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In defense of stamp collecting: the importance of case studies for Geology teaching†

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Abstract: It is attempted to present here a hopefully illustrative discussion of the use of single images (treated here as stamps representing case studies) in the teaching of diverse geological concepts, based on outcrops and products of anthropogenic activity.

Keywords: Observations; Epistemology; Field work; Built environment

1. Introduction

The expression "stamp collecting" is commonly used in a derogatory way for study areas that frequently rely on case studies and observations, sometimes resulting of chance, which can be perceived as akin to a mere accumulation of facts without value for theories or as being only usable in an inductive perspective. However, even the main opponent of inductivism of the last century, Karl Popper, admitted that "some [scientists] may get their ideas by observing, or by repeating observations" [1] (albeit this was put at the same level of getting ideas from smoking or drinking coffee or whisky). But even what was perhaps the example most frequently referred by this great philosopher of science (Einstein's relativity theory) benefited from something that can be, almost literally, described as a "stamp" result (Eddington's image from an eclipse). In Geosciences there is a long history of the relevance of case observations that can serve to refute models or as catalyzers of ideas, namely for features that cannot be replicated under controlled experimental conditions (one can see the similarities with the eclipse observation for the theory of relativity). Illustrative classical cases can be found on Lyell [2]. For example, the logical principles of relative dating are presented by stamps in chapter IV (the question of the rejection of the Neptunists views will be more complex, in my view) and a very eloquent stamp was proposed for the rejection of Werner's proposal in relation to the relative age of the porphyry: "Thus, for example, within a day's journey of his school, the porphyry, called by him primitive, has been found not only to send forth veins or dikes through strata of the coal formation, but to overlie them in mass". In a converging vein, one can recall the case of the age of Earth (see [3], [4]), which geologists at the end of the 19th century, after looking at so many stamps (including stamps that show changes along time, which will be referred here as 4D stamps), suggested was very great, an idea strongly opposed and "discredited" by a physical-mathematical model of Kelvin that proposed an "age estimation" (a number!), pointing to between 20 and 400 million years (perhaps Kelvin did not look carefully at the stamps?).

The present work aims to present an overview of examples illustrating how case observations can contribute to Geology teaching, based in the author's own experience concerning both rock outcrops and stones present in the built environment. The examples presented will concern diverse study areas namely Mineralogy, Geomorphology, Geochemistry, Petrology, Ore deposits, Engineering Geology and Mineral Exploration. These case observations will be also used to highlight the importance of hypothesis discussion and critical thinking.

2. Cases (stamps) organization

The first issue for the preparation of this communication concerns the organization of the illustrative cases (stamps) considered. One possible option will be to organize them by concepts or subjects. However, each of the cases presented here can serve to discuss diverse subjects and issues. My researching experience perhaps biased me to organize the stamps in a perspective related to the anthropogenic influence: outcrops, anthropogenic rock-cuts, built structures and anthropogenic analogues (these categories will be explained in the following sections).

3. Outcrops

The term outcrop will be used in what I believe to be its classical meaning: portions of geological objects in expositions that are not the result of human action. These are the classical founding objects of Geology and the large majority of Geological studies are based on them (even if this has been somehow changing). The perspective here is to look and collect the highest amounts of stamps and there are recommendations on field recognition that amount to a kind of stamp collecting rules (see, e.g. the classical work of Compton [5]) but, paraphrasing the words of Laznicka [6] in relation to mineral exploration, "everything goes" as long as it leads to new discoveries (which will be suited to the stamp collecting perspective). An example is presented in Figure (stamp) 1, showing the typical boulder weathering of granitic massifs. This view can also be used to discuss hazards related to rock boulders movement and similar stamps were used by Sanjurjo-Sánchez and Alves [7] to discuss the potential advantage of these processes to obtain stones suitable for structure building with minimal processing.

Figure 1. Observation of granite outcrops in mountains around the town of Braga (NW Portugal).

But outcrop observation has had a major change in recent years due to freely, easily accessible aerial views (with equipments below 100 USD) available through diverse online sites. For example, the use of Google Maps can show a wide region where it is possible to identify the presence of extensive rock masses and structures in them (https://goo.gl/13SQ3X) and increasing the observation scale (https://goo.gl/7pAXD2) it is possible to get an assessment of rock block size.

4. Anthropogenic rock-cuts

This category corresponds to surfaces cut in rock masses by human action (roads, quarries and mines). They offer fresh stamps in directions and depths that are frequently unavailable in outcrops. Tools like Google Maps can be also useful here, namely when combined with Street view (generally no available for outcrops). For example, one could (in the past, this specific rock cut is not longer available) combine the plan available in https://goo.gl/z6VQcb with the Street View available in https://goo.gl/maps/T1jHE1fk7212 and in https://goo.gl/maps/EzLnnqnDGTF2 for showing the effect of the direction of the available rock surface on joint density (lower in the first case where the road slope azimuth is nearer the main joint family direction), as well as other issues such as conditions for planar failure (changing in the same rock mass according to slope azimuth). There is another use of these online tools that was implicitly introduced by the comment above on the present unavailability of the rock-cut: 4D stamps, showing evolution along time (this will also feature in the two following categories). Another example is discussed in Sanjurjo-Sánchez and Alves [7] that compare images of different times of the road slope presented in Figure 2b. The image of Figure 2b can be also compared with the Google Street View image of November of 2014 (https://goo.gl/maps/bBNNCjDYt992), being visible the intense development of biological colonization (this can also be used to exemplify examples of natural mitigation). Besides more traditional geological observations, anthropogenic rock cuts frequently also allow the observation of the implementation of procedures to deal with geological hazards, namely in relation to mass movements. The examples presented in Figure 2 can be used to present concepts related to geological structures (bedding, rock joints families), weathering degree of rock masses and their products (which can be related to the development of mineral deposits), the presence of rock boulders within saprolite zones (relevant for discussions of geotechnical survey), characteristics of rock masses with relevance for geotechnical classifications (such as those presented in Hoek [8]), including joint length and joint walls coating (which can be related to mineralogical concepts), conditions for rock failure (planar and wedge failure are visible) and intervention to minimize these hazards (metallic net).

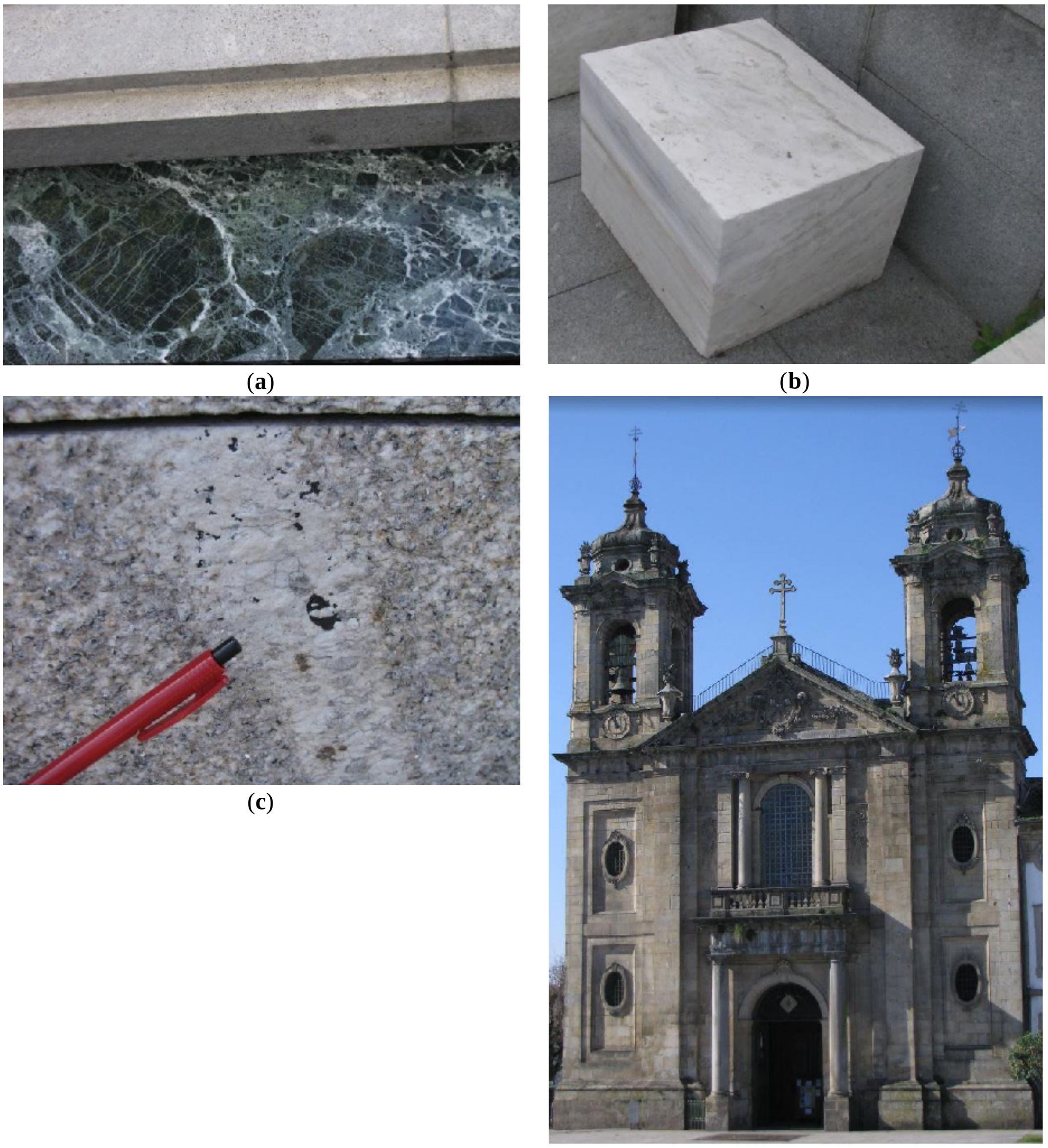
(**a**) (**b**)

Figure 2. Stamps from anthropogenic rock-cuts: (**a**) road slope on a limestone mass showing bedding, joints and the effects of weathering (terra rosa); (**b**) road slope on a granite mass showing jointing that can promote rock movements, supporting net (to minimize that hazard) and natural recovery of vegetation.

5. Built structures

While the previous categories concerned exclusively the local (in fact in loco) geological products, this category, and the next one, can offer exotic stamps from faraway lands and processes that are absent in the human-free geological local context (what Hazen et al. [9] refer as anthropogenic xenoliths).

Figure 3a shows a stamp from Braga's center where granite stones similar to the local rock are juxtaposed to stones of very exotic rocks that, furthermore, serve to illustrate structural features. Figure 3b shows another exotic stone (a marble stone in a granite region) where additionally one can see planar structures illustrating the apparent variation of dip according to plane of view. In Figure 3c it is possible to observe a pegmatite veinlet discordant on the granite with tourmaline crystals (which can also be useful to discuss the concentration of incompatible elements on pegmatites). Some built structures stamps can also suggest implicitly interesting features of rock masses: Figure 3d shows a façade with slightly yellowed (weathered) granite but perhaps the most striking feature will be the very big monolithic columns, which will have required blocks of great size. The comparison of granite stones in different structures or on the same structure can help to illustrate textural and mineralogical variations as well as different weathering degrees of the same kind of rock; some historical structures are particularly interesting as the builders used stones from different places.

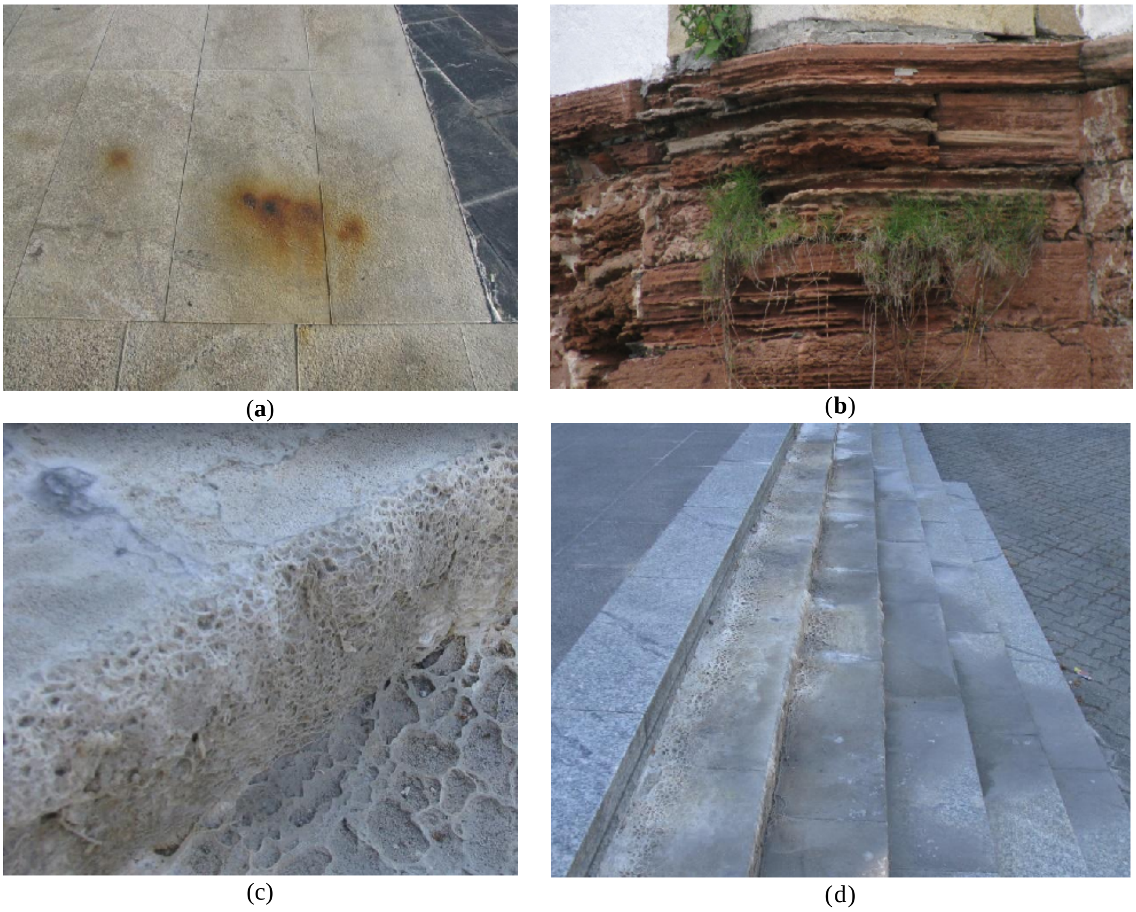


(**a**) (**b**) (**c**) (**d**)

Figure 3. Stamps from built structures: (**a**) Juxtaposition of granite stones (similar to the local stone) and exotic green breccia; (**b**) marble block with planar structures that illustrate apparent variation of dip with view plan; (**c**) pegmatite veinlet on a granite stone; (**d**) image from the main façade of the Populo's church in Braga (Portugal).

6. Anthropogenic analogues

This section comprises cases that are related to anthropogenic action and that might be not considered "geological" from a more traditional point of view (see discussion in [10]) but that nonetheless can be used to illustrate geological processes and products. All the cases considered are unintended consequences of anthropogenic action, unintentional being a critical issue in the delimitation discussed in Alves [10], based on considerations from Lyell [1], Emerson [11], Popper [12] and Dawkins [13]. Figure 4a illustrates stains related to sulphide oxidation (which can be used to discuss such issues as mineral exploration and impact of mine wastes). Furthermore, this image also serves to discuss some limitations of this kind of stamp (and stamps in general): in some cases the stain is contained within a single stone (and it can be discussed whether the stain was presented before the stone emplacement or developed afterwards) while in others the stain crosses that limits between stones (allowing to introduce a discussion in relation to the Principle of Intersection). Figure 4b shows the effects of erosion along structural features (stratification) as well as illustrating the relationship between substrate characteristics and the start of biological colonization. As closing example, I have attempted in Figure 4c-d something somewhat similar to what Taleb did with a lens cap in [14], with one stamp showing what looks like a place of travertine or tufa forming (Figure 4c), while in Figure 4d one can see that this occurs in stair steps of the built environment. This last example illustrates a particularly important feature of anthropogenic analogues, as they can illustrate the forming process of exotic geological substances (see [15]). The example in Figure 4c-d can also be used for 4D stamps in relation to processes (as is discussed in relation to carbonate crusts in Alves and Sanjurjo-Sánchez [16]) and an example of the use of online tools for 4D stamps on the built environment has already been referred in [10] in relation to biological colonization. Finally, the example of Figure 4c-d also serves to highlight the care that must be used with anthropogenic analogues, since the process at the origin of these crusts presents clear genetic differences in relation to the classical carbonate deposits [17]; but these differences can also be helpful in a teaching perspectives, for example, in this specific case, to introduce the issue of carbon sequestration.



(**a**) (**b**)

(c) (d)

Figure 4. Stamps of anthropogenic analogues: (**a**) stains from oxidation of sulphides on granite stones; (**b**) erosion along stratification planes and biological colonization; (**c**) image of calcium carbonate deposition (a kind of "travertine" or "tufa" in the built environment); (**d**) zoom-out showing the context of the previous precipitate on stairs.

7. Conclusions

It is proposed that the cases (stamps) presented here, from traditional outcrops to unintended anthropogenic analogues that might be frowned upon from a more traditional geological perspective, serve to show diverse potential situations related to observations that will be useful to teach geological concepts associated with processes and products (highlighting also limitations related to scale effects and specific features of the anthropogenic analogues).

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