

***Rusophycus petraeus* from the late Dobrotivian (Middle-Upper Ordovician interval) of the Cadena Ibérica Oriental (NE Spain)**

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Introduction

The ichnospecies *Cruziana petraea* Seilacher, 1970 and *Rusophycus petraeus* (Seilacher, 1970) (the prevalent rusophyciform expression of the former) are cited in the palaeoichnological literature from Ordovician rocks (mostly dated as Caradoc) of Jordan, Benin, Libya and Chad (Seilacher, 1970, 2007). Here we report a new finding of *Rusophycus petraeus* – the first documented out of the African continent – in rocks dated as late Dobrotivian. This was preliminary reported by Carls (1975) as “*Cruziana* sp.”.

Geographic and geological setting

The studied locality (known as La Rebosilla) is located on the southern slope of “cabezo de la Fuente”, a hill 1.5 km to the SW of the village of Luesma (southern Zaragoza province, NE Spain) in the heart of the Iberian Mountains. From a geological point of view, La Rebosilla lies in the Cadena Ibérica Oriental (a chain built up of rocks ranging from upper Neoproterozoic to Permian in age), in the central sector of the Herrera Unit.

Lithostratigraphy and environmental setting

In the Cadena Ibérica Oriental, the Middle (to lowermost Upper) Ordovician Castillejo Formation rests paraconformably above the Armorican Quartzite, a reference stratigraphic unit in the region. The trace fossils studied herein come from the uppermost beds of the Sierra Member of the Castillejo Formation. According to Carls (1975) and Villas (1985), in the area of Fombuena-Luesma this formation is 350 m-thick and consists – from bottom to top – of three members: Marité (a few metres thick), Alpartir (>100 m), and Sierra (>150 m).

The top of the Sierra Member in the area of Luesma (horizon O3q in the terminology of Carls, 1975) is composed of ca. 50 m of grey-brownish, dominantly quartzitic sandstone in beds up to 0.5 m in thickness, to some extent similar to the upper member of the Armorican Quartzite (Carls, 1975). The particular beds bearing the studied rusophyci are located on top of horizon O3q, and are composed of well sorted, fine-grained (recrystallized) quartzitic sandstone; they are centimetric in thickness, occasionally with flaser stratification (Fig.1B) and soft pebbles; current ripple, trough cross lamination and rippled top beds are frequent (Fig.1B); some beds are massive at the bottom and show trough cross lamination at the top; scour structures (tool and drag marks and casts) and erosional surfaces are frequent.

Quartzitic sandstones of the horizon O3q are only present between the sector Fombuena-Luesma and the eastern slope of the Sierra de Herrera. They represent a particular, very shallow environment undergoing clastic discharge from the “Azulara structure”, placed to the ENE. This environment must have had adequate living conditions for the trilobites, since they met in big number as evidenced by the ichnological record. The Castillejo Formation is bracketed by two oolitic ironstone horizons (one each marking a stratigraphic lacuna; the upper one composes the basal

member of the overlying Fombuena Formation – which rests paraconformably – and spans a part – not the basal one – of the earliest Late Ordovician or Sandbian). Those oolites needed warm climatic conditions for its formation, and thus the present ichnofauna originated under warm temperatures and not in close proximity to the South Pole.

Biostratigraphy and age

In the neighbour section Fombuena 2 (located 1.2 km to the south-west of La Rebosilla), the last occurrence of the species *Heterorthina kerfornei* reaches two meters below the top of the Castillejo Formation (Villas, 1985, 1992). In Central Spain, this species ranges from the late Dobrotivian to the earliest Sandbian (Reyes-Abril *et al.*, 2011). On the other hand, clastics underlying the sandstones of the top of the Sierra Member in a locality 1.5 km to the west of El Poyo del Cid (located some 35 km from our study locality in Luesma; Cadena Ibérica Occidental; Teruel province), yielded the graptolite species *Oepikograptus bekkerei* which indicates the uppermost Dobrotivian (i.e., the global lower Sandbian Stage, lowermost Upper Ordovician) (Gutiérrez-Marco *et al.*, 1999; J.C. Gutiérrez-Marco, pers. comm., 2011). Finally, at the top of the basal ooidal ironstone horizon of the Fombuena Formation (O5), Caradoc brachiopods were described by Villas (1992). Taking these data into consideration, the specimens of *Rusophycus petraeus* described herein are late Dobrotivian in age, which may be equivalent either to the latest Darriwilian (terminal Middle Ordovician) or to the earliest Sandbian (basal Late Ordovician). This uncertainty in the dating leads to read with caution the assumption of a Middle Ordovician age for the Iberian occurrence of “*Cruziana petraea*” formerly suggested by one of the present authors (*in* Seilacher, 2007: p. 194).

Palaeoichnology

Description and interpretation of the trace

The studied material consists of several tens of rusophyci preserved as hypichnial casts, in general equidimensional (4–6 cm in width x 4–7,5 cm in length), with steep-sided lobes. In most cases, the axis of the trace run straight, but it is slightly curved in some cases. Specimens appear in great density, often overlapping (Fig. 1A) or running parallel.

Some of the rusophyci are in ontogenetic connection with a cruzianiform segment showing anastomosing, longitudinal ornamentation and a wide median furrow (Fig. 1J). Such transitional forms of *R. petraeus* were not illustrated in the previous literature. Moreover, cruzianiform segments connected to *R. petraeus* differ from the drawing of *Cruziana petraea* (ribbon forms) figured by Seilacher (1970). Nevertheless, the latter ribbon forms are also present among our collected samples, but as isolated ones.

Endopodal scratch marks are organised into sets of three to five. Sets may be distinctly separated resulting in two distinct regions (front and rear; Fig. 1C,D,F). On two specimens, the scratch marks of the left lobe pass into the right one without interruption (Fig. 1E).

Retroverse endopodal scratches (slightly proverse on the front part of a few specimens; Fig. 1D) are rather blunt and in general almost smooth since, due to preservational bias by the grain size and recrystallization, claw marks are poorly preserved. When faint claw marks are visible, they are found in a number of three to four and are subequal, blunt, somewhat knobby and of very low relief (Fig. 1I). As in other occurrences of this ichnospecies, claw marks ornamenting the bigger endopodal scratches tend to concentrate on the posterior half of the latter (Fig. 1I). The profile of the endopodal marks is usually symmetric, but the front or rear slope of the scratch can be steeper in different specimens (Fig. 1H). A faint and dense, transverse striation may ornament some of the endopodal scratches (Fig. 1I,H).

Some specimens show a strongly asymmetric transverse profile, not in terms of lobe depth but of inclined lateral margins, which are vergent to the same direction (Fig. 1F). This indicates that, if needed, the producer (most likely a trilobite) was able to withdraw the appendages of one side of

the body under the dorsal skeleton and to stretch those of the opposite side, while digging intensity remained the same on both sides. On the other hand, burrow reactivation is commonly observed (both stationary and dynamic).

Other palaeoichnological contents

Domichnia of several millimetres to one centimetre in cross section are frequent; i.e. *Cylindrichnus*, *Skolithos* and *Monocraterion*, the former two going through the trilobite burrows (Fig.1A, arrows). Exichnial *Palaeophycus* (filled with sand from the upper level) are found in thin mudstone laminae interbedded with bedding planes where the trilobite burrows occur, while planolitics tend to be located near the *Rusophycus* medial axis. *Bifungites* and small-size, retrusive *Teichichnus* are also found.

Conclusions

According to the data presented herein:

– Beyond their known occurrences in Upper Ordovician rocks from Africa (generally published under the synonym *Cruziana petraea* Seilacher, 1970), the lowest biostratigraphic range of *Rusophycus petraeus* (Seilacher, 1970) is placed at a late Dobrotivian age, which may be equivalent either to the latest Darriwilian (terminal Middle Ordovician) or to the earliest Sandbian (basal Late Ordovician).

– The number of longitudinal claw marks found on each endopodal scratch mark of our material of *Rusophycus petraeus* is three to four, and thus the diagnosis of this ichnospecies should perhaps be slightly re-evaluated.

– The occasional existence of faint and dense, transverse striation on the endopodal scratch marks is pointed out to complete the morphological characterisation of this ichnotaxon.

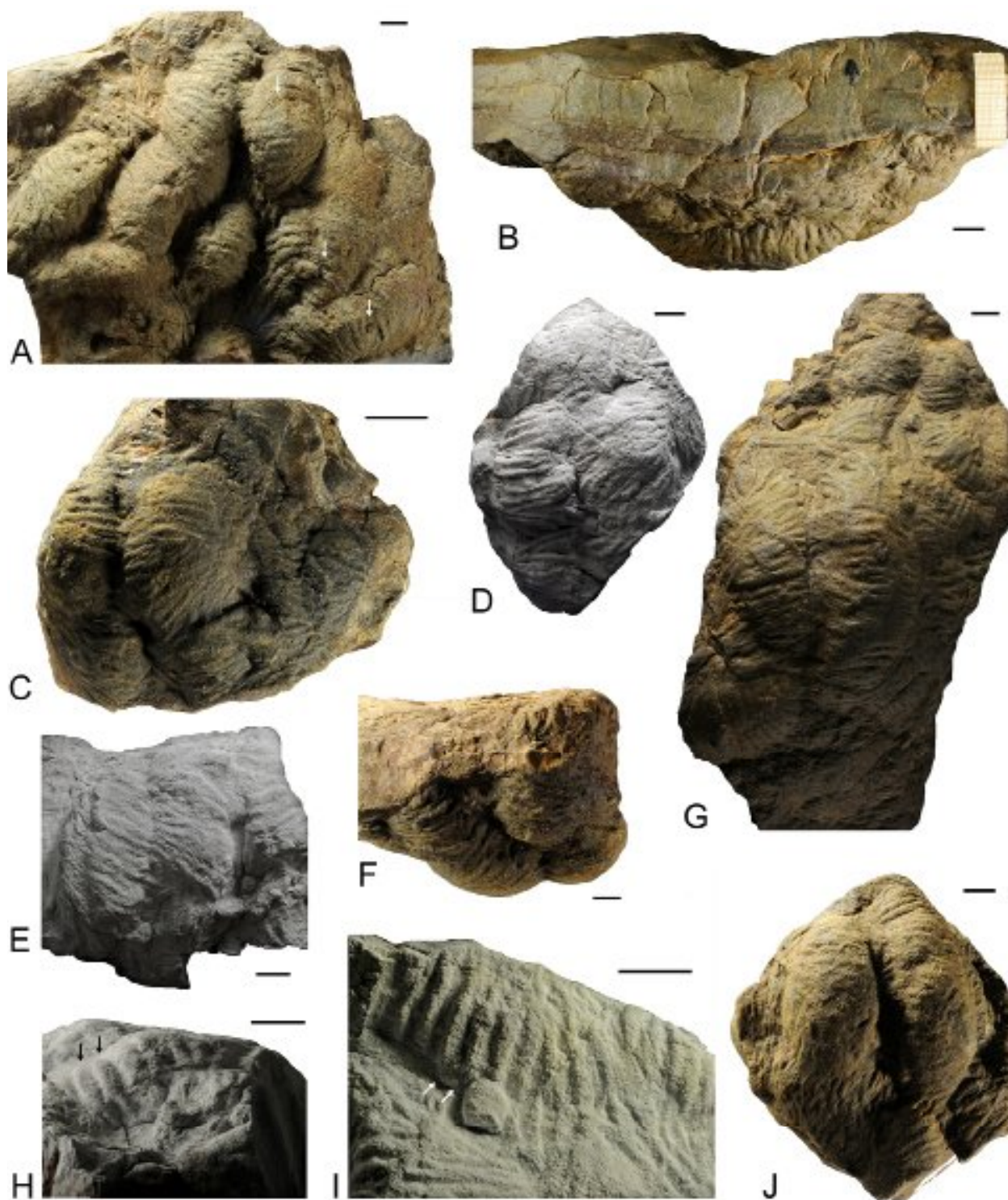


Figure 1. (A) Several superimposed specimens (MPZ 2011/73 - MPZ 2011/77) of *Rusophycus petraeus* (Seilacher, 1970). *Skolithos* going through the trilobite burrows are observed (arrows). (B,G) Specimen MPZ 2011/66. Right side and bottom views, respectively. (C, F) MPZ 2011/67. Bottom and rear views, respectively. (D) MPZ 2011/68. (E) MPZ 2011/69. (H) MPZ 2011/70. Side view. (I) MPZ 2011/71. Side view. (J) MPZ 2011/72. Material deposited in the Museo Paleontológico de la Universidad de Zaragoza. Scale bar = 1 cm. (D,E,H,I) specimens coated with ammonium chloride. (A-C,F,G,J) uncoated. Further explanations in the text.

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