The K3 Copper Deposit in the Bakhuis Granulite Belt, West Suriname

Restudy of the characteristics of the copper mineralization at Bakhuis Mountains after Dalhberg (1975- 1989)

FACULTEIT der TECHNOLOGISCHE WETENSCHAPPEN

Raysree S. Patadien[1]; Dennis J. LaPoint[2]; Emond de Roever[3]

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[1]*Anton de Kom University of Suriname, raysree.patadien@gmail.com*

[2] *Appalachian Resources LLC, United Stated of America, dennis.lapoint@gmail.com*

[3]*Earth Sciences, VU Amsterdams, Netherland, ederoever@ziggo.nl*

Introduction

The K3 deposit lies in the SW part of the Bakhuis Granulite Belt (BGB) (Figure 1), a metamorphic terrain located in the Bakhuis Mountains, West Suriname, in the center of the Paleoproterozoic Guiana Shield. Strong magnetic and electromagnetic anomalies were detected here during an airborne geophysical survey carried out for the Geological and Mining Service of Suriname (GMD) in the early sixties. In the 70"s the GMD carried out exploration at the site to determine the economic potential of the copper and phosphate occurrences. Diamond drilling was part of the program and 66 shallow holes were completed, with a maximum depth of 100m. Dalhberg (1987) summarized this research and concluded that the copper and phosphate mineralized syenitic and monzonitic rocks and lenses of clinopyroxene-apatite rocks represent metamorphosed cupriferous felsic to intermediate volcanics and phosphatic siliceous carbonate sediments of the supracrustal succession.

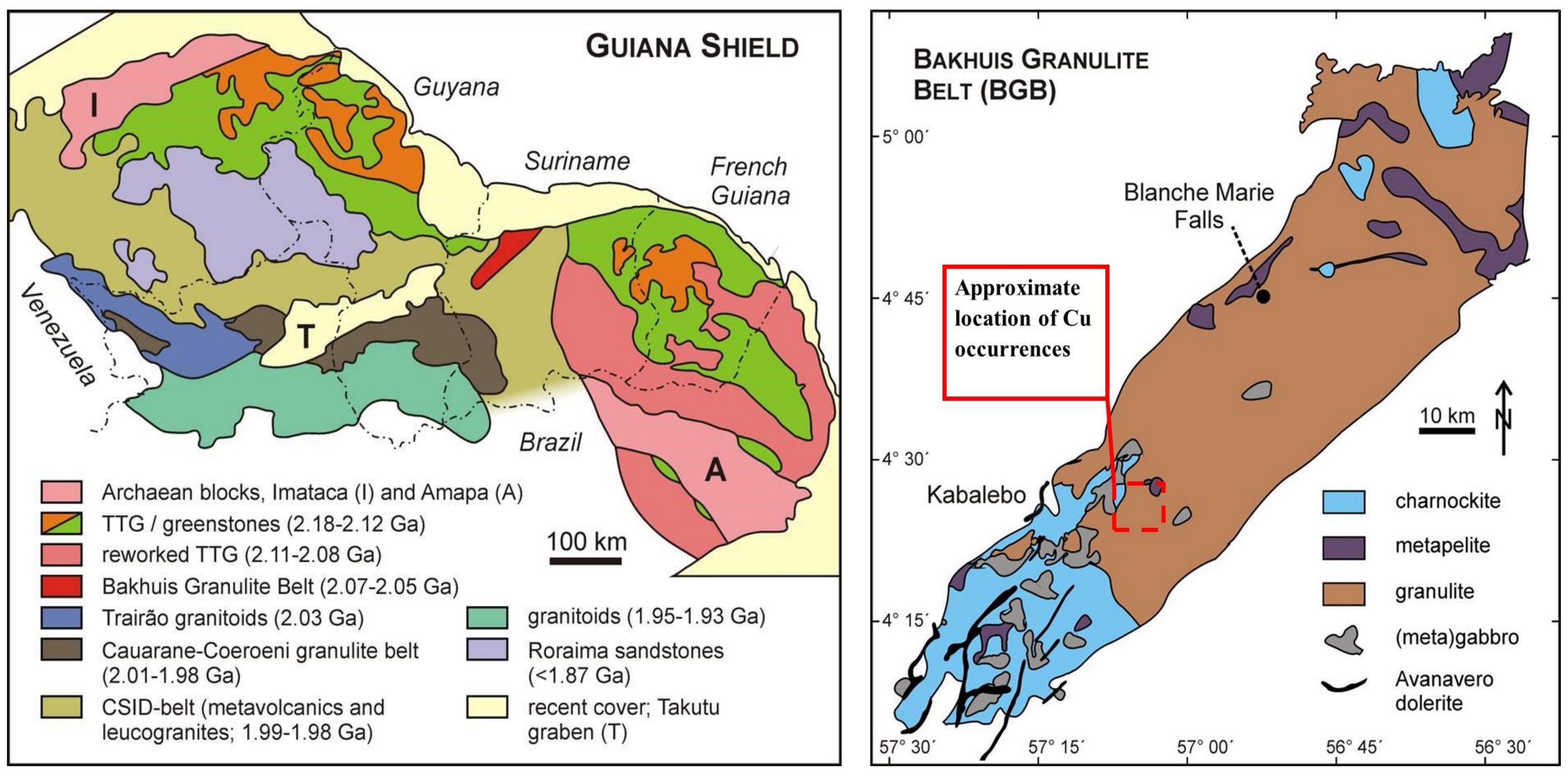

Figure 1: Simplified geology of the northern part of the Guiana Shield (left), Geology of the Bakhuis Granulite Belt (right) (Klaver et al, 2015)

Current Research

The current research involved macroscopic study of core from 22 drill holes, thin section study from 17 holes using an optical microscope and analyses of 220 pulp and sludge sample using ICP-OES. Historic data including yearly and quaternary GMD reports, maps and publications were reviewed. Interpretation of geochemical data is in progress and final conclusions are yet to be drawn. Copper models are being reviewed.

Results- Rock Types

For main rock types were distinguished: migmatitic granulite, Ca-silicate granulite, metagabbros and ultramafics. These names are based on their mineralogy and texture and they are different from the names assignment by Dalhberg.

The granulites show a conspicuous banding and foliation and they occur parallel to subparallel relative to core-axis.

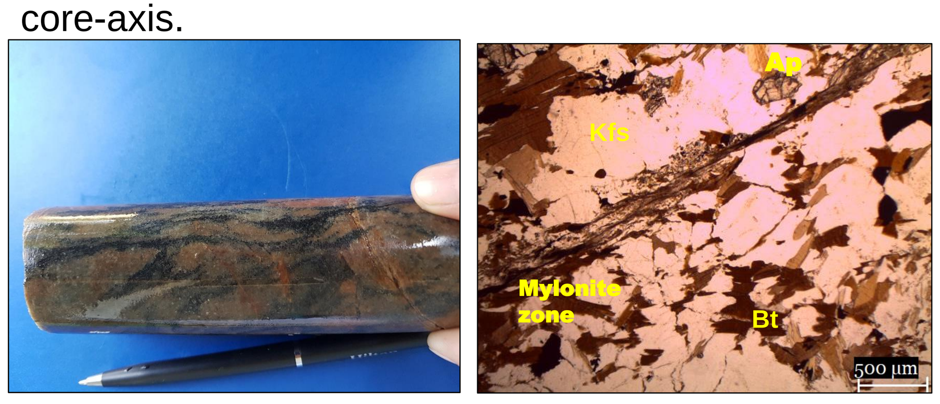

Figure 3: Migmatitic granulite showing it's typical leuco- and melanosome (left); Thin section in XPL of the leucosome with biotite and K-feldspar (right)

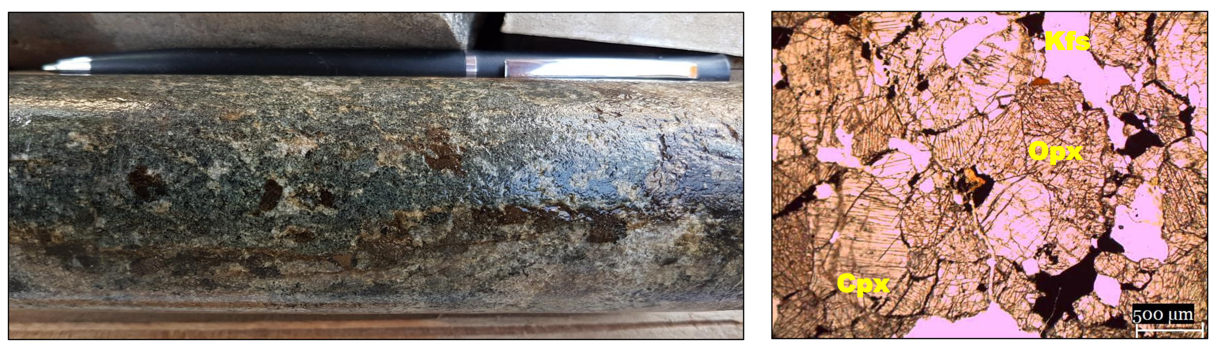

Figure 4: Ca- silicate granulite with cpx and opx (left); Thin section in PPL showing cpx, opx, K-feldspar and opaque minerals between contacts (right)

Aim of Research

The current research compiled and georeferenced the historic data and re-examined core and thin sections plus new ICP-MS analysis of pulps that are still retained. The intent of this research is to update and attempt to re-study the core and thin section, using new technology and mineralization models since the extensive investigation of Dalhberg and other geologists in the seventies and eighties of the previous century on this mineralization.

Historic Study

In the 70's Dahlberg carried out an extensive program of exploration on the K3 Cu-phosphate anomaly in the SW part of the BGB, including a combined magnetic- induced polarization- resistivity survey, soil sampling, geological mapping and diamond drilling (Figure 2). The drill core with the strongest copper mineralization average 0.33% (Dahlberg, 1987). The drill-core did not go deeper than ~ 100m. The sulfidic copper mineralization consists mainly of chalcopyrite and bornite.

Phosphate mineralization in the form of apatite-rich lenses is associated to the Cu mineralization, but does not coincide exactly, the highest phosphate values were found outside the main copper mineralized zone (Dahlberg, 1987). Anomalous P, Ce, Th, Zr and Sr soils in an approximate north tending zone were thought to correspond to buried apatite-rich lenses. This zone is part of a larger northeast- trending Ce-Th anomaly found by stream sediment sampling (Dahlberg, 1987)

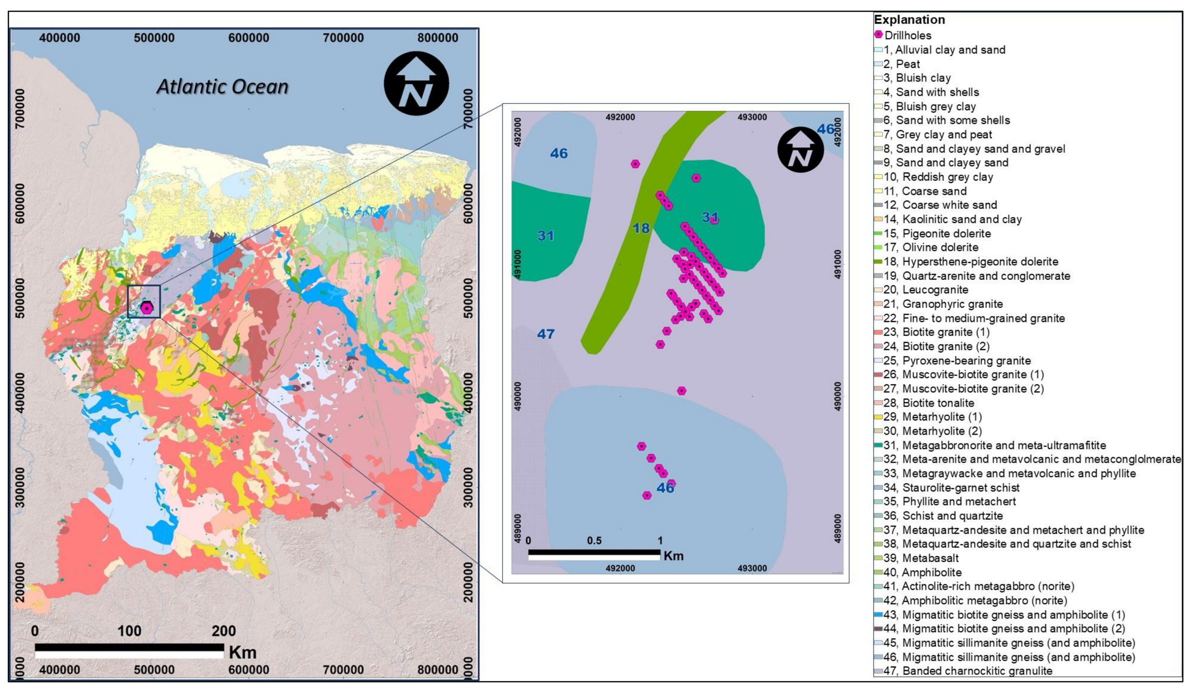

Figure 2: Location of the diamond drillholes drilled in K3 prospect relative to the geological map of Suriname (1977).

Results- Copper and Phosphate mineralization

Geochemical analyses shows that the copper mineralization is distributed over various rock types, but higher values occur mainly in the migmatitic granulites and occasionally in the Ca-silicate granulites. Macroscopic determination showed that the copper is mostly concentrated in the pink to cream bands of the migmatitic granulites, in the form of bornite, chalcopyrite and secondary minerals.

The bornite is frequently present in fractures, accompanied with the secondary minerals. The bornite may represent a supergene enrichment based on presence in fractures. These fractures are irregular in length and crosscutting the foliation/lineation of the rock. These fractures are also frequently filled with magnetite. Geochemical analyses shows that high Cu values are concentrated in shallow depth (5-50m) and decreasing with depth, suggesting a supergene enrichment.

Chalcopyrite appears as fine grain and disseminated usually found in the mafic layering and streaks and sometimes filled in minor fractures.

Phosphate as apatite occurs in the migmatitic granulites, but higher concentrations have been observed in the Ca-silicate granulites

Figure 5: Leucosome of migmatitic granulite containing copper minerals (left), Ca-silicate granulite showing high concentration of apatite (right)

Copper Models

	Porphyry copper (Sillitoe 2010)	Skarns (Hammerstrom et al, 1995)	Volcanogenic massive sulfide (VMS) (Shanks et al, USGS, 2010)	Sedimentary hosted (Hayes et al, 2015)	IOCG (Pirajno, 2009)		Bakhuis Cu (Dalhberg, 1987)	Bakhuis (Patadien et al, 2019)
Host Rock Type	Intermediate to felsic porphyry intrustions	Highly calcareous sedimentary rocks or metamorphosed carcareous sedimentary rocks; Carbonate rocks and clastic rocks as pelite, argillite, shale, graywacke etc	Volcanic and sedimentary rocks as tuffs, shales, siltstones, and (or) sandtsones, coarse volcanic breccias and fragmental pyroclastic rocks	Sedimentary rock sequences, deposited within 20- 30 degree of the paleo-equator	Variable	**Host Rock Type**	Metamorphosed felsic to intermediate volcanics and phosphatic siliceous carbonate sediments of the supracrustal succesion.	Migmatitic granulite, Ca-silicate granulite
Depositional Environment	Magmatic arc subjected to a spectrum of regional-scale stress regimes	Granitoid pluton intrusion in sedimentary strata of carbonate-rich rocks.	At or near seafloor where circulating hydrothermal fluids driven by magmatic heat are quenched through mixing with bottom waters or porewaters in near-seafloor lithologies	Proto-oceanic rifts/ post-collisional molasse	Forms in shallow crustal environments (4-6 Km) in Intrusion related magmatic-hydrothermal systems	**Deposition Environment**	Mafic rocks intrusion assimilate Cu, S and P from supracrustal sequence including copper-rich volcanices, phosphorites and sulphur-rich evaporites	
Structural Controls	Moderately extensional through oblique slip to contractional	No structural controls, related to magmatic- hydrothermal activity	Extensional oceanic seafloor spreading ridges, volcanic arcs (oceanic and continental margin), and related back-arc basin environments	Virtually undeformed to intense folded and thrust-faulted	Related to deep- seated megasturctures in intracontinental rifts	**Structural Controls**	Unknown; general trend of the rocks is northeast to north-northeast and dipping subvertical to steep to the north-west, cross cuts of strike -slip faulting	Not observed. Host rock oriented subparallel to core-axis and minor folds resulted from
Ore minerals	Quartz, tourmaline, specularite, chalcopyrite and pyrite	Chalcopyrite, pyrite, hematite, magnetite, sphalerite, galena, arsenopyrite	Pyrite, pyrrhotite, chalcopyrite, sphalerite and galena	Chalcocite, bornite, pyritic	Chalcopyrite, bornite, chalcocite, pyrite Magnetite, hematite	**Ore Minerals**	**Primary (Cu):** Bornite, chalcopyrite, accompanied by pyrite, pyrrothite, pentlandite, sphalerite, gold, magnetite, rutile and chromite **(P2O5):** Fluor Apatite **Secundary:** Covelite, Digenite, Chalcocyte	Primary (Cu): Bornite, chalcopyrite, pyrite. (P2O5): Apatite Secundary: Azurite?
Alteration	Potassic ± chlorite- sericite	Hornfels, narble, bleached limestone, skarn zones: potassic, sericite, argillic, propylitic alteration	Wide variety of hydrothermal alteration among individual deposits; Advanced argillic, argillic, sericitic, chloritic, carbonate propylitic	Albitization, hematitization	Allkali-rich alteration (Sodic-calcic-Na (Ca) and potassic-K, biotite, amphibole	**Alteration**	Montmorillonite, calcite, apatite, magnetite, microline, albite, biotite, muscovite, quarts, zircon, ilmenite, goethite, tremolite, epidote	Potassic and albitization?
Element Enrichment	Cu, Mo, Au, Pb, Zn, Ag	Cu, Au, Zn-Pb, Fe	Cu, Zn, Pb, Au, Ag	Cu, Ag, Co, Ba, Mg, B	Cu with/ without Au, Fe	**Element Enrichment**	Cu, Phosphate	Cu, Phosphate
						Metamorphic facies	Granulite Facies	Granulite Facies

Discussions and Conclusions

Some preliminary conclusions can be drawn from the drill-core and thin sections study.

The copper mineralization is typically found in light pinkish-cream colored band rich in feldspar, intercalated between dark bands, associated with chalcopyrite, bornite and secondary Cu minerals that are macroscopically visible. The fresh appearance of the Cu mineralization and the lack of younger associated alteration suggests that the Cu enrichment occurred during UHT metamorphism, or even before, during the precursor stage of the granulites. Correlation matrix of ICP-OES data shows that copper is strongly correlated with sulphur, indicating presence of sulfide minerals. Ag, Na, B, Be, Li, Pb, Sb, Se and Sn show weak correlation with Cu. Similar weak correlation is found with phosphate. Supergene enrichment maybe a factor, due to Cu enrichment in shallow depth and reducing with depth.

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