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Basalt stratigraphy and silica gossans in Campo Grande and Serra de Maracaju, Mato Grosso do Sul, Paraná Volcanic Province

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ABSTRACT

Thousands of silica gossans are exposed at the top of the Lower Cretaceous basalt hills in the Paraná volcanic province, strongly indicating the presence of calcite, amethyst and agate geode deposits along with native copper mineralization. The Embrapa silica gossan in the northwestern portion of the province (Campo Grande region) is an excellent example of such novel geological structure in the continental flood basalts. This silica gossan has a size of 450 × 350 m standing out as a treeless area in the densely wooded savanna and makes part of the stratigraphy of six basalt flows of Paranapanema intermediate-Ti chemical type. The base of the volcanic column is constituted by two Pitanga types and the overlying column is Paranapanema type. Every basalt flow has a silicified sand layer or breccia at the top and these are fed by abundant sand dikes. The Anel Viário Norte (AVN) flow is the most intensely altered by hydrothermal fluids producing voluminous secondary calcite infillings in the amygdales and fractures. In this region the basalts contain higher copper content than the average of the volcanic province. The studied silica gossans display negative anomalies in gamma spectrometry as a response to K, U and Th depletion during alteration. We propose a new exploration methodology by observing GoogleEarth images complemented with field studies and geochemistry to readily locate favorable areas for amethyst and agate geode deposits and native copper mineralization.

1. Introduction

The identification of silica gossans in the Paraná continental flood basalt (CFB) province (Fig. 1) of South America opens the possibility of the existence of many hitherto unsuspected hydrothermal deposits. Almost every erosional remnant hill in the province seems to contain silica gossans. Gossans commonly occur above high-sulfidation ore deposits (Scott et al., 2001; Pirajno, 2009), but the low-sulfide gossans in the Paraná volcanic province are also enriched in goethite-limonite, clay minerals and silica (silicified sandstone dikes and sills). This leads to the use of the expression “silica gossan” as an adequate name for the geological structure resulting from supergene alteration of the hydrothermal deposits. An extensive literature survey did not provide any additional information on silica gossans within continental basaltic provinces. This is thus a novel approach to a common geological structure, because a low-sulfide intraplate volcanic province hosts many hydrothermal deposits and associated silica gossans.

The earlier study of gossans in the southern part of the province (Pertille et al., 2013) is extended with the present investigation to the northwestern extreme of the Paraná basin. Because silica gossans in the Campo Grande region may contain unexplored deposits, the basalt stratigraphy is here established with the use of field description, gamma-spectrometry and rock geochemistry to adequately position the gossans in the host basalt flow.

2. Regional geology

The Paraná continental flood basalt (CFB) province of South America is one of the largest igneous provinces in the world and covers an area of 917,000 km^2 (Frank et al., 2009) in Brazil, Uruguay, Argentina and Paraguay (Fig. 1) with a lava volume of 450,000 km^3 at the surface in addition to 112,000 km^3 of lava that remained in the subsurface as sills and dikes. The Cuiabá Paulista borehole suggests the total thickness of the volcanic pile to be 1723 m. To the south, the lava pile becomes progressively thinner reaching 50 m along the Brazil–Argentina border (Almeida, 1986). The thickness of individual flows (Peate et al., 1999) is 5 to 80 m, with an average of 20 m. Although the most abundant rocks are basalt and basaltic andesite, dacites, rhyodacites and rhyolites do occur in the upper part of the volcanic pile in the southern portion of

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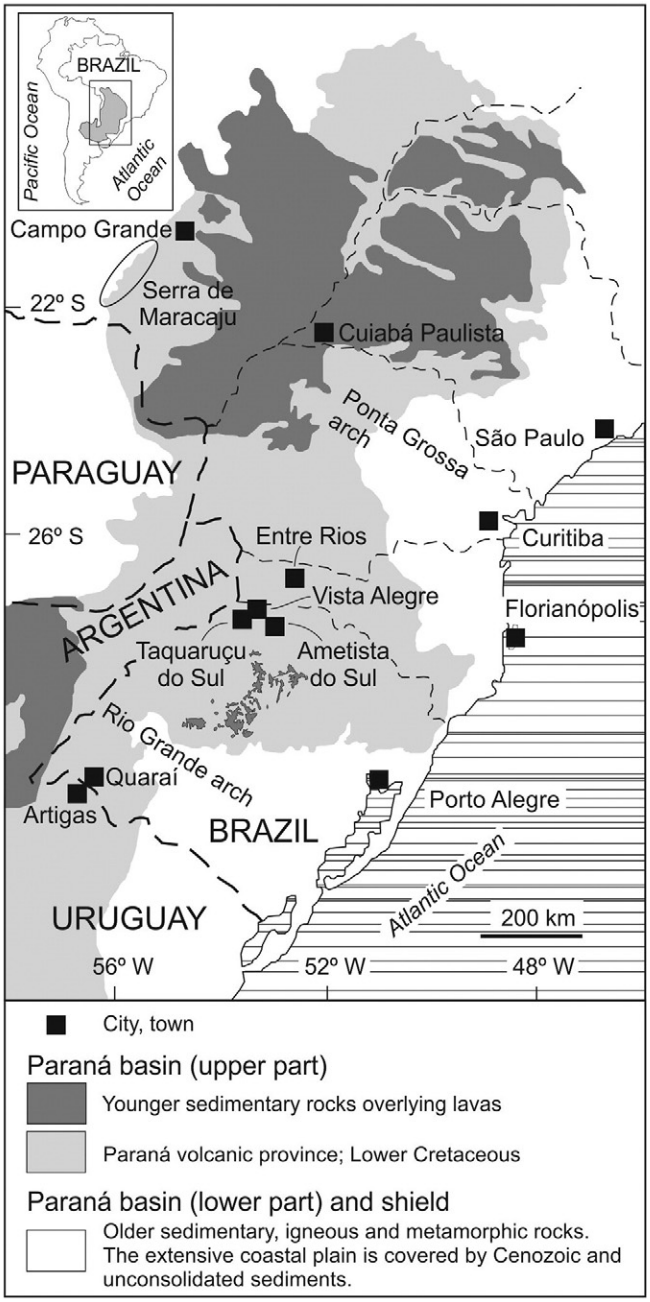

Fig. 1. Geological map of southeastern South America highlights the Paraná Basin. The Paraná volcanic province in light gray. Younger sedimentary rocks overlying lavas (dark gray), represented by the Bauru Group in Brazil, Acaray Formation in Paraguay (correlated with the bottom of Bauru Group) and as Mariano Boedo Formation and sands from the Chaco Group in Argentina. Older sedimentary, igneous and metamorphic rocks and an extensive coastal plain covered by Cenozoic sediments (blank area). Campo Grande city is at the center of the study area. Hydrothermal deposits (amethyst and agate) and native copper occurrence are shown.
Modified from Peate et al. (1992).

the province (Melfi et al., 1988). Pyroclastic rocks are also described by some authors (e.g. Licht et al., 2012) but their occurrence is restricted.

The volcanic rocks constitute the Serra Geral Group in Brazil (Wildner et al., 2009). The age of the group is under debate (e.g., Mantovani et al., 1985; Rocha-Campos et al., 1988; Mincato, 2000; Lustrino et al., 2005; Wildner et al., 2006) and recent studies (Pinto et al., 2011a, zircon U–Pb SHRIMP; Janasi et al., 2011, baddeleyite TIMS) confirmed the age of 133–135 Ma for the peak of volcanism. The geochemical subdivision of the Serra Geral Group was made based on the TiO_2 content of the rocks (Bellieni et al., 1984; Mantovani et al., 1985) into high-Ti (TiO_2 >2%) in the north and low-Ti (TiO_2 <2%) in the south. Peate et al. (1992) reassessed these two groups and proposed a new classification based on major and trace elements and element ratios. The low-Ti group was divided into Gramado, Esmeralda and Ribeira magma types and the high-Ti group into Urubici, Pitanga and Paranapanema magma types. The world's largest deposits of amethyst and agate are hosted in rocks from the two magma types. The main exploration areas are concentrated in Ametista do Sul in Brazil and Los Catalanes in Uruguay (Juchem et al., 2010; Silva, 2010). Native copper mineralization hosted in basalts and in hydrothermal breccias is also widespread.

Until recently, the Serra Geral Group was studied mostly with respect to magmatic interactions (temperatures around 1150 °C), but from 2005 a new aspect of the Serra Geral Group was evaluated (e.g. Duarte et al., 2009; Hartmann et al., 2010, 2012a, 2012b; Pinto et al., 2011b) with the identification of low temperature hydrothermal events (150 °C). This new approach to studies of the Serra Geral Group allowed the understanding of a set of unique geological features such as the heat source, the water source in the Guarani aquifer, the unconsolidated sands of the Botucatu desert, the type I basalt flows (Gomes, 1996) and the intraplate tectonic environment (horizontal lavas). The combination of these factors triggered intense hydrothermal events defined as H1, H2 and H3 (Hartmann, 2008; Hartmann et al., 2012a, 2012b) which were responsible for the rising of hydrothermal fluids (boiling water and its vapor) that transported upward through the basalt flows a huge quantity of sand from the Botucatu Formation. Evidence of the injected sand is widespread in several areas of the province (Hartmann et al, 2013) forming silicified hydrothermal structures as sand dikes, sand sills, sand layers and even hydrothermal breccia at

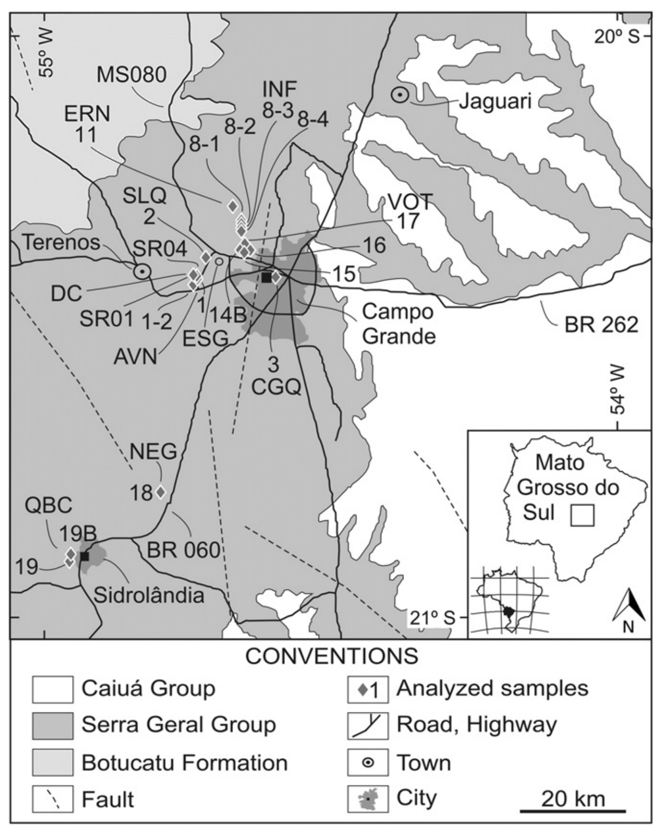

Fig. 2. Geological map of the Campo Grande region (modified from Lacerda Filho et al., 2006) with the location of the analyzed samples (all sample numbers have an MS prefix; e.g., 17 = MS17). Symbology used: AVN — Anel Viário Norte section, ESG — Embrapa silica gossan, SLQ — São Luiz quarry, VOT — Votorantim quarry, CGQ — Campo Grande quarry, INF — Cascata Inferninho section, ERN — Ernesto section, DC — Drill cores (SR1 and SR4), NEG — Negrimaq quarry, and QBC — Quebra-Coco quarry. Highways indicated (e.g., BR060, MS080). The studied area is indicated by the square in the inset map.