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14363: Slope stability assessment based on a Digital Outcrop Model: a case-study at Jardim Garcia quarry

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INTRODUCTION

Natural rock masses present different geological risks and interesting grades to the climbing practice. The quarries have a considerable potential for climbing sport and outdoor activities because of their location near to urban centers, easy access by roads and parking spots. However, the “artificial” rock masses, beyond the geological-geotechnical properties, have fissured and damage zones produced by drilling and blasting operations, which deserve even more attention in the rehabilitation for use with another purpose.

The Jardim Garcia quarry is composed of mafic intrusive rocks from the Serra Geral Formation, Paraná Basin. Together with the Dib and São Roque comprise some of the deactivated quarries used to climbing close to Campinas and São Paulo metropolitan regions, Brazil, (Figure 1a). Among the quarries, the west wall of Jardim Garcia area was chosen due to recent removal of blocks by climbers and to be a potential zone of falling of blocks (Figure 1b-c). It is a 23 m high and 195 m long SSE-NNW rock wall with 38 mapped climbing routes (or craigs).

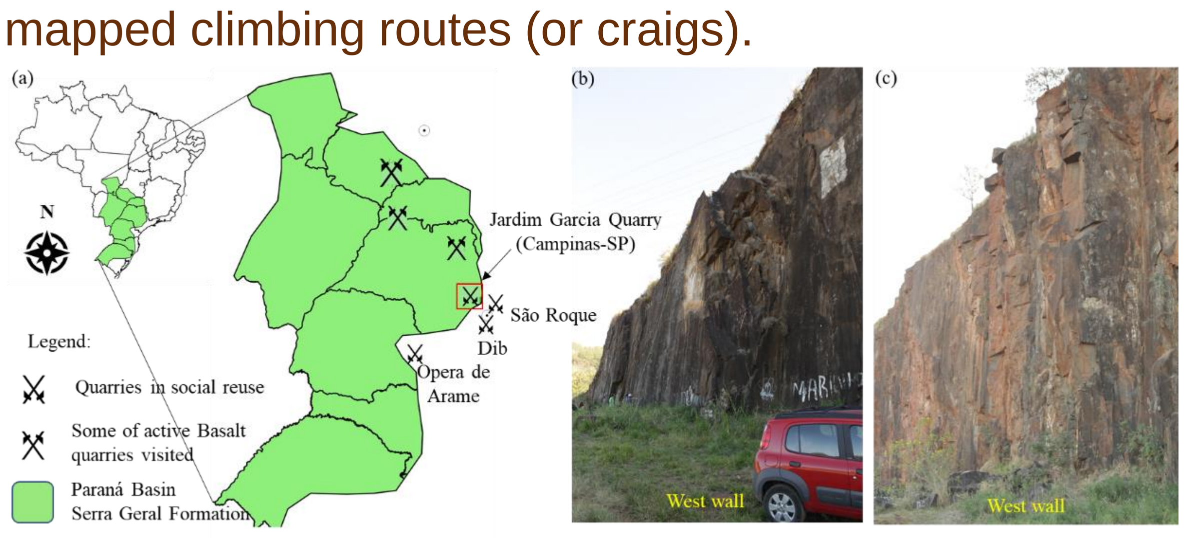

Figure 1. Location site of Jardim Garcia quarry (a) and recent (b) and old (c) traces of block falling in the west wall.

METHODS

3D model was generated using Agisoft Photoscan Professional (Agisoft 2018), and image survey was made with a DJI Phantom 4 Pro drone, for which the flights were planned with the Litchi application (<https://flylitchi.com>). The mission was flown 20 m away from the wall, with 6 flight lines spaced 4 m vertically. For each line, 6 images (at 285, 265 and 250 Az with camera horizontal and inclined -15 degrees) were acquired every 8 m, totaling 540 images, of which 534 were selected for 3D model construction (Figure 2). Images containing features such as sky and vegetation were masked to reduce processing time. For ground control, climbing anchors were surveyed by irradiation from a total station located in a georreferenced polygonal. The polygonal’s georreferenced coordinates were obtained by geodetic GNSS post-processing (Figure 3).

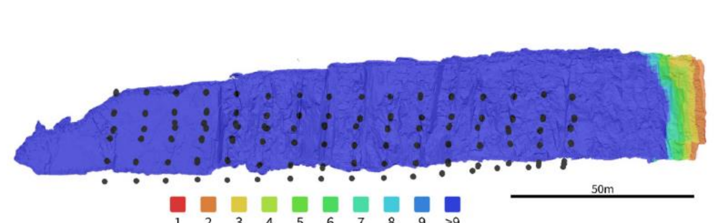

Figure 2. Camera positions (black dots) along lines of flight. Colors represent number of image overlap.

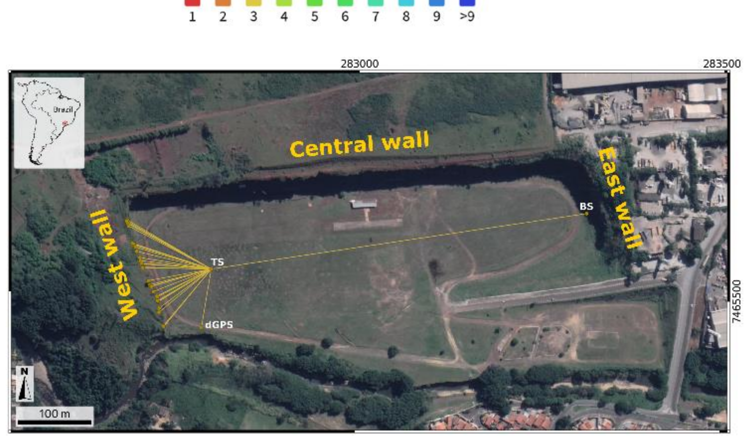

Figure 3. Situation map of Jardim Garcia Quarry with surveyed traverse and control points. TS: Total Station; BS: Backsight; dGPS: GPS base station. Satellite imagery 2018 Digital Globe, powered by Google. UTM coordinates, zone 23 (South), WGS84.

The resulting model was divided into 3 sectors considering field observations and major structures detected on the DOM (Figure 4). For each sector, visible joints were selected using MeshLab and had their attitude and persistence calculated according to the methods of Viana et al. (2016). Results were plotted on stereonets for kinematic analysis. In addition, the recent proposal for rock mass slope classification, Q - Slope (Bar & Barton 2017), was used to classify each sector and integrate the geomechanical classes and failure predictions to the failures modes.

Figure 4. 3D model of the quarry wall with defined sectors (1 - blue, 2 - red and 3 - yellow). Orange lines indicate the sector limits.

RESULTS

The resulting model is a dense cloud with 39.599.660 points and the final mesh comprises 3.996.392 vertices and 7.919.932 faces. DOM analysis showed that slope dip gradually increases towards north from 79 degrees on sector 1 to 83 degrees on sector 3. This is reflected on the increasing difficulty level of climbing routes from south to north as reported by the climbers.

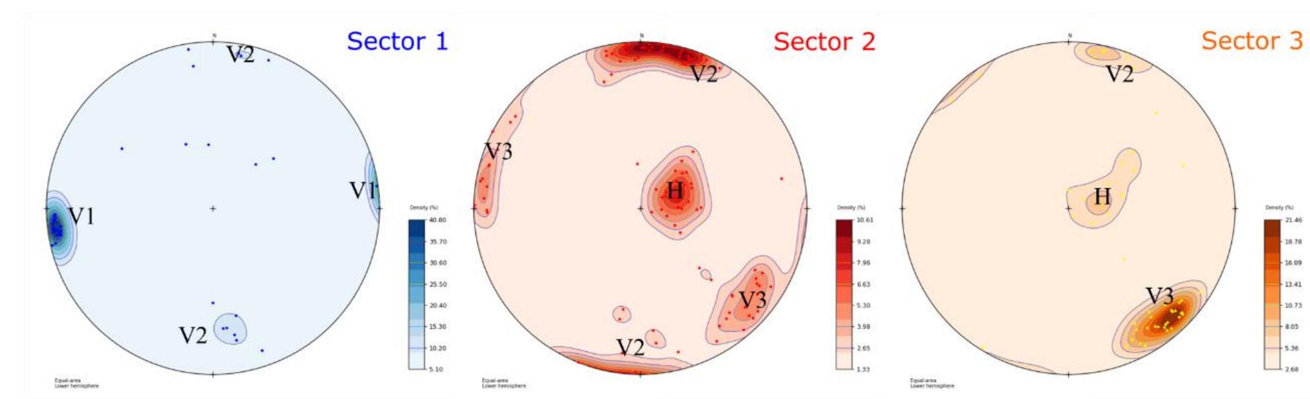

Figure 5. . Stereonets of the three sectors (1, 2 and 3) showing the discontinuity mapping: sub-parallel (V) and sub-horizontal sets (H). Equal area, lower hemisphere.

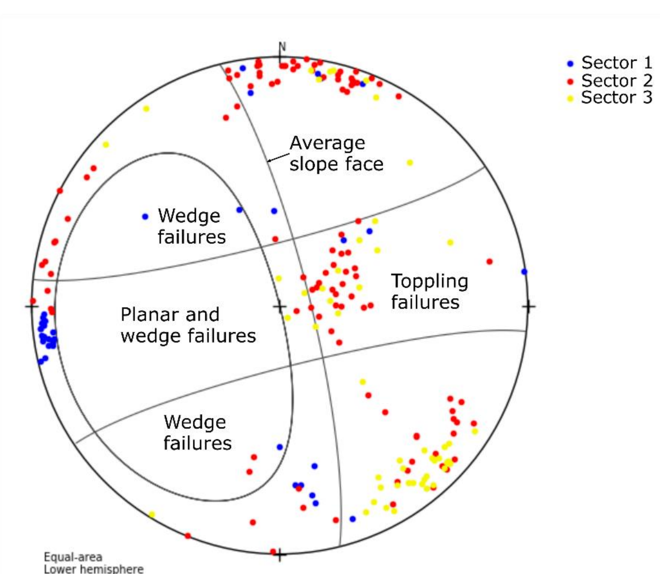

Figure 6. Kinematic analysis of sectors.

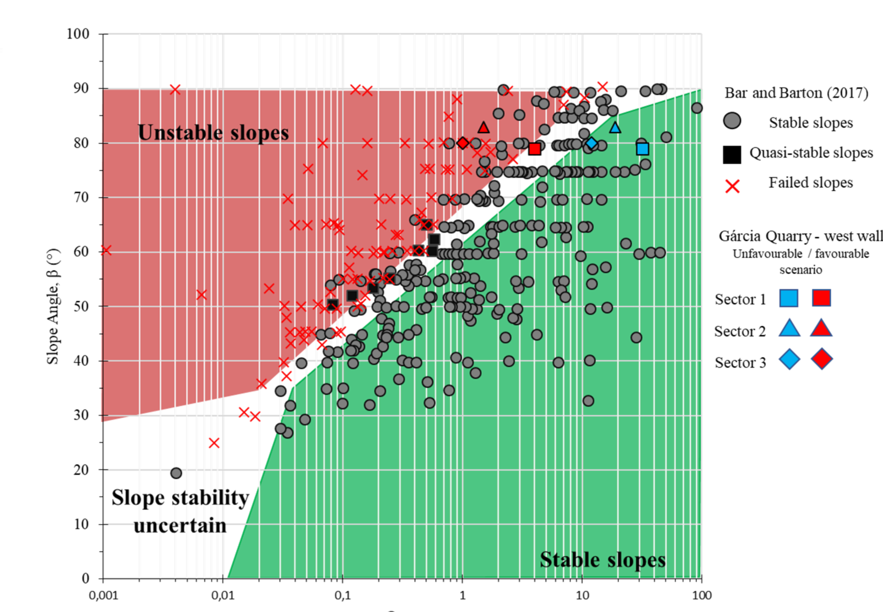

Figure 7. Qslope probability of failure based on unwanted events (failed or quasi-stable slopes) and the quarry sectors classifications.

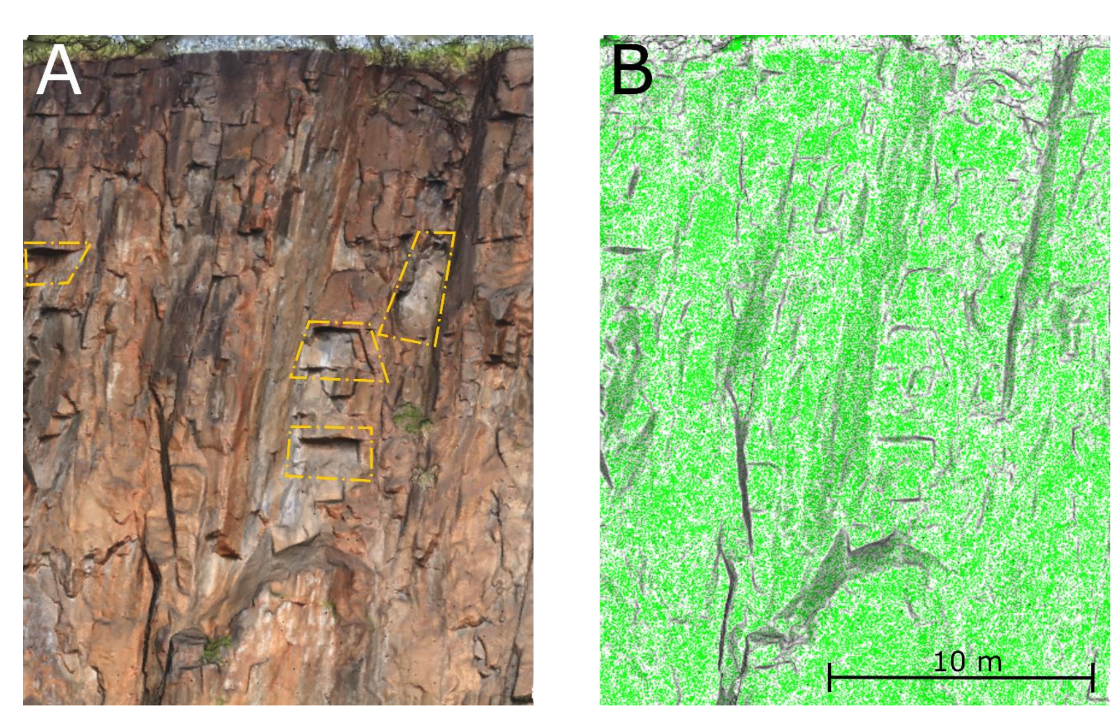

Figure 8. Detail of 3D model of Sector 2: textured mesh (A) and shaded point cloud (B). The removed or the fallen rock blocks are shown with the yellow dashed boxes.

CONCLUSION

The application of DOM on rock slope stability analysis is of great value as it allows a more dynamic visualization of structures and the collection of a large number of structural data.

The kinematic analyses integrated with the Qslope classification raised some geological-geotechnical information, that will guide the actions to be taken to promote the safety of climbing routes. The model applied in this work is flexible and low cost, being easily reproducible and allowing the decommissioning of quarries to be done in a way that promotes their reintegration into society. It is clear that the use of 3D models should be associated to field inspection, but its application provides an additional tool in the geological-geotechnical evaluation.

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