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The Armorican Quartzite: When Trilobites Ruled the Ordovician Seas of the Villuercas-Ibores-Jara UNESCO Global Geopark, Spain

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Abstract

***Cruziana* is a common and widespread trace fossil in Lower Palaeozoic strata that is generally attributed to the activity of trilobites. The Lower to Middle Ordovician Armorican Quartzite Formation of southern Europe contains well-preserved examples of the *Cruziana rugosa* Group. This paper outlines how *Cruziana* forms an important part of the geological heritage in the Villuercas-Ibores-Jara UNESCO Global Geopark, Cáceres Province (SW Spain).**

Keywords: *Cruziana*, Trace fossils, Urban fossils.

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Introduction

Cruziana is a common and widespread trace fossil in Lower Paleozoic siliciclastic successions. It is typically found preserved on the soles of sandstone beds in the form of two parallel lobes, each decorated with ridges that represent the imprints of movement by the producers' limbs. The arrangement and form of these ridges are important for the differentiation into ichnospecies. In *Cruziana* the length of the trace fossil exceeds its width whereas in the otherwise similar *Rusophycus* these are approximately equal. *Cruziana* was named by the French paleobotanist Alcide d'Orbigny in 1842 in honor of the general and politician Andrés de Santa-Cruz y Calahumana, based on material from what is now Bolivia (Egenhoff *et al*. 2007). As was the norm at the time, *Cruziana* was generally interpreted as the remnants of a plant, but already by the end of the 19th century it was increasingly realized that it is a trace fossil. Most Lower Paleozoic *Cruziana* can with reasonable confidence be attributed to the activity of trilobites. This is based on the general coincidence in the diversity trends of *Cruziana*, and *Rusophycus* with that of trilobites and, more directly, from imprints of hard parts compatible with trilobites in some specimens and, very rarely, trilobites found in direct association with a trace fossil (e.g., Seilacher 1970, 2007; Fortey & Seilacher 1997). However, *Cruziana* and *Rusophycus* are found also after the extinction of trilobites and there is always the possibility that the producer was an arthropod other than a trilobite. Regardless, *Cruziana* is unusual among trace fossils in that it can be reasonably narrowed down to a particular type of producer and studies on *Cruziana* have provided much material for discussion of the habits of trilobites (e.g., Seilacher 2007).

Cruziana is a highly characteristic trace fossil in the Villuercas-Ibores-Jara UNESCO Global Geopark, Spain, and the Naturtejo (e.g., Neto de Carvalho 2006; Neto de Carvalho & Baucon 2016; Neto de Carvalho *et al*. 2021) and Arouca (e.g., Sá *et al*. 2006, 2009) UNESCO Global Geoparks in Portugal. The purpose of this paper is a brief presentation of *Cruziana* in the Villuercas-Ibores-Jara Geopark (Fig. 1).

Cruziana in the Armorican Quartzite of the Villuercas-Ibores-Jara UNESCO Global Geopark

During the Early to Middle Ordovician (approximately 470 million years ago) sand-rich sediments were deposited in deltaic and shallow marine settings over vast areas marginal to northern Gondwana, including territories in present-day Spain, Portugal, France and northern Africa. Distributed by rivers, these sands were reworked by tidal currents and storms into beds separated by muddy sediment deposited during calmer periods. In France and the Iberian Peninsula these rocks are known as the Armorican Quartzite (e.g., Sá *et al*. 2014; Bayet-Goll & Neto de Carvalho 2020). Composed largely of sand, in which skeletal fossils typically degrade and dissolve, body fossils are rare but trace fossils are diverse and well preserved. The lower, sandstone-dominated, part of the Armorican Quartzite typically contains dense concentrations of *Skolithos*, simple vertically oriented tubes constructed by unknown animals. Higher in the unit is found the more complex *Daedalus* and, along sandstone-mudstone alternations, the bilobed *Cruziana.*

The most common ichnospecies of *Cruziana* in the Armorican Quartzite belong to the *Cruziana rugosa* Group, characterized by multiple ridges in groups up to 12. These include *Cruziana furcifera*, first described by d'Orbigny in 1842, and *Cruziana goldfussi* (Rouault) first described from the Armorican Quartzite in France in 1850 (Fig. 2). Together with *Cruziana rugosa* d'Orbigny, these are widely distributed Ordovician trace fossils that have found use as biostratigraphically significant fossils in otherwise unfossiliferous sandstone-dominated areas (e.g., Seilacher 1970; Meischner *et al*. 2020). The most likely producers of these trace fossils are asaphoid trilobites, and

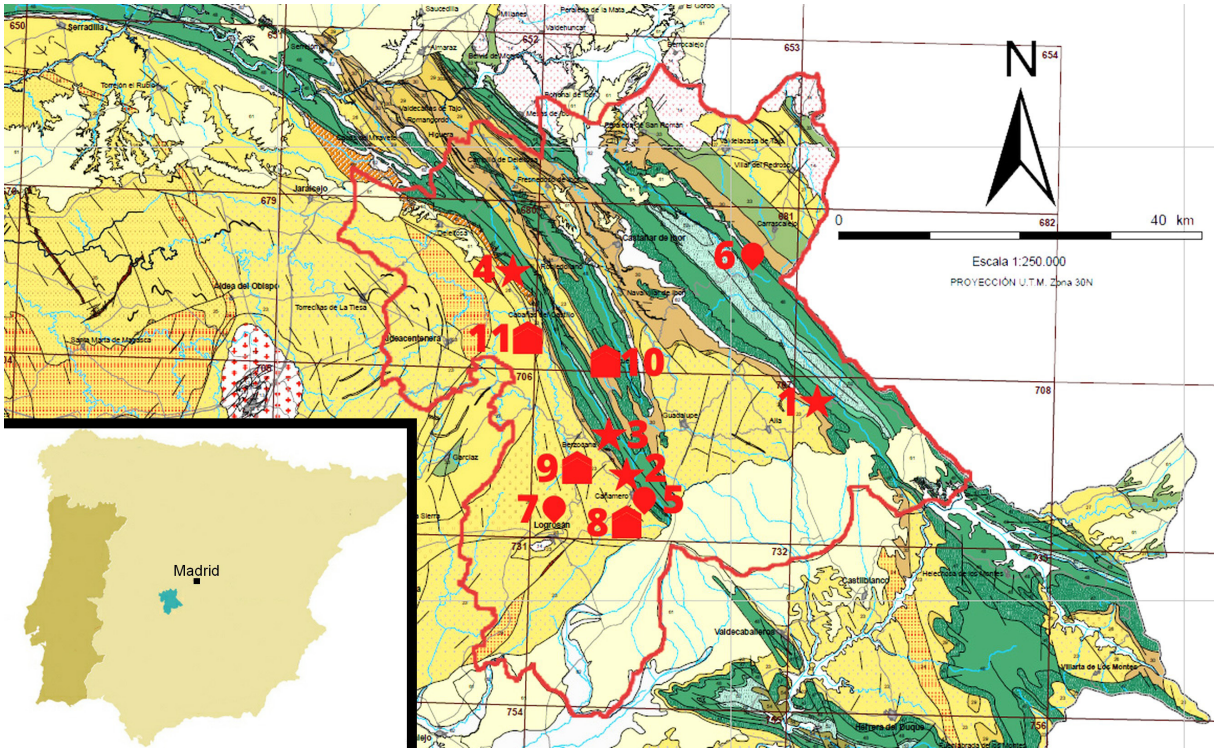

Figure 1. Map showing the location and geological context of the Villuercas-Ibores-Jara UNESCO Global Geopark and selected locations relevant to *Cruziana*. Inset shows location within Iberian Peninsula. Geology in main map is based on "Mapa Geológico de Extremadura a escala 1:250.000". The Armorican Quartzite is represented by green color with white dots. Details on other lithostratigraphic units can be consulted at: http://sigeo.juntaex.es/portalsigeo/web/guest/geologia-de-extremadura.
Symbols: 1, Geosite Estrecho de la Peña Amarilla; 2, outcrop at La Sierra de la Madrilla; 3, Geosite Canchos de la Sabana; 4, outcrop at Los Moros; 5, reception center in Cañamero village; 6, interpretation center in Navatrasierra village; 7, interpretation center in Logrosán village; 8, urban fossils in Cañamero village; 9, urban fossils in Berzocana village; 10, urban fossils in Navezuelas village; 11, urban fossils in Cabañas de Castillo village.

an exceptionally preserved trilobite from Morocco shows limb details that may explain the ridges observed in this type of *Cruziana* (Gutiérrez-Marco *et al*. 2017). These *Cruziana* were made within the sediment and probably represent combined feeding (of small food particles but possibly also scavenging) and locomotion (Figs. 3, 4). Bed soles may be densely covered with *Cruziana* allowing the movement of their producers to be traced out for great distances on large slabs (Fig. 4A).

Cruziana as an Urban Fossil

Slabs of Armorican Quartzite covered with *Cruziana* have been traditionally used as ornamentation on buildings. This practice has been common in villages in the border regions of the provinces of Cáceres and Salamanca, a particularly striking example being the village of Monsagro (Simón-Porcar *et al*. 2020). In the Villuercas-Ibores-Jara UNESCO Global Geopark this practice can be found in several villages (see Fig. 1). These urban fossils often include particularly well-preserved material of *Cruziana* (Figs. 2, 5A).

Cruziana in the Villuercas-Ibores-Jara UNESCO Global Geopark: Paths to Sustainable Development.

An important aim of UNESCO Global Geoparks is to protect the paleontological heritage and use

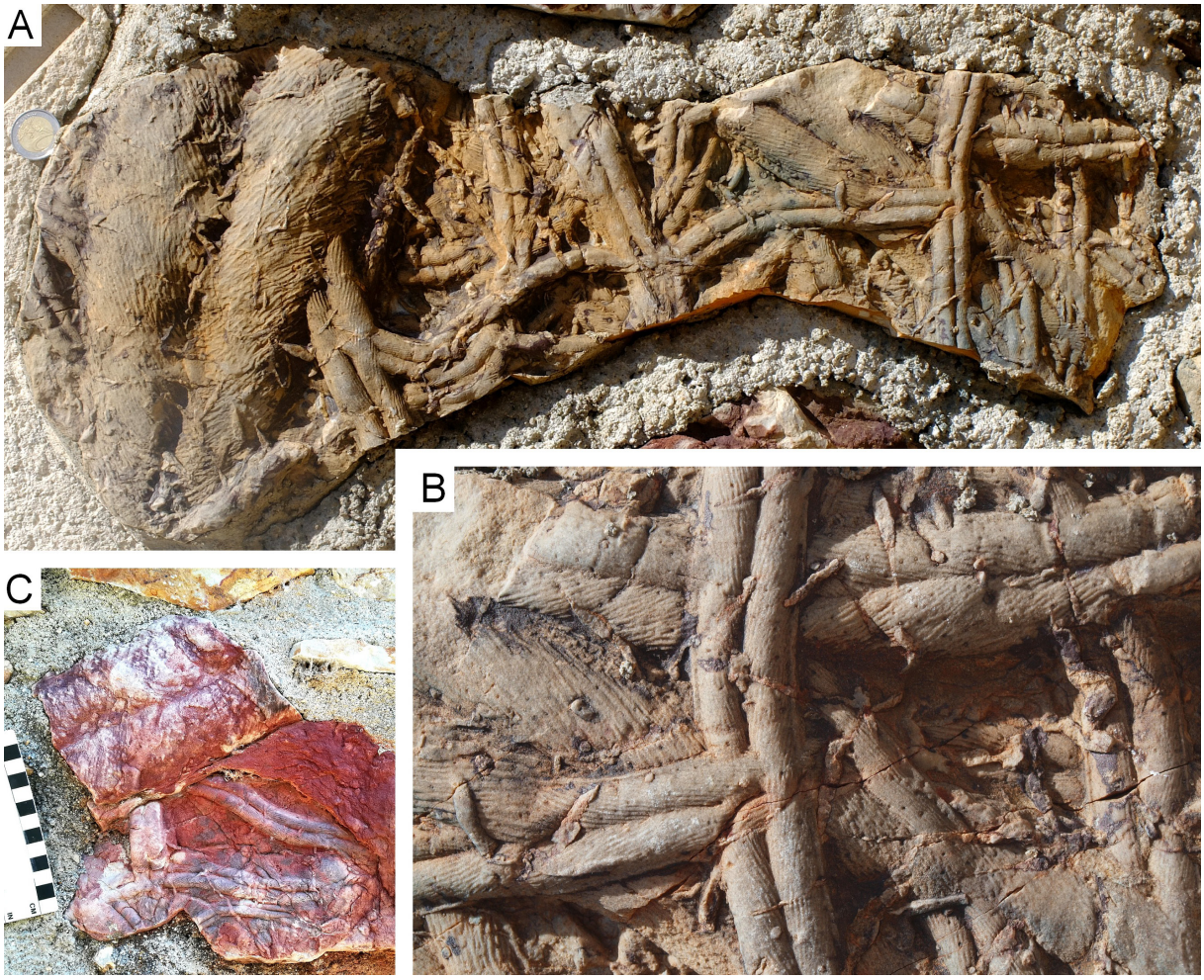

Figure 2. *Cruziana* as an urban fossil in building decoration: A, B) Well-preserved *Cruziana* from Navezuelas village. The larger forms are *Cruziana furcifera*. Most of the narrower forms are *Cruziana goldfussi*. B provides a closer view of the right portion of A to better show scratch marks and the marginal ridges flanking the bilobed surface. Coin for scale in A is 25 mm. C) Large and small *Cruziana* from Cabañas de Castillo village.

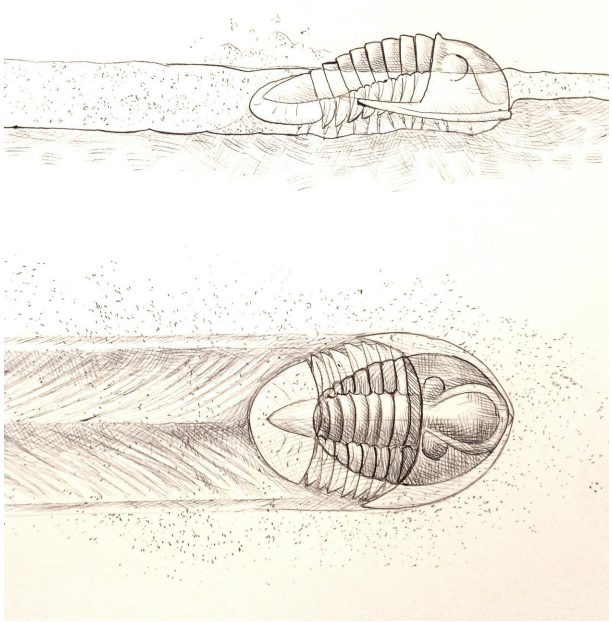

Figure 3. Interpretative reconstruction of an asaphoid trilobite producing *Cruziana*. Artwork by Manuel García.

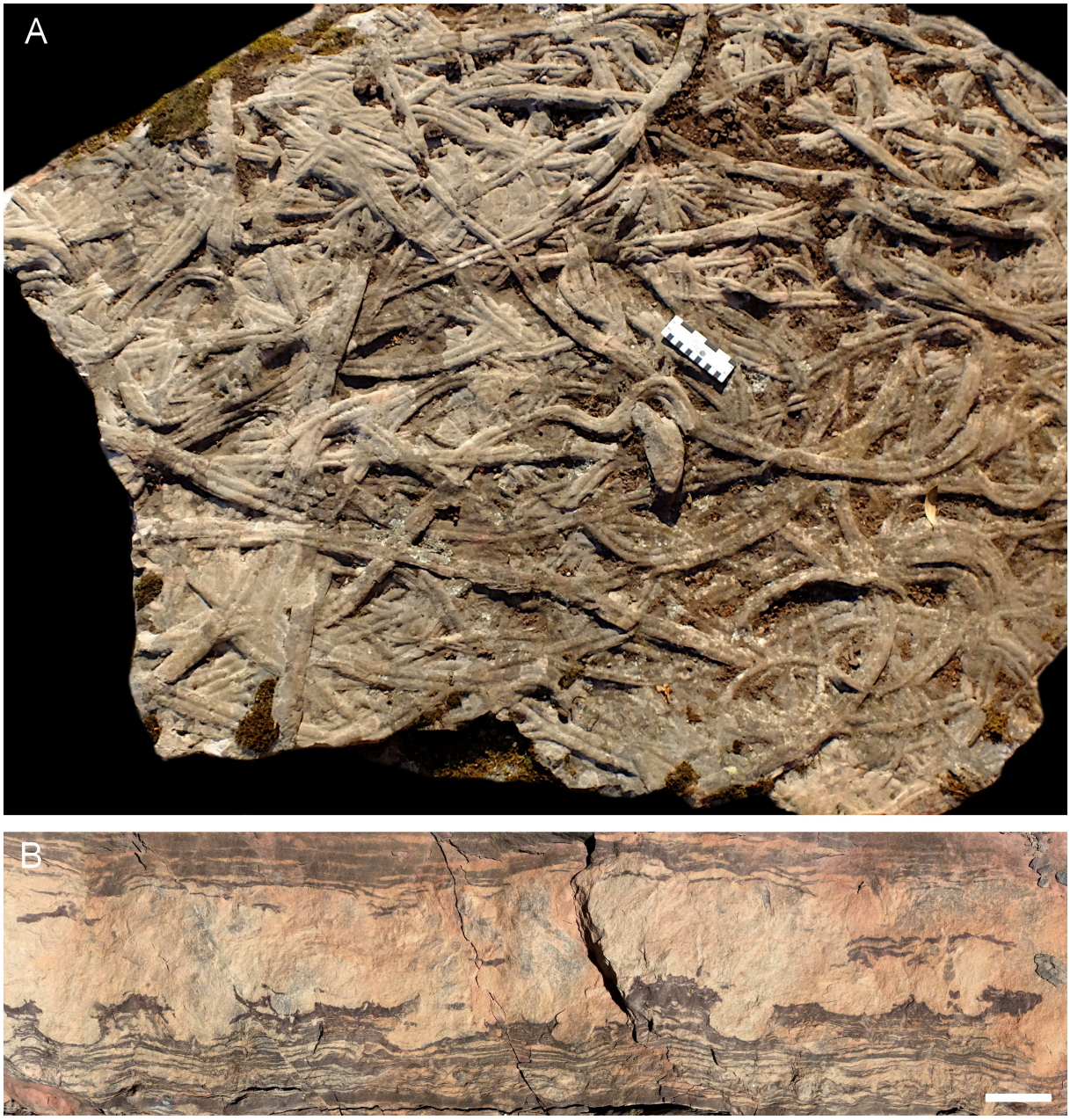

Figure 4. A) Large surface covered with *Cruziana goldfussi* from Los Moros outcrop. The finer scale divisions are in centimeters. B) Armorican Quartzite with thick and thin sandstone beds (lighter) and mudstone (darker). Several *Cruziana* are seen in cross-section close to base of the thicker sandstone bed. Geosite Estrecho de la Peña Amarilla. Scale is 5 cm.

it to tell the history of our planet and to improve the lives of its inhabitants through education and sustainable development. In the Villuercas-Ibores-Jara Geopark, information on *Cruziana* is provided by samples and interpretative material on display in visitor centers, especially in the Geopark Visitors' Reception Center in Cañamero village, the Fossil Interpretation Center in Navatrasierra village and in the Vicente Sos Baynat (1895–1992: Spanish geologist who contributed significantly to mining exploration in Extremadura) geo-mining museum in Logrosán village (Figs. 1, 5B). Many of the geological itineraries and touristic routes run through sections of the Armorican Quartzite and

include outcrops with well preserved *Cruziana*. At such geosites and viewpoints are generally found informative panels on *Cruziana*, for example in the Estrecho de la Peña Amarilla geosite (Fig. 5C). *Cruziana,* and the manner in which it was created, is a popular educational tool. In addition to the visitor centers mentioned above, urban fossils provide a popular and effective resource (Fig.

Figure 5. Paleontology of the Armorican Quartzite in the Villuercas-Ibores-Jara Geopark's infrastructures and activities: A) Urban fossils in Navezuelas village being used as an educational tool. B) *Cruziana* samples in the reception center in Cañamero village. C) Panel installed in the Estrecho de la Peña Amarilla geosite with interpretation of *Cruziana.* Armorican Quartzite towering in the background. D) The *Trilobite Hunt* board game, an example of educational material (created by Jesús Vázquez). E) Discussion on the formation of *Cruziana* during a European Geoparks Week activity.

5A). Replicas of trilobites and *Cruziana* form part of a "Geobox" that is distributed to local schools. The use of games has proven to be very helpful in generating interest and understanding of the Geopark. This includes the *Trilobite Hunt* game (Fig. 5D), developed from a game described in the "Libro de los juegos" ("Book of games"), commissioned by King Alfonso X, "The Wise

man", and completed in his *scriptorium* in Toledo in 1283. The lines of the board are *Cruziana*. This not only is an abstract board game for the development of logical reasoning, but also touches upon Ordovician ecosystems (bricks depict trilobites and *Anomalocaris*, the latter a potential predator on trilobites). As an example of cultural heritage related to *Cruziana* can be noted stories that relate *Cruziana* to giant snakes or dragons, such as that of the La Chiquita cave in Cañamero village.

During the confinement in 2020 due to the Covid-19 crisis, diverse material was developed for the Geopark's social networks, including a series of cards called "Learning with Geopaca." In these, the Villuercas-Ibores-Jara Geopark mascot explained curiosities related to the geological, natural and cultural heritage, including *Cruziana.*

Cruziana invariably stimulates discussion and interest among specialist and non-specialist alike (Fig. 5E) and is particularly appreciated by the tourism companies in the Geopark. Many aspects of *Cruziana* remain incompletely understood, including details on its formation (cf. Goldring 1985), for which outcrops such as that in Fig. 4B provide fantastic material for discussion. Research on *Cruziana* and other trace fossils in the Armorican Quartzite is therefore an ongoing process.

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Conflict of Interest

The authors have no known conflict of interest.

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