First Late Ordovician conodont fauna in the Betic Cordillera (South Spain): a palaeobiogeographical contribution

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ABSTRACT

The youngest Ordovician conodont fauna in SW Europe has been found in the Malaguide Complex of the Betic Cordillera, SE Spain. It is also the first Ordovician conodont fauna in the Western Mediterranean Alpine Orogen. The conodont association, attributed to the Hirnantian (upper part of the *Amorphognathus ordovicicus* Biozone), is characterized by the predominance of *Walliserodus amplissimus* and *Scabbardella alt- ipes* and by the absence of *Sagittodontina* and *Istorinus*, typical of the Mediterranean Province. This fauna differs markedly from those of the same biozone recorded in the Spanish Variscan Orogen of the Iberian Massif, which are attributed to the Katian. The Malaguide fauna shows, however, striking similarity to faunas of the Carnic Alps and some resemblance to those of the Pyrenees, Northern England and North Wales. These features suggest that Palaeozoic terranes of the Betic Cordillera were located far to the east of their present location and displaced westward during the Alpine Orogeny.

Introduction

In southernmost Spain, Palaeozoic rocks, usually metamorphic, are exposed only in the Internal Domain of the Betic Cordillera that is the westernmost European Alpine Belt (Herbig, 1984; Martín-Algarra, 1987; Martín-Algarra *et al.*, 2004). Nonetheless, thick terrigenous-clastic sedimentary Palaeozoic successions are present in the Malaguide Complex, where Llandovery to Bashkirian deposits have been dated mainly by conodonts. Conodonts are, consequently, essential tools for improving the poorly known Palaeozoic stratigraphy, and understanding the very complicated Alpine and pre-Alpine tectonic structure and geological history of this belt.

Silurian, Devonian and Carboniferous conodonts were reported by Kockel (1959) and Kockel and Stoppel (1962) in the western outcrops of the Malaguide Complex and, a few years later, in the eastern regions (van den Boogaard, 1965). Herbig (1984, 1985) identified several Middle and Upper Devonian and Carboniferous biozones; Rodríguez-Cañero (1993a) demonstrated the presence of many conodont biozones of the Middle and Upper Silurian, the Lower, Middle and Upper Devonian, and the Lower Carboniferous (Table 1). Most of these conodonts were obtained from: (i) tectonically isolated and scattered Silurian and Devonian carbonate outcrops with stratigraphic successions that vary from a few metres to several tens of metres in thickness (Kockel, 1959; Kockel and Stoppel, 1962; Herbig, 1984, 1985; Rodríguez-Cañero, 1993a,b); (ii) Lower Carboniferous thin siliceous and carbonate deposits intercalated between unfossiliferous turbiditic slates and greywackes (Herbig, 1983; Rodríguez-Cañero and Guerra-Merchán, 1996; O'Dogherty *et al.*, 2000; Navas-Parejo *et al.*, 2008); and (iii) centimetre- to few metre-sized Devonian–Carboniferous carbonate clasts included within Carboniferous conglomerates (Buchroithner *et al.*, 1980; Herbig, 1984).

The existence of Ordovician deposits in the Malaguide Complex of the Betic Cordillera was suspected (Martín-Algarra *et al.*, 2004) but, until now, not biostratigraphically demonstrated. The present study reveals the existence of Upper Ordovician strata, which have been dated by conodonts of the *Amorphognathus ordovicicus* Biozone for the first time in the Betic Cordillera. In spite of its local character, this discovery is relevant because it represents the firstsolid evidence of the presence of ordovician rocks in the Palaeozoic successions of the Western Mediterranean Alpine Chains that extend from southern Italy to Gibraltar. Consequently, this allows correlation with the well-known succession in the Alps and in other North-Gondwanic areas, and with the new standard chronostratigraphic scale (Bergström *et al.*, 2009).

Geological setting

As is usual for mountain belts in the Western Mediterranean Alpine Orogenic System, the Betic Cordillera is divided into tectonic units belonging to the External, Flysch and Internal Domains (Durand-Delga and Fontboté, 1980; Vera and Martín-Algarra, 2004). As a consequence of the post-Palaeozoic Pangaea breakoff, these domains constituted, from mid- Jurassic time, the northern (External) and southern (Internal) continental margins of a narrow, deep marine (Flysch) basin that connected the western Tethyan and central Atlantic oceans. Cretaceous to Miocene subduction and metamorphism followed by continental collision transformed these former margins and basin, and their basements, in the Alpine stack of thrust nappes that constitute the Betic Cordillera today.

Palaeozoic terranes are practically absent in the External and Flysch

Table 1 Conodont biozones in the Malaguide Complex after Rodríguez-Cañero (1993a). Numbers correspond to samples.

Epoch/period	Stage/Epoch	Localities / *Conodont biozones*	Arroyo de las Viñas	Peña del Castillo de Ardales	Almogía I	Almogía II	Almogía IIIA	Almogía IIIB	Almogía IV	Fuengirola	Arroyo de Casa Otero
Lower Carboniferous	Visean	*bilineatus*									103
		transatlanticus									
		homopunctatus									
	Tournaisian	*anchoralis-latus*									
		typicus									
		isosticha-crenulata									
		sandbergi									
		duplicata									
		sulcata									
Upper Devonian	Famennian	*praesulcata*									
		expansa									
		postera									
		trachytera								167	
		marginifera								165	
		rhomboidea							230		
		crepida u.m.	190								
		crepida u.						102	231		
		crepida m.						89			
		crepida l.						87	232		
		triangularis u.							238		
		triangularis m.							233		
		triangularis l.					305				
	Frasnian	*linguiformis*					94				
		rhenana					92		229		
		jamiae									
		hassi									
		punctata									
		transitans			70					172	
		falsiovalis									
Middle Devonian	Givetian	*disparilis*			74						
		hermanni									
		varcus u.									
		varcus m.			78						
		varcus l.				86					
		ensensis				110					
	Eifelian	*kockelianus*				82					
		costatus									
		partitus									
Lower Devonian	Emsian	*patulus*									
		serotinus									
		inversus-laticostatus									
		gronbergi	200	187							
		dehiscens									
		kitabicus									
	Pragian	*pirenae*									
		kindlei									
		sulcatus		308							
	Lockovian	*pesavis*									
		delta	197								
		eurekaensis	196	311							
		postwosch/woschmidti									
Silurian	Pridoli	*eosteinhornensis*									
	Ludlow	*crispa*		185							
		latialata									
		siluricus		184							
		Ploeckensis									
	Wenlock	*crassa*									
		sagitta		183							
		patula									
		amsdeni-ranuliformis		182							
	Llandovery	*amorphognathoides*	189								
		celloni									
Ordovi.	Hirnantian / Katian	*ordovicicus*	69*								

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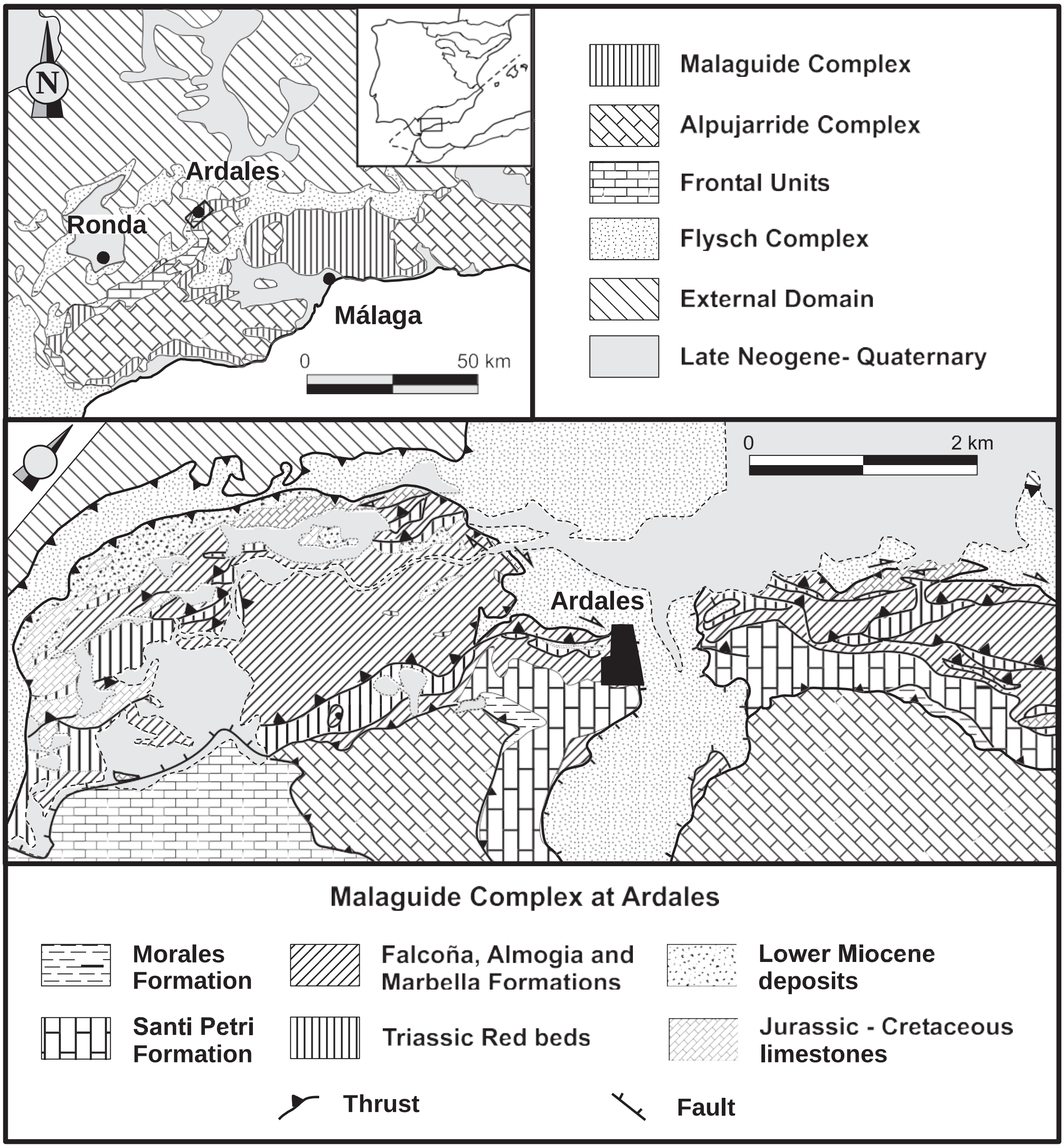


Fig. 1 Tectonic sketch of the Western Betic Cordillera and simplified geological map of the Malaguide Complex at Ardales.

Domains, as well as in the Frontal Units of the Internal Domain. They are, however, widely present in the other three tectonic complexes distinguished within the Internal Domain, which are named, from bottom to top, the Nevado-Filabride, Alpujarride and Malaguide complexes respectively. The Nevado-Filabride and Alpujarride Palaeozoic terranes consist exclusively of metamorphic rocks; pre-Mesozoic fossils have rarely been found there (Lafuste and Pavillon, 1976; Gómez-Pugnaire *et al.*, 1982). However, the Malaguide Palaeozoic terrain consists of thick, mainly siliciclastic and deep marine (turbiditic) successions bearing fossils (Martín-Algarra *et al.*, 2004, and references therein).

The Malaguide Complex is exposed widely at Ardales, 30 km to the NE of Málaga, where it forms a narrow, discontinuous and strongly tectonized klippen belt (Fig. 1). The Malaguide succession cropping out there (Fig. 2) consists of Ordovician to Upper Carboniferous rocks that were strongly deformed during pre-Alpine and Alpine events (Martín-Algarra *et al.*, 2009a). Palaeozoic rocks include turbidites and slates, with subordinate conglomerate, chert and pelagic limestone bearing conodonts, and make up part of two superimposed Variscan tectonic units with different Palaeozoic successions, assigned to the Ermita (lower) and Peña del Castillo (upper) units (Martín-Algarra *et al.*, 2009b).

From bottom to top, the studied succession in the Ermita Unit consists of (Figs 2 and 3): (a) a few metres of

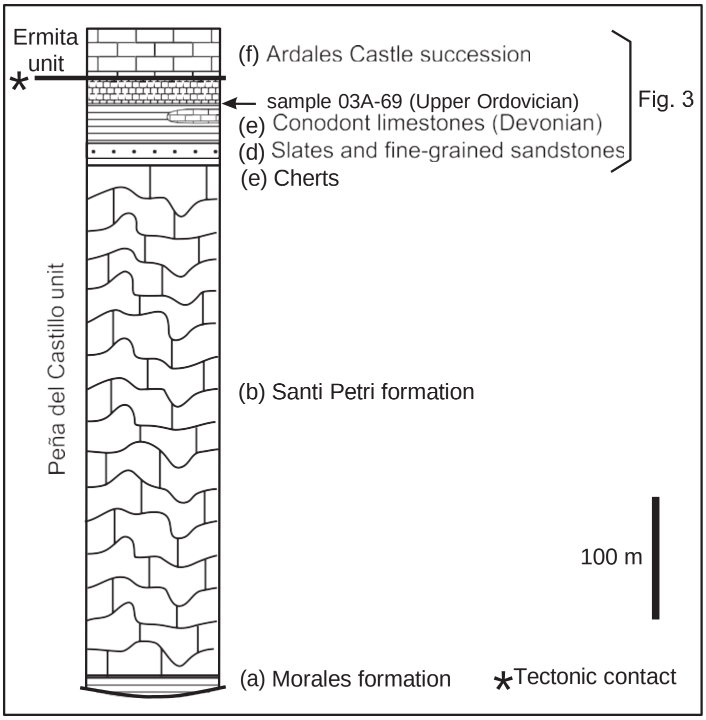


Fig. 2 Stratigraphy of the Malaguide Palaeozoic succession at Ardales.

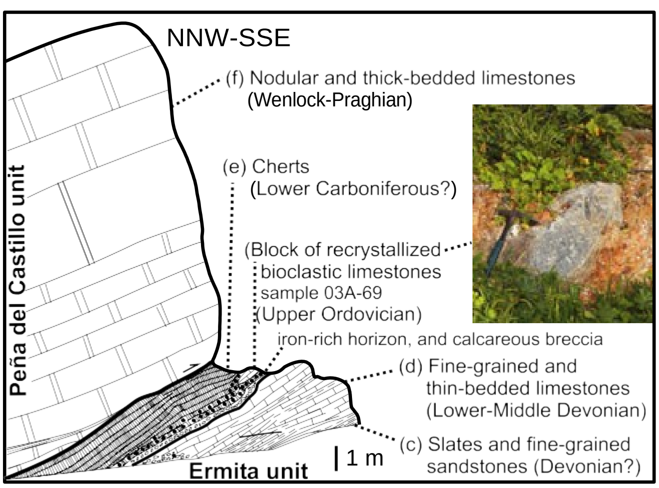


Fig. 3 The Ardales Castle Rock section and the location of the limestone conodont sample.

slightly metamorphic pre-Devonian slate and metasandstone belonging to the Morales Formation; (b) a thick and strongly folded succession of Devonian (?) calcareous slate and fine-grained turbiditic limestone of the Santi-Petri Formation; (c) a few tens of metres of slate and fine-grained sandstone with some discontinuous bodies of basic volcanic rock; (d) a few-metre-thick lens of grey-bluish fine-grained and thinly bedded pelagic limestone, with Lower to Middle Devonian conodonts and dacryoconarids (Rodríguez-Cañero, 1993a), which is bound by a thin brecciated horizon; and (e) a few metres of strongly sheared black radiolarian cherts, which are locally associated with bluish limestone bearing Lower Carboniferous (Visean) conodonts. This chert and limestone belonging to the Falcoña Formation is truncated by a pre-Alpine thrust fault that

Table 2 Late Ordovician conodont taxa from Ardales.

The Ardales castle rock section	
Sample number	03A – 69
Amount of dissolved sample	1975 g
Amorphognathus cf. *ordovicicus*	
Pa element	6 frag.
Pb element	3
Scabbardela altipes	
a element	9
b? element	7
e element	10
Scabbardella sp.	5
Walliserodus amplissimus	
a element	3
b element	2
c element	2
d element	2
e element	9
Fragments	18
Walliserodus cf. *amplissimus*	
d ? element	4
e element	1
Fragments	7
Walliserodus? sp.	7
Protopanderodus? sp.	1
Hamarodus europaeus	
Sc element	1
Eocarniodus	2
Gen et sp. indet.	9
Fragmentary specimens	38
Total	146

divides the top of the lower (Ermita) Variscan tectonic unit from the base of the upper (Penña del Castillo) Variscan unit.

The Peñ a del Castillo Unit (Figs 2 and 3) is composed of Silurian–Lower Devonian nodular and thickly bedded limestone with conodonts (f), consti- tuting the approximately 30-m-thick Ardales Castle succession (Rodríguez-Cañero,1993a; Rodríguez-Cañero *et al.*, 1997).

Results and discussion

The Ordovician conodont association was found in a block of recrystallized bioclastic limestone that lies within a siliceous–ferruginous–calcareous claystone horizon (<1 m thick) with discontinuous calcareous breccia, in the basal chert beds on top of the Middle Devonian pelagic limestone (levels e and d, above mentioned, respectively). The inclusion of the Ordovician block within surrounding sediments was probably the result of submarine sliding and resedimentation (see discussion in Martı´ n-Algarra *et al.*, 2009a; p. 256). The sampled limestone block has a volume of about 0.3 m^3 (Fig. 3).

In total, 146 conodont elements were recovered; the recognized taxa are summarized in Table 2. Specimen abundance is moderately high, with 75 elements per kg of dissolved sample. Conodont element size ranges from 0.2 to 1 mm, thus indicating that hydrodynamic sorting was minimal. The specimens are well preserved in general: only a few are fragmentary; the colour alteration index of Epstein *et al.* (1977) is 4–4.5.

The low-diversity conodont fauna from Ardales includes *Walliserodus* Serpagli, 1967; *Scabbardella* Orchard, 1980; *Amorphognathus* Branson and Mehl, 1933; *Hamarodus* Viira, 1974 and *Protopanderodus*? Lindströ m, 1971 (Figs 4 and 5). Coniform ele- ments comprise more than 80% of the conodont collection; *Walliserodus*, including forms closely related to Silurian species, dominates the fauna (Figs 4 and 5). The genera *Sagitto- dontina* Knü pfer, 1967 and *Istorinus* Knü pfer, 1967 are, however, absent, although they are typical genera of the Mediterranean Province and indica- tive of the polar to subpolar regions of higher latitudes around Northern Gondwana (Sweet and Bergströ m, 1984). Consequently, the Late Ordo- vician fauna found at Ardales cannot be ascribed to any of the Ordovician palaeobiogeographic provinces de- fined by Bergströ m (1973, 1990) and Sweet and Bergströ m (1984), neither can it be ascribed to any of the biofacies proposed by Sweet and Bergströ m (1984).

The conodont association of the Malaguide Complex at Ardales is very peculiar and differs significantly in taxonomic composition from associa- tions in other areas of the Variscan Orogen of the Iberian Peninsula dated as Katian, where *Sagittodontina* Knü pfer, 1967 and *Istorinus* Knü pfer, 1967 are common (Fuganti and Serpagli, 1968 Carls, 1975; Hafenrich- ter, 1979; Sarmiento, 1990, 1993; Sarmiento *et al.*, 1995, 1999, 2001, 2008; Sarmiento and Gutié rrez-Mar- co, 1999; Del Moral, 2003, 2005, 2007; Del Moral and Sarmiento, 2008). These Katian conodonts have been recorded from several lithostrati- graphic units belonging to different structural and palaeogeographic zones of the Variscan Iberian Massif (Ta- ble 3, Fig. 6): (i) the Cantabrian Zone (an unnamed formation at Portilla de Luna: Del Moral, 2003); (ii) the West Asturian Leonese Zone (La Aquiana Fm.: Sarmiento, 1993); (iii) the Ibe- rian Cordillera (Cystoid Limestone and Ojos Negros formations: Carls, 1975; Hafenrichter, 1979; Del Moral, 2007); (iv) the Pyrenees (El Baell Fm.: Sanz-Ló pez and Sarmiento, 1995; and references therein); (v) the Catalonian Coastal Ranges (Madremanya Lime- stone: Sarmiento *et al.*, 1995); (vi) the Central Iberian Zone (Casaio Fm., limestone pebbles of the Rozadais Fm., Urbana Limestone, Ferradosa Fm., and Adamuz Variscan olisto- liths: Fuganti and Serpagli, 1968; Hafenrichter, 1979; Sarmiento, 1990, 1993; Sarmiento and Gutié rrez-Mar- co, 1999; Sarmiento *et al.*, 2001; Del Moral, 2007; Del Moral and Sarmi- ento, 2008); and (vii) the Ossa-Mor- ena Zone (Pelmatozoan Limestone: Hafenrichter, 1979; Sarmiento *et al.*, 2008).

The Ardales conodont fauna also differs from those of many other Southern European and North African sites: Thuringia (Knü pfer, 1967; Fer- retti and Barnes, 1997), NW France (Lindströ m and Pelhate, 1971; Weyant *et al.*, 1977), Sardinia (Ferretti and Serpagli, 1999) and Libya (Bergströ m and Massa, 1992), where *Sagittodonti- na* and *Istorinus* are common but *Wall- iserodus* is scarce or absent.

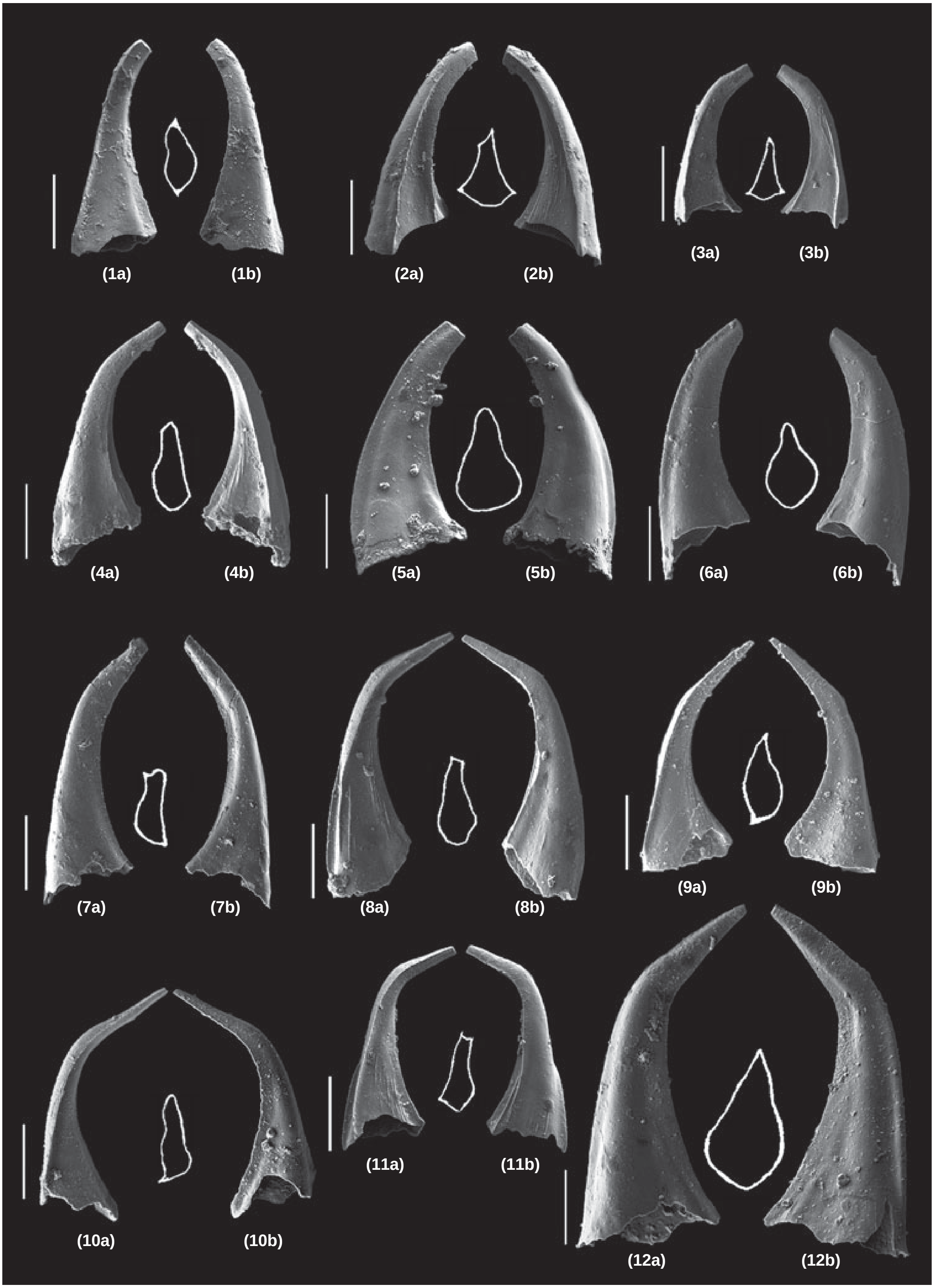
Nevertheless, Late Ordovician conodont faunas from the Carnic Alps (Schö nlaub, 1988; Bagnoli *et al.*, 1998; Ferretti and Schönlaub, 2001), North- ern England and North Wales (Orch- ard, 1980), and the Spanish Pyrenees (Sanz-López and Sarmiento, 1995) are similar to the Ardales fauna. Bagnoli *et al.* (1998) reported a more diverse conodont fauna without *Sagittodonti- na* and *Istorinus* from the Uggwa Formation of the Valbertad section (Carnic Alps). Ferretti and Schö nlaub (2001) also noticed the absence of *Sagittodontina* and *Istorinus* and sta- ted that (p. 9) *Walliserodus amplissi- mus becomes dominant in the uppermost horizons* of the Uggwa and Wolayer limestones of the Central Carnic Alps (Austria) and that (p. 10) *Important levels with Hirnantia fauna were reported at the top of the Uggwa Limestone, immediately before the beginning of the Plö cken Unit.* Orchard (1980) showed that *A. ordovicicus*?, *W. aff. amplissimus* and *Hamarodus europaeus* are the only conodonts present in Hirnantian levels of the Ashgill Series of Northern England and North Wales. Finally, in the associations from the Spanish Pyre- nees, *Sagittodontina* and *Istorinus* are absent but *Walliserodus* is relatively abundant (Sanz-Ló pez and Sarmien- to, 1995) (Table 3).

As previously indicated, the Ardales fauna contains *Walliserodus* elements with a morphology similar to that of Silurian species (Figs 4 and 5). This suggests a replacement of Ordovician taxa by Silurian-like faunas in the latest Ashgill, as proposed by Barnes and Bergströ m (1988).

The Ardales conodonts correspond to generalist and eurythermal species from the Atlantic Faunal Region, as

Fig. 4 Late Ordovician conodonts of the Malaguide Complex at Ardales 1. *Walliserodus amplissimus* (Serpagli, 1967), a element; 03A-69-58. (a) Inner lateral view; (b) outer lateral view. 2. *Walliserodus amplissimus* (Serpagli, 1967, b element; 03A-69-60.

(a) Inner lateral view; (b) outer lateral view. 3. *Walliserodus amplissimus* (Serpagli, 1967), c element; 03A-69-50. (a) Inner lateral view; (b) outer lateral view. 4. *Walliserodus amplissimus* (Serpagli, 1967), d element; 03A-69-40. (a) Outer lateral view; (b) inner lateral view. 5. *Walliserodus amplissimus* (Serpagli, 1967), e element; 03A-69-57. (a) Inner lateral view; (b) outer lateral view. 6. *Walliserodus amplissimus* (Serpagli, 1967), e element; 03A-69-5. (a) Inner lateral view; (b) outer lateral view. 7. *Walliserodus* cf. *amplissimus* (Serpagli, 1967), a element; 03A-69-29. (a) Outer lateral view; (b) inner lateral view. 8. *Walliserodus* cf. *amplissimus* (Serpagli, 1967), b element; 03A-69-39. (a) Inner lateral view; (b) outer lateral view. 9. *Walliserodus* cf. *amplissimus* (Serpagli, 1967), a element; 03A-69-26. (a) Inner lateral view; (b) outer lateral view. 10. *Walliserodus* cf. *amplissimus* (Serpagli, 1967), a element; 03A-69-17. (a) Inner lateral view; (b) outer lateral view. 11. *Walliserodus* cf. *amplissimus* (Serpagli, 1967), b element; 03A-69-59. (a) Inner lateral view; (b) outer lateral view. 12. *Walliserodus* cf. *amplissimus* (Serpagli, 1967), e element; 03A-69-2. (a) Outer lateral view; (b) inner lateral view. White drawings correspond to the basal sections. Scale bars = 200 lm.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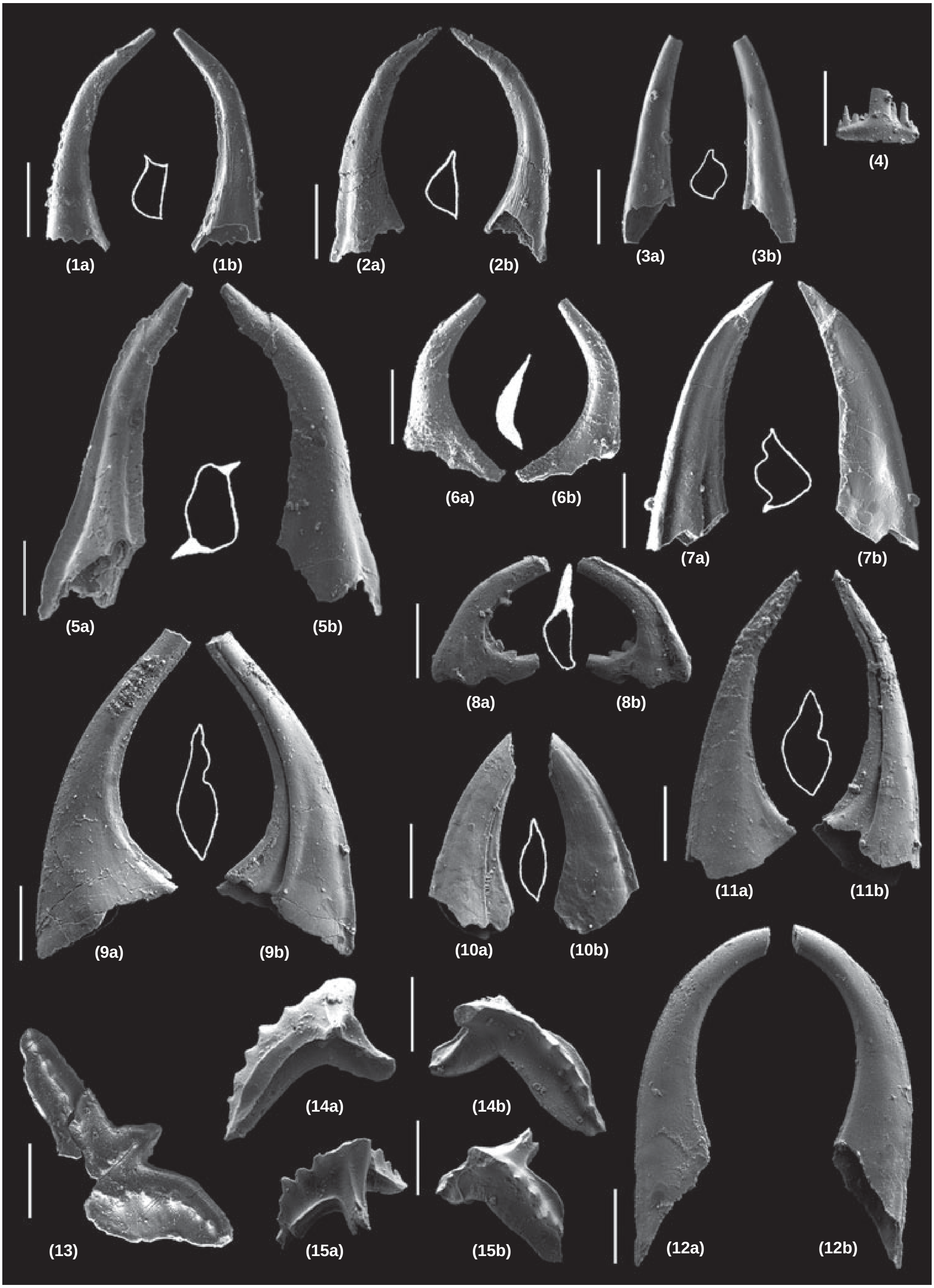
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indicated by their low diversity and by the predominance of coniform taxa (Bergström, 1990). This suggests that the Malaguide fauna evolved under ecologically stressed conditions, and that only species adapted to rapidly changing environments survived. Hir- nantian conodont associations from the Atlantic Faunal Region are, in general, very scarce and poorly diversified (Orchard, 1980; Bergströ m and Orchard, 1985; Barnes and Williams, 1988). Moreover, they are absent from Hirnantian strata in other Spanish sites (Iberian Massif), where the sed- iments are dominated by glaciomarine diamictites (Carls, 1975; Robardet, 1981; Fortuin, 1984; and Robardet and Doré, 1988, among others).

Fig. 5 Late Ordovician conodonts of the Malaguide Complex at Ardales 1. *Walliserodus*? sp., 03A-69-7. (a) Outer lateral view; (b) inner lateral view. 2. *Walliserodus*? sp., 03A-69-8. (a) Outer lateral view; (b) inner lateral view. 3. *Walliserodus*? sp., 03A-69-12. (a) Outer lateral view; (b) inner lateral view. 4. Eocarniodus element, 03A-69-104. 5. Gen et sp. indet., 03A-69-61. (a) Inner lateral view; (b) outer lateral view. 6. *Protopanderodus*? sp., 03A-69-16. (a) Outer lateral view; (b) inner lateral view. 7. Gen et sp. indet., 03A-69-36. (a) Inner lateral view; (b) outer lateral view. 8. *Hamarodus europaeus* (Serpagli, 1967), Sc element; 03A-69-106. (a) Inner lateral view; (b) outer lateral view. 9. *Scabbardella altipes* (Henningsmoen, 1948), a element; 03A-69-74. (a) Outer lateral view; (b) inner lateral view. 10. *Scabbardella altipes* (Henningsmoen, 1948), b? element; 03A-69-79. (a) Inner lateral view; (b) outer lateral view. 11. *Scabbardella alt- ipes* (Henningsmoen, 1948), a element; 03A-69-74. (a) Outer lateral view; (b) inner lateral view. 12. *Scabbardella alt- ipes* (Henningsmoen, 1948), e element; 03A-69-64. (a) Outer lateral view; (b) inner lateral view. 13. *Amorphognathus* cf. *ordovicicus* Branson and Mehl, 1933, Pa element; 03A-69-67, upper view. 14. *Amorphognathus* cf. *ordovicicus* Branson and Mehl, 1933, Pb element; 03A-69-72. (a) Outer oblique view; (b) upper view. 15. *Amorphognathus* cf. *ordovicicus* Branson and Mehl, 1933, Pb element; 03A-69-71. (a) Outer lateral view; (b) upper view. White drawings correspond to the basal sections. Scale bars = 200 lm.

Table 3 Late Ordovician conodont associations in the Iberian Peninsula, with the total number of elements so far published for each area, to enhance the differences in abundance of some genera (e.g. *Walliserodus*) between the (Alpine) Malaguide Complex of the Betic Cordillera (*this paper, Hirnantian) and other (Variscan) Iberian sites (Katian).

	Cantabrian Zone	West Asturian Leonese Zone	Iberian Cordillera	Central Iberian Zone					Ossa-Morena Zone	Catalonian Coastal Ranges	Pyrenees	Betic Cordillera
Late Ordovician conodont associations in Iberian Peninsula	Unnamed Fm. Portilla de Luna	La Aquiana Fm.	Cystoid Limestone and Ojos Negros Fms.	Casaio Fm.	Limestone pebbles of the Rozadais Fm.	Urbana Limestone Fm.	Ferradosa Fm. (Portugal)	Adamuz (Córdoba)	Pelmatozoan Limestone	Madremanya Limestone	El Baell Fm.	Malaguide Complex*
Sagittodontina		3	326	1	134	1413	9		53			
Istorinus			56			106	1	2	3			
Eocarniodus			36			2057	4		2	1		1
Icriodella	1		14			74		4	1	2		
Amorphognathus	7	1	418		24	1933	4		37	6	8	9
Hamarodus			19	1	11	79			2			
Protopanderodus												1
Panderodus	2		221			176	3			1	7	1
Scabbardella	3	2	515	6	17	3229	6	1	101	3	4	31
Walliserodus						2	1	6	1		3	55
Gen et sp. indet.								1				9

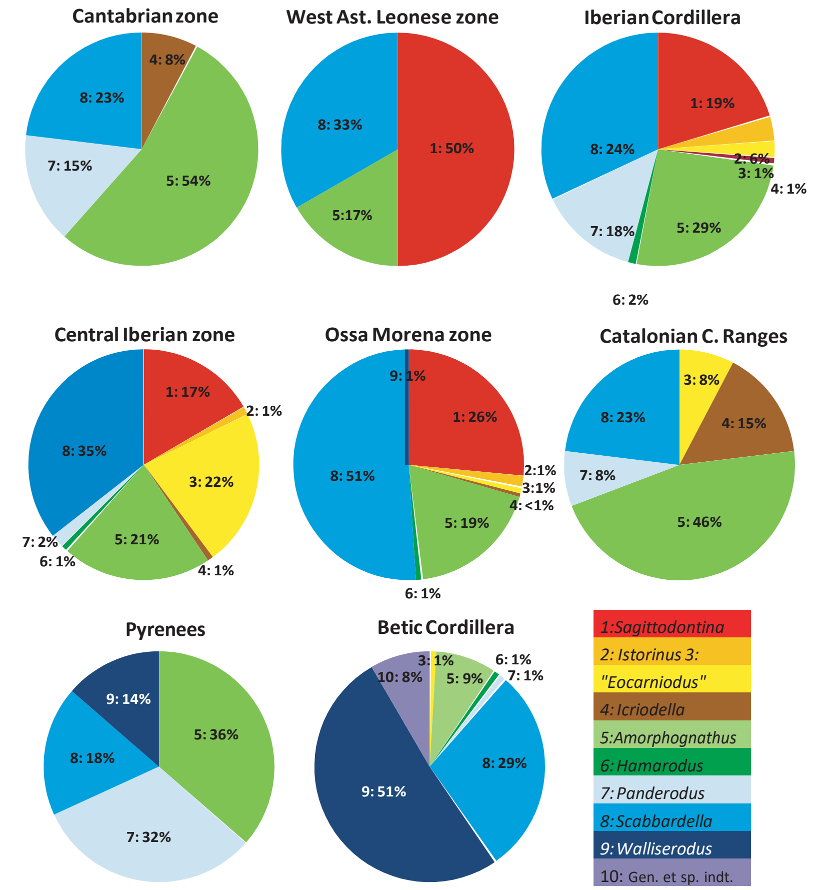

Fig. 6 Taxonomic compositions of Late Ordovician conodont taxa from different tectonostratigraphic zones of the Iberian Peninsula.

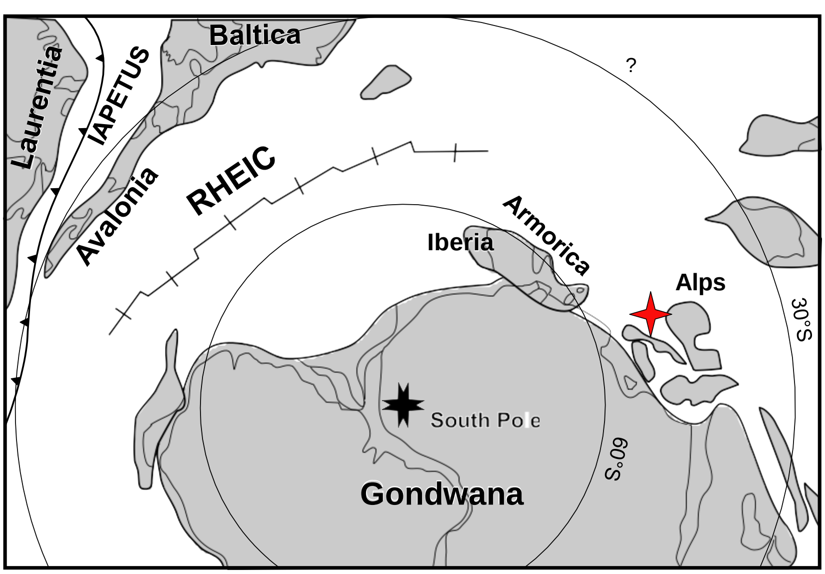

Fig. 7 Palaeogeographic reconstruction of North Gondwana during the Upper Ordovician (simplified from Cocks and Torsvik, 2006). The star indicates the proposed location of the Malaguide Complex of the Betic Cordillera 440 Ma ago.

Lindström (1976), Sweet and Bergström (1984) and Bergström (1990) located the Iberian Peninsula at very high palaeolatitude, as part of the Perigondwanic margin, during the latest Ordovician. This would explain quite well the absence of conodonts and the predominance of glaciomarine sediments during the Hirnantian in most Iberian areas. Nevertheless, the affinities between the Ardales Ordovician fauna and the conodont associations found in the Carnic Alps rather suggest a palaeogeographical location for the Malaguide Complex at lower palaeolatitude than the Iberian Massif, as proposed by Cocks and Torsvik (2002, 2006) for the Carnic Alps, or by Vennin *et al.* (1998) for the north-eastern regions of Iberia. This palaeobiogeographical interpretation is geologically significant and reinforces a previous hypothesis supporting close palaeogeographical relationships between the Palaeozoic (and younger) successions of the Betic-Rifian Internal Domains and those of the Alps (see Chalouan and Michard, 1990; Michard *et al.*, 1991, among others).

Conclusions

1 The presence of Upper Ordovician rocks in the Malaguide Complex is demonstrated for the first time.
2 The Late Ordovician conodont fauna discovered at Ardales is correlated with the upper part of the *A. ordovicicus* Biozone, corresponding to the Hirnantian Stage. This is supported by: (i) its dissimilarity from typical Katian associations of the Mediterranean Province reported in other areas of the Iberian Massif; (ii) its similarity to associations recorded from the upper levels of the Uggwa limestones of the Carnic Alps and to the Hirnantian fauna of the Ashgill Series of Northern England and North Wales; and (iii) the presence of *Walliserodus* elements showing morphological affinities to Early Silurian species.
3 The conodont association found at Ardales indicates deposition at a lower palaeolatitude than that of other Iberian regions. It is similar to conodont faunas from the Carnic Alps, thus suggesting that close palaeogeographical relationships

exist between the Malaguide Complex and the Alps.

4 Accordingly, during the Late Ordovician, the Malaguide Complex was located at an intermediate palaeogeographic position between the Carnic Alps and the Iberian terranes (Fig. 7).

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