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Sieve-type pore canals in the Timiriaseviinae—A contribution to the comparative morphology and the systematics of the Limnocytheridae (Ostracoda, Crustacea)

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Innovation comes only from the assault on the unknown
Sydney Brenner Nobel Lecture 2002 (Brenner 2003, p.281)

Abstract

Examination of normal pore canals, especially sieve-type pore canals, in living and fossil representatives of ten genera of the family Limnocytheridae, subfamily Timiriaseviinae, has revealed important diversity of structure. These complex pore canals have been studied via high-resolution scanning electron microscopy (the Cartographic Method) and analysed via the application of newly devised indices to assess patterns of consistency and variation in both detailed structure of individual pores and of their distribution on the calcified valve. The timiriaseviine taxa are compared with species of the genera *Limnocythere*, sub-family Limnocytherinae and *Cyprideis* (family Cytherideidae). The relationship between the living animal and its aquatic environment is discussed in the light of previous studies and of new evidence herein. The importance of normal pore canals for systematics is highlighted by the recognition and definition of the new tribe Gomphodellini Danielopol, Cabral & Lord nov. tribe, subfamily Timiriaseviinae, family Limnocytheridae.

Key words: Non-marine ostracods, valve morphology, systematics, Gomphodellini Danielopol, Cabral & Lord nov. tribe

Introduction

The idea of the Sieve-type Pore Canals (StPC) project

Pores of different sizes are commonly visible on the surface of ostracod carapaces. Such minute openings are the outlet of canals which traverse the calcified procuticular layer of the valves. Numerous sensorial setae emerge through the pores at the surface of the valves. Other pores represent either the outlet of glandular structures or are openings of simple invagination of the epicuticle that protrudes deeper into the valve's calcified wall. The first volume of the Hartmann's monograph "Ostracoda in the "Bronns Klassen und Ordnungen des Tierreichs (Hartmann 1966) offers details on these morphological structures.

A special type of pore canal visible on the valves of the dominant marine ostracod group the suborder Cytherocopina is represented by a cluster of valve perforations continuing within the valve-wall and in many cases surrounding a sensorial seta. Müller (1894, p. 104) made a first description for such structures that he named "siebförmigen Porencanäle", nowadays termed in English "Sieve-type Pore Canals" (StPC). Note that ostracodologists distinguish between two major types of pore canals, namely the "normal pore canals that cover the surface of the valve, and the "marginal ones that generally traverse the fused zone of the valve duplicature (Athersuch *et al.* 1989; Yamada 2007). The Sieve-type Pore Canals belong to the former group. These morphologic structures differ from the simple normal pores that are visible on the valves. On fossil valves normal pore canals, both simple perforations and in the form of sieve-plates, are visible on the outer side of the calcitic wall and in some cases as large holes on the inner side (Figs 1A–B, 2).

Cytherocopina belong to the most widely spread and taxonomically diverse post-Palaeozoic ostracod group, the order Podocopida (for a recent treatment of the systematic framework of Ostracoda, see Horne *et al.* 2002). Within the marine domain, cytherocopine taxa, as free-living crustaceans, display high species diversity, i.e. thousands of species have been recorded from Late Palaeozoic sediments through to the present (Kempf 1986; 1995). The situation is different for the non-marine domain where the dominant group of free-living ostracods is represented by the suborder Cypridocopina. The number of cytherocopine species that colonised non-marine habitats is lower than those known for the marine realm (Kempf 1980; 1997). The Limnocytheridae, represented by two taxonomically different groups, the Limnocytherinae and the Timiriaseviinae, is nowadays the most diverse free-living non-marine cytherocopine group. One hundred and fifty-eight Recent (or extant living) species have been recorded (Martens & Savatenalinton 2011), of which 67 are Timiriaseviinae. The number of fossil taxa presumed to belong to the Timiriaseviinae is much higher than those reported for the living timiriaseviines (Kempf 1980; 1997; Karanovic & Humphreys 2014). This is partly due to the difficulties in characterising taxonomically fossil timiriaseviines (discussion inter alia in Whatley *et al.* 2002; 2003). Hence, the search for new morphological traits with potential application for systematics of the Limnocytheridae is a preoccupation for ostracodologists dealing with non-marine fossil material.

One of the prominent specialists of Timiriaseviinae, the late Jean-Paul Colin, during the 17th International Symposium on Ostracoda (ISO) in Rome 2013, suggested a project on the sieve-type pore canals of this group having in mind that their positions on the valves could be important for taxonomic characterization. This present study deals mainly with the subject proposed by Jean-Paul Colin; it is an homage to our colleague and friend who passed away in 2013, soon after the end of the 17th ISO.

Since the description of the StPC, more than one hundred years ago, studies on the sieve-plates became more and more frequent. Three research directions developed, namely studies on the morphology of these sieve-plates, studies related to the practical usage of the StPC for taxonomic purposes, and finally studies related to the role of these structures for sensing the environmental quality of the surrounding water.

Considering the ostracods of the Timiriaseviinae, one finds only occasional records of StPC without any interpretation of their importance for the taxa to which they belong (Karanovic 2006; 2009). The same situation exists for the ostracods of the Limnocytherinae where the StPC were seldom mentioned and/or figured (Whatley & Cholich 1974; Martens 1989; 1990; Danielopol *et al.* 1989; Fürstenberg *et al.* 2015). Our recent research on StPC convinced us that their morphologic details are useful as diagnostic traits for identification of various Limnocytheridae taxa. A preliminary presentation of StPC data for the Limnocytheridae was given to the 25th Meeting of the "Ostracodologistes de Langue Française" (ROLF), 2014 in Perpignan. Here we present new information on this topic, stressing again the obvious interest of StPC for a precise characterization of the non-marine Ostracoda Limnocytheridae at various levels of their systematic hierarchy.

Puri & Dickau (1969), in a seminal paper, offered a synthesis on the various types of normal pores (Fig. 3). They recognized three classes of pores, which they classified in four groups, named with letters from A to D. The A type represents simple pores from which a seta emerges, the B type corresponds to StPC devoid of seta, the C type combines a pore with seta inserted within the area of StPC, finally the D type is a combination of the previous types A and B.

Our topic here deals mainly with the so-called normal pores of type B. For comparative purposes we will also give information on the normal pores of type A and type C. The last part of our contribution proposes improvements to the systematics of the subfamily Timiriaseviinae and a new approach to the examination of the putative functional role of the sieve-type pore canals.

The taxonomy of the family "Limnocytheridae Sars, 1925"—In need of improvement

Our readers will be surprised to see that the priority for authorship of the taxon Limnocytheridae does not belong to W. Klie (cf. "Die Tierwelt Deutschlands", Klie 1938, p. 149) as one finds commonly in compendia dealing with taxonomic systems of Ostracoda, but to G.O. Sars (Sars 1925, p. 148). This latter author derived the name of his new taxon from the misspelled name *Limnicythere* proposed by G.S. Brady in "A monograph of British Ostracoda", communicated first in 1866 at the Linnean Society (Brady 1868a, p. 419). But in the same year Brady published "A synopsis of the Recent British Ostracoda" in the journal "Intellectual Observer" where the correct name *Limnocythere,* with the type species *L. inopinata* Baird*,* was clearly proposed as a new genus (Brady 1868b, p. 121). So in the case of the priority of the term Limnocytherinae and its subsequent elevation to the family rank, Limnocytheridae, when corrected for misspelling (Sars 1928, Annex Corrections, p. 6), and following the International Code of Zoological Nomenclature, Article 19.2 (ICZN 2000, p. 21), the authorship and date of the original name is Sars, 1928. Therefore this year correction needs to be adopted for taxonomic studies.

A consistent diagnosis for the family Limnocytheridae was provided by Meisch (2000, p. 424). There are several morphological traits of the limbs that characterise the Limnocytheridae: (1) the fused distal antennular aesthetasc with one distal seta; (2) the presence of three claws on the distal endopodial segment of the antenna; (3) presence on the limbs P5 to P7 (cf. for the nomenclature of those limbs Horne *et al*. 2002, p. 11) of the distal claw fused with the 4th endopdial segment; (4) on the posterior side of this latter endopodial segment a minute seta is always present and visible only with high microscope magnification (Danielopol 1969; Martens 1990; Karanovic 2006).

Danielopol (1965) used both morphology of the limbs (antennae) and the carapace structure to divide the subfamily Limnocytherinae Sars (what is now considered the family Limnocytheridae) into two tribes, the Limnocytherini Sars and the Metacyprini Danielopol. Later on it appeared that the name Metacyprini was a synonym for what Mandelstam (1960) named Timiriaseviinae. Colin & Danielopol (1978) separated the Limnocytheridae into two subfamilies, the Limnocytherinae Sars, 1925 and the Timiriaseviinae Mandelstam, 1960. Initially, this latter taxon was placed in the family Cytheridae Baird (Mandelstam 1960, p. 372). There are two diagnostic traits offered by Mandelstam which allow the recognition of Timiriaseviinae: (1) the dimorphism of the carapace (i.e. the female is larger than the male and the posterior part is inflated due to the development of a brood pouch) and (2) the reduced development of the carapace hinge. We know nowadays that Limnocytherinae display generally a different carapace dimorphism, namely the male is generally larger than the female and the female does not display a brood pouch. During the last years the identification criteria for the Timiriaseviinae became more complicated because in several cases there are species where the female does not display a carapace with well inflated posterior, the typical dimorphism mentioned above and/or with different lengths of valves (i.e. female valves are longer than those of the male). Such cases were mentioned for species belonging to the genera *Gomphocythere* (Martens 1993; Boomer & Gearey 2010; Külköylüoğlu *et al.* 2015), *Dolekiella* (Gidó *et al.* 2007) and *Elpidium* (Danielopol *et al*. 2014). Therefore we need an additional morphological trait to characterise one or the other subfamily when one has only the hard parts of the ostracod, as in the case of any micropalaeontological research. This objective will be here fulfilled using morphological aspects of the StPC.

For the living species there are two other morphological traits which discriminate between the two subfamilies of the Limnocytheridae:

1   The distal lobe of the hemipenis in the Timiriaseviinae is articulated and moveable, while in the Limnocytherinae it is immobile being fused to the hemipenis body (Martens 2003, p. 126).

2   Hartmann & Puri (1974, p. 28–29) mention a second key diagnostic trait which allows discrimination of living Limnocytherinae from those belonging to Timiriaseviineae, namely the special position of the posterior (ventral in the terminology of the authors) antennular seta on the 2nd segment, the so-called *p2* seta. The Limnocytherinae have it at the distal corner of the segment (cf. here Fig. 4A, for *Limnocythere inopinata*). Timiriaseviinae have this seta inserted proximally on the 2nd segment (Fig. 4B for *Cytheridella ilosvayi* Daday (sensu lato).

Karanovic (2006, p.102) noticed that Australian species of the genus *Gomphodella* (Timiriaseviinae) have no seta on the inner side of the 2nd segment of the antennule (cf. here *G. maia* De Deckker, Fig. 4C). This obliges us to emend the diagnosis of the subfamily Timiriaseviinae including also the case of the absence of this antennular seta. It determined us also to look for new morphological traits that allow recognition of representatives of the genus *Gomphodella* using only valve traits.

The recent detailed description by Fürstenberg *et al.* (2015) of the limbs of *Leucocytherella sinensis* Huang, a species known until then only from the calcareous valves of Recent and fossil material (Frenzel *et al.* 2010), obliges us to emend the diagnosis of the family Limnocytheridae: *L. sinensis* bears on the antenna at the distal segment of the endopodite only two claws (Fürstenberg *et al.* 2015, Figs 11–2, 5, 6; 12–4) instead of three claws as in all the living species of this family. Therefore one has to expand the diagnosis to "antenna with two or three distal claws". The presence of a proximal seta on the posterior side of the protopodite of the same antenna (Fürstenberg *et al.* 2015, Figs 11–2, 12–4) obliges taxonomists to revise the systematic position of this species considered by these authors to belong to the Limnocytherinae, tribe Leucocytherini.

Karanovic (2012, p. 126) noted that the genus *Limnocytherina* (Negadaev-Nikonov 1967), proposed for the Quaternary species *Limnocythere manjtschensis* Negadaev-Nikonov, cannot easily be differentiated from the genus *Limnocythere* using the traits of the valves. Therefore in her monograph "Recent freshwater ostracods of the world" (Karanovic 2012) proposed to keep species assigned to this genus (e.g. *Limnocytherina sanctipatricii* Brady & Robertson) in the widely accepted genus *Limnocythere* Brady until a review of the Negadaev-Nikonov genus can be undertaken. This idea was discussed by Dykan (2006, p. 107–108) who pointed out that Negadaev-Nikonov (1967; 1968) had mistakenly considered the male dimorphic valves of *Limnocythere sanctipatricii* as belonging to a supraspecific taxon *Limnocytherina*. For the present project we examined carefully the description of *Limnocytherina* in the two publications of Negadaev-Nikonov previously mentioned and we can confirm that *Limnocytherina* is a synonym for *Limnocythere* and therefore should be abandoned. In the following sections we will treat *L. sanctipatricii* as a member of the genus *Limnocythere*.

Another aspect related to improvement of the Limnocytheridae taxonomy is the need of improved differential diagnoses based on new and/or better morphologic traits. This is clearly the case for the genus *Cytheridella* Daday where such character-traits as the "hinge adont" is no longer adequate as such a trait occurs in other related genera like *Elpidium* (Karanovic 2012). New or better morphologic traits require research and incorporation, in addition to information on the origin and evolutionary pathway of the trait. Taking as an example *Cytheridella*, it appears to us that the simplified definition of the 7th limb as a reduced organ (cf. diagnosis of Karanovic 2012) is not enough, because the structure of the 7th limb represents a unique evolutionary trait due to the transformation of the distal part of the endopodite into a pincer type structure by the co-option of setae and the distal endopodial segments in both the female and the male (Colin & Danielopol 1980, Figs 1E–F). This impressively complicated morphological trait occurs in *Cytheridella* species from the Americas and from Africa (information in Rome & De Deckker 1977; Victor 1977). It now becomes necessary to investigate the details of the 7th limb of the various Recent *Cytheridella* species in order to look for possible subtle differences that one expects to exist, suspecting that this complex trait is the product of a long evolutionary history. Colin *et al.* (1997) documented from non-marine Upper Cretaceous sediments of Mali a *Cytheridella* species that presents a strong sexual dimorphism of the carapace similar to those one finds in Recent species.

In the present contribution we use the principle of taxonomic harmonisation (Danielopol *et al.* 2015) when discussing the systematic status of *Cytheridella ilosvayi* Daday, 1905. This species was originally described from Paraguay (Daday 1905) and further recorded through the whole Neotropics (Cohuo *et al.* 2017). Recently Wrozyna *et al.* (2016) reported the existence of several morphotypes of *C. ilosvayi* which differ from a closely related

species *C. danielopoli* Purper (sensu Gross *et al.* 2013). In order to avoid the difficulties of taxonomic identification of those morphotypes (possibly some of them are new species) we will treat taxonomically *Cytheridella ilosvayi* (*sensu lato*) with the connotation of a "consensus species" as proposed by Danielopol *et al.* (2015) for similar "harmonised taxa".

If one goes a step further, we have to note that within the subfamily Timiriasevinae Mandelstam, Danielopol & Martens (in Danielopol *et al.* 1989) recognised two tribes, the Timiriaseviini Mandelstam, 1960 and the Cytheridellini Danielopol & Martens, 1989.

In our discussion of the necessary improvements of diagnostic traits used for identification of Limnocytheridae one of us (AL) suggested that ostracodologists should pay attention also to morphologic traits that are poorly documented and for which we have little morpho-functional information. This problem arises for instance with morphologically distinct setae emerging from two of the A pores (Fig. 5) named A1 and A2 by Puri & Dickau (1969). These setae, covering the valves of living Cytheridellini, were first illustrated by De Deckker (1981, Fig. 26). The cartography of the A2 pores and setae is interesting, as we noticed for different representatives of the subfamily Timiriaseviinae, in that they have a stable location on valves (Figs 6V-2, 7A–C), a fact that was observed by Wrozyna *et al.* (2016) who studied various *Cytheridella* populations from the Americas. Therefore, A2 pores and setae can be considered homologous traits, sensu Slice *et al.* (2016). They are potentially useful in geometric morphometrics and systematics (Wrozyna *et al.* 2016).

Before concluding this section it is important to stress the contribution of Sames (2011) to the morphology and systematics of the subfamily Timiriaseviinae. Our colleague proposed a useful protocol for the detailed description of the valves and carapaces combining the elementary morphological traits, like tubercles or pores, with sections of the valve's outline. Considering the aspects of outline, it is emphasised in Sames (2011) the necessity to consider both the details of the curvature line of the valves or the carapace (an idea taken from Lüttig 1962) and those of the marginal line, which in the case of Timiriaseviinae are partly superimposed (Sames 2011, Text-figs 5–6).

Studied material

Abbreviations: V = Valve; LV = Left Valve; RV = Right Valve; C = Carapace; m = adult male; f = adult female; j = juvenile; E = External side; I = internal side; Recent = live specimens.

"*Leptocythere*" sp. Triebel, 1941

Age: Bathonian, Middle Jurassic.
Locality: Hambühren WA2, NW Germany.
Study material: numerous f and m and juvenile V and C.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23703 and 23704.
Remarks: Not a leptocytherid in the modern sense. An adult V and fragment (?both f) figured as example of ancient StPC.

Gomphocythere Sars, 1924

Gomphocythere besni Külköylüoğlu, Yavuzatmaca, Cabral & Colin, 2015
Age: Recent.
Locality: man-made pool, Besni, Adiyaman, Turkey.
Study material: 2 Cf, 2 Cm.
Repository: University of Lisbon, Catalogue OK-AD-2012: 09–12.
Remarks: Study material derived from sample with 48 C, 35 with limbs, stored in the Department of Biology, Abant İzzet Baysal University, Bolu, Turkey (Külköylüoğlu *et al*. 2015). *G. besni* is the reference descriptive model for this present study and represents a group of species whose adult females display only a moderate posterior inflation.

***Gomphocythere* sp. (aff. *G. angulata* Lowndes, 1932)**
Age: Quaternary.
Locality: Lake Bogoria, Kenya; Hannington S1 core.
Study material: 2 LVf, 1 RVf.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211475.
Study material: 1 LVm, 1 RVm.
Repository: University of Bordeaux, UMR CNRS, EPOC, Catalogue C.O. 6016–6017.
Remarks: Typical *Gomphocythere* with posterior inflation; differs from *G. angulata* Lowndes *sensu-stricto* by a thin longitudinal ridge on the ventral side and which in dorsal view is obscured by the valve curvature, whereas in *G. angulata* (Lowndes 1932, Figs 1 and 2) a ridge is visible in the central third in dorsal view. Host sediments had a strongly alkaline chemical signature (Carbonel *et al*. 1987).

***Gomphocythere* sp. (aff. *G. alata* Rome, 1962)**
Age: Recent.
Locality: Cameron Bay, SW Lake Tanganyika, Zambia.
Study material: 2 LVf.
Repository: University of Bordeaux, UMR CNRS, EPOC, Catalogue C.O. 6100.

***Cytheridella* Daday, 1905**

***Cytheridella ilosvayi* Daday, 1905 (sensu lato)**
Age: Quaternary.
Locality: Wallywash Great Pond, Jamaica; WGP core site of Holmes (1998, Fig. 2).
Study material: 1 Cm, 1 Cf, 1 LVf, 1 RVf.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211257.
Age: Holocene, < 5ka.
Locality: Laguna Tuspan, Petén, Guatemala (see Fleury *et al.* 2016).
Study material: 1 Cf, 1 LVf.
Repository: University of Bordeaux, Catalogue UMR CNRS, EPOC, Catalogue C.O. 6000.
Age: Recent.
Locality: Eirunepé, northern Brazil (Gross *et al*. 2013).
Study material: 1 RVf, 1RVj, 1 LV j.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 210903.
Age: Recent.
Locality: Shell Creek, Peace River, Florida, USA.
Study Material: 1 RVf.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 210903.
Remarks: (1) Widely distributed in Neotropics: Paraguay (Daday 1905), Brazil (Purper 1974; Gross *et al*. 2013; Wrozyna *et al*. 2016), Central America (Mexico, Guatemala—Pérez *et al*. 2010; Wrozyna *et al*. 2016), Jamaica (Holmes 1997; 1998), Cuba (= *Cytheridella* sp. in Colin & Danielopol 1980), Florida (Keyser 1976; Teeter 1980; Wrozyna *et al*. 2016). (2) We provide a scanning electron microscope (SEM) image of RVf from the same Brazilian population used by Purper (1974) from near Porto Alegre to redescribe *C. ilosvayi* to verify our identifications (material stored in the Museu de Paleontologia da Universidade Federal do Rio Grande do Sul—Fig. 4D (herein) of valve MP-O-314 provided by Cristianini Trescastro Bergue).

***Cytheridella boldi* Purper, 1974**
Age: Recent.
Locality: Lake Valencia, Venezuela (coll. W.A. Van Den Bold).
Study material: 1 RVf, 1 LVf.
Repository: Museu de Paleontologia da Universidade Federal do Rio Grande do Sul, Brazil, Catalogue MP-O-320 (RV f), MP-O-321 (LV f), paratypes of Purper (1974).

Remarks: Valves of *C. boldi* display minimal differences as compared to the lectotype of *C. ilosvayi* designated by Purper (1974). The posterodorsal curvature of the RVf in lateral view is less arched than in *C. ilosvayi* (cf. Figs 4D with 4E herein). This detail was mentioned by Purper in her description for this species (Purper 1974, p. 654), but the valve was not illustrated. We figure the lateral view of this valve for the first time. Additionally we illustrate a StPC (Fig. 4F), a detail which was not considered by Purper (1974) in her *C. boldi* description. The minimal difference of the dorso-posterior curvature of the valve between *C. ilosvayi* and *C. boldi* suggests that the latter taxon is probably a junior synonym of the former and should be treated as *C. ilosvayi* (sensu lato).

Cytheridella gantensis Monostori, 1975
Age: Lutetian, Eocene.
Locality: Gánt, Transdanubian Mountains, Hungary.
Study material: 1 RVf, 1 LVf, 2 RVm, 1 LVm
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 213874.
Remarks: see Monostori (1975; 1993).

Cytheridella chariessa Rome, 1977 (in Rome & De Deckker 1977)
Age: Recent.
Locality: shore Lake Kivu, Bukavu-Goma, Democratic Republic of Congo
Study material: 1 RVf, 1 LVf, 1 RVm, 1 LVm.
Repository: Royal Museum of Natural History, Brussels.
Remarks: SEM-images supplied by Koen Martens.

Gomphodella De Deckker, 1981

Gomphodella maia De Deckker, 1981
Age: Recent.
Locality: Turner Springs, Margaret River, Western Australia (coll. S. Eberhard).
Study material: 2 LVf, 2 RVf.
Repository: Western Australian Museum, Perth, Catalogue C28409.
Remarks: Type species of the genus, described from oligohaline Dip Lake, South Australia, and freshwater habitats (De Deckker 1981). Genus and its type species redefined by Karanovic (2006) who has more recently pointed out the peculiar morphology of the antennule, which lacks a seta on the posterior side of the 2nd antennular segment (Karanovic 2012). Turner Springs has variable salinity from freshwater to slightly saline (Eberhard 2004).

Gomphodella aura Karanovic, 2009
Age: Recent.
Locality: Yule River, Yandeyarra Reserve, Pilbara, Western Australia (subterranean aquatic habitat—borehole YAN13).
Study material: 1 Cf, 4 LVf, 4 RVf.
Repository: Western Australian Museum, Perth, Catalogue C72677.
Remarks: See Karanovic (2009) for morphological details and Eberhard *et al*. (2005) for a review of the unique Pilbara stygobitic fauna.

Gomphodella quasihirsuta Karanovic, 2009
Age: Recent.
Locality: Uaroo Station, east of Rouse Creek, Pilbara, Western Australia (subterranean aquatic habitat—borehole UAR002).
Study material: 1 LVf (without soft parts).
Repository: Western Australian Museum, Perth, Catalogue C72676.
Remarks: Type locality of *G. quasihirsuta*. See Table 17 where the ionic composition of the water points to a higher salinity than the water where *G. aura* was sampled. This point is important for discussion of StPC in relation to water chemistry.

***Theriosynoecum* Branson, 1936**

***Theriosynoecum fittoni* (Mantell, 1844)**
Age: Early Cretaceous.
Locality: Compton Bay, Isle of Wight, U.K.
Study material: 1 LVm, 2 LVf, 1 LVj.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23705.
Remarks: Strongly dimorphic species. Material matches description given by Sohn & Anderson (1964, text-figures 1a and 3i) who defined a lectotype. Surface ornament differs from that of North American material figured by Sames (2011, plates 1 & 2)

***Theriosynoecum kirtlingtonense* Bate, 1965**
Age: Oxfordian, Late Jurassic.
Locality: Kirtlington, Oxfordshire, U.K.
Study material: 1 LVf, 1 RVm.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23706 and 23707.
Remarks: Type locality. Originally dated as Bathonian.

***Theriosynoecum* sp.**
Age: Bathonian, Middle Jurassic.
Locality: Lathen 8, NW Germany.
Study material: 1 Cf, 1 RVf.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23708 and 23709.
Remarks: Probably new species.

"*Theriosynoecum*" *pygmaea* Stoica, 2007
Age: Early Cretaceous (? early Berriasian).
Locality: Nazarcea, southern Dobrodgea, Romania.
Study material: 1 RVf, 3 LVf.
Repository: Department of Geology, Faculty of Geology and Geophysics, University of Bucharest, Micropalaeontology Collection, Catalogue 0321.
Remarks: The generic assignment requires review.

***Theriosynoecum fluxans* Helmdach, 1972, *T. helmdachi* Sohn, 1982**
Age: Oxfordian, Late Jurassic.
Locality: Pedrógão, western Portugal.
Remarks: Valves of Portuguese material of these two species were examined but StPC not observed due to recrystallisation. See Azerêdo *et al.* (2002), Pais *et al.* (2016).

***Sinuocythere* Colin, Cabral, Dépêche & Mette, 2000**

***Sinuocythere pedrogaensis* Cabral & Colin, 2000 (in Colin *et al.* 2000)**
Age: Oxfordian, Late Jurassic.
Locality: Pedrógão, western Portugal.
Study material: 1 LVf.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23601.
Remarks: Type locality. Other C and V examined but no StPC observed externally or internally due to recrystallisation.

***Sinuocythere sinuosa* (Mette, 1995)**
Age: Callovian, Middle Jurassic.

Locality: Tataouine, Tunisia.
Study material: 1 Cf.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23710.
Remarks: Type species, type locality. Other C and V examined but no StPC observed externally or internally due to recrystallisation.

Timiriasevia **Mandelstam, 1947**

Timiriasevia mackerrowi **Bate, 1965**
Age: Oxfordian, Late Jurassic.
Locality: Kirtlington, Oxfordshire, U.K.
Study material: 1C.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23711.
Remarks: Type locality.

Timiriasevia guimarotensis **Schudack, 1998 (in Schudack *et al.* 1998) and *T.* aff. *uptoni* Timberlake, 1988**
Age: Oxfordian, Late Jurassic.
Locality: Serra do Bouro, central-western Portugal.
Remarks: Valves and carapaces of Portuguese material of these two species were examined but StPC not observed due to recrystallisation. See Azerêdo *et al.* (2010).

Metacypris **Brady & Robertson, 1870**

Metacypris cordata **Brady & Robertson, 1870**
Age: Recent.
Locality: Lake Caldarusani, Floating fen, near Bucharest, Romania.
Study material: 1 RVf, 1 LVf .
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211256
2 RVf, 2 LVf, 1 Cf, 2 Cj.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211476.
Age: Late Holocene.
Locality: Lake Wigry, NE Poland, core W4 (12–16 cm).
Study material: 2 RVf, 2 LVf.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211477.
Remarks: *M. cordata* has a wide distribution in Europe (Löffler & Danielopol 1978) and occupies shallow limnic and/or semi-terrestrial habitats (Meisch 2000). With its cordiform carapace shape *Metacypris* resembles fossil *Timiriasevia* and Recent *Gomphocythere*, thus pioneers such as Grékoff (1958) and Pinto & Sanguinetti (1961) made comparative studies of these genera. More recently Colin & Danielopol (1980) reviewed the taxonomy and biogeography of *Metacypris*, and Danielopol *et al.* (1996) discussed the ecology of *M. cordata*.

Kovalevskiella **Klein, 1963**

Kovalevskiella **sp**.
Age: Recent.
Locality: Eberschüttwasser, Lobau, Vienna, Austria.
Study material: 1 LV f, 1 RV f, 1 A-1j.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211479.
Remarks: Sampling area B of Danielopol *et al.* (2001, Fig. 4), groundwater well "E". New species awaiting description (DLD).

***Rosacythere* Colin, 1980 (in Colin & Danielopol 1980) emend. Colin & Carbonel, 1996**

***Rosacythere lacobrigensis* Cabral & Colin, 1998**
Age: early Aptian, middle Cretaceous.
Locality: Praia da Luz, near Lagos, southern Portugal.
Study material: 1 Cm.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23589.
Remark: Type locality.

***Dolekiella* Gidó, Artheau, Colin, Danielopol & Marmonier, 2007**

***Dolekiella europaea* Gidó, Artheau, Colin, Danielopol & Marmonier, 2007**
Age: Recent.
Locality: Calmeilles, SW France.
Study material: 1 LVf, 1 RVf (paratypes).
Repository: Natural History Museum, Vienna, Crustacea Department, Catalogue 20713.
Remarks: Stygobitic species from groundwaters of rivers Tech, Têt and Réart. See Gidó *et al.* (2007), and additional ecological information in Danielopol *et al.* (2009).

***Limnocythere* Brady, 1868b**

***Limnocythere sanctipatricii* Brady & Robertson, 1869**
Age: Late Holocene.
Locality: Lake Wigry, NE Poland, core W8 (1–3 cm).
Study material: 1 RVm, 1 LVm, 1 RVf.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211474.
Remarks: Widely distributed in Holarctic (Meisch 2000). Stored with *L. inopinata* material Catalogue UMJG&P 211474.
Age: Recent
Locality: Lake Mondsee, Upper Austria.
Study material: 1 LVm, 1 RVm.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211478.

***Limnocythere inopinata* (Baird, 1843).**
Age: Late Holocene.
Locality: Lake Wigry, NE Poland, core W4 (0–4 cm).
Study material: 1 LVf.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211474.
Remarks: Widely distributed in Holarctic (Meisch 2000).

***Cyprideis* Jones, 1857**

***Cyprideis torosa* (Jones, 1850)**
Age: Recent.
Locality: Carrasqueira, Sado Estuary, SW Portugal.
Study material: 1 LVm, 1 RVf, 1 RVm.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23712.
Remarks: Sample CAR-P1, Spring, see Cabral *et al.* (2017). Salt marsh with high salinity (30.9–41.7 ‰) in spring (May 2006) when sample collected.

Age: Recent.
Locality: Melides Lagoon, SW Portugal.
Study material: 1 RVm, 1 LVf, 1 RVm.
Repository: Senckenberg Museum Frankfurt, SMF Xe 23713 and 23714.
Remarks: Samples MEL-6, Winter and MEL-7, Winter, low salinity 15.1 ‰ and 8.5 ‰ respectively, in winter (February 2015) when samples collected; see Cabral *et al.* (2017).

***Cyprideis americana* Sharpe, 1908**
Age: Recent.
Locality: Parrotee Pond, SW Jamaica.
Study material: 1 RVf, 1 LVm.
Remarks: (1) SEM-images supplied by J. Meyer. The valves were further used for isotope analyses at the Institute of Earth Sciences, University of Graz. (2) The species lives in waters with high ionic concentration. Parrotee Pond is a coastal lagoon with salinities >20, high electrical conductivity (ca. 35,600 µS/cm), very high chloride concentrations (12,597 mg/l) and oversaturated with calcite (Meyer *et al*. 2017).

***Cyprideis ituiae* Gross, Ramos & Piller, 2014**
Age: Miocene.
Locality: Sucuriju, Rio Itui, western Amazonia, Brazil; core 1AS-10-AM.
Study material: 2 LVm.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211038.
Remarks: Main material in Museu Paraense Emílio Goeldi, Belém, Brazil.

***Cyprideis munoztorresi* Gross, Ramos & Piller, 2014**
Age: Miocene.
Locality: Sucuriju, Rio Itui, western Amazonia, Brazil; core 1AS-10-AM.
Study material: 1 LVm.
Repository: Universal Museum Joanneum, Graz, Catalogue UMJG&P 211038.
Remarks: Main material in Museu Paraense Emílio Goeldi, Belém, Brazil.

Methodology

Sieve-type Pore Canals—Descriptive aspects

Abbreviations: NPC = Normal Pore Canals; A (A1, A2), B, C, D = Normal pore types following the nomenclature of Puri & Dickau (1969); R, O, I = Round (or subround), Oblong, Irregular shapes of StPC; le1 and le2 = length of Ellipse axis 1 (length) and 2 (width) for computation of Oblong-shape areas; SI = the Size Index; TAT-S-StPC = Total Area of Tubuli for Standardised StPC; DI = the Distance Index; Mean CL95% = Arithmetic mean with 95% Confidence Limits.

    We will use as an introduction to the descriptive aspects of StPC data derived from the material of Erich Triebel published as "*Leptocythere*?" sp. (Triebel 1941). This material allows a very good visualisation of the general morphology of StPC. Figures 1A–B (cf. black arrows) show well defined areas with minute pores. These latter open in the valve's wall at approximately right angles as thin, round tubules (Latin name commonly used, tubuli). They display a diameter of about 1 µm or less, and open on the inner side of the valve, within a bell-shaped cavity (Figs 2A–D). We name such morphologic entities Sieve-type Pore Canals (StPC). Such morphologic entities are randomly dispersed on the valves' wall and are mainly visible on the lateral side of the ostracod carapace. On ornamented valves with fossae surrounded by muri, StPC are generally located on the tectum (Latin name meaning roof, here used for the upper place of the muri) and only seldom occur as isolated entities on the solum of the fossae (see below for definition of the terms for valve ornamentation used here). In most cases the tubules of StPC are placed in well delineated areas, mainly of round shape (see below).

    The morphology of the StPC contrasts with the simple "normal" pores which display generally a diameter

larger than one micron (see Figs 1A–B, white arrows). These latter pores bear also a seta visible on living ostracod valves; such seta are rarely preserved as fossils.
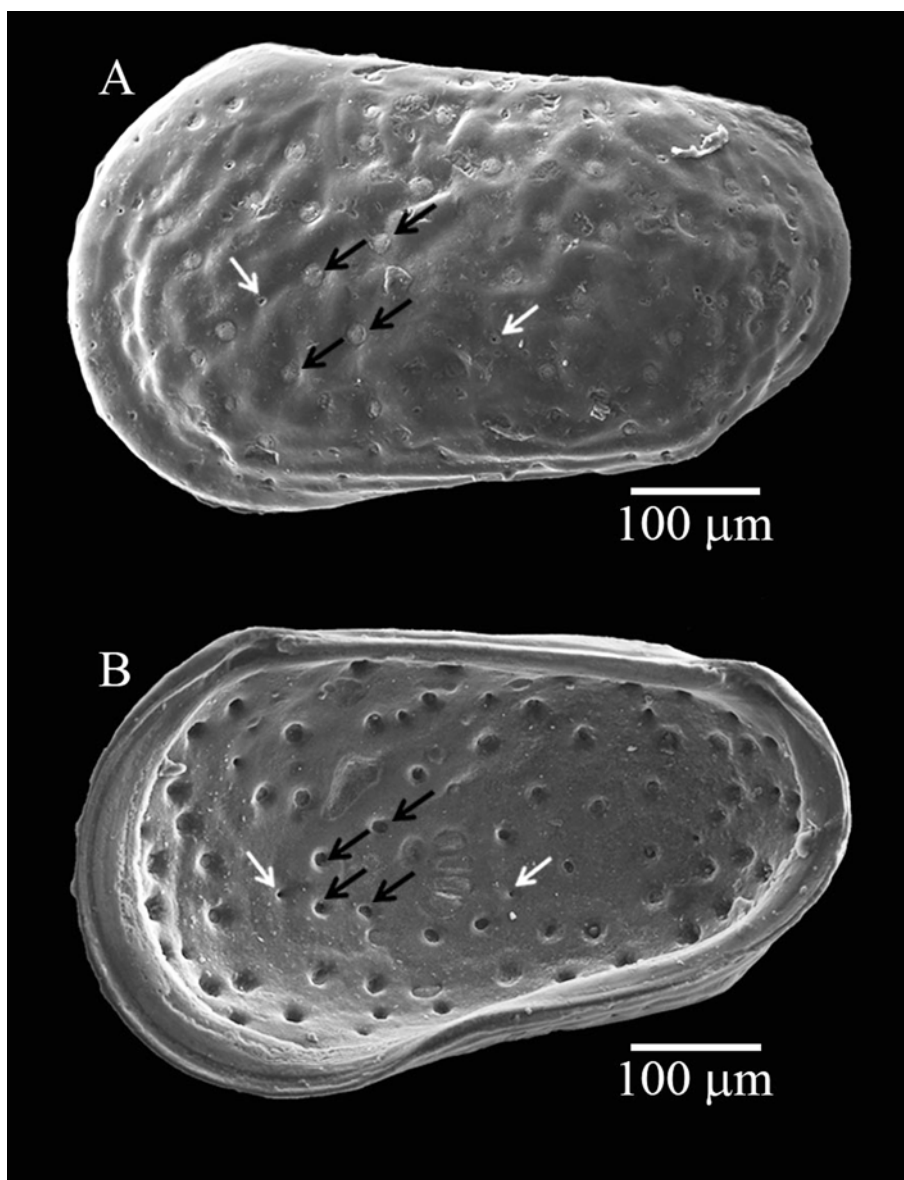

FIGURE 1. General view of valves with visible normal pores belonging to "*Leptocythere*" sp. Triebel, 1941, Borehole Hambühren WA2, 171–174 m, NW Germany, Jurassic, Bathonian, LVf; A—left valve external side; B—left valve reverse view, inner side; white and black arrows point to normal pores, white ones to the opening of a normal simple pore, black ones to StPC.

StPC differs from the so-called "Pore Clusters" as described by Ishizaki & Gunther (1974) for reticulated valves of various representatives of the family Cytheruridae. Pore Clusters are located on the soli of the fossae of the reticulate valves. The diameter of a Pore Cluster-tubule is larger than those of the StPC. As an example, for the valves of *Eucytherura pinasensis* Ishizaki & Gunther, 1974 we calculated from the information given by Ishizaki & Gunther (1974, Plate 3, Figs 12–15) that the tubules have diameters of about 2.3 μm, resembling those of two deep-sea Cytherurinae taxa figured by Van Harten (1993). In both cases we noted that tubules open on the inner side of the valve directly at the level of the valve's surface. In the case of the StPC, the tubules are thinner and open on the inside face of the valve in a bell-shape cavity (see below additional details).
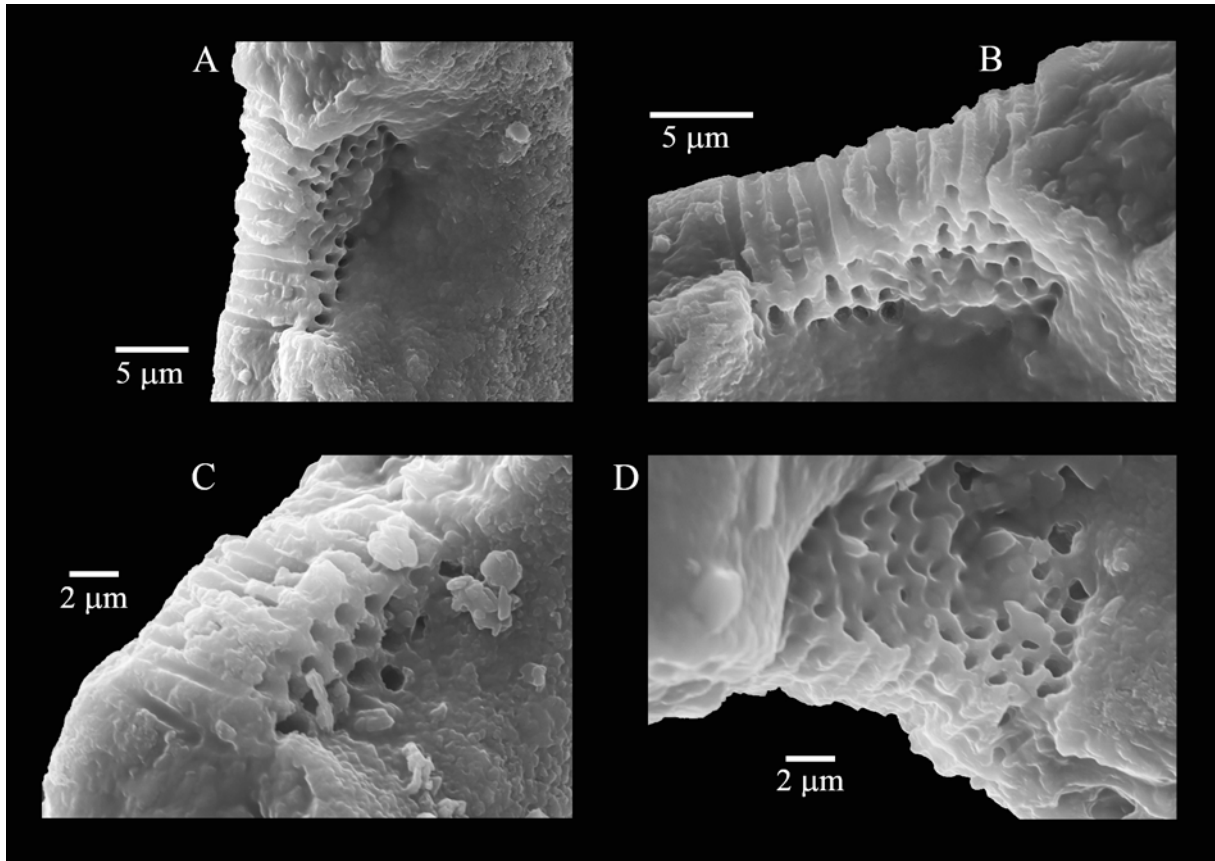
FIGURE 2. Four details of a fragment of right valve, "*Leptocythere*" sp. Triebel, 1941, Borehole Rodewald WA12, 390 m, NW Germany, Jurassic, Bathonian, showing sections of the inner side of sieve-pore tubes and the internal space below.
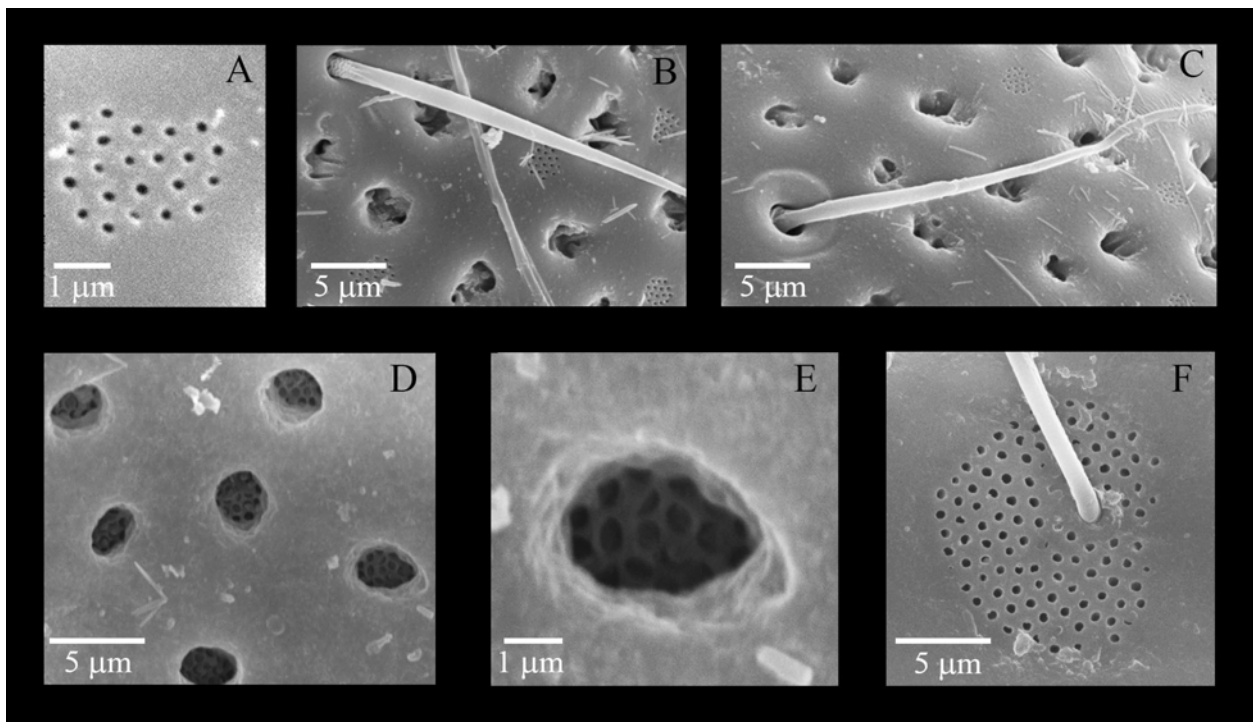

FIGURE 3. General view of normal pores Type A, Type B and Type C; A–E, *Gomphodella maia* De Deckker, Turner Springs, Australia, LVf; A–C, external view; A—pore B; B—Pore A1 with seta, and pore B; C—Pore A2 with seta, and pore B; D–E— inner side view, canals of pores B with sieve-plates, within the valve's calcified lamella; F—*Cyprideis torosa* (Jones), Sado estuary, Carrasqueira, Portugal (Cabral *et al.* 2017, Fig. 17–4), RVEf, pore C with sieve-plate and seta.
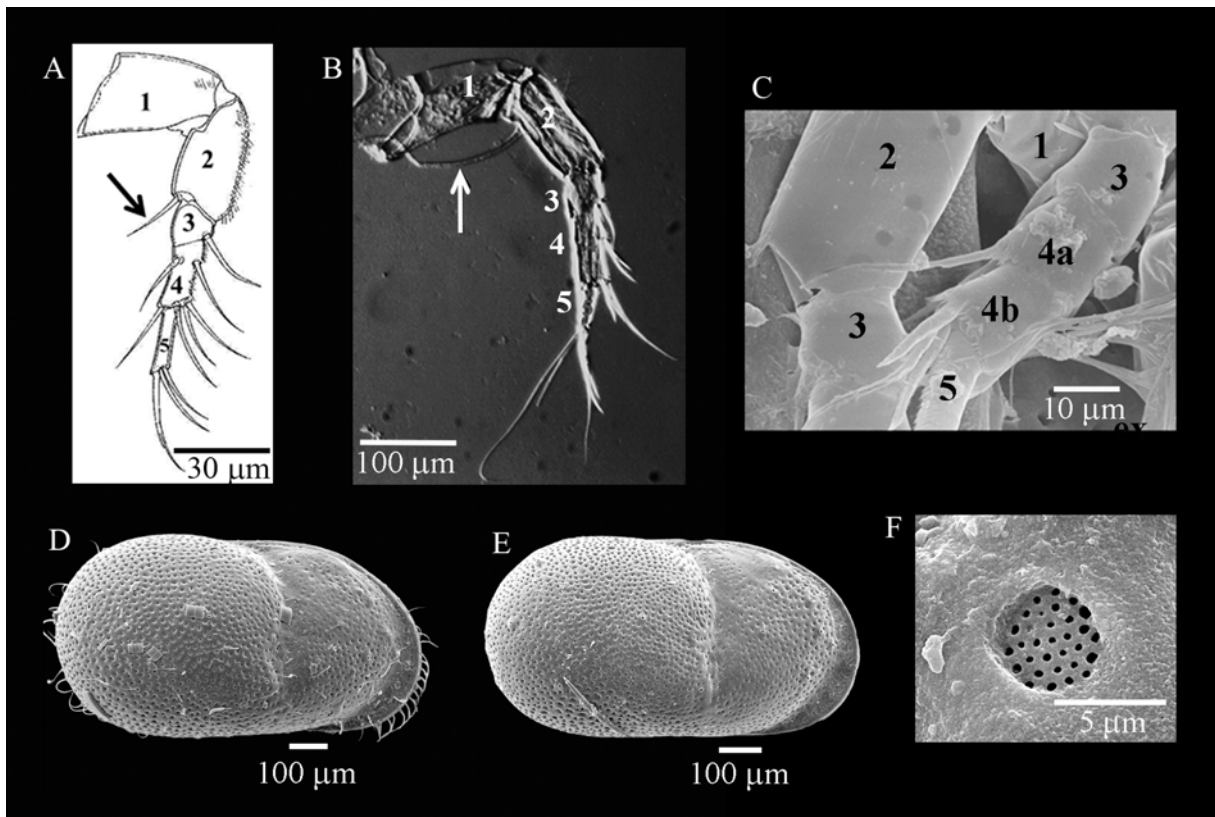
FIGURE 4. A–C, Antennula, female adult; A—*Limnocythere inopinata* Baird, Mondsee, Austria (leg. & del. Yu Yin); B—*Cytheridella ilosvayi* Daday (sensu lato), Shell Creek, Peace River, South-Florida, USA; C—*Gomphodella maia* De Deckker, Turner Springs, Australia; 1–5, segments label; arrow points to the position of diagnostic seta *p2* of the Limnocytheridae and Timiriaseviinae (note absence of seta *p2* is a diagnostic trait for *Gomphodella*); D—*Cytheridella ilosvayi* Daday, RVEf, specimen MP-0-314, coll. Y. Purper, in Rio Grande do Sul State, Brazil (see Purper 1974, p. 639); E–F, *Cytheridella boldi* Purper, coll. W. A. Van den Bold, Lake Valencia, Venezuela, RVEf, specimen MP-0-320; E—general view; F—StPC, detail from E.
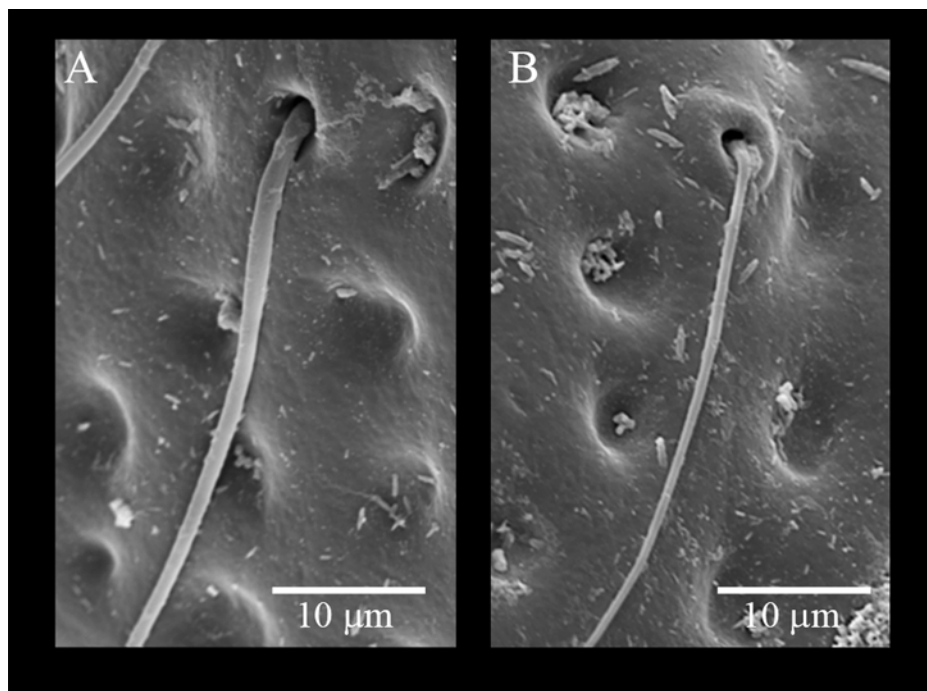

FIGURE 5. Details of normal-pores Type A with seta; *Metacypris cordata* Brady & Robertson, Caldarusani, Romania, RVEf; A—pore and seta type A1; B—pore and seta type A2.
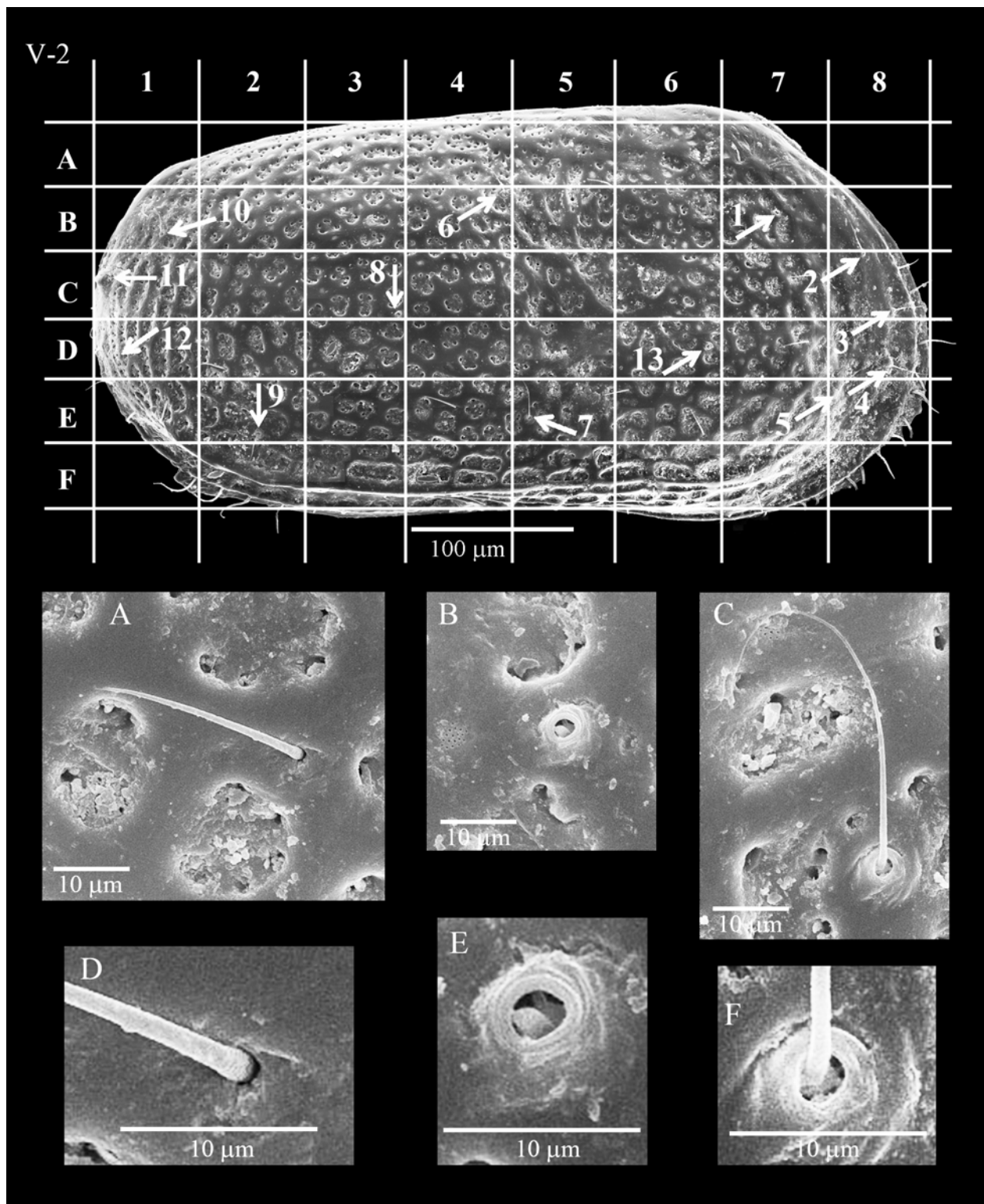
FIGURE 6. Cartographic representation of pores on the lateral side of the ostracod valve; Upper panel—*Gomphocythere besni* Külköylüoğlu, Yavuzatmaca, Cabral & Colin, Adıyaman, Turkey, RVEf, specimen V-2, with the location of the A2 pores/setae (1–13); Lower panel—A–F, details of pores Type A and setae on the valve V-2; A, D—pore A1 and seta, (cf. position in cell C3); B, E and C, F—pores A2 and setae (cf. pores 8 and 7, position in cells E5 and C3).

Terminology of the surface features of ornamented valves. We largely use the terms proposed by Sylvester-Bradley & Benson (1971). Considering the so-called negative features of the valve we make here the following distinction between reticulum, fossae, foveolae and puncti related to their decreasing size from large to small. A reticulum, following Sylvester-Bradley & Benson (1971), is a meshwork pattern of rounded or polygonal fossae.

These latter formations are large depressions on the surface of the valve surrounded by walls (muri). The bottom area of a fossa is termed the solum. Foveolae are small concavities without clear walls. Puncti are minute pits or shallow depressions on the valve surface (they do not traverse the valve's wall). Our classification of hollow features differs from that of Sylvester-Bradley & Benson (1971) where a punctum is a structure larger than a foveola.
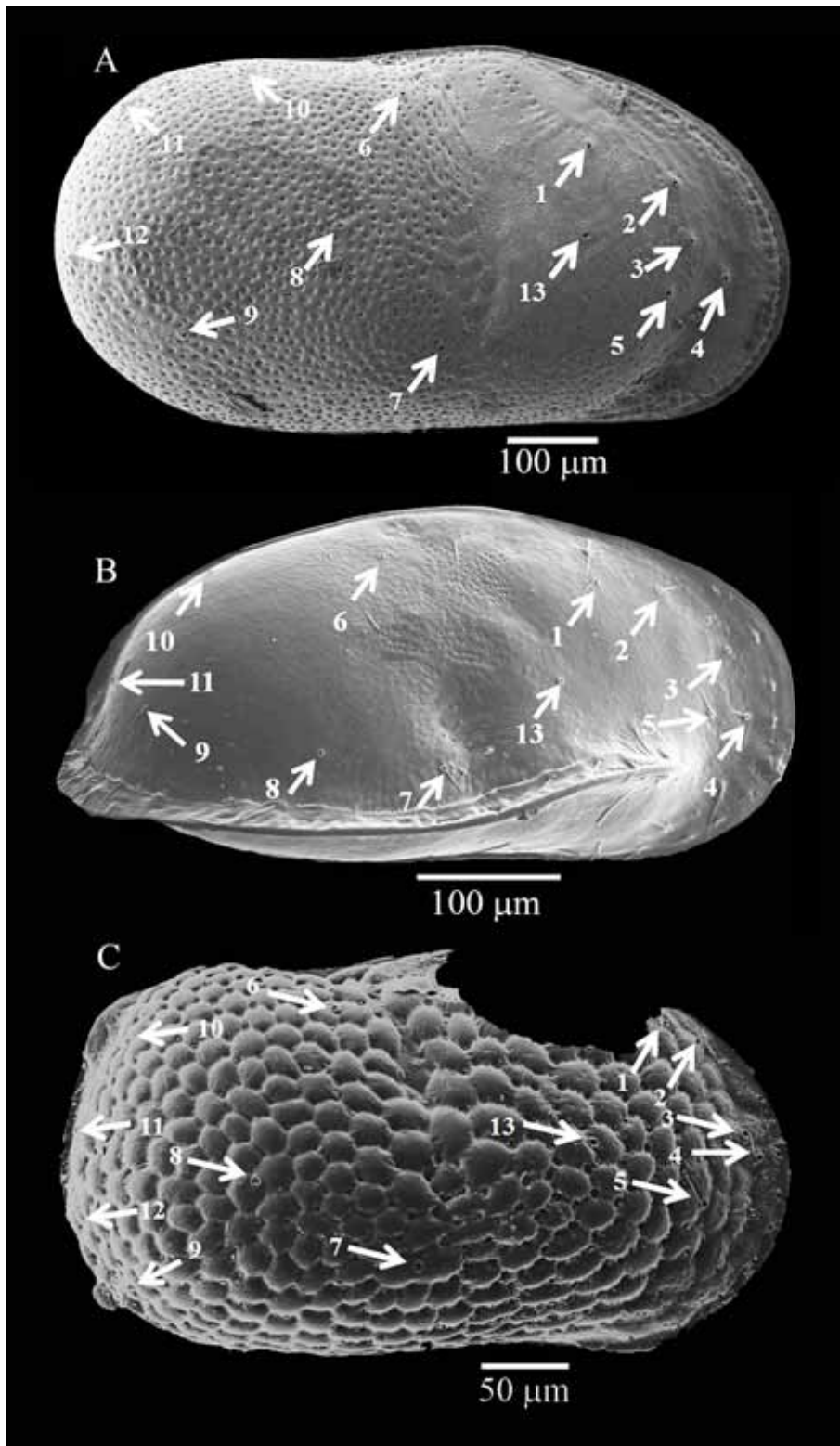

FIGURE 7. Position of pores Type A2 of Timiriaseviinae, RVEf; A—*Cytheridella ilosvayi* Daday, Wallywash Great Pond, WGP2, Jamaica; B—*Gomphodella aura* Karanovic, Yandeyarra Reserve, Yule River, Pilbara, Australia; C—*Kovalevskiella* sp., Lobau, Austria; arrows indicate the location of the pores A2 (1–13).
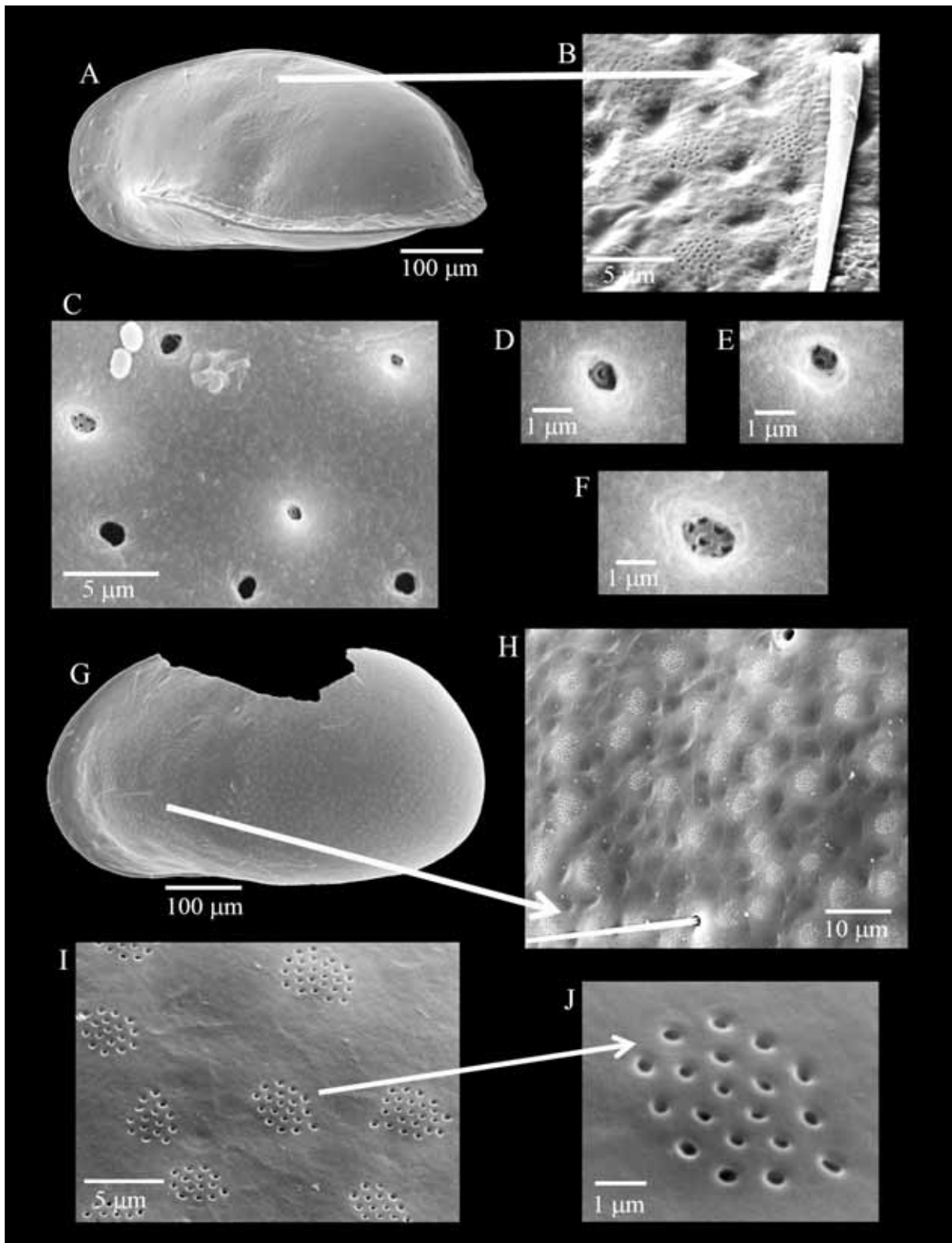
FIGURE 8. *Gomphodella* species, general view of LVf and details of pores Type A, Type B; A–F, *Gomphodella aura* Karanovic, Yandeyarra Reserve, Yule River, Pilbara, Australia; A—LVEf, general view; B—Detail from A with a seta emerging from an A1 pore; C–F—LVIf, details of the canals belonging to pores A1 and B; D—canal A1; E–F—aperture canal pore B; G–J, *Gomphodella quasihirsuta* Karanovic, Uaroo Station, East of Rouse Creek, bore UAR002, Australia; G—LVEf, general view; H–I—enlarged view of anterior area of the valve with distribution of StPC; J—detail of a pore B.

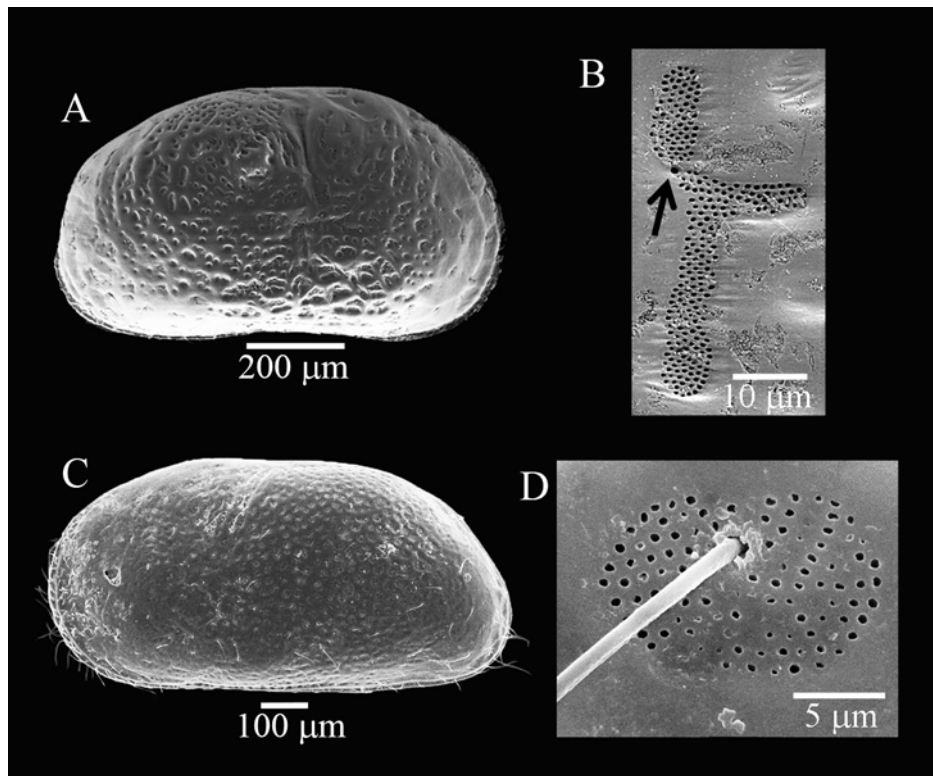**FIGURE 9.** *Cyprideis* species valves with details of pore C; A–B, *Cyprideis americana* Sharpe, Parrotee Pond, Jamaica, RVEf; A—general view; B—detail from A, pore C (arrow indicates the aperture of the setal canal); C–D, *Cyprideis torosa* (Jones), Sado estuary, Carrasqueira (CAR-P1), Portugal (Cabral *et al.* 2017, Fig. 17-1, 2), LVEm; C—general view; D—detail of pore C from C.

The Puri & Dickau dichotomic system for the description of "normal pores". As we briefly mentioned in the introduction, Puri & Dickau (1969) distinguish between simple type pores, named pore type A with an aperture of a single tube, and sieve-type pores, as defined above. These latter exist in two variants Pore B and Pore C. The former is represented by a simple sieve-plate traversed by tubuli which does not bear a seta within its perforated surface (Figs 3A, 4F). By contrast in pore type C a seta is located within the sieve area represented by a hole in the calcite valve (Fig. 3F).

For the pore type A Puri & Dickau (1969) distinguish two variants, A1 and A2. The former pore type opens directly at the surface of the valve and commonly bears a medium length-seta with a larger diameter than that of A2 (Figs 3B, 5A, 6A, D); the space between the seta and surrounding pore is small. The aperture of the type A2 pore is surrounded by a rim; it has generally a slightly larger diameter than the A1 pore and bears a longer seta, more slender than the A1 seta. Additionally, the space between the seta and the tube is wider in the case of the A2 type as compared to the A1 (Figs 3C, 5B, 6B–C, E–F). Sylvester-Bradley & Benson (1971) confusingly named the type A2 pore either as "rimmed-funnel pore", "rimmed pore-canal" or simply "funnel pore".

In some cases within the A2 pore a perforated membrane (possibly an epicuticule) is visible (Figs 6E–F). It is debatable if the type A2 pore is a simple normal pore (Karanovic 2012) or a special variant of the sieve-plate C (as figured in Okada 1983, p. 641, Fig. 1/3). Figure 8E shows from the inner side of the valve of *Gomphodella aura* a small sieve-plate, but no central lumen through which the seta traverses the pore. Therefore, the whole complex entity could represent a minute B pore. Because of the uncertainty of the nature of such a perforated plate in the case of the Timiriaseviinae studied we will mention only briefly morphological details of the A2 pores, mainly the diameter of the external aperture of the lumen. Additionally, in several cases we will mention the spatial distribution of the A2 pores on the valve.

Within our project, for comparative purposes, we use additionally morphologic information on StPC belonging to the Limnocytherinae and Cytherideidae ostracods. We try as far as possible to use for the description of the StPC a quantitative approach, where the morphological details were examined on different scales of visualisation (Schneider 1994 for this approach). We started with the general cartography of StPC on the whole valve (at a

millimetre size-scale) and continued with the description of specific morphologic details, like the tubuli, at micrometre and/or nanometre size-scales. The characterisation of StPC using SEM images for the same entity visualised at various size-scales, allows identification or interpretation of morphologic details potentially useful for systematics or for functional ecology.

Characterisation of the StPC shape following Rosenfeld & Vesper (1977). We classify the sieve-plate shapes into three classes, those with "Round" or subrounded shape, "Oblong" ones approaching an ellipse shape, and the "Irregular" ones. This latter apparently is built by the coalescence of two or three oblong StPC (Fig. 9B).

The distinction between the first two classes is made using the rule-of-thumb for the limits of the ratio height/width with its critical value of 1.5, namely one should consider a round shape of StPC with a lenght/width ratio of less than 1.5 and an oblong one with a ratio larger than 1.5.

The Cartographic Method

Modern cartography is an attractive tool for scientific description, which can be widely used outside its original domain of interest, geography. Azócar (2012), who reviewed the present state of cartographic research, pointed out that present day cartography is an important method for spatial visualisation in the widest sense. It is a way to perceive and interpret spatial structures with modern techniques of exploration like computer graphic technology.

In our case we produced for two species *Gomphocythere besni* and *Gomphodella maia* a general map of the spatial distribution of the StPC using the SEM, followed by increased degrees of magnification of various areas in order to describe and interpret specific morphological details. The cartographic descriptive approach for ostracod valves we propose is, in our opinion, superior to the classic general representation of valves at low magnification with separate presentation of details for the StPC with high magnification but without a clear indication of their original position on the valve.

The practical implementation is as follows: two adult female valves of *G. besni* and one of *Gomphodella maia* were imaged with the SEM at 1500x magnification for the former species and 2000x for the latter one (Figs 6, 10–14). Around 75 images (87 for V-1, 72 for V-2 and 68 for V3) were produced covering the whole external surface of the valve. The 1500x magnification is the minimum enlargement for sieve-plates to be identified and to define their spatial positions. The figures were combined into a general image for the valve. The advantage is that it can be enlarged and minute details of the pores become visible within the general space of the valve. For exact location of pore positions we placed the valve within a rectangle which was further divided into equal cells. These cells were labelled with numbers (X axis) and letters (Y axis). In this way the pores can be easily located (Fig. 6). For *G. besni* we have 48 cells each with a surface area of about 4212 μm^2. In this way the number of StPC for each cell could be counted (Figs 10, 12). For the valve of *Gomphodella maia*, because the size is smaller than *Gomphocythere besni,* we have only 42 cells with a mean area per cell of 2200 μm^2 (Fig. 14). The number of cells that cover 100% of the valve's surface is restricted mainly to the central part for both species. For comparative purposes we present the number of the StPC for these latter cells using standard statistics.

The Cartographic Method has the additional advantage that we can extract specific structures and further examine with higher magnification details unobserved at previous stages of our investigation. For instance, the number of the tubuli in each sieve-plate can be counted on the enlarged figures, and the sieve-plates' shapes, especially the ratio between the length and width axes, can be traced on each enlarged detail extracted from the general figure (Figs 6, 10, 12, 14).

Quantitative analysis of the StPC

The StPC size. For the subrounded StPC we calculated the mean value of the orthogonal maximal lengths of the StPC and expressed the value as the diameter of an approximate circular shape. The computation of the surface area for the three main types of StPC shapes, the round (circular), the oblong one (approaching an ellipse shape) and the irregular was as follows: for the circular shape we used the radius as the half of the mean of the diameter computed as above. For the oblong sieve-plates we used the ellipse formula, Pi multiplied by the product of half of the length axis (le1) and half of the width axis (le2). For irregular StPC we calculated partial surface areas either of

segments which approach an elongated shape or a round one. For each segment we calculated the surface as in the previous cases using either the circle formula or the ellipse one and the results were summed to a total surface area.

The Size Index (SI). It is a ratio that characterises in an objective way the relative size of round StPC as dependent on the size of the valve. We use two size classes, "Small" and "Large". When the SI displays values in milli units (10^{-3}) we attribute the pore size to the "Small" class, while the "Large" class is represented by values expressed in centi units (10^{-2}). As an example: the mean value for the diameter of the StPC tagged with black arrows on Fig. 1A is 14.71 μm and the length of the valve is 612 μm; the SI value is 0.024 (14.71/612), hence a "Large" dimension. The SI index can be calculated also with entities visible on the inside of the valve.

The number of tubuli within one StPC. If one accepts as a hypothesis that the surface area of a StPC is related to the number of pores that open at the surface of the valves then the density of the tubuli traversing such sieve-plates represents an important variable in the description and quantification of the StPC. We counted them on SEM pictures using high magnifications for the species studied here. The counts we offer are not absolute values because some of the pores are masked by particles that stick on the valve or even by setae, which can cover some of the pores. For the fossil species, especially for *Theriosynoecum fittoni*, we could see only parts of the total number of tubuli because of the eroded or overgrown surface of the StPC, hence the total tubuli numbers are underestimated. For other fossil taxa belonging to *Theriosynoecum* and *Sinuocythere* even an approximate count of tubuli was not possible, therefore we do not include information on this trait.

Sieve-plates with less than 60 tubuli are classified by their numbers as "Low" type, while entities with values above this are qualitatively valued as "Large" type. For the so-called "Irregular" StPC we counted the number of tubuli using the same principle as those described above for the computation of the surface area of the Irregular StPC.

The size of tubuli (diameter and approximate surface). The measurement is possible only when examined on SEM images at very high magnification. We used as diameter the inner dimension of the canal, which on the pictures appears as a dark area, either from the external or from the internal side. This type of observation was made on SEM pictures using the program Adobe-Photoshop CS3 Version 10.0. Observation of the size of tubuli can be in principle made directly with the SEM. In our case the image material came from diverse sources and we were obliged to analyse it in a standardised way.

Total Area of Tubuli for Standardised StPC (TAT-S-StPC). We developed for such computation the following algorithm: area of a number of tubuli from which we calculated the arithmetic mean. This value was further multiplied with the mean number of tubuli per StPC we already calculated for the characterisation of the various taxa we studied. We obtain in this way an approximation of the total area of tubuli for a standardised StPC.

Values of TAT-S-StPC theoretically could be used for ecological monitoring in a similar way to the method of Rosenfeld & Vesper (1977). More precisely, we want to see with this procedure if the species which live in aquatic conditions of higher ionic concentration display larger areas derived from the accumulated value of tubuli than those living in less saline waters. We first tested two species of *Gomphodella,* namely *G. aura* and *G. quasihirsuta.* We expanded our experiment using information from other species known to live in aquatic habitats with different salinities (Table 15 and additional information in 2. Studied Material).

The density of StPC on the valve. We calculated the number of StPC for rectangular areas with different sizes depending on the possibility to calculate the surface without the distortion of the valve curvature. For *Gomphocythere besni* and *Gomphodella maia* where we have relatively flat valves in lateral view we could map the whole valve applying a rectangular grid (Figs 6, 10–14). We counted all the StPC we identified at high magnification from the cells covering 100% of the surface area (cf. Cartographic Method). They were expressed by their total numbers and by their mean and range per unit cell (Table 14). For species having valves with significant curvature or displaying important lateral projections we counted StPC from smaller areas. This is the case for *Cytheridella ilosvayi*, *Gomphodella aura* and *Gomphodella quasihirsuta.* The observed data were further extrapolated to a standard area of 5000 μm² in order to compare the density pattern of StPC of various ostracod taxa. The number of StPC per standard surface area were qualitatively valued as "Low", less than 10 entities and "High" above 10.

The Distance Index (DI). This expresses the spatial dispersion of pores on the valves. It is related to the densities of StPC on the valve and is calculated using length units. The data are extracted from triads of pores and measure the distance between opposite pores. We produce a mean value between the three distances. We classify the data in two distance categories: "Wide" and "Narrow" spaced. As a rule-of-thumb, values larger than 10 μm are "Wide" and below this value "Narrow" spaced. As an example, in Fig. 1A the 4 black tagged pores show the construction