HOST ROCKS, ALTERATION MINERALOGY, AND MINERALIZATION STYLES OF VMS-TYPE DEPOSITS IN THE SERRA NORTE AND SERRA SUL REGIONS, CARAJÁS PROVINCE, BRAZIL

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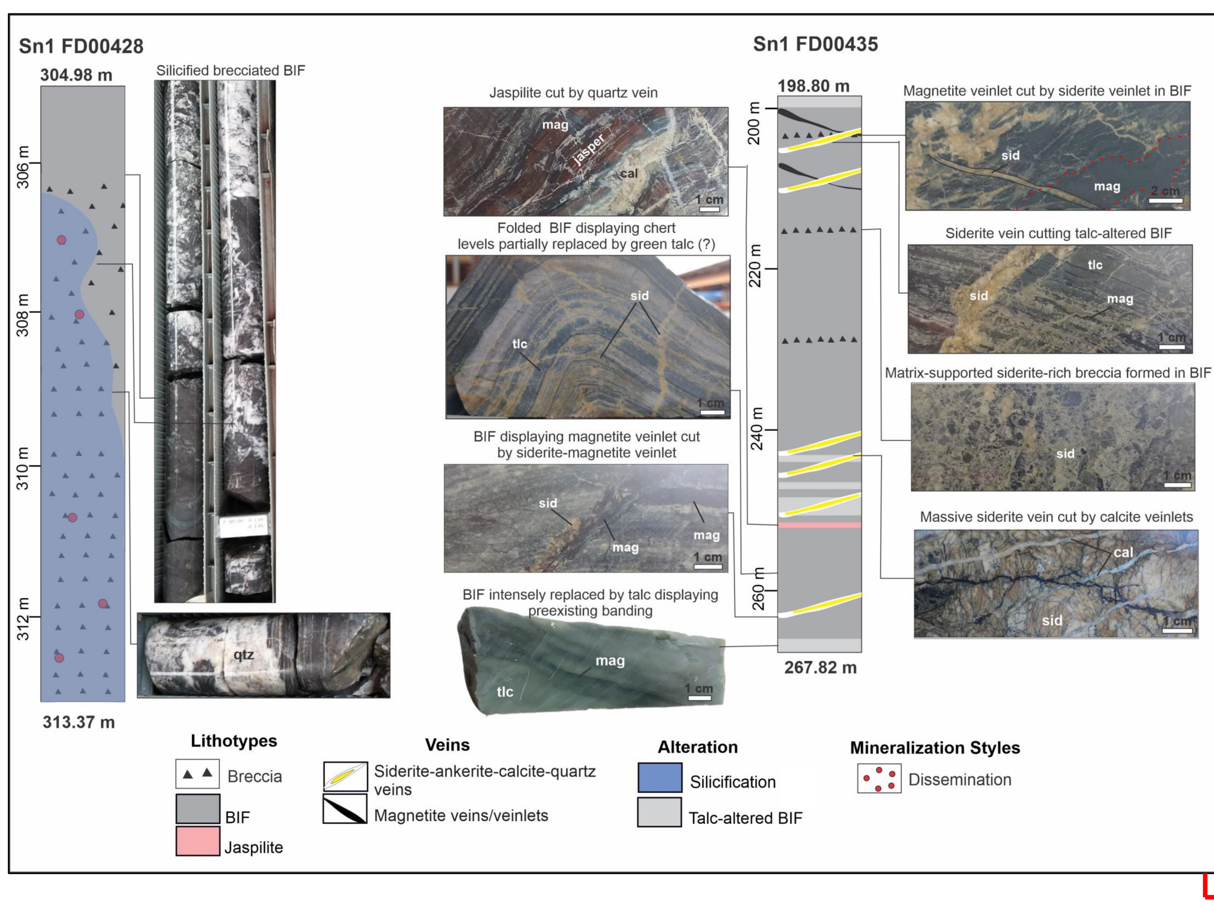
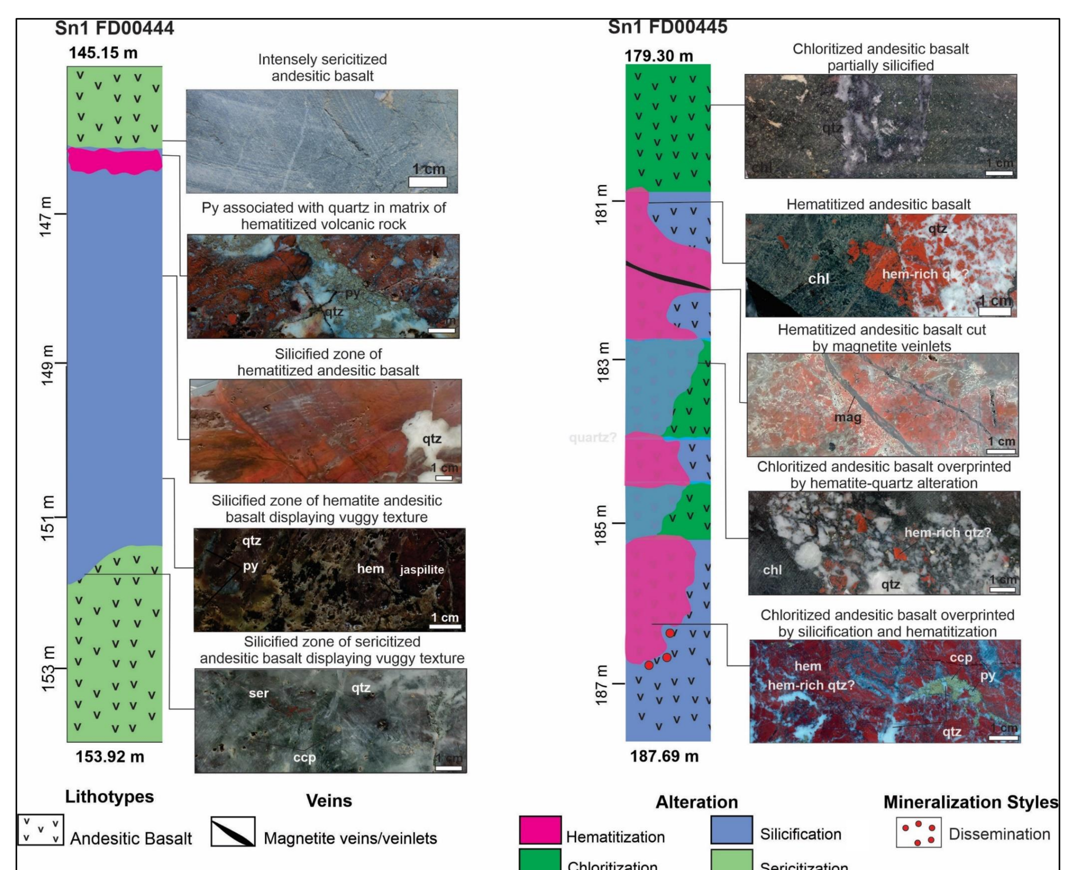
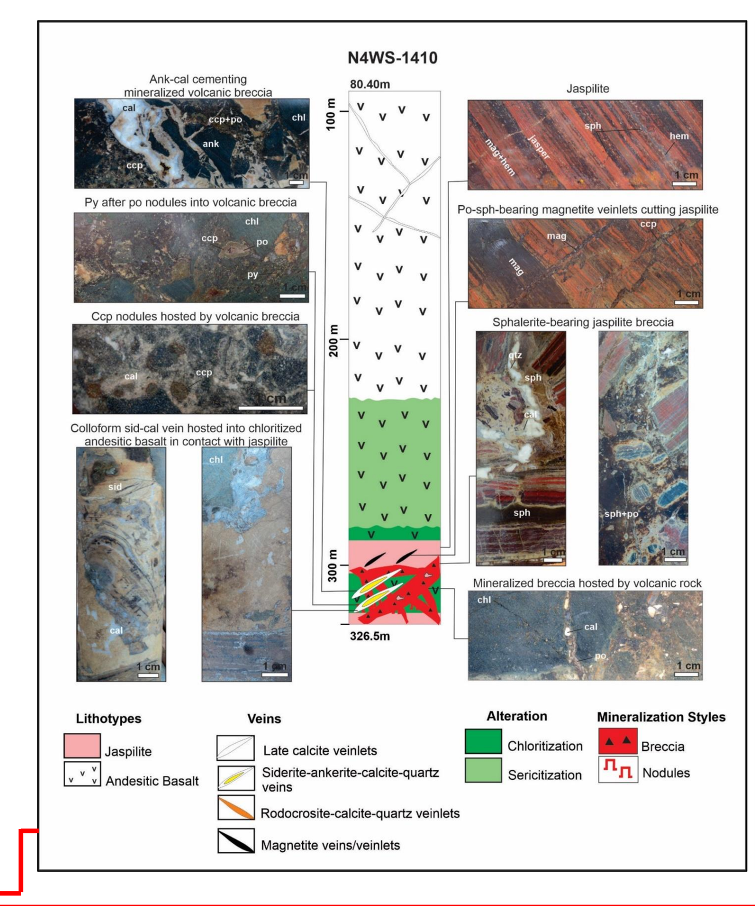
INTRODUCTION

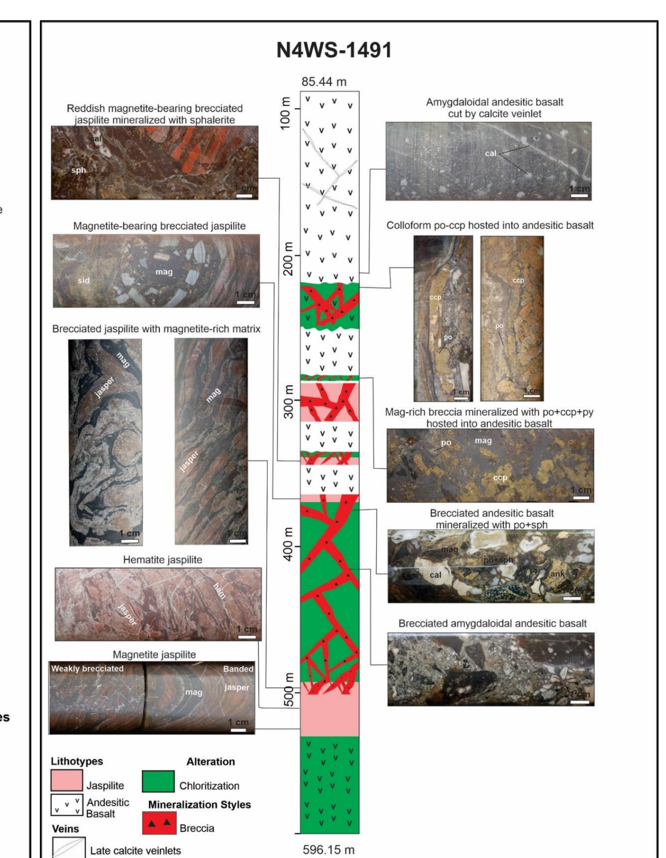
The first major metallogenic epoch ca. 2.76-2.74 Ga in the Carajás Mineral Province (CMP), southeastern Amazonian Craton, is marked by the formation of giant syngenetic iron and manganese deposits. Minor copper-zinc mineralization formed by processes similar to those of massive volcanogenic sulfide (VMS) deposits has also been recognized and attributed to that epoch. This is the case for the N1, N4WS, and GT-57 deposits as well as the S11D deposit which are located in the Serra Norte and Serra Sul regions of the CMP, respectively. Detailed core description was carried out to evaluate the host rocks, alteration zones, as well as ore assemblages and styles in these deposits.

RESULTS









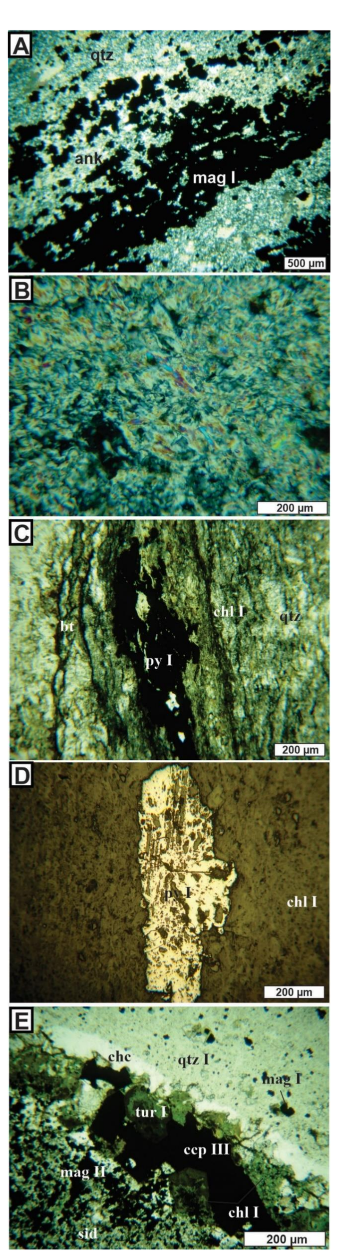
[A] Fine lamination in grey iron formation composed of chert, ankerite and magnetite (I) (SN1-FD00428/305.65m).

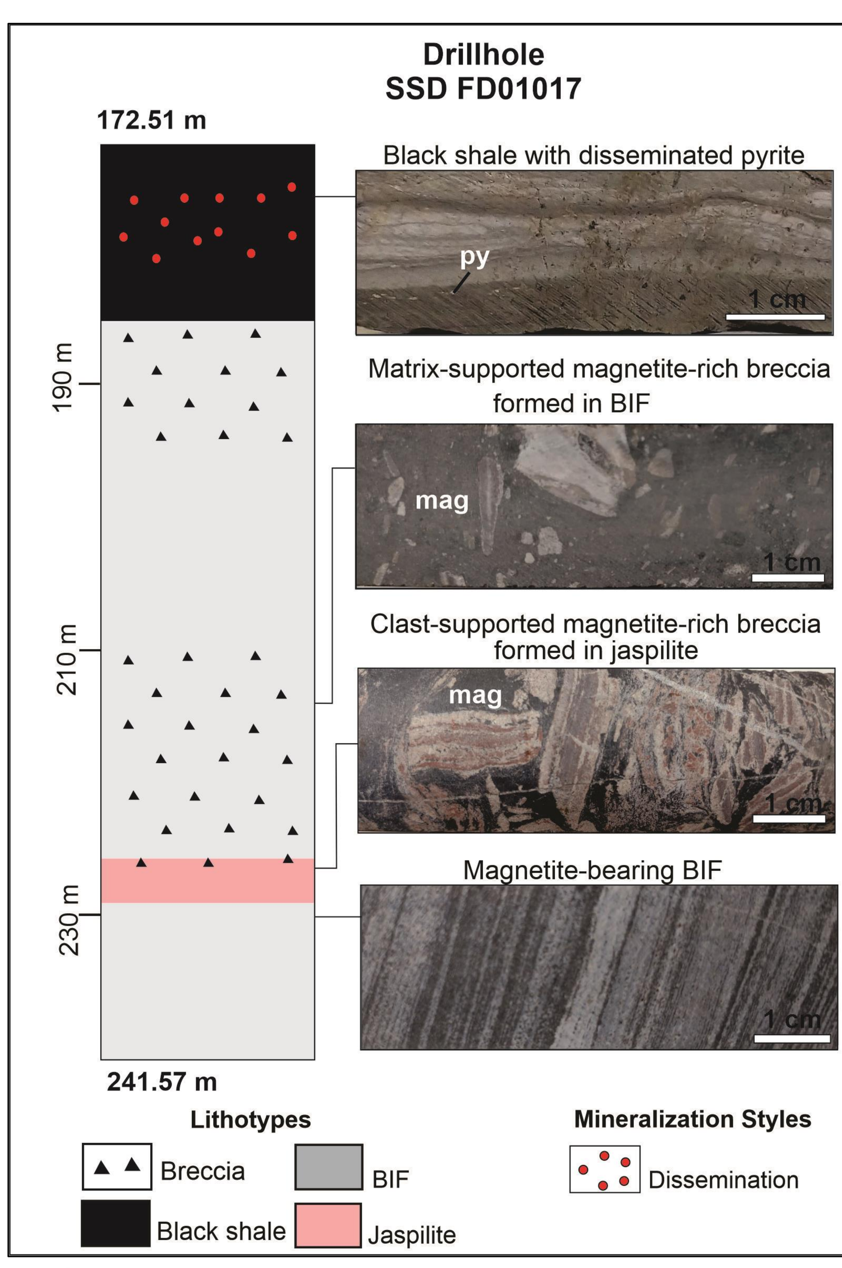
[B] Grenalite/muscovite rich matrix in magnetite-bearing iron formation (SN1-FD00435/267.15m).

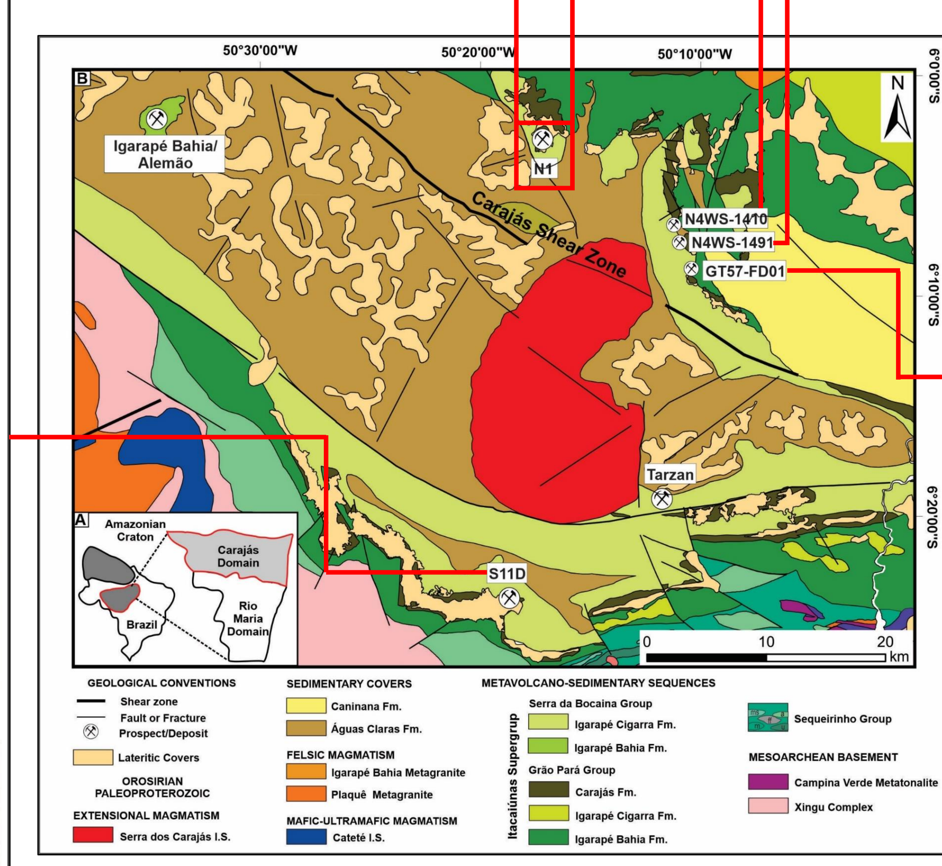
[C] Intercalation of quartz and chlorite laminae in black shale displaying

[D] hypidiomorphic diagenetic pyrite (I) crystal (SSD-FD01017/174.55m)

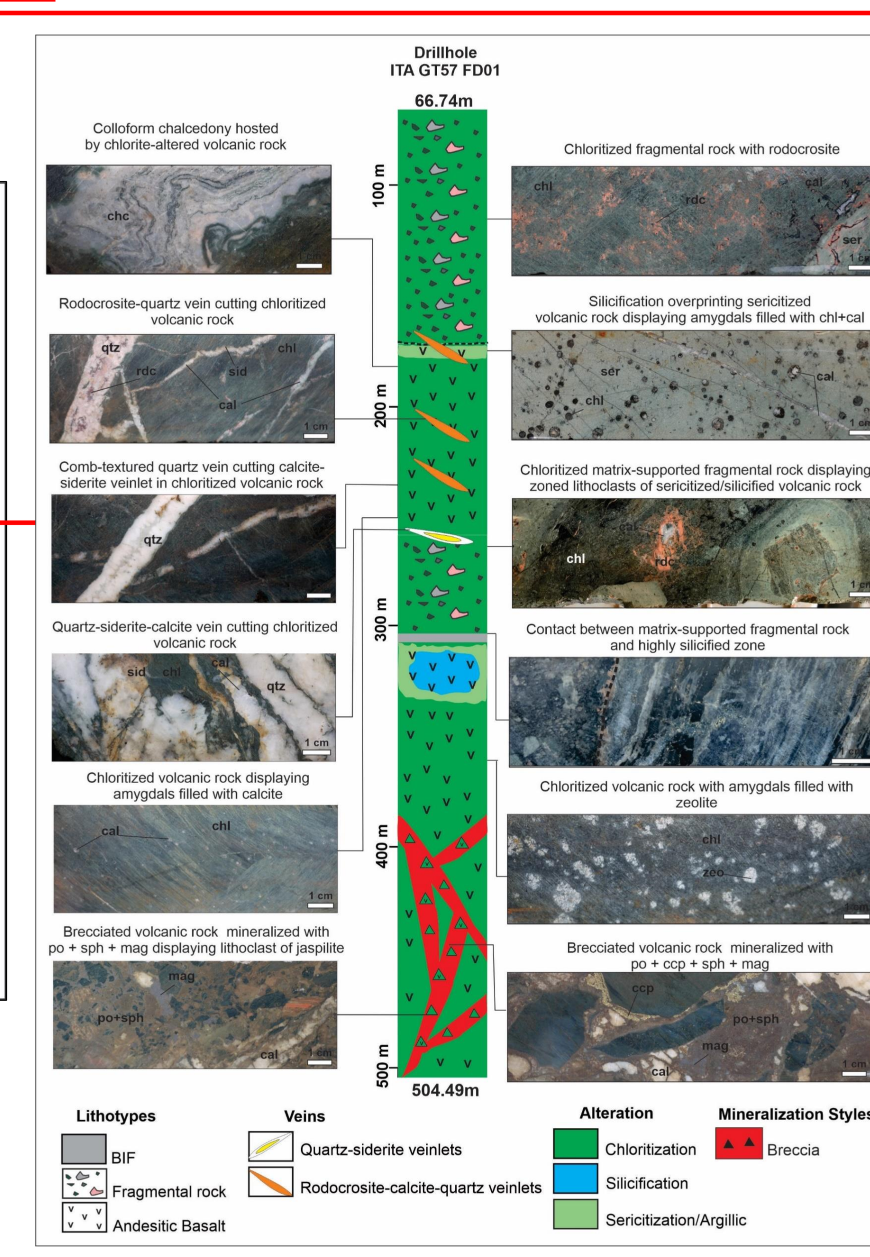
[E] Contact between a BIF lithoclast and siderite-magnetite (II) rich zone in the breccia matrix (SSD-FD01017/211.30m)

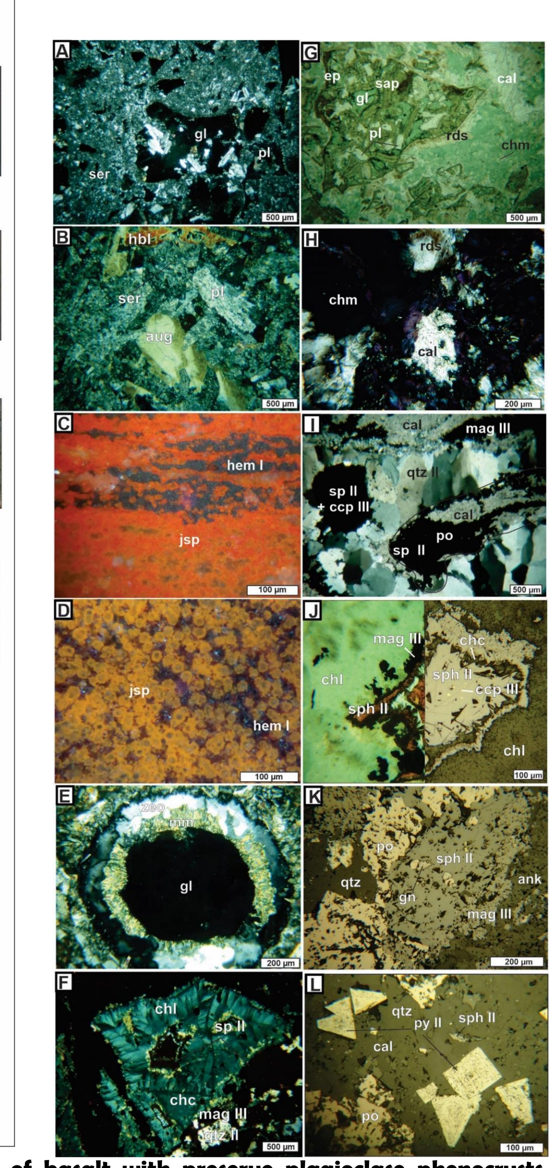






Location of the Carajás Domain in the Amazonian Craton and its simplified geological map and location of the drillcores studied as shown by the red rectangles (extracted from Costa et al., 2016).





[A] Matrix of fragmental rock intensely chloritized displaying lithoclasts of basalt with preserve plagioclase phenocrysts (GT57-FD01/68.74m). [B] Matrix of andesitic basalt displaying subophitic arrangement and aureoles of hornblende around augite (N4WS-1491/153.12m). [C] Fine lamination in jaspilite composed of hematite (I) and jasper (N4WS-1491/509.08). [D] Spherulites in jasper layer in jaspilite (N4WS-1491/509.08m). [E] Basalt amygdala filled with from the center to the border by glass, smectite, and zeolite (GT-57 FD01/304.4m). [F] Strongly brecciated basalt displaying chloritization superposed by silicification (fibrous chalcedony) with focus on red sphalerite to the center (GT-57 FD01/420.8m). [G] Relict fragment of basalt completely altered by fibrous smectite immerse in glass and chlorite rich groundmass (GT-57 FD01/116.1m). [H] Chamosite-clinochlore rich matrix in carbonatic propylitic alteration zone (GT-57 FD01/116.1m). [I] Sphalerite and pyrrhotite disseminated in calcite-magnetite-quartz rich zone in brecciated basalt (GT-57 FD01/483.15m). [J] Red sphalerite intergrown with with magnetite and carbonate in chloritized and silicified fragment of andesitic basalt (GT57-FD01/420m). [K] Sphalerite II in carbonate-rich matrix of brecciated andesitic basalt (GT57-FD01/420m). [L] Square pyrite crystals associated with ankerite-calcite rich matrix (GT57-FD01/411m). [L] Close detail of pyrite crystals in breccia matrix (GT57-FD01/420m).

Table 1. Summary of the geology of the studied deposits in the Serra Norte and Serra Sul regions.

Region	Serra Sul	Serra Norte		
Characteristic/Deposit	SSD	N1	N4WS	GT-57
Host rocks	Banded iron formation (magnetite facies), Black shale, Jaspilite (magnetite facies)	Andesitic basalt, Banded iron formation (magnetite facies) Jaspilite (magnetite facies)	Andesitic basalt, Jaspilite (hematite facies)	Fragmental rock, Andesitic basalt
Hydrothermal alteration	Absent	Sericitization, Chloritization, Silicification, Hematitization	Chloritization, Sericitization, Carbonatic Propylitic	Argillic, sericitization, Silicification, Chloritization, Carbonatic propylitic
Ore assemblage/style	Minor pyrite disseminated along the layering of black shales	Minor chalcopyrite and pyrite disseminated in silicified zone Minor chalcopyrite along siderite veins	Sphalerite-pyrrhotite-chalcopyrite rich breccias hosted into jaspilite Pyrrhotite-chalcopyrite-pyrite-magnetite-sphalerite-galena-rich breccias hosted into andesitic basalt	Pyrrhotite-chalcopyrite-pyrite-magnetite-galena-rich breccias hosted into andesitic basalt
Distinctive features	1. Matrix-supported magnetite-rich breccia (BIF); 2. Absence of mineralization and hydrothermal alteration	1. Greenalite-rich levels; 2. Abundance of siderite veinlets and veins	1. High sulfide content; 2. Lower degree of alteration (sericitization > chloritization > carbonatic propylitic)	1. The presence of fragmental rock unit; 2. Rhodochrosite-rich alteration zone (carbonatic propylitic); 3. Higher sulfide content; 4. Higher degree of alteration (chloritization > carbonatic propylitic > sericiticitization);

Host rocks are represented by the intercalation of fragmental rocks, andesitic basalt, and banded iron formation in these deposits. The Serra Sul deposit occur in settings with pyrite-bearing black shales overlying dominantly magnetite-rich banded iron formation (BIF). The latter contains magnetite-rich matrix-supported to clast-supported breccias, and subordinate intercalations of magnetite-rich jaspilite.

The alteration types observed for the VMS deposits are observed at with distal local hematite and sericite alteration (~40 to 200 m) and proximal argillic and chloritized zones (< 40 m). However, the main ore stage is associated with the precipitation of variably Mn and Fe-rich carbonate that cement the matrix of breccias hosted into chloritized andesitic basalts. The mineralized breccias consist of a carbonate-rich (calcite-ankerite-rhodochrosite) matrix intergrown with an assemblage of magnetite-pyrrhotite-pyrite-chalcopyrite-sphalerite-galena-cobaltite. Magnetite is xenomorphic, granular and fine-grained (50 to 800 μm) and makes up between 5 to almost 30% of the volume.

Pyrrhotite is hypidiomorphic to xenomorphic and granular, varying in size between 50 and 7000 μm, and occupies up to 20%. Pyrite is idiomorphic and makes up to 10% in volume of the breccia matrix, where it commonly occurs in square and triangular sections of 100 to 1300 μm in size. Sphalerite grains up to 100 μm in size occupies up to 3% in volume of the breccia matrix and contain high contents of Mn and inclusions of galena. Cobaltite only occurs as trace amount in association with pyrrhotite.

DISCUSSION AND CONCLUSION

The fragmental unit here identified matches the description of rocks previously described at the Igarapé Bahia deposit which have been attributed either to syndepositional faulting (Dreher & Xavier, 2001; Dreher et al., 2005) or later hydrothermal activity (Tavaza & Oliveira, 2000; Tallarico et al., 2005). Detailed petrographical analysis and drill core relationships at GT-57 revealed the gradual contact between undoubtely mineralized brecciated basalt and pervasively and strongly altered fragmental rock unit.

This indicates that the so-called fragmental rock unit at GT-57 could instead result from the infiltration of seawater and progressive replacement of primary assemblage to the extent that the andesitic basalt of the Parauapebas Formation was barely recognizable.

The alteration zones and respective gangue minerals textures at the studied deposits are consistente with diagnostic assemblages for unmetamorphosed deposits as mainly demonstrated by the presence of lower temperature (150-400 °C) minerals, such as chalcedony and smectite (Bonnet & Corriveau, 2007; Shanks et al., 2012).

The studied deposits can be lithologically classified as back-arc mafic VMS deposits (Galley et al., 2007) or formerly Besshi type (Cox & Singer, 1986) on the basis of the dominant basic nature of the magmatism and the previously back-arc settings (Silva et al., 2020) interpreted for the formerly Carajás Basin, which is also corroborated by the presence of Algoma-type BIFs (Justo et al., 2020).

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