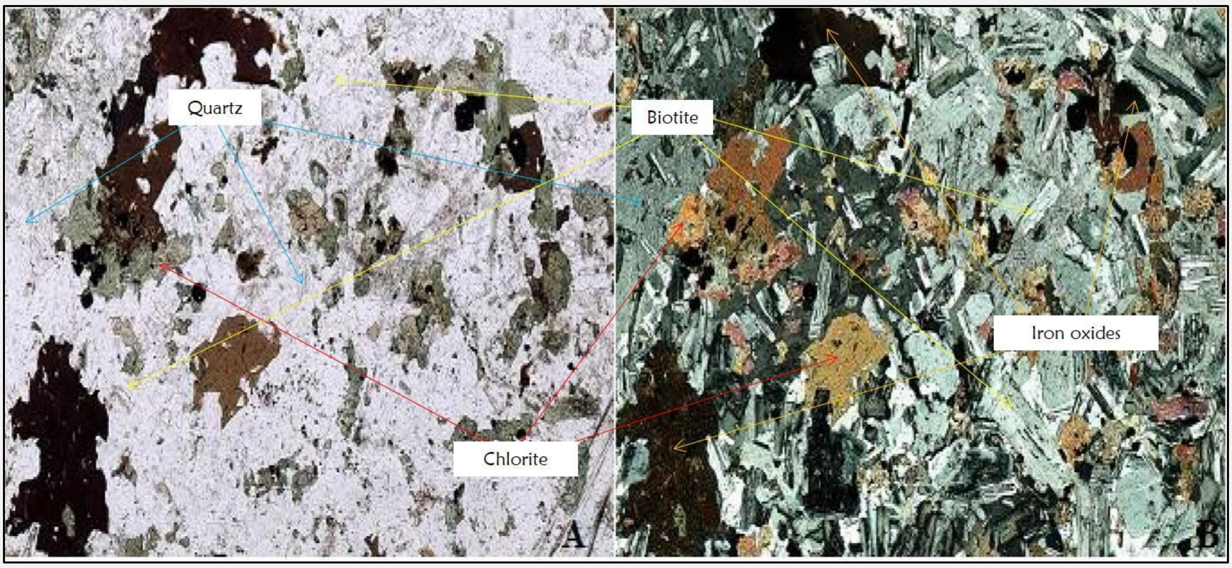


Figure 9. (a) A weathered microdiorite to the unanalyzed polarized light (LPNA) and (b) the same sample but to the analyzed polarized light (LPA).

Sample KM37

This rock has been named as a metaquartzite (Figure 10). It is a metamorphic rock resulting from the stress recrystallization of a sandstone. The orientation of the quartz minerals (multi-millimeter) is parallel to the plane. It was described as follows: a) At LPNA: Quartz with low relief; clear appearance. Oxides with brown absorption color, clear pleochroism and numerous parallel cleavages (in sheets); 1st order gray low birefringence meshed quartz.

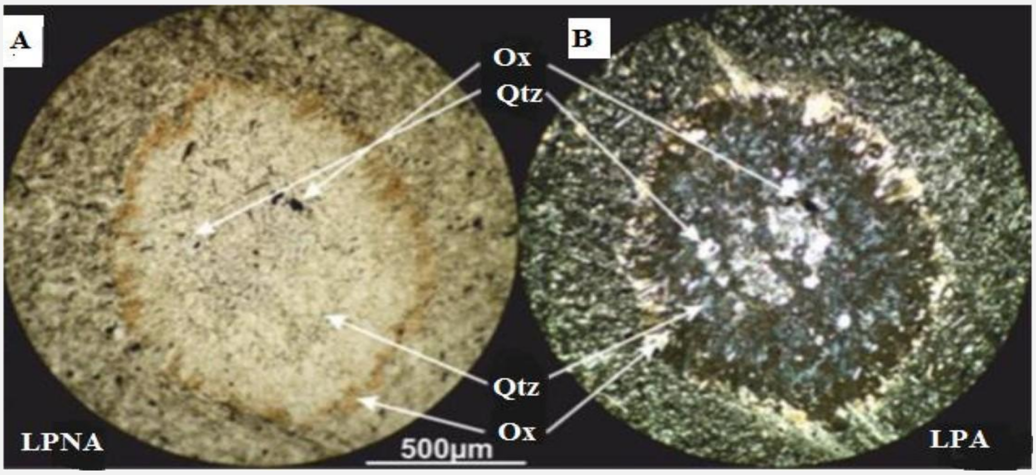


Figure 10. (a) A metaquartzite in unanalyzed polarized light (LPNA) and (b) in analyzed polarized light (LPA)

Sample KM41

Microscopic observation of this polished blade reveals the following: a) Mineral A: whitish in color, the mineral is weakly represented in the rock by fine crystals in the form of rods which show a rolling extinction in polarized light. Its relief and polish are difficult to identify because of its size. The crystals are found disseminated or scattered in the cement. The rods show a preferential direction. This mineral is Quartz; b) Mineral B: we observe clay minerals represented by almost acicular and tangled phyllites and occupying a large part of the rock; c) Mineral C: this mineral is recognized by a black color, appears in small crystals sub-automorphic to automorphic disseminated sometimes concentrated in certain places of the rock. These are opaque iron oxides in transmitted light; they occupy about 2 to 3% of the rock; d) Mineral D: mica is observed in a very small proportion, i.e. less than 1%. This rock is a ferruginous sandstone (Figure 11).

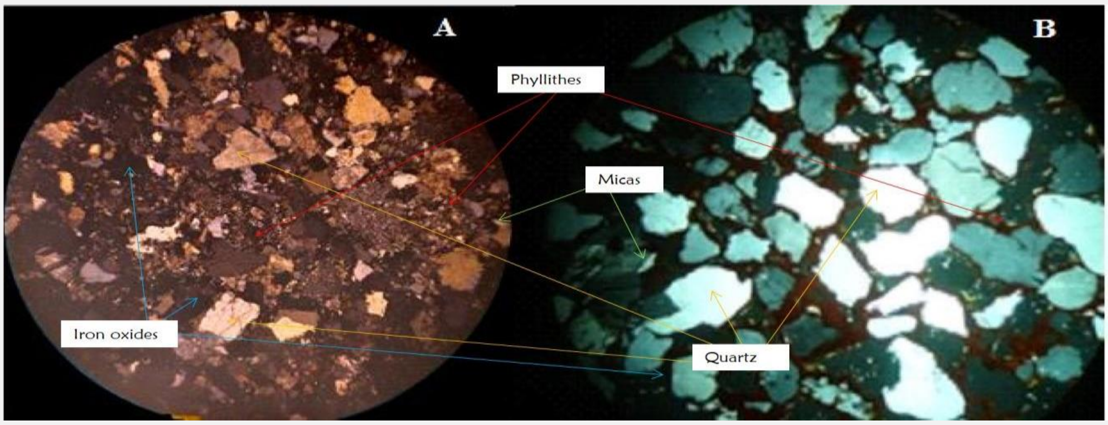
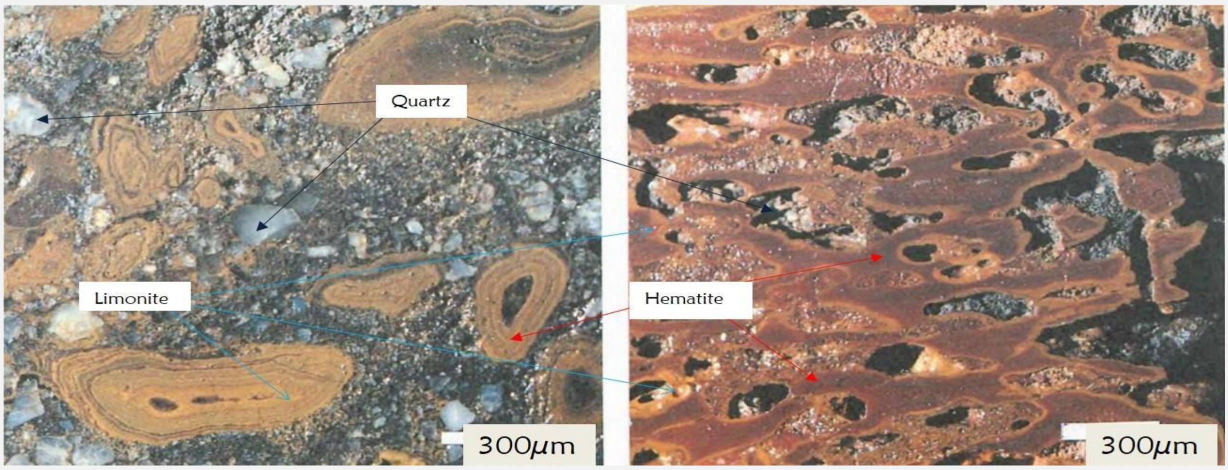


Figure 11. (a) Ferruginous cement sandstone in unanalyzed polarized light (LPNA) and (b) in analyzed polarized light (LPA).

Sample KM44

Observation of the preparation in transmitted light reveals a rock consisting essentially of iron oxides. These are mostly hematite, in the background goethite and finally amorphous limonite which cannot be precisely identified given their extra fine grain size, which require X-ray diffractometry for their efficient diagnosis. In some cavities, automorphic crystals of authigenic quartz can be observed.

The oxides and hydroxides are in concentric layers and their axes are parallel to each other as evidenced by the photo presented below. Quartz crystals are almost equigranular, clear in natural light and rolling extinction in polarized. Their cracks are sealed by the opaque and sometimes brownish material. These plasmas would correspond to the metalliferous minerals that reflection microscopy will have to specify. The rock is a portion of a high-grade pisolithic ferruginous cuirass (Figure 12).



(a) (b)

Figure 12. (a) A pisolithic ferruginous cuirass in unanalyzed polarized light (LPNA) and (b) in polarized light analyzed (LPA).

DISCUSSION

Geological map

The geological survey carried out in the locality of Mabuku shows that the geology of this entity consists of seven different lithologies, two of which are sedimentary (Figure 13). These are sandstone and laterite. There are also plutonic igneous rocks such as diorite and dolerite. The latter is often crossed by very thick quartzite veins. We also note the presence of metamorphic rocks, represented in this locality by orthogneisses and schists.

Indeed, the existence of these metamorphic rocks in the context of Kivu, the Kibarian and a rifting zone, is not strange (Kampunzu et al., 1991; Prakash, 1993; Kokonyangi, 2001; Cito & Ongezo, 2015; Dewaele et al., 2016; Ilombe et al., 2017; Oyediran et al., 2020; Kawa et al., 2022). These geological formations have been found in Butembo (a town located about a ten of kilometers south of the study area) during the work of the first Belgian explorers (Cahen, 1952; BRGM, 1976). This was reaffirmed by Sahani (2012) in his thesis work on the hydrological risks of the city of Butembo. Thus, the geology of Butembo is made up of four main types of rock: the basic complex of Luhule-Mobisio formed of metabasalts, dolerites, diorites and islets of quartzites; the sedimentary base of Luhule - Mobisio composed of schists, quartzites with limestone intercalations; the orthogneissic complex made up of a set of granites and granodiorites, sometimes homogeneous orthogneisses and migmatites, and finally the Lubero series made up of micaschists with granitic intrusions, phyllites, schists, sandstones and quartzites (BRGM, 1976; Sahani, 2012).

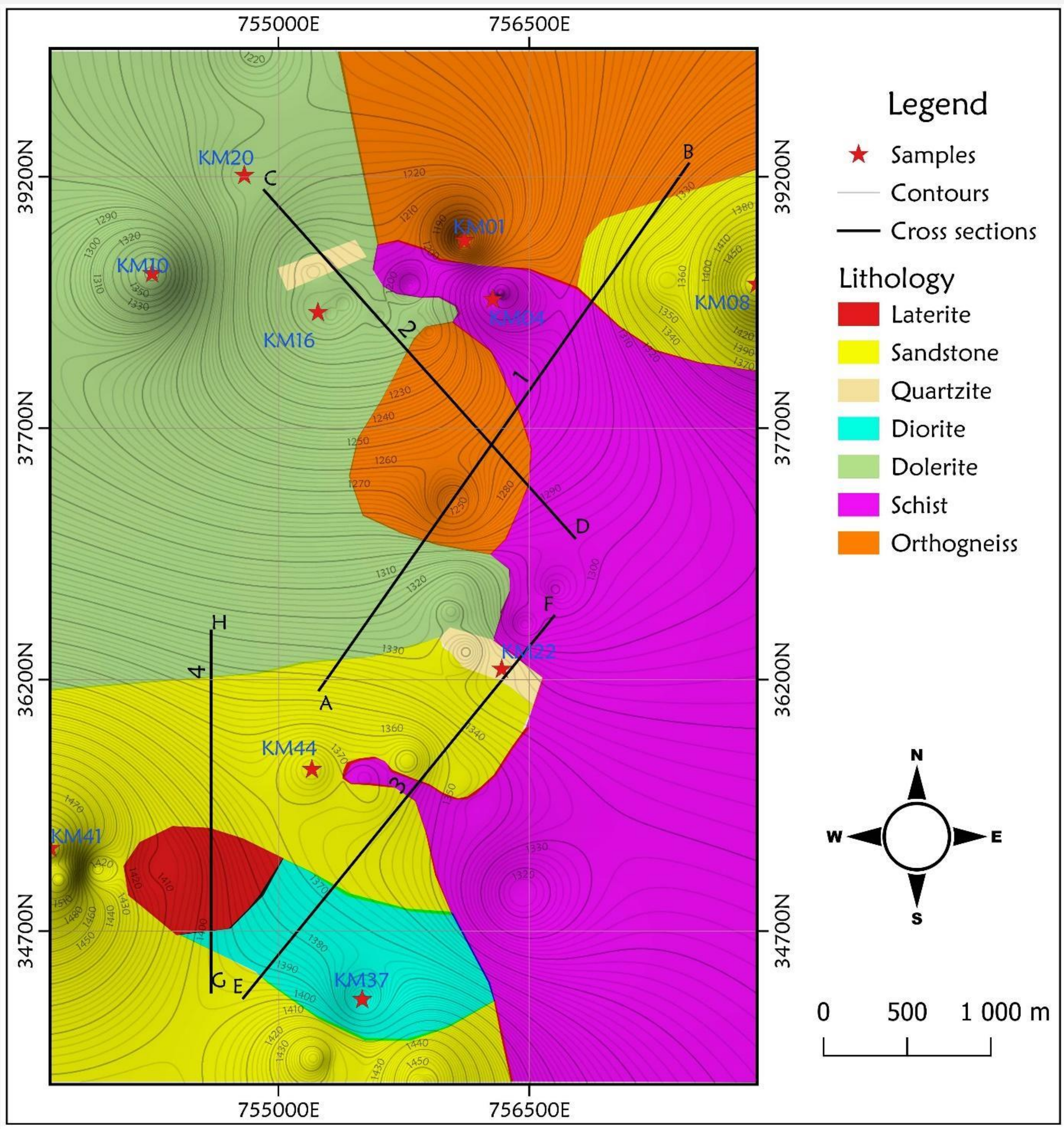


Figure 13. The geological map of Mabuku

In addition, recent studies by Benjamin (2022) on the cartography and petrography of the southwestern part of the city of Butembo, have shown that the basement of this part of the city is formed of quartzite, sandstone (sandstone quartzite), schist which is similar to argillite, and doleritic intrusions. Which is no different from what his predecessors found in Butembo (Sawasawa & Vweya, 2021; Benjamin, 2022).

In this same angle of idea, the schists, the orthogneisses, the dolerites and the diorites which outcrop in the locality of Mabuku would be a continuity of these rocks resulting from the orthogneissic complex and the sedimentary and basic base of the Luhule - Mobisio. Compared to the presence of laterite in Mabuku, lateritic formations are very abundant in the southwestern part of the territory of Beni, with Butuhe as a reference (Odhipio et al., 2022). According to our previous research, these laterites would come from the chemical alteration of the diorites of the basic complex of the Luhule Mobisio (Odhipio, et al., 2022).

On the other hand, in the recent publication of Sawasawa & Vweya (2021) on the lithology and geochemistry of the rocks of Lukanga, in the territory of Lubero, they state that the geology of this part is characterized by an abundance of sandstones, quartzites, schists, gneisses and conglomerates. Which is a repetition of almost the same types of rock found in the locality of Mabuku.

Looking at the east of Mabuku, in the Ruwenzori sector, Michot (1938) had already highlighted the existence of most of these formations. Thus, among the rocks he identified in the Ruwenzori sector, we have: doleritic dykes and their diabasic varieties, gabbros and their different metamorphic varieties, and the sedimentary series of cipolins, amphibolites and amphiboloschists (Michot, 1938). Some of these rocks like dolerite and schist appear in Mabuku.

Geological sections

According to Raoult and Foucault, a geological section is a representation of the section of land by a generally vertical plane. The term geological profile is sometimes used, but it is wrong, the word profile designates only the outer contour of the section or topographic profile (Lohest, 1946; Lombard & Bordet, 1956; Audebaud et al., 1976; Kowalski, 1983; Teixell, 1993). It can be built from the geological map and the different surface inclinations of the geological structures that we try with more or less difficulty to reconstruct their appearance in depth (Maravic et al., 1989; Simon et al., 2013; Geirsson et al., 2017; Odhipio et al., 2022).

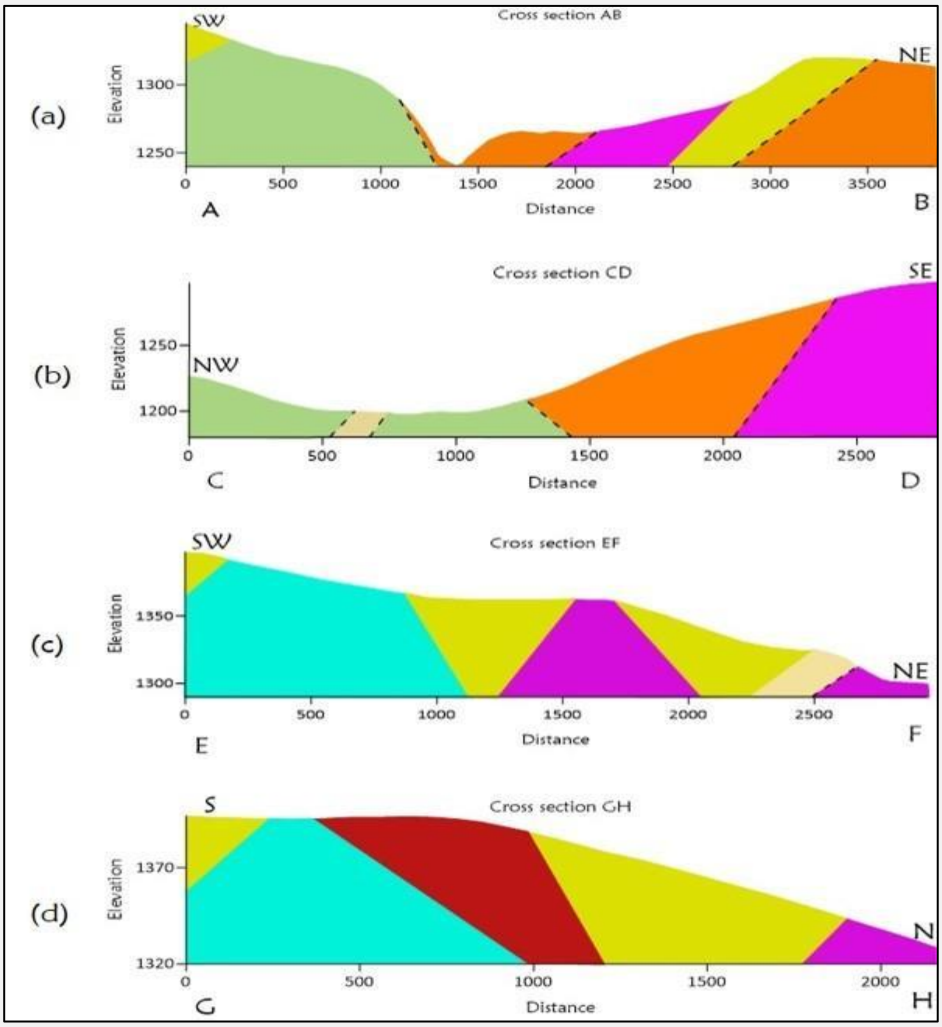


Figure 14. The geological sections done in the locality of Mabuku

Indeed, no geological reconnaissance drilling has yet been carried out so far in the locality of Mabuku or in the surrounding regions to know with great precision the litho-stratigraphy of this entity (Boven et al., 1998; Villeneuve & Chorowicz, 2004; Geirsson et al., 2017; Rooney, 2020). Thus, to try to circumvent this difficulty, four cuts were made (Figure 14). These are: 1° the AB section, approximately four kilometers long, it is oriented SW-NE and crosses four formations including sandstone (twice), dolerite, orthogneiss (also twice) , shale (Figure 14a); 2° the CD section, about three kilometers long, it is oriented NW-SE and crosses four formations including dolerite (twice), quartzite, orthogneiss, and schist (Figure 14b). These two cuts intersect with each other. 3° section EF, approximately three kilometers long, it is oriented SW-NE parallel to section AB, but it is further south (Figure 13) and also crosses four formations, among which we have: sandstone (in three occasions), diorite, shale (in two occasions), and quartzite (Figure 14c). And finally, 4° the GH section, more than two kilometers long, it is oriented S-N and crosses four formations, including sandstone (twice), diorite, laterite, and shale (Figure 14d).

The chronology of lithological units carried out by BRGM (1976) on the geological formations of Butembo shows that the orthogneissic complex dates from the Pre-Kibalian or Lower Kibalian (about 2800 Ma). This complex is composed of granites and granodiorites. It is surmounted by the Lubero series which dates from the Lower Burundian (about 1200 Ma). In this set, there are mica schists with granitic intrusions, phyllites, schists, sandstones and quartzites. Then the sedimentary base of the Luhule-Mobisio composed of schists, quartzites with limestone intercalations. These shales date from the Lower and Middle Burundian, i.e. around 1235 ± 40 Ma. And the recent formations of the basic Luhule-Mobisio complex formed of metabasalts, quartzites (BRGM, 1976; Sahani, 2012; Odhipio et al., 2022).

Examination of the geological map and sections made in the locality of Mabuku shows that the oldest formation of Mabuku would be orthogneiss, followed by schists, then dolerite and diorite. Recent formations in the region would be quartzites, laterite and sandstone. As no dating study has yet been considered, this chronology remains provisional.

CONCLUSION

The locality of Mabuku is a mixed terrain where all major rock types are present. These are metamorphic formations such as orthogneisses, schists, and quartzites; magmatic and intrusive formations such as dolerites and diorites; and sedimentary formations such as sandstones and laterite. These sedimentary formations rest unconformably on the aforementioned metamorphic and magmatic rocks. However, there are four dominant formations. These are the orthogneiss found to the north; shales, dominant in the eastern part; doleritic intrusions in the northwest part; and the sandstones which are distributed along a SW-NE diagonal.

This study was very important because it allowed us to know the different types of rock encountered in the locality of Mabuku, and their spatial distribution in the region. However, important gaps still remain to be completed from a geochemical and metallogenic point of view. On the geochemical level, it will be necessary to make chemical analyzes of these rocks to know their composition. And from the metallogenic point of view, the evaluation and identification of valuable minerals in this locality.

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