



# Micrometric detail in palaeoscolecid worms from Late Ordovician sandstones of the Tafilalt Konservat-Lagerstätte, Morocco



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## ABSTRACT

The late Ordovician Tafilalt Biota of Morocco is a recently discovered Konservat-Lagerstätte that provides abundant paropsonemid eldonioids – resembling those from the Cambrian Burgess Shale and Chengjiang biotas, or other paropsonemid occurrences from the Ordovician to Silurian of the US and Australia – large discoidal ?hold-fasts, non-biomineralised cheloniellid arthropods, rare vermiform fossils and articulated skeletons of echinoderms and trilobites. Exceptional preservation of soft-bodied organisms occurs in medium- to coarse-grained sandstones, in a style reminiscent of the soft-bodied Ediacaran fossils of the White Sea Assemblage. Here, we describe the first articulated scleritomes of a large palaeoscolecid worm from Africa. In addition to the mineralised sclerites, the specimens also exhibit extensive soft-tissue preservation down to micron-scale, including fine detail of annuli with their plate, platelet and microplate arrangement on a reticulate cuticle. Compression fossils of the new species *Gamascolex vanroyi* are represented by external moulds with remains of phosphatised cuticular structure, secondarily weathered into strontian crandallite. Partial foregut fossilisation is seen in one specimen, and phosphatised digestive structures are also reported in three co-occurring trilobite genera at the Bou Nemrou locality. From a palaeogeographic point of view, these North African palaeoscolecids represent the highest palaeolatitudinal occurrence of this Palaeozoic group in Gondwana, being described for the first time in cold-water areas adjacent to the Late Ordovician South Pole. It also provides a palaeobiogeographic link to the original distribution of the genus *Gamascolex* in a central European Peri-Gondwanan terrane.

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## 1. Introduction

Exceptionally preserved soft-bodied faunas, belonging to the Fezouata and Tafilalt biotas, were recently discovered from the Early and Late Ordovician of Morocco. Both show that analogues of the Cambrian Burgess Shale (i.e. Fezouata) and terminal Neoproterozoic Ediacaran (Tafilalt) taphonomic windows were still open in the Ordovician (Van Roy, 2006; Van Roy et al., 2010; Van Roy, 2011). One of the most prominent fossil sites of the Tafilalt Konservat-Lagerstätten occurs in the Jbel Tijarfaïouine area of the eastern Anti-Atlas, halfway between the town of Mecissi (Msissi) and the city of Erfoud (Fig. 1B). Although a number of early Sandbian to late Katian echinoderm localities showing exceptional preservation were reported from this area (Hunter et al., 2010; Lefebvre et al., 2010), Ediacara-style preservation of soft-bodied

metazoans mainly occurs in the early Late Ordovician sandstones. This is the case of a locality with abundant paropsonemid eldonioids (Fig. 2C) and large discoidal fossils, also yielding lightly sclerotised cheloniellid arthropods (Fig. 2D) and the rare palaeoscolecid worms described here (Figs. 2A–B and 4). These beds also provide an assemblage of articulated skeletons of benthic echinoderms and trilobites (Fig. 2E–G).

Palaeoscolecids are a group of Cambrian to late Silurian worms characterised by an annulated cuticle with rows of organo-phosphatic plates, an evertible proboscis and spines or nipples at the posterior end. They are widely recorded in the famous Cambrian sites with exceptional preservation, such as Chengjiang (Han et al., 2007), Guanshan (Hu et al., 2012), Zhongbao (Zhang and Pratt, 1996) and Wangcun (Duan et al., 2012) in South China, Spence (Conway Morris and Robison, 1986), Latham and Kinzers shales (Conway Morris and Peel, 2010) in the USA, Sirius Passet (Conway Morris and Peel, 2010) in Greenland, Sinsk (Ivantsov and Wrona, 2004) in Russia and Emu Bay Shale (Glaessner, 1979; García-Bellido et al., 2013) in Australia. However, post-Cambrian records are very sparse, and articulated palaeoscolecid scleritomes (other than cuticle fragments possibly derived from moulds) were so far only known from some Ordovician localities of Britain, Bohemia, Peru, USA and China (see Botting et al., 2012; Muir et al., 2014). The material shown here thus represents the

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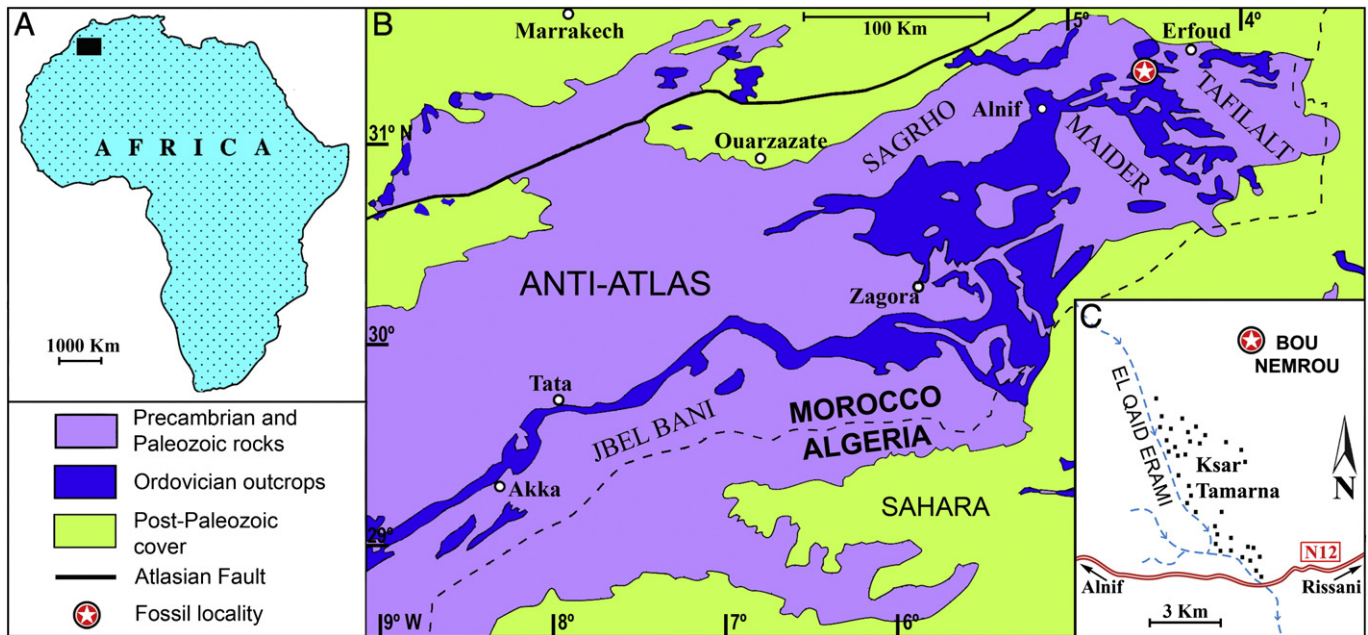


Fig. 1. A, Map indicating the position of the studied region in Africa. B, Geological sketch map of the central and eastern Anti-Atlas of Morocco, showing the position (star) of the Jbel Tijarfaiouine area (modified from Gutiérrez-Marco et al., 2003). C, Sketch map of the area around the Bou Nemrou locality.

first description of Ordovician palaeoscolecid from the African continent, their presence in the older Fezouata Biota so far only mentioned in passing (Van Roy et al., 2010; Martin et al., 2013).

## 2. Geologic setting

The studied fossils come from the main sandstone quarry made for commercial exploitation of fossils at the site of Bou Nemrou (Lat.  $31^{\circ} 19' 35''$  N, Long.  $04^{\circ} 31' 35''$  W), located east of the El Qaid Erami (El Caïd Rami) valley near Ksar (village) Tamarna, and 9.8 km to the north of the Alnif–Rissani road (Fig. 1C). The site was first mentioned and studied in some detail by Van Roy (2006), who found large paropsonemid specimens (closely resembling “*Eldonia*” *berbera* of Alessandrello and Bracchi, 2003), problematic discoidal fossils, the non-biomineralised cheloniellid arthropod *Duslia insignis* Jahn, 1893 (*D. cf. insignis* according to Alessandrello and Bracchi, 2006), diverse trilobites and “a new, enigmatic vermiform fossil” represented by a single specimen (Van Roy, 2006, Fig. 3.7; Lefebvre et al., 2011, Fig. 3A). The rich echinoderm fauna collected from the locality (labelled as KR-1, CRF-4 or ECR-F4 by previous authors) comprises about 14 genera of eocrinoids, ophiuroids, stylophorans, edrioasteroids, crinoids and a single cyclocystoid (Regnault, 2007; Hunter et al., 2010; Lefebvre et al., 2010, 2011; Sumrall and Zamora, 2011). Trilobites are represented by seven poorly described species (Vela and Corbacho, 2009; Corbacho, 2011). None of the identified taxa allows for precise dating, and no graptolites or microfossils have yet been found at the locality.

From a stratigraphic point of view, the assemblage is restricted to several sandstone beds located close to the top of the lateral equivalent of the First Bani Group, which in the western Tafilalt area cannot be subdivided into formations. In particular, the fossiliferous beds have often been correlated with the Izegguirene Formation of the central Anti-Atlas, which has been dated as early Sandbian (basal “Caradoc”), Gutiérrez-Marco et al. (2003) assigned the top of the First Bani Group to the upper Dobrotivian, a regional stage division that spans the Darriwilian/Sandbian boundary of the global scale (Bergström et al., 2009). This correlation is reinforced by the first Moroccan record of *Gamascolex* Kraft and Mergl, 1989, a palaeoscolecid genus that so far

has been restricted to the type Dobrotivian (Dobrotivá Formation) of Bohemia (Kraft and Mergl, 1989).

## 3. Preservation and palaeoecology

Articulated palaeoscolecid scleritomes are delicately preserved as compression fossils in fine- to medium-grained micaceous sandstone, co-occurring on the same slabs with complete and articulated thecae of the eocrinoid *Ascocystites* Barrande, 1887. From consideration of the echinoderm taphonomy, the lithology and sedimentary structures, previous studies suggest a rapid, storm-influenced burial, in a relatively shallow-water environment, with specimens undergoing no significant transportation: burial is estimated to have taken place within two days to one week (Hunter et al., 2010). Palaeoscolecid preservation includes fine details of the dorsal and ventral plates and their original arrangement in transverse rows, intercalary dorsal platelets and the extensive areas covered by microplates, arranged on a cuticle with polygonal to subquadrate reticulation (Fig. 4E–S). From the seven studied palaeoscolecid specimens, five are preserved stretched and the others are partially contracted, with annuli having a slightly concave forward shape in the anterior part of the body (Figs. 2B and 4B). In the dorsal part of each annulus, the contraction is shown by the out-folding of the central band of microplates into a crest, accentuated by the in-folding of the intercalary region between consecutive annuli (Fig. 4C), in an originally elastic body. This flexible, sclerite-covered cuticle has often been related with an infaunal mode of life (Kraft and Mergl, 1989), with occasional epifaunal excursions (Conway Morris and Peel, 2010), with alternating phases of muscular contraction and extension in which the plates grip onto the sediment while burrowing in a weakly cohesive substrate.

Preservation of palaeoscolecids is usually associated with mud-sized sediments from relatively deep-water or restricted environments, as is the case in most Cambrian and Ordovician Konservat-Lagerstätten around the world, but until now the group had never been recorded in shallow-water sandstones. In the Moroccan locality, the specimens range between dorso-ventrally to laterally compressed, and there is no evidence for sediment infilling between the body layers. The

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