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GEOMORPHOLOGICAL MAPPING AND GEODIVERSITY: STUDY AT THE MINAS DO CAMAQUÃ GEOSITE PROTECTION AREA (BRAZIL)

CARTOGRAFIA GEOMORFOLÓGICA E GEODIVERSIDADE: ESTUDO NA ÁREA DE PROTEÇÃO DO GEOSSÍTIO DAS MINAS DO CAMAQUÃ (BRASIL)

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Abstract:

Geomorphological mapping allows the evaluation of geoheritage and subsidizes geoconservation efforts. This work aimed at identifying and analyzing the landforms at the Minas do Camaquã Geosite Protection Area (MCGPA) – Rio Grande do Sul state – Brazil, emphasizing the anthropogenic morphologies to subsidize the conservation of the studied area's geomorphological heritage. A geomorphological map (2015) of the MCGPA was made (1:25.000) to recognize and identify the natural and anthropogenic landforms. Based on this map, four sectors were identified according to the representativeness of the landforms: (1) Mineral extraction sector; (2) Tailings deposition sector; (3) Structural features sector; and (4) Boundary sector. The mining activities were the main reason for the geomorphological alterations and the creation of anthropogenic morphologies in the site. Despite the significant disturbance caused by the mining activity, there are still features of geologic-geomorphological interest fairly preserved. The identified and analyzed anthropogenic morphologies can describe the history of the mining activities that took place in the area and which formed a set of landforms currently present in the MCGPA. Although the surface features are not originated from natural morphogenesis, they belong to the area's geodiversity. Furthermore, considering these features as geoheritage would create the need for management aiming at avoiding the collapse and degradation of these forms. Nowadays, the mining activities have remained inactive, and this set of anthropogenic morphologies need to be understood under a geomorphological point of view which will allow future exploitation of its potential touristic, scientific, pedagogical and cultural uses. The best way to promote and develop strategies of geoconservation for this place is to create and foment geotourism in this area.

Resumo:

A cartografia geomorfológica possibilita a avaliação do geopatrimônio subsidiando ações de geoconservação. Este artigo foi desenvolvido com o objetivo de identificar e analisar as formas do relevo da Área de Proteção do Geossítio das Minas do Camaquã (APGMC) – Rio Grande do Sul, Brasil, com ênfase nas morfologias antropogênicas, a fim de subsidiar a conservação do geopatrimônio, bem como contribuir para ações de geoconservação. Foi elaborado um mapa geomorfológico da APGMC, na escala 1:25.000, referente ao ano de 2015, afim de reconhecer e identificar as formas de origem natural e antropogênicas. Com base nesse mapeamento, quatro setores foram analisados devido à representatividade das formas do relevo que ocorrem na área em estudo: (1) Setor de extração mineral; (2) Setor de Deposição de Rejeitos; (3) Setor de Predomínio das Feições estruturais; e (4) Setor de contato com as feições ruiniformes do Geossítio das Guaritas do Camaquã. As atividades de mineração foram as principais responsáveis pelas alterações geomorfológicas e criação de morfologias antropogênicas na área. Apesar das perturbações significativas ocasionadas pela mineração, ainda existem feições de interesse geológico-geomorfológico bastante preservadas, fato que reforça a necessidade de um monitoramento da dinâmica de cobertura e uso da terra na APGMC. As feições antropogênicas identificadas e analisadas permitem descrever a história das atividades de mineração que ocorreram na área e que se constituem no conjunto de formas atualmente presentes na APGMC. Apesar de não serem feições do relevo de morfogênese natural, pertencem à geodiversidade da área e se consideradas enquanto geopatrimônio precisam ser manejadas a fim de evitar que ocorra o seu colapso e degradação. Na atualidade as atividades de mineração se encontram inativas e o conjunto de antropoformas precisa ser compreendido sob o ponto de vista geomorfológico para que possa ser explorado diante de seu potencial turístico, pedagógico, científico e cultural. A proposição de roteiros geoturísticos voltados à interpretação das formas do relevo naturais e antropogênicas pode se consolidar como uma estratégia de geoconservação e educação ambiental com forte potencial.

1. Introduction

The concept of geodiversity and the recognition of geosites emerged from the studies in geological heritage (JOHANSSON *et al.,* 1999; NIETO, 2001; STANLEY 2001), being fairly recent the ones which have taken into consideration geomorphological elements (PANIZZA, 2001; REYNARD *et al.,* 2007; PRIETO, 2013; PEREIRA *et al.,* 2013a, 2013b; SILVA *et al.,* 2015; REYNARD *et al.,* 2016), and studies in geodiversity that have evaluated the forms created by men (with scientific, pedagogical, cultural and economical relevance), Alexandrowicz (1999); Serrano (2002); Kozlowski (2004); Serrano and Ruiz-Flaño (2007).

One of the most thorough concepts for geodiversity is given by Kozlowski (2004, pg. 834) that defines it as *"the natural variety of terrestrial surface, including the geological and geomorphological aspects, soil, surface water, as well as other systems created as result of endogenous and exogenous natural processes and human activity".*

Geoconservation comprises a set of strategies to protect the geodiversity (SHARPLES, 2002; BRILHA, 2005). It aims at preserving the geological-geomorphological features (geosites/geomorphosite) which appeared as the result of natural and/or anthropic processes that have undeniable scientific, touristic, pedagogical or cultural value (BRILHA, 2005). The set of geosites and geomorphosites from a given territory represents its geoheritage, which involves geologic features, the landforms and its related deposits (VIEIRA and CUNHA, 2004; BRILHA, 2005; BORBA, 2011).

Carton *et al.* (2005) suggest guidelines to identify and to evaluate geosites and/or geomorphosites using geomorphological maps. They point out that although extremely relevant, the cartographical representation of these spaces has not been fully explored and may cause problems for those who work with geodiversity and geoconservation. The main purpose of the cartography of geosites and geomorphosites is to easily allow the perception of the distribution of the landforms on the territory, for both technical and general audiences (CARTON *et al.,* 2005). Furthermore, according to Carton *et al.,* (2005), geosites and geomorphosites must be represented by a symbology which is capable of easing up the process of interpretation of the spatial organization of the geological-geomorphological elements. It is an effective way to communicate and to disseminate knowledge, especially to allow the awareness of the society as a whole. To Forte (2008), the geomorphological mapping of geosites and geomorphosites must be adopted when inventorying places of geomorphological interest, and it should be used as a tool to popularize the geomorphological heritage.

A few pioneer studies have showed the cartographic representation of geosites and geomorphosites by making geomorphological maps (ZOUROS, 2005; SANTOS, 2016), maps of geomorphosites (PEREIRA, 2006; REYNARD *et al.,* 2007) and geomorphological heritage maps (ZOUROS, 2005; CUNHA and VIEIRA, 2006; PEREIRA, 2006).

In Brazil, the studies on geodiversity and the systemization of geoconservation strategies are fairly recent (VON AHN *et al.,* 2016). Within this context, the Geological and Paleobiological Sites Project (SIGEP) was a pioneer in Brazil, and it was responsible for the inventorying of geological and geomorphological sites of interest between 1997 and 2012. More recently, another initiative, the Geoparques Brasileiros Project, in association with the Geological Survey of Brazil (CPRM), has studies based on the Global Geoparks Network, and also stands out for valuing and promoting geosites of geologic-geomorphological interest through geotourism initiatives.

SIGEP and CPRM have defined types of geosites and geomorphosites based on their characteristics and intrinsic value to geodiversity. Geosites in open-pit mining areas are very particular within this geoconservation context, as the anthropic activity (the work applied on the land to facilitate the exploitation of the mineral) acts directly as a geomorphological agent. The evaluation of the anthropic geomorphological heritage of these geosites must be done by geomorphological maps that are made according to an anthropogeomorphological perspective and based on the propositions of Nir (1983) and Rodrigues (2005).

Nir (1983) suggests that the anthropogeomorphological analysis should be done in a unifying way. It must comprise the cartographic representation of landforms during pre and post significant human intervention periods; an analysis of the socioeconomic dynamic; and the study of the anthropogenic environments. Rodrigues (2005) recommends the analysis of the anthropogenic geomorphological systems in their different stages of anthropic intervention (pre-disturbance, active disturbance and post-disturbance), in order to identify spatial units which have their own original and anthropogenic morphologies.

The geosites and geomorphosites located in open-pit mining areas also become particular if the anthropogeomorphological approach is considered. While the anthropic activity altered the dynamic balance of the natural systems, by reconfiguring the geological-geomorphological processes, the heritage of the interventions can be characterized and analyzed to enable the use of this anthropogenic geodiversity for pedagogical, cultural, scientific and touristic purposes.

One of these areas in Brazil is the Minas do Camaquã Geosite and its Protection Area (MCGPA) (Von Ahn, 2016). The post-disturbance forms identified in the MCGPA originated from the mining activities and from the occupation and use of that pace. Although the MCGPA has gone through severe anthropic alterations, common to mining areas, this specific location has a geomorphological heritage of substantial scientific, touristic, educational, cultural and historical value, and it needs to be evaluated by a cartographic representation of its landforms for future conservation.

Therefore, the aim of this study is to identify and analyze the landforms at the Minas do Camaquã Geosite Protection Area (MCGPA) RS - Brazil, emphasizing the anthropogenic morphologies, in order to subsidize the conservation of the studied area's geomorphological heritage.

2. Characterization of the Area

The Minas do Camaquã Geosite Protection Area is located in the central portion of Rio Grande do Sul state - Brazil (Figure 1). The access to the area, from Porto Alegre, can be done by heading west on BR-290 until reaching the intersection with BR-153, where the BR-153 should then be followed south until reaching the intersection with the RS-625 intersection.

The MCGPA boundary was drawn based on the proposition of Borba (2013). He identified 46 geosites in the Caçapava do Sul municipality, which comprises the Minas do Camaquã Geosite. A five kilometers radius was established, starting from the central point of the geosite (30º 54' 31'' S and 53º 26' 57'' W) to create the MCGPA boundary. The establishment of this boundary considered the spatial organization of natural and anthropogenic morphologies (which resulted from the mining activities).

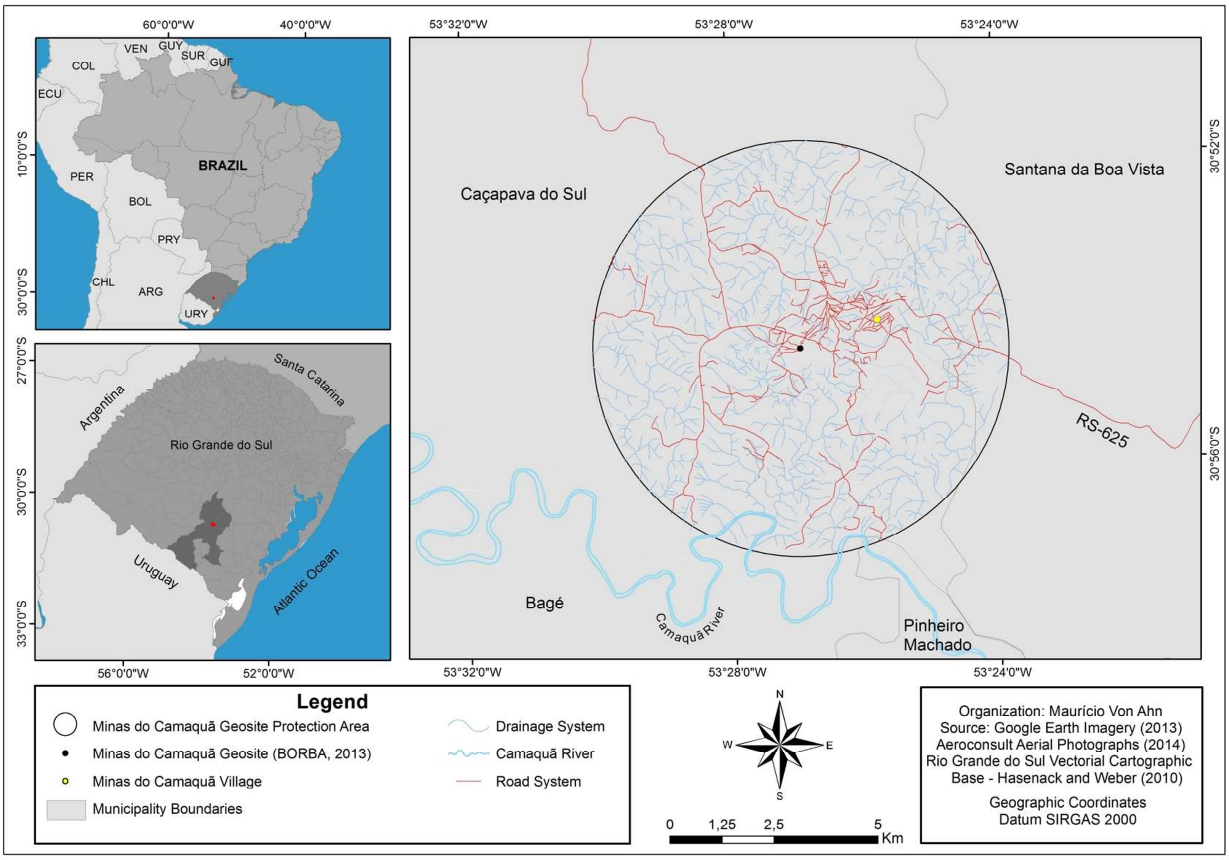

Figure 1 – Location map of MCGPA.

The MCGPA is located in the Camaquã Sedimentary Basin (CSB), which is characterized by the alternation of depositional events (stack of thick sedimentary and volcano-sedimentary sequences) and intense subsidence stages (voluminous sedimentary discharge and erosion intervals) (PAIM *et al.,* 2000).

The deposited and registered allostratigraphic units in the MCGPA are organized, from bottom to top, by the following layout: Bom Jardim Allogroup (deltaic front deposits created between 592 Ma and 573 Ma); Cerro do Bugio Allogroup (represented by the Santa Fé Alloformation – Alluvial Facies created between 573 Ma and 559 Ma); Santa Bárbara Allogroup (comprised by the Serra dos Lanceiros Alloformation created between 559 Ma and 540 Ma); and Guaritas Allogroup (comprised by the Pedra Pintada Alloformation, desert facies and volcanic facies - and Varzinha Alloformation, fluvial/alluvial facies, created between 470 Ma and 19 Ma) (CHEMALE, 2000; PAIM *et al.,* 2000).

The MCGPA is located in the Pampa´s biome (IBGE, 2004; LEITE, 2002). This biome is one of the world’s richest regions in grasses. It also has a combination of microtherm and megatherm species, with a prevalence of the megatherm ones (BURKART, 1975).

The anthropic disturbance associated to the extraction of copper, which took place from the 18th century until the 1980 and 1990 decades, has caused the modification of the natural environment at Minas do Camaquã and contributed to the organization of anthropogenic morphology found there nowadays.

3. Methods

The identification of the landforms in the MCGPA was done based on the digitally-executed geomorphological map, which used the guidelines proposed by Cunha *et al.,* (2003) and Simon *et al.,* (2008), adapted from Tricart (1965) and Verstappen and Zuidan (1975). The organization of a symbology to represent the geomorphological features was done into a single legend, in order to offer a better readability and understanding of the represented data (Figure 2). Cunha *et al.,* (2003) considers that changes in the propositions of Tricart (1965) and Verstappen & Zuidan (1975) can be applied to different contexts and then they should be simplified according to the environment. This becomes relevant when the application of the geomorphological map is done in a geosite or a geomorphosite to subsidize geoconservation. Other symbologies were also selected due to their suitability to represent the anthropogenic features proposed by Paschoal *et al.,* (2016) and Von Ahn (2015), whose maps and geomorphological analysis were done in mining areas (Figure 2).

LITHOLOGICAL INFORMATION	Guaritas Allogroup (470 +- 19 Ma)	Varzinha Alloformation fluvial/alluvial facies			Cartographic Convention
		Pedra Pintada Alloformation desert facies			Cartographic Convention
		Pedra Pintada Alloformation Volcanic Facies			Cartographic Convention
	Santa Bárbara Allogroup (559 +- 7 a 540 +- 11Ma)	Serra dos Lanceiros Alloformation			Cartographic Convention
	Serra do Bugio Allogroup (573 +- 18 a 559 +- 7Ma)	Santa Fé Alloformation Fluvial Facies			Cartographic Convention
	Bom Jardim Allogroup (592 +- 5 A 573 +- 18Ma)	Turbidite Fáceis and Delta Front			Cartographic Convention
STRUCTURAL FEATURES	Faults and Fractures				Cartographic Convention / Tricart (1965)
	Structural Terrace				Verstappen & Zuidam (1975)
	Structural Ridge				Verstappen & Zuidam (1975)
FORMS OF SLOPES AND INTERFLUVES	Slope	Concave			Verstappen & Zuidam (1975)
		Convex			Verstappen & Zuidam (1975)
	Ridge	Acute			Verstappen & Zuidam (1975)
		Soft			Tricart (1965)
	Topographic and Morphometric Features	Topographic fall			Tricart (1965)
		Contour Line			Cartographic Convention
		Spot Height			Cartographic Convention
	Localized Forms	Saddle			Tricart (1965)
	Residual Forms	Residual hill			Tricart (1965)
WATER FLOW ACTIVITY	Hydrographic Features	River Channel			Cartographic Convention / Tricart (1965)
		Stormwater Channel			Cartographic Convention / Tricart (1965)
		Water bodies			Cartographic Convention
	Carved Landforms	Topographic Rupture	Soft		Verstappen & Zuidam (1975)
			Steep		Verstappen & Zuidam (1975)
		Valley Bottom	V-shape		Verstappen & Zuidam (1975)
			Flat Bottom		Verstappen & Zuidam (1975)
	Accumulation Forms	Fluvial Accumulation Area			Adapted from Tricart (1965)
ANTHROPIC LANDFORMS	Inactive Minning				Verstappen & Zuidam (1975)
	Tailings Hill Ledge				Von Ahn (2015)
	Tailings Hill Slope				Von Ahn (2015)
	Abrupt Terraces at Mining Pits				Paschoal et al. (2010)
	Cuts for Access Roads				Tricart (1965)
	Embankment for Secondary Roads				Tricart (1965)
	Embankment Slopes for Secondary Roads				Von Ahn (2015)
	Penstock				Verstappen & Zuidam (1975)
	Quarry Lake				Paschoal et al. (2010)
	Deposits Resulting from Mineral Extaction				Von Ahn (2015)

Figure 2 – Legend's structuring from the geomorphological map of MCGPA.

The preparation of the geomorphological map was based on the interpretation of three-dimensional anaglyphs derived from color aerial photographs. The aerial photographs had a scale of approximately 1:25.000. They were taken between June and July 2004 by AEROCONSULT Ltda. and donated by Fibria Cellulose. Next, the following flight strips were selected: Strip 28A (photographs 10, 11, 12, 13, 14, 15); Strip 29 (photographs 12, 13, 14, 15, 16, 17) and Strip 30 (photographs 14, 15, 16). The three-dimensional anaglyphs were georeferenced on a 1:50.000 scale vectorial cartographic base (HASENACK and WEBER, 2010) using ArcGIS 10.

Three fieldtrips were conducted: February 22-23rd 2014, November 15-16th 2014 and May 3-4th 2015. These fieldtrips collected information to update the geomorphological information obtained from the interpretation of the aerial photographs obtained in 2004. Thus, the geomorphological map was dated as from the year 2015.

4. Results and Discussion

The landforms identified in the MCGPA revealed a space that was once organized to meet the needs of the mining activity in an area which underwent a downturn and stagnation period leaving a set of anthropogenic morphologies printed on the landscape. The geomorphological map of MCGPA (Figure 3) emphasized anthropogenic landforms, structural features, slopes and interfluves forms and the features resulting from water flow activity.

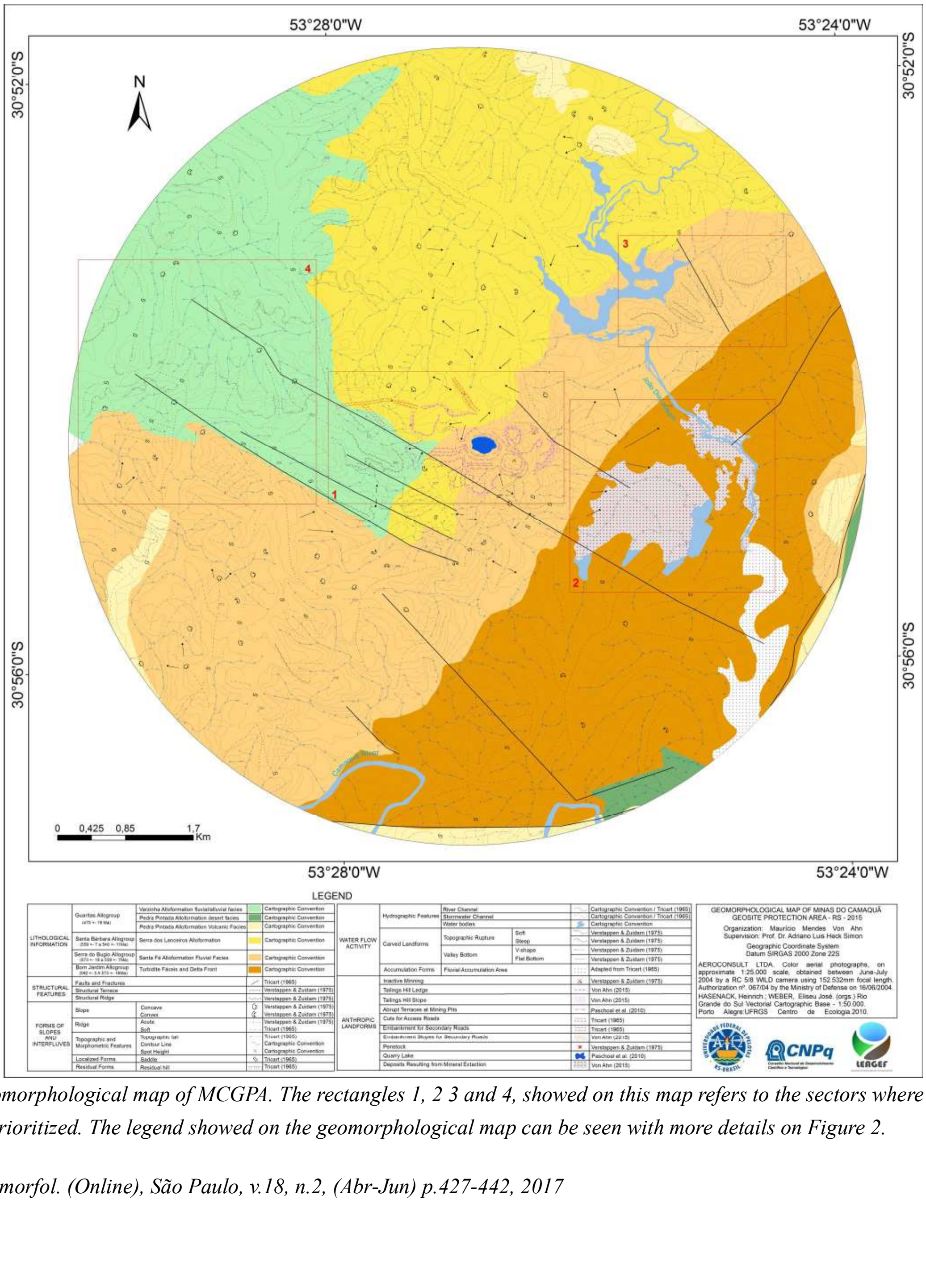

Figure 3 – Geomorphological map of MCGPA. The rectangles 1, 2 3 and 4, showed on this map refers to the sectors where the analysis of result will be prioritized. The legend showed on the geomorphological map can be seen with more details on Figure 2.

The analysis of the geomorphological map was done based on four sectors that were selected due to the representativeness of their natural and anthropogenic features: (1) Mineral extraction sector; (2) Tailings deposition sector; (3) Structural features sector; and (4) Boundary Sector (Figure 3).

The mineral extraction and the tailings deposition sectors are the main responsible for most of the anthropogenic landforms in the MCGPA. Their analysis was performed based on the interpretation of the morphologies created by the execution of the open-pit mining plan (Figure 4).

According to Ferreira (2013), the mineral extraction process in open-pit mines involves operations of digging or blasting, loading and hauling and dumping, and those were the ones responsible for creating the anthropogenic morphologies found in the MCGPA (Figure 4).

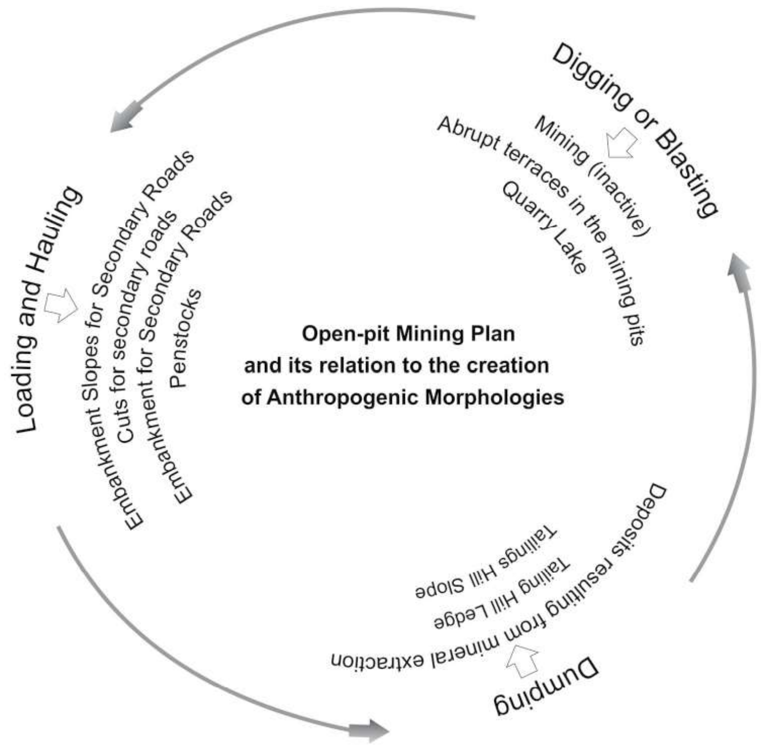

Figure 4 – Steps of the open-pit Mining Plan and its relation to the creation of anthropogenic morphologies found in the mineral extraction and tailings deposition sectors that are detailed in the geomorphological map legend showed on Figure 2.

The *digging or blasting* activities in this area resulted in the creation of abrupt terraces in the mining pits which derived from the removal of large amounts of feedstock (Figure 5-a, b, c, d). These terraces are the most evident morphologies in the mining pits, and the cuts that were performed in order to create these morphologies allowed the exhumed sedimentary layers from the copper prospection to be visualized. The end of the mineral extraction activities created a quarry lake in one of the open-pit mines (Figure 5c).

The morphologies created during the digging or blasting step can be seen in Figure 5 (c, d). The magnitude of the terraces reveals the intensity of the techniques used during the time copper was exploited. A relationship between the terraces and the area's initial contour lines shows the changes, in the topography and in the drainage system, which resulted from the removal of the material from this surface (Figure 5a).

During the digging or blasting step, the material which underwent degradation was transported and deposited within different distances (RICARDO and CATALANI, 2007). Such processes demanded roads that were built with a succession of cuts and embankments in the terrain. The preparation of these accesses created features named as cuts for secondary roads, embankments for secondary roads and penstocks (Figure 6).

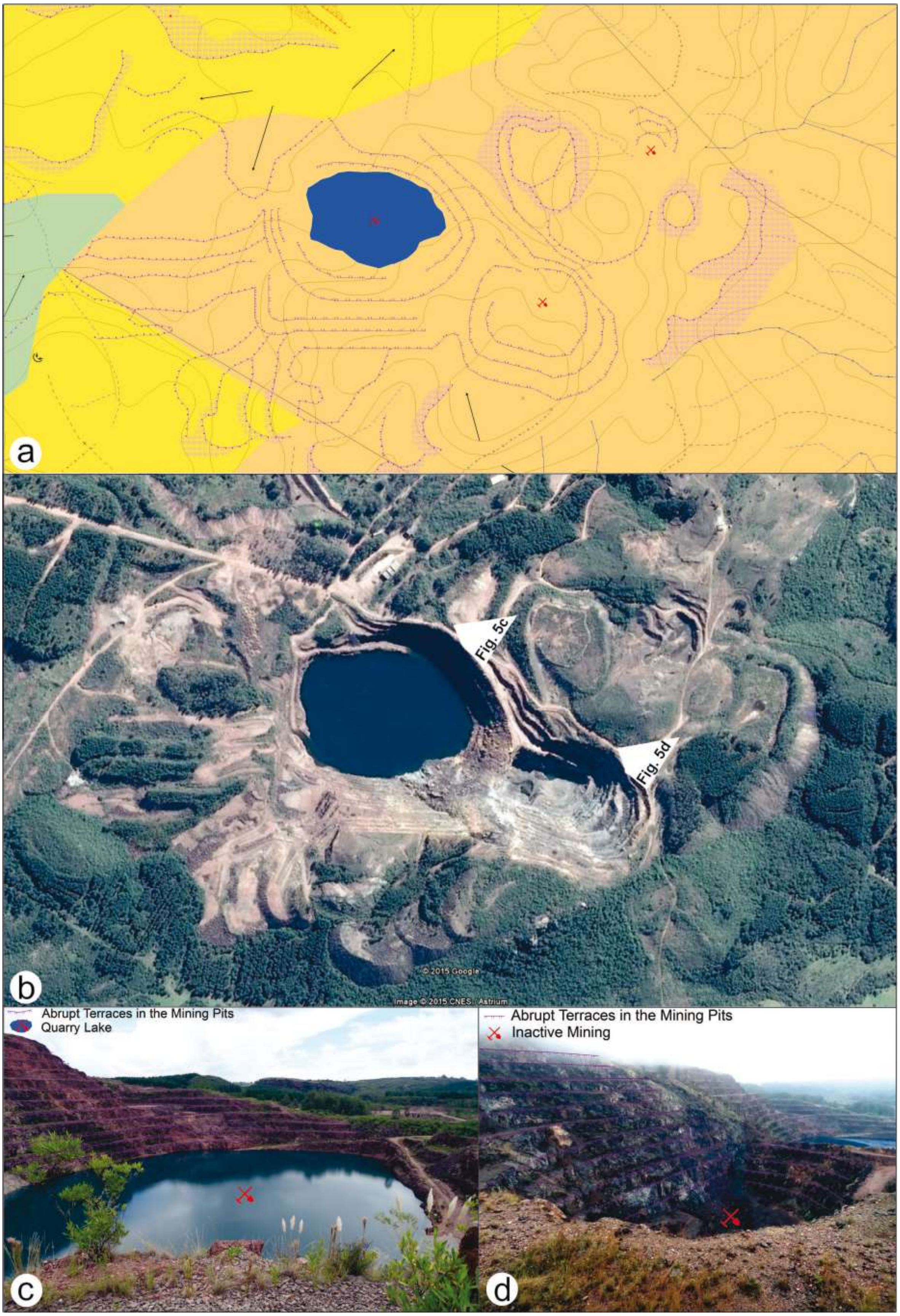

Figure 5 – Anthropogenic morphologies created from the digging/blasting step. The legend with the presented symbology in the geomorphological map excerpt and in the photography obtained in field can be seen with more details on Figure 2.

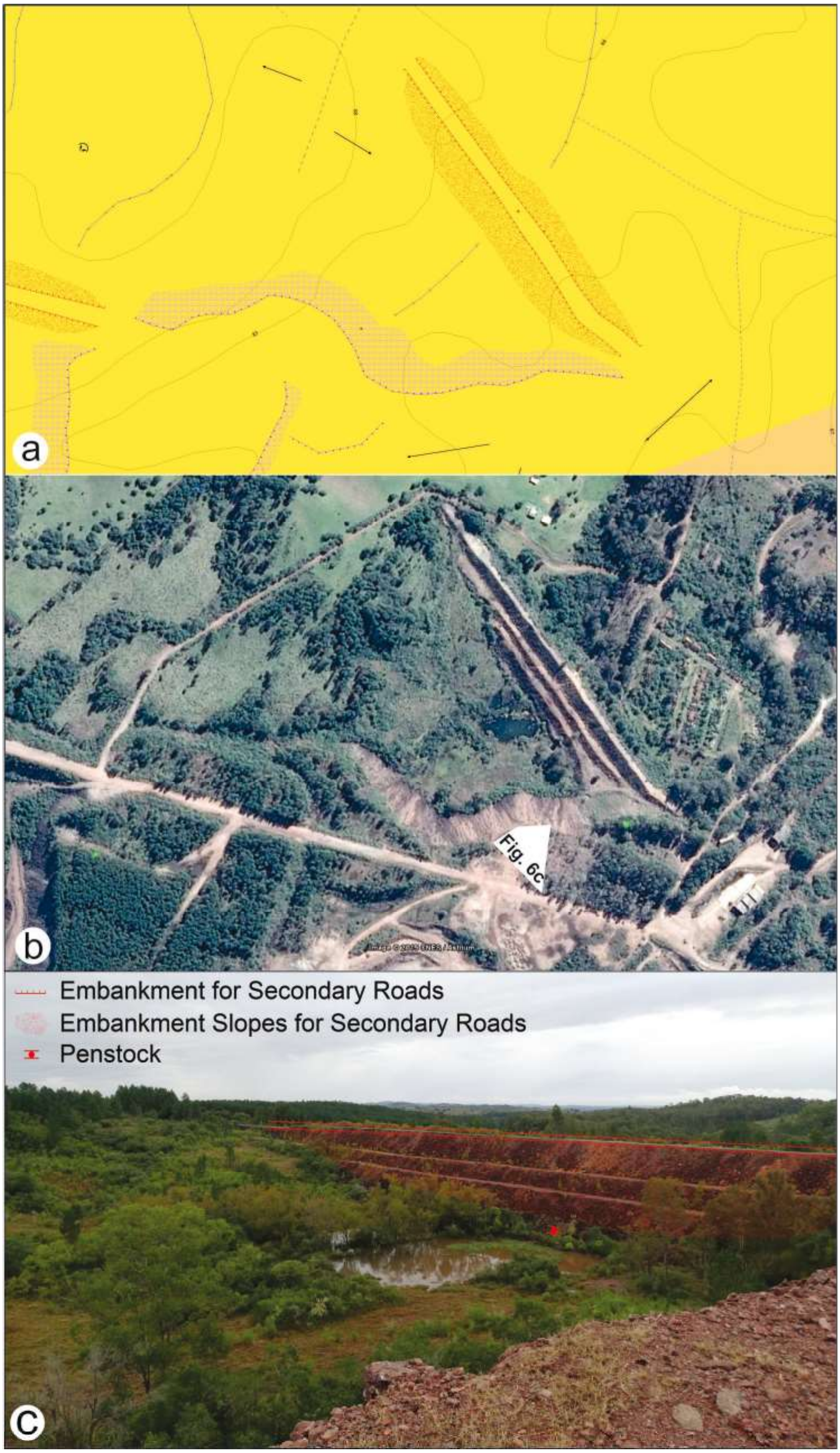

Figure 6 – Anthropogenic morphologies created from the loading and hauling step. The legend with the presented symbology in the geomorphological map excerpt and in the photography obtained in field can be seen with more details on Figure 2.

By executing embankments to prepare secondary roads, valley bottom compartments were divided, intercepting the river channels and forcing the drainage system to adjust to the penstocks which work like an artificial sill (Figure 6 – a, c). The cuts were made in order to allow a minimum corrugation and sinuosity of the secondary roads. They were connected to the embankments created on depressed surfaces, such as valley bottoms and floodplains.

The embankment slopes for secondary roads are directly associated with other kinds of embankments (Figure 6 – a, c). The embankment slopes were built in different levels and the deposition of the material was executed using techniques that allowed enough stability and safety for the roads that were used to support heavy loads. Some penstocks that crossed the embankments and the slopes were not capable of sustaining the outflow, which forced the upstream deposition of material (Figure 6 – b, c). This situation contributed to the organization of the alluvial deposits identified at the site. These deposits are currently in a development stage together with the intercepted valley bottom sectors, in which, under natural circumstances, would not face such conditions (Figure 6c).

The material originated from the processes of loading and hauling was taken to different *dumping* areas that, according to Quevedo (2009), can be divided in tailings piles, homogenization piles and beneficiation areas. The tailings piles (located in the Mineral extraction sector), and the beneficiation area (located in the Tailings deposition sector) were associated with the creation of anthropogenic morphologies in the MCGPA.

According to Ferreira (2013), tailings are defined as a natural aggregate, consisting of one or more minerals, that is removed from the mine to further release of the ore, having no economic value. The deposition of piles of tailings created morphologies known as tailing hill ledges and tailings hill slopes (Figure 7 – a, b, c). At the Minas do Camaquã Geosite, these features are spatially organized in a particular way, which allows the understanding of the precision and complexity of the engineering techniques used to create them. Such characteristics determined the relevance of these features as geomorphological heritage, and it is an example of how the interference of the human activity can impact on to the creation of anthropogenic landforms. The material of this kind of morphology in this area created a hostile environment for the development of exotic or native plants due to the concentration of a wide variety of minerals and toxins at these deposits (Figure 7d). According to Bruch (2014), after 1981, the dumping of mining tailings at the MCGPA were carried out in a tailing dam, that started to be built in 1980 by the Companhia Brasileira de Cobre (CBC) (Figure 7 – b, d).

The Structural Features Sector comprises sedimentary outcrops originated from the Santa Fé Alloformation (Cerro do Bugio Allogroup) that arose at end of the Precambrian, generating faults, from shearing and traction, towards a prevalent NW-SE direction, which were associated to deep strike-slip moves (BICCA, 2013). These outcrops are delimited by terraces and structural ridges (Figure 8c), being regionally called Cerro da Cruz (RONCHI *et al.,* 2000; PAIM, 2002; BORBA, 2013).

Regarding the intrinsic value of these features, Borba (2013) highlighted that the Cerro da Cruz comprises a set of geological-geomorphological elements which have eminent potential to be subject to strategies of geoconservation. The analysis of the geomorphological map (Figure 3) shows that not only the geological aspects have contributed to Cerro da Cruz's physical characteristics and scenic beauty, but also the differential erosion processes played its part by modifying the outcrops and contributing to the organization of such angled and asymmetrical residual features (100 meters of altitude range). Figure 8c illustrates the symbology used in the geomorphological map to represent these structural features, with special focus on the Pedra da Cruz.

In the Boundary sector there is a prevalence of geomorphological features shaped as rugged hills that presents a ruiniforme aspect and similar characteristics to the adjacent geosite: the Guaritas do Camaquã Geosite – delineated by Paim *et al.,* (2002) (Figure 3).

The residual features are connected to convex slopes, concavities that allow the emergence of water springs, acute and soft ridges (sometimes interrupted by saddles), topographic falls, and soft and steep ruptures (Figures 3 and 9). Such conditions distinguish this sector from the others and explain its connection with the Guaritas do Camaquã Geosite. Figure 9 shows the contact between the analyzed sector and the ruiniforme features of Guaritas do Camaquã Geosite.

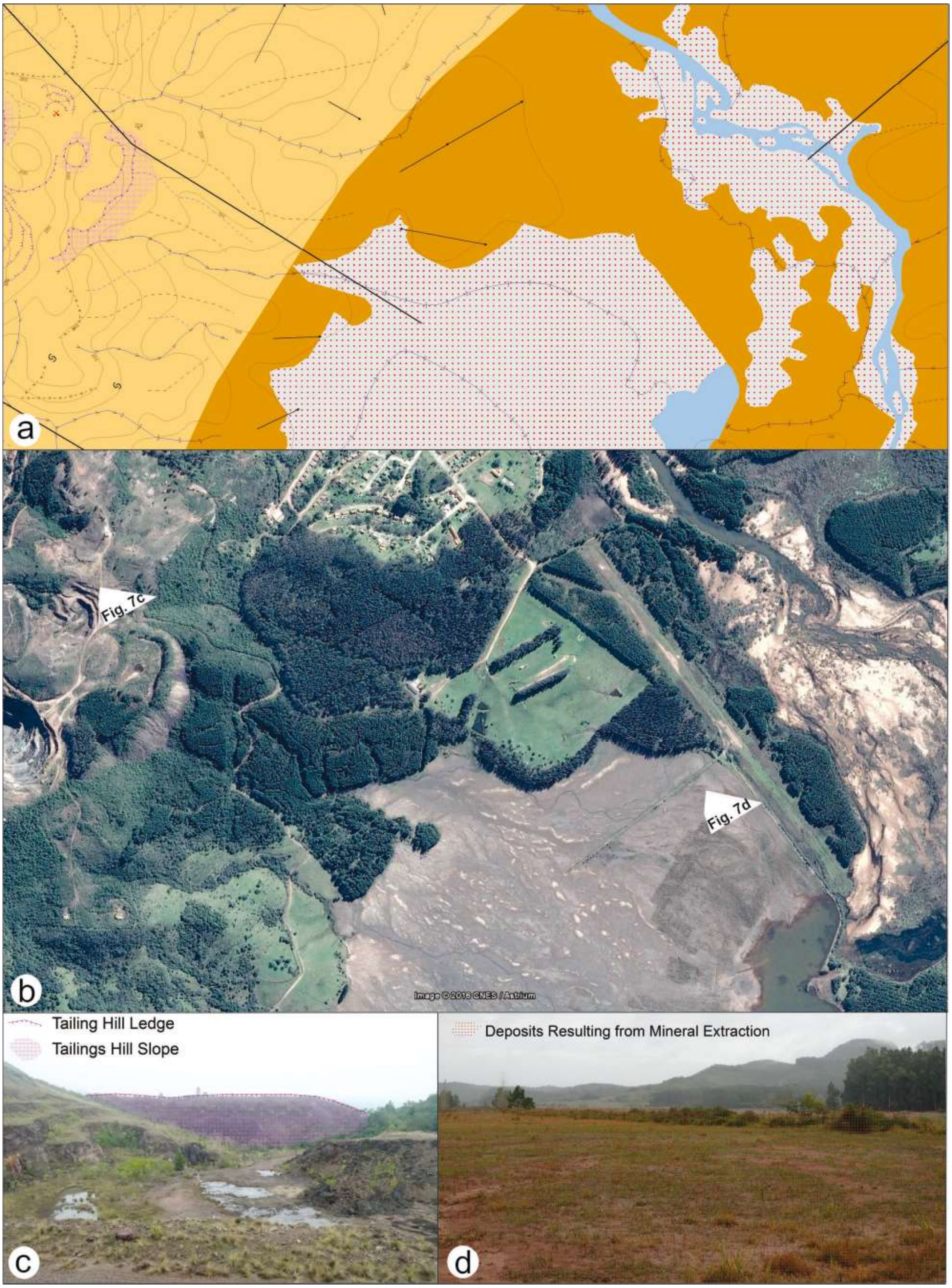

Figure 7 – Anthropogenic morphologies created from the dumping at tailings piles and dumping at beneficiation area steps. The legend with the presented symbology in the geomorphological map excerpt and in the photography obtained in field can be seen with more details on Figure 2.

Figure 8 – Landforms found in the Structural Features Sector of MCGPA. Emphasis on the Pedra da Cruz formation, located on the João Dias stream banks. The legend with the present symbology in the geomorphological map excerpt and in the photography obtained in field can be seen with more details on Figure 2.

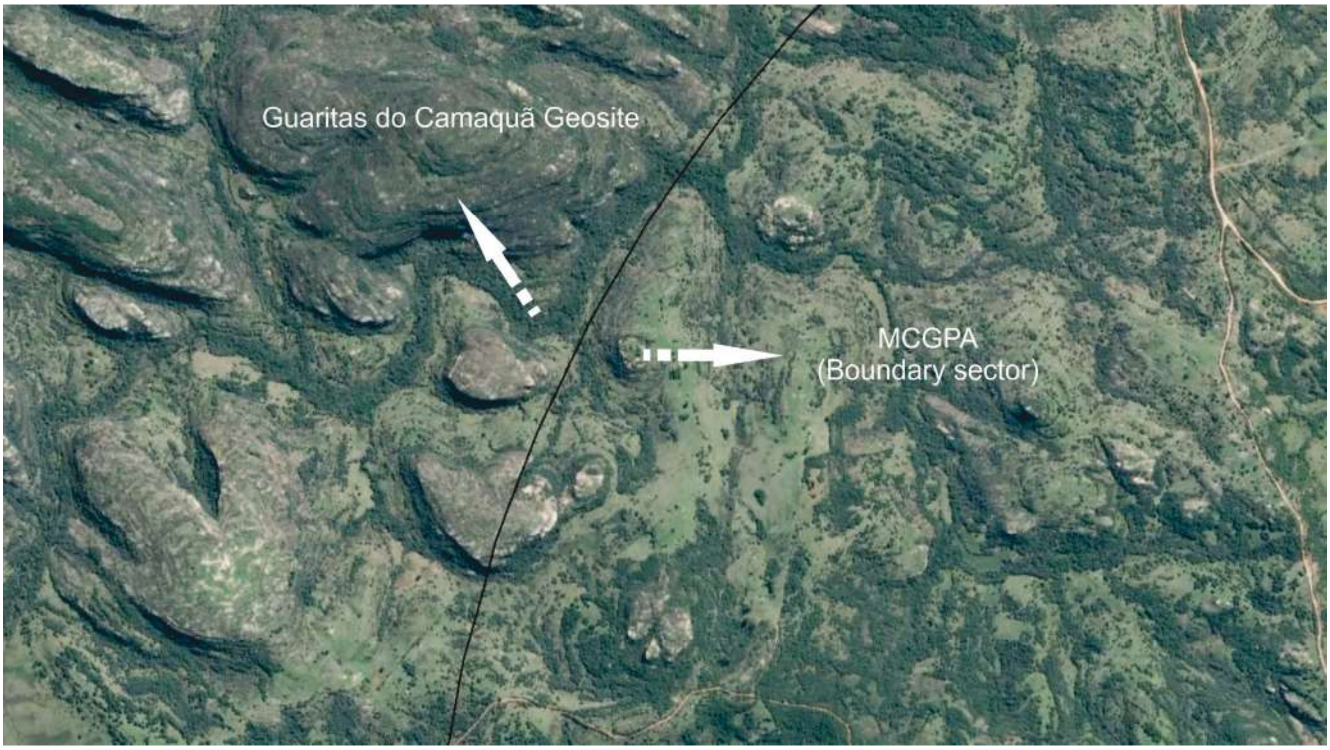

Figure 9 – Contact area between the Boundary Sector of MCGPA and the ruiniform relief of Guaritas do Camaquã Geosite.

The existing geomorphological features in this sector present aggressive and fairly developed stages of erosive processes. Topographic ruptures located in high slopes were identified, which indicates an adjustment to the incision of the river channels that are, mostly, located in V-shaped compartments of valley bottoms.

Although suffering distinct alteration from the anthropic pressure conditions from the other analyzed sectors, the contact with the Guaritas do Camaquã Geosite ruiniform relief is located within the MCGPA boundaries and it needs to be preserved from human activities that may take place in this area. Furthermore, it is important to highlight the function of this sector when it is seen in association with the highly impacted areas which underwent mining activities.

5. Conclusions

Based on the theoretical propositions and the results, a few conclusions were identified:

1. Despite the disturbances caused by the mining activity, there are features of geological and geomorphological interest in the Minas do Camaquã Geosite Protection Area that are well preserved. The proposition of geotouristic itineraries directed to the interpretation of natural and anthropogenic landforms can become a geoconservation and environmental educational strategy.
2. The existence of well-preserved geological-geomorphological features also reiterates the need for land use and land cover monitoring dynamics in the MCGPA. Although the land use was the reason for most of the geomorphological alterations at the mining areas, agricultural activities (food crops and silviculture), as well as livestock, can contribute to alter the morphodynamics and, consequently, the preserved forms.
3. The anthropogenic features that were identified and analyzed allow the history of the mining activities carried out in the MCGPA to be interpreted. Despite the fact that these land features are not originated form a natural morphogenesis, they belong to the area's geodiversity and must be comprehended as mining geoheritage, which qualifies the Minas do Camaquã Geosite as a geosite which is part of the mining's history.
4. The recognition and valuing of the anthropogenic-origin geomorphological heritage is capable of promoting a better engagement and use by the locals – which is constituted mostly by former workers of the mining activities. These people know about each

stage of the mineral extraction, and they can assist by pointing out the historical aspect of the features – which keep a singular potential and aesthetics to scientific/educational studies.

5. Although the features located in the extraction/blasting, loading and hauling and dumping areas have an anthropogenic aspect, it is necessary to comprehend that they are vulnerable to alterations caused by the action of chemical and biological weathering agents. These features are landforms that were created, and if considered as part of the geomorphological heritage, they should be managed to avoid their degradation and collapse. The degradation has a negative effect over the area where anthropogenic morphologies show a significant scenic beauty.

The geomorphological map of MCGPA can be interpreted and used by many professionals to promote geoconservation, geotourism and environmental education efforts. This document must be used to subsidize a time analysis of the anthropic activity in the MCGPA. Thus, a retrospective geomorphological mapping will generate a fully understanding of the progression of the various spatial organization stages of this geomorphological system which led to the current scenario of anthropogenic morphologies.

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