Ostracods (Crustacea) from thermal waters, southern Altiplano, Argentina

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ABSTRACT: The ostracod fauna from la Terma hot spring (26°55'31" S - 68° 08'45.7"W, 4026m above sea level), Southern Altiplano, Argentina, is described and the pool itself characterized. The occurrence of ostracods in this type of environments is registered for the first time in Argentina. Six species were found, two of which are new to the fauna of Argentina: *Penthesilenula incae* (Delachaux) and *Hemicypris panningi* (Brehm). Two species were found for the first time in the Altiplano: *H. panningi* (Brehm) and *Cypridopsis fuhrmanni* (Méhes). Some comments concerning how and when these species could spread to populate the Dry Altiplano are discussed briefly taking into account paleoclimatic data. This paper provides the first record of recent ostracods from the Southern Altiplano, Argentina.

INTRODUCTION

The southern Altiplano (NW Argentina, South America) has several archaeological sites that certify the occupation of highland settings by hunter-gatherer groups since 8000yr before present (Ratto 2000). It is generally accepted that these hunter-gatherer populations were strongly influenced by environmental and climatic factors. The knowledge of holocene climate fluctuations will help to determine the impact of climate change in the evolution of these ancient societies. This requires the analysis of high-resolution natural archives containing centennial- to- millennial-scale records.

Several sources of holocene continental records were identified in Catamarca, Southern Altiplano. Paleolakes and other fossil environments were sampled in order to obtain natural archives of paleoenvironmental evolution, including ostracods (Valero-Garcés et al. 2000, 2003). Ostracods are excellent paleoenvironmental indicators and they have proved to be valuable in paleolimnology. They are widely distributed in all aquatic habitats and very sensitive to water conditions, specially conductivity, pH, and chemical composition. Valves can easily fossilize and represent one of the principal sources of biogenic carbonate in continental environments.

The application of ostracod analysis to quaternary paleoclimatic reconstructions requires a database concerning the modern ecology and the distribution patterns of local species in order to extrapolate these data to the fossil record. Because present knowledge of ostracods from the Southern Altiplano is limited, samples from different modern aquatic habitats in Catamarca were taken to provide better insight into the relationship between distribution of species and environmental parameters.

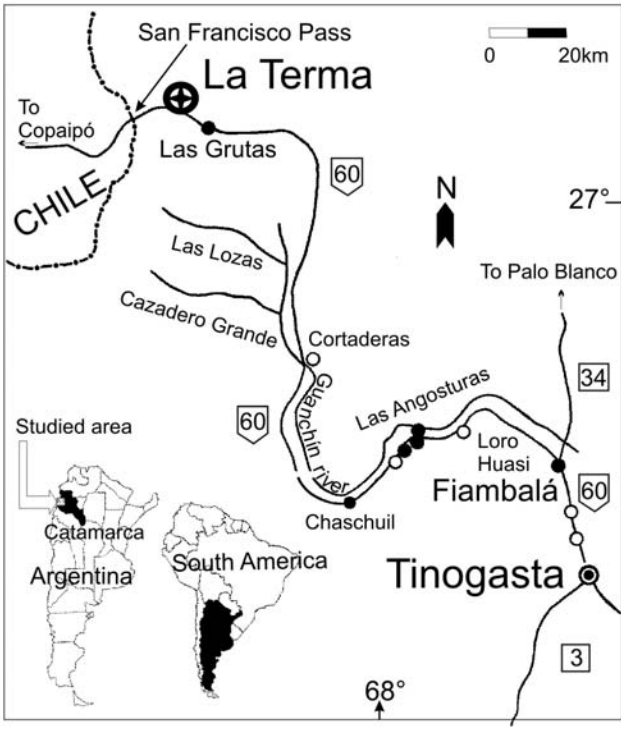
Our main objective here is to describe the ostracod fauna inhabiting in an isolated hot spring in the Southern Altiplano, at ca. 4000m above sea level. Firstly, we describe the morphology and the taxonomic position of species. Some physicochemical properties are given in order to allow the application of these data to future paleolimnology and paleoclimatic reconstructions. Finally, some comments concerning how and when these species could spread to populate these isolated settings are discussed briefly taking into account paleoclimatic data.

PREVIOUS WORKS

The knowledge of recent freshwater ostracods from South America is still incomplete (Mourguiart and Montenegro 2002). Martens and Behen (1994) and Martens et al. (1998) have listed about 300 present-day species but some regions have been neglected and there are a lot of unexplored areas, so we consider that the number of species must be higher. Ostracods from the Peruvian Altiplano have been early described by Delachaux (1928), but much of our knowledge of quaternary and recent ostracods comes from the Titicaca Lake in Bolivia (Mourguiart 1992, 2000, Mourguiart et al. 1992, 1997, 1998 and Mourguiart and Corrège 1998). Recently Schwalb et al. (1999) analyzed fossil holocene ostracods from sediment cores from Chilean Altiplano lakes. More to the south in the Andes but outside the Altiplano, some recent species have been reported from Andean lakes of Mendoza (Mèhes 1914) and from Patagonia (Daday 1902, Whatley and Cusminsky 1995, 1999, 2000; Cusminsky and Whatley 1996, Schwalb et al. 2002). This paper provides the first record of ostracods from the Southern Altiplano, Argentina.

MATERIALS AND METHODOLOGY

Samples were collected in northwest Tinogasta County, Catamarca province, Argentina (text-fig. 1). Altitude varies be-



TEXT-FIGURE 1
Map of Tinogasta, Catamarca, Northwestern Argentina. The map shows the approximate location of the sampled site. La Terma hot spring is 21km to the San Francisco International Pass to Chile. The area belongs to the Southern Altiplano for its phytogeography but also for its geological and structural features.

tween 3500m and 4700m above sea level. The region is flanked by mountain chains: the Cordillera de San Buenaventura to the north, the Sierra Las Planchadas to the east, and the Cordillera de los Andes to the west. The area belongs to the Puneña Province of the Andean Dominion (Cabrera 1976, Cabrera and Williink 1980). The region is considered belonging to the Southern Altiplano not only for its phytogeography but also for its geological and structural features (*cf.* Argerich 1976, Costello and Aguirre de Costello 1999).

The area is characterized by a very dry, cold climate and summer (December-March) rains. Precipitations are less than 100mm/year and the evaporation is *ca*. -570mm/year, which denotes high evaporation rates (Buitrago and Larrán 1994; Morlans written communication, 1985). Snow is the dominant moisture source in winter. There is high daily thermal amplitude and well marked seasonality. Temperatures in summer vary between *ca*. 20°C to *ca.* -10°C during nights while in winter temperatures can reach easily -20°C. Springs and a few perennial creeks are focal points for any life present.

In this study, thermal water designates an aquatic habitat in which temperature is higher than the mean annual temperature of the region. The sampled site (26°55'31.0" S - 68°08'45.7" W, 4026m asl) is situated near Las Grutas, at 21km to the international San Francisco Pass to Chile. It is a little stream of 8-10m wide and 40-50cm deep originated in a well of thermal water. Temperature in the well was 38°C. Sediments at the bottom are medium and coarse sands and fine gravels. The current speed is *ca.* 0.5m/sec. The surface is covered by floating and rooting vegetation.

Samples, sampling dates, microhabitat description, temperature, pH and conductivity are consigned in Table 1. Sediment samples were hand taken with a sieve (10cm diameter, mesh of 100μm) from the first 2-3cm of bottom sediments. Samples of macrophytes were taken with a net (diameter 30cm, 50cm long and mesh of 55μm). Water temperature, pH and conductivity were measured with a portable pHmeter Hanna model HI 8424. Water analysis was made by the Instituto Nacional de Geología Isotópica (INGEIS), Argentina. In this study, only living individuals (specimens containing soft parts even when they were not well preserved) were considered.

Samples were washed with running water and dried in a stove at 40°C. Dried samples were examined and picked. Carapaces and valves were described as only they are usually preserved in fossil sediments. Soft parts were considered only in order to confirm systematic position in the Darwinulidea. The dry soft parts were placed in a one-cavity glass-slide containing a 2% solution of trisodium phosphate during 24-36 hours for softening (Moguilevsky written communication 1976). The material examined in this study is listed in Table 2. Analyzed material is deposited at the Departamento de Ciencias Geológicas, Universidad de Buenos Aires, Argentina. The following abbreviations are used in text and plates: **Cp**, carapace; **LV**, left valve; **RV**, right valve; **Cms**, central muscle scar(s); **Rcp**, Radial pore canals; **asl**, above sea level; **A1**, antennula; **A2**, antenna.

SYSTEMATICS

Class OSTRACODA Latreille 1802
Subclass PODOCOPA G.W. Müller 1894
Order PODOCOPIDA Sars 1866
Superfamily DARWINULOIDEA Brady and Norman 1889
Family DARWINULIDAE Brady and Norman 1889
Genus *Darwinula* (Brady and Robertson 1870)

Darwinula stevensoni (Brady and Robertson 1870)
Plate 1, figures 1-6

Polycheles stevensoni BRADY and ROBERTSON 1870, p. 25, pl. 7, fig. 17, pl. 10, fig. 13.
Darwinula stevensoni (Brady and Robertson) ROSSETTI and MARTENS 1996, p. 77 and 82, figs. 2-11. – ROSSETTI and MARTENS 1998, p. 59-60, figs. 1a-f, 24d, 27a-d. – ROSSETTI, HORNE and MARTENS 1998, p. 17-22, pl. 25, 18 and 25, 20.

Material: The following material is deposited at the Laboratorio de Micropaleontología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires; repository numbers are given in brackets: a) LV preserved on a cavity slide (FCEN-LM 2920); b) LV preserved on a cavity slide (FCEN-LM 2921); c) RV preserved on a cavity slide (FCEN-LM 2922); d) Cp preserved on a cavity slide (FCEN-LM 2923); e) LV preserved on a cavity slide (FCEN-LM 2924); f) RV preserved on a cavity slide (FCEN-LM 2925).

Measurements: Carapace length 673-624μm (n=5); height 267-249μm (n=3); width 283-255μm (n=2).

Remarks: Specimens from La Terma differ from those of *Darwinula stevensoni* illustrated by Rossetti and Martens

TABLE 1
Sampling dates, location, description of microhabitats, pH, temperature and conductivity of samples from La Terma hot spring, Southern Altiplano. Later2, Later3 and Terma4/4 were hand taken with a sieve (100µm mesh) whereas Later1 was taken with a small plankton net (55µm mesh). Environmental data were measured *in situ* with a portable pHmeter.

Sample	Date	Location	Microhabitat description	Tº	pH	Conductivity
Later 1	January 10th, 2004	S 26º 55' 31" W 68º 08' 45,7"	Rooted and floating macrophythes 8m downstream of a little dam	28ºC	8.3	204µS/cm
Later2			Bottom sediments beneath Later1 macrophythes, 40cm depth. Grain size: coarse sand and fine gravel			
Later 3			Bottom sediments in active channel, 50cm depth. Grain size: coarse sand and fine gravel			
Terma 4/4	April 12th, 2004	S 26º 55' 31" W 68º 08' 45,9"	Bottom sediments 5 m upstream of a little dam, 20cm depth. Grain size: coarse and medium sand and fine gravel with organic matter	30ºC	8.1	N/D

(1998) in having the posterior margin broader and symmetrically rounded. Additionally, Rossetti and Martens (1998), Rossetti et al. (1998) and Martens and Rossetti (2002), consider that *Darwinula stevensoni* is rather large (ca. 0.8-0.7 mm), whereas our specimens are smaller (ca. 0.65 mm), but Rossetti and Martens (1996) analyzed morphological variability of *D. stevensoni* and consider that size can vary significantly between populations. They also observed small differences in the curvature of the postero-ventral corner. To confirm systematic position, soft parts were analyzed in conjunction with hard parts, and they fit well in the diagnosis of *D. stevensoni* after Rossetti and Martens (1998) and Rossetti et al. (1998): RV without external keel; LV without internal teeth; RV overlapping LV; last segment of Md-palp with four claws; A1 with second segment of endopodite with two large dorsal setae; penultimate segment of Md-palp with seta *z* long, seta *y* short; last segment with *a, b* and "poil stevensoni" setae.

Distribution: Darwinula stevensoni is ubiquitous and cosmopolitan. In La Terma it was registered living in association with macrophytes (Later 1) and in clean coarse-grained sands (Later 2).

Genus *Penthesilenula* Rossetti and Martens 1998

Penthesilenula incae (Delachaux 1928)
Plate 1, figures 7-10

Darwinula incae DELACHAUX 1928, p. 54-56, pl. 5, figs. 28-39. – ROSSETTI, MARTENS and MOURGUIART 1996, p. 35-40, pl. 23, 36 and 23, 38.
Penthesilenula incae (Delachaux 1928). – ROSSETTI and MARTENS 1998, p. 79 and 81, figs. 13a-d and 28g-j.

Material: The following material is deposited at the Laboratorio de Micropaleontología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires; repository numbers are given in brackets: a) RV preserved on a cavity slide (FCEN-LM 2926); b) LV preserved on a cavity slide (FCEN-LM 2927); c) RV preserved on a single cavity slide (FCEN-LM 2928); d) LV preserved dry on a cavity slide (FCEN-LM 2929).

Measurements: carapace length 695-648µm (n=8); height 327-303µm (n=6); width 257-249µm (n=2).

Remarks: Our specimens are smaller than the holotype described by Delachaux (1928) from Perú and smaller than specimens described by Rossetti et al. (1996) and Rossetti and Martens (1998) from Bolivia. Additionally Cms consists in 11 small spots instead of 13-14 spots as described in Rossetti et al. (1996). Specimens from La Terma are attributed to *P. incae* because of the great similarity with the description made by Rossetti et al. (1996) and Rossetti and Martens (1998) in several diagnostic details of the appendages and valves: LV with internal tooth along the caudal margin, LV overlapping RV on all sides, first segment of A1 with two dorsal setae; second segment with three ventral setae, two short and one longer, and one short dorso-apical seta; third segment with one ventral and one dorsal seta; four segment with one ventral seta and two dorsal setae; A2 exopodite with two long setae and one short lateral spine. Specimens from La Terma are very similar to *Penthesilenula setosa* (Daday, 1902) described from Patagonia, but the former has an inadequate original description and probably it have to be considered as senior synonym of *P. incae* (Rossetti et al. 1996). *Penthesilenula brasiliensis* (Pinto and Kotzian 1961) is smaller and shorter (normal length range between 0.47-0.55 mm), and it is characterized by small antero-ventral and large postero-ventral internal tooth in LV, and Cms consisting of *ca.* 9 relatively large scars. *Penthesilenula aotearoa* (Rossetti and Martens 1998) is smaller (0.58-0.61mm) and it has posterior and antero-ventral internal teeth in LV.

Distribution: In La Terma, Southern Altiplano, *Penthesilenula incae* was found in still water, inhabiting humic coarse-grained sands, 20cm depth (Terma 4/4). It was originally described from Perú (Delachaux 1928, Mourguiart et al. 1997, 1998) and thereafter it was found in Bolivian lakes (Rossetti et al. 1996).

Infraorder CYPRIDOCOPINA Jones 1901
Superfamily CYPRIDOIDEA Baird 1845
Family CANDONIDAE Kaufmann 1900
Subfamily CANDONINAE Kaufmann 1900
Genus *Candona* Baird 1845

Candona sp.
Plate 1, figure 11

Material: The following material is deposited at the Laboratorio de Micropaleontología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires; repository numbers are given in brackets: a) RV from Later1 preserved on a cavity slide (FCEN-LM 2930).

Description: RV subtrapezoidal in lateral view. Anterior margin obliquely rounded, asymmetric; posterior margin rounded. Dorsal margin short and straight, with a soft inclination to the anterior margin; cardinal anterior angle visible; posterior angle not visible. Ventral margin sub-parallel to the dorsal margin, weakly sinuous with a concavity in the mid-length. Surface of valves smooth, with just few simple normal pores. Few long setae more abundant at the anterior margin. Greatest height coincident with the posterior third of the valve, greatest length just in the mid-height. Hinge adont. Cms consisting of a dorsal compact group of scars and six shorter scars that formed a rosette. Calcified inner lamella widest in the anterior margin with a well developed vestibule.

Measurements: RV length 486µm; height 262µm.

Remarks: Candona sp. has certain similarities with *Candona pedropalensis* Mèhes, 1914 but the former is more elongated and the dorsal margin is arched while in *Candona* sp. the dorsal margin is shorter and straight. *Candona* sp. has also some similarities with *Candona incarum* (Moniez 1889) described from the Titicaca Lake, Bolivia, but its dorsal margin is shorter and straighter.

Local distribution: a single valve of *Candona* sp. with soft parts not well preserved was found among macrophytes (Later1).

Family CYPRIDIDAE Baird 1845
Subfamily CYPRINOTINAE Bronstein 1947
Genus *Hemicypris* Sars 1903

Hemicypris panningi (Brehm 1934)
Plate 2, figures 1-7

Heterocypris panningi BREHM 1934, p. 83-84, figs. 13-14. – HARTMANN 1962, p. 182. – PURPER and WÜRDIG-MACIEL 1974, p. 77.

Material: The following material is deposited at the Laboratorio de Micropaleontología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires; repository numbers are given in brackets: a) Cp female preserved on a cavity slide (FCEN-LM 2931); b) Cp female preserved on a cavity slide (FCEN-LM 2932); c) Cp female preserved on a cavity slide (FCEN-LM 2933); d) LV female preserved on a cavity slide (FCEN-LM 2934); e) Cp male preserved on a cavity slide (FCEN-LM 2935); f) RV female preserved on a cavity slide (FCEN-LM 2936); g) LV male preserved on a cavity slide (FCEN-LM 2937).

Description: Cp female subtriangular, reniform in lateral view with subumbonate dorsal margin passing into anterior and posterior margins without cardinal angles. Anterior margin broadly rounded, posterior not evenly rounded. Ventral margin sinuate in the central region. Greatest height situated slightly in the front of the middle; greatest large in the 1/3 of the height. RV larger and higher than LV overlapping it in the antero-dorsal margin. In dorsal view, Cp sub-elliptical, compressed. Surface of valves pitted with abundant setae. Central and dorsal muscle scars evident in external view as smooth areas. Adont hinge, LV with large groove, RV with corresponding smooth ridge. Cms consisting of a group of six large elongated spots typical of the genus. Calcified inner lamella widest in the anterior margin, with relatively narrow vestibule. Rcp shorts, numerous and closely spaced. Inner margin of LV with minute tubercles.

Sexual dimorphism present, males bigger and more elongated than females.

Measurements: Carapace length ?675-647µm (n=5), ?592-534µm (n=3); height ?420-398µm (n=5), ?371-347µm (n=2); width ?292µm (n=1).

Remarks: This species has been ascribed to *Heterocypris* (Brehm 1934, Purper and Würdig-Maciel 1974, Martens and Behen 1994) but actually it belongs to *Hemicypris* because RV is larger than LV and the free margin of LV has minute tubercles. It can be easily distinguished because is smaller than the majority of South American species of *Hemicypris* and because both valves are subtriangular in lateral view. It is rather similar to *Heterocypris wolffhugeli* (Mèhes, 1914), but in the former the dorsal margin of the LV is evenly arched, whereas in *Hemicypris panningi* is pointed in the front of the mid-length.

Distribution: Hemicypris panningi is the most abundant species in La Terma. It was found living attached to rooted macrophytes (Later1) as well as in clean and humic coarse-grained sediments (Later2 and Terma 4/4). It was previously registered from Chile and Perú (Brehm 1934, Klie 1941, Hartmann 1962).

Subfamily HERPETOCYPRIDINAE Kaufmann 1900
Genus *Herpetocypris* Brady and Norman 1889

***Herpetocypris* sp.**
Plate 2, figure 8

Material: The following material is deposited at the Laboratorio de Micropaleontología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires; repository numbers are given in brackets: a) one immature LV preserved on a cavity slide (FCEN-LM 2938).

Measurements: LV length 876µm, height 400µm (n=1)

Remarks: Herpetocypris sp. is quite similar in outline to *Herpetocypris reptans* (Baird 1835), a cosmopolitan, widely distributed species inhabiting in ponds, small lakes and slowly flowing waters. In accordance to diagnosis (González Mozo et al. 1996) the length of *Herpetocypris* carapaces varies between 1.5-2.5mm. Specimens recovered from La Terma are left in open nomenclature since they are probably 7-8th instars because the length is less than 1mm, and the calcified inner lamella is very narrow.

Local distribution: Immature valves of *Herpetocypris* sp. with soft parts not well preserved were recovered from sediments of the active channel (Later3).

Subfamily CYPRIDOPSINAE Bronshtein 1947
Genus *Cypridopsis* Brady 1868

Cypridopsis fuhrmanni (Mèhes 1914)
Plate 2, figure 9-11

Cypridopsis fuhrmanni MÈHES 1914, p. 646-648, figs. 3a-h, figs. 4a-e.

Material: The following material is deposited at the Laboratorio de Micropaleontología, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires; repository numbers are given in brackets: a) LV preserved on a cavity slide

TABLE 2
Abundance of ostracods in La Terma hot spring, Catamarca, Southern Altiplano. Only living individuals (specimens containing soft part even when they were not well preserved) were considered. For microhabitat description, see Table 1.

Sample	*Darwinula stevensoni*		*Penthesilenula incae*		*Hemicypris panningi*		*Candona* sp.	*Cypridopsis fuhrmanni*	*Herpetocypris* sp.
	adults	juvenils	adults	juvenils	adults	juvenils	adults	adults	juvenils
Later 1	19	66	0	0	62	7	1	0	0
Later 2	4	12	0	0	15	1	0	2	0
Later 3	0	0	2	0	3	2	0	3	2
Terma 4/4	0	0	18	4	40	3	0	0	0

(FCEN-LM 2939); b) Cp preserved on a cavity slide (FCEN-LM 2940); c) RV preserved on a cavity slide (FCEN-LM 2941).

Description: Cp subtriangular, reniform no elongated in lateral view, greatest height of anterior margin situated almost exactly in the middle. Dorsal margin strongly arched, defining an obtuse angle whose apex coincides with the anterior cardinal angle. Posterior cardinal angle visible. Anterior margin evenly nearly rounded, the posterior one truncated, ventrally sub-rounded and dorsally straight. Ventral margin with an anterior smooth concavity, posterior moderately convex, anterior straight. External surface of the valves smooth, pitted in the anterior margin and extended to the postero-ventral margin. Few simple and spread normal pores. Few setae in the anterior margin. Adont hinge. LV with a smooth bar. Calcified inner lamella narrow but widest in the anterior margin. Anterior margin with well developed vestibule. Rcp short, straight and numerous. Cms forming not a very compact group with four big spots and two shorter of antero-ventral position.

Measurements: length 901-920µm (n=3); height 577-599µm (n=3).

Remarks: This is the first record of *Cypridopsis fuhrmanni* since its original description by Mèhes (1914). *Cypridopsis fuhrmanni* is quite similar to *Cypridopsis* sp. aff. *C. huaronensis* (Mourguiart written communication 1987) from Titicaca Lake, Bolivia, but the former is smaller (maximum length 0.42mm to 0.36mm) and the posterior margin is lower.

Distribution: individuals with soft parts not well preserved were found in La Terma hot spring bottom sediments (Later3 and Later2). *Cypridopsis fuhrmanni* was originally described from Andean lakes from Colombia and Argentina between 1530 and 2640m asl (Mèhes 1914).

DISCUSION

Recent ostracods have been described from lakes, streams, ponds, groundwater environments, damp leaf litter, soils, marshes and hot springs. In the former, occurrence in waters with temperatures beyond 30°C has been reported from Africa (Moniez 1893), Europe (Gülen 1985; Ponyi 1992), and Asia (Menzel 1923). In America, hot springs from the United States contain a relatively well studied fauna (Wickstrom and Castenholz 1973, 1985; Petersen and Mott 2002; Külkoylouglu et al. 2003).

Two thermophilic species are found in the genus *Heterocypris*: *H. balnearia* (Moniez 1893) and *H. sabirae* Gülen 1985 both from spring waters with temperatures reaching 50ºC- 51.5ºC (Moniez 1893, Klie 1939, Gülen 1985). *Thermopsis thermophila* Külköylüoglu, Meisch and Rust were found at a maximum of 54ºC (Külköylüoglu et al. 2003). Several other species such as *Cypria ophtalmica* (Jurine), *Cypridopsis vidua* (Müller), *Plesiocypridopsis thermarum* (Tagliasacchi-Masala), *Darwinula stevensoni, Metacypris cordata* (Brady and Robertson), *Limnocythere sappaensis* Staplin, *Cyprinotus fuscus* (Jurine) as well as other species with no taxonomic indications or not properly described belonging to *"Darwinula", Physocypria, Chlamydotheca, Herpetocypris, Eucypris, Cyprinotus, Candona* and *Potamocypris* (these later probably identical with *T. thermophila,* Külköylüoglu et al. 2003), were reported from European and American hot springs (Ponyi 1992, Brues 1932, Castenholz 1967, Wickstrom and Castenholz 1973, 1985, Furnish et al. 2002).

We consider La Terma hot spring as thermal waters because temperature is higher than the annual mean temperature of the region. Air mean temperature in the area (2 to 12 daily measures from 01/13/2004 to 09/04/2004) was 3.9ºC, while water temperature was 38ºC in the discharge well, and 30ºC to 28ºC in the sampled sites. The water is of Na^{+}-Ca^{++}-$HCO3^{-}$-Cl^{-} type with a total mineralization of 1349g/l and neutral pH. The genesis of these thermal waters and their warming remain still not investigated, but active thermal springs in NW Argentina are related to volcanic activity (Kasemann et al. 2004).

Living ostracods of La Terma hot spring are actually taxonomically expected, represented by *Darwinula stevensoni, Penthesilenula incae* and *Hemicypris panningi.* The former is ubiquitous and represents the most abundant and widely distributed species, living in coarse-grained sediments and in relation with aquatic plants. *Darwinula stevensoni* lives attached on leaves of aquatic macrophytes and floats behind the surface layer. *Penthesilenula incae* is bottom-dweller, especially abundant in coarse-grained sediments with abundant organic matter.

In addition of species mentioned above, also individuals with soft parts not well preserved of *Candona* sp., *Herpetocypris* sp., and *Cypridopsis fuhrmanni* were found. Due to the features of the environment (the sampled site is just only 200m downstream of the well and there is no any other freshwater input) it is considered that these species are actually autochthones and the absence of living individuals is exclusively due to the deficiency of sampling.

All the nominated species from La Terma hot spring were previously described from non-thermal waters. They have regional or cosmopolitan distribution, and belong to genera with effective dispersal strategies and wide ecological tolerances. Species from La Terma hot spring should be considered eurythermic species well represented in warm water habitats, but no thermophilic species linked to 'high' temperatures. The cosmopolitan and ubiquitous *Darwinula stevensoni* has a worldwide distribution. Able to survive in a wide range of environmental conditions including hot springs, it has an unusual wide tolerance range for both salinity (0-30 gr/l) and temperature (2°C to 30°C) (Van Doninck et al. 2002). The presence of *Darwinula stevensoni* in these thermal waters is not surprising, but the discovery of *P. incae, H. panningi,* and *C. fuhrmanni* in La Terma hot spring improves the knowledge of their ecological requirements -especially ranges of thermal tolerance- since these species have been previously described only from Andean ponds and lakes without thermal influences. Rossetti et al. (1996) redescribed *Penthesilenula incae* from a "shallow pool and canal in largely dry Laguna, turbid, many algae, c. 10cm deep, c. 150 X 50m large; water temperature=15.2°C, pH=9.3, conductivity=767ìS/cm" in Bolivia at 3810m asl. Mourguiart et al. (1986, 1997), Mourguiart (1992) and Mourguiart and Montenegro (2002) mention *P. incae* (sometimes as *Darwinula* sp.) inhabiting nearshore environments in the Titicaca Lake and adjacent areas, associated with macrophytes and organic rich sediments, salinity range between 0.8 to 2g/l, 0-60m deep. Ecological data have not been published for *Hemicypris panningi* neither *Cypridopsis fuhrmanni.*

In a regional context, this fauna represents an interesting finding because it is an assemblage of darwinulids and cypridoids facing extreme environmental factors (e.g., high UV radiation, sustained strong wind action), inhabiting a very isolated high-altitude warm-water environment. The surroundings provide several examples of high-Andean saltpans and saline wetlands locally called *vegas*. According to preliminary studies, nearest *vegas* are inhabited mainly by limnocytherids, whereas cypridoids dominates flowing waters such as rivers, streams and springs (Laprida et al., 2006). Although the taxonomic composition of the fauna from La Terma hot spring is predictable, the great abundance of individuals is surprising in comparison with other samples in the area, in which the fauna is relatively scarce and darwinulids are rare. We think that La Terma hot spring represents a more stable and predictable environment in comparison with the surroundings as consequence of the thermal origin of its waters, and this allows the development of rather big populations.

An interesting question is when and how these species could spread to populate this isolated setting. Several studies have documented strong environmental changes in the Altiplano during the last few millennia with large implication for temperature and water availability (Grosjean 2001; Grosjean et al. 2001; Bobst et al. 2003, Kull et al. 2003). In northern Chile and in the Bolivian Altiplano, paleoecological data show a remarkable change from cool and very arid conditions at the LGM (Late Glacial Maximum) to relatively humid conditions during LG (Late Glacial) and Early Holocene (Núñez et al. 2002, Argollo and Mourguiart 2000, Bobst et al. 2003; Grosjean et al. 2001). It is possible that much of the recent ostracods including those of La Terma could have reached southern Altiplano when new lakes, ponds, rivers and other aquatic habitats became available. Unfortunately, there are no detailed studies of ostracods in the Altiplano concerning the distribution in space and time to test this hypothesis. The continuous sedimentary record before 20000 year BP is documented only at a limited number of sites (Argollo and Mourguiart 2000), and the majority of previous studies on ostracods have no detailed systematic descriptions (i.e., Mourguiart et al 1986, Wirrmann et al. 1988, Mourguiart 1992, among others).

Since the majority of the species of La Terma have a distribution that includes areas outside of the Altiplano, a colonization starting from lower surrounding areas can be considered. *Darwinula stevensoni* is common, ubiquitous and cosmopolitan. In South America it has been described from lowlands from Argentina and Brazil (Martens and Behen 1994, Würdig and Pinto 1999, Laprida 2006). *Cypridopsis fuhrmanni* was previously found in Andean lakes from Argentina and Colombia between 1530 and 2640m asl (Mèhes 1914) and *Hemicypris*

PLATE 1

1-6 *Darwinula stevensoni* (Brady and Robertson 1870).

1 left valve, lateral external view, length: 619µm, height: 236µm, Sample Later1, FCEN-LM 2920;

2 left valve, lateral external view, length: 594µm, height: 194µm, Sample Later1, FCEN-LM 2921;

3 right valve, lateral external view, length: 647µm, height: 262µm, Sample Later2, FCEN-LM 2922;

4 carapace, dorsal view, length: 600µm, width: 260µm, Sample Later1, FCEN-LM 2923;

5 left valve, lateral internal view, length: 597µm, height: 239µm, Sample Later1, FCEN-LM 2924;

6 right valve, lateral internal view, length: 648µm, height: 268µm, Sample Later2, FCEN-LM 2925.

7-10 *Penthesilenula incae* (Delachaux 1928).

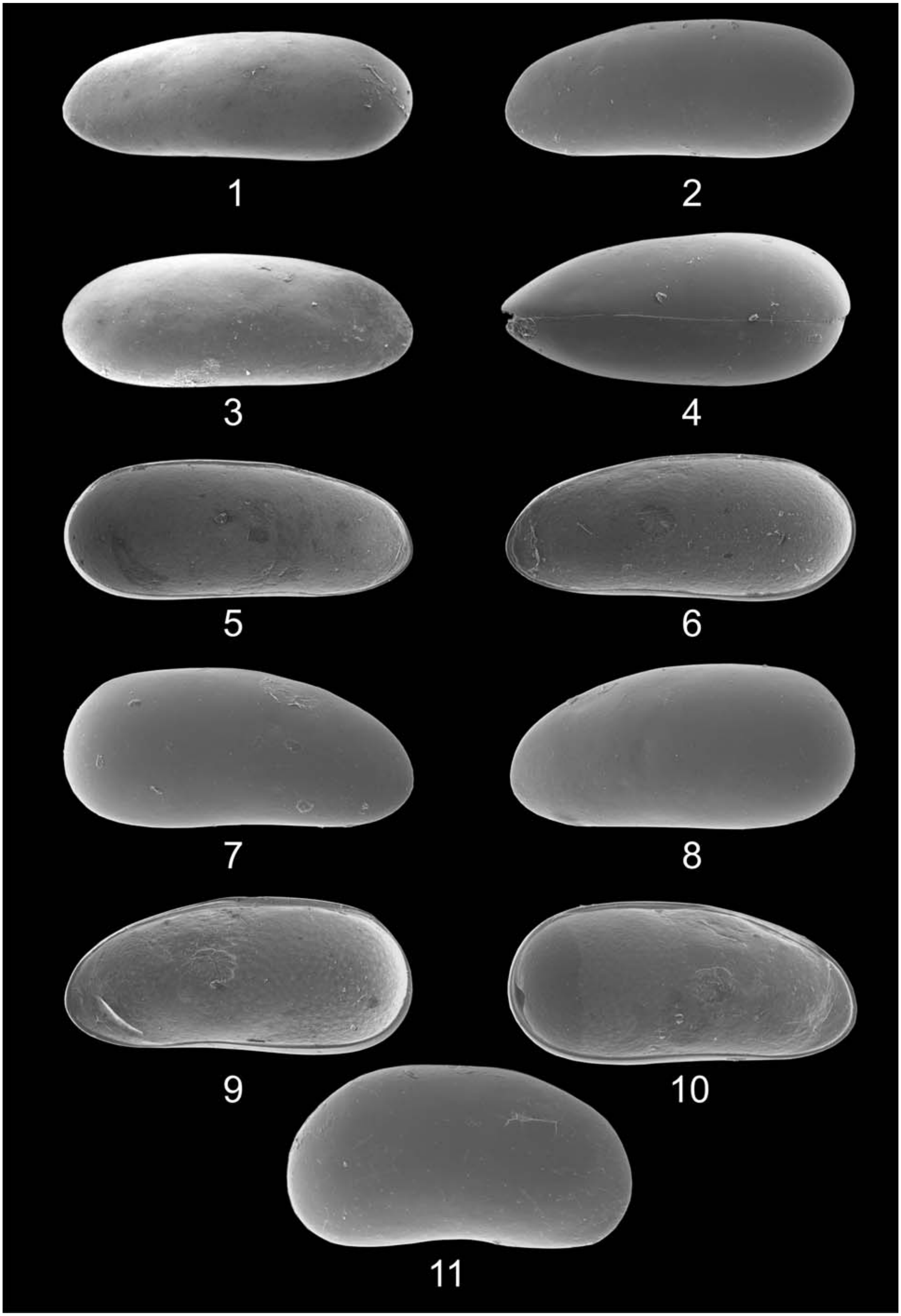
7 right valve, lateral external view, length: 673µm, height: 323µm, Sample Terma4/4, FCEN-LM 2926;

8 left valve, lateral external view, length: 651µm, height: 298µm, Sample Terma4/4, FCEN-LM 2927;

9 right valve, lateral internal view, length: 653µm, height: 295µm, Sample Terma4/4, FCEN-LM 2928;

10 left valve, lateral internal view, length: 668µm, height: 287µm, Sample Terma4/4, (FCEN-LM 2929).

11 *Candona* sp., right valve, lateral external view, length: 480µm, height: 287µm Sample Later1, (FCEN-LM 2930).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panningi was previously registered from central Chile (Valparaiso) and Perú (Brehm 1934, Klie 1941, Hartmann 1962). Only *P. incae* is exclusively known from the Altiplano. The first record of this species is from about 20000 years BP (during LGM times) from the Titicaca lake (Mourguiart et al. 1997, 1998). Thereafter, during the LG and Holocene the record of *P. incae* is almost continuous in the Titicaca area (Rossetti et al. 1996; Mourguiart and Montenegro 2002). If the endemism of *P. incae* is confirmed, it will be necessary to analyze if, as other faunistic elements, endemic ostracods have resisted the drier periods (i.e. LGM, Mid-Holocene) surviving in high altitude ecological refuges. In a dry-environment scenario, lake levels were extremely low, most basins were completely dry, and the fauna can only survive in areas with better local conditions, the so called "ecological refuges". During dry mid-Holocene, most faunal elements including mammals and their main predators (i.e., humans), concentrated their activities around the few remaining water bodies (Núñez and Grosjean 2003). This could have been either the LGM scenario, when only a few hardy species would have been able to survive remained in special places with large springs, regional river systems, and great lake basins -like the Titicaca basin- where resources remained stable through time and thresholds of water shortage were not surpassed. When more aquatic habitats were available again due to the more humid conditions, a rapid colonization of the dry Altiplano by species with effective dispersal strategies and wide ecological tolerances would have occurred. However, the only authoritative answer to this question would be documented in the sedimentary record, and this hypothetical scenario can be tested only by analyzing ostracod fossil assemblages from Late Quaternary sequences.

It is important to continue studying the distribution and ecology of recent ostracods of the Southern Altiplano in order to generate a solid database to enhance paleoenvironmental studies in this region and to give information about the timing of appearance of recent ostracods in this amazing corner of the world.

CONCLUSIONS

This study represents a first attempt to describe ostracod species from the Southern Altiplano of Argentina. Six taxa inhabiting in an isolated hot spring at 4000m asl were found. *Darwinula stevensoni* is ubiquitous and cosmopolitan: in South America it has been previously described from lowlands from Argentina and Brazil. *Hemicypris panningi* and *Cypridopsis fuhrmanni* were previously known from lower Andean areas situated to the north and to the south of the Altiplano. Only *Penthesilenula incae* is exclusively known from the Altiplano. Other two taxa, *Candona* sp. and *Herpetocypris* sp. are left in open nomenclature. *Hemicypris panningi, Cypridopsis fuhrmanni,* and *Penthesilenula incae* are found for the first time in thermal waters. Even when this fauna is taxonomically predictable in a hot spring, this is an interesting finding because it represents populations inhabiting an isolated high-altitude setting. The abundance of individuals in La Terma hot spring is surprising in comparison with other sampled sites in the area, in which total fauna is extremely scarce and darwinulids are rare. We think that La Terma represents a predictable environment in comparison with the surroundings as consequence of the thermal origin of its waters, and this allows the development of bigger populations.

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PLATE 2

1-7 *Hemicypris panningi* (Brehm 1934)

1 female carapace, left lateral view, length: 589µm, height: 362µm, FCEN-LM 2931;

2 female carapace, dorsal view, length: 519µm, width: 275µm, FCEN-LM 2932;

3 female carapace, right lateral view, length: 596µm, height: 364µm, FCEN-LM 2933;

4 female left valve, lateral internal view, length: 582µm, height: 347µm, FCEN-LM 2934;

5 male carapace, dorsal view, length: 586µm, width: 288µm, FCEN-LM 2935;

6 female right valve, lateral internal view, length: 625µm, height: 385µm, FCEN-LM 2936;

7 male left valve, length: 601µm, height: 350µm, FCEN-LM 2937.

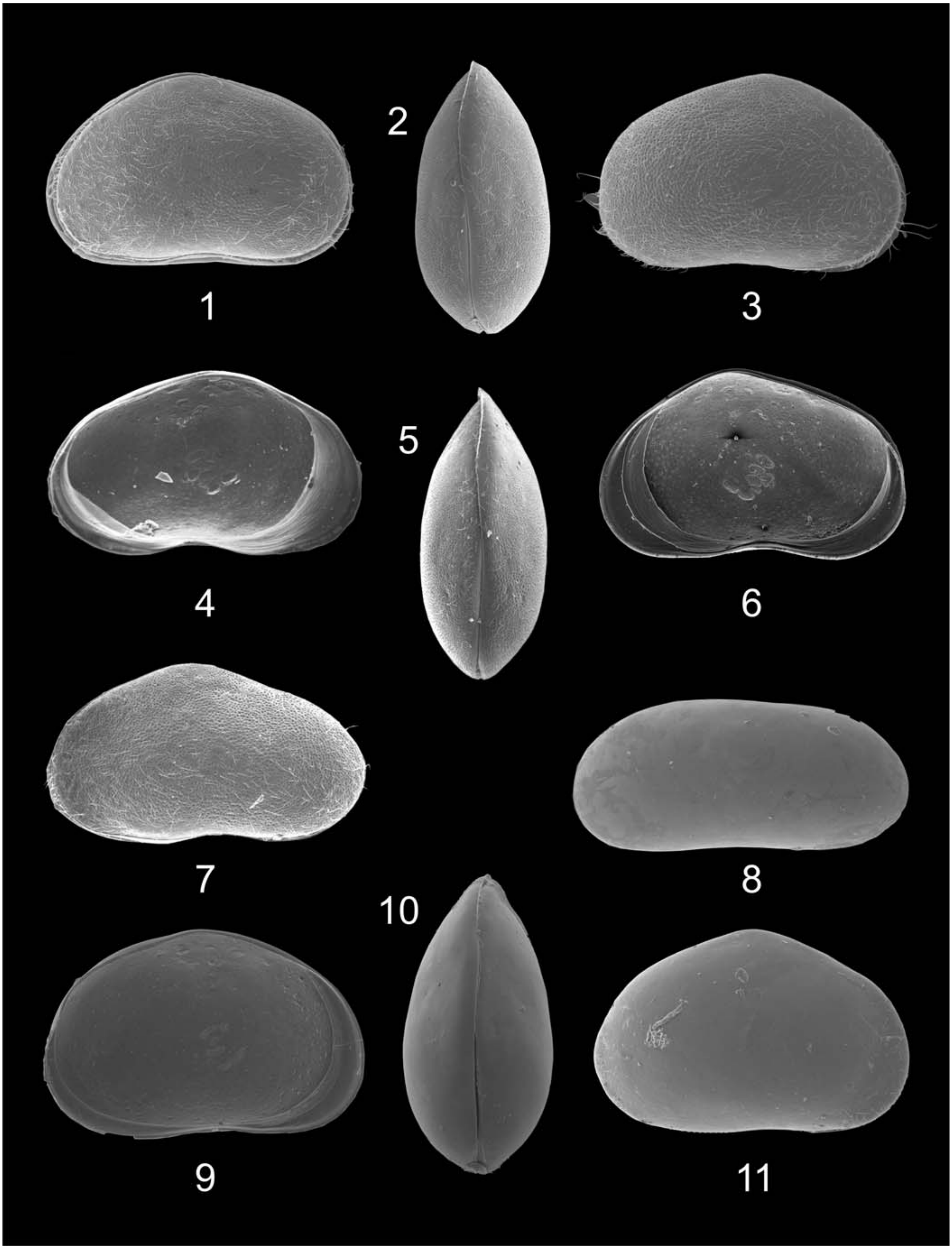
8 *Herpetocypris* sp. Immature left valve, lateral external view, length: 876µm, height: 400µm, Sample Later3, FCEN-LM 2938.

9-11 *Cypridopsis fuhrmanni* (Mèhes 1914).

9 left valve, lateral internal view, length: 871µm, height: 572µm, Sample Later3, FCEN-LM 2939;

10 carapace, dorsal view, length: 913µm, width: 470µm, Sample Later3, FCEN-LM 2940;

11 right valve, lateral external view, length: 887µm, height: 589µm, Sample Later3, FCEN-LM 2941.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