ANTON DE KOM UNIVERSITY OF SURINAME

FACULTY OF TECHNOLOGICAL SCIENCES

MINERAL RESOURCE MANAGEMENT

A PETROGRAPHIC STUDY OF THE OLD PEGMATITE MINE, JORKA CREEK, MAROWIJNE

A Thesis submitted in partial
fulfillment for the degree of
Bachelor of Science (Bsc.)
in
Mineral Resource Management

[date]

Paramaribo, Suriname

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A Petrographic study of the Old Pegmatite Mine, Jorka Creek, Marowijne

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SUMMARY

PREFACE

In order to acquire a Bachelor's degree in Mineral Resource Management, a research project must be carried out and based on that a thesis must be written. The main goal of this research is to find out if there are any rare minerals in the fresh rock of the old pegmatite mine. This can be explained by the samples of fresh rock that were taken and studied microscopically. Mineral identification can help clarify the geology of the study area.

It would have been impossible to execute this project without the guidance of Prof. dr. S. B. Kroonenberg and Faculty Supervisor D. Monsels. I also would like to thank Mr. Paansa, Mr. Pinas, K. Poleon, C. W, G. Wijngaarde and K. Goenopawiro, Msc for their field guidance and support. Furthermore, I would like to express my gratitude to my fellow students: G. Arga, N. Sardjoe, R. Ghogli and N. Kioe-A-Sen, Msc for their support, advice and motivation. Finally, I would like to thank my parents, my boyfriend and close friends for their immense support, patience and motivation during this journey.

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LIST OF ABBREVIATIONS

Amb	Amblygonite
LCT	Lithium-Cesium-Tantalum
Li	Lithium
NYF	Niobium- Yttrium-Fluorine

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1 INTRODUCTION

1.1 Location Study Area

The old pegmatite mine in the Jorka Creek area was first discovered during a fieldtrip by the Suriname Government Geological and Mining Service. The mine is situated in the Eastern of Suriname in the district Marowijne. About 35 km upstream from Albina, the capital of the Marowijne district, the outcrop was located at a short distance from the Marowijne river (see **Figure *1***). A conspicuous amount of angular quartz and sub-rounded masses of amblygonite was observed on top of a small hill with an elevation of ±50m. After panning the soils from different part of the hill, minor percentages of cassiterite and tantalite was shown (Montagne, 1964).

Curious if the outcrop was economically feasible, N.V. Billiton Maatschappij Suriname started an exploration program in the area in 1961 with a purpose for a detailed investigation of the pegmatite body and a prospection for similar pegmatite bodies in the surrounding area. Prospection ended in 1962 and delivered a negative. In contrast to that, numerous small pegmatite bodies were found but none however had a trace of Li-minerals and contained only very low percentages of cassiterite and tantalite. The deposit was too small for economic extraction (Montagne, 1964).

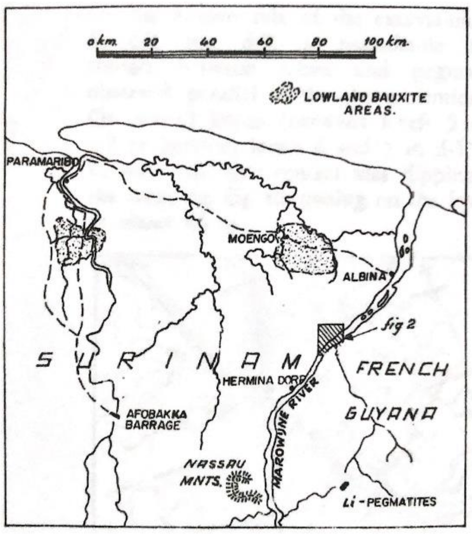

Figure 1. Old map of the localization of the pegmatite mine in the Marowijne area, Eastern of Suriname. (Montagne, 1964)

1.2 Problem Statement

The pegmatite mine of the Jorka Creek area has been abandoned for over 60 years. To know more about the mine concerning its geology and other aspects in the present, new studies are of importance. Therefore, a heavy mineral research concerning the Rare Earth Elements of the minerals Cassiterite and Tantalite was conducted and also a petrographic study of the fresh rock whose origin is from the area.

The petrographic study of the fresh rock in the old pegmatite mine is to identify the appearances of the important minerals such as Amblygonite, Cassiterite and Tantalite. The main research question is as follows:

"**To which class does this pegmatite body specify according to the Classification of Granitic Pegmatites?"**

Other research questions are:

1. What are the physical characteristics of this pegmatite body?
2. Is there zoning present of the pegmatite body?
3. Are the mentioned minerals economically viable?

1.3 Thesis Outline

The content of this thesis consists of five (5) chapters. The first chapter gives an introduction of the research and the research questions related to this project. In chapter 2, theoretical background information of the geology of the study area is described. The third chapter covers the methodology that was used during the research. As last, the results and discussions are presented in chapter 4, which is then followed by conclusions and recommendations in chapter 5.

2. THEORETICAL REVIEW

2.1 Metamorphic rocks

The Earth consists of many type of rocks that in turn contain different minerals. The rocks can further be classified into three main groups: Igneous rocks, Sedimentary rocks and Metamorphic rocks. This classification is initially based on the formation of the rock itself and not on the basis of its mineralogical or chemical composition. (Wong et al., 2017)

A Metamorphic rock can be of Igneous or Sedimentary origin, called a protolith, and are formed when these existing rocks undergo metamorphism by higher temperatures and pressure and being pressed together. The rocks are brought further into the Earth's crust by processes of subduction (Wong et al., 2017). Due to different pressures and temperatures at which Metamorphic rocks are formed, there are distinct degrees of metamorphism and metamorphic facies namely low, medium and high grade which are respectively associated with the greenschist facies, amphibolite facies and granulite facies.

2.1.1 Schist

Schist is a medium – grade Metamorphic rock, amphibolite facies. The mineral assemblage and texture change by compression of the rock under high temperatures and pressure. Due to the change of clay minerals, the rock acquires a characteristic fissility called schistosity. This schistosity is easily recognized by micas that appear in the schistosity plane. The protolith of a schist is of Sedimentary origin which is called *shale*, at a low-grade metamorphism the schistosity plane is mat and is called a *slate*. After this, slate turns into *phyllite* and here can be perceived that the mica's have grown and the schistosity plane exhibits a satin like luster. When mica booklets are visible to the naked eye, the rock has undergone a medium-grade metamorphism and is now a *schist*. (Wong et al., 2017)

2.2 Pegmatites

According to London's article "Ore-forming processes within granitic pegmatites", "Pegmatites are texturally complex igneous rocks marked by some combination of coarse but variable crystal size, mineralogical zonation, prominent anisotropy of crystal orientations from the margins inward, and skeletal, radial, and graphic intergrowth habits of crystals." (London, 2018)

Pegmatites are known for the comprisement of their large crystal size (see **Figure *2***) and the enrichment of rare earth elements which may or may not be economically viable. Because pegmatites have a composition which is almost the same as granites, with minerals such as quartz, feldspar and mica, they are usually called "granitic-pegmatites". Other plutonic rocks such as gabbro and syenite can also be combined with the name "pegmatite". Pegmatites are differentiated from other igneous rocks by the coarseness and different size of its crystals, abundance of crystals with skeletal, graphic or other growth habits or mineral assemblages with significant spatial zoning which includes mono minerallic zones. (London, 2018)

Discovery of Pegmatites are found through the roof contact of their source pluton, which emanates as dike swarms from the plutons through the igneous and metamorphic rocks that surround them, and as planar to lenticular intrusive bodies that are not exposed to their origins. (London, 2020)

Figure 2. Tourmaline pegmatite from Haapaluoma, Finland; black tourmaline (schorl), white plagioclase and gray quartz (www.sandatlas.org)

2.2.1 Granite – pegmatite affiliation

What can be understood is that pegmatites are igneous plutonic rocks with a granitic composition because of the similar composition to granites. Although granites are formed by slowly cooling of magma, pegmatites are formed during the final stage of a magma's crystallization. Therefore, the crystals in pegmatites are extremely large, while that of granites are medium. In igneous rocks, large crystals are commonly linked to a slow crystallization of magma, but the reason why crystals in pegmatites grow so large in size is because they are related to low viscosity fluids that allow ions to be flexible. In the initial stages of a magma's crystallization, the melt is comprised of a mixture of a large amount of dissolved water and other volatiles such as chlorine, fluorine and carbon dioxide. Water is not removed when in the early stages of crystallization, so as the crystallization process continues its concentration increases. When there is plenty of water present, it begins to separate from the melt creating pockets of heated-rich-dissolved water. The ions present in the water are much more flexible than those in the melt, which allows them to move easily and quickly form crystals. (King, n.d.-a)

Pegmatites lacking any evident parental granite are widely recognized, since the pegmatite-forming dikes can travel kilometers from their source (see **Figure *5***). Where the pegmatites source granites are known, they are usually small plutons that developed chemically and texturally and are linked to declining stages of a more voluminous granite magmatism. Li-rich pegmatites were thought to be produced by partial melting of metamorphic rocks at extremely low degrees on the basis of that it should be a reversible process, because of fractional crystallization of granitic to rare-element-rich compositions that occur at low temperatures. (London, 2018)

Zonation of pegmatites

Granitic pegmatites can exhibit internal zonation which are segregations based on texture, mineralogy or the size of crystals. It can be divided into unzoned and zoned pegmatites:

- *Unzoned pegmatites*

  According to its name, these kind of pegmatites don't exhibit segregations. They have no internal heterogeneous assemblages and are only identified by their coarse grain size, in comparison to other plutonic rocks. Minerals such as anhedral plagioclase and quartz have a uniform size, whereas alkali feldspar is likely to be porphyritic. Within the cupolas and close to the edges of their small leucocratic source granites, these pegmatites can be found. These kind of pegmatites are the main ore sources of feldspar, quartz and mica. (London, 2018)

  Unzoned spodumene pegmatites

  Spodumene is a pyroxene and lithium source mineral which is commonly found in pegmatites with a high lithium content. The spodumene-bearing pegmatites are generally homogeneous rocks with slightly porphyritic spodumene crystals of about 10 cm.(King, n.d.-b) (London, 2018)

- *Zoned pegmatites*

  In comparison to unzoned pegmatites, zoned pegmatites have an internal assemblage which are more complex and diverse. There are three distinct features that are important: habits of the individual crystals, orientation of long axes of crystals and the spatial segregations of minerals by zonal assemblages as can be seen in ***Figure 4***. (London, 2018)

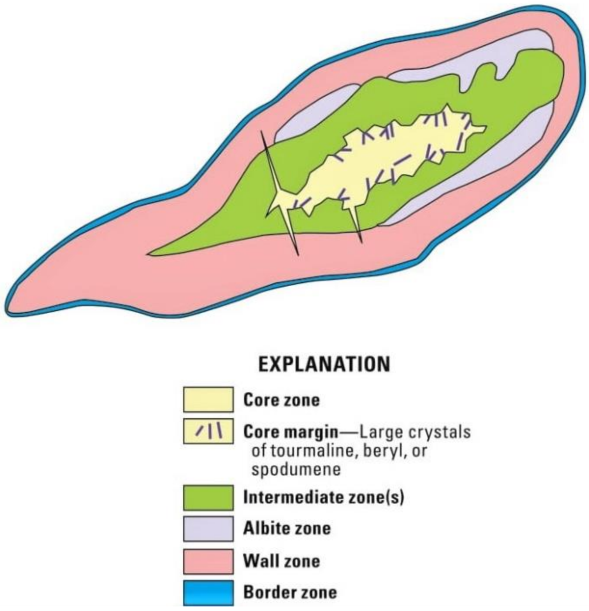

Figure 3. Idealized pegmatite with specific zonation patterns (D. C. Bradley et al., 2017)

Components of a zoned pegmatite (London, 2018):

- *Border zone:* this is a thin layer, usually 1-3 cm, comprised of fine-grained granitic rock upon contact with the host rock. The mineralogy mainly consists of quartz-plagioclase-muscovite but also contains minerals such as garnet, apatite, tourmaline, beryl, biotite and columbite.
- *Wall zone:* A sudden increase in crystal size and unidirectional solidification texture, crystals that are elongate perpendicular to the contact of the body, is visible as you move inwards from the boundary. Minerals associated with this texture include alkali feldspar, tourmaline, mica's and beryl.
- *Intermediate zone:* Compared to the outer zones, the intermediate zones are coarser grained, richer in alkali feldspar and quartz grows in abundance.
- *Core:* The core consists of pure quartz. As the last position in the zoning sequence it is determined that quartz cores of pegmatites are the last to form, but in Li-rich pegmatites this is not the case. Rare minerals such as beryl, tantalite, amblygonite can form with quartz bodies in the core.

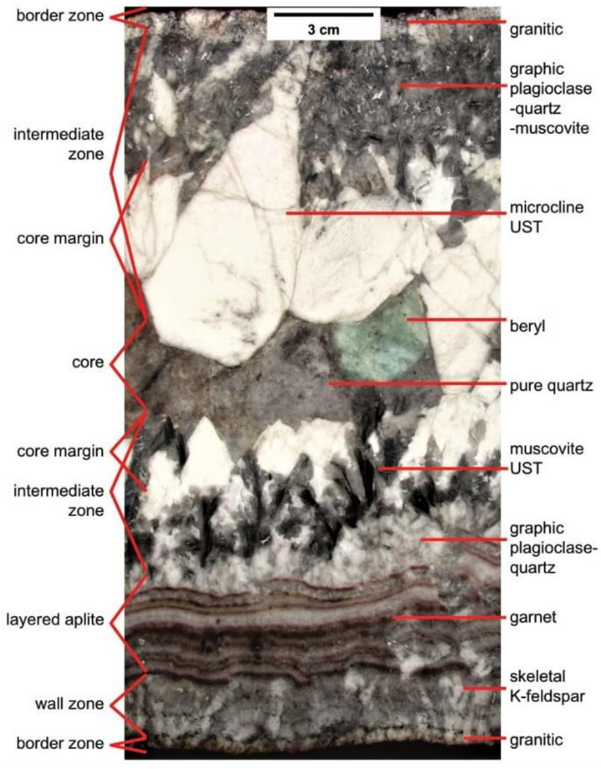

Figure 4. Part of a pegmatite dike, showing the different zones and mineral habits and textures; San Diego County, California (United States). (London, 2020)

Granitic-pegmatite families

It was suggested by Černý, 1991 that the characteristics for trace-elements of pegmatites be classified in two unique groups called pegmatite families. Knowing that a family's characteristic only occurs in the group's fractional member in the form of rare minerals such as spodumene, tantalite, pyrochlore, pollucite, etc., the suggested families were the **NYF** (Niobium-Yttrium-Fluorine) family and the **LCT** (Lithium-Cesium-Tantalum) family. (London, 2018)

1. **NYF family**

   This family is characterized by Nb-dominant oxides, enrichment in silicates and oxides in HREE (Heavy Rare Earth Element) and Y (Yttrium), and a high F (Fluor) content that frequently occurs with Y-rich fluorite. The pegmatites of this family are mainly linked to the A-granites (A= anorogenic), which is part of the two-way magmatism of gabbro-granite found in rift zones. (Černý & Ercit, 2005; London, 2018)

2. **LCT family**

   Usually, this pegmatite family is enriched in incompatible elements such as Li, Rb, Cs, Be, Sn, Ta, Nb (with Ta>Nb), and this distinctive set of elements distinguishes them from other rare-element pegmatites. The melts from which they crystallize are complemented by components which include water, fluorine, phosphorus, and boron; the solidus temperature, viscosity and density is reduced while the bulk diffusivity of the melt is increased. Even though they have a felsic composition and a remarkable sub-liquidus undercooling, the pegmatites form thin dikes and large crystals. These pegmatites are the most fractionated and ultimate components to crystallize of certain granitic melts. Parental granites include S-type granites which are peraluminous, but some Archean cases are I-type granites, which are metaluminous.(D. Bradley & McCauley, 2013; London, 2018)

3. **Mixed NYF + LCT family**

   They consist of granites and pegmatites that exhibit an assortment of geochemical and mineralogical attributes. (Černý & Ercit, 2005)

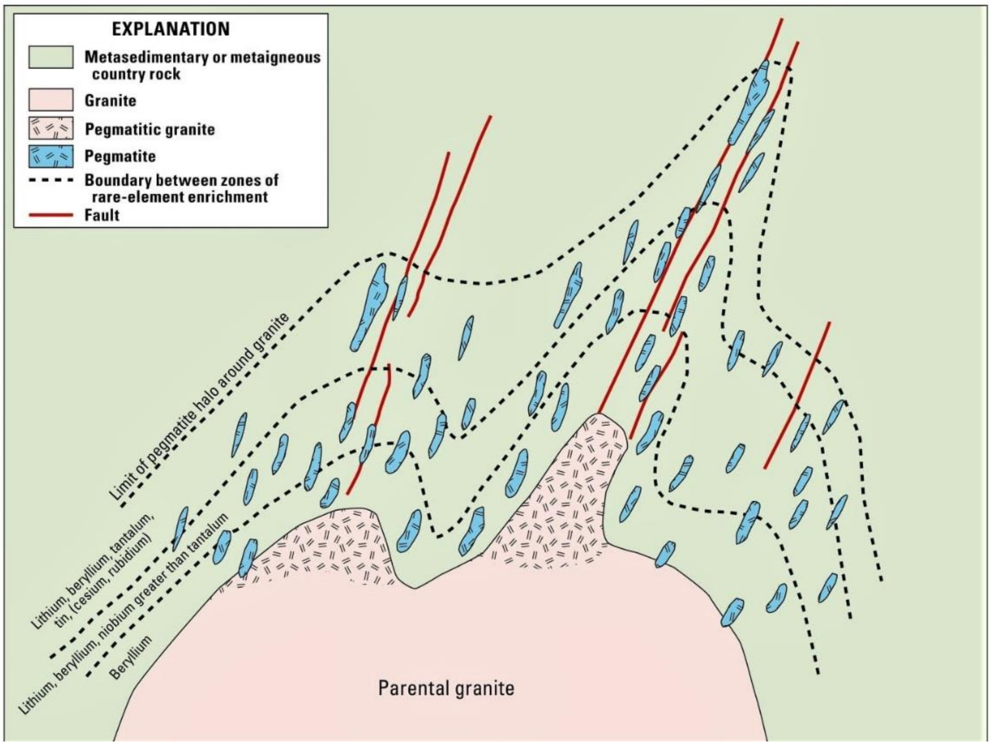

Figure 5. A concentrated and regional zoning displayed in a field of pegmatites with indications of rare-element enrichments in between zones. The parental granite shows that enriched pegmatites occur distally. (D. C. Bradley et al., 2017)

2.2.2 Černý's classification system of granitic pegmatites

Attempts to classify granitic pegmatites on the basis of mineralogy, geochemistry, texture and economic were made during the early stages and included a diversity of criteria such as internal structure, paragenetic relationship, bulk chemical composition, petrogenetic aspects, nature of parent medium, and geochemical signatures, among others. (Černý & Ercit, 2005)

The classification of granitic pegmatites was initially heralded by Ginsburg et al, who divided these pegmatites into four main classes (Abyssal, Muscovite, Rare-element and Miarolitic) based on their crustal environment, specifically the depth of their intrusion, and on their connection to metamorphism and granitic plutons. (Černý & Ercit, 2005)

After a while this classification was altered by Černý and included a better petrological, paragenetic and geochemical criteria. An evaluation of REE-bearing granitic pegmatites was done, information on the Abyssal- and Muscovite- class was also gathered in the process. The original versions of the two classes were not well characterized, with the main focus on the rare-element class.(Černý & Ercit, 2005)

The 5 classes that are discerned by Černý are (Černý & Ercit, 2005):

1. Abyssal (AB)
2. Muscovite (MS)
3. Muscovite – Rare element (MSREL)
4. Rare element (REL)
5. Miarolitic (MI)

The tables below (see **Table *1***, **Table *2***, **Table *3***, **Table *4*** and **Table *5***) provide a more comprehensive view of the subdivisions and characteristics of the different classes of granitic pegmatites.

Table 1. Subdivision and characteristics of granitic pegmatites of the Abyssal class revised after Černý & Ercit (Černý & Ercit, 2005)

Class	Subclass	Geochemical signature	Typical minerals	Metamorhpic environment	Relation to granites
Abyssal (AB)	HREE	HREE, Y	Y-Nb-oxide minerals, uraninite, zircon, (allanite)	Upper amphibolite, low- to high-P granulite facies	None
	LREE	LREE	allanite, monzanite, (uraninite, thorite)		
	U	U, Th	uraninite, thorite, zircon, (allanite)		
	BBe	B, Be	dumortierite, grandidierite, kornerupine, werdingite, chrysoberyl, sapphirine series, surinamite		

Table 2. Subdivision and characteristics of granitic pegmatites of the Muscovite class revised after Černý & Ercit (Černý & Ercit, 2005)

Class	Subclass	Geochemical signature	Typical minerals	Metamorhpic environment	Relation to granites
Muscovite (MS)	Unsubdivided	Ca, Ba, Sr, Fe>Mn	muscovite, biotite, almandine-spessartine, (kyanite, sillimanite)	High-P, Barrovian amphibolite facies	None to marginal and exterior

Table 3. Subdivision and characteristics of granitic pegmatites of the Muscovite - Rare-element class revised after Černý & Ercit (Černý & Ercit, 2005)

Class	Subclass	Geochemical signature	Typical minerals	Metamorhpic environment	Relation to granites
Muscovite-Rare-element (MSREL)	REE	Be, Y, REE, Ti, U, Th, Nb-Ta	muscovite, fergusonite, samarskite, monazite, beryl, almandine-spessartine	Moderate to high P, (T) amphibolite facies	Interior to exterior; locally poorly defined
	Li	Li, Be, Nb	beryl, cassiterite, columbite, lepidolite, (spodumene)		

Table 4. Subdivision and characteristics of granitic pegmatites of the Rare-element class revised after Černý & Ercit (Černý & Ercit, 2005)

Class	Subclass	Subtype	Geochemical signature	Typical minerals	Metamorhpic environment	Relation to granites
Rare-element (REL)	REE	allanite-monazite	LREE, U, Th, (Be, Nb>Ta, F. [P])	allanite, monazite,zircon,rutile, fluorite, ilmenite	variable, largely shallow and postdating regional events affecting the host rocks	Interior to marginal (rarely exterior)
		euxenite	L-H-REE, Y, Ti, Zr, Nb>Ta, (F, P)	euxenite, monazite, xenotime, zircon, rutile, ilmenite, (fergusonite, aeschynite, zinnwaldite)		
		gadolinite	Be, Y, HREE, Zr, Ti, Nb>Ta, F, (P)	gadolinite, fergusonite, samarskite, zircon, rutile, ilmenite, fluorite, (zinnwaldite)		
	Li	***beryl***			Low-P, Abukuma amphibolite (andalusite-sillimanite) to upper greenschist facies	(interior to marginal to) exterior
		beryl-columbite	Be, Nb-Ta, (±Sn, B)	beryl, columbite, tantalite, (rutile)		
		beryl-columbite phosphate	Be, Nb-Ta, P, (Li, F; ±Sn, B)	beryl, columbite, tantalite, triplite, triphylite		
		complex				
		spodumene	Li, Rb, Cs, Be, Ta-Nb, (Sn, P, F; ±B)	spodumene, beryl, columbite, tantalite, (amblygonite, lepidolite, pollucite)		
		petalite		petalite, beryl, columbite-tantalite, (amblygonite, lepidolite, pollucite)		
		lepidolite	Li, F, Rb, Cs, Be, Ta-Nb, (Sn, P, B)	lepidolite, beryl, topaz, microlite, columbite-tantalite, (pollucite)		
		elbaite	Li, B, Rb, Sn, F, (Ta, Be, Cs)	tourmaline, hambergite, danburite, datolite, microlite, (polylithionite)		
		amblygonite	Li, Rb, Cs, Ta-Nb, Be, (Sn)	amblygonite, beryl, columbite-tantalite, (lepidolite-pollucite)		
		albite-spodumene	Li (Sn, Be, Ta-Nb ± B)	spodumene, (cassiterite, beryl, columbite-tantalite)		
		albite	Ta-Nb, Be, (Li; ± Sn, B)	columbite-tantalite, beryl, (cassiterite)		

Table 5. Subdivision and characteristics of granitic pegmatites of the Miarolitic class revised after Černý & Ercit (Černý & Ercit, 2005)

Class	Subclass	Subtype	Geochemical signature	Typical minerals	Metamorphic environment	Relation to granites
Miarolitic (MI)	REE	topaz-beryl	Y, REE, Be, Nb, F, Ti, U, Zr	topaz, "amazonite", zinnwaldite, fluorite, beryl, (zircon, euxenite, xenotime, monazite, cheralite)	Very low P, postdating regional events that affect the host rocks	Interior to marginal
		gadolinite-fergusonite				
	Li	beryl-topaz	Li, Be, B, F	tourmaline, beryl, topaz, lepidolite, (spodumene, petalite, pollucite, spessartine, microlite)	Low-P amphibolite to greenschist facies	(interior to) marginal to exterior
		spodumene				
		petalite				
		lepidolite				

Table 6. The family system of petrogenetic classification of granitic pegmatites of plutonic derivation (Černý & Ercit, 2005)

Family	Dominant subclass of pegmatites	Geochemical signature	Bulk composition of pegmatites	Associated granites	Bulk composition of granites	Source lithologies
LCT	REL - Li	Li, Rb, Cs, Bc, Sn, Ga, Ta>Nb, (B, P, F)	peraluminous to subaluminous	(synorogenic to) late-orogenic (to anorogenic); largely heterogeneous	peraluminous, S, I, or mixed S + I types	undepleted upper- to middle- crust supracrustal rocks and basement gneisses
	MI - Li					
NYF	REL - REE	Nb>Ta, Ti, Y, Sc, REE, Zr, U, Th, F	subaluminous to metaluminous (to subalkaline)	(syn-, late, post-) to mainly anorogenic; quasi-homogeneous)	(peraluminous to) subaluminous and metaluminous; A and I types	depleted middle- to lower-crust granulites, juvenile granites, mantle-metasomatized crust
	MI - REE					
Mixed	Crossbred LCT and NYF	mixed	(metaluminous to) moderately peraluminous	(postorogenic to) anorogenic; heterogeneous	subaluminous to slightly peraluminous	mixed protoliths or assimilation of supracrustal rocks by NYF granites

2.2.3 Rare minerals in pegmatites

Pegmatites of economic value

Granitic pegmatites are main sources for industrial minerals (feldspar, quartz, muscovite, spodumene, petalite), gem stones (tourmaline, beryl, topaz, and others) and rare metals (lithium, cesium, tin, niobium, tantalum, and uranium). Their economic feasibility mainly depends on the quantity of the materials, the value, and the accessibility to the plant where the ore is processed. (London, 2018)

Industrial minerals; the main components for the glass – ceramic industries are both sodic- and potassic- feldspar and quartz. They can be found in zoned and unzoned pegmatites. In zoned pegmatites, pure quartz occurs in the core. Because of its mellowness, muscovite is grinded into a powder and used for a variety of purposes such as paint, cosmetics etc. Lithium aluminosilicates, spodumene and petalite, are used in batteries. (London, 2018)

Gem stones; the chemical association of gem-bearing pegmatites with LCT or NYF families were assessed and confirmed. It was indicated that gem production in pegmatites was shown to be irregular and therefore mining activities are occasional. In LCT families, gems include to be variations of beryl (aquamarine, heliodor, and morganite), Li-rich tourmaline (elbaite-rossmanite and liddicoatite), blue and sherry topaz, transparient varieties of spodumene (kunzite), low-iron (orange) spessartine, and optical-grade quartz (rock crystal and smoky). In NYF families, they are mainly aquamarine and heliodor, topaz, rock crystal or smoky quartz, and optical-grade fluorite. (London, 2018)

Rare metals; Columbite, source for niobium, and tantalite, source for tantalum, occur in pegmatites and in alluvial gravels from which they derive. Combined with cassiterite and amblygonite, respectively sources for tin and lithium, this metal group occurs with pegmatite minerals. (Keersemaker, 2020)

Niobium when pure is soft, elastic, white, and shiny. It has important uses such as being superconductive, and when used in alloys it is resistant to corrosion, strength and toughness.

In the late 20th century and early 21st century, tantalum's extraordinary traits lead to its increased use. At temperatures below 150° Celsius, the element becomes stable and must react with hydrofluoric acid to cause corrosion. Because of oxides of tantalum on the metal surface, a natural protective layer is formed which protects from corrosion. Tantalum is an important usage in devices in cell phones and televisions to increase the quality of audio and used to create surface acoustic wave filters.

Tin is mainly used in the solder industry and also plating for steel, especially for food preservation. Because of its usage in batteries in electric vehicles, lithium is a desired element.

<u>**Rare minerals of Jorka Creek**</u>

In the study area, Jorka Creek, there are interesting minerals that were found and described in a paper by Montagne. Most important minerals are:

1. *Amblygonite*

   Basic fluophosphate of aluminum, sodium, and lithium; with chemical formula: $(Li,Na)Al(PO_4)(F,OH)$ and density: 3.04 – 3.11 g/cm^3

   Physical characteristics: the visual color varies from colorless, white, yellowish, beige to green, blue, gray. On the Mohs hardness scale it has a hardness of 5.5 to 6 and luster can range from vitreous to greasy, pearly with a perfect cleavage in one direction. (Johnsen, 2010)

   Optical characteristics: the relief is moderate, pleochroism is weak to none, the interference color is 0.020 and polysynthethic twinning is common with equal size lamellae.

   Amblygonite forms a series with montebrasite ($LiAlPO_4(OH,F)$), in which montebrasite contains low fluorine. This phosphorous mineral occurs in granitic pegmatites typically alongside apatite and other lithium bearing minerals such as spodumene, lepidolite and tourmaline. They are often confused with feldspars, but are differentiated on the basis of cleavage and density. (Johnsen, 2010)

In the pegmatite body of the Jorka creek area, amblygonite was the most important ore mineral that was excavated during the pilot exploitation. It was found as massive boulders in the core.

2. *Cassiterite*

It is a tin oxide mineral with a chemical composition of SnO_2

Physical characteristics: the visual color can vary from reddish brown to brown, black. Its hardness is 6-7 on the Mohs hardness scale and a metallic luster.

This mineral occurs as small amounts in Igneous and Metamorphic rocks and as a residual mineral in soils and sediments. Primary cassiterite is found in high-temperature hydrothermal veins that go with granitic intrusions and is associated with minerals such as apatite, tourmaline, topaz and fluorite. The tin mineral is more weather resistant than other minerals, which ensures that it is concentrated in stream and shoreline sediments. (King, 2017)

In the Jorka creek area, cassiterite was found to be scattered all over the pegmatite body as crystals and aggregates. There was an unequal distribution of throughout the whole pegmatite body with low values along the contact with the surrounding country rock, which increased towards the interior. (Montagne, 1964)

3. *Tantalite*

The main source of this mineral is the element tantalum and can contain metals such as iron and manganese which makes the chemical composition: $(Fe,Mn)(Ta,Nb)_2O_6$.

Physical characteristics:

In the pegmatite body, tantalite was found in the same way cassiterite was found, scattered throughout as crystals and aggregates. The difference being, coarser grains and a broader zone with low values near the contacts with the surrounding country rocks. Also some idiomorphic crystals ranging up to 12 cm were observed. (Montagne, 1964)

2.3 Geology of Suriname

Suriname consists of two large landscapes (Wong et al., 2017) :

- The interior or Precambrian basement that makes up most of the Guiana Shield
- The coastal area which extends across the Guiana Shield on the southern part of the Guiana basin.

Suriname is situated in South America and is bordered by Guyana in the west, French-Guiana in the east, Brazil in the south and the Atlantic Ocean in the north. In the South American continent lies the Amazonian Craton which is situated in the core and is one of the largest cratonic areas in the world. The Guiana Shield is a Precambrian Shield that is deeply weathered and is covered by rainforest hill and mountain which extends from the Amazon river in Brazil to the Orinoco in Venezuela. This Shield forms the northern part of the Amazonian Craton and covers about one tenth of Suriname.(Bosma et al., 1984) (Kroonenberg et al., 2016)

Divided by a vast area of granitoid and metavolcanic rocks, the Precambrian Shield is comprised of three distinctive belts that are made up of low- and high grade metamorphic rocks (Bosma et al., 1984):

- The low-grade Marowijne Greenstone Belt that is located in northeast.
- The high-grade Bakhuis Granulite Belt located in northwest.
- The high-grade Coeroeni Gneiss Belt located in southwest.

Remnants of the Roraima sandstone formation, also called the Tafelberg formation, overlay the crystalline basement of the Guiana Shield. They are divided between the Proterozoic and early Jurassic dolerite dikes. (Kroonenberg et al., 2016)

The coastal area is part of the Suriname-Guyana sedimentary basin and can be divided into the Young Coastal Plain and the Old Coastal plain. These are covered by sediments of the Mesozoic era to the Holocene epoch. (Bosma et al., 1984)

2.4 Geology of the Study Area

The low-grade Metamorphic Marowijne Greenstone Belt was generated around $\pm$ 2000 Ma during a key period of the Trans-Amazonian orogeny and can be geographically subdivided into a western part and eastern part of the Bakhuis Horst, but mainly occurs in the northeast and east of Suriname.

This Metamorphic Belt includes the following sequences, from old to young, each containing different rock types. These rock Formations have been metamorphosed in the greenschist- or lower amphibolite-facies in which the last part relates to granitoid intrusions (Kroonenberg et al., 2016) (Bosma et al., 1984):

- *Paramaka Formation:* Contain metabasalts, metacherts and phyllites, some metagrabbroic rocks.
- *Armina Formation:* Contain flysch-type metagreywackes and phyllites, which were deposited as turbidites in a marine environment. This makes them metaturbidites.
- *Rosebel Formation:* The Paramaka and Armina Formation unconformably overlay this young metasandstone Formation. It is made up of meta-arenites, metaconglomerates and metavolcanics which are metamorphosed fluvial sediments that indicate a molasse-type sequence.

Besides the various rock Formations that are present, the Greenstone Belt also includes the *Taffra Schist* and the *two-mica granite*. The Armina Formation and these two mineralogically diverse rock units are localized in the northeast of Suriname and pertain to the study of the pegmatites of Jorka Creek. In **Figure** *6* , the different rock units are displayed in a detailed geological map of Suriname.

Taffra Schist

The Armina Formation is intruded by small plutons of two-mica granite which causes aureoles of staurolite-garnet-biotite schists, called the Taffra Schist. This makes Taffra Schist the contact zone between the Armina Formation and two-mica granite and is about 5 km wide with a well-foliated coarse grained texture. Minerals such as kyanite, andalusite or fibrolite can also be found. The mentioned schistosity and array of minerals indicate that this rock unit is the result of regional metamorphism instead of contact metamorphism of the pelitic protolith. (Kroonenberg et al., 2016)

Two-mica granite

These granites, also called the Patamacca Granite, exhibit a gneiss-like texture and at the edges a lot of lens-shaped metasedimentary enclaves are seen. Together with the schistosity and medium-pressure mineral assembages of the nearby Taffra Schist, and the characteristics of the granite, it is indicated that the plutons of this granite may have been diapiric. Furthermore, there are many pegmatite veins in the area between the Taffra Schist and the granite, some of which contain amblygonite, cassiterite, tantalite and beryl (Kroonenberg et al., 2016). One of these pegmatite veins, in particular the ones containing amblygonite, cassiterite and tantalite pertains to this study.

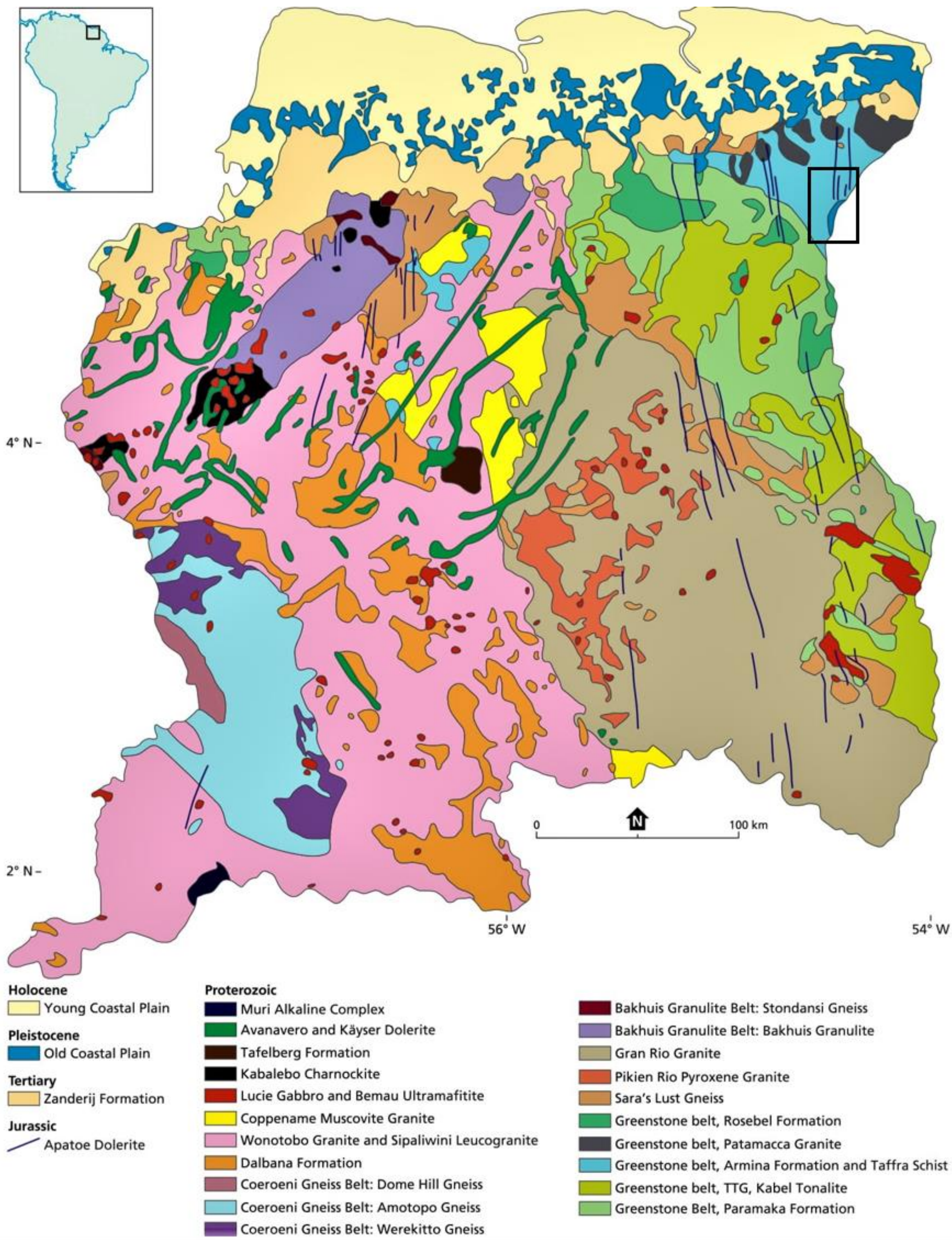

Figure 6. Simplified geological map of Suriname with the study area mapped out as the black rectangle. (Kroonenberg et al., 2016)

2.4.1 Jorka Creek area

As mentioned above, there are numerous pegmatite veins between the Taffra Schist and the Patamacca Granite contact zone. In an early study, the area investigated the most and in-depth was in the basin of the Jorka creek (see **Figure 7**), because the contact there was clearly observed between the schists of the Bonidoro series (Taffra group) and what was called granite no. 3. Granite no. 3 was thought to be related to pegmatites that occurred in the northeast of Suriname, its age is estimated to be of Under Paleozoic. Studies in French-Guiana have shown that Granite no 3 is not a single granite; but an older granite of sedimentary origin and a younger intrusive granite, which is connected to the rare-minerals bearing pegmatites. The pegmatite of the Jorka creek area, known as the amblygonite-cassiterite bearing pegmatite, was given the name *Pegmatite EP4* during preliminary investigations. (Eyk, 1957)(Eyk, 1958)

Rama pegmatite?

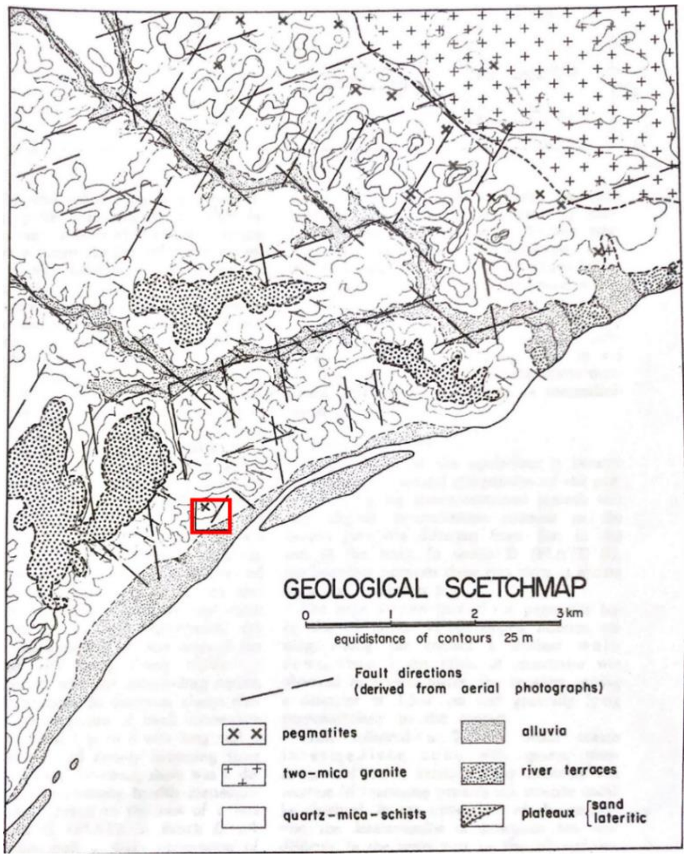

Figure 7. Geological map of a part of the northeastern area, with the study area mapped out (red rectangle). (Montagne, 1964)

Metamorphic and granite rocks are the most essential types in the vicinity. The pre-cambrian quartz-mica schists often contain an considerable amount of staurolite and garnet. The two-mica granite has somewhat of a grainy texture and often shows a faint orientation. Small pegmatites outcrops, of which they are both homogeneous and heterogeneous, were recognized in the near surroundings of the contact between granite and schists. None of which indicated a Li-mineralization and the values of cassiterite and tantalite were low. (Montagne, 1964)

Throughout the pegmatite body, the contact between schists and pegmatite was not the same. The south and east sides were relatively smooth lined and less curved, whereas the northwestern and southwestern sides were more angular lined. The angular contact line is caused by the repeated offsetting of a smooth, straight contact perpendicular to schistosity by numerous small faults in the direction of schistosity. (Montagne, 1964)

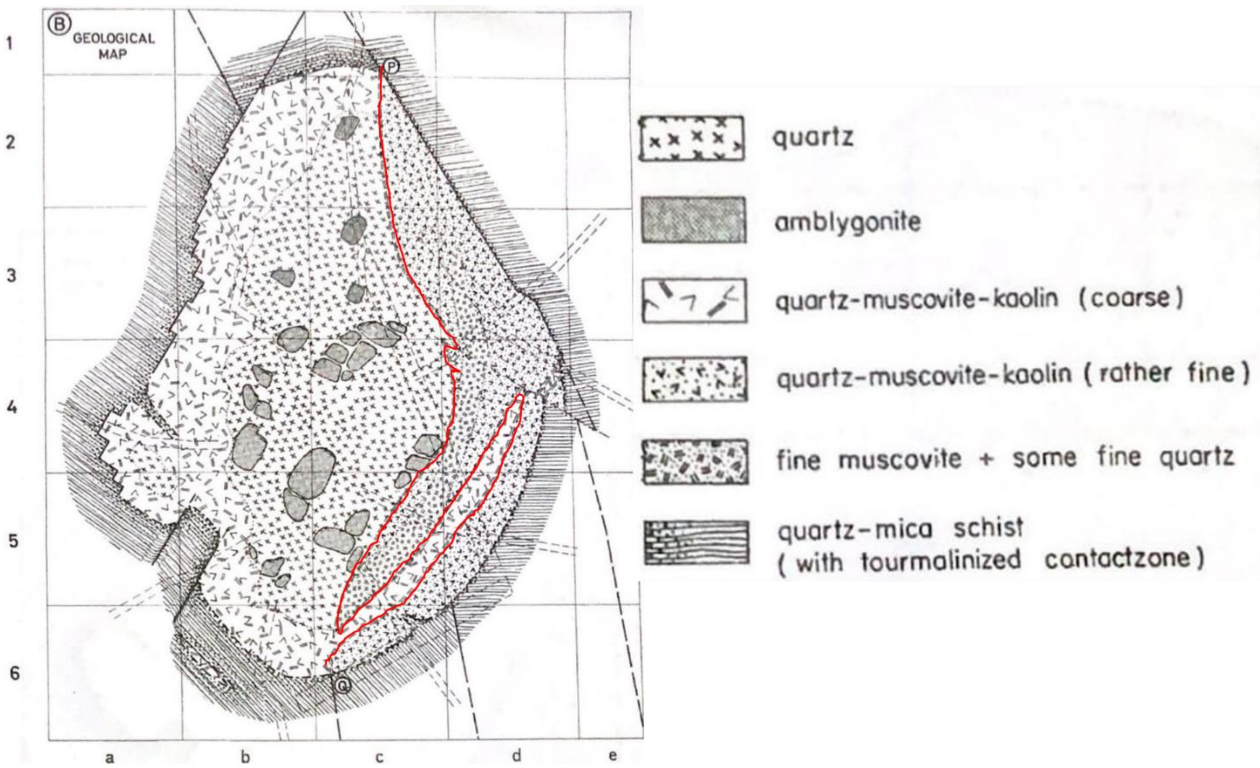

Figure 8. Geological map of the pegmatite body in which the red line indicates the boundary between the larger western part and smaller eastern part. (Montagne, 1964)

In the pegmatite body, tourmalinization with coarse prismatic black tourmalines could be seen on all contacts that surround the schists which quickly becomes finer towards the exterior. The internal structure of the respective pegmatite body consists of an western and eastern part and exhibits a clear zonation as can be seen in ***Figure 8***. In the smaller eastern part of the pegmatite body, the tourmaline contact line was different than the rest of the body. The larger, western part of the body is, according to the aspects of zonation, divided into (Montagne, 1964):

- *Wall zone:* This zone starts along the tourmalinized contact; its width is about 2 cm and consists mostly of muscovite which lies perpendicular to the contact and some pieces have a diameter of 1.5-2 cm.
- *Intermediate zone:* This zone is immediately followed after the wall zone; it is about 2-6 m broad and includes coarse material of quartz, muscovite and kaolinitic clay. Increasing towards the center an unusual content of tantalite and cassiterite minerals were noticeable, these minerals often were found as clusters of crystal aggregates. Also, some "cracked" beryl was rarely observed and kaolinized crystals that appeared to be spodumene but ultimately were just kaolin.
- *Core zone:* This zone consists mostly of big masses of angular bluish quartz which encircled boulders of amblygonite. Because of many faults and joints in the quartz, they appeared to be cracked. Crystals of tantalite and some cassiterite were also found.

The eastern part, which is significantly smaller, consisted mostly of quartz, muscovite and kaolin with a coarser to medium texture and traces of tantalite and low values of fine cassiterite was also observed.

3. METHODOLOGY

Different types of research methods were used to draw practical conclusions for the research questions. These are a theoretical foundation, fieldwork and a petrographic analysis of the study area.

3.1 Theoretical study

Old reports, articles and maps of the study area were used to gather more information about this project for a better understanding. Also existing thin sections of the area at the GMD (Geologische Mijnbouw Dienst) that were made during the preliminary investigations were reanalyzed, these are: AM 20A, AM 20B and LA112 (includes 35 thin sections).

3.2 Fieldwork

The field study took place at the beginning of March 2020. The search for the old pegmatite mine started, based on an old map found in the article of Montagne. The team resided at a campsite about 30 km upstream from Albina, which is located in the district Marowijne and is also at the border of Eastern Suriname and across from Saint-Laurent-du-Maroni in French-Guyana (see **Figure** *9*). Distance from the campsite to the beginning point from where the search started was about 4km. Due to overgrown vegetation there was a difficulty in finding the Pegmatite mine. After sometime one specific mark, and old railroad, helped in finding the mine. The old railroad was probably used by miners in the past to transport material (amblygonite and loose material containing cassiterite and tantalite).

Three (3) rock samples – RJR04, RJR05 and RJR06 – were taken from the mine for a thin section preparation to understand more about the how the pegmatite may have originate. A chemical analysis was also done on sample RJR06 to determine whether there was tantalite present in the sample. Since amblygonite had been extracted primarily in the past, a sample was also taken.

At the campsite an evident outcrop of the Taffra schist, which is a high metamorphic rock containing staurolite and garnet, was observed. A rock sample of the Taffra schist was also gathered in order to understand more about this metamorphic rock and what the correlation might be between this staurolite schist and the Pegmatite.

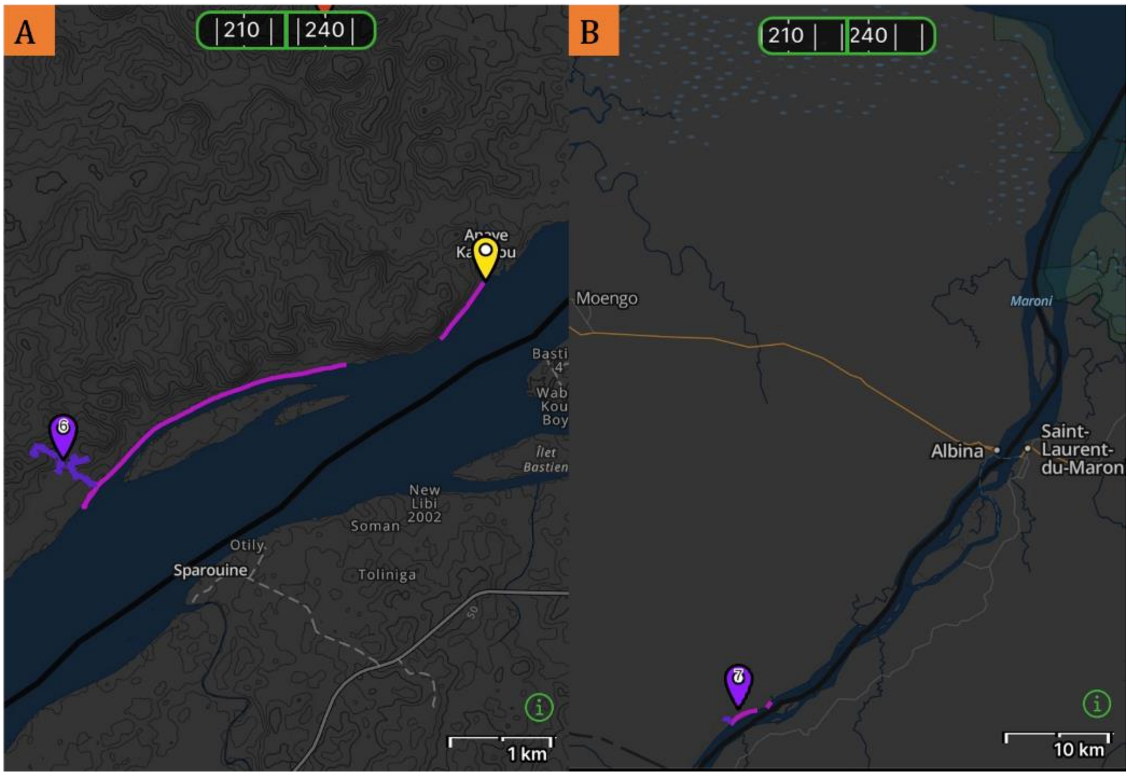

Figure 9. Figure A shows the distance between the campsite (yellow icon) and the starting point of the search to the mine (purple icon). Figure B shows the location of the mine (purple icon) with respect to Albina. (Screenshot is made using the GAIA application)

3.3 Microscopic Lab work

The rock samples were subsequently sent to the University of Utrecht for thin sections. To understand more about what kind of minerals and textures these rocks encircle, the thin sections were studied meticulously under a petrographic microscope. Different properties helped to determine what kind of minerals there could be present in such a thin section, which in turn helped to determine the origin of such minerals.

For a mineral of petrographic study, the petrographic microscope is specifically used. The microscope consists of various parts which help identify thin sections. To determine the thin sections, the Leica DM750P was used.

The microscopic properties in PPL (Plane Polarized Light). To have a brighter view, the analyser is turned off (Gribble & Hall, 1985):

a) *Form:* This describes the shape that a particular mineral exhibits in various rock types. (Gribble & Hall, 1985)
   Euhedral: the mineral has well defined straight edges, in which a clear shape can be identified.
   Subhedral: the mineral has a few straight edges
   Anhedral: the mineral doesn't have any edges.

b) *Relief:* This is the definition of the line around the edge of a mineral if it's visibly clear or unclear, this determines if the relief is high, medium or low. A thin band of light, the Becke line, also determines if the relief is positive (when the Becke line appears to move inwards) or negative (when the Becke line appears to move outwards). (Gribble & Hall, 1985)

c) *Color/Pleochroism:* The color that is described is the color that is visible. Pleochroism is the attribute where a change in color is observed when rotating the microscopic stage. A mineral may exhibit a weak, strong or no change in color.

d) *Cleavage/Fracture:* In a mineral fractures can be seen as irregular streaks in random directions, whereas cleavage is seen as regular stripes in a specific direction.

e) *Inclusions:* Material that is trapped within a mineral during its formation can be seen as an inclusion.

f) *Alteration:* A new, stable mineral phase that is produced by a chemical reaction with elements within a mineral (Gribble & Hall, 1985).

The microscopic properties in XPL (Crossed Polarized Light). For a dark, colorful view the analyser is inserted into the optical path (Gribble & Hall, 1985):

a) *Isotropism:* Occurs when the mineral goes dark if the analyser is turned on. All other minerals that appear to be colorful are anisotropic (Gribble & Hall, 1985).

b) *Interference color:* The color of a mineral which appears on the basis of the color chart of the Michel-Lévy according to its crystalline structure.

c) *Extinction:* During a 360° rotation, anisotropic minerals go into extinction four times when the microscopic stage is rotated. A crystal goes into extinction if it exhibits cleavage and is length cross-section (Gribble & Hall, 1985).

d) *Twinning:* is seen as an intergrowth of two or more crystals of the same substance. (Michel, 2012)

e) *Zoning:* described as a texture which is formed in solid minerals and can optically be defined by a change in color or extinction angle of the mineral from the center to the edge (Alex, n.d.)

4. RESULTS AND DISCUSSION

4.1 Fieldwork observations and results

Field observations are crucial into understanding more about how the Pegmatite body may have originate. At first the Pegmatite was difficult to find because of the overgrown and dried vegetation, but due to the partial railroad (see ***Figure 10***) that was found it became clear that if the railroad was followed it would ultimately lead to the Pegmatite mine. Near the railroad, which was used to transport loose material and amblygonite in wagons, big boulders blue-gray amblygonite was found.

On the path leading up to the mine, booklets of muscovite were found in abundance (see ***Figure 11***). Also a rock containing quartz and tantalite was observed.

Figure 10. Old wagon holder probably used to transport material (Gaya Arga, March 2020)

Figure 11. The path which lead up to the mine, where booklets of muscovite were clearly visible.

When arrived in the mine itself, it was clear that it was overgrown with trees and grass. Blue-ish Quartz and boulders of blue-gray Amblygonite was observed which indicates that it was the core of the Pegmatite body. It signifies that this Pegmatite body exhibits zoning. Another indication was that leading up to the mine muscovite booklets were found in abundance, but were absent in the core.

Figure 12. Figure A depicts the top of the mine, where the overgrown trees are clearly seen. Figure B shows the crew standing in the mine pit.

Figure 13. A Wall of angular quartz and amblygonite boulders in the mine pit

According to the article of Montagne, in the core of the Pegmatite, large blocks of angular quartz encircled and occurred together with amblygonite boulders. This was evident and also an indication of the core of the mine (see **Figure *13***).

In the core, weathered feldspar which was on top of quartz was also clearly visible. This probably indicated that around the quartz blocks there was feldspar present which then weathered over time and this resulted in kaolinite (see **Figure *14***).

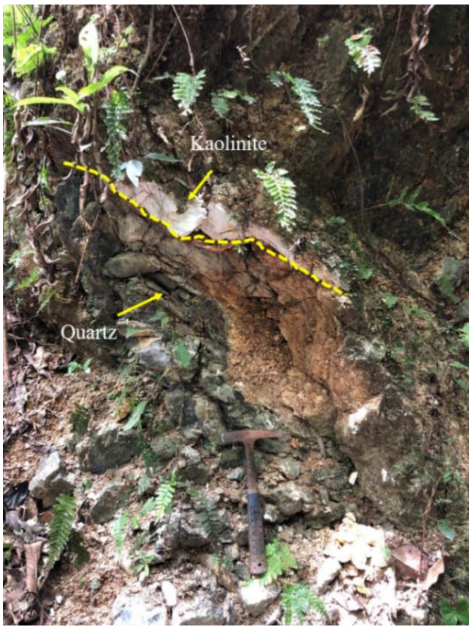

Figure 14. Weathered feldspar on top of an irregular vein of quartz in the mine pit.

After the field observations, three (3) samples were taken near and/or in the mine:

- *RJR04* – This sample is a tourmaline schist which was found at the bottom of the pit in the mine.
- *RJR06* – This sample is a rock which contains Quartz and Tantalite.
- *Amblygonite sample* – This was taken because it was primarily mined in the past. Also to determine its physical properties.

The sample *RJR05* was taken of the outcrop of the Taffra schist, this could give some insight as to how the staurolite schist correlates with the Pegmatite.

RJR04 – Tourmaline Schist

Figure 15. Schist from the Pegmatite mine with quartz, mica and tourmaline from the contact zone.

In **Figure** *15*, a Tourmaline Schist sample can be seen that was taken from the bottom of the pit, in the core where boulders of amblygonite and angular quartz were present. The schist exhibits a typical foliation and weathering and looks to be of sedimentary origin. The reddish color can be an indication for oxidized minerals and the dark color can indicate tourmalines. There are also two (2) dark layers observed, which may represent deeply weathered tourmalines, with a quartz vein between them.

RJR06 – Rock bearing Quartz and Tantalite

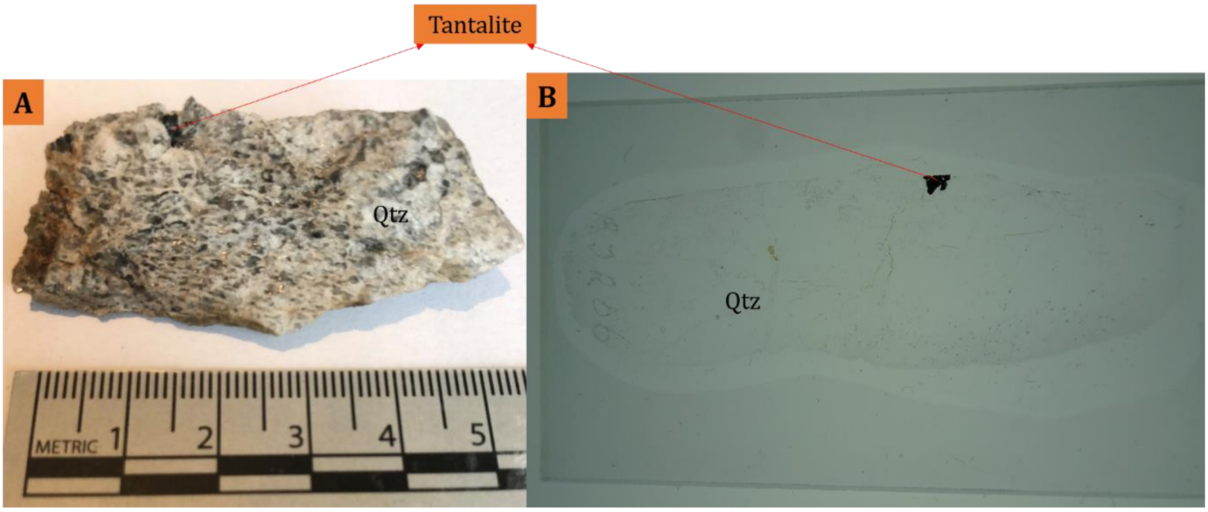

Figure 16. Rock sample with tantalite and quartz next to the thin section of that rock.

The sample in **Figure *16*** A was collected to determine whether the dark mineral present is tantalite and was subsequently send to the University of Utrecht for chemical testing. In **Figure *16*** B, a thin section is seen of the sample. The rock looks to be of igneous origin because of its quartz composition, which means it is silica rich. The rock also seems to be slightly weathered.

Amblygonite sample

Figure 17. Figure A shows an amblygonite sample in which the weathered layer is clearly seen all around the interior. Figure B shows amblygonite and blue-ish quartz next to each other taken in the mine pit.

After this sample was taken back from the field, its physical properties were determined to be sure if it is amblygonite. A clear distinction can be seen within the sample (see **Figure** *17* A). The visual color is blue-gray and at the edges, a white, chalky aggregate can be seen. This is the result of weathering of amblygonite in which the lithium is leached out. Using the Moh's Hardness Scale, the hardness of the fresh amblygonite can be concluded as 5-6, and exhibits good to perfect cleavage and a greasy luster.

In **Figure** *17* B, a sample of amblygonite and blue-ish quartz can be seen side to side. At first sight the two minerals seem to have no differences, but a closer look into these minerals the differences can be distinguished. The blue-ish quartz exhibits a greasier luster than the amblygonite next to it. After physically inspecting the minerals, there was a difference in weight. Amblygonite felt heavier than quartz, this is due to the fact that the density of amblygonite is on average 3,04 g/cm^3 and the density of quartz is 2,65 g/cm^3.

RJR05 – Taffra Schist

Figure 18. Figure A shows a sample from the Staurolite and Garnet bearing schist. Figure B shows the outcrop of the Taffra Schist which was taken from the campsite.

At the campsite (see **Error! Reference source not found.**), an outcrop was clearly observed (see **Figure** *18* B). The surface of this outcrop was rough and because staurolite minerals are resistant to weathering they were seen at the surface. Also a smooth transition from coarse-grained to fine-grained was visible to the naked eye. After a close examination of this outcrop, the rock exhibited a clear foliation with an attitude of 220° SW. Furthermore, rounded and slightly weathered garnets, staurolites and micas were seen.

4.2 Microscopic Labwork Results

In this section, the results of the thin sections will be explained. These include the samples taken from the fieldwork and the existing thin sections from GMD.

The samples RJR04, RJR05 and RJR06, three (3) thin sections were made and determined. These determinations will explain more about the rock, based on its mineralogy, structure and texture.

4.2.1 Sample RJR04

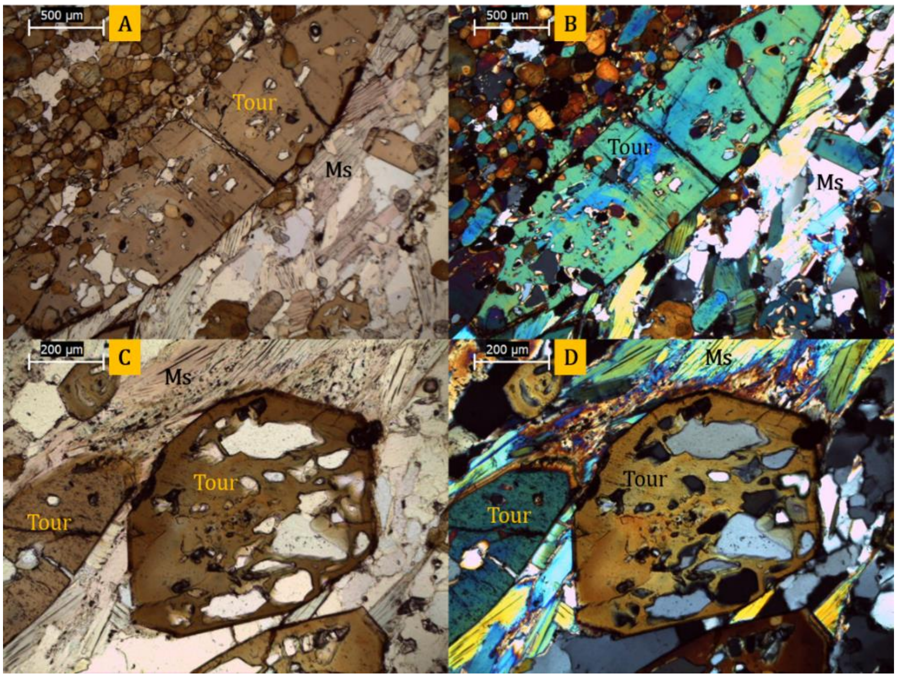

Figure 19. Magnification of tourmaline under the microscope as length section (A and B) and basal section (C and D). Figures A and B show a length section of tourmaline encircled by a cluster of small tourmaline crystals and muscovites. Figures C and D show a basal section of tourmaline also encircled by muscovites and other tourmalines.

According to its mineral composition, this thin section can be described as a Tourmaline – Muscovite Schist. Tourmaline, muscovite and quartz are the most occurring minerals. The length section of the tourmaline minerals (see **Figure** *19* A and B) have subhedral forms, most have a rectangular shapes while some have a prismatic shape. They exhibit a high-positive relief and a strong pleochroism with a dark brown-green color.

In XPL, a 2nd order blue-green interference color with a parallel extinction is observed. The length sections also showed a 2nd to 3rd order Length Fast – Addition elongation. Many tourmaline crystals have quartz inclusions.

Basal sections (see **Figure** *19* C and D) of tourmaline are more common throughout the thin section and also occur as clusters. These have a weak to none pleochroism, exhibit an apparent isotropy in XPL and have uniaxial negative sign.

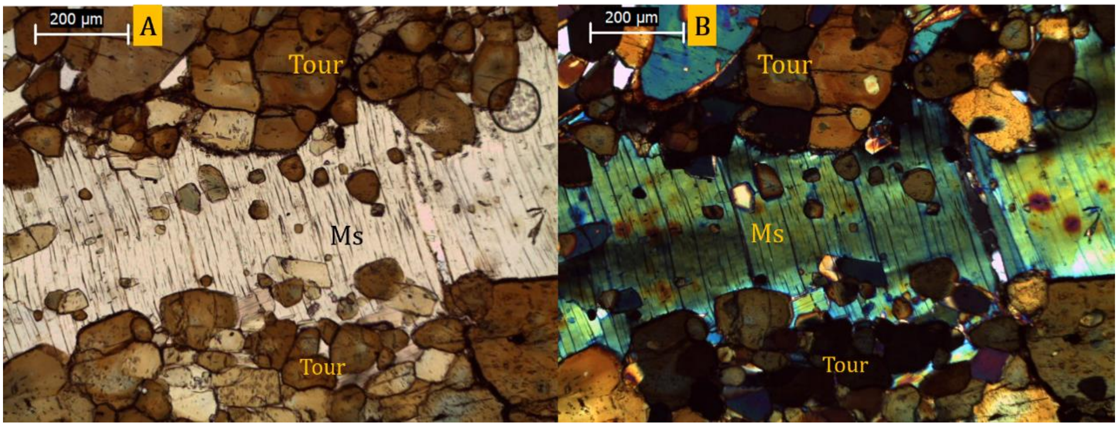

Figure 20. Figure A and B (PPL and XPL respectively) – muscovite encircled by clusters of length and basal sections of tourmaline.

The muscovite minerals have subhedral elongated shapes, with a moderate-positive relief and a colorless weak pleochroism. In XPL they exhibit a parallel extinction with bird's eye and a 3rd order blue-green – interference color. In **Figure** *20*, the muscovite mineral seems to have inclusions of tourmaline.

Figure *21* shows a vein with quartz crystals and tourmaline and muscovite crystals in between. Identifying for the quartz minerals is its anhedral form with a low relief; in XPL it exhibits the well-known undulating extinction and has a 1st order gray – interference color. The quartz vein can clearly be seen back in the sample.

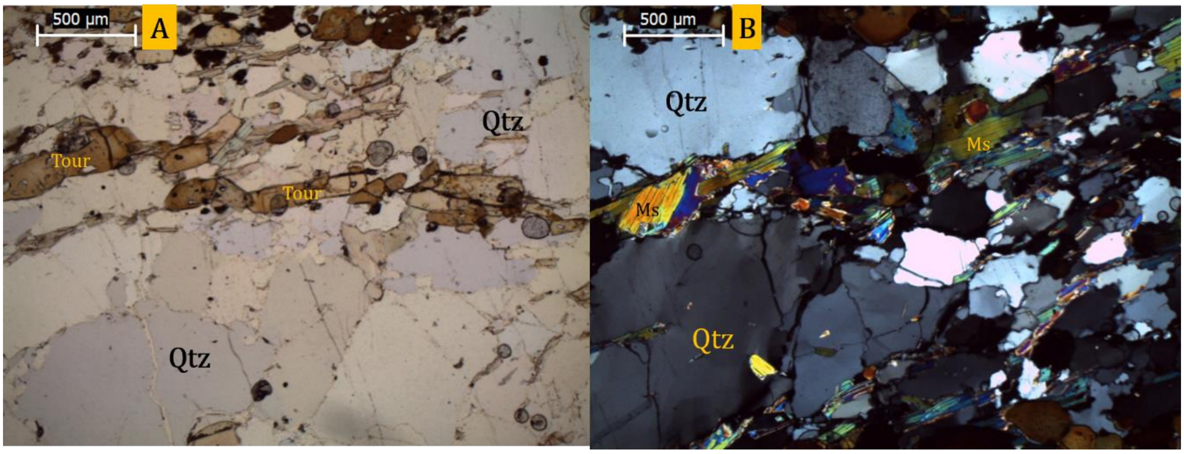

Figure 21. Figure A (PPL) – tourmaline crystals in between a quartz vein. Figure B (XPL) – muscovites with a preferred orientation in between the quartz vein.

4.2.2 Sample RJR05

Figure 22. Figure A and B (PPL and XPL respectively) – porphyroblastic garnet alongside quartz and biotite.

The mineral composition of this thin section is comprised of staurolite, garnet, biotite and quartz, which makes it a Staurolite – Garnet schist (Taffra schist). This particular thin section consists of three distinct layers. A quartz vein separates a layer of fine-grained quartz and biotite which have a preferred NW-SE direction from a layer of finer grains of quartz, biotite and staurolite. Rectangular crystals of "cracked" staurolite also occur while garnet occurs in lesser amounts with a grano-porphyroblastic texture.

In *Figure 22*, a garnet crystal can be seen, most of the garnets that occur have a subhedral prismatic shape and a high-positive relief with none pleochroism. This mineral is isotropic in XPL, which means it goes dark when the analyser is turned on.

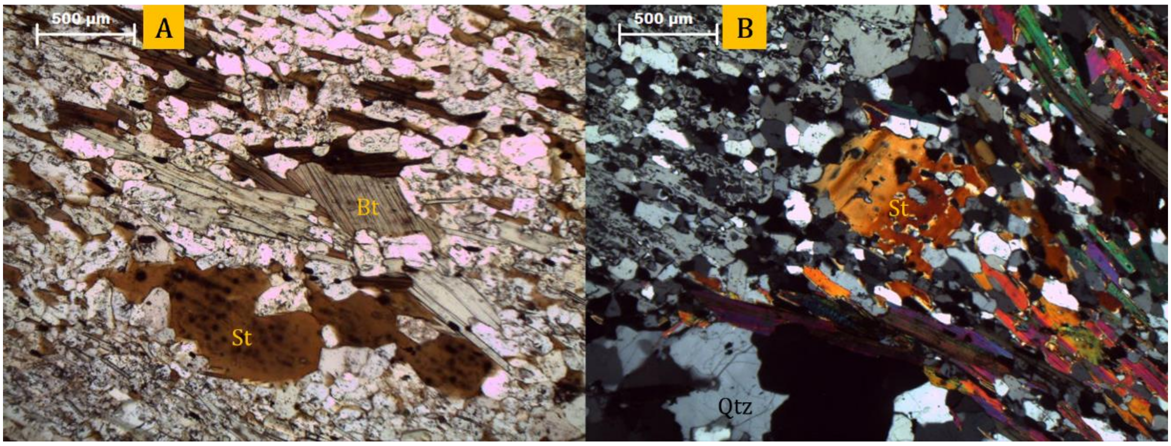

Figure 23. Figure A (PPL) – staurolite and biotite along with quartz. Figure B (XPL) – staurolite and micas with a preferred orientation.

Most of the staurolite minerals have subhedral shapes as can be seen in **Figure** *23* and a high positive relief with a brown-yellow moderate pleochroism. In XPL, it exhibits a 1st order brown – interference color. Most of the staurolite minerals have inclusions of quartz.

The optical difference between muscovite and biotite minerals, both are micas, lies in the pleochroism. The biotite minerals have a light brown to dark-red brown strong pleochroism and elongated shapes with a moderate-positive relief. In XPL, they also exhibit bird's eye, like muscovites and have a 2nd order pink-orange-green – interference color.

Figure *24* clearly shows elongated biotite crystals with its preferred direction and fine-grained quartz.

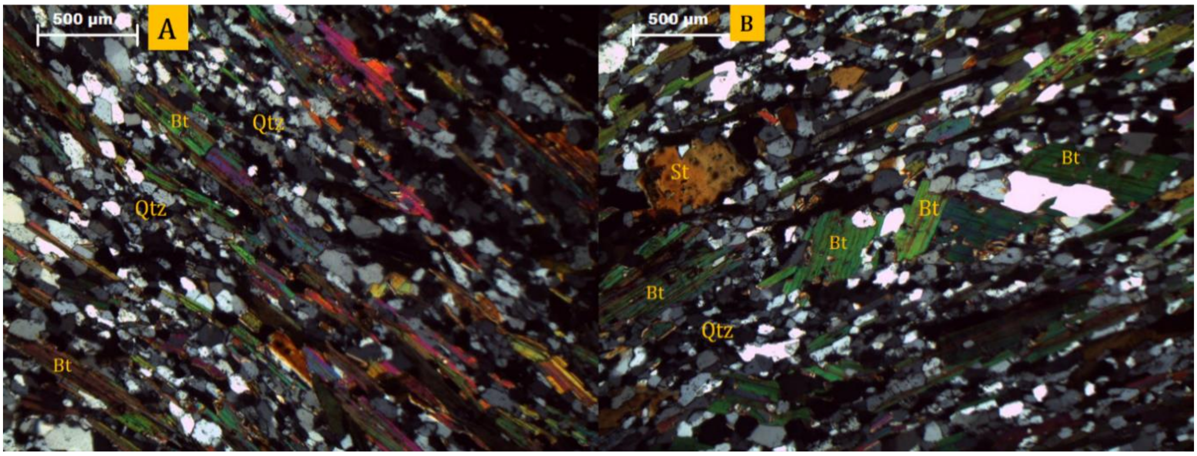

Figure 24. Figure A and B (XPL) – staurolite-biotite schist in its entirety, with biotite a preferred orientation.

4.2.3 Sample RJR06

From this sample a thin section was made (see ***Figure 25*** A) and chemical testing was done on the black mineral present in the thin section. In ***Figure 25*** B, four (4) points can be seen which pinpoints where the testing was done on the mineral itself. The elements that were tested are oxygen (O), silicon (Si), iron (Fe), niobium (Nb), tin (Sn) and tantalum (Ta). These were all tested purely as elements and as oxides. **Table** *7* (oxides) and **Table** *8* (pure) show the values for the different elements along with the average and deviation.

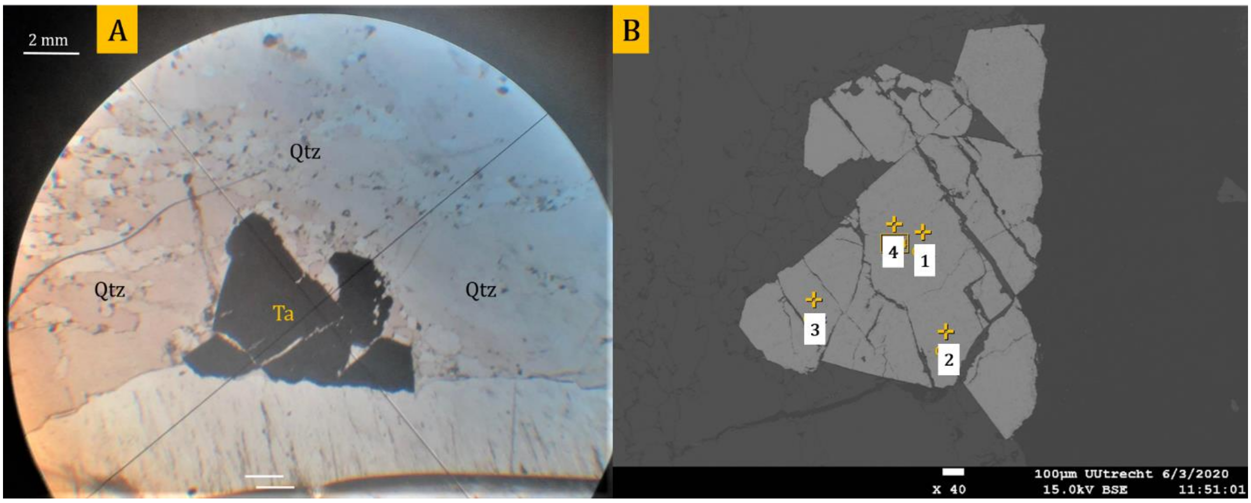

Figure 25. Figure A shows a tantalite crystal encircled by quartz in PPL. Figure B shows the points (indicated with numbers) on which chemical testing was done on the same tantalite crystal. (Source: Professor S. B. Kroonenberg and University of Utrecht)

Table 7. Oxide elemental distribution results of the indicated numbers on sample RJR06 (Source: University of Utrecht)

	O	SiO2	FeO2	Nb2O5	SnO2	Ta2O5
1	0		14.97	7.55	2.06	75.43
2	0		16.7	6.21	0.99	76.09
3	0		12.09	7.63	5.19	75.09
4	0	9.18	15.79	10.7	2.68	61.64
Average	0	9.18	14.89	8.02	2.73	72.06
Deviation	0	0	2	1.9	1.78	6.96

Table 8. Pure elemental distribution results of the indicated numbers on sample RJR06 (Source: University of Utrecht)

	Fe	O	Si	Nb	Sn	Ta
1	11.32	17.09		5.18	1.64	64.77
2	12.76	15.74		4.33	0.8	66.36
3	9.22	16.32		5.3	4.18	64.98
4	12.02	20.39	3.99	7.51	2.17	53.91
Average	11.33	17.39	3.99	5.58	2.2	62.5
Deviation	1.52	2.08	0	1.36	1.44	5.77

The table with the elemental oxide values on the four points shows low SiO_2, Nb_2O_5 and SnO_2 values, meaning percentages <10% which in turn also ensures a low average. FeO_2 has values a bit more than 10%, but Ta_2O_5 shows percentages of more than 70%.

The pure elemental table shows <10% values of Si, Nb and Sn with Fe and O showing values of 10%-20% and Ta having values of >50%. The combination of the oxides and pure elements indicate that the present mineral contains >50% Ta and >70% Ta_2O_5 meaning this mineral is proven to be tantalite.

4.2.4 GMD thin sections

The following described thin sections were made during the preliminary investigations of the Jorka creek area; the thin sections were analyzed again for a better geological perspective. These are: AM 20A, AM 20B and LA112. LA112 consists of 35 thin sections which were taken at different depths, so some of the thin sections have the same mineral composition.

Thin section AM20 A

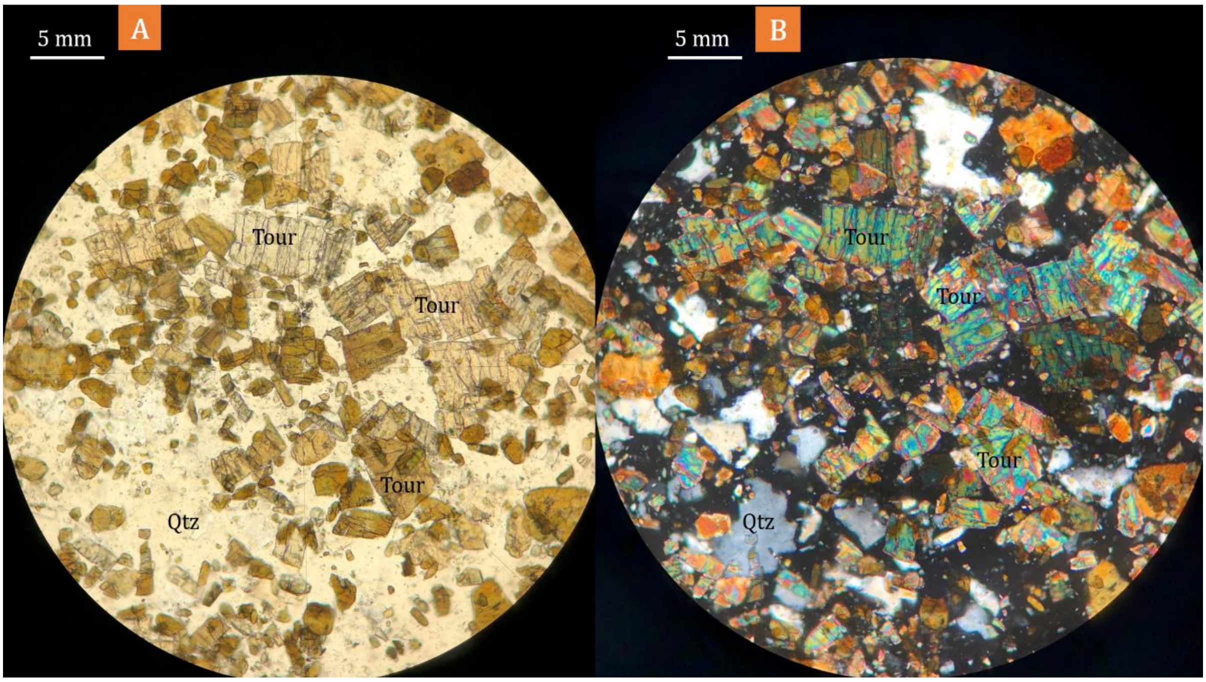

Figure 26. Figure A shows coarse and fine grained tourmaline and quartz crystals in PPL. Figure B is in XPL.

The mineral composition of this thin section (see **Figure *26***) consists mostly of coarse and fine grained anhedral quartz crystals – low relief, 1st order interference color and an undulating extinction – and rectangular shaped tourmaline crystals – high relief, strong pleochroism, 2nd order blue-green interference color and a parallel extinction. Its mineral composition indicates to a Tourmaline schist.

Thin section AM 20B

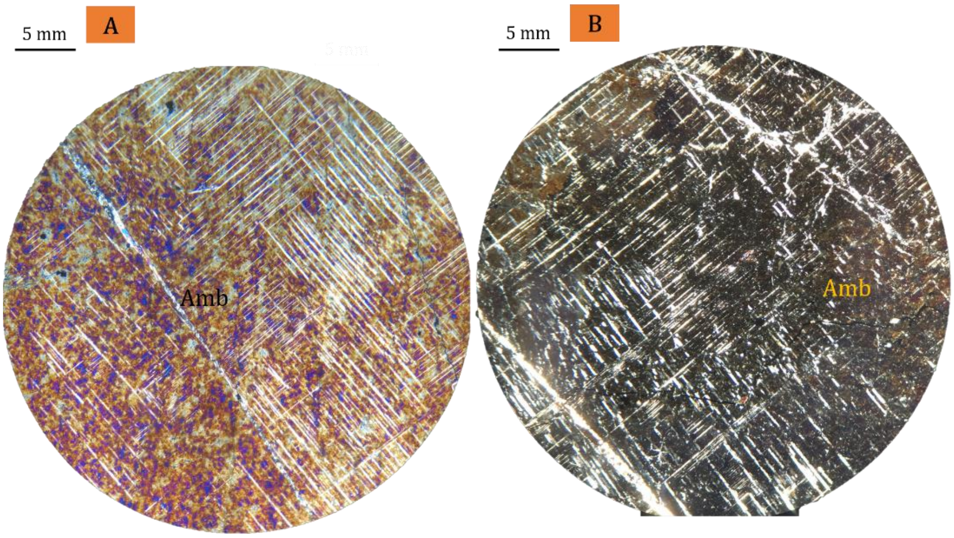

Figure 27. Amblygonite with its polysynthetic twinning in XPL and in extinction.

Thin section AM 20B consists only of amblygonite. In PPL, the mineral has a moderate-positive relief, colorless to yellow-ish – weak to none pleochroism. In XPL (see **Figure** *27*), it exhibits a 2nd order brown-pink ish interference color with an oblique extinction (40°). **Figure** *27* also shows a polysynthetic twinning with an equal size lamellae which is optically characteristic for this mineral.

Thin section LA112 D

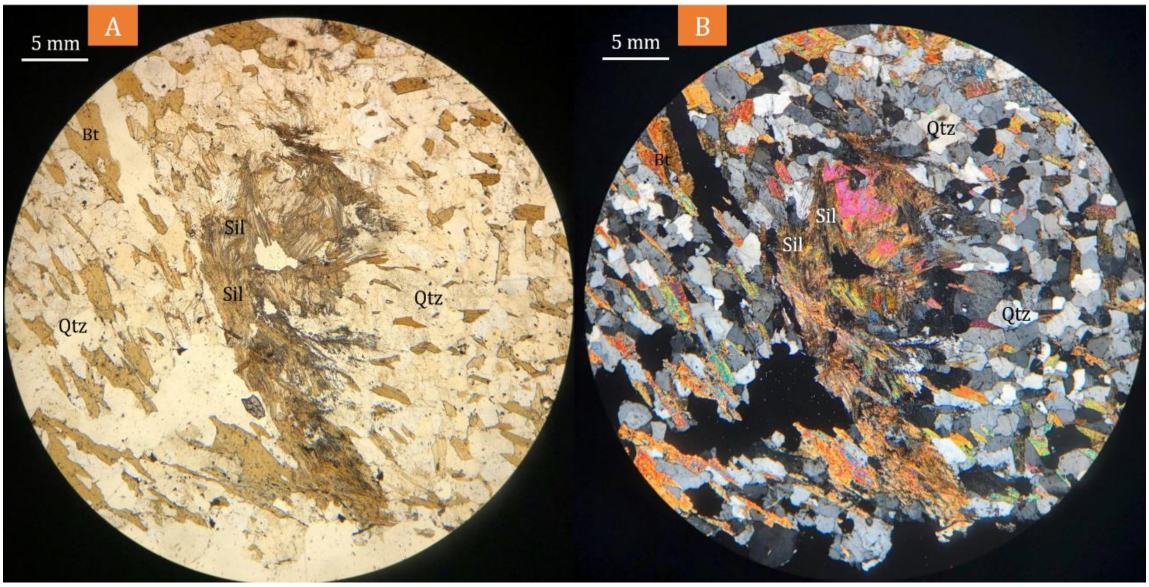

Figure 28. A and B (PPL and XPL respectively) show a biotite schist with sillimanite needles.

The mineral composition of ***Figure 28*** clearly shows a biotite schist and sillimanite needles, with fine grained anhedral quartz minerals and elongated biotite crystals with a preferred direction. The sillimanite needles (also called fibrolite) occur together with the biotite minerals. Sillimanite occurs as fibrous crystals and have a moderate-positive relief with brown to colorless – none pleochroistic and a 1st order interference color. In this thin section garnet is also observed.

4.3 Discussions

5. CONCLUSIONS AND RECOMMENDATIONS

BIBLIOGRAPHY

Alex, S. (n.d.). *Zoning*. Retrieved March 6, 2021, from https://www.alexstrekeisen.it/english/vulc/zoning.php

Bosma, W., Kroonenberg, S. B., Van Lissa, R. V., Maas, K., & De Roever, E. W. F. (1984). An Explanation to the Geology of Suriname. In *Contributions to the Geology of Suriname 8* (pp. 31–82).

Bradley, D. C., McCauley, A. D., & Stillings, L. M. L. (2017). Mineral-Deposit Model for Lithium-Cesium-Tantalum Pegmatites Mineral Deposit Models for Resource Assessment. *Scientific Investigations Report*, 1–48. https://pubs.er.usgs.gov/publication/sir20105070O%0Ahttps://pubs.usgs.gov/sir/2010/5070/o/sir20105070o.pdf

Bradley, D., & McCauley, A. (2013). A Preliminary Deposit Model for Lithium-Cesium-Tantalum (LCT) Pegmatites. *Usgs*, *December*, 6. https://pubs.er.usgs.gov/publication/ofr20131006

Černý, P., & Ercit, T. S. (2005). The classification of granitic pegmatites revisited. *Canadian Mineralogist*, *43*(6), 2005–2026.

Eyk, H. T. L. van. (1958). *Preliminary Abstract Concerning Pegmatite Investigations in Northeastern Surinam*.

Eyk, H. T. L. van. (1957). *Some Remarks About a Pegmatite Investigation in North Eastern Surinam*. 99–101.

Gribble, C. D., & Hall, A. J. (1985). *Optical Mineralogy: Principles & practice* (1st ed.). George Allen & Unwin Ltd.

Johnsen, O. (2010). *Minerals of the World*. Princeton University Press.

Keersemaker, M. (2020). *Suriname Revisited: Economic Potential of Its Mineral Resources*.

King, H. M. (n.d.-a). *Pegmatite: An Extreme Igneous Rock with Large Crystals and Rare Minerals*. Retrieved June 1, 2021, from https://geology.com/rocks/pegmatite.shtml

King, H. M. (n.d.-b). *Spodumene: An important source of high-purity lithium and a gemstone with collector appeal*. Retrieved June 2, 2021, from https://geology.com/minerals/spodumene.shtml

King, H. M. (2017). *Cassiterite*. https://geology.com/minerals/cassiterite.shtml

Kroonenberg, S. B., De Roever, E. W. F., Fraga, L. M., Reis, N. J., Faraco, T., Lafon, J. M., Cordani, U., & Wong, T. E. (2016). Paleoproterozoic evolution of the Guiana Shield in Suriname: A revised model. *Geologie En Mijnbouw/Netherlands Journal of Geosciences*, *95*(4), 491–522. https://doi.org/10.1017/njg.2016.10

London, D. (2018). Ore-forming processes within granitic pegmatites. *Ore Geology Reviews*, *101*(May), 349–383. https://doi.org/10.1016/j.oregeorev.2018.04.020

London, D. (2020). *Pegmatites*.

Michel, D. (2012). *Mineralogy for Petrologists*. Taylor & Francis Group LLC.

Montagne, D. G. (1964). An Interesting Pegmatite Deposit in Northeastern Suriname. *Geologie En Mijnbouw*, 360–374.

Wong, T., Kroonenberg, S., & Augustinus, P. (2017). *Geologie en lanschap van Suriname*. LM Publishers.