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Influence of the structural framework on peat bog distribution in the tropical highlands of Minas Gerais, Brazil

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ABSTRACT

Peat bogs are ecosystems characterized by high levels of organic matter (OM), which accumulates in environments of low biological activity. The peat bogs present in the tropical highlands of Serra do Espinhaço Meridional (SdEM), Brazil, are associated with hydromorphic environments formed under specific conditions and the strong influence of the quartzite basement, whereby a complex pattern of faults, fractures and folds has deeply affected the drainage network and geomorphological framework. This study investigated the influence of the structural framework on the distribution and morphology of these ecosystems within a hydrological and geomorphological context. The physical features of the landscape were analyzed using geological maps, a digital elevation model and by mapping the main geomorphological feature patterns obtained from geographic information systems (GIS). Ground Penetrating Radar transects were taken in representative areas, as the best strategy for detection of buried peat bogs, as well as to analyze bedrock configuration and infer its relationship with water flow. Four peat bog typologies were identified: "entrenched bogs", "subsurface bogs", "structural bogs", and "hanging bogs". The distribution and morphology of these typologies display a strong relationship either with alluvial sediments and floodplains or with structural/lithological features which caused water retention.

1. Introduction

Peat bogs are ecosystems formed through the accumulation of vegetal remains in environments presenting conditions unfavorable to the activity of decomposing microorganisms (Moore, 1997). Reduction in the energy of water flow is a requisite for bog formation, as this maintains a wet environment favoring the development of hygrophilous vegetation and organic matter (OM) accumulation. In Brazil, the tropical highlands of Serra do Espinhaço Meridional (SdEM) constitute a relevant region for the presence of peat bogs. These highlands consist principally of quartzite rocks and are characterized by a diversity of geomorphic features influenced by lithological and structural aspects.

There is a predominance of sheared and fractured quartzite rock substrate, which has been influential in delineating ridges, cliffs, depressions, deep valleys and alluvial plains aligned to tectonic directions, as well as delineating dissected plateaus and plateau remnants at different topographic levels. These morphologically resistant rocks provide structural obstacles preventing free drainage and therefore controlling the distribution and morphology of the peat bogs in the area. In the depressed areas of the landscape and on the valley floors, there are extensive deposits of sandy sediments from the Holocene and Pleistocene, with bogs occurring in certain places (Saadi, 1995; Augustin et al., 2011; Barreto et al., 2013). Given the right conditions, bogs can be found buried beneath sediments of alluvial or colluvial origin, but can be observed in places where erosion ravines expose the peat deposits.

Peat bogs represent an important genetic reservoir of plant and animal species (Silva et al., 2012a, 2012b; Horak-Terra et al., 2014). As these environments are highly sensitive to climatic changes, plant remnants and pollen in the peat bog enable reconstruction of environmental change during the Late Pleistocene - Holocene (Horak-Terra et al., 2014; Zádorová et al., 2015).

As a record of climate change, the peat bogs of the SdEM are of great importance, because the climate of the region is influenced by the South

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American monsoon system and by the convergence zone of the South Atlantic (Horak-Terra et al., 2014). These conditions therefore make the results obtained from the peat bogs of the SdEM highly representative in terms of global climate changes (Horak-Terra et al., 2014; Bispo et al., 2016). The SdEM peat bogs also influence water dynamics and water quality in the region, ensuring sustainability of watercourses and formation of C storages (Comas and Slater, 2007; Campos et al., 2011, 2012).

Although not common in the tropical zone of South America due to high temperatures and seasonal wet periods that promote high rates of organic matter decomposition (Martinez-Cortizas et al., 2002), peat bogs can form at high altitude, on river plains and on wetlands, where climatic conditions and drainage favor the deposition of OM (Pontevedra-Pombal and Martínez Cortizas, 2004). In the SdEM, peat bogs are formed through the combined influence of the morphology and lithology, but precisely how this works is essentially unclear. It is our purpose to elucidate these factors by analyzing the influence of substrate features on the landforms and their relationship with the distribution and morphology of the peat bogs.

2. Material and methods

2.1. Location and characterization of the study site

The study area extends for 5200 km^2 and consists of Quartzites, Metassiltites, Phyllites, Granites, Migmatites and Metamagmatic rocks (Fig. 1).The climate is mesothermic (cwb on the Köppen classification) with an average annual temperature of 18.7 °C. Winters are cold and dry, while summers are mild and wet. The average annual precipitation is 1500 mm (Silva et al., 2012a, 2012b).

2.2. Geomorphology

The influence of lithological and structural characteristics of the substrate on the landform framework, and its relationship with peat bog distribution and morphology, were analyzed through the elaboration of thematic maps. This analysis aimed to identify relationships between major lithological and structural features of the substrate, different relief compartmentations and peat bog distribution and morphology.

Thus, information on the principal lithological and structural characteristics of the substrate was acquired from geological maps and from mapping of the structural lineaments in the study area.

Information on the types of rock found in the area was obtained through the compilation of geological maps of Rio Vermelho (Tupinambá et al., 1996), Diamantina (Fogaça, 1996), Presidente Kubitschek (Knauer and Fogaça, 1996) and Serro (Knauer and Grossi Sad, 1996), all at a scale of 1:100,000 and provided by CODEMIG - Company for the Economic Development of Minas Gerais. The compilation of maps was carried out using the Geographic Information System (GIS), with WGS 1984 23S as the Datum.

To map the geomorphological features and identify areas favorable to peat bog formation, we used images from the SRTM (Shuttle Radar Topography Mission) and Landsat 7. The images were processed in GIS in order to obtain the following products: slope map (Fig. 2b), hypsometric map (Fig. 2a) and relief shading with structural lineaments (Fig. 2c) (Grohmann et al., 2007; Carvalho and Bayer, 2011; Augustin et al., 2011). The drainage network (Fig. 2d) was compiled from maps at a scale of 1:100,000 from CODEMIG.

Structural lineaments were mapped from the drainage network and hypsometric maps by tracing linear segments along drainage anomalies such as straight segments, linear valleys, elbows, alignments of confluence points and sub-catchment asymmetries. The delineation of prominent straight escarpments and linear ridges was carried out using the same method (Roldan et al., 2010; Couto et al., 2011). Several lineaments were checked in the field in order to verify the reliability of the results.

Features considered as similar were grouped together based on morphosculptural characteristics (shapes resulting from water action and denudation processes) and morphostructural framework (relief shapes associated with tectonic and stratigraphic aspects) and classified according to Pavlopoulos et al. (2009) and Augustin et al. (2011). Special attention was given to flat environments, such as valley floors, which represent potential locations for the occurrence of peat bogs.

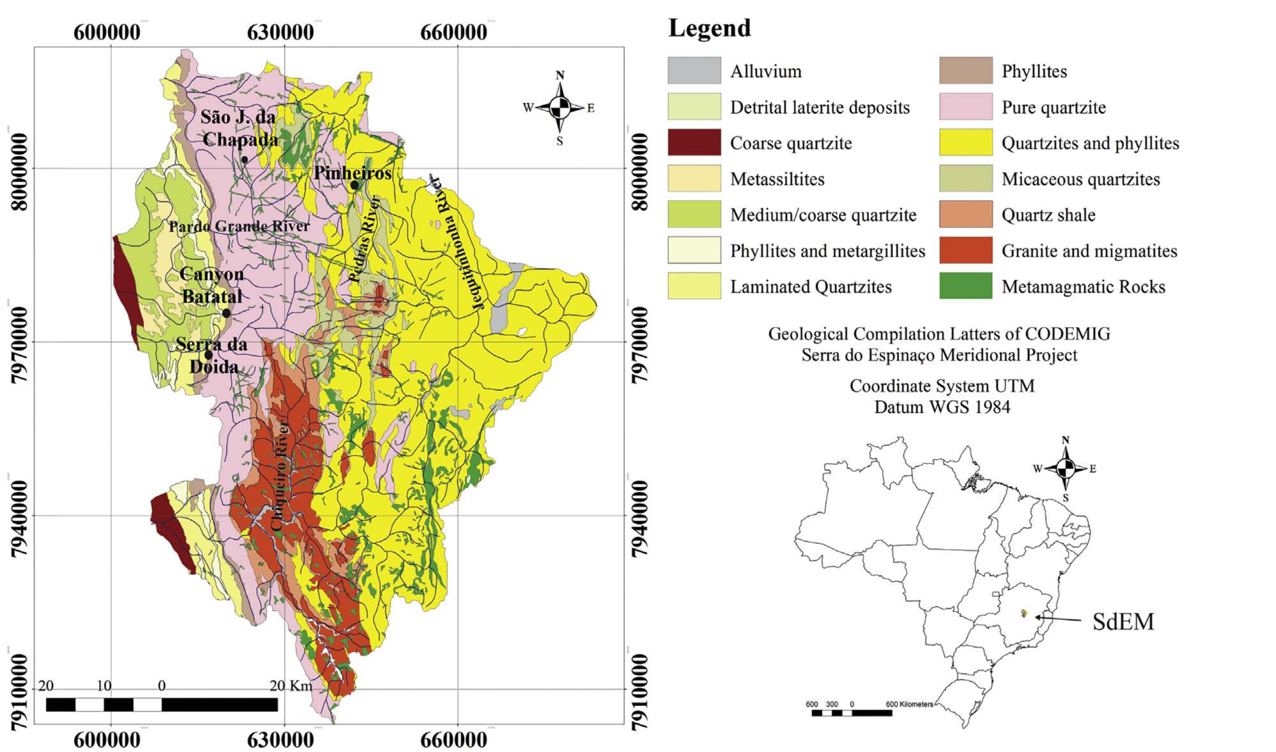

Fig. 1. Location and geological map of the study area.