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Ocurrence of free gold in hydrothermally-altered volcanic rocks at Castro Basin, State of Paraná, Brazil: perspectives for new potential areas

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Abstract

New occurrences of free gold were identified during fieldwork at outcrops located in the western part of the Castro Basin, state of Paraná. These are associated with silicified and sulfide-rich zones in hydrothermally-altered volcanic rocks. The aerogeophysical data indicate that the areas of the new targets show high K and eU relative to eTh, suggesting intense hydrothermal alteration. The stream sediment geochemistry shows anomalies with up to 60 ppb of Au and whole-rock geochemical results confirm the presence of up to 54 ppb of Au in rock samples. The data obtained until now are consistent with those observed in mineralized targets previously described in the same basin, in which an epithermal setting was suggested for the origin of the gold mineralization. Ongoing studies of the new occurrences may indicate an increase in the mineral potential of the Castro Basin.

Keywords: Castro Basin, Gold, Silicified breccia, Epithermal, Low-sulphidation.

INTRODUCTION

In the Castro Basin (Figure 1), State of Paraná, Brazil, at least two gold mineralized areas are recognized so far: Torre (deposit) and São Daniel (prospect). In these areas, auriferous mineralization is associated with hydrothermal veins that consist of siliceous-ferruginous hydraulic breccias hosted in hydrothermally-altered volcanic and sedimentary rocks. The veins are composed by quartz-adularia-sericite gangue and occur in association with hydrothermal alteration zones (Abreu et al., 2013), similar to the veins from low-sulphidation epithermal systems (Hedenquist et al., 1996). The Torre deposit has total reserve of 4,055,861 t of ore, with average grade of 0.43 g/t of Au, calculated for a 0.2 g/t Au cutoff (Piekarz, 1999), i.e., 1.74 t of contained Au. At São Daniel bonanza-type veins were found having up to 42 g Au/t (Abreu et al., 2013). Sillitoe and Hedenquist (2003) suggested that veins of this type are more common at extensional setting with bimodal magmatism. The Castro basin has similar setting, which is favorable for epithermal mineralizations.

Despite the gold potential observed by previous investigations in the region (Seoane, 1999), the Castro Basin is still poorly studied. This fact motivated the work in this area, through the Vale do Ribeira ARIM (Relevant Interest Mineral Area) Project. From the study of known targets, we attempted to the understanding of mineralization controls, in order to stablish criteria to investigate new areas with mineral potential. Thus, we performed fieldwork, remote sensing image and geophysics analyses, along with stream sediment geochemistry. At the locality named Domo de Iapó new gold occurrences were found in a sulfide-rich zone with associated free gold (location: 24°39'43'' S; 50°08'34'' W) and silicification zone (location: 24°40'15'' S; 50°09'01'' W). These two occurrences are hosted by basic to intermediate volcanic rocks, situated at western Castro Basin (Figure 1b). Furthermore, we observed that the auriferous occurrences of this basin (Torre, São Daniel and Domo do Iapó targets) are associated to areas with intensely hydrothermally-altered rocks (chloritization, sericitization, argillization, potassification and silicification).

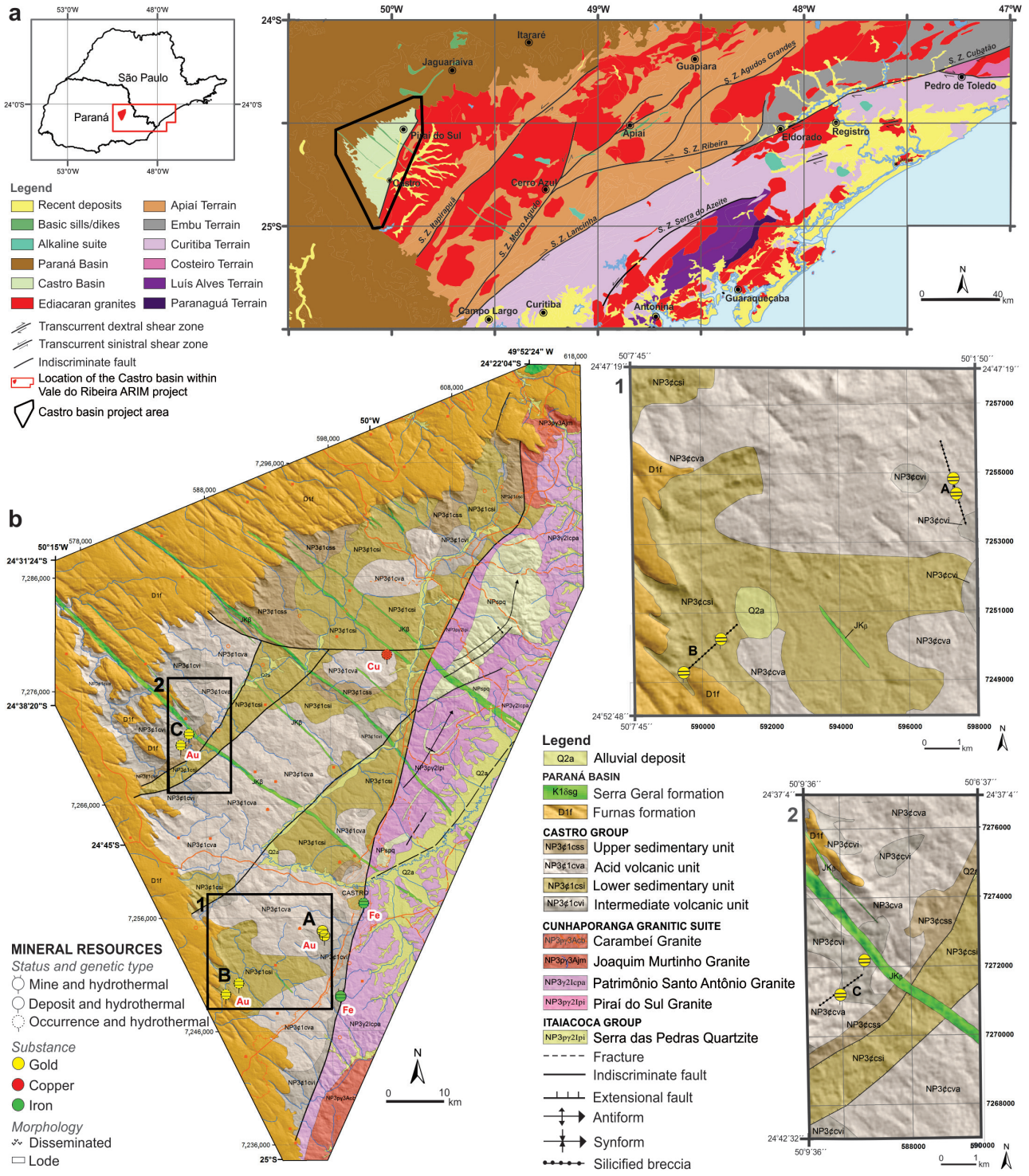

Figure 1: *Tectonic (a) and geological (b) maps with location of areas discussed in this report. a) Location of the Castro Basin within the Vale do Ribeira ARIM Project area. b) Location of the detailed areas within the Castro Basin. 1 – Torre deposit (A) and São Daniel target (B); 2 – Domo do Iapó Target (C) with new occurrences described in this report. Adapted from Mapa et al. (2015).*

The characterization of these occurrences, through petrography, lithogeochemistry and isotopic geology is being undertaken. Some partial results are presented in this report.

GEOLOGICAL SETTING

The Castro Basin is located in the western border of the Meridional Ribeira Belt, in contact with Paraná Basin rocks. The Castro Basin is limited to the east by the Castro Fault, which is a ~65 km long lineament striking NNE-SSW, which separates the rock units of the Castro Group from those of the Cunhaporanga Granitic Suite (Figure 1a). The Castro Group (Trein, 1967; Fuck, 1967) is composed of an Ediacaran (549.6 ± 4.4 Ma, zircon U-Pb from rhyolite; Almeida et al., 2010) volcano-sedimentary sequence. Moro (1993) subdivided this group, from bottom to top, into four distinct units: I) Lower Volcanic Unit, composed of andesite, rhyolite, tuff, ignimbrite and conglomerate; II) Lower Sedimentary Unit, constituted by siltstone with intercalations of fine-grained sandstone and pelite with volcanic contribution; III) Upper Volcanic Unit, composed of rhyolite, ignimbrite, quartz-latite, tuff and pyroclastic breccia; IV) Upper Sedimentary Unity, constituted by conglomerate, and conglomeratic and arkosic sandstones (Figure 1b).

Soares (1987, 1988) stated that the Castro Basin was formed during a transtentional event. Almeida et al. (2010) suggested formation as a rift system, which acted during the Ediacaran throughout southeastern South America. In this project, we observed that the units that form the Castro Basin show compartmentation on the NE-SW direction, which is related to the lineaments observed on satellites images and in airborne photographs, and with limits established by airborne geophysical data. This compartmentation, partly investigated during fieldwork, indicates a possible extensional fault system, which acted during the basin-forming event, which corroborates the Almeida et al. (2010) proposal.

OCCURRENCE DESCRIPTION

The Domo do Iapó occurrence is characterized by a tabular silicification zone, which comprises subvertical, ENE-WSW-striking vein, enveloped by an argillic zone. The exposed part of the vein is 50 m long and 10 m thick. It is composed essentially by brecciated white quartz, with fractures filled by iron oxide (Figure 2a), and grey chalcedony with cavities (Figure 2b). We have also observed dendritic pyrolusite in cavities and fractures. This occurrence, classified as a silicified hydraulic breccia, is located at the margins of the Piraí-Mirim River, near the inferred "Piraí-Mirim River Fault". Approximately 1.2 km northeast from this occurrence, still at the margins of this river, a sulfide-rich and silicified zone occurs, apparently without structural control. This zone is essentially composed of very fine-grained quartz and pyrite with massive structure (Figure 2c), in which we observed little specks of free gold associated to oxidized rock portions (Figure 2d). Arsenopyrite and, possibly, cinnabar (HgS – reddish mineral), also occur. However, the petrographic characterization of the sulfide-rich zone was not yet concluded. Both occurrences are hosted by the Lower Volcanic Unit (Figure 1b). In this area, there is a predominance of grey andesite with amygdaloidal texture and magmatic flow structure, and with oriented amygdales filled by celadonite. Grey tuff, purple lapilli-tuff and pyroclastic breccia varied in color occur subordinately. We also observed that nearby the occurrence the rocks of this unit are affected by selective pervasive chloritization.

LITHOGEOCHEMISTRY

Six samples were collected, being two from the new occurrences of Domo do Iapó and four from the Torre and São Daniel areas. The whole-rock fire assay method was used to detect gold, platinum and palladium. The analyses were performed at the SGS-GEOSOL laboratory by ICP-AES (Inductively Coupled Plasma – Atomic Emission Spectrometry). The results (Table 1) confirm gold presence in the occurrences described in the field; with the greatest values detected in the silicification zones at Domo do Iapó, Torre and São Daniel. Despite the gold from Domo do Iapó be lower than those observed in the Torre and São Daniel areas, and be < 200 ppb, a value considered anomalous in prospection campaign by DOCEGEO (Seoane, 1999), the veins can represent a distal part of a system with greater gold concentration. The measured value at the Torre argillic zone (Table 1) indicates that the peripheral zone of a possible auriferous vein can contain small quantities of gold. However, systematic analyses of the silicified and sulfide-rich zones are still lacking.

AEROGEOPHYSICAL DATA

The study region is covered by airborne magnetometric and gamma-spectrometric data from the Paraná-Santa Catarina Project (CPRM, 2011). Magnetometry data from the Castro Basin show anomalies striking NE-SW, which are related to the Ponta Grossa Arc dyke swarm. This response complicates the individualization of other magnetic sources.

The hydrothermally-altered areas, highlighted on ternary RGB (K, eTh, eU) images (Figure 3a), are correlated to the magenta and red portions (Figures 3b and 3c), which reflect the greatest concentrations of potassium (K) and equivalent uranium (eU) relative to equivalent thorium (eTh). The F Factor images (Figures 3d and 3e), reinforce this correlation, indicating quantitatively the areas with K anomaly. Thus, we suggest that regions with anomalous K concentrations can be used as prospective vector to delimit hydrothermally-altered areas, possibly with auriferous mineralization.

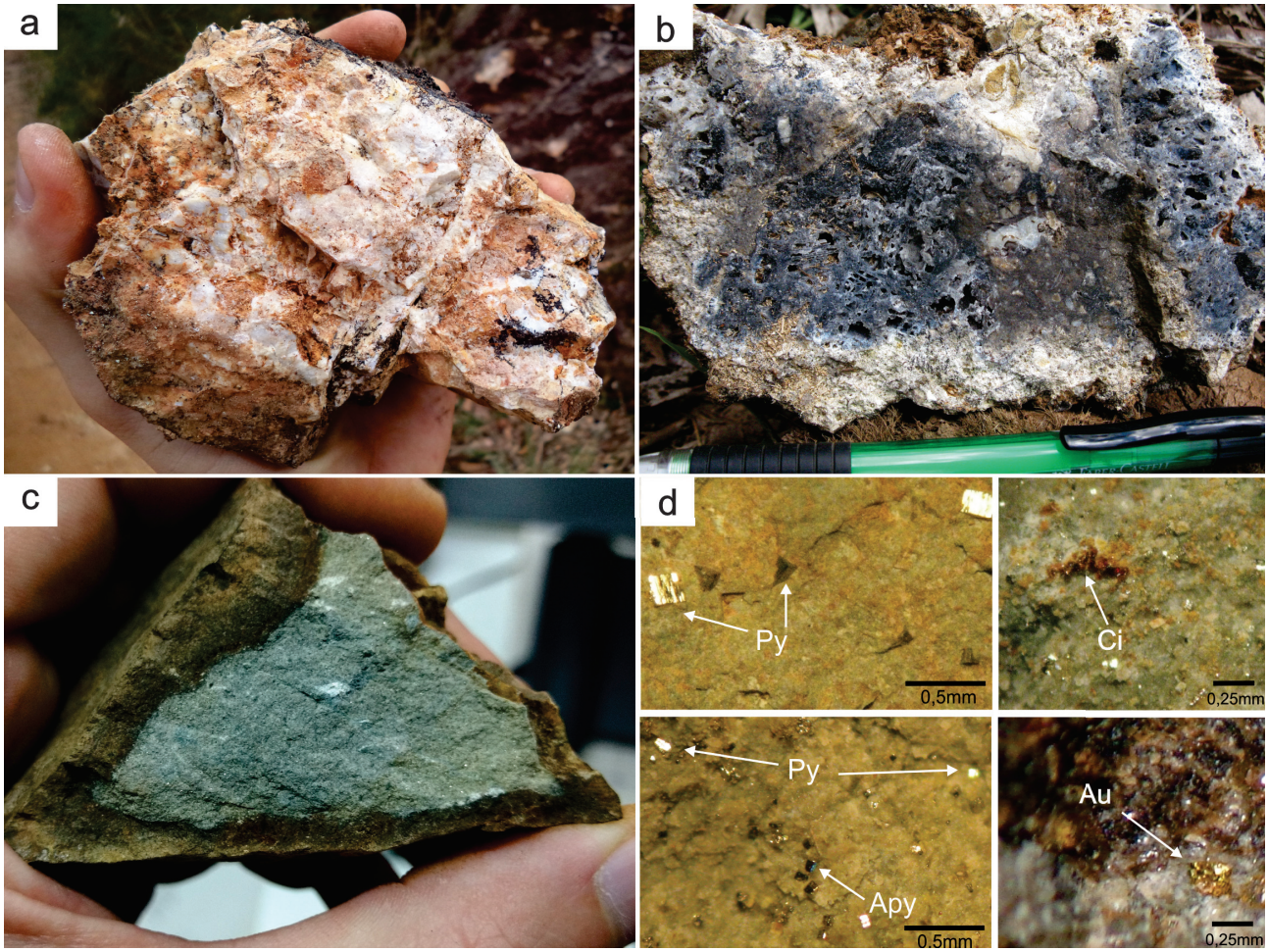

Figure 2: *Images of the occurrences of the Domo do Iapó area. a) Silicified hydraulic breccia, composed of quartz, with fractures filled by iron oxide; b) grey chalcedony vein with cavities; c) Sulfide-rich and silicified zone, with pyrite (Py), arsenopyrite (Apy), cinnabar (Ci) and gold (Au); d) Detail of the sulfide-rich sample from photograph "c", highlighting sulfides and free gold particle in the rims of a the oxidized zone.*

Table 1: *Chemical analyses results obtained by fire assay from the auriferous occurrences.*

Sample	Deposit/ocurrence	Alteration Zone	Latitude	Longitude	Au (ppb)	Pd (ppb)	Pt (ppb)
ICO-194	Torre	Silicification	-24.818356	-50.037588	609	< 5	< 5
ICO-197	Torre	Argilization	-24.822106	-50.035847	14	< 5	< 5
ICO-211	São Daniel	Silicification	-24,868931	-50.114289	1,030	< 5	< 5
ICO-210	São Daniel	Argilization	-24.871596	-50.089681	10	< 5	< 5
ICO-205	Domo do Iapó	Silicification	-24.670883	-50.150129	54	< 5	< 5
ICO-552	Domo do Iapó	sulphidation	-24.662022	-50.142686	18	< 5	< 5

SURFACE GEOCHEMISTRY

Stream sediment samples from 108 catchment basins, with average surface density equal to 8 km², covering the entire Castro Basin were analyzed at the SGS-GEOSOL laboratory, using the < 80 mesh fraction, to detect gold, platinum and palladium. The results indicate gold anomalies in 20 catchment basins, with values between 6 and 80 ppb. In the mineralized São Daniel target area, gold concentrations varied between 11 and 80 ppb (4 analyses in continuous catchment basins). In the Domo do Iapó occurrence area, gold concentrations varied between 6 and 60 ppb (5 analyses in continuous basins). The gold geochemical map for the Castro Basin (Figure 4) shows that the occurrences described in this report are coincident with some of the anomalous catchment basins. It is noteworthy that the geochemical background value in the area is < 5 ppb Au (method detection limit), observed on 80% of the analyzed samples.

FINAL REMARKS

Gold in the Castro Basin occurs in silicified hydraulic breccias, in tabular veins striking to NNW-SSE and NNE-SSW, and associated to hydrothermally-altered rocks. The presence of mineralized

bodies within different basin units suggests that the lithologic/stratigraphic control was not preponderant for mineralization.

At the Torre target, the gold ore is contained essentially in quartz veins. These are tabular, sub-horizontal to horizontal, with varied dimension at surface (between 10 m and 200 m). Host rocks are aphanitic, white, with cavities that are locally filled by 1-2 mm quartz grains (Piekarz, 1999). During the fieldwork, we observed that the mineralized layer described by Piekarz (1999) occurs in a 1.5 km-long silicification zone striking to NNE-SSW, composed of locally brecciated quartz veins and stockworks. Veins cutting the advanced argillic zone show syntaxial growth, which is typical of extensional regime. This zone has massive structure and is predominantly composed of kaolin and sericite, forming an alteration halo that envelops the main mineralized vein. This zone is interpreted as a product of intense pervasive (argillic) and fissural (silicification) hydrothermal alteration, which was probably synvolcanic. However, more accurate investigations are necessary to confirm this hypothesis.

Mineralization at the Torre and São Daniel areas are here interpreted as siliceous hydraulic breccia, which also is suggested for the new Domo do Iapó target occurrences. At Domo do Iapó and São Daniel, the main strike of the mineralized vein is NE-SW, and the new gold occurrences of these areas are hosted, respectively, by the Lower Volcanic and Lower Sedimentary units. At Torre, the main mineralization strike is NNW-SSE, and the ore occurs in acid volcanic rocks of the Superior Volcanic Unit (Figure 1b).

The presence of silicified zones with chalcedony, calcite and sericite, and sulfide-rich zones with pyrite, arsenopyrite, cinnabar and free gold, which is a common association in low-sulphidation epithermal deposits, reinforces the metallogenic model previously suggested for the basin. Despite the low gold contents in rocks from the Domo do Iapó target, the presence of sulfide-rich zones with free gold can be related to a peripheral zone of a possible deposit with higher gold content. The presence of bonanza zones in other areas enhances the potential for the discovery of new gold deposits in the Castro Basin, including the area of the new occurrence described here.

The ongoing Vale do Ribeira Project involves petrographic, geochemical and isotopic analyses in order to characterize the age, composition, and origin of the mineralizing fluids. This metallogenic study will allow a better understanding of the evolution of mineral system in the Castro Basin, providing more substantial data to characterize the ore and the search for new potential areas.

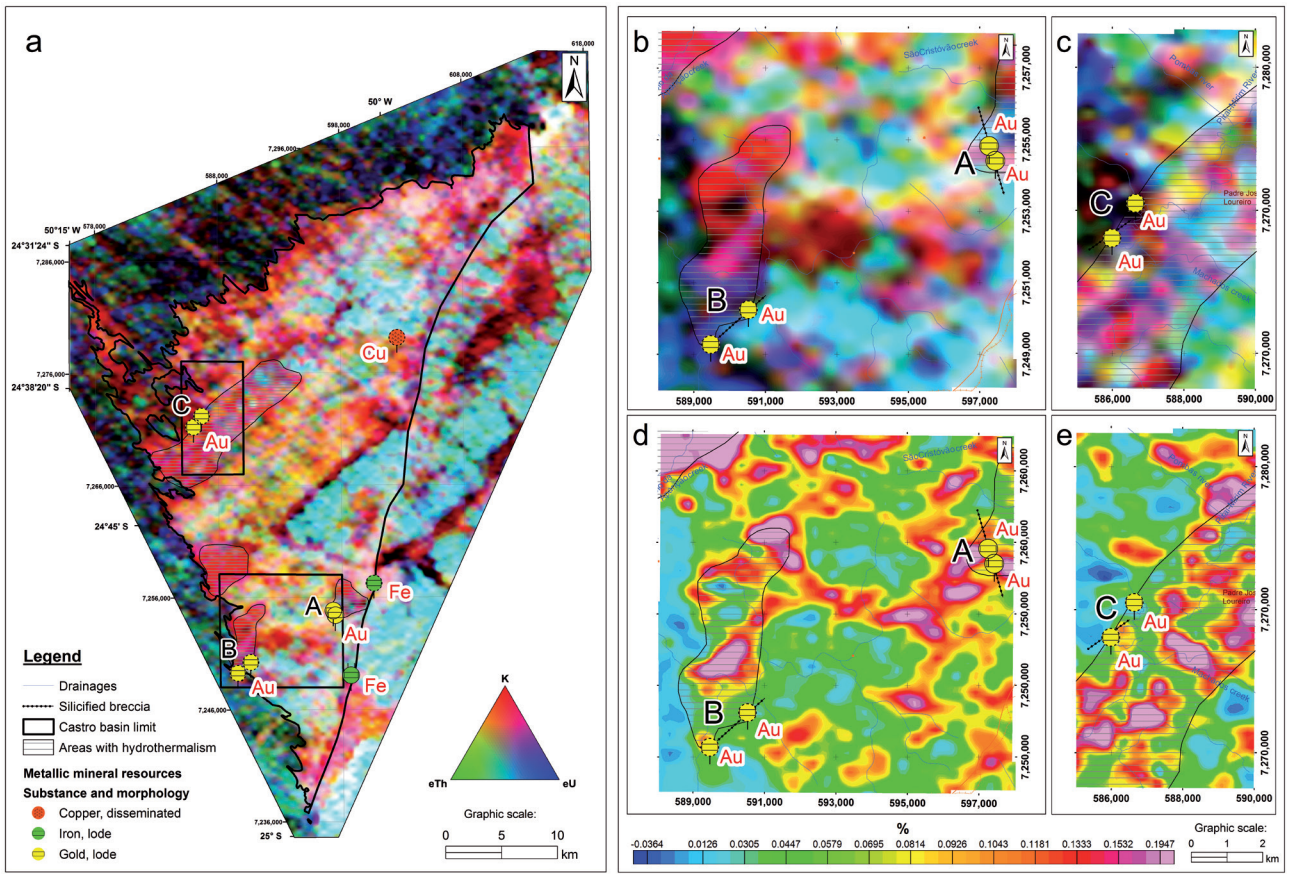

Figure 3: *Gamma-spectrometric maps from the areas with auriferous occurrences: (A) Torre deposit, (B) São Daniel and (C) Domo do Iapó targets. RGB ternary composition images (K, eTh, eU) of Castro Basin (a), Torre and São Daniel areas (b), and Domo do Iapó target (c), evidencing areas with greater K and eU (red and magenta in color) concentrations. F Factor images of the Torre and São Daniel areas (d), and Domo do Iapó target (e), showing areas with larger probability to contain hydrothermally-altered rocks (red and magenta colors). Hatched polygons are areas with intense hydrothermally-altered rocks observed in the field.*

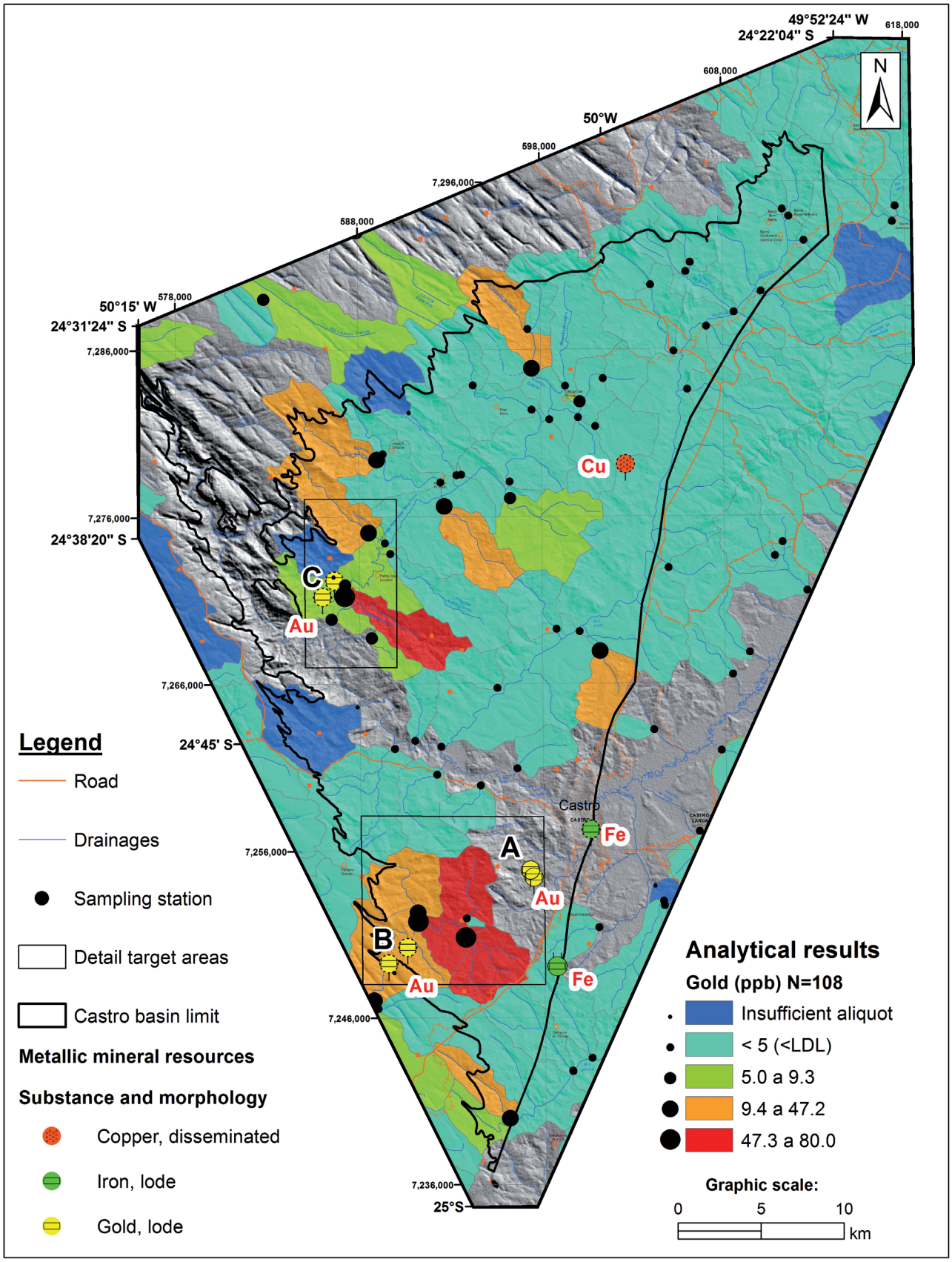

Figure 4: *Stream sediments gold geochemical map, indicating the anomalous catchment basins and location of the gold occurrences (A: Torre deposit; B: São Daniel target; C: Domo do Iapó occurrence). The detailed polygons were delimited as a consequence of these geochemical results and they are anomalous nearly in the entire area. LDL: lower detection limit.*

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