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Subsurface features of areas in the vicinity of a granite quarry in the town of tracuateua (Pará, Brazil), based on ground penetrating radar (GPR) data

Características de subsuperfície de áreas próximas a uma pedreira de granito na cidade de tracuateua (Pará, Brasil), com base em dados de radar de penetração no solo (GPR)

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ABSTRACT

An underground deposit of granite in the municipality of Tracuateua, in the Brazilian state of Pará, is being quarried by the Santa Mônica Mining Company for the extraction of raw material for the local construction sector. This deposit is exploited in traditional fashion, by using dynamite to dislodge the rock. This activity appears to have caused cracks in buildings in the region, as well as degrading features of its ground, landscape, and relief, and even contaminating one of the the principal local rivers. In the present study, the Ground Penetrating Radar (GPR) tool was used to evaluate the structure of the subsurface and possible environmental impacts caused by quarrying with dynamite at the study site.

Key words: Geological structures, faults, water table, degradation, environmental impact, energy dispersion.

RESUMO

Um depósito subterrâneo de granito no município de Tracuateua, no estado brasileiro do Pará, está sendo extraído pela mineradora Santa Mônica para a extração de matéria-prima para o setor de construção local. Esse depósito é explorado da maneira tradicional, usando dinamite para desalojar a rocha. Essa atividade parece ter causado rachaduras nos edifícios da região, além de características degradantes do solo, da paisagem e do relevo, e até mesmo contaminar um dos principais rios locais. No presente estudo, a ferramenta Radar de penetração no solo (GPR) foi usada para avaliar a estrutura da subsuperfície e os possíveis impactos ambientais causados pela extração de dinamite no local do estudo.

Palavras-chave: Estruturas geológicas, falhas, lençol freático, degradação, impacto ambiental, dispersão de energia.

1. INTRODUCTION

The contamination of underground water sources is one of the principal risk factors for the quality of the environment. Contamination may result from a number of human activities, including the digging of wells, the lack of adequate public sanitation systems in areas of urban development, the inadequate disposal of solid waste, the unregulated application of fertilizers and pesticides on farmland, the discharge of contaminated effluents by local industries, leakage of hydrocarbons into the ground, the contamination of the subsoil by leachate from cemeteries, and quarrying at inappropriate sites (modified from Zoby, 2008). Although quarrying may have devastating effects on local landscapes, few data are available on the environmental impacts of this activity.

Quarries may cause a number of different types of impact on the environment (Bacci et al., 2006), including the degradation of the landscape, atmospheric pollution caused by dust clouds, and the siltation and blockage of watercourses. Quarrying may also modify geological processes, such as erosion and hydrogeological dynamics, as well as altering geomorphological features and hillsides, impacting the local fauna and flora, and affecting the health of local residents.

The use of explosives in quarries may have a number of social and environmental impacts, which will vary in intensity, depending on the location, the mining technique, the type of material extracted, and the disaggregation process. All these activities may contribute to the physical and chemical degradation of local soils and substrata, given that the use of explosives and other substances may alter the structure of rocks (modified from Mendes et al., 2013).

Aviz and Pinheiro (2013) discussed the environmental impacts caused by the exploitation of mineral resources in Tracuateua (Pará), based on data collected using oral interviews, photographic records and observations. This study found that the exploitation of local deposits of sand and gravel has resulted in the visual degradation of the ground, the landscape, and local relief, as well as the intensification of erosive processes, which have impacted the course of the Quatipuru River, and also demonstrates what actions the public authorities have taken to restrict these impacts.

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In the present study, the geophysical tool, Ground Penetrating Radar (GPR), was used to survey the environmental impacts and other problems caused by the use of explosives by the Santa Mônica Mining Company to quarry granite in the town of Tracuateua, northeastern Pará (Brazil).

2. MATERIALS AND METHODS

2.1. STUDY AREA

The study area is located in the municipality of Tracuateua, in the northeastern extreme of the Brazilian state of Pará (Fig. 1), approximately 169 km from the state capital, Belém. The municipality is located at 01°58'12.48" S, 46°56'29.97" W, and has a total area of approximately 934.272 km^2 (IBGE, 2013).

Quarrying is the principal economic activity in this municipality, given the presence of a number of deposits of granite, which are exploited by the Santa Mônica Mining Company (*Santa Mônica Mineração Ltda.*) from open-cast pits using dynamite on a daily basis (Palheta et al., 2009). These explosions not only disturb the bedrock, but also damage buildings and equipments, as well as causing objects in local residences to shake or fall to the ground. Three sites were selected within the region for the collection of geophysical data (Figure 1). These sites are located in the vicinity of the Santa Mônica Quarry, and approximately 3 km from the center of the town of Tracuateua.

2.2. GROUND PENETRATING RADAR (GPR)

Ground Penetrating Radar (GPR) is a geophysical tool based on the emission of high frequency (10 MHz to 2.5 GHz) electromagnetic waves to obtain high-resolution images of objects, structures or interfaces in the subsurface (Davis and Annan, 1989).

The GPR system consists of a signal generator (control box), two antennas (one [Tx] for transmission and the other [Rx] for reception), and a datalogger for the digital recording of the data. The source-receptor configuration of the GPR was of the common offset type. The data were collected at three sites in two months of 2017, representing the rainy (February) and dry (July) seasons.

3. RESULTS AND DISCUSSION

One radargram survey was conducted in the vicinity of the Santa Mônica Quarry in Tracuateua (profile 1), with a W-E direction, using transmission antennas of 200 Mhz and 400 Mhz, and time windows of 100 ns, 150 ns, 200 ns and 250 ns, respectively. This first profile was surveyed in the rainy season (February) of 2017, and was 45 m long (Fig. 2).

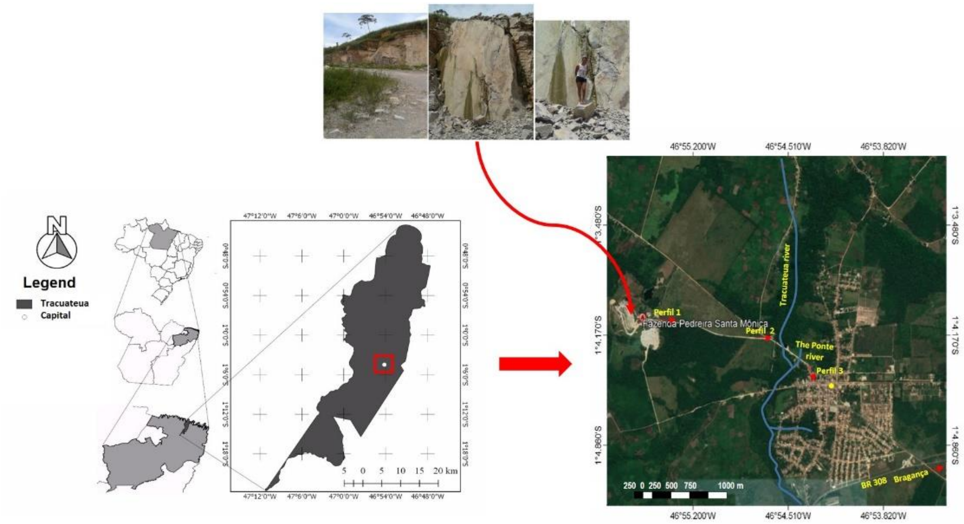

Fig. 1. Map of the GPR data collection sites in the town of Tracuateua, Pará (Brazil). Source: Adapted from IBGE (2013) and Google Earth, 2017.

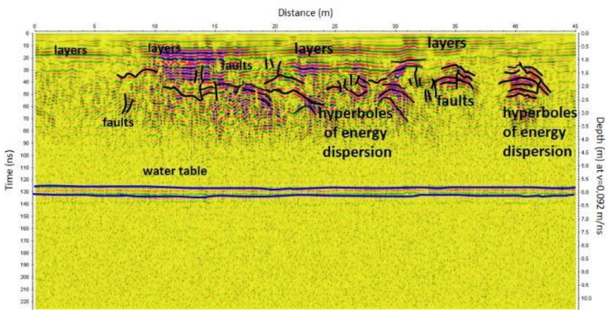

Fig. 2 - Radargram of profile 1 (near the Santa Mônica Quarry, 200 Mhz antenna, 250 ns time window, rainy season, 2017).

In the upper part of profile 1 (Fig. 2), a set of layers was detected at depths of 0 - 1 m. Minor faults were also identified at depths of around 0.5 - 4 m. Distinct hyperboles of energy dispersion were also observed within this stratum, which may indicate the presence of material either in a deposit or buried at the site. One important feature of this profile is the existence of a strong horizontal reflexion at a depth of 6 m, which is associated with the water table, as determined by Santos et al. (2018) and confirmed by the local excavators of artesian wells.

The same profile (1) was surveyed in the dry season (July) of 2017 (Fig. 3), also in a W-E direction, with the same technical specifications of the rainy season profile.This profile (Fig. 3) revealed the same features recorded in the previous profile (Figure 2), that is, the faults, hyperboles of energy dispersion, and the presence of the water table. This 45 m profile also revealed the presence of faults near the surface, at depths of 0 - 1 m. The water table was shallower (no more than 5 m in depth) in comparison with the first profile.

The second GPR profile (profile 2) was obtained from the vicinity of da Ponte River (Fig. 1). In this case, the survey was conducted in an NW-SE direction using the same transmission antennas (frequency of 200 Mhz and 400 Mhz) and windows of 100 ns, 150 ns, 200 ns and 250 ns, respectively. This profile was obtained in the rainy season (February) of 2017, and was also 45 m long (Fig. 4).

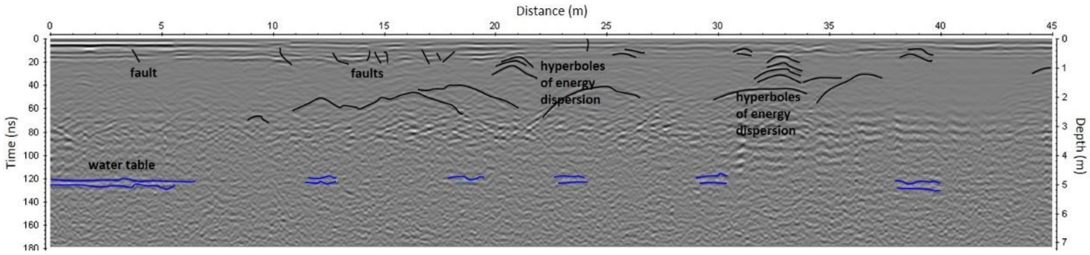

Fig. 3 - Radargram of profile 1 (near the Santa Mônica Quarry, 200 Mhz antenna, 200 ns time window, dry season, 2017).

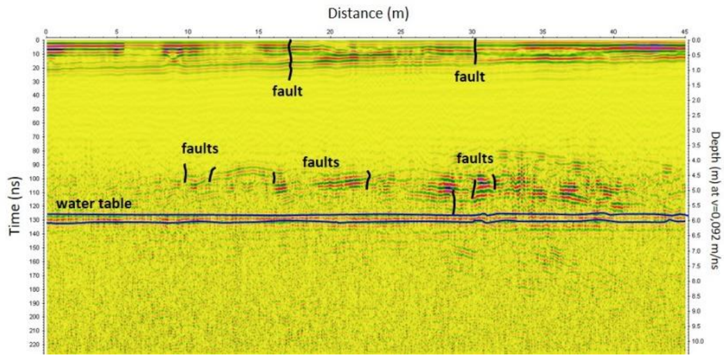

Fig. 4 - Radargram of profile 2 (near of da Ponte River, 200 Mhz antenna, 250 ns time window, rainy season, 2017).

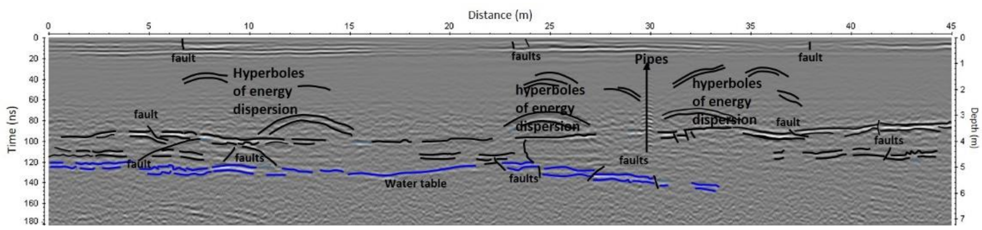

Fig. 5 - Radargram of profile 2 (near the Ponte River, 200 Mhz antenna, 200 ns time window, dry season, 2017).

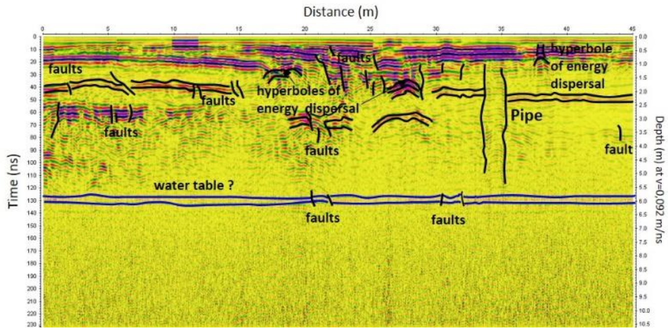

Fig. 6 . Radargram of profile 3 (near the town of Tracuateua, 3 km from the Santa Mônica Quarry, 200 Mhz antenna, 250 ns time window, rainy season, 2017).

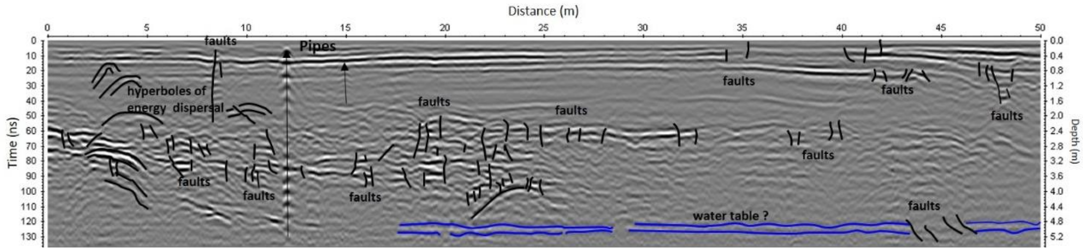

Fig. 7 - Radargram of profile 3 (near the town of Tracuateua, 3 km from the Santa Mônica Quarry, 200 Mhz antenna, 250 ns time window, dry season, 2017).

As in profile 1, a set of layers were found at depths of between 0 m and 1 m in profile 2 (Fig. 4). Similarly, small vertical faults were found within this set of layers. No structures or layers were detected at 1–3.5 m, but between 3.5 m and 5.75 m, the survey identified layers with curved interfaces and a small dip. At a depth of around 6 m, a strong horizontal reflexion was detected, which corresponds to the water table detected in profile 1. The profile was surveyed again by GPR during the dry season (July) of 2017 (Fig. 5).

This profile confirmed the same characteristics detected near the surface (Fig. 5), with the difference that hyperboles of energy dispersion that may be related to buried material. A strong reflexion was detected at a depth of between 3 m and 4 m. A pipe was also detected at approximately the 30 m marker, which was possibly in contact with the apparent water table.

The third profile was located near the town of Tracuateua, approximately 3 km from the Santa Mônica Quarry, with the same specifications as the previous ones (transmission antenna frequencies of 200 Mhz and 400 Mhz, and time windows of 100 ns, 150 ns, 200 ns and 250 ns). Like profile 2, this profile was also surveyed in a NW-SE direction. The survey was conducted along a 45 m profile in the rainy season of 2017 (Fig. 6).

As in the previous profiles, this survey (Fig. 6) detected a set of layers close to the surface, which contained faults. Similarly, hyperboles of energy dispersion were identified, which may be related to buried material. The water table was confirmed at a depth of 6 m, as in the previous profiles. The same features just below the surface were also confirmed in the dry season profile (Fig. 7), as were the faults near and below the surface. Similarly, hyperboles of energy dispersion were detected, that may be related to buried material. A strong reflexion was recorded at a depth of between 4.8 m and 5 m, which is probably related to the water table detected in the previous profiles. Evidence was also found of a buried pipe (see Fig. 7) at the 12 m marker, approximately.

4 CONCLUSIONS

The use of the geophysical Ground Penetrating Radar (GPR) tool provided reliable data on the feature of the subsurface in the region surrounding the Santa Mônica Quarry in the town of Tracuateua, in Pará (Brazil).

A series of small faults (vertical and normal) were detected in a set of layers near the surface, at a depth of 0–1 m. These faults were detected in most of the radargrams. Hyperboles of energy dispersion were also found, which may be related to the presence of material deposited or buried in all the profiles.

A strong horizontal reflexion was also identified, at depths ranging from 5 to 6 m, depending on the site, which corresponds to the water table in the study area.

The variation in the depth of the possible water table may be associated with the local topography, in particular the presence of deposits of granite.

The features detected in the radargrams, such as faults and hyperboles of energy dispersion were identified in both seasons (rainy and dry). The possible presence of buried pipes in the vicinity of the water table was also detected in this study.

The presence of the faults may be associated with the activities at the Santa Mônica Quarry, where explosives are used to mine the granite deposit. According to local residents, explosions occur continuously throughout the week, often up to 18:00 h. These explosions cause tremors that impact the houses in the vicinity of the quarry.

During the GPR surveys, it was possible to cofirm personally the presence of cracks in the walls of houses in the town of Tracuateua, which may be related to the use of explosives for the extraction of granite at the Santa Mônica Quarry.

Brazilian Journal of Development

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