

## **Gold mineralization in veins of massive pyrite at Serra da Paciência, Bahia State, Brazil – a different typology from that of Au-U conglomerates of the Jacobina Group**

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### **Abstract**

Gold mineralization that differs from the classic conglomerate-hosted Au-U mineralization from Serra da Jacobina was found at Serra da Paciência, 6 km north-northwest of Pindobaçu town, Bahia State. The mineralization occurs 100 meters south of garimpo Mina Velha and consists of a 40 cm-thick gold-bearing vein of massive pyrite hosted in a chloritite (metamorphosed ultramafic dike), which intrudes quartzites of the Cruz das Almas Formation (Jacobina Group). The chloritite has N-S direction, thickness between 1,5 and 2 m and is affected by a reverse fault of 095/63 attitude. Samples of massive pyrite returned Au grades of 336 and 385 ppb. At the garimpo Mina Velha gold mineralization is related to pyrite-bearing quartz veins hosted by chloritite affected by the same reverse fault. Gold values in samples from Mina Velha range from 239 ppb, in the chloritite, to 22,660 ppb, in the pyrite-bearing quartz vein. The gold occurrence related to massive pyrite vein reveals to be a prospective alternative different from the conglomerate-hosted Au-U of the Jacobina Group.

**Keywords:** Serra de Jacobina, Hydrothermalism, Gold.

### **INTRODUCTION**

The Au-U conglomerates of Serra de Jacobina are known worldwide for characteristics that allow correlating them with Witwatersrand-like paleoplacer deposits in South Africa (Bateman, 1958). Nevertheless, several other hydrothermal auriferous occurrences associated with quartzites, ultramafic and mafic rocks are exploited by artisanal miners (garimpos), which occur along the entire Serra de Jacobina (Teixeira et al., 2001; Pearson et al., 2005).

This study intends to complement the description of auriferous occurrences by addressing a usually overlooked typology, which is associated with massive pyrite veins hosted in ultramafic rocks. Al-

though such style is known by the exploratory works of companies in the region, no specific studies were found focused on the description of this typology.

This study stems from the Geological Integration and Metalogenetic Potential Assessment of the Serra de Jacobina and the Mundo Novo Greenstone Belt Project (ARIM Jacobina), linked to the Program “Areas of Relevant Mineral Interest” (ARIM).

### **GEOTECTONIC SETTING AND REGIONAL GEOLOGY**

The Serra de Jacobina is located in the eastern margin of the Gavião Block, São Francisco Craton (Figure 1), and comprises a 220 km-long, N-S-trending struc-

ture produced during the amalgamation of metasedimentary basins represented by the Jacobina Group and Saúde Complex, and metavolcanosedimentary rocks of the Mundo Novo Greenstone Belt. These sequences were deposited on a TTG basement and were intruded by several leucogranites (Leite & Marinho, 2012).

Mascarenhas et al. (1998) presented a comparative study of the several stratigraphic columns proposed for the Paleoproterozoic basin represented by the Jacobina Group, and proposed a subdivision into five formations: Serra do Córrego, Rio do Ouro, Cruz das Almas, Serra do Meio and Serra da Paciência. These formations are composed of, from the bottom to the top, an intercalation of quartzites and conglomerates, quartzites with ripple marks and bidirectional cross bedding, and quartzites with intercalations of andalusite schists. Mascarenhas et al. (1994) and Teles et al. (2015) interpreted this sequence as deposited in a rift basin, while Ledru et al. (1997) suggested a foreland basin model.

The Jacobina Group has intercalations of chloritized ultramafic rocks, trending to the N-S direction, whose stratigraphic position is controversial (Teixeira et al., 2001). Couto et al. (1978) described these lithotypes as intrusive into the Jacobina Group and related to the Itapicuru Complex. Mascarenhas et al. (1998) correlated these rocks to the Mafic/Ultramafic Domain of the Mundo Novo Greenstone Belt and interpreted them as tectonic layers imbricated with the Jacobina Group. Late-tectonic dikes of metagabbro and metadiorite are intrusive into the metasedimentary rocks of the Jacobina Group and into the ultramafic intercalations of N-S direction (Teixeira et al., 2001; Pearson et al., 2005).

## TYPOLOGY OF THE AURIFEROUS MINERALIZATIONS

There are several models about the origin of the Au-U mineralizations associated with the conglomerates of the Serra do Córrego Formation. Bateman (1958) suggested a sedimentary origin (paleoplacer), Gross (1968) indicated a modified sedimentary origin (modified paleoplacer), whilst White (1961) and Cox (1967) argued for an epigenetic origin for the mineralization. Milesi et al. (2002) presented the “hydrothermal shear-reservoir” model, in which they admit an epigenetic gold enrichment without highlighting a primary sedimentary origin associated with the conglomerates.

In addition to the gold associated with the conglomerates of the Serra do Córrego Formation, there are at least four other types of gold mineralization in the Serra de Jacobina. These are associated to: (i) the Jacobina Group (Rio do Ouro and Cruz das Almas formations); (ii) the N-S- trending ultramafic rocks; (iii) the mafic to intermediate dikes; (iv) the Mundo Novo Greenstone Belt. Teixeira et al. (2001) and Pearson et al. (2005) classified these typologies according to the host rock. Based on the observation of the structural control of mineralized bodies with hydrothermal alteration and the occurrence of gold in different units, the authors proposed a model of epigenetic mineralization for these typologies.

The typology presented in this paper is associated to the N-S-trending ultramafic rocks, and had not been described in previous works so far.

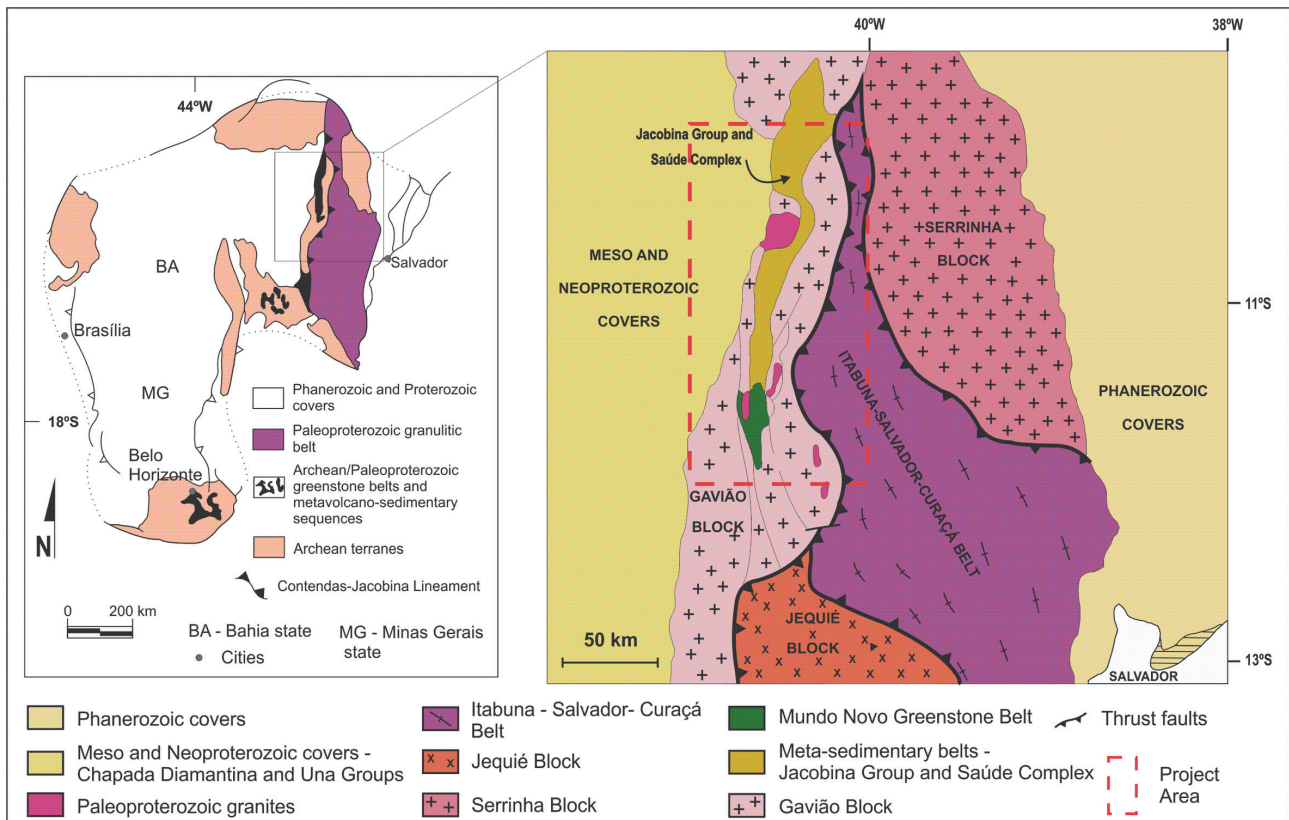


Figure 1: Geotectonic setting of the Serra de Jacobina. Modified from Leite e Marinho (2012).

## OCCURRENCE DESCRIPTION

The studied occurrence is located at the UTM coordinates N 8,817.880, E 349,298, with elevation of 781 meters (Zone 24L, datum SIRGAS 2000), in the vicinity of the Mina Velha garimpo, at Serra da Paciência, approximately 6 km NNW from Pindobaçu town, Bahia State (Figure 2).

At Serra da Paciência, quartzites with channelled, bidirectional cross bedding and ripple marks predominate. These quartzites belong to the Cruz das Almas Formation, denomination used in this paper, as defined by Couto et al. (1978), and also adopted by Teixeira et al. (2001). Pearson et al. (2005) refer to these quartzites as Serra da Paciência Formation. This unit shows a series of open antiforms and synforms, with axes trending NNE-SSW and plunging about 10° to NNE. The dip of the axial plane is subvertical and the direction is NNE-SSW.

Figure 3 presents the geological sketch of the Mina Velha garimpo region and the location of the massive auriferous pyrite occurrence. The mined pit is 100 m long in the NNE direction, with estimated thickness between 2.5 and 3 m.

In the Mina Velha garimpo, the mineralization is hosted in an oblique reverse fault (Figure 4A). The ore mined by the garimpeiros is the weathered chloritite hosted by the fault plane (Figure 4B). This chloritite is interpreted as an ultramafic dike, which hosts strongly oxidized quartz veins. In thin section we observed that the matrix is composed mainly of chlorite. The rock is tectonized, with presence of ribbon quartz and pyrite grains oriented along the foliation planes (Figures 5A and 5B). In other parts of Serra de Jacobina, serpentinites, pyroxenites, tremolitites and gabbros occur in spatial association with the chloritites.

The observed hydrothermal mineralogy is composed of quartz + magnesian chlorite + magnetite, and the sulfide phases comprise pyrite + chalcopyrite and pyrite + covellite associations (Figures 6A and 6B).

The outcrop/occurrence here described is located about 100 m towards the south of the mined pit, following the structural lineament. The geological setting is similar to that of the Mina Velha garimpo, in which a fault zone intersects the quartzites of the Cruz das Almas Formation and the chloritite. The latter has a thickness between 2.5 and 3 m, is mylonitized, with quartz veinlets subparallel to the foliation planes. In this different typology, the auriferous mineralization is associated with a 40 cm thick massive pyrite vein with some associated smoky quartz (Figures 7A and 7B).

## CHEMICAL ANALYSES

The method used to analyze the rock samples from Mina Velha garimpo and the massive pyrite vein was fire assay (samples with mass > 0.5 kg) and detection of Au, Pt and Pd by ICP-AES (Inductively

Coupled Plasma – Atomic Emission Spectroscopy), with a lower detection limit of 5 ppb. In the Mina Velha garimpo 8 chloritite samples were collected along the 100 m extension of the open pit (Table 1). The concentrations are between 69 and 2901 ppb Au, with the highest values occurring in samples HHI-271 and HHI-272. Pd contents are between 8 and 31 ppb; for Pt, almost all samples graded below the detection limit.

Also in the Mina Velha pit (Figure 8), a quartz vein with pyrite yielded values between 148 and 22660 ppb Au and 41 to 70 ppb Pd. The ferruginous margin occurring in the contact between the vein with pyrite and the chloritite yielded values of 161 to 166 ppb Au, and 179 to 212 ppb Pd. The chloritite samples yielded 239 to 357 ppb Au, and 63 to 113 ppb Pd. For all samples, the platinum values are below detection limit (Table 2).

In the massive pyrite occurrence, values of 336 and 385 ppb Au were found, whereas Pt and Pd concentrations were below detection limit (Table 2).

## DISCUSSIONS AND CONCLUSIONS

The auriferous mineralization associated with massive pyrite veins reported here is not present in the literature about the Serra de Jacobina region. The closest description on this type of mineralization was made by Silveira and Conceição Filho (2001) at the Mina Velha garimpo, who report higher gold content associated with quartz veining with large concentrations of sulfides. Thus, it is our goal the disclosure of this type of mineralization found in the Jacobina Group.

The characteristics of the studied occurrence allow the following conclusions:

i) The mineralized massive pyrite vein is hosted in the N-S trending chloritite. It is not possible to correlate this lithotype with units from the Mundo Novo Greenstone Belt or Itapicuru Complex.

ii) The observed contact relationship indicates that the chloritite intruded into the quartzite of the Cruz das Almas Formation (Jacobina Group). The occurrence of mafic to ultramafic magmatism after the deposition of the sediments of the Jacobina Group can be inferred.

iii) The ultramafic rock that hosts the massive pyrite vein was affected by a reverse fault with vergence to the west, and is part of the same structural trend of the Mina Velha garimpo. This structural control indicates a possible genetic relationship between the mineralization in the garimpo and the massive pyrite vein.

iv) The hydrothermal mineralogy, composed of pyrite, chalcopyrite and magnetite, in addition to the structural control by the reverse fault, suggests that the auriferous mineralization in the massive pyrite may come from the interaction of tectonically channelled hydrothermal fluids and placed in contact with mafic and ultramafic intrusions.



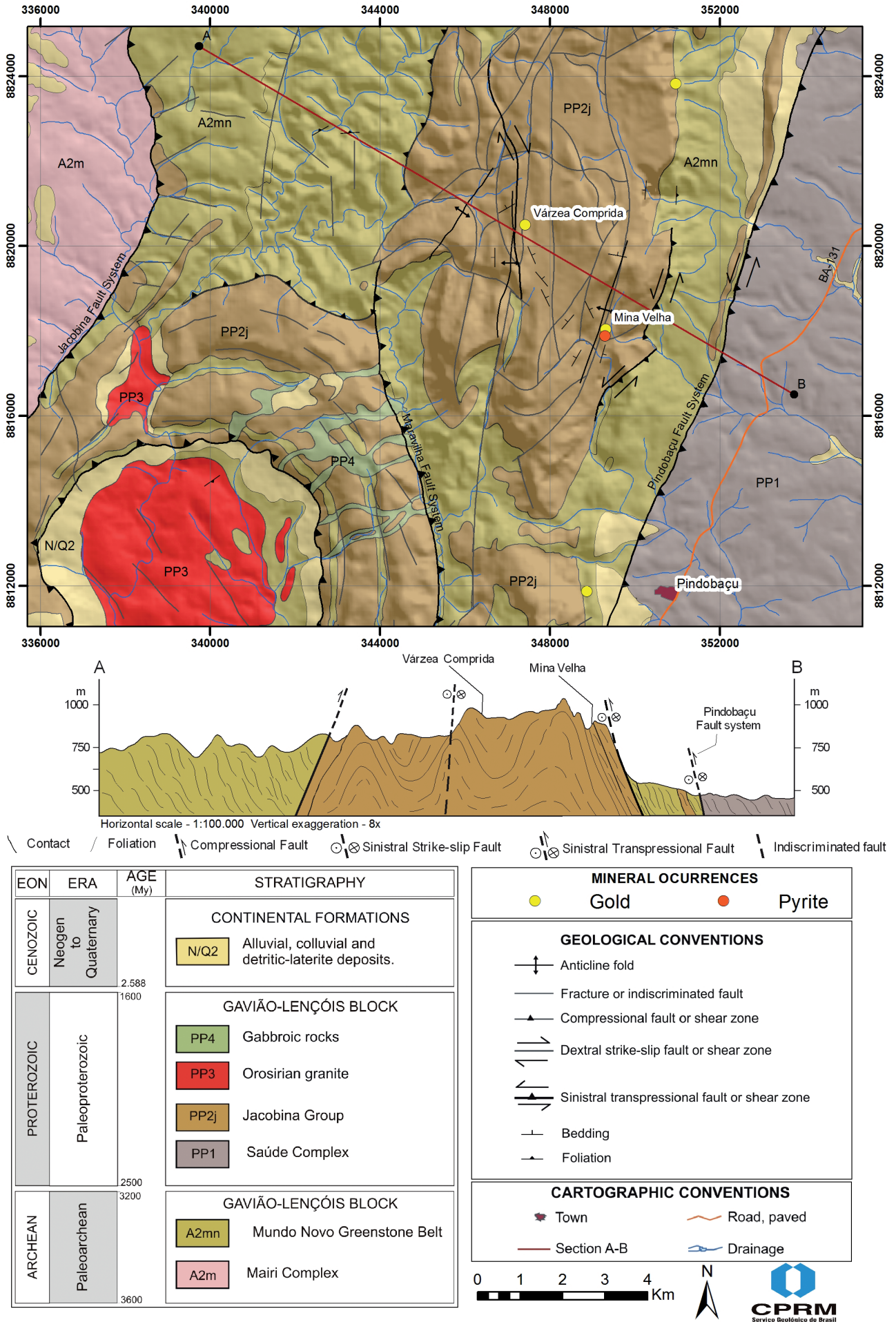


Figure 2: Geological map and section of the Serra da Paciência region.



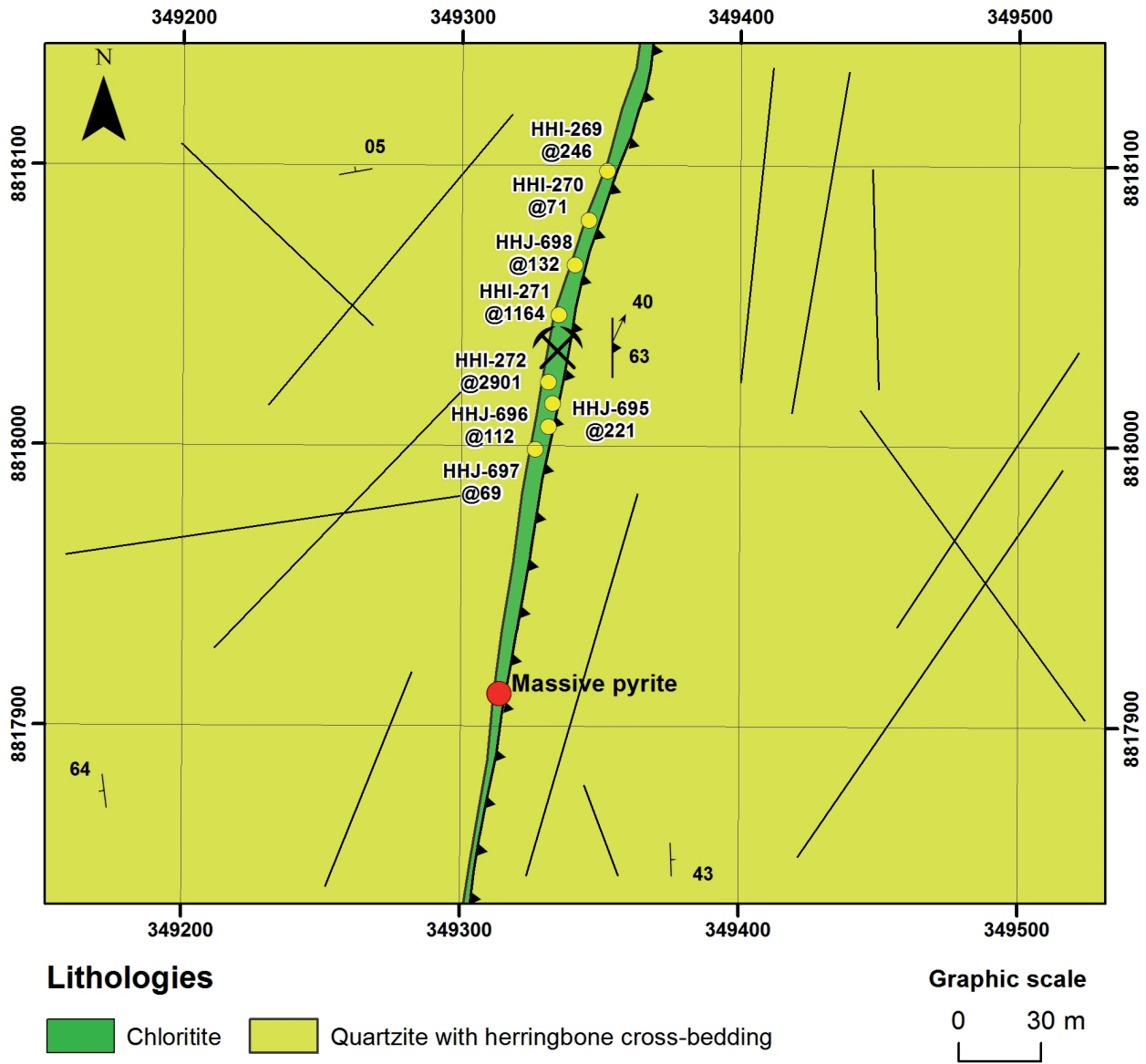


Figure 3: Geological sketch of the Mina Velha "garimpo" and its surroundings.



Figure 4: A) Fault plane hosting the mineralization; attitude 095/63; stretching lineation 034/40. B) Outcrop of chloritite.



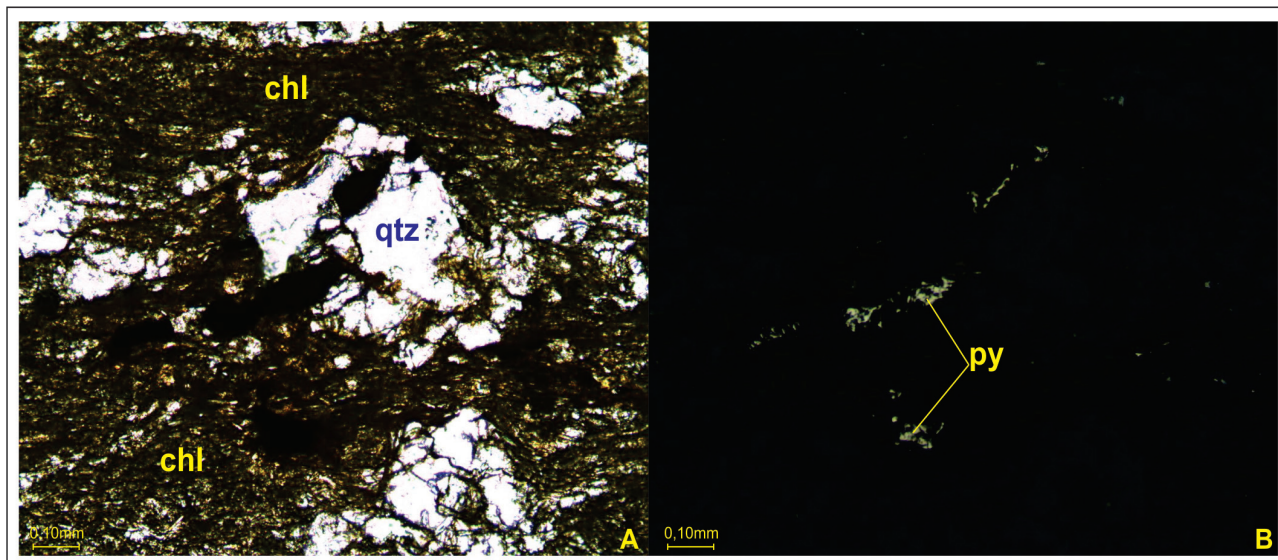


Figure 5: A) Mainly chlorite (chl) matrix. Parallel Nicols, 10X magnification. B) Pyrite (py) crystals oriented according to foliation and associated with quartz (qtz). Reflected light, 10X magnification.

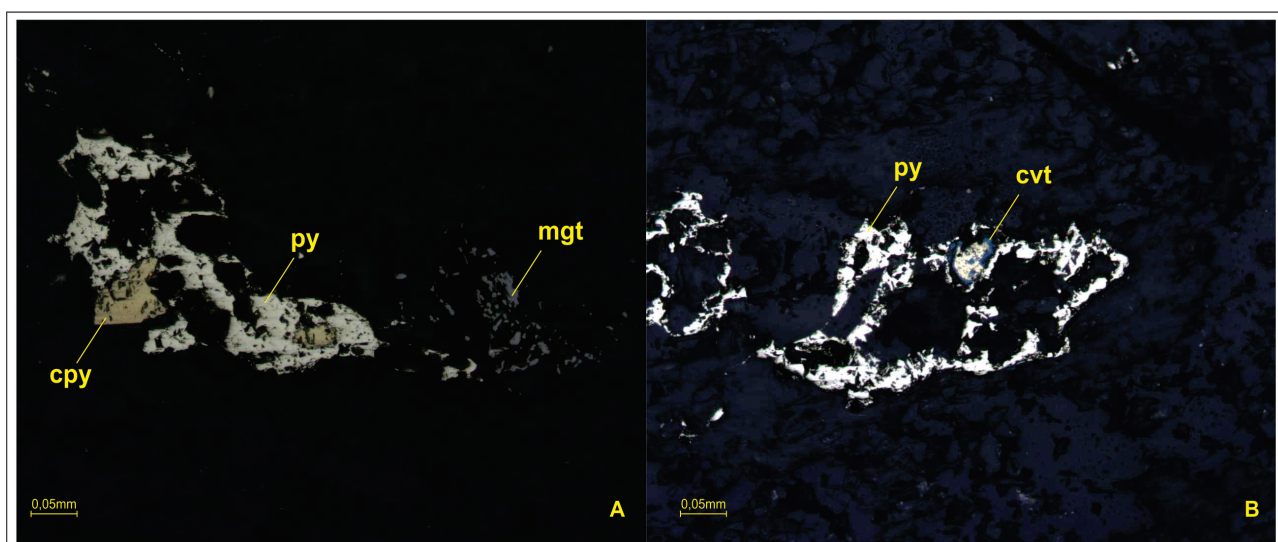


Figure 6: A) pyrite+chalcopyrite+magnetite association (py+cpy+mgt). Reflected light, 20X magnification. B) pyrite+covellite association (py+cvt). Reflected light, 20X magnification.

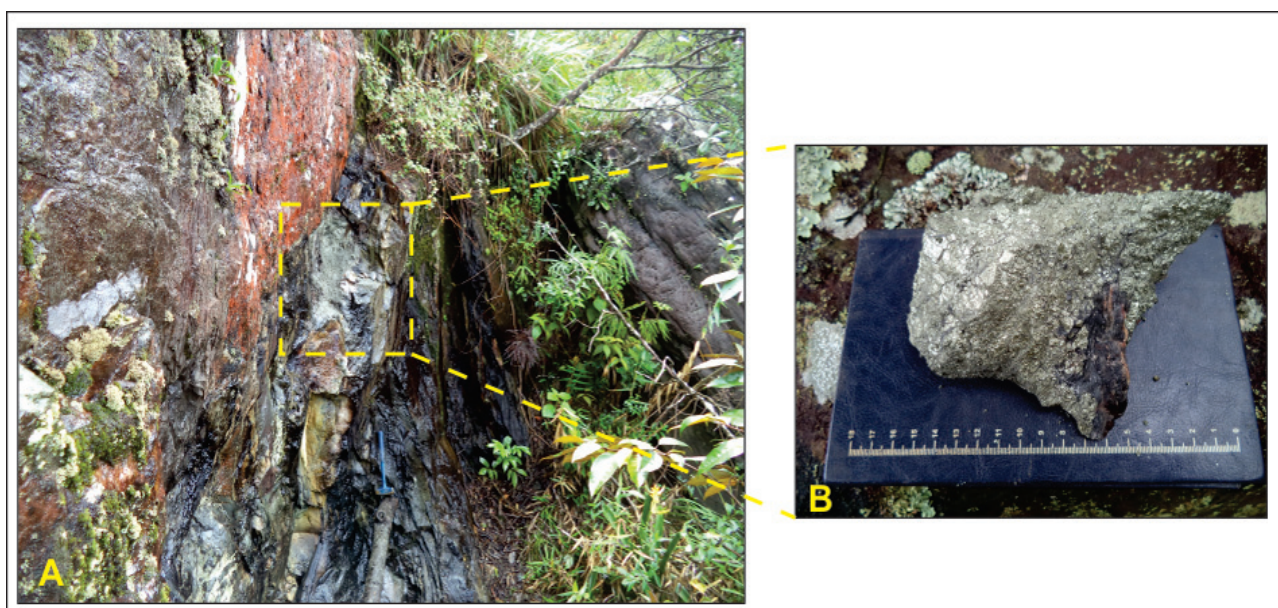


Figure 7: A) Fault zone overview; HHI-267 sample location shown in 7B.



Table 1: Results of the chemical analysis of chloritite.

Sample	Au (ppb)	Pd (ppb)	Pt (ppb)
HHI-269	246	26	< 5
HHI-270	71	8	< 5
HHI-271	1,164	15	< 5
HHI-272	2,901	16	11
HHI-695	221	18	< 5
HHI-696	112	18	6
HHI-697	69	16	< 5
HHI-698	132	31	< 5

Table 2: Results of whole-rock chemical analysis from the Mina Velha garimpo and massive pyrite vein.

Sample	Site Name	Rock	Au (ppb)	Pd (ppb)	Pt (ppb)
HHJ-689	Mina Velha	Quartz vein with pyrite	283	41	< 5
HHJ-690	Mina Velha	Quartz vein with pyrite	148	70	< 5
HHJ-693	Mina Velha	Quartz vein with pyrite	22,660	46	< 5
HHJ-694	Mina Velha	Quartz vein with pyrite	15,920	41	< 5
HHJ-691	Mina Velha	Ferruginous alteration	166	212	< 5
HHJ-692	Mina Velha	Ferruginous alteration	161	179	< 5
HHJ-687	Mina Velha	Chloritite	357	113	< 5
HHJ-688	Mina Velha	Chloritite	239	63	< 5
HHI-267	Mina Velha - south extension	Massive sulphide	336	< 5	< 5
HHI-268	Mina Velha - south extension	Massive sulphide	385	< 5	< 5

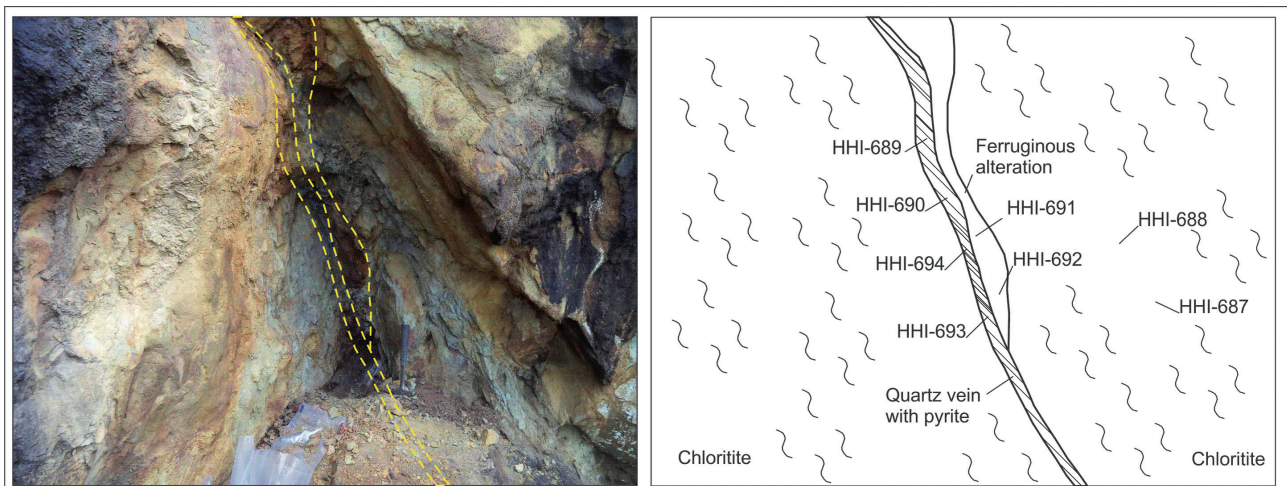


Figure 8: Sampling sketch indicating the position of the samples in Table 2.

In the Mina Velha garimpo it is possible to interpret a zoning in the auriferous mineralization, with a gold-enriched core represented by the quartz veins with pyrite. The gold contents decrease toward the edges of the veins and disseminate in the ultramafic wall rock. Palladium contents associated to the edge of alteration in the contact between the veins and the chloritite indicate the potential for mineralization of this element associated with gold.

Thus, the auriferous mineralization in massive pyrite veins hosted in ultramafic rock dikes, tectoni-

cally affected by the several faults that occur at Serra de Jacobina, is shown as an alternative for mineral exploration in a different setting different from that of the auriferous conglomerates of Serra do Córrego, exhaustively prospected in that region.

## REFERENCES

BATEMAN, J.D. Uranium-bearing auriferous reefs at Jacobina, Brazil. *Economic Geology*, v. 54, p. 417-425, 1958.

COUTO, P. A.; SAMPAIO, A. R.; GIL, C. A. A.; LOUREIRO, H. C.; ARCANJO, J. B. A.; FERNANDES FILHO, J.; GUIMARÃES, J. T.; CAMPELO, R.; MASCARENHAS, J. F.; BRUNI, D. C.; TOLEDO, L. A. A.; GONÇALVES, G. D. Projeto Serra de Jacobina: geologia e prospecção geoquímica. Relatório final. Texto. Salvador: CPRM, 1978. v. 1. Convênio DNPM/CPRM.

COX, D. P. Regional environment of the Jacobina auriferous conglomerate, Brazil. *Economic Geology*, v. 62, p. 773-780, 1967.

GROSS, W. H. Evidence for a modified placer origin for auriferous conglomerates, Canavieiras Mine, Jacobina, Brazil. *Economic Geology*, v. 63, p. 271-276, 1968.

LEDRU, P. et al. Foreland basins and gold-bearing conglomerates: a new model for the Jacobina Basin (São Francisco Province, Brazil). *Precambrian Research*, v. 86, p. 155-176, 1997.

LEITE, C. M. M.; MARINHO, M. M. Serra de Jacobina e Contendas-Mirante. In: BARBOSA, J. S. F. (Coord.). *Geologia da Bahia: pesquisa e atualização*. Salvador: CBPM, 2012. v. 1, p. 397-441.

MASCARENHAS, J. F.; SILVA, E. F. A. Greenstone Belt de Mundo Novo: caracterização e implicações metalogenéticas e geotectônicas no Cráton do São Francisco. Salvador: CBPM, 1994. (Série Arquivos Abertos, 5).

MASCARENHAS, J. F. et al. Geologia e recursos minerais do Grupo Jacobina e da parte sul do Greenstone

Belt de Mundo Novo. Salvador: CBPM, 1998. (Série Arquivos Abertos 13).

MILESI, J. P. et al. The Jacobina Paleoproterozoic gold-bearing conglomerates, Bahia, Brazil: a "hydrothermal shear-reservoir" model. *Ore Geology Reviews*, v. 19, p. 95-136, 2002.

PEARSON, W. et al. Geology and gold mineralization of the Jacobina Mine and Bahia Gold Belt, Bahia, Brazil and a comparison to Tarkwa and Witwatersrand. In: RHODEN, H. N., STEININGER, R. C., AND VIKRE, P. G. (Ed.) *Geological Society of Nevada Symposium 2005*. Reno, Nevada: GSN, 2005. p. 757-785.

SILVEIRA, W. P.; CONCEIÇÃO FILHO, V. M. Avaliação geológica do potencial aurífero do prospecto Varagem Comprida, Pindobaçu, Bahia. Relatório Interno, CBPM, 1991, 18 p.

TELES, G.; CHEMALE, F.; OLIVEIRA, C. G. Paleoarchean record of the detrital pyrite-bearing, Jacobina Au-U deposits, Bahia, Brazil. *Precambrian Research*, v. 256, p. 289-313, 2015.

TEIXEIRA, João Batista Guimarães et al. Gold mineralization in the Serra de Jacobina region, Bahia Brazil: tectonic framework and metallogenesis. *Mineralium Deposita*, v. 36, p. 332-344, 2001.

WHITE, M. G. Origin of uranium and gold in the quartzite-conglomerate of the Serra de Jacobina. Washington: USGS, 1961. (Paper 424B, 9B).

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