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CHRONOLOGY OF QUARTZITIC SLOPES FROM MINAS GERAIS, BRAZIL

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Abstract

Quartzitic mountain reliefs developed in a tropical savanna climate tend to have shallow sedimentary deposits. This is due to low level weathering processes of quartzite rocks and formation of colluvium ramps on the slopes. This study aims to determine the characteristics of colluvial materials, particularly grain size, and to analyze sediment chronology above the saprolite, seeking to identify accumulation rates and make correlations with the dynamics of the recent geomorphological evolution of the Canastra range in Minas Gerais, Brazil. Samples collected in different morphological positions were submitted to granulometric analysis and dated by Optically Stimulated Luminescence Single Aliquote Regeneration (OSL/SAR) and radiocarbon dating. Grain size analysis showed a predominance of sandy and gravel materials and demonstrated that the colluvial ramps in the study area contain materials derived from the decomposition of quartzite rocks, accumulated in shallow and sandy profiles. LOE/SAR dating indicated ages between the end of the Pleistocene, not exceeding 30,500 +/- 4,950 BP, to 500 years BP, whereas the 14C dating showed ages between 4460 +/- 30 BP and 1140 +/- 30 BP. These data indicate that the deposits from the study area are relatively recent, which demonstrate that variations in the weathering process and deposit formation have undergone recent changes, probably due to climatic fluctuations and changes in the regional hydrological regime.

Keywords: Canastra Range, Paleogeomorphological Reconstruction, Weathering of Quartzites, OSL, Tropical Range

Resumo / Resumen

CRONOLOGIA DE VERTENTES QUARTZÍTICAS EM MINAS GERAIS, BRASIL

Os relevos de montanhas quartzíticas desenvolvidos em um clima de savana tropical tendem a ter depósitos sedimentares rasos. Isso se deve aos processos de intemperismo de baixo nível das rochas quartzíticas e à formação de rampas de coluvião nas encostas. Este estudo tem como objetivo determinar as características dos materiais coluviais, principalmente granulometria, e analisar a cronologia sedimentar acima do saprólito, buscando identificar as taxas de acumulação e fazer correlações com a dinâmica da evolução geomorfológica recente da serra da Canastra em Minas Gerais, Brasil. Amostras coletadas em diferentes posições morfológicas foram submetidas à análise granulométrica e datadas por Regeneração de Alíquota Única por Luminescência Oticamente Estimulada (OSL/SAR) e datação por radiocarbono. A análise granulométrica mostrou predominância de materiais arenosos e pedregosos e demonstrou que as rampas coluviais da área de estudo contêm materiais derivados da decomposição de rochas quartzíticas, acumuladas em perfis rasos e arenosos. A datação LOE/SAR indicou idades entre o final do Pleistoceno, não ultrapassando 30.500 +/- 4.950 BP, a 500 anos BP, enquanto a datação 14C mostrou idades entre 4460 +/- 30 BP e 1140 +/- 30 BP. Esses dados indicam que os depósitos da área de estudo são relativamente recentes, o que demonstra que as variações no processo de intemperismo e na formação dos depósitos sofreram mudanças recentes, provavelmente devido a flutuações climáticas e mudanças no regime hidrológico regional.

Palavras-chave: Serra da Canastra, Reconstrução Paleogeomorfológica, Intemperismo de Quartzitos, OSL, MontanhasTropical

CRONOLOGÍA DE TALUDES CUARCÍTICOS DE MINAS GERAIS, BRASIL

Los relieves montañosos cuarcíticos desarrollados en un clima de sabana tropical tienden a tener depósitos sedimentarios poco profundos. Esto se debe a los procesos de meteorización de bajo nivel de las rocas de cuarcita y la formación de rampas de coluvión en las laderas. Este estudio tiene como objetivo determinar las características de los materiales coluviales, particularmente el tamaño de grano, y analizar la cronología de los sedimentos por encima del saprolito, buscando identificar tasas de acumulación y establecer correlaciones con la dinámica de la evolución geomorfológica reciente de la cordillera Canastra en Minas Gerais, Brasil. Las muestras recolectadas en diferentes posiciones morfológicas se sometieron a análisis granulométrico y se fecharon mediante regeneración de alícuota única de luminiscencia estimulada ópticamente (OSL/SAR) y datación por radiocarbono. El análisis granulométrico mostró un predominio de materiales arenosos y gravosos y demostró que las rampas coluviales del área de estudio contienen materiales derivados de la descomposición de rocas cuarcíticas, acumuladas en perfiles someros y arenosos. La datación LOE/SAR indicó edades entre el final del Pleistoceno, sin exceder los 30.500 +/- 4.950 AP, hasta los 500 años AP, mientras que la datación 14C mostró edades entre 4460 +/- 30 AP y 1140 +/- 30 AP. Estos datos indican que los depósitos del área de estudio son relativamente recientes, lo que demuestra que las variaciones en el proceso de meteorización y formación de depósitos han sufrido cambios recientes, probablemente debido a las fluctuaciones climáticas y cambios en el régimen hidrológico regional.

Palabras-clave: Cordillera Canastra, Reconstrucción Paleogeomorfológica, Meteorización de Cuarcitas, OSL, Cordillera Tropical

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INTRODUCTION

One of the most notable characteristics of reliefs formed in quartzite rocks from Central Brazil is the elevated topographical position, generally associated with the predominance of rocky outcrops and the development of shallow colluviums. This type of landscape is found in Mountain Ranges such as Chapada dos Veadeiros and Pirineus (State of Goiás); Estrondo (State of Tocantins); Cipó, São Tomé das Letras and Canastra (State of Minas Gerais). The Canastra Mountain Range is located at the meridional sector of the Tocantins fold system, characterized by the occurrence of pure or micaceous quartzite outcrops in a large sector of the mountain range.

Research carried out by Nazar (2018), Araújo (2017) and Magalhães (2015) showed geomorphological aspects and the evolution of the drainage network in the extreme eastern section of the Canastra Mountain Range, regionally known as Chapadão do Diamante. This area shows the highest reliefs of the entire regional system, with presence of quartzitic outcrops on hilltops, that form a chaos of blocks on the surface. There are also colluvial slope deposits, generally rich in gravel, sand and organic material that form shallow deposits. Ferricretes are also found in both surface and subsurface soils.

Nazar (2018) and Nazar and Rodrigues (2019a), pointed out that the Chapadão do Diamante landscape favors good results in OSL and c14 studies as it presents favorable conditions such as: materials rich in quartz, colluvium deposits materials on the slopes; the homogeneous texture of surface materials, the presence of herbaceous and shrubs vegetation and preserved from agricultural activities due to the poor fertile soil and mountainous relief. Also organic deposits are observed in several slope segments, forming small peatlands, in addition to small pocket plains along the river channels.

We studied a rural area which was previously natural pastureland which was converted into a National Park in 1972. The current human activity is limited to areas of visitation in the Canastra Range Park. Nowadays there are small areas of anthropic activity restricted to the margins of roads and old abandoned farms buildings.

These occupation characteristics indicate that the vast majority of surface materials were not modified during the recent human colonization period during about 200 years (Rodrigues, 2002).

The surface materials are products of onsite weathering, and the studied deposits are located in the vicinity of its source area with short distance transportation of the sediments. These colluvial ramps are located down slope of rocky outcrops.

The configuration of this landscape, associated with the preliminary studies mentioned above, raised some questions about the age of both the materials and surfaces found in this area. In this sense, the objective of this research is to find out the age of surface materials using the technique of Optically Stimulated Luminescence (OSL) for quartz deposits and Carbon 14 (14C) for organic materials.

These samples were collected in trenches at transition between erosion and deposition soil levels, aiming to present data on the question of evolution and changes of environmental dynamics in weathering layers and colluvial deposits of this recent landscape.

By using two independent dating techniques, we can test the reliability of chronostratigraphic significance of identified ages. This allows the use of one technique to validate the data found by the other.

Optically Stimulated Luminescence (OSL) dating determines the age that has elapsed since the last exposure of the sediment to atmospheric radiation. This allows to measure the total amount of stored signal as a result of the annual exposure of the sediment to a known background radiation dose (Yukihara and Mckeever, 2011; Guedes et al, 2013).

The concept of luminescence dating is based on defects in the crystalline network of minerals, most commonly quartz and feldspar, which trap the energy produced during the interaction between electrons within the crystal and background radiation from the radioactive decay of Uranium (U), Thorium (Th) and Potassium (K) and cosmic rays. In the case of OSL, this energy is released as luminescence (light) when the quartz minerals are exposed to visible (bleached) light, that is, during sediment erosion, transport and deposition, or through laboratory stimulation. (Mellett, 2013).

Under favorable conditions during the determination by OSL, the radiation signals can be totally cleared in seconds of exposure to light, thus enableling precise dating of buried sediments

(Godfrey-Smith et al., 1988, Madsen and Murray, 2009, Stokes, 1999). The routine dating of quartz in sediments by OSL can determine ages of up to 150 ka. (Duller and Wintle, 2012). The advantage of luminescence over other dating methods is its ability to directly date the deposition of clastic sediments (Lian and Roberts, 2006). However, Sohbati (2015) and Meyer et al. (2020) also present the possibility of dating rocky surfaces in quartzite rock blocks in addition to the commonly used techniques for sediments.

OSL dating techniques are widely used in geomorphological studies, covering diversity of environments, such as studies involving aelioan (ChongYi et al., 2019, Peng, Dong and Han, 2015; Tissoux et al, 2010), fluvial (Keen-Zebert at al, 2013; Rittenour, 2008;), and glacial environments (King et al, 2014; Smedley, Glasser and Duller, 2016).

The slope deposits are an important sedimentary file for geomorphological and paleoenvironmental research carried out in spatially restricted study areas (Augustin et al, 2014; Paisani et al, 2017). The short transport distance of sediments within colluvium materials doesn't increase the complexity of these deposits, allowing for an easy delineation of the source area of the sediments.

This would favor a more precise determination of ages through OSL, when compared to 14C dating, without generating overestimation of results as pointed out by Fucks and Lang (2009).

Quartzitic landscapes from different regions in the world are being submitted to OSL chronological analysis. The landscape formed on quartzites located in the Harayana region south of Delhi (India), is very similar to the Canastra Mountain Range, either due to its weak weathering, or to the outcropping of strongly inclined quartzites ridges.

Despite the climatic difference between these environments, the weathering of the quartzite plays a predominant role in shaping the surface, especially through the process of removing silica and the permanence of minerals rich in iron (Tripathi and Rajamani, 2003). Furthermore in this same region, Gupta and Rao (1998) showed that the characteristics of the different stages of quartzite weathering are indicatives of the weathering difficulty of this type of rock, due to their low porosity, high tensile strength and high compression.

Thermo Luminescence was used by Richards (1992) to date archaeological fragments originating from quartzite rocks at the Diring Yuriak Site, Siberia. As a result he found other alternatives of dating quartzite grains extracted from the artifacts and in addition discovered ages of approximately 74,000 bP. A similar study was carried out by Sohbati et al (2012) in the region of Tapada do Moutinho, Portugal, where studies at archaeological levels that contain quartzite pebbles shows results between 19,000 and 45,000 years bP.

In Brazil, studies that use OSL and 14C dating techniques for slope environments are not a common practice. Examples of this type of study were developed in mountainous environments by Augustin et al (2014) who has studied covering slope deposits in the Serra do Espinhaço region. Paisani et al (2017) studied slope environments on the Palmas/Água Doce (PR) surface, aiming to determine the dynamics of the colluvium ramps along the Late Quaternary period. Pinheiro, et al (2016) carried out studies on the reverse of Serra de São Pedro (SP) seeking to identify the origin of the materials and their relationship with the geomorphological evolution of the area.

STUDY AREA

Chapadão do Diamante is located in Southeastern Brazil (Figure 1). It is the extreme eastern part of Serra da Canastra Mountain Range where the historical springs of the São Francisco River are located. It also covers a substantial part of the Serra da Canastra National Park. The structural context is a range of Neoproterozoic folds, currently exposing strata predominantly of quartzitic rocks from the Canastra Formation (Simões et al., 2015; Souza and Rodrigues, 2014; Valeriano et al., 2004; Uhlein et al., 2012).

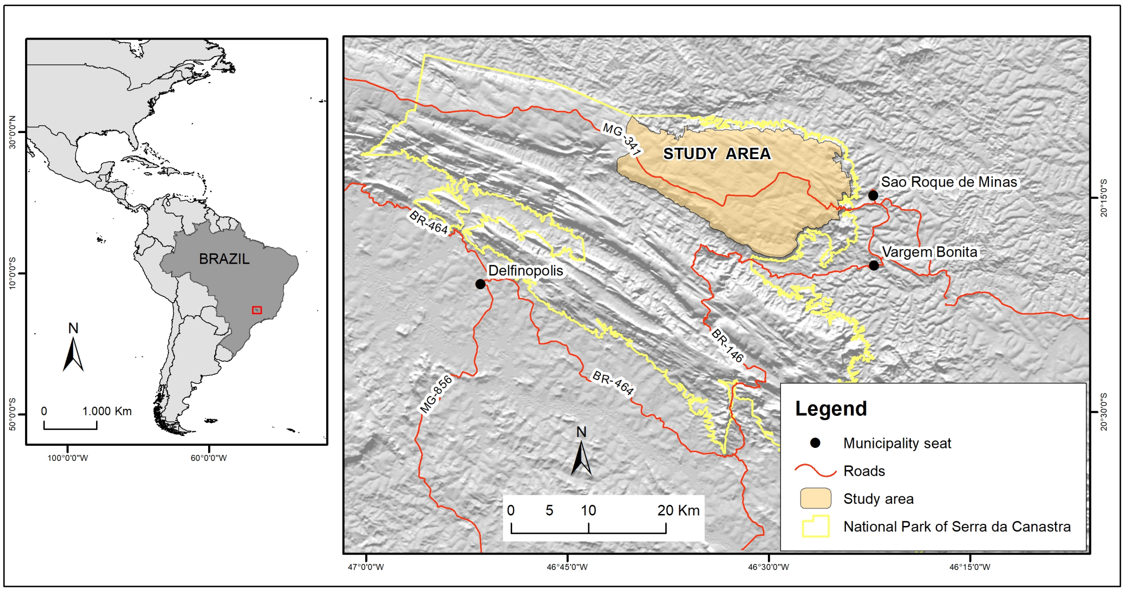

Figure 1 – Relief of the study area in the context of Brazilian territory. Source: The authors.

Figure 2 is the landform includes an aligned mountain range, with convex and dissected hills on top, delimited by fault line escarpments that measure more than 250 meters in height and form a large structural block which can easily be distinguished in the landscape.

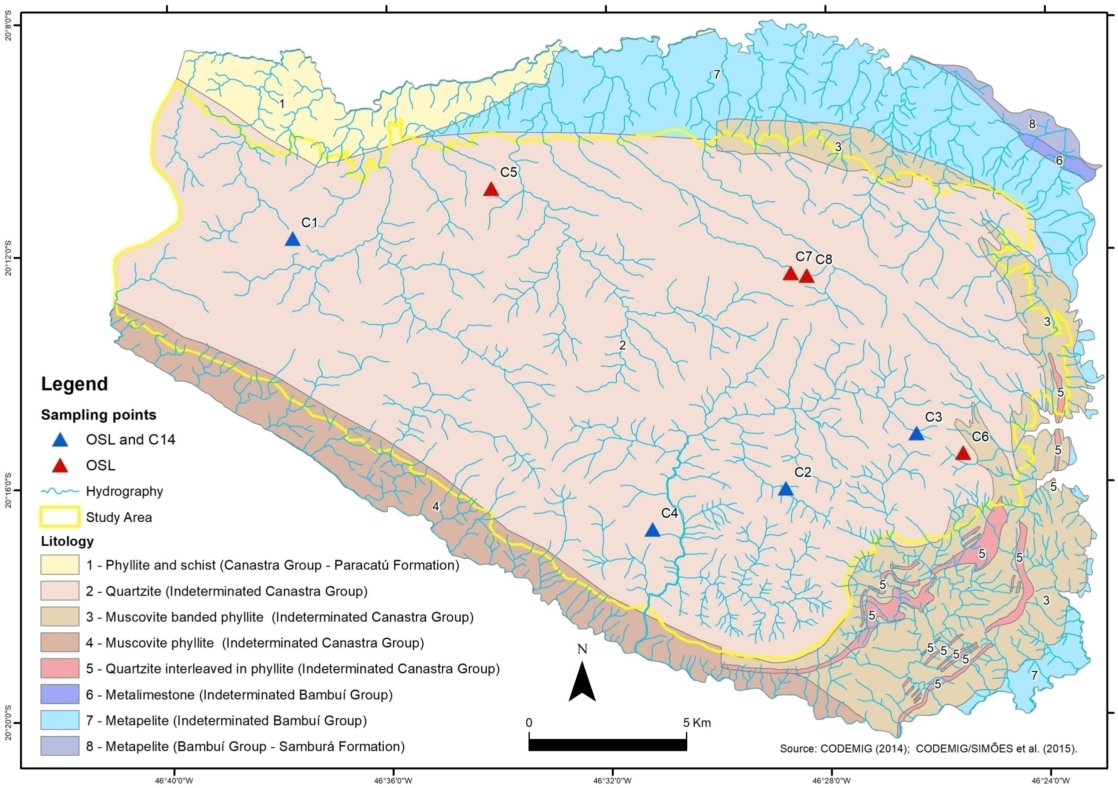

Figure 2 - Geological map of the study area. Source: Nazar and Rodrigues (2019a).

The drainage network consists of two drainage headwaters, one facing south, which forms the headwaters of the São Francisco River, and the other in the northern portion with the drainage headwaters of the Santo Antonio River basin. The main characteristics of the drainage network are the structural lineation control, mainly associated with NW-SE directions, perpendicular to the compression direction of the folds system, and SW-NE as secondary axis.

Nazar and Rodrigues (2019a) show that the Chapadão do Diamante hilltops are composed by outcrop rocks and a chaos of boulders. The geocover materials were mapped by these authors and present a large concentration of materials with coarse granulometry, with the presence of gravel, coarse and medium sand. They also highlighted areas with outcrops of ferricretes in both fragmented and conserved forms. The direction of the valleys is controlled by rock lineation, and several knick points are defined by rocky outcrops in the channel beds. On studying the distance/slope ratio of the drainage network, Araújo (2017) and Magalhães and Rodrigues (2020) detected anomalous behavior in all channels which shows that their notching is strongly affected by local knick points.

METHODS

The fieldwork was divided into two phases, one for the recognition and pre-selection of sampling areas and the other for the collection of soil samples. Topographic and geomorphological maps created by Nazar and Rodrigues (2019a) present a detailed cartography of the Chapadão do Diamante, based on geomorphometric and geocover data. Drainage network, lithology, and geophysical data were also obtained by Nazar and Rodrigues (2019a), Santos and Rodrigues (2019) and Magalhães and Rodrigues (2020).

The location of the sampling areas was selected to cover the largest possible number of topomorphological and geocover features of the Chapadão do Diamante Mountain Range numbered as C1 to C8 (Figure 3). The laboratory work consisted of grain size analysis and geochronological analysis by means of OSL and ^{14}C datings. The grain size of 67 samples from 8 plots was obtained using the sieve-pipette method described by Gee and Bauder (1986), Santos and Rodrigues (2019) and EMBRAPA (2011). For the geochronological analysis we performed 8 OSL datings of samples collected from the biggest possible depth of each deposit, in the soil/saprolite transition.

This was done in order to reveal the transition from predominant erosive processes to the level of deposition processes. The samples were collected with 60cm PVC tubes, following the method described by Mellet (2013). The OSL analysis was carried out by the Datação, Comércio e Serviços Laboratorio do Brasil, using the SAR protocol (Single-Aliquot Regenerative-dose) with 15 Aliquots. In this protocol, the sample age is based on the average of 15 OSL ages which are estimated from 15 individual calibration curves. In 4 trenches, numbered as C1, C2, C3 and C4) we performed ^{14}C dating of samples collected at the maximum depth of the deposit (Figure 3). The samples were analyzed by the Beta Analytic Laboratory, using an Accelerator Mass Spectrometry (AMS) Dating.

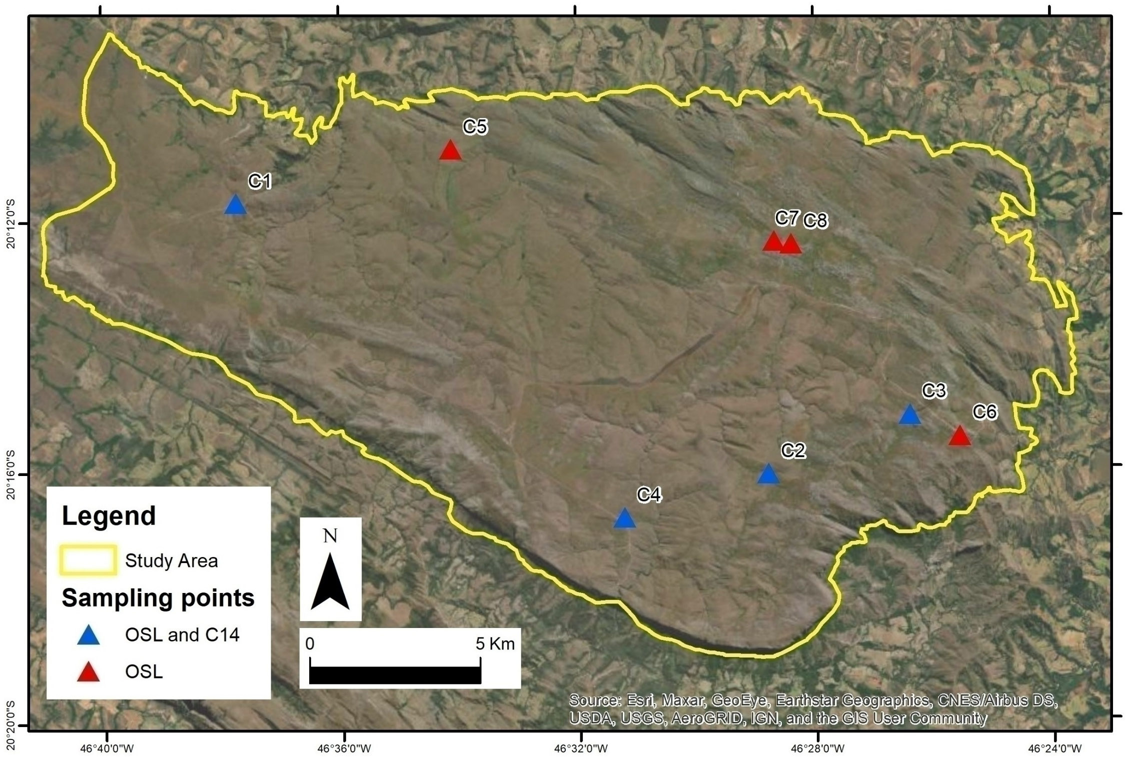

Figure 3 – Aerial image of the study area and location of the samples analyzed in this work. Source: The authors

RESULTS

Recent studies carried out at Chapadão do Diamante (Nazar, 2018) show that there are three main groups of surface geocovers (Figure 4). The first group which sums approximately 60% of the study area consists of mostly rocky and weakly weathered materials denominated as gravel-sandy with a chaos of blocks, undifferentiated gravel-sand and rocky outcrops. The second group is associated with humid areas, denominated as peat bogs and undifferrentiated bioturbation comprising roughly 22% of the total area.

The third group which comprises 18% of the study area has superficial materials that contain clay or show a strong presence of both lateritic blocks and lateritic gravels. As a common feature, all these units presents a small depth, generally not exceeding 1 meter in thickness, and rarely reaching 2 meters.

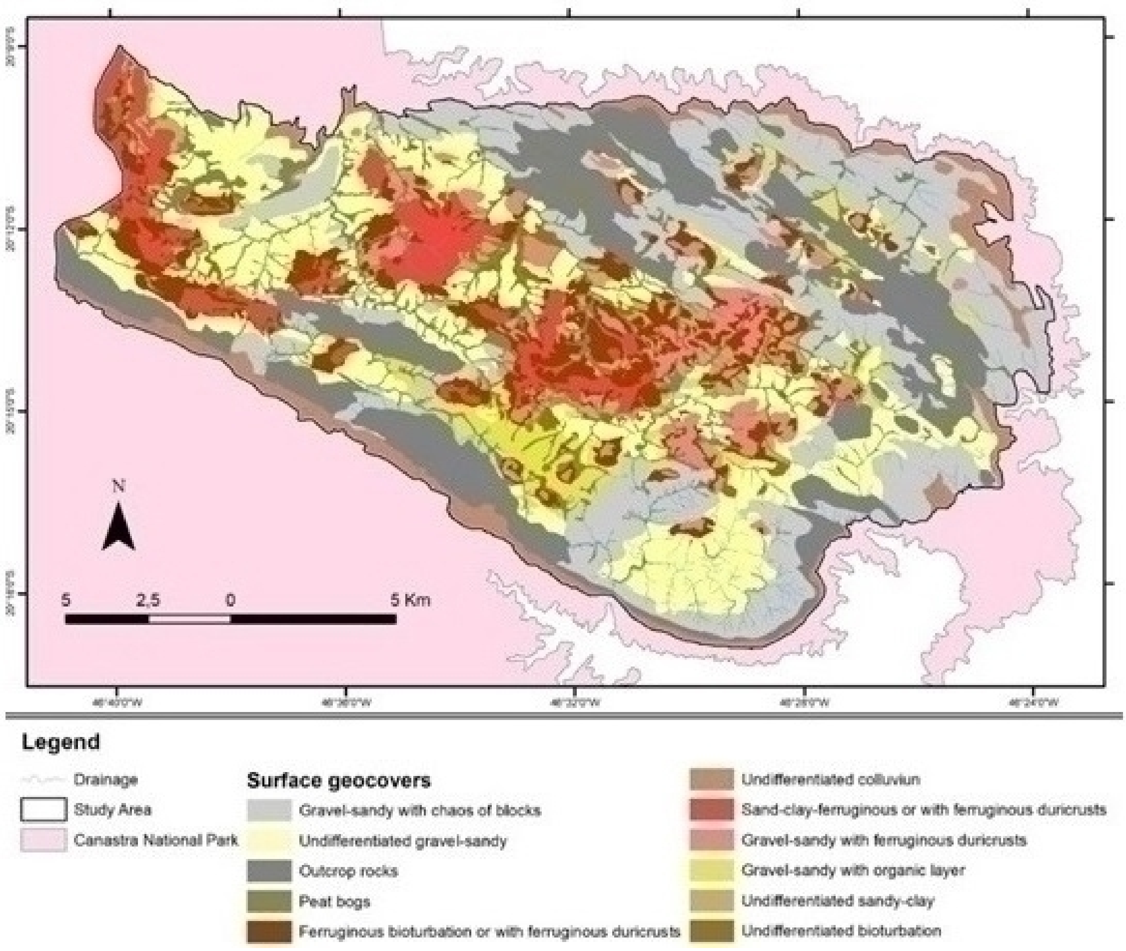

Figure 4 – Distribution of surface geocovers of the Chapadão do Diamante. Modified from Nazar (2018).

Figure 5 shows the results of the granulometric analysis carried out for eight profiles which shows a clear predominance of sands and silt. The samples C2 and C4 present some different tendencies due to a higher proportion of silt without variation of texture in depth. None of the 8 plots had a relevant variation as regards the depth, and in the profiles the textures remain practically the same as presented in sample C7 Figure 6.

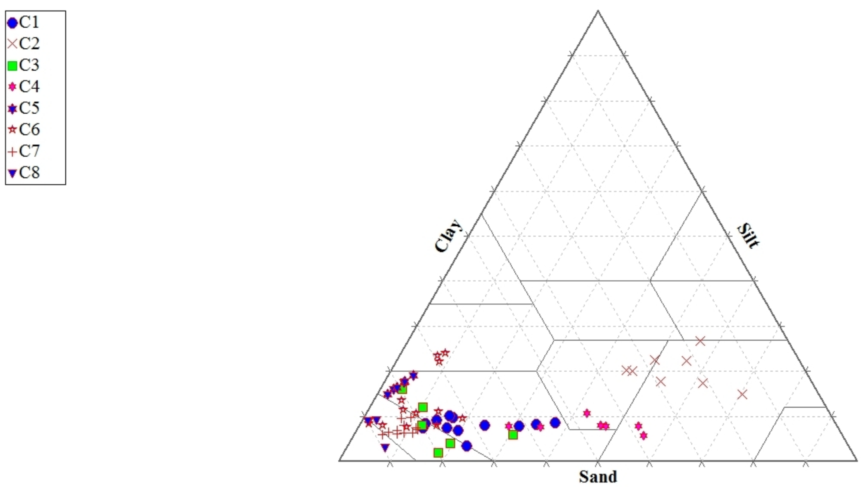

Figure 5 – Soil texture triangle with the results of eight OSL profiles.

The study area presents two characteristics related to rock fragments: one related to irregularly shaped gravel which cover the surface and another as a layer of irregular shaped gravel located a few centimeters deep, covered by sandy layers, which are probably colluvial on genesis.

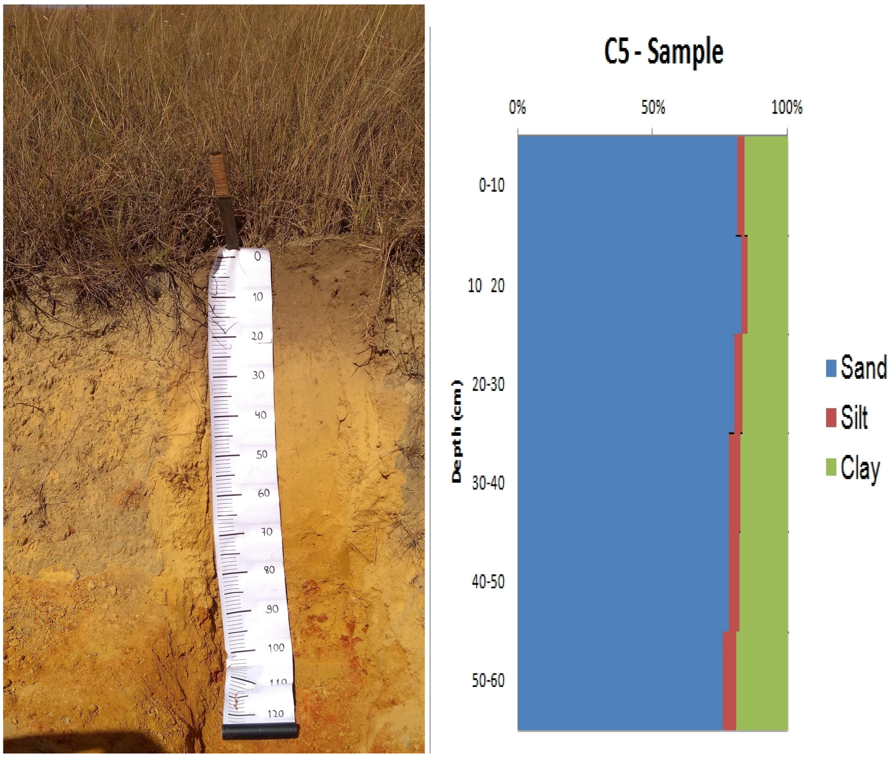

Figure 6 - Soil profile and texture analysis.

OSL dating performed in eight profiles (see Table 1) shows that six samples originate from the Medium to Late Holocene while the remaining two are from the Late Pleistocene. This indicates that the surface materials from this region are extremely recent, and it also shows that not too long ago these areas were probably more arid, with a greater predominance of rocky outcrops and less weathering.

It is important to stress that these deposits are located at a short distance from the source areas and undergo important geochemical processes that are concomitant to the transport. Such processes consist mainly of iron (Fe) mobilization and formation of ferruginous crusts, which indicates intense water circulation at a subsurface level.

In areas located near elevated rocky outcrops, close to the main water divide of the hydrographic basins (samples C1 and C7) we can find very recent deposits which are mostly below 1500 years BP.

This indicates that these superficial sand deposits reflect the present weathering conditions, characterized by strong sediment mobilization along the slope, with important erosion processes. The oldest ages from this study are found in the secondary dividers of the hydrographic basins (samples C4 and C6), located in topographically lower areas.

The chronology from these samples dates back to the end of the Pleistocene, and does not exceed the 30500 ± 4950 years BP. The topomorphological conditions in these dividers indicate that these areas have been present in the landscape for a longer period of time. In other words, these areas are located far from the rocky outcrops (source areas) and apparently remained unaffected by erosional processes for a long time.

Samples taken from the medium slope areas (C5 and C8), show ages from the medium to recent Holocene, between 2620 ± 400 and 4200 ± 1080 years BP. These samples prove the presence of sedimentary deposits which are slightly older than the ones found near elevated rocky outcrops, but more recent than deposits from the secondary hydrographic dividers. This could indicate more permanent deposition conditions.

Table 1 - Characteristics of sample points and OSL dating (annual dose, mean paleo dose and sample age).

Sample number and Depth	Altitude (m a.s.l.)	Slope position	Slope relative to the top (m)	Main grainsize	Additional observations	Th (ppm)	U (ppm)	K (%)	Humidity (%)	Annual dose (µ Gy/yr)	Mean Paleo dose - P (Gy)	OSL Age (yrs BP)
C1 – 50 cm	1333	High	10	Sandy loam	Base of rocky outcrop	1,865 ± 0,232	0,699 ± 0,132	0,525 ± 0,132	6,1	990 ± 110	< 0,5	<500 yrs
C2 – 60 cm	1363	Valley floor	60	Silty loam	5 meters from channel	4,176 ± 0,273	0,612 ± 0,112	0,885 ± 0,203	11,6	1.410 ± 155	9,0	6.350 ± 865
C3 – 45 cm	1384	Valley floor	20	Loamy sand	Base of rocky outcrop	1,816 ± 0,211	0,397 ± 0,113	0,366 ± 0,121	7,4	780 ± 100	7,0	9.000 ± 1.370
C4 – 30 cm	1325	Medium	20	Sandy loam	Secondary divide	1,853 ± 0,200	0,588 ± 0,108	0,238 ± 0,111	10,9	700 ± 90	21,3	30.500 ±± 4.950
C5 – 40 cm	1286	Medium	15	Sandy loam	Deposited on laterite	3,976 ± 0,272	0,773 ± 0,124	1,105 ± 0,154	3,6	1.710 ± 130	4,5	2.620 ± 400
C6 – 35 cm	1396	High	5	Sandy clay loam	Next to the main interfluvium	2,299 ± 0,228	0,304 ± 0,115	0,416 ± 0,125	4,5	850 ± 100	21,9	25.850 ± 3.770
C7 – 45 cm	1446	High	10	Loamy sand	Downslope of rocky outcrop	1,466 ± 0,183	0,470 ± 0,101	0,485 ± 0,108	7,8	880 ± 90	1,3	1.500 ± 290
C8 – 35 cm	1437	Medium	20	Sand	Deposited on laterite	4,630 ± 0,288	0,932 ± 0,118	0,923 ± 0,123	5,0	1.620 ± 100	6,8	4.200 ± 1.080

The results from the OSL dating reveal a scenario in which the topomorphological conditions clearly affect the erosion/deposition conditions, which decreases the chances of sediments being exposed to radiation and remaining in the slope system. The areas close to the valley floor (samples C2 and C3) showed ages from the Lower Holecene, between 6350 ± 865 and 9000 ± 1370 years BP.

These areas present the best deposition conditions of the Chapadão do Diamante, which are associated with an increase of sedimentation processes of materials coming from the upper slopes. The results from OSL dating show that six of the eight analysed samples date back to the Holocene, indicating that slope deposition is very recent.

Furthermore, the fact that the oldest samples of our study come from areas close to the slope base which presents more favourable deposition conditions. This is compatible with the results presented by Paisani et al (2017), who reports that intense erosion in the colluvial slopes inhibits the deposition of sediments and generates sediment accretion in the valley bottoms and their surroundings. Table 2 shows the AMS ^{14}C dating of 4 plots of the study area. According to the results sample C2 has the oldest ^{14}C age (4460 ± 30 years BP). The profile of this sample which is located near a valley floor is the thickest of the sampled plots.

For this same profile, the OSL dating from the base of the deposit, indicates an age of 6350 ± 865 years BP. The age difference of these two chronological analyses may show a period of approximately 2000 years of sterile deposit or low amount of organic deposits. This indicates at least two depositional phases in different environmental conditions.

Table 2 – 14C dating of four samples from the study area.

Sample number	**Slope position**	**Conventional radiocarbon age (BP)**	**Calibrated age (BP) (2 sigma)**	**Mean values and ranges derived from calibrated ages (BP)**	**δ13C‰ PDB**
C1	High	2060 +/- 30 BP	2050 - 1896 cal BP	1973±77	-16.7
C2	Valley floor	4460 +/- 30 BP	5069 – 5169 cal BP	5119±50	-14.6
C3	Valley floor	1140 +/- 30 BP	1060 - 936 cal BP	998±62	-16.0
C4	Medium	3610 +/- 30 BP	3975 – 3724 cal BP	3850±126	-17.4

The other three samples (C1, C3 and C4) show early ^{14}C ages, which apparently indicates accumulation processes triggered by the runoff dynamics and slope surface fluxes, which theoretically could hinder the development of thicker deposits and the presence of erosive episodes. Such factors would favor the formation of shallow sedimentary deposits, less favorable conditions for the accumulation of organic material. There are also two other factors that can contribute to a lower accumulation of organic material.

For samples C1 and C3, the location of the profiles is near a rocky outcrop, in an interfluvial position, which represents a small catchment area. These areas are also currently characterized by herbaceous and shrubby vegetation. Such environmental conditions may hinder the growth of arboreous vegetation and consequently reduce the amount of organic material.

Based on the recent dating of our study we can assume that the environmental conditions in the past were less favorable for the development of densely vegetated areas. This could be one of the reasons why lower organic content was found in slope deposits. This also reinforces our assumption that rocky outcrops occupy larger areas and that the shallow surfaces deposits have developed between approximately 4500 years BP until the present day.

DISCUSSION

Studies on chronological analysis of quartzitic colluvial slopes are uncommon. This study is originated from a specific geomorphological condition, characterized by Neoproterozoic quartzite bedrock, with an elevated topographic position in relation to the regional relief. The characteristics of quartzites associated with a humid tropical environment (with two seasons) creates favors the combined action of mechanical and chemical weathering.

We used two different dating techniques OSL and ^{14}C, to analyze the slope deposit geochronology of the Chapadão do Diamante. The chronology results showed that the materials are recent, with oldest samples from the Late Pleistocene.

The combination of the chronology of the sample points and the geomorphological characteristics of the different geocovers may help us determine the environmental conditions and predominant processes during the period of sediment deposition. A common feature of quartzitic mountainous reliefs in Brazil are shallow weathering profiles, with a predominance of sandy to loamy-sandy sediments, often enriched with iron (Fe) that could create ferruginous crusts.

These features are common in our study area and can also be found in other similar environments in Brazil, such as the Espinhaço Range (Augustin et al.; 2014), the Caraça Range (Cavalcante et al., 2010), the Ibitipoca Range, the Cipó Range, the Itacolomi Range and the Chapada Diamantina (Benites et al, 2007).

The iron enrichment of the superficial layers is a response to laterization processes, with the presence of iron oxides and hydroxides at the fluctuation boundary of surface water (Augustin et al., 2013, Nazar and Rodrigues, 2019b). The water weathering processes and the role of water in the hydrolysis reactions, generate the depolymerization of the silicate structure, with the release of silicon and basic Cations from the weathered solution. Therefore, according to the intensity of the hydrolysis (total or partial) and the leaching processes, there may be formation of non-silicate minerals: iron hydroxides and oxides (Atkins, 2002).

These minerals contribute to the typical red or yellowish color of their formations. Intense water flow in the fluctuation boundary, may result in a proportionally expressive leaching process. This could promote the complete sediment desilication, leaving behind only aluminum or iron minerals causing the formation of crusts.

The same processes are also found in quartzite environments outside Brazil, as Meyer et al (2020) describes in studies from Tibet. In this case, the authors state that precipitation of iron hydroxides affects the opacity characteristics and even the penetration of cosmic rays, which can affect the chronological OSL analysis.

Augustin et al. (2014), working at the Espinhaço Mountain Range, found interesting results regarding the chronological analysis of materials originating from quartzite rocks. These authors analyzed a shallow 60cm-thick profile which presented ages between 10506 to 10230 yrs BP from samples at the base of the deposit, ages from 5919 to 5664 yrs BP at 55 cm deep, 2335 to 2152 yrs BP between 25 and 40cm deep and 629 to 519 yrs BP between the surface and 25cm deep. These ages as well as the thickness of the deposits are very similar to the results of our study. This indicates that in this region of Brazil there are predominantly very slow accumulation processes, resulting in shallow mineral deposits and sediments with low organic content.

Santos and Confessor (2020) studied the same region of the Canastra Mountain Range,but focused on the OSL dating of micromorphologies generated by bioturbation. Their findings show deposits with an age of 950 ± 145 yrs BP at 30 cm deep and 2,500 ± 390 yrs BP at 60 cm deep. These ages are also compatible with the findings of our study, as they indicate that the action of bioturbation in the formation of this micromorphology is more recent than most of the deposits analyzed in the current paper.

For this reason, we consider that the action of bioturbation appears more recently than the beginning of the quartzite weathering processes. It is only after the beginning of these processes that there is sufficient material for the animals to initiate bioturbation processes.

Both the chronological data analyzed in this paper and the chronology carried out in similar environments in central Brazil (Augustin et al. (2014); Ledru (1993), Oliveira et al. 2018, Santos and Confessor (2020), show that colluvial materials are recent. This could indicate that at the end of the Pleistocene and beginning of the Holocene, this region probably presented a drier environment than the current climatic conditions (Barros et al., 2012). The low availability of water would favor chemical weathering processes and it is also worth noting that the weathering of quartzitic rocks is far slower than other rock types. For these reasons, rocky outcrops would probably be more widespread than at present time.

Paleoclimatic studies from nearby regions indicate that during the Holocene climatic conditions were generally more humid than during the Pleistocene (Behling, 1995, Behling, 2002; Ledru 1993). The Holocene also presented some fluctuations that indicate drier moments than the present day (Enters et al, 2010).

These conditions contribute to changes in the water regime and an increase in weathering and downslope sediment transport, which generate colluvium deposition. We can assume that with the increase of humidity and the availability of seasonal water, there was an increase of subsurface hydrogeochemical processes, that contributed to the formation of ferruginous crusts, as well as some interesting surface dissolution features.

The establishment of a more humid environment during the Holocene climatic optimum probably increased the colonization of vegetal and animal species, which in turn contributed to the formation of some peat deposits in depressions or valley floors and the enrichment of organic material in surface layers of coarse quartzite and sands. The maintenance of humid climatic conditions towards the present, allowed the generation of micromorphologies from bioturbation (Santos and Confessor, 2020). This interpretation is also supported by changes in the fluvial systems in the region (Carvalho et al. 2018; Magalhães Jr, at al. 2012; Oliveira et al. 2018).

CONCLUSION

The combined results of granulometry, ^{14}C, and OSL, supported by field observation and geomorphic analysis seem to indicate that the sediments of the hilly landforms in the Canastra Mountain Range are made up of colluvium from the outcrop of quartzite rocks located in higher areas. Our study also showed that these colluvial deposits are normally very shallow (less than 2m thick) with predominantly coarse characteristics, mainly gravels and sands. We observed several quartzitic outcrops in the middle of the deposits and the presence of lateritic ferruginous concretions, either on the surface, or at levels within the superficial soil horizons. The results of the sample chronology indicate that the deposition environment is recent and OSL and ^{14}C dating indicate that most of the deposits belong to the Holocene. Only two samples, which are from the end of the Pleistocene, reached older ages. The existence of such young deposits underlines a change in the humidity patterns, the weathering processes and the formation of colluviums related with short distance sediment transport. The present warmer and humid climatic conditions tend to produce changes in the preservation of the weathering mantles which cause an increase of surface erosion and even the formation of drainage systems. Most of the vegetation cover is considered recent, with the formation of peat deposits which do not exceed 4460 ± 30 yrs BP. The presence of bioturbation micromorphologies with younger ages than the colluvial materials, indicate that these types of processes can only occur after more intense weathering periods, caused by an increase of humidity during the Late Holocene.

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