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Latest Campanian and Maastrichtian Siderolitidae (larger benthic foraminifera) from the Pyrenees (S France and NE Spain)

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ABSTRACT

The siderolitids from the uppermost Campanian and Maastrichtian deposits of the Pyrenees have been re-studied. This has revealed a high diversity and rapid replacement of taxa, confirming the group as a good tool for high resolution biostratigraphy. Two genera have been found in the uppermost Campanian–Maastrichtian interval in the Pyrenean deposits: *Siderolites* Lamarck, and *Wannierina* Robles-Salcedo. *Siderolites*, with canaliferous spines or denticulate periphery, is represented by four species replacing each other from the latest Campanian to Maastrichtian: *Siderolites praecalcitrapoides* (latest Campanian), *S. pyrenaicus* sp. nov. (early Maastrichtian), *Siderolites calcitrapoides* (late Maastrichtian) and *Siderolites denticulatus* (late Maastrichtian). *Wannierina* is characterised by well-developed keels and ramified marginal canals. Two species of *Wannierina* have been identified and they succeeded one another from latest Campanian to early Maastrichtian: *Wannierina vilavellensis* sp. nov. (latest Campanian) and *Wannierina cataluniensis* (early Maastrichtian). The species of the genus *Siderolites* inhabited shallow waters of tropical to subtropical platforms with moderate-to-high water-energy conditions and those of the genus *Wannierina* are typical of deep–water low-energy environments but still in the eutrophic zone.

1. Introduction

The Upper Cretaceous shallow-water deposits of the contain rich and diverse siderolitid associations that underscore the ecological success and biostratigraphic importance of larger benthic foraminifera through geological times. The siderolitids are bilamellar perforate foraminifera exhibiting a planispiral-involute chamber arrangement, a row of multiple foramina communicating the consecutive chambers, and a complex canal system, which is diagnostic for genus-level classification (Wannier, 1980, 1983). They can be found in high to low water-energy facies deposited in shallow-water environments, mainly carbonates, of tropical to subtropical platforms (Robles-Salcedo et al., 2013; Robles-Salcedo, 2014; and the papers cited therein). Deposits containing siderolitids have been found from the south of Scandinavia in the Northern Hemisphere to Madagascar in the Southern Hemisphere, and from Western Europe to Central Asia and Africa (Goldbeck and Langer, 2009; and the papers cited therein). We have found one citation of siderolitids in America, Brown and Bronnimann (1957) who ascribed the species *Cibicides? vanbelleni* van den Bold (1946) from Cuba to the genus *Siderolites*, but we have undertaken a tentative revision of the figures presented therein (see figs. 5-10 in Brown and Bronnimann (1957)) that allows us to suggest that this species lacks the typical characteristics defining the siderolitids. Furthermore, its trochospiral chamber arrangement seems to indicate a closest phylogenetic relationship with rotaloideans, although a detailed analysis of this taxon is needed to clarify its architecture and systematic position.

The extremely complex architecture of the siderolitids, together with the difficulty of recognising the diagnostic internal structures in random sections, might be the cause of several misidentifications found in regional studies. All this has hampered the use of this group in biostratigraphy for a long time.

In the present paper, the latest Campanian and Maastrichtian siderolitids from selected localities of the Pyrenees are re-examined in order to broaden our knowledge in terms of taxonomy and stratigraphic distribution. Specifically, this study is focused on giving the reader the tools needed for recognizing taxa easily from thin sections, which is essential for using them in applied micropalaeontology. The siderolitids from the Pyrenees have been compared with the

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representatives of this group found in the type section from Maastricht, Netherlands. Exceptional materials, in terms of abundance and preservation, from other reference localities in the northern Betic Mountains, Spain have also been used for comparison.

2. Historical background

The first mention of siderolitid morphology appeared in the palaeontological literature in the 18th Century, with Knorr (1705–1761, vol. 3 page 158, reference extracted from Faujas-Saint-Fond, 1798) referring to the siderolitiform specimens collected in Saint-Pierre Mountain (Maastricht, Netherlands) as "marine stars". Faujas-Saint-Fond (1798, see pl. 34, Figs. 5–6) reproduced a gravure of Knorr with drawings of those siderolitid specimens, which were named at that time "numismales". These specimens figured by Knorr and reproduced by Faujas-Saint-Fond were used later by Lamarck (pl. 34, fig. 12, 1801) to describe the genus *Siderolites* (type species: *S. calcitrapoides*). Early in the 19th century, d'Orbigny (1826, p. 297) assigned a new species, also collected from the Maastrichtian of Saint-Pierre Mountain, *S. laevigata*, to *Siderolites* but it does not seem to have been mentioned in following studies until cited by Renema and Hart (2012).

Despite the aforementioned early descriptions of siderolitids, the detailed studies dealing with their architecture started almost a hundred years later, at the beginning of the 20th Century. Douvillé, in 1906, was the first author to undertake a careful architectural study of this group, with good illustrations of the material analysed. He described two new species of *Siderolites*, *S. vidali* from the Campanian deposits of Pobla de Segur (Lleida, southern Pyrenees) and *S. denticulatus* from Maastricht, the same locality as that of *S. calcitrapoides* and *S. laevigata*. Douvillé also described a new genus, *Arnaudiella* (type species: *A. grossouvrei*), from the Campanian of Charente (SW France). In the original description, Douvillé mentioned the "presence of vacuolar chamberlets" as a diagnostic criterion for identifying *Arnaudiella*. These "vacuolar chamberlets" are currently named supplementary chamberlets (see Hottinger, 2006a). In spite of this step forward in the knowledge of siderolitids, however, a comprehensive and more complete study of their internal structure was still lacking.

In the following decades, Arni (1932, Fig. 15) produced the first three-dimensional model of a siderolitid shell, with details of its internal structure. Moreover, he defined a new species of siderolitid from Turkey, *Siderolites heracleae*, which was also found in Greece (Arni, 1933). Other authors contributed to the knowledge of the group, namely, Finlay (1939), who formally defined the Siderolitidae family, and Smout (1955), who introduced the genus *Pseudosiderolites* (type specie: *S. vidali* Douvillé) to group siderolitid morphotypes lacking spines in the equatorial plane.

In the nineteen eighties, the knowledge of the Siderolitidae family advanced significantly with the work of Wannier (1980, 1983). This author, following Arni's observations, created models to facilitate genus-level identification based mainly on the complexity of the different typologies of siderolitid canal systems. He considered the three genera previously described, namely, *Siderolites*, *Arnaudiella* and *Pseudosiderolites*, to be valid, and erected a new genus, *Praesiderolites* (type specie: *P. douvillei*), to include the simplest and oldest morphotypes. Unfortunately, Wannier's study was not followed by the foraminiferal French school of Paris, which produced a parallel classification, based mainly on the external characteristics of the shells; see, for instance, Andreieff and Neumann (1983) and Neumann (1986; 1997). These authors considered only two genera: *Siderolites* and *Arnaudiella*, and they described several new species of the former genus. Recently, Robles-Salcedo (2014) described two new species in open nomenclature, *S.* aff.*calcitrapoides* and a new species for the genus *Siderolites*.

3. Material and methods

3.1. Material

The architectural and taxonomic revisions of the latest Campanian and Maastrichtian siderolitids are based on samples collected in the northern Pyrenees (Petites Pyrenées, South of France) and southern Pyrenees (south central Pyrenean unit, north-eastern Spain) (Fig. 1). Specimens collected in the ENCI quarry (Maastricht) and in the northern Betic Mountains of Alicante province (eastern Spain) have also been used for comparison (Fig. 1).

3.1.1. Northern Pyrenees

The samples have been collected near the localities of Saint Marcet, Larcan and Gensac, in the Saint Marcet-Saint Marthory Anticline, Latoue-Sepx Syncline and Blajan-Bazordan Anticline, respectively (Fig. 2A). They belong to two successive stratigraphic units: Nankin limestone and Gensac yellow calcareous marl units (Fig. 3). At the well-known section of Saint Marcet, the Nankin limestone unit (Leymerie, 1853) is constituted by a sequence about 85 m-thick of fine-grained yellow calcarenites, probably deposited in a shallow open platform, grading upwards to reddish sandy calcarenites and bioclastic limestones, deposited in a subtidal environment with frequent episodes of high water-energy conditions (Lepicard, 1985). LBF from the Nankin limestone unit are abundant and diversified. The major components are *Lepidorbitoides socialis* (Leymerie, 1851), *Hellenocyclina beotica* Reichel, 1949, *Orbitoides apiculata* Schlumberger, 1901, *Clypeorbis mammillata* Schlumberger, 1902, *Siderolites calcitrapoides*

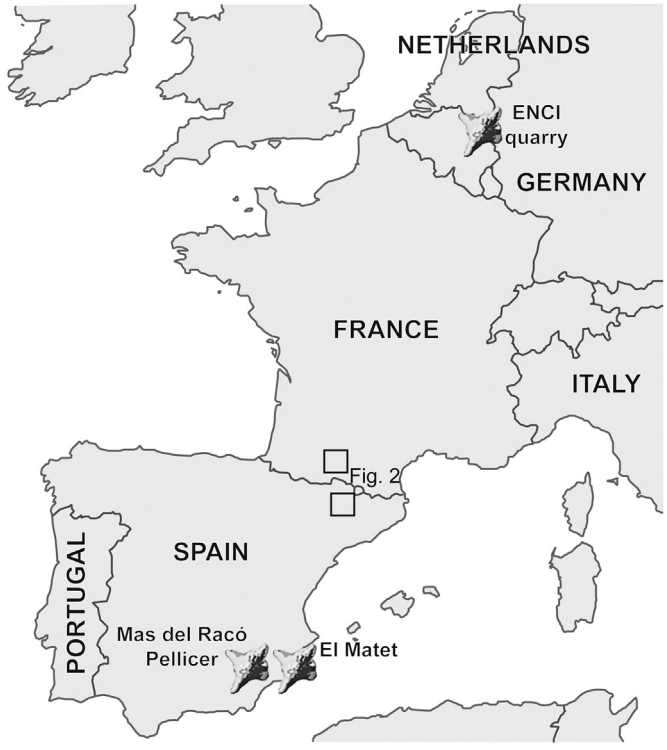

Fig. 1. Location of the studied outcrops.