Lower Devonian rugose coral faunas from the Cantabrian Mountains (NW Spain): phases of development and response to sea-level fluctuations

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Abstract: The Devonian history of the Cantabrian Mountains (NW Spain), as registered in the stratigraphic series, is characterized by events of variable importance and geographic significance, which are reflected in the lithology and in the fossil content. They are called geobiologic events.

BARNES et al. (1996) mentioned more than 14 Devonian global bioevents. Three of them, the *sulcatus*, Zlichov-Basal and Daleje-*Cancellata* events, have been recognized in the Lower Devonian (Rañeces-La Vid Groups, Lebanza and Abadía Formations). Another one, the Chotec-*Jugleri* event, is observed close to the Lower-Middle Devonian boundary (uppermost part of the Moniello, Santa Lucía and Polentinos Formations; lowermost Eifelian) of the Cantabrian Mountains.

In this paper, six phases of development of the Lower Devonian rugose corals from the Cantabrian Mountains, their relation to global sea-level fluctuations as well as lithologic and palaeontologic features are analyzed in the neritic (Asturo-Leonian) and pelagic (Palentine) domains.

Key words: Cantabrian Mountains, reefal phases, stratigraphy, bioevents, sea-level fluctuations

Contents

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1. INTRODUCTION

The marine Devonian series of the Cantabrian Mountains (NW Spain) has been divided stratigraphically into two different facies domains: the Asturo-Leonian Domain and the Palentine Domain (Brouwer, 1964) (Fig. 1). The Asturo-Leonian Domain is characterized by an alternation of clastic and carbonate formations, principally with benthic fauna, deposited on a shallow marine platform. In some of these carbonate successions, important reef formations were developed. In contrast, beginning with the Lower Emsian, the Devonian succession in the Palentine Domain consists of an alternation of nodular limestones and shales, with a nectonic and pelagic fauna, indicating a quieter and deeper environment than in the Asturian-Leonian Domain. In the Palentine Domain, reef development is restricted to the occurrence of rare local biostromal units linked to carbonate episodes (e.g. the Lebanza Formation).

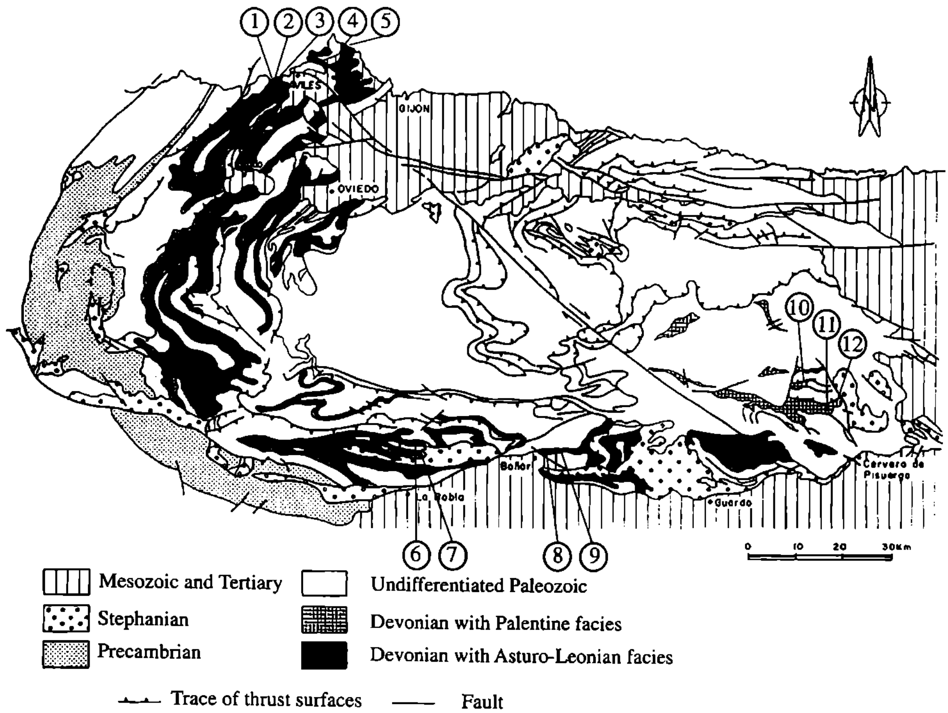

Fig. 1: Structural sketch map of the Cantabrian Zone showing the distribution of the Devonian outcrops in the Asturo-Leonian and Palentine facies and localities mentioned in the text: 1 – Santa María del Mar; 2 – La Ladrona Island; 3 – "Arnao Platform"; 4 – Bañugues Beach; 5 – Moniello Inlet; 6 – La Vid; 7 – Santa Lucía; 8 – Adrados; 9 – Colle; 10 – Araúz Peak; 11 – Vañes Reservoir; 12 – Lebanza.
(modified from Julivert, 1971).

Historically, the knowledge of the stratigraphical succession in the Devonian of the Asturo-Leonian Domain was obtained by different authors independently. Among others, Barrois (1882) studied the Devonian in the northern slope of the Cantabrian Zone, Comte (1936, 1938, 1959) studied both sides (northern and southern slopes) and Veen (1965), Binnekamp (1965), etc. studied the southeastern part of the Cantabrian Mountains (Fig. 1). Because of those studies, the lithostratigraphic nomenclature used nowadays is different for the two domains. In Fig. 2 the equivalent names for the two facietal domains are shown.

The carbonatic Moniello/Santa Lucia Formation (Upper Emsian-Lower Eifelian) (Fig. 2), in the Asturo-Leonian Domain, shows a great richness in coral faunas and represents one of the most important episodes of reef development in the Cantabrian Devonian. In contrast, the detrital Furada-San Pedro (upper Wenlockian-lower Lochkovian), Naranco-Huergas (Eifelian-lower Givetian), Piñeres-Nocedo (Frasnian), Fueyo (upper Frasnian-lower Famennnian) and Ermita (upper Famennian) Formations show a rather poor content in corals, which is restricted to interbedded and discontinuous carbonate levels. Finally, the Rañeces/La Vid (Lochkovian-Upper Emsian) Groups show a variety of lithologies consisting of dolostones, limestones, shales and marls with, in general, abundant pelagic, benthic and nectobenthic fossils. Among the benthic fossils there is a great diversity of solitary rugose corals belonging mainly to the so-called "*Adradosia* Fauna" in the Cantabrian Mountains (equivalent to the "*Cyathaxonia* Fauna") and, in lesser proportion, to colonial corals which built thin, locally distributed biostromal levels.

The Lower Devonian history of the Cantabrian Mountains, as registered in the stratigraphic column (Fig. 2), is characterized by events of variable importance and geographic significance, which are reflected in the lithology and in the fossil content. They are called geobiologic events or, just, events.

Many bioevents follow a pattern called E/R (extinction/radiation) sequence with a mass extinction phase followed, after some time, by a radiation phase. Although the phenomena that trigger the faunistic changes most likely have an effect on the fauna prior to an extinction phase, in fact, the bioevent is identified by an extinction (Walliser, 1995) and the most clear abiotic signals usually coincide with it.

The majority of bioevents represent the disappearance of such faunal elements, which are most vulnerable to the environmental changes in the different ecosystems. Barnes et al. (1996) mentioned more than 70 Phanerozoic global bioevents, of which more than 14 correspond to the Devonian. Three of them, the *sulcatus*, Zlichov Basal and Daleje-*Cancellata* Events, have been recognized in the Lower Devonian (Rañeces-La Vid Groups, Lebanza and Abadia Formations) and another one, the Chotec-*Jugleri* Event, close to the Lower-Middle Devonian boundary (uppermost part of the Moniello, Santa Lucia and Polentinos Formations) in the Cantabrian Mountains (Fig. 2). On the other hand, a possible new event, the *serotinus* Event, is being nowadays studied in the Lower Devonian (upper part of the Rañeces-La Vid Groups) and it could be extended to the Iberian Peninsula and, possibly, to other countries (Johnson et al., 1985).

In this paper, six phases of development of the Lower Devonian rugose corals from the Cantabrian Mountains (NW Spain), their relation to global sea-level fluctuations as well as lithologic and palaeontologic features are analyzed in the neritic (Asturo-Leonian) and pelagic (Palentine) domains.

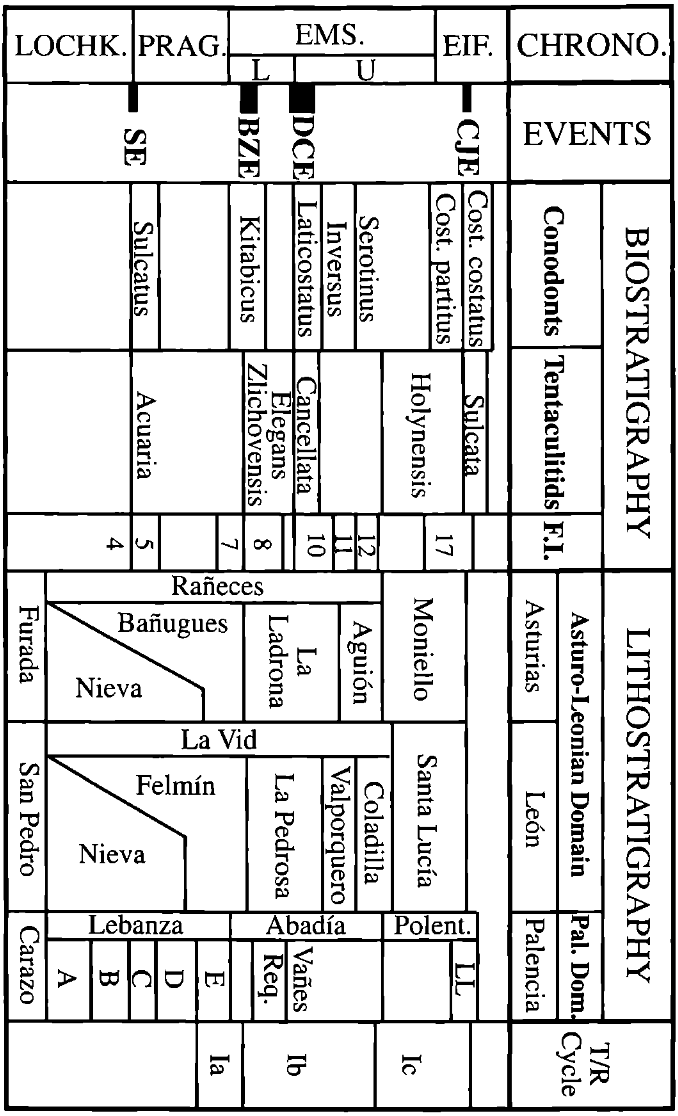

Fig. 2: Stratigraphic position of the global events and the phases of coral development in the Lower Devonian of the Cantabrian Mountains (Asturo-Leonian and Palentine Domains). SE- *sulcatus* Event; BZE- Basal Zlichov Event; DCE- Daleje-*Cancellata* Event; CJE- Chotec-*Jugleri* Event.
F.I.: Faunal Intervals (brachiopods)
Req.: Requejada member
LL: La Loma beds
AL-1, 2,...: Coral levels in the Asturo-Leonian Domain
P-1,2,.. : Coral levels in the Palentine Domain
(modified from García-Alcalde, 1998).

2. PHASES OF CORAL DEVELOPMENT IN THE LOWER DEVONIAN OF THE CANTABRIAN MOUNTAINS AND THEIR RELATION TO BIOEVENTS

AL-1/P-1 (Fig. 2): The first levels containing corals and stromatoporoids in the Lower Devonian (lowermost Pragian) of the Cantabrian Mountains constitute reef episodes of minor significance, appearing only locally. They are represented by biostromal patches composed of branching rugose corals (disphyllids) (Pl. 2, Fig. 9), branching tabulate corals (thamnoporids), laminar to tabular stromatoporoids and tabulate corals (favositids) (GARCIA-ALCALDE et al., 1990). They have been located at Santa María del Mar (Asturias; Asturo-Leonian Domain), in the upper part of the Nieva Formation, and at Lebanza, Vañes Reservoir and Araúz Peak (Cervera de Pisuerga Area; Palentine Domain), in the middle part (Member C) of the Lebanza Formation (KRANS et al., 1982; GARCÍA-ALCALDE et al., 1990), during the Lower Devonian (Figs. 1, 2).

The chronostratigraphic Lochkovian-Pragian transition is located, as in Bohemia (where the event was defined with the name of the transition), slightly below a marked color change of the carbonate rocks from dark to light, indirectly correlated with the *Eognathodus sulcatus* Zone (*Nowakia acuaria* Zone) (hence the name *sulcatus* Event from GARCÍA-ALCALDE et al., 1990; GARCIA-ALCALDE, 1998). This color event is recognized in the Palentine Domain by a change from reddish bioclastic grainstones to white or grey crinoidal grainstones and light grey packstones, wackestones and mudstones, and in the Asturo-Leonian Domain from dark grey packstones and shales to light crinoidal grainstones, wackestones and mudstones. Such a lithologic change was interpreted in different Devonian basins of the world as indicating a quick regression accompanied by a short-term anoxic event (CHLUPAC & KUKAL, 1988). The color change coincides with a faunal turnover consisting of the decline of several brachiopod (Faunal Intervals 4–5 transition; GARCÍA-ALCALDE, 1996) and trilobite lineages, and shortly afterwards the appearance for the first time of new elements, specially among the benthic faunas (brachiopods and corals-stromatoporoids). In short, the *sulcatus* Event is a geo-event of minor importance but it is well represented worldwide, with substantial change in the faunal associations and appearance of the first reef episodes from the Lochkovian to Pragian.

AL-2 (Fig. 2): New coral levels, accompanied also by stromatoporoids, constitute a second well developed reef episode in the northern part (Asturias) of the Asturo-Leonian Domain. This reef development consists of thin biostromal levels, mainly constituted by bafflestones of branching rugose corals (disphyllids), branching tabulate corals (thamnoporids) and framestones of subspherical to irregular stromatoporoids and tabulate corals (favositids) (GARCÍA-ALCALDE, 1997). They have been located in Santa María del Mar and La Ladrona Island (Asturias), in the uppermost part of the Bañugues Formation (lowermost Lower Emsian) (Figs. 1, 2).

AL-3/P-2 (Fig. 2): In the lowermost part of La Ladrona and La Pedrosa Formations (La Ladrona Cliff and Adrados localities, respectively; neritic Asturo-Leonian Domain), a marked lithologic change from intertidal dolomites to open marine shales and limestones becomes apparent, whereas in the lower part of the Abadia Formation (Requejada Member; Vañes Reservoir; pelagic Palentine Domain) there is a lithologic change from dark grey, micaceous, silty shales to dark grey mudstones, wackestones and bioclastic packstones which are interbedded with very fossiliferous calcareous siltstones (García-Alcalde, 1997). This lithologic transition occurs at the *Polygnathus kitabicus* Zone (*Nowakia zlichovensis* Zone) and could correspond to the global Basal Zlichov Event. This event has been characterized as a minor global event in the Zlichov-Praha Formations transition, in Bohemia (Chlupac & Kukal, 1986, 1988) and was correlated with a transgressive pulse within the T-R cycle Ib (Johnson et al., 1985). In the Cantabrian Mountains, the biologic change consists of the extinction of trilobites, brachiopods and reef-building corals and the appearance of new forms of dacryoconarids (*Nowakia* cf. *zlichovensis*) (Truyols-Massoni & García-Alcalde, 1994), brachiopods (particularly, *Arduspirifer, Euryspirifer* and *Acrospirifer*; lower part of the Faunal Interval 8) (García-Alcalde, 1996), important associations of ichnofossils (*Chondrites* and *Zoophycus*), abundant and diverse trilobite faunas (proetids, aulacopleurids, scutellids, phacopids, homalonotids and asteropyginids) (Arbizu, 1997; Smeenk, 1983) and very diverse and abundant solitary rugose corals of the "*Cyathaxonia* Fauna" (*Enterolasma, Schindewolfia, Boolelasma, Syringaxon, Nicholsoniella, Adradosia, Ufimia, Oligophyllym* and *Pentaphyllum*) (Pl. 1, Figs. 7–15; Pl. 2, Figs. 1–3) as well as pleurodictid tabulate corals (*Pleurodictyum, Cleistodictyum, Proterodictyum*) that constitute the most diverse Lower Emsian "*Cyathaxonia* Fauna" known worldwide (Soto, 1986; Soto & Kullmann, 1996).

AL-4 (Fig. 2): A gradual lithologic change appears usually at the basal Upper Emsian, where dark to black shales begin to dominate over limestones and marls (upper part of La Ladrona Formation: east of La Ladrona Cliff; transit levels from La Pedrosa to Valporquero Formations: La Vid, Colle and Adrados localities; upper part of the "Vañes beds": Vañes Reservoir) (Figs. 1, 2) and coincides with the Faunistic Interval 10 of brachiopods (García-Alcalde, 1996). This lithologic transition correlates to the *Polygnathus laticostatus* Zone (*Nowakia elegans/N. cancellata* Zone boundary) and could correspond to the Daleje-*Cancellata* Event (Walliser, 1984, 1995; House, 1985). Globally, this event becomes apparent as a gradual rise of the sea level within the T-R cycle Ib (Johnson et al., 1985) and it is one of the Devonian events recognized worldwide. In the Cantabrian Mountains, the biologic change was rather gradual in the neritic Asturo-Leonian Domain and is more reflected in the appearance of some new species of brachiopods (Faunal Interval 10) and trilobites, than in the extinction of the latter. Coinciding with the climax of the event, the corals of the "*Cyathaxonia* Fauna" (*Adradosia, Gymnaxon, Petronella, Neaxon, Hadrophyllum,* and *Microcyclus*) (Pl. 1, Figs. 1–6, 10–12) become important again (Birenheide & Soto, 1977; Soto, 1983). In the Palentine Domain, the bioevent affected exceedingly the ammonoid faunas. The so-called "*Anetoceras* Fauna" (*Erbenoceras, Mimosphinctes, Mimagoniatites* and *Calaeceras*) disappeared below the *Nowakia elegans/N. cancellata* Zone boundary (Montesinos & Truyols-Massoni, 1987). Because the general scarcity of fossils excepting dacryoconarids in the shaly facies of the upper part of the "Vañes beds", other faunal markers for the Daleje-*Cancellata* Event are lacking.

AL-5 (Fig. 2): The next coral levels appear locally at Colle (León) and at the so-called "Arnao Platform" (Asturias) in the lower Upper Emsian of the La Vid Group (uppermost part of the Valporquero Formation) and in the upper part of the Rañeces Group (lowermost part of the Aguión Formation), respectively (Figs. 1, 2). Near the village of Colle, only one reef deposit has been described in the upper part of the Valporquero Formation. This unit consists of biostromal layers, less than 1 m thick, mainly built by branching rugose corals (*Synaptophyllum*) (Pl. 2, Figs. 4–6), massive rugose corals (*Cantabriastraea* SCHRÖDER & SOTO, 2003), tabulate corals (favositids and alveolitids) and stromatoporoids (SOTO, 1982; FERNÁNDEZ et al., 1995). The only known reef development within the lowermost part of the Aguión Formation occurs at the "Arnao Platform". It is a biostrome, 5 m thick, mainly built by tabulate corals (alveolitids) and bryozoans. In this reefal unit the communities show an ecological succession represented by four different stages (ARBIZU et al., 1993, 1995). The occurrence of these biostromal levels in the neritic Asturo-Leonian Domain took place at the *inversus-serotinus* Zone boundary (lower part of the Faunal Interval 11 of brachiopods) and could be related with the final phase of gradual rise of the sea level within the T-R cycle Ib (JOHNSON et al., 1985).

The middle and upper part of the Upper Emsian Aguión Formation and the upper part of the Coladilla Formation (neritic Asturo-Leonian Domain) are constituted by red or pink coloured crinoidal limestones and marlstones interbedded with shales including a very abundant benthic community. These faunas include the so-called "Sabero fossils" (COMTE, 1959), which derive from the village of Colle (León), near Sabero (Fig.1). The acme of these faunas is reported at the Faunal Interval 12 of brachiopods (GARCIA-ALCALDE, 1996). Along this interval, at Colle (Coladilla Formation) frequent bryozoan-brachiopod-crinoid mound structures also exist (SCHMID et al., 2001). These conditions of great provincialism could indicate the beginning of the final regression of the T-R cycle Ib (JOHNSON et al., 1985). In the upper part of the Aguión Formation (Aguión Headland, Asturian coast) (Figs. 1, 2) there are dolomitic levels and mud-cracks suggesting that the regressive conditions reach a maximum at this interval. This lithologic change, occurring in the *serotinus* Zone, could represent a new Devonian event (Fig. 2), corresponding to the final regressive pulse of the T-R cycle Ib (JOHNSON et al., 1985: Fig. 12). The study of the features of this possible event and the establishment of the local extinction and radiation phases related to it, are currently being studied and probably can be extended across the Iberian Peninsula and into other areas.

AL-6/P-3 (Fig. 2): In the neritic Asturo-Leonian Domain, the next and one of the most important episodes of reef development took place during the Upper Emsian, coinciding with the deposition of the Moniello Formation, on the northern slope, and Santa Lucía Formation, on the southern slope, of the Cantabrian Mountains. These formations are equivalent and consist of grey limestones and argillaceous limestones interbedded with thin shaly levels. Towards the outer part of the Asturian Arc (Fig. 1) they are very fossiliferous, while towards the interior part of the Arc they are mostly composed of limestones with birdseyes and laminated limestones with mud-cracks. Accordingly, the greatest reef development (built mainly by stromatoporoids, rugose and tabulate corals) occurred in the outermost zone of the Asturian Arc. Illustrative examples of the internal structures and faunal composition of the biostromes and bioherms developed in these formations at their type-localities (Moniello Inlet, Asturian coast, and Puerto Creek, León) have been given by several authors (MÉNDEZ-BEDIA, 1976; MÉNDEZ-BEDIA & SOTO, 1984; MÉNDEZ-BEDIA et al., 1994; SOTO et al., 1994; FERNÁNDEZ et al., 1995) (Pl. 2, Figs. 7–8, 10). In the pelagic Palentine Domain, the Upper Emsian/Eifelian Polentinos Formation (Fig. 2) consists of an alternation of platy to nodular grey limestones and dark grey sandy shales and siltstones, the latter being more frequent in the upper part of the formation (Eifelian, "La Loma beds"). Poor neritic (trilobites, solitary rugose corals of the "*Cyathaxonia* Fauna", pleurodictid tabulate corals and rare brachiopods) and pelagic (ammonoids, dacryoconarids and ostracods) faunas have been recorded in this formation (Veen, 1965; Jahnke et al., 1983; García-Alcalde et al., 1998, 2002).

In the uppermost part of the Moniello and Santa Lucia Formations and in the upper part of the Polentinos Formation (Lower Eifelian) there is a lithologic change from light coloured limestones to dark or black pyritic shales of the lowermost Naranco and Huergas Formations and to dark or black micritic limestones of the "La Loma beds" (Polentinos Formation). This corresponds to a deepening event, considered as a minor transgressive pulse (Chotec-*Jugleri* Event) and an expansion of anoxic bottom water conditions across the shallow shelf areas, within T-R cycle Ic (Johnson et al., 1985; García-Alcalde, 1998). The litho-event occurs, as in Bohemia, where it was recorded for the first time (Chlupac & Kukal, 1988), at the *Nowakia holynensis/N. sulcata* Zone boundary (*Polygnathus costatus partitus/P. c. costatus* Zones transition and Faunal Interval 17 of brachiopods) (Jahnke et al., 1983; García-López, 1986; García-Alcalde, 1996; García-López & Sanz-López, 2000; García-López et al., 2000), just above the Emsian/Eifelian boundary.

In the Cantabrian Mountains, the faunal turnover is gradual and more clearly outlined by extinctions than innovations (García-Alcalde, 1998; García-Alcalde et al., 2001). In the neritic Asturo-Leonian Domain, the most marked change is the disappearance of the OCA fauna (brachiopod association of *Uncinulus orbignyanus*, *Paraspirifer cultrijugatus* and *Alatiformia alatiformis*) and numerous forms of the Faunal Interval 17 (García-Alcalde, 1996, 1998). Slightly below the event level the reef episodes developed within the Moniello and Santa Lucía Formations (Méndez-Bedia et al., 1994) are terminated. In the pelagic Palentine Domain, Henn (1985) and Montesinos (1987), recorded the disappearance of *Anarcestes lateseptatus* in the "La Loma beds" (upper part of the Polentinos Formation) and its replacement by an important association of ammonoids, constituted by *Agoniatites*, *Werneroceras* and *Foordites*. However, *Pinacites jugleri*, one of the best markers of the event, appears slightly above the event level. Smeenk (1983) noted an important faunal change in the trilobites, which involves the total extinction of the Asteropyginae and the Proetidae in this domain. Pleurodictid tabulate corals and the last representatives of the very important "*Cyathaxonia* Fauna" during the Emsian disappear completely in the Palentine Area because of the Chotec-*Jugleri* Event (García-Alcalde et al., 2001, 2002).

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References

Arbizu, M., 1977: Asteropyginae (Trilobita) du Dévonien des Montagnes Cantabriques (Espagne). – Bulletin de la Société Géologique et Minéralogique de Bretagne, C, **9** (2): 59–102, Rennes.

ARBIZU, M., ALVAREZ-NAVA, H., MÉNDEZ-BEDIA, I. & GARCÍA-LÓPEZ, S., 1993: Las comunidades bióticas de las "Capas de Trybliocrinus" (Devónico Inferior) en la Plataforma de Arnao (Asturias, Noroeste de España). – Revista Española de Paleontología, N° Extra: 71–77, Madrid.

ARBIZU, M., MÉNDEZ-BEDIA, I. & SOTO, F., 1995: Fossil communities in the Aguion Formation (Lower Devonian) of the Arnao Platform (Asturias, NW Spain). – Geobios, **28** (5): 567–571, Lyon.

BARNES, C., HALLAM, A., KALJO, D., KAUFFMAN, E.G. & WALLISER, O.H., 1996: Global Event Stratigraphy. In: WALLISER, O.H. (Ed.): Global events and event stratigraphy in the Phanerozoic. – 319–333, Berlin (Springer Verlag).

BARROIS, Ch., 1882: Recherches sur les terrains anciens des Asturies et de la Galice. – Mémoires de la Société Géologique du Nord, **2** (1): 1–630, Lille.

BINNEKAMP, J.G., 1965: Lower Devonian brachiopods and stratigraphy of Nord Palencia (Cantabrian Mountains, Spain). – Leidse Geologische Mededelingen, **33**: 1–62, Leiden.

BIRENHEIDE, R. & SOTO, F., 1977: Rugose corals with wall-free apex from the Lower Devonian of the Cantabrian Mountains (Spain). – Senckenbergiana lethaea, **58** (1/3): 1–23, Frankfurt.

BROUWER, S.A., 1964: Deux faciès dans le Dévonien des Montagnes Cantabriques Méridionales. – Breviora Geológica Astúrica, **8** (1–4): 3–10, Oviedo.

CHLUPAC, J. & KUKAL, Z., 1986: Reflection of possible global Devonian events in the Barrandian area, C.S.S.R. – In: WALLISER, O.H. (Ed.): Global Bio-Events. A critical approach. – Lecture Notes in Earth Sciences, **8**: 169–179, Berlin, Heidelberg (Springer Verlag).

CHLUPAC, J. & KUKAL, Z., 1988: Possible global events and the stratigraphy of the Palaeozoic of the Barrandian (Cambrian-Middle Devonian), Czechoslovakia. – Sbornik geologickych Ved Geologie, **43**: 83–146, Praha.

COMTE, P., 1936: Le Dévonien Inférieur de Leon. – Comptes Rendus de l'Académie des Sciences de Paris, **202**: 771–773, Paris.

COMTE, P., 1938: Les faciès du Dévonien Supérieur dans le Cordillère Cantabrique. – Comptes Rendus de l'Académie des Sciences de Paris, **206**: 1496–1498, Paris.

COMTE, P., 1959: Recherches sur les terrains anciens de la Cordillère Cantabrique. – Memorias del Instituto Geológico y Minero de España, **69**: 1–440, Madrid.

FERNÁNDEZ, L.P., FERNÁNDEZ-MARTINEZ, E., MÉNDEZ-BEDIA, I., RODRIGUEZ, S. & SOTO, F., 1995: Devonian and Carboniferous reefal facies from Cantabrian Zone (NW Spain). – In: PEREJÓN, A. (Ed.): Guide Book of the Field Trip A. VII International Symposium on Fossil Cnidaria and Porifera. – 1–76, Salamanca (Gráficas Varona).

GARCÍA-ALCALDE, J.L., ARBIZU, M., GARCÍA-LÓPEZ, S., LEYVA, F., MONTESINOS, R., SOTO, F. & TRUYOLS-MASSONI, M., 1990: Devonian stage boundaries (Lochkovian-Pragian, Pragian-Emsian and Eifelian-Givetian) in the Cantabric region (NW Spain). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen **180** (2):177–207, Stuttgart.

GARCÍA-ALCALDE, J.L., 1996: El Devónico del Dominio Astur-Leonés en la Zona Cantábrica (N de España). – Revista Española de Paleontologia, N° Extra: 58–71, Madrid.

GARCÍA-ALCALDE, J.L., 1997: North Gondwanan Emsian Events. – Episodes, **20** (4): 241–246, Beijing.

GARCÍA-ALCALDE, J.L., 1998: Devonian events in northern Spain. – Newsletters on Stratigraphy, **36** (2/3): 157–175, Berlin, Stuttgart.

GARCÍA-ALCALDE, J.L., ARBIZU, M. & TRUYOLS-MASSONI, M., 2001: Extinciones masivas en el Devónico. – In: GÁMEZ-VINTANEZ, J.A. & LIÑÁN, E. (Eds.): Memorias de las VII Jornadas Aragonesas de Paleontología: "La Era Paleozoica. El Desarrollo de la vida marina". – 147–168, Zaragoza.

GARCÍA-ALCALDE, J.L., CARLS, P., PARDO ALONSO, M.V., SANZ LÓPEZ, J., SOTO, F., TRUYOLS-MASSONI, M. & VALENZUELA RIOS, J.J., 2002: Devonian. – In: GIBBONS, W. & MORENO, T. (Eds.): Geology of Spain: 1–649. Chapter 6: 67–91, London (The Geological Society).

GARCÍA-LÓPEZ, S., 1986: Los conodontos y su aplicación al estudio de las divisiones cronoestratigráficas mayores del Devónico Astur-Leonés (España). – Publicaciones Especiales del Boletin Geológico y Minero, **97** (3–5): 1–112, Madrid.

García-López, S. & Sanz-López, J., 2002: Devonian to Lower Carboniferous conodont biostratigraphy of the Bernesga Valley section (Cantabrian Zone, NW Spain). – Serie Cuadernos del Museo Geológico del Instituto Geológico y Minero de España, 1: 163–206. – In: Garcia-López, S. & Bastida, F. (Eds.): Palaezoic Conodonts from Northern Spain: 1–438, Madrid.

Garcia-López, S., Jahnke, H. & Sanz-López, J., 2002: Uppermost Pridoli to Upper Emsian stratigraphy of the Alto Carrión Unit, Palentine Domain (Northwest Spain). – Serie de Cuadernos del Museo Geológico del Instituto Geológico y Minero de España, 1: 229–258. – In: García-López, S. & Bastida, F. (Eds.): Palaeozoic Conodonts from Northern Spain: 1–438, Madrid.

Henn, A.H., 1985: Biostratigraphie and Facies des hohen Unter-Devon bis tiefen Ober-Devon der Provinz Palencia, Kantabrisches Gebirge, N-Spanien. – Göttinger Arbeiten zur Geologie und Paläontologie, **26**: 1–100, Göttingen.

House, M.R., 1985: Correlation of Mid-Palaeozoic ammonoid evolutionary events with global sedimentary perturbations. – Nature, **313**: 17–22, London.

Jahnke, H., Henn, A., Mader, H. & Schweineberg, J., 1983: Silur und Devon im Arauz-Gebiet (Prov. Palencia, N-Spanien). – Newsletters on Stratigraphy, **13**: 40–66, Berlin, Stuttgart.

Johnson, J.G., Klapper, G. & Sandberg, C.A., 1985: Devonian eustatic fluctuations in Euroamerica. – Geological Society of American Bulletin, **96**: 567–587, Boulder.

Krans, T.F., Guit, F.A. & Ofwegen, L.P. van, 1982: Facies-patterns in the Lower Devonian carbonates of the Lebanza Formation (Cantabrian Mountains, Province of Palencia, NW Spain). – Neues Jahrbuch für Geologie und Paläontologie Abhandlungen, **163** (2): 192–212, Stuttgart.

Méndez-Bedia, I., 1976: Biofacies y litofacies de la Formación Moniello-Santa Lucia (Devónico de la Cordillera Cantábrica, NW de España). – Trabajos de Geologia, **9**: 1–93, Oviedo.

Méndez-Bedia, I. & Soto, F., 1984: Paleoecological succession in a Devonian organic buildup (Moniello Formation, Cantabrian Mountains, NW Spain). – Geobios, **8**: 151–158, Lyon.

Méndez-Bedia, I., Soto, F. & Fernández-Martinez, E., 1994: Devonian reef types in the Cantabrian Mountains (NW Spain) and their faunal composition. – Courier Forschungsinstitut Senckenberg, **172**: 161–183, Frankfurt.

Montesinos, J.R., 1987: Agoniatitina y Anarcestina del Devónico Medio de la Cordillera Cantábrica (Dominios Palentino y Astur-Leonés, NO de España). – Cuadernos del Laboratorio Xeolóxico de Laxe, **12**: 99–118, La Coruña.

Montesinos, J.R. & Truyols-Massoni, M., 1987: La Fauna de *Anetoceras* y el límite Zlichoviense-Dalejiense en el Dominio Palentino (NO de España). – Cuadernos del Laboratorio Xeolóxico de Laxe, **11**: 191–208, La Coruña.

Montesinos, J.R. & Garcia-Alcalde, J.L., 1996: An occurrence of the Auguritid ammonoid *Celaeceras* in the Lower Devonian of Northern Spain. – Palaeontology, **39** (1): 149–155, Cambridge.

Schmid, D.V., Leinfelder, R.R. & Nose, M., 2001: Growth dynamics and ecology of Upper Jurassic mounds, with comparisons to Mid-Palaeozoic mounds. – Sedimentary Geology, **145**: 343–376, Berlin.

Smeenk, Z., 1983: Devonian trilobites of the southern Cantabrian Mountains (Northern Spain) with a systematic description of the Asteropyginae. – Leidse Geologische Mededelingen, **52** (2): 383–511, Leiden.

Soto, F., 1981: *Synaptophyllum* (Rugosa) aus dem Unterdevon des kantabrischen Gebirges (Colle, prov. Leon). – Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, **163** (2): 236–238, Stuttgart.

Soto, F., 1983: Hadrophyllinae (Coelenterata, Rugosa) del Devónico Inferior de la Cordillera Cantábrica (NO de España). – Trabajos de Geología, **13**: 97–112, Oviedo.

Soto, F., 1986: Asociaciones coralinas del Devónico Astur-Leonés (Cordillera Cantábrica, NO de España). – Trabajos de Geologia, 16: 25–35, Oviedo.

Soto, F., Méndez-Bedia, I. & Fernández-Martinez, E., 1994: Construcciones arrecifales del Devónico de la Cordillera Cantábrica (NO de España). – Revista Española de Paleontología, **9** (1): 29–36, Madrid.

Soto, F. & Kullmann, J., 1996: Hornförmige Einzelkorallen (Rugosa) vom Typ der "*Cyathaxonia* Fauna" im Unter-Emsium des östlichen kantabrischen Gebirges, NW Spanien. – Geobios, **29** (6): 651–669, Lyon.

Truyols-Massoni, M. & Garcia-Alcalde, J.L., 1994: Faune rhéno-bohémienne (Dacryoconarides, Brachiopodes) à la limite Emsien Inférieur/Supérieur au Cabo La Vela (Asturies, Espagne). – Geobios, **27** (2): 221–241, Lyon.

Veen, J. van, 1965: The tectonic and stratigraphic history of the Cardaño Area, Cantabrian Mountains, Northwest Spain. – Leidse Geologische Mededelingen, **35**: 45–104, Leiden.

Walliser, O.H., 1984: Geologic processes and global events. – Terra Cognita, **4**: 17–20, Paris.

Walliser, O.H., 1995: Global events in the Devonian and Carboniferous. – In: Walliser, O.H. (Ed.): Global Events and Event Stratigraphy in the Phanerozoic. – 225–250, Berlin (Springer Verlag).

Plate 1

Figs. 1–3: *Microcyclus truyolsi* Soto, 1983. Holotype DPO 1887. Distal, proximal and lateral views; x 3. La Pedrosa-Valporquero Formations transition (Phase AL-4), Adrados (León).

Figs. 4–6: *Hadrophyllum neritae* Soto, 1983. Holotype DPO 2022. Distal, proximal and lateral views; x 3. La Pedrosa-Valporquero Formations transition (Phase AL-4), Adrados (León).

Figs. 7–9: *Nicholsoniella pauciseptata* (Kullmann, 1965)

Fig. 7: DPO 14569. Transverse thin section; x 3

Fig. 8: DPO 14572. Transverse thin section; x 3

Fig. 9: DPO 14574. Longitudinal thin section; x 3. Abadía Formation (Requejada Member) (Phase P-2), Vañes Reservoir (Palencia).

Figs. 10–11: *Adradosia nodosa* (Kullmann, 1965)

Fig. 10: DPO 14584. Transverse thin section; x 3

Fig. 11: DPO 14582. Transverse thin section; x 3. Abadía Formation (Requejada Member) (Phase P-2), Vañes Reservoir (Palencia).

Fig. 12: *Adradosia barroisi* Birenheide & Soto, 1977. DPO 14579. Transverse thin section; x 3. Abadía Formation (Requejada Member) (Phase P-2), Vañes Reservoir (Palencia).

Figs. 13–15: *Ufimia prior* (Kullmann, 1965)

Fig. 13: DPO 14583. Transverse thin section; x 4

Fig. 14: DPO 14576. Transverse thin section; x 3

Fig. 15: DPO 14590. Transverse thin section; x 3. Abadía Formation (Requejada Member) (Phase P-2), Vañes Reservoir (Palencia).

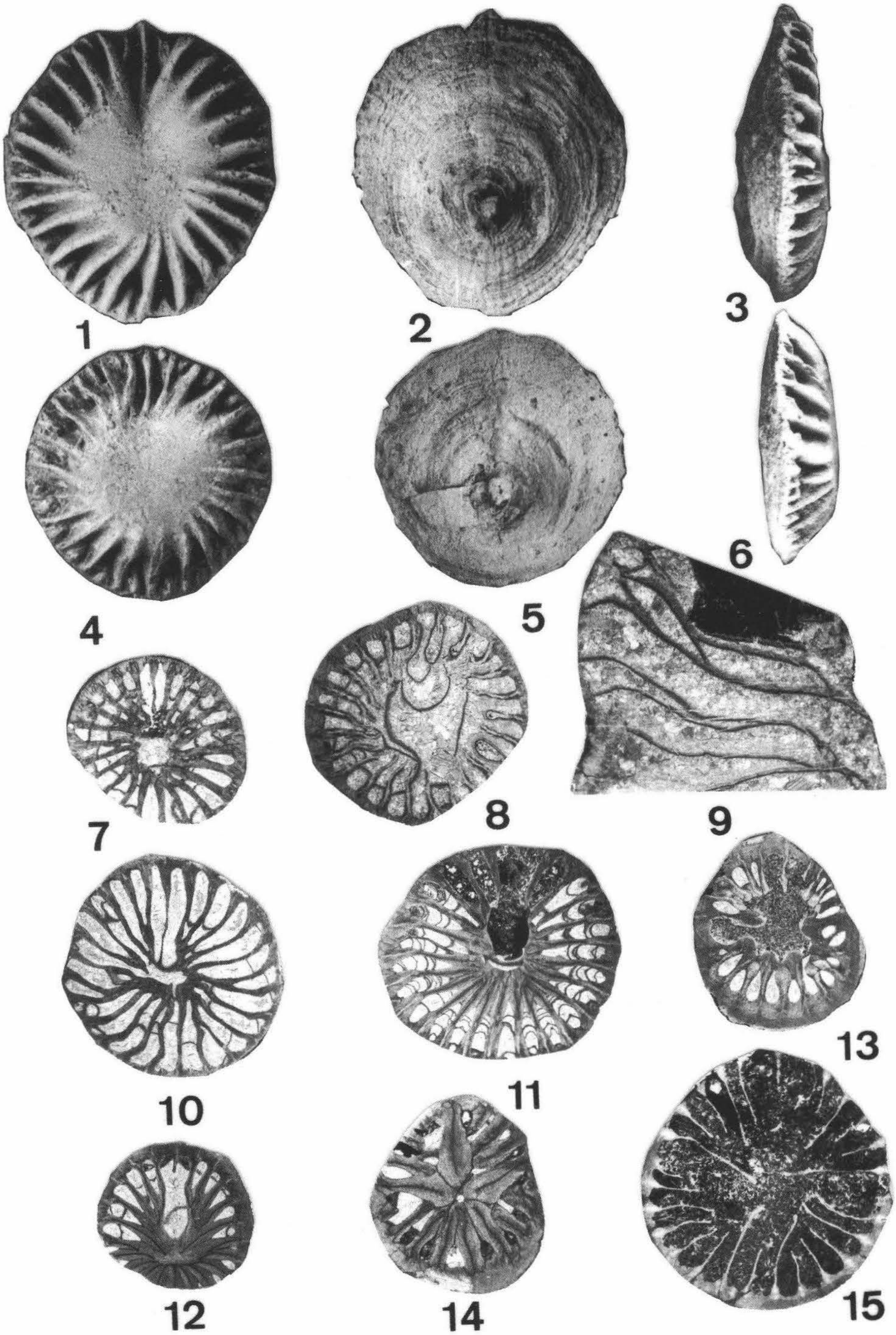
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Plate 2

Fig. 1: *Oligophyllum (Pentelasma)* cf. *kullmanni* WEYER, 1973. DPO 14598. Transverse thin section; x 4. Abadía Formation (Requejada Member) (Phase P-2), Vañes Reservoir (Palencia).

Figs. 2–3: *Pentaphyllum irregulare* KULLMANN, 1965

Fig. 2: DPO 14563. Transverse thin section; x 4

Fig. 3: DPO 14527R. Transverse thin section; x 4. Abadía Formation (Requejada Member) (Phase P-2), Vañes Reservoir (Palencia).

Figs. 4–6: *Synaptophyllum multiseptatum* SOTO, 1981

Fig. 4: DPO 13355. Lateral view of a branch from the colony; x 1,5

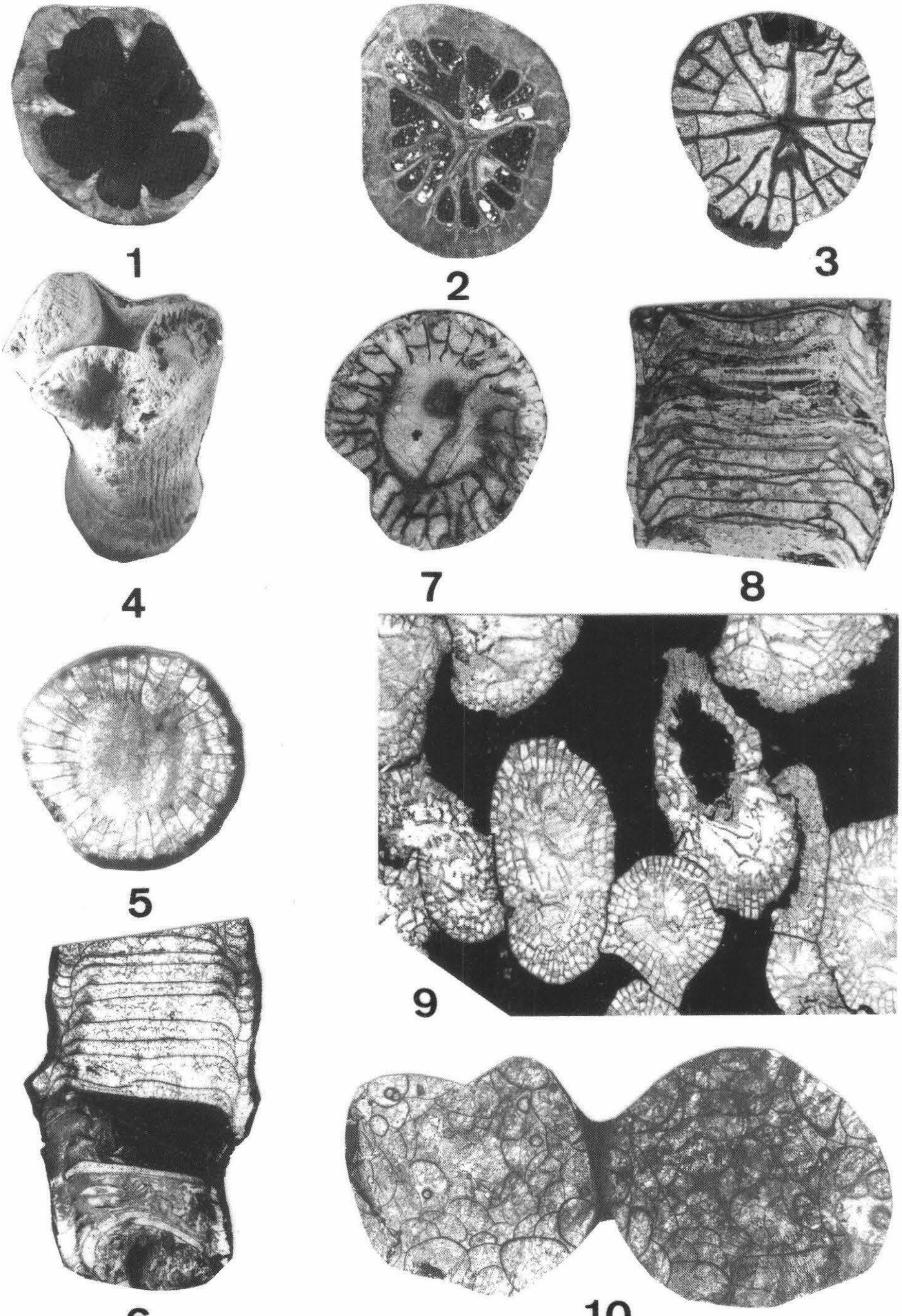
Figs. 5–6: DPO 13340. Transverse and longitudinal thin sections; x 2. Valporquero Formation (Phase AL-5), Colle (León).

Figs. 7–8: *Synaptophyllum* sp. DPO 14830. Transverse and longitudinal thin sections; x 2,5. Moniello Formation (Phase A-6), Moniello Inlet (Asturias).

Fig. 9: *Zelolasma* sp. DPO 14831. Transverse thin section; x 3. Nieva Formation (Phase AL-1), Santa María del Mar (Asturias).

Fig. 10: *Mesophyllum (Cystiphylloides) monielloense* BIRENHEIDE & SOTO, 1981. DPO 11915.

Transverse thin section; x 2. Moniello Formation (Phase AL-6), Moniello Inlet (Asturias).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