Serviço Geológico do Brasil

Brazil

Geological Survey under the Spotlight

SGB-CPRM
Focus on Development of Brazilian Mineral Sector

SGB-CPRM Programs:

Program I
Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brazilian Shields

Program II
Basic Geological Mapping

Program III
Mineral Potential Assessment of the Brazilian Volcano-Sedimentary Sequences

Program IV
Crustal Evolution and Metallogeny of the Brazilian Mineral Provinces

Program V
Thematic Projects

Project Areas:

Carajás
Fe, Mn, Cu-Au, Ni, Au-PGE, PGE-Ni, Au-Mo-W-S, Cu-Zn, Sn.

Tapajós
Au, Au-Cu, Sn, W

Quadrilátero Ferrífero
Fe, Au, Mn, Sn, Au-U

Alta Floresta
Au, Au-Cu, Zn-Pb-Cu-Au

Borborema (Seridó)
W, Au, Fe, Fe-Ti, Cr, Cr-PGE, Cu, Pb-Zn

Nova Brasilândia
Zn-Pb, Au

NW Ceará
Cu, Pb-Zn, Mn

Gurupi
Au

There is a global consensus: Brazil is one of the world top players in the mining industry. The country covers a very large area (8.5 million km2), 43% of which with potentials for iron ore, precious and base metals, diamonds, bauxite, manganese, tin, rare earths, graphite and other mineral commodities. Brazil has low maturity despite of high fertility due to its very low levels of investments in mineral exploration, offering therefore a significant potential for new discoveries. The Geological Survey of Brazil (CPRM) provides the state of the art of the mineral potential of the country, with focus on the main mineral provinces like Carajás, Iron Quadrangle and others. The studies presented in this document consolidate the knowledge accumulated during the last decades, by integrating disciplines like geology, geochemistry, geophysics and metallogenesis. Their interpretations in progress for the most important mineral provinces of Brazil can result in great exploratory programs, leveraging the mineral exploration and adding value to the Brazilian mining sector.

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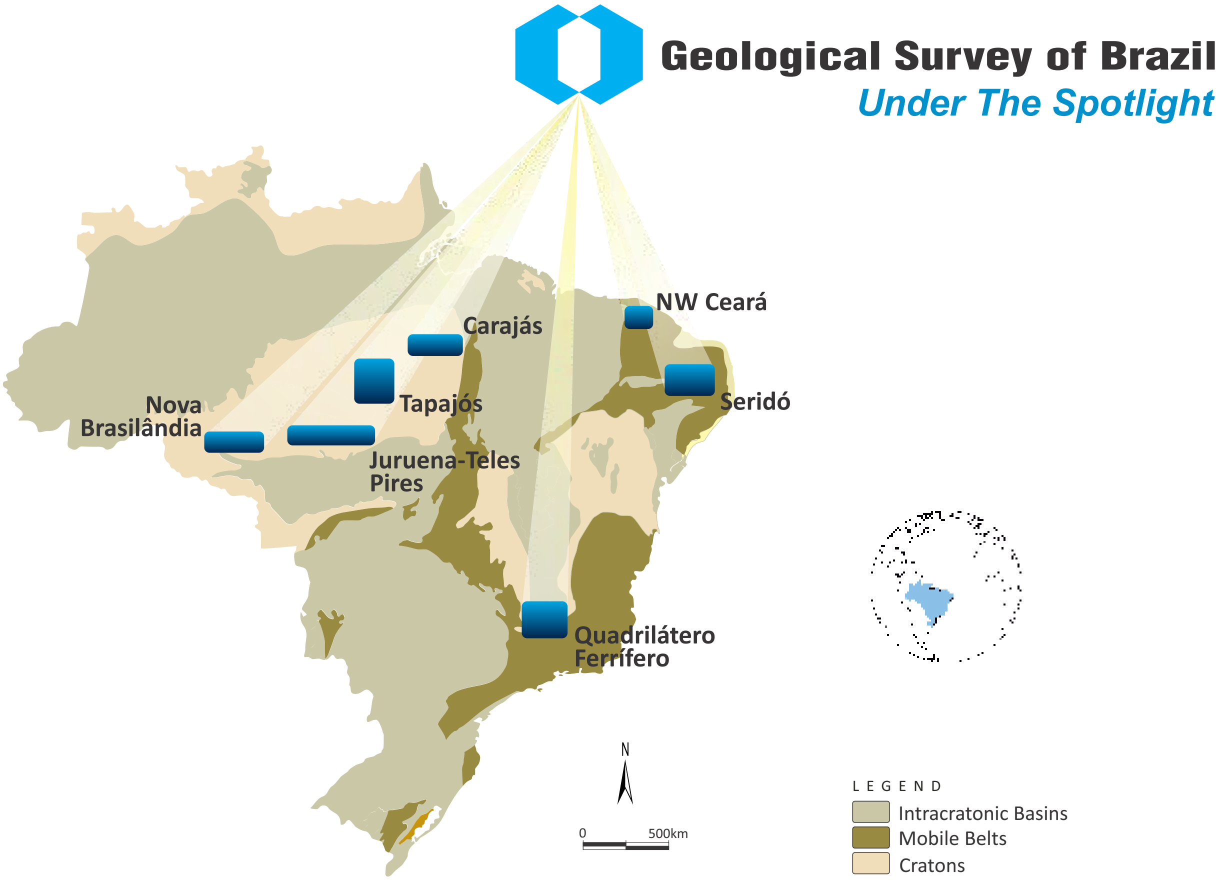

Highlights

BRAZIL

- ✓ Brazil is a world key player in the mining sector and will continue to be. All the efforts are being made by the Brazilian Government to bring back the attractiveness of the country, including major investments by the Geological Survey of Brazil (CPRM) to generate high quality geological, geophysical and geochemical data.
- ✓ Most of the Brazilian cratonic areas are already covered by airborne magnetic and radiometric survey with 500-m line spacing. Semi-regional geochemical sampling and assessment already cover many parts of the main mineral provinces. Geological mapping at 1:100,000 scale, focusing on areas with greater mineral potential, is in progress. All the data are freely accessible from the online GeoSGB database (http://geosgb.cprm.gov.br/).
- ✓ The geological endowments of Brazil are similar to those of major ore producing countries such as Australia, Canada and South Africa. 43% of the continental area is covered by Neoproterozoic-to-Archean terrains, all with high potential for metals.
- ✓ Compared with countries of similar geological setting such as Australia and Canada, Brazil benefits from many less investments in mineral exploration, making its exploratory potential underestimated.
- ✓ Brazil is one of the world leading producers of niobium, iron ore, vermiculite, bauxite, graphite and kaolin, as well as an important exporter of tin, nickel, magnesite, manganese, chromium, gold and dimension stones.
- ✓ Despite its large potential, Brazil continues to import copper, sulfur, titanium, phosphate, diatomite and zinc, and also has a deep external dependence on coal, potassium and ETR. The window of opportunities is open for small-to world-class mines.
- ✓ Gold and diamond productions are rising thanks tonew discoveries and mining development.

- Limited deep mineral exploration has been carried out in Brazil, including in "mature" provinces as exemplified in the Quadrilátero Ferrífero. Less than 15 underground mines of gold, chromite, copper and zinc are currently in operation in Brazil, which corresponds to less than 4% of the total number of mines. There is an increasing potential for deep discoveries and mining development.
- Archean and Paleoproterozoic greenstone belts are widely distributed in Brazil, both in São Francisco, Amazon and São Luís cratons, with a clear potential for significant new discoveries, in particular for gold and sulfide nickel.
- The country has also a real potential for new discoveries in geological formations derived from Earth´s mantle processes: carbonatites, IOCG, intraplate magmatic gold deposits, TZ diamonds and epithermal gold in anorogenic complexes.
- Brazil has an important history of alluvial diamond production. The current number of known outcrops of kimberlites, lamproites and related rockssums up to 1,344, with only one primary mine to date that produces high quality gemstones (Braúna Mine, in Bahia State).
- The world-class discovery of the Zn-Cu Aripuanã deposit opens a new exploratory frontier related to Paleoproterozoic continental rifts, particularly in northern Mato Grosso and Rondônia states.
- The probability of new Cu-Au discoveries in the Goiás Magmatic Arc is high. Recent understanding has emerged on the role of metamorphism and deformation in the origin of porphyry-style mineralization.
- The Neoproterozoic belts at the margin of the cratons have characteristic tidal-flats and organic-rich lagoon sedimentary facies, which are still largely unexplored for Morro do Ouro type gold mineralization (Kinross, >20 MOz Au).
- The potentials are considered very high for Ni in magmatic conduits, iron oxide-nickel-copper (IOCG and IONC) mineralization, and Zn-Cu-rich sediments related to the Amazonian intracratonic rifts.

Quadrilátero Ferrífero

- The Quadrilátero Ferrífero (QF) is one of the most important mineral provinces in the world. First gold discovery dates from 1695, with continuous production since then (>50 MOz Au).
- Current known resources and reserves exceed 20 MOz. There are six gold mines in operation. The two major deposits are Morro Velho that produced 470 tons of gold between 1725 and 2003, and Cuiabá with 150 tons of gold in past production and reserves.
- For indication, AngloGold Ashanti produced 421,000 Oz Au in 2015 in three mines (Cuiabá, Lamego and Córrego do Sítio) while Jaguar Mining produced 96,536 Oz from three other operations (Turmalina, Pilar and Roça Grande mines) in 2016.
- There are currently 52 iron ore mines in operation at QF, some in care-and-maintenance due the low commodity prices in 2016. More than 12 billion tons of iron ore have already been produced at QF, with grades above 50%.
- The western portion of the QF, where the Turmalina mine (Jaguar) is located, includes occurrences of komatiite flows, felsic pyroclastic rocks, BIF sulfide facies, and unusual clay epithermal alteration systems. A new discovery by Iamgold (São Sebastião) confirms the high potential for this underexplored portion of the QF.

Carajás

- The Carajás Mineral Province (CMP) is among the largest polymetallic mineral provinces in the world, the second largest for IOCG (Cu-Au).
- The CMP iron ore deposits have the highest grades in the world with >65% Fe. Current resources and reserves are estimated >20 billion tons. Vale currently operates mines at the northern (N4 and N5) and southern (S11D) portions of the province.
- There are four copper-gold mines currently in operation at Carajás including Salobo (200,000 tpy, Vale), Sossego and Sequeirinho (100,000 tpy combined, Vale), and Antas North (Avanco Resources).

- ✓ The nickel produced at Carajás comes from the Onça-Puma laterite nickel operation, with production of 24,400 tons in 2015. Other important deposits are Vermelho, Jacaré, Jacarezinho and Mundial.
- ✓ Other mining operations at Carajás include the Azul and Buritirama manganese mines and small cassiterite operations at São Felix do Xingu.
- ✓ Carajás is a polycyclic geological province with several mineralizing periods leading to different types of deposits: Cu-Au-Zn, PGE-Ni reef, IOCG, IONC, Cu-(Au-Mo-W-Sn), Cu-Au-Mo-F, Fe, Mn, laterite nickel.
- ✓ The most significant deposits in Carajás were discovered from geochemical and magnetometric surveys. The discovery of even undetected magnetic IOCGs is considered also possible.
- ✓ New discoveries of IOCG deposits are to be expected, particularly when more detailed works will be developed in the areas where the presence of BIF might possibly mask magnetic responses of the IOCG.
- ✓ The targeting of small-size, high-grade Cu-Au deposits, such as in progress by Avanco at Antas and Pedra Branca deposits, and by Tessarema Resources at Maravaia Project, represent an important development step for CMP.
- ✓ There are also possibilities for base metal discoveries along lateral variations in BIFs. Possible syn-sedimentary faults with evidences of exhalative feeding have been found.
- ✓ The Cu-Au mineralizing corridors extend the area of the Carajás basin mainly to the south into the Rio Maria Domain.

Tapajós

- ✓ The gold mineralization of Tapajós Gold Province (TGP) has some characteristics similar to several other Au-Cu mineralized areas around the world.
- ✓ The TPG is essentially a siliceous large igneous province with a magmatic system covering an area of 480,000km^2. The quartz-sulfide-gold veins there represent roots of mineralizing processes associated with the past activity of hundreds of calderas and other volcanic edifices. High and low sulfidations were both parts of the overall mineralizing process.
- ✓ About 700 tons of gold have already been produced by artisanal prospectors (garimpeiros) from mostly alluvial formations. The economic potential of the area remains underestimated due to a limited scientific exploration that has been carried out until now.
- ✓ The main deposits already determined at TGP are Tocantinzinho (3.9 MOz Au reserves and resources), São Jorge (1.58 MOz Au), Coringa (913 KOz Au), Palito (668 KOz Au) and Boa Vista (336 KOz Au).

Juruena – Teles Pires

- ✓ The Alta Floresta Mineral Province (AFMP) extends from northern Mato Grosso State to Amazonas State. A 600 km long prolific gold trend gave rise to a past production of 300 t Au.
- ✓ Au-Cu occurrences, hosted in subvolcanic felsic rocks and associated to propylitic and phyllic alterations, have been identified at AFMP without however having been adequately drilled for exploration.
- ✓ Almost all the gold deposits in Brazil have been so far discovered by “garimpeiros” or by broad geochemical reconnaissance. Little scientific exploration has been carried out. Gold, gold-copper and polymetallic sulfide deposits have been discovered at AFMP, which are coeval with volcanic-plutonic rocks dated between 1.82-1.70 Ga. The main deposit is Aripuanã and consists of world-class Zn-Pb-Ag-Cu-Au concentrated at northern Mato Grosso State.
- ✓ There are currently only one small gold mine (Paraíba) in operation and one project under licensing (Aripuanã) in the whole AFMP.

Seridó

- ✓ The Seridó Mineral Province (SMP) has been hosting tungsten mines since the 1940´s with some that are still in production, and more recently gold, iron ore, gemstones and kaolin mines.
- ✓ The SMP has over 700 skarn occurrences containing W-Mo (Brejuí, Bodó, Bonito, Malhada Limpa and Quixadá mines), gold (Itajubatiba mine) and gold with associated W-Mo-Bi-Te (Bonfim mine).

- ✓ The main tungsten deposits are located at Brejuí (initially 11 Mt of WO_3 - 5.5 Mt remaining at 0.5-1.0% WO_3) and Bodó (9 Mt at 2% of WO_3).
- ✓ The potential for base metals associated with the skarns has yet to be explored, even with the presence of massive sulfide lenses associated to some of the tungsten mineralizations.
- ✓ The São Francisco deposit, in licensing process by Crusader Resources, contains 1.61 Mt of proven and probable reserves and a total of 2.43 Mt in all-categories resources (http://www.crusaderresources.com/projects/borborema-gold/, 19/02/2017).
- ✓ Mineral exploration at SMP has been very limited until now, focusing mainly on tungsten. New opportunities for gold and base metals are being considered from their discovery in Mesoarchean volcano-sedimentary sequences.

Gurupi

- ✓ The São Luis cratonic fragment was isolated from the West Africa Craton and remained in South America after the opening of the Atlantic Ocean.
- ✓ The Chega Tudo and Igarapé de Areia formations are therefore comparable to their African counterparts represented by the Ashanti Belt, Sefwi and Tarkwan Groups, which host giant ore deposits with a total endowment of about 125 MOz.
- ✓ The Tentugal shear zone with its gold trend extends for more than 100 km along strike and is interpreted to continue to the North beneath the Cambrian-Phanerozoic cover. The similarities between the Tentugal shear zone and Birimian mineralizations are particularly evident in terms of host rocks, mineralizing processes and tectonic control.
- ✓ New exploration targets have been highlighted by the Geological Survey of Brazil (CPRM) on its predictive prospectivity map of Gurupi Belt, which are associated to both first- and second-order structures and their extension underneath the sedimentary cover. All the relevant geological, geophysical and geochemical informations are freely accessible from the online GeoSGB database (http://geosgb.cprm.gov.br/).
- ✓ Four main deposits with already defined resources are known at Gurupi Belt and São Luís cratonic fragment, while dozens of other deposits are still being explored. Current resources for these main deposits are estimated to about 6.1 MOz Au. The only operation in the area is the Aurizona gold mine owned by Trek Mining.

Northwest Ceará

- ✓ The geology of northwestern Ceará State comprises a metasedimentary sequence with potential for SEDEX-type deposits, formed on a passive continental margin between 800-750Ma and deformed during the Brasiliano/Pan-African Orogeny.
- ✓ A series of NE-SW shear zones, extending over 200km, hosts distinct deposits and mineral occurrences of copper, lead, zinc, manganese and iron.
- ✓ The three main Cu-Pb-Zn exploration targets include Uruoca, Pedra Verde Mine and Serra de São José.
- ✓ Geophysical anomalies indicate potential for copper of undetermined mineralization, including underneath the Silurian sediments of the Parnaíba Basin.

Nova Brasilândia

- ✓ The Nova Brasilândia Group in Rondônia State (western Brazil) hosts recently discovered polymetallic sulfide mineralizations (Zn-Cu-Pb-Ag-Au) that are associated to a meta-sedimentary sequence (Migrantinópolis Formation).
- ✓ Geophysical data suggests that this sequence is continuous for at least 500 km in the E-W direction, with its eastern and western portions covered by Cretaceous sediments and Quaternary sediments, respectively.
- ✓ The polymetallic occurrences are 5-40 m thick and 0.3-3 km long, and characterized by massive and disseminated sulfide zones (gossans at surface) that are strongly oxidized, iron oxide veinlets and stockworks, siliceous breccia and quartz veins.
- ✓ Most of the sulfide-rich zones occur along a >50 km long magnetic lineament which was interpreted as a sinistral transpressional fault. Other parallel lineaments were observed and represent a potential for future exploration programs.

Geotectonic Setting of Brazilian Mineral Deposits

Noevaldo A. Teixeira, Leonardo B.L. Lopes, Anderson D.R. da Silva

Brazil is a major world producer of mineral commodities such as Fe, Nb, Au, Cu, Zn, Mn, diamonds, Sn, Cr, Ta, and P_2O_5, which are mainly derived from the two world-class mineral provinces of Carajás (State of Pará) and Quadrilátero Ferrífero (State of Minas Gerais) (Figure 01). The main deposits and tectonic settings for each region of interest in Brazil are discussed below. The eastern part of the Brazilian territory is mainly formed of

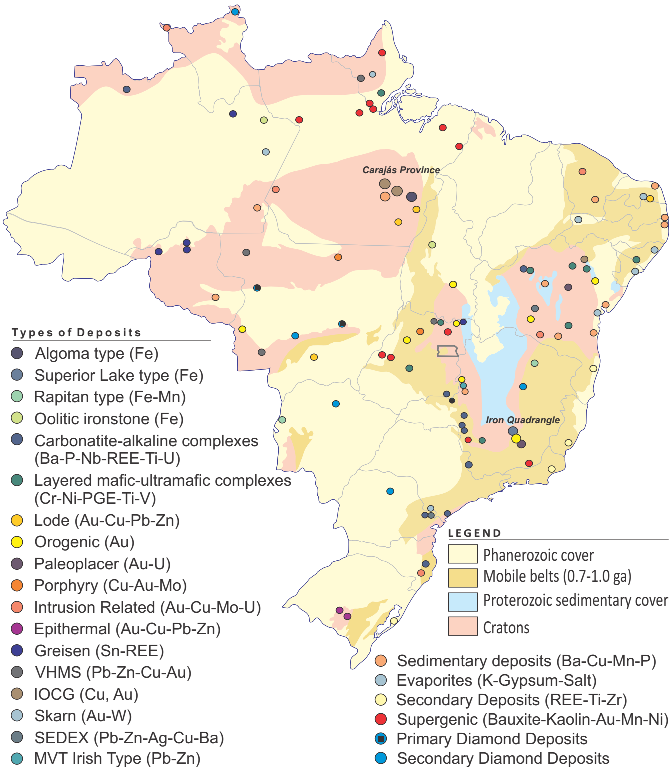

Figure 01 - Location map of the main mineral deposits in Brazil.

Archean and Paleoprotherozoic cratonic nuclei that are surrounded by Neoproterozoic mobile belts (Figure 02). These old terrains are covered by Phanerozoic intracratonic basins making up an important part of the Gondwana paleocontinent (Cordani et al., 2000). Most of these belts are orogenic and built up by rifting, ocean floor formation, subduction-related volcanic arcs, and collision processes (e.g. Brasília, Araguaia belts, Borborema Province). The Amazonian region (Central Brazil and Guianas shields) has a different setup where the cratonic nuclei are progressively surrounded by younger terrains, and for which the geotectonic setting is still poorly understood due to the scarcity of Neoprotherozoic records. The reconstruction of evolutionary models involving island and/or continental arcs derived from subduction processes remains fragile and lacks of complete field evidences (e.g. oceanic crust, ophiolites, sutures, paired metamorphic belts and tectonic vergence). Furthermore, there is a predominance of extensional structures and bimodal magmatism that are better explained by underplating processes induced by mantle plumes (e.g. Uatumã, Parauari).

The Brazilian metallogenic setting results from two geodynamic processes including subduction of the oceanic lithosphere and interaction of a mantle plume head with a continental lithospheric keel. The

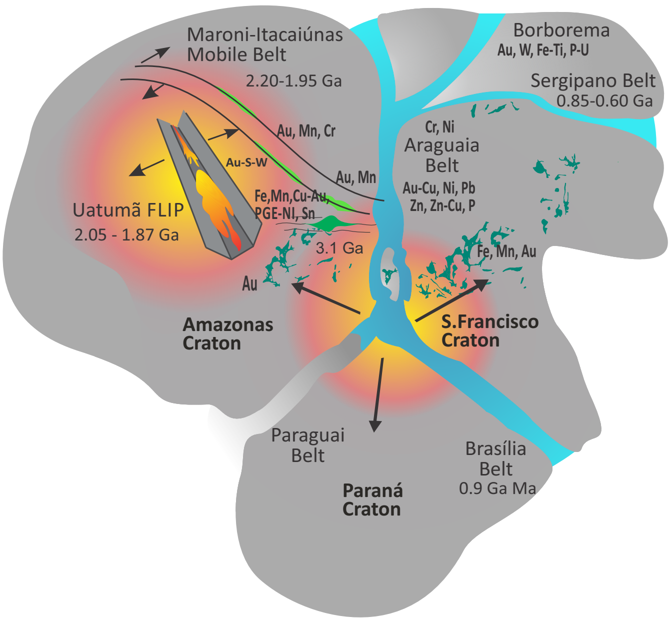

Figure 02 - Disruption of the continental crust in the central region of Brazil at the beginning of the orogenic belts formation. The disruption was caused by plume impact and ocean floor formation, with mantle dynamics having a major influence on the formation of Neoproterozoic mineral deposits.

eastern portion of Brazil (São Francisco Craton) was surrounded by Neoproterozoic Brazilian orogenies that were built up by the subduction of the oceanic crust. This region hosts mineral deposits such as sedimentary exhalative (SEDEX), porphyry copper, podiform chromite, volcanogenic massive sulfides (VMS), and orogenic gold. The origin of these deposits is linked to asthenospheric fertilization caused by dehydration of the subducting slab, with the release and interaction of fluids with pelagic sediments. At the base of the Archean Amazonian Craton, i.e. subcontinental lithospheric mantle (SCLM), intense magmatism occurred during plume-related rifting and extensional tectonics, without however reaching an open-ocean stage. In the Carajás Mineral Province located in the Amazon Craton, deposits of iron oxide copper-gold (IOCG) and tin (Sn), banded iron formations (BIFs), and Ni-PGE (platinium group elements) reef deposits were predominantly formed in association with underplating-driven tholeiitic magmatism. Strong interaction of mantle-derived hydrothermal fluids and intense magma production due to thermal instabilities from a probable mantle plume, seem to have played a major role at the base of the Amazonian Craton (Teixeira et. al., 2009).

Plume-Related Ore Deposits (Figure 03)

The Carajás rift (ca. 2.7 Ga) was formed along the edge of an Archean subcontinental lithosphere keel (Amazonian Craton). Three main ore-forming stages are recognized in Carajás : (1) The plume stage (or decompression melting stage) at ca. 2.7 Ga, creating supergiant exhalative sedimentary biochemical iron deposits (Carajás Formation with a total of 18 billion tons at 60-67% Fe), exhalative Cu-Au-Zn (Pojuca deposit) related to volcano-sedimentary sequences and A-type granite intrusion (ca. 2.7 Ga), and finally minor Ni-PGE reef deposits in tholeiitic mafic-ultramafic layered intrusions (Luanga deposit); (2) The fluid-metasomatized mantle stage at ca. 2.5 Ga, concentrated along deep transtensional faults, with IOCG deposits such as Salobo, Alemão, and Sequeirinho, with total resources of the order of 2500 Mt at 1% Cu and 0.5 g/t Au (Teixeira et al., 2010). (3) The re-melted hydrothermal underplating stage at ca. 1.8 Ga, producing Cu-(Au-Mo-W-Sn) greisen (Breves deposit) and Cu-Au-Mo-F vein deposits (Gameleira deposit) associated with A-type granites (Teixeira et. al., 2009).

The central portion of the Amazonian Craton, especially the Juruena and Tapajós provinces, encompasses extensive areas of alluvial and primary gold deposits - e.g. Tocantizinho with 49 Mt at 1.25 g/t Au, Juruena with 1.3 Mt at 5.6 g/t Au, Palito with 2.1 Mt at 5.85 g/t Au and 0.27% Cu, X1 with 8.5 Mt at 1.35 g/t Au and 4.6 g/t Au, Batalha, Paraíba, etc. The primary mineralization occurs mainly in granite-hosted quartz veins and resulted from magmatic fluid interaction causing phyllic alteration in the host rocks. They were classified more recently by authors as porphyry and epithermal systems, genetically linked to subduction-related hydrothermal systems (Juliani et al., 2014; Assis et al., 2015). We consider that the major gold deposits in these two regions are associated with intraplate bimodal igneous assemblages (Uatumã-Parauari, Teles Pires LIPs). The subvolcanic- and volcanic gold mineralizations are related to intraplate magmatism (plume-related?) at the base of the SCLM (Amazon Craton). The Araí, Chapada Diamantina and Espinhaço groups in the São Francisco Craton were all deposited in an intracontinental rift during the Statherian period and host Sn deposits associated

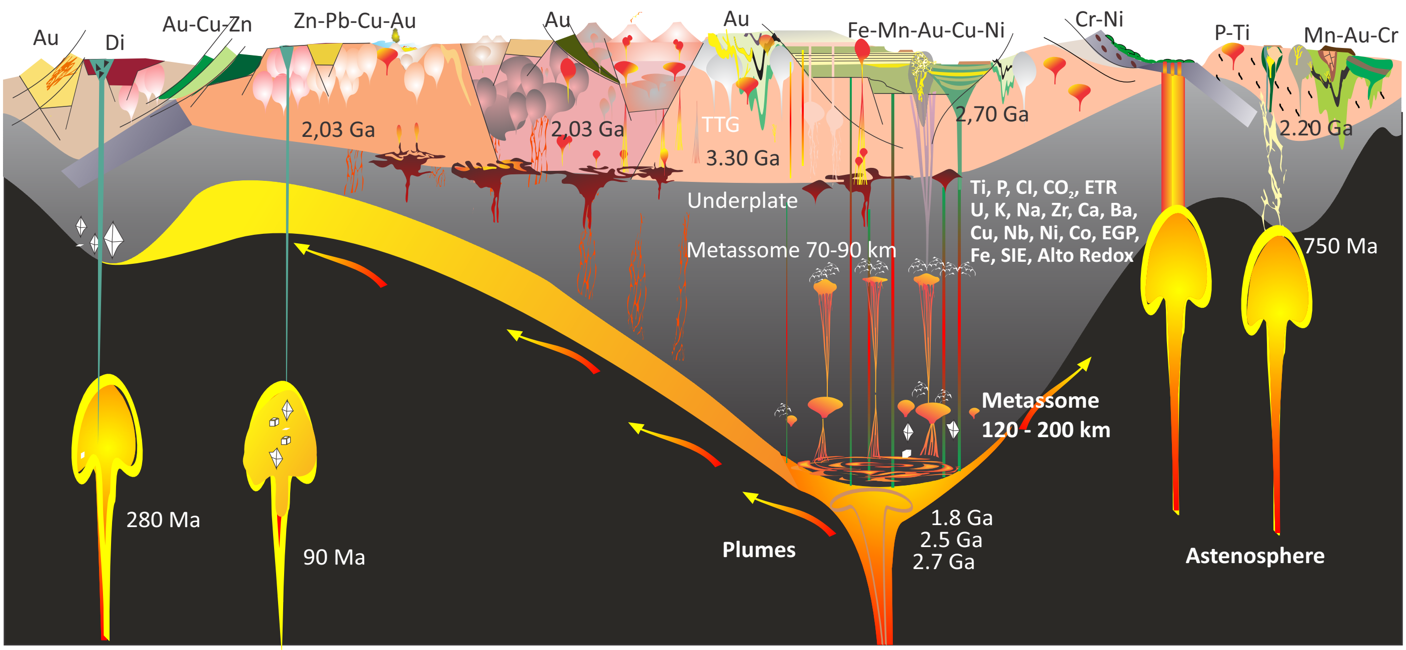

Figure 03 - Schematic section across the Amazon Craton showing the distribution of thermal anomalies (adiabatic melts or plumes) and the major paths for magmas and hydrothermal fluids. Some units were represented without deformation effect.

with greisens. In addition, Au in veins cutting tidal-flats and organic lagoon sedimentary facies were also found. Nonetheless, the Mesoproterozoic rifts in the northern portion of the Mato Grosso and Rondônia states host the greatest potential for the discovery of new Pb-Zn-Cu SEDEX and VMS, like the world-class Aripuanã deposit, with 34 Mt at 4.27% Zn, 1.50% Pb, 0.29% Cu, 0.30 g/t Au and 37.39 g/t Ag (Votorantim Metais, 2011) and the Nova Brasilândia deposit, both being explored.

The presence of extensive translithospheric fault zones throughout the Brazilian Shield favored the intrusion, during the Cretaceous period, of several alkaline bodies - e.g. Poxoréu, Iporá, Alto Paranaíba, Serra do Mar, Cajati, Jacupiranga, Catalão, Araxá - some of them alkali-ultramafic and carbonatites hosting supergiant Nb and large P_2O_5 deposits originated from lateritic weathering. Brazilian kimberlites occur mostly along pericratonic mobile belts with thinned or metasomatized lithospheric keel. However, there are kimberlites in the São Francisco Craton where it was possible to infer, via deep seismic and thermobarometry of mantle xenocrysts, a depleted harzburgitic keel, >150 km thick, as in the case of kimberlites of the Nordestina region, State of Bahia (Braúna 3, the first kimberlite-hosted diamond mine in Brazil). In the Amazonian Craton, mineralized kimberlites are found both in the depleted harzburgitic keel (State of Rondônia) and in mobile belts without lithospheric root. Until now there is no robust scientific explaination for the source of several tens of alluvial diamonds over 100 carats from Douradinho, Santo Inácio, and Paranaíba, this making the diamond occurrence from the Triângulo Mineiro in the State of Minas Gerais (Coromandel, Alto Paranaíba) a new objective for exploration.

Subduction-Related Ore Deposits (Figure 04)

In the central portion of Brazil, Cu-Au deposits (Chapada region) occur in a Neoproterozoic subduction-related magmatic arc within the Brasília Orogenic Belt. These porphyry Cu-Au deposits, with 420.94 Mt at 0.29% Cu and 479.84 Mt at 0.25 g/t Au (Oliveira et al., 2016), were metamorphosed to the amphibolite facies and strongly folded. Brazil has favorable geological environments for volcanogenic deposits linked to volcanic rifts and paleo-volcanic arcs - e.g. Palmeirópolis, Bom Jardim, Vale do Ribeira, Salobro, Cabaçal. Behind the Brasilia Arc, in the opposite passive continental margin, the metasedimentary sequence is thrusted over the edge of the São Francisco Craton. This sequence hosts Morro do Ouro Au deposit, Vazante Zn deposit and Morro Agudo Pb-Zn deposit. Morro do Ouro is a world-class gold deposit (600 t) that was possibly formed by biological accumulation of gold in a back-reef environment before being remobilized by metamorphic fluids during thrusting. Vazante and Morro Agudo deposits, with 18.3 Mt at 5.08% Zn and 1.75% Pb (Neves, 2011), were formed in an exhalative setting controlled by faults and diagenesis of a back-reef facies, respectively. Both deposits are hosted in Neoprotherozoic carbonate

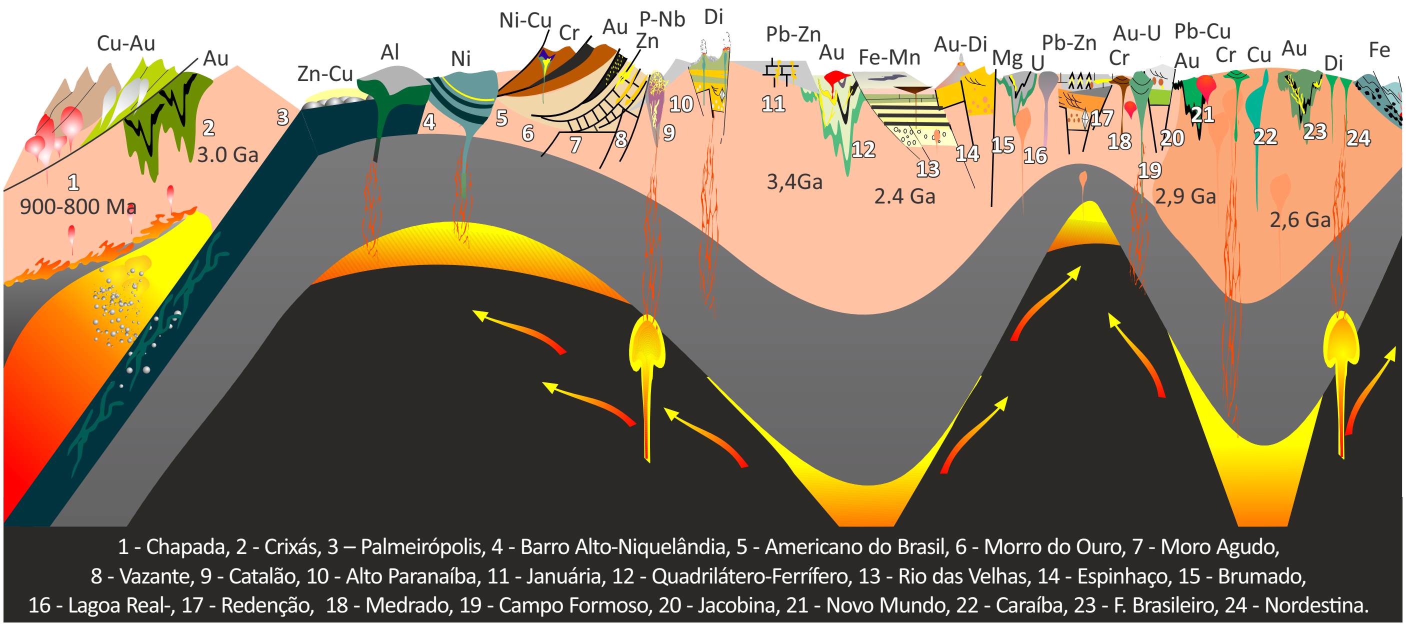

Figure 04 - Schematic section across the São Francisco Craton showing the distribution of thermal anomalies (adiabatic melts or plumes) and the major paths for magmas and hydrothermal fluids. Unlike for the Amazon Craton, the mineralizing processes resulted from the interaction between the subducting oceanic slab and asthenospheric wedge, with the release of hydrothermal fluids.

rocks that were deformed during the Brasiliano Orogeny. In the northeast region of Brazil, the end of this orogeny (Seridó foreland basin) was marked by the emplacement of large granitic plutons with Au and W mineralizations. This magmatism was generated by delamination of the lithospheric mantle, producing high heat flow by the invasion of asthenospheric material into the base of the continental crust, and generating W and Au mineralizations (Ganade et al., 2013).

Ore Deposits Related to both Plume and Subduction (Figure 05)

It is possible that during the evolution of TTG (tonalite-trondhjemite-granodiorite) greenstone belts, subductions and plumes have acted on a conjugate manner (Arnt and Nisbet, 1982). Brazil has a significant extension of these belts including for example the Archean Rio das Velhas greenstone belt (Iron Quadrangle), which comprises thick piles of metakomatiites, basaltic flows, felsic metavulcanics, BIF and metavolcanoclastics. Its gold deposits such as Morro Velho, Cuiabá and São Bento, with respectively >470 t Au, >180 t Au and >80 t Au (Abreu et al. 1988), are hosted in BIFs that were sulfurized by metamorphic fluids during regional deformation and low-grade metamorphism (greenschist facies). The giant iron ore deposits of the Minas Group occur in exhalative chemical sediments that were deposited on TTG greenstone belts substratum (bedrock) in a context of passive continental margin. Numerous other Archean and Paleoproterozoic greenstone belts in Brazil contain orogenic gold deposits - e.g. Crixás, Itapicuru, Cipoeiro, Aurizona, Chega Tudo, Amapari, Salamangoni, Volta Grande - that lay on terranes of the Amazonian and São Francisco cratons.

Brazil has also a significant number of diversified mafic-ultramafic bodies formed by plumes or mantellic adiabatic fusion occurring in a subduction context. The mafic-ultramafic complexes are distributed infive main geotectonic settings: (1) TTG terranes and greenstone belts; (2) Intracratonic granulitic belts and roots of orogenic belts; (3) Ensialic rifts; (4) Subduction zones in Neoproterozoic orogenic belts; and (5) Intracratonic basins. The most significant associated deposits are: (a) Ni-Cu-PGE deposits in reefs of intracratonic layered complexes (e.g. Luanga); (b) Ni-Cu deposits in Archean komatiite lava channels (e.g. Fortaleza de Minas); (c) Disseminations in magmatic conduits controlled by translithospheric fault - e.g. Limoeiro and Caraíba with a total of 42 Mt at 1.82 % Cu (Dardenne and Schobbenhaus, 2001); (d) Synorogenic hydrated magmachamber (e.g. Americano do Brasil); (e) Disseminations in differentiated magmachamber (e.g. Mirabela); (f) Podiform chromite deposits in residual harzburgites (e.g. Morro Feio, Quatipuru); (g) Stratiform chromitite in cumulate at the bottom of layered complexes (e.g. Bacuri); (h) Fe-Ti-V-PGE deposits in magnetite-rich layers between gabbro and piroxenite (e.g. Maracás); and (i) Lateritic nickel (e.g. Niquelândia, Barro Alto, Vermelho, Onça-Puma).

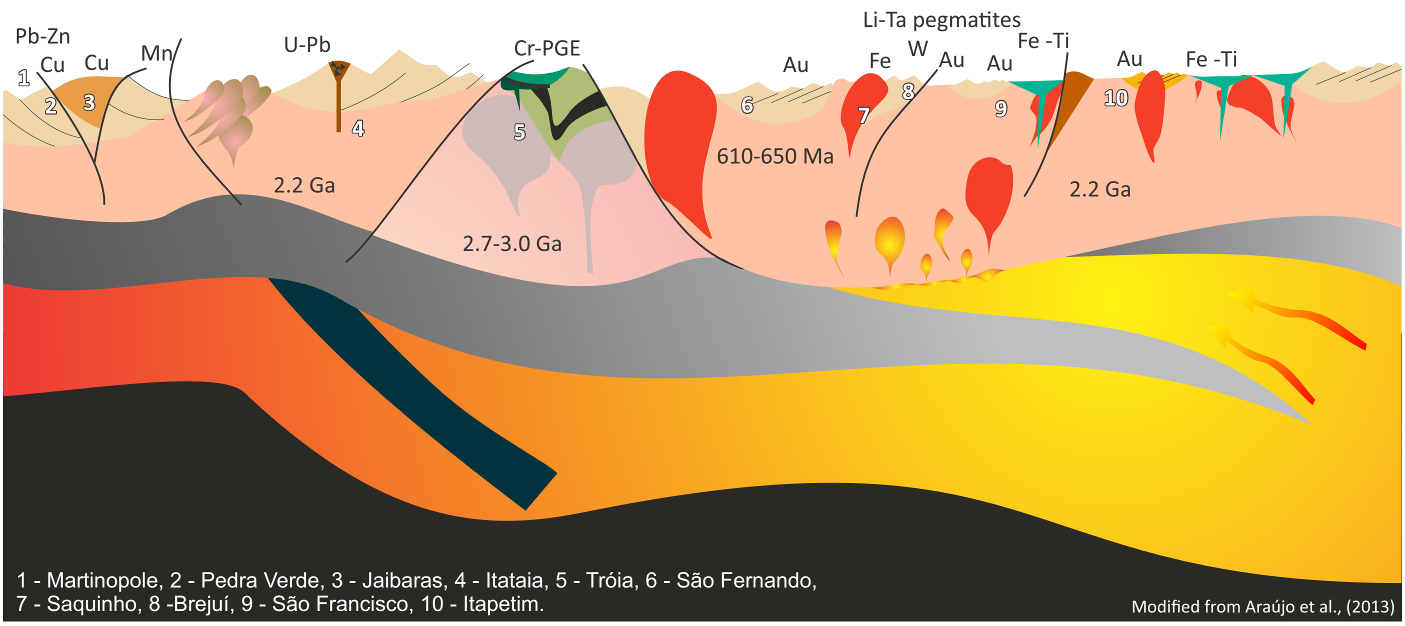

Figure 05 - Schematic section of the NE region in Brazil showing the mechanical erosion derived from delamination of the lithospheric mantle. High heat flow produced huge felsic plutonism after continental collision of the Neoproterozoic Brazilian fold belt.

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Carajás Project

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The Carajás Project is being developed by the Geological Survey of Brazil (CPRM) as part of its programs "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brasilian Shields" (Program I) and "Mineral Potential Assessment of the Brazilian Volcano-Sedimentary Sequences" (Program III). Considering the broad picture of the southeastern part of the Amazon Craton, the region is characterized by the presence of important polymetallic deposits that can be grouped into three main types according to their respective geotectonic setting: (1) Archean TTG (tonalite-trondhjemite-granites) and greenstone belts hosting orogenic gold deposits (e.g. Rio Maria Province); (2) Archean polymetallic subcontinental lithospheric mantle (SCLM) rifts hosting world-class Fe, Cu-Au (IOCG), Ni (IONC and laterite), Au-PGE deposits (e.g. Carajás Mineral Province); and (3) Proterozoic epithermal and quartz veins gold deposits in the Tapajós area. The Carajás Mineral Province (CMP), formed from 2.76 to 2.55 Ga, is located in the eastern portion of the Amazon Craton, northern Brazil. It is considered as one of the world most important mining areas, including several world-class IOCG, nickel, PGE, iron ore and manganese deposits (Figure 01).

The Geological Survey of Brazil (CPRM) currently conducts three work programs dedicated to offer basic geological data and knowledge to investors, including: (1) Geophysical-geological integration maps of ten 1:100,000 scale sheets; (2) Detailed mapping along the Cinzento Lineament aimed at establishing the main regional controls of the copper deposits located in this transcurrent system; (3) Detailed mapping of the Mn deposits to define their stratigraphic and faciological controls. Detailed mapping at 1:50,000 scale is being additionally carried out for the volcano-sedimentary sequences that include the Aquiri unit.

The large amount of geological data already published on the Carajás Mineral Province (CMP), together with recently acquired airborne radiometric (Figure 02), magnetic (Figure 03) and gravity data, and remote sensing images, make the basis for the geophysical-geological interpretation maps in progress at the Geological Survey of Brazil (CPRM). All these data are freely accessible from its online GeoSGB database (http://geosgb.cprm.gov.br/).

The Mesoarchean Carajás basement assemblage consists of TTG granite-gneiss-migmatite (Xingu Complex), mafic granulites (Xicrin Cateté orthogranulite), and greenstone belts (Sequeirinho, Selva and Rio Novo groups) that were dated at around 3.07-3.0 Ga (Pidgeon et al., 2000; Moreto et al., 2011; Silva, 2014). The Neoarchean Carajás basin comprises metavolcano-sedimentary units, dated at 2.76 Ga for the Itacaiúnas Supergroup (DOCEGEO, 1988), and that host the main Fe and Cu-Au deposits. The succession from base to top consists of bimodal mafic-felsic metavolcanic rocks, BIFs (hosting giant iron ore deposits), metapyroclastic and metasedimentary rocks deposited in a marine rift environment (Gibbs et al., 1986). Metamorphism grade ranges from low greenschist to amphibolite facies. Coeval mafic-ultramafic layered complexes (2.76 Ga, e.g. Luanga Complex; Machado et al., 1991) hosting PGE-Ni deposits and syn-tectonic alkaline to sub-alkaline granites (2.76-2.70 Ga, e.g. Estrela and Gelado granites; Barbosa et al., 2001) are widespread in the Carajás Basin, as well as 2.65 Ga gabbroic dikes and

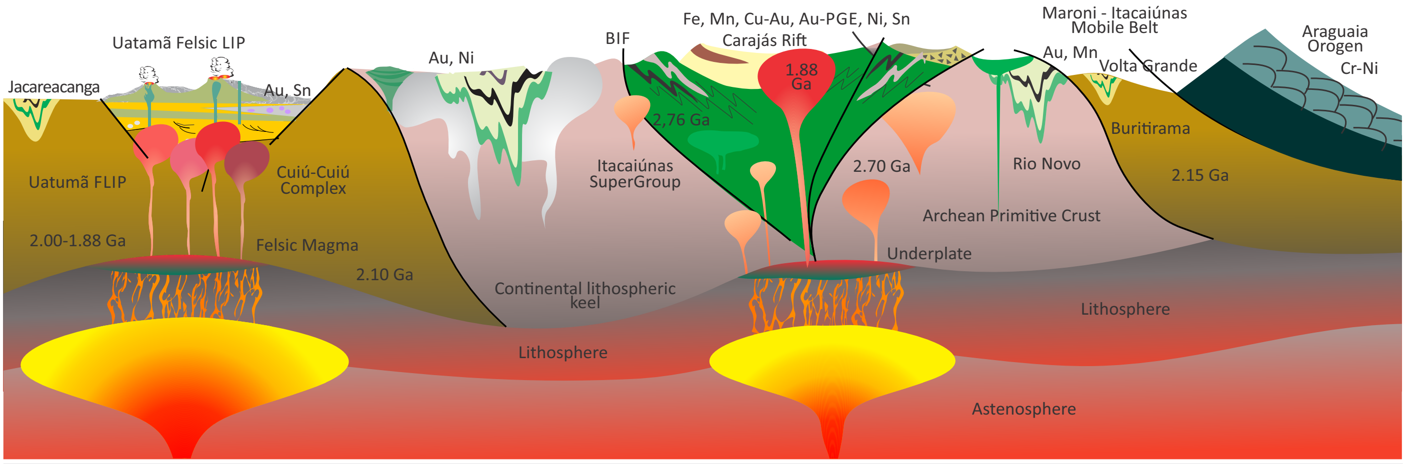


Figure 01 - Geotectonic setting of Carajás Basin interpreted either as a rift-related or strike-slip basin. It presents a typical sigmoid structure controlled by transcurrent shear zones (Araujo and Maia, 1991). The basement is composed of TTG greenstone belt. The eastern border of the Amazon Craton is delimited by the Bacajá fold belt (2.2 Ga) and obducted Neoproterozoic Araguaia ophiolite. The western limit was streched during a large Paleoproterozoic extensional event (Tapajós region).

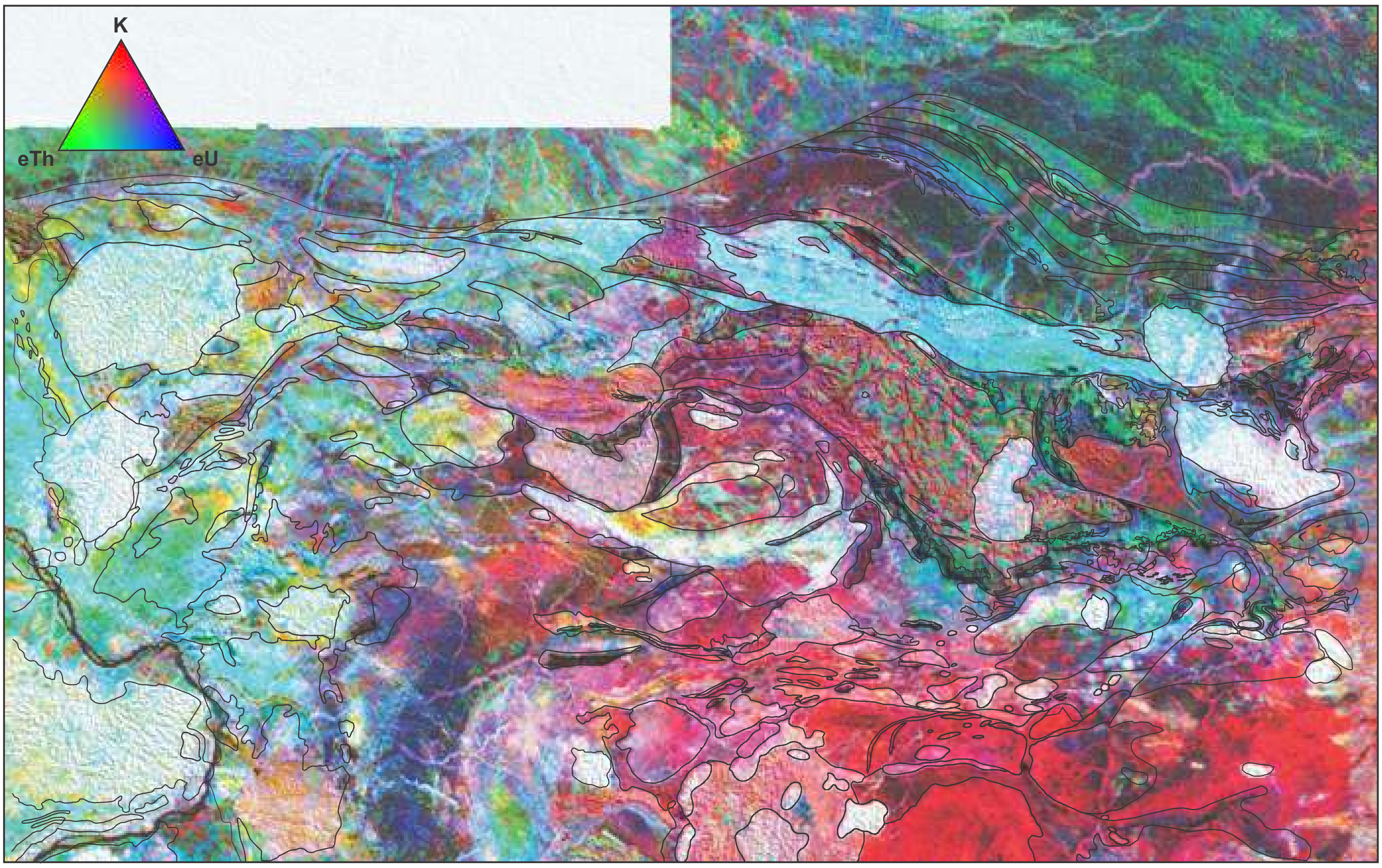


Figure 02 - Ternary gamma-spectrometry map (K, eU, eTh) of the Carajás project area and correlation with known geological features.

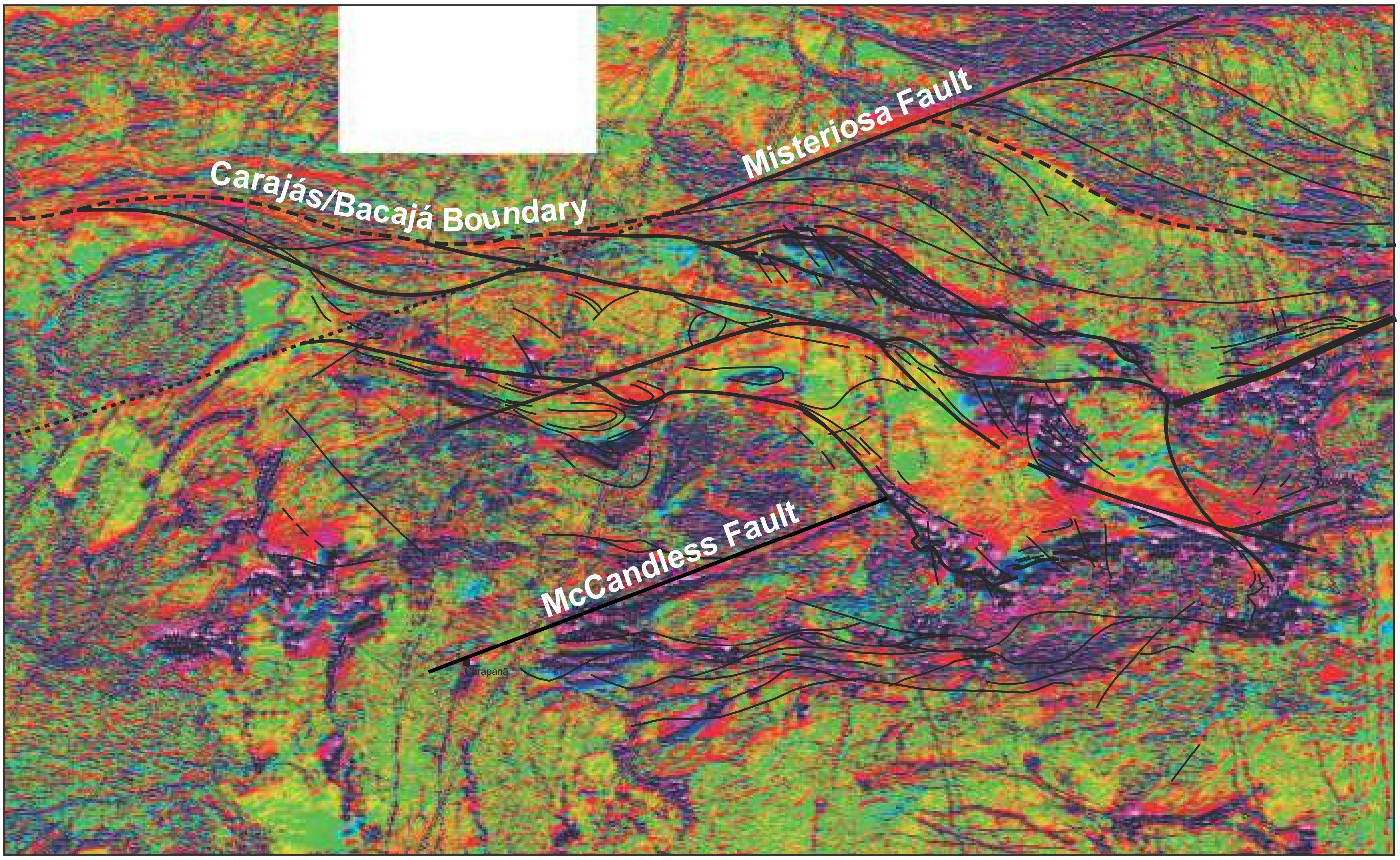


Figure 03 - Magnetic interpretation of lineaments based on total magnetic intensity (first derivative of magnetic anomaly field).

sills. A Paleoproterozoic low-grade sedimentary sequence overlies the Itacaiúnas Supergroup and comprises fluvial to shallow marine sandstones and siltstones (Águas Claras Formation; Nogueira et al., 1995) containing manganese deposits (Azul Mine). Paleoproterozoic A-type granites (1.88 Ga; Dall'Agnol et al., 2005) outcrop throughout the Carajás region, as well as mafic and felsic NE and NW dikes (Figures 04, 05, 06 and 07).

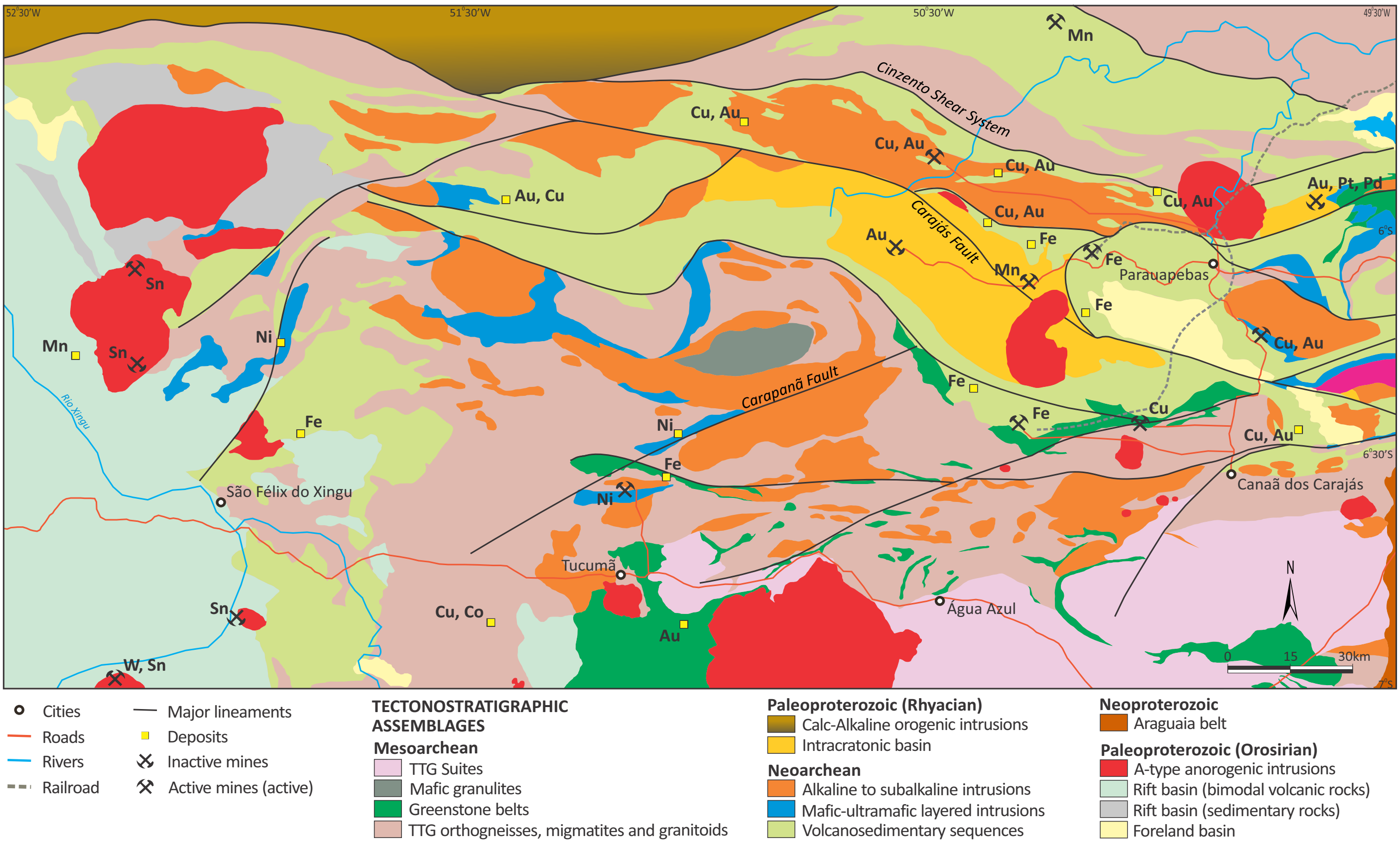


Figure 04 - Geological map of Carajás Mineral Province.

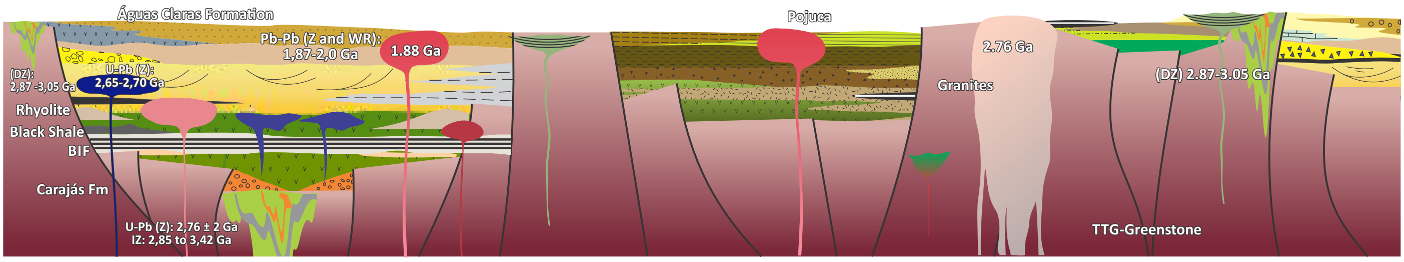


Figure 05 - Carajás depositional environment showing high variability due to the strong tectonic compartmentation of the rift-related (or strike-slip) basin.

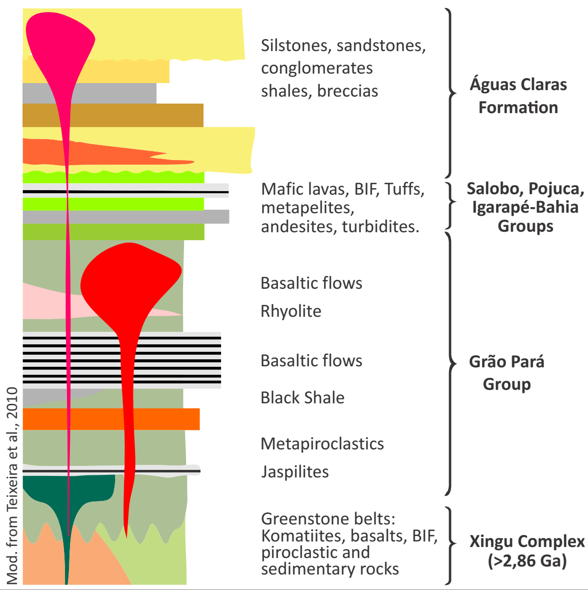


Figure 06 - Stratigraphic column of Central Carajás.

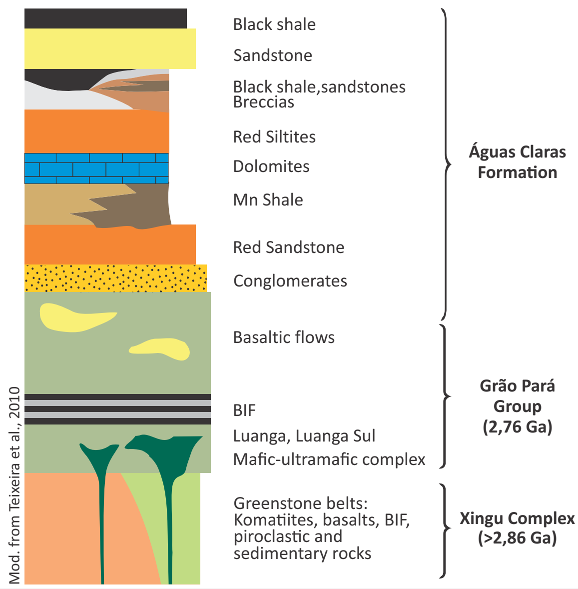


Figure 07 - Stratigraphic column of Serra Pelada.

Despite the mineral importance of the area its basic geological and geochronological knowledge is poor. The depositional environment of Carajás is highly variable due to the strong tectonic compartmentation of the rift-related (or strike-slip) basin. There is no single stratigraphic column that can apply to the entire Carajás region. In addition the stratigraphic units of Salobo, Igarápé Bahia, and Pojuca were only defined from drill hole observations due to the absence of outcrops.

New geochronological data obtained from detrital zircons shows that the Aquiri Unit has a maximum depositional age around 2.86 Ga (Figures 08 and 09). This age does not indicate however whether the metavolcano-sedimentary sequence of Aquiri Unit is part of the greenstone belt or is related to the Itacaiúnas Supergroup. The maximum depositional age of the Água Claras Formation obtained from detrital zircons is 3.24 Ga (Figure 10), highlighting the absence of Transamazonic zircon ages.

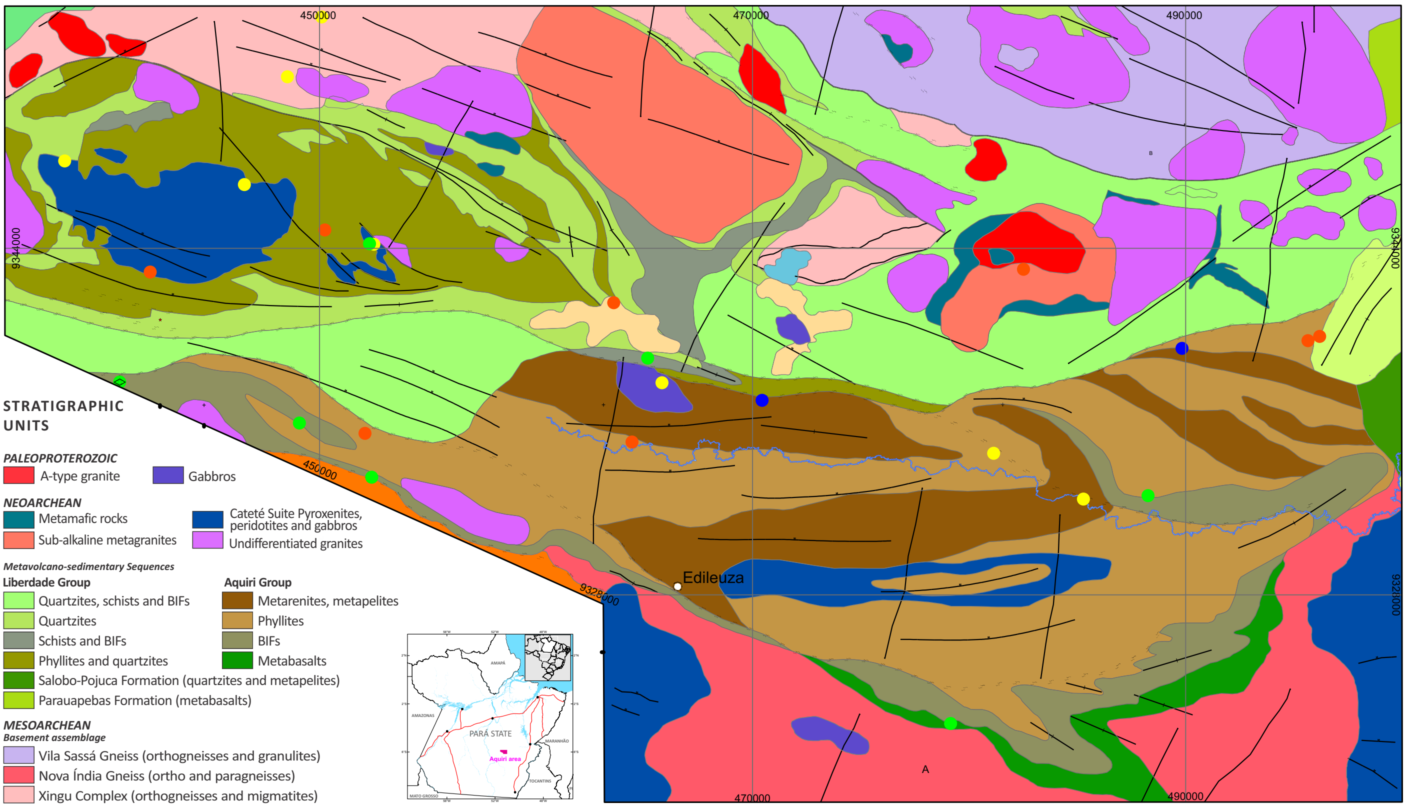


Figure 8 - Aquiri geological map. The western portion of Carajás is only covered by maps of 1:250,000 scale. The Geological Survey of Brazil (CPRM) is currently developing a 1:50,000 scale mapping program of the volcano-sedimentary sequences in this region (North of São Feliz). Its interpreted results will help separating the greenstones belts from the western continuity of the Itacauinas Supergroup, while more precisely defining the limits of the Carajás Basin.

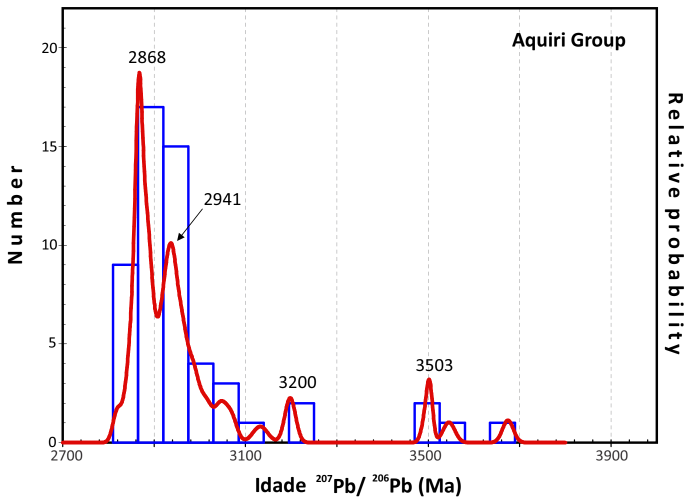


Figure 9 - Combined histogram and probability density diagram of detrital zircon U-Pb ages from quartzite of the Aquiri Group. The maximum depositional age is indicated by the youngest peak of 2868 Ma.

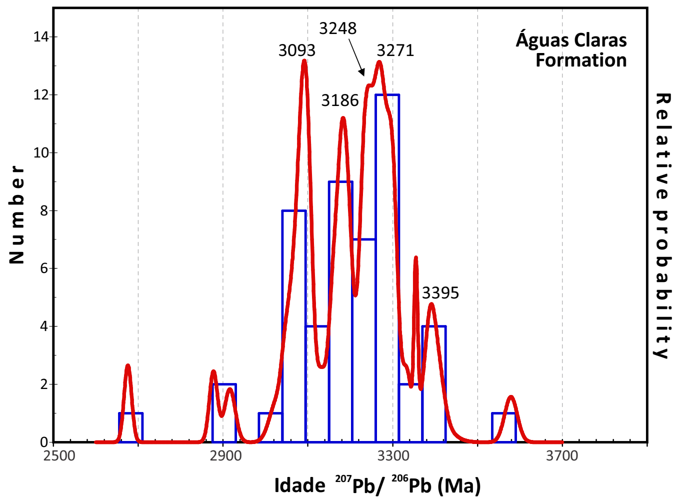
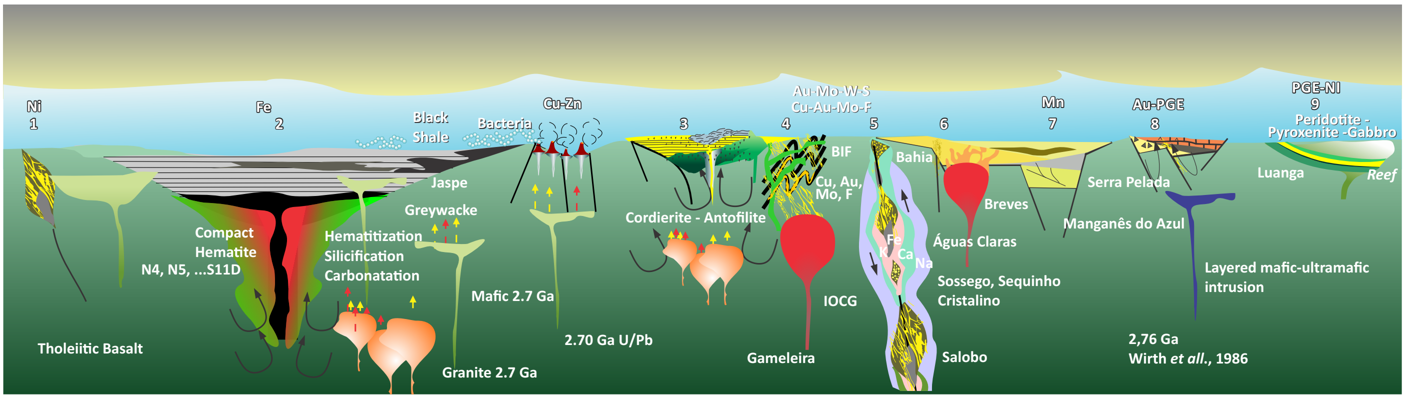


Figure 10 - Combined histogram and probability density diagram of detrital zircon U-Pb ages from the Águas Claras Formation. The youngest peak of 3093 Ma indicates the maximum depositional age. Although three crystals with younger age have been identified, due to their small number they were not further considered in the interpretation.

Three main mantle-related mineralizing events are recognized in the Carajás rift (Teixeira et al., 2009): (1) 2.76 Ga crustal extension related to plume or descompression of the astenospheric mantle, resulting in basaltic and rhyolitic flows and giant hydrobiogenic volcanic-exalative iron deposits (e.g. N4, S11D), minor disseminated volcanogenic Cu-Zn deposits (e.g. Pojuca), tholeiitic mafic-ultramafic layered intrusions (Onça-Puma, Jacaré, Jacarezinho) with PGE-Ni reefs (e.g. Luanga) and IOCG deposits (e.g. Sequeirinho-Pista; Moreto et al., 2015); (2) 2.61-2.55 Ga crustal extension with decompression of the metasomatized mantle, and formation of saturated- (O-H-C-S-Cl-rich), blind metasomatic mantellic alkaline rocks and IOCG deposits (e.g. Salobo, Alemão); (3) 1.88 Ga intrusion of A-type granites refleting a huge mantle plume event that affected the whole central Amazonian Craton, producing in the Carajás Province Cu-(Au-Mo-W-Sn), greisens (e.g. Breves), Cu-Au-Mo-F intrusion-related deposit (e.g. Gameleira), manganese deposits and the unusual Au-PGM Serra Pelada deposit. The last two of these deposits were correlated to the lowermost unit of the Águas Claras Formation (Figure 10). Grainger et al. (2008) and Teixeira et al. (2009) considered that the metallogeny of the CMP is petrologically related to SCLM dynamics in an active rift setting. Conjugate metamorphic, hydrothermal and magmatic events, dated between 2.70-2.55 Ga, were found to be contemporaneous with the reactivation of extensive regional shear zones, and important contributing factors for the Carajás metallogenetic evolution (Figure 11).

CMP has some of the largest high-grade iron ore deposits in the world. These deposits in the Carajás Iron Formation are interbedded with metabasalts of the Grão Pará Group as part of the Itacaiúnas Supergroup. Rocks of the Grão Pará Group are exposed along the northern and southern flanks of a synclinal structure (Carajás syncline) that includes a major shear zone (Carajás shear zone) along its axis. Vale is the largest mine operator at CMP and has recently launched the S11D project, the world's largest iron ore mine with a production capacity of 90 Mtpy. The total iron ore resources from all known deposits exceed 20 billion tons with grades over 65% Fe. The orebody thicknesses vary between 250-300 m. Jaspilites constitute the proto-ore of CMP iron ore deposits, with weathering being at the origin of such a high enrichment. High-grade iron ore mineralizations (>65 % Fe) consist of both hard- and soft ores. The hard ores are banded, massive and/or brecciated, and mainly composed of microplaty hematite. Comparatively the soft ores are very porous, discontinuous and tabular, friable and banded. The basal contact of high-grade iron ores is defined by a hydrothermally altered basaltic rock that is mainly composed of chlorite and microplaty hematite (Silva, 2009). The mineralizing process is considered as vulcanogenic, with the high-grade portion reflecting the proximity of the exhalative centers (Teixeira et al., 2009) (Figure 12).

CMP is the second largest IOCG (Cu-Au) province in the world (Figure 13). The IOCG deposits do not show any stratigraphic preference or lithological control. They occur in granites, metabasalts, metarhyolites and metasedimentary rocks. The level of deformation of the host rocks varies greatly, from cataclastic- (e.g. mylonite at Salobo) to weakly deformed rocks, which nevertheless determine the style of the ore bodies. The more competent rocks



Sin - Rift Fase (2.76 Ga)
1. IONC
2. Hydrobiogenic volcanic-exhalative iron deposit
3. BIF host volcanogenic Cu-Zn
5. IOCG
9. PGE-Ni Reef

Post-Rift Fase
7. Mn Sedimentary
8. Au-PGE Redox Sedimentary
4 and 5. Felsic Intrusion Related (1.80 Ga)

Mod. from Teixeira et al., 2009

Figure 11 - Types of mineralization in the Carajás Mineral Province (CMP).The Carajás Archean rift hosts a 200x100 km^2 giant ore system. The basin was filled with continental tholeiitic basalts and rhyolites followed by BIFs and vocanogenic sediments. The upper unit is mainly composed of sedimentary rocks. Three main mantle-related mineralizing processes were recognized in Carajás rift. They involve magmatic activity, exhalative solutions and hydrothermal fluids that contributed to the different types of mineralization.

Figure 12 - Pit of the N-5 iron mine.

Figure 13 - Pit of the Sossego copper gold mine.

include more veins and breccias and less substitution. The Cu-Au Salobo mine has been in activity since 2012 and is one of Vale's most important operations. It is also the largest copper mine in Brazil with a production of 200,000 tpy of Cu concentrate. The IOCG deposit there is the most deformed of all comparable deposits in CMP. It has undergone Paleoproterozoic deformation and metamorphism, which resulted in a strong structural control materialized by E-W ductile-brittle shear zones with high-angle fault bends and jogs (Figure 14 and 15).

Carajás IOCG deposits have strong calcic, iron and sodic hydrothermal alterations. The formation depth of the metal deposits is important to determine from these associated alterations. The Salobo deposit represents the root of a hydrothermal system. As part of this system, Alemão and Igarapé Bahia deposits are positioned higher in the stratigraphic sequence, as reflected by their lower-temperature mineral associations. Schistosity and mineral lineation are also observed in the deposits and were formed during the hydrothermal alteration process. They were interpreted as resulting either from the final stage of the complex deformation history of mineralized conduits (2.5 Ga), or from the effect of later orogenies (Tavares, 2015). Carajás IOCG deposits have stable isotope signatures reflecting deeply formed and/or mantle-derived magmas. The ore forming process involved aqueous hypersaline, acidic and oxidizing convective fluids, which interacted with cooler and less saline

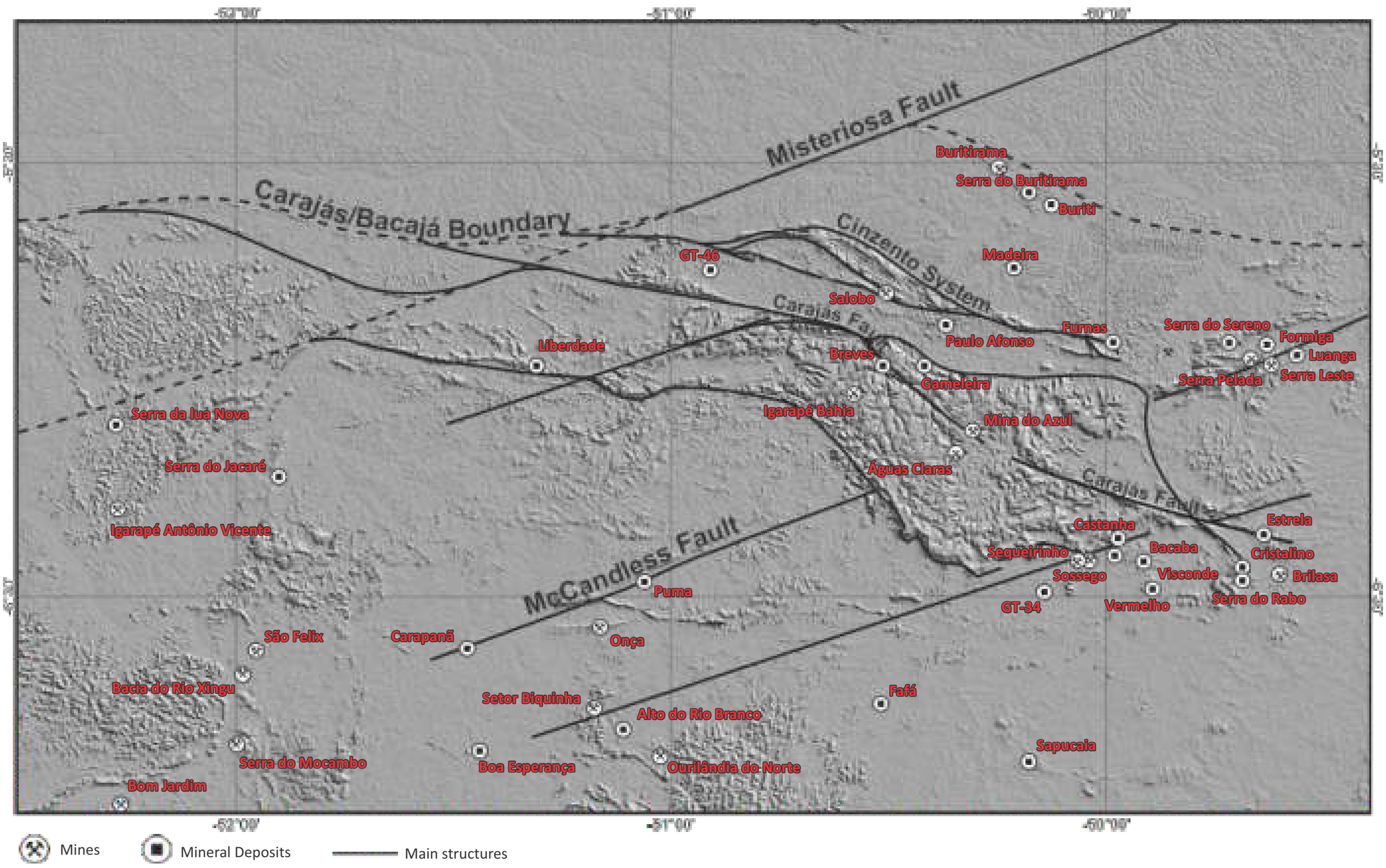


Figure 14 - Tectonic controls of IOCG mineralizations with the Carajás sigmoid structure in the central part of the figure. The extrapolated Cu-Au mineralizing corridor extends the Carajás Basin area mainly to the south into the Rio Maria Domain.

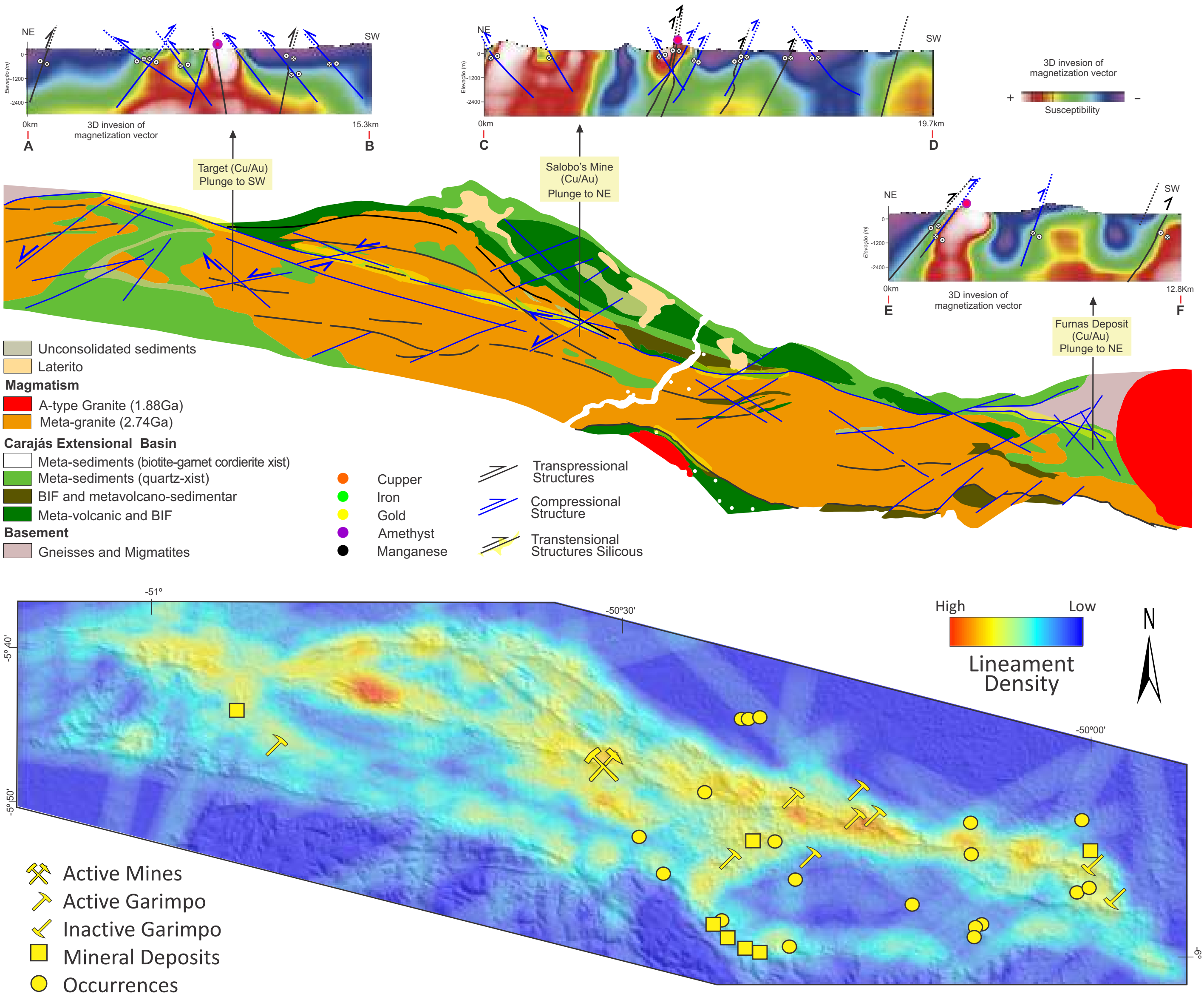


Figure 15 - Results of detailed mapping along the Cinzento shear zone showing a correlation between the intensity of the magnetic lineaments and the mineralized areas.

meteoric water and/or basin fluids (aquifers). The interaction of fluids with contrasting salinity and temperature favored the metal precipitation in the majority of the Carajás IOCG deposits (Monteiro at al., 2014).

Manganese is another of the most important mineral resources at CMP. Two world-class mines are currently in operation, including the Azul mine, owned by Vale and in production since 1985 (Figure 16), and the Buritirama mine, owned by a Brazilian private group (Mineração Buritirama) and in operation since 2002. In addition, there are two other remarkable manganese deposits in Carajás that both belongto Vale (Serra do Sereno, Antônio Vicente). The manganese-rich sedimentary successions of Azul and Serra do Sereno were deposited in the same geological context. They are represented by siliciclastic rocks (mudstones, red siltstones, manganesiferous pelites, coarse- to fine-grained sandstones and conglomerates) of the Águas Claras Formation. The sedimentary facies hosting the primary Mn deposits are restricted to an offshore zone nearby the shoreface, and overlies thick turbiditic deposits rich in organic matter (Figure 17).

Figure 16 - Pit of the Azul manganese mine.

The metasedimentary sequences (quartzite, BIF, banded manganesiferousof the Serra da Buritirama and Antônio Vicente regions evolved in the Neoarchean and were probably deposited during rift-related volcanic events.

Besides their sedimentary origin, all known Mn deposits are also characterized by conjugate tectonic and hydrothermal processes that remobilized and precipitated the manganese along the major structures, mostly into fault systems. This type of occurrence forms the main economically viable zones. Supergenic enrichment is the important manganese concentration processes (Figure 18).

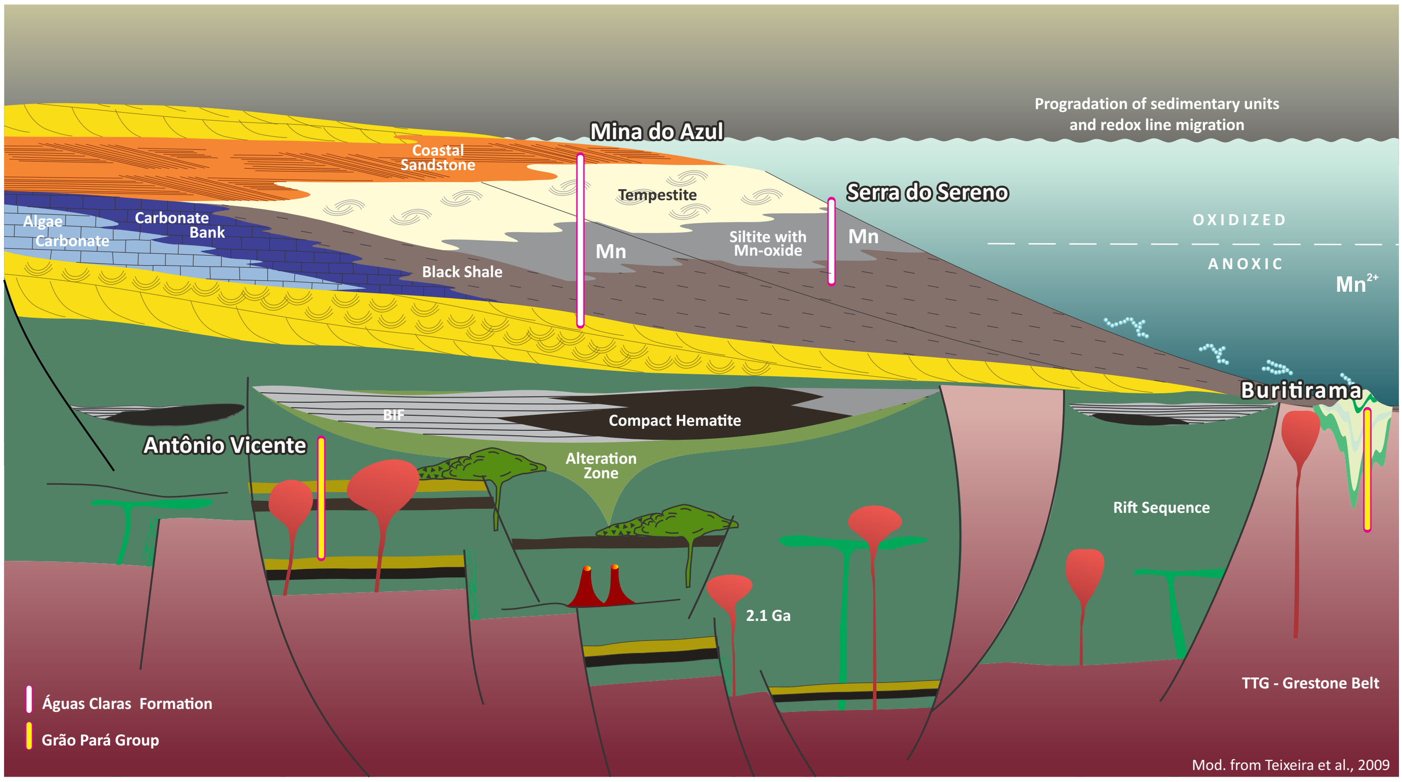


Figure 17 - The Azul and Sereno Mn deposits located in offshore zone nearby the shoreface, and overlying thick organic-rich turbidites of the Águas Claras Formation. Also shown the Buritirama Mn deposit hosted in a metavolcano-sedimentary sequence (amphibolite, quartzite, BIF), probably deposited during rift-related volcanic events.

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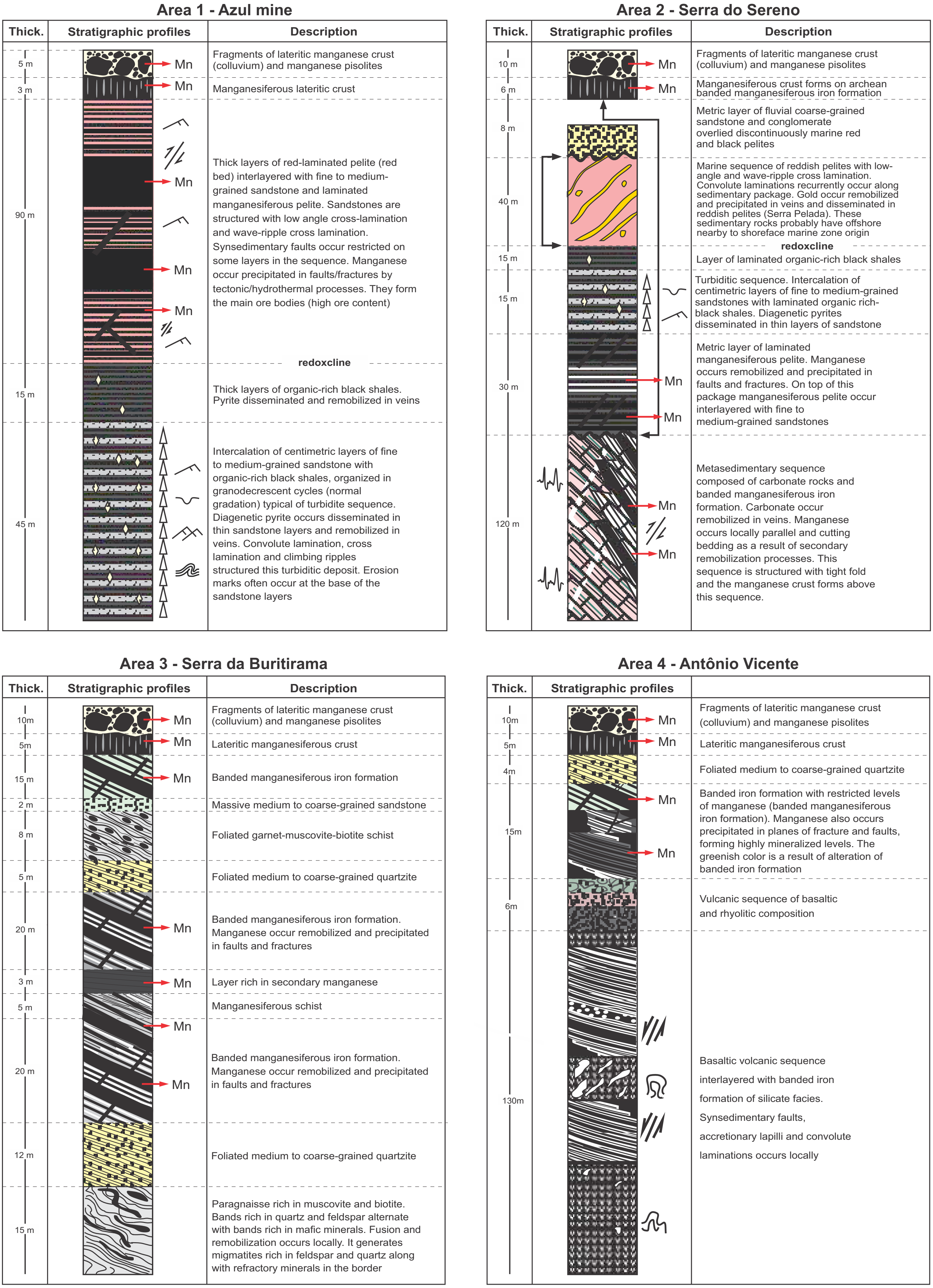


Figure 18 - Stratigraphic columns of Carajás manganese deposits.

Quadrilátero Ferrífero Project

Joanna C.S. Araújo, Denise C. Brito, Jose A.D. Cavalcanti, Marco A. Couto, Wilson L. Feboli, R.C.R. Ferreira, Frederico M. Freitas, Marcelo d.S. Marinho, Sabrina F. de Queiroz, Luiz P.P. Di Salvio, Luana D. Santos, Rosane N. Silva

The Quadrilátero Ferrífero Project is being developed by the Geological Survey of Brazil (CPRM) as part of its programs "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brasilian Shields" (Program I) and "Mineral Potential Assessment of the Brazilian Volcano-Sedimentary Sequences" (Program III). The Quadrilátero Ferrífero (QF) extends over an area of 7,000 km^2 in central Minas Gerais State, Brazil (Figure 01). Its name is due to the form of abundant occurrences of iron formation and iron ore. The aim of this project is to develop geological and metallogenetic models for gold and base metals, expanding the knowledge on the economic potential of this important Brazilian mineral province. In 2016 the preliminary mapping products of the project were presented. Theyinclude a mineral resources map at 1:100,000 scale of the QF and its surrounding area and geological maps at 1:100,000 scale of the QF. These products are freely accessible from the online GeoSGB database (http://geosgb.cprm.gov.br/). The QF region has been also covered by airborne geophysical surveys that include magnetic (Figure 02), radiometric (Figure 03) and helicopter transient electromagnetic (HTEM). The Geological Survey of Brazil (CPRM) has been modeling several areas with the Magnetization Vector Inversion (MVI) technique that provides good solutions for characterizing magnetic bodies, with the results that were afterward correlated with the structural control of gold mineralized bodies and their host rocks (Figures 04 and 05). These results were integrated with the HTEM and airborne radiometric data.

The Precambrian section exposed in the QF consists of four major lithostratigraphic units that include: (1) Archean metamorphic complexes composed of TTG (tonalite-trondhjemite-granodiorite) suites and high-

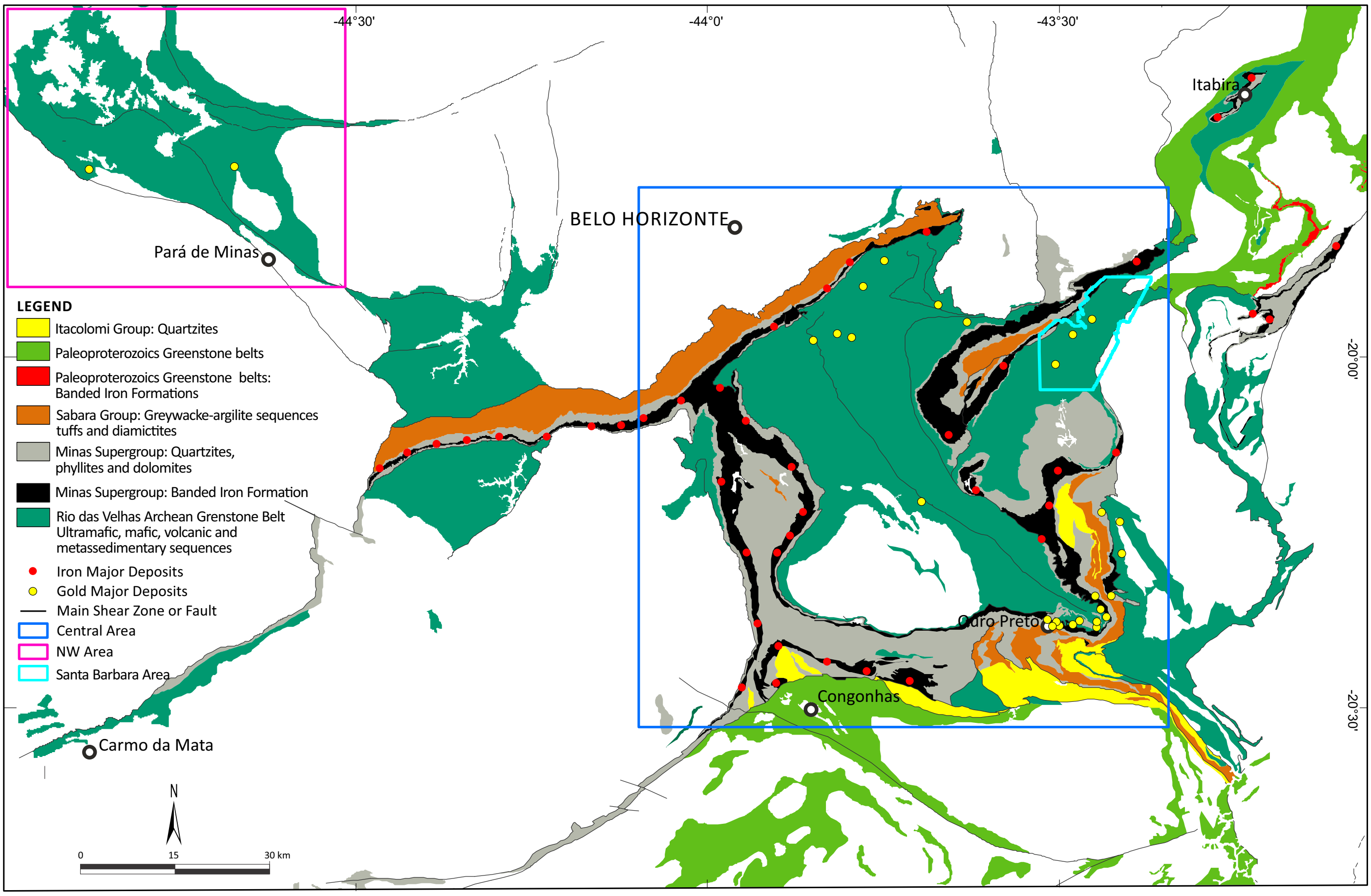


Figure 01 - Simplified geological map of the Quadrilátero Ferrrífero project area showing the central (blue polygon) and NW (pink polygon) areas that are being mapped. The map shows the Rio das Velhas Archean greenstone belts and Minas Supergroup that host world-class gold and iron deposits, respectively. Light blue polygon indicates the area modelled using the Magnetization Vector Inversion (MVI) technique.

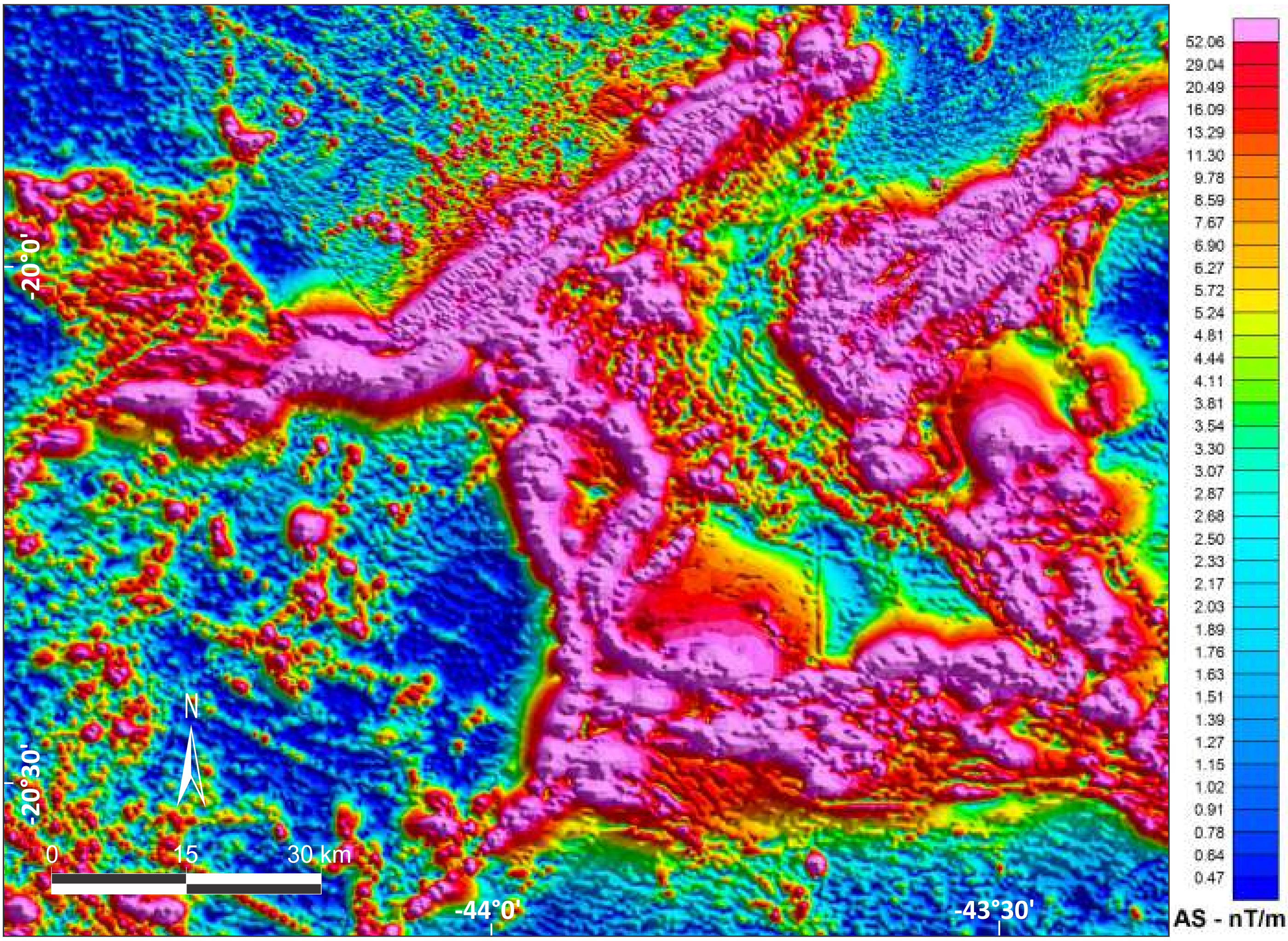


Figure 02 - Analytic signal map of the Quadrilátero Ferrrífero project area showing strong magnetic anomalies associated with the BIF-rich Minas Supergroup.

K granites; (2) Archean Rio das Velhas Supergroup with typical greenstone belt sequence overlaid by low-to-medium grade metasedimentary units; (3) Paleoproterozoic Minas Supergroup and Sabará Group consisting of low-to-medium grade metasedimentary rocks; and (4) Itacolomi Group composed of metasandstones and conglomerates. The Archean metamorphic complexes comprise 3.2-2.9 Ga gneisses and migmatites with typical TTG suite signatures. These rocks show well developed compositional banding and several successive deformation structures. Two generations of late intrusive granitoids are found in the region. The oldest has a calc-alkaline affinity and yields U-Pb zircon ages between 2.78-2.76 Ga while the youngest shows high-K signatures and was dated between 2.75-2.6 Ga. The intrusive bodies have dome shapes with diameter >50 km. Both isotropic fabrics and discrete shear zones are developed especially along the contact with the supracrustal units.

The metavolcano-sedimentary rocks of the Rio das Velhas Supergroup are subdivided into the Nova Lima and Maquiné Groups (Figure 06). The former occurs at the base of the sequence and contains the major Au deposits. Four depositional cycles were differentiated by Baltazar and Zucchetti (2007), with cycles I, II and III forming the Nova Lima Group (Figure 06).

Cycle I occurred between 2,800-2,780 Ma based on ages determined on the mafic and felsic rocks. It predominantly comprises mafic-ultramafic (tholeiitic-komatiitic) flows intercalated with chemical sedimentary rocks. The cycle is related to the initial extensional stage of the greenstone belt development, with the deposition of sediments contemporaneous with the volcanic flows that formed the submarine oceanic plains.

Cycle II encompasses a clastic-chemical sedimentary association and distal turbidites in the eastern sector of the Quadrilátero Ferrífero. It was deposited during the initial stage of the subduction phase. In the southern sector of QF it includes coastal sandstones (with medium-to-large scale cross-bedding, ripple marks, herringbone cross-bedding, sandstone-siltstone) and resedimented associations (graywacke-argillite).

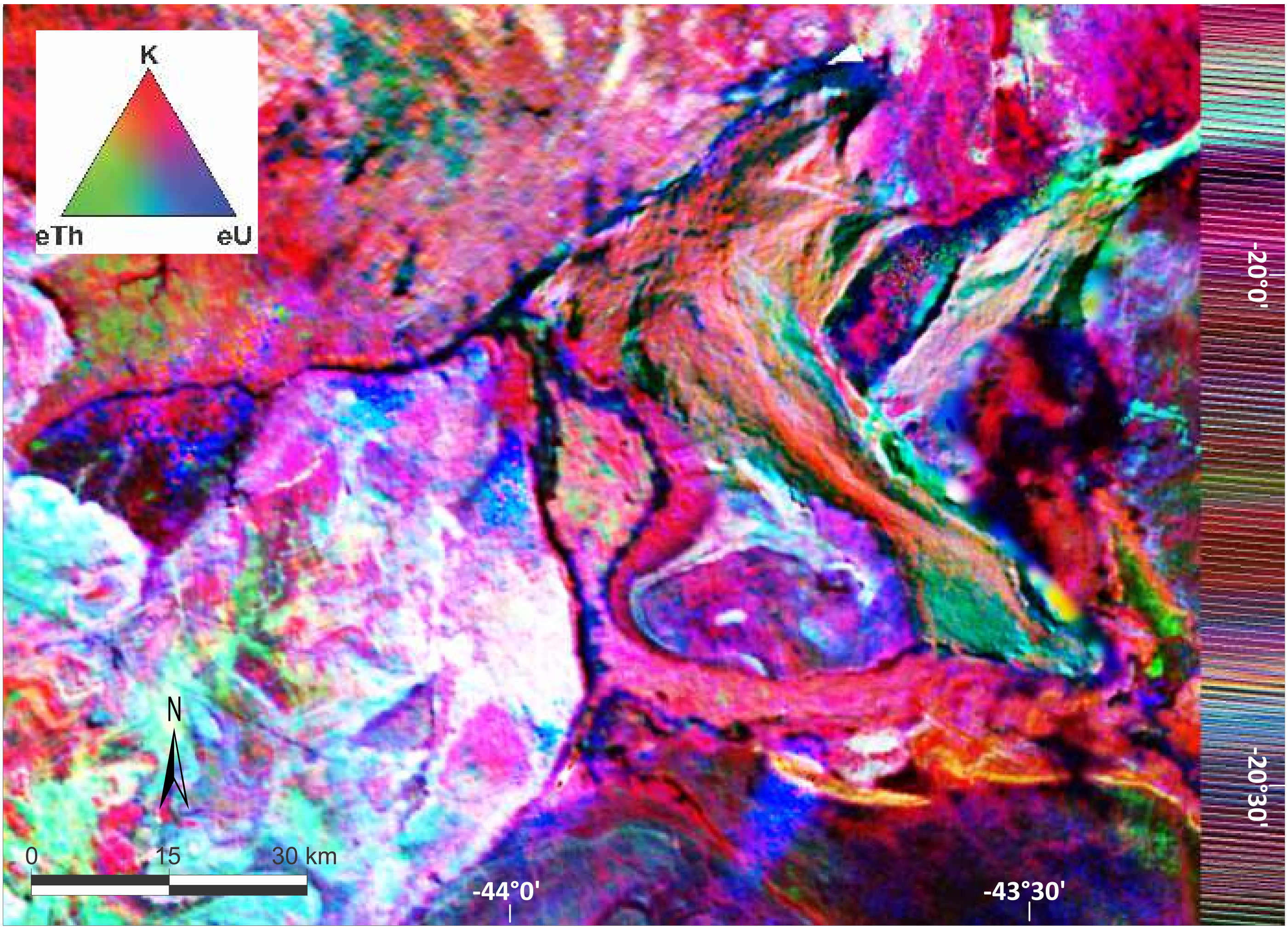


Figure 03 - Ternary gamma-spectrometry map (K, eU, eTh) of the Quadrilátero Ferrífero project area. The mafic and ultramafic rocks of the Rio das Velhas Supergroup basal unit are poor in radioelement concentrations and marked by dark zones. The regions with the highest K concentration are interpreted as hydrothermal zones commonly associated with gold deposits.

Cycle III mainly outcrops in the northern sector of QF and comprises felsic volcanic, volcaniclastic and resedimented rocks (monomictic and polymictic breccias, conglomerate-graywacke, graywacke-sandstone, graywacke-argillite). These rock associations indicate a submarine fan environment, progressively evolving to non-marine successions and the building of felsic volcanic edifices during the island arcs formation. The felsic metavolcanics were U-Pb dated to 2,776 Ma and 2,772 Ma. U-Pb zircon dating of the volcaniclastic rocks at 2,792 Ma, 2,773 Ma, and 2,751 Ma suggests that the felsic volcanic event lasted about 40 Ma as part of the greenstone belt formation. This magmatism was found to be coeval with the oldest QF group of calk-alkaline granitoids.

Cycle IV includes clastic sedimentary rocks belonging to a non-marine lithofacies association (conglomerate-, coarse-grained and fine-to-medium grained sandstones) of the Maquiné Group. Their depositional environments were interpreted as braided-river plains and alluvial fans in a retroarc foreland basin that was filled with debris from the previous cycles.

Gold deposits in the Rio das Velhas greenstone belt are structurally controlled and associated with hydrothermal alterations along Archean thrust shear zones. They were classified by Lobato et al. (2001) as orogenic gold deposits formed between 2.72-2.67 Ga, during the final stages of the Archaean orogenesis (Figure 08). The main mineralization styles are: (1) structurally controlled sulfide-replacement zones in BIF; (2) disseminated sulfides in hydrothermal rocks along shear zones; (3) quartz-carbonate-sulfide veins in mafic-felsic volcanic and clastic rocks. The gold-bearing mineralizations are disseminated in massive sulfide strata-bound ores of the Rio das Velhas Supergroup. They likely formed as epigenetic replacements in oxides and sulfides, or carbonate facies BIF (Figures 09 and 10). The chemical sediments make most of the country rocks of the gold deposits. The fluids at the orgin of these deposits were enriched in CO_2 and ^{18}O and reached temperatures between 325-400°C for low-to-moderate salinity.

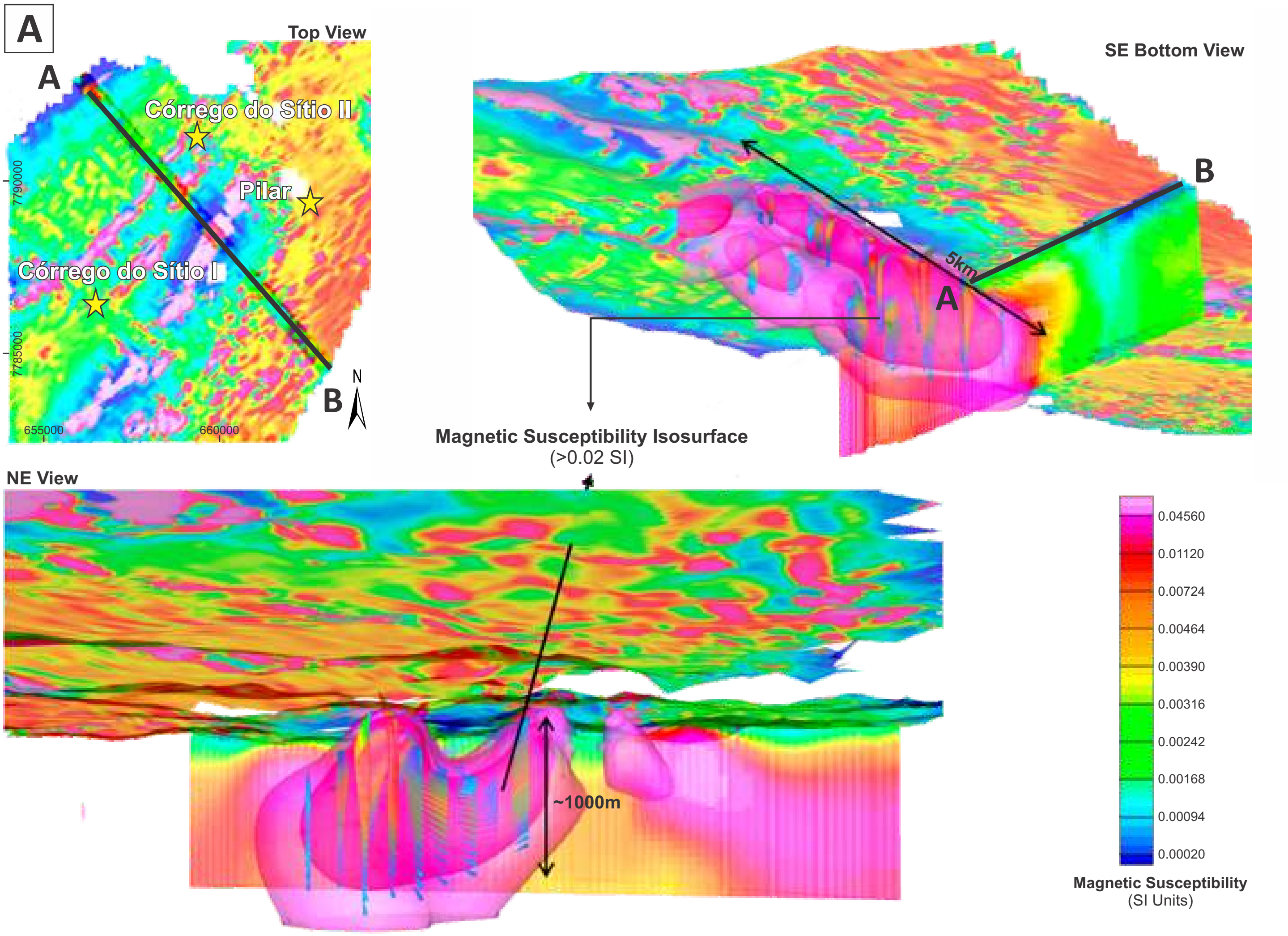


Figure 04 A - Magnetization Vector Inversion (MVI) results for the Santa Bárbara region showing a strongly magnetized body (k>0.02 SI) associated with BIFs and that correlates well with a NE-SW linear magnetic anomaly. The magnetic body shows a strong remanent magnetization as indicated by the vectors directions, with a synform structure (NE view) about 1000 m deep and 5 km long in the NE direction. This magnetic body can possibly be correlated with the Conceição syncline that is associated with the Córrego do Sítio Lineament. Further studies including MVI technique and integration with the HTEM modeling could help to better understand this structure and its association with gold deposits along this lineament.

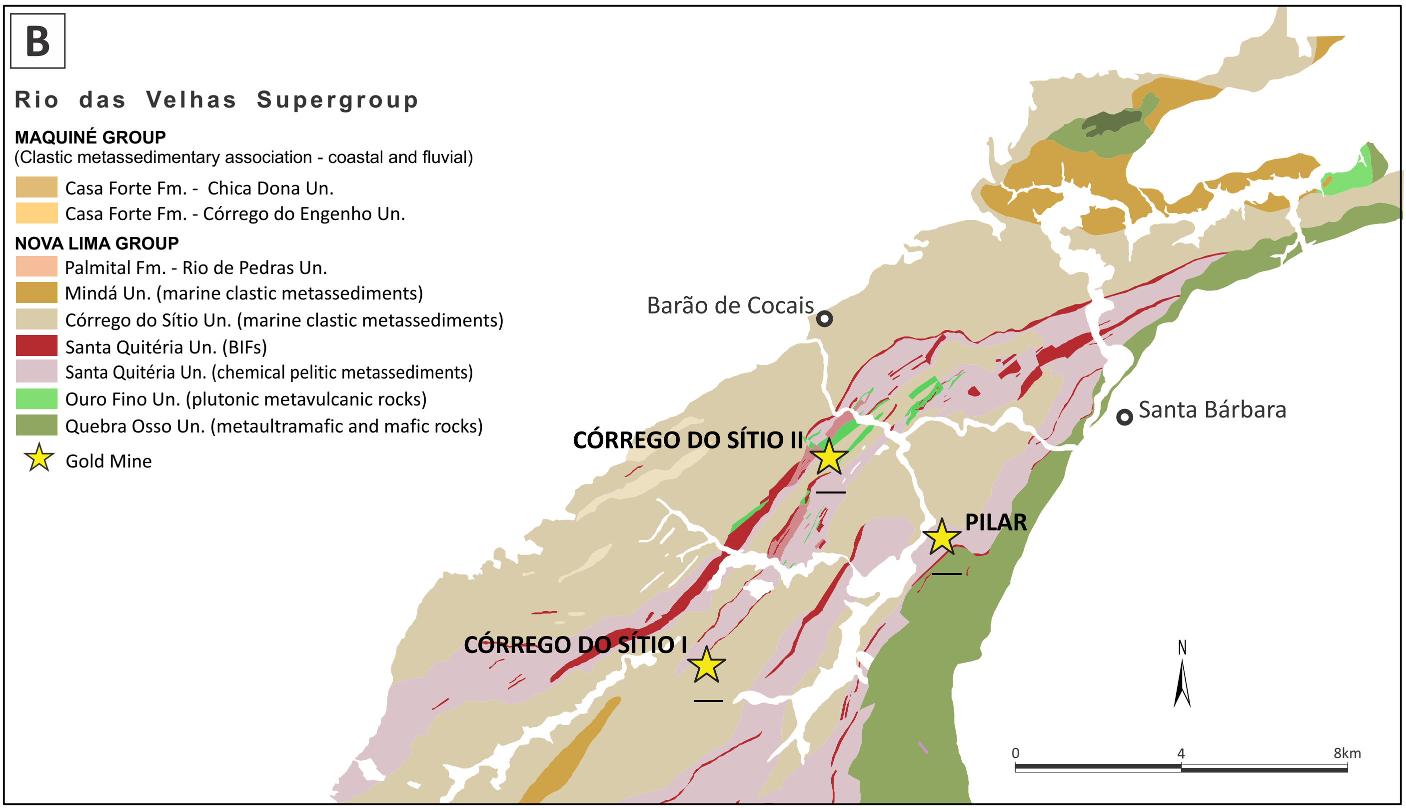
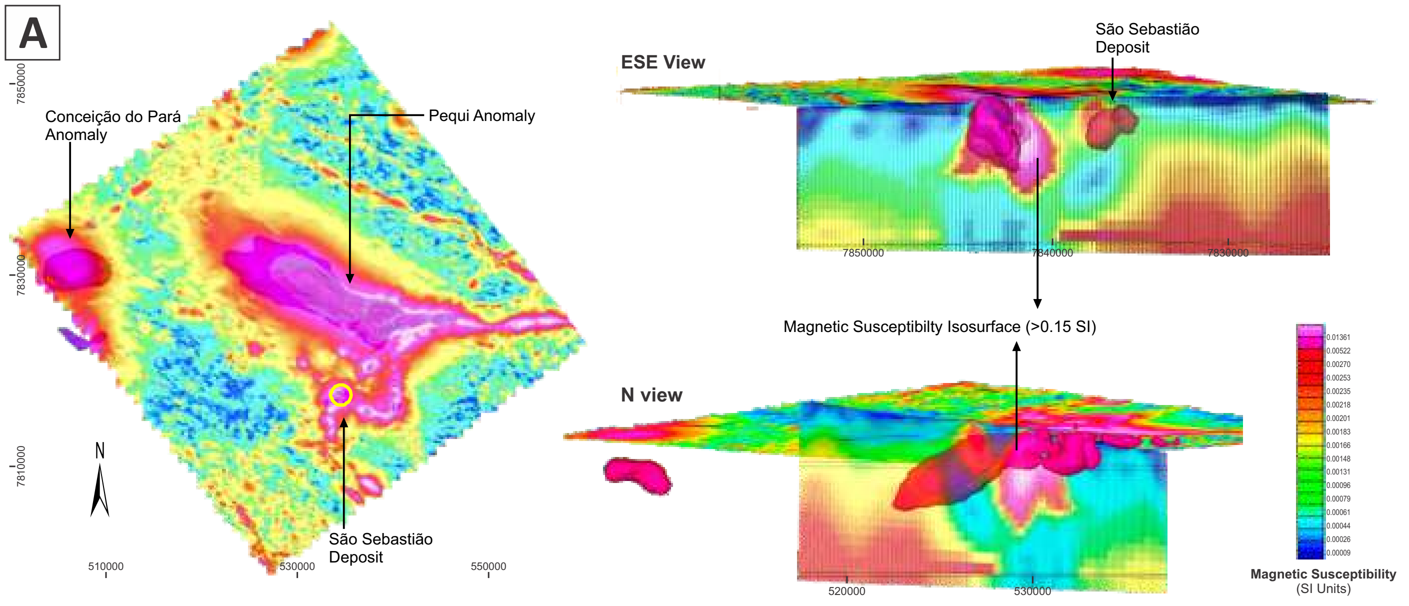


Figure 04 B - Geological map of the Santa Bárbara region. The main rock units comprise a metamorphosed succession of schistose sediments of the Nova Lima Group, Rio das Velhas greenstone belt, which hosts lode-gold mineralization associated with BIFs (Pilar and Córrego do Sítio II deposits) and quartz-carbonate-sulfide-sulfosalt-rich veins (Córrego do Sítio I deposit).



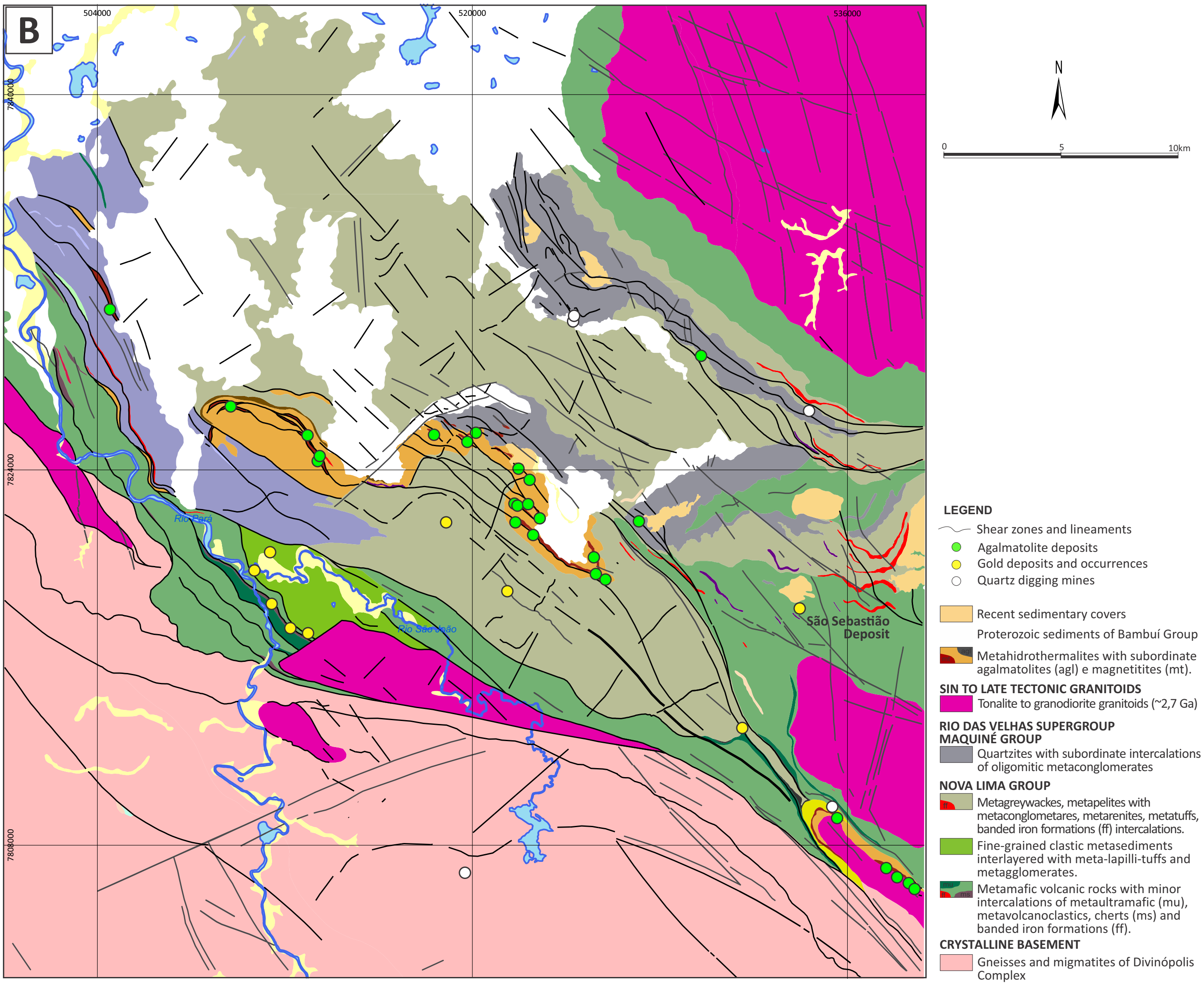


Figure 5A - Magnetization Vector Inversion (MVI) results for the Pará de Minas region showing a strongly magnetized body associated with the NW lineament (Pequi anomaly - shear zone). The NW portion of this magnetic body is likely correlated with magnetic BIFs, with an ellipsoidal shape dipping 40-45° to the NW. This magnetic body is of great importance for prospectivity, with its interpretation that could greatly contribute to the metallogenic and structural understanding of the area.

Figure 5B - Simplified geological map of the NW area showing the Rio das Velhas Supergroup lithostrigraphic units, the main gold, agalmatolite and quartz occurrences, with the São Sebastião deposit highlighted

Stratigraphic Columns of the Rio das Velhas Greenstone Belts

Gold mine	Lithological Association	Depositional Systems	Cycle	Stratigraphic Unit	Group	Supergroup
	Sandstone-conglomerate (matrix and clast-supported)	Continental alluvial fan and fluvial deposits	CYCLE IV	Casa Forte Fm.	MAQUINÉ GROUP	RIO DAS VELHAS SUPERGROUP
	Sandstone-siltstone	Proximal volcanogenic turbidites	CYCLE III	Rio das Pedras	NOVA LIMA GROUP	
	Greywacke-argilite,	Volcanogenic distal turbidites of Na-rich felsic source		Mestre Caetano		
1 ★	Volcanogenic conglomerate-greywacke, breccias (polymitic and monomitic), greywacke-sandstones	Volcanoclastic rocks of emergent island arcs, fluvial braided sandstones, alluvial fan breccias and conglomerates		Ribeirão Vermelho		
	Sandstone	Coastal sediments (aeolian, tidal plain)	CYCLE II	Andaimes (São Bartolomeu Domain)		
2 ★	Graywacke-argilite (calc-silicatic rocks and banded iron formations)	Resedimented turbidites (distal or proximal) of felsic and mixed sources		Catarina Mendes, Pau d'Óleo, Córrego Paina, Fazenda Velha (São Bartolomeu Domain) Córrego do Sítio, Mindá (Santa Bárbara Domain)		
3 ★	Pelites and banded iron formations	Pelagic and chemical marine sedimentary rocks		Santa Quitéria (Santa Bárbara Domain)		
4 ★	Basalts and banded iron formations Komatiites, basalts (cherts and banded iron formations)	Subaqueous mafic-ultramafic-volcanics partially associated with chemical sediments	CYCLE I	Morro Vermelho Ouro Fino Quebra-Osso, Córrego dos Boiadeiros Complex		

Scale: 1000, 500, 0 Meters

★ Gold mines: (1) Morro Velho, Cuiabá, Lamego; (2) Córrego do Sítio; (3) São Bento; (4) Raposos

Figure 06 - Stratigraphic column of the Rio das Velhas Greenstone Belt (adapted from Baltazar and Zucchetti, 2007).

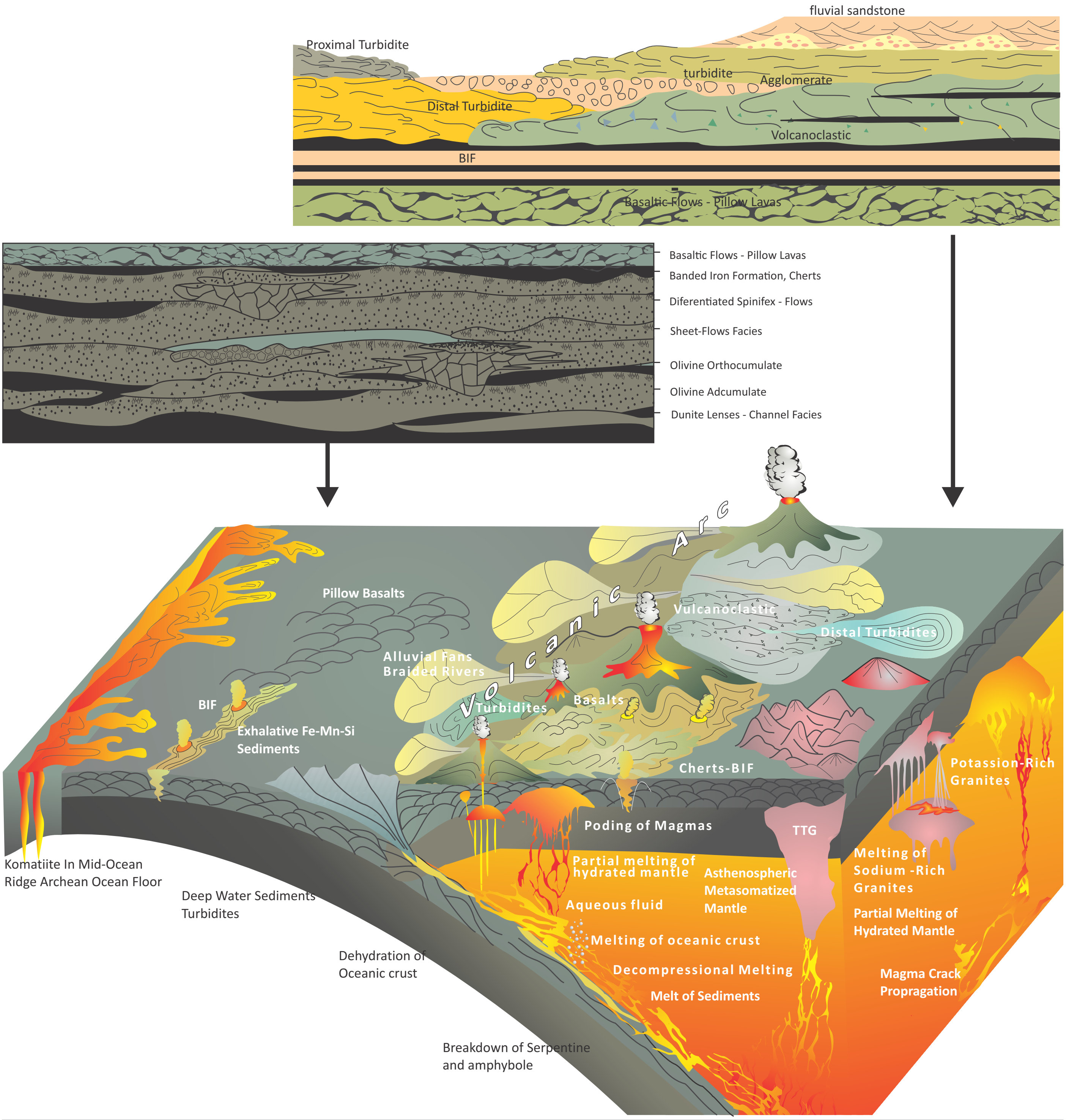


Figure 07 - Schematic model of greenstone belt evolution.

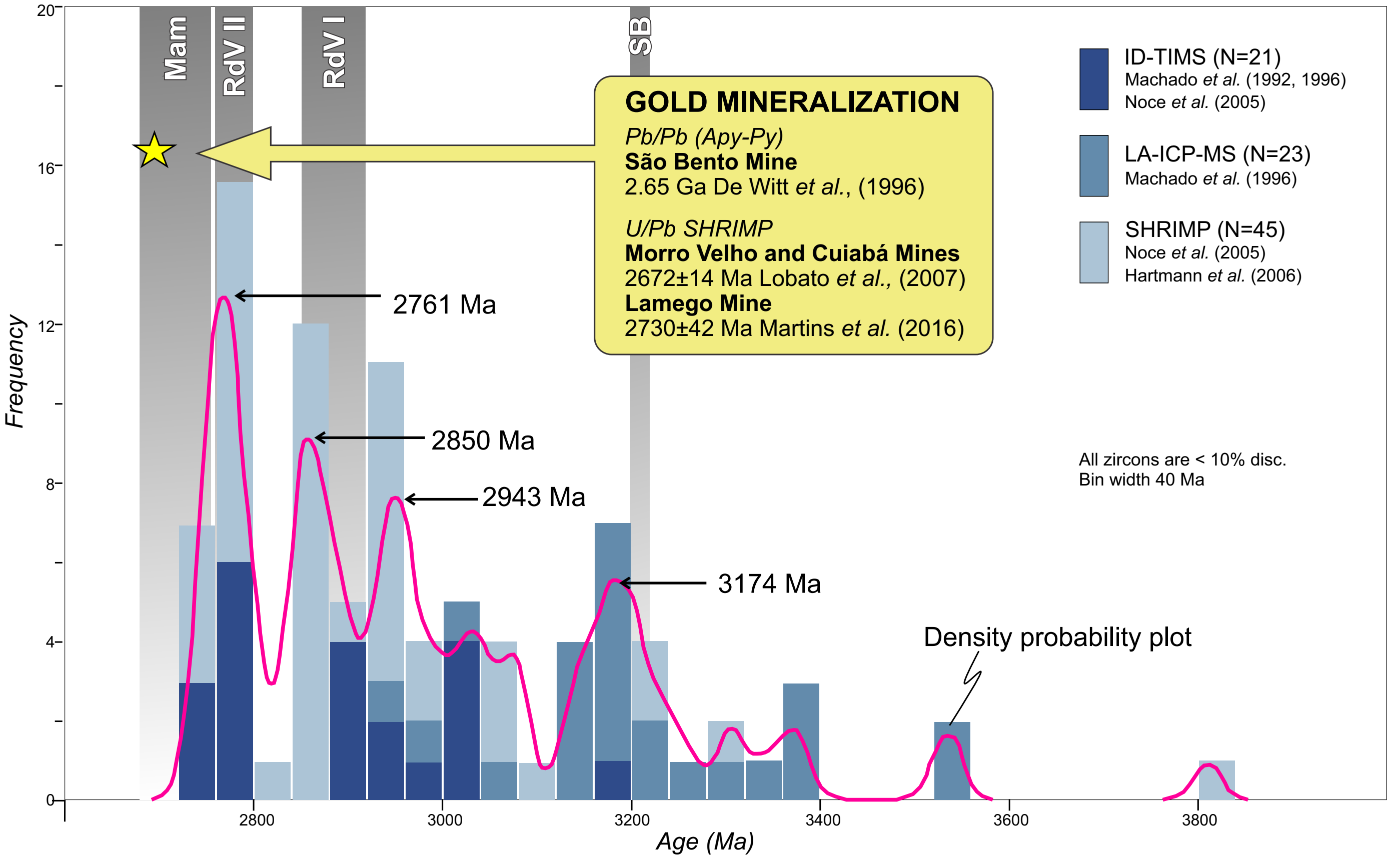


Figure 08 - Combined histogram and probability density diagram of detrital zircon U-Pb ages from rocks of the Rio das Velhas Supergroup. Vertical bands and yellow star mark the main magmatic events and gold mineralizations in the Quadrilátero Ferrífero region, respectively. The data was compiled from Farina et al. (2015) and linked references.

Figure 09 - Rock exposure of banded and massive sulfide ores. Insert photo of a drill core section presenting free gold in a quartz vein (Cuiabá mine).

Figure 10 - Rock exposure of sulfide-rich BIF hosting the Lamego orogenic gold deposit from the Rio das Velhas Greenstone Belt (Lamego mine operated by AngloGold Ashanti - photo credit: Joanna C.S. Araújo).

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Tapajós Project

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The Tapajós Project is being developed by the Geological Survey of Brazil (CPRM) as part of its program "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brazilian Shields" (Program I). This project aims to determine the regional and local controls of the known gold and base metals mineralizations, and to indicate favorable areas for mineral exploration. The project encompasses portions of two geochronologically distinct provinces that are located along the southwestern edge of the Amazon Craton (northwest Brazil): Tapajós-Parima (2.03-1.88 Ga) and Central Amazônia (1.88 Ga) (Santos, 2003). According to Cordani et al. (1984) the Archean Amazon Craton is surrounded by progressively younger orogenic belts that amalgamated to form a coalescence of accreted terranes (Figure 01).

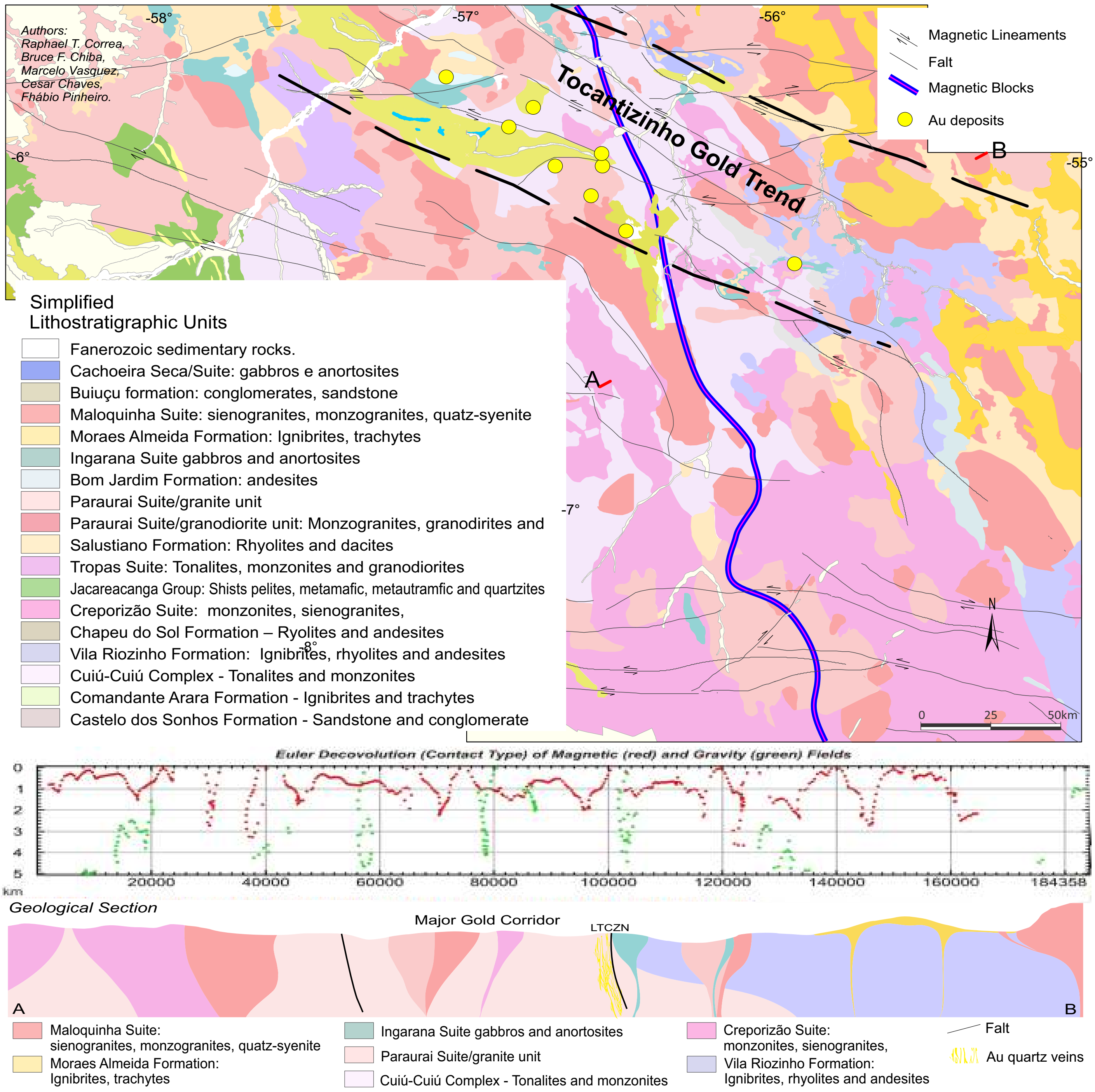
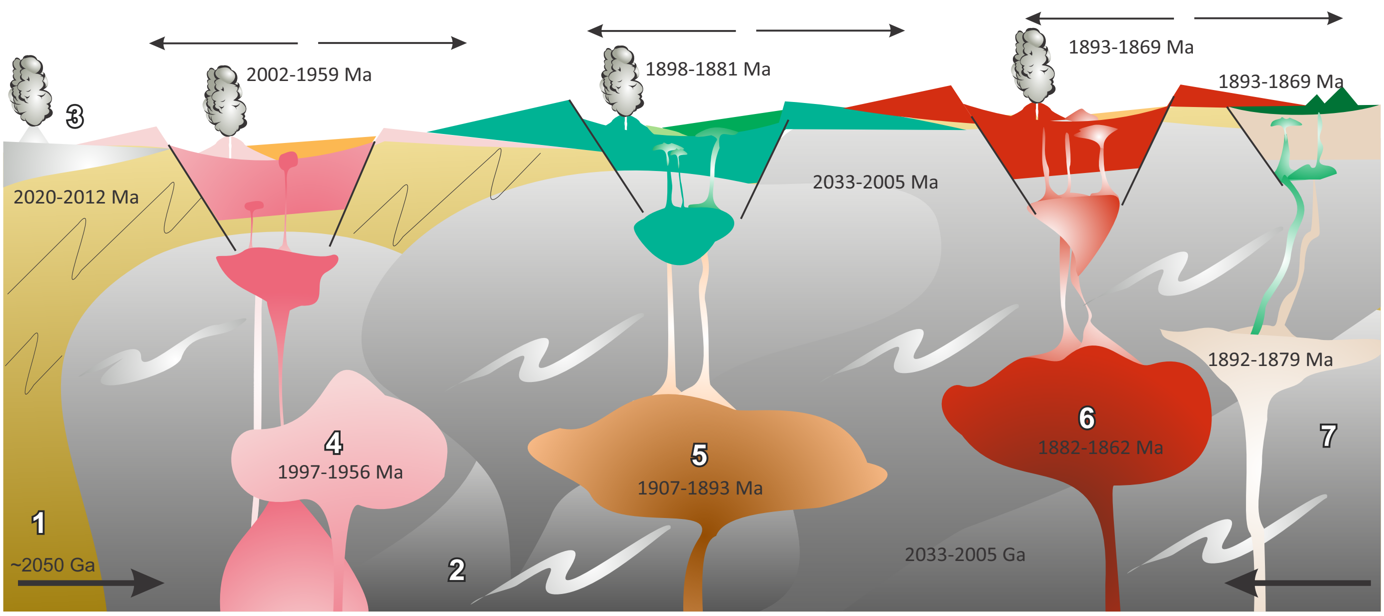


Figure 01 - Geological map of theTapajós project area. The Euler deconvolution of magnetic and gravity data (middle panel) was used to delineate the main geological contacts and faults. The geological model (lower panel) shows that the Tocantizinho gold trend is associated to a deep crustal discontinuity.

The Tapajós Gold Province (TGP) (Coutinho, 2008) is located on the south-central portion of the Amazonian Craton, in the states of Pará and Amazonas. It has a total historical production of about 780 tons of gold, extracted mainly by handcrafted digging of rivers and streams, and subordinately from hundreds of artisanal small open pits and underground mines. There is currently only one mine in activity at Tapajós (Palito mine, 668 KOz Au, Serabi Gold) and one major project under development (Tocantinzinho, 1,824 MOz Au in reserves, 2.115 MOz Au in resources, Eldorado Gold). Other significant deposits are still in exploration phase, e.g. São Jorge (1,584 MOz Au, Gold Mining), Coringa (913 KOz Au, Anfield), Boa Vista (336 KOz, Gold Mining). A total resource of 7.5 MOz has been reported from the five main gold deposits in the region, which are under development mainly by Canadian and Australian mining companies.

The basement rocks of the Tapajósarea comprise plutonic rocks, gneisses, migmatites (2.04-2.02 Ga - Cuiú-Cuiú Complex) and a relatively thin volcano-sedimentary unit (Jacareacanga Group). These rocks have calc-alkaline affinities with medium-K and juvenile isotopic signatures. The Cuiú-Cuiú granitoids are characteristic of magmatic arcs or active continental margins (Almeida et al., 2007; Vasquez et al., 2008). Figure 02 shows underformed plutonic-volcanic sequences that partially cover the basement, including few that are considerated by Fraga et al. (2015) as belonging to the Uatumã Siliceous Large Igneous Province (SLIP).



1 → **Jacareacanga Group (2,050 Ga)** - pelític shist, quartzites, metamafic and metaultramafic
2 → **Cuiú-Cuíu Complex** - Tonalites, Monzogranites and migmatites
3 → **Comandante Arara Formation** - Ignibrites, rhyolites, andesites e vulcanoclástic
4 → **Crepori / Vila Riozinho Event** - Ignibrites traquites, andesites, Ryolites, vulcanoclastic and sediments.
5 → **Tropas Event**- Tonalitos e Monzogranitos Dacitos, latitos, andesitos e basaltos
6 → **Maloquinha / Iriri Event** - Sieno granitos, monzogranitos e granitos Ignibritos, riolito, dacitos e traquitos
7 → **Parauari / Bom Jardim Event** - Monzogranites e diorites, dacites and basalts

Figure 02 - Schematic representation showing the basement of the Tapajós area, including the Cuiú-Cuiú complex and Jacareacanga volcano-sedimentary sequence, with four main dated plutonic-volcanic events that were accompanied by sedimentary events.

The SLIP plutonic and volcanic rocks have geochemical signatures compatible with an A-type or high-calcium alkaline suite (Vasques and Dreher, 2011). They comprise several volcanic lithostratigraphic units (e.g. Iriri, Bom Jardim) and granitoids (e.g. Maloquinha, Velho Guilherme, Rio Dourado, Parauari, Tropas), with ages ranging between 1.90-1.86 Ga (Fraga et al., 2015). Rhyacian- and few Neoarchean ages for the Tapajós Domain were inferred using Sm-Nd system, with εNd(t) between -6.7 and -0.7, whereas Meso-to-Neoarchean ages were inferred for the Iriri-Xingu Domain, with εNd(t) between -5.35 and -12.1. The volcanic rocks dominantly comprise rhyolitic and dacitic ignimbrites, also described as ash-flow tuffs. Felsic- to andesitic lavas, subvolcanic rocks, and ash-fall tuffs occur subordinately as compared to the extensive ignimbrite deposits. Lithology and eruption mode of the Vila Riozinho volcanic unit appear similar to the older Iriri unit. The unit consists of strongly welded dacitic ignimbrites with phenocrysts of plagioclase, K-feldspar and subordinate quartz crystals, flattened pumice clasts, in a microcrystalline, felsic, flow-foliated matrix (Figure 03). Other rock-types in this unit occur as trachytic and andesitic flows (Figures 03, 04 and 05).

Figure 03 - Dacitic ignimbrite of the Vila Riozinho Formation containing plagioclase (Pl) and K-feldspar (Kf) crystals, and flattened pumice clasts (Pm) in a microcrystalline felsic flow-foliated matrix. Thin section of sample MV-265 viewed under plane polarized light (horizontal scale: 1 mm).

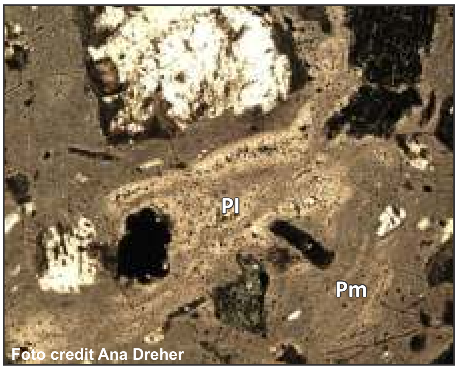


Figure 04 - Welded dacitic-to-andesitic ignimbrite belonging to the Iriri unit and showing zoned plagioclase crystals (Pl), altered mafic phases and pumiceclasts (Pm), in a very fine-grained groundmass. Thin section of sample CE-24 viewed under plane polarized light (horizontal scale: 1 mm).

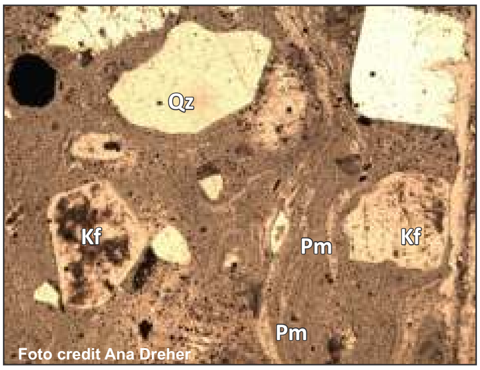


Figure 05 - Densely welded rhyolitic ignimbrite of the Moraes de Almeida sequence, containing K-feldspar (Kf) and quartz (Qz) crystals, and a foliation defined by flattened aligned pumice lapilli (Pm). Thin section of sample AT-02 A viewed under plane-polarized light (horizontal scale: 1 mm).

Three main types of gold mineralization are known at TGP (Figures 06, 07 and 08): (1) Compressional shear veins associated with the Jacareacanga and Cuiú-Cuiú units, with restricted alterations of sericite, carbonate and chlorite (Espírito Santo, Bom Jesus, Pepeu, Chico Torres, Jerimum de Cima garimpos). These mineralizations are considered as orogenic gold or intrusion-related type deposits (Coutinho, 2008; Vilas et al., 2013; Assunção and Klein, 2014); (2) Extensional epithermal high-grade quartz veins with comb texture and adularia. These mineralizations are hosted by the plutonic-volcanic sequences of Creporizão-Riozinho (2,000-1,968 Ma), Parauarí-Moraes de Almeida (1,898-1,880 Ma) and Maloquinha-Iriri (1,890-1,864 Ma), and found as well from the artisanal extractions (garimpos) of Carneirinho, Goiano, Pison and Abacaxis (Dreher et al., 1998), and; (3) High sulfidation low-grade gold deposits (e.g. V3) (Jacobi, 1999; Juliani et al., 2014).

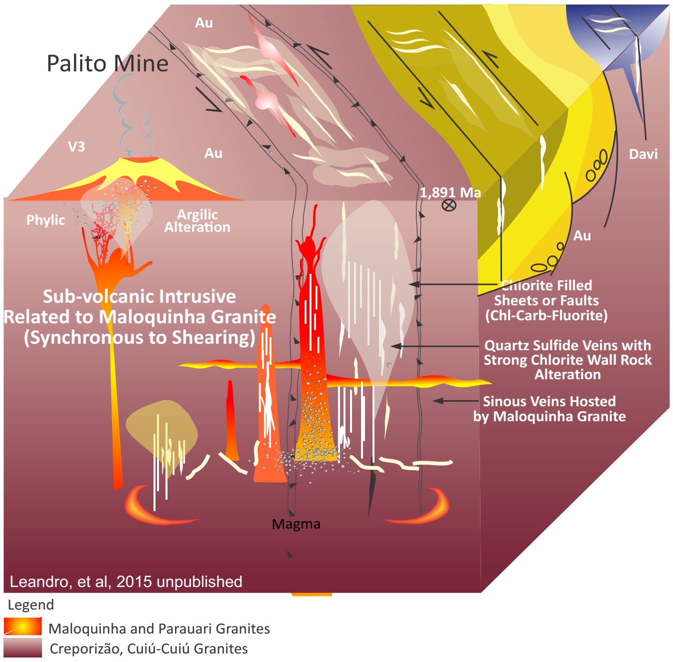


Figure 06 - Schematic model of Tapajós gold mineralizations. Note that the mineralized veins and subvulcanic bodies are controlled by britte shear zones. Palito mine in detail.

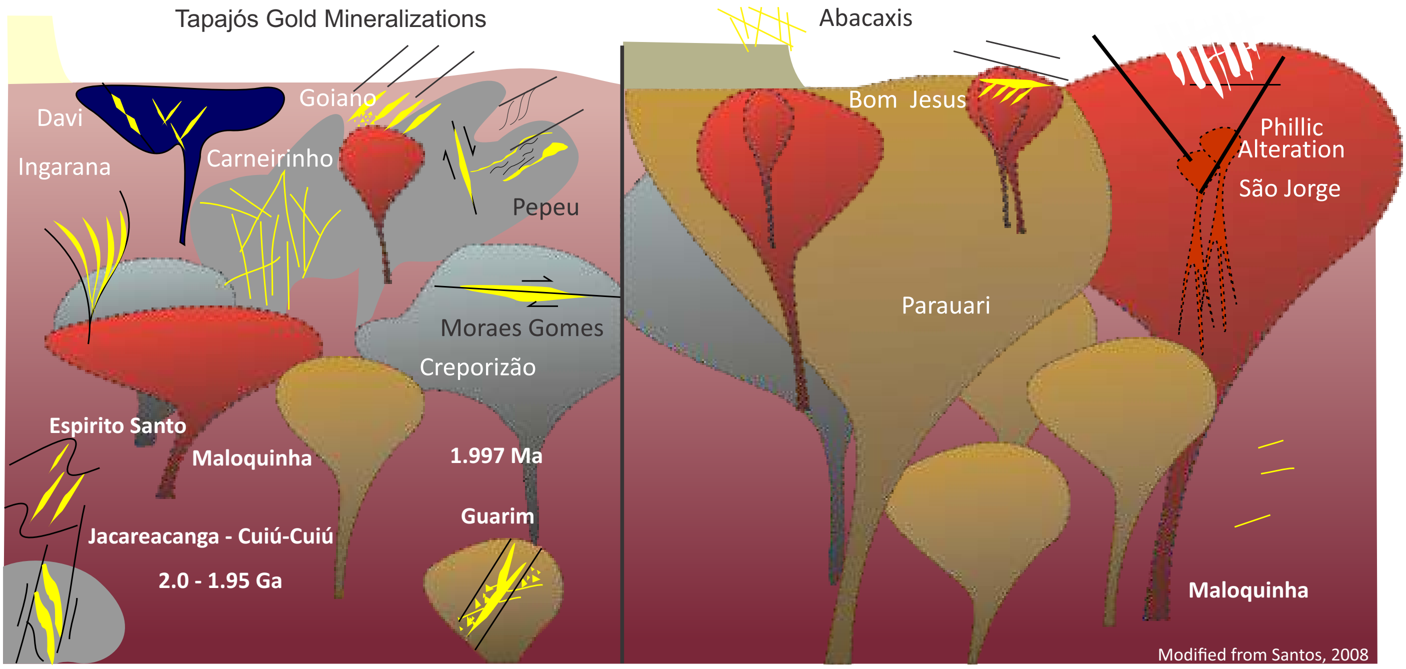


Figure 07 - Schematic representation of small gold deposits in the Tapajós region. Note the predominant occurrence of quartz veins in the shear brittle zones surrounded by phyllic alteration.

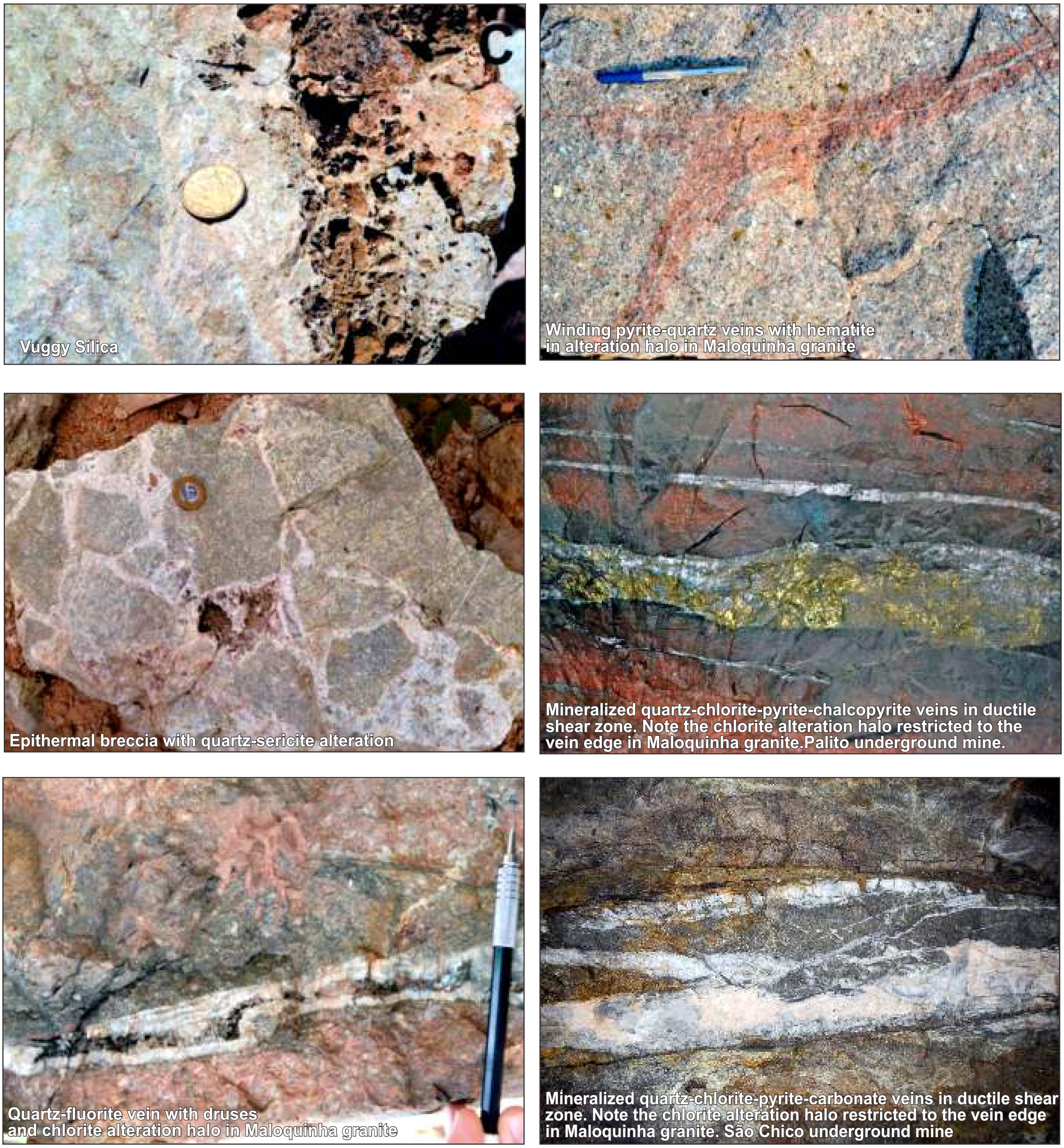


Figure 08 - Geological features of Tapajós gold mineralizations.

The geotectonic evolution of TGP and adjacent terranes is subjected to strong scientific debate. Teixeira et al. (2014) suggested that the TGP gold deposits are related to intra-continental magmatism originated at a rifted cratonic keel, with asthenospheric melts rising through the rift margins at 2.0-1.88 Ga (Figure 09). The predominance and large volume of felsic magma can be explained by the influence of a mega plume that pounded at the base of the crust, yielding extensive underplating and bimodal volcanism (Santos, 2015) (Figures 10 and 11).

.The TGP gold mineralization has about the same age as the Maloquinha and Parauarí plutonic-volcanic sequences, which are derived from a huge continental magmatic event that affected a large portion of the Amazon Craton (Fraga et al., 2015) (Figures 12, 13 and 14).

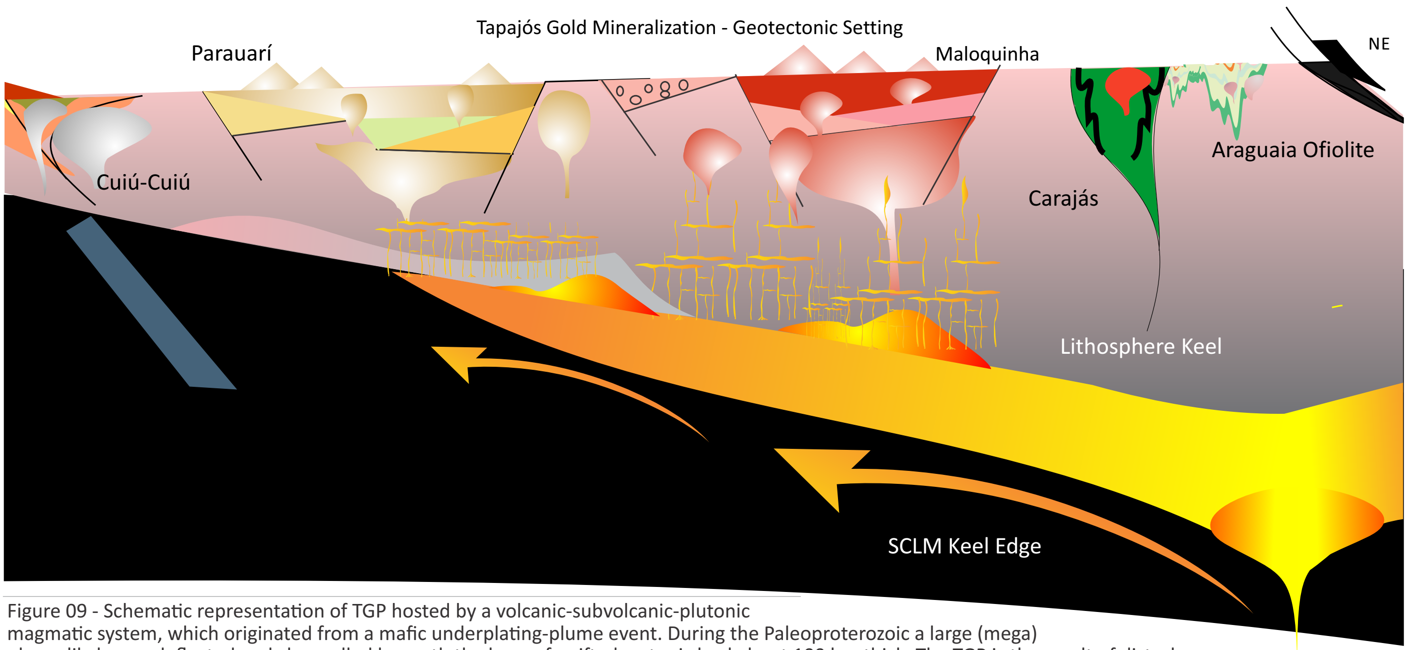
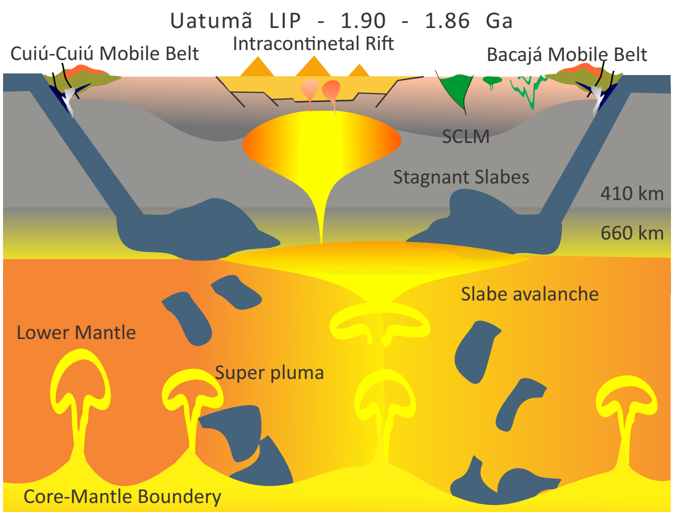


Figure 09 - Schematic representation of TGP hosted by a volcanic-subvolcanic-plutonic magmatic system, which originated from a mafic underplating-plume event. During the Paleoproterozoic a large (mega) plume likely was deflected and channelled beneath the base of a rifted cratonic keel about 100 km-thick. The TGP is the result of disturbances affecting the Subcontinental Lithospheric Mantle (SCLM) during rifting events and therefore is not related to the formation of a convergent plate margin. .



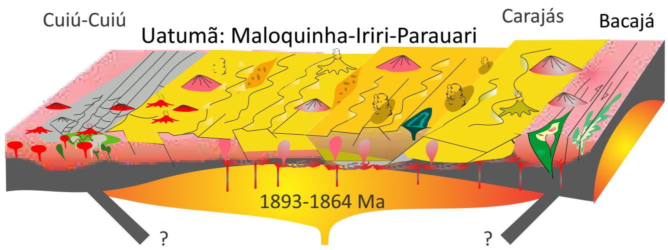


Figure 11 - Schematic representation of the Uatumã SLIP geotectonic setting. The large (mega) plume may have been triggered by gravitational fall of Transamazonian slabs in the Transition Zone, in a similar model as proposed by Pirajno and Santosh (2014). .

Figure 10 - Fraga et al. (2015) proposed that the subduction of oceanic plates adjacent to the Amazon Craton may have favoured the formation of the Siliceous Large Igneous Province (SLIP) of Uatumã. Pirajno and Santosh (2014) explained the worldwide development of enormous amounts of felsic magmas by plumes triggered by gravitational fall of destabilized pieces of ocean floor in the Transition Zone.

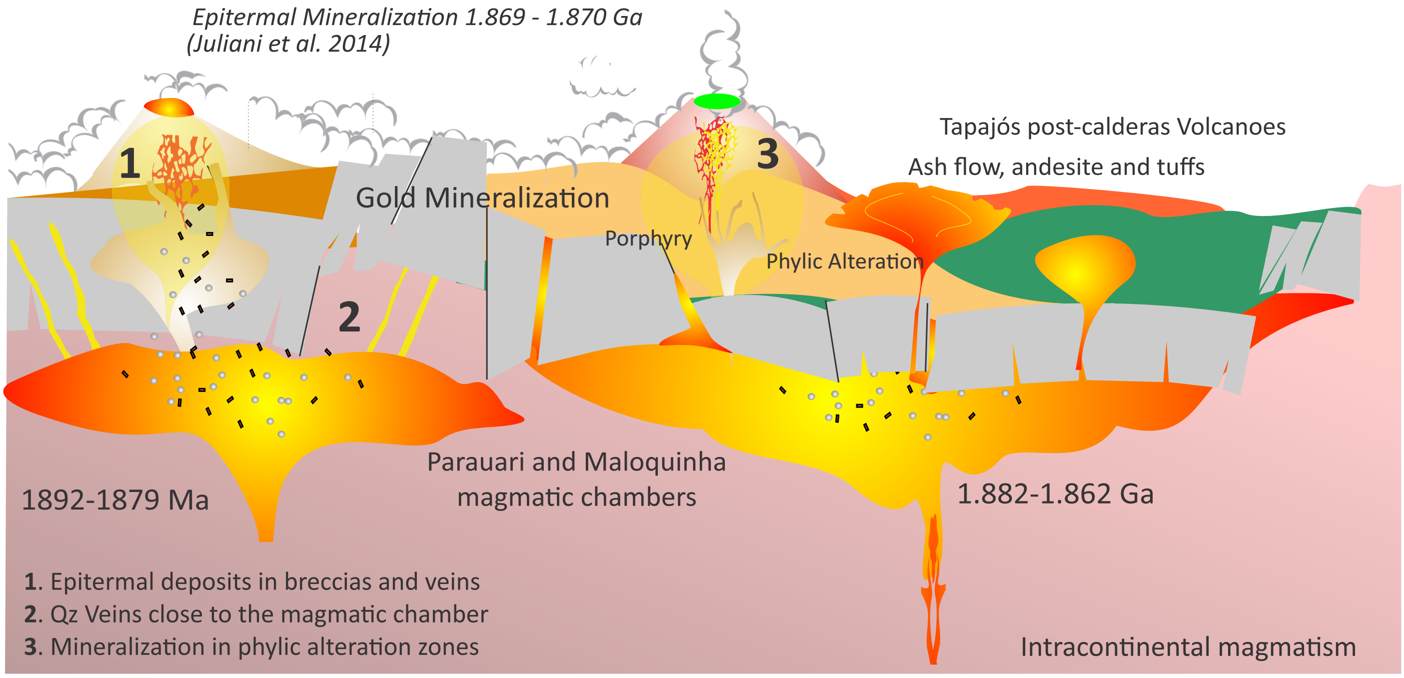


Figure 12 - Schematic representation of Tapajos volcanic setting formed by ignimbrites, rhyolitic and dacitic flows erupted from subaerial calderas (modified from Juliani et al., 2014). The gold mineralization is related to sub-vulcanic phorphyry, plugs and quartz veins surrounded by a phyllic alteration zone.

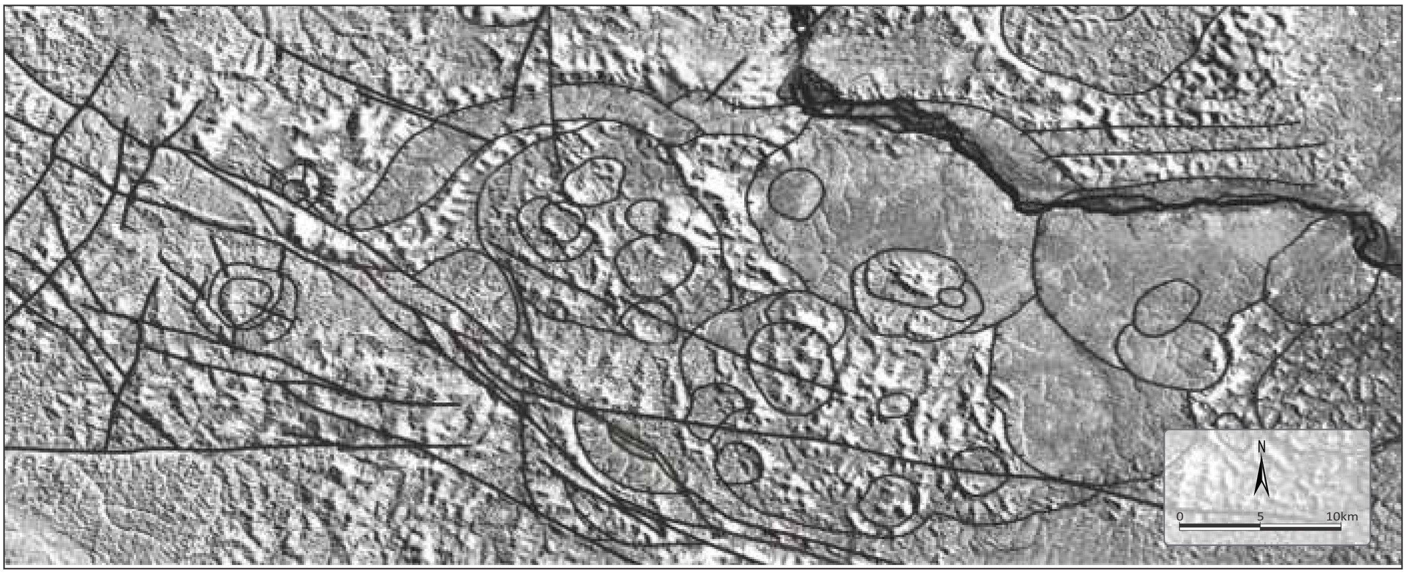


Figure 13 - Maloquinha and Parauari volcanic region formed by the coalescence of calderas and covered by ignimbrites, rhyolites and dacites (taken from Juliani and Fernandes, 2010).

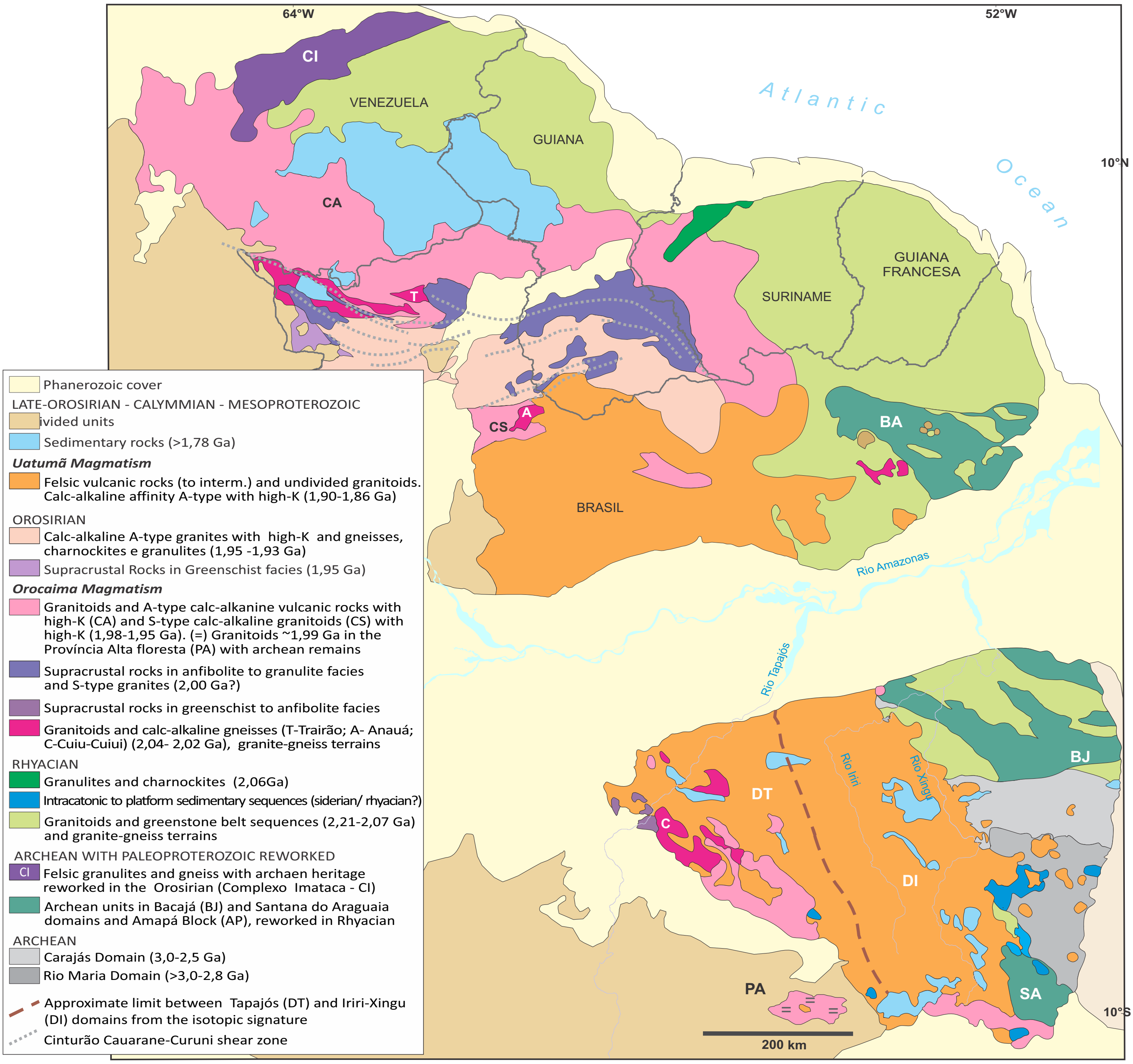


Figure 14 - Geological map of the Amazonian region showing the continental extension of the Uatumã SLIP as highlighted in orange (Fraga et al., 2015).

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Juruena-Teles Pires Project

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The Juruena-Teles Pires Project is being developed by the Geological Survey of Brazil (CPRM) as part of its program "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brazilian Shields" (Program I). The Project is focused on the Alta Floresta Gold Province (AFGP) which historically has produced around 300 tons of gold (Figure 01). This province is located in the north of Mato Grosso State and consists of a 600 km long section of alluvial and primary gold occurrences, extending from the Peixoto de Azevedo and Matupá towns (eastern part) to the Juruena river (western part). This region also includes the Zn-Pb-(Cu) deposit of Aripuanã.

Despite its mineral importance, the geological and geochronological knowledge of the area is limited. Different types of deposit have been inaccurately described at the AFGP - e.g. porphyry-, epithermal-, orogenic- or intrusion-related. Part of this difficulty results from the complexe and uncertain classification schemes that were used.

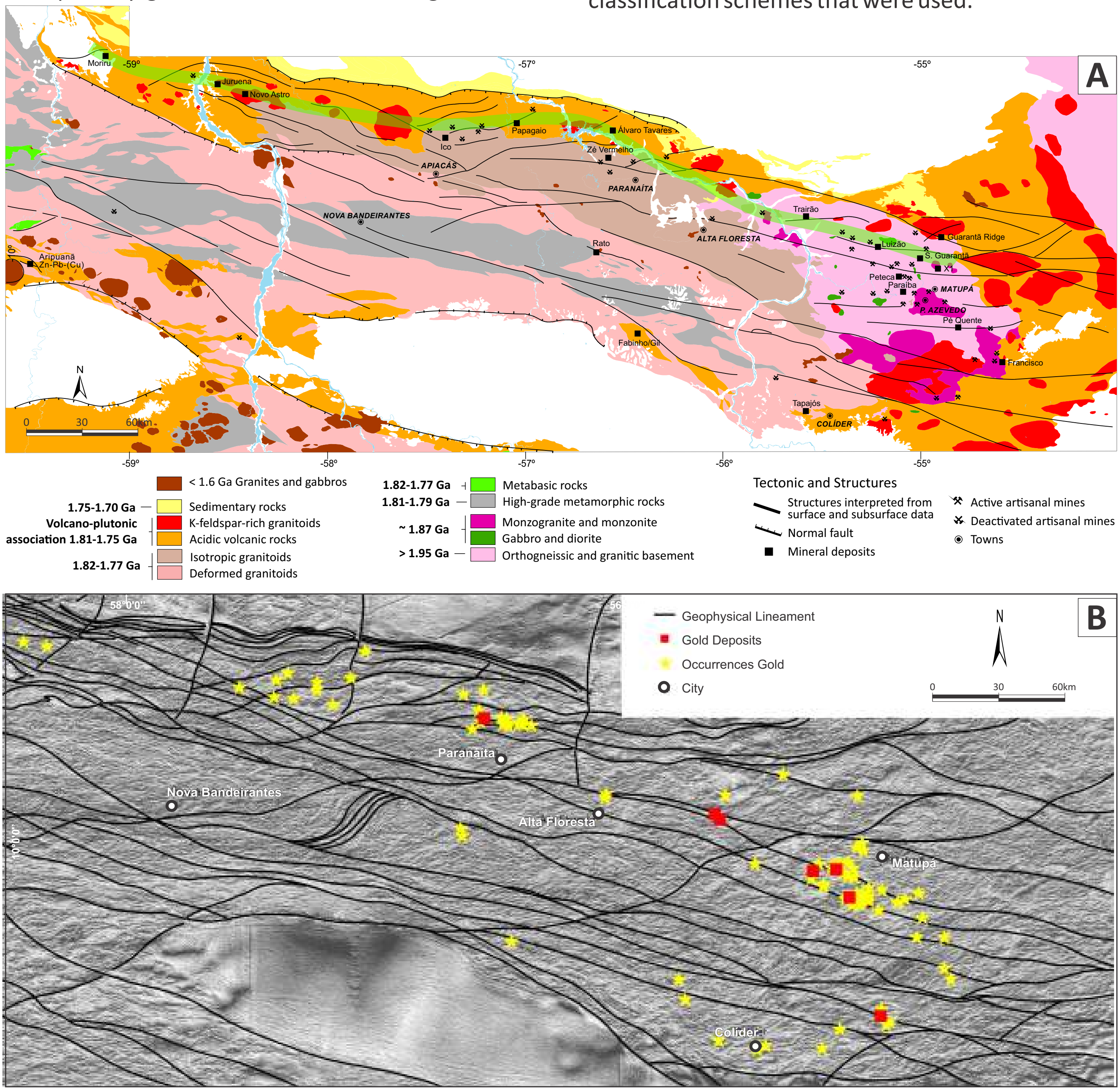

Figure 01 - (A) Simplified geological map of the Juruena-Teles Pires project area.
(B) Geophysical lineament interpretation surimposed on the principal gold occurrences and deposits.

The Juruena-Teles Pires Mineral Province (JTPMP) is located at the southern margin of the Amazonian Craton. This region experienced three main magmatic events that include: (1) 1.99-1.93 Ga granitic and metamorphic basement composed of felsic intrusions and highly deformed metamorphic rocks; (2) ca. 1.87 Ga granitic and basaltic magmatism; and (3) 1.82-1.70 Ga felsic and mafic volcanic-plutonic magmatism (Figure 02). During this third event a high-grade metamorphic core complex that comprises metasedimentary and meta-igneous units (upper amphibolite to granulite facies) also formed (Figure 03). The Beneficent Group (1.5-1.4 Ga) overlies all the above described units and is characterized by a rift-related sedimentary sequence composed of arenite and pelite intruded by mafic and felsic rocks.

The Colíder Group was formed during an acidic volcanic event of high-K, calc-alkaline, meta- to peraluminous compositions and mainly comprising rhyolite, dacite, andesite and pyroclastic rocks (ignimbrite, tuff). Compiled U-Pb ages from the Colíder Group indicate a magmatic activity concentrated between 1.82-1.77 Ga. Sm-Nd isotopic data indicates model ages ranging between 2.8-1.8 Ga with ƐNd(t) between +5.45 and -3.06, indicative of anheterogeneous magmatic source with contribution of both the mantle and the crust. The Teles Pires Suite is composed of alkali-feldspar granite, syenogranite, monzogranite, monzonite and granophyre, showing mixing textures such as rapakivi, fine-grained mafic and felsic enclaves. U-Pb crystallization ages range between 1.81-1.75 Ga while Sm-Nd model ages between 2.4-1.94 Ga, with ƐNd(t) between +3.0 and - 3.4, suggesting the same conditions of formation as for the Colíder Group.

Assis (2015) dated the mineralization in three gold deposits located in the eastern part of JTPMP : (1) Pé Quente (Re-Os in pyrite) -- 1.792 ± 9 Ma to 1.784 ± 11 Ma; (2) Luizão (Re-Os in pyrite) -- 1.790 ± 9 Ma to 1.782 ± 9 Ma; and (3) X1 (Re-Os in molybdenite) -- 1.787 ± 7 Ma to 1.785 ± 5 Ma. The yielded isochron

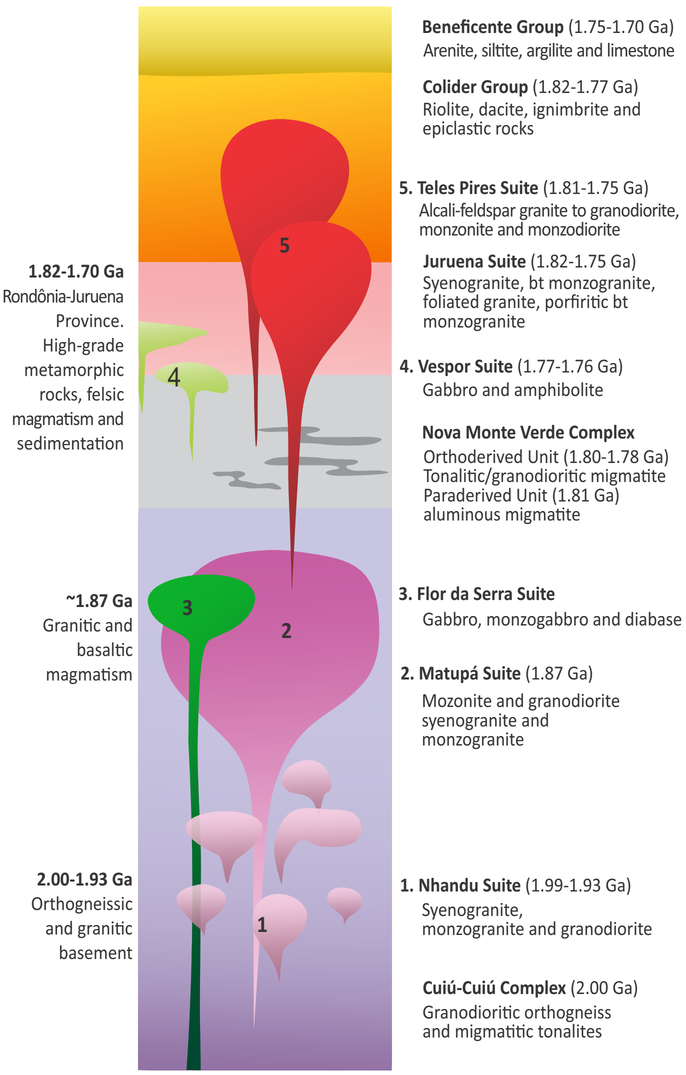

Figure 02 - Schematic representation of the JTPMP units with the different types of intrusions involved.

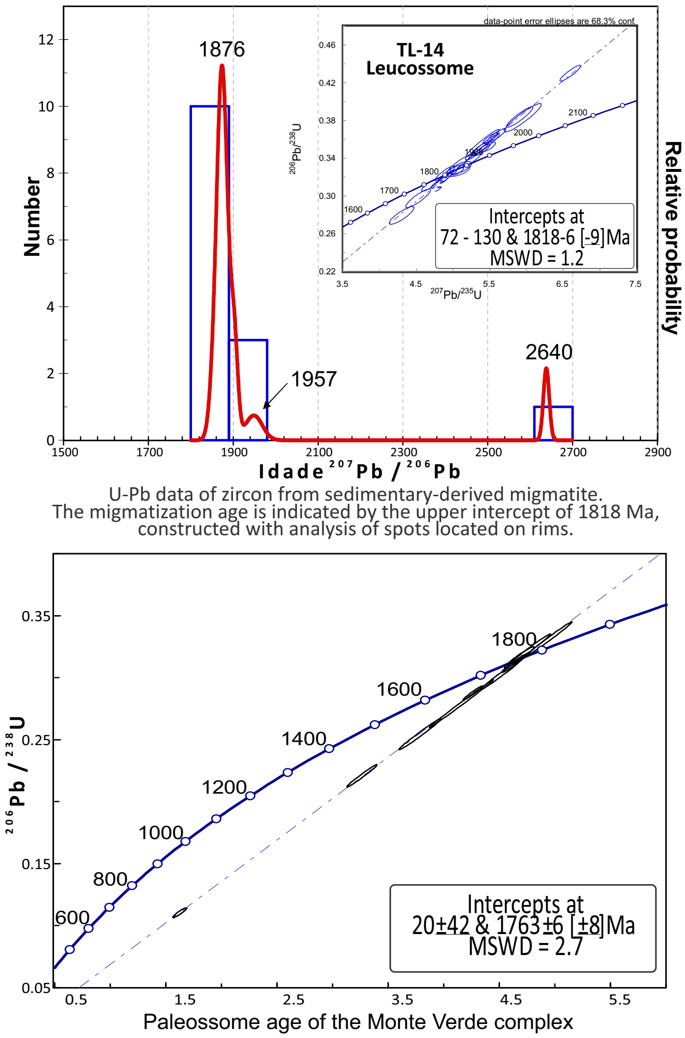

Figure 03 - Combined histogram and probability density diagram (upper panel) with the corresponding concordia (lower panel) of U-Pb zircon ages obtained from leucosome, with the upper intercept interpreted as the age of migmatization.

age of 1.786 ± 1 Ma was interpreted as the age of a single mineralizing event for these three gold deposits (Assis, 2015). Those results corroborate with the ages obtained from porphyritic granite bodies (União do Norte porphyry: Miguel-Jr, 2011; Assis, 2015), which have been interpreted as the source of the mineralizing agent. Some authors do not discard the possibility of more than one mineralizing event at JTPMP. This province is considered as the counterpart of the Tapajós Mineral Province, located to the north and separated by the Cachimbo graben, and whose isotopic data suggests an age of 1.87 Ga for the mineralizing event.

The main characteristics of gold mineralization in the Alta Floresta region are the same as in the Tapajós area and only differ by slightly younger ages. There are two main types of gold mineralization in the Alta Floresta area: (1) Small disseminated and structurally-controlled deposits of Au ± Cu - (Bi, Te, Ag, Mo), associated with pervasive silicification and sulfidation; and (2) Structurally-controlled vein-type deposits of Au + Zn + Pb ± Cu. Both deposit types are hosted by granites (Assis, 2015). Serrinha and Juruena deposits have been additionally considered as porphyry type (Abrão) emplaced in a volcanic arc setting. The gold mineralization in the province occurs along transtensional faults and ductile-brittle shear zones (Figure 01). Most of the deposits are hosted in quartz veins and veinlets cutting granite bodies and volcanic rocks. The shapes of the ore-bodies are variable but predominate as pyrite, chalcopyrite and/or galena-bearing quartz veins, with gold concentrated in dilatational fault jogs or transtensional faults (Figures 04 and 05). Most of the veins are up to 3 m thick and several tens of meters long (e.g. Paraíba deposit -in the Peixoto de Azevedo region). The mineralization also occurs as disseminated sulfides within the hydrothermal alteration zones of volcanic and granitic rocks (Figure 06). The hydrothermal alterations associated with mineralization are mainly phyllic and containsericite, quartz and pyrite. The more distal of these alterations are represented by propylitic

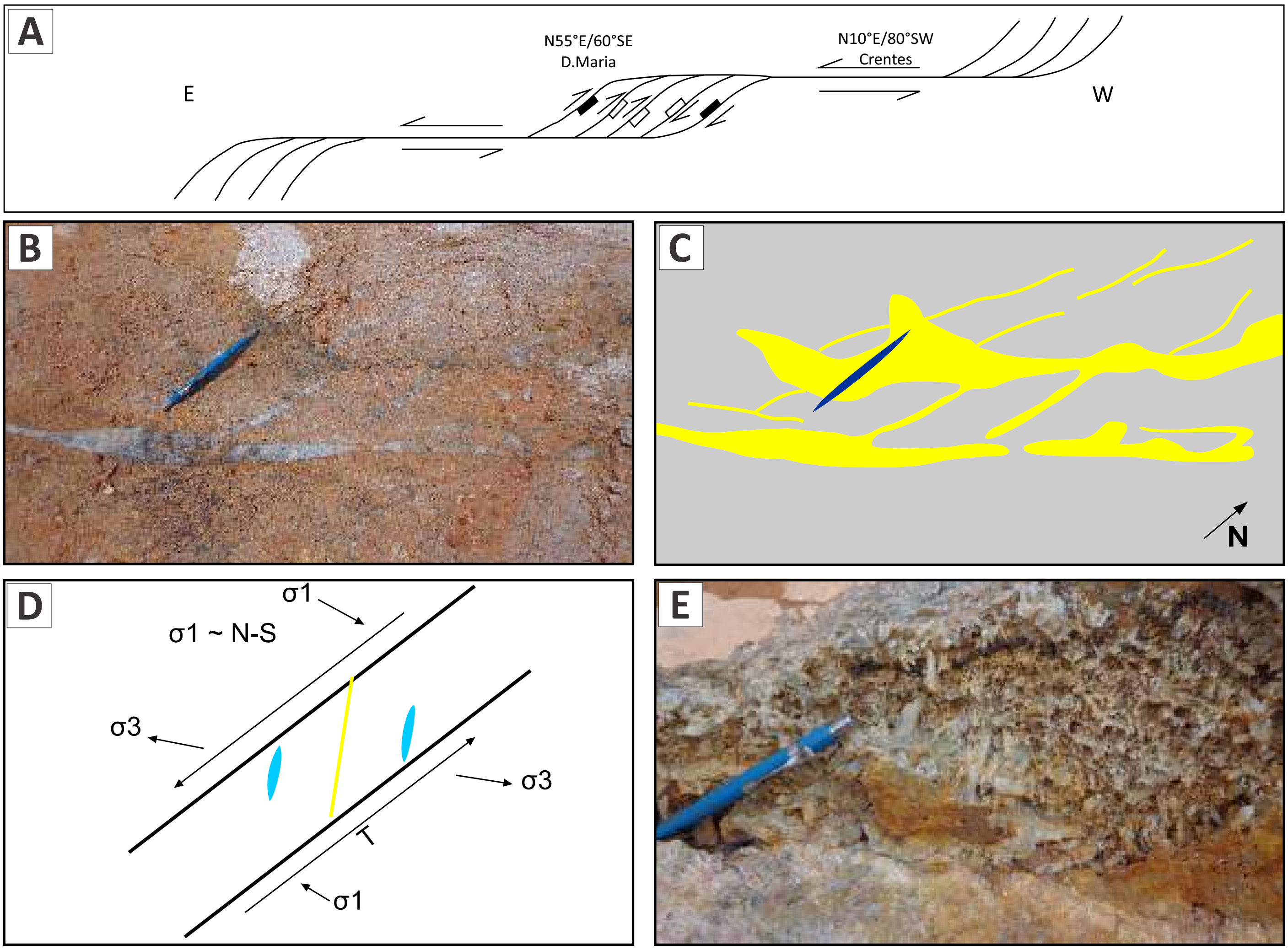

Figure 04 - (A) Structural model of the shear zone identified in the Crentes and Dona Maria deposits. (B) (C) (E) Shear zone filled by quartz and sulfide and extensional veins filled by drusiform quartz. (D) Riedel scheme showing σ1 and σ3 vector directions.

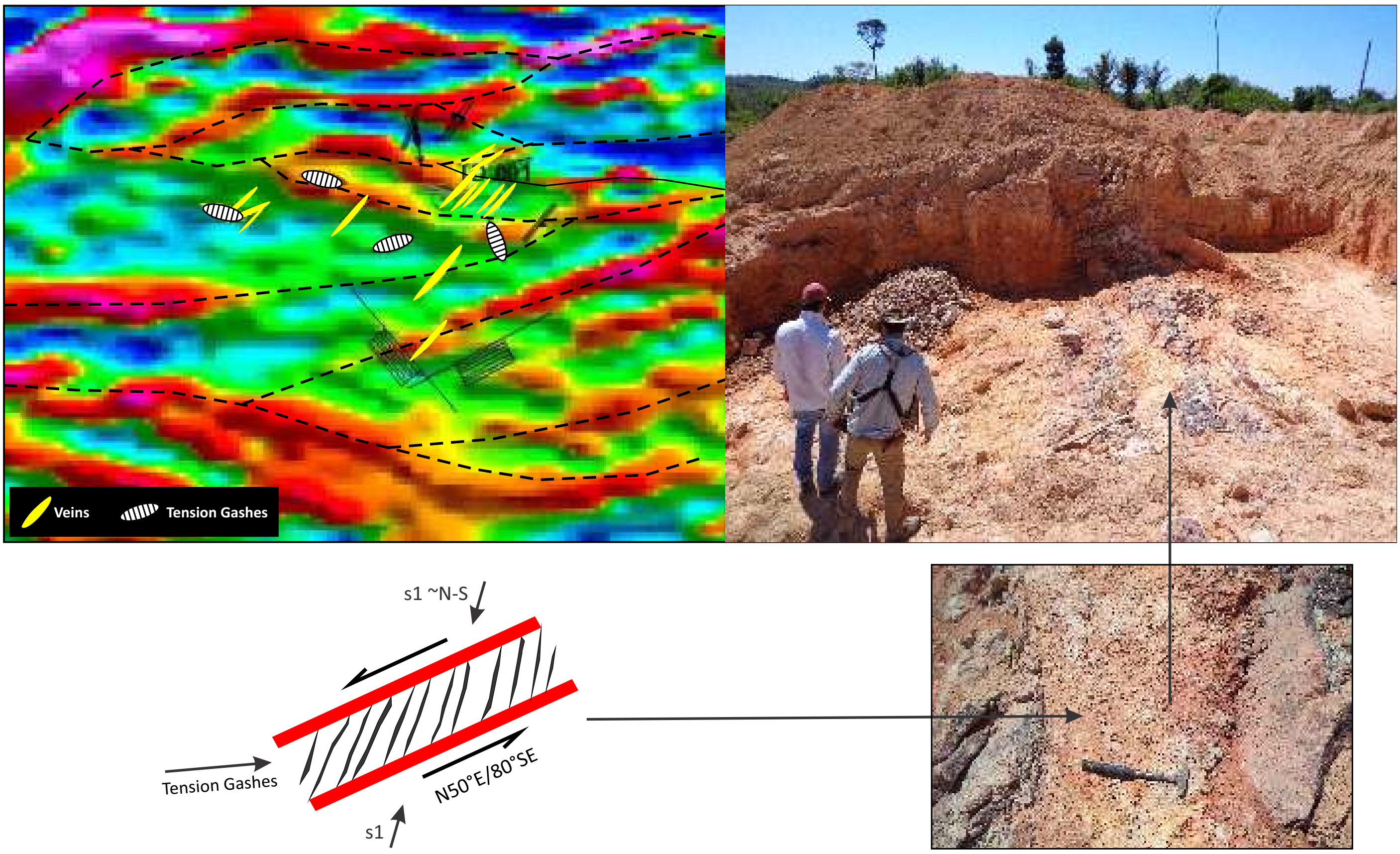

Figure 05 - Geometric interpretation of the shear zone identified in the Cajueiro Project. Tension gashes with N-S direction, filled by quartz and kaolin, and formed in a sinistral shear zone (σ1 = NNE-SSW).

haloes with epidote and chlorite. Potassic alterations (K-feldspar) are mainly barren zones. The Au-bearing quartz veins contain CO_2-rich fluid inclusions with <25% NaCl, with spiky high gold hosted by pyrite- and carbonate-rich phyllic alteration. The disseminated gold mineralization in the Alta Floresta region is spatially and genetically related to acid porphyritic dykes and small plugs. The intrusive rocks have a granophyric texture indicating an emplacement at shallow crustal levels.

The conceptual model in Figure 07 shows that the Colíder magmatism, responsible for the gold mineralization, occurred simultaneously with the neosome formation of the migmatites, corroborating its intraplate signature (Rizzotto et al., 2016). This is in accordance with the previous proposal made by Teixeira et al. (2015) on the origin of the gold mineralization in the AFGP.

Copper and base metals occurrences are also present in the province. One of the most famous deposits is Aripuanã, which consists of a Zn-Pb-Ag-Cu-Au deposit hosted by felsic volcanic rocks of Roosevelt Group - i.e. the counterpart of the Colíder Group and located southward. This deposit is being developed by Votorantim Metais and with a real potential for new discoveries in the region. Another known Pb-Zn deposit with gold is the Francisco deposit, nearby the União do Norte village in the region of Peixoto de Azevedo. There is also an exploration target for base metals named "Guarantã Ridge" that is in the preliminary study phase. At this target (Serrinha de Guarantã), although no viable copper deposits have been discovered until now, a drill hole previously explored by Rio Novo Gold intercepted a 45 m long section with 0.5% Cu.

Figure 06 - Exposure and hand specimen from the Peixoto de Azevedo gold district. (A) Banded quartz vein with quartz bands alternating with chlorite and sulfides bands, as exposed at Serrinha do Gurantã gold deposit shaft. (B) Free gold in rusty sulfide-rich quartz vein from Valentim deposit. (C) Quartz vein with chlorite and pyrite bands. (D) Vein samples from Serrinha do Gurantã deposit with copper-rich sulfides (bornite and chalcocite) and secondary copper minerals (malachite, azurite and chrysocolla). (E) Cut sample of granite from X1 deposit with phyllic alteration and disseminated pyrite (blue circles). (F) Hand specimen of hydrothermal breccia from Gurantã Ridge deposit, with venules filled by galena and disseminated chalcopyrite.

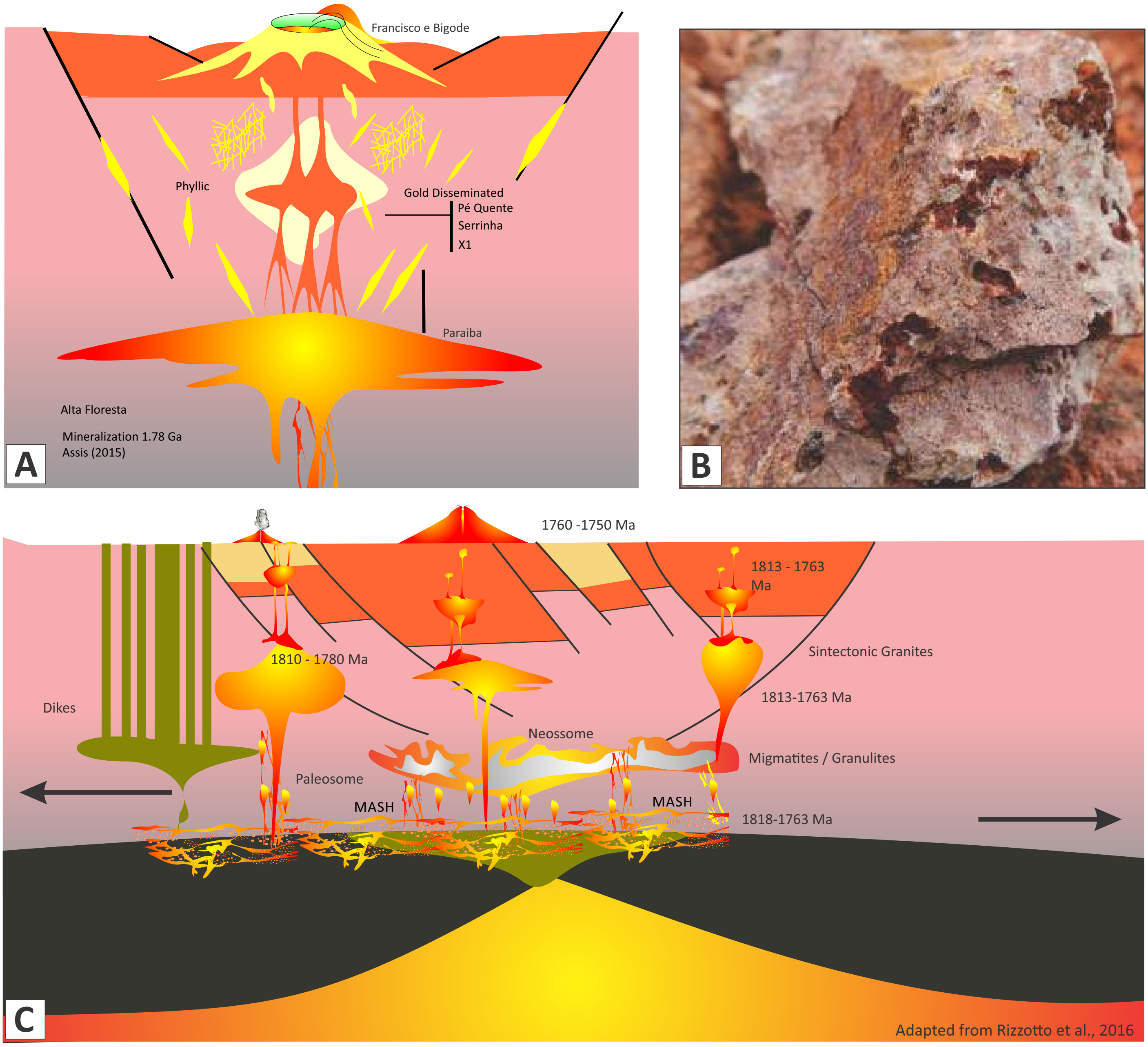

Figure 07 - (A) Schematic representation of the Alta Floresta gold deposits, including: (1) Disseminated gold in phyllic alteration zones, associated with acid subvolcanic dykes and plugs; (2) Massive quartz veins and stockworks with epizonal to mesozonal tectonic fabrics and restricted wall-rock alteration (adularia, sericite, K-feldspar, chlorite); and (3) Spatial and temporal association with post-tectonic granites. Note that the União do Norte, X1, Pé Quente gold deposits are related to phorphyry rocks and phyllic alteration zones. (B) Hand specimen of vuggy quartz vein. (C) Schematic model showing extensional environment and underplating development as causes for generating felsic magmas (1.82-1.70 Ga). The ages of neosomes in migmatites coincide with the ages of the volcanic and subvolcanic rocks (1.82-1.77 Ga) related to the gold mineralization (1.78 Ga). Fluids responsible for the gold and polymetallic deposits of the Alta Floresta were exsolved from underplate magmas at a rifted cratonic margin, and probably derived more from mantle upwelling than slab subduction.

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Seridó Project

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The Seridó Project is being developed by the Geological Survey of Brazil (CPRM) as part of its programs "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brasilian Shields" (Program I) and "Mineral Potential Assessment of the Brazilian Volcano-Sedimentary Sequences" (Program III). The Borborema Province is a poly-deformed Neoproterozoic Brasiliano/Pan-African belt in northeastern Brazil that covers a total area of over 450,000 km^2. It is located to the north of the Archean-Paleoproterozoic São Francisco Craton. Its architecture results from a diachronic collage of Archean nuclei, Paleoproterozoic terranes and Tonian-Ediacaran belts during the closure of western Gondwana. It is enclosed between São Luis/West African and São Francisco/Congo cratons (Brito Neves et al., 2000), and distributed in five large domains or terranes (Médio-Coreau, Ceará Central, Rio Grande do Norte, Zona Transversal and Meridional) that are separated by deep transcurrent shear zones (Transbrasiliano, Senador Pompeu, Patos and Pernambuco). An Archean/Paleoproterozoic basement is recognized to the north of the Patos shear zone while Tonian-Ediacaran belts predominate in the Transversal and Southern domains.

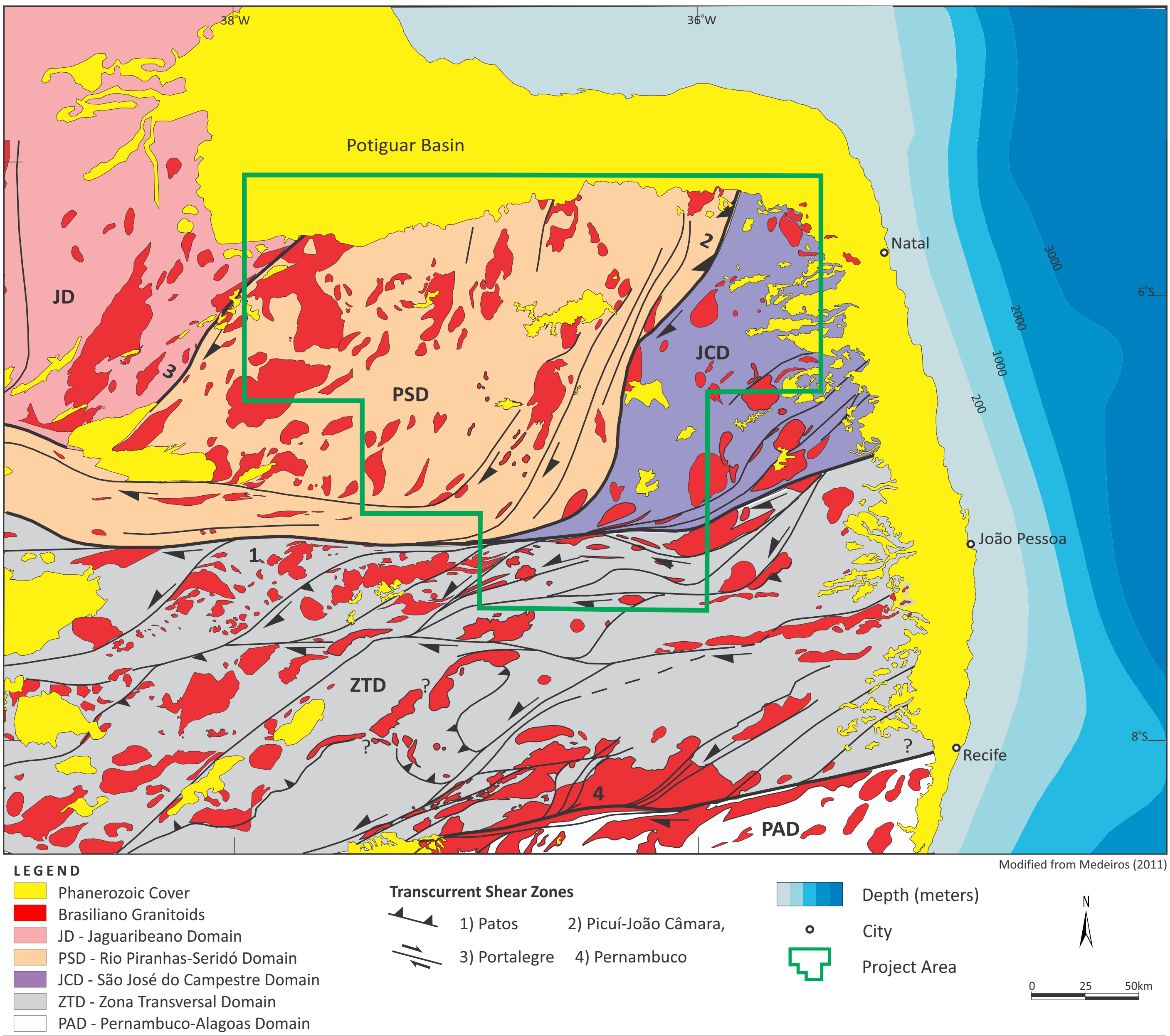


Figure 01 - Location of the Seridó Mineral Province within the geological and metalogenetic Borborema Province (adapted from Medeiros et al., 2011).

The Seridó Mineral Province (SMP) is part of the Rio Piranhas-Seridó subprovince (PSD) of the Rio Grande do Norte Domain (Figure 01). It hosts historical tungsten mines back to the 1940´s, some still in production, and more recent gold and iron ore mines. It has a great diversity of mineral deposits (Au, W, Fe, Nb, Ta, Mo, kaolim) and gemstones that were mostly explored by artisanal prospectors and small-cap mining companies.

The Geological Survey of Brazil (CPRM) is currently developping the Seridó Project aims at providing a geological-geophysical integration map of the SMP and a semi-regional geochemical survey on fifteen 1:100,000 sheets. Also as part of this project the metavolcano-sedimentary Jucurutu Formation, hosting most of the W and Fe occurrences in the province, is being mapped at 1:50,000 scale, including detailed studies of the main mineral deposits (W: Brejuí and Bodó; Au: São Francisco, Bonfim; Fe: Saquinho).

Figure 01 shows the coverage of the fifteen sheets mapped at 1:100,000 scale by the Geological Survey of Brazil (CPRM) and that encompass the Seridó Mineral Province. The western Jaguaribeano Domain (JD) and the eastern São José do Campestre Domain (JCD) are bordered by the Portalegre (3) and Picuí-João Câmara (2) shear zones respectively, with the central Rio Piranhas-Seridó Domain (PSD) between. The southern Zona Transversal Domain (ZTD) is delimited by the Patos (1) and Pernambuco (4) shear zones.

The São José do Campestre Domain (JCD) remains poorly explored and is characterized by a smooth relief and scarce outcrops. It has preserved a Paleo-to-Neoarchean block (Núcleo Bom Jesus-Presidente Juscelino: Bizzi et al., 2001), which is surrounded by agglutinated Palaeoproterozoic migmatized units (Santa Cruz Complex). Entangled metaplutonic suites with TTG (tonalite-trondhjemite-granodiorite) affinity, and some scarce and discontinuous metavolcanic and Algoma-type BIF are reported.

The Rio Piranhas-Seridó Domain (PSD) is composed of a Siderian-Rhyacian-Orosirian basement (Arabia and Caicó complexes) with scarce Archean relics and supracrustals rocks of the Ediacaran Seridó Group. The Arabia complex mainly comprises ortho-derived metaplutonic units, whereas the Caicó complex is a heterogeneous, polydeformed and widely migmatized gneiss with metavolcano sedimentary and metaplutonic protholites. Recent geophysical survey and field investigation have identified kimberlite intrusions hosted by the Arabia complex in the northwest of Lages city, Rio Grande do Norte State (Cabral Neto et al., 2015).

The Seridó Group consists of low-to-medium grade metasediments, with the basal Jucurutu Formation locally composed of discontinuous volcano-sedimentary sequences that include the mineralized BIF of Saquinho Fe mine. The Jucurutu Formation is overlaid by a carbonate platform and siliciclastic rocks of the Equador Formation, both being overlapped by the turbidite-flyschoid sequence of the upper and extensive Seridó Formation.

Plutonism related to the Brasiliano Event (Ediacaran age) intrudes all the Seridó units. Its main phase was dated between 580-550 Ma and is represented by the extensive porphyritic high-K calc-alkaline Itaporanga suite and other minor plutonic rocks. Isotropic granitic bodies of non-determined chemistry and late orogenic pegmatitic dykes were dated between 514-509 Ma.

The most significative W occurrences at SMP are charaterized on the airborne magnetic maps (Figure 02) by shallow anomalies that coincide with negative gravimetric anomalies. These anomalies are interpreted to represent a series of structurally controlled granitic intrusions (Itaporanga suite), whose the interaction with the metasedimentary Seridó Group formations formed rheological and chemical interfaces favorable to W concentration.

The gamma-spectrometric survey (Figure 03) identified strong potassium anomalies correlated with the major W deposits, and a discontinuous potassium anomaly along the second-order structure of São Francisco shear zone and where is located a gold deposit. The Saquinho Fe deposit is correlated to positive gravimetric and magnetic anomalies.

More than 700 skarn occurrences are listed in SMP, with some that were intermittently explored since the 1940's for W-Mo (Brejuí, Bodó, Bonito, Malhada Limpa and Quixadá mines), gold (Itajubatiba mine), and gold associated with W-Mo-Bi-Te (Bonfim mine). The main deposits are Brejuí and Bodó that respectively contain 11 Mt of WO_3 (with 5.5 Mt remaining at 0.5-1.0% WO_3) and 9 Mt at 2% of WO_3.

Iron deposits also occur as magnetite-hematite bearing deposits, with grades commonly around 43% Fe and up to 60% Fe, with the major body

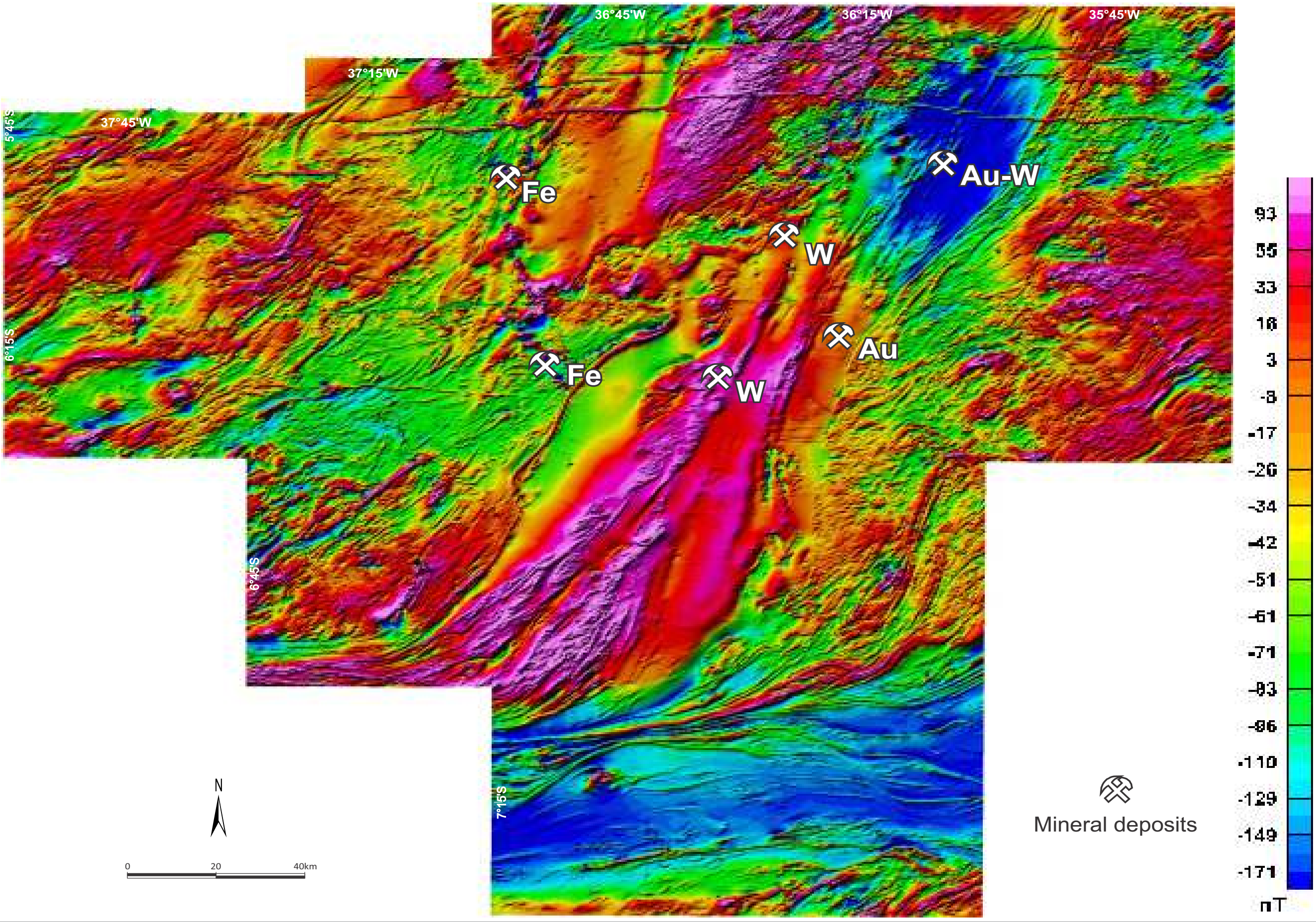


Figure 02 - Reduced-to-pole (RTP) magnetic map of the Seridó project area showing magnetic alignments, mainly orientated between azimuths 90°and 45° and, to a lesser extent, between azimuths 270° and 290°.

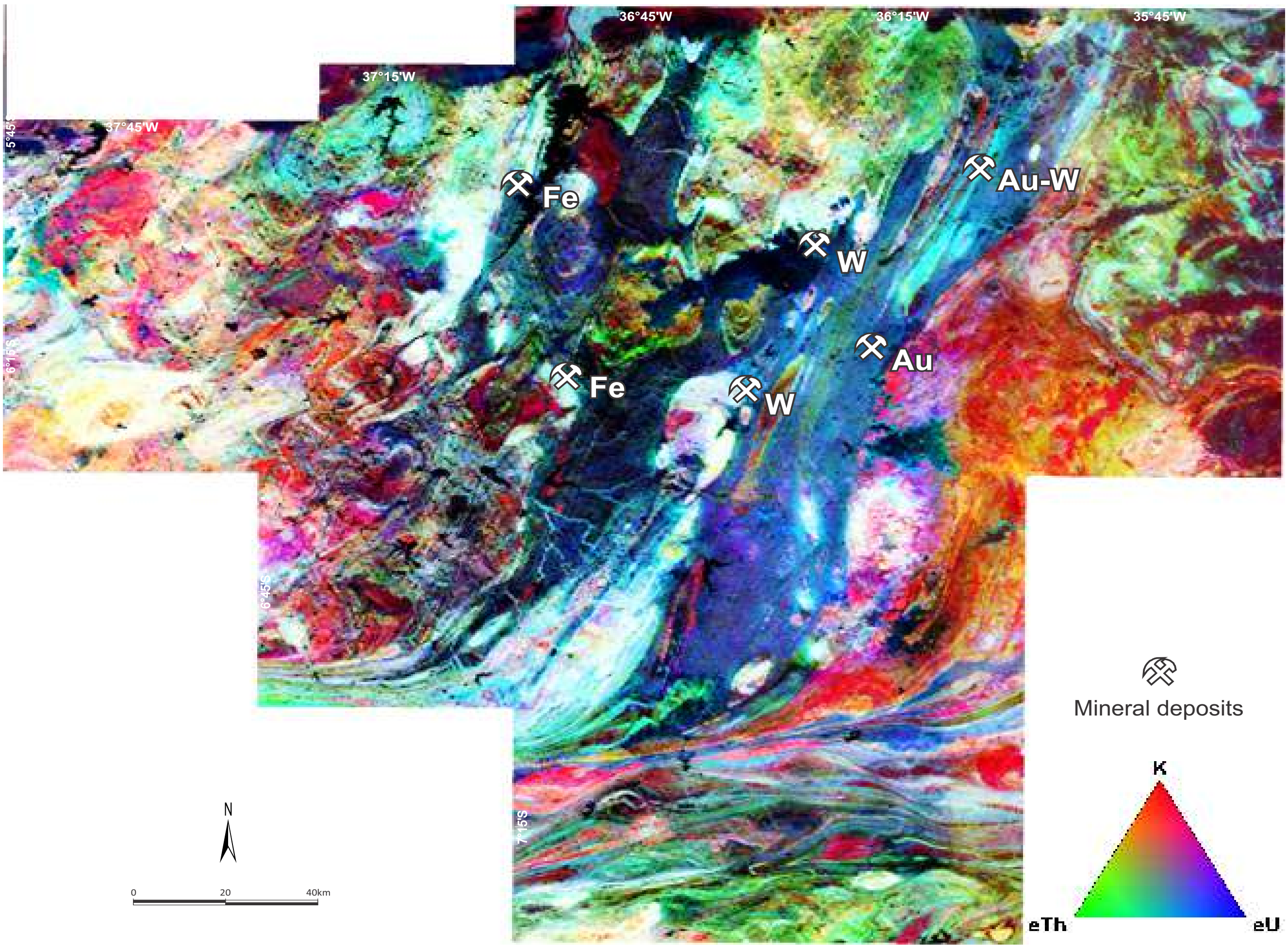


Figure 03 - Ternary gamma-spectrometry map (K, eU, eTh) of the Seridó project area. The high-K contents are mainly related to granitic intrusions and Neoproterozoic pegmatites that host gemstones, kaolin and wolframite mineralizations.

(Saquinho iron mine) containing 38 Mt at 55% Fe (Santos et al., 2014).

The mineralogy of the gold deposits comprises sulfides and oxides, with a paragenetic association of pyrite-chalcopyrite, pyrrhotite, magnetite and ilmenite. Galena, Ag-arsenopyrite and molybdenite were also reported in the São Francisco deposit. Gold grades are usually in the range of 1-5 g/t up to 30 g/t. Based on a cut-off grade of 0.25 g/t Au, the total reserves are expected to edge up to 10,890 tons at 0.91 g/t Au, corresponding to about 318 ounces of gold (Aura Minerals on-line report, 2011).

The tungsten (W) deposits are spatially related to the Itaporanga high-K calc-alkaline suite that shows an extensive skarnification along the contact between rocks with constrasting rheologies. The main mineralized bodies occur interstratified in the marble lenses of the Jucurutu Formation (Figure 04). Skarnification is also present as endoskarn within the granite (e.g. in the Bodó and Itajubatiba mines) and at the contact with the basal shear zone with the Caicó complex. Polymetallic sulfides are also reported but their potential remains unexplored.

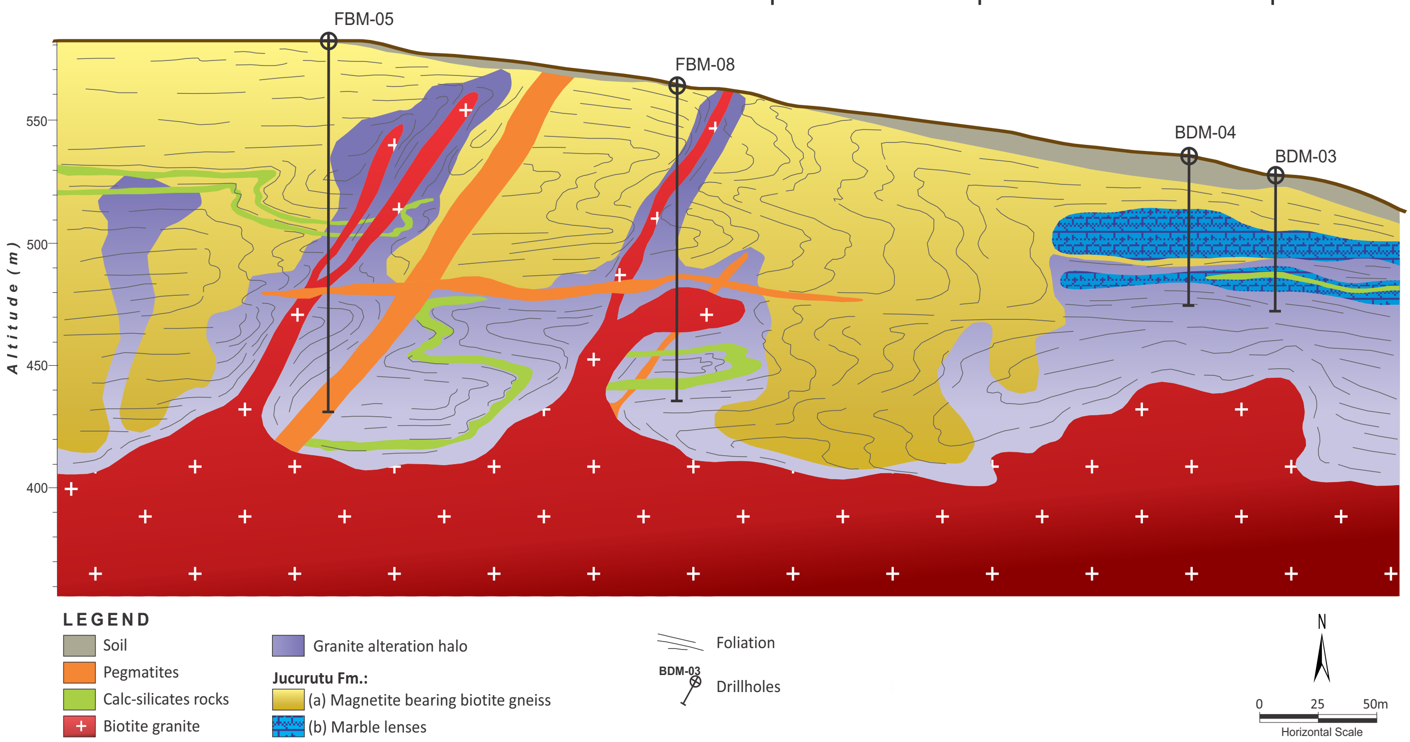


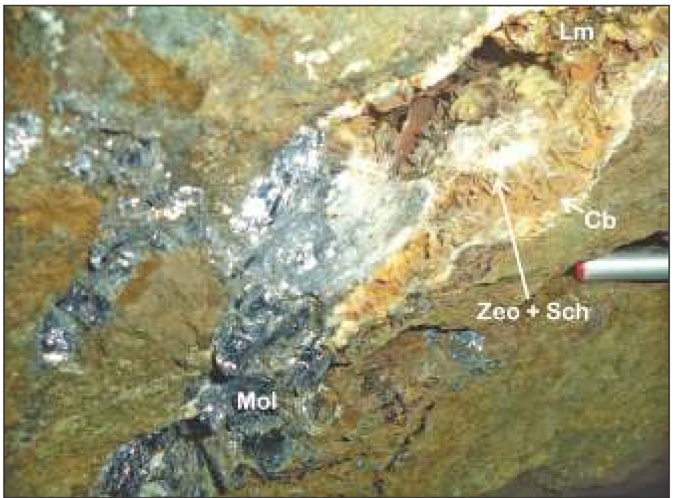
Figure 04 - Vertical E-W cross-section 01 of the Bodó tungsten mine, with drill holes FBM-05, FBM-08, BDM-04 and BDM-03.

The ore deposits show evidence of high-temperature calcic alteration (up to 650°C) forming anhydrous calc-silicates (diopside, andradite, wollastonite). Medium-temperature alteration followed with the formation of hydrated silicates (hornblende, vesuvianite, escapolite, epidote, actinolite, grunerite), scheelite and disseminated sulfides. Carbonate veins and cavities filled with sericite, zeolite, limonite and powdery scheelite, indicate alteration by fluids of progressively decreasing temperature (Figure 05).

The banded iron formation from Saquinho, Serra da Formiga, Bonito, Serra do Feiticeiro, Riacho Fundo and Serra dos Quintos occur associated with mafic volcanics at the base of the Jucurutu Formation (Figure 06). The BIF are anomalous in Cr, Ce, REE and Eu, confirming a volcanic influence on its genesis (Algoma-type), whereas stable and radiogenic isotopes (negative $\delta^{13}C$ and $^{87}Sr/^{86}Sr$) suggest a glacial influence (Sial et al., 2015).

The gold deposits of São Francisco, Simpatico, Ponta da Serra, São Fernando and Bonfim, are lode-gold deposits related to high-angle shear zones cutting Neoproterozoic (Seridó Group) and Palaeoproterozoic rocks (basement gneisses), and that were active during a late deformation event dated between 520-500 Ma. This age obtained from $^{40}Ar/^{39}Ar$ dating of mica (Araújo, 2001) is similar to other orogenic-gold age models. The basement of Bonfim gold deposit, located to the north of the São Francisco fault, yields an Archean age (3.508 Ma) based on U-Pb zircon dating (Velásquez et al., 2016). This suggests that Archean inliers below the São Francisco shear zone may have contributed to the gold mineralization.

Bodó Mine - High grade ore. Scheelite bearing veins and disseminated scheelite in epidote-diopside skarn. Scale: 15x23 cm. Mineral abbreviations according to Whitney & Evans, 2010: Sch - Scheelite, Di - Diopside, Ep - Epidote, Grt - Garnet, Ves - Vesuvianite



Breji Mine - Epidote-diopside skarn cross-cutted by molybdenite veinlet associated with partially filled cavity with carbonate, zeolite, limonite and powdery scheelite
Mineral abbreviations according to Whitney & Evans, 2010: Sch - Scheelite, Zeo - Zeolite, Cb - Carbonate, Mol - Molybdenite

Figure 05 - Rock exposures with tungsten ore at the Bodó and Brejuí mines.

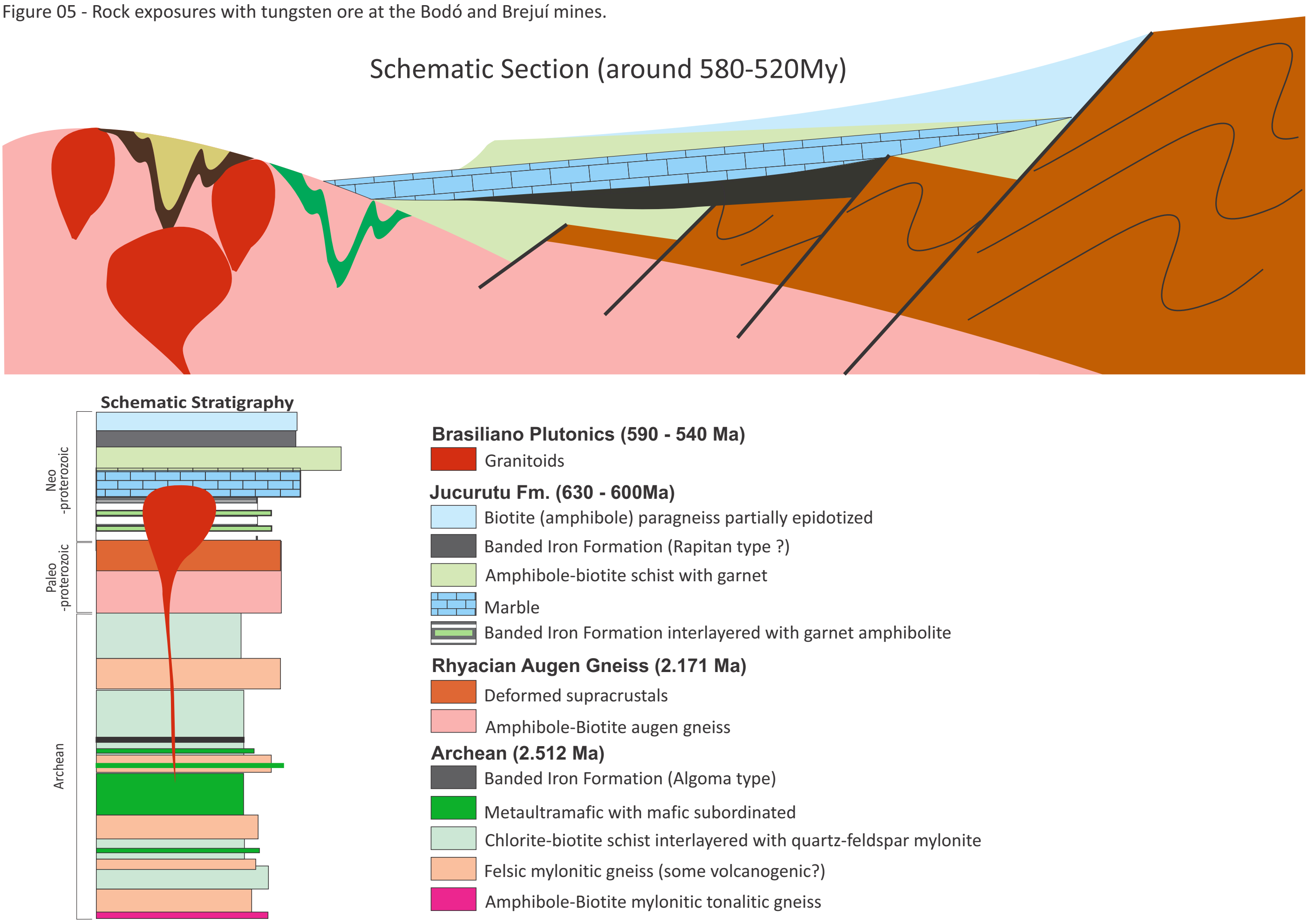


Figure 06 - Schematic cross-section at around 580-520 Ma and stratigraphic column of the basal units of the Jucurutu Formation.

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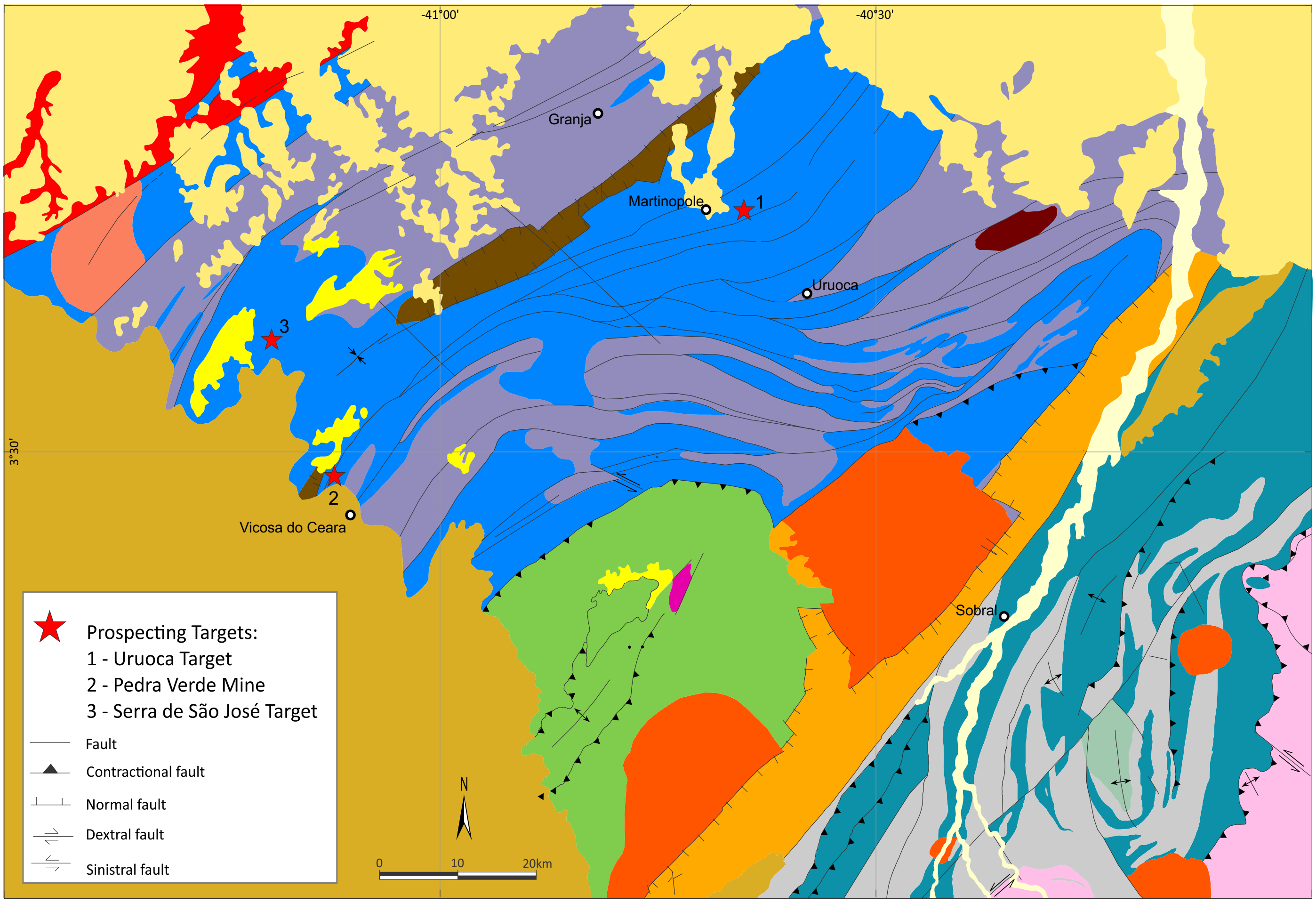
NW Ceará Project

Tercyo R.G. Pinéo, Alex F. Lima, Mariane D. Martins, Maria D.M.R. Bessa

The Northwest Ceará Project is being developed by the Geological Survey of Brazil (CPRM) as part of its program "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brazilian Shields" (Program I). The main objective of this project is to study the metallogenic potential and to identify new mineral occurrences in the Martinópole Group, a Neoproterozoic meta-volcano-sedimentary sequence which hosts polymetallic Cu-Pb-Zn sulfides, copper, iron ore, manganese and barite mineralizations (Figures 01 and 02).

The Granja Complex represents the basement of this supracrustal sequence and is composed of



LITHOSTRATIGRAPHIC UNITS

PALEOGENE

BARREIRAS GROUP

Sandstones, conglomarates and laterites.

SILURIAN

SERRA GRANDE GROUP

Sandstones, siltites, argillites and conglomarates.

CAMBRO-ORDOVICIAN

RIACHO SAIRI GROUP

Conglomarate (Fazenda Fortaleza Formation).Sandstone, siltite and argillites (Morada Nova Formation). Polimitic Conglomerate (Barra do Sairi Formation).

JAIBARAS GROUP

Polimitic Conglomerate (Aprazível Formation).Basalts and rhyolite (Parapuí Formation). Sandstone and siltite intercaleted (Pacujá Formation). Polimitic conglomerate (Massapê Formation).

MERUOCA GRANITOIDS

Batholiths ans stocks of red granites (532 Ma).

NEOPROTEROZOIC

Brejinho Suite - Syenites and alkaline piroxenites (554 Ma).

Tucunduba - Green Granite and granodiorite (574 Ma).

Chaval Suite - Porfiritic monzogranite, granites, syenites (591 Ma).

Metatexites, diatexites, gneisses and porfiritic pink granites (650 Ma).

UBAJARA GROUP

Metasandstones (Goiabeira Formation).Gray and blue Metamarbles (Frecheirinha Formation). Slate, phyllite and metasandstone (Caiçaras Formation). Quartzites and metasandstone (Trapiá Formation).

MARTINÓPOLE GROUP

Phyllites, marbles, quartzites, metacherts, metavulcanics, and BIF's (Santa Terezinha Formation). Schists, phyllite, and BIF's (Covão Formation). Quartzites with intercalation of schists, alc-silicate and BIF's (São Joaquim Formation). Schists, quartzites, and paragneisses (Goiabeira Formation).

MESOPROTEROZOIC

Migmatitic paragneisses with lenses of quartzite, calc-silicate, marble, amphibolite, metavolcanics (700 Ma).

PALEOPROTEROZOIC

SAQUINHO VOLCANIC UNIT

Metarhyolite, metabasalt, BIFs, calc-silicate, and volcanoclastic rocks (1785 Ma).

FORQUILHA ORTHOGNEISSE

Tonalitic to granodioritic orthogneisses with amphibolite enclaves (2049 Ma).

Milonitic gneisses, paragneisses, metaultramafic rocks, marbles, amphibolite, and calc-silicate. Granitic to granodioritic orthogneisses intrusive (2100 Ma).

GRANJA COMPLEX

Orthogneisses, migmatites, granulite gneisses, leucogneisses, calc-silicate, quartzite, paragneisses and amphibolite (2357 Ma).

Figure 01 - Geological map of the NW Ceará project area.

TTG orthogneisses, paragneisses and granulites of Paleoproterozoic age (2.3 Ga) (Santos, 1999).

The Martinópole Group is divided in four lithological formations (Figure 03) deposited on a passive continental margin between 800-750 Ma (Santos, 1999), and later deformed by the Brasiliano/Pan-African Orogeny (ca. 600 Ma) and metamorphosed to low- to medium grade (i.e. from greenschist to amphibolite facies) (Figure 04). The Goiabeira Formation at the base of the Martinópole Group consists of schists, quartzites and paragneisses. The São Joaquim Formation is mainly composed of quartzites. The Covão Formation comprises schists and phyllites. The uppermost Santa Terezinha Formationconsists of phyllites, carbonate phyllites, marbles, quartzites, metacherts, calc-silicatic rocks, BIFs, and meta-volcanic rocks, dated by zircon U-Pb at 800 Ma (crystallization age). This formation hosts deposits and mineral occurrences of copper, lead, zinc, manganese and iron, which are grouped into three separate exploration targets (Uruoca, Pedra Verde Mine and Serra de São José) (Figure 05).

The Uruoca targethas been investigated by the Geological Survey of Brazil (CPRM) during the 1980´s. It is composed of phyllites and quartzites with mylonitic structure, metachert, hydrothermal breccia, meta-rhyodacite, and laterite covers. The metachert contains concentrations of manganese-iron oxide and minor widespread crystals of bornite and pyrite. The hydrothermal breccia has a typical boxwork texture and is distributed along a NE-SW shear zone (Figure 06).

The manganese mineralization at Uruoca is related to laterites aligned NE-SW, with hydroxide, iron hydroxide, hematite, magnetite and quartz fragments also arranged in a boxwork texture. The presence of manganese layers and phyllites, both intercalated and folded, suggests a syngenetic occurrence with superimposed weathering processes. Chalcopyrite, pyrite, bornite, sphalerite and galena were described from borehole samples, occurring both in fractures and veins of associated metacarbonate rocks (marbles, carbonatic phyllites, and calc-silicatic rocks) and meta-acidic volcanic rocks (Prado et al., 1980).

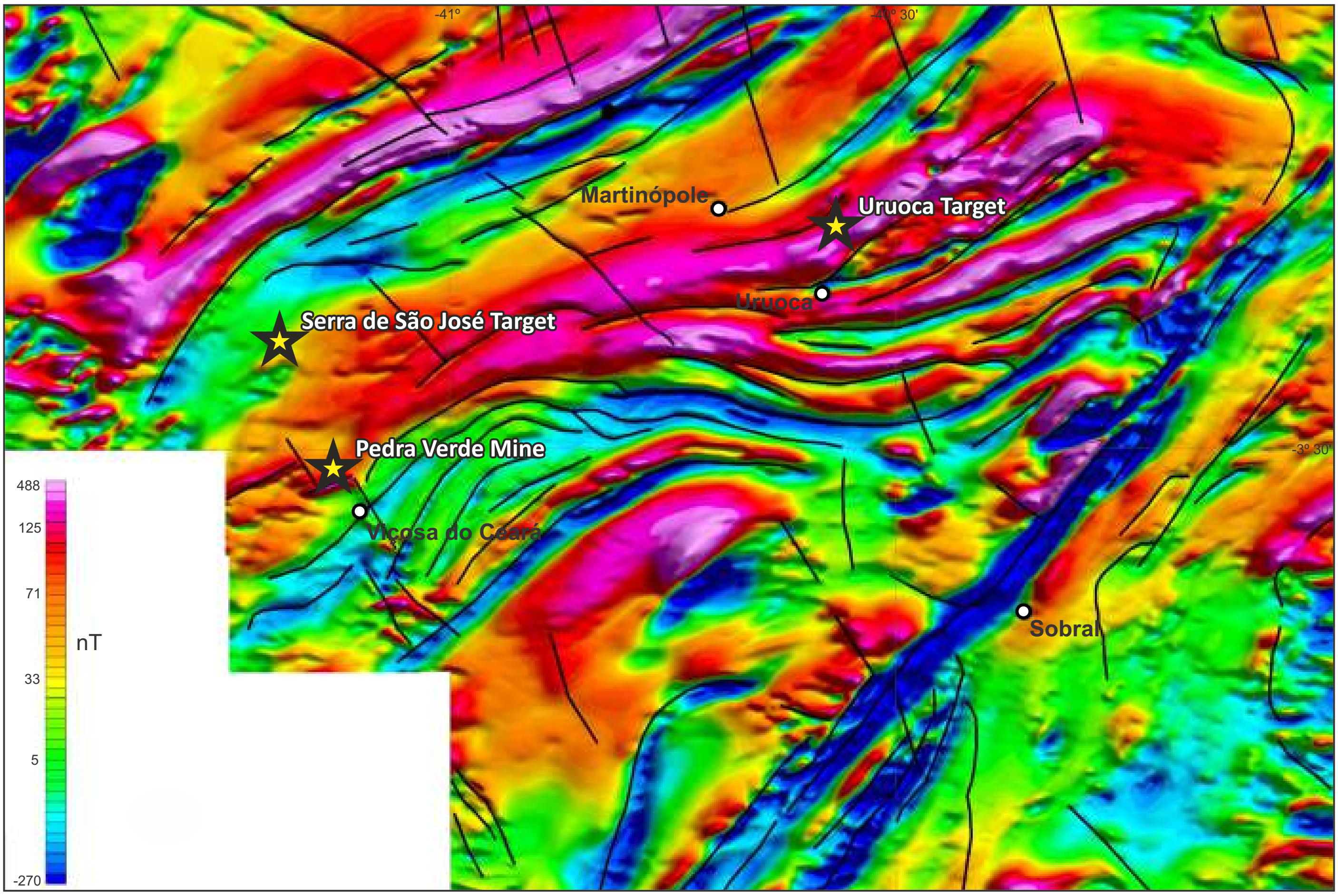


Figure 02 - Reduced-to-pole (RTP) magnetic map showing the distribution of magnetic bodies to depth of 1-2 km, with interpreted structural lineaments marked by black lines.

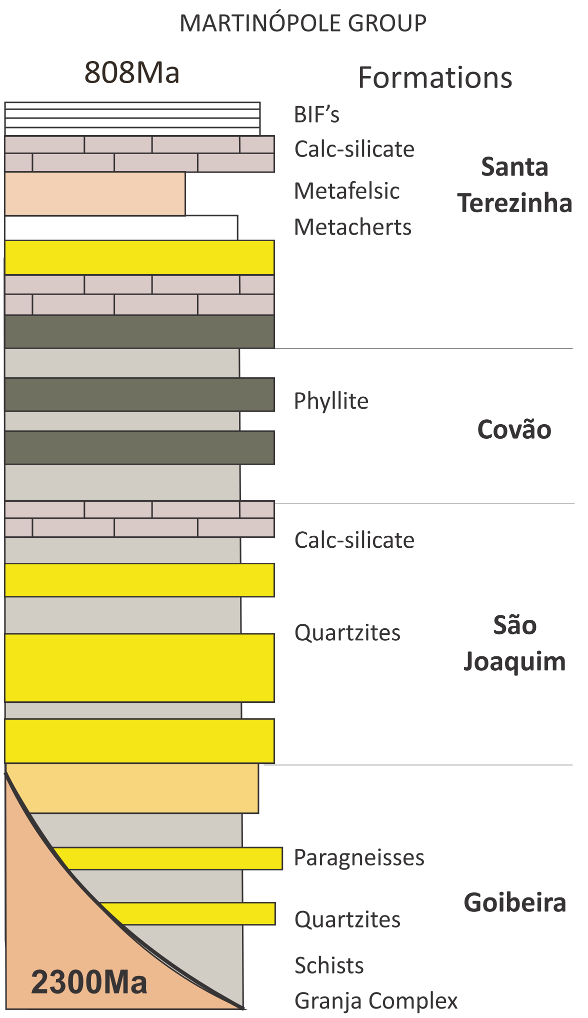


Figure 03 - Lithostratigraphic column of the Martinópole Group.

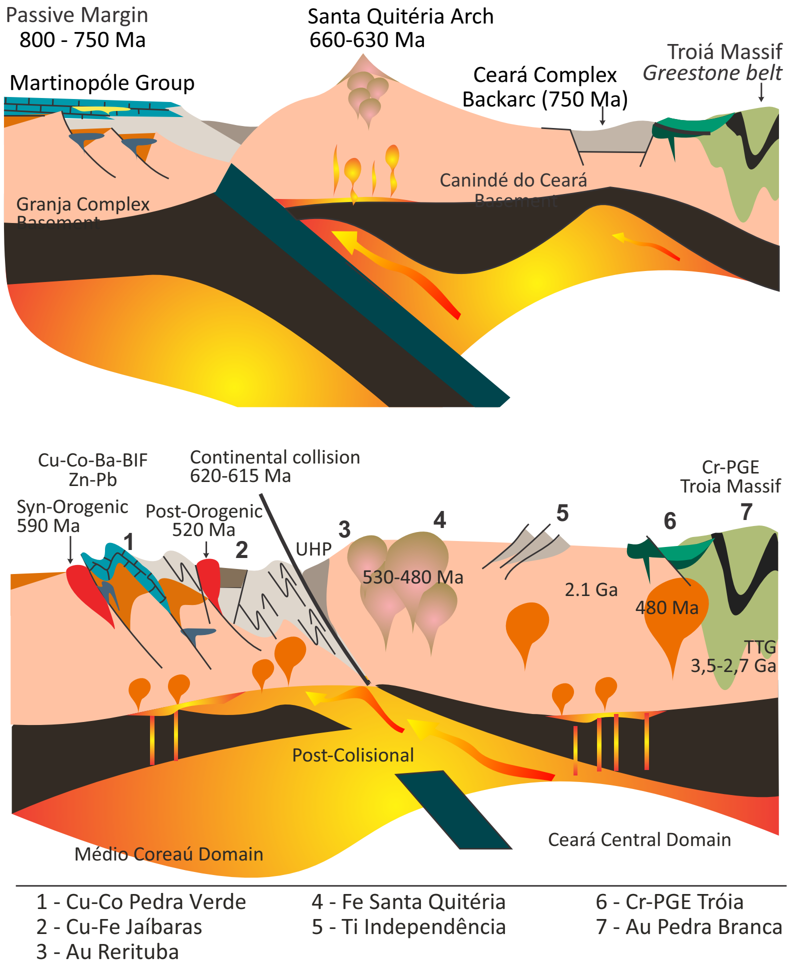


Figure 04 - Geodynamic model of Northwest Ceará including the Martinópole Group, showing the evolution from a passive margin to continental collision between Médio Coreaú and Ceará Central domains (modified from Araujo, 2014).

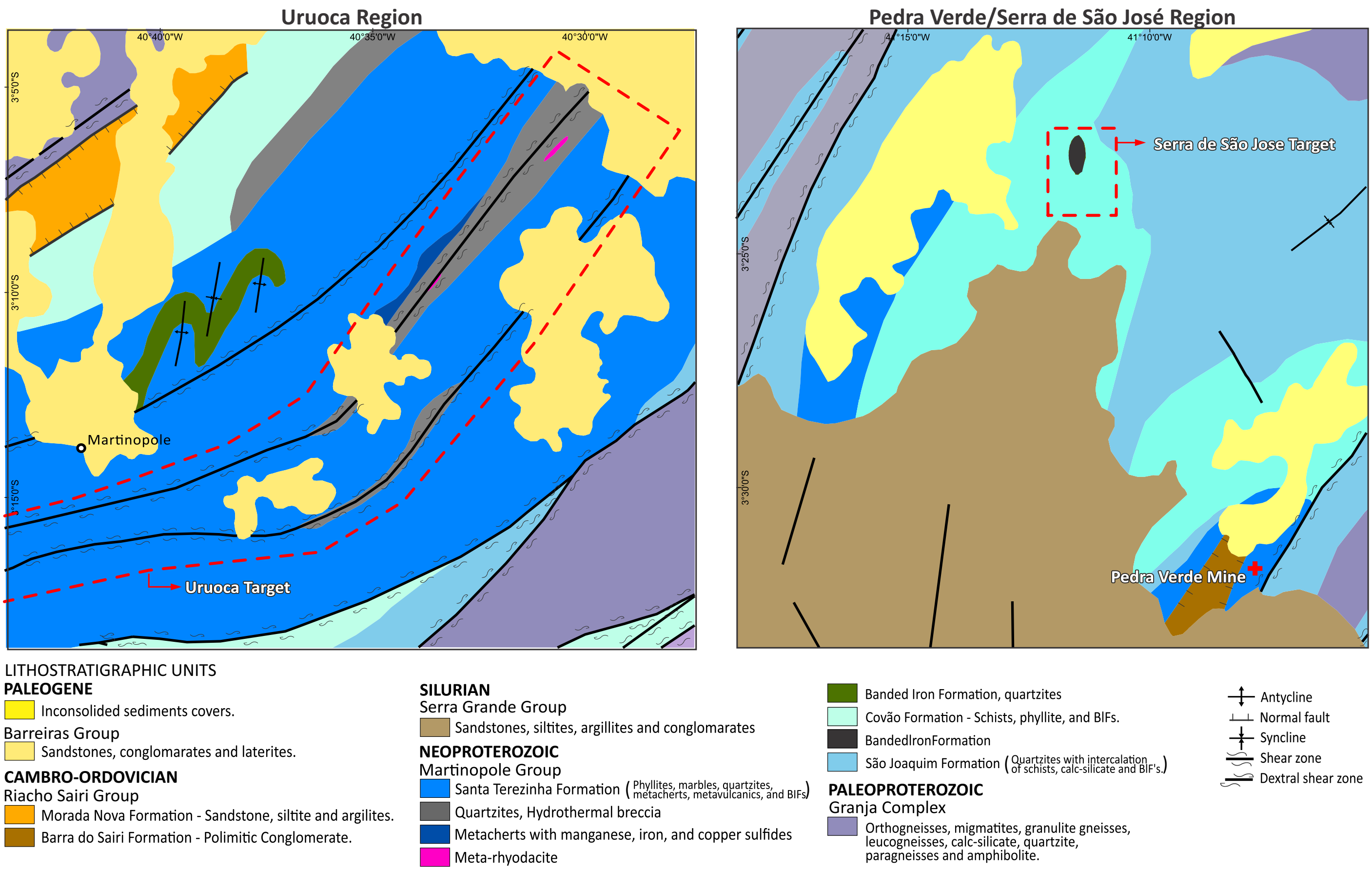


Figura 05 - Geological maps of the exploration targets in NW Ceará.

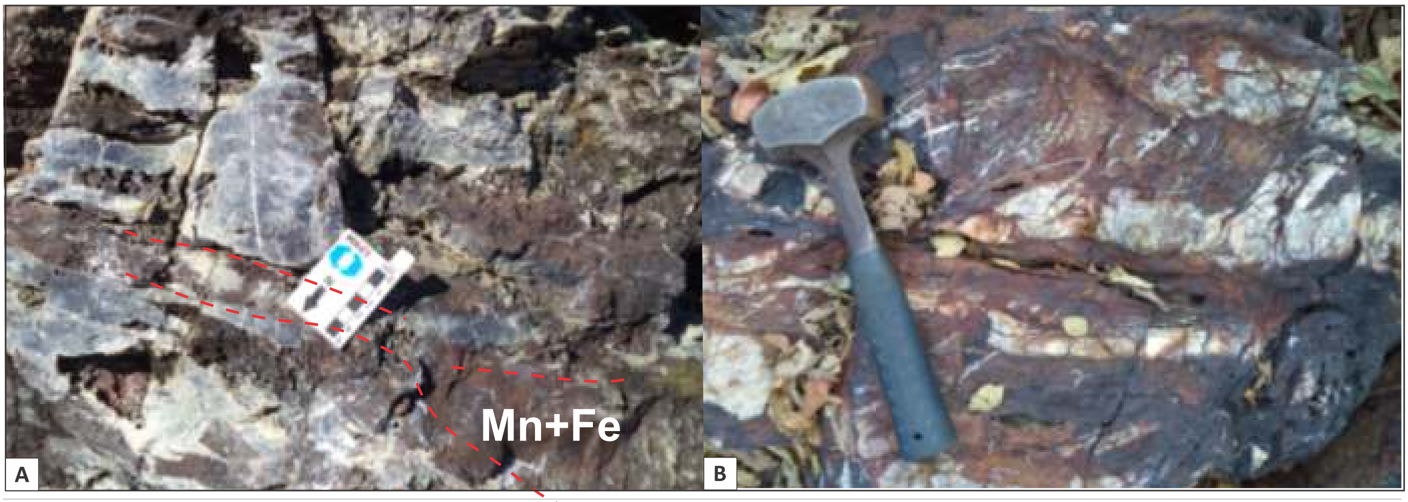


Figure 06 - Rock exposures from the Uruoca target: (A) Metachert with iron-copper sulfide and concentrations of Fe-Mn oxides. (B) Hydrothermal breccia with manganese, iron and quartz.

During the 1980´s a small copper mine (Pedra Verde Mine) operated in the region. The host rocks are along a NE-SW shear zone that is marked by one staggered magnetic lineament. They consist of altered phyllite progressively replaced by carbonated phyllite. The altered phyllite is 22 m thick and contains malachite and azurite as main secondary copper minerals (Figure 07). The ore is zoned and marked by chalcocite-bornite-chalcopyrite-pyrite-galena-sphalerite (Collins and Loureiro, 1971). The sulfides occur either deformed along the mylonitic foliation of the host carbonated phyllite, or along carbonate veins indicating hydrothermal precipitation (Matos, 2012).

Figure 07 - Hand specimen and rock exposure from Pedra Verde mine: (A) Borehole sample of phyllite carbonate with sulfide-rich carbonate veins. (B) Malachite resulting from leaching of phyllite carbonate.

The Serra de São José target contains barite associated with Ni (500 ppm) and Co (500 ppm) anomalies in folded BIFs (Figure 08). Its rock formations comprise marbles, phyllites, schists, metagreywackes, metacherts and BIFs (Prado et al., 1979). Geophysical data indicates the possible continuity of this target underneath the Silurian sediments of the Parnaíba Basin.

Field observations and a desktop study indicate the possibility of SEDEX-type deposits that formed on a passive continental margin between 800-750 Ma (Figure 09). This sedimentary event was followed by hydrothermal mobilization and precipitation along the NE-SW structures, during the Brasiliano/Pan-African Orogeny (ca. 600 Ma).

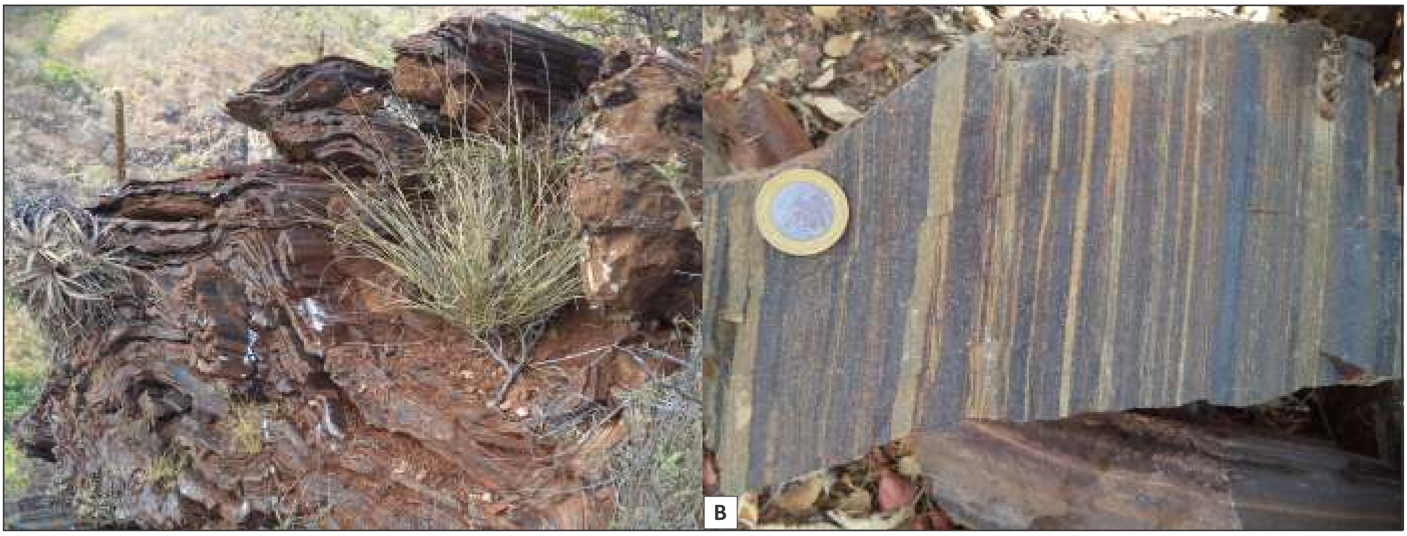


Figure 08 - Rock exposures from the Serra de São José target: (A) Outcrop of folded BIF. (B) BIF hand specimen.

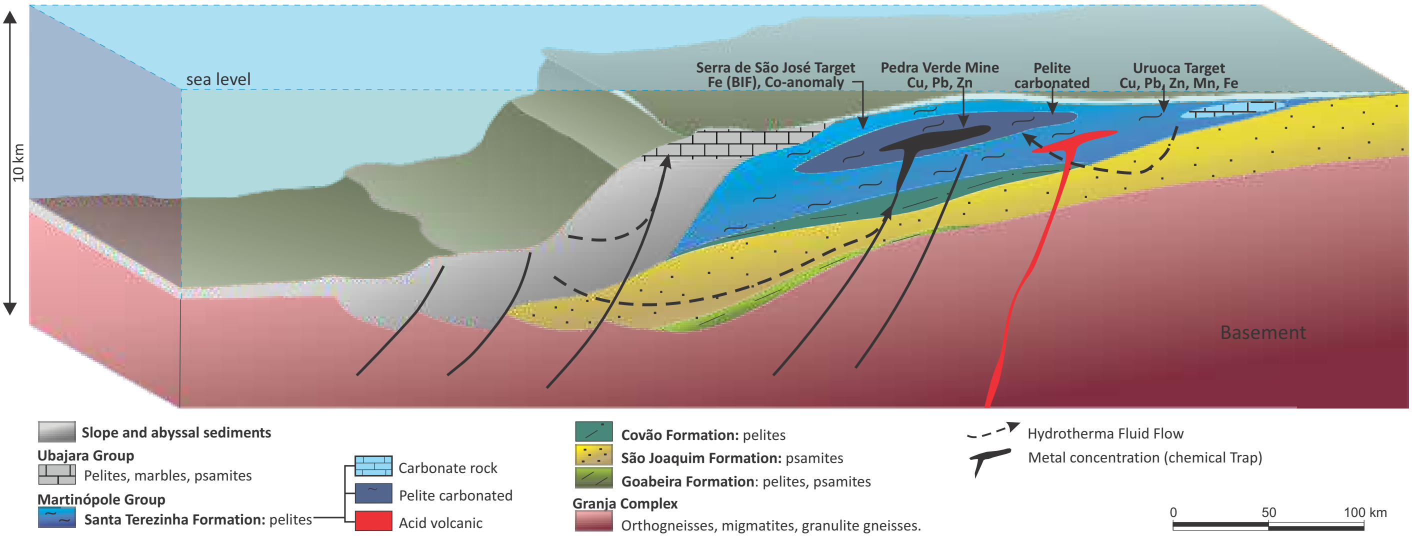


Figure 09 - Geologic conceptual model for SEDEX deposits (modified from Emsbo, 2009).

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Gurupi Project

Leandro D. Campos, Sulsiene M. de Souza, Diogo A. de Sordi, Felipe M. Tavares, Evandro L. Klein, Elem C.d.S. Lopes

The Gurupi Project is being developed by the Geological Survey of Brazil (CPRM) as part of its program "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brasilian Shields" (Program I). The project area sits on the borders of Pará and Maranhão states in north-northeast Brazil. The area is regionally divided into two geotectonic compartments that evolved during specific cycles, including the São Luís cratonic fragment (2695-2078 Ma) to the east-northeast and the Gurupi orogenic belt (980-591 Ma) to the west (Klein et al., 2014). The Gurupi Belt comprises Neoproterozoic sedimentary and intrusive igneous rocks. Its evolution is related to the breakup of western Gondwana and further tectonic inversion from passive to active margin

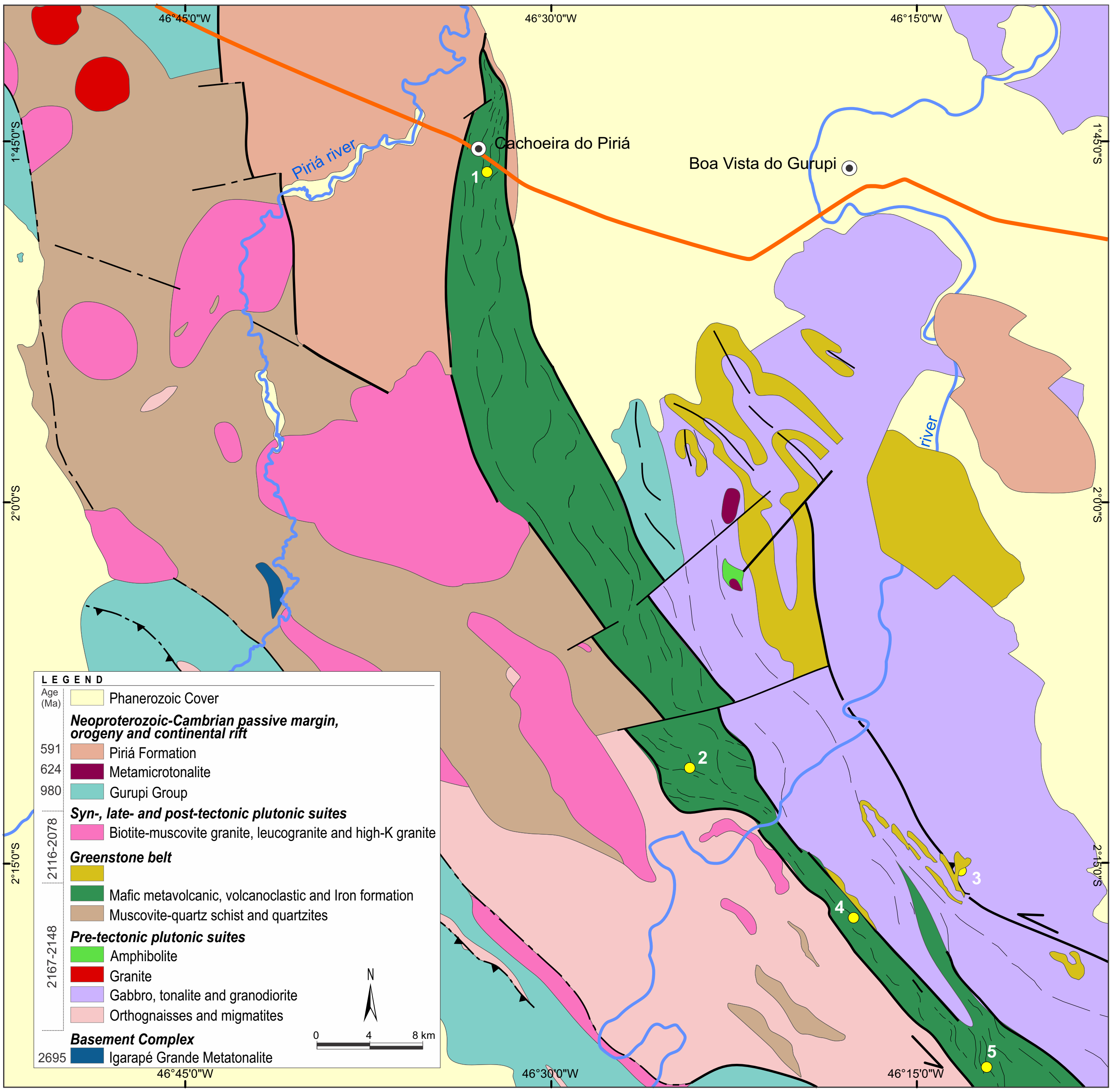

Figure 01 - Geological map of Gurupi orogen and Chega-Tudo greenstone belt (adapted from Klein et al., 2014).

during mid- to late Neoproterozoic. Most of the Neoproterozoic rocks are thought to be buried under the Paleozoic Parnaiba Basin (Figure 01). In the project area the Gurupi Belt is represented by metasediments of the Gurupi Group, the metamorphosed Caramujinho microtonalite and the Piriá Formation. The Gurupi Orogeny affected the borders of the cratonic basement during the late Neoproterozoic and was responsible for low-grade metamorphism, local heating and possibly minor gold remobilization.

The São Luis cratonic fragment represents an extension of the West Africa Craton that remained in South America after the opening of the South Atlantic Ocean. It comprises Paleoproterozoic volcanic-sedimentary sequences (greenstone belt) and plutonic suites developed in an island-arc system (Figure 02). The main rock formations of this cratonic fragment include: (1) Ultramafic rocks intercalated with carbonated-talc schists, mafic and felsic rocks (2160-2148 Ma), as well as volcanoclastic rocks from the Chega Tudo

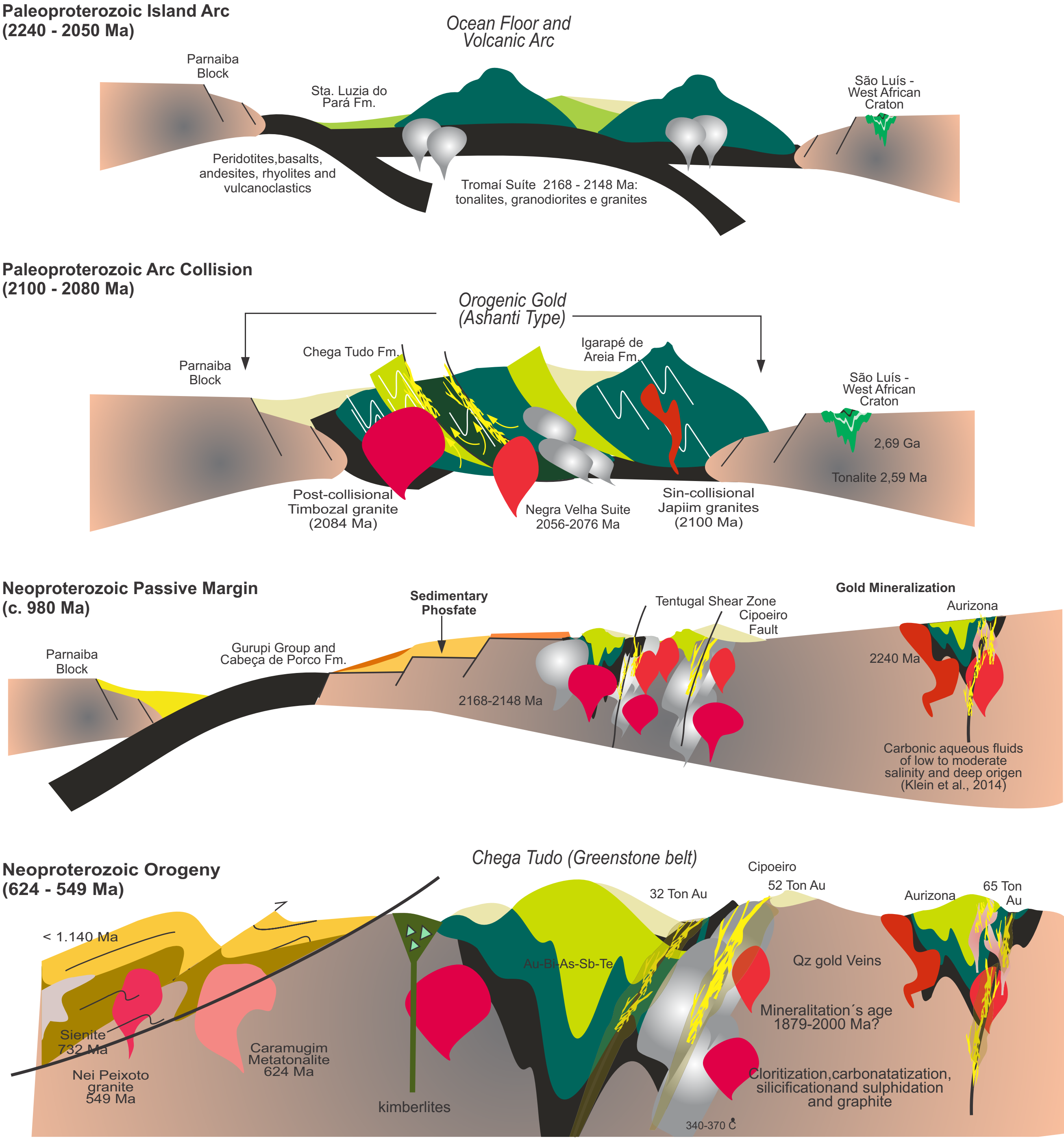

Figure 02 - Reconstructed evolution of the Gurupi orogen, from a passive continental margin to an island arc system marked by volcano-sedimentary sequences. The gold mineralization is restricted to the Chega-Tudo greenstone belt, within sulfide-graphitic quartz veins occurring in brittle-ductile shear zones.

Formation; (2) Muscovite-quartz schists and quartzites from the Santa Luzia do Pará Formation; and (3) Clast-supported conglomerates and quartzites (<2078 Ma) from the Igarapé de Area Formation. These sequences were intruded by syntectonic biotite-muscovite leucogranites and post-tectonic high-K granites (2116-2078 Ma). During the same Rhyacian period, basin inversion (with collision?) and metamorphism of amphibolite to upper-greenschist facies released fluids that contributed to the extraction, transport and deposition of metals, resulting in an orogenic gold system hosted in the Chega Tudo and Igarapé de Areia formations. Chega Tudo, Santa Luzia do Pará and Igarapé de Areia formations, in addition to the Rhyacian plutonic suites and Archean basement, compose the South American counterpart of the West Africa Craton (e.g. Ashanti Belt of Birimian age). Chega Tudo and Igarapé de Areia formations can therefore be compared with their African analogues (Ashanti Belt, Sefwi and Tarkwan group), which host major gold deposits with a total gold endowment of ca. 125 MOz.

The gold mineralization is exclusively hosted by the Rhyacian volcanic-sedimentary sequences and pre-tectonic plutonic suites. It occurs in disseminated sulfides, quartz-sulfide crack-seal shear veins, and quartz stockwork zones related to brittle-ductile deformation. The hydrothermal alterations are composed of quartz, chlorite, sericite, carbonate, albite and sulfide minerals (e.g. pyrite, arsenopyrite and rare chalcopyrite). The mineralization is concentrated along the Tentugal shear zone and its subsidiary branches. This shear zone is delimited to the west and east by the Chega Tudo and Cipoeiro faults, respectively. The majority of the gold occurrences and deposits are aligned along these faults that were interpreted as deep crustal faults from the magnetic source modelling (Figures 03, 04 and 05). The Tentugal shear zone and its gold trend extend for more than 100 km along strike and are thought to continue northward under the Cambrian-Phanerozoic cover. Fluid inclusion and isotope studies indicate that the gold was deposited by aqueous-carbonic fluids of low salinity. Temperature-pressure conditions of these fluids of metamorphic origin were estimated between 260-380°C and up to 3 kbar (Klein, 2014). The similarity between the mineralizations of the Tentugal shear zone (N-NE Brazil) and Birrimian formations (W Africa) is particularly evident from the presence of graphite-bearing material associated with both ore bodies.

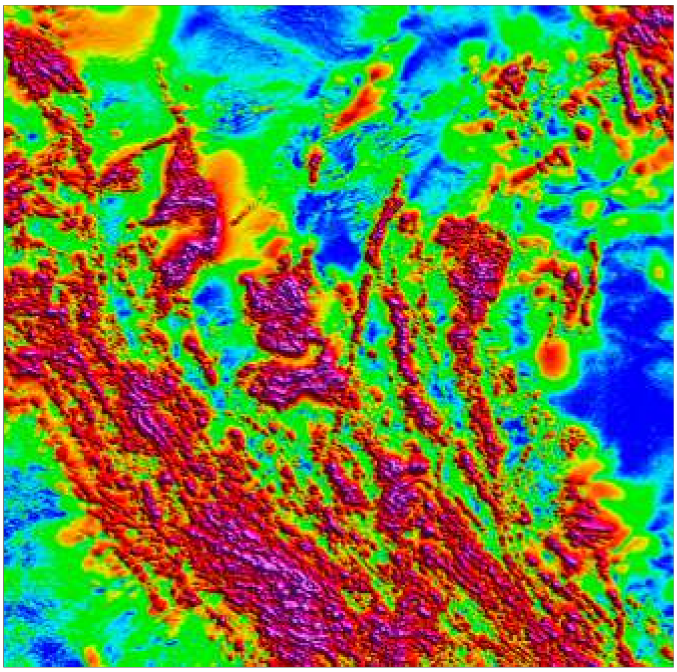

Figure 03 - Analytic signal map of the Gurupi project area.

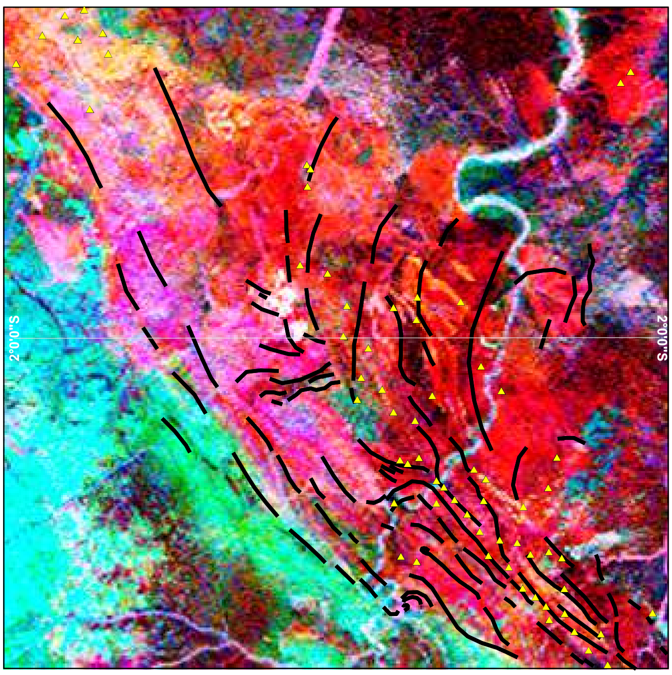

Figure 04 - Colour composite (ternary) image of the Gurupi project area with interpreted structures.

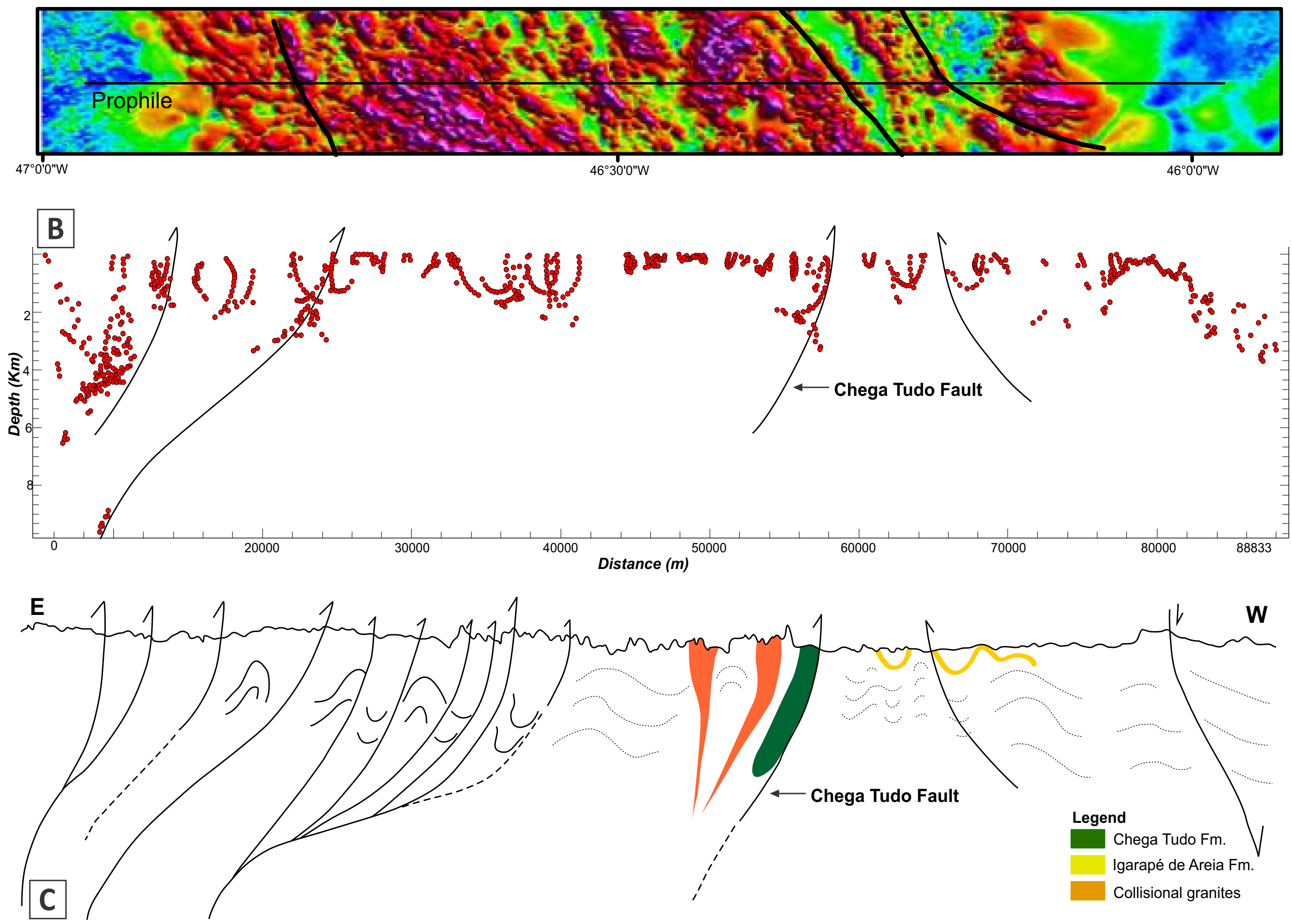

Figure 05 - (A) Area of the analytic signal map used for structural interpretation. (B) E-W profile of magnetic source depths (red dots) and inferred structures. (C) Regional geological interpretation and location of the Chega Tudo fault system.

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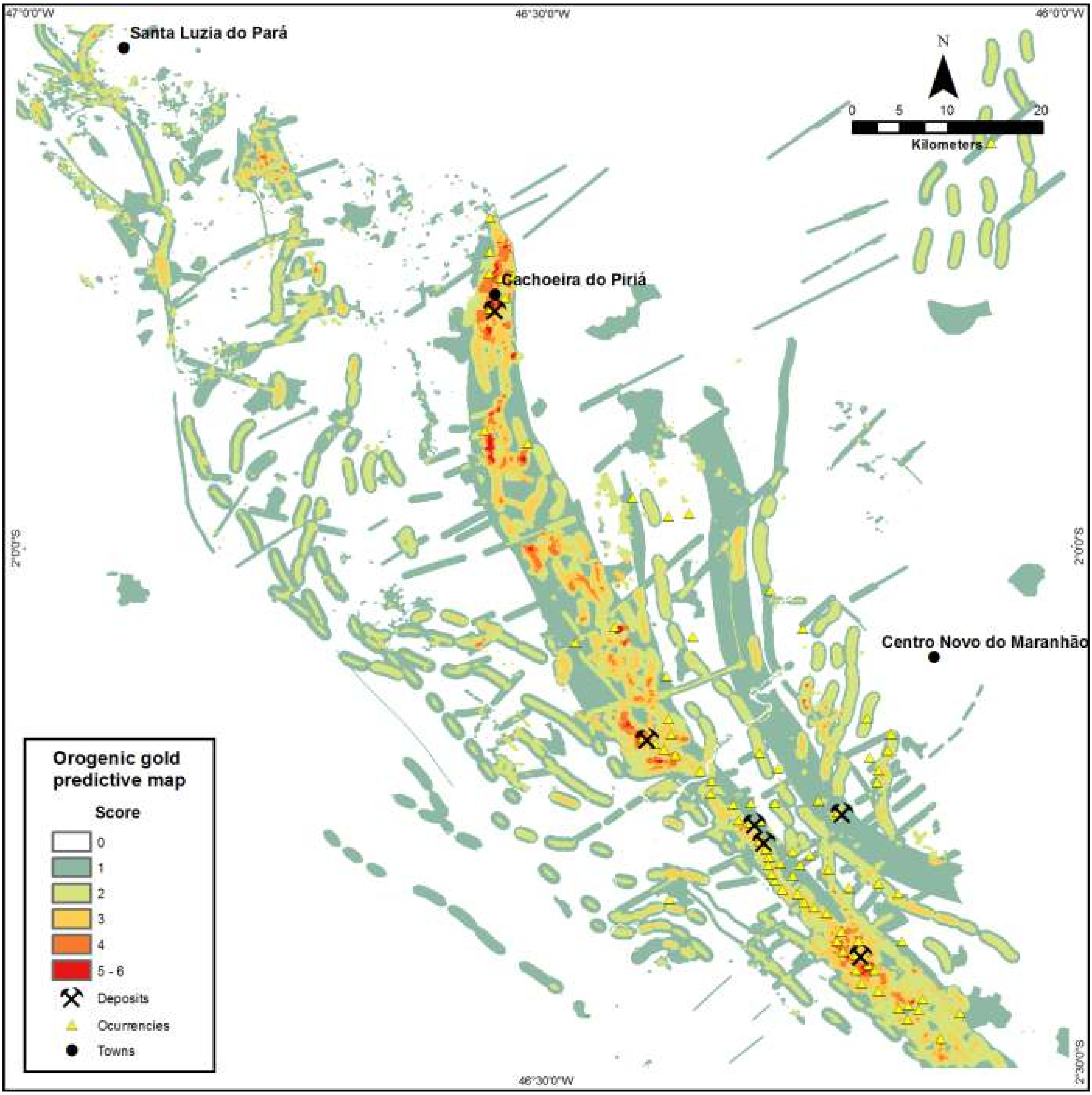

Figure 06 - Predictive map of the Gurupi Belt orogenic gold system based on the integration of geophysical and geological data. Areas with a score higher than 3 are considered as the most prospective, as exemplified by the deposits of Cachoeira, Mina Nova Sul, Cachoeira, Chega Tudo and Cipoeiro.

Nova Brasilândia Project

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The Nova Brasilândia Project is being developed by the Geological Survey of Brazil (CPRM) as part of its programs "Geological Geophysical Integration and Predictive Prospectivity Mapping of the Brasilian Shields" (Program I) and "Mineral Potential Assessment of the Brazilian Volcano-Sedimentary Sequences" (Program III). The studied area is located in Rondônia State and was selected after the recent discovery of polymetallic sulfides in the metasedimentary sequence of Migrantinópolis Formation, Nova Brasilândia Group (Figure 01).

The Nova Brasilândia Group (NBG) is divided into the Rio Branco and the Migrantinópolis formations (Scandolara and Rizzotto, 1994). The Rio Branco Formation comprises coarse and fine-grained amphibolites, metagabbros and gabbronorites, in tectonic contact with hornblende-tremolite-garnet gneisses. It exhibits a strong positive magnetic anomaly, with rocks that were interpreted by Scandolara and Rizzotto (1994) as formed during rifting and opening of a narrow proto-ocean.

The Migrantinópolis Formation on top is composed of siliciclastic sediments with a minor volcanic component, including kyanite-staurolite gneiss, sillimanite-muscovite-biotite gneiss, muscovite-biotite-feldspar-quartz gneiss with lenses of hornblende-tremolite-garnet gneiss, fine-grained amphibolite, metagabbroic sills and scarce metabasalts. The mineral assemblages of these rocks indicate metamorphism of upper amphibolite to granulite facies related to the closure of the basin. Low-angle tectonics

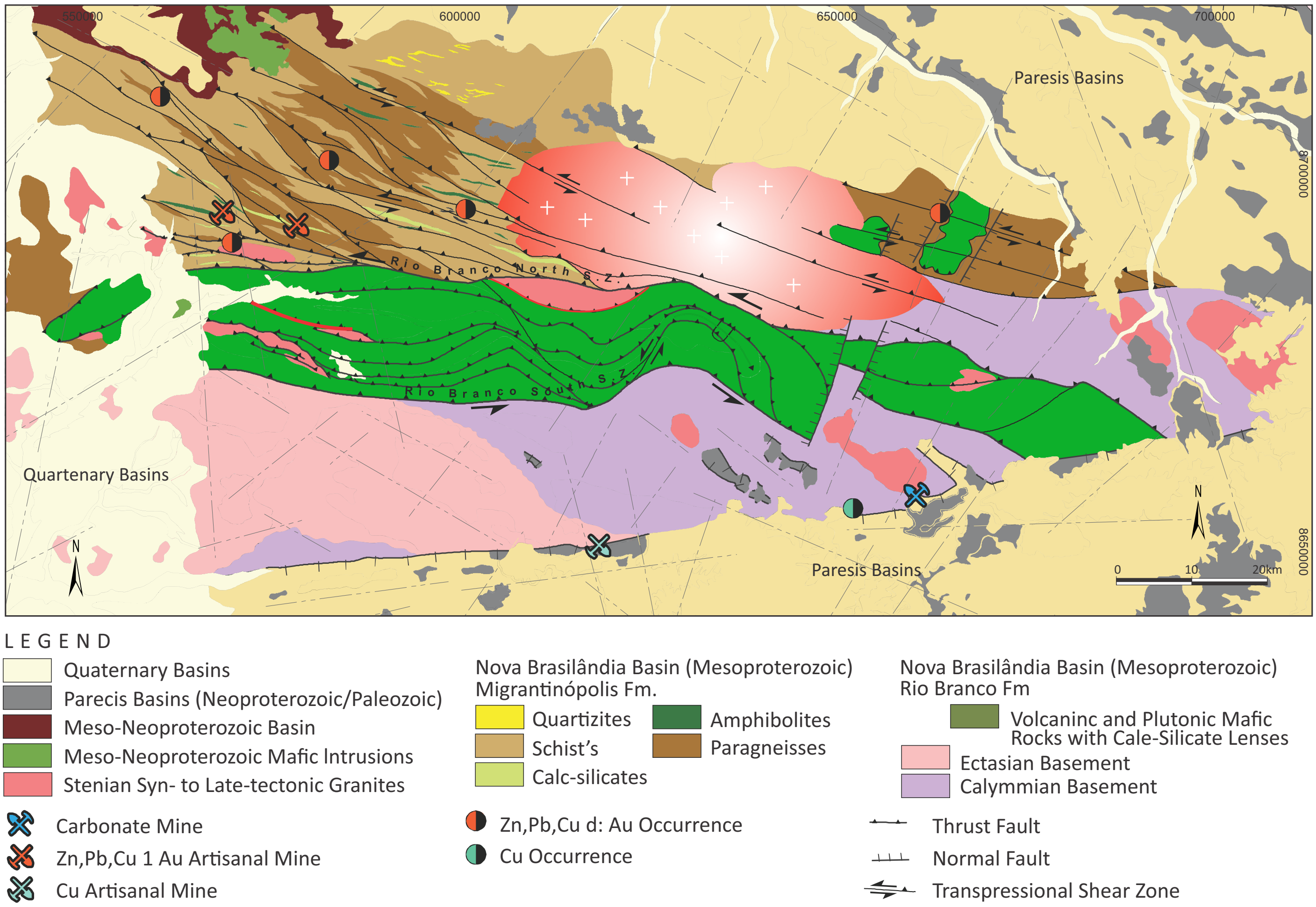

Figure 01 - Geological map of the Nova Brasilândia project area.

affecting the units masks the primary contacts between the metasediments and the mafic rocks. From the highly deformed rock sequences (Figure 02), a schematic stratigraphic column prior to deformation was reconstituted (Figure 03).

The Migrantinópolis sediments were deposited around 1215 ± 20 Ma either in an intracontinental rift or on a passive margin of the Amazonian Craton (Rizzotto et al., 1999) (Figure 04). Aeromagnetic anomalies suggest that the NBG sedimentary sequence extends at least 500 km in the E-W direction, with its eastern and western ends covered by Cretaceous and Quaternary sediments, respectively (Figure 05).

Occurrences of Zn-Pb-Cu polymetallic sulfides were identified in areas prospected by Mineração Santa Elina. They are characterized by strongly oxidized massive and disseminated sulfide zones (surface gossans), iron oxide veinlets and stockworks, siliceous breccia and quartz veins. The Zn-Pb-Cu sulfide-rich hydrothermal breccia and gossans are hosted by muscovite-biotite-feldspar-quartz gneiss intercalated with sillimanite-biotite-muscovite gneiss, hornblende-tremolite-garnet gneiss (calc-silicate rocks), fine-grained amphibolite (metagabbro) and BIF. The massive sulfide zones occur as stratiform mineralized lenses alternating

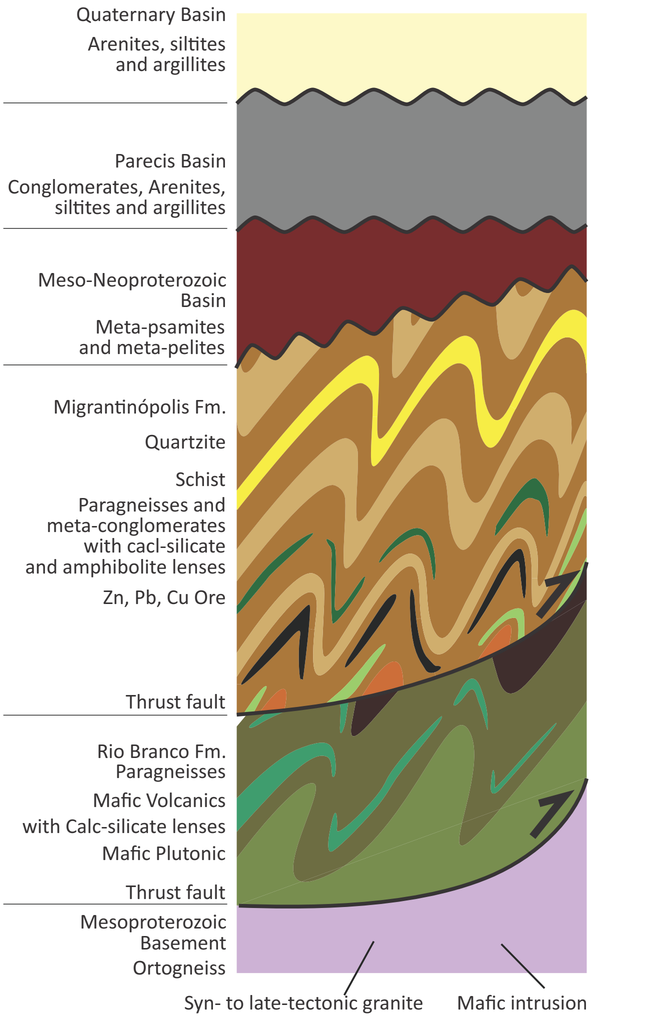

Figure 02 - Stratigraphic column of the deformed Nova Brasilândia volcano--sedimentary sequence.

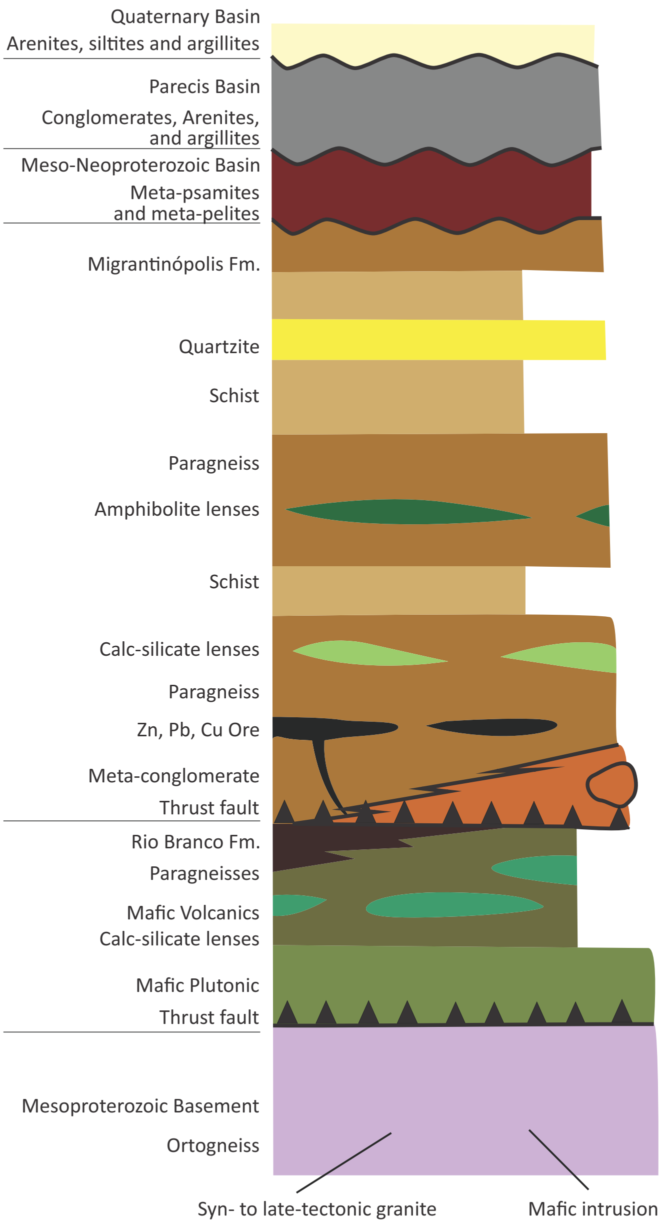

Figure 03 - Reconstituted stratigraphic column of the Nova Brasilândia volcano--sedimentary sequence prior to deformation.

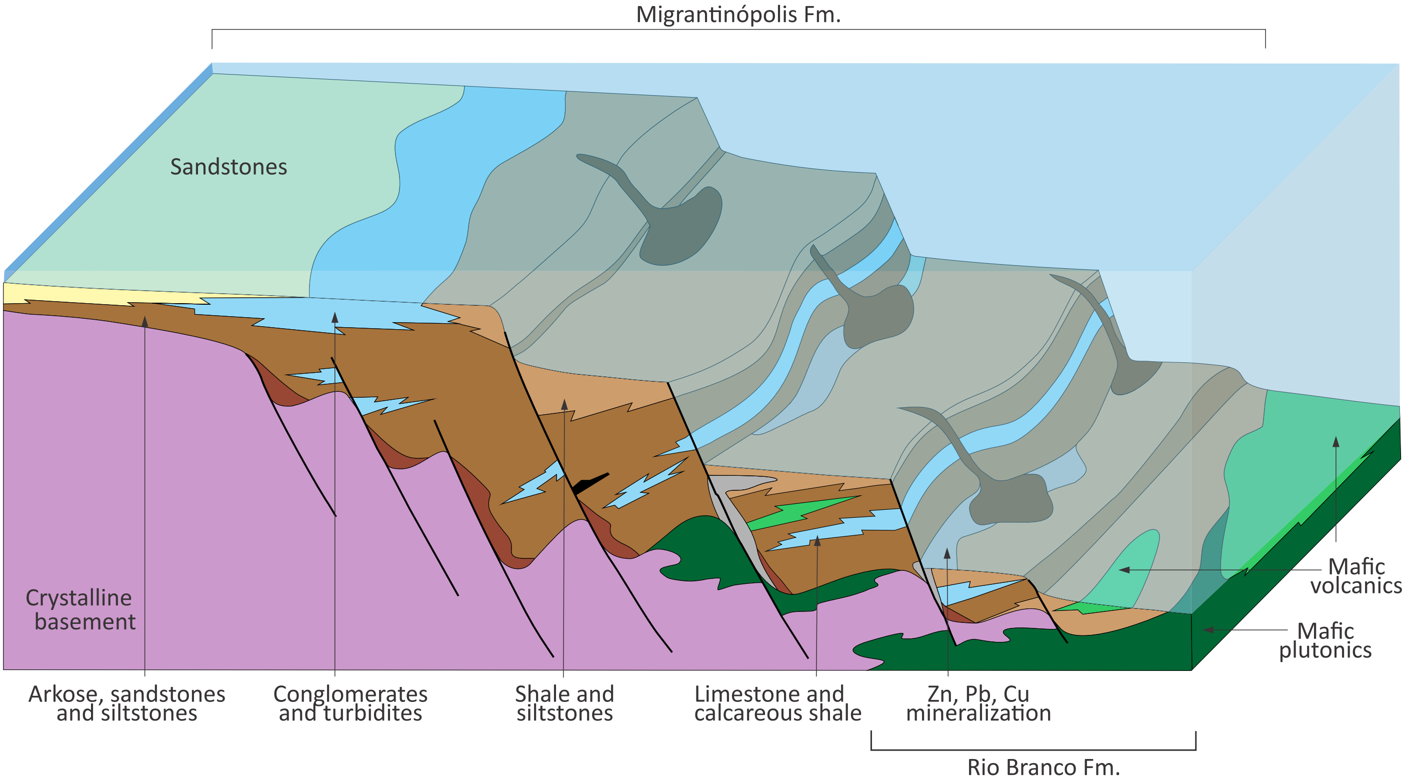

Figure 04 - Paleoenvironmental reconstruction of the Nova Brasilândia volcanosedimentary sequence, based on the model of SEDEX deposits from Emsbo (2009).

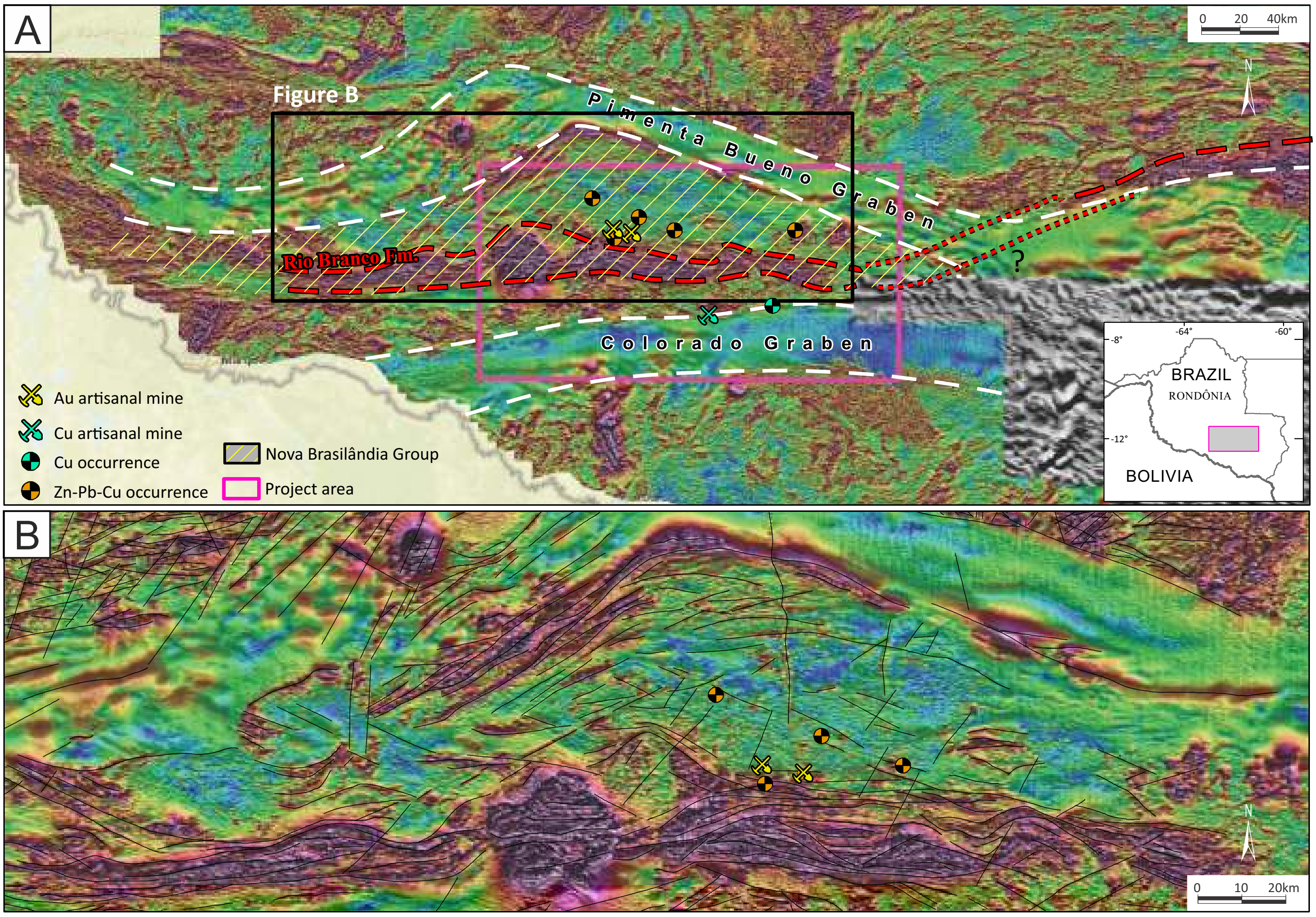

Figure 05 - Aeromagnetic map of the Nova Brasilândia project area. (A) Regional coverage showing the major magnetic lineaments, Nova Brasilândia Group area, and metallic mineral occurrences. (B) Detailed coverage of the Nova Brasilândia Group area.

with sulfide-bearing muscovite-biotite-feldspar-quartz gneiss. These polymetallic sulfide zones are 5-40 m thick and 0.3-3 km long.Hydrothermal alterations with >25% of gahnite (Zn oxide) near siliceous breccias were continuously mapped along a 2.5 km ESE-WNW trend. Most of the sulfide-rich zones occur concentrated along a magnetic lineament of at least 50-km long, which was interpreted as a sinistral transpressional fault (Figure 06).

The Zn-Pb-Cu sulfide deposit of Nova Brasilândia presents similarities with SEDEX-type deposits that have undergone high- grade metamorphism such as for example in Broken Hill, Australia. The two deposits have comparable host rocks, geotectonic setting, and metamorphic conditions. Further studies by the Geological Survey of Brazil (CPRM) and associated universities will be aimed at better understanding the factors controlling this mineralization and at establishing a geological model.

Syn and late tectonic A-type granites intruded NBG and affected the mineralization by increasing Sn and W grades in the gossans, in particular near the contact with the plutonic bodies.

Figure 06 - (A) Gossan exposure including a massive sulfide vein (4 m thick) hosted by paragneiss of the Migrantinópolis Formation. Sample from this outcrop contains quartz, sulfides, gahnite and iron oxides, with composition of 5.9% Zn, 0.74% Pb and 0.17% Cu; (B) Hand specimen showing weathered sulfides along the foliation plane and in veins, with composition of 0.61% Zn, 1.1% Pb and 0.24% Cu.

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