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Donezella-chaetetid mounds in the Valdeteja Formation (Bashkirian, Pennsylvanian) at Truébano, Cantabrian Mountains, northern Spain

Isabel Rodríguez-Castro*, Sergio Rodríguez & Marián Fregenal-Martínez

I. Rodríguez-Castro, Departamento de Geodinámica, Estratigrafía y Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, c/ José Antonio Novais 2, E-28040 Madrid, Spain; isrodr01@ucm.es *corresponding author*

S. Rodríguez, Departamento de Geodinámica, Estratigrafía y Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, c/ José Antonio Novais 2, E-28040 Madrid, Spain; Departamento de Geología Sedimentaria y Cambio Medioambiental, Instituto de Geociencias, CSIC, UCM, c/ José Antonio Novais 2, E-28040 Madrid, Spain; sergrodr@ucm.es

M. Fregenal-Martínez, Departamento de Geodinámica, Estratigrafía y Paleontología, Facultad de Ciencias Geológicas, Universidad Complutense de Madrid, c/ José Antonio Novais 2, E-28040 Madrid, Spain; mariana@ucm.es

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ABSTRACT - The Bashkirian-lower Moscovian Valdeteja Formation crops out in the Cantabrian Zone (NW Spain). It is composed of pale grey limestone with a diverse fossil content, calcareous breccias and massive limestone composed of algal and microbial mounds accumulated in a high relief carbonate platform. Outstanding outcrops of that formation appear near the village of Truébano (León Province, North Spain) at the old coal mine "Mina Rosario." The mine is a peculiarity in the formation as it shows interbedded siltstones and coal beds containing coal balls. The studied succession above the coal seam is lower Bashkirian and 20.2 m thick. Dark grey, massive to well-bedded limestones interbedded with thin marly beds are dominant in that interval. The main component of the limestones is the algospongia Donezella *that is found in two different facies: packstone of resedimented* Donezella*, which appears in the lower beds of the section, and boundstone of* Donezella*,* Girvanella *and chaetetids, in the upper beds. Additional components are highly diverse including foraminifera, other calcified microbes, rhodophyta, sponges, echinoderms, arthropods, brachiopods, bryozoans and scarce corals and molluscs. Organic matter is abundant in the marly beds, but palynomorphs are poorly preserved. An interbedded layer of quartz sandstones lacking fossil content occurs in the upper part of the sequence.*

The depositional environment of the facies is part of a carbonate platform top near the fair-weather wave base, within subtidal zone, with development of "algal" mounds and sedimentation of debris from the same buildups. The composition and components distribution of both microfacies fit well with the mounds previously described in other outcrops of the Valdeteja Formation, with the exception of the participation of chaetetids as a main building component in some beds.

INTRODUCTION

Algal mounds are common in the Pennsylvanian and have been described in locations such as the American Midcontinent China, the Carnic Alps and the Cantabrian Mountains, in Spain (Samankassou, 2001, 2003; Gong et al., 2007). The main builders of these mounds are phylloid algae, but there are reports of mounds built by other organisms. For instance, Dasycladales (Samankassou, 2001) and algospongia such as donezellids, formerly considered algae (Vachard & Cozar, 2010). "Algospongia" is a Class proposed by Vachard & Cózar (2010). It includes problematic organisms, traditionally assigned to Porifera, Chlorophyta and Rhodophyta, and regroups them in two orders: Moravamiinida and Aoujgaliida. Algal mounds are common in the Carboniferous limestones from the Cantabrian Mountains (northern Spain), mainly in the Valdeteja, Picos de Europa and San Emiliano formations. The algospongia *Donezella* is the main builder of many of these mounds, which have been reported and studied in different locations by authors such as Bowman (1979), Riding (1979), Eichmuller (1985), Samankassou (2001), Della Porta et al. (2002a) and Chesnel et al. (2016, 2017). All the *Donezella* mounds reported by those researchers are upper Bashkirian and Moscovian, except for the lower Bashkirian mounds studied by Eichmüller (1985) near the Valdeteja village.

This study focuses on the "Mina Rosario", an abandoned coal mine that provides an excellent outcrop of the Valdeteja Formation. The mine is in the place known as "Cuesta del Sol" next to Truébano, a village in the San Emiliano municipality in the León Province, northern Spain (Fig. 1).

Here we report the first description and analysis of the *Donezella*-bearing limestones strata overlying the carbonaceous marls of the coal mine. The aim of the palaeontological and sedimentological analyses herein presented is to establish the sedimentary environment and the age of the *Donezella* mounds. This analysis is part of a larger study about the palaeontology and microfacies in the "Mina Rosario" outcrop, part of which is published by Rodríguez-Castro et al. (2019).

GEOLOGICAL SETTING

The Valdeteja Formation (Bashkirian) crops out in Northwest Spain in the Cantabrian Zone of the Iberian Massif. The Cantabrian Zone consists in a thick succession of Palaeozoic deposits that was deformed into a set of imbricated thrusts during the Variscan Orogeny (Bahamonde et al., 2000; Alonso et al., 2009). It is characterised by a low-degree or null metamorphism, low deformation and thin-skinned tectonic structure (Julivert, 1971; Bastida, 2004). The thrust sheets divide the zone

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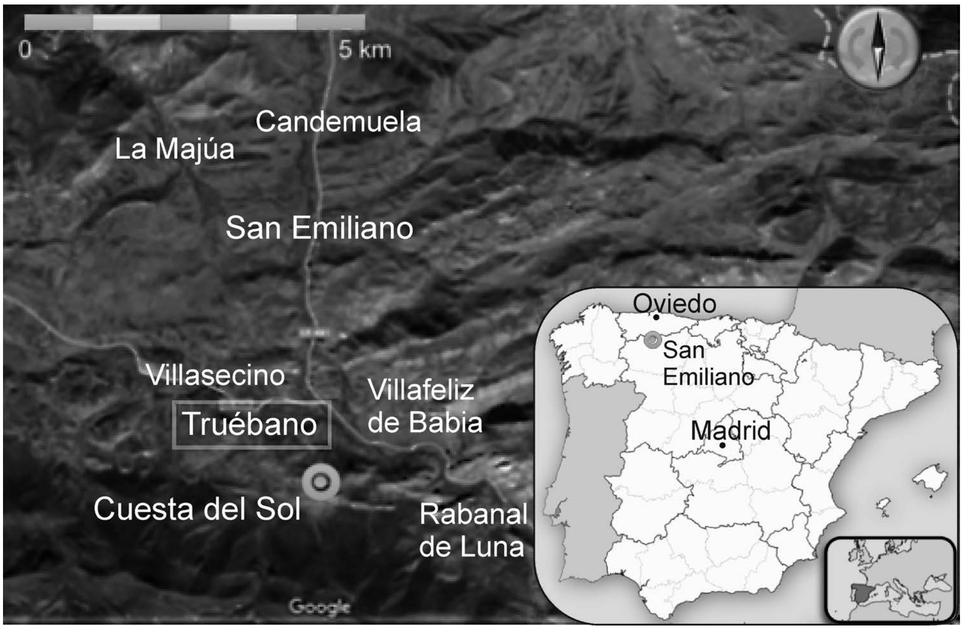


Fig. 1 - Location of the Mina Rosario outcrops. Modified from google maps (image property of TerraMetrics) and WikimediaCommons (author HansenBCN).

in multiple tectonic units (Bastida, 2004), such as the Sobia-Bodón Unit, where the study area is located.

The sedimentary record of the Cantabrian Zone can be divided in two thick sedimentary sequences: the pre-orogenic sequence (Precambrian-Devonian) and the syn-orogenic sequence (Carboniferous) (Julivert, 1978; Marcos & Pulgar, 1982), which records the sedimentation in carbonate platforms developed in the foreland basin of the Variscan orogen currently located in the north of the Iberian Massif. The studied succession belongs to this sequence.

Winkler Prins (1968) originally defined as "Valdeteja" the Valdeteja Member of the Caliza de Montaña Formation. This member is now a formation of its own, and "Caliza de Montaña" has turned into an informal term for both the Barcaliente Formation (Serpukhovian-Bashkirian) and the Valdeteja Formation (Bashkirian). The former appears in all the tectonic units of the Cantabrian Zone, while the latter is limited to the Sobia-Bodon, Áramo and Picos de Europa units, and to the Central Carboniferous Basin (Bastida, 2004).

Bastida (2004) described the Valdeteja Formation as an ensemble of light-coloured limestones with diverse fossil content, calcareous breccias and massive microbial and algal boundstones. Although it is a well-known formation, detailed sedimentological and microfacies studies of the Valdeteja Formation are scarce in the León Province. The facies of the Carboniferous carbonate platform have been studied in higher detail in several outcrops in Asturias, especially in the Sierra de Cuera, where it is hard to distinguish the Valdeteja Formation from the overlying Picos de Europa Formation (Moscovian) (Bahamonde et al., 1997). Moreover, most of those studies focus on the later formation and substage (Bahamonde et al., 2004, 2008), and when they also address the Bashkirian they usually just include a few samples or a small section of the stratigraphic logs from the upper Bashkirian (Della Porta et al., 2002a, b, 2003, 2004; Verwer et al., 2004). The main exceptions are Bahamonde et al. (1997, 2007), which analyse more in detail the facies of Valdeteja.

Most studies in the León Province focus on its palaeontological content and biostratigraphy based on foraminifera and macroflora (Wagner et al., 1971; Villa, 1982; Ginkel & Villa, 1991; Villa et al., 2001). The main sedimentological study of the Valdeteja Formation in the province is that of Eichmüller (1985), who established the depositional environment of the formation as a high relief carbonate platform surrounded by a deep siliciclastic basin. This interpretation is confirmed by Bahamonde et al. (2000), Della Porta et al. (2002b), Kenter et al. (2002) and Chesnel et al. (2016, 2017). These authors described accurately the geometry and stratigraphic architecture of the carbonate platform in the Picos de Europa unit based on exceptional outcrop conditions at Las Llacerias, Sierra de Cuera and Valdorria.

The "Mina Rosario" outcrop is a peculiarity inside the Valdeteja Formation, because of the presence of carbonaceous marls with coal balls. It was first studied while the mine was still active (Gómez-de-Llarena & Rodríguez-Arango, 1946). Those authors described the coal balls, called "Tacañas" by the miners, and their fossil content (*Calamites*, other vegetal remains, corals, crinoids, brachiopods and small gastropods). They also established the age of the carbonaceous marls as early Westfalian (Moscovian).

Other authors that studied the mine have also focused on the coal balls, analysing their depositional environment, formation processes and their fossil content, specifically the foraminifera and algae (Vachard & Beckary, 1988, 1991). Despite the interest that the carbonaceous bed has awakened among the researchers, the rest of the outcrop and its unique features have been ignored until now.

METHODS

Field work includes measurement of stratigraphical log (Fig. 2), observation and description of rock structures and textures and sedimentological and palaeontological sampling of each bed. The carbonaceous marls serve as the base of the log, while the top is the first bed that could not be measured due to the difficult access. The palaeontological samples include palynomorphs, microfossil and macrofossil samples, which are stored in the Facultad de Ciencias Geológicas (Universidad Complutense de Madrid). The palynological samples have been treated with acids for extraction of palynomorphs in the laboratory of the Huelva University by F. González, who also analysed them. Horizontal and vertical thin sections have been prepared from each sedimentological and palaeontological sample. They have been studied with optical microscope. The thin sections from bed 9 have been stained for checking the presence of carbonate cements (Lindholm & Finkelman, 1972). The carbonate rocks have been described using the Dunham (1962) and Embry & Klovan (1971) classifications, while for sandstones we apply Pettijohn (1954). For the environmental reconstruction we employed the method described by Said et al. (2010). It consists in the identification of environmental factors (such as hydrodynamic energy, salinity, depth and oxygenation), which then are used to deduce the sedimentary environment.

DESCRIPTION OF THE "MINA ROSARIO" OUTCROP

The studied succession crops out in two open pit mines at the Mina Rosario (Fig. 3). In the biggest open pit, the bedding planes strike roughly east-west and dip almost vertical due to its location next to the overthrust of the Sobia-Bodón Unit by the Somiedo Unit, which in this area is E-W directed. In the western open pit, of smaller size, the bedding planes' strike and dip are conditioned by a local fault (Fig. 3). The carbonaceous marls are lenticular and present lateral thickness changes.

The measured and studied succession is 20.2 metres thick. It is mainly composed of decimetric to metric grey limestones and marl beds. The limestones are laterally continuous in thickness along the mine, while the marl beds are thinner, and some of them disappear laterally. Stratification is irregular because of the amalgamation of the mounds, already reported in other areas of the Cantabrian mountains (Bahamonde et al., 2000; Corrochano et al., 2011). Bioturbation is common in all the carbonate beds.

The packstones that occur in the 13.5 m thick lower part of the succession (beds 1-6 in Fig. 2) are fine-grained, bioclastic, and do not contain any fossil identifiable at field scale. Beds 2 and 6 are well bedded in decimetric layers, and bed 6 even contains interbedded thin marl layers, but most of the limestone levels are massive. Petrographic

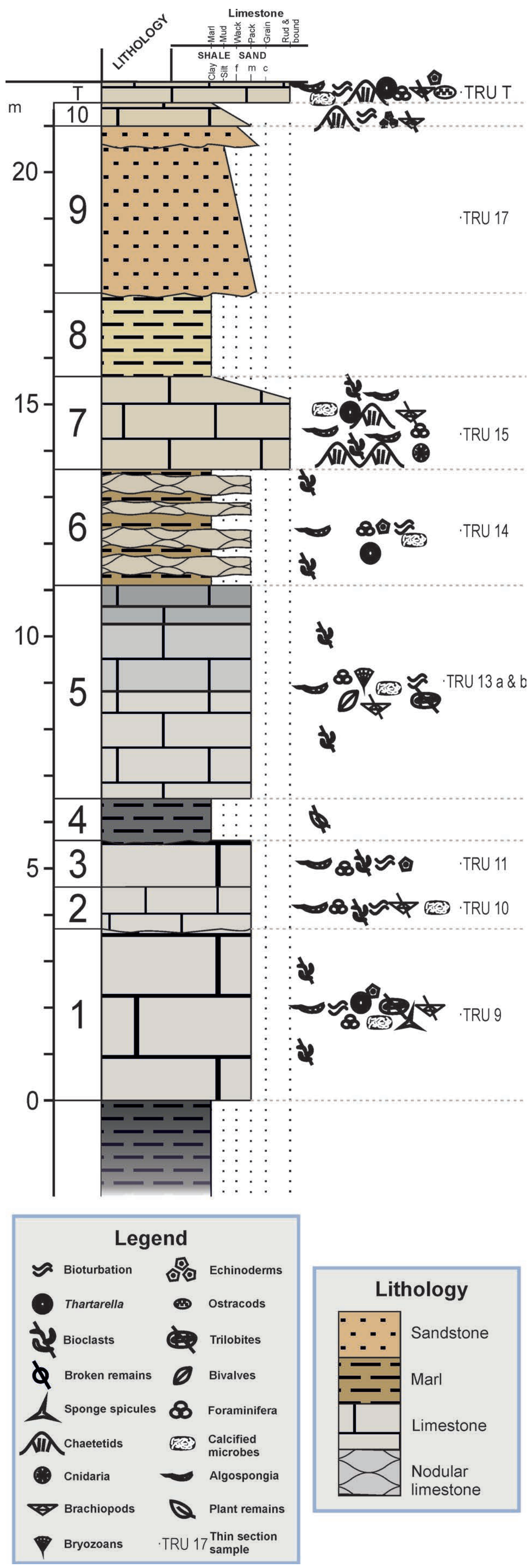


Fig. 2 - (color online) Stratigraphic log of the studied succession. The carbonaceous marls serve as a base for the log, while the top (T) marks the start of beds that could not be reached. Intervals 1 to 10 based on lithological features. Colors in the log represent the actual colors of the rocks on the field.

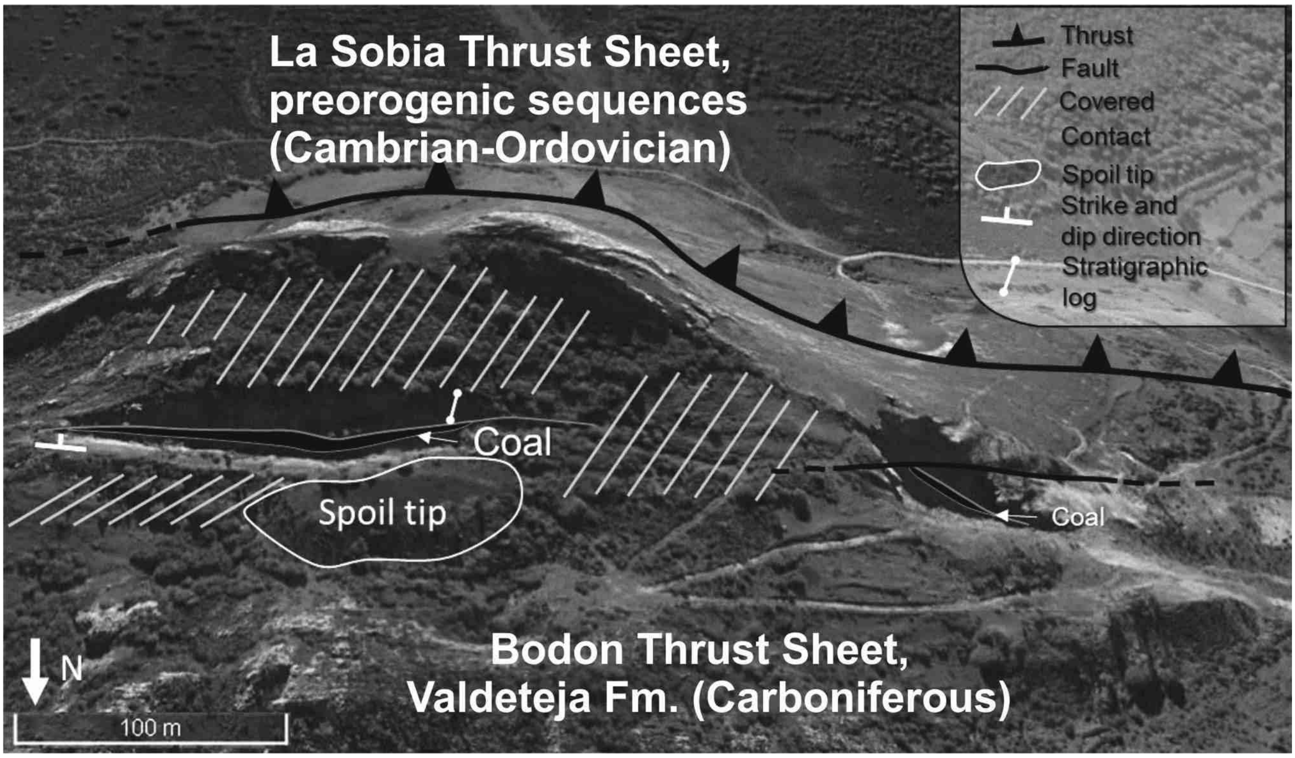


Fig. 3 - Sketch diagram of the outcrop over aerial photograph. Satellite image from google maps (image property of TerraMetrics).

analysis shows a diverse fossil assemblage, composed mainly of broken *Donezella* thalli and other algospongia genera such as *Ungdarella*, *Petschoria*, *Faciella*, *Beresella* and *Uraloporella*. Other components are crinoids and undetermined echinoderm plates, foraminifera (mainly fusulinids and endothyrids), broken brachiopod shells, ostracods, bryozoans and *Girvanella*. Scarce trilobites, mollusc fragments, rugose corals and sponge spicules are found in some samples.

The limestones of the upper part of the succession (beds 7 to top in Fig. 2) are boundstones, and their main components are chaetetids, algospongia (mainly

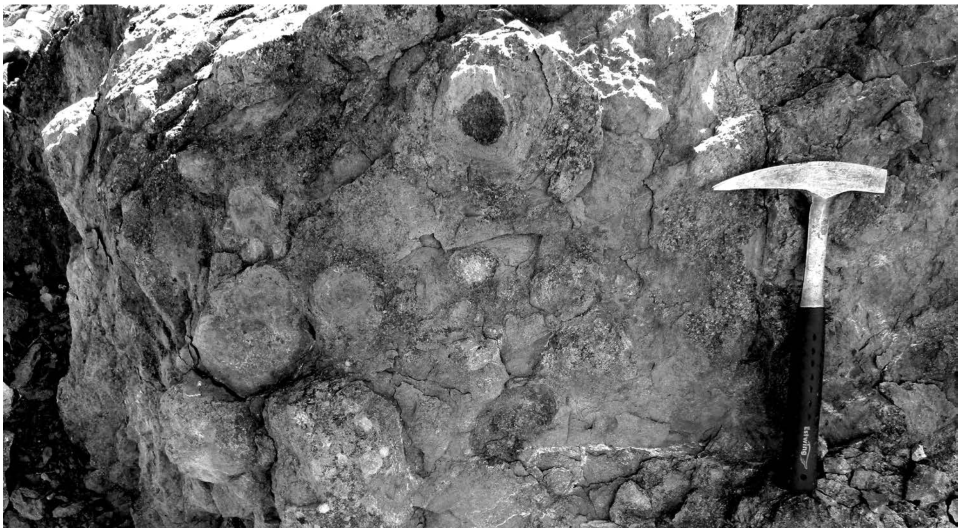


Fig. 4 - Field photograph of base of bed 6. The dome-shaped chaetetids form a framestone that serves as a base for the mound. Geological hammer (30 cm) as size reference.

Donezella) and *Girvanella*. The mounds range from 40 centimetres to two metres in thickness. The base of some of the buildups is a continuous framestone of chaetetids (Fig. 4), which become less common towards the upper part of the stratum. The spaces between the chaetetids are filled with a bafflestone composed of *Donezella* and *Girvanella*, and with bioclasts. The grain size decreases upwards, and bed 7 passes gradually upwards to a marl layer. The beds overlying the studied succession appear to be similar buildups, with different thickness of the individual beds.

The marl beds are laminated and do not contain macrofossils. They vary from black and dark brown marls in bed 4 to brown in bed 6 and to light brown in bed 8. The darker levels contain abundant organic matter and degraded phytoclasts.

An ochre quartz sandstone appears near the top of the succession (bed 9). It is composed of two fining-upwards sequences with irregular bases. The sandstone completely lacks fossil content or carbonate components, as it is only composed of well sorted quartz grains. Until now, this is the only sandstone bed described for the Valdeteja Formation in the León Province.

FOSSIL CONTENT

The thin sections show a high-diversity assemblage, where at least seven animal Phyla are represented: Porifera, Cnidaria, Arthropoda, Echinodermata, Mollusca, Brachiopoda, Bryozoa (Fig. 5). There are also members of the Phyla Foraminifera, Cyanobacteria, Rhodophyta and the Class Algospongia (undetermined Phylum and Kingdom) (Fig. 6). The palinomorph samples just yielded scarce and unidentifiable spores and continental amorphous organic matter (degraded phytoclasts).

Most fossil remains are broken and/or disarticulated. It was possible to identify foraminifera, algospongia, cyanobacteria, rhodophyta, rugose corals and sponges on the genus level. The abundance and diversity of foraminifera and algospongia made possible to identify even some species.

Porifera - Chaetetids are one of the main components of the boundstones in beds 7 and 10. They range from 10 to 20 centimeters and are dome-shaped (Fig. 4). Moreover, scarce sponge spicules appear in bed 1.

Cnidaria - Scarce tabulated and rugose corals appeared in scree from the section. The only identifiable specimen was the rugose coral *Semenophyllum* sp., which was found in scree probably from bed 7.

Arthropoda - Ostracods occur as a secondary component in all units, and scarce broken trilobite fragments appear in beds 1 and 5.

Echinodermata - Echinoderm plates are frequent in every bed. Most of them are crinoid and undetermined plates, but Echinoidea spines appear in some thin sections too.

Brachiopoda - They occur in the whole outcrop as a secondary component of the fossil assemblage. All of them are broken shells that cannot be assigned to any Class.

Mollusca - Molluscs are scarce and mainly found in the first bed. Most of them are broken unidentifiable shells, but a few gastropods are present in thin sections.

Bryozoa - They occur in every bed of the outcrop, but they are not abundant. Most of them are broken and cannot be identified, but a few of them belong to the Order Fenestrata.

Algospongia, algae and cyanobacteria - Those are some of the most diverse groups in the studied section. The most abundant fossils in the studied outcrop belong to Algospongia, such as *Donezella*, the main mound-builder (along with chaetetids and some cyanobacteria). *Ungdarella* is also abundant, along with the red algae *Archaeolithophyllum* and the cyanobacteria *Girvanella*.

Foraminifera - Foraminifera are the most diverse Phylum in the outcrop. At least twenty species and genera have been identified. They are frequent in every bed, and most of them belong to Fusulinida and Endothyrida, while Archeodiscida are scarcer. There is just one genera (*Tuberitina*) of Afusulinina, but it is abundant in all the samples.

The list of all the identified taxa and their distribution is shown in Fig. 7.

MICROFACIES

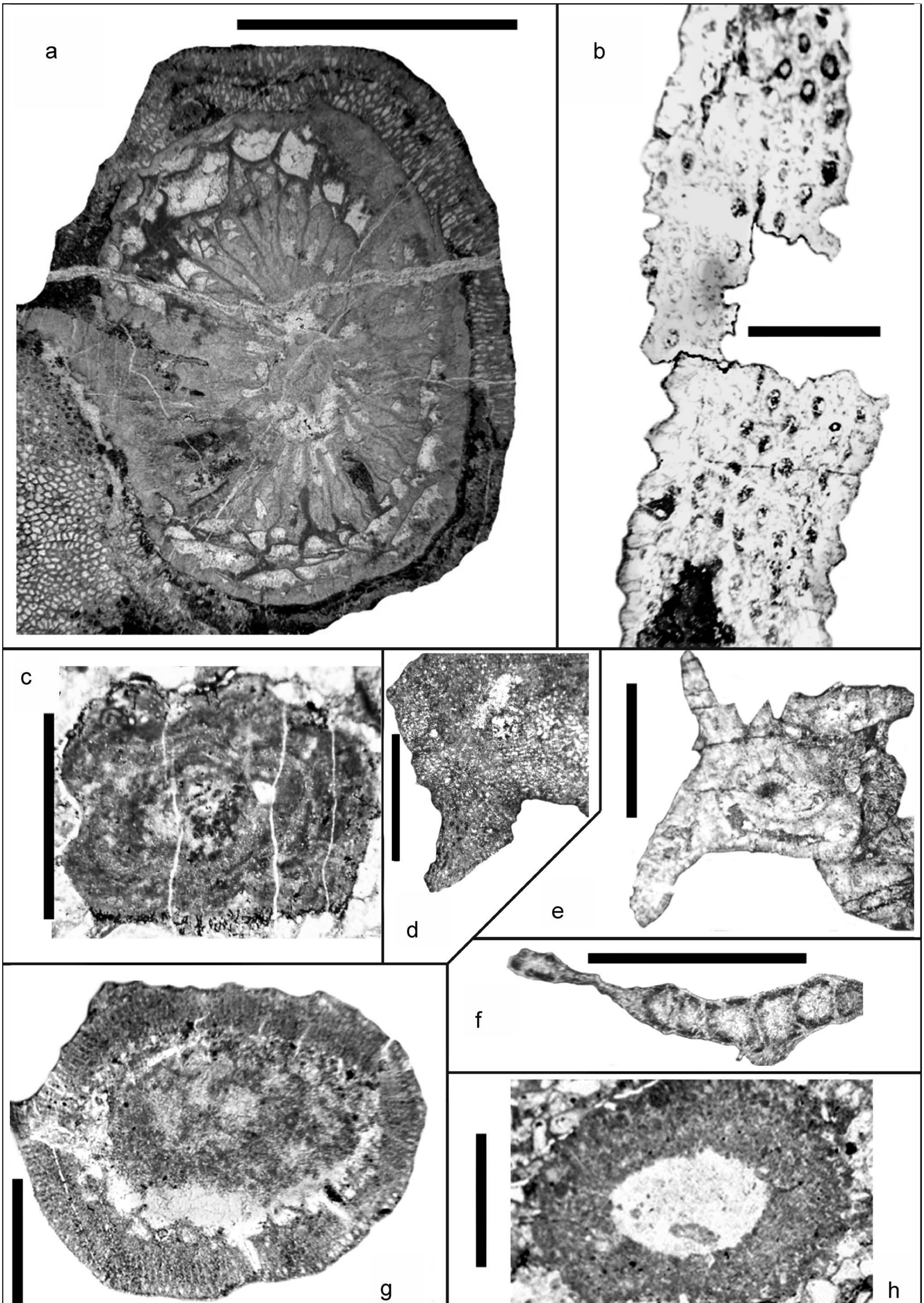
Two carbonate microfacies, characterised by distinct depositional textures, fossil assemblages and taphonomic preservation states, can be differentiated in the studied section.

Microfacies 1: resedimented algospongia packstone

It is the most frequent microfacies in the studied levels and appears in samples in all limestone beds (Fig. 2). This packstone is defined by the presence of broken and resedimented *Donezella* as the main component (Fig. 8). Grain size varies between samples and even between different areas of the same sample, but most samples are fine-grained.

The secondary components are other algospongia such as *Beresella*, *Petschoria* and *Fasciella*, broken brachiopod shells, crinoid plates, sea urchin spines and foraminifera. There are abundant fusulinids, endothyrids and *Tuberitina*, and scarce or even absent archaeodiscids. There are also ostracods, abundant red algae (*Archaeolithophyllum*), mollusc remains, some bryozoans, trilobite fragments, cyanobacteria (*Girvanella* and *Renalcis*) and isolated rugose corals.

This assemblage is relatively diverse, with seven animal Phyla and more than twenty-five genera of Foraminifera, Algospongia, Cyanobacteria and Rhodophyta (Fig. 7). The equitability is low, as *Donezella* absolutely dominates the assemblage.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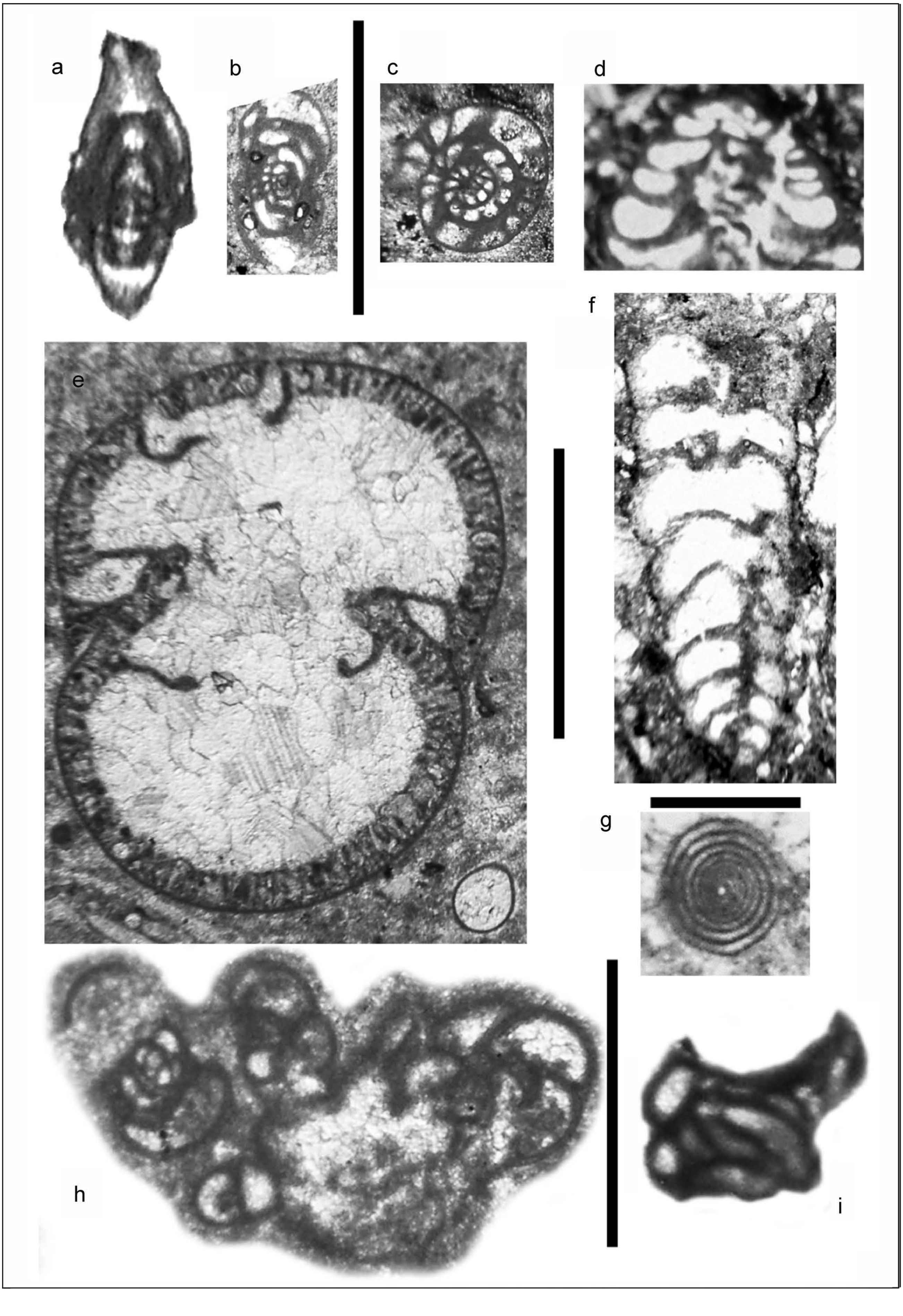
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Fig. 5 - (pag. 252) Mound builders and dwellers. a) Rugose corals, *Semenophyllum* sp. incrusted by a chaetetid, scree, DPM 12066 TRU 0. b) Bryozoans, fenestrate bryozoan, DPM 12066 TRU 13. c) Calcified microbes, *Girvanella* sp., DPM 12066 TRU 14. d-g) Algospongia, *Ungdarella* sp. (d), DPM 12066 TRU 9; *Fasciella* sp. (Aoujgaliida) (e), DPM 12066 TRU 13b, *Donezella lutugini* Maslov, 1929 (Moravamminida) (f), DPM 12066 TRU 10; *Uraloporella* sp. (Moravamminida) (g), DPM 12066 TRU 10. h) Ichnofossil, *Thartarella* sp. (worm tubes), DPM 12066 TRU 14. Scale bars: a, 1 cm; b-h, 1 mm.

Fig. 6 - (pag. 253) Foraminifera. a) *Ozawainella umbonata*, DPM 12066 TRU 15. b) *Eostaffella postmosquensis*, DPM 12066 TRU 15. c) *Pseudostaffella* sp., DPM 12066 TRU 15. d) *Tetrataxis* sp., DPM 12066 TRU 13b. e) *Bradyina nautiliformis* Möller, 1878, DPM 12066 TRU 10. f) *Climacammina* sp., DPM 12066 TRU 18. g) *Monotaxinoides* sp., DPM 12066 TRU 11. h) *Insolethiteca* sp., DPM 12066 TRU 9. i) *Hemiegordierina* sp., DPM 12066 TRU 10. Scale bars: 1 mm for all specimens, except g = 0.25 mm.

Fossil remains are disorganised, with some areas composed almost exclusively of *Donezella* remains, while others are more diverse. Most fossils appear to be oriented roughly horizontally, and most remains are broken and disarticulated, specially the bigger ones. These features suggest the fossils are resedimented (sensu Fernández-López, 1991), but there are no signs of prolonged transport.

Microfacies 2: Donezella*,* Girvanella *and chaetetids boundstone*

It occurs in the limestone beds in the upper part of the succession, specifically in some areas of samples TRU 15 and TRU T (Fig. 2). It is defined by the presence of chaetetids and *Donezella* in growth position, creating an organic frameworтk with gaps inhabited by cyanobacteria like *Girvanella* and burrowers, like the *Thartarella* producers (Fig. 9).

Besides *Donezella* and *Girvanella*, which are the absolute main components of the assemblage, there are fusulinids, Endothyrida (specially paleotextularids), archaeodiscids, *Tuberitina*, red algae, some disperse echinoderm plates and broken brachiopods shells.

This boundstone presents a fossil assemblage very similar to the "algal" mounds described in other outcrops of the Valdeteja Formation, which have been thoroughly studied by Eichmüller (1985), Samankassou (2001), Della Porta et al. (2002a), and Chesnel et al. (2016, 2017). The main difference between the boundstone from the Mina Rosario and those described by these researchers is the higher abundance of *Girvanella* and chaetetids occurring in the mine.

This fossil assemblage is less diverse than the assemblage of the microfacies 1, but the equitability is higher, since chaetetids and cyanobacteria are also main components of the limestone, along with *Donezella*. Some remains are broken and may have undergone resedimentation, but most of them are in growth position.

ENVIRONMENTAL RECONSTRUCTION

The previous observations allow the identification of some environmental factors for the limestone sedimentary environment.

The presence of *Donezella* and chaetetids in growth position suggests a low to moderate hydrodynamic energy, while the abundance of broken and disarticulated remains appears to indicate the opposite. Moreover, the presence of abundant micrite implies periods of low energy. These features suggest an environment with moderated and discontinuous sea swell influence. The cyanobacteria and chaetetids in the mounds provide a stronger framework that allows the *Donezella* to resist the waves, but some specimens are still broken and deposited around the mounds. The limestones in the lower half of the section represent the sedimentation of the debris and broken fossils from the mounds, while the buildups form beds 7 and 10.

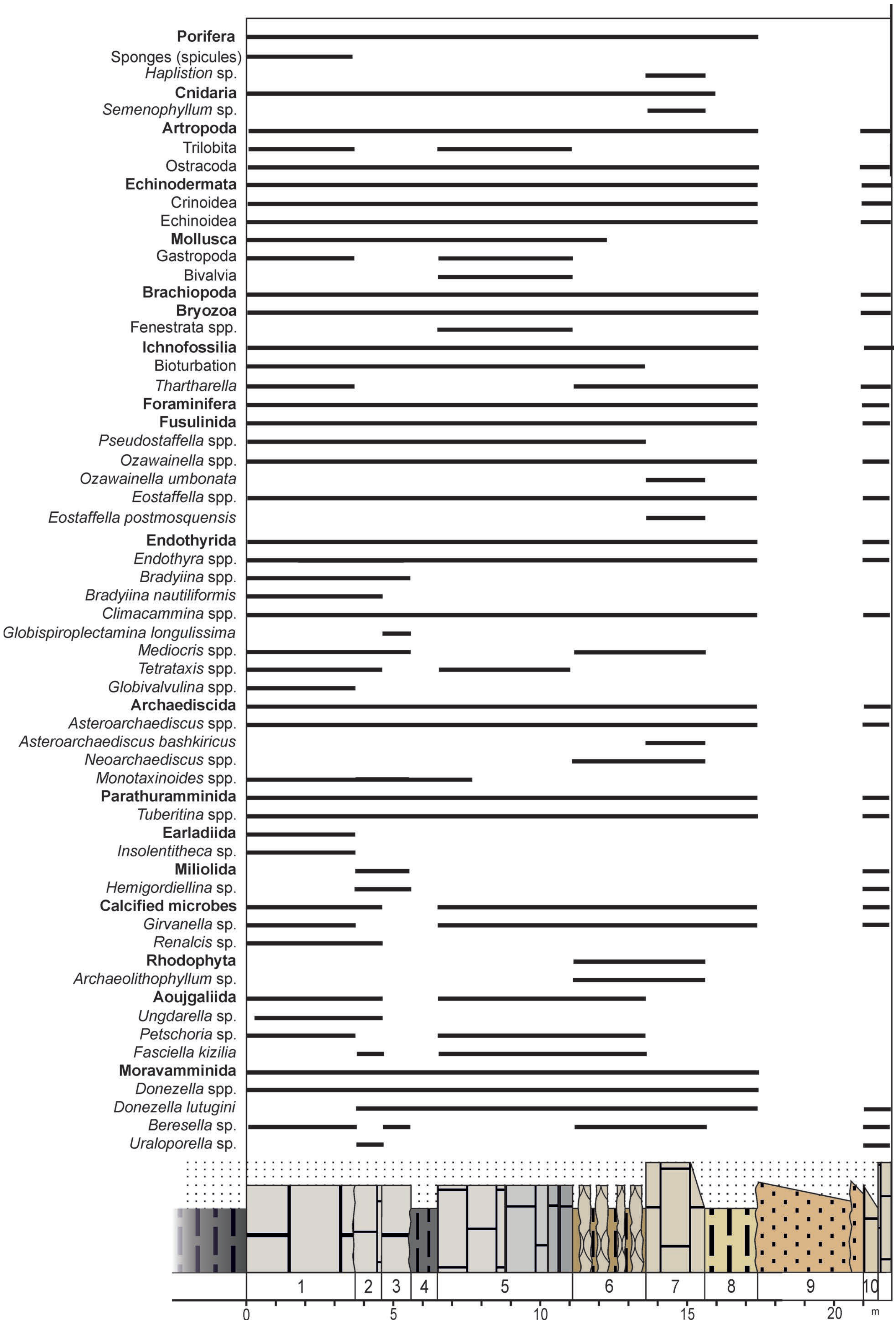
The diversity of the fossil assemblages and the presence of stenohaline organisms, such as brachiopods, echinoderms and chaetetids, indicate a normal marine salinity, about 36-40 ppm (Fürsich, 1993). Moreover, the abundant bioturbation and the biodiversity both suggest a well-oxygenated environment. All these features are characteristic of an open sea and imply that the mounds did not form a barrier that isolated the inner platform, but they represent patches widely developed in a shallow platform, in a situation similar to that of the *Donezella* buildups described in Della Porta (2002a).

The presence of autochthonous inferred photosynthetic organisms, such as cyanobacteria (*Girvanella*) and algae, indicates that the mounds were in the photic zone. The influence of the sea swell also rules out a high depth. This implies that the mound organisms inhabited a relatively shallow environment, but with no evidences of subaerial exposure. Presence of beds in the lower part of the succession with abundant *Donezella* shingle indicates periodical erosion by waves and resedimentation of the mounds.

The marl beds are the result of the sedimentation in periods with less hydrodynamic energy and higher influx of sediment from the continent, which includes fine clastic sediment and organic matter.

Therefore, the sedimentary environment would have been a carbonate platform close to the fair-weather wave base, in the subtidal zone. The rocks that crop out in the Mina Rosario are the result of the development of "algal" mounds in that platform (microfacies 2), and the detrital sedimentation of thalli between and around them (microfacies 1).

Fig. 7 - Stratigraphical distribution of the identified fossils. Patterns according to the legend in Fig. 2.


Porifera
Sponges (spicules)
Haplistion sp.
Cnidaria
Semenophyllum sp.
Artropoda
Trilobita
Ostracoda
Echinodermata
Crinoidea
Echinoidea
Mollusca
Gastropoda
Bivalvia
Brachiopoda
Bryozoa
Fenestrata spp.
Ichnofossilia
Bioturbation
Thartharella
Foraminifera
Fusulinida
Pseudostaffella spp.
Ozawainella spp.
Ozawainella umbonata
Eostaffella spp.
Eostaffella postmosquensis
Endothyrida
Endothyra spp.
Bradyiina spp.
Bradyiina nautiliformis
Climacammina spp.
Globispiroplectamina longulissima
Mediocris spp.
Tetrataxis spp.
Globivalvulina spp.
Archaediscida
Asteroarchaediscus spp.
Asteroarchaediscus bashkiricus
Neoarchaediscus spp.
Monotaxinoides spp.
Parathuramminida
Tuberitina spp.
Earladiida
Insolentitheca sp.
Miliolida
Hemigordiellina sp.
Calcified microbes
Girvanella sp.
Renalcis sp.
Rhodophyta
Archaeolithophyllum sp.
Aoujgaliida
Ungdarella sp.
Petschoria sp.
Fasciella kizilia
Moravamminida
Donezella spp.
Donezella lutugini
Beresella sp.
Uraloporella sp.
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Further data are required to understand the spatial distribution, extension and morphology of the mounds, since this analysis comprises just one stratigraphic succession, which is not enough to completely characterise the carbonate platform.

AGE

There are few previous biostratigraphic studies conducted in the Mina Rosario. Vachard & Béckary (1991) studied the foraminifera from the coal bed and determined a Prikamian (Askinbasian) age, which is the highest horizon of the lower Bashkirian, according to the chronostratigraphic scale defined in the Russian platform. Vachard & Béckary (1991) also studied the macroflora they found in the coal balls, which belongs to the Namurian C regional substage (Yealdonian). However, they state that it is hard to distinguish between Namurian C and Westphalian A (Langsetian) regional substages with the findings from the mine. Other authors that have studied the macroflora from the Mina Rosario in the past (Gómez de Llarena & Rodríguez Arango, 1946, 1948) also maintain this ambivalent situation between upper Namurian and lower Westphalian.

The new results are consistent with previous studies. Since there were more identifiable species in the lower beds, the Fusulinoidea recorded in the whole outcrop were used, instead of relying on the specimens from the beds over the coal level. *Eostaffella postmosquensis* Kireeva in Rauzer-Chernousova,1951, *Millerella concinna* Potievskaya, 1964, *Ozawainella umbonata* Brazhnikova & Potievskaya, 1948 and *Pseudostaffella variabilis* Reitlinger, 1961 were also found by Vachard & Béckary (1991). These species only overlap in Severokeltmenian (Akavasian) and Prikamian horizons (lower Bashkirian). Vachard & Béckary (1991) were able to narrow the age down to the Prikamian horizon because of the presence of *Pseudostaffella praegorskyi* Rauzer-Chernousova, 1949, which has not been found in our thin sections. However, we have no reason to argue their findings, so it is most likely that the outcrop belongs to the Prikamian and not the Severokeltmenian with no doubt that it is lower Bashkirian. Moreover, the overall assemblage matches the one described by Vachard & Béckary (1991) as the usual assemblage in both Spain and the Donetz basin: the firsts *Ozawainella* and abundant *Monotaxinoides transitorius* Brazhnikova & Yartseva, 1956, Archaediscida and Ozawainelloidea, like *Eostaffella*, *Millerella* and *Plectostafella*.

The Rugosa genus *Semenophyllum* is reported exclusively in the Bashkirian (Rodríguez-García, 1984; Coronado & Rodríguez, 2009), which further supports the age based on the foraminifera.

Most *Donezella* mounds in the Valdeteja Formation are upper Bashkirian and/or Moscovian (Bahamonde et al., 2004; Chesnel et al., 2016). This means that these results imply that these are some of the oldest mounds described in the Valdeteja Formation, along with the mounds from the type section, described by Eichmüller (1985).

CONCLUSIONS

The Mina Rosario outcrop is unique in the Valdeteja Formation because of the carbonaceous marls with coal

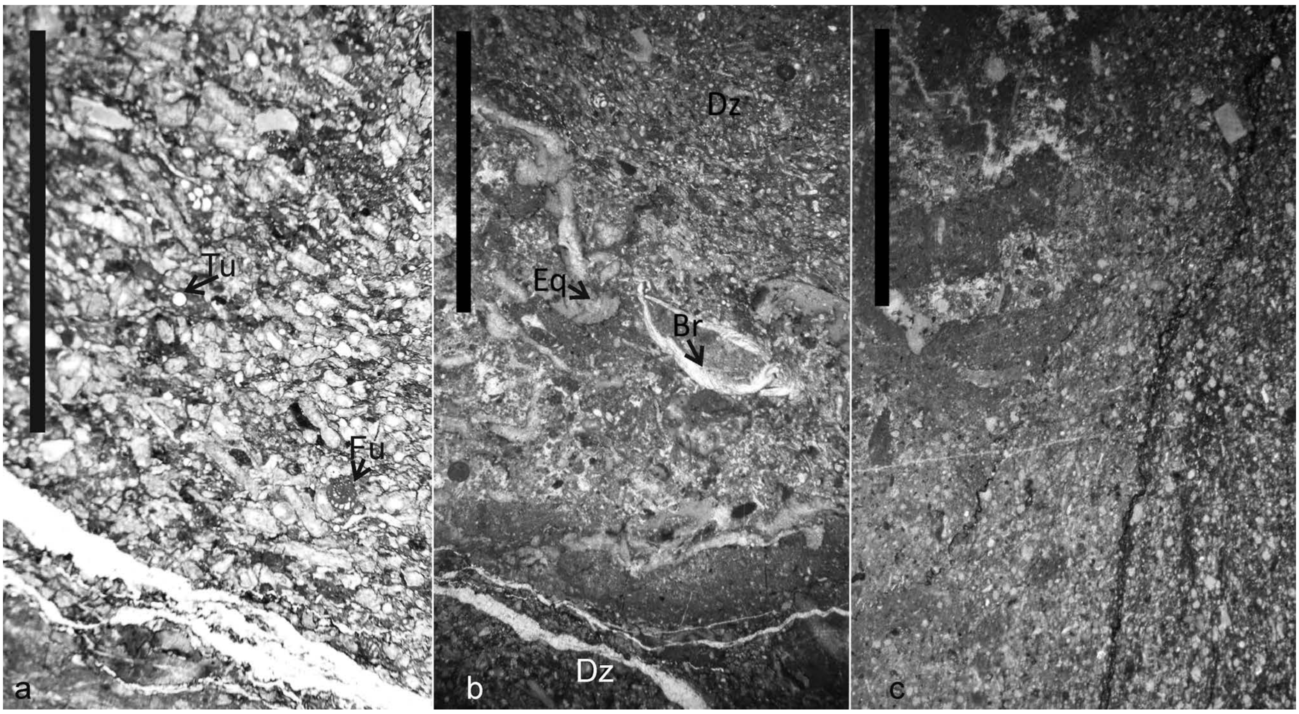

Fig. 8 - Microfacies 1. a) Resedimented algospongia packstone, vertical thin section (bed 2). Very small bioclasts, mostly algospongia fragments with homogeneous distribution. Fu: Fusulinina, Tu: *Tuberitina* sp. Scale bar: 5 mm. b) Horizontal thin section (bed 1) showing some larger bioclasts. Eq: echinoderm plates, Br: brachiopod shell, Dz: *Donezella* fragments of branches. Scale bar: 1 cm. c) Horizontal thin section (bed 3) showing intense bioturbation (upper left). Scale bar: 1 cm.

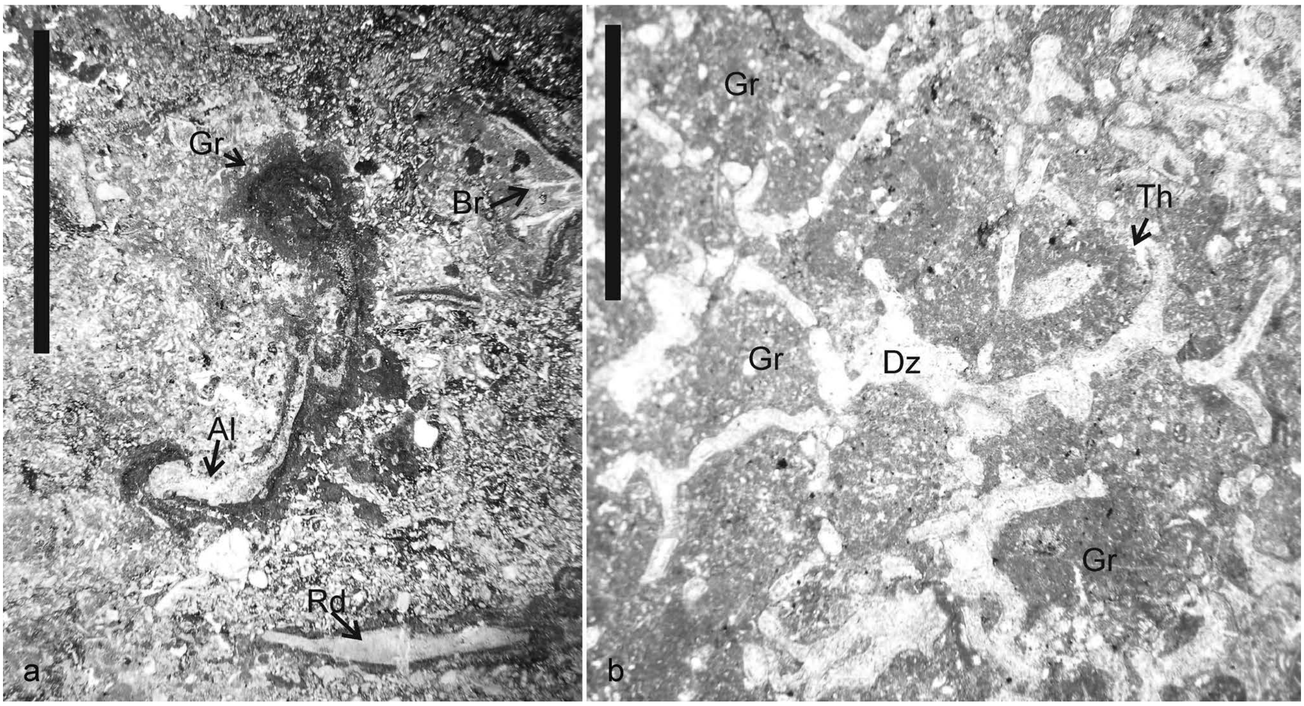

Fig. 9 - Microfacies 2. a) Horizontal thin section (bed 7). *Girvanella* masses coating different clasts. Gr: *Girvanella*, Al: algospongia, Br: brachiopod, Rd: Rhodophyta. Scale bar: 1 cm. b) Horizontal thin section (bed T). *Donezella* in growth position (Dz), masses of *Girvanella* (Gr) and *Thartarella* (Th) worm tubes. Scale bar: 2 mm.

balls that were mined in the 1940s. The strata above the coal bed are composed of marl and limestone beds, formed mainly by resedimented *Donezella* or by chaetetids, *Donezella* and *Girvanella* in growth position, building mounds. These beds have a relatively high diversity and contain abundant Foraminifera, crinoids and undetermined echinoderm plates, brachiopods, ostracods, bryozoans and corals. We have differentiated two carbonate microfacies: resedimented algospongia packstone limestones (microfacies 1) and chaetetids, *Donezella* and *Girvanella* boundstone (microfacies 2). The latter is very similar to the typical "algal" mounds in the Valdeteja Formation. The sedimentary environment is part of an open carbonate platform. The limestones were deposited near the fair-weather wave base. The fossils identified in this study support the previous dating by other authors. The fusulinid assemblage confirms the early Bashkirian age and places the outcrop between the Severokeltmenian and Prikamian Russian horizons. The west-European equivalent would be the Namurian C and Westphalian A substages.

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REFERENCES

Alonso J.L., Marcos A. & Suárez A. (2009). Paleogeographic inversión resulting from large out of sequence breaching thrusts: The Leon Fault (Cantabrian Zone, NW Iberia). A new picture of the external Variscan Thrust Belt in the Ibero-Armorican Arc. *Geologica Acta*, 7: 451-473.

Bahamonde J.R., Colmenero J.R. & Vera C. (1997). Growth and demise of Late Carboniferous carbonate platforms in the eastern Cantabrian Zone, Asturias, northwestern Spain. *Sedimentary Geology*, 110: 99-122.

Bahamonde J.R., Kenter J.A.M., Della Porta G. & Hoeflaken F. (2008). Facies belt of a Carboniferous carbonate platform (San Antolin-La Huelga section, NE Cantabrian Zone). *Trabajos de Geologia*, Universidad de Oviedo, 28: 69-86.

Bahamonde J.R., Kenter J.A.M., Della Porta G., Keim L., Immenhauser A. & Reijmer J.J.G. (2004). Lithofacies and depositional processes on a high, steep-margined Carboniferous (Bashkirian–Moscovian) carbonate platform slope, Sierra del Cuera, NW Spain. *Sedimentary Geology*, 166: 145-156.

Bahamonde J.R., Merino-Tomé O.A. & Heredia N. (2007). A Pennsylvanian microbial boundstone-dominated carbonate shelf in a distal foreland margin (Picos de Europa Province, NW Spain). *Sedimentary Geology*, 198: 167-193.

Bahamonde J.R., Vera C. & Colmenero J.R. (2000). A steep-fronted Carboniferous carbonate platform: clinoformal geometry and lithofacies (Picos de Europa Region, NW Spain). *Sedimentology*, 47: 645-664.

Bastida F. (2004). Zona Cantábrica (Capítulo 2, Macizo Ibérico). *In* Vera J.A. (ed.), *Geología de España*, SCE-IGME: 25-49.

Bowman M.B.J. (1979). The depositional environment of a limestone unit from the San Emiliano Formation (Namurian/Westphalian), Cantabrian Mountains, NW-Spain. *Sedimentary Geology*, 24: 25-43.

Brazhnikova N.E. & Potievskaya P.D. (1948). Results of the foraminiferal study of materials from wells of the western outskirts of Donbass. *Collection of works about paleontology and stratigraphy*, 1: 76-101.

Brazhnikova N.E. & Yartseva M.V. (1956). To the question of evolution of the genus *Monotaxis*. *Academy of Sciences Union of Soviet Socialist Republics Questions of Micropaleontology*, 1: 62-68.

Chesnel V., Merino-Tomé O.A., Fernández L.P., Villa E. & Samakassou E. (2017). Spatial and temporal distribution of microbial carbonates, skeletal and non-skeletal grains in a Pennsylvanian carbonate platform (Valdorria, Northern Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology,* 476: 106-139.

Chesnel V., Samankassou E., Merino-Tomé Ó., Fernández L.P. & Villa E. (2016). Facies, geometry and growth phases of the Valdorria carbonate platform (Pennsylvanian, northern Spain). *Sedimentology*, 63: 60-104.

Coronado I. & Rodríguez S. (2009). Análisis de microfacies de los montículos de la Formación Cosgaya. Sección de Las Ilces, Pensilvánico, Cantabria. *Coloquios de Paleontología*, 59: 61-91.

Corrochano D., Barba P. & Colmenero J.R. (2011). Transgressive-regressive sequence stratigraphy of Pennsylvanian *Donezella* bioherms in a foreland basin (Lena Group, Cantabrian Zone, NW Spain). *Facies*, 28: 457-476.

Della Porta G., Kenter J.A.M. & Bahamonde J.R. (2002a). Microfacies and Paleoenvironment of *Donezella* Accumulations across an Upper Carboniferous High-rising Carbonate Platform (Asturias, NW Spain). *Facies*, 46: 149-168.

Della Porta G., Kenter J.A.M. & Bahamonde J.R. (2004). Depositional facies and stratal geometry of an Upper Carboniferous prograding and aggrading high-relief carbonate platform (Cantabrian Mountains, NW Spain). *Sedimentology*, 51: 267-295.

Della Porta G., Kenter J.A.M., Bahamonde J.R., Immenhauser A. & Villa E. (2003). Microbial boundstone dominated carbonate slope (Upper Carboniferous, N Spain): microfacies, lithofacies distribution and stratal geometry. *Facies*, 49: 175-208.

Della Porta G., Kenter J.A.M., Immenhauser A. & Bahamonde J.R. (2002b). Lithofacies character and architecture across a Pennsylvanian inner-platform transect (Sierra de Cuera, Asturias, Spain). *Journal of Sedimentary Research*, 72: 898-916.

Della Porta G., Villa E. & Kenter J.A.M. (2005). Facies distribution of Fusulinina in a Bashkirian-Moscovian carbonate-platform top (Cantabrian Mts, NW Spain). *Journal of Foraminiferal Research*, 35: 1-24.

Dunham R.J. (1962). Classification of Carbonate Rocks According to Depositional Textures. *In* Ham W.E. (ed.), *Memoires of the American Association of Petroleum Geologists*, 1: 108-121.

Eichmüller K. (1985). Die Valdeteja Formation: Aufbau und Geschichte einer oberkarbonischen Karbonatplattform (Kantabrisches Gebirge, Nordspanien). *Facies*, 13: 45-155.

Embry A.F. & Klovan J.E. (1971). A late Devonian reef tract on northeastern Banks Island, N.W.T. *Bulletin of Canadian Petroleum Geology*, 19: 705-724.

Fernández-López S. (1991). Taphonomic concepts for a theoretical biochronology. *Revista Española de Paleontología*, 6: 37-49.

Fürsich F.T. (1993) Palaeoecology and evolution of Mesozoic salinity-controlled benthic macroinvertebrate associations. *Lethaia*, 26: 327-348.

Ginkel A.C. van & Villa E. (1991). Some fusulinids from the Moscovian-Kasimovian transition in the Carboniferous of the Cantabrian Mountains (NW Spain). *Proceedings of the Koninklijke Nederlandse Akaddemie van Wetenschappen*, 94: 299-359.

Gómez de Llarena J. & Rodríguez Arango C. (1946). Las «tacañas» (Coal balls) de la Mina «Rosario», de Truébano (Leon). *Notas y Comunicaciones del Instituto Geológico y Minero de España*, 16: 215-236.

Gomez de Llarena J. & Rodríguez Arango C. (1948). Datos para el estudio geológico de la Babia Baja (León). *Boletín del Instituto Geológico y Minero de España*, 61: 79-206.

Gong E., Zhang Y., Guan C., Samankassou E. & Sun B. (2007). Paleoecology of Late Carboniferous Phylloid Algae in Southern Guizhou, SW China. *Acta Geologica Sinica*, 81: 566-572.

Julivert M. (1971). Décollement tectonics in the Hercynian cordillera of Northwest Spain. *American Journal of Science*, 270: 1-29.

Julivert M. (1978). Hercynian orogeny and Carboniferous paleogeography in Northwestern Spain: A model of deformation-sedimentation relationships. *Zeitschrift der Deutschen Geologischen Gesellschaft*, 129: 565-592.

Kenter S.A.M., Van Hoeflaken F., Bahamonde J.R., Bracco Gartner G.L., Kleim L. & Besems R.E. (2002). Anatomy and lithofacies of an intact and seismic-scale Carboniferous carbonate platform (Asturias, NW Spain): analogues of hydrocarbon reservoirs in the Pricaspian basin (Kazakhstan). *In* Zemplolich W. & Cook H.E. (eds), Paleozoic Carbonates of the Commonwealth of Independent States (CIS): Subsurface Reservoirs and Outcrops Analogues. *Society of Economic Paleontologists and Mineralogists, Special Publication*, 74: 181-203.

Lindholm R.C. & Finkelman R.B. (1972). Calcite Staining: Semiquantitative Determination of Ferrous Iron: NOTES. *Journal of Sedimentary Petrology*, 42: 239-242.

Marcos A. & Pulgar F.J. (1982). An approach to the tectonostratigraphic evolution of Cantabrian thrust and fold belt, Variscan Cordillera of NW Spain. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen*, 163: 256-260.

Maslov V.P. (1929). Microscopic algae of the Carboniferous limestones from the Donetz Basin. *Bulletin du Comité géologique*, 48: 115-139.

Möller V. von (1878). Die Spiral-gewundenen Foraminiferen des russischen Kohlenkalks. *Mémoires de l'Académie impériale des sciences de Saint Pétersbourg*, 7th series, 25: 1-147.

Pettijohn F.J. (1954). Classification of sandstones. *The Journal of Geology*, 62: 360-365.

Potievskaya P.D. (1964). Some fusulinids and small Foraminifers from the Bashkirian sediments of the Greater Donbass. *Trudy Geological Institute Nauk, Academy Nauka, Ukranian Sovietic Socialist Republic, Series on Stratigraphy and Paleontology*, 48: 31-59.

Rauzer-Chernousova D.M. (1949). On the ontogeny of some Palaeozoic foraminifera. *Trudy Paleontological Institut Akademy Nauk Union of Soviet Socialist Republic*, Moskva, 20: 339-353.

Rauzer-Chernousova D.M., Gryzlova N.D., Kireeva G.D., Leontovich G.E., Safonova T.P. & Chernova E.I. (1951). Middle Carboniferous fusulinids of the Russian Platform and Neighboring Regions. 380 pp. Academy of Sciences Union of Soviet Socialist Republics, Moscow.

Reitlinger E.A. (1961). Stratigraphy of the Middle Carboniferous (Krasnaja Poljana, boring well no 1) of the TransVolga. *Regional Stratigraphy*, 5: 218-260.

Riding R. (1979). *Donezella* bioherms in the Carboniferous of the southern Cantabrian Mountains, Spain. *Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine*, 3: 787-794.

Rodríguez-Castro I., Rodríguez S. & Fregenal-Martínez M. (2019). Depósitos de flujos en masa y carbón en la Formación Valdeteja (Bashkiriense) en Truébano (León, Cordillera Cantábrica). *In* Martínez-Navarro B., Palmqvist P., Espigares M.P. & Ros-Montoya S. (eds), Libro de Resúmenes XXX Jornadas de la Sociedad Española de Paleontología, Baza 2-5 de Octubre de 2019: 247-250.

Rodríguez-Garcia S. (1984). Corales rugosos del Carbonífero del Este de Asturias. *Colección Tesis Doctorales UCM*, 109/84: 1-594.

Said I., Rodríguez S., Berkhli M, Cózar P. & Gómez-Herguedas A. (2010). Environmental parameters of a coral assemblage from the Akerchi Formation (Carboniferous), Adarouch Area, central Morocco. *Journal of Iberian Geology*, 36: 7-19.

Samankassou E. (2001). Internal structure and depositional environment of Late Carboniferous mounds from the San Emiliano Formation, Cármenes Syncline, Cantabrian

Mountains, Northern Spain. *Sedimentary Geology*, 145: 235-252.

Samankassou E. (2003). Upper Carboniferous-Lower Permian Buildups of the Carnic Alps, Austria-Italy. *Society for Sedimentary Geology Special Publication*, 78: 201-217.

Vachard D. & Béckary S. (1988). Les «tacañas», coal balls mixtes du Carbonifère de Truébano (León, Espagne). *Bulletin de la Société Géologique de France,* 8: 1271-1278.

Vachard D. & Béckary S. (1991). Algues et foraminiferes Bachkiriens des coal balls de la Mine Rosario (Truebano, Leon, Espagne). *Revue de Paléobiologie*, 10: 315-357.

Vachard D. & Cózar P (2010). An attempt of classification of the Palaeozoic *incertae sedis* Algospongia. *Revista Española de Micropaleontología*, 42: 129-241.

Verwer K., Kenter J.A.M., Maathuis B. & Della Porta G. (2004). Stratal patterns and lithofacies of an intact seismic-scale Carboniferous carbonate platform (Asturias, NW Spain): A virtual outcrop model. *In* Curtis A. & Wood R. (eds), Geological Prior Information: Informing Science and Engineering. *Geological Society, London, Special Publication*, 239: 29-41.

Villa E. (1982). Foraminíferos de la Formación Valdeteja (Carbonífero, NW de España) en su área tipo. *Revista Española de Micropaleontología*, 14: 63-72.

Villa E., Sánchez de Posada L.C., Fernández L.P., Martínez-Chacón M.L. & Stavros C. (2001). Foraminifera and Biostratigraphy of the Valdeteja Formation Stratotype (Carboniferous, Cantabrian Zone, NW Spain). *Facies*, 45: 59- 86.

Wagner R.H., Winkler-Prins C.J. & Riding E. (1971). Lithostratigraphic units of the lower part of the Carboniferous in northern León, Spain. *Trabajos de Geología*, 4: 603-663.

Winkler Prins C.F. (1968). Carboniferous Productidina and Chonetidina of the Cantabrian Mountains (NW Spain): Systematics, Stratigraphy and Palaeocology. *Leidse Geologische Mededelingen*, 43: 41-126.

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