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A Visual Approach to the Damage Diagnosis of Monoliths from the Monquira Archaeological Park - El Infiernito in Colombia

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Highlights

- Revealing the deterioration of the pre-Hispanic phallic monoliths in the site El Infiernito.
- Identify the main causes of damage and understand their relationship its environment.
- Presentation results in visual synoptic posters that describe the deterioration.

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Abstract

Monuments made of natural stones represent an important part of our world's cultural heritage but deteriorate by the direct or indirect interaction of mineral and stone weathering. Application of damage indices improves stone damage diagnosis and is very appropriate for the determination of necessary preservation procedures as well as the long-term survey and maintenance of stone monuments. The sandstones used at El Infiernito in Villa de Leyva, Colombia, today show weathering damages of partly extreme intensity. In-situ surveys allowed damage mapping which help to identify major causes of damage and to understand their relationship with stone and environment characteristics. In this research, the state of deterioration of the pre-Hispanic phallic monoliths in the Archaeological Park of Monquira "El Infiernito", is presented in the form of monument visual posters. Based on the visualizing of weathering forms at representative monoliths, the state of deterioration is precisely characterized and evaluated. The monument mapping and photographic documentation method can also be useful for reassessing weather damage in the framework of long-term monitoring and maintenance of monuments. This article presents the methodology of mapping weathering forms of stone monuments by using a visual classification system developed over the years with various applications.

1. INTRODUCTION

The monoliths at Monquira Archaeological Park - El Infiernito have been the subject of interest since the colonial period because of their alleged association with Muisca ceremonies and rituals. Silva Celis [1] who excavated and researched this archaeological site deeper, concluded that it was a sacred site for astronomical observation. The local Muisca people here measured and calculated the movements of the sun, and determined the rain and drought periods that regulate their production activities by calculating the solstices and equinoxes. Phallic-shaped monoliths of varying sizes made of local sandstone bear witness of the chipping work of the ancient Muisca culture and are among Colombia's most important historical and cultural monuments (Figure 1). The 54[1] phallic-shaped monoliths made of sandstone as well as a dolmen tomb found at El Infiernito, which now serves as an Archaeological Park, suggest that this region was a central place for prehispanic inter-communal activities (Figure 2).

[1]Most of the nearly 200 monolithic stones today inside the El Infiernito Parque, were found in the surrounding areas and moved to the Monquira Archaeological Park.

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Figure 1. *General view of the Monquira Archaeological Park - El Infiernito near the colonial village of Villa de Leyva in Colombia*

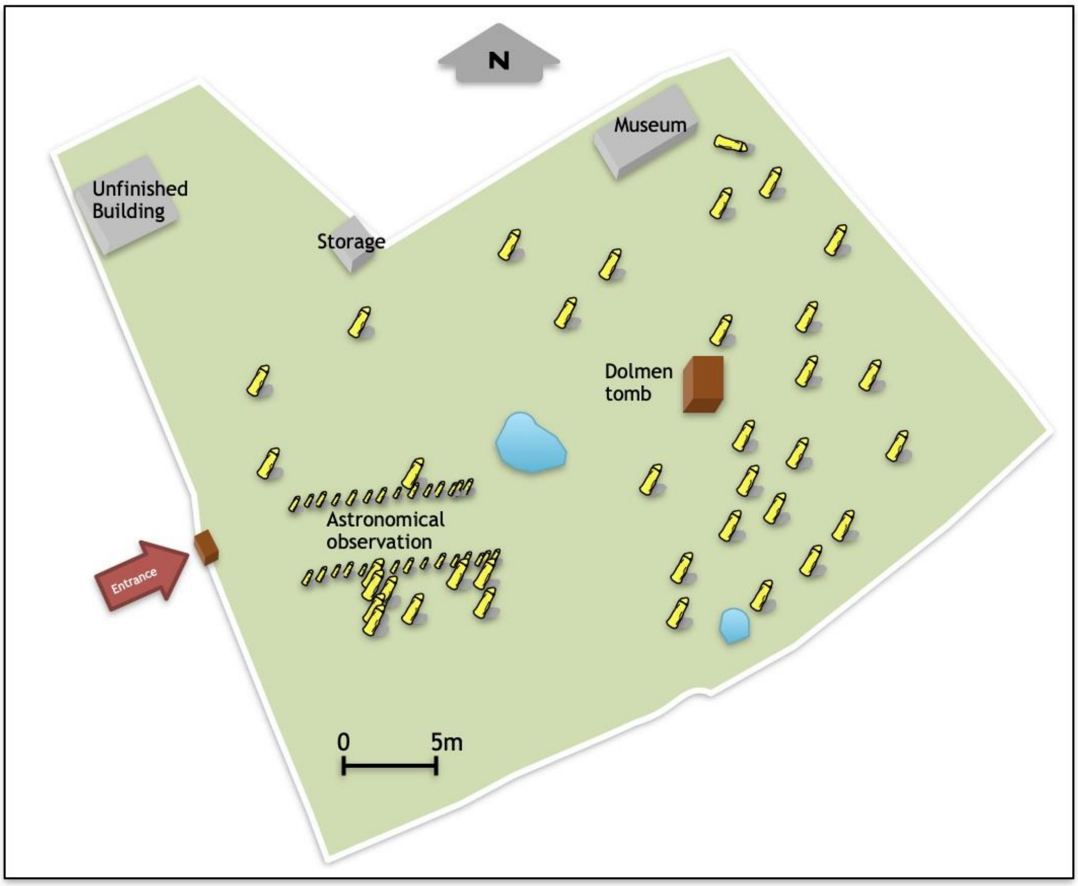

Figure 2. *General plan of the actual Monquira Archaeological Park - El Infiernito*

The megalithic works of El Infiernito constitute a unique example of the monumentality produced by the pre-Hispanic Muisca communities of Colombia, for which a National Protected Archaeological Area had been declared by the ICANH[2], the highest authority institution of cultural heritage in Colombia. The cultural and historical importance of the El Infiernito site goes beyond the monumentality of the monoliths and the astronomical observatory. It is also based on the possibility that the site and its surroundings offer to delve deeper into the processes of pre-Columbian social complexity in Colombia. It is an astronomical observatory, and a place of fertility worship, constituting as a whole a civic and religious ceremonial center from the pre-Columbian era, which is why it is considered an important tourist destination in Colombia. The damage categories and damage indices that were evaluated in El Infiernito reveal an alarming state of damage, and that is why it is urgently necessary to take preventive measures against the damage presented by the monoliths.

The Monument Mapping system is a non-destructive method that is widely used today as it facilitates the identification, recording and measurement of many monuments in historical buildings. In addition to being normally implemented manually [2-6], when digitized and transferred to a computer environment, it provides information with geometric qualities that can be correlated, compared, used to produce statistical information, and allows semantic data to be attributed about material properties and their analysis. A different approach to the assessment of deterioration in monuments is to visualize damage forms that can be obtained directly by analyzing mapped deterioration patterns [7-17].

For this study, the synoptic-graphic-photographic method was used for reporting the weathering features occurring in monoliths. This method, which is performed without damaging the monuments, reveals an evaluation of the phenomenon of segregation in stone artifacts. Mapping wear patterns based on a classification scheme in which all weathering patterns occurring in a monument are precisely defined provides an objective and reproducible record. The method uses a visual evaluation of the degradation and provides a detailed knowledge of the entire surface of the monuments. The damage mapping[3] is a graphic-photographic, synoptic representation, where all deterioration manifestations of the monument are photographed rigorously and in detail. Based on this classification scheme, all occurring weathering forms as well as their combinations and intensities were registered as part of a mapping of the monoliths front side. Additionally, state information was recorded, which is taken into account for the final damage assessment.

More than 150 monoliths of various shapes, sizes and layouts on the grounds of the Monquirá Archaeological Park "El Infiernito" have been studied in detail [18-20] and the deterioration indicators were defined in situ (Figure 3). The deterioration of a stone monument is characterized by the type and extent[4] of the damage. In order to accurately record deterioration phenomena, a differentiated classification scheme was needed.

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[3]"Mapping" referred here is the technique that typically describes the representation of monument deterioration through a photographic approach.

[4] Visually, since the severity and intensity of degradation can be perceived from photographs, there is no need to specify it separately.

Figure 3. *Images of the monoliths with people to get a general idea of their sizes; some monoliths are fallen on the ground*

2. MATERIAL METHOD

Sandstone monoliths exhibited in the open air present significant problems due to environmental conditions and varying mineralogical nature and show various, partially exposition-specific, weathering patterns. Different sandstone types were used as source rocks for the monoliths, which were obtained from the vicinity of the archaeological park in which they are now exhibited. They may come from one of the four nearby sedimentary geologic formations of Late Jurassic-Cretaceous age, Arcabuco, Ritoque, Paja and Churuvita, from which Paja-Formation sandstones exhibit most similarities [21].

For this research process, we used the previously applied methodologies and terminology based on a classification scheme developed by Fitzner [2], Fitzner&Heinrichs [3,4] and Heinrichs [11]. Based on an inventory of the weathering forms and their intensities occurring at the monuments, the classification scheme for the application to monoliths of Monquira Archaeological Park - El Infiernito was optimized. In essence, the preliminary stage (1), the on-site survey (2) and the evaluation and presentation stage (3) have been determined as the path followed in this damage assessment research process (Figure 4). Due to the cultural value of the archaeological constructions of the Monquirá "El Infiernito" Archaeological Park, sampling was carried out using non-destructive techniques. All monoliths were visually examined systematically macroscopically and under a magnifying glass and a portable microscope[5].

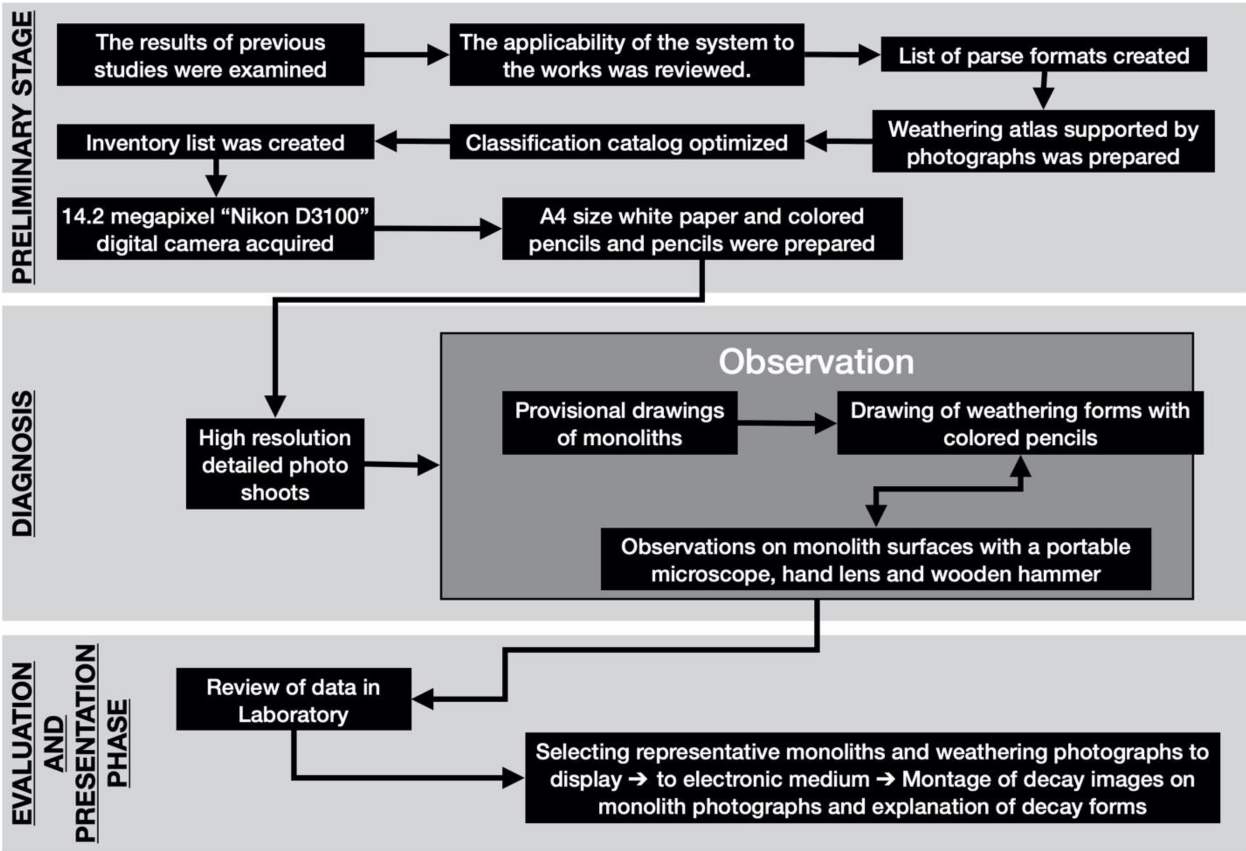

Figure 4. *Schematic representation of the workflow*

This study focused on the sandstone monoliths decay using photographic documentation and in situ observations. As the first step, preliminary preparations were undertaken by compiling earlier photographic materials, documents concerning production and previous methodologies. With or without earlier documents, a damage picture is only useful as a deformation-based inventory measurement, utilized to precisely record existing sculpture details. Thus, the natural stones found were registered in lithographic inventories, including any existing stonemason's marks, inscriptions, small art pieces, etc. Sculptural details such as defects, damages and recognizable repairs were also documented.

In the second stage, the observations at the monuments site were integrated into a temporary deterioration map. The activities at the research site included the description of the monoliths and photographic documentation. These documentations were conducted on the determination of the damage of the monoliths that were necessary to provide sufficient information for an adequate diagnosis and selection of the solutions for their conservation and maintenance. In the third and final stage of the study, the temporary weathering-state map created was evaluated and the work was continued by moving to the final mapping that concerned the accomplishment of the final version of the deterioration map. Moreover, at this stage, synoptic damage posters of selected monoliths were arranged and visual descriptions of the deterioration of the artifacts were developed.

Nowadays, archaeological documentation must address all available information about a monument or architectural structure, and should comprise all aspects of a study, ranging from the diagnosis and

[5] In addition to this restriction, it was not possible to obtain permission from the authorities of the Archaeological Park of Monquira - El Infiernito to collect samples of the monoliths for experiments/analysis in the laboratory.

identification of a stone object to the sustainability of conservation measures. In the context of understanding of modern sustainable monument preservation, it is recommended to carry out the study phases that include successive anamnesis, diagnosis and restoration/conservation steps for monument protection, which require detailed documentation at each stage (Figure 5).

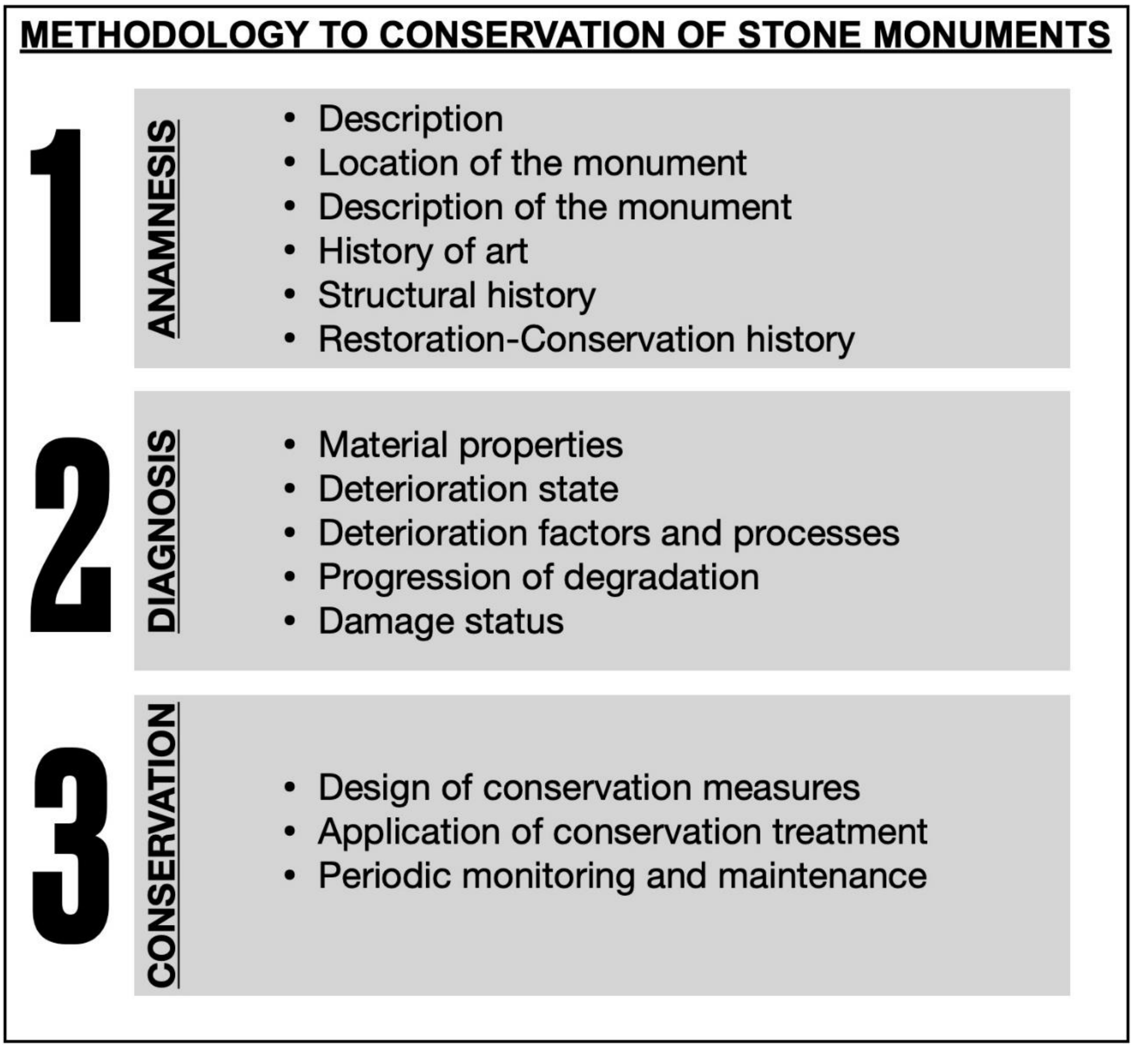

Figure 5. *The processes to be followed in the protection of monuments: Anamnesis-diagnosis-conservation*

2.1. Weathering Forms of Monoliths

The monoliths in the Archaeological Park were photographically documented and petrographically described via expert knowledge. Information about the quarries concerning the origin of the rocks of the monoliths is desirable, however, can often only be acquired through time-consuming archive documents search and geological, petrographical and geochemical studies. In the second study step, the front and side areas were mapped using large-format photos or drawings[6] to record the areal distribution of the monoliths.

The weathering conditions of the natural stones can be determined by different methods and with varying degrees of accuracy. Primarily by visual recording of the weathering conditions of the rock according to phenomenological criteria or by measuring on site or on rock samples in the laboratory by the naked eye coupled with polarizing microscopy. To localize the damage, an extensive assessment of the conditions of the sculpture is required. Here, with the help of a classification scheme for weathering forms, the surfaces

[6] Since priority is given to displaying photographic documents in this publication, monument drawings are not included in this article.

of the natural stone can be precisely described and the monolith structures can be mapped. This scheme, which allows an exact design language and reproducible registration, was developed on the basis of numerous processing of small objects in different countries of the world.

Based on the system prepared by Fitzner and Heinrichs [3,4,6], the classification system of weathering forms is hierarchically based on 4 large groups in the first stage. These were named as the stone material loss (Group 1), discoloration/deposits (Group 2), stone material weathering (Group 3) and cracks/deformation (Group 4), and different tones were used to record them in the mapping system. This 4 major decomposition groups were completed with a second level consisting of 29 main decomposition forms and a third level consisting of 60 individual decomposition forms [4,22-24]. Short definitions explain the weathering forms abbreviations, symbols and a color code allow the forms to be entered and represented in photos and plans.

As part of a monument mapping, the characteristic weathering forms are registered and photographically recorded using the classification scheme described. This documentation represents an important mapping supplement to be carried out afterwards. In the detailed mapping, all monolith surfaces are systematically examined visually and manually, precisely registered and entered in the recording documents. This mapping includes all damages that can be identified by visual inspection and careful tapping. In the case of a lack of accessibility and the corresponding task, high-intensity binoculars were used to carry out rough mapping with reduced recording accuracy[7]. The mapping results were ideally presented in photogrammetric building plans, supplemented by an explanatory description. In a further step, the weathering forms were assigned to damage classes. In contrast to the weathering forms, these do not represent objective state variables since the damage is largely determined by the cultural-historical value of the damaged component and can therefore vary from building to building.

Weathering forms describe the natural stone surface with regard to geometric and color changes, rearrangements, accumulation of foreign substances, material detachment and deformations. Mapping these weathering forms and physical changes enables a recording of high-level accuracy. The mapping basis is a classification scheme in which all weathering forms and transitional forms are clearly defined and described. This is the only way to ensure that the various forms are registered in their entire range. In addition to these, depending on the individual decomposition-type differences, the decomposition density is shown as a fourth level. Consequently, the intensity of the weathering degree becomes an important criterion for visual modelling researchs and estimating the deterioration of artifacts. The overall damage classes resulting from the mapping of the weathering forms and the assessment of supplementary status information were then merged. This process was based on the classification and registration of weathering forms and intensities, where previous research has been relied on to establish damage categories and damage indices for quantification and grading of weathering damage [20-25].

The damage detection in the monoliths used the synoptic photographic presentation experiments (Figure 6-8) in this study, which were conducted to ensure a more rapid perception of the damage on the artifacts in search of an alternative visuality, in addition to the preparation of damage maps. This type of a synoptic poster shows ways of presenting and characterizing the processes of morphological change occurring in monoliths. This photographic approach can provide researchers and decision makers with a brief view of the conservation processes, the types of degradation revealed as a result of the research, and can help speed up the monument preservation process as it will be easier to understand.

[7] It was necessary to resort to this path because some monoliths reach 4 meters in length.

Figure 6. *Visual representation of the deterioration on the synoptic damage poster of the selected monolith V-0149*

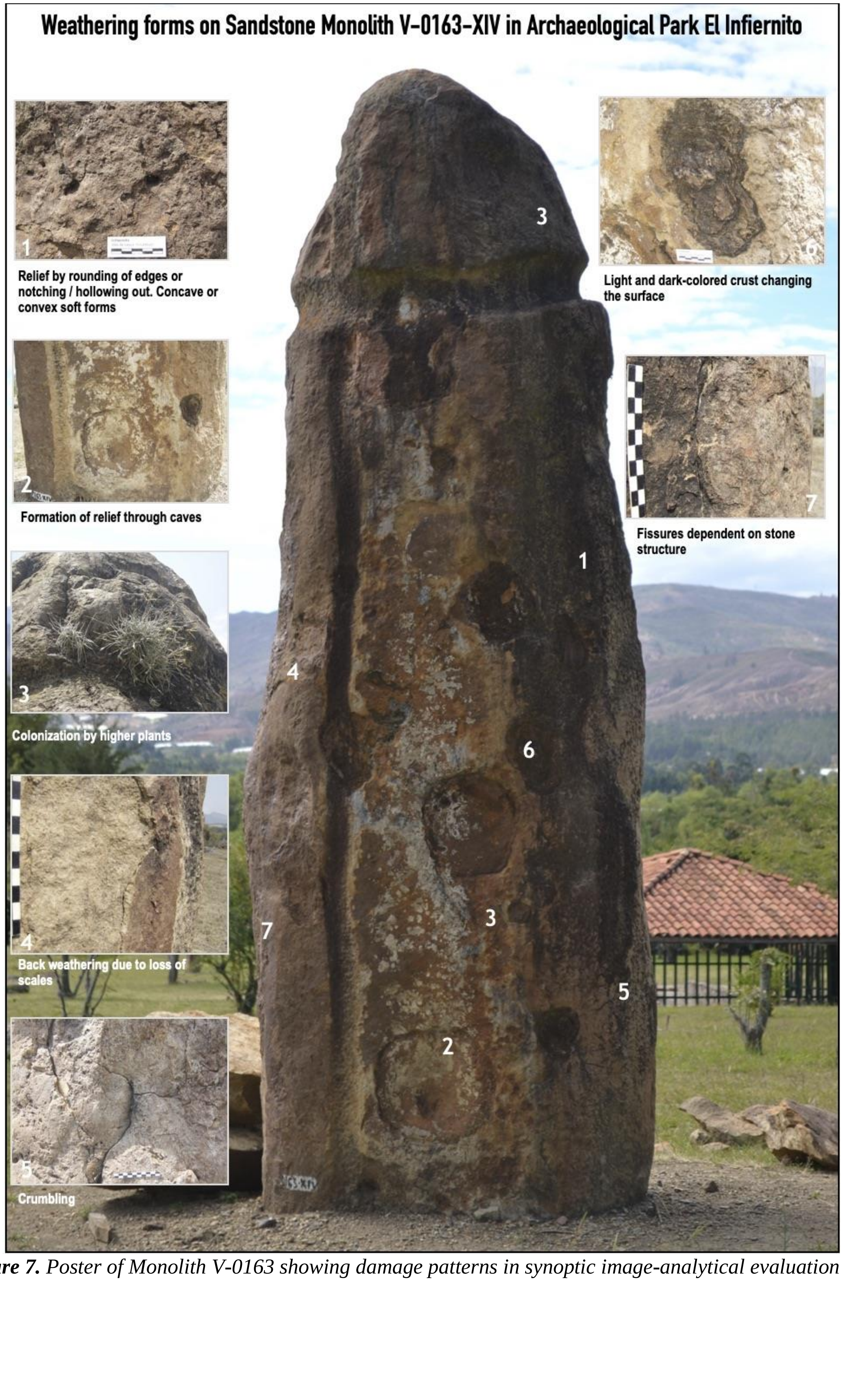

Figure 7. *Poster of Monolith V-0163 showing damage patterns in synoptic image-analytical evaluation*

Figure 8. *Synoptic damage poster of monolith V-0191 with well-represented degradation samples*

2.2. Causes of Damage

The predominantly occurring types of damages observed on the monoliths are: alveolization, bursting, back-weathering, relief and covings and rounding. Areas near the surface of the stone erode to different degrees and create a relief in movement, by loss of components or by weathering parallel to the outer or sedimentary layer. As typical of alveolar weathering, honeycomb-shaped structures frequently occur in monoliths (Figure 9).

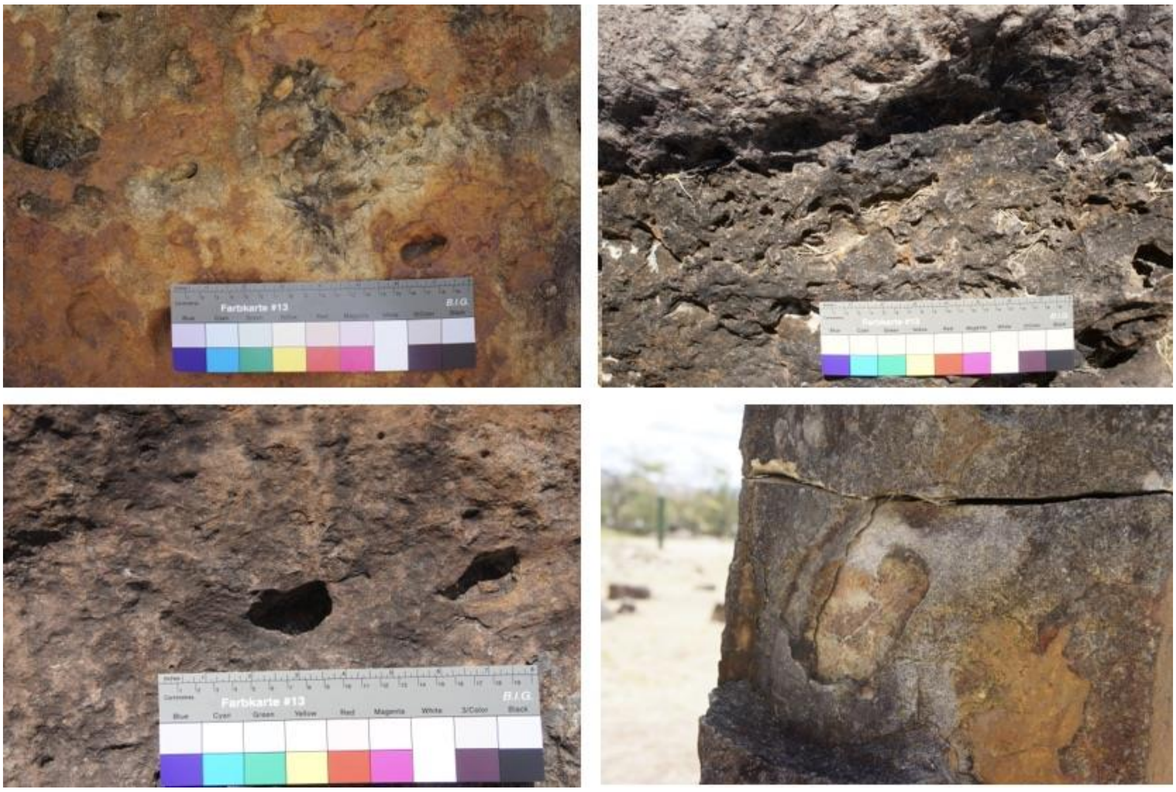

Figure 9. *Relief caused by out-weathering of fossil components (upper left) and alveolar weathering (upper right); cavernous weathering (down left) and bursting on the monoliths*

Causes of monument weathering most likely stem from structural and lithological peculiarities as well as excess salt accumulation and surface abrasion/erosion by wind completed by depositions of dirt and dust particles in pore spaces. This leads to a gradual surface crusting and/or crusted relief of the surface favoring biological growth on several monoliths. In most of the monoliths, gray to brownish crusts (Figure 9) varying in size from millimeters to centimeters-thick as coherent layers were visually determined on the monolith stone surface. During visual observations, the boundary between the natural patina and the damage pattern of the crust was difficult to clearly distinguish. An extensive biological colonization formed by lichens, green algae and higher plants was found in all monoliths within the area (Figure 9). Bird feces were also observed to be deposited on all monolith surfaces most likely causing damage by promoting further accumulation of dust and soot particles subsequently enhancing deposition as well as chemical reactions by phosphate and organic acids. Moreover, the droppings create a breeding ground for organic infestation.

In this infected environment, water alone, absorbed on these infested crusty surfaces, induces accumulation of harmful salts onto and into the stone, and causes bursting of the shells or minerals of the rock with the increasing volume of the salt crystals during upwards circulation, evaporation and osmosis. This process occurred in the monoliths where the efflorescence of loosely adhered whitish salt was an indication of the accumulation of damaging salts forming in the stone (Figure 9). The transitional forms, such as crumbling, peeling, sanding, exfoliation, and flaking visible on several monoliths (Figure 9) consequently lead to relief formation which is the most common damage form of the monoliths. Sandblasting follows as the second most common form of deterioration with variable intensities, such as flaking, sanding, and flaking of plate-like areas parallel to the surface that were responsible for the total loss in some monoliths. These phenomena were probably related to salt crystallization and expansive and contractive behavior, as they can be fostered by the strong insolation during the day followed by cold nights. In most cases, crack formation is a result of stress in the rock structure. But the most noticeable damage is the formation of the large flakes parallel to the surface produced on stone surfaces. Inevitably, catastrophic damage events can sometimes occur in exposed monoliths, as in the case of "Monolith V-0163", which was the subject of damage mapping in 2007, and suffered considerable damage with a great loss of material 12 years later (Figure 10). The heterogeneity of the stony material, such as the almost invisible mica and clay layers within the rock, was probably an important primary damage factor for this monolith. With the increase in salt accumulation, especially in the sites of water splashes, salt was visibly produced. Loss of material and discoloration were observed in some monoliths, whereas other sites show large cracks while exposure-related flake formations are clearly recognizable.

Figure 10. *The weathering of the Monolith V-0163 within 10 years (2009 to 2019), probably because the necessary conservation measures were not taken*

The most important alteration factors are those related to humidity and salt migrations, with their cycles of humidification-drying, crystallization-dissolution and hydration-dehydration. There are namely two types of causes for the deterioration of the El Infiernito monoliths. These are the external and internal causes that always act in combination, producing varied effects. The main external causes are water and living organisms. In the processes of deterioration, intrinsic characteristics of the rocks have a great influence, such as their chemical-mineralogical composition, their texture and their structure. The water forms acids with the contaminants leached into the rock, especially carbonic and sulfuric acids, which chemically transforms the binder in the rock. This can result in leaching of transformation products. The monoliths are made of local sandstones, which easily get water-saturated and thus can lose up to 30% of their strength, a damage mechanism of rainwater observed on the monoliths. In addition, water penetrated through pores and capillaries into the monolith may burst the stone structure during frosts due to the volume increase of ice.

Another factor of deterioration that may probably be the origin of the surface alveolization of sandstone monoliths is wind abrasion generated by sand-loaded winds mainly from the semi-arid south and west. The winds exert their abrasive action on the monoliths, causing surfaces with alveolization and rounding of the reliefs, also contributing to accelerate the process of evaporation of the water that saturates the monoliths after the rains, thus increasing the speed of salts crystallization.

During the field studies, in the first stage, detailed photographs of the selected monoliths of El Infiernito were taken and documented, and drawings of the monuments were made to a certain scale. The second stage of the study was to describe and record the weathering forms and to show this information on the monument drawings prepared beforehand. The photographic documentation of identified weathering forms serves to visualize and document damages to columns. Such classification, necessary to develop a classification scheme of weathering forms, is the most important aid in mapping weathering events on a monument according to objective and reproducible criteria. As part of the mapping, rock surfaces are inspected visually and, if possible, manually. Later, on these drawings, the deterioration patterns observed on the monument were drawn using colored pencils. While a portable microscope and hand lens were used to understand better the quality and quantity of weathering, the object was touched by hand to estimate the intensity of weathering, and in some cases a wooden hammer was used. While making observations on the monument surfaces, the studies were continued by indicating the decomposition forms determined on the 1/100-scale drawings of these surfaces, which were prepared beforehand[8].

Photogrammetrically or hand-created plans and distortion-free photographs represent the most suitable mapping documents, while appropriate registration documents are an important prerequisite for the precise recording of rocks and weathering patterns. The size and geometry of the structure or monument significantly control the time required for mapping, while accessibility to the study area determines the possible consequences for the accuracy of the mapping. In addition to registration documents, classification schemes and weathering forms of lithotypes are an indispensable prerequisite for successful building mapping and provide an objective and reproducible record of condition information.

2.3. Damage Assessment

Within the scope of this research project, the deterioration of monuments in different archaeological sites in Colombia was investigated in detail using the monument mapping method. The results obtained from the examinations carried out on selected sandstone objects were documented and their qualitative and quantitative degradation states were evaluated. Digital photographs taken in situ in the field were used as a source for drawing the surface degradation of the monument. In the observations conducted, different types of weathering forms were determined on the artifacts, and they were shown as posters by utilizing the drawings or photographs.

The applicability of the system to selected works was reviewed by examining the catalog created as a result of previous studies on the monument mapping system. Considering that the type of weathering may vary according to the type of stone, a list of possible weathering forms was drawn up. Along with the created list, a printout of the weathering atlas [23,24] enriched with many photographs was prepared to be taken to the field together with other materials. The classification catalog in question was prepared and optimized according to the works to be studied.

The evaluation and presentation part, which constitutes the third and final stage of the research, started with a review of the data obtained during and after the field studies. Since the field studies were documented on paper, they had to be transferred to the computer environment, which is a more common presentation environment of the relevant studies. For this, the drawings transferred to the electronic environment using a scanner, were redrawn at a computer, and the final evaluation of the weathered surfaces of the monuments was accomplished by coloring the state of deterioration. The evaluation of the deterioration results was shown in a weathering state map as weathering types and degrees. The classification system to be included in the damage state map, the explanation of its mechanism and the parameters plus their intensities, with typical examples, were included in the form of detailed descriptive information. Consequently, each damage form and its intensity were shown on the map in different colors. The overall damage classes obtained from the mapping of the weathering forms were merged with the supplementary status information.

3. RESULTS AND CONCLUSIONS

In this study we presented the structure of the classification scheme and the classification of the weathering forms registered at the El Infiernito site. The weathering maps of some of the monoliths selected from a total of 150 monoliths within the El Infiernito archaeological park area are shown in detail. Among the possible degradation factors, the most effective is the weathering caused by the physical and chemical processes under the ruling climatic conditions. These processes were responsible for the chemical and structural breakdown and/or alteration of the minerals that make up the rock structure. In due respect to the highly cultural-historical-archaeological value of the natural stone structures, only non-destructive methods were used for the on-site investigation, i.e. mapping as a phenomenological method, coupled with image

[8] In the selection of the monuments, considering the multiplicity of the monument surfaces, it is not possible to study all of them due to both the time constraint and the inability to keep the scope of the project too broad, so the monuments with the most distinctive features were preferred in showing the forms of decomposition.

analysis, photogrammetry and multispectral photography. Thus, this study suggests the need of laboratory studies in the next phase of the project, focusing on the visual photometric posters, in order to compare the degradation of the natural stone monuments at El Infiernito. As an example, attention must be drawn to the synoptic image-analytical[9] evaluations of photographs of monoliths that allow for a wide range of surface measurements of photo-recognizable weathering patterns such as inflorescences, dirt and crusts. However, direct indications of the formation of the weathering profile can only be obtained to a limited extent with these methods. Nevertheless, methods related to laboratory analyses should be employed in this context for obtaining further and more detailed weathering information of the monument surfaces.

The speed and nature of weathering upon the stone-work depends on the amount and duration of the climatic variables, rock type and time together with their combined effects. In this context, the effect of chemical dissolution on the rock type is primarily associated with the presence of water, its acidity and the environmental temperature. Nevertheless, the climate variables also determine the type and density of vegetation that is indirectly effective on the weathering of the stone-work. Consequently, climate is a factor controlling the distribution of deterioration processes on monuments exhibited outdoors. The data obtained from the evaluation of the monoliths provide a comprehensive basis for the interpretation of the weathering damage suffered by these archaeological monuments and provide useful clues for their prevention and successful conservation.

Mineral content, porosity, expandability, the distribution of the crack patterns and their uniformity determine the nature of weathering of the rock materials. As the rate and amount of weathering can vary according to ambient conditions, an arid climate is much less effective than a high-rainfall tropical region climate in terms of both the rate and amount of deterioration, i.e., chemical decay, but imply other challenges. Physical, chemical and biodegradation processes occur together, enhancing the weathering of the priorly fragmented particles and/or aggregates by initial physical breakdown, in turn increasing surface area and accelerating chemical decomposition. Further, accelerated chemical deterioration induces the physical decomposition of the monumental rock materials by weakening the crystal structural bonds of the minerals.

The "Monument-mapping"-method, although proven to be reliable and efficient, is not yet sufficiently recognized in many parts of the globe. With this method, the degradation observed in ancient rock artifacts can be characterized, documented and evaluated. Further, it will be possible to develop different perspectives on conservation studies for preserving rock artifacts elsewhere. However, concerning this study, it has enabled us to determine the weathering patterns of the Infiernito monoliths and evaluate the decay processes and the relevant causes. The work accomplished within this pilot site is expected to be an appropriate example of an interdisciplinary approach to restoration of historical monuments that exist under similar conditions as El Infiernito.

With this study, an additional step will be taken in providing infrastructure support from different disciplines to conservation studies by using an easy-to-implement method in the conservation works to be carried out in order to transfer cultural assets to future generations. Using digital photographic images as well as synoptic posters that can be prepared with the help of in-situ observations in the field, determining the characteristics of the deterioration seen in the artifacts by digital image processing in the computer environment will bring additional convenience to field and laboratory studies related to conservation by integrating science branches such as mineralogy and petrography into archeology.

Colombia is recognized for the wide range of rock art representations. Throughout the country, from the coastlines to the Andean heights, in valleys and slopes, or on riverbeds, it is possible to find rock art. Numerous rock sites have been discovered so far in the country, and the number of finds that show the immense abundance and variety of these manifestations is increasing. Many of these sites remain among thick vegetation or in the middle of crop or livestock pastures, half buried under a layer of soil found on all types of rock surfaces, and in various locations. Scientific research into rock art in Colombia has yet to be developed. Although today it is possible to have a general overview of the location of paintings and

[9] Term coined by this study.

engravings in the national territory, few studies are carried out to record and protect Colombian rock art, especially the diagnosis of the state of deterioration.

The synoptic posters, which were used during the development of the research, due to their ease of use, can be applied to other sites, particularly to the petroglyphs, as an essential record which allows viewing the complete state of the petroglyph and allows observing different aspects of rock deterioration. Because, as far as our experiments have shown, damage to stone monuments that can be seen with the naked eye requires more priority protection measures than invisible damage. For this reason, we think that the holistic visual poster application will be useful in the protection of the work, especially if the conservation procedures cannot be started immediately for various reasons, at least in terms of facilitating the first interventions. Considering that precolombian rock arts are abundant in Colombia and that these works are generally concentrated in highly unaccessible areas, we believe that it will fill an important gap in antiquities conservation plans due to the ease of implementation (both temporal and technically).

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] Silva Celis, E., “Investigaciones arqueológicas en Villa de Leiva”, Boletín Museo Del Oro, (10): 1–18, (1981).

[2] Fitzner, B., “Evaluation and documentation of stone damage on monuments”,International Symposium of Stone Conservation, May 29, 2007, Seoul, Korea: 25-30 (English), 31-35 (Korean), National Research Institute of Cultural Heritage, Daejeon, Republic of Korea, (2007).

[3] Fitzner, B., Heinrichs, K., “Bauwerkskartierung - ein Verfahren zur quantitativen Bewertung der Verwitterungsschäden an Natursteinbauwerken”, - In Siegesmund, S., Auras, M. & Snethlage, R. (Hrsg.): STEIN Zerfall und Konservierung, 56-60, Edition Leipzig, (2005).

[4] Fitzner, B., Heinrichs, K., “Kartierung und Bewertung von Verwitterungsschäden an Natursteinbauwerken, - Z. dt. Ges. Geowiss., Band 156, Heft 1, Themenheft: Geowissenschaften und Denkmalpflege - Bauwerkskartierung, Natursteinverwitterung, Konservierungsstrategien - herausgegeben von S. Siegesmund, M. Auras, J. Ruedrich und R. Snethlage, 7-24, E. Schweizerbart´sche Verlagsbuchhandlung, Stuttgart, (2005).

[5] Heinrichs, K., Fitzner, B., “Stone monuments of the Nemrud Dag sanctuary / Turkey - petrographical investigation and diagnosis of weathering damage", - Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 158/3 "Rohstoff Naturstein - Teil 1" / "Natural Building Stone Resources - Part 1”, 519-548, (2007).

[6] Fitzner, B., Heinrichs, K., “Damage diagnosis on stone monuments – weathering forms, damage categories and damage indices”, In Prikryl, R. & Viles, H.A. (ed.): Understanding and managing stone decay, Proceeding of the International Conference “Stone weathering and atmospheric pollution network (SWAPNET 2001)”, 11-56, The Karolinum Press, Charles University, Prague, Czech Republic, (2002).

[7] Inkpen, R., Duane, B., Burdett, J., Yates, T., “Assessing stone degradation using an integrated database and geographical information system (GIS)”, Environmental Geology, 56: 789–801, (2008).

[8] Brunetaud, X., Luca, L.D., Janvier-Badosa, S., Beck, K., Al-Mukhtar, M., “Application of digital techniques in monument preservation”, European Journal of Environmental and Civil Engineering, 16(5): 543–556, (2012).

[9] Öcal, A.D., “Kayaçtan yapilmis eski eserlerin koruma çalismalarina arkeometrik bir yaklasim: ayrisma durumu haritası. Türkiye ve Kolombiya’daki anit eserlerin bozunma analizleri - An Archaeometrical Approach to Conservation Works of Archaeological Stone Monuments: Monument Mapping. Analysis Of Damage Diagnosis of Monuments from Turkey and Colombia”, Cukurova University, Department of Archaeometry, (M.Sc. thesis), Adana, (2010).

[10] Fitzner, B., Heinrichs, K., Bouchardiere, D.L., “Weathering damage on Pharaonic sandstone monuments in Luxor-Egypt”, Building and Environment, 38(9–10): 1089–1103, (2003).

[11] Heinrichs, K., “Diagnose der Verwitterungsschäden an den Felsmonumenten der antiken Stadt Petra / Jordanien”. - Dissertation - RWTH Aachen, Aachener Geowissenschaftliche Beiträge, Band 41, Wissenschaftsverlag Mainz, Aachen, (2005).

[12] Heinrichs, K., “Diagnosis of weathering damage on rock- cut monuments in Petra”, Jordan Environmental Geology, 56(3–4): 643–675, (2008).

[13] Delgado Rodrigues, J., “Defining, mapping and assessing deterioration patterns in stone conservation projects”, Journal of Cultural Heritage, 16: 267–275, (2008).

[14] Franković, M., Novaković, N., Matović, V., “Damage quantification of built stone on Dark Gate (Belgrade, Serbia): sample of damage index application for decay rate evaluation, Environmental Earth Sciences, 73(10): 6181–6193, (2015).

[15] Gizzi, F.T., Sileo, M., Biscione, M., Danese, M., Alvarez de Buergo, M., “The conservation state of the Sassi of Matera site (South- ern Italy) and its correlation with the environmental conditions analysed through spatial analysis techniques”, Journal of Cultural Heritage, 17: 61– 74, (2016).

[16] Germinario, C., Gorrasi, M., Izzo, F., Langella, A., Limongiello, M., Mercurio, M., Musmeci, D., Santoriello, A., Grifa, C., “Damage diagnosis of Ponte Rotto, a Roman bridge along the ancient Appia”, International Journal of Conservation Science, 11(1): 277–290, (2020).

[17] Randazzo, L., Collina, M., Ricca, M., Barbieri, L., Bruno, F., Arcudi, A., La Russa, M.F., “Damage indices and photogrammetry for decay assessment of stone-built cultural heritage: the case study of the San Domenico church main entrance Portal (South Calabria, Italy)”, Sustainability, 12(12): 5198, (2020).

[18] Öcal, A.D., Cramer, T., Siegesmund, S., “Caracterización de agentes del deterioro de los monolitos de piedra arenisca del Infiernito–Colombia”, 2do. Congreso Argentino y 1ro. Latinoamericano de Arqueometría, 6 al 8 de junio de 2007, Comisión Nacional de Energía Atómica, Buenos Aires, Argentina, (2009).

[19] Öcal, A.D., Dal, M., “An archeometric approach for the conservation of archaeological monuments: deterioration mapping: A comparative analysis of the deterioration of the Karatepe-Aslantas orthostats of Turkey and the monoliths of the Archeological Park of Infiernito de Colombia”, Paper presented at the Workshop Objects of Art: Archeometry - Conservation - Chemistry WC2017, Bogota, Colombia, May 31-June 2, (2017).

[20] Pötzl, C., Öcal, A.D., Cramer, T., Siegesmund, S., “Decay of pre-colombian phallic stone monoliths”, In: Siegesmund, S. & Middendorf, B. (EDS.): Monument Future: Decay and Conservation of Stone, – Proceeding of the 14th International Congress on the Deterioration and Conservation of Stone - Volume 1 and Volume II, Mitteldeutscher Verlag, (2020).

[21] Patarroyo Gama, P., "La Formacion Ritoque en la zona de Vélez (Santander-Colombia)", Geología Colombiana 33, 109–110, (2008).

[22] Heinrichs, K., "Diagnose der Verwitterungsschäden an den Felsmonumenten der antiken Stadt Petra / Jordanien", - Dissertation - RWTH Aachen, Aachener Geowissenschaftliche Beiträge, Band 41, Wissenschaftsverlag Mainz, Aachen, (2005).

[23] Anson-Cartwright, T. (Ed.), "Illustrated glossary on stone deterioration patterns:Illustriertes Glossar der Verwitterungsformen von Naturstein, Monuments and sites Monuments et sites Monumentos y sitios", Vol. 15, First Edition, ICOMOS, International Scientific Committee for Stone (ISCS); Imhof, Paris, Petersberg, (2010).

[24] Fitzner, B., and Heinrichs, K., "Photo atlas of weathering forms on stone monuments", www.stone.rwth-aachen.de.llis, (2004).

[25] Öcal, A.D., and Dal, M., "Doğal Taşlardaki Bozunmalar", Mimarlık Vakfı İktisadi İşletmesi, İstanbul, (2012).