Taxonomy and Evolution of the Triassic Conodont Pseudofurnishius

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Introduction

Most Middle to Late Triassic conodonts represent a single clade classified in the family Gondolellidae. The gondolellids inherited their apparatus structure after the Late Devonian prioniodinid Brannmehla (Dzik 2006) and preserved its fifteen-element composition without significant change until their extinction near the end of the Triassic (von Bitter and Rieber 1999). Most of the gondolellids develop a regular platform in their P1 elements but in the lineage of Pseudofurnishius, the former process bearing S3 element, but an eight-element type has been recognised more recently (Ishida and Hirsch 2011).

Pseudofurnishius is a late Anisian (Pelsonian)–early Carnian (Cordevolian) conodont genus of gondolellid stock, characteristic for the Sephardic Province and restricted to the “Southern Tethys” region of the northern margin of Gondwana. Its most commonly found species, Pseudofurnishius murcianus, appears at the base of the Ladinian (Fassanian). The Ladinian material of Spain reveals its ontogeny characterised by initial lateral protrusions from the carina that may develop first mono-platform and later bi-platform units, finally evolving into elaborated multi-denticulated forms. The late Anisian–early Carnian phylogenesis of Pseudofurnishius priscus → P. shagami → P. murcianus is proposed. At the end of the Ladinian, Pseudofurnishius expanded to the entire “Southern Tethys” shelf and into Cimmerian terranes that drifted away from northern Gondwana, now accreted to Eurasia, such as the Sibumasu terrane (Southwest China–Malayan Peninsula).

Key words: Conodonta, Pseudofurnishius, taxonomy, evolution, Triassic, Sephardic Province.

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Pseudofurnishius is the only conodont present in many localities of the Middle Triassic in the Sephardic Province and often the only fossil available for biostratigraphic control. However, despite improved knowledge of element morphology, the biostratigraphic position of each of its species has long remained the subject of debate (Gullo and Kozur 1991; Hirsch 1997; Plasencia et al. 2007; Plasencia 2009). The objective of this work is to discuss new evidence in taxonomy, biostratigraphic correlation, geological age, and evolutionary relationships of the genus in general and P. murcianus, in particular.

Material and methods

The material of Pseudofurnishius murcianus (Fig. 2D), the most common species of the genus, consists of several thousand specimens from mostly Sephardic localities (Fig. 1). This study is based on specimens from 24 Ladinian sections in the eastern part of the Iberian Peninsula that spreads, from N to S, from the Pyrenees and Catalan Coastal Ranges in the north-east to the Iberian Range in the centre-east and the Betic Cordilleras in the south-east (Plasencia et al. 2010). In many horizons, samples with P. murcianus are monospecific. Most representative, from a biostratigraphic point of view, is the section of Calasparra, which encompasses a continuous early Fassanian to middle Longobardian sequence (Plasencia and Márquez-Aliaga 2011).

The materials of the other species of the genus are much scarcer: (i) Pseudofurnishius shagami (Fig. 2A) 50 specimens from the late Illyrian to early Ladinian (Benjamini and Chepstow-Lusty 1986); (ii) Pseudofurnishius priscus (Fig. 2B) and P. siyalaensis (Fig. 2C) 7 and 1 specimens, respectively from the late Pelsonian of Wadi Siyala (Jordan; Sadeddin 1990 and Sadeddin and Kozur 1992); (iii) Pseudofurnishius sosioensis (Fig. 2E) 23 specimens from the Sosio Valley (Sicily, Italy; Gullo and Kozur 1989).

Institutional abbreviations.—BGU, Department of Geology, Ben Gurion University, Beer-Sheva, Israel; DGES, Department of Geology and Environmental Sciences, Yarmouk University, Irbid, Jordan; MGUV, Museo de Geología de la Universitat de València, Spain; DGG, Dipartimento di Geologia e Geodesia, Palermo, Italy.

Systematic palaeontology

For the nomenclature of the taxon Pseudofurnishius we follow that proposed by Purnell et al. (2000) and the reorientation of the element proposed by Plasencia (2009) (Fig. 3).
Review of the species included within *Pseudofurnishius*

**Anisian**

The following three Anisian species of *Pseudofurnishius* are considered valid:

*Pseudofurnishius shagami* (Benjamini and Chepstow-Lusty, 1986) (Fig. 2A).—The species, characterised by a blade-shaped neospathodid P₁ element, occurs in the lower member of the Saharonim Formation, Makhtesh Ramon, Israel. A late Illyrian to the early Fassanian age is attributed to this interval on the base of the ammonoids: *Gevanites inflatus* Parnes, 1975, *G. altecarinatus* Parnes, 1975, *Israelites ramonensis* Parnes, 1962, and *Eoprotrachyceras curionii ramonensis* (Parnes, 1986) (Benjamini et al. 2005). Its evolutionary relation with *Pseudofurnishius* is inferred from the shape of the basal cavity (Fig. 4A) and the slight curvature of the P₁ element (Plasencia et al. 2007).

*Pseudofurnishius priscus* (Sadeddin, 1990) (Fig. 2B).—The smooth, reduced platform with sigmoidal bending, and the denticles, less inclined than in any younger species of *Pseudofurnishius*, make *P. priscus* the most primitive species of the genus. The holotype (Sadeddin 1990: 374, fig. 3.1) is reported from level TJ17, Wadi Siyala (Jordan), and a juvenile specimen (Sadeddin 1990: 375, fig. 3.4) from a “Lower Longobardian” level Ab8, Wadi Naur (Jordan). Sadeddin and Kozur (1992: 361, fig. 2) modified the age of sample TJ17 to Fassanian (lower Ladinian). However, the correlation of Triassic across the Dead Sea Rift (Hirsch 1997; Benjamini et al. 2005) suggests that the Wadi Siyala section is coeval with the lower part of the Gevanim Formation of Pelsonian age in Har Arif (Israel) and that level Ab8 at Wadi Naur appears to be equivalent to the late Anisian–early Ladinian lower part of the Saharonim Formation, from where Benjamini and Chepstow-Lusty (1986) described *N. shagami*. The material was recovered from level TJ17.
of the Wadi Siyala section in Jordan, the same level from where Sadeddin (1990) described *P. priscus*. Diagnostic for *P. siyalaensis* are a broad, smooth and slightly asymmetric platform, a free ventral and dorsal blade, and a sigmoidal keel. These morphological characters differentiate *P. siyalaensis* from other *Pseudofurnishius* species, especially from *P. priscus* and *P. shagami*. The suggestion by Sadeddin and Kozur (1992) that the Fassanian *Neogondolella mostleri* (Kozur, 1980) was the ancestor of *P. siyalaensis*, based on common short asymmetric platforms, is untenable in view of the Pelsonian age of the level, in which *P. siyalaensis* occurs. The attribution of a late Ladinian P element to *P. siyalaensis* (Rigo et al. 2007: fig. 4.3b) is unlikely, as it is shorter, having a rounded anterior basal cavity, a more anterior pit and fewer posteriorly inclined denticles than the Pelsonian holotype of *P. siyalaensis*.

**Early Ladinian–early Carnian**

Apart from *Pseudofurnishius murcianus* Van den Boogaard, 1966 (Fig. 2D), the type species, several other species, and subspecies have been described: *Pseudofurnishius regularis* Budurov and Pantić, 1973 (figs. 1, 16–18); *Pseudofurnishius huddlei* Van den Boogaard and Simon, 1973 (fig. 2i); *Pseudofurnishius murcianus murcianus* Van den Boogaard, 1966 (in Gullo and Kozur 1991: pl. 5: 6); *Pseudofurnishius murcianus praecursor* Gullo and Kozur, 1991 (Kovác and Kozur 1980: pl. 2:6); *Pseudofurnishius murcianus* subspp. B of Gullo and Kozur (1991: fig. 3f); and *Pseudofurnishius sosioensis* Gullo and Kozur, 1989 (Fig. 2E). The taxonomic status of these taxa is discussed below.

**Pseudofurnishius murcianus Van den Boogaard, 1966** (Fig. 2D).—To date, specimens of *P. murcianus* were recovered from Ladinian sediments of Spain (Van den Boogaard 1966; Van den Boogaard and Simon 1973; March Benlloch 1986, 1991; Plascencia 2009), Tunisia (Rakus 1981), Egypt and Israel (Huddell 1970; Hirsch 1972; Eicher and Mosher 1974), Jordan (Bandel and Waksandumzi 1985), Slovenia (Ramovš 1977, 1978; Krivic and Stojanovic 1978; Kolar-Jurkovšek 1973), Croatia (Jelaska et al. 2003; Balini et al. 2006), Serbia (Budurov and Pantić 1973), Turkey (Nicora 1981), and Sicily (Catalano et al. 1990; Gullo and Kozur 1991). Late Ladinian to early Carnian occurrences of the species are known from the Southern Alps of Italy (Mastandrea et al. 1998; Balini et al. 2000; Jadoul et al. 2002), Dinardies (Kolar-Jurkovšek et al. 2006, Buser et al. 2008) as well as displaced terranes in Hungary (Kozur 1993) and the Cimmerian terrane of Sibumasu from South-West China (Yang et al. 2001) and Malay Peninsula (Nogami 1968; Hirsch et al. 2007; Ishida and Hirsch 2011) (Fig. 2).

In the Betic Ranges of Murcia (Spain) the section of Calasparra, one of the most complete Ladinian localities in the Iberian Peninsula, has delivered ammonoids of early and late Ladinian ages (Pérez-Valera et al. 2011). In this section, Plascencia and Márquez-Aliaga (2011) have found *P. murcianus* from the very base of the Fassanian, ranging upwards through the Ladinian. Earlier, the first appearance of *P. murcianus* in the Fassanian was suggested in Israel (Hirsch 1972; Hirsch and Gerry 1974), based on ammonoids at Makhtesh Ramon (Parnes 1962, 1975, 1986; Parnes et al. 1985). The section of Calasparra is not far from that of Fuente Aledo (Serra de Carrascoy, Murcia, Spain) from where the holotypes of *P. murcianus* and *P. huddlei* originated (Van den Boogaard and Simon 1973). The basal unit of the Calasparra section contains the *Eoprotorachyceras curionii* and *Gevanites awadi* subzones of the *E. curionii* Zone. Both subzones yield specimens of *P. murcianus* with one and two lateral platforms (Fig. 2H, I). Brack et al. (2005) established the Ladinian GSSP at the first appearance datum of *E. curionii*. That raises the Anisian–Ladinian boundary upwards, with the result that the first appearance datum (FAD) of *P. murcianus* occurs at the very base of the Fassanian. The type locality of *P. murcianus* (and *P. huddlei*) once dated as Longobardian by Kozur and Simon (1972), using ostracods, also yields the above men-

tioned Fassanian ammonites (Sanz de Galdeano 1997; Pérez-López and Pérez-Valera 2007).

The characteristic morphology of *Pseudofurnishius murcianus* consists in the variability of ornamentation of the generally larger rostral platform and occasional smaller caudal platform. Additionally, the complexity in distribution of the denticles that cover the rostral platform, directed both inward and orally, and the presence of denticles on the caudal side, frequently isolated and rarely developed as a platform create the wide morphological variability of this often asymmetrical species (Fig. 5A–I).

**Taxonomic status of *Pseudofurnishius huddlei***.—Rich samples in the early Fassanian at Calasparra and Alós de Balarager (Spain), Har Gevanim (Israel) and Wadi Naur (Jordan), as well as in the Longobardian at Henarejos (Spain) and Har Gevanim (Israel) contain both “mono-” and “bi-platform” specimens of *Pseudofurnishius murcianus* that appear without any sequential discrimination as a single taxon. The variability in the irregular pattern of distribution of denticles on both platforms is observable during growth (Fig. 5A–I). The number of blade denticles varies between five and fifteen, among which three to six on its ventral side and two to ten on its dorsal side. Starting with the cusp, located above the basal cavity tip, the denticles of the dorsal blade are large and triangular in shape with a progressively increasing dorsal inclination. The platform typically consists of only a short inner-lateral expansion with short rounded denticles pointing both inwardly and orally. Some specimens may in addition have one or more denticles located on the caudal margin. These characteristics show that *P. huddlei* is actually the mature *P. murcianus*.

**Taxonomic status of subspecies within *Pseudofurnishius murcianus* lineage***.—In their attempt to unravel variability in *P. murcianus*, Gullo and Kozur (1991) established several subspecies based on material from Sosio Valley (Sicily, Italy) that comprise (in chronological order): *Pseudofurnishius murcianus praecursor* Gullo and Kozur, 1991, that has a rostral and caudal platform, often reduced to one to four denticles or a narrow ridge; *P. murcianus murcianus* Van den Boogaard, 1966, without any denticle on the caudal side of the blade and *P. murcianus* subsp. B, with a very small platform comprising a single large denticle and occasionally one or two small additional denticles. These authors interpret this succession as the “phylo-morphogenetic” lineage of the ge-
nus Pseudofurnishius that is believed to consist in the generic evolutionary trend of reducing the extension of the platform, starting from the denticulated bi-platform species *P. huddlei* and ending-up in a single inner-lateral platform species *P. murcianus* subsp. B.

In the first place, we must stress that the establishment of subspecies, as in biology, is valid only in case of geographical isolation and incompatible with the occurrence in the same sample of several subspecies, as it is the case of the subspecies proposed by Gullo and Kozur (1991). See also Dzik and Trammer (1980).

At Bugarra (Iberian Range, Spain), Plasencia et al. (2010) found sample Bu-1-26 to contain 283 well preserved *P.* elements of several different ontogenetic stages of *P. murcianus* showing the morphological variability within a population of that species.

The comparison of total length of the element/number of blade denticles (Fig. 6A); caudal platform length; rostral platform length between points of union with the blade (Fig. 6B), and caudal platform length between points of connection with the blade (Fig. 6C), clearly evidences the continuous variability of *P. murcianus* throughout the entire population. These measurements show a correlation between development, size and number of denticles on each unit. A majority of specimens (185 specimens or 65.3%) have seven to nine denticles on the blade, three or four denticles on the triangularly shaped rostral platform (Fig. 5D, I). This scheme represents the most common morphology. When more denticles are present, the rostral platform shows a very wide variability, as denticles are added in a very irregular pattern (Fig. 5A–C, E, F). This mono-platform morphology would correspond to the type of *P. murcianus* (Gullo and Kozur 1991), while specimens with eight or nine denticles on the blade and presenting a reduced rostral platform with only one or two denticles would correspond to the morphology described as *P. murcianus* subsp. B of Gullo and Kozur (1991). Although the caudal side of most specimens is a smooth surface devoid of any kind of clearly defined structures, it however, occurs relatively frequently that one or more isolated denticles develop on this side of the blade, from almost germinal to well developed. The presence of at least one of these caudal denticles, which is the main characteristic defining *P. murcianus praecursor*, is quite common in the sample, amounting to 105 specimens or 37.1% (Fig. 5B, E, H) with between one to four denticles. Finally, 14 specimens display a well-developed caudal platform, similar in size to the rostral one, a morphology regarded typical of the species *P. huddlei* (Fig. 5C, F). Furthermore, rare elements with bilateral platforms have been found at Henarejos (Fig. 5C; Longobardian), Wadi Naur, Jordan (middle Longobardian), the Sosio Valley, Sicily (middle–late Longobardian) and at Alós de Balager (Fig. 7; Pyrenees, Fassanian), where accompanied by *Sephardiella truempyi* (Hirsch, 1971).

According to Bandel and Waksmundzki (1985), differences in development of the platform seem to correspond to different ontogenetic stages, and have little to do with the evolution. Consequently, the alleged subspecies in Gullo and Kozur (1991), as well as the species *P. huddlei* Van den Boogaard and Simon, 1973 and *P. regularis* Budurov and Pantic, 1973 correspond merely to ontogenetically more advanced forms, as also pointed out by Ramovs (1977), Bandel and Waksmundzki (1985), and Plasencia (2009).

Summing up, the analysis of the different morphologies present in sample Bu-1-26 shows the same range of morphological variability that has been observed within any normal population of *P. murcianus*, and that all the subspecies of *P.*
murcianus (and also P. huddlei) proposed by Gullo and Kozur (1991) can be identified in the same sample. These cannot be understood as stages in an evolutionary lineage according to modal values of their variability (not in typological terms) but they are parts of the ontogeny of the same species. Other populations, as those studied by Ramovs (1977), Bandel and Waksmundzki (1985), and Plasencia (2009) seem to be consistent with this conclusion.

As a second objection to the “Sosio” model of Gullo and Kozur (1991), besides the absence of a coherent description of the section with the position of the samples as evidence in support of their interpretation, the stratigraphic ranges of the successive subspecies, overlapping each other over a short “middle–late Longobardian” time span, strongly contrast with the late Anisian–early Ladinian evolution of the successive species of Pseudofurnishius and long Fassanian–Early Cordevolian range of the species P. murcianus in particular.

Pseudofurnishius sosioensis Gullo and Kozur, 1989 (Fig. 2E).—Gullo and Kozur (1989) have erected P. sosioensis, characterised by a smooth and small platform on both sides of the element, in the lower part of Torrente San Calogero section (Pietra di Salomone, Sosio Valley, Sicily), followed by bi-platform specimens of P. murcianus, which they identified as P. huddlei, and mono-platform specimens of P. murcianus, higher up in the section. Gullo and Kozur (1991) interpreted as complete “phylomorphogenetic” evolutionary lineage of the genus Pseudofurnishius, the succession of P. priscus (absent in Sosio) → P. sosioensis → P. huddlei → P. murcianus → P. murcianus praecursor → P. murcianus murcianus → P. murcianus subsp. B, shortly later split in two branches (Sadeddin and Kozur 1992) (Fig. 8A), suggesting P. sosioensis as the successor of P. priscus. The latter, based on ammonoid evidence, together with Pseudofurnishius siyalaensis are Pelsonian (Hirsch 1997) and can consequently not have derived from the Fassanian Neogondolella mostleri. The stratigraphic range of P. sosioensis from Late Fassanian to Early Longobardian may well be in continuation of the apparently closely related late Anisian–early Ladinian P. shagami, and the two are also very similar to each other, sharing the same morphological characteristics of basal cavity and denticulation. Although having rudimentary double platforms, such morphs may also represent a juvenile stage in another taxon of Sephardiellinae taxon. Lack of material however, impeaches a more accurate taxonomic attribution, here.
Evolution of *Pseudofurnishius*

Alternatively to that of Sadeddin and Kozur (1992), we recognize a well age-constrained upper Pelsonian to lower Carnian *Pseudofurnishius* lineage (Fig. 8B). Starting in the late Pelsonian—earliest Illyrian shallow Southern Tethys environments during the initial development of the “Sephardic Province”, are both *P. siyalaensis* and *P. priscus* sharing characters that fit in a possible ancestry of *P. shagami* and *P. murcianus*.

*Pseudofurnishius priscus* and *P. shagami* are so similar to each other that they may well be conspecific (Plasencia et al. 2007). The morphology of the basal cavity of *P. shagami* and *P. murcianus* (Fig. 4) suggests a close evolutionary relationship between both species. As the most successful species of the genus, *P. murcianus* persisted during the whole Ladinian, until its extinction at the beginning of the Carnian.

*Mosherella* may have originated from *Pseudofurnishius*, as proposed by Kozur (1972), based on the similarities of the blade shape and the basal field in both genera that from the point of view of morphological resemblance is plausible. We must, however, bear in mind that neospathodid morphs originated recurrently as a result of paedomorphosis, presumably in connection to sea level changes (Dzik and Trammer 1980; Hirsch 1994). *Mosherella*, may thus be a neospathodid that resulted from paedomorphosis, a phenomenon recurring with *Neocavitella* (Sudar and Budurov 1979).

Conclusions

- *Pseudofurnishius* is a late Anisian–early Carnian conodont genus characteristic for its occurrence in the “Sephardic Province” and restricted to the Southern Tethys.
- *Pseudofurnishius murcianus* appears in the early Fassanian; it ranges from the Fassanian to the Longobardian characterised by the presence of both “mono”- and “bi-platform” specimens, invalidating the species *P. huddlet*.
- The same morphological varieties found in large Fassanian and Longobardian *P. murcianus* populations are ontogenetical stages of one and the same species. They cannot be understood as stages in an evolutionary lineage.
- Derived from an unknown gondolellid ancestor, the lineage *Pseudofurnishius priscus* → *P. shagami* →*P. murcianus* is proposed.
- During the late Ladinian, *Pseudofurnishius* expanded beyond the “Sephardic Province”, spilling over to the Southern Alps and to the Cimmerian terranes as they drifted away from Gondwana.

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References


