

Universidade do Minho
Escola de Ciências

Andrey Nicolas Campos Corredor

Inventory of Urban Fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark, Spain: Use and Potential for Geoeeducation and Geotourism

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Andrey Nicolas Campos Corredor

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Geopark, Spain: Use and Potential for
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Geoconservação

Trabalho efetuado sob a orientação dos

Doutor Diamantino Manuel Insua Pereira

Doutor Iván Cortijo Sánchez

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Inventory of Urban Fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark, Spain: Use and Potential for Geoeducation and Geotourism

ABSTRACT

Urban fossils are part of the urban geodiversity, which refers to the geological, geomorphological, and hydrological features present in urban areas, including natural formed and human-driven *in situ* and *ex situ* geological elements. They have been documented in rocks used as decorative and ornamental elements in buildings, houses, monuments, cemeteries, among others. Urban fossils provide excellent archives to understand the evolution of the Earth and have been used for educational and tourist purposes in different cities around the world and represent a convenient strategy of geoconservation since they have great advantages such as easy accessibility and favorable safety conditions for the public.

The Villuercas-Ibores-Jara UNESCO Global Geopark (Cáceres Province, Extremadura, Spain) exhibits impressive ichnofossils that have been incorporated into the house facades in some villages. These ichnofossils mainly belong to the *Cruziana*, *Rusophycus*, *Daedalus* and *Skolithos* ichnogenera that are contained in sandstones and quartzites coming from the Armorican Quartzite Formation (Lower-Middle Ordovician). However, the lack of documentation of these urban fossils in the territory is a limitation to developing conservation strategies that help their promotion as geoeducation and geotourism resources.

This study presents the development of an inventory of urban fossils in selected villages of the geopark: Berzocana, Cañamero, Navezuelas, Cabañas del Castillo and Roturas (one of its hamlets), Guadalupe and Logrosán, as well as a quantitative assessment of the scientific, educational, tourist, added, and conservation values, and risk of degradation. Besides, it proposes tools to enhance the educational and tourism potential of these elements by means of interactive routes in three villages (Berzocana, Cañamero and Navezuelas) and infographics. It is expected that this work will help promote the dissemination of urban fossils in the geopark in safe spaces not only for schoolchildren but also for wider audiences that do not have the possibility to go to the field. Besides, it will provide a database that can be considered in urban planning to ensure the conservation of these valuable resources.

Key words: geoeducation, geotourism, ichnofossils, inventory of urban fossils, quantitative assessment

Inventário de Fósseis Urbanos no Geoparque Mundial da UNESCO de Villuercas-Ibores-Jara, Espanha: Utilização e Potencial para a Geoeducação e o Geoturismo

RESUMO

Os fósseis urbanos fazem parte da geodiversidade urbana, que se refere às características geológicas, geomorfológicas e hidrológicas presentes nas áreas urbanas, incluindo elementos geológicos *in situ* e *ex situ*, de formação natural e de origem humana. Têm sido documentados em rochas utilizadas como elementos decorativos e ornamentais em edifícios, casas, monumentos, cemitérios, entre outros. Os fósseis urbanos constituem excelentes arquivos para compreender a evolução da Terra e têm sido utilizados para fins educativos e turísticos em diferentes cidades do mundo e representam uma estratégia conveniente de geoconservação, uma vez que apresentam grandes vantagens como a fácil acessibilidade e condições de segurança favoráveis para o público.

O Geoparque Mundial da UNESCO de Villuercas-Ibores-Jara (Província de Cáceres, Extremadura, Espanha) exhibe icnofósseis impressionantes que foram incorporados nas fachadas das casas de algumas aldeias. Estes icnofósseis pertencem principalmente aos icnogêneros *Cruziana*, *Rusophycus*, *Daedalus* e *Skolithos* que estão contidos em arenitos e quartzitos provenientes da Formação Quartzítica Armoricana (Ordovícico Inferior-Médio). No entanto, a falta de documentação destes fósseis urbanos no território é uma limitação ao desenvolvimento de estratégias de conservação que ajudem à sua promoção como recursos de geoeducação e geoturismo.

Este estudo apresenta o desenvolvimento de um inventário de fósseis urbanos em municípios selecionados do geoparque: Berzocana, Cañamero, Navezuelas, Cabañas del Castillo e Roturas (uma das suas aldeias), Guadalupe e Logrosán, bem como uma avaliação quantitativa dos valores científico, educativo, turístico, acrescentado, de conservação e risco de degradação. Além disso, propõe ferramentas para melhorar o potencial educativo e turístico destes elementos através de rotas interactivas em três aldeias (Berzocana, Cañamero e Navezuelas) e infografias. Espera-se que este trabalho ajude a promover a divulgação dos fósseis urbanos no geoparque em espaços seguros, não só para crianças em idade escolar, mas também para públicos mais alargados que não têm a possibilidade de ir ao terreno. Além disso, fornecerá uma base de dados que pode ser considerada no planeamento urbano para garantir a conservação destes valiosos recursos.

Palavras-chave: avaliação quantitativa, geoeducação, geoturismo, icnofósseis, inventário de fósseis urbanos

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1. INTRODUCTION

A UNESCO Global Geopark corresponds to a single, unified geographic area in which landscapes and sites of international geological significance exist and are managed according to a holistic concept involving protection, education and sustainable development (UNESCO, 2025). The UNESCO Villuercas-Ibores-Jara Global Geopark contains rocks about 475 million years old belonging to the Armorican Quartzite Formation that have been used in some villages as building material. Pieces with impressive fossils were used in some constructions as ornamental and decorative elements. These rocks were extracted from the surrounding areas and represent valuable windows to understand the past life and geological history of the region. However, the geoconservation initiatives around these elements have been scarce. This research aims to document urban fossils in selected villages to explore their use and potential for educational and tourist purposes.

While most work has been focused on *in situ* findings and museum exhibits, fossils embedded in building facades remain overlooked and largely unexplored. To frame this study, the next section reviews the current literature on examples from different urban areas to provide a broader understanding of the strategies used for geoconservation and methodologies for inventorying, as well as the main urban fossils found in the geopark.

1.1. Background Information

Urban geodiversity encompasses the geological, geomorphological, and hydrological features present in urban areas, including natural formed and human-driven *in situ* and *ex situ* geological elements (Wolniewicz, 2022). The presence of unique geological features in urban environments, either naturally or artificially exposed, may be valuable for research, education or tourist purposes, and might be considered as part of the heritage of a city (Habibi *et al.*, 2018). Nevertheless, the geoheritage found in urban areas has drawn much less attention for research and the management provided by the local government is scarce (Vegas & Díez-Herrero, 2021).

Urban geoheritage refers to unique geological elements and processes located in or close to urban areas that are important because of their scientific, educational, and tourist value (Habibi *et al.*, 2018). Brocx & Semeniuk (2019) focus on those ornamental rocks that have been polished and provide

excellent archives of geological information for educational, tourist and research use and highlight the need to create ornamental rock inventories. There is some work on urban geodiversity inventories where ornamental rocks have been included or mentioned, for example in Poznań (Poland), Shiraz city (Iran), and Clermont-Ferrand (France) (Wolniewicz, 2022; Habibi *et al.*, 2018; and Vereb *et al.*, 2020). Wolniewicz (2022) proposes a classification of urban geodiversity where urban fossils can be included within the *ex situ lato sensu* anthropogenic section corresponding to building, decorative and ornamental rocks.

Urban fossils have been documented in ornamental rocks in several cities around the world making part of buildings, houses, churches, statues, street benches, cemeteries, among others (e.g., da Silva, 2019; Del Lama, 2019). It has advantages in terms of accessibility as they are found in public areas with better accommodation and mobility options. These elements are found in more densely populated places, including schoolchildren, relative to remote areas in the countryside (Vegas & Diez-Herrero, 2021), and also allow interaction between culture, architecture, and historical heritage (Wolniewicz, 2022).

De Wever *et al.* (2017) highlight the importance of the use of natural stones in urban contexts usually found in historical buildings and monuments to promote geoeducation and geotourism. Examples of urban fossils are found in emblematic buildings such as the Ajuda National Palace (Lisbon) exhibiting corals and rudists (Pacheco & Cachão, 2021), and the Museum of Tomorrow (Rio de Janeiro) with gastropods (Polck *et al.*, 2018). Other studies and practical cases involving urban fossils took place in Buenos Aires, Argentina (Padula & Lazo, 2021); Lisbon, Portugal (da Silva, 2009, 2019); Rio de Janeiro, Brazil (Medeiros & Polck, 2017; Polck *et al.*, 2020); Poznań, Poland (Wolniewicz, 2019); Doha, Qatar (Siddall, 2017); Cabra, León and Monsagro, Spain (Cabra Jurásica, n.d.; Castaño de Luis *et al.*, 2011; Martínez-Graña *et al.*, 2017; Simón-Porcar *et al.*, 2020); and Washington D. C., USA (Strellich, 2018).

Among the largest initiatives to promote urban geodiversity and geoheritage are the *Balades géologiques* ("geological walks"): self-guided itineraries to promote the link between geology and humanity, which were created by the *Société Géologique de France* and the *Muséum National d'Histoire Naturelle* having presence in different cities of France (De Wever *et al.*, 2017); *Geología* ("Geo-day"): an outreach event guided by earth sciences professionals, which takes place in a different city in Spain every year (Sociedad Geológica de España, 2025), and *Urban Geology*: a compilation of self-guided tours across London (Siddall, n.d.).

In terms of quantification, it is usual to find methods for sites of geological interest and geomorphosites in rural and natural areas (e.g., Brilha, 2016, 2018; Pereira *et al.*, 2007), while within urban areas they are scarce (Kubalíková *et al.*, 2020). Sites in urban environments, specifically those corresponding to ornamental rocks, often present greater educational and tourist potential compared to scientific potential, so the approach to their evaluation should consider this point. Among the first assessment proposals for urban environments are Kubalíková (2013), focused on geotourism purposes and Pica *et al.*, (2017), applied on geomorphosites in Rome. Subsequently, Kubalíkova *et al.*, (2019) and Vegas & Díez-Herrero (2021) developed more comprehensive methods that consider different values, e.g., scientific, educational, tourist, added, and conservation values, among others. An example of the application of the method proposed by Kubalíkova *et al.*, (2019) is found in Wolniewicz (2022), who found that those sites that generated greater interest for geotourists did not correspond necessarily to those that obtained the highest values in the quantitative analysis. Furthermore, in a later study focused on the use of natural stone in urban areas, Wolniewicz (2024) states that it should not be reduced to a simple *ex situ* element of geodiversity, but it should be seen as a bridge to connect abiotic and cultural aspects such as architectural trends. In other words, its geological and historical context should not be separated.

Currently, there is no specific methodology to determine the risk of degradation of urban geodiversity. Although Smith *et al.* (2013) study the level of conservation of rocks in historic buildings by analyzing decay processes, their scope is too limited to consider all the factors concerning to the risk of degradation. For this reason, it becomes necessary to use more common methodologies for sites of geological interest in natural and rural environments, e.g., Marjanović *et al.* (2024) applied the method of Brilha (2016) to evaluate the Sokograd Fortress in Serbia.

1.2. Urban fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark

The practice of collecting stones from the countryside was the traditional way of building houses and other structures. It has been progressively discouraged and is now prohibited for most modern constructions due to the confluence of environmental and landscape protection laws, building regulations requiring certified materials, and property laws preventing extraction without a permit. Currently, for any legal construction, traceable materials with guaranteed quality are required, which excludes the use of "wild" stones for structural purposes. For decorative or landscaping purposes, stone extraction may be regulated by specific permits, especially in protected areas. A good example is Law 42/2007 on Natural

Heritage and Biodiversity (Spain, 2007), in which the conservation of geodiversity is one of its principles with fossil material falling under the definition of Geological Heritage:

“the set of geological natural resources of scientific, cultural and/or educational value, whether they are geological formations and structures, landforms, minerals, rocks, meteorites, fossils, soils and other geological manifestations that allow to know, study and interpret: a) the origin and evolution of the Earth, b) the processes that have shaped it, c) the climates and landscapes of the past and present, and d) the origin and evolution of life”.

The urban fossils of the Villuercas-Ibores-Jara UNESCO Global Geopark correspond mainly to ichnofossils of the Armorican Quartzite Formation, from the Lower-Middle Ordovician. Although the preservation of skeletal fossils is scarce due to the sandy composition of this geological formation, it is not the case for trace fossils, which are exceptionally preserved. Ichnofossils reflect the activity of the metazoans and are captured in the form of imprints that may indicate feeding, movement, or resting. The use of ichnofossils such as *Cruziana* on house facades in the geopark territory was reported by Cortijo *et al.* (2021) (Figure 1), while Simón-Porcar *et al.* (2020) present another remarkable example in Monsagro (Salamanca) with trace fossils belonging to the same formation. The most common urban fossils found in the geopark are presented below.



Figure 1. Examples of house facades decorated with *Cruziana* and other ichnofossils in the Villuercas-Ibores-Jara UNESCO Global Geopark. A,B) Cañamero; C,D) Navezuelas.

1.2.1. *Cruziana*

Trilobites were arthropods with a three-part segmented exoskeleton that lived on the sea floor. They appeared at the beginning of the Cambrian and became extinct at the end of the Permian, about 250 million years ago. Among the trace fossils left by trilobites is *Cruziana*: bilobed trails that represent the activity of trilobites on shallow sandstones that left a furrowing in their path while digging the sea floor (Aceñolaza *et al.*, 2015), which indicates that these organisms moved on the sea floor in search of food. These structures are formed by a central furrow and limb drag marks that allow defining the direction of movement (Figure 2).

The formation of these structures occurred mostly when the organism broke through the sandy sediment and came into contact with the underlying muddy layer, i.e., formed between strata (Goldring, 1985). However, some may have been generated at the mud-water interface and then cast by sediment later. For these marks to be exceptionally preserved, relatively rapid casting by storm deposits is required (Savrda, 2007). *Cruziana* is a representative trace fossil of the Upper Cambrian and Ordovician periods and it is commonly found in deltaic to shallow marine facies rocks with sandstone and mudstone intercalations (Goldring, 1985).

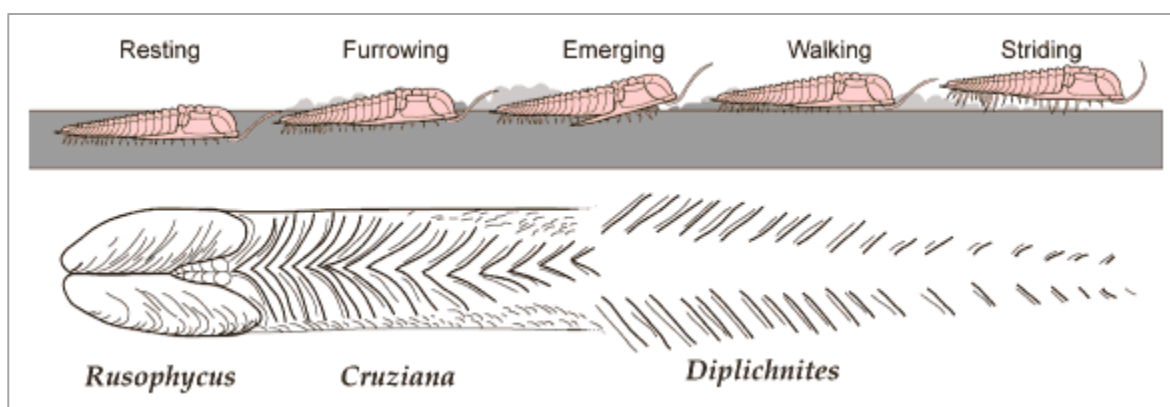


Figure 2. The main types of trilobite trace fossils: *Rusophycus*, *Cruziana*, and *Diplichnites*. (Gon III, 2008)

Following Cortijo *et al.* (2021), the most common *Cruziana* ichnospecies in the Armorican Quartzite correspond to the *Cruziana rugosa* Group, which is characterized by dig marks in groups of up to 12. This group includes *Cruziana rugosa* d'Orbigny, *Cruziana furcifera* d'Orbigny, and *Cruziana goldfussi* Rouault. The distinction among the three can be problematic due to transitional specimens, so they are considered as subichnospecies of the *C. rugosa* Group (Rodríguez-Tovar *et al.*, 2014). The

identification of the organism that produced this trace fossil presents a challenge, as other arthropods may leave similar feeding traces such as aglaspids, limulids or phyllopo­ds, while *C. rugosa* is restricted to trilobites (Rodríguez-Tovar *et al.*, 2014). Gutiérrez-Marco *et al.* (2017) propose that *C. rugosa* could be attributed to asaphoid trilobites that combined feeding or scavenging and locomotion.

C. rugosa Group presents large sizes in the Armorican Quartzite (e.g., in Penha Garcia, Portugal) associated with the geographic position of the Iberian territory, which was located on the Gondwana coasts at high latitudes near the South Pole during the Ordovician. This allowed paleoenvironmental conditions (cold waters, oxygen depletion and low predation pressure) and food availability to lead to gigantism (Neto De Carvalho & Baucon, 2016). In addition, the *C. rugosa* Group has been used for its biostratigraphic importance in other regions with “non-fossiliferous” sandstones where its use has allowed paleogeographic correlations (e.g. Aceñolaza *et al.*, 2015 & Meischner *et al.*, 2020). The geopark has developed educational tools that include *Cruziana* through the development of replicas that are added to the “Geomaletas”(Geobox) distributed to local schools and board games (Cortijo *et al.*, 2021).

1.2.2. *Rusophycus*

Rusophycus is an ichnogenus produced by trilobites and reflects a resting, stationary feeding or concealment state (Figure 2). Both *Cruziana* and *Rusophycus* give an idea of the width of the trace maker. While *Cruziana* presents elongated structures with morphological features such as anterior, posterior and declined parts, *Rusophycus* are characterized by their vertical character and are distinguished for being coffee bean-shaped (Gibb *et al.*, 2016). These bilobed elliptical forms are generally striated and taper toward one end (IBGS Research Group, n.d.).

1.2.3. *Daedalus*

Daedalus corresponds to a complex ichnogenus present in the Armorican Quartzite that is characteristic of the Lower Paleozoic with excellent examples in both Villuercas-Ibores-Jara and Naturtejo UNESCO Global Geoparks. These ichnofossils are composed of vertical and transverse backfill structures (*spreiten*), with J-shaped inclined burrows and helical displacement (Seilacher, 2000). They were formed at the bottom of the ocean, from a practically fixed point at the water-substrate interface where they

translocate vertically and can pierce themselves or other structures. They can cross one or more layers, reaching depths of up to 1 m. Although the trace maker is unknown, it is believed that they were vermiform animals that reworked the soil opportunistically in search of food. The main ichnospecies found in the Armorican Quartzite are *Daedalus desglandi* Rouault, *Daedalus halli* Rouault and *Daedalus labechei* Rouault (Figure 3) (Neto de Carvalho *et al.*, 2021; Neto de Carvalho *et al.*, 2016).

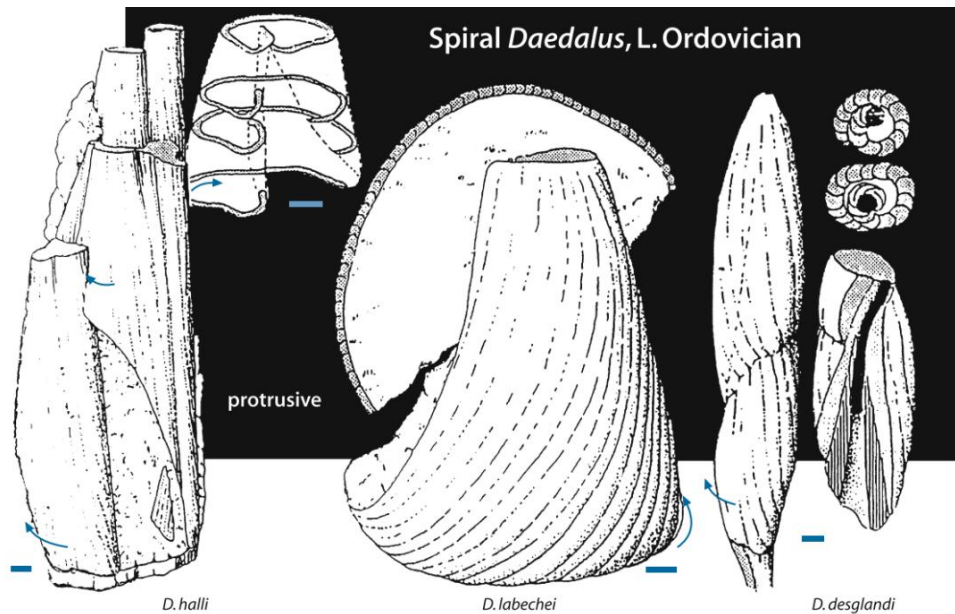


Figure 3. Main *Daedalus* ichnospecies identified in the Armorican Quartzite: *D. halli*, *D. labechei*, and *D. desglandi*. (Modified from Seilacher, 2007)

1.2.4. *Skolithos*

Skolithos is a very common ichnogenus present since the Early Cambrian that consists of simple vertical burrows used as habitation galleries, which were mainly found in sandstones in high-energy shallow marine environments. These ichnofossils compose the so-called “piperocks” by Hallam & Swett (1966) to refer to sandstones with high to moderate level of bioturbation caused by vertical burrows generated by vermiform organisms, possibly generated by polychaetes or phoronids (Neto de Carvalho *et al.*, 2021). These suspension-feeder organisms were endobenthic and were commonly found perpendicular to the surface on which they were hosted (i.e., to the stratification). Among the ichnospecies identified in the Armorican Quartzite is *Skolithos linearis* Haldeman either as individual burrows or dense

clusters (Gutiérrez-Marco *et al.*, 2019), and they are commonly found with other ichnofossils such as *Cruziana*, *Rusophycus*, and *Daedalus*, and often crossing them. Other similar vertical galleries of habitation are *Monocraterion* sp. (trumpet-shaped) or U-shaped as *Arenicolites* sp. and *Diplocraterion* sp. (Figure 4) (Catana, 2015).

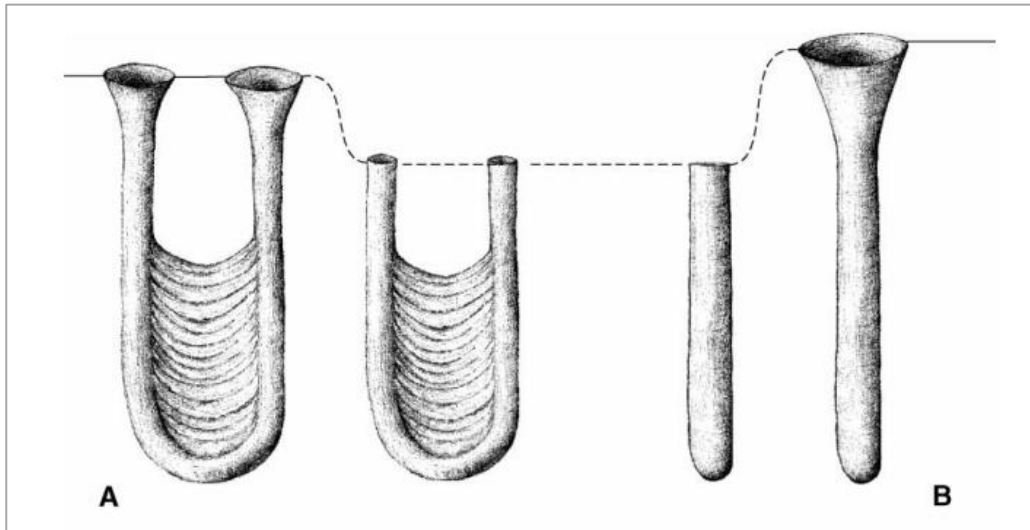


Figure 4. Examples of vertical galleries. A) U-shaped funnels of *Diplocraterion*; B) Funnels of *Skolithos* (Modified from (Bertling *et al.*, 2006).

1.2.5.Others

The following fossils are located in Guadalupe and are not abundant compared with the previous ichnofossils. The first one is probably *Helminthoidichnites* sp., which corresponds to slightly curved straight cylindrical traces that are arranged horizontally on the bedding plane. These ichnofossils are found in shales of the Guadiana Formation (Upper Ediacaran) and are common in Ediacaran and Phanerozoic sequences in marine environments (Gougeon *et al.*, 2018). The second one is ammonites; cephalopods with a coiled external shell that was divided into chambers separated by walls (septa). These ammonites are found with other macro and microfossils in red limestones of Ammonítico Rosso facies (Middle/Upper Jurassic - Lower Cretaceous) from Subbética of Córdoba, which were formed in deep marine settings far from the coast with low sedimentation rates (Molina & Ruiz Ortiz, 2007).

1.3. Relevance of the study

The presence of fossils in ornamental and decorative rocks in urban environments of the Villuercas-Ibores-Jara UNESCO Global Geopark provides a great platform to promote geoeducation and geotourism. However, the lack of documentation of urban fossils in the territory is a limitation to developing conservation strategies. The study of these elements is important to design tools that can be accessible to the general public. A society properly informed about the geology of its territory is more willing to accept geoconservation and education plays a crucial role to make it possible (Brilha, 2014). This study proposes the identification and documentation of urban fossils, which represents an innovative contribution to the geoconservation of the geopark and will allow the development of educational and tourism tools. The results can be used by educational institutions, tourists and the general public to disseminate knowledge of the natural environment of the territory. In addition, it will allow the identification of sites that can be considered in urban development plans to promote their management and conservation.

1.4. Objectives

The main objective of this study is to create and inventory of urban fossils in selected villages to enhance the understanding of the geological evolution in the Villuercas-Ibores-Jara UNESCO Global Geopark for educational and tourism purposes, promoting learning and exploration of these elements by students, tourists and the general public. The specific objectives are:

- To determine the educational and tourism potential of urban fossils through a quantitative analysis.
- To develop tools that allow the dissemination of urban fossils to the general public aiming to increase their educational and tourist value.

2. MATERIALS AND METHODS

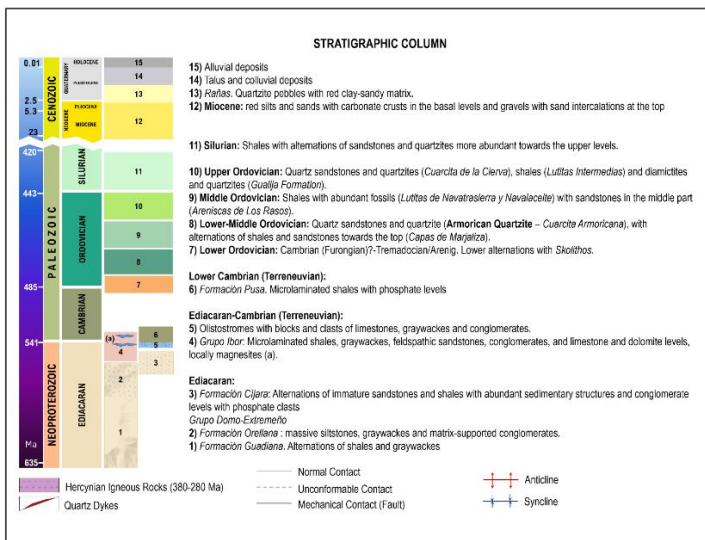
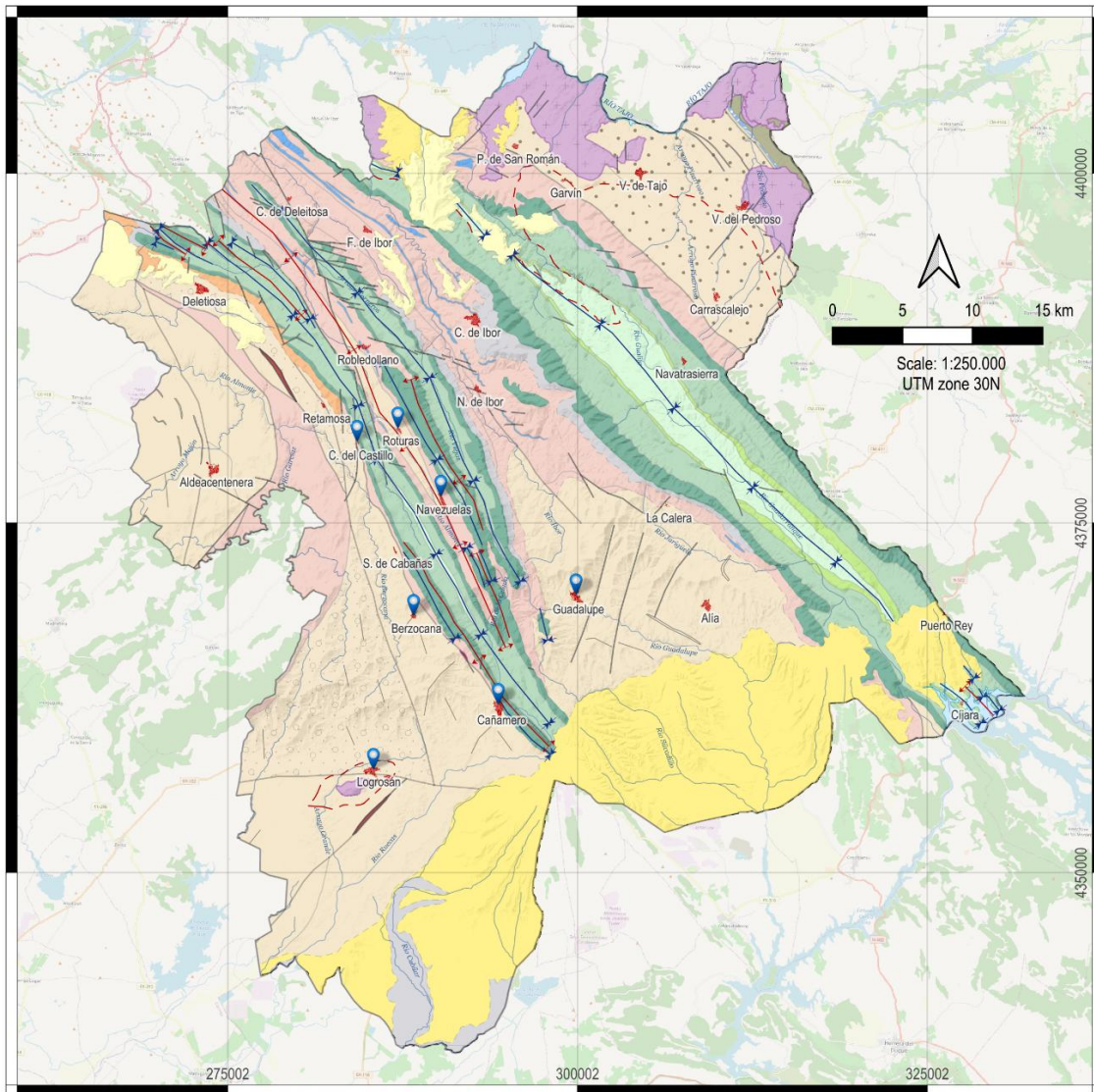
This chapter describes the study area and its geological context. It also presents the stages of the development of this work including the methodologies and tools used.

2.1. Villuercas-Ibores-Jara UNESCO Global Geopark

The Villuercas-Ibores-Jara UNESCO Global Geopark is located in the southeast of the Province of Cáceres, Extremadura, Spain, between the basins of the Tagus River and the Guadiana River (Figure 5). It has an area of 2,544 km² and a population of approximately 12,225 inhabitants (2024 Census) spread across 19 municipalities and 8 hamlets: Aldeacentenera, Alía (Guadisa, La Calera, Pantano de Cijara, and Puerto Rey), Berzocana, Cabañas del Castillo (Retamosa, Roturas, and Solana), Campillo de Deleitosa, Cañamero, Carrascalejo, Castañar de Ibor, Deleitosa, Fresnedoso de Ibor, Garvín de la Jara, Guadalupe, Logrosán, Navalvillar de Ibor, Navezuelas, Peraleda de San Román, Robledollano, Valdelacasa de Tajo and Villar de Pedroso (Navatrasierra) (Corrales *et al.*, 2013).

The highest peak is the “Risco de La Villuerca” (1,601 m) and it includes mountain ranges, valleys and *rañas*. It was declared a Geopark since September 2011 being part of the European and Global Geoparks Networks, and since November 2015, it has the designation of UNESCO Global Geopark (Geoparque Mundial de la UNESCO Villuercas Ibores Jara, n.d.-a). Among the most famous sites of the geopark are the Royal Monastery of Santa María de Guadalupe, World Heritage Site since 1993, and the Cave of Castañar, declared a Natural Monument of Extremadura.

The geopark has a paleontological richness of great value dating back to the Ediacaran period (635-542 million years ago) with the appearance of *Cloudina carinata*, the first organism that generated a mineralized exoskeleton. In addition, fossils from the Cambrian and Ordovician are recorded such as trilobites, brachiopods, bryozoans, echinoderms, mollusks (bivalves and cephalopods) and graptolites (Geoparque Mundial de la UNESCO Villuercas Ibores Jara, n.d.-b). The ornamental and decorative use of rocks with fossils, particularly ichnofossils, in urban settlements is common in the territory. The scope of the present study focuses on the municipalities of Berzocana, Cañamero and Navezuelas, where more specimens were previously located, and it also includes some localities of Cabañas del Castillo, Roturas, Guadalupe, and Logrosán.



Locations of urban fossils recorded in this study



Figure 5. Location and Geological map of the Villuercas-Ibores-Jara UNESCO Global Geopark, Spain. Note the Armoric Quartzite in dark green (8). Blue pins show the urban centers with fossils that were recorded in this work. (Modified from Junta de Extremadura & Universidad de Extremadura, 2010 and Geoparque Mundial de la UNESCO Villuercas Ibores Jara, n.d.-d)

2.2. Geological context

The geopark has a complex geological history with rocks belonging to the Ediacaran, Cambrian, Ordovician and Silurian periods (650 to 400 million years ago) and more recent Neogene materials and Quaternary deposits (Gil Montes, 2012). It exhibits a characteristic Appalachian-type relief composed of a series of mountain ranges and valleys that are aligned parallel in a northwest-southeast (NW-SE) direction. It is limited to the north and south by two Cenozoic grabens corresponding to the Tagus and Guadiana rivers, respectively, and it is surrounded by extensive Precambrian peneplains from east to west generating a strong landscape contrast (Fernández *et al.*, 2014). This relief is the result of rocks folding during the Hercynian Orogeny (more than 280 million years ago), which were subsequently eroded during the Mesozoic and influenced again by the Alpine Orogeny (30 million years ago), when the rocks were fractured producing uplifting and depression of faulted blocks (Corrales *et al.*, 2013; Gil Montes, 2012). Finally, the drainage network was superimposed on these rocks in the Quaternary period, giving rise to the current geomorphology of the area (Fernández *et al.*, 2014). The main fold structures that make up this relief are the Guadarranque-Gualija Syncline, Santa Lucía Syncline, Viejas Syncline, Ibor Anticline and Almonte Anticline, among others.

Differential erosion allows placing the hardest rocks in the upper part of the sierras, which correspond to quartzite ridges, while in the valleys are the less competent rocks and the detrital material of the ridges (talus deposits) (Corrales *et al.*, 2013). Following Fernández *et al.* (2014), the three main forms that shape the relief of the area can be classified as (Figure 5):

- Surrounding peneplains formed by Precambrian shales and greywackes.
- Quartzite sierras (Ordovician) that stand out for their steep slopes and ridges.
- Inner valleys resulting from the erosive action of rivers (e.g., Almonte, Viejas, Ibor, Guadarranque, and Gualija).

2.2.1. Armorican Quartzite

The geopark area is located in the Central-Iberian Zone of the Hesperian (Iberian) Massif. This massif has the most extensive outcrops of Ordovician and Silurian rocks in Europe and a remarkable Ordovician paleoichnological heritage related to the Armorican Quartzite (Gutiérrez-Marco *et al.*, 2008). The Armorican Quartzite is also present in other regions of the Iberian Peninsula in Portugal, Spain and

France, and usually appears unconformably over Upper Proterozoic and/or Cambrian rocks representing a transgressive unit (Gutiérrez-Marco *et al.*, 2002). In the area of Cáceres, the most representative points are located in Monfragüe and the Guadarranque Syncline (Gutiérrez-Marco *et al.*, 2008).

The Armorican Quartzite is of Arenig age (Lower-Middle Ordovician, about 470 million years old) and is composed of powerful sandstone and quartzite series, which generate high and abrupt reliefs that stand out in the field (Figure 6). Its thickness varies from 300 meters in the north to 5 meters in the southern areas of Extremadura. This formation changes progressively to a set of alternating sandstones and shales (*Capas de Marjaliza*) towards the top. This change reflects a transgressive period that begins with fluvial deposits that evolve into subtidal deposits (Junta de Extremadura & Universidad de Extremadura, 2010b).

It was formed from sand-rich sediments that were transported to shallow marine and deltaic environments, accumulating on the continental margin north of Gondwana at high latitudes, and were then under the influence of tidal currents and storms (Cortijo *et al.*, 2021; Gutiérrez-Marco *et al.*, 2002). Concentrations of *Skolithos* stand out in the lower part of the unit, while ascending *Daedalus* appears, and among the sandstone-mudstone alternations, *Cruziana* (Cortijo *et al.*, 2021). *Skolithos* and *Cruziana* ichnofacies are representative of the transgressive sequence that took place during the Floian (Lower Ordovician) (Gutiérrez-Marco *et al.*, 2019).

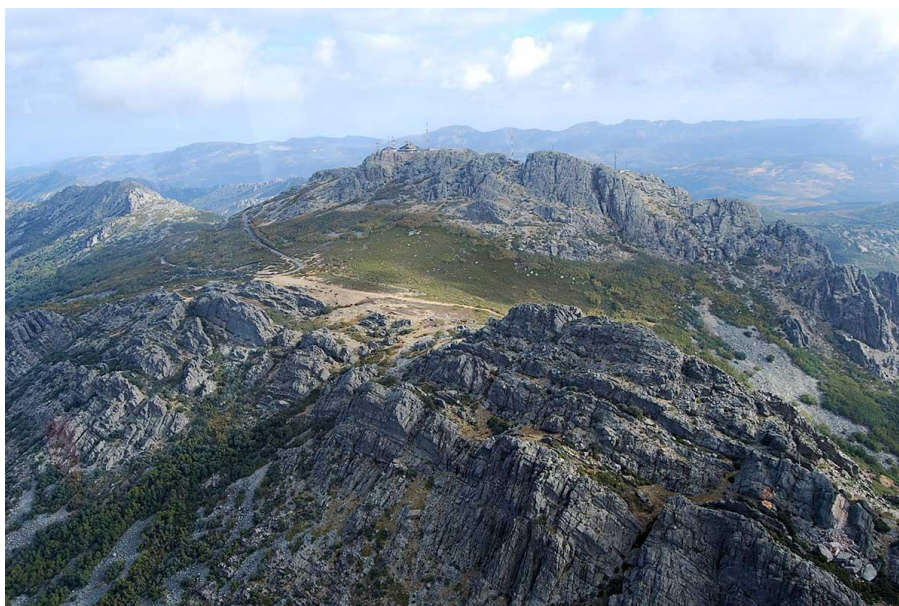


Figure 6. Armorican Quartzite ridges alternated with valleys making up the Appalachian-type relief. (Geoparque Mundial de la UNESCO Villuercas Ibores Jara, n.d.-c)

2.3. Methodology

This work was developed in five main phases: literature review, fieldwork and inventory, quantitative assessment, development of tools and analysis of results (Figure 7). In order to support the theoretical framework of the research, a bibliographic review was first carried out using databases and editorial repositories such as Scopus, Web of Science, Springer Nature Link and ScienceDirect, and the official website of the UNESCO Global Geopark Villuercas-Ibores-Jara (<https://geoparquevilluercas.es/>). Scientific articles, books, conference proceedings, monographs, reports, maps and guides were considered. Keywords such as “urban fossils”, “urban geodiversity”, “urban geoheritage”, “urban paleontological heritage” and “urban geodiversity assessment” were used to filter, and the information was collected and organized using the bibliographic manager Mendeley.

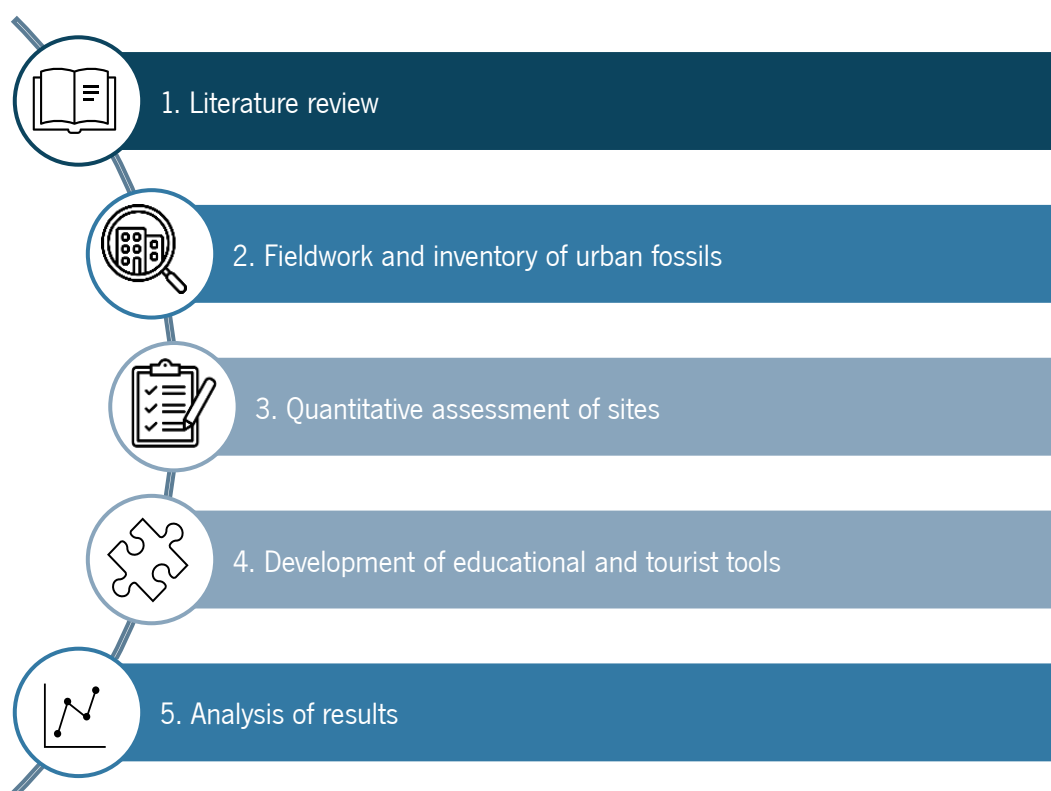


Figure 7. Stages of the methodology of this study

The next phase corresponded to the organization of the visits in the urban centers of the municipalities of Berzocana, Cañamero and Navezuelas. Specific sites were also included in Cabañas del Castillo, Roturas, Guadalupe, and Logrosán. Information on the location of potential points of interest was

requested from the local governments, schools and communities. In all cases, there was a preliminary identification that made it easier to locate some of the points. Subsequently, each site was recorded in a format that includes the following information:

- Code
- Name
- Municipality and address
- Coordinates
- Use
- Accessibility
- Legal protection
- Geological interest
- Description
- Geological formation (rocks)
- (Ichno)fossils
- Other interests
- Links with other cultural and ecological assets
- Vulnerability and threats
- State of preservation
- Photos

This information was digitized and georeferenced in QGIS to create the inventory.

Continuing with the quantitative evaluation, the method proposed by Kubalikova *et al.* (2019) for anthropogenic landforms was used, which considers the scientific, educational, tourist, added and conservation values. This method remains relatively stable and has been applied in other works in urban settings (e.g., Wolniewicz, 2022). The evaluation criteria and scores for each value are presented in Table 1. Additionally, the risk of degradation was evaluated following Brilha (2016) (Table 2). Both methods present some adaptations according to the needs of the present study. After assigning the values to each criterion and calculating the scores, the values were interpreted on a scale of low, moderate and high according to the ranges presented in Table 3.

The next step was the development of educational and tourism tools. Infographics on the urban fossils of the geopark and didactic routes were designed to create a booklet. Google Maps served as the platform to develop the routes, QGIS base cartography was used to create the maps, and Inkscape was

used for the assembly of the didactic material. The content of this tools was reviewed and validated by experts in the area. Subsequently, the results of the quantitative evaluation were analyzed, focusing mainly on the educational and tourist values considering the positive aspects, weaknesses, limitations and opportunities for improvement. Finally, the proposed tools were analyzed with reference to other case studies to determine their potential utility.

Table 1. Criteria for the quantitative assessment
(adapted from Kubalikova *et al.*, 2019)

Values	Criteria	Numerical Assessment	
Scientific value	Integrity or current status of the site	1	Conserved
		0.5	Partly conserved
		0	Damaged
	Diversity of the Earth science features	1	4 and more different features
		0.5	2-3 features
		0	1 feature
	Rarity	1	The site is unique within study area
		0.5	There are 2 or 3 similar sites
		0	More than 3 similar sites
	Scientific knowledge of the site	1	World known site
0.5		Regionally/nationally known site, several scientific papers	
0		The site has been researched marginally	
Educational Value	Exemplarity and representativeness	1	Good
		0.5	Comprehensible, but short explication is needed
		0	Not legible to the lay public; professional explication is needed
	Presence of educational facilities	1	Presence of educational trails or information panels with relevant information
		0.5	Existing educational facilities but with limited information
		0	No educational facilities on the site
Tourist Value	Accessibility	1	Access without problems
		0.5	Limited access
		0	Inaccessible to the public (or access is possible at own risk)
	Safety	1	Safety is not a problem
		0.5	Some specific limitations
		0	Visiting the site is not recommended and it is dangerous
	Tourist infrastructure (accommodation, food, toilets)	1	Tourist infrastructure situated within walking distance
		0.5	Limited tourist infrastructure is accessible
		0	No tourist infrastructure
	Viewpoints and visibility	1	1 or more viewpoints and/or all the features are perfectly visible
0.5		The features are partially visible	
0		Visibility is very limited	

Table 1. (Continuation) Criteria for the quantitative assessment
(adapted from Kubalíková *et al.*, 2019)

Values	Criteria	Numerical Assessment	
Added Value	Ecological aspect	1	Yes
		0	Absent
	Cultural aspects	2	4 and more different cultural aspects
		1.5	3 different cultural aspects
		1	2 different cultural aspects
		0.5	1 cultural aspect
		0	No cultural aspect
Conservation Value	Existing legislative protection	1	Existing legislative conservation
		0.5	The site is proposed for conservation or is registered as an important landscape element
		0	No legal protection or proposals for conservation
	Current threats	2	No threats, risks or hazards
		1.5	Existing threats, but the risk is low or already being managed
		1	Existing threats with an average or high risk, but there is a certain conception of how to manage them or how to mitigate the impacts
		0.5	Existing threats with high risks which are not managed and resolved
		0	Currently the site is in danger, there are some processes that can lead to its devastation

Table 2. Criteria for the assessment of the degradation risk
(Adapted from Brilha, 2016)

Criteria	Weight	Numerical Assessment	
Deterioration of geological elements	35	Possibility of deterioration of all geological elements	4
		Possibility of deterioration of the main geological elements	3
		Possibility of deterioration of secondary geological elements	2
		Minor possibility of deterioration of secondary geological elements	1
Proximity to areas/activities with potential to cause degradation	20	Site located less than 1 m of a potential degrading area/activity	4
		Site located less than 10 m of a potential degrading area/activity	3
		Site located less than 100 m of a potential degrading area/activity	2
		Site located less than 1 km of a potential degrading area/activity	1

Table 2. (Continuation) Criteria for the assessment of the degradation risk
(Adapted from Brilha, 2016)

Criteria	Weight	Numerical Assessment	
Legal protection	15	Site located in an area with no legal protection and no control of access	4
		Site located in an area with no legal protection but with control of access	3
		Site located in an area with legal protection but no control of access	2
		Site located in an area with legal protection and control of access	1
Accessibility	15	Site located less than 100 m from a paved road and with bus parking	4
		Site located less than 500 m from a paved road	3
		Site accessible by bus through a gravel road	2
		Site with no direct access by road but located less than 1 km from a road accessible by bus	1
Density of population	10	Site located in a municipality with more than 1,000 inhabitants/km ²	4
		Site located in a municipality with 250–1,000 inhabitants/km ²	3
		Site located in a municipality with 100–250 inhabitants/km ²	2
		Site located in a municipality with less than 100 inhabitants/km ²	1

Table 3. Interpretation of quantitative assessment

Criteria	Score	Interpretation
Scientific Value and Tourist Value	4.0	High
	2.0 – 3.5	Moderate
	0.0 – 1.5	Low
Educational Value	2.0	High
	1.0 – 1.5	Moderate
	0.0 – 0.5	Low
Added Value and Conservation Value	3.0	High
	1.5 – 2.5	Moderate
	0.0 – 1.0	Low
Degradation Risk	301 – 400	High
	201 – 300	Moderate
	< 200	Low

3. RESULTS

This chapter presents the findings related to the inventory and its respective quantitative evaluation. It also presents the educational and tourism tools developed.

3.1. Inventory of Urban Fossils

A total of 55 sites with urban fossils were recorded, which were mainly found adorning the facades of houses on exterior wainscots and on door/window frames. Fossils were present to a lesser extent on storefronts, walls in public spaces or as part of historical buildings (e.g., San Juan Bautista Church, Castle of Cabañas del Castillo, and the Royal Monastery of Santa María de Guadalupe). The sites are distributed across the following municipalities:

- Berzocana (10)
- Cañamero (26)
- Cabañas del Castillo (2)
- Roturas (Cabañas del Castillo) (1)
- Guadalupe (3)
- Logrosán (1)
- Navezuelas (12)

The fossils identified correspond mostly to ichnofossils of the *Cruziana* (*C. rugosa* Group), *Skolithos* (*S. linearis*), *Rusophycus*, and *Daedalus* (*D. halli*) ichnogenera from the Armorican Quartzite (Lower-Middle Ordovician) (Figure 8). In addition, simple horizontal galleries, ichnofossils that probably belong to the ichnogenus *Helminthoidichnites*, ammonites, and other elements such as sedimentary structures like ripples, rocks (sandstones, shales and carbonates) and minerals (calcite, quartz and pyrolusite) were recorded. The inventory summary is presented in Table 4 and an example of the record sheet can be seen in Table 5.

The most abundant ichnofossils correspond to *Skolithos*, which is present in 49 sites, followed by *Cruziana* with 41. In smaller proportions are *Rusophycus* (11) and *Daedalus* (5).

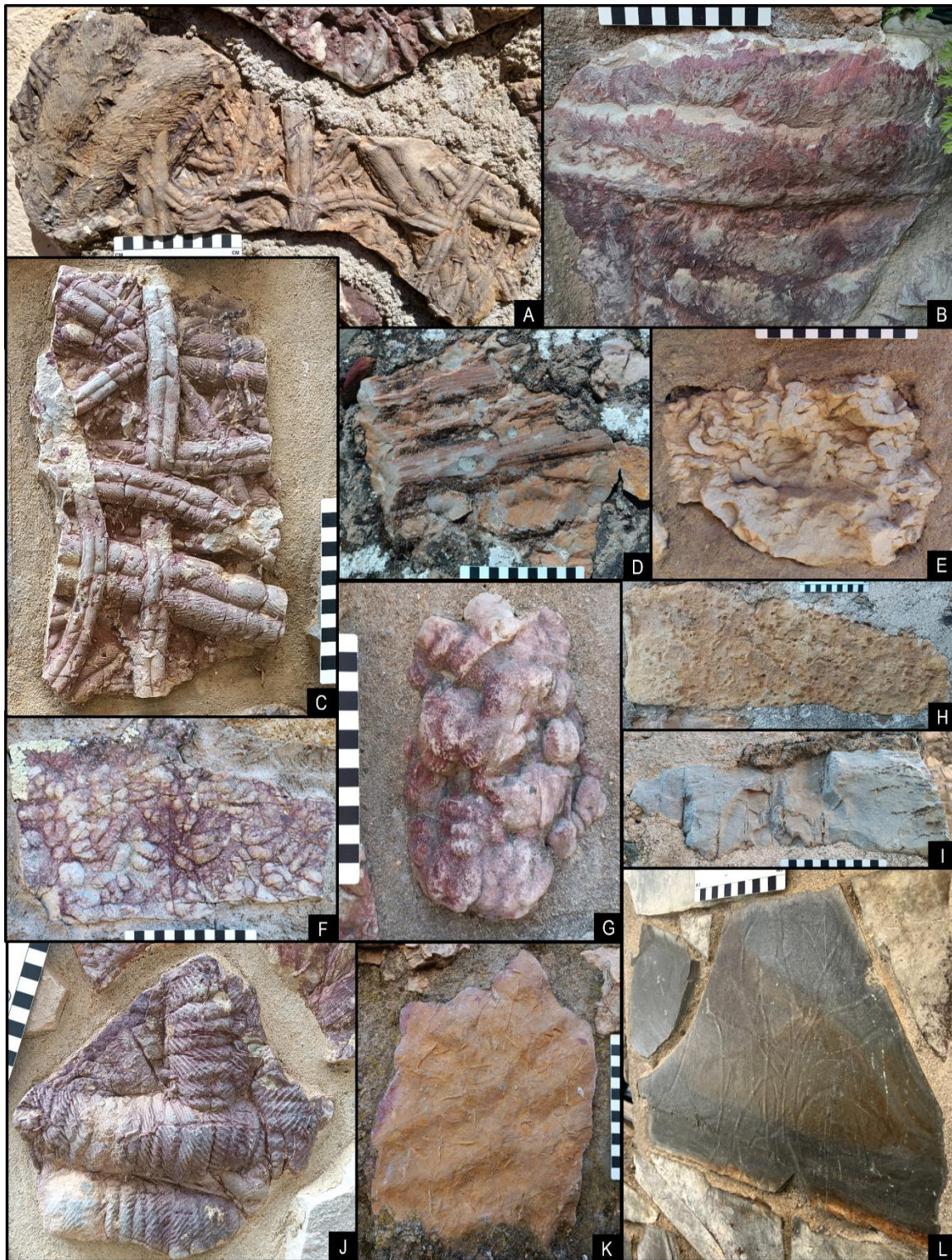


Figure 8. Examples of urban fossils recorded in the inventory. A) *Cruziana furcifera* (wider forms) and *Cruziana goldfussi* (narrower forms) - NAV01; B) *C. furcifera* - CAN26; C) *C. furcifera* and *C. goldfussi* crossed by *Skolithos* sp. - NAV09; D) *Daedalus halli* - CAN02; E) *Daedalus* sp. - CAN09; F,G) *Rusophycus* sp. - NAV03 and NAV07; H) *Skolithos* sp. - BER05; I) *Skolithos linearis* - BER05; J) *Cruziana rugosa* - NAV09; K) Ripples with simple horizontal galleries - CAN07; L) *Helminthoidichnites* sp. - GUA02.

The ichnofossils come from the Armorican Quartzite with the exception of *Helminthoidichnites* sp. (Figure 8 - L), which are found in shales of the Guadiana Formation (Upper Ediacaran) and are probably some of the oldest urban fossils in the world. In addition, ammonites in red limestones were found in the Camarín de la Virgen inside the Royal Monastery of Santa María de Guadalupe, which come from Subbética of Córdoba, Andalucía (Figure 9).



Figure 9. Tiles of red limestones with ammonites in the Camarín de la Virgen (Royal Monastery of Santa María de Guadalupe). These rocks come from Subbética (Córdoba Province) and are connection with the Sierras Subbéticas UNESCO Global Geopark.

Table 4. Synthesis of the inventory of urban fossils
(*Cruziana* (C.), *Rusophycus* (R.), *Daedalus* (D.), *Skolithos* (S.))

Code	Coordinates (DD)		Municipality	Address	Ichnofossils				Other Elements
					C.	R.	D.	S.	
BER01	39.437142	-5.460617	Berzocana	Plaza de España				X	Pyrolusite
BER02	39.436409	-5.461288	Berzocana	C. Pilar, 18	X	X		X	
BER03	39.436709	-5.459603	Berzocana	C. Prado, 16	X			X	
BER04	39.437136	-5.459543	Berzocana	C. Extremadura, 10	X	X		X	
BER05	39.438047	-5.461155	Berzocana	C. Carretas, 9	X			X	Calcite
BER06	39.438802	-5.461004	Berzocana	C. Fontanillas, 4	X			X	
BER07	39.438634	-5.461102	Berzocana	Plaza Cortés, 23	X			X	
BER08	39.438203	-5.462050	Berzocana	Plaza Vieja				X	
BER09	39.436820	-5.461939	Berzocana	C. Balcones, 29				X	
BER10	39.436921	-5.461702	Berzocana	C. Sta. Florentina, 27	X				

Table 4. (Continuation) Synthesis of the inventory of urban fossils
(*Cruziana* (C.), *Rusophycus* (R.), *Daedalus* (D.), *Skolithos* (S.))

Code	Coordinates (DD)		Municipality	Address	Ichnofossils				Other Elements
					C.	R.	D.	S.	
CAN01	39.378671	-5.390797	Cañamero	P.º Extremadura, 73	X		X	X	Simple burrows
CAN02	39.380176	-5.389290	Cañamero	P.º Extremadura, 6			X	X	
CAN03	39.380597	-5.388894	Cañamero	C. Conquistadores, 9	X			X	
CAN04	39.381428	-5.389511	Cañamero	C. Berzocana, 30	X			X	
CAN05	39.382099	-5.390679	Cañamero	C. Prensa, 1 & 4	X			X	
CAN06	39.382000	-5.391221	Cañamero	C. Prensa, 8	X	X		X	
CAN07	39.382212	-5.391333	Cañamero	Paraje Valbellido, 2	X			X	Ripples
CAN08	39.382176	-5.392166	Cañamero	C. Higueras, 6	X			X	
CAN09	39.382529	-5.389943	Cañamero	C. Zurbarán, 11 & C. La Madrila, 7	X		X	X	
CAN10	39.381640	-5.388331	Cañamero	C. Pizarro, 51	X	X			
CAN11	39.381323	-5.388183	Cañamero	C. Pizarro, 41	X			X	
CAN12	39.381075	-5.388072	Cañamero	C. Pizarro, 36	X			X	
CAN13	39.380389	-5.386389	Cañamero	C. Castillo, 7	X	X		X	
CAN14	39.380552	-5.386821	Cañamero	C. Castillo, 3			X	X	
CAN15	39.381712	-5.388851	Cañamero	Av. de Cervantes, 19					Carbonate rocks and ripples
CAN16	39.380749	-5.388561	Cañamero	Av. de Cervantes, 3	X				
CAN17	39.380054	-5.388386	Cañamero	C. José Fernández, 2				X	
CAN18	39.380004	-5.387658	Cañamero	C. Alcornocal, 4				X	
CAN19	39.379669	-5.387737	Cañamero	C. Fontanilla, 22 & 24	X	X		X	Simple burrows
CAN20	39.378982	-5.386910	Cañamero	C. Luis Chamizo, 11	X			X	
CAN21	39.378072	-5.386116	Cañamero	C. Coto, 23 & 25	X			X	
CAN22	39.377703	-5.386386	Cañamero	C. Coto, 23 & 48	X			X	
CAN23	39.377668	-5.386769	Cañamero	C. Chorro Gordo, 2	X	X		X	
CAN24	39.376985	-5.387159	Cañamero	C. José Manuel Durán Peloché, 18	X			X	
CAN25	39.375887	-5.389455	Cañamero	C. del Membrillo, 8	X		X	X	Conglomerate, limestone, granite, magnesite, and pyrolusite
CAN26	39.377196	-5.387903	Cañamero	C. Rodríguez de la Fuente, 27	X			X	
CDC01	39.547767	-5.509869	Cabañas del Castillo	Castillo de Las Cabañas	X			X	
CDC02	39.547887	-5.511759	Cabañas del Castillo	C. de La Jara, 18 y C. de la Peña Buitrera, 27 & 11	X			X	
GUA01	39.467576	-5.380847	Guadalupe	Near the access road to Risco de La Villuerca				X	
GUA02	39.451065	-5.326587	Guadalupe	C. Gregorio López, 21					? <i>Helminthoidichnites</i> sp.
GUA03	39.452374	-5.327338	Guadalupe	Plaza Sta. María de Guadalupe, 10140					Ammonites

Table 4. (Continuation) Synthesis of the inventory of urban fossils
(*Cruziana* (C.), *Rusophycus* (R.), *Daedalus* (D.), *Skolithos* (S.))

Code	Coordinates (DD)		Municipality	Address	Ichnofossils				Other Elements
					C.	R.	D.	S.	
LOG01	39.338284	-5.488767	Logrosán	C. Cristóbal Colón 18				X	Simple burrows
NAV01	39.512389	-5.440930	Navezuelas	Av. de Extremadura, 12, 25 & 6	X	X		X	
NAV02	39.512977	-5.441042	Navezuelas	Av. de Extremadura, 8				X	
NAV03	39.512510	-5.440582	Navezuelas	C. Martínez, 40 & C. Sahujal	X	X		X	Calcite and quartz
NAV04	39.512006	-5.440193	Navezuelas	C. Martínez, 23	X			X	
NAV05	39.512197	-5.440589	Navezuelas	Trav. C. Martínez (20D)	X			X	
NAV06	39.508712	-5.437786	Navezuelas	Av. de Extremadura, 101	X			X	
NAV07	39.508404	-5.437877	Navezuelas	Av. de Extremadura, 100	X	X		X	
NAV08	39.508306	-5.437192	Navezuelas	Av. Virgen de Guadalupe, 43 & 58	X	X		X	Ripples
NAV09	39.508768	-5.437394	Navezuelas	Av. Virgen de Guadalupe, 50	X			X	
NAV10	39.509148	-5.437016	Navezuelas	C. Francisco Pizarro, 5	X			X	
NAV11	39.508392	-5.436768	Navezuelas	C. Francisco Pizarro, 14	X			X	
NAV12	39.510874	-5.439360	Navezuelas	Plaza de España, 2	X			X	Simple burrows
ROT01	39.556500	-5.477081	Roturas (Cabañas del Castillo)	Grupo Escolar				X	

3.2. Quantitative Assessment

The general values obtained in the quantitative assessment were low to moderate. The highest scores were associated with the conservation and tourism values, while the scientific value was the lowest. The overall results are shown in Table 6 (for more detail, see Appendix 1).

3.2.1. Scientific Value

The scientific value for all sites in the inventory was low, which is attributed to the low rarity and diversity of the places, which present similar elements throughout the study area. In addition, scientific knowledge of the specific sites is practically absent, with the exception of site NAV01 which is mentioned in a scientific publication. The integrity parameter is the only one in which all the sites obtained a score different from zero since they are all conserved or partially conserved.

Table 5. Example of a descriptive sheet (NAV01) - Inventory of urban fossils

Descriptive Sheet - Inventory of Urban Fossils Villuercas-Ibores -Jara UNESCO Global Geopark			
Code	NAV01		
Name	"Cruziana" Garden	Municipality	Navezuelas
Address	Av. de Extremadura,12, 25 & 6	Coordinates (DD)	39.512389, -5.44093
Use	Residential	Accessibility	Easy
Legal Protection	Absent	Geological Interest	Paleontological
Description	<p>Three houses along the main road containing impressive sandstone fragments full of <i>Cruziana</i>, <i>Skolithos</i> (mainly crossing other ichnofossils), and <i>Rusophycus</i>, which are adorning the base of the facades. The contrast between the fresh rock and the more altered rock is evident. The ichnofossils are present in different scales and dispositions and are easy to identify thanks to the excellent state of preservation. Some pieces have abundant tracks of <i>Cruziana</i> intersecting in different layers.</p> <p>The surrounding houses also exhibit <i>Cruziana</i> and it was used on a small bench (house number 6). On a visual level, these ichnofossils are very eye-catching and raise interest for the general public. Additionally, the peaks of the Armorican Quartzite Formation are observed in the mountains behind the houses.</p>		
Formation (Rocks)	Armorican Quartzite (Sandstones / Orthoquartzite)	(Ichno)fossils	<i>Cruziana rugosa</i> Group, <i>Rusophycus</i> sp., <i>Skolithos</i> sp.
Other Interests	Educational and aesthetic		
Link with cultural / ecological assets	Popular architectural style in the area		
Vulnerability and threats	Low / None	State of preservation	Excellent
Limitations	None		
Photos			
A-C) House facades; D) <i>Cruziana</i> ; E) <i>Cruziana</i> and <i>Skolithos</i> ; F) <i>Rusophycus</i> ; G) Bench with <i>Cruziana</i>			

3.2.2.Educational Value

Educational values range from low to moderate. Some sites have well-preserved ichnofossils that serve as examples to explain the geological evolution of the area. However, in most cases, recognition of the ichnofossils is not evident to a general public. On the other hand, the lack of educational tools had a great influence on these results since practically all the sites go unnoticed without any visual aid to recognize the elements. The only sites with informative panels are Castle of Cabañas del Castillo (CDC01) and Pozo de la Nieve de Guadalupe (GUA01), although in the latter case, there is no reference to the presence of ichnofossils in the blocks that make up this structure.

3.2.3.Tourist Value

The tourist value in all cases was moderate. In terms of accessibility and safety, the sites are located in urban areas where it is easy to reach on foot and visitors are not at risk. In addition, most of the sites have good visibility of all elements. In the case of GUA01, which is located on the outskirts of town and is visited by people who follow the La Villuerca Geological Itinerary, it does not present a real limitation since it is very close to the main road, while CDC01 presents some limitations to reach the viewpoint at the top because the road needs maintenance. However, the lowest criterion corresponds to the tourism infrastructure because the supply of restaurants and lodging is very limited. According to the official website of the Geovilluercas Association (geovilluercas.org) and Google Maps, as of May 2025, the following tourism infrastructure is available¹:

- Berzocana: 1 hotel, 1 restaurant and 3 café-bars
- Cañamero: 1 hotel, 2 rural houses², 2 restaurants, 2 cafés-bars in the urban area, and 4 rural houses in the outskirts
- Navezuelas: 2 hotels, 1 restaurant and 2 café-bars

¹ The total number is lower since, in most cases, hotels coincide with restaurants in the same establishment.

² A rural house (*casa rural*) is a common type of tourist accommodation in Spain, which is independent and autonomous and it may be located in the countryside or in rural areas.

Table 6. Synthesis of Quantitative Assessment of Values and Degradation Risk

Code	Scientific Value	Educational Value	Tourist Value	Added Value	Conservation Value	Total Value	Degradation Risk
BER01	0.5	0.5	3.0	0.5	2.0	6.5	112
BER02	1.0	1.0	3.5	0.5	2.0	8.0	112
BER03	1.0	1.0	3.5	0.5	2.0	8.0	112
BER04	1.0	1.0	3.5	0.5	2.0	8.0	112
BER05	1.0	0.5	3.5	1.5	3.0	9.5	108
BER06	1.0	1.0	3.5	0.5	2.0	8.0	112
BER07	1.0	0.5	3.5	1.0	2.0	8.0	112
BER08	0.5	0.5	3.5	0.5	2.0	7.0	112
BER09	0.5	0.5	3.5	0.5	2.0	7.0	112
BER10	1.0	2.0	3.5	1.0	2.0	9.5	112
CAN01	1.0	1.0	3.5	0.0	2.0	7.5	112
CAN02	1.0	0.5	3.5	0.5	2.0	7.5	112
CAN03	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN04	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN05	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN06	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN07	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN08	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN09	1.0	0.5	3.5	0.5	2.0	7.5	112
CAN10	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN11	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN12	1.0	0.5	3.5	0.5	2.0	7.5	112
CAN13	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN14	1.0	0.5	3.5	0.5	2.0	7.5	112
CAN15	1.5	0.5	3.5	0.5	2.0	8.0	112
CAN16	0.5	1.0	3.5	0.5	1.0	6.5	217
CAN17	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN18	1.0	0.5	3.5	0.5	2.0	7.5	112
CAN19	1.0	1.0	3.5	1.0	2.0	8.5	112
CAN20	0.5	0.5	3.5	0.5	2.0	7.0	112
CAN21	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN22	0.5	0.5	3.5	0.5	1.0	6.0	182
CAN23	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN24	1.0	1.0	3.5	0.5	2.0	8.0	112
CAN25	1.5	1.0	3.5	0.0	2.0	8.0	112
CAN26	1.0	1.0	3.5	0.0	2.0	7.5	112
CDC01	1.0	1.0	1.5	2.0	2.5	8.0	89
CDC02	1.0	1.0	3.0	0.5	2.0	7.5	112
GUA01	1.0	1.5	3.0	2.0	1.0	8.5	89
GUA02	1.5	0.0	3.5	0.0	1.0	6.0	182
GUA03	2.0	1.0	3.5	1.5	3.0	11	106
LOG01	1.0	0.5	3.5	0.0	2.0	7.0	112
NAV01	1.5	1.0	3.5	0.5	2.0	8.5	97
NAV02	0.5	0.0	3.0	0.5	2.5	6.5	128
NAV03	1.0	1.0	3.5	0.5	2.0	8.0	97

Table 6. (Continuation) Synthesis of Quantitative Assessment of Values and Degradation Risk

Code	Scientific Value	Educational Value	Tourist Value	Added Value	Conservation Value	Total Value	Degradation Risk
NAV04	1.0	0.5	3.0	0.5	2.0	7.0	97
NAV05	0.5	0.5	3.0	0.5	2.0	6.5	97
NAV06	0.5	0.0	3.0	0.5	1.5	5.5	132
NAV07	1.0	1.0	3.0	0.5	2.0	7.5	97
NAV08	0.5	0.0	3.0	0.5	2.0	6.0	97
NAV09	1.0	1.0	3.5	0.5	2.0	8.0	97
NAV10	0.5	0.5	3.0	0.5	2.0	6.5	97
NAV11	0.5	0.0	2.5	0.5	2.0	5.5	97
NAV12	1.0	1.0	3.5	0.5	2.0	8.0	97
ROT01	1.0	0.0	2.5	0.0	1.5	5.0	97

3.2.4.Added Value

In most of the evaluated sites, the added value was low and is mainly related to the popular architectural style of the area, where rock fragments extracted from nearby talus deposits were used. Sites such as the Church of San Juan Bautista (BER05), the Castle of Cabañas del Castillo (CDC01), and the Camarín de la Virgen de Guadalupe (GUA03) obtained moderate values due to their architectural, religious, and/or historical importance. The relationship with the ecological component is attributed to bird watching and biodiversity, found only in sites located on the outskirts of the villages (CDC01 and GUA01).

3.2.5.Conservation Value

Conservation value was moderate for the vast majority of cases because no threats to the elements were found beyond vegetation growth at few sites. In general, the urban fossils are in good condition and the community takes care of them since they are part of their homes. In some specific cases, signs of vandalism were identified, such as graffiti at NAV02 or at GUA02 where the rock pieces are scratched. However, these cases are isolated. On the other hand, only four sites have legal protection such as the Royal Monastery of Santa María de Guadalupe (GUA03) declared National Monument and *BIC*-cultural asset- in 1879, and UNESCO World Heritage Site in 1993, the Church of San Juan Bautista

(BER05) declared a National Monument (1977), the Castle of Cabañas del Castillo (CDC01) (*Decreto de 22 de abril de 1949* and *Ley 16/1985*), and the Pozo de la Nieve de Guadalupe (GUA01) (located in the *Corredor Ecológico y de Biodiversidad del Río Guadalupe*). The rest of the sites do not have any type of legal figure beyond the protection of private property contemplated in the general law of the country.

3.2.6. Risk of Degradation

In spite of the lack of legal protection on most sites (see previous section), the scores obtained for degradation risk were low (Table 6, for more detail, see Appendix 2). This is mainly due to the low possibility of deterioration despite the location in urban areas with easy accessibility, and the low density of population in all the municipalities. Ichnofossils are part of the facades of houses, where the action of nature is reduced (e.g., erosion and weathering). The constant presence of people and the flow of vehicles does not represent a major risk since the fossils are cared for by the homeowners and the local community. In the case of site CAN16, which scored moderate, this is because the risk increases due to the possibility of being stepped on because the fossil is embedded in the floor.

3.3. Educational and tourist tools

3.3.1. Infographics

Two infographics related to ichnofossils were designed for the general public as a first approach to the urban fossils of the Villuercas-Ibores-Jara UNESCO Global Geopark. The first one is called “How did these fossils get here?”, which seeks to explain the formation of the ichnofossils taking *Cruziana* as an example and its relationship with the Armorican Quartzite and the Appalachian-type relief (Figure 10). A general context of the paleogeographic configuration of the Iberian Peninsula in the Lower-Middle Ordovician (475 million years ago) is provided and the process is divided into four stages: formation, folding, erosional and present. The urban fossils are related to the rocks exposed in the talus slopes, which are collected by the inhabitants to decorate their houses.

How did these fossils get here?



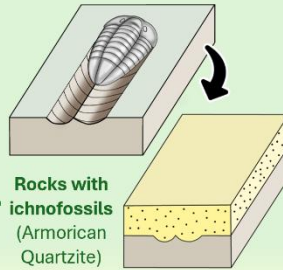
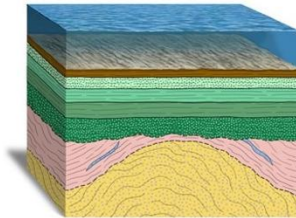
This journey begins
475 million years ago
(Lower-Middle Ordovician)

At that time, the territory of the Villuercas-Ibores-Jara UNESCO Global Geopark, together with the Iberian Peninsula, was located under the sea near the South Pole and was part of the ancient supercontinent Gondwana.



The environmental conditions were very different: **a shallow sea with cold waters and rich in nutrients**. On the sands of these ecosystems lived organisms such as gastropods (like snails), bivalves (like clams), marine worms and the now extinct **trilobites**, which generated tracks and galleries in the sediments. These marks that reflect the activity of these organisms are called **ichnofossils** and were recorded in a group of rocks called **Armorican Quartzite**. Today, it is possible to find these ichnofossils adorning the facades of houses and other surfaces in urban environments within the geopark.

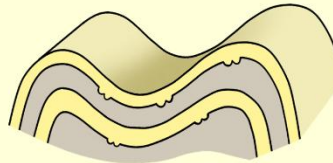
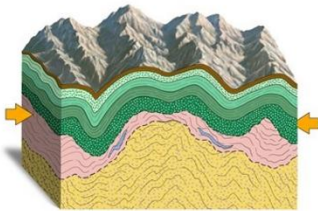
1 Formation Stage



Rocks with ichnofossils (Armorican Quartzite)

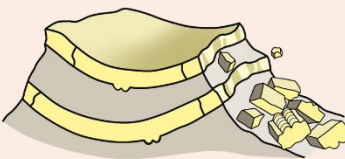
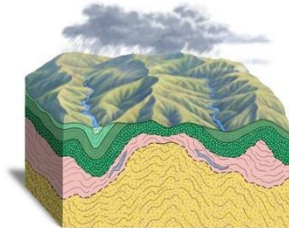
Trilobites were animals that moved on the sea floor and left traces or tracks known as **Cruziana**. These tracks were filled by sandy sediment (forming the mold), which was compacted giving rise to **sandstones and quartzites** (very hard rocks composed mainly of quartz). Subsequently, these rocks were buried by other rocks that were deposited on top of them.

2 Folding Stage



Altogether, these rocks were folded by compressional processes more than 280 million years ago, generating a mountainous relief.

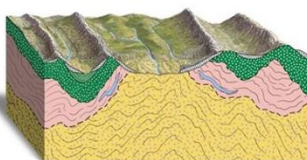
3 Erosional Stage



During the Mesozoic Era (251 to 66 million years ago), these rocks were eroded by the action of rivers and wind. Then they were again fractured and folded 30 million years ago, allowing the rocks with ichnofossils to be exposed at the surface.

The exposed layers with *Cruziana* casts were eroded and accumulated with other materials in the form of blocks and loose fragments on the mountain slopes. These accumulations are known as "**pedreras**" (talus).

4 Current Stage



Today, the highest parts of the geopark's mountain ranges correspond to these sandstones and quartzites, which are very easy to recognize because they stand out from the rest of the landscape. The characteristic **Appalachian-type relief** can be seen, consisting of a series of mountain ranges and valleys aligned in parallel.

People have taken advantage of the accumulation of these rocks with impressive ichnofossils to decorate the facades of their houses giving a distinctive feature to the architecture of the region.

Illustrations by Antonio Grajera. *Cruziana* evolution model modified from Simón-Porcar et al. (2020)

Figure 10. "How did these fossils get here?" infographic.

Reference model adapted from Simón-Porcar et al. (2020).

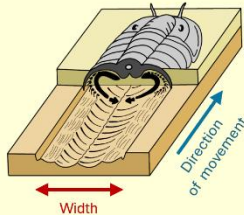
Illustrations of the evolution of the geopark and paleoreconstruction by Antonio Grajera.

Urban fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark

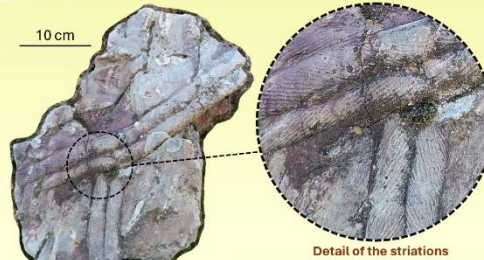


1 Cruziana

Cruziana is the most representative urban fossil of the geopark. They are fossilized traces left by **trilobites** and other arthropods as they moved along the marine sediment in search of food.



The marks or striations generated by the legs are “V” shaped and indicate the direction of movement of the organism. The open part of the V indicates the direction of displacement.



Av. de Extremadura, Navezuelas

It is recognized as a path with a central groove that divides two lobes with striations generated by the legs of the organism.

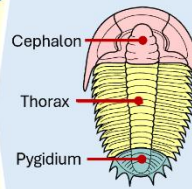
Trilobites moved between the sandy layers of the seafloor and left a trail that was then filled in by sediment forming the mold we see today.

Trilobites moved through different layers in the marine sediment causing the tracks to cross each other. A high abundance of these tracks is related to a nutrient-rich seafloor where living conditions were favorable.

Trilobites

were arthropods (like crabs) that had a body divided into three parts. They were one of the most successful living groups on the planet, being present for about 270 million years. They lived in the seas and became extinct about 250 million years ago.

Trilobites varied in size from the size of a fingernail up to 70 cm, depending on environmental conditions and species.

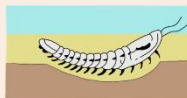


Did you know that they generated more than one type of ichnofossil?

2 Rusophycus

This ichnofossil is also produced by trilobites and is related to a resting state or hiding from predators. It is recognized because it has a coffee bean shape that narrows towards one end. It is usually divided into two lobes with striations.

Rusophycus makes it possible to determine more accurately the length of the organism.



Av. de Extremadura, Navezuelas



C. Martínez, Navezuelas

3 Daedalus

It is believed that these trace fossils were perhaps produced by worm-like organisms, which moved in circles under the sediment looking for food while forming complex spiral-shaped galleries. These ichnofossils could be up to 1 meter long.



10 cm

C.E.I.P. Fausto Maldonado, Cañamero



P.º Extremadura, Cañamero



C. Zurbarán, Cañamero

4 Skolithos

These ichnofossils are simple vertical tubes that were used as burrows by various marine organisms such as gastropods (snails), bivalves (such as mussels) and annelids (worms). They lived in the sediment perpendicular to the seafloor surface, which differentiates them from other simple galleries that were formed horizontally.



The creators of these ichnofossils were filter feeders, that is, they captured small food particles that were suspended in the water. They are very common to find with the other ichnofossils and are recognized as elongated tubes or small dots.



In cross section (dots) – C. Conquistadores, Cañamero



In longitudinal section (tubes) – San Juan Bautista Church, Berzocana

Illustrations modified from Catana (2015) y Antonio Grajera

Figure 11. “Urban fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark” infographic.

Illustration of *Cruziana* and *Rusophycus* modified from Catana (2015) and illustrations of *Daedalus* and *Skolithos* adapted from Antonio Grajera.

The second infographic “Urban fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark” shows the main genera of ichnofossils found: *Cruziana*, *Rusophycus*, *Daedalus* and *Skolithos* (Figure 11). This material seeks to provide information on how they were formed and a quick guide to recognize them including photos of some sites in the municipalities.

3.3.2.Routes

Three routes were designed for the municipalities of Cañamero, Berzocana and Navezuelas, which can be obtained in printed or digital format and are also available on Google Maps (Figure 12). Each stop has brief information about the ichnofossils or other elements found and reading time is estimated to be between 1 to 2 minutes . The Cañamero route has 23 sites along a total walking route that takes about 1 hour and 40 minutes, while the Navezuelas route with 11 stops takes 50 minutes, and the Berzocana route with 10 takes about 40 minutes.

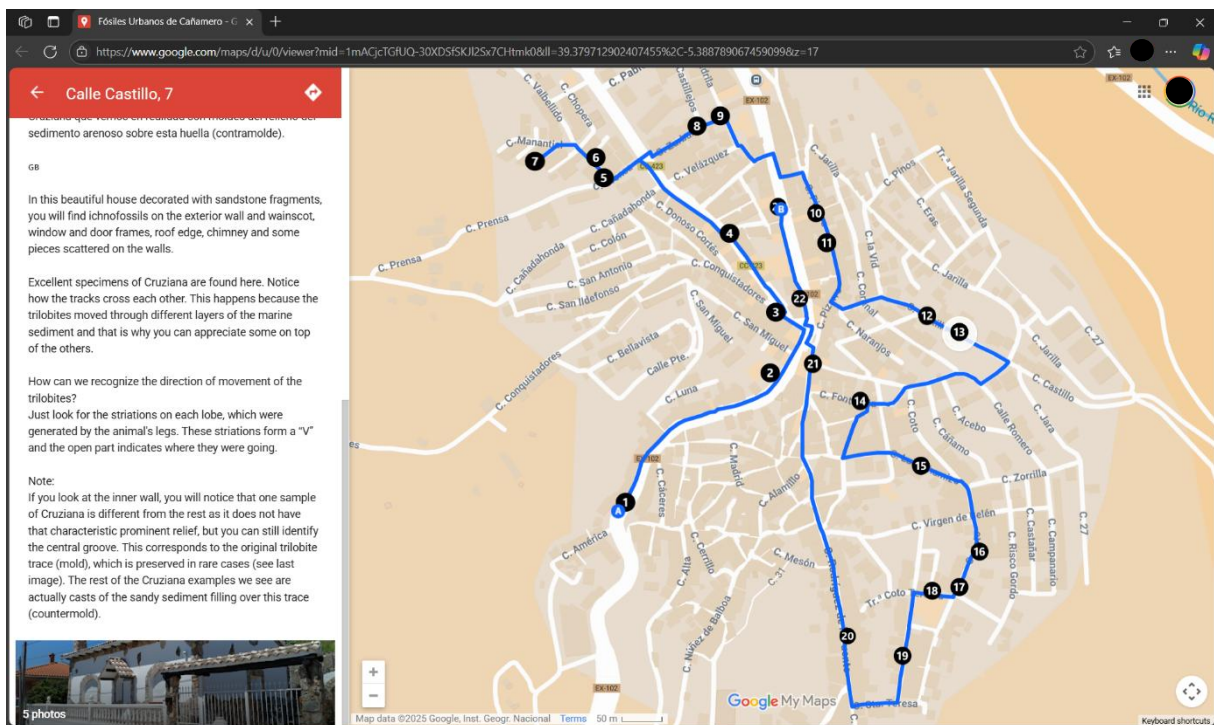


Figure 12. Visualization of the Cañamero Route in Google Maps. The description of stop 13 is displayed on the left along with the photos.

All this information was compiled in a booklet that will be distributed to the Interpretation Centers and schools of the geopark (physically and virtually). The routes are freely accessible and QR codes have been included in the physical maps that redirect to the Google Maps application . They will also be added to the “Tourism” area of the official geopark website, in the “Routes” section (in both, Spanish and English once the final version is ready). They can also be accessed through the following links:

- Berzocana (Figure 13):
<https://www.google.com/maps/d/u/3/edit?mid=1rQfcK76oWRRfhBBY71jeO4FReuuSDdo&usp=sharing>
- Cañamero (Figure 14):
<https://www.google.com/maps/d/u/3/edit?mid=1mACjcTGfUQ-30XDSfSKJI2Sx7CHtmk0&usp=sharing>
- Navezuelas (Figure 15):
<https://www.google.com/maps/d/u/3/edit?mid=1fiCnB7nIPS08zT8ZYCKE4EXriuuY-0Y&usp=sharing>

Ruta de fósiles urbanos de Cañamero

Urban Fossil Route of Cañamero

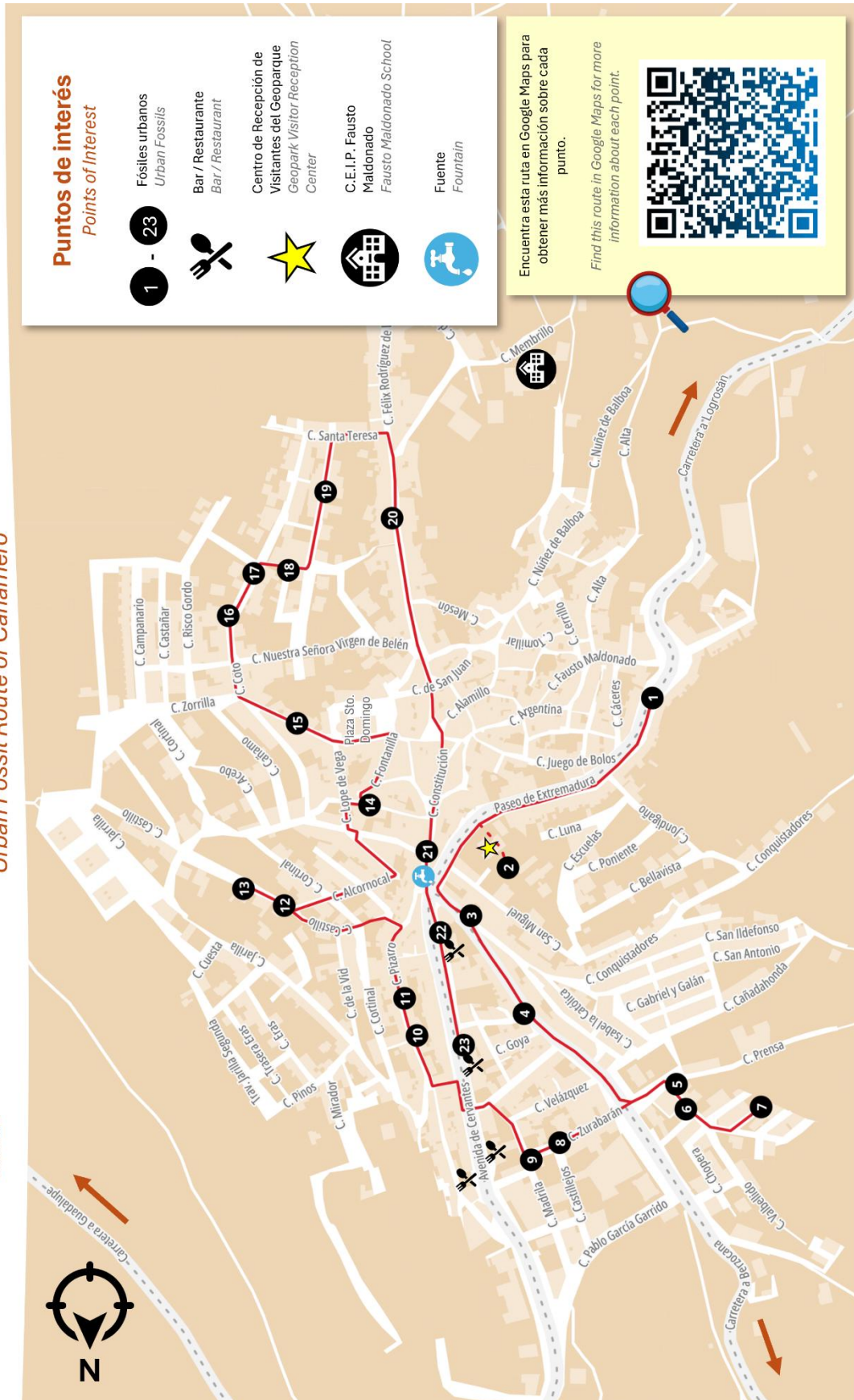


Figure 14. Urban Fossil Route of Cañamero

4. DISCUSSION

The main findings of this study related to the assessment with emphasis on the educational and tourism potential are discussed below. An analysis of the values obtained is made considering the strong and weak points, limitations and aspects to be improved. Also, the potential application of the tool in real contexts and recommendations for future work are discussed.

4.1. Quantitative Analysis

The overall results of the quantitative analysis in this study suggest that all values range from low to moderate. According to Wolniewicz (2022), the method of Kubalikova *et al.* (2019) performs best when geodiversity elements are numerous. In this case, the sites present low geodiversity as they contain elements that are limited to fossils, rocks and in some cases, minerals.

This has a direct impact on the scientific value since the diversity of elements is considered. The low scores in this value are consistent with what was expected. Although these rocks come from the Armorican Quartzite, which is included in the Geological Context of the Lower and Middle Paleozoic Stratigraphic Successions (Gutiérrez-Marco *et al.*, 2008), their scientific value is low since they correspond to *ex situ* material that was taken from talus slopes and their stratigraphic use is null. Additionally, these results are influenced by the lack of studies specifically related to urban fossils and the low rarity of elements. This suggests that the strong focus of these sites is not scientific, however, in the educational and tourist areas there is a greater potential.

As part of the role of UNESCO Global Geoparks, is the development of educational activities and resources, with education being one of the three pillars of any geopark along with geoconservation and geotourism (Catana & Brilha, 2020). Low to moderate scores for educational value indicate that it is important to implement strategies to make the sites accessible to the general public. The lack of educational resources around urban fossils has a major impact on these results, as the sites that have some type of tool are those that are farthest away from urban centers, while the vast majority go unnoticed.

Recognition of ichnofossils such as *Cruziana* is relatively straightforward for a non-specialist audience as they have a very distinctive and striking structure. However, others such as *Daedalus* may present a challenge due to the low degree of preservation. In the particular case of *Cruziana*, specimens are found with an excellent level of preservation where the central groove, lateral striae, in some cases lateral margins, and also the direction of movement of the organism can be clearly identified. These traces can be found in dense concentrations, overlapping and in circular to sinusoidal patterns. Similarly, *Rusophycus* is recognized by its distinctive bilobed and striated coffee bean shape, although well-preserved specimens are not abundant. The ichnogenus *Skolithos* is the most common in the inventory and its identification is relatively straightforward due to its simplicity. It tends to stand out more when the rock is altered because it generates a greater contrast between the ichnofossils and the matrix. In some places *Skolithos* are presented in longitudinal and transversal sections in a very clear way representing a good didactic material, e.g., CAN04. On the other hand, the best example of *Daedalus* is found in the Fausto Maldonado School (Cañamero), which is not integrated into any building but is part of the educational material available to students (additionally, it is visited by other educational centers in Extremadura and geotourism companies that request it; see section 4.2). Among the urban ichnofossils found, these require a higher degree of abstraction and interpretation. Nevertheless, there are few examples of *Daedalus halli* located in the geopark in outcrop and site CAN02 presents a good specimen of this ichnospecies (S. Jensen, personal communication, June 3, 2025).

When identifying ichnofossils, it should be considered that their preservation varies according to factors such as the initial position of the organism, burial time, diagenesis, lithology, conditions of the depositional environment, bioturbation and tectonic activity. Therefore, it is important to show how each fossil varies in different sections and degree of preservation. For example, Catana (2015) presents a characterization of the types of ichnofossils found in Penha Garcia (Portugal) using real examples and diagrams to make it easier. The creation and implementation of tools to identify urban fossils in the geopark is key to enhancing the educational value. Ichnofossils can be used as resources to contribute to environmental education in local schools taking advantage of the fact that they are very accessible within the villages (Kubalíková *et al.*, 2020). In addition, these resources function as an alternative for field trips, where organization with groups of several students can be difficult.

In terms of tourism value, the lack of infrastructure to receive visitors negatively influences the results, since there is a limited supply of hotels and restaurants to spend a day in the villages. One of the tourist focuses of the geopark is concentrated in Guadalupe, because it hosts the Royal Monastery of

Santa María de Guadalupe, an important religious tourist reference, and has a wider range of tourist services such as museums (Pablos Heras, 2014). This also means that visits to other villages are greatly reduced. Therefore, it is crucial to continue promoting tourism through the adhesion of partner companies that can have visibility on the Geopark website and the Geovilluercas Association with information constantly updated. Although geotourism is usually related to non-urban areas, sites with geological interest are not limited to rural areas (Palacio-Prieto, 2015). The incorporation of urban fossils within the tourism offer can give greater visibility to the geodiversity of the geopark and works as a bridge for people to have an easier approach to the geology of the territory.

The presence of fossils in the decorative rocks of houses, as part of urban geodiversity, influences the perception of the streetscape and is important for the growth of tourism (Habibi *et al.*, 2018). These fossils give a distinctive stamp to the popular architecture of the territory and can be used to create strategies that promote their dissemination and connection with cultural heritage. It is possible to raise awareness around the importance of these resources through urban geotourism with strong educational and geoconservation aspects (Kubalíková *et al.*, 2020). Furthermore, the accessibility and safety conditions are positive as there are no restrictions on observing the sites without major risks, as could happen in the field. Tourism around urban fossils is suitable for all audiences and ages and includes people with reduced mobility and blind people who can make use of touch.

The added value can be enhanced by promoting the popular architectural identity of the villages around the ichnofossils. The use of local stones and research on their provenance contributes to the historical knowledge of the territory and leads to create a stamp on the architecture and typical appearance of the villages, helping to differentiate them from others (Damas Mollá *et al.*, 2023; Kubalíková & Zapletalová, 2021). It can even be considered an ethnopaleontological phenomenon related to the use of rocks with ichnofossils in the style of architectural ornamentation (Astudillo, 2010). This practice is also identified in several towns in the Province of Salamanca, with Monsagro being the most remarkable (Simón-Porcar *et al.*, 2020). Additionally, in emblematic buildings such as the Church of San Juan Bautista and the Castle of Cabañas del Castillo (Figure 16), the cultural value increases and a great opportunity for dissemination is presented. Due to their cultural importance, these sites tend to be more visited and accessible to a varied public (e.g., Polck *et al.*, 2020).

The conservation value is a point in favor in the vast majority of sites and is directly related to the risk of degradation. It is important to clarify that the quantification of degradation risk may present bias, since the method selected (Brilha, 2016) is focused on geosites in the absence of one for urban sites.

However, the results are congruent with what was expected. The low risk of degradation suggests that the ichnofossils are in particularly good condition despite the proximity to anthropogenic sources. The fossils are protected in some way by the community and have been intact for many years, as vandalism is minimal. In addition, the influence of natural factors such as erosion and weathering is greatly reduced. However, for site GUA02 it is necessary to promote the conservation of *Helminthoidichnites* sp. ichnofossils (Figure 8 - L) through outreach to tourists visiting Guadalupe in order to raise awareness about their protection and care, since it is the only site that presents these fossils and might be among the oldest urban fossils in the world.

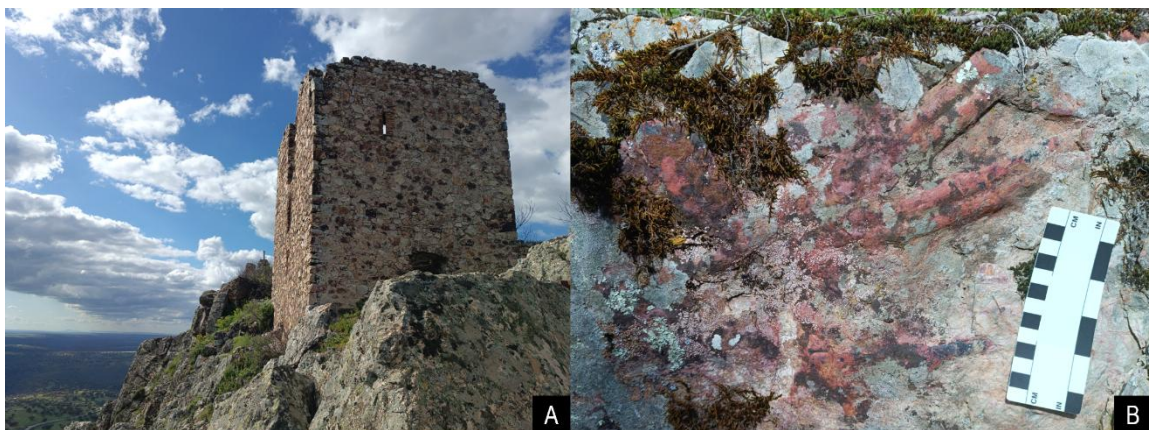


Figure 16. Castle of Cabañas del Castillo (CDC01); a cultural asset that was built in the 12th century along with other castles to control the *Marca Media*. A) View of the castle on the top of the Armorican Quartzite; B) Outcrop with *in-situ Cruziana* on the path leading to the castle.

The fossils were incorporated into the houses prior to the entry into force of the Law 42/2007 on Natural Heritage and Biodiversity and currently, the extraction of this material from the talus slopes is not permitted. Therefore, the importance of their conservation and appropriate dissemination through educational and tourism resources should be emphasized. Simón-Porcar *et al.* (2020) point out that the use of these ichnofossils in the urban landscape of Monsagro should be considered as a *BIC* (*Bien de Interés Cultural* – cultural asset) and be legally protected within the category of ethnological site, which would contribute significantly to increase the conservation value and could attract more visitors. Even without this, it is necessary to promote the importance and care of these elements that add a special value to the villages.

The inventory is a fundamental step to promote the conservation of urban fossils and opens the way to continue identifying sites throughout the geopark territory. Through this resource, initiatives can

be proposed for inclusion in urban development plans to ensure their protection. In addition, it is encouraged to integrate more sites located in different villages to enrich the database and continue improving it. The use of this resource will make it possible to develop strategies to take full advantage of it for the benefit of the community.

4.2. Educational and Tourist Potential

The Villuercas-Ibores-Jara UNESCO Global Geopark provides information on fossils through information and interpretation centers such as the Visitor Reception Center in Cañamero, the Vicente Sos Baynat Geological and Mining Museum in Logrosán, and the Fossil Interpretation Center in Navatrasierra. Initiatives such as the “*Patio de las rocas del Geoparque*” (Courtyard of the Geopark rocks) at the Fausto Maldonado School in Cañamero represent a very ingenious resource for children to have an approach to fossils and the geodiversity of the territory from an early age (Figure 17).



Figure 17. "Patio de las rocas del Geoparque" at Fausto Maldonado School, Cañamero (CAN25)

Cruziana is the most popular ichnofossil in the area and is appreciated by tourist companies in the geopark being considered in tourist routes and geological itineraries that include *in situ* exhibits, e.g., in the geosite *Estrecho de la Peña Amarilla*, which has a very illustrative panel (Cortijo *et al.*, 2021). The presence of *Cruziana* and other ichnofossils in the villages should also be considered as part of the itineraries. An important reference is the “*Ruta de las Huellas Fósiles*” of Monsagro, Salamanca, where they implemented different tools mainly focused on the dissemination of the ichnofossils coming from the

Armorican Quartzite, which are present in the architecture of the village (Martínez-Graña *et al.*, 2017). As part of the ornamental rocks, the ichnofossils function as important educational resources that are available within the villages and are close to educational institutions such as schools. Besides, there is the possibility to interact directly with these materials, unlike in a museum, and an interpretation related to the paleogeographic context and geological processes that have taken place in the area can be done (Habibi *et al.*, 2018).

Although the tools designed in this study could not be tested in a practical setting with students and tourists due to time and logistical limitations, validations by experts in the field (Geopark's Educational and Scientific Committee and staff from the Department of Sustainable Development and Tourism of the Cáceres Provincial Council) were carried out and recommendations were followed to create a didactic and understandable material. It is recommended that their effectiveness be evaluated in future work through application, collection of experiences, suggestions, and feedback that will allow improving them. Similar projects such as the "*Ruta de las huellas fósiles*", "*Paleo Ruta de Salamanca*", and "*Cabra Jurásica*" have shown favorable results due to the good public reception (Martínez-Graña *et al.*, 2017; García *et al.*, 2022; Cabra Jurásica, n.d.). Following García-Ortiz & Fernández-Martínez (2013), in the city of León, Castilla y León, the demand for guided routes to different audiences has increased after the implementation of initiatives such as the "*Fósiles Urbanos de León*" guide (Castaño de Luis *et al.*, 2011).

These examples allow to assume that the tools proposed in this work could achieve positive results. With the help of narrative and storytelling elements (e.g., Wolniewicz, 2019), this strategy is expected to help promote the conservation of urban fossils and enhance the educational and touristic value through a clear, eye-catching and friendly language. It should be noted that dissemination through social media, the official website of the Geopark and the interpretation centers, is key to reaching different types of audiences efficiently. Additionally, access to the routes is a strength as they are available in Google Maps; a widely used free application that comes pre-installed on most Android devices. Considering all of the above, the UNESCO Villuercas-Ibores-Jara Global Geopark has excellent urban fossils that can be used for educational and touristic purposes, which represent a great opportunity to expand and develop different conservation strategies that promote the dissemination of the paleontology of the territory.

5. CONCLUSIONS

The present study allowed the creation of an inventory of urban fossils in the Villuercas-Ibores-Jara UNESCO Global Geopark focused on the municipalities of Berzocana, Cañamero and Navezuelas, and specific locations in Cabañas del Castillo, Roturas, Guadalupe and Logrosán. With a total of 55 sites recorded, the great majority of the urban fossils correspond to ichnofossils of the *Cruziana*, *Skolithos*, *Rusophycus* and *Daedalus* genera found in sandstones and orthoquartzites of the Armorican Quartzite Formation (Lower-Middle Ordovician). Other fossils recorded are *Helminthoidichnites* sp. (Upper Ediacaran) and ammonites from Subbética, Córdoba Province (Middle/Upper Jurassic - Lower Cretaceous).

This material comes mainly from the talus slopes near the villages, from where the inhabitants took loose fragments of rock and integrated them into the facades of the houses as decorative and ornamental elements, adding value to the popular architectural style. The ichnofossils are in good preservation conditions despite the anthropogenic pressure that may exist in urban centers as they are protected from natural factors such as erosion and weathering that favor their degradation. Besides, it is evident the social awareness of the local inhabitants since the fossils have been present in the villages for many years, and signs of vandalism are minimal. This inventory allowed the identification of urban fossil locations that can be considered in urban planning, in order to contribute to their conservation and is open for the addition of other municipalities (e.g., Castañar de Ibor, Navalvillar de Ibor and Navatrasierra). They do not only have an aesthetic value but also have the potential to promote geoeducation and geotourism within the geopark.

The quantitative analysis determined that the scientific value of the sites is low, as they are undocumented *ex situ* material. However, the focus of the value is on the educational and touristic areas. While the educational value varies from low to moderate due to the lack of visual tools focused on urban fossils, which go virtually unnoticed, the moderate tourist value is impacted by the low supply of tourist infrastructure to receive visitors. However, favorable aspects that allow enhancing these values are the easy accessibility and safety conditions within the villages. This allows to work more easily with local schools and to include wider audiences that do not have the possibility to go to the field, e.g., people with reduced mobility and blind people. For this reason, it is necessary to explore conservation strategies that include outreach tools and to reinforce the tourism infrastructure (i.e., hotels and restaurants) with updated information.

In this study, two infographics were designed related to the process of formation of the ichnofossils until they reach the facades of the houses, and their identification and interpretation. Furthermore, interactive routes were developed in Google Maps for the municipalities of Berzocana, Cañamero and Navezuelas, which are freely accessible and promote tourism through the exploration of the local architecture. These tools can be used by local schools, visitors and local people, since an accessible and understandable language was sought for a non-specialized public. Although they could not be tested in a practical context, it is expected that they will contribute to enhance the educational and touristic values of urban fossils in the geopark, taking as references initiatives in other locations in Spain such as Cabra, Monsagro, Salamanca and León, where favorable results were obtained with a positive perception by the community.

This material will be implemented in a real context through its distribution in local schools and interpretation centers of the geopark and is open to receive feedback on its usefulness from the general and scientific community. In addition, it opens the possibility of implementing other interactive tools in the future through the Geocaching and MathCityMap platforms. They can be included into the itineraries or guided tours already offered in the area as well as in future events of *Geología*.

Finally, the urban fossils of the Villuercas-Ibores-Jara UNESCO Global Geopark represent an ethnopaleontological phenomenon that is part of the popular architectural style and represents an important resource for understanding the history and geological evolution of the territory. These open-air museums tell the story of organisms that lived in a shallow sea approximately 475 million years ago and present an innovative way to be used for educational and tourism purposes thanks to their easy accessibility for all audiences.

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Appendices

Appendix 1. Quantitative Assessment of the Inventory of Urban Fossils

Appendix 2. Quantitative Assessment of Degradation Risk (Weighted)

Appendix 1. Quantitative Assessment of the Inventory of Urban Fossils

- S1: Integrity or current status of the site
- S2: Diversity of the Earth science features
- S3: Rarity
- S4: Scientific knowledge of the site
- E1: Exemplarity and representativeness
- E2: Presence of educational facilities
- T1: Accessibility
- T2: Safety
- T3: Tourist infrastructure
- T4: Viewpoints and visibility
- A1: Ecological aspect
- A2: Cultural aspects
- C1: Existing legislative protection
- C2: Current threats

Code	Scientific value					Education Value			Tourist Value					Added Value			Conservation Value			Total Value
	S1	S2	S3	S4	Total	E1	E2	Total	T1	T2	T3	T4	Total	A1	A2	Total	C1	C2	Total	
BER01	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	0.5	3	0	0.5	0.5	0	2	2	6.5
BER02	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
BER03	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
BER04	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
BER05	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	1.5	1.5	1	2	3	9.5
BER06	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
BER07	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	1	1	0	2	2	8
BER08	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
BER09	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
BER10	1	0	0	0	1	1	1	2	1	1	0.5	1	3.5	0	1	1	0	2	2	9.5
CAN01	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0	0	0	2	2	7.5
CAN02	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7.5
CAN03	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN04	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN05	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN06	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN07	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN08	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN09	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7.5
CAN10	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN11	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN12	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7.5
CAN13	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN14	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7.5
CAN15	0.5	0	1	0	1.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN16	0.5	0	0	0	0.5	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	1	1	6.5
CAN17	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN18	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7.5
CAN19	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	1	1	0	2	2	8.5
CAN20	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	7
CAN21	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN22	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	1	3.5	0	0.5	0.5	0	1	1	6
CAN23	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
CAN24	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8

Appendix 1. (Continuation) Quantitative Assessment of the Inventory of Urban Fossils

- S1: Integrity or current status of the site
- S2: Diversity of the Earth science features
- S3: Rarity
- S4: Scientific knowledge of the site
- E1: Exemplarity and representativeness
- E2: Presence of educational facilities
- T1: Accessibility
- T2: Safety
- T3: Tourist infrastructure
- T4: Viewpoints and visibility
- A1: Ecological aspect
- A2: Cultural aspects
- C1: Existing legislative protection
- C2: Current threats

Code	Scientific value					Education Value			Tourist Value					Added Value			Conservation Value			Total Value
	S1	S2	S3	S4	Total	E1	E2	Total	T1	T2	T3	T4	Total	A1	A2	Total	C1	C2	Total	
CAN25	1	0.5	0	0	1.5	1	0	1	1	1	0.5	1	3.5	0	0	0	0	2	2	8
CAN26	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0	0	0	2	2	7.5
CDC01	0.5	0.5	0	0	1	0	1	1	0.5	0.5	0	0.5	1.5	1	1	2	1	1.5	2.5	8
CDC02	1	0	0	0	1	1	0	1	1	1	0	1	3	0	0.5	0.5	0	2	2	7.5
GUA01	1	0	0	0	1	0.5	1	1.5	1	1	0	1	3	1	1	2	0	1	1	8.5
GUA02	0.5	0	1	0	1.5	0	0	0	1	1	0.5	1	3.5	0	0	0	0	1	1	6
GUA03	1	0	1	0	2	1	0	1	0.5	1	1	1	3.5	0	1.5	1.5	1	2	3	11
LOG01	1	0	0	0	1	0.5	0	0.5	1	1	0.5	1	3.5	0	0	0	0	2	2	7
NAV01	1	0	0	0.5	1.5	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8.5
NAV02	0.5	0	0	0	0.5	0	0	0	1	1	0.5	0.5	3	0	0.5	0.5	1	1.5	2.5	6.5
NAV03	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
NAV04	1	0	0	0	1	0.5	0	0.5	1	1	0.5	0.5	3	0	0.5	0.5	0	2	2	7
NAV05	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	0.5	3	0	0.5	0.5	0	2	2	6.5
NAV06	0.5	0	0	0	0.5	0	0	0	1	1	0.5	0.5	3	0	0.5	0.5	0	1.5	1.5	5.5
NAV07	1	0	0	0	1	1	0	1	1	1	0.5	0.5	3	0	0.5	0.5	0	2	2	7.5
NAV08	0.5	0	0	0	0.5	0	0	0	1	1	0.5	0.5	3	0	0.5	0.5	0	2	2	6
NAV09	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
NAV10	0.5	0	0	0	0.5	0.5	0	0.5	1	1	0.5	0.5	3	0	0.5	0.5	0	2	2	6.5
NAV11	0.5	0	0	0	0.5	0	0	0	1	1	0.5	0	2.5	0	0.5	0.5	0	2	2	5.5
NAV12	1	0	0	0	1	1	0	1	1	1	0.5	1	3.5	0	0.5	0.5	0	2	2	8
ROT01	1	0	0	0	1	0	0	0	1	1	0	0.5	2.5	0	0	0	0	1.5	1.5	5

Appendix 2. Quantitative Assessment of Degradation Risk (Weighted)

Code	Deterioration of geological elements	Proximity to areas/ activities with potential to cause degradation	Legal protection	Accessibility	Density of population	Total
BER01	35	8	8	60	1	112
BER02	35	8	8	60	1	112
BER03	35	8	8	60	1	112
BER04	35	8	8	60	1	112
BER05	35	8	4	60	1	108
BER06	35	8	8	60	1	112
BER07	35	8	8	60	1	112
BER08	35	8	8	60	1	112
BER09	35	8	8	60	1	112
BER10	35	8	8	60	1	112
CAN01	35	8	8	60	1	112
CAN02	35	8	8	60	1	112
CAN03	35	8	8	60	1	112
CAN04	35	8	8	60	1	112
CAN05	35	8	8	60	1	112
CAN06	35	8	8	60	1	112
CAN07	35	8	8	60	1	112
CAN08	35	8	8	60	1	112
CAN09	35	8	8	60	1	112
CAN10	35	8	8	60	1	112
CAN11	35	8	8	60	1	112
CAN12	35	8	8	60	1	112
CAN13	35	8	8	60	1	112
CAN14	35	8	8	60	1	112
CAN15	35	8	8	60	1	112
CAN16	140	8	8	60	1	217
CAN17	35	8	8	60	1	112
CAN18	35	8	8	60	1	112
CAN19	35	8	8	60	1	112
CAN20	35	8	8	60	1	112
CAN21	35	8	8	60	1	112
CAN22	105	8	8	60	1	182
CAN23	35	8	8	60	1	112
CAN24	35	8	8	60	1	112
CAN25	35	8	8	60	1	112
CAN26	35	8	8	60	1	112
CDC01	35	4	4	45	1	89
CDC02	35	8	8	60	1	112
GUA01	35	4	4	45	1	89
GUA02	105	8	8	60	1	182
GUA03	35	8	2	60	1	106

Appendix 2. (Continuation) Quantitative Assessment of Degradation Risk (Weighted)

Code	Deterioration of geological elements	Proximity to areas/ activities with potential to cause degradation	Legal protection	Accessibility	Density of population	Total
LOG01	35	8	8	60	1	112
NAV01	35	8	8	45	1	97
NAV02	70	8	4	45	1	128
NAV03	35	8	8	45	1	97
NAV04	35	8	8	45	1	97
NAV05	35	8	8	45	1	97
NAV06	70	8	8	45	1	132
NAV07	35	8	8	45	1	97
NAV08	35	8	8	45	1	97
NAV09	35	8	8	45	1	97
NAV10	35	8	8	45	1	97
NAV11	35	8	8	45	1	97
NAV12	35	8	8	45	1	97
ROT-01	35	8	8	45	1	97