Studying the degree of granite alteration using open spatial data platforms. Case studies: Guarda urban area and Estrela Geopark

Estudio del grado de alteración del granito utilizando plataformas de datos espaciales abiertas. Caso de estudio: área urbana de Guarda y Geoparque Estrela

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Abstract

The continuous reorganization of the territory, whether due to the appearance of new buildings or to the alteration and reformulation of the existing space, requires updated cartographic information. This update is intended to represent the present situation, and the various updates allow us to obtain a territorial history of recognized importance.

In geotechnical cartography, the urban reorganization that includes excavations, foundations, trenching, wells and boreholes, etc., allows the collection of information that constitutes a large collection of data. This territorial reorganization is more urgent in urban areas, however, in rural and natural areas of great geological emphasis, the existence of rocky outcrops and the possibility of identifying and analyzing these rocky outcrops is also of great importance for geotechnical cartography.

The present study analyzes the use of spatial data infrastructures from the free Street View - Google Maps platform, which, duly incorporated in open-source free software (QGIS), allows the elaboration of geotechnical cartography in urban and rural areas.

The case studies presented here refer to the urban area of the city of Guarda and to the rural zone defined as Estrela Geopark (Estrela Mountain), in which granite areas are identified through modules with connection to Google Street View and where the degree of granite alteration is analyzed. The validation of the degree of alteration of the granite is later verified through in-situ observations to validate the assigned classification. Through this methodology and in an expeditious way, it is possible to create geotechnical cartography and the respective database with relevant and complementary information to the existing geological cartography.

Resumen

La reorganización permanente del territorio, ya sea por la aparición de nuevas edificaciones o por la alteración y reformulación del espacio existente, requiere una información cartográfica actualizada. Esta actualización tiene como objetivo representar la situación actual y las diversas actualizaciones nos permiten obtener una historia territorial de reconocida importancia.

En la cartografía geotécnica en particular, la reorganización urbana, que incluye excavaciones, cimentaciones, zanjas, pozos y perforaciones, etc., permite la recolección de información que constituye una gran colección de datos. Esta reorganización territorial, es más urgente en las áreas urbanas, sin embargo, en áreas rurales y naturales de gran énfasis geológico, la existencia de afloramientos rocosos y la posibilidad de identificar y analizar estos afloramientos rocosos también es de gran importancia para la cartografía geotécnica.

El presente estudio analiza el uso de infraestructuras de datos espaciales de la plataforma gratuita Street View - Google Maps, que, debidamente incorporada en software libre de código abierto (QGIS), permite la elaboración de cartografía geotécnica en áreas urbanas y rurales.

Los casos de estudio aquí tratados hacen referencia al área urbana de la ciudad de Guarda y al área definida como Geoparque Estrela (Serra da Estrela), en la que se identifican áreas de granito mediante módulos con conexión a Google Street View y donde se analiza el grado de alteración del granito. Posteriormente se verifica la validación del grado de alteración del granito mediante observaciones in situ para evaluar la clasificación asignada. A través de esta metodología y de manera expedita, es posible crear cartografía geotécnica y su respectiva base de datos con información relevante y complementaria a la cartografía geológica existente.

Keyword: GIS, Cartography, Geology, Open Source Platforms.

Palabras clave: SIG, Cartografía, Geología, Plataformas de código abierto.

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1. INTRODUCTION

According to the International Association of Engineering Geology (IAEG), geotechnical cartography is a type of geological cartography that classifies and represents the components of the geological environment that influences engineering, planning, construction, exploration and preservation activities, allowing the formulation of predictive models of land behavior and the study of solutions to problems arising from anthropological intervention on the physical environment (Diniz, 1998). The elaboration and updating of this or any other type of cartography depends on obtaining data, as well as the associated methods of data acquisition. In the case of geotechnical cartography, the associated methods must encompass the traditional methods of geological engineering, completed with indirect prospecting methods and direct prospecting methods (Table 1), according to the type and objective of the map and the complexity of the area under study (Pereira, Costa. 2011). Traditional methods (e.g. boreholes) make this phase very time consuming and expensive.

The spread of Geographic Information Systems (GIS), intensified in the last decades, has provided a significant advance in the development of geotechnical cartography through the use of geographic databases and new analysis tools (Rodrigues Carvalho et al., 2010), in addition to the emergence of web platforms that provide cartographic information (e.g. Google Maps, Bing Maps, Open Street Map). The information and data provided by these platforms must be evaluated in order to verify their potential contribution.

This work intends to demonstrate that geotechnical cartography can be elaborated using geographic information from free platforms and free and open source software. The work was developed for the delimitation of areas identifying the degree of alteration of rock masses, in particular the degree of alteration of granite, through modules connected to the Google Street View platform using the GIS - QGIS software version 3.0.1.

The characterization of the properties of the rocky environment is essential because it conditions the demands imposed by a construction site (ABGE, 2010). These characteristics vary from place to place, depending on the geological history of the region considered and the degree of alteration of the rock mass. The classification of lands, from the point of view of Geology for Engineering, is of special importance when these lands are intended to be used by Civil Engineering. This classification must be universal, regardless of the geologist's opinion,

Table 1. Methods for obtaining geotechnical data

Method	Data for geotechnical cartography
Photointerpretation and remote sensing	- Cartography of soils and rocks - Geological structures - Hydrology and drainage networks - Dynamic processes
Recognition and collection of field data	- Geological and geomorphological aspects - Geological-geotechnical data and measurements
Geophysical methods	- Electrical resistivity: - Porosity, fracture, saturation, salinity - Depth of the water table - Depth of rocky substrate - Seismic: - Density, deformation module - Degree and depth of altered zones - Depth of rocky substrate
Drills, ditches and samples	- Collection of representative samples - Direct observation of materials - Physical properties and characteristics of the terrain - Hydrogeological conditions
"In situ" tests	- Resistance and deformational properties - Natural stresses - Permeability, water pressure - Data from tests in polls
Laboratory tests	- Physical and mechanical properties of materials

based on quantifiable parameters based on observations, and simple and expeditious tests.

The first classification of geological materials from the point of view of Engineering Geology, as well as in Civil Engineering, is in:

- Earth massifs / Soils: lands that disintegrate when agitated in water. The soil classification criteria are universally accepted and studied in the field of soil mechanics.
- Rock massifs: There is still no unanimous classification, but two groups were created, one in 1972 from the International Society for Rock Mechanics (ISRM) and another in 1975 from the International Engineering Geology Association (IAEG), with the aim to establish a classification system that would be accepted internationally.

From the point of view of geology for engineering, land classification should be based on either geological criteria or parameters that aim at practical applications in the field of civil engineering. In most cases, it seems appropriate to consider five degrees of change in rock masses as outlined in the following table (Table 2). This was the classification used in the work exposed here for the degree of alteration of the rock masses, in particular for the degree of alteration of granite, since the case studies are located in granite zones.

2.STUDY AREAS

The case studies presented here refer to the urban area of the city of Guarda (Figure 1) and the area defined as Estrela Geopark (Figure 2). The urban area of the city of Guarda is located on the largest granite outcrop in Portugal. It is inserted in a mountainous, granitic region, with affluent bare rock, which sometimes gives rise to a thin, sandy soil. The rock mass is very fractured and eroded due to the continuous and prolonged action of physical agents, namely the ice and thaw cycles and the displacements caused by the rejection of the NE-SW orientation failures, e.g., straight tectonic valleys of some tributaries of the Mondego and Zêzere rivers - the Caldeirão and Gaia streams respectively.

The zone defined as UNESCO's world geopark Estrela (UGGP), is located in the center of Portugal, has an area of 2216 km^2, comprises 9 municipalities (Belmonte, Celorico da Beira, Covilhã, Fornos de Algodres, Gouveia, Guarda, Manteigas, Oliveira do Hospital and Seia), is deeply marked by the heritage of the mountain, and the mountain itself is the binding element. The Estrela UGGP also includes the entire protected area of Serra da Estrela natural park, which corresponds to about 40 % of the territory classified by UNESCO.

The Estrela UGGP has a geological and geomorphological heritage of national and international scientific relevance, with special emphasis on the marks of the last glaciation. Its geodiversity is mainly composed of a wide variety of hercynian granitic rocks, between the ages of 340 and 280 million years old, and of metasedimentary formations - mainly schist and gradevaques - that date back to around 1 billion years.

The heart of the Estrela UGGP is Serra da Estrela, a predominantly elongated plateau mountain with SW-NE direction and bounded by two large fault cliffs that separate it from the foothills of the upper Mondego (NW) and Cova da Beira (SE). The granitic terrains reveal well-preserved plateaus, with linear tectonic control valleys. The metasedimentary areas show deep and winding valleys, with a dense drainage network.

Figure 1. Urban area of the city of Guarda represented by the red dashed line

Table 2. Degree of alteration of rock masses, ISRM (1978, 1981)

CLASSIFICATION	DESIGNATION	CHARACTERISTIC
W1	Sane	Without any signs of change
W2	Slightly altered	Signs of change only at the limits of discontinuities
W3	Moderately altered	Visible change in the entire rock mass but the rock is not friable
W4	Very altered	Visible change in the entire rock mass and the rock is partially friable
W5	Decomposed (gravel)	The rock massif is completely friable with soil behavior

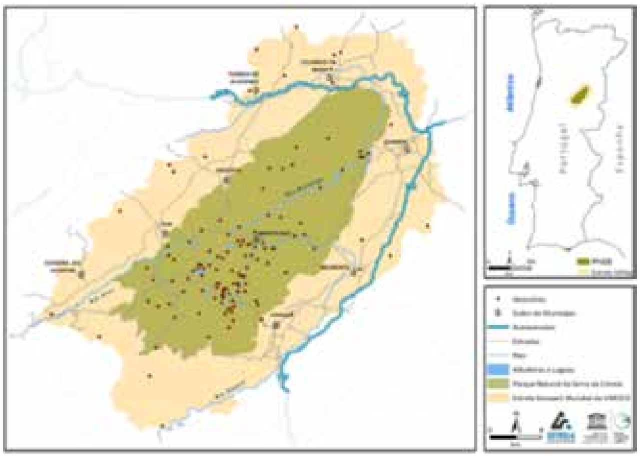


Figure 2. Area defined as Estrela Geopark represented by beige colour

3. METHODOLOGY

Taking into account the objectives referred to in the Introduction section, the possibility of collecting geographic information of geological and geotechnical interest was investigated from open access platforms, namely the Street View of Google Maps. To this end, the "go2streetview" plugin was installed in QGIS, thus making it possible to check the existing coverage for a given area and to browse these areas by accessing images with great proximity and high resolution. Figure 3 presents an example of an image from the Street View platform. Figure 4 presents an example of integration of the Street View platform in a QGIS environment where it is possible to verify the existence of excavations at the time that the Street View observation campaign was carried out. Figure 5 presents, as an example, the Street View coverage for the case study of the urban area of the city of Guarda. This will always be the first analysis to be carried out: check the coverage density and evaluate the amount of information that can be extracted according to the objectives. The density of Street View coverage varies from zone to zone as well as the information that can be considered relevant according to the objectives. It should also be noted that Street View presents a history of the various observation campaigns, and that the density of coverage and the quality of information (photos, resolution) has been improving, and this is what is expected to continue to happen in future campaigns. Sometimes, during observation campaigns, it is possible to find areas under excavation, as shown in Figure 4, which also allows obtaining relevant information for geotechnical cartography.

After assessing the coverage density, the process of analyzing the images provided by the platform begins. These images are analyzed in order to ascertain the possibility of identifying the degree of alteration of the rock mass. If so, the respective areas are vectored (Figure 6) and their classification is added as well as additional information that is considered relevant.

Figure 3. Example image in Street View - Google Maps

Figure 4. Example of Street View integration in the GIS software *- QGIS*

Figure 5. Street View coverage for the urban area of the city of Guarda

In order to optimize this process, forms were created to facilitate data filling in the respective fields of the attribute table, allowing that, when a graphic element is created, the data that characterizes that element are simultaneously inserted. Thus, in relation to the subject in question, the degree of alteration of granite, the following fields were created: 1) ID; 2) Degree of Alteration of Granite; 3) Entry Date; 4) Current Photo (photo of the area under study captured by Google or otherwise). Figure 7 represents an example form for a given zone.

After the entire area being characterized and classified and in order to evaluate this methodology, that is, the use of Google Street View as an useful and efficient method in the collection of data for the characterization of rock masses, in

Figure 6. Vectorization and classification of changes in rock masses

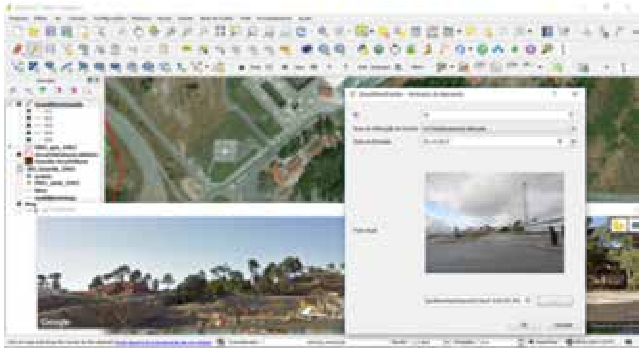
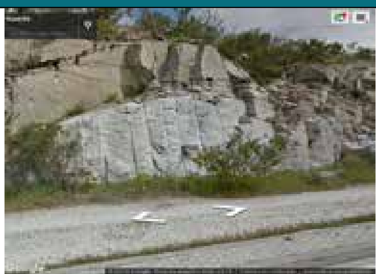


Figure 7. Creation of the graphic element and respective form in QGIS environment

situ observations and respective photographic documentation were made from all points where Street View images had been classified. A table was built with the Street View image and the respective photograph taken on the spot to compare

Table 3. Comparative table between Street View images and In Situ photography's.

Photo Street View	Photo In Situ
	
	
	
	

both methods. Some examples can be seen in the following table (Table 3).

This approach and the methodology here applied/developed to determine the degree of alteration of granite can be applied to other themes (e.g. land use), with the aim of replicating it in other mapped areas or spaces, contributing to the updating and improvement of the generation of geotechnical thematic maps, helping in the decision and planning phase, and in construction and sustainability.

4. RESULTS AND DISCUSSION

The methodology described in the previous section was applied to two case studies: I) Urban area of the city of Guarda and II) Estrela Geopark. The results are presented below.

4.1. CASE STUDY I - URBAN AREA OF THE CITY OF GUARDA

169 images were collected through Google Street View where it was possible to identify and classify the rock mass. In total, 513 polygons were defined (Figure 8) that were classified with the following distribution: 5 polygons with W1 (which represents 1 %); 52 polygons with W2 (10.1 %); 68 polygons with W3 (13.3 %); 44 polygons with W4 (8.6 %) and 344 polygons with W5 (67.1 %). The graph in Figure 9 illustrates the distribution of the polygons according to the respective degree of change in the rock mass.

For validation purposes, in situ observations and respective photographic documentation were made of all the places from which 169 images with Street View had been collected and which later gave rise to 513 classified polygons.

The graph in the following figure (Figure 10) shows the distribution for each degree of change in the rock mass through Street View and in situ observations.

As we can see, there were no significant differences between the two methods. From the analysis performed, it was found that 89.9 % of the points were properly classified, there were 17 points (10.1 %) where the classification was changed.

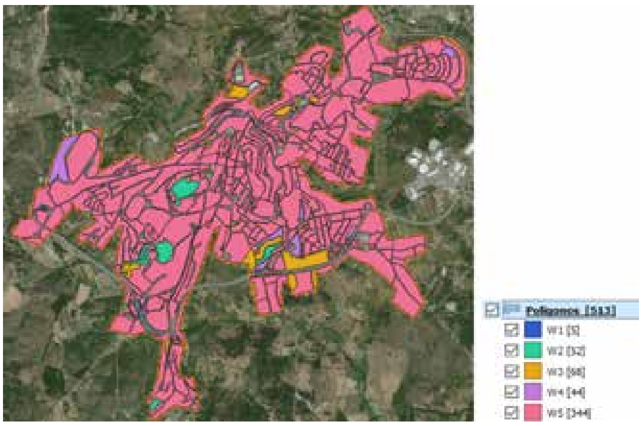


Figure 8. Areas with delimitation of the degree of alteration of the rock mass in QGIS.

Of the total 17 changes, 6 were from grade W4 to W3 (3.6 %), 5 from grade W2 to W3 (3.0 %), 1 from grade W1 to W2 (0.6 %), 1 from grade W3 for W4 (0.6 %), 1 of grade W3 for W4 (0.6 %), 1 of grade W3 for W2 (0.6 %), 1 of grade W3 for W5 (0.6 %), 1 of grade W4 to W5 (0.6 %), and grade 1 W4 to W2 (0.6 %), as shown in Figure 9. It can also be seen that the changes were mostly of only one classification grade and that occurred more frequently in grade W2 for W3 and in grade W4 for W3.

It was verified that the observed points adequately present the classification given without previous confirmation (in situ). It can be inferred that, for this area, this method allows an initial approach with good results and it can be a way to bridge the existing data fulfilling the observations gaps.

These results can be cross-checked with other data, e.g., ex. slope of the terrain, in order to calculate the degree of danger in terms of slope instability. To this end, a hazard chart and respective hazard scale were generated based on the slope of the terrain and the degree of change in the rock mass (Figure 12). Not being the objective of the study, it serves only as an example to highlight possible contributions.

4.2. STUDY CASE II – ESTRELA GEOPARK

Figure 13 shows the zone defined as Estrela Geopark and where it is possible to view the respective Street View coverage represented by the yellow line. The same methodology

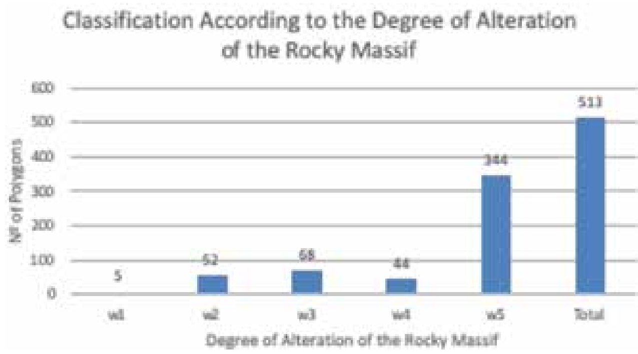


Figure 9. Distribution of the classification of the degree of alteration of the rock mass in 513 polygons defined for the urban area of the city of Guarda

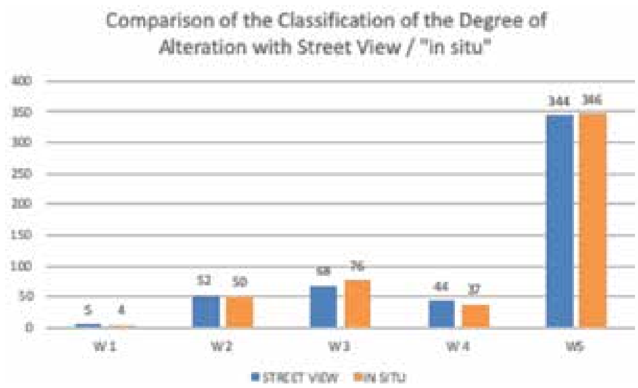


Figure 10. Comparison of the degree of alteration of the rock mass, polygons of the urban area of Guarda

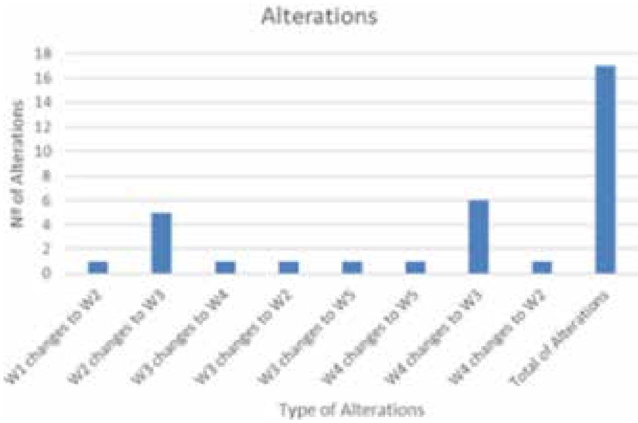


Figure 11. Distribution of altered classification grades

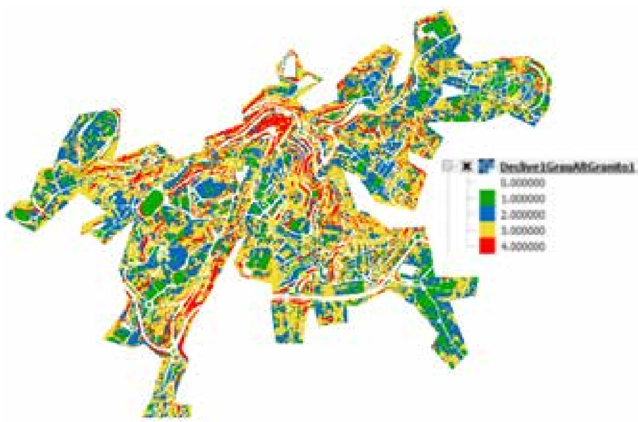


Figure 12. Hazard chart resulting from the slope with the degree of granite alteration.

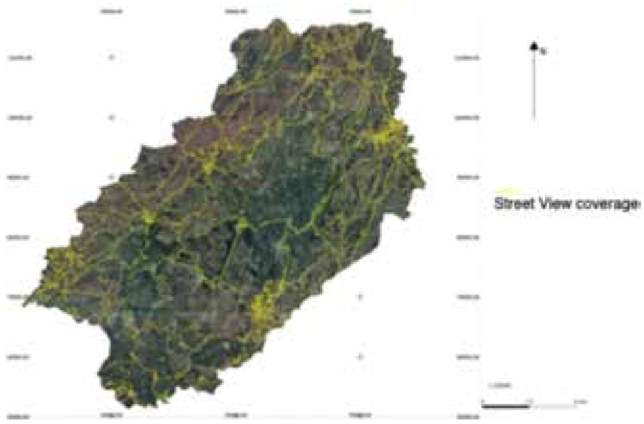


Figure 13. Street View coverage represented by the yellow line for Estrela Geopark

previously described was applied and the areas covered by Street View were analyzed, vectorized and classified. In total, 339 polygons were defined with the respective classification of the degree of alteration of granite.

For validation, in-situ observations were made with the respective photographic documentation of all the points where the images had been collected using Street View. The graph in Figure 14 shows the distribution of the number of polygons and the respective assigned classification and the graph in Figure 15 compares to the results with the in-situ observations.

The graphic shows that there were no significant differences between the two methods. The areas observed via Street View were adequately classified without prior confirmation (in situ).

5. CONCLUSIONS

This work demonstrated the possibility of creating a geographic information base for the elaboration of geotechnical/geological cartography using cartographic sources from open platforms, together with open source software.

Although there are some limitations: a) one is inherent to the subjectivity of the classification of the degree of alteration of the rock mass, as it is dependent on the observer. However, being the same observer, this subjectivity is applicable in both situations (Street View observation and in situ observation), and there is a balance in the criteria. b) other limitations are associated with the Street View platform. Coverage varies depending on the location as well as the information that can be extracted. The quality of the photographs is also variable (quality, resolution, light effects and image dragging, etc.). However, it is expected that the

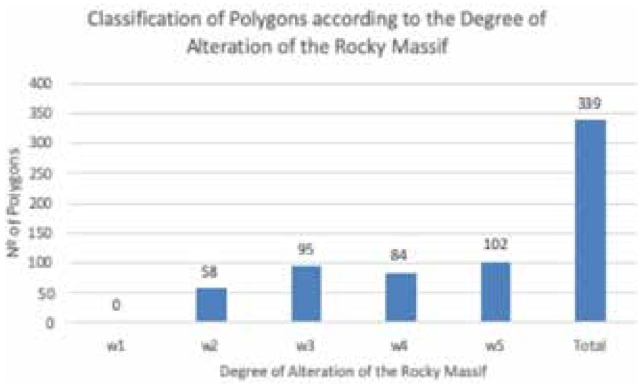


Figure 14. Distribution of the classification of the degree of alteration of the rock mass in 339 polygons defined for the Estrela Geopark area

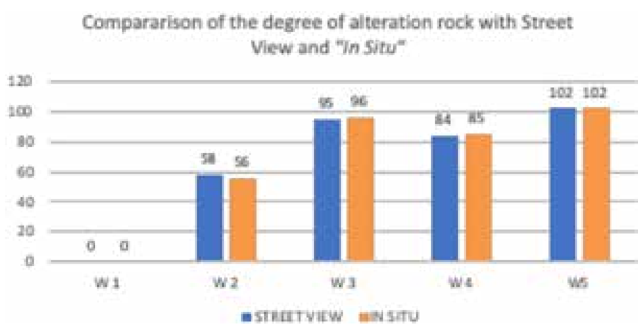


Figure 15. Distribution of the classification of the degree of alteration of the rock mass in 339 polygons defined for the Estrela Geopark zone

coverage density and the quality of the photographs will be improved in future observation, as has been the case so far.

The mentioned limitations do not outweigh the advantages due to the fact that we are facing data coming from free platforms, data which in situations where there are observational gaps, can be a valuable help. The results obtained in both case studies also prove that about 90 % of the classifications previously assigned via Street View corresponded to the classifications obtained with in situ observation. In addition, the existing classification changes had mostly a classification change of 1 grade value. To conclude, it can be said that:

- Street View can be a geographic information base for the elaboration of geotechnical cartography.
- Despite the possible limitations of coverage, it allows a quick collection of information.
- Careful observation of images can reveal important details for geological and geotechnical cartography.
- The history of the various updates allows for a temporal assessment.
- It is an excellent complement to the existing geological mapping and presents a relevant contribution to its update.

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