J.C. Gutiérrez-Marco, I. Rábano and D. García-Bellido (eds.), *Ordovician of the World.*
Cuadernos del Museo Geominero, 14. Instituto Geológico y Minero de España, Madrid. ISBN 978-84-7840-857-3

A BRIEF SUMMARY OF ORDOVICIAN CONODONT FAUNAS FROM THE IBERIAN PENINSULA

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Keywords: Ordovician, conodonts, biostratigraphy, palaeobiogeography, reworked faunas, Spain, Portugal.

INTRODUCTION

Ordovician conodont studies in the Iberian Peninsula were initiated by Fuganti and Serpagli (1968), who recognized 21 morphospecies included in 15 morphogenera in the Upper Ordovician Urbana Limestone from a single locality in the Central Iberian Zone. Two years later Boersma (in Hartevelt, 1970) identified several morphotaxa in the Upper Ordovician Estana Formation of the Central Pyrenees. In the type section of the Upper Ordovician Cystoid Limestone of the Eastern Iberian Cordillera, Carls (1975) recognised 31 conodont morphotaxa. These pioneer findings were followed by the contributions of Kolb (1978), Hafenrichter (1979), Robert (1980), Robardet (1982) and Sanz (1988), who increased the number of taxa and localities with Katian conodonts, mostly attributed to the *Amorphognathus ordovicicus* Zone.

For twenty years, our knowledge on Ordovician conodonts came only from the single ubiquitous limestone unit that occurs in the upper part of many Iberian successions. Nonetheless, these are predominantly composed of terrigenous rocks (shales, siltstones and sandstones) which were deposited at high Gondwanan paleolatitudes near the South Pole (Gutiérrez-Marco et al., 2002, 2004). Then, some of these clastic deposits (siltstones, shales and storm-induced coquinoid lenses, sometimes calcareous) were also sampled for conodonts: while siltstones and shales produced only fragmentary specimens, bioclastic beds in tempestites yielded usually fragmentary, but recognisable, elements.

EARLY TO EARLY-MID ORDOVICIAN CONODONTS

The oldest Ordovician conodont assemblage from the Iberian Peninsula was found by Sarmiento and Gutiérrez-Marco (1999) near Adamuz (Fig. 1, loc. 17) in the tectonically-complex boundary area between

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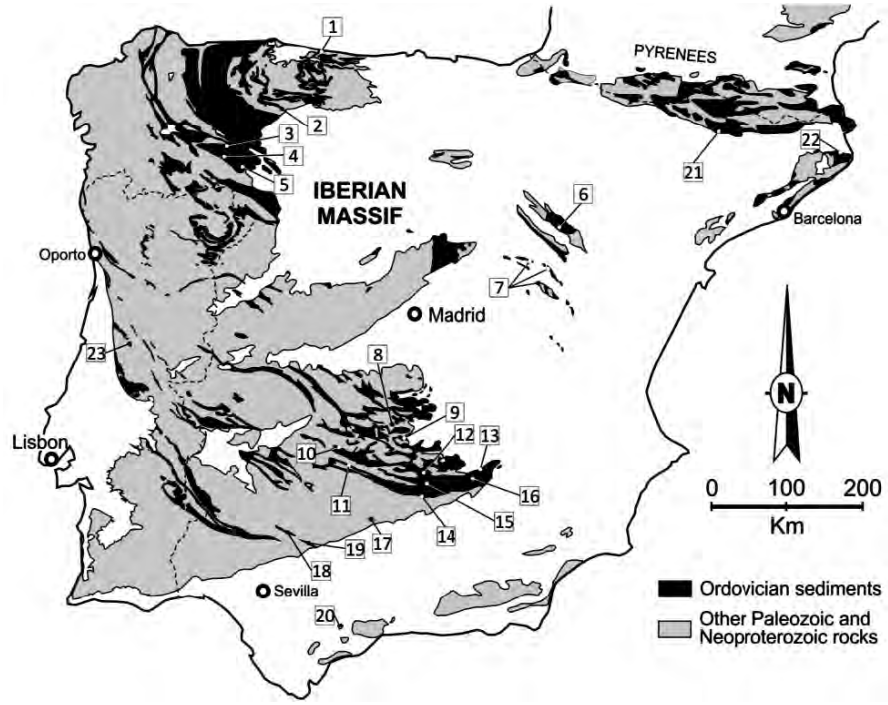

Figure 1. Map of the main Ordovician outcrops in the Iberian Massif, with locations of mentioned conodont localities in Spain and Portugal. 1, Sueve and Ordovician tunnel; 2, Portilla de Luna; 3, La Aquiana; 4, Casaio; 5, Rozadais-Truchas; 6, Fombuena; 7, Aragoncilo, Ojos Negros and Checa areas; 8, Porzuna; 9, Corral de Calatrava; 10, north of Chillón; 11, Alamillo; 12, Calzada de Calatrava; 13, Villamanrique-Terrinches; 14, El Centenillo; 15, Huertezuelas and Viso del Marqués; 16, Aldeaquemada; 17, Adamuz; 18, Cazalla de la Sierra; 19, Constantina; 20, Ardales; 21, Els Castells; 22, Les Gavarres; 22, Buçaco.

the Central Iberian and Ossa-Morena zones. Conodonts were obtained from a few decalcified (iron-rich) limestone cobbles embedded as olistholits in a Mississipian olisthostrome unit from the Guadalmellato domain, Los Pedroches Basin (Cózar et al., 2004; Armendáriz Dufur, 2009 and references therein). Besides some indeterminate brachiopod and trilobite fragments, the transported limestone contains a diverse and partially reworked conodont assemblage that includes a mixture of Lower and Middle Ordovician taxa. Sarmiento and Gutiérrez-Marco (1999) emphasized the importance of the reworked conodonts to infer the existence of unknown units with Early Ordovician limestones in an area exclusively characterized by siliciclastic deposits at that epoch. The existence of the so-called "phantom formations" (Branson and Mehl, 1940) can be assumed to have occurred in some original areas located westwards, that were tectonically juxtaposed to the southern border of the Central Iberian Zone during the Variscan collision. These would have been partially eroded and resedimented in a typical syn-orogenic foredeep basin during the Mississippian, as can be reconstructed by the presence of a continuous record of Early Ordovician to Devonian fossiliferous olistoliths.

Most of the recovered conodont elements from the older limestone cobbles are poorly preserved, preventing an accurate taxonomic identification. Preliminary studies reveal the presence of *Cordylodus*? sp., *Paltodus* cf. *deltifer* (Lindström), *Paltodus* cf. *subaequalis* Pander, *Drepanodus* cf. *arcuatus* Pander, *Drepanodus* spp. *Scolopodus striatus* Pander, *Teridontus* spp., *Acanthodus?* sp., *Acodus* spp.,

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Hammannodus sp., *Protopanderodus*? sp., *Gothodus* cf. *costulatus* (Lindström), *Baltoniodus* cf. *triangularis* (Lindström), and *Baltoniodus* sp., beside other coniform elements yet to be identified (Pl. 1, fig. 1-5). The Lower Tremadocian *Paltodus deltifer* Zone can be inferred by the presence of *Paltodus* cf. *deltifer* (Lindström) and *Hammannodus* sp., but the record of *Cordylodus*? sp. with robust elements of *Acanthodus?* sp. and *Teridontus?* sp. does not exclude the existence of an even older reworked conodont fauna in the assemblage. We propose here a correlation of these "phantom limestone formations" with the Upper Cambrian to Lower Ordovician sequence of the southern Montagne Noire (France), which occasionally incorporates thin limestone beds formed in temperate waters of the Gondwanan margin (Álvaro et al., 2003). This may be confirmed by the Spanish record of *Hammannodus,* a genus so far only known from the Saint Chinian Formation of the southern Montagne Noire (Serpagli et al., 2007).

The younger elements recorded in the mixed Early Ordovician conodont sample from Adamuz may compose an assemblage of elements doubtfully related with *Baltoniodus triangularis* (Lindström), *Baltoniodus* sp., *Drepanodus arcuatus* Pander, *Scolopodus striatus* Pander and possible representatives of the genera *Drepanoistodus* and *Protopanderodus,* among other taxa. This association can be tentatively assigned to the *Baltoniodus triangularis* Zone, broadly representative of Lower Dapingian strata (lowermost Middle Ordovician), which must be simultaneous with the sedimentation of the local limestone also bearing the previously mentioned reworked conodonts.

The only Floian conodonts known from the Iberian Peninsula occur in a lingulid shell-bed located near the top of the Barrios Formation, a local equivalent of the Armorican Quartzite in the Cantabrian Zone of northern Spain (Fig. 1, loc. 1). The assemblage is currently being studied, but preliminary data indicate the presence of coniform elements of the genera *Drepanodus*, *Drepanoistodus* and *Protopanderodus* (Gutiérrez-Marco and Bernárdez, 2003).

MID TO EARLY-LATE ORDOVICIAN CONODONTS

Conodont assemblages representative of the late Darriwilian–early Sandbian interval are assigned to the Dobrotivian stage in Mediterranean regional chronostratigraphy (Gutiérrez-Marco et al., 2008; Bergström et al., 2009), and were reported by Sarmiento et al. (1995a). These occur in thin lenses of calcareous coquinas intercalated in sandy tempestites, or interbedded with quartzite and micaceous shale alternations. All of them belong to a thick siliciclastic group dominated by dark shales and sandy tempestites, broadly known in central Spain as the "Tristani Beds" (San José et al., 1992, with previous references). These have similar counterparts in the Iberian Cordillera and also in the French Armorican Massif, where related conodonts were described by Lindström et al. (1974: age reviewed by Lindström, 1976).

A stratigraphically older conodont assemblage (early Dobrotivian) was recognized in the Central Iberian Zone, as occurring near the top of the El Caño Formation (loc. CC-II), southwest of Calzada de Calatrava (Ciudad Real) (Fig. 1, no. 9). Some other stratigraphically younger conodonts (late Dobrotivian) come from the lower part of the Botella Quartzite in a nearby outcrop (loc. VM-X), and from the La Cierva Quartzite (loc. POR-V) near Porzuna (Ciudad Real) (Fig. 1, no. 8). Similar Dobrotivian conodonts from the Iberian Cordillera have been identified near Fombuena (Zaragoza) in a calcareous intercalation occurring in the middle part of the Sierra Member of the Castillejo Formation (FB-II: Fig. 1, loc. 6).

Most of the conodont taxa recorded from these localities were identified in open nomenclature due the scarcity of elements and their poor preservation. The presence of *Amorphognathus* aff. *inaequalis*

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Rhodes, *Amorphognathus* sp, *Baltoniodus* aff. *variabilis* (Bergström), *Coelocerodontus* sp. *Complexodus* sp, *Drepanoistodus* sp., *Icriodella* cf. *praecox* Lindström, Racheboeuf and Henry, *Plectodina* cf. *flexa* Rhodes, among other indeterminate specimens (Pl. 1, figs. 6-16), suggests a biostratigraphical interval below or within the basal part of the *Amorphognathus tvaerensis* Zone. The existence of some reworked conodonts from older conodont biozones occuring in the assemblages from both the Central Iberian and the Eastern Iberian Cordillera localities cannot be ruled out. However, the exact dating of these sequences is firmly established by a combination of graptolite and chitinozoan data, as well by the local trilobite and brachiopod biozones (see Gutiérrez-Marco et al., 2002).

Bedding plane assemblages of lower Dobrotivian conodonts occur in shales from the Sueve Formation of the Cantabrian Zone (Fig. 1, loc. 1). A preliminary identification of these (Gutiérrez-Marco and Bernárdez, 2003) reveals several forms of *Drepanoistodus, Panderodus* and *Semiacontiodus*, that are being presently studied.

LATE ORDOVICIAN CONODONTS

The presence of mid Berounian (= late Sandbian to early Katian) conodonts in the Central Iberian Zone was first mentioned by Sarmiento (1993) as coming from an ironstone level at the base of the Cantera Shales near the El Centenillo, Jaén (Fig. 1, no. 14). Only *Amorphognathus* sp., *Panderodus* sp. and *Icriodella* sp. (Pl. 1, figs. 17-18) were identified from this level. This finding allows a chronostratigraphical correlation with equivalent levels of the Piedra del Tormo Member of the Fombuena Formation, Eastern Iberian Cordillera, where Kolb (1978) previously identified and illustrated one fragment of *Icriodella* sp. The mid Berounian age of these conodonts was provided by their association with index species of brachiopod and trilobite biozones.

Plate 1. Some Ordovician conodonts from Spain. 1-3, Early Ordovician reworked specimens from Adamuz; 3-4, Early Mid Ordovician autochthonous assemblage from Adamuz; 6-16, Dobrotivian (late Darriwilian-early Sandbian) beds from Central Iberian localities; 17-18, mid Katian specimens (?*Amorphognathus superbus* Zone) from the Central Iberian Zone; 19-34, mid-late Katian conodonts (*Amorphognathus ordovicicus* Zone) from Central Iberian localities; 35-39, Hirnantian assemblage (upper *A. ordovicicus* Zone) from the Malaguide Complex.– 1, *Teridontus*? sp. ADZ-OI-9875; 2, *Drepanodus*? sp. ADZ-OI-9359; 3, *Cordylodus*? sp. ADZ-OI-9859; 4-5, *Baltoniodus* cf. *triangularis* (Lindström) [4, Pb element ADZ-OI-9374; 5, Pb element ADZ-OI-9375)]; 6, *Complexodus*? sp. Pb element POR-V-134A; 7, *Icriodella* aff. *praecox* Lindström, Rachebeouf and Henry. S element POR-V-0834; 8-9, *Amorphognathus* aff. *inaequalis* Rhodes [8, Pa element POR-V-091A; 9, M element POR-V-093A]; 10, *Plectodina* sp. Sa element, CC-II-164A; 11-13, *Plectodina* cf. *flexa* (Rhodes) [11, Pa fragmentary element POR-V-163A; 12, Sa element POR-V-162A; 13, Sc element POR-V-161A]; 14-15, *Baltoniodus* aff. *variabilis* (Bergström) [14, Sa element POR-V- 103A; 15, M element POR-V-108A]; 16, *Baltoniodus* sp. Sa element POR-V-104A;17, *Icriodella* cf. *superba* Rhodes, fragmentary Pa element LC-IV-109; 18, *Panderodus* sp. LC-IV-102; 19-20, *Hamarodus europaeus* (Serpagli) [19, Sc element HZ-IA/6-6567L; 20, M element HZ-IA/7-2735G]; 21, *Scabbardella altipes* (Henningsmoen), a element HZ-IA/6-2547F; 22, *Panderodus gracilis* (Branson and Mehl), ?graciliform element RN-X-6564L; 23-26 and 32, *Saggittodontina robusta* Knüpfer [23, Pb element CO-B/5-2073F; 24, Sb element HZ-IA/6-1708D; 25, indeterminate element HZ-IB/III-1709D; 26, Pb? element HZ-IA/6-1711D; 32, Pb element CT-III/7-1]; 27-30, *Amorphognathus ordovicicus* Branson and Mehl [27, M element HZ-IB/VIII-2743G; 28, Pb element (left) HZ-IA/6-885H; 29, Pb element (right) HZ-IA/6-951H; 30, Sb element HZ-IA/6-965H]; 31, *Eocarniodus gracilis* (Rhodes), CO-A/8-2293F; 33-34, *Istorinus erectus* (Knüpfer) [33, CT-I/1-36; 34, CS-VII/A-6-7]; 35-39, *Walliserodus amplissimus* (Serpagli), elements in inner and outer lateral views [35, a element 03A-69-58; 36, b element 03A-69-60; 37, c element 03A-69-50; 38, d element 03A-69-40; 39, e element 03A-69-57]. Scale bars=100 µm (figs. 1-34) and 200 µm (figs. 35-39)

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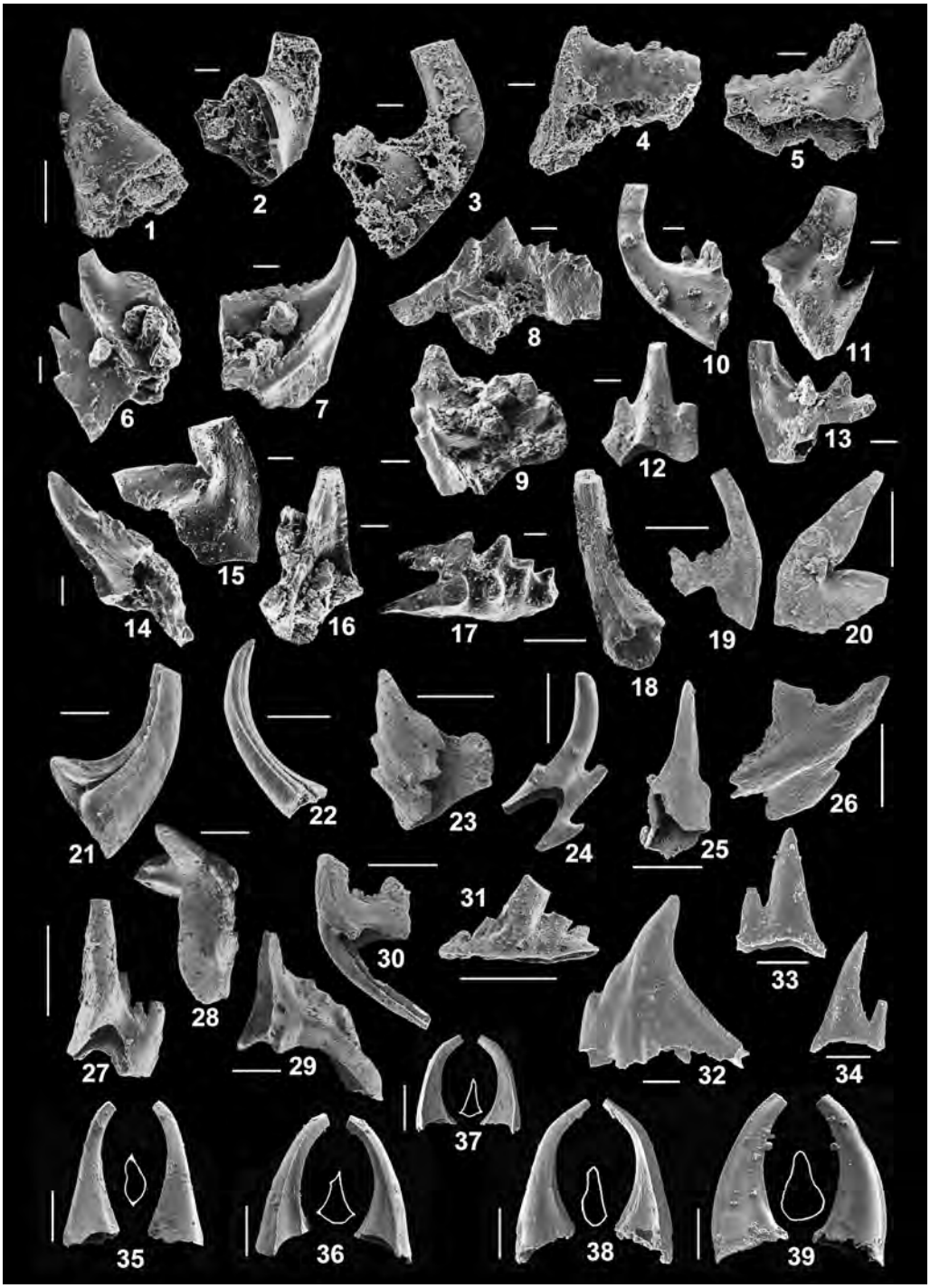
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Amorphognathus superbus Zone

In the Ossa-Morena Zone, conodonts that are attributed with doubts to the *A. superbus* Zone were obtained from a redeposited horizon occurring in the basal part of the Pelmatozoan Limestone Formation from the northern flank of the Valle syncline, west of Cazalla de la Sierra, Seville (Robardet et al. 1998, Sarmiento et al., 2000c). The conodont assemblage includes few but well preserved elements of *Icriodella* sp., *Amorphognathus* aff. *complicatus* Rhodes, *Plectodina* sp. and *Aphelognathus*? sp.

In the Central Iberian Zone, Del Moral (2004, 2007) described and illustrated conodonts of the *Amorphognathus superbus* Zone coming from the upper beds of the Bancos Mixtos Formation in the sections of Corral de Calatrava, Huertezuelas and Viso del Marqués (Fig. 1, loc. 15). The conodont record includes *Amorphognathus superbus* (Rhodes), *Sagittodontina robusta* Knüpfer, *S.* cf. *robusta, Dichodella*? sp., *Icriodella superba* Rhodes and *I.* cf. *superba.*

Amorphognathus ordovicicus Zone

Pioneering conodont studies developed in Spain before 1990 (see Introduction) were centered in a single Ordovician limestone deposit found throughout the Iberian Peninsula, and that was correctly attributed to the middle to upper Katian (Ka3-4) *Amorphognathus ordovicicus* Zone, and referred to the Kralodvorian stage of the Mediterranean regional scale.

The common assemblage from this Zone in Spain (Pl. 1, figs. 19-34) is represented by *Amorphognathus ordovicicus* Branson and Mehl, *Eocarniodus gracilis* (Rhodes), *Hamarodus europaeus* (Serpagli), *Istorinus erectus* Knüpfer, *Panderodus gracilis* (Branson and Mehl), *Saggittodontina robusta* Knüpfer, *Scabbardella altipes* (Henningsmoen), and several species identified in open nomenclature belonging to the genera *Drepanoistodus*, *Nordiodus*, *Panderodus*, *Protopanderodus*, *Pseudooneotodus* and *Walliserodus*?.

In NW Spain, records of this conodont zone occur in an unnamed limestone near Portilla de Luna (Fig. 1, loc. 2) in the Cantabrian Zone (Del Moral, 2003; Del Moral et al., 2003), as well as in the La Aquiana and Casaio formations of the Ollo de Sapo domain of the northern Central Iberian Zone (Fig. 1, locs. 3-5), also from limestone pebbles redeposited in the Hirnantian shales of the Rozadais Formation (Sarmiento, 1993; Sarmiento et al., 1999).

In the Iberian Cordillera conodonts of the *A. ordovicicus* Zone were identified in the Cystoid Limestone (Fig. 1, loc. 6) and Ojos Negros formations (Fig. 1, loc. 7) by Sarmiento (2002) and Del Moral (2007), as well as from limestone pebbles and dropstones incorporated into the Hirnantian Orea Formation.

In the Central Iberian Zone, the Urbana Formation is a characteristic and widespread limestone unit, in spite of its lensoid character, the scarcity of its outcrops and its reduced and highly variable thickness. More than twenty sections belonging of twelve localities, mainly in the southern Central Iberian Zone (Fig. 1, locs. 9-16), were carefully sampled for conodonts since 1990, which constitutes a very important increase in our knowledge of Katian conodont faunas in the Iberian Peninsula (Sarmiento, 1990, 1993; Sarmiento et al., 2000b; Del Moral, 2002a, 2002b, 2007; Del Moral and Sarmiento, 2008) (Pl. 1, figs. 19-34). In the Portuguese part of the Central Iberian Zone, conodonts from the *A. ordovicicus* Zone have been also recorded in the Poiares Member of the Ferradosa Formation, Serra do Buçaco (Sarmiento et al., 2000a, 2001).

In the southern border of the Central Iberian Zone, a few conodont elements obtained from rare Katian pebbles in a Mississippian olisthostrome from the Adamuz area (Córdoba: Fig. 1, loc. 17) were assigned, with doubts, to the *A. ordovicicus* Zone.

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In the Ossa Morena Zone, conodonts indicative of the *A. ordovicicus* Zone have been recorded in the Pelmatozoan Limestone Formation of the Valle and Cerrón del Hornillo synclines, northern Seville province (Fig. 1, loc. 18-19) by Sarmiento (1993) and Sarmiento et al. (2008).

In NE Spain, conodonts of the *A. ordovicicus* Zone have been identified in the Pyrenees (Fig. 1, loc. 21) and in the Catalonian Coastal Ranges (Fig. 1, loc. 22), occurring in the El Baell Formation of the Freser valley (Sanz-López and Sarmiento, 1995) and in the Madremanya limestones of Les Gavarres massif (Sarmiento et al., 1995b), respectively.

All the mentioned Late Ordovician conodont occurrences of the *A. ordovicicus* Zone, with the exception of that from the Pyrenees and others with very low number of specimens, have been ascribed to the Mediterranean Province of the North Atlantic Realm, by the presence of the typical genera *Saggittodontina* and *Istorinus* (Sweet and Bergström, 1984).

Recently, a peculiar conodont fauna dominated by simple cones of *Walliserodus amplissimus* (Serpagli) and *Scabbardella altipes* was found in the Malaguide Complex of the Betic Cordillera (Fig. 1. loc. 20; Pl. 1, figs. 35-39), and referred to the extension of the *A. ordovicicus* Zone into the Hirnantian stage. This conodont association significantly differs in composition from older assemblages (Ka2-3) of the same Zone occurring in the remaining areas of the Iberian Peninsula, but it is very similar to the assemblage recorded from the upper levels of the Uggwa limestones of the Carnic Alps, thus suggesting close palaeogeographical relationships between the Malaguide Complex and the Alps (Rodríguez-Cañero et al., 2010). This Betic fauna represents the youngest Ordovician conodont record in SW Europe and the first Ordovician conodonts found in the Western Mediterranean Alpine Orogen.

CONCLUSIONS

Ordovician conodonts from the Iberian Peninsula account for the following record: early Tremadocian *Paltodus deltifer* Zone, the early Dapingian *Baltoniodus triangularis* Zone, some Floian forms are under study, successive poorly known assemblages from the latest Darriwilian to early Sandbian, and late Sandbian to early Katian intervals, the Katian *Amorphognathus superbus* Zone and the mid-late Katian to Hirnantian *Amorphognathus ordovicicus* Zone. The very sporadic and incomplete record of conodont associations previous to those from the *A. ordovicicus* Zone is common in all areas placed at high latitudes near the south polar margin of the Gondwanan continent. Nevertheless, these occurrences can be used for regional correlations and can provide palaeogeographical inferences for this characteristic domain of the North Atlantic Conodont Realm. CAI data derived from Ordovician conodonts occurring in several places of the Iberian Massif were summarized by Sarmiento and García-López (1996) and Sarmiento et al. (1999).

Acknowledgements

Financial support was received from Spanish Ministry of Science and Innovation projects CGL2009-09583/BTE and CGL2009-09242, and by the RNM groups 208 and 3715 (Junta de Andalucía, Spain). Diego García-Bellido (CSIC, Madrid) is thanked for his help in improving the English version of this paper.

REFERENCES

Álvaro, J.J., Gómez, C. and Vizcaíno, D. 2003. Paleogeographic patterns of the Cambrian-Ordovician transition in the southern Montagne Noire (France): preliminary results. *Bulletin de la Societé Géologique de France*, 174, 23-31.

Armendáriz Dufur, M. 2010. *Génesis y evolución tectonosedimentaria de la parte meridional de la cuenca mississipiense de Los Pedroches (SO del Macizo Ibérico): Implicaciones paleogeográficas.* Publicaciones del Instituto Geológico y Minero de España, serie Tesis Doctorales, 18, 452 pp.

Bergström, S.M., Chen, X., Gutiérrez -Marco, J.C. and Dronov, A. 2009. The new chronostratigraphic classification of the Ordovician System and its relations to major regional series and stages and $\delta^{13}C$ chemostratigraphy. *Lethaia*, 42, 97-107.

Branson, E.B. and Mehl, M.G. 1940. The recognition and interpretation of mixed conodont faunas. *Denison University Bulletin, Journal of Sciences Laboratory,* 35, 195-209.

Carls, P. 1975. The Ordovician of the Eastern Iberian Chains near Fombuena and Luesma (Prov. Zaragoza, Spain). *Neues Jahrbuch für Geologie und Paläontologie Abhanlungen*, 150 (2), 127-146.

Cózar, P., Rodríguez, S. and Mas, R. 2004. Análisis sedimentológico y bioestratigráfico de afloramientos del Serpujoviense inferior (Mississipiense) en las proximidades de Adamuz (Córdoba, SO de España). *Coloquios de Paleontología*, 54, 115-130.

Del Moral, B. 2002a. Conodontos de la Formación Caliza Urbana (Kralodvoriense) en el Sinclinal de Guadalmez (Ciudad Real, España). *Coloquios de Paleontología*, 53, 69-85.

Del Moral, B. 2002b. Nuevos datos sobre conodontos kralodvorienses de la Fm. Caliza Urbana en el Sinclinal de Guadalmez (Ciudad Real, España). In J. Civis and J.A. González Delgado (eds.), *Libro de Resúmenes de las XVIII Jornadas de la Sociedad Española de Paleontología y II Congreso Ibérico de Paleontología*, Salamanca, 41-42.

Del Moral, B. 2003. Primeros conodontos kralodvorienses (Ordovícico Superior) de la Zona Cantábrica, Portilla de Luna, León (España). *Revista Española de Micropaleontología*, 35 (3), 275-283.

Del Moral, B. 2004. Conodontos de los "Bancos Mixtos" (Ordovícico Superior) en el sinclinal de Viso del Marqués (Ciudad Real, España). In A. Calonge, R. Gozalo, M.D. López Carrillo and M.V. Pardo Alonso (eds.), *Libro de Resúmenes de las XX Jornadas de la Sociedad Española de Paleontología*. Alcalá de Henares, 55-56.

Del Moral, B. 2007. *Conodontos y microfacies del Ordovícico Superior de la Cordillera Ibérica y Sierra Morena oriental*. Universidad Complutense de Madrid (unpublished PhD thesis), 427 pp.

Del Moral, B. and Sarmiento, G.N. 2008. Conodontos del Katiense (Ordovícico Superior) del sector meridional de la Zona Centroibérica (España). *Revista Española de Micropaleontología*, 40 (3), 169-245.

Del Moral, B., Sarmiento, G.N. and Bernárdez, E. 2003. Conodontos del Ordovícico Superior en Portilla de Luna, Provincia de León (Zona Cantábrica, Noroeste de España). In M.V. Pardo Alonso and R. Gozalo (eds.), *Libro de Resúmenes de las XIX Jornadas de la Sociedad Española de Paleontología*. Morella (Castellón), 69.

Fuganti, A. and Serpagli, E. 1968. Geological remarks on Urbana Limestone and evidence for its Upper Ordovician age by means of conodonts-Eastern Sierra Morena, South Spain. *Bolletino della Società Paleontologica Italiana*, 87, 511-521.

Gutiérrez-Marco, J.C. and Bernárdez, E. 2003. *Un tesoro geológico en la Autovía del Cantábrico. El Túnel Ordovícico del Fabar, Ribadesella (Asturias)*. Ministerio de Fomento, Madrid, 398 pp.

Gutiérrez-Marco, J.C., Sá, A.A. and Rábano, I. 2008. Ordovician time scale in Iberia: Mediterranean and global correlation. In: *Development of Early Paleozoic biodiversity: role of biotic and abiotic factors, and event correlation*. KMK Scientific Press, Moscow, 46-49.

Gutiérrez-Marco, J.C., Robardet, M., Rábano, I., Sarmiento, G.N., San José Lancha, M.A., Herranz Araújo, P. and Pieren Pidal, A.P. 2002. Ordovician. In W. Gibbons and T. Moreno (eds.), *The Geology of Spain*. The Geological Society, London, 31-49.

Gutiérrez-Marco, J.C., Herranz Araújo, P., Pieren, A.P., Rábano, I., Sarmiento, G.N., San José, M.A., Barnolas, A. and

CONTENTS →

Villas, E. 2004. El margen pasivo ordovícico-silúrico. In J.A. Vera (ed.), *Geología de España*. Sociedad Geológica de España-Instituto Geológico y Minero de España, 473-475.

Hartevelt, J.A. 1970. Geology of the Segre and Valira valleys, Central Pyrenees, Andorra/Spain. *Leidse Geologische Mededelingen*, 45, 167-236.

Hafenrichter, M. 1979. Paläontologisch-ökologische und Lithofazielle Untersuchungen des "Ashgill-Kalkes" (Jungordovizium in Spanien. *Arbeiten aus dem Paläontologischen Institut Würzburg*, 3, 139 pp.

Kolb, S. 1978. *Erläuterungen zur geologischen Kartierung des Gesbietes S Cerveruela in den östlichen Iberischen Ketten (NE-Spanien)*. Diplomarbeit Universität Würzburg (unplublished), 122 pp.

Lindström, M. 1976. Conodont paleogeography of the Ordovician. In M.G. Basset (ed.), *The Ordovician System*. University of Wales Press and National Museum of Wales, Cardiff, 501-522.

Lindström, M., Racheboeuf, P. and Henry, J.-L. 1974. Ordovician conodonts from the Postolonnec Formation (Crozon Peninsula, Massif Armoricain) and their stratigraphic significance. *Geologica et Palaeontologica*, 8, 15-28.

Robardet, M., Piçarra, J.M., Storch, P., Gutiérrez-Marco, J.C. and Sarmiento, G.N. 1998. Ordovician and Silurian stratigraphy and faunas (graptolites and conodonts) in the Ossa Morena Zone of the SW Iberian Peninsula (Portugal and Spain). *ITGE, Temas Geológico-Mineros*, 23, 289-318.

Robert, J.F. 1980. *Étude géologique et métallogénique du Val de Ribas sur le versant espagnol des Pyrénées Catalanes*. Thése a la faculté des Sciences et des Techniques de L'Université de Franche-Comté, Besançon, 294 pp.

Rodríguez-Cañero, R., Martín-Algarra, A., Sarmiento, G.N. and Navas-Parejo, P. 2010. First Late Ordovician conodont fauna in the Betic Cordillera (South Spain): a palaeobiogegraphical contribution. *Terra Nova*, 22, 330-340.

San José, M.A., Rábano, I., Herranz Araújo, P. and Gutiérrez-Marco, J.C. 1992. El Paleozoico Inferior de la Zona Centroibérica meridional. In J.C. Gutiérrez-Marco, J. Saavedra and I. Rábano (eds.), *Paleozoico Inferior de Ibero-América*. Universidad de Extremadura, 505-521.

Sanz-López, J. 1988. *Informe bioestratigráfico del Ordovícico de la Hoja Nº 256 (Ripoll), del Mapa Geológico de España a escala 1:50.000*. Instituto Geológico y Minero de España (unpublished report).

Sanz-López, J. and Sarmiento, G.N. 1995. Asociaciones de conodontos del Ashgill y del Llandovery en horizontes carbonatados del valle del Freser (Girona). In A. Obrador and E. Vicens (eds.), *Libro de Resúmenes de las XI Jornadas de la Sociedad Española de Paleontología*. Tremp (Lérida), 157-160.

Sarmiento, G.N. 1990. Conodontos de la Zona Ordovicicus (Ashgill) en la Caliza Urbana, Corral de Calatrava (Ciudad Real). *Geogaceta*, 7, 54-56.

Sarmiento, G.N. 1993. *Conodontos ordovícicos de Sierra Morena (Macizo Hespérico meridional)*. Universidad Complutense de Madrid (unpublished PhD thesis), 597 pp.

Sarmiento, G.N. 2002. Lower Palaeozoic of the Iberian Cordillera. In S. García-López and F. Bastida (eds.), *Palaeozoic conodonts from northern Spain*. Cuadernos del Museo Geominero, 1. Instituto Geológico y Minero de España, Madrid, 281-297.

Sarmiento, G.N. and García-López, S. 1996. El método del Índice de Alteración del Color (CAI) de los conodontos: limitaciones y posibilidades. Ejemplos de su aplicación en el Hercínico ibérico. *Revista de la Sociedad Geológica de España*, 9, 112-123.

Sarmiento, G.N. and Gutiérrez-Marco, J.C. 1999. Microfósiles ordovícicos en olistolitos carboníferos de la Cuenca del Guadiato, Adamuz (Córdoba). In I. Rábano (ed.), Actas de las XV Jornadas de Paleontología y Simposios de los Proyectos PIGC 393, 410 and 421. IGME, *Temas Geológico-Mineros*, 26 (2), 580-584.

Sarmiento, G.N., Del Moral, B. and Piçarra, J,M. 2001. Conodontos del Ordovícico Superior (Ashgill) en la Serra do Buçaco, Portugal. *Coloquios de Paleontología*, 52, 95-105.

Sarmiento, G.N., García-López, S. and Bastida, F. 1999. Conodont Colour Alteration Index (CAI) of Upper Ordovician limestones from the Iberian Peninsula. *Geologie en Mijnvow*, 77, 77-91.

Sarmiento, G.N., Gutiérrez-Marco, J.C. and Del Moral, B. 2008. Conodontos de la "Caliza de Pelmatozoos" (Ordovícico Superior), Norte de Sevilla, Zona de Ossa-Morena (España). *Coloquios de Paleontología*, 58, 73-99.

Sarmiento, G.N., Gutiérrez-Marco, J.C. and Rábano, I. 1995a. A biostratigraphical approach to the Middle Ordovician conodonts from Spain. In J.D. Cooper, M.L. Droser and S.C. Finney (eds.), *Ordovician Odyssey*. Pacific Section Society for Sedimentary Geology, Book 77, Fullerton, 61-64.

Sarmiento, G.N., Gutiérrez-Marco, J.C. and Robardet, M. 1999. Conodontos ordovícicos del noroeste de España. Aplicación al modelo de sedimentación de la región limítrofe entre las zonas Asturoccidental-Leonesa y Centroibérica durante el Ordovícico Superior. *Revista de la Sociedad Geológica de España*, 12 (3-4), 477-500.

Sarmiento, G.N., Sanz López, J. and Barnolas, A. 1995b. Conodontos del Ashgill en las Calizas de Madremanya, Les Gavarres (Girona). In A. Obrador and E. Vicens (eds.), *Libro de Resúmenes de las XI Jornadas de la Sociedad Española de Paleontología*. Tremp (Lérida), 161-163.

Sarmiento, G.N., Gutiérrez-Marco, J.C., Hacar Rodríguez, M.P., Robardet, M. and Rábano, I. 1992. Hallazgo de conodontos en lutitas con cantos calizos del Sinclinorio de Truchas (Ordovícico Superior, NO de España). *Publicaciones del Museo de Geología de Extremadura,* 2, 131-132.

Sarmiento, G.N., Gutiérrez-Marco, J.C., Robardet, M. and Piçarra, J.M. 2002a. Conodontos de la Formación Ferradosa (Ashgill), Serra do Buçaco, Zona Centroibérica portuguesa. In J.B. Diez and A.C. Balbino (eds.), *Libro de Resúmenes de las XVI Jornadas de la Sociedad Española de Paleontología y I Congreso Ibérico Paleontología*. Évora (Portugal), 282-283.

Sarmiento, G.N., Leyva, F., Gutiérrez-Marco, J.C. and Del Moral, B. 2000b. Conodontos de la Caliza Urbana (Ashgill) de Sierra Morena oriental (Zona Centroibérica). In J.B. Diez and A.C. Balbino (eds.), *Libro de Resúmenes de las XVI Jornadas de la Sociedad Española de Paleontología y I Congreso Ibérico Paleontología*. Évora (Portugal), 280-281.

Sarmiento, G.N., Robardet, M. and Gutiérrez-Marco, J.C. 2000c. Conodontos del Caradoc (Ordovícico Superior) del Macizo Hespérico. In J.B. Diez and A.C. Balbino (eds.), *Libro de Resúmenes de las XVI Jornadas de la Sociedad Española de Paleontología y I Congreso Ibérico Paleontología*. Évora (Portugal), 286-287.

Serpagli, E., Ferretti, A., Vizcaíno, D. and Álvaro, J.J. 2007. A new Early Ordovician conodont genus from the southern Montagne Noire, France. *Palaeontology*, 50 (6), 1447-1457.

Sweet, W.C. and Bergström, S.M. 1984. Conodont provinces and biofacies of the Late Ordovician. *Geological Society of America, Special Paper*, 196, 69-87.

CONTENTS