**ANTON DE KOM UNIVERSITY OF SURINAME**

**FACULTY OF TECHNOLOGICAL SCIENCES**

**MINERAL RESOURCE MANAGEMENT**

# Distinguishing the Rosebel Formation from the Armina Formation, a case study at the Rosebel Gold district, Suriname.

A thesis submitted in partial
fulfillment for the degree of
**Bachelor of Science (BSc.)**
in
**Mineral Resource Management**

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Paramaribo, Suriname

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- Renoesha Naipal, MSc, (Co- faculty Supervisor/ Lecturer at Anton de Kom University of Suriname)

*"I dedicate this thesis to my fiancé and kids for their love, support and motivation"*

# Abstract

A study of the occurring rock types and depositional environment has been carried out at Hill 24. Hill 24, situated in the upper reaches of a tributary of the Mamanari Creek which lies in the Rosebel Gold Mines property, Suriname, South America. The company had carried out exploration activities in this area for gold occurrences. Some drill cores from this area, drilled, in 1956, by the Geological and Mining Department of Suriname (GMD) were borrowed for further studies at the Anton de Kom University of Suriname, department of Geosciences. A project was initiated to carry out detailed research of the rock types and their depositional environment in the area. In light of my bachelor thesis, I was assigned to accomplish this study.

The cores were logged in detail and some thin sections were made of parts of the cores. Some of these thin section have been studied under the microscope by me. The results of this study shows that there is not a big variety of rock types in this area, probably because the bore hole locations are not so far from each other. Microstructure such as shearing indicates that the cores were drilled near a shear zone.

# Preface

This research aims to find indications of the possible source rocks of the Rosebel Formation (Sandstones) from the Rosebel Gold Mine area, based on the minerals present in sandstone samples. Mineral identification can help clarify and understand the geology of the study area also it can help clarify, in this case, the differences between the Armina and Rosebel Formation therefore help explain some questions regarding this area.

This research is a microscopic and literature study on thin section of samples from the Rosebel gold district area. The data consist of a combination of primary sources (samples) and secondary resources (literature data from other researches done is the area). All these data will be defined and correlated in order to answer the research questions.

During this study I have gained a lot of experience in mineral determination and analyzing research papers. Furthermore I also learned how to interpret the gathered data and how to correlate various types of data.

# List of figures

# List of mineral abbreviations

| | |
|---|---|
| Ab | Albite |
| Bt | Biotite |
| Chl | Chlorite |
| Mc | Muscovite |
| Plag | Plagioclase |
| Grt | Garnet |
| Ep | Epidote |
| Cld | Chloritoid |
| Ser | Sericite |
| Cpx | Clinopyroxene |
| Qtz | Quartz |

# Table of Contents

# 1. Introduction

The IAMGOLD Rosebel Gold Mine (RGM), in northeastern Suriname, is set in Paleoproterozoic volcanic and sedimentary rocks that form part of the Marowijne Greenstone Belt, consisting of the mafic volcanic volcanosedimentary Paramaka and the turbiditic Armina Formation unconformably overlain by the fluvial sediments of the Rosebel Formation (Bosma et al, 1978, 1984).

The rocks of the Armina Formation consist of a rhythmic sequence of mudstone, siltstone and graded greywacke interpreted as flysch sequence derived from the erosion of rocks of the underlying Paramaka Formation. According to Gibbs and Barron (1993), the Rosebel Formation is mainly derived from the erosion of the volcanic rocks of the Paramaka Formation. The Rosebel Formation was deposited in a fluvial environment and was traditionally interpreted as a continental molassic sequence (Bosma et al, 1983). Ledru et al (1991) and, Manier et al (1993) considered the Rosebel Formation to be equivalent of the Orapu Formation (or Upper Detrital unit) in French Guiana and deposition to have occurred in pull-apart basins during the Main Transamazonian Orogeny.

The IAMGOLD Rosebel Gold Mines concession comprises several gold mine pits, and also an unexploited occurrence of alluvial diamonds, the primary source of which is thus far unknown (Van Kooten, 1954, Schönberger, 1975). According to Van Kooten (1954) the Rosebel diamonds come from the Rosebel conglomerates. However, he has never been able to prove that which is why Schönberger (1975) suspected that there must be a primary ultramafic source in the area, but he never found it either.

The stratigraphy of the concession in relation to the gold mineralisation has been described in detail by Watson (2008), Daoust et al., (2011) and Daoust, (2016). However, there is disagreement between these authors about the role of the Armina and Rosebel Formations in the southern part of the concession, first author shows Armina-type rocks in this area, although he does not give specific Formation names, while the latter authors include the whole southern area in the Rosebel Formation.

The main question of this study is: Can the Rosebel Formation be distinguished from the Armina Formation?

” The objectives of this study were:

To determine the rock types and their depositional environment

To carry out microscopic study

To determine the differences between the Armina-/ Rosebel Formation

This thesis is organized in four chapters. Chapter 2 consists of background information about the study area. The methods and techniques are described in Chapter 3, while Chapter 4 presents the obtained results and the discussion. The conclusions and recommendations are given in Chapter 5.

# 2. Background information

## 2.1. Location and Accessibility

The study area is located in the Rosebel Gold Mine area, District of Brokopondo between the Suriname River to the East and the Saramacca River to the West, approximately 80 kilometers south of the capital City of Paramaribo.

Presently, there are two access routes from Paramaribo to the Gross Rosebel area. The first route utilizes a 30 kilometer paved road which connects Paramaribo with Paranam. From Paranam, the Afobaka road due south, the paved road to the village Brownsweg, and the unpaved road to the village Koffiekamp courses west to reach the study area. The second route from Paramaribo using the Indira Gandhi Road, Martin Luther King Road, Road to Kraka to reach the Afobaka Road and continue as described above.

## 2.2. Geological setting

### 2.2.1. Regional geology

The study area is located in the crystalline basement of Suriname, which is part of the Guiana Shield and is situated on the north-eastern coast of the South American continent. The Guiana shield which stretches from the Orinoco River in Venezuela in the west to the Amazon River in the east (Brazil), covers an area of more than 900.000 square kilometers (Daoust,et al.,2011).

Most of the rocks of the shield have been formed during the Paleoproterozoic Trans Amazonian Orogeny. This orogeny was an important episode of granitoid magmatism, deformation and metamorphism. Locally, Archean crust is found. The Paleoproterozoic part of the shield becomes progressively younger towards the southwest, with tonalite- trondhjemite-granodiorite (TTG) Greenstone Belt to the north (Fig. 1), granitoid successions mainly in the central-eastern part (Fig. 1) and Late Paleoproterozoic to Mesoproterozoic volcanic, intrusive and sedimentary rocks to the south (Fig. 1). (Daoust, et al., 2011)

The geological evolution of the Guiana Shield can be divided in four distinct stages. These stages are: (1) formation of the Archean basement, (2) main Trans-Amazonian orogeny, (3) Late Trans-Amazonian orogeny and (4) subsequent Meso-Neoproterozoic and Paleozoic anorogenic events (Daoust, et al., 2011).

Between 2.26 Ga and 2.08 Ga, the Main Trans Amazonian Orogeny (D1) was a crustal growth event that generated the TTG- Greenstone Belts which are found in the northern part of the Guiana shield. The first part (D1) of the Main Trans Amazonian orogeny was linked with the north-south convergence of the north Amazonian and West African cratons in a context of south- verging subduction. This resulted in the consumption of a juvenile crust which has given rise to the greenstone-TTG belts associated with sedimentation. The TTG greenstone belts can be found on both sides of the Bakhuis horst in western Suriname (Daoust, et al., 2011).

In the Proterozoic basement of Suriname, three metamorphic belts can be found: (1) the lowgrade Marowijne Greenstone Belt in the northeast, (2) the high-grade granulite Belt in the northwest and (3) the Coeroeni Gneiss Belt in the southwest ( (Kroonenberg, et al., 2016). These Belts are separated in the central part of the country by a large area with various types of granitoid rocks and felsic metavolcanic rocks. The basement is overlain by the Mid-Proterozoic Roraima Formation, consisting of sandstone and pyroclastic rocks, and all rocks are transected by Late-Proterozoic and early Jurassic dolerite dykes (Kroonenberg, et al., 2016).

Gradually, the north-south convergence is inferred to have switched to a NE-SW oblique convergence that has generated a regional strike-slip movement (D2a) associated to syntectonic granitic accretion. The development of these strike-slip structures has led to the formation of pull-apart basins along the North Guiana through that have been synchronously filled with arenitic sediments. These pull-apart basins unconformably overlie the TTG greenstone belts, and were deformed and metamorphosed during the later phases of the Trans Amazonian orogeny (Daoust, et al., 2011).

The Late-Trans Amazonian event (D2b), which extends from 2.07 Ga and 1.93 Ga, was associated with extreme crustal stretching of the Guiana Shield in continuation with the sinistral shearing that has dominated the Main Trans-Amazonian orogeny. As a result of mantle upwelling, granulite grade metamorphic rocks developed, and charnockitic magmatism exposed at the surface due to the development of normal faults, which can be seen in the Bakhuis horst in Western Suriname (Daoust, et al., 2011)

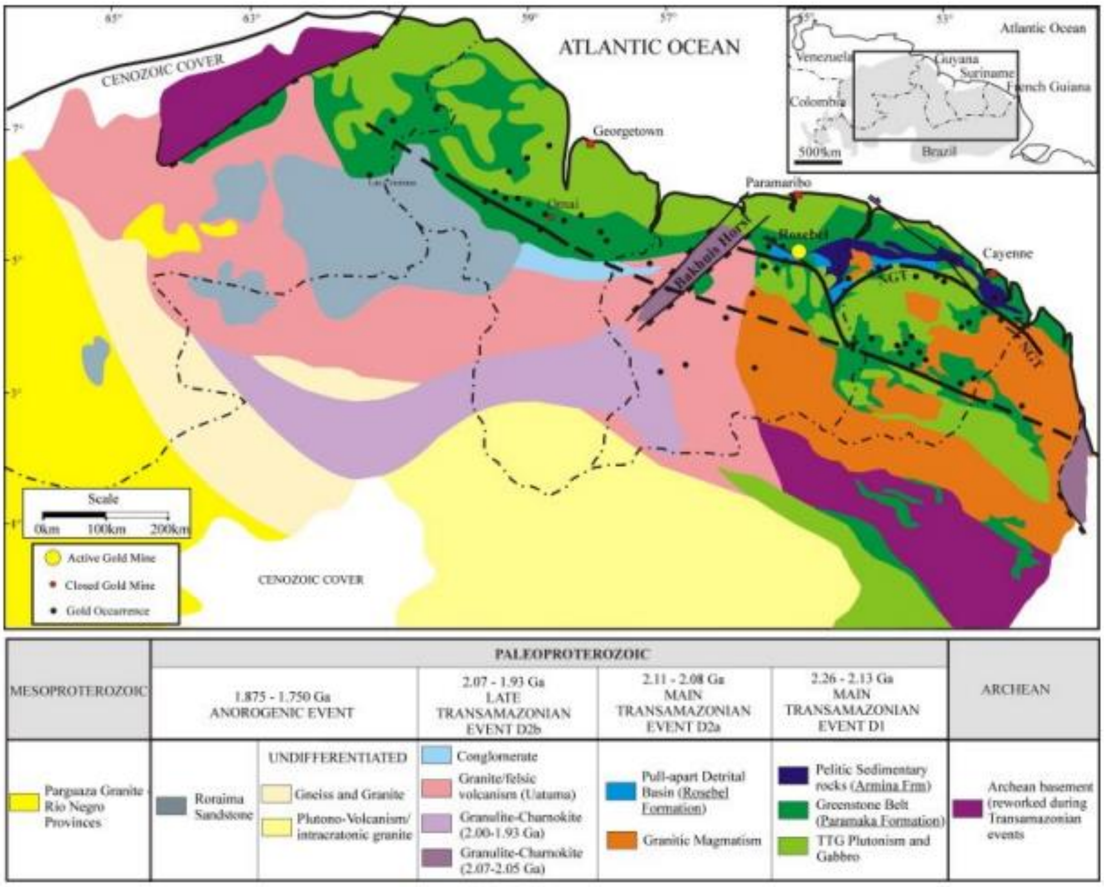


***Figure 1. Simplified geological map of the Guiana Shield modified from (Delor et al., 2003) showing the Geological evolvement of the Guiana Shield (Daoust, et al., 2011)***

The Suriname part of the Guiana Shield greenstone belt is represented by the Paramaka Formation, which together with the Armina Formation and Rosebel Formation is grouped in the Marowijne Greenstone Belt (Fig 2).

The Formations of the Marowijne Greenstone Belt are described here below from old to young:

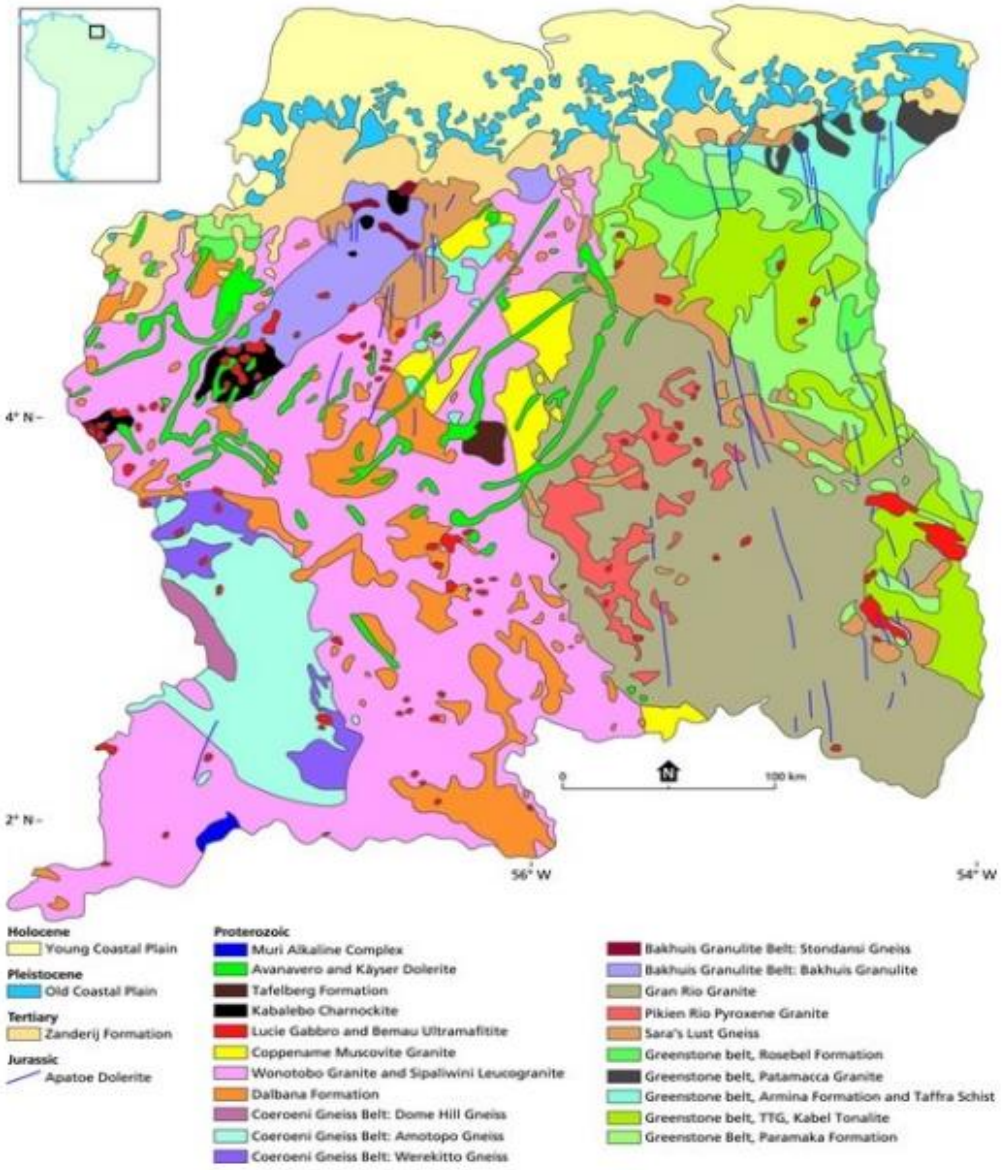


*Figure 2. Simplified geological map, according to modern data. This map gives an overview of the Marowijne Greenstone belt and the Formations (Kroonenberg, et al., 2016)*

### *Paramaka Formation*

A series of lava flows (including basalt, andesite, rhyolite and dacite) and volcaniclastic sediments (pyroclastic rocks and tuffs) with some intercalated chemical sediments, metamorphosed in the greenschist facies, can be found in this Formation. According to (Kroonenberg, et al., 2016), metabasalts with pillow structures were observed in the Gross Rosebel area and the base of this sequence is probably formed by these metabasalts, although their lower contact has not been observed. Higher in the sequence more differentiated metaandesites, metadacites, metarhyolites and associated tuffs occur with calc-alkaline signature, while towards the top of the sequence, intercalated phyllites and carbonaceous and ferruginous cherts increase (Kroonenberg, et al., 2016). Through greenschist-facies metamorphism, basalts are converted into massive actinolite-epidote-chlorite-sodic plagioclase greenstones with commonly relict porphyritic, amygdaloidal and fluidal textures, as well as amphibole textures. Andesites and rhyolites are metamorphosed into chlorite and sericite schist (Kroonenberg, et al., 2016).

### *Armina Formation*

The Armina Formation consist of regularly alternating sequences of low-grade metagreywacke and phyllite, called flysch facies by Bosma & Groeneweg (1973) and since then indeed recognized as metaturbidites (Bosma et al., 1983, 9184; Daoust et al., 2011; Naipal & Kroonenberg, 2016; Watson, 2008). Three differ metaturbidite facies have been distinguished on the basis of field, petrographic and diagentic features, showing northwards slightly increasing maturity. Metamorphic grade also increase northwards, ranging from chlorite-sericite-rich assemblages to biotite- and garnet- bearing ones, though all within the greenschist facies. Conspicuous calcsilicate nodules in one of the three metaturbidite facies consist of garnet, actinolite, clinozoisite and plagioclase. Chemically the variability within the individual flow units is greater than between the different facies. Monomineralic clasts are mainly quartz and (igneous) plagioclase grains. Lithic clasts are Paramaka metavolcanics, chert and phyllites, but also tonalite or trondhjemite fragments, suggesting that the TTG batholiths were already exhumed when the turbidites were deposited (Naipal & Kroonenberg, 2016). This is corroborated by juvenile isotopic character of metagreywackers in French Guiana, which might testify to the erosion of the TTG granitoids, although metapelites give negative epsilon Nd isotope values, indicating a possible Archean source (Delor et al., 2003a).

The Armina Formation metaturbidites in the Rosebel Gold Mine have conspicuous conglomeratic intercalations, consisting mainly well- rounded, tectonically flattened metavolcanic and metagabbroic clasts, with little evidence for tonalitic sources (Watson, 2008; Daoust et al., 2011; Naipal & Kroonenberg, 2016). According to the latter authors detrital zircons in the Armina Formation would indicate a maximum age of 2127 ± 7 Ma for the deposition of the metaturbidite sequence, citing Milési et al. (1995). However, Milési et al. (1995) refers to this age as belonging to the Rosebel Formation.

### *Rosebel Formation*

The uppermost metasedimentary Formation in the Marowijne Greenstone Belt is the Rosebel Formation, named by Schols & Cohen (1951) for the Rosebel Savanna area, the site of the present-day open- pit Rosebel Gold Mine. The Rosebel Formation overlies the Armina and Paramaka Formations unconformably with a basal metaconglomerate, as has been observed in the mine (Watson, 2008; Daoust et al., 2011). Higher in the sequence conglomeratic intervals also occur. The most characteristic component is a cross- bedded greyisch quartz- rich meta-arenite, with magnetite grains concentrated at the base of the forest (fig, 7). The metaconglomerates are polymictric, quartz-rich, but with also abundant phyllite clasts (Fig. 8) supposedly derived from the underlying Armina Formation (Bosma et al., 1984). Soils on the Rosebel Formation are whitish and sandy, while those in the Armina Formation are reddish and clayey. Nevertheless distinction between the two Formations is sometimes difficult in the field, especially when less mature sediments are intercalated (cf. Daoust et al., 2011). Naipal & Kroonenberg (2016), using factor analysis on major element analytical data, show that real Rosebel rocks are consistently lower in Fe and Na than Armina sediments, and that many samples from the mine may have been misclassified by Daoust et al. (2011) as Rosebel.

Sedimentary structures in the Rosebel metasandstones suggest deposition in a fluvial environment. The higher maturity of the sediments suggests provenance from more weathered hinterland; the magnetite may be all that is left from deep chemical weathering of the Paramaka metavolcanics. This means that an interval of uplift, erosion and deep weathering must have occurred between the deposition of the Armina turbidites and the Rosebel fluvial sands. The equivalent in French Guiana, the Upper Detrital Unit, is supposed to have been deposited in pull apart basins formed in a late stage of transpressional deformation of the greenstone belt (Milési et al., 1995; Daoust et al., 2011), and possible derivation from the Kabel Tonalite.

### *Differences between Armina and Rosebel Formation according to Naipal & Kroonenberg*

The arenite samples from Koolhoven of Carlier (2012), and from Pay Cairo and Royal Hill of Daoust et al. (2011) seem to be the only 'real' Rosebel Formation arenites. Probably Royal Hill pit is still in the transition zone of Armina and Rosebel because some samples of the Royal Hill pitt are plotted as Armina. The other samples from Mayo and Roma of Daoust et al. (2011) are very rich in Fe and Na, which means these ' arenites' are probably greywackes of the Armina Formation. The very mature arenites are poor in $Fe_2O_3$, MgO and $TiO_2$, which represent the mafic minerals, and very high in $SiO_2$. It is suggested that the name Rosebel Formation should only be used for the very mature quartz-rich rocks. The 'real' quartzarenites and the other immature greywackes of the Daoust et al. (2011) might be better grouped as Armina Formation. The difference in interpretation might be due to the fact that the contact between these two Formations is not clear, and RGM is situated on the contact of the Armina and Rosebel Formations, not in the middle of the syncline basin where probably the very mature arenites predominate. The mature Rosebel arenites have probably been deposited in an epicontinental fluvial environment, from a source area that was much more weathered than any of the source areas of the turbidites.

### 2.2.2. Geology of the Rosebel area

The study area forms part of the Marowijne Greenstone Belt of Suriname, northeastern Suriname,

*Lithologies*

According to Voicu (2010) five distinct lithological associations have been identified in the Gross Rosebel area: (1) felsic to mafic volcanic rocks, (2) deep water-sediments, (3) shallow water sediments, (4) felsic intrusions and (5) late diabase dykes.

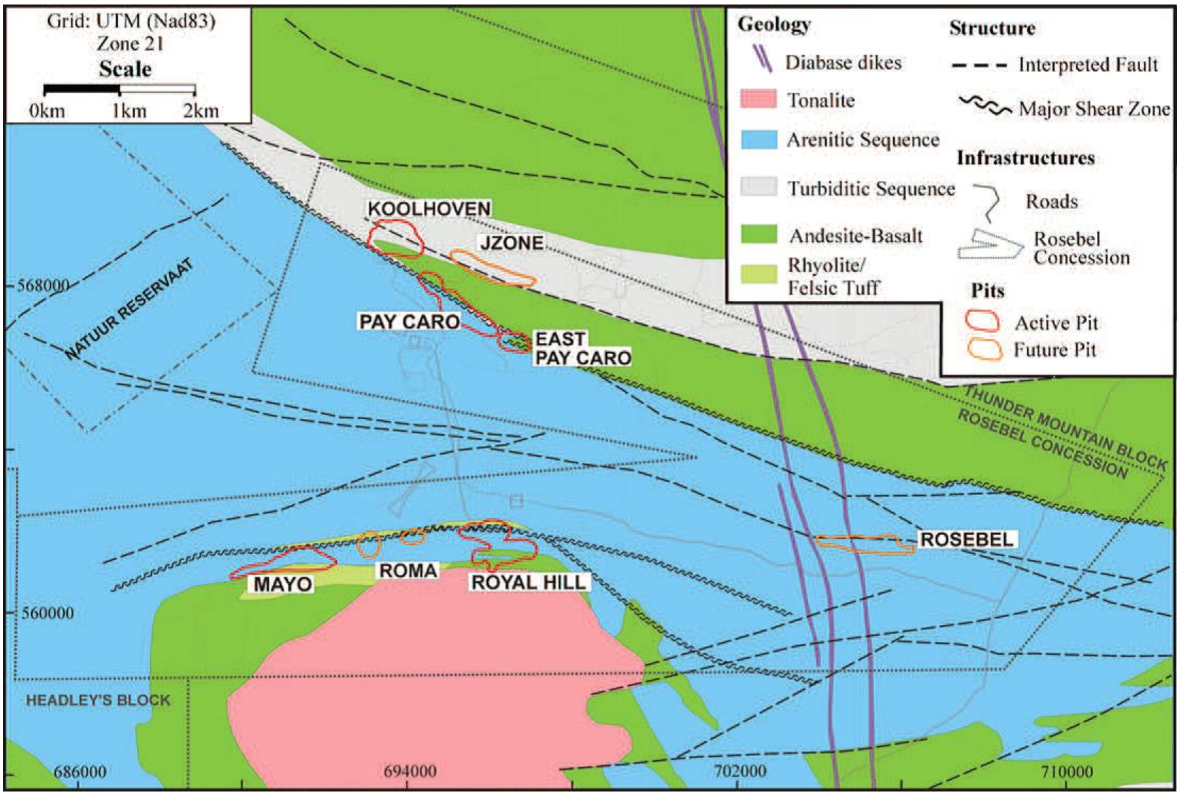


***Figure 3. Geological map of Rosebel Concession showing the active and future mining areas, and the exploration areas. Interpreted fault zones were deduced from aeromagnetic survey, while shear zones were identified in the field. Map of Daoust, 2016.***

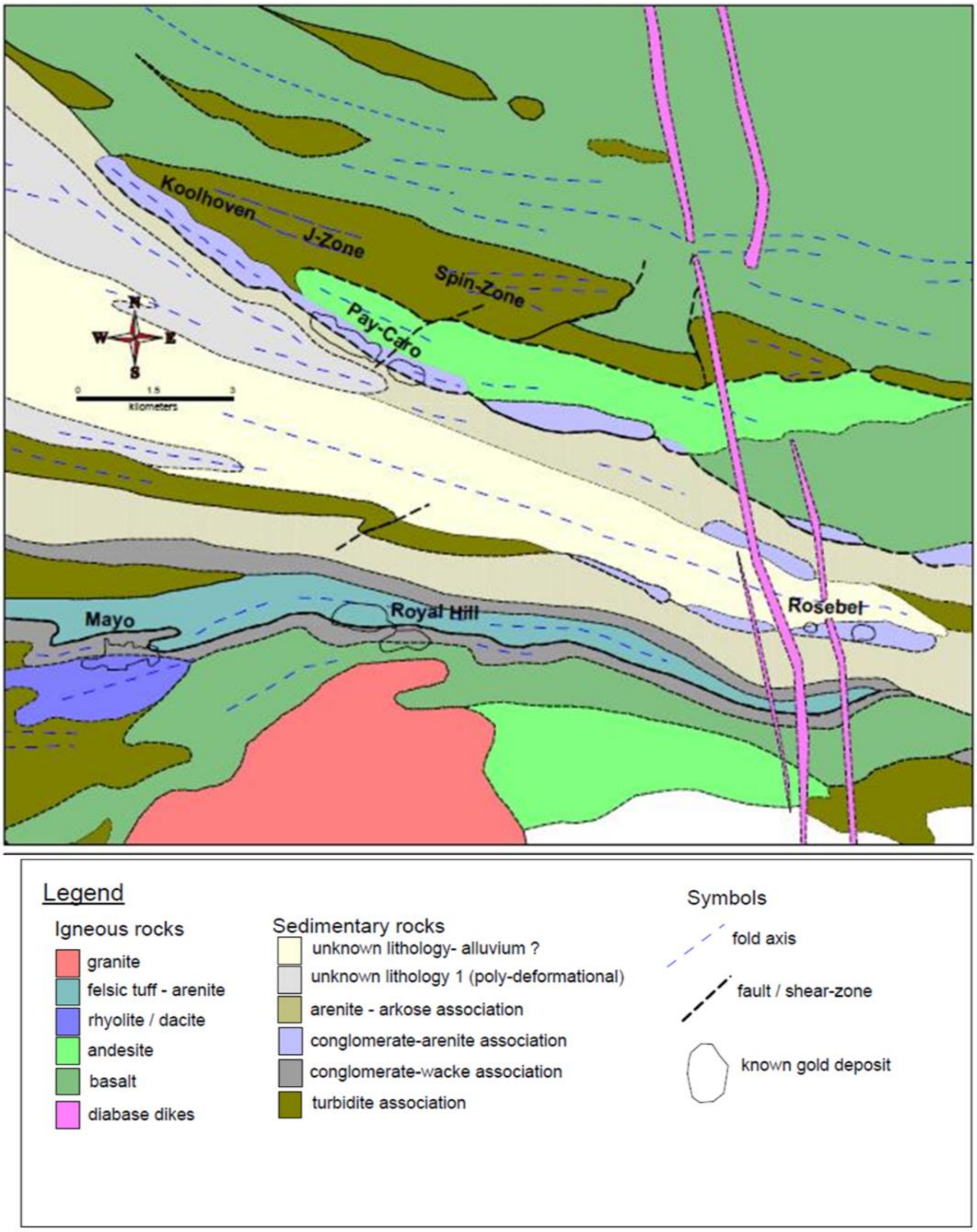


*Figure 4. General geologic map of the Rosebel Gold Mine. Map of Watson 2008*

The drill holes obtained from GMD are situated in the southern part of the IAMGOLD Rosebel Gold Mines Concession, on a hill referred here as Hill 24, on the basis of the number with which it is indicated on the detailed map by Van Kooten (Fig. 5, 1954). On Daoust’s map the area is underlain exclusively by Rosebel sediments, dissected by three NNW dolerite dykes, from east to west the Rosebel dyke, the Tubukumau dyke and the Mato dyke. All three dykes form prominent ridges in the gently rolling landscape. On Watsons map there is a succession of basalts, andesites, conglomerate-wacke association and felsic tuff-arenite. The rainforestcovered Hill 24 is situated just west of the westernmost Mato dyke, at an elevation of 60 m according to the 1956 field survey.

Gold mineralization has been recognized in sedimentary and volcanic rocks, whereas the intrusion only hosts rare gold occurrences and the dykes lack any gold mineralization. Regional metamorphism that has affected the whole rocks except the diabase dikes is restricted to greenschist facies, and is more easily distinguished in volcanic rocks than in the sedimentary rocks, because of the primary mineralogy of those.

The different lithologies of the Rosebel gold area were correlated to the geological Formations of the country as follow:

The dominant volcanic rocks of the property were considered as part of the Paramaka Formation, while small lenses of arenite, greywacke, siltstone and mudstone present in each deposit were associated to the sedimentary rocks of the same Armina Formation. In the northern part of the property, a thin layer of undifferentiated and unmineralized volcanic rock was associated to the volcanic rocks of the Paramaka Formation, and the presence of an intrusive was thought to be closely related to the mineralization. An arenitic gold-barren sequence of the Rosebel Formation was interpreted as covering the central part of the property and to be unconformably overlying the different gold deposits.

This had a significant impact for the exploration since more than half of the property was considered as gold-barren (Daoust et al, 2011).

### *Formation of host rocks*

The stratigraphic and geochemical characterization of the volcanic rocks has first invalidated the correlation of those units with the Armina Formation, which is rather defined in the literature by a flysch-like sequence. The established volcanic stratigraphy of the Rosebel area, which records a progression from tholeiitic basalt to andesite and finally to calc-alkaline volcanic rocks, correlates with stratigraphic succession described for the Paramaka Formation (Holtrop, 1965; Bosma and de Roever, 1975; Gibbs and Barron, 1993). Flysch sequences of the Armina Formation were subsequently deposited in marginal basins over the volcanic rocks. The succession of mudstone, siltstone and greywacke, classified as the turbiditic sedimentary sequence present in the North domain of the Rosebel district, correlates with the Armina Formation as described by Bosma et al. (1984) and Gibbs and Barron (1993) in Suriname. The arenitic sedimentary sequence exposed in the Rosebel deposits and characterized by abundant cross-bedding and conglomerate lenses is similar to the Rosebel Formation described by Bosma et al. (1984). This sequence is recognized in both unmineralized and mineralized area, indicating that mineralization postdates its deposition everywhere in the Rosebel gold district. The presence of mudstone, siltstone, chert and volcanic fragments in basal conglomerate units indicates erosion of the turbiditic sedimentary rock sequence during arenitic sedimentation and therefore, a younger depositional age. The contact between the two depositional sequences is not exposed, but is interpreted as major unconformity. This hypothesis is supported by the absence of two phases of deformation in the overlying arenitic rocks. In Surname, rocks of the Rosebel Formation unconformably overlie volcanic rocks of the Paramaka Formation (Gibss and Barron 1993). Geochemicaly, the REE signatures of both sedimentary rocks sequences in the Rosebel area indicate that they are derived from underlying calc-alkaline volcanic rocks that correlate with those of the Paramaka Formation. A similar call-alkaline source has been suggested for the Armina and Rosebel Formations in Suriname and French Guiana (Bosma et al., 1984; Vanderhaeghe et al., 1998). The known age of the stratigraphic equivalent of the Rosebel Formation in French Guiana (2.115 Ga; Milési et al., 1995) indicates a maximal age for the mineralization, but considering the sedimentation processes and the deformation that has affected those rocks during the Transamazonian orogeny, the mineralization in Rosebel gold district is thought to be much younger (Daoust et al, 2011).

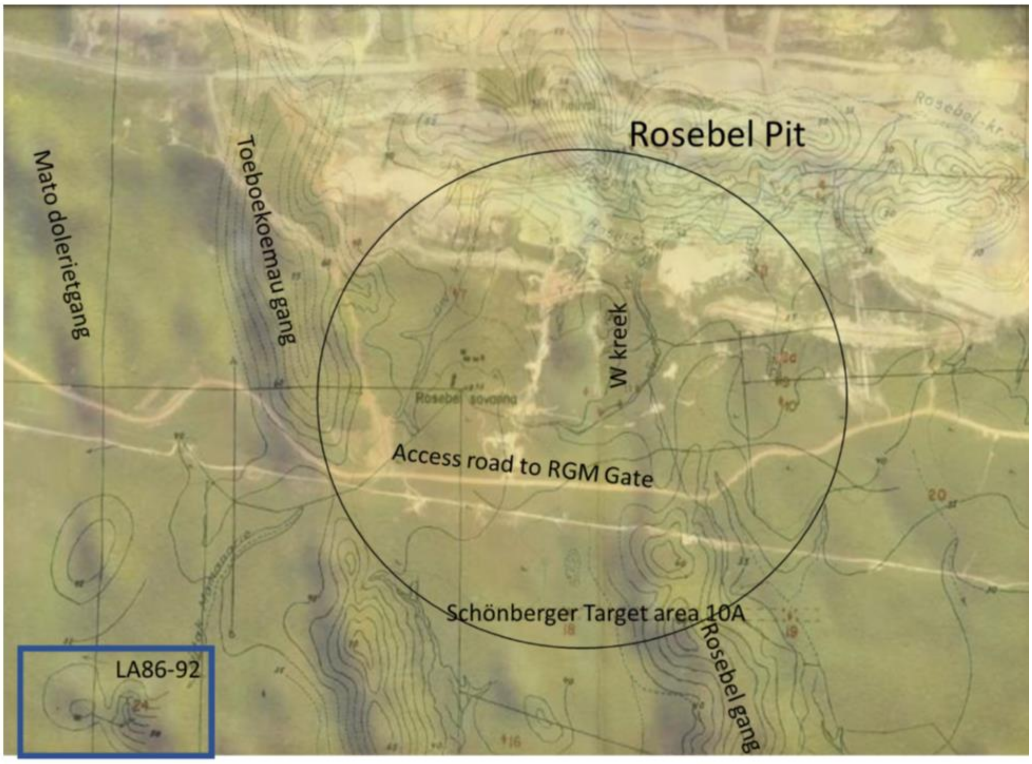


*Figure 5. Google Earth Image of the study area with topography from Van Kooten (1954).*

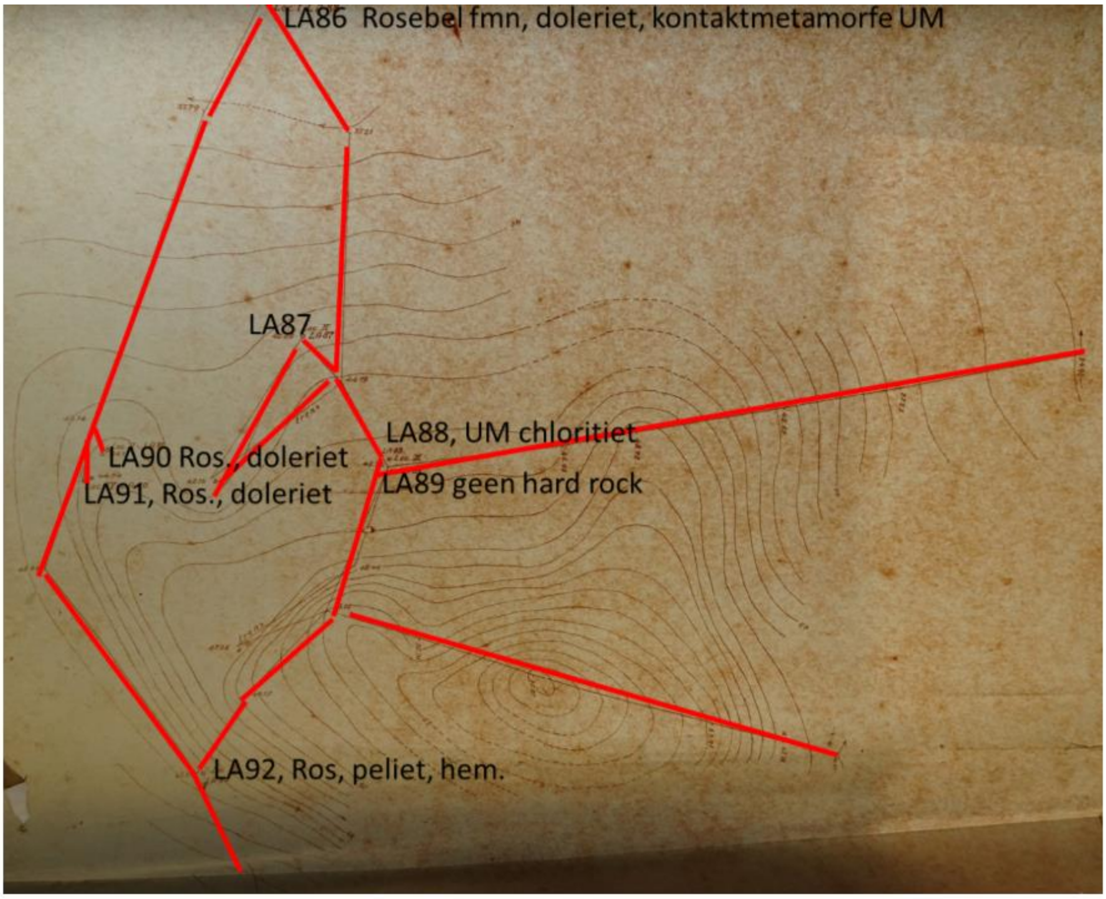


*Figure 6. Field sketch of Hill 24 (Beckering Vinckers, 1957) and location drill holes.*

In the second quarter of 1956 and around the second and third quarter of 1957, under the leadership of Ir. H. Beckering Vinckers, a number of diamond core drillings were carried out on the former placer Rosebel east of kilometer 106 on the railway track, numbered LA86-92 according to the GMD system. Here, Ir. C. van Kooten had found a breccious zone in the westernmost dolerite dyke, Mato dyke, a few years ago, in which very small amounts of copper minerals occur. Furthermore, the secondary rock, a subgraywacke, contains a striking content of magnetite near this disturbance zone. The terrain was recorded in the field magnetometrically; it was also included in the aerogeophysical test shot of 1956.

After using four shallow boreholes of 35 to 40m to have scanned the position of the dolerite dyke under the weathering layer, the next five holes were drilled as deep as possible, up to a maximum of approx. 80m. The dyke runs according to N162E with a slope of 49° to the west; the thickness varies from 2.5 to 15.5 m. Over a distance of approx. 250 m in the vicinity of the core drilling no mineralization of any significance are located. Although some weak mineralization could be seen in some preparations of the drill cores, both of the dolerite and of the secondary rock, not once was the material found on the surface in loose blocks (van Kooten, C. 1954).

# 3. Methods and Techniques

In the course of this study, literature research, macroscopic and microscopic work has been carried out on thin sections of cores LA91 and 92. The cores were logged in detail and some thin sections were made of parts of the core.

## 3.1 Petrographic study

The thin sections were studied at the Mineralogy and Petrology Laboratory of the Department of Geosciences at Anton de Kom University of Suriname. A Leica petrographic microscope was used for the study of the thin sections (Fig. 7). The optical properties of minerals were studied in both plane polarized light (PPL) and crossed polarized light (XPL).

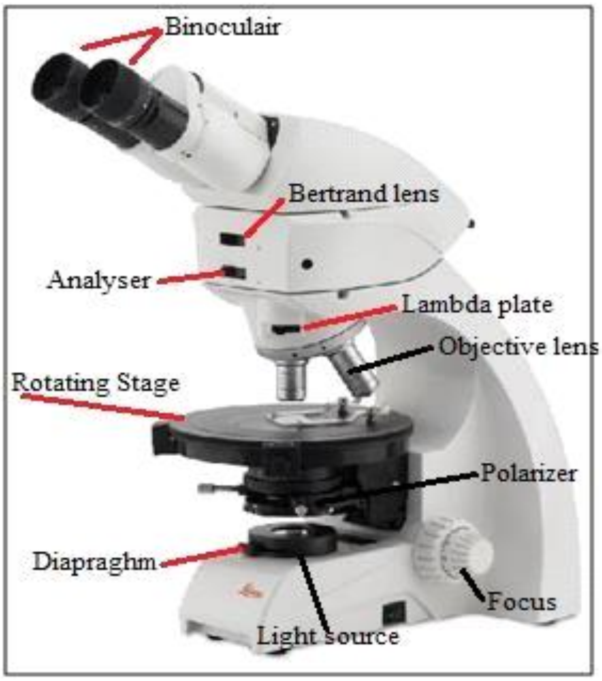


*Figure 7. A petrographic microscope used to analyse the thin sections.*

The characteristics of the rocks including the mineralogy and textural relationships were determined in thin sections using the petrographic microscope shown in figure 7.

## Chart for estimating amount of grains

To estimate the grains of the minerals the following chart was used:

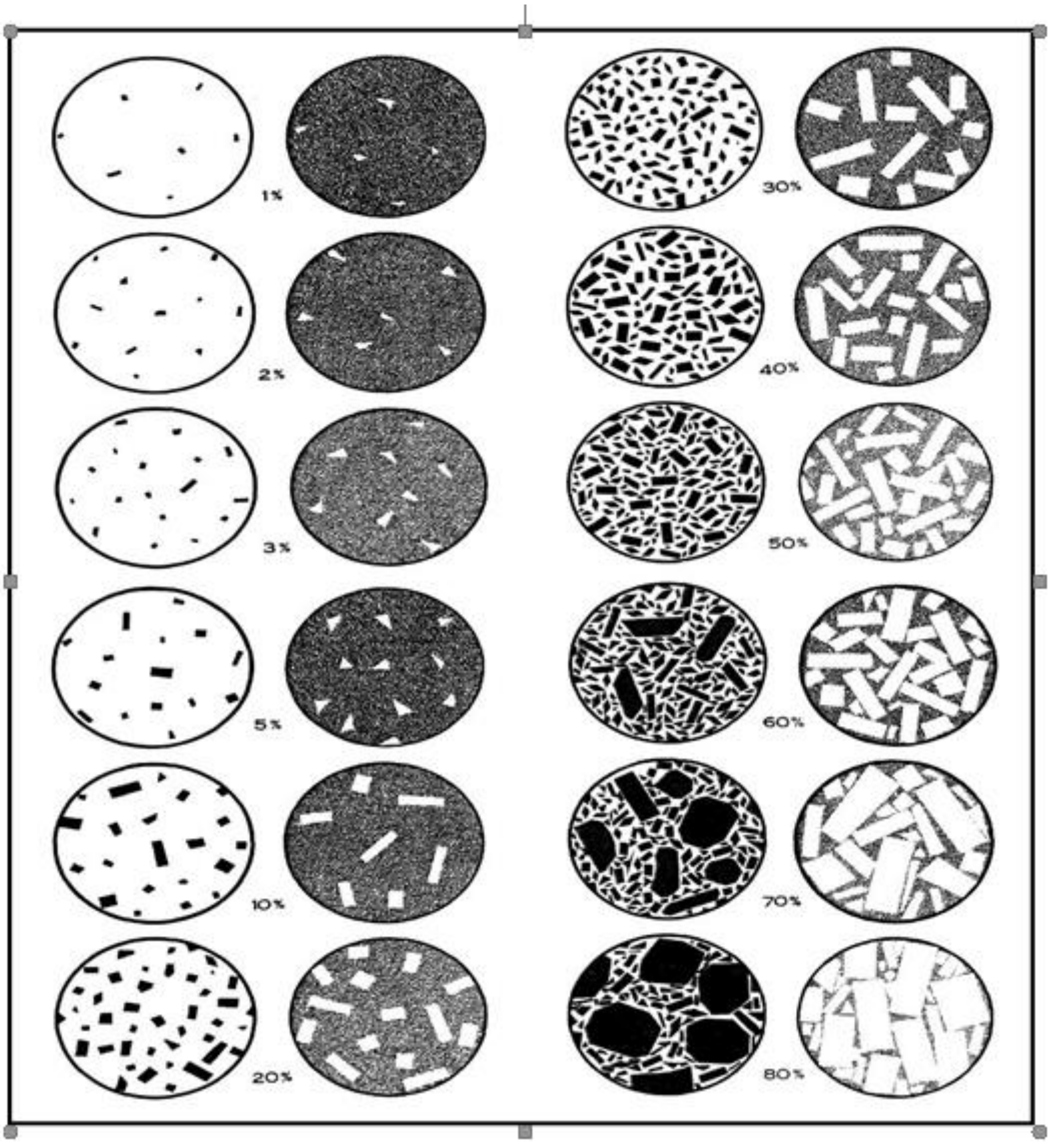


*Figure 8. Chart for determining the approximate modal percentages of minerals in rocks (Australian Institute for Geoscientists)*

# 4. Results

In this chapter the results of this study are presented as follow: petrographic analysis and macroscopic analysis (see table 1).

## 4.1. Petrographic analysis

In this paragraph the results of the petrographic analysis are presented and discussed.

### 4.1.1 Macroscopic studies

*Figure 9. Drill cores of metasedimentary rocks (LA91 no. 129-130-132, depth 27-30m)*

*Figure 10. Some typical drill cores of metasedimentary rocks (LA91 no. 129-130-132, depth 27-30m)*

*Table 1. Show the results from the macroscopic study of the cores*

| Core | Core No. | Depth (m) | Minerals | Structure | Observation |
|---|---|---|---|---|---|
| **LA91** | 129 | 27-30 | Opaque | Medium grained | Sedimentation/Folding |
| | | | Quartz | | Foliation/ Quartz > Opaque |
| | 130 | 27-30 | Opaque | Medium grained | Sedimentation |
| | | | Quartz | | Foliation/ Quartz > Opaque > Feldspar |
| | | | Feldspar | | |
| | 131 | ±38 | Opaque | Medium grained | Opaque minerals (40%) > Quartz (50%)> Plagioclase (10%) |
| | 132 | | Quartz | | Mafic minerals |
| | 133 | | Plagioclase | | |
| | 134 | | | | |
| | 132 | 48 > | Opaque | Fine grained | More mafic minerals |
| | 133 | | Quartz | | |
| | 134 | | Plagioclase | | |

## 4.1.2 Microscopic results

### Metasedimentary rocks

The following minerals in the samples LA91 & LA92 were identified:

- ***Quartz:*** *quartz is one of the most common rock-forming minerals. It is abundantly present in most of the samples. In figure 11- 12 & 13 all the quartz minerals are invariably clear and unaltered. In XPL, it is recognized by the white/grey interference color.*
- ***Plagioclase:*** *In figure 11-12 & 13 the plagioclase are not lath-shaped as in the dolerite samples. They are very dusty. In figure 13 the lath-shape with polysynthetic twinning of the plagioclase can be seen.*
- ***Opaque:*** *From figure 11 till figure 17 you can see the concentration of opaque minerals. These are concentrations of heavy minerals.*
- ***Matrix:*** *The matrix mainly consist of fine sericite and quartz.*
- ***Epidote:*** *this mineral is greenish in color (figure 15 A), has a medium-high relief with a negative character. In XPL, this mineral shows a yellow/brown color with bright interference color (figure 15 B). These can be anomalous (do not appear in the color chart). Its habit is subhedral and is not present in al samples.*
- ***Biotite:*** *is invariably brown in PPL (figure 16 & 17) or green in color in XPL with a strong pleochroism and a medium-high relief with a positive elongation. In both figures clean cleavage of biotite is displayed, the biotite is totally metamorphosed. Figure 17 displays the sedimentation clearly, fine- grained and course- grained. This indicates that it is a conglomerate.*
- ***Garnet:*** *forms irregular yellowish grains surrounding plagioclase. It is characterized by high relief and isotropic character.*

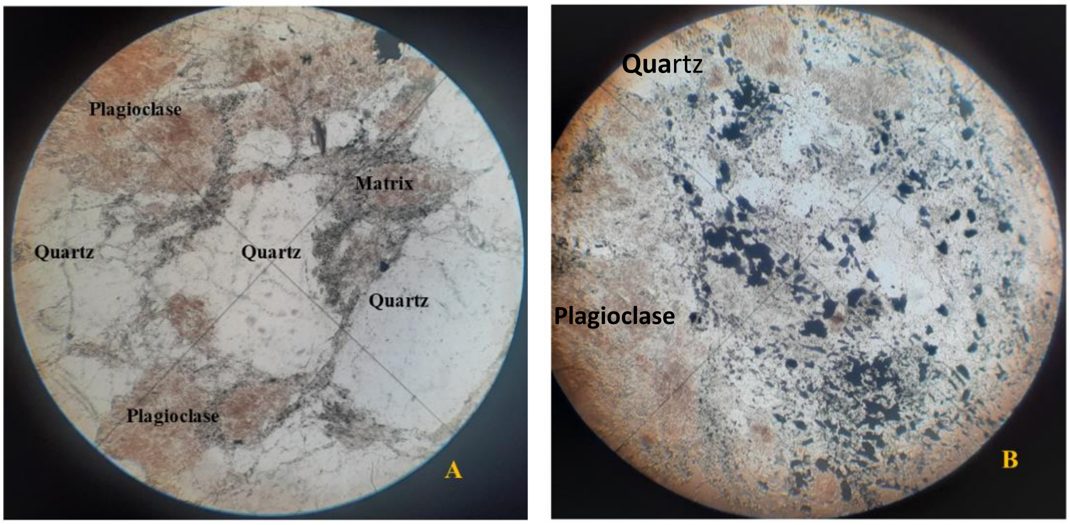


*Figure 11. (A) LA91 bottom 7525 49m the minerals: plagioclase, quartz and some opaque. (B) LA91 bottom 7518 34.50m displays the following minerals: plagioclase, quartz and a concentration of heavy minerals (black minerals).*

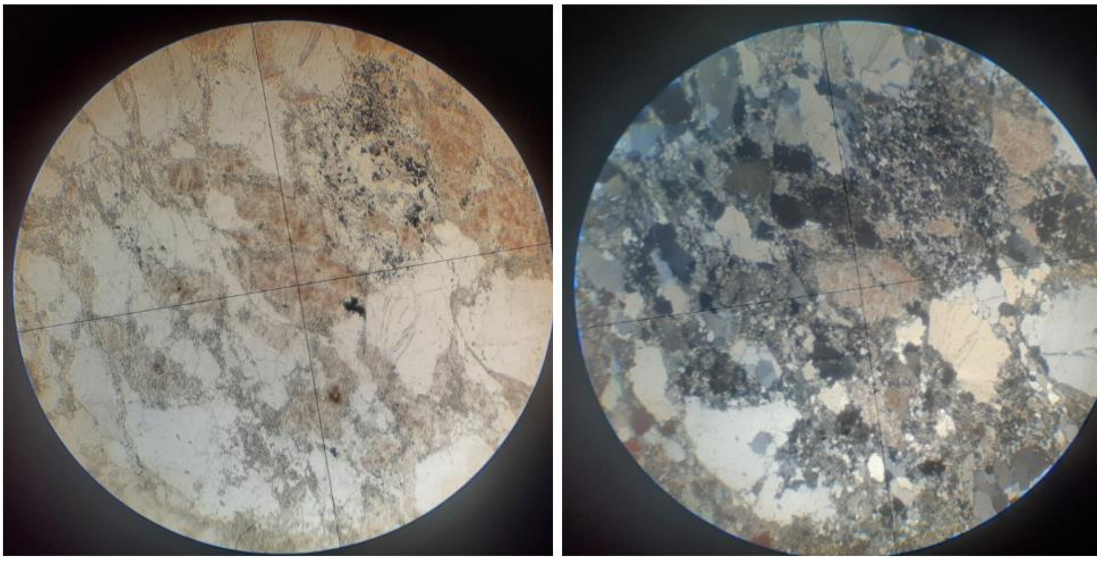


*Figure 12. LA91 DD7525 Bottom: 49m. Does not differ much from figure 11. Like in figure 11 the minerals: quartz, plagioclase and opaque can be seen.*

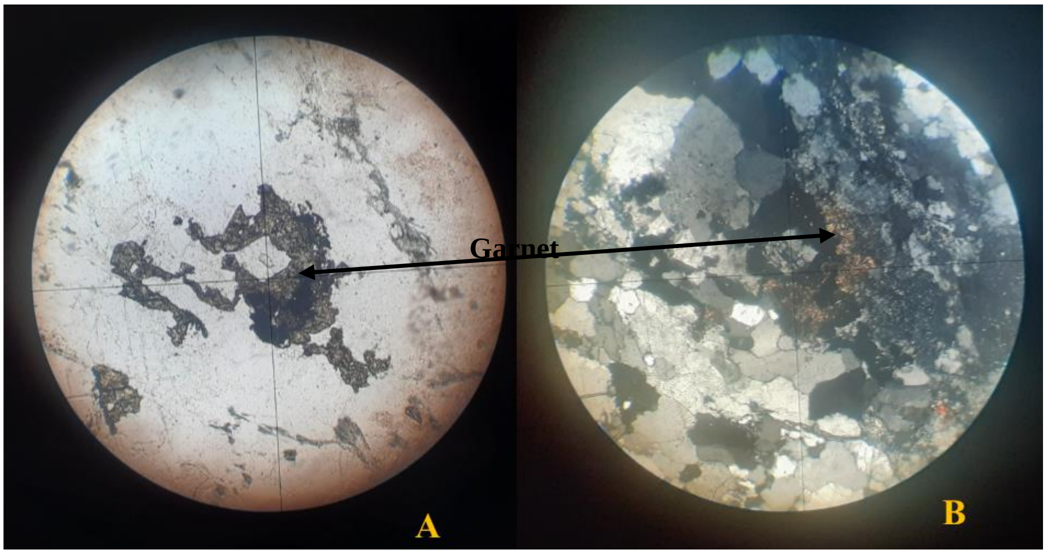


*Figure 13. LA91 49m Displays Late yellow garnet surrounding plagioclase, some titanite in PPL and XPL.*

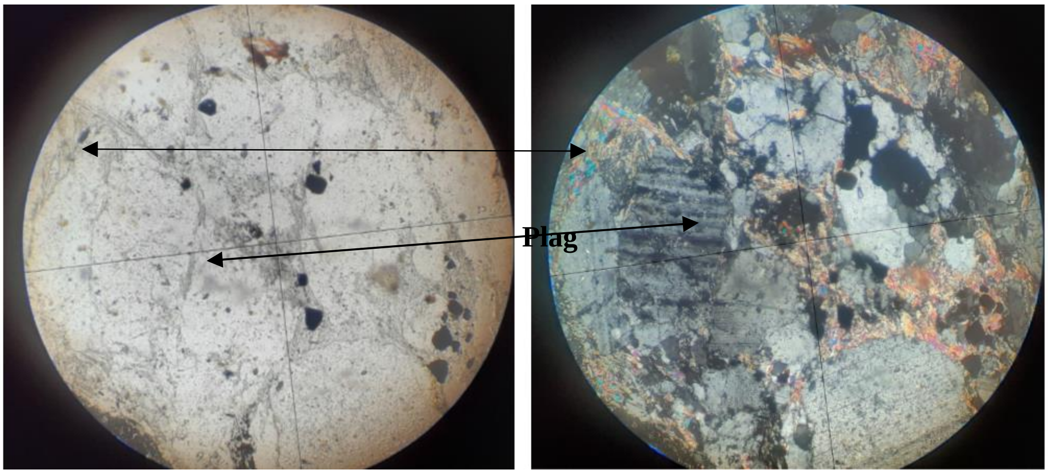


*Figure 14. LA91 DD7518 Bottom: 34.50m. Displays plagioclase, sericite (blueish color) and matrix (yellowish).*

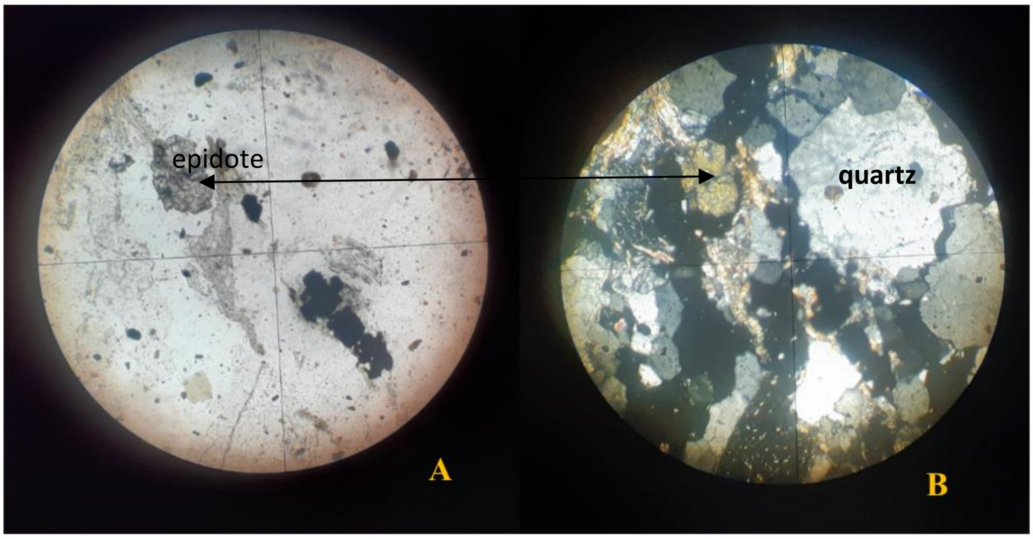


*Figure 15. LA92 8126 Bottom 60.10-62.68. (A) displays an epidote with medium-high relief, greenish color; a concentration of opaque minerals (heavy minerals); (B) displays the epidote with yellow/brown color with bright interference color; quartz with white or grey interference color, opaque and sericite.*

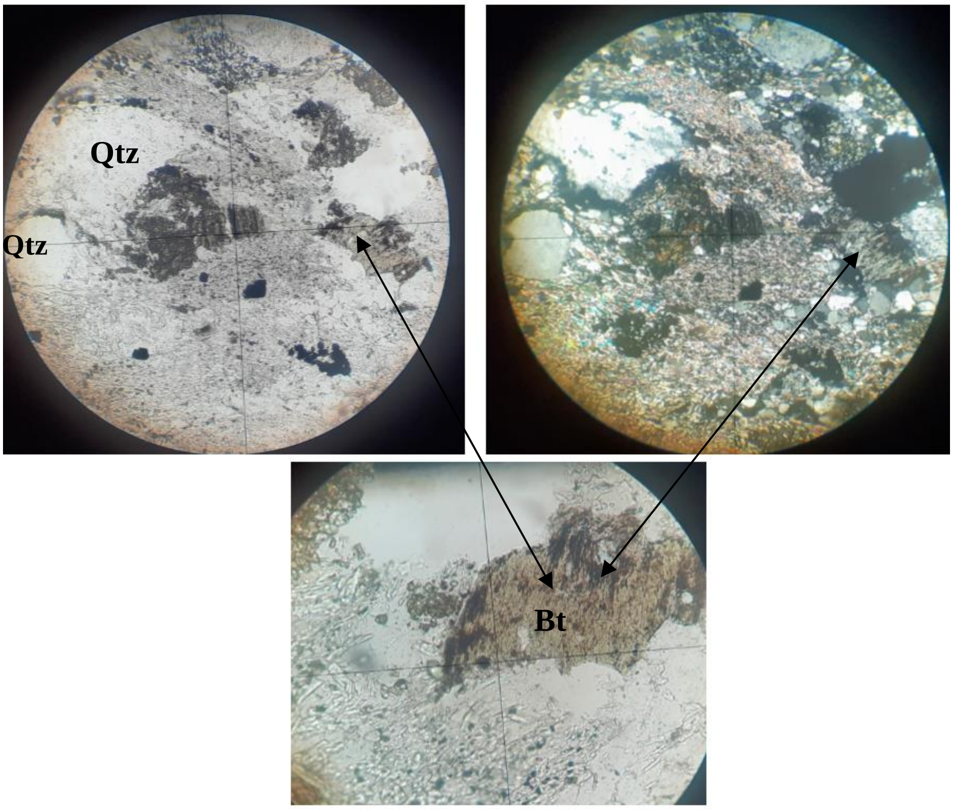


*Figure 16. LA92 DD8123 TOP: 56.36-57.16 Displays weathered micas in particular biotite.*

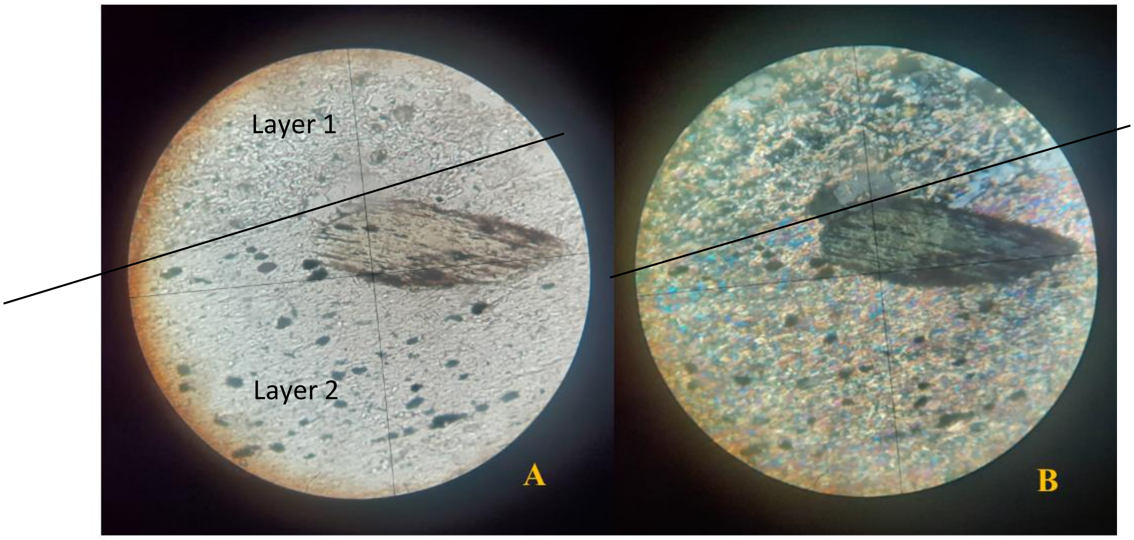


***Figure 17. A shows a brown mineral that can possibly be a biotite porphyroblast (chloritized) or chloritoid; B shows the dark greenish shade of the possibly chloritized biotite or chloritoid in XPL. In both figures, cleavage, opaque minerals and two layers of fine- and course- grained minerals can be seen.***

### Dolerites samples

The following minerals in the thin sections of LA91 (bottom) were identified:

- ***Plagioclase:*** *In all the figures (18 to 26) the plagioclase are lath-shaped, colorless (PPL) with polysynthetic twinning (XPL).*
- ***Clinopyroxene:*** *are the transparent to brownish minerals (PPL) with very clear cleavage*
- ***Opaque:*** *are the black minerals.*
- ***Chlorite:*** *all the light green minerals in all the samples (figure 18-26, PPL) are to be Chlorite. No pleochroism to be seen. Their interference colors are dark green/brownish (XPL).*

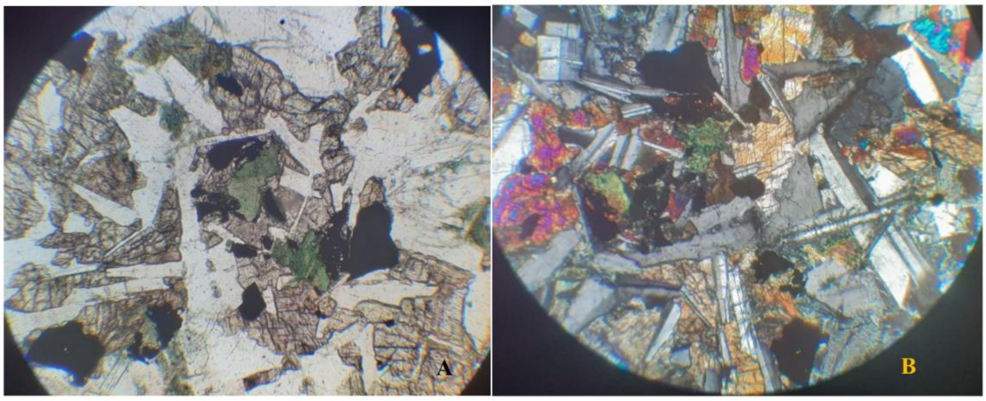


*Figure 18. LA91 7540 Bottom 58.37-60.37. (a) PPL: displays minerals that are lath-shaped plagioclase, green (chlorite), brownish (clinopyroxene) and black (opaque minerals). There is no pleochroism. (b) displays the minerals in XPL: Polysynthetic twinning can be seen in the plagioclase, the clinopyroxene shows very clear cleavage and the opaque minerals are more likely magnetite.*

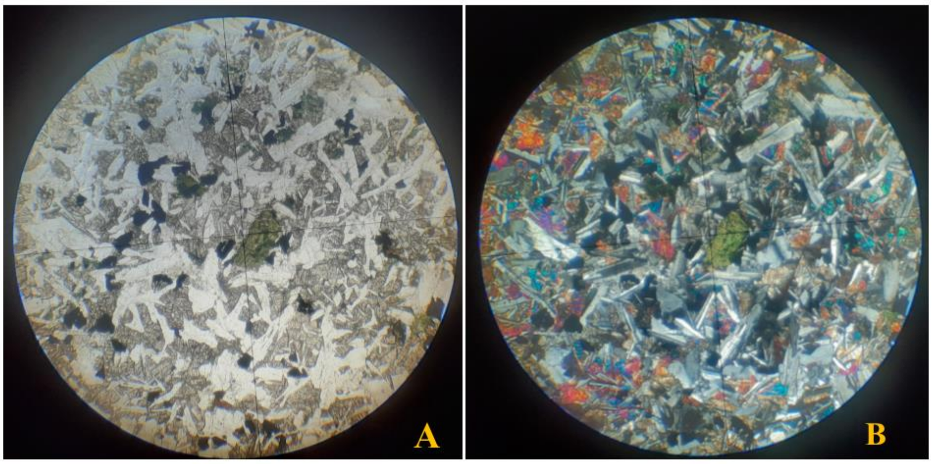


*Figure 19. LA91 DD7545 St10589. Bottom: 56.38-58.17. A&B are showing the same minerals as in figure 16. Figure C&D are the same samples but with larger magnification (6/0.18)*

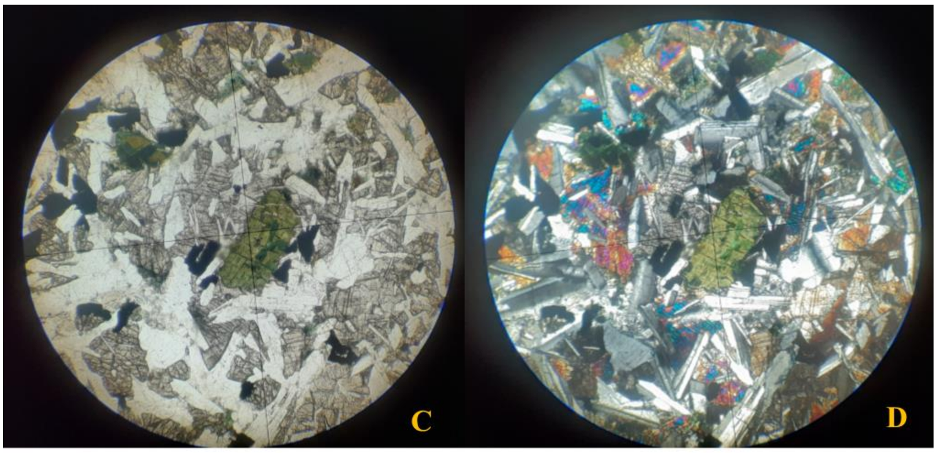


*Figure 20. LA91 DD7545 St10589. Bottom: 56.38-58.17. Figure C&D are the same sample but with larger magnification (6/0.18)*

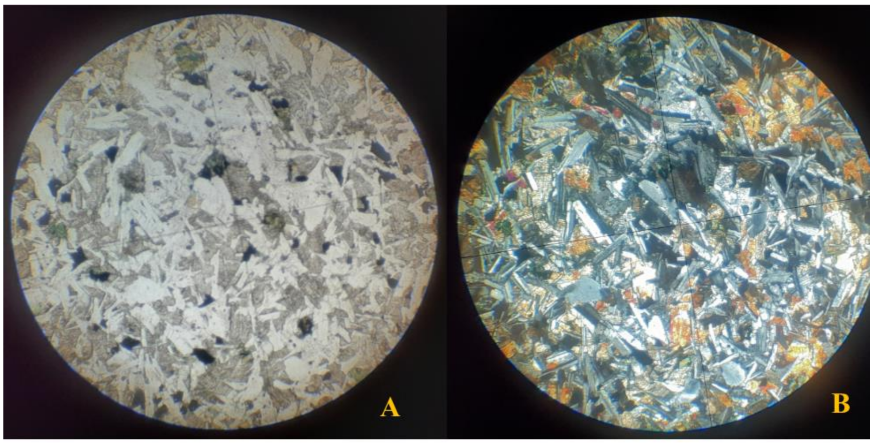


*Figure 21. LA91 DD7545 Bottom: 53.99-56.38 showing the same minerals like above*

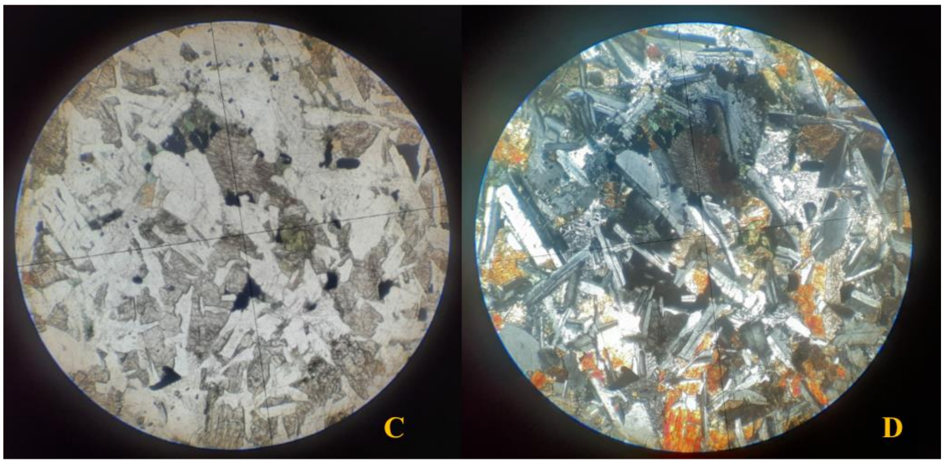


*Figure 22. LA91 DD7545 Bottom: 53.99-56.38 showing a larger magnification of A&B*

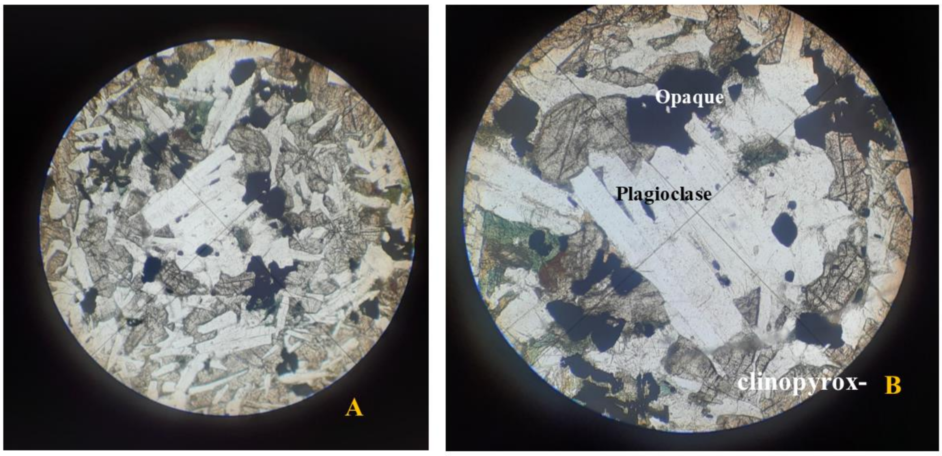


*Figure 23. LA91 DD7533 Bottom: 53.99-56.38 displays transparent lath-shape plagioclase, brownish clinopyroxene, black minerals (opaque) and some green-brown minerals (chlorite)*

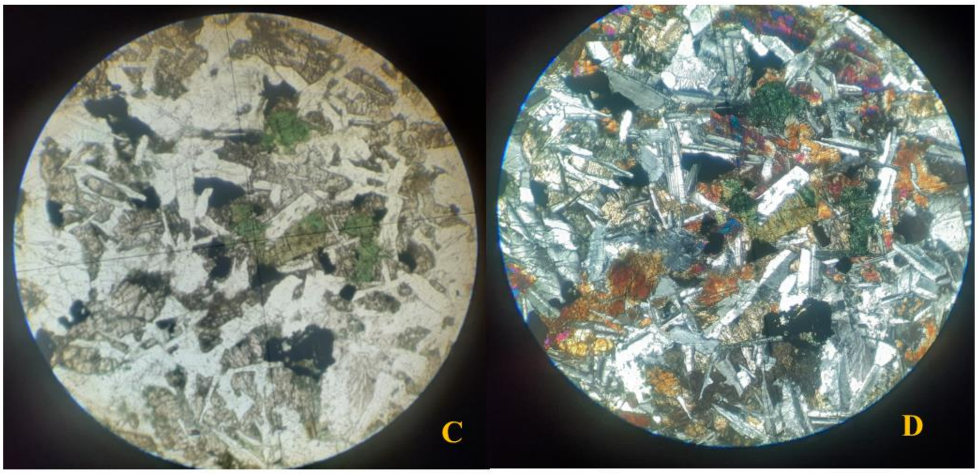


*Figure 24. LA91 DD7536 TOP: 58.17-58.73. In both thin section samples (top and bottom) the same minerals are found. Minerals like: plagioclase, clinopyroxene, chlorite and opaque*

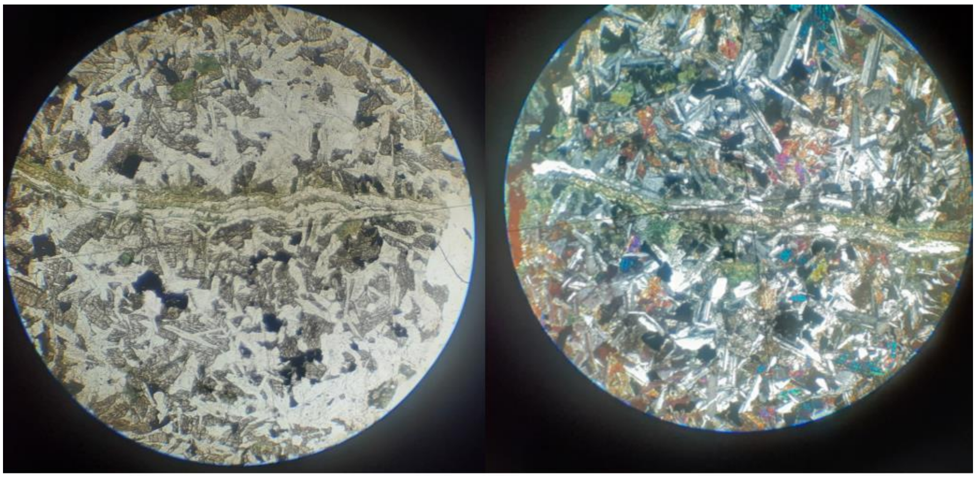


*Figure 25. LA91 DD7534 TOP 56.38-58.17 A chlorite vein, consisting of chlorite, carbonite and most likely albite can be seen*

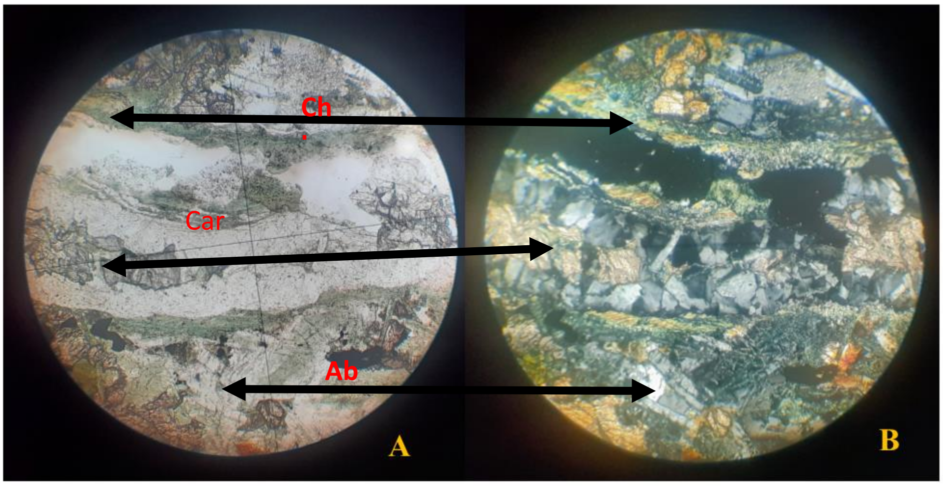


*Figure 26. shows a larger magnification of figure 25 with the following minerals, chlorite, carbonite and albite.*

## 4.2. Discussion

### (1) Metasediments:

The studied cores show typical Rosebel characteristicts.

The minerals found in the thin sections of this study are: quartz, plagioclase, opaque with some matrix, epidote, biotite and garnet.

As said earlier, the plagioclase in the studied thin sections are very dusty. It can be said that they are heavily sausseritized.

The appearance of opaque (magnetite) heavy mineral concentration in several thin sections is a typical Rosebel feature. ‘Lag deposits’, which because of their high density settle early during fluviatile transport and are thus concentrated at the bottom of the layers. This suggests that the studied rocks are essentially Rosebel deposits. There is no evidence for Armina metasediments. The opaque minerals do not transmit light through the thin sections and cannot be identified with translucent light. The opaque minerals could indicate oxides such as magnetite (present in the samples).

Another distinguishing feature is the appearance of weathered micas, epidote, and a small piece of schist, as seen in the Rosebel conglomerates.

Phyllite clasts with chloritised biotite porphyroblasts are probably eroded from the Armina Formation thus proving that the Armina had already been folded and uplifted before Rosebel was deposited.

The Rosebel Formation is also folded and has undergone additional metamorphism in which garnet has formed, possibly due to contact metamorphism by the dolerite.

Core samples collected by Daoust et al. (2011) and Carlier (2012) from Pay Caro, Mayo, Royal Hill and Rosebel pits in the RGM were classified by them as Rosebel Formation arenites. But according to the study of Naipal & Kroonenberg the arenite samples from Koolhoven of Carlier (2012), and from Pay Caro and Royal Hill of Daoust el al. (2011) seem to be the only ‘real’ Rosebel Formation arenites.

The contact between the two depositional sequences, (1) deposition of the flysch sequences of the Armina Formation and (2) deposition of the arenitic sedimentary sequences in the Rosebel deposits and characterized by abundant cross-bedding and conglomerate lenses is similar to the Rosebel Formation, is not exposed but is interpreted as major unconformity. This hypothesis is supported by the absence of two phases of deformation in the overlying arenitic rocks.

### Dolerites:

The studied cores show that:

There is not so much variety in the dolerite samples of LA91 (bottom and top). They all have very much the same minerals, fresh pyroxene and plagioclase. Most dolerites are fresh and have only green pseudomorphoses of chlorite which have probably been olivine.

Because the dolerite dikes are Jurassic in age, the fractures along which alteration into chlorite, albite and carbonate occurred imply that there were tectonic movements after the Jurassic. This is most likely why the westernmost Mato dike, where this image appears, is so poorly visible in the topography: the conversion zone weathers more easily.

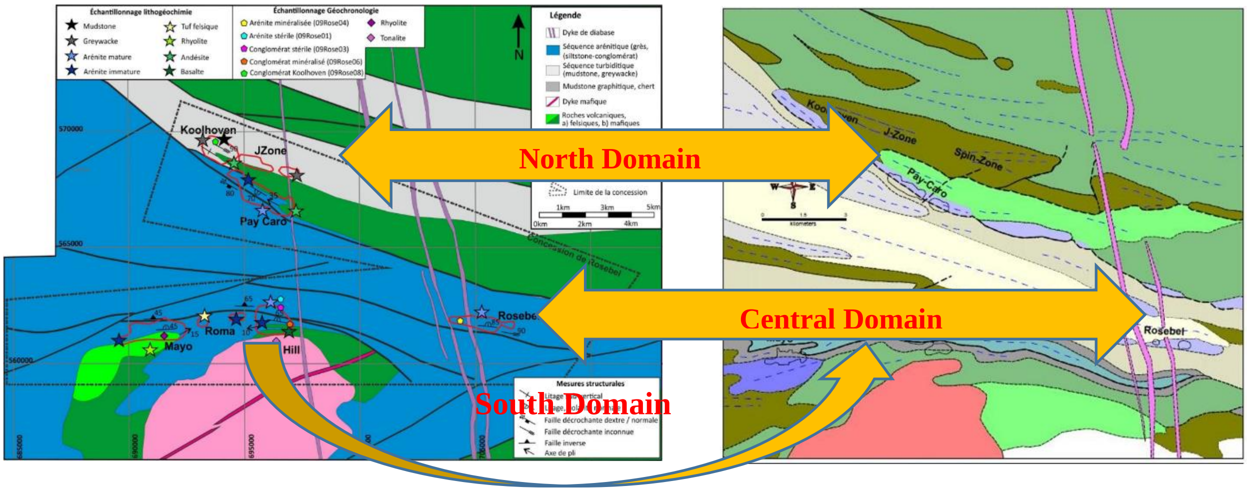
Chlorite is common secondary mineral in the dolerite samples.

# 5. Conclusions and recommendations

## 5.1 CONCLUSIONS

This research has shown that the studied metasediments all belong to the Rosebel Formation.

Daoust includes the entire southern area in the Rosebel Formation, but Watson shows Armina-type rocks in this area but does not give precise Formation names.
The argument between the two writers, Watson and Daoust, about the function of the Armina and Rosebel Formations in the concession's southern half can now be resolved, as no Armina sediments were found in the drill cores. From the two contrasting maps of Fig. 3 and Fig. 4 the one by Daoust et al (2011) appears to be the most correct one.



According to Watson:

- The location of the Rosebel Formation is the bedrock of the Savannah area and the Armina Formation is in the northern and southern flanks of the RGM concession.
- The Rosebel series comprises most of the sedimentary rocks of the known gold deposits of RGM, excluding the bedrock of the Savannah. These rocks are now known as the Armina Formation. Little is known about the bedrock geology of the Savannah area, and the area has not been extensively drilled by the RGM, except in the case of the Rosebel gold deposit.
- Economic gold deposits are not suspected by RGM geologists to occur in this area.
- The basal conglomerate and immature wackes of the Royal Hill deposit are considered by mining geologists to be part of the Armina Formation, but due to the magnetite-hematite concentration in the cross- bedding found in the study drill core those wackes are the Rosebel Formation.

## 5.2 RECOMMENDATIONS

In order to get more detailed information about the Formations especially the Rosebel Formation, the following may be recommended:

- More drilled holes (new ones) should be logged.
- Different field works should be carried out in the study area to gather more and new field data and to understand the depositional environment and sedimentary and tectonic structures.
- To carry out more petrological and geochemical analysis to get detailed information of the rock types.
- It may not be of economic value, but it can be used for students and other researchers to understand the geology of this area.

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