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THE FIRST RECORD OF THE FAMILY FUSHUNOGRAPTIDAE ('CONCHOSTRACA', SPINICAUDATA) FROM THE CAÑADÓN ASFALTO FORMATION (UPPER JURASSIC), PATAGONIA, ARGENTINA

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Abstract. A description is provided for *Wolfestheria smekali* gen. and sp. nov., a new member of the family Fushunograptidae, from the "Estancia La Sin Rumbo" locality in the Puesto Almada Member of the Cañadón Asfalto Formation. Assignment to the family Fushunograptidae is supported by evidence from detailed scanning electron microscope studies of this species. An assessment of the complex carapace ornamentation is also provided, as *W. smekali* exhibits an array of ornamentations that cover the entire carapace surface. These consist of irregular, thick radial lirae with numerous thin cross-bars on the dorsal middle-upper third of the carapace, changing to straight, thick radial lirae with fewer cross-bars restricted to the upper half of the growth band in the ventral third of the carapace, with the interspaces between the radial lirae wider than the lirae themselves, and with the radial lirae terminating in the upper part of the growth bands, where they then enlarge to form a triangular shape upon contact with the following growth line. These characteristics allow us to compare *W. smekali* with the eosestheriid genera *Yanjiestheria* Chen and *Abrestheria* Wang, as well as with the other fushunograptids from the Upper Jurassic to Lower Cretaceous of China such as *Cratostracus* Huang and *Qinghaiestheria* Wang. *W. smekali* is also comparable to fushunograptids and related forms from the Jurassic system of Argentina. The occurrence of *W. smekali* correlates biostratigraphically with the "*Eosestheriopsis dianzhongensis* fauna" of China, as well as with other Jurassic faunas from Africa and Europe. This correlation supports a Late Jurassic age for these fossiliferous assemblages (Puesto Almada Member, Cañadón Asfalto Formation) from the province of Chubut, Argentina.

Keywords. Spinicaudata. Fushunograptidae. Upper Jurassic. Cañadón Asfalto Formation. Patagonia.

Resumen. PRIMER REGISTRO DE LA FAMILIA FUSHUNOGRAPTIDAE ("CONCHOSTRACA", SPINICAUDATA) DE LA FORMACIÓN CAÑADÓN ASFALTO (JURÁSICO SUPERIOR), PATAGONIA ARGENTINA. Se describe *Wolfestheria smekali* gen. y sp. nov., Familia Fushunograptidae de la Formación Cañadón Asfalto, Miembro Puesto Almada, localidad "Estancia La Sin Rumbo". Los estudios detallados a través de la microscopía electrónica de barrido de la nueva especie, brindaron características que permitió asignarla a dicha familia. También aportaron información sobre la compleja ornamentación que cubre la totalidad del caparazón, compuesta por gruesas estrías radiales con numerosas y delgadas barras transversales en el tercio medio-dorsal del caparazón, cambiando a gruesas y rectas estrías radiales con unas pocas barras transversales en el tercio ventral del caparazón, estas barras están restringidas a la mitad superior de las bandas de crecimiento, los espacios entre las estrías radiales son más anchos que las estrías mismas, éstas no alcanzan la parte superior de las bandas de crecimiento y en su base se ensanchan hasta formar una estructura de forma triangular. Estas características permitieron comparar el nuevo taxon con los géneros de eosestherideos *Yanjiestheria* Chen y *Abrestheria* Wang, y también con otros fushunograptideos, como *Cratostracus* Huang y *Qinghaiestheria* Wang del Jurásico Superior y Cretácico Inferior de China. También, la nueva especie fue comparada con los fushunograptideos y formas relacionadas del Sistema Jurásico de la Argentina. Desde el punto de vista bioestratigráfico, *W. smekali* permitió comparar nuestra asociación con la "fauna de *Eosestheriopsis dianzhongensis*" y con otras faunas Jurásicas de África y Europa que apoyan la edad jurásica tardía para el Miembro Puesto Almada de la Formación Cañadón Asfalto (Provincia del Chubut, Argentina).

Palabras clave. Spinicaudata. Fushunograptidae. Jurásico Superior. Formación Cañadón Asfalto. Patagonia.

THIS paper describes a new fossil clam shrimp (*Wolfestheria smekali* gen. nov. sp. nov., "Conchostraca", Fushunograptidae: Spinicaudata) from the Cañadón Asfalto Formation (Middle–Late Jurassic) in the province of Chubut, Argentina. This is the second spinicaudatan recorded (Gallego *et al*., 2010) from the Puesto Almada Member (upper section of the Cañadón Asfalto Formation); and this new fushunograptid occurs in association with insect (trichopteran) fossil cases, ostracods and bivalve mollusks (Gallego *et al.*, 2011). Previous records of "conchostracans" (Tasch and Volkheimer, 1970; Vallati, 1986;

Gallego, 1994) are from the Las Chacritas Member (the lower section) of the classic localities situated at the south of Cerro Condor village. A more recent contribution (Gallego and Shen, 2010) described the first conchostracan record (*Congestheriella rauhuti*: Afrograptioidea) from the Puesto Almada Member (Cañadón Asfalto Formation), in the Sierra de la Manea, Puesto Limonao, Cerro Bayo and Estancia Fossati localities.

Since the first publication of conchostracan descriptions from the Cañadón Asfalto Formation by Tasch and Volkheimer (1970), a total of fourteen species of Jurassic spinicaudatans have been described, with ten of these from the Cañadón Asfalto Formation (Vallati, 1986; Gallego, 1994; Gallego and Rinaldi, 2001; Gallego *et al.*, 2010). In Argentina, the records of Jurassic continental invertebrate faunas are scarcer than for Triassic ones, since they come from only two Patagonian areas (Deseadean massif, La Matilde Formation and extra-Andean Chubut, Cañadón Asfalto Formation). Piatnitzky (1933, 1936), Feruglio (1949) and Frenguelli (1949) also published early reports of Jurassic invertebrates (as "*Estheria*" sp.) from the Chubut and Santa Cruz provinces (see Gallego, 1994).

Monferran *et al.* (2010) and Gallego *et al.* (2011) presented the first descriptions of the 45-meter thick fossil-bearing section of the "Estancia La Sin Rumbo" locality, which is composed of yellowish tuffs, tuffites and subordinated argillites. This section bears fossil spinicaudatans (*Wolfestheria smekali* gen. and sp. nov., described here), ostracods (*Penthesilenula*? *sarytirmenensis* (Sharapova) of Mandelstam, 1947; *Theryosinoecum barrancalensis minor* Musacchio *et al.*, 1990 and *Mandelstamia*? sp. Ljubimova, 1955), bivalves (cf. *Diplodon* Spix in Spix and Wagner, 1827), a gastropod mollusk and the first record of insect (trichopteran) cases (*Conchindusia* isp. Vialov and Sukatcheva, 1976; *Ostracindusia* isp. Vialov, 1973 and *Terrindusia* (*Terrindusia*) isp. Vialov, 1973). Gallego *et al.* (2011) have also described the presence of mud cracks in several levels of the section, indicating arid environmental conditions during deposition of the Puesto Almada Member. The presence of *W. smekali* gen et sp. nov., in addition to the stratigraphic correlations of this section as discussed in Gallego *et al.* (2011), support an Upper Jurassic age (Oxfordian–Tithonian) for the Puesto Almada Member. Radiometric age U/Pb (Cabaleri *et al.*, 2010b) obtained from zircons of the fossiliferous tuffites levels was 161±3 Ma (Oxfordian–Late Callovian?).

GEOLOGICAL SETTING

The Cañadón Asfalto Basin, located in the extra-Andean region of the Chubut province in southern Argentina (Fig. 1), is composed of several depocenters (Cabaleri *et al.*, 2006; Silva Nieto *et al.*, 2007), interpreted as pull-apart type basins related with the transcurrency of the Gastre System (Coira *et al.*, 1975). The sequences associated with the filling of these depocenters make up the Cañadón Asfalto Formation (Bajocian–Tithonian). These sequences begin with lacustrine limestones associated with pyroclastic deposits and basaltic rock of the Las Chacritas Member (Cabaleri and Armella, 1999; Silva Nieto *et al.*, 2003; Cabaleri *et al.*, 2008a,b, 2010a,b). The Puesto Almada Member represents the progradation of the lacustrine system from the Las Chacritas Member towards a fluvial system (Cabaleri *et al.*, 2005). This unit is characterized mainly by tuff deposits, intercalated with laminated, varvitic limestones, mudstones and sandstones.

The "Estancia La Sin Rumbo" locality is an outcropping of the Puesto Almada Member of the Cañadón Asfalto Formation, consisting of a monotonous sequence of tuffs and tuffites (Fig. 1). The base is covered and the tuffaceous levels are prevailing. The environment determined for the "Estancia La Sin Rumbo" locality corresponds to shoreline areas of the Cerro Condor palaeolake. The geology, sedimentology, environment and paleontology of the "Estancia La Sin Rumbo" locality (Cerro Cóndor depocenter) have been analyzed in more detail in Gallego *et al.* (2011).

MATERIAL AND METHODS

The materials studied here were first collected in 1994 by Wolfgang Volkheimer (Mendoza, Argentina) and Helga Smekal Bariloche Paleontological Association, at the locality informally known as Km 40 ("Estancia La Sin Rumbo"). This locality lies on the west side of the Chubut river, near provincial road No. 12 (km 88.7), 40 km to the north of Cerro Condor village (GPS 12: 43°16′49.2″S–69°07′45.3″W; GPS 13: 43°9′22.2″S–69°16′46.9″W). The original samples include conchostracans, bivalve mollusks, ostracods and fossil tricopteran cases. These have been assigned to the Cañadon Asfalto Formation, but until recently their exact stratigraphic position remained unresolved (Gallego *et al.*, 2011). During two other field projects in December 2007 and March 2009, the present authors performed a detailed study of a profile in this sequence and collected further samples.

The taxonomy adopted here mainly follows that of Chen and Shen (1985) and Martin and Davis (2001), while the measurement abbreviations correspond to those of Defretin-LeFranc (in Tasch, 1987): **L,** valve length; **H,** valve height; **Ch,** hingeline length; **Cr**, distance from beak to anterior end of the valve; **Av**, distance from anterior end of the dorsal margin to the anterior end of the valve; **Arr**, distance from the posterior end of the dorsal margin to the posterior end of the valve; **a**, distance from maximum anterior bulge to dorsal margin; **b**, distance from maximum posterior bulge to dorsal margin; **c**, distance from maximum ventral bulge to the anterior end of the valve. The morphological terms used include (*sensu* Reible, 1962): Telliniform, when the dorsal margin is joined continuously with the posterior margin; and Cicladiform, when the posterior and dorsal margins form an obtuse angle between them.

The repository and institutional abbreviations used here are: **MPEF-PI**, Paleoinvertebrates Collection, Museo Paleontológico Egidio Feruglio, Trelew, Argentina and **CTES-PZ**, Paleontological collections of the Universidad Nacional del Nordeste, Corrientes, Argentina. Scanning electron microscope (SEM) studies were carried out with a JEOL JSM-5800-LV electron microscope (of the Secretaría General de Ciencia y Técnica - Universidad Nacional del Nordeste, Corrientes, Argentina) and microphotographs were taken to provide more detailed evidence on the morphologic characteristics of the conchostracan species described here. Detailed studies and description were also made with the aid of an Olympus SZ51

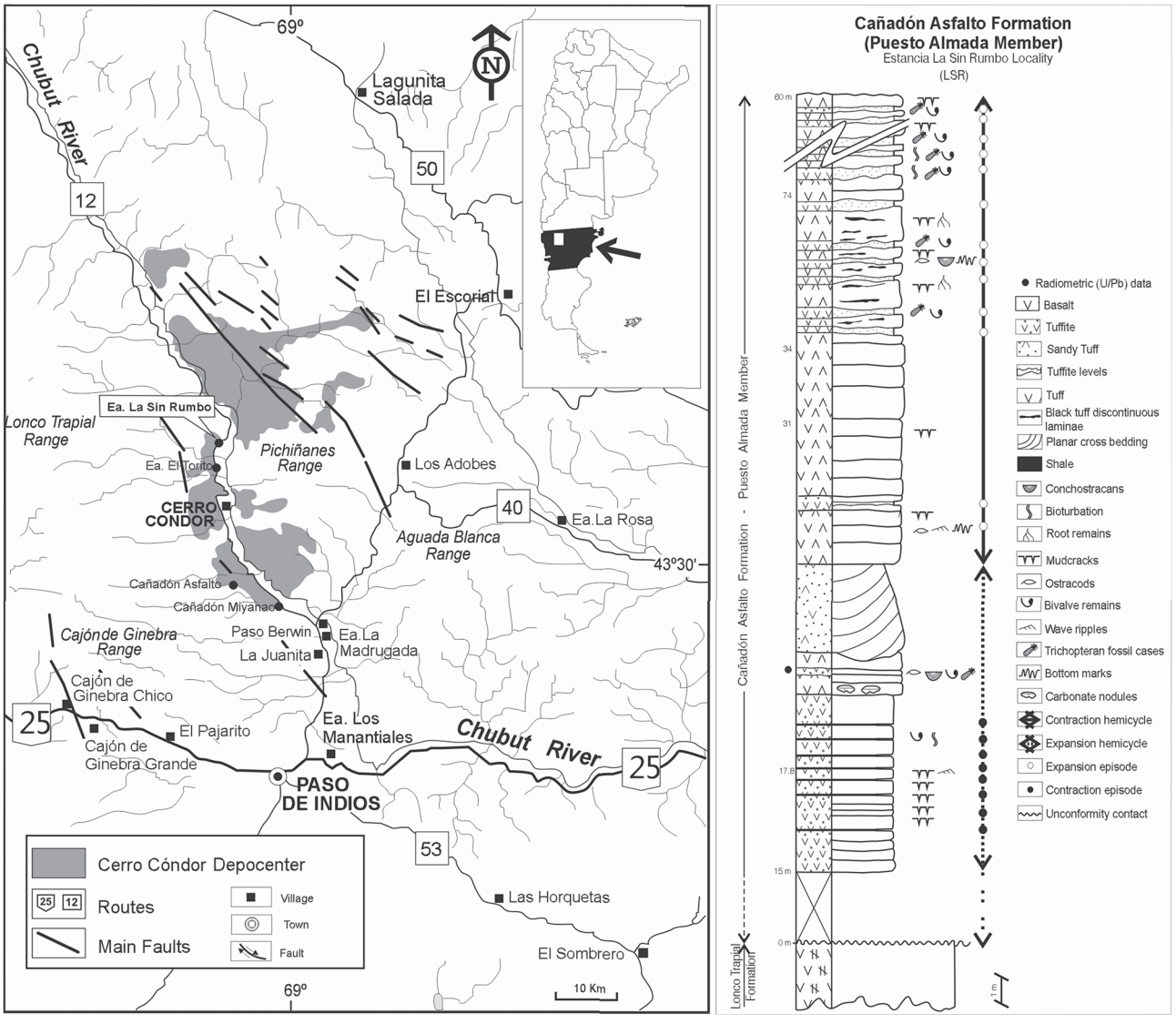

Figure 1. Location map and columnar section of the "Estancia La Sin Rumbo" locality, modified from Gallego *et al.* (2011).

binocular microscope (Centro de Ecología Aplicada del Litoral, Centro Científico Tecnológico Nordeste, Consejo Nacional de Investigaciones Científicas y Técnicas, Corrientes, Argentina).

SYSTEMATIC PALEONTOLOGY

Order Diplostraca Gerstaecker, 1866

For more information about the use and meaning of the names "Conchostraca" and Diplostraca (see Gallego, 2010 and Gallego *et al.*, 2010), consult the following references for fossil and extant forms (Fryer, 1987, Martin and Davis, 2001, Olesen, 1998, Shen, 2003, 2011, Shen and Huang, 2008, Shen *et al.*, 2006, Stenderup *et al.*, 2006).

Suborder Spinicaudata Linder, 1945

Superfamily Estheriteoidea Zhang and Chen (in Zhang *et al.*, 1976)

Family Fushunograptidae Wang (in Hong *et al.*, 1974)

Genus ***Wolfestheria*** gen. nov.

Type species. *Wolfestheria smekali* gen. nov. sp. nov., described here.

Derivation of name. Dedicated to Wolfgang Volkheimer (Mendoza, Argentina), who discovered the locality and collected the first samples.

Type stratum and age. "Estancia La Sin Rumbo" locality, Cerro Cóndor, Chubut (Argentina), Cañadón Asfalto Formation, Puesto Almada Member, Late Jurassic.

Diagnosis. Small fushunograptid spinicaudatan, with an outline varying from telliniform ovate-elliptical (male?) to cicladiform subcircular-subtriangular (female?), anterior and posterior margins with equal convexity and length, sub-central umbo, and growth bands ornamented with irregular, thick radial lirae (>7.7 µm in width), with numerous cross-bars in the dorsal medium-upper third of the carapace, changing to straight, thin radial lirae (<7.7 µm width) with fewer cross-bars (4.1–8.3 µm in width) restricted to the upper half of the growth band in the ventral third of the carapace, the interspaces between the radial lirae are wider (7.7–15.4 µm) than the radial lirae themselves, the radial lirae do not reach the upper part of the growth bands, but enlarge to form a triangular part upon contact with the following growth line, and with number of growth lines varying from 14 to 25, occasionally up to 50.

Remarks. The morphological features (outline and ornamentation) and size of the *Wolfestheria* carapace allow us to define it as a new genus in the family Fushunograptidae. *Wolfestheria* differs from the most common eoesetheriid genus, *Yanjiestheria* Chen, in that the carapace is smaller than those of typical yanjiestheriids (5–15 mm long) and the ornamentation differs in that the interspaces between the radial lirae are wider than the radial lirae themselves (Li *et al.*, 2007).

Other eosestheriids, like *Abrestheria* Wang, appear similar to *Wolfestheria* because the radial lirae are enlarged to form a triangular terminus, which results in an almost serrate-like pattern immediately above the preceding growth line, however, *Abrestheria* differs by the presence of some serration structure in the lower margin of the growth lines and transitional ornamentation between reticulate and radial lirae (Li *et al.*, 2006).

Comparisons with other fushunograptids also reveal similarities with *Cratostracus* Huang, in that the radial lirae do not reach the upper part of the growth bands, although this taxon also differs by the lack of serrations along the lower margin of the growth lines (Li and Batten, 2004a,b). According to the ornamentation on the new genus is somewhat similar to that of *Qinghaiestheria* Wang from the Upper Jurassic Hongshuigou Formation in Qinghai and the Penglaizheng Formation in Sichuan (Wang, 1983; Shen and Chen, 1982; Li, 2004), as this genus also has serrate structure along the lower margin of the growth lines.

Wolfestheria smekali gen. nov. sp. nov.

Figures 2, 3

Derivation of name. Dedicated to Helga Smekal (Bariloche Paleontological Association, Río Negro, Argentina) who provided the samples from this new fossiliferous locality in Chubut province.

Holotype. MPEF-PI 1180, dimensions (mm): L= 3.8; H= 2.6; H/L= 0.68.

Paratypes. MPEF-PI 1178, 1185, and 1187; CTES-PZ 7475 and 7477; 7288 (MEB 2), 7360 (MEB 9), and 7483 (MEB 16) SEM samples.

Additional materials. MPEF-PI 1182. CTES-PZ 7476, 7478, 7479, and 7480.

Geographic provenance. Cerro Cóndor, Chubut (Argentina), GPS 12: 43°16′49.2″S–69°07′45.3″W.

Stratigraphic source. Cañadón Asfalto Formation, Puesto Almada Member, Oxfordian–Tithonian, Late Jurassic.

Repository. Paleoinvertebrates Collection, Museo Paleon-

tológico Egidio Feruglio, Trelew, Chubut (Argentina) and Paleontological collections of the Universidad Nacional del Nordeste.

Diagnosis. Same as the genus.

Measurements (in mm). L= 3–5.5, H= 2–4; H/L= 0.62–0.89, Ch= 1.6–2.1, Arr= 0.5–1.1, Av= 0.3–0.6, Cr= 0.5–1.5, a=1–1.5, b= 1–1.6, c= 1.5–2.

Description. Small fushunograptid spinicaudatan (Figs. 2, 3.1–2), with an outline varying from telliniform ovate-elliptical (males?, Figs. 2.2, 2.4, 3.1) to cicladiform subcircular-subtriangular (females?, Figs. 2.1, 2.3, 3.2), dimensions ranging from 3–5.5 mm in length (L) and 2–4 mm in height (H), H/L ratio ranging from 0.62–0.78 (males?) and 0.8–0.89 (females?), dorsal margin nearly straight (female?) to convex (males?), markedly upper posterior angle (female?), anterior and posterior margins with equal convexity and length, subcentral umbo and growth bands ornamented with irregular, thick radial lirae (>7.7 µm in width), with numerous cross-bars in the dorsal medium-upper third of the carapace knit into a lattice-like reticulation (Fig. 3.3–4), changing to straight, thin radial lirae (<7.7 µm in width) with fewer cross-bars (4.1–8.3 µm) restricted to the upper half of the growth band in the ventral third of carapace (Fig. 3.5–6), the interspaces between the radial lirae are wider (7.7–15.4 µm) than the radial lirae themselves, the radial lirae do not reach the upper part of the growth bands, but enlarge to form a triangular part from where they reach the growth line downwards (Fig. 3.6), number of growth lines varying from 14 to 25 up to 50.

Discussion. The morphological features (outline and ornamentation) and size of the carapace, allow us to define this material as a new genus and species in the family Fushuno-

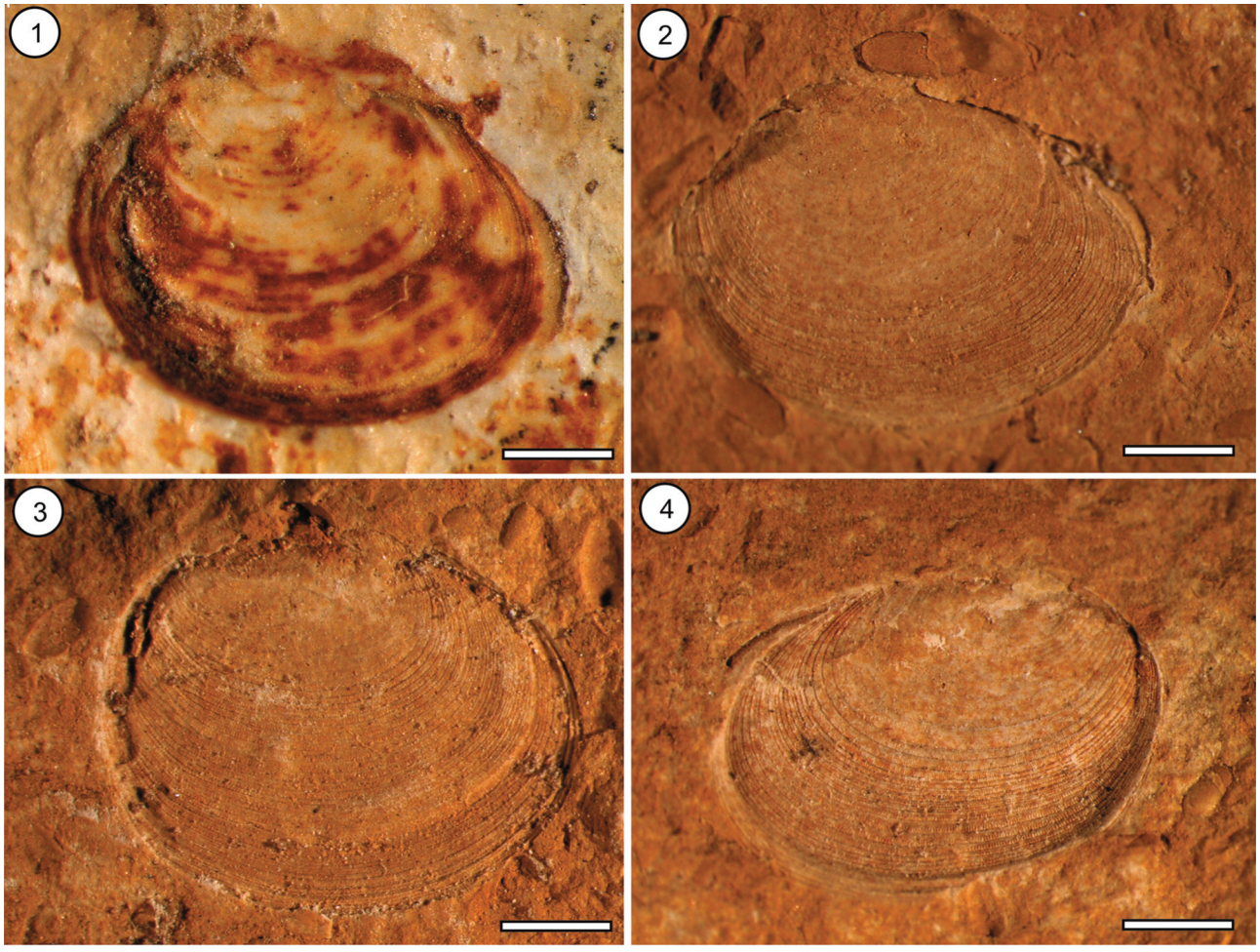

Figure 2. ***Wolfestheria smekali*** gen. nov. sp. nov., from the Puesto Almada Member, Cañadón Asfalto Formation. General shell morphology, external mould; **1,** MPEF-PI 1180, holotype, female subtriangular-cicladiform left valve; **2,** MPEF-PI 1178 paratype, male ovate-telliniform left valve; **3,** MPEF-PI 1178 paratype, female subcircular-telliniform left valve; **4,** MPEF-PI 1178, paratype, male elliptical-telliniform right valve. Scale bar= 1 mm.

graptidae. It differs from other Argentinean Jurassic species (all from the Cañadón Asfalto Formation except for *Cyzicus (Lioestheria) malacaraensis* Tasch, 1987 from the La Matilde Formation) based upon the morphological features summarized in Table 1.

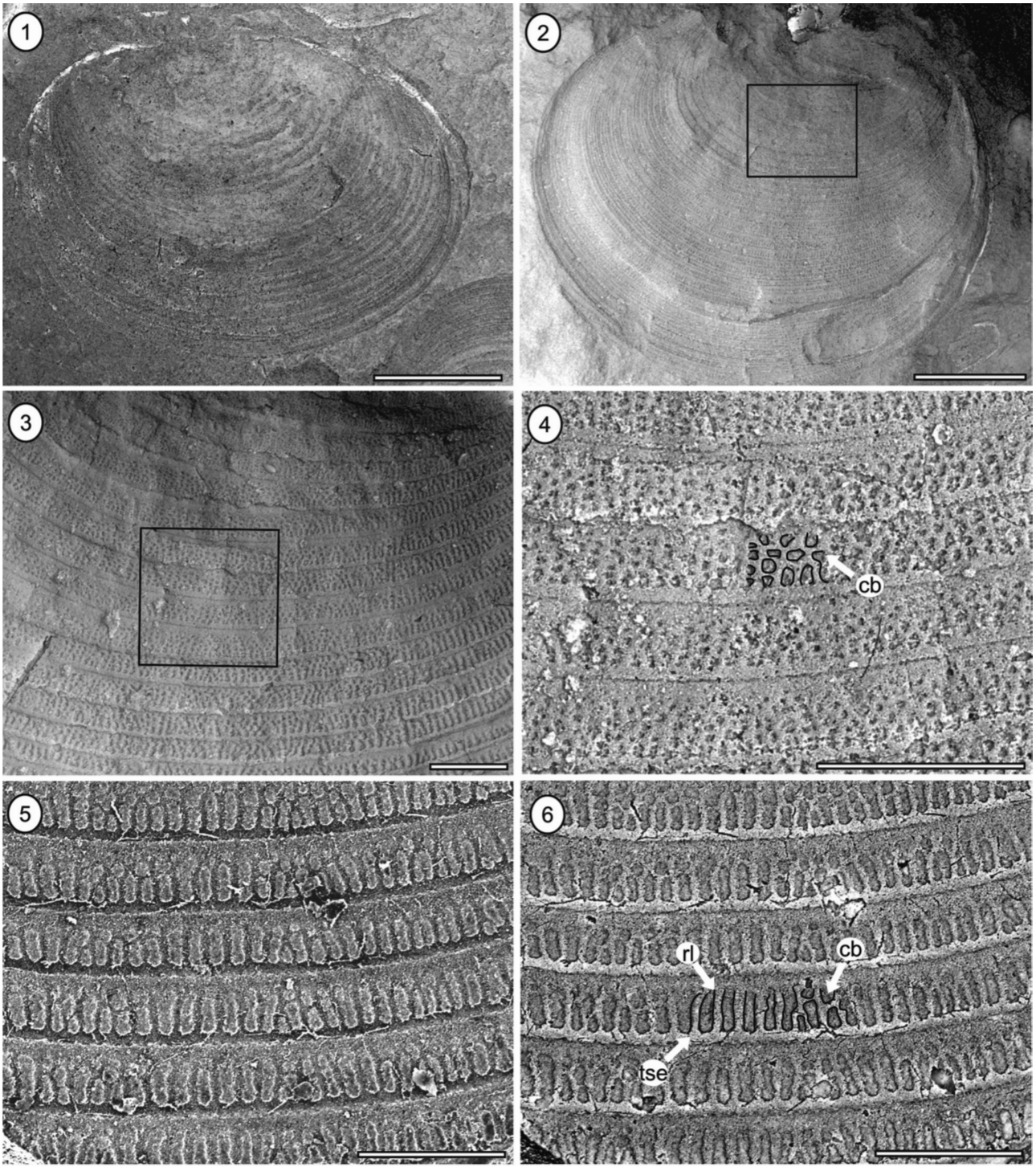

Figure 3. ***Wolfestheria smekali*** gen. nov. sp. nov., **1, 5, 6.** CTES-PZ 7360; **2, 3, 4.** CTES-PZ 7483, SEM micrographs. **1,** general view of a elliptical male valve; **2,** general view of a subcircular female valve; **3,** Details of the mid-dorsal ornamentation, from the square seen in figure 3.2; **4,** details of growth band ornamentation, from the square seen in figure 3.3; **5,** details of growth band ornamentation from the ventral area of the valve; **6,** inverted image of figure 5. **cb,** cross bars; **rl,** radial lirae; **tse,** triangular shape end. Scale bar **1**–**2**= 1 mm; **3**–**6**= 0.2 mm.

TABLE 1. Fushunograptid spinicaudatan records (including some doubtful forms) from the Jurassic of Argentina.

Geological Units		Localities	Taxa/Authors	Main diagnostic features	Current taxonomic status
Cañadón Asfalto Fm.	Chubut Province	Cañadón Lahuincó	**Cyzicus (Lioestheria) patagoniensis** *Tasch Tasch and Volkheimer, 1970*	*Ovate to subelliptical outline, umbo subterminal to subcentral, straight dorsal margin and ornamentation of very fine close spaced hachure-type marking.*	*Family Eosestheriidae*
			Cyzicus (Lioestheria) *sp. A Tasch and Volkheimer, 1970*	*Slightly convex dorsal margin, subcentral umbo raised above dorsal margin and ?poustulate ornamentation between growth lines.*	*Family Fushunograptidae*
		Cañadón Las Chacritas	**Cyzicus (Lioestheria)** *sp. C Tasch and Volkheimer, 1970*	*Form similar to the species patagoniensis with anterodorsal margin strongly rounded than posterodorsal one.*	*Family Fushunograptidae*
		Colan Conhué	**Cyzicus (Lioestheria)** *sp. B Tasch and Volkheimer, 1970*	*Slightly convex dorsal margin, subterminal umbo and pustulate ornamentation.*	*Family Fushunograptidae*
		Cerro Cóndor and Cerro Bayo	**Cyzicus (Lioestheria)** *sp. 1 Vallati, 1986*	*Morphotypes B with radial lirae and growth line beads and morphotype C with punctuate ornamentation and growth line beads.*	*Family Fushunograptidae*
		Estancia La Sin Rumbo	**Wolfestheria smekali** *gen. nov. sp. nov.*	*Telliniform ovate-elliptical to cicladiform subcircular-subtriangular outline, sub-central umbo, growth bands with irregular, thick radial lirae with numerous cross-bars changing to straight, thin radial lirae.*	*Family Fushunograptidae*
La Matilde Fm.	Santa Cruz Province	*Estancia El Malacara*	**Cyzicus (Lioestheria) malacaraensis** *Tasch, 1987*	*Elliptical outline, anterior umbo and strong radial lirae ornamentation.*	*Family Fushunograptidae*
		Gran Bajo de San Julian, Puesto Raspuzzi	**Cyzicus (Lioestheria) santacrucensis** *Gallego, 1994*	*Ovate-subcircular pteriforme outline, straigth to slightly convex dorsal margin, areolar to radial striated ornamentation pattern.*	*Family Palaeolimnadiopseidae*

TAXONOMY AND EVOLUTION

Jurassic records for Gondwanan spinicaudatans

Jurassic spinicaudatan faunas from the Southern Hemisphere (Tasch, 1987) are known from Antarctica (45 spp.), Africa (13 spp.), South America (19 spp. from Brazil, Colombia, and Venezuela; not including Argentina), and India (7 spp.). Many of the Argentinean Jurassic conchostracans (14 spp.) are in need of taxonomic review and possible re-assignment. If we compare all of the southern conchostracan faunas (at the specific and familial levels), the Argentinean fauna appears to be the least diversified, lacking four or five of the families known to occur in Antarctica and the rest of South America.

Although the African and Indian faunas include fewer described species, they are actually equal to or greater than the Argentinean fauna in terms of species diversity, and they also contain families not recorded in Argentina. Tasch (1987) has proposed that the low diversity and rather sparse fossil record of Jurassic conchostracans in Argentina is due to the presence of palaeogeographic barriers (along with other sources of error such as collection bias). Geographic barriers, like those proposed by Tasch (1987), would explain the lack of dispersal routes between Argentina and Brazil and account for the subsequent disparity between the taxonomic composition of the fossil faunas from the two countries. However, recent studies based upon ostracod and conchostracan records contradict this proposition (Musacchio, 2001; Gallego, 2002). If we apply the taxonomic opinions of Chen and Shen (1985), Shen (1994), Gallego and Covacevich (1998) and Gallego (2010), the Argentinean fauna is composed of "Lioestheriidae" or family Fushunograptidae (46.6%), Eosestheriidae (30.0%), Euestheriidae (22.7%) and Paleolimnadiopseidae (7.7%), accounting for all currently known taxa.

Fushunograptids from West Gondwana

The fourth formally recognized record of these spinicaudatans from South America involves the occurrence of species within the superfamily Estheriteoidea (Shen *et al.*, 2004; Prámparo *et al.*, 2005, Rohn *et al.*, 2005). Zhang *et al.* (1976) assigned spinicaudatans with ornamentation featuring radial lirae to the superfamily Estheriteoidea, which includes the families Asmussiidae, Polygraptidae (now belonging to Eosestherioidea), Fushunograptidae, Jilinestheriidae, Halysestheriidae, Estheriteidae and Dimorphostracidae. This superfamily ranges from the Devonian to the Eocene (Paleogene) of China, Mongolia, Russia, Germany, England, North America, Antarctica and South America.

There are many Gondwanan records of forms belonging to the family Fushunograptidae (Lioestheriidae *sensu* Tasch, 1969). In most of the South American records these are referred to as "lioestheriids" (also "bairdestheriids", according to Gallego and Martins-Neto, 2006), with many of these probably belonging to the Eosestherioidea–Estheriteoidea group from Chen and Shen's systematics scheme). This is the most abundant type in the South American Jurassic–Cretaceous, and it is also problematic because of its inclusion of so many different type of conchostracans, some of which are species in common with central Africa. This group includes ten species, with different types of ornamentation. These occurrences have diversified the Jurassic–Lower Cretaceous record in South America and support the presence of the superfamily Estheriteoidea since the Late Triassic, based upon records of *Liograpta zavattieri* Gallego (1999), *Polygrapta troncosoi* (Gallego and Covacevich, 1998, Gallego *et al.*, 2005) and *Bairdestheria barbosai* Almeida, 1950 (with a doubtful Cretaceous record). The Argentinean conchostracan record is augmented by the occurrence of Middle–Late Jurassic species, such as *Cyzicus (Lioestheria)* sp. A, B and C (Tasch and Volkheimer, 1970), *Cyzicus (Lioestheria)* sp. 1 (Vallati, 1986), *Cyzicus* (*Lioestheria*) *malacaraensis* Tasch, 1987, and *Euestheria* sp. 1 (Vallati, 1986). All of these taxa are in need of further microscopic (SEM) study, in order to arrive at accurate taxonomic assignments. Furthermore, Shen (1994) has suggested that *Cyzicus* (*Lioestheria*) *malacaraensis* Tasch, 1987 from the La Matilde Formation (Middle–Upper Jurassic) in Argentina's Santa Cruz province, could also be an eosestheriid. Recent unpublished studies however, suggest that at the type locality for this species (El Malacara farm), there is also *Cyzicus* (*Lioestheria*) *malacaraensis* coexisting (which may be a fushunograptid or "lioestheriids" *sensu* Tasch 1969), as well as a true eosestheriid, probably belonging to the genus *Carapacestheria*. The most recent record, *Orthestheria (Migransia) ferrandoi* Herbst from Jurassic–Cretaceous sequences in Uruguay (Shen *et al.,* 2004), completes the scenario for this group in southern South America. The Lower Cretaceous fushunograptid fauna is completed with the records of *Lioestheria cassambensis* Teixeira, *Lioestheria mirandibensis* Cardoso, and *Lioestheria mawsoni* Jones, which have strongly striated ornamentation (sinuous and anas-

tomose). Another Cretaceous form with the same type of sculpture is *Pseudograpta brauni* Cardoso, but this species has other variations such as crenulations and nodes. Again, SEM studies are required in order to define the most likely taxonomic positions of these taxa. Other forms are referred to as "lioestheriids" based upon details such as the alveolar sculpting in *Pseudestheria iphygenioi* Cardoso or the microalveolar ornamentation found in *Pseudestheria pricei* Cardoso. *P. pricei* and *P. brauni* are mentioned by Rohn *et al.* (2005) as being related to *Bauruestheria sancarlensis* Rohn, Shen and Dias Brito (Jilinestheriidae), the only Late Cretaceous members of the Estheriteoidea group recorded in South America. The Lower Cretaceous conchostracan record from Argentina consists of the family Polygraptidae (Eosestherioidea), represented by *Dendrostracus lagarcitoensis* Gallego (Prámparo *et al.*, 2005) and the genus belonging to the Jilinestheriidae, the only member of the Estheriteoidea recorded from the Cretaceous in Argentina (Volkheimer *et al.*, 2009).

Evolutionary implications

The record of spinicaudatans belonging to the family Fushunograptidae in West Gondwana offers new possibilities for understanding the evolution and distribution of this group. Based upon uncertain records mentioned by Tasch (1969) and Chen and Shen (1985), the first "lioestheriids" or fushunograptid probably evolved early during the Devonian. It is also possible that these are derived from the large "euestheriid" group, which contains many other taxa including *Asmussia*, *Rhabdosthicus*, *Euestheria*, *Lioestheria* and *Cyclestherioides*). Pre-Devonian conchostracans such as the Cambrian marine bivalves calcareous specimens assigned by Ulrich and Bassler (1931) to the family Limnadidae and mentioned as conchostracan ancestors, have likely been assigned to the Branchiopoda in error. These forms were included by Kobayashi (1954) in the family Lepidittidae and were considered by Novojilov (1960) and Tasch (1963) as unacceptable conchostracans.

According to Chen and Shen (1985: 187–197), in their chapter on the rise and evolution of conchostracans with radial striae ornamentation:

The early representative of the superfamily Estheriteoidea with radial lirae ornamentations came from the Middle Devonian from the Northern Hemisphere. Few forms of that superfamily were found in the Permian and Triassic. Then, the superfamily is rapidly developed in the Early Cretaceous and early Late Cretaceous. *Orthestheria* and *Orthestheriopsis* became important representatives of the Tethys biogeographic province. It is an evolutionary trend from simple radial striae to complex striae, such as *Orthestheria* with simple regular radial striae in the Early Cretaceous changing into *Nemestheria* with long radial striae intercalated with short striae in the early Late Cretaceous, into *Halysestheria* with chainwork sculpture in the Late Cretaceous and into *Dimorphostracus* with dendrite sculpture in the Late Cretaceous and into *Estherites* with radial striae and concave sculpture in Late Cretaceous. Seven conchostracan zones have been established, based on their rapid evolution in the Late Cretaceous of Songliao Basin, NW China (Zhang *et al.*, 1976).

This quoted paragraph shows that the evolution of the estheriteoids–fushunograptids during the Jurassic is less well-known. In this context, the earliest (but not the oldest) members of the group in southern South America are represented by the new records of *W. smekali* discussed here (with a complex ornamentation pattern) as well as by existing occurrences of *L. malacaraensis* (with an orthestheriid ornamentation pattern), both from Middle–Late Jurassic sequences in Patagonia, and also by *Orthestheria* (*Migransia*) *ferrandoi* Herbst from the Late Jurassic–?Early Cretaceous in Uruguay. As noted by Chen *et al.* (2007), this fauna lacks an analog in Eurasia. Eurasian conchostracan faunas are mainly composed of eosestheriids, euestheriids, monilestheriids, nestoriids and keratestheriids, along with other taxa that form the complex of orthestheriid–fushunograptid groups that appear at the end of the Late Jurassic.

Biostratigraphic and paleobiogeographical significance

According to Chen *et al.* (2007), during the extensive early Late Jurassic transgression in Western Europe, the *Pseudograpta* fauna migrated to East Asia where *Ambonella*, *Jibeiestheria*, *Keratestheria*, *Mesolimnadia*, *Monilestheria*, *Nestoria*, *Pseudograpta* and *Sentestheria* became the dominant taxa. *Pseudograpta morrisi* Chen and Hudson, the possible ancestor of *Eosestheria*, has not been encountered in Late Jurassic Oxfordian (Tuchengzian) and Kimmeridgian (Dabeigouan) deposits. However, towards the end of the Jurassic Period, intensive tectonic (Yanshan) activity coincided with a warm, arid climate in eastern Asia. As a result, almost all of the components of the *Nestoria–Keratestheria* fauna (middle Late

Jurassic) appear to have gone extinct. They were replaced by a fauna in which *Eosestheria* occurred abundantly and radiated rapidly to occupy the entire drainage system of the ancient Amur River, including southern Mongolia, northern and northeastern China and Transbaikalia (Chen, 1987), which also coincided with the areal extent of the middle Jehol Biota (Chen, 1999). The *Eosestheria* fauna is an important component of the Jehol Biota, which has become well known in recent years because of the discovery of feathered dinosaurs, early birds, early angiosperms and primitive mammals. This biota, originally called the *Eosestheria middendorfii – Ephemeropsis trisetalis* (insect) – *Lycoptera* (fish) fauna, includes about 20 fossil groups and the rudiments of the dominant modern land biota. Although there are no eosestheriids in the "*Eosestheriopsis dianzhongensis* fauna", there are small orthestheriids: *Qinghaiestheria chuanzhongensis* (Shen and Chen), *Q. sichuanensis* (Shen and Chen), *Q. suboblonga* (Shen and Chen) (Li, 2004) and *Orthestheria* sp. Orthestheriids bearing serrate growth lines are common in Late Jurassic–Early Cretaceous sequences in South America (Shen *et al*., 2004; Prámparo *et al*., 2005) and the Wealden succession of southern England, and they are also abundant in the Early Cretaceous deposits of coastal southeast China. Although they have not been found in the *Eosestheria* fauna in the past, recently a few specimens of *Cratostracus*? *cheni* Li and Batten (which should be of an Early Cretaceous age) have been recovered from the Yixian Formation at Sanguanmiao and Gujialing in Kazuo, western Liaoning (Li and Batten, 2004a). At present the origin of these forms is unclear. The genus *Qinghaiestheria* Wang (which should be Kimmeridgian in age) was originally recorded from the Hongshuigou Formation (Mangya, Qinghai), and it also occurs in the Penglaizhen Formation (Sichuan Basin, southwestern China), with both of these considered to be Late Oxfordian in age. According to Li and Matsuoka (2012) the *Qinghaiestheria* fauna has been assigned to the Kimmeridgian. *Qinghaiestheria* is similar to *Polygrapta biaroensis* Defretin-LeFranc, 1967 (ascribed to the fushunograptid *Migransia* by Chen and Shen, 1977) from the Upper Jurassic Stanleyville Series (Congo Basin, Africa), while the Hongshuigou Formation has yielded *Sinoestheria* Chang, which strongly resembles *Palaeolimnadiopsis lombardi* Defretin-LeFranc (Stanleyville Series). The Stanleyville Series is dated as Kimmeridgian in age (Defretin-LeFranc, 1967).

The presence of a fushunograptid (*Wolfestheria smekali* gen. nov. sp. nov.) in the Jurassic of South America and the addition of two unpublished records for the Palaeolimnadiopseidae (from the Puesto Almada Member, Cañadón Asfalto Formation and from the La Matilde Formation), allows us to correlate our sequences with Jurassic sequences from Asia, Africa and Europe, and mainly to correlate our faunas with coeval ones that characterize bioestratigraphical units from China and Asia. This finding also supports the previously proposed Late Jurassic Oxfordian to Tithonian age (Cabaleri *et al*., 2010a, b; Gallego *et al*., 2011) for the Puesto Almada Member of the Cañadón Asfalto Formation (Chubut Province, Argentina).

CONCLUSIONS

The new record presented here for *Wolfestheria smekali* gen. nov. sp. nov., a member of the family Fushunograptidae from the western margin of Gondwana, provides new evidence related to the development and evolution of this spinicaudatan family, while also implying a need for new evaluations and interpretations. These new findings allow us to correlate Jurassic sequences from South America with coeval stratigraphic levels from China and Asia and also to correlate our Jurassic faunas with the Jehol Biota and the Upper Jurassic *Eosestheria* fauna from China.

Finally, it is worth noting that the spinicaudatan genus *Qinghaiestheria* has been recovered from the Late Jurassic (Kimmeridgian) of China with an associated palaeolimnadiopsid spinicaudatan and similar associations have been recorded in the Late Jurassic (Kimmeridgian) of Africa and the Middle to Late Jurassic (Callovian–Oxfordian, La Matilde Formation) of Patagonia in Argentina. An undescribed species from the family Palaeolimnadioseidae has also been recorded from the Puesto Almada Member (at the Estancia Fossati locality). When combined, these data offer new evidence for paleontological and paleobiogeographical spinicaudatan relationships between central Africa and South America (ASA province), as suggested by Gallego and Martins-Neto (2006) and Gallego *et al*. (2010).

Finally, in addition to the other faunas mentioned above, the assemblage studied allows us to compare our association with the "*Eosestheriopsis dianzhongensis* fauna" (Chen *et al*., 2007; Li, 2004). Such comparisons support a Late Jurassic age for the levels bearing *Wolfestheria smekali* gen. nov. sp. nov. in the Puesto Almada Member, Cañadón Asfalto Formation.

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