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The Valanginian Olcostephaninae Haug, 1910 (Ammonoidea) from the Andean Lower Cretaceous Chañarcillo Basin, Northern Chile

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ABSTRACT. Ammonites of the genus *Santafecites* Etayo-Serna and subgenus *Olcostephanus* (*Viluceras*) Aguirre-Urreta and Rawson are described for the first time from Chile. The succession of Olcostephaninae from the Chañarcillo Basin of northern Chile is described in the light of new collections and revision of historical material. The occurrence of mixed Andean and Mediterranean faunas supports the correlations proposed with the ammonite scales of the Neuquén Basin and the Mediterranean Province.

Keywords: Olcostephaninae, Lower Cretaceous, Northern Chile, Systematic Paleontology, Biostratigraphy.

RESUMEN. Los Olcostephaninae Haug, 1910 (Ammonoidea) valanginianos de la cuenca andina de Chañarcillo del Cretácico Inferior del Norte de Chile. Son descritos amonites del género *Santafecites* Etayo-Serna y del subgénero *Olcostephanus* (*Viluceras*) Aguirre-Urreta y Rawson, por primera vez en Chile. Se describe la sucesión de Olcostephaninae de la Cuenca de Chañarcillo en el Norte de Chile sobre la base de nuevas colecciones y revisión de material histórico. La ocurrencia de una mezcla de faunas andinas y mediterráneas sustenta las correlaciones propuestas con las escalas de amonites en la cuenca de Neuquén y la provincia Mediterránea.

Palabras clave: Olcostephaninae, Cretácico Inferior, Norte de Chile, Paleontología Sistemática, Bioestratigrafía.

1. Introduction

Olcostephanids are an important component of the Valanginian ammonite faunas of the Chañarcillo Basin (northern Chile), where they occur at two discrete intervals in the lower part of succession. The first one is characterized by the conspicuous occurrence of the cosmopolitan *Olcostephanus* (*Olcostephanus*) *atherstoni* (Sharpe, 1856) whereas the other is a level with *Olcostephanus* (*Viluceras*) *permolestus* (Leanza, 1957).

The first Olcostephaninae species mentioned in the Chilean literature is *Olcostephanus* (*O.*) *curacoensis* (Weaver, 1931) but the ammonites were not described and/or illustrated (Tavera, 1956; Corvalán, 1974; Corvalán *in* Segerstrom *et al.*, 1963). These authors assigned the Argentinean species to different genera, all of which are now regarded as junior objective synonyms of *Olcostephanus* Neumayr, 1875. It was reported from several localities of the Punta del Cobre and Abundancia formations south and north of Copiapó. *O.* (*O.*) *curacoensis* is herein considered, in agreement with Riccardi *et al.* (1971) and Aguirre-Urreta and Rawson (1997), a synonym of *O.* (*O.*) *atherstoni*.

The second level is characterized by a very distinctive fauna of evolute olcostephanids. This was recorded by Corvalán *in* Segerstrom *et al.* (1963) and Corvalán (1974) with a new species, '*Holcostephanus copiapoensis* nov. sp.', but neither a description nor an illustration was given; this is therefore a *nomen nudum* according to the International Code of Zoological Nomenclature. Examination of the specimen labeled '*Holcostephanus copiapoensis* nov. sp.' in the Corvalán collection by one of us (FAM), allows us to regard this taxon as an invalid synonym of *Olcostephanus* (*Viluceras*) *permolestus*.

The insights issued from this paleontological study permits to discuss and precise the former ammonite biostratigraphic long distance correlations between the European and South Central Andean regions. In this way, the stratigraphic record of the Andean Chañarcillo Basin, represent a link between the Neuquén Basin and Tethys ammonite biostratigraphic record.

2. Stratigraphy and fossil localities

The oldest sequences recorded until now from the marine Chañarcillo Basin are the Punta del Cobre and Abundancia formations, which are respectively assigned to an Early and Late Valanginian age (Mourgues, 2004; Aguirre-Urreta *et al.*, 2007). These outcrops are located southeast of the city of Copiapó, in the northernmost part of the Chañarcillo Basin (Fig. 1). Nevertheless, (?) Middle to Upper Berriasian ammonites (*Malbosiceras* gr. *malbosi in* Aguirre-Urreta *et al.*, 2007, fig. 6A) were collected 80 km north of Copiapó and are currently under study.

The Abundancia Formation ('Capas de Abundancia', Biese *in* Hoffstetter *et al.*, 1957) is the oldest lithological unit of the Chañarcillo Group (Segerstrom and Parker, 1959). It is characterized by well bedded grey mudstones interbedded with arkoses, which pass vertically and laterally into the Nantoco Formation limestones, and lies on the Punta del Cobre Formation (Segerstrom and Ruiz, 1962; Marschik and Fontboté, 2001, p. 413). This latter unit is composed of a pile of andesitic to basaltic andesitic lava flows, conglomerates, sandstones, tuffs and dacitic dome complexes, including sedimentary layers in its upper levels. The contact between this unit and the overlying Abundancia Formation is transitional, and has been defined by the first occurrence of a continuous bed of massive limestone or its metamorphosed equivalent. The following localities have been investigated.

2.1. Cerro La Vinchuca

Discontinuous outcrops of the Chañarcillo Group were observed southwest of Inca del Oro, which were previously investigated by Moraga (1977). Two different levels have yielded ammonites, where two distinctive faunas were identified. From bottom to top these are: *Lissonia* Gerth, 1925 (to which *Raimondiceras* Spath, 1924 is likely to be a synonym) and *O.* (*O.*) *atherstoni*. The historical collection of SERNAGEOMIN contains a single specimen herein identified as *Santafecites santafecinus* (d'Orbigny, 1842) from the same locality (Chong collection, SNGM 07) and described below.

2.2. Puquios area

The Puquios area is characterized by complex tectonics that affects the whole Mesozoic sequence. It is known in the literature as the 'Caos de Puquios' and was studied by Sepúlveda and Naranjo (1982) and Mpodozis and Allmendinger (1992). These authors describe a series of 200 m of bioclastic and

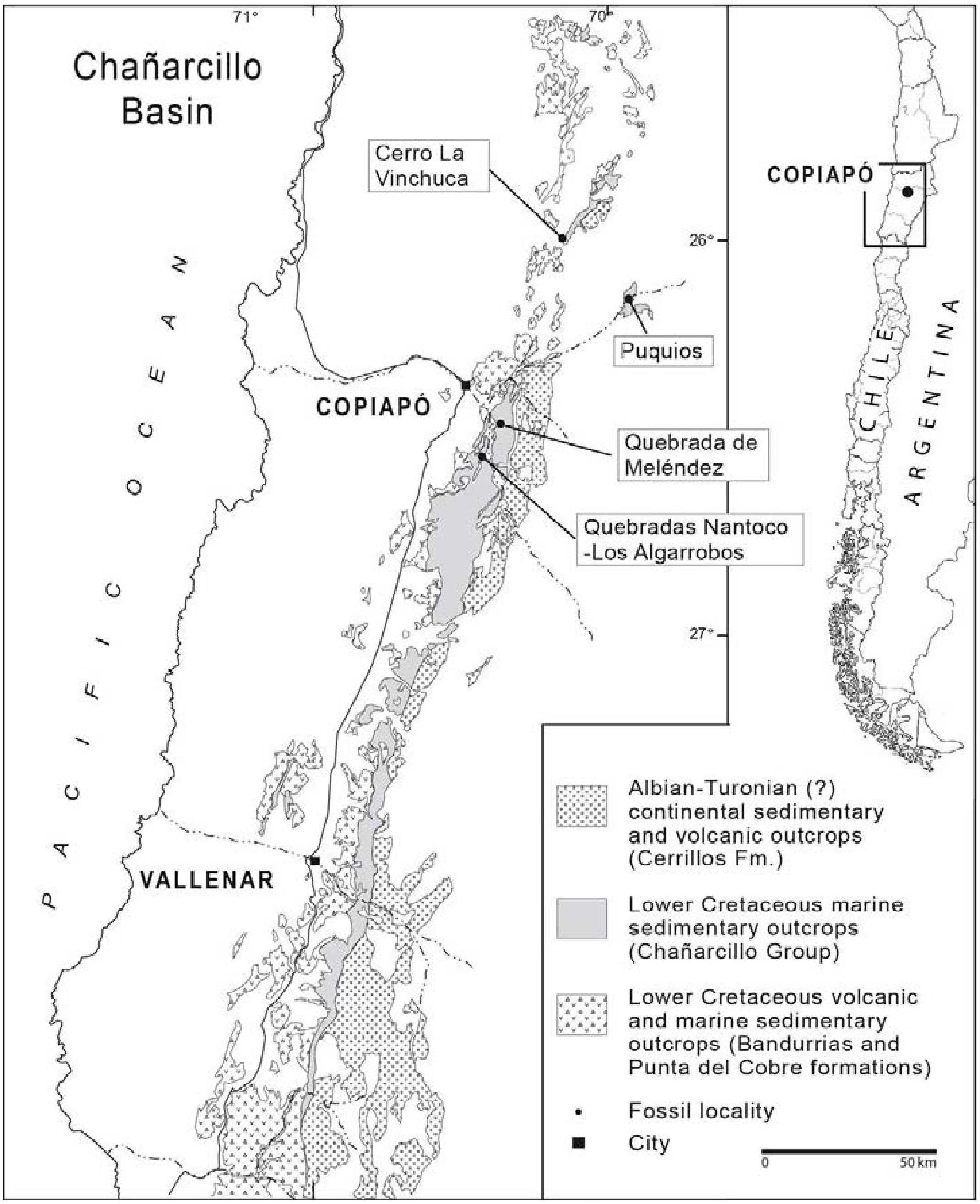

FIG. 1. Geographic distribution of the olcostephanid faunas of the Chañarcillo Basin (simplified after SERNAGEOMIN, 2002).

oolithic limestones that yielded ammonites of Late Valanginian to Barremian age. The material is kept in the collection of SERNAGEOMIN and contains a single specimen of *Santafecites santafecinus* (Sepúlveda collection, SNGM 1536) described below.

2.3. Quebrada Meléndez

The Quebrada Meléndez is one of the reference sections for the Lower Cretaceous of the Chañarcillo Basin. The succession crops out in a tributary creek, east of the Copiapó valley (Fig. 2). It shows the most complete series of the Upper Valanginian to Lower Aptian strata. From this locality *O.* (*O.*) *curacoensis* and *Lissonia riveroi* (Lissón, 1907) were reported (Corvalán, 1974). We have observed that near the top of the Abundancia Formation, an 'Ammonitico rosso' bed contains abundant *O.* (*Viluceras*) *permolestus* associated with numerous neocomitids, such as juvenile *N.* (*Neocomites*) *peregrinus* (Rawson and Kemper, 1978), *Neocomites* (*Sabbaiceras*) *beaumugnensis* (Sayn, 1907) and *Rodighieroites cardulus* Company, 1987. These neocomitids are under study with associated material from others localities.

2.4. Quebradas Nantoco-Los Algarrobos

A volcanoclastic succession in the upper part of the Punta del Cobre Formation crops out at Quebrada Los Algarrobos. Two fossiliferous siltstone levels were recognized; a lower one with *Lissonia* sp., and an upper one containing *O.* (*O.*) *atherstoni* (Fig. 2). From the same locality, previous investigators have mentioned *L. riveroi* and *O.* (*O.*) *curacoensis* and other neocomitids such as '*Acanthodiscus'*, '*Thurmanniceras'* by Corvalán *in* Segerstrom *et al*. (1963) and '*Cuyaniceras'* by Marschik and Fontboté (2001).

The upper fossiliferous level with *O.* (*O.*) *atherstoni* was also identified at Quebrada Nantoco. We collected three specimens from that locality (SNGM 1021 [7-9]), which are associated with a specimen of *Bochianites sensu lato*, several meters above a bed with *Lissonia*.

3. Systematic Paleontology

The material described herein is stored in the Paleontological Collections of the Servicio Nacioal de Geología y Minería (SERNAGEOMIN) Museum, Santiago, with the prefix SNGM. Most of the material belongs to the collection of one of us (F.A.M.). Specimens from the Corvalán, Chong and Sepúlveda collections have also been included in this study.

Dimensions of specimens are indicated as follow: **d:** diameter; **wh:** whorl height; **wt:** whorl thickness; **wu:** width of umbilicus. **M:** macroconch; **m:** microconch. In the synonymy list, **v** indicates that we have seen the specimen(s).

Superfamily Perisphinctaceae Steinmann, 1890
Family Olcostephanidae Haug, 1910
Subfamily Olcostephaninae Haug, 1910

(=Taraisitinae Cantú-Chapa, 1966; Capeloitinae Cantú-Chapa, 2009; =Garcitinae Cantú-Chapa, 2012; =Saynoceratinae Cantú-Chapa, 2012)

The subfamily Taraisitinae is herein as a junior subjective synonym of Olcostephaninae since its type genus *Taraisites* Cantú-Chapa, 1966 is a junior subjective synonym of *Olcostephanus* (*Olcostephanus*) (see discussion in González Arreola *et al*., 2014, p. 59). The type genus of Garcitinae is *Garcites* Cantú-Chapa, 2001, a taxon based on pyritized internal moulds of juveniles olcostephanids. In our opinion the diagnostic features retained by Cantú-Chapa (2001) are diagenetic artifacts due to the alteration of pyrite on the ventral area of the moulds. As a consequence Garcitinae is a *nomen dubium* based on olcostephanids that cannot be identified at the genus level. Bulot *et al*. (1990a) showed that the *Valanginites*-*Saynoceras* lineage directly derives from the subgenus *Olcostephanus* by complex heterochronies. Placing *Valanginites* Kilian, 1910 and *Saynoceras* Munier-Chalmas, 1894 in different subfamilies is artificial and do not reflects the iterative evolution of the Olcostephaninae. We therefore regard Saynoceratinae as an artificial grouping of micromorphic genera that derivates from *Olcostephanus sensu stricto* at different moments (Bulot *et al*., 1990a). The same is true for the Capeloitinae, whose type genus *Capeloites* Lissón, 1937a, derivates from the *Olcostephanus* rootstock in the late Lower Hauterivian (Kemper *et al*., 1981; Bulot, 1990a; Rawson, 2007).

Genus *Santafecites* Etayo-Serna, 1985

Type-species: *Ammonites santafecinus* d'Orbigny, 1842, by original designation of Etayo-Serna (1985, p. xxiv-22).
Remarks: In Colombia, *Santafecites* was reported from the base of the Upper Valanginian together with *Saynoceras verrucosum* (d'Orbigny, 1841), above the *Valanginites, Raimondiceras*, *Lissonia* and *Acantholissonia* Leanza, 1972 assemblage that characterize the Lower Valanginian (Etayo-Serna, 1985 and personal communication, 1999). It should be noted that there is striking similarities between

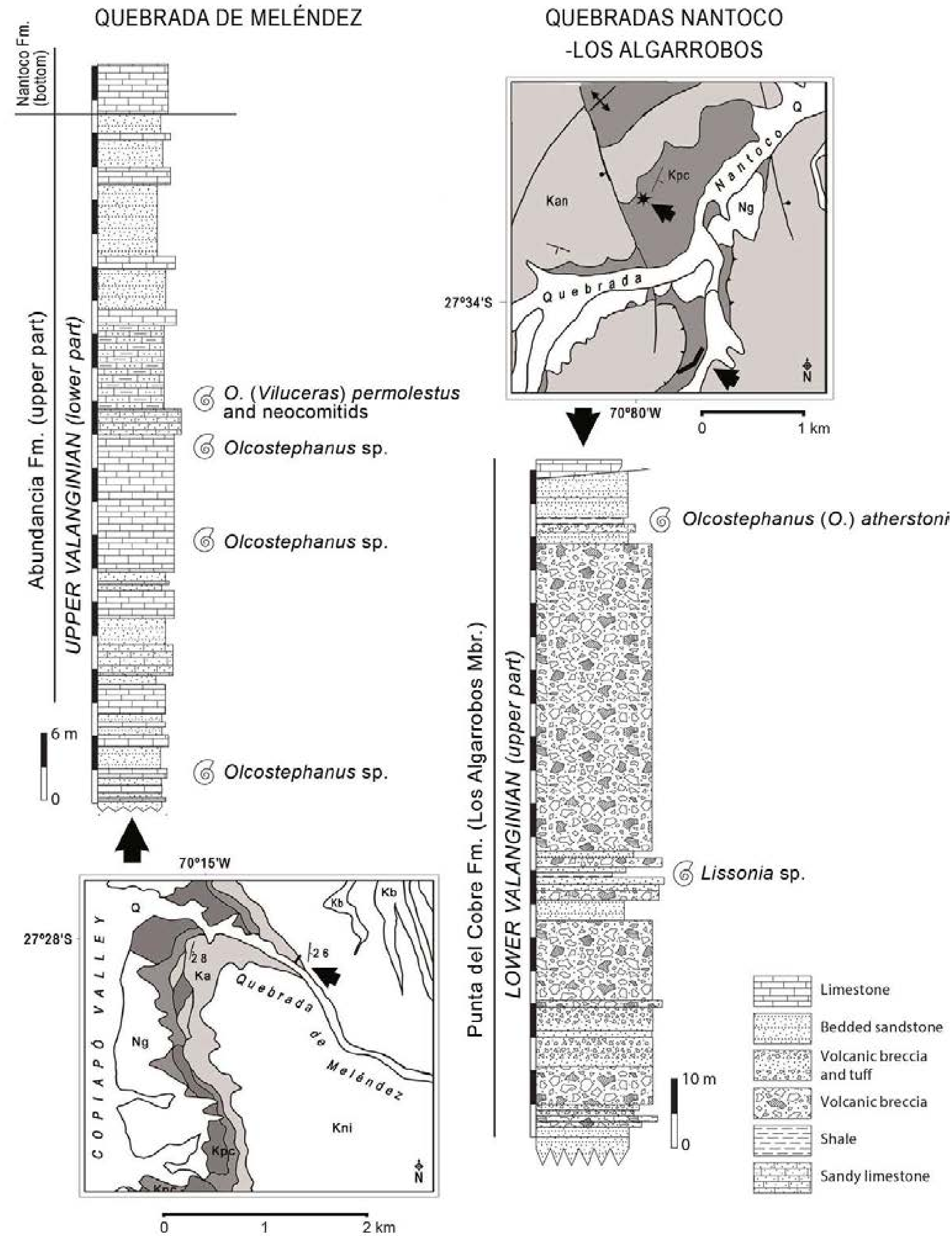

FIG. 2. Lithologic sections of the upper part of the Abundancia Formation (Quebrada Meléndez) and upper part of the Punta del Cobre Formation (Quebradas Nantoco-Los Algarrobos).

S. santafecinus and *Sphaeroceras broggianus* Lissón, 1937b from the Valanginian of Peru. This later species that has been differently interpreted in the literature (Benavides-Cáceres, 1956; Nikolov, 1965; Riccardi and Westermann, 1970; Klein, 2005) and recently designated as the type species of *Peruvites* by Cantú-Chapa (2012). Unfortunately the exact stratigraphic position of the Peruvian taxon is poorly constrained even if it seems closely allied to *Valanginites argentinicus* Leanza and Wiedmann, 1980 from the early Lower Valanginian of the Neuquén Basin. *Santafecites* is therefore likely to derivate from an endemic *Valanginites*-like form (=*Peruvites*), but pending a thoroughful description of the Colombian representative of the latter this hypothesis remains speculative.

Occurrence. Early Upper Valanginian of Colombia (Etayo-Serna, 1985). The genus is herein reported from Chile for the first time (?Upper Valanginian). Ammonites santafecinus was also mentioned from Perú by Steinmann (1930) and Lissón and Boit (1942) but this occurrence was never confirmed.

FIG. 3. *Santafecites santafecinus* (d'Orbigny, 1842). Holotype, MHNP R-3148, d'Orbigny (specimen figured by d'Orbigny, 1842, p. 34, Pl. 1, Figs. 3, 4, from Santa Fe (de Bogotá).

***Santafecites santafecinus* (d'Orbigny, 1842)**
Figs. 3, 4A-J

v 1842 *Ammonites santafecinus* d'Orbigny, p. 34, Pl. 1, Figs. 3, 4.
1985 *Santafecites santafecinus* (d'Orbigny), Etayo-Serna, p. xxxiv-22.

Holotype: By monotypy, the specimen figured by d'Orbigny, 1842, p. 34, Pl. 1, Figs. 3, 4, from Santa Fe (de Bogotá), Colombia, kept in the Museum National d'Histoire Naturelle de Paris (d'Orbigny collection, R-3148).

Material: Two specimens (table 1). One large and crushed adult from the Puquios area (SNGM 1536, Sepúlveda collection) and a fragmentary specimen from Cerro La Vinchuca (SNGM 07, Chong collection).

Description: Umbilicus small with poorly defined umbilical region. Ribs organized in bundles with branching at, and above, the umbilical shoulder. The ornamentation seems to be smoother on the outer part of the whorl (? body chamber). No clear bullae or tubercles are visible. The ribs are interrupted on the venter and form a weak groove. They are alternate on both sides of the groove. Suture line is too poorly preserved for description.

Remarks: Since the original figure and description by d'Orbigny (1842), the species was never figured nor described again. The holotype is illustrated here as well as some Colombian specimens (Figs. 4A, B, E, F, H, and I) from the Breistroffer collection (Grenoble University). The larger crushed specimen matches well the holotype (Fig. 3) and the reference material from these collection (compare Figs. 4A, B, E, F, H, and I). It shows all typical features of the genus and species, *e.g.,* ribs originating from periumbilical bullae interrupted on the ventral area and not opposite. The smaller specimen (Dmax

TABLE 1. DIMENSIONS *SANTAFECITES SANTAFECINUS* (D'ORBIGNY) SPECIMENS.

Specimen	d	Wh	wh%d	wt	wt%d	wu	wu%d
SNGM 07	37.2	18.7	-	23.4	-	5.1	-
SNGM 1536	71.4	37.0	-	36.7	-	11.0	-

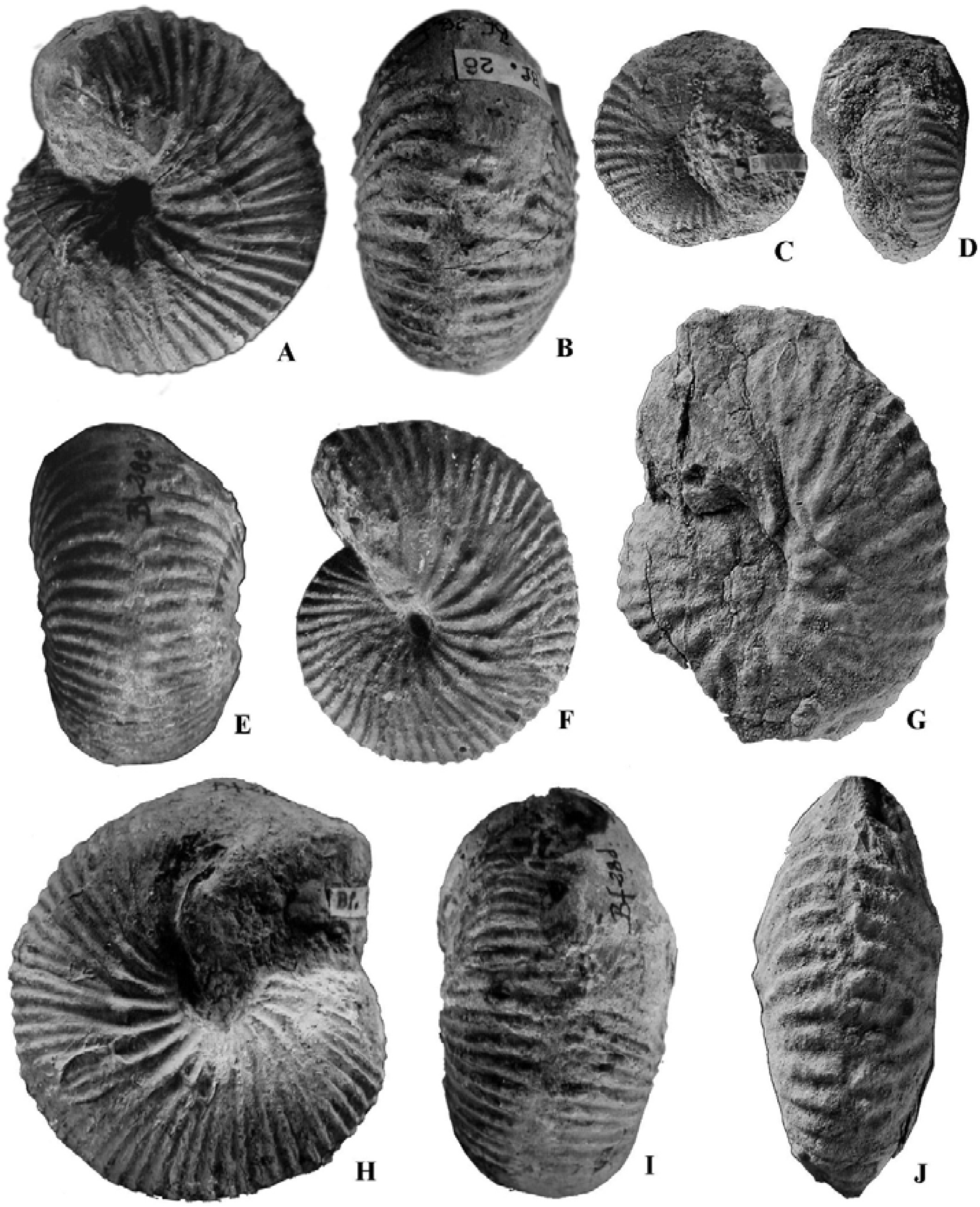

FIG. 4. *Santafecites santafecinus* (d'Orbigny, 1842). **A-B, E-F, H-I.** side and ventral view of BF-28d to f from Colombia (Breistroffer collection, University of Grenoble); **C-D.** side and ventral view of SNGM 07 (Chong collection, Cerro La Vinchuca, Chile); **G, J.** side and ventral view of SNGM 1536 (Sepúlveda collection, Puquios, Chile).

ca. 40 mm), represented by half a whorl still septate at D. *ca.* 36 mm, is slightly different. It is also a typical sphaerocone with rounded venter and whorl section broader than wide, with the maximum width on the umbilical wall. The smaller specimen (SNGM 07) differs from the Colombian material in its smaller size, lack of bullae and weaker ornamentation. Nevertheless, there is no doubt that it belongs to

the genus *Santafecites* (general morphology, ventral groove and alternate ribs that are interrupted on the venter). It may represent the microconch form of *S. santafecinus*.
Occurrence: As for genus.

Genus *Olcostephanus* Neumayr, 1875

Remarks: As herein understood, the genus *Olcostephanus* is subdivided into three subgenera: *Olcostephanus*, *Jeannoticeras* Thieuloy, 1965 and *Viluceras* Aguirre-Urreta and Rawson, 1999. *Parastieria* Spath, 1923a and *Mexicanoceras* Imlay, 1938 are considered as separate genera. *Holcostephanus* Sayn, 1889 and *Astieria* Pavlow, 1892 are junior objective synonyms of *Olcostephanus*. *Subastieria* Spath, 1923b; *Rogersites* Spath, 1924; *Maderia* Imlay, 1938; *Taraisites, Satoites* Cantú-Chapa, 1966 and *Lemurostephanus* Thieuloy, 1977 are junior subjective synonyms of *Olcostephanus*.

Subgenus *Olcostephanus* Neumayr, 1875

Type-species: *Ammonites asterianus* d'Orbigny, 1840, p. 115, Pl. 28, Figs. 1, 2 (only), by subsequent designation of Baumberger (1910, p. 3). As already pointed out by Bulot (1990a, p. 5), the specimen from the d'Orbigny collection figured and considered as lectotype by Baumberger (1910, Pl. 32, Figs. 1, 2) does not match the original description or figure of d'Orbigny. The revision of the type material (Bulot, 1990a) suggests that the original drawing is reconstructed from different specimens, some of which belongs to *O.* (*O.*) *guebhardi* (Kilian, 1902), a taxon closely allied to *O.* (*O.*) *atherstoni* (see below); the others to the *O.* (*O.*) *densicostatus* (Wegner, 1909)-*sayni* (Kilian, 1895) lineage. This view was supported by Busnardo *et al.* (2003, p. 48-49) and Gauthier *et al*. (2006, p. 29-30).

Diagnosis: Compressed to strongly inflated cadicones, with strongly arched to well rounded venter. Primary ribs usually present on umbilical wall, commonly terminating in tubercles at umbilical shoulder, from which arise straight or slightly curved secondary ribs, usually in fasciculate bundles. Commonly 3-4 secondaries per bundle, although there may be as many as 6-9 or as few as 2. Secondary ribs may bifurcate on the flanks, while intercalated ribs between bundles are the rule. Ribbing always passes uninterrupted across venter; also it may weaken in some species. Parabolae or constrictions may or may not be present, but are absent on the outer whorls of macroconchs. The genus is dimorphic; microconchs are small and bear lappets on the aperture; macroconchs are larger, with a simple peristome (modified after Cooper, 1981, p. 161).
Occurrence: *Olcostephanus* (*Olcostephanus*) is widely distributed in the Mediterran-Caucasian and Indo-Pacific subrealms of the Tethyan Realm and adjacent areas of the Boreal Realm *sensu* Westermann (2000). In the western Tethys, the subgenus is known to range from the highest Upper Berriasian (*F. boissieri* Zone, *T. otopeta* Subzone) to the high Lower Hauterivian, *L. nodosoplicatum* Zone, *O.* (*O.*) *variegatus* biohorizon (Bulot, 1990a; Bulot, 1992; Bulot *et al.*, 1993; Bulot and Thieuloy, 1995). In South America, *Olcostephanus* (*Olcostephanus*) is known from Colombia, Perú, Chile and Argentina. The oldest occurrence was reported from the early Valanginian of the Neuquén Basin (Aguirre-Urreta and Rawson, 1999) and possibly Colombia (Etayo Serna, written communication 1999). 'Middle' Valanginian *Olcostephanus* of the *atherstoni* group occur in all countries listed above except Perú (Riedel, 1938; Haas, 1960; Riccardi *et al*., 1971; this paper). Late early Hauterivian *Olcostephanus* of the *sayni-variegatus* (Paquier, 1900) plexus are known from all those countries except Chile (Riedel, 1938; Haas, 1960; Robert *et al*., 1998; Aguirre-Urreta and Rawson, 2001).

Olcostephanus (*Olcostephanus*) *atherstoni* (Sharpe, 1856)
Figs. 5, 6

v 1856 *Ammonites Atherstoni* Sharpe, p. 196, Pl. 23, Figs. 1a, b.
v 1856 *Ammonites baini* Sharpe, p. 197, Pl. 23, Figs. 2a-b.
v 1860 *Ammonites asterianus* (d'Orbigny), Pictet and Campiche, p. 298, Pl. 43, Figs. 1, 2.
1863 *Ammonites Schenki* Oppel, p. 286, Pl. 81, Figs. 4a-c.
v 1878 *Ammonites asterianus* (d'Orbigny), Bayle, Pl. 55, Fig. 1 (only).
v 1902 *Holcostephanus* (*Astieria*) *guebhardi* Kilian, p. 866, Pl. 57, Fig. 2.

1902 *Astieria* cf. *atherstoni* (Sharpe), Karakasch, p. 11, Pl. 1, Fig. 3.
1903 *Holcostephanus* (*Astieria*) *schencki* (Oppel), Uhlig, p. 130, Pl. 18, Figs. 2a-c.
v 1907 *Astieria atherstoni* (Sharpe), Baumberger, p. 39-47, Pl. 21, Fig. 3, Pl. 23, Fig. 1, Pl. 24, Figs. 2, 5, Text-figs. 114-117.
v 1907 *Astieria* cf. *atherstoni* (Sharpe), Baumberger, Pl. 25, Fig. 4.
v 1908 *Astieria leptoplana*, Baumberger, p. 9-12, Pl. 26, Fig. 4, Pl. 28, Fig. 2.
v 1908 *Astieria imbricata* Baumberger, p. 14-18, Pl. 26, Figs. 2-3, Text-figs. 123-126.
v 1908 *Astieria actinota* Baumberger, p. 18-20, Pl. 26, Fig. 1.
v 1908 *Holcostephanus wilmanae* Kitchin, p. 195, Pl. 9, Figs. 1,1a.
v 1908 *Holcostephanus rogersi* Kitchin, p. 201, Pl. 9, Fig. 3, Pl.10, Fig. 2.
v 1908 *Holcostephanus modderensis* Kitchin, p. 202, Pl.10, Fig. 3.
v 1919 *Astieria catulloi* Rodighiero, p. 83, Pl. 9, Fig. 9.
v 1930 *Rogersites sphaeroidalis* Spath, p. 144, Pl. 13, Fig. 5, Pl. 15, Fig. 1.
v 1930 *Rogersites otoitoides* Spath, p. 149, Pl. 14, Fig. 1.
v 1930 *Astieria psilostoma* var. *lateumibilicata* Roch, p. 314, Pl. 16, Figs. 3a, b
1931 *Astieria curacoensis* Weaver, p. 427, Pl. 49, Figs. 326-327, Pl. 50, Fig. 328.
1931 *Astieria sudandina* Windhausen, Pl. 33, Fig. 1 (*nomen nudum*).
v 1932 *Rogersites douvillei* Besairie, p. 44, Pl. 5, Figs. 9, 9a, Text-fig. 2.
1933 *Astieria atherstoni* (Sharpe), Roman, p. 21-22, Pl. 4, Fig. 1 (only)
v 1936 *Rogersites curvicostatus* Besairie, p. 141, Pl. 12, Figs. 7, 10, Pl. 13, Fig. 8.
v 1936 *Rogersites douvillei* Besairie, p. 138, Text-fig. 9, n° 2.
v 1936 *Rogersites baini* var. *ambikyi* Besairie, p. 138, Pl. 13, Fig. 5, Text-fig. 9, n° 3.
v 1939 *Olcostephanus (Rogersites) schencki* (Oppel), Spath, p. 30, Pl. 2, Fig. 6, Pl. 18, Figs. 9-10.
1944 *Holcostephanus midas* Leanza, 1944, p. 16, Pl. 1, Figs. 1a-c.
1944 *Holcostephanus auritus* Leanza, 1944, p. 18, Pl. 2, Figs. 1a-c.
1958 *Olcostephanus curacoensis* (Weaver), Corvalán and Pérez, 1958, p. 38, Pl. 12, Fig. 27.
1970 *Olcostephanus* cf. *O. atherstoni* Baumberger (non Sharpe), Imlay and Jones, p. B38-B39, Pl. 8, Fig. 15, Pl. 9, Figs. 1-3, 6-10.
v 1962 *Holcostephanus schencki* Uhlig (non Oppel), Collignon, p. 36, Fig. 859.
v 1962 *Holcostephanus atherstoni* (Sharpe), Collignon, p. 38, Fig. 860.
v 1962 *Holcostephanus douvillei* (Besairie), Collignon, p. 43, Fig. 869.
v 1971 *Olcostephanus atherstoni* (Sharpe), Riccardi *et al.*, p. 91, Pl. 12, Figs. 3-4, Pl. 13, Figs. 1-5, Text-figs. 3-10.
1980 *Olcostephanus* (*Olcostephanus*) *atherstoni* (Sharpe), Leanza and Wiedmann, p. 945, Pl. 1, Fig. 1.
1980 *Olcostephanus (Olcostephanus) sakalavensis* (Besairie), Leanza and Wiedmann, p. 946, Pl. 1, Fig. 3.
v 1977 *Olcostephanus (Olcostephanus) salinarius* Spath, Fatmi, Pl. 3, Figs. 1a, b (only).
v 1981 *Olcostephanus (Olcostephanus)* sp. (= '*Proastieria*' Stolley), Kemper *et al.*, p. 268-269, Pl. 35, Fig. 2.
v 1981 *Olcostephanus* (*Olcostephanus*) *atherstoni* (Sharpe). Cooper, 1981, p. 182, Figs. 19, 24-26, 27A-D, 28-33, 38, 40-43, 55, 118, 143C-D, 151A.
v 1981 *Olcostephanus* (*Olcostephanus*) *rogersi* (Sharpe), Cooper, 1981, p. 221, Figs. 70-73, 74A-B, 75A-B, 76, 131A-B, 150E-G.
v 1981 *Olcostephanus* (*Olcostephanus*) *baini baini* (Sharpe), Cooper, 1981, p. 263, Figs. 114-129, 130A-B, 131C-J, 132-135, 143A-B, 144A-D, 150C-D, 151B-D.
v 1981 *Olcostephanus* (*Olcostephanus*) *baini* var. *sphaeroidalis* (Spath), Cooper, 1981, p. 263, Figs. 144E-G, 145-146, 149, 150A-B, F.
v 1981 *Olcostephanus (Olcostephanus) ventricosus* (von Koenen), Cooper, p. 300, Fig. 154 (only).
v 1981 *Olcostephanus atherstoni* (Sharpe), Leanza, p. 169-170, Pl. 15, Figs. 1-8, Pl. 19, Figs. 16-17.
v 1985 *Olcostephanus astierianus* (d'Orbigny), Cecca, p. 157, Pl. 6, Figs. 1a, b.

v 1985 *Olcostephanus densicostatus* (Wegner), Company, p. 118, Pl. 1, Figs. 3-7.
v 1986 *Olcostephanus psilostomus psilostomus* (Neumayr and Uhlig), Kvantaliani and Sakharov, p. 56, Pl. 1, Figs. 1, 2.
v 1986 *Olcostephanus convolutus* (von Koenen), Kvantaliani and Sakharov, p. 57, Pl. 1, Figs. 3.
1986 *Olcostephanus* cf. *guebhardi* (Kilian), Howlett, p. 71, Figs. 2a, b.
v 1987 *Olcostephanus densicostatus* (Wegner), Company, p. 594, Pl. 6, Figs. 5-6.
v 1988 *Olcostephanus atherstoni* (Sharpe), Riccardi, Pl. 5, Figs. 1-2.
v 1990a *Olcostephanus (Olcostephanus) guebhardi* (Kilian), Bulot, p. 87, Pl. 6, Figs. 1-10, Pl. 7, Figs. 1-3, Pl. 8, Figs. 1-7, Pl. 11, Figs. 1-2.
v 1990b *Olcostephanus (Olcostephanus) guebhardi* (Kilian), Bulot, p. 8, Pl. 1, Figs. 4, 5.
v 1991 *Olcostephanus (Olcostephanus) guebhardi* morphotype *querolensis* (Kilian), Ettachfini, p. 113, Pl. 11, Figs. 1, 3, 7, 8.
v 1991 *Olcostephanus (Olcostephanus) guebhardi* aff. morphotype *querolensis* (Kilian), Ettachfini, p. 113, Pl. 11, Fig. 2.
v 1991 *Olcostephanus (Olcostephanus) guebhardi lateumbilicatus* (Roch), Ettachfini, Pl. 11, Figs. 4, 6.
v 1991 *Olcostephanus (Olcostephanus)* cf. *psilostomus lateumbilicatus* (Roch), Ettachfini, Pl. 11, Figs. 10, 11.
v 1992 *Olcostephanus (Olcostephanus) guebhardi* morphotype *querolensis* Bulot, Pl. 1, Fig. 1.
v 1992 *Olcostephanus (Olcostephanus) guebhardi* (Kilian), p. 151, Bulot, Pl. 1, Figs. 2a, b.
1992 *Olcostephanus* aff. *guebhardi* (Kilian), Kemper, Pl. 35, Figs. 1a, b.
v 1993 *Olcostephanus (Olcostephanus) atherstoni* (Sharpe), Aguirre-Urreta, Pl. 2, Figs. 6, 7.
v 1995 *Olcostephanus atherstoni* (Sharpe), Aguirre-Urreta and Rawson, p. 453, Figs. 6h-i.
v 1997 *Olcostephanus atherstoni* (Sharpe), Aguirre-Urreta and Rawson, Pl. 1, Figs. c-e.
1997 *Olcostephanus (O.) catulloi* (Rodighiero), Faraoni *et al.*, Pl. 5, Fig. 17.
2001 *Olcostephanus (Olcostephanus) guebhardi* (Kilian), Wippich, Pl. 10, Figs. 2-11, Pl. 11, Figs. 1-2.
2003 *Olcostephanus (Olcostephanus) guebhardi* (Kilian), Wippich, Fig. 8d, Fig. 9e.
2003 *Olcostephanus (Olcostephanus) guebhardi* (Kilian), Lukeneder and Harzhauser, Fig. 3a.
2004 *Olcostephanus (Olcostephanus) guebhardi* (Kilian), Lukeneder, Fig. 6.
2004 *Olcostephanus (Olcostephanus) atherstoni* (Sharpe), Mourgues, Fig. 5a, g.
2004 *Olcostephanus (Olcostephanus) guebhardi lateumbilicatus* (Roch), Ettachfini, Pl. 23, Fig. 2-6.
2004 *Olcostephanus (Olcostephanus) guebhardi* morphotype *querolensis* Bulot, Ettachfini, Pl. 23, Fig. 7-10.
2005 *Olcostephanus (Olcostephanus) atherstoni* (Sharpe), Aguirre-Urreta *et al.*, Fig. 5a.
2007 *Olcostephanus (Olcostephanus) guebhardi* morph. type *querolensis* Bulot, Lukeneder, Fig.4F-I.
2007 *Olcostephanus (Olcostephanus) atherstoni* (Sharpe), Aguirre-Urreta *et al.*, Fig. 6C, G, Fig. 10F.
2010 *Olcostephanus guebhardi* (Kilian), Vašíček, p. 399, Pl. 1, Fig. 2, Pl. 2, Fig. 2.
? 2010 Olcostephanus guebhardi (Kilian), Özy *et al.*, Fig. 3R.

Holotype: By monotypy, the specimen figured by Sharpe (1856, p. 196, Pl. 23, figs. 1a, b), from the Sundays River, South Africa (British Museum, BM-C32202), refigured by Cooper (1981, p. 183-184, figs. 24, 25).

Material: 41 specimens (tables 2 and 3): 3 from Quebrada Nantoco (SNGM 1021 [7-9]), 36 from Quebrada Los Algarrobos (SNGM 1021 [10-28], SNGM 1022 [2-18]) and 2 from 3 km to northwestern of Cerro La Vinchuca (SNGM 1537 [1-2]).

Description: Microconch [m]: the microconch consists of immature examples of 25-30 mm diameter, with at least some part of the body chamber preserved. Septation ceases at diameters of about 20-25 mm. The shell is slightly involute, cadicone with moderately depressed to semicircular whorls. The umbilical slope is moderately steep with a rounded margin. The umbilicus is moderately deep and narrow where its diameter (**wu**) is approximately 28% of the shell diameter (**d**). The venter and flanks

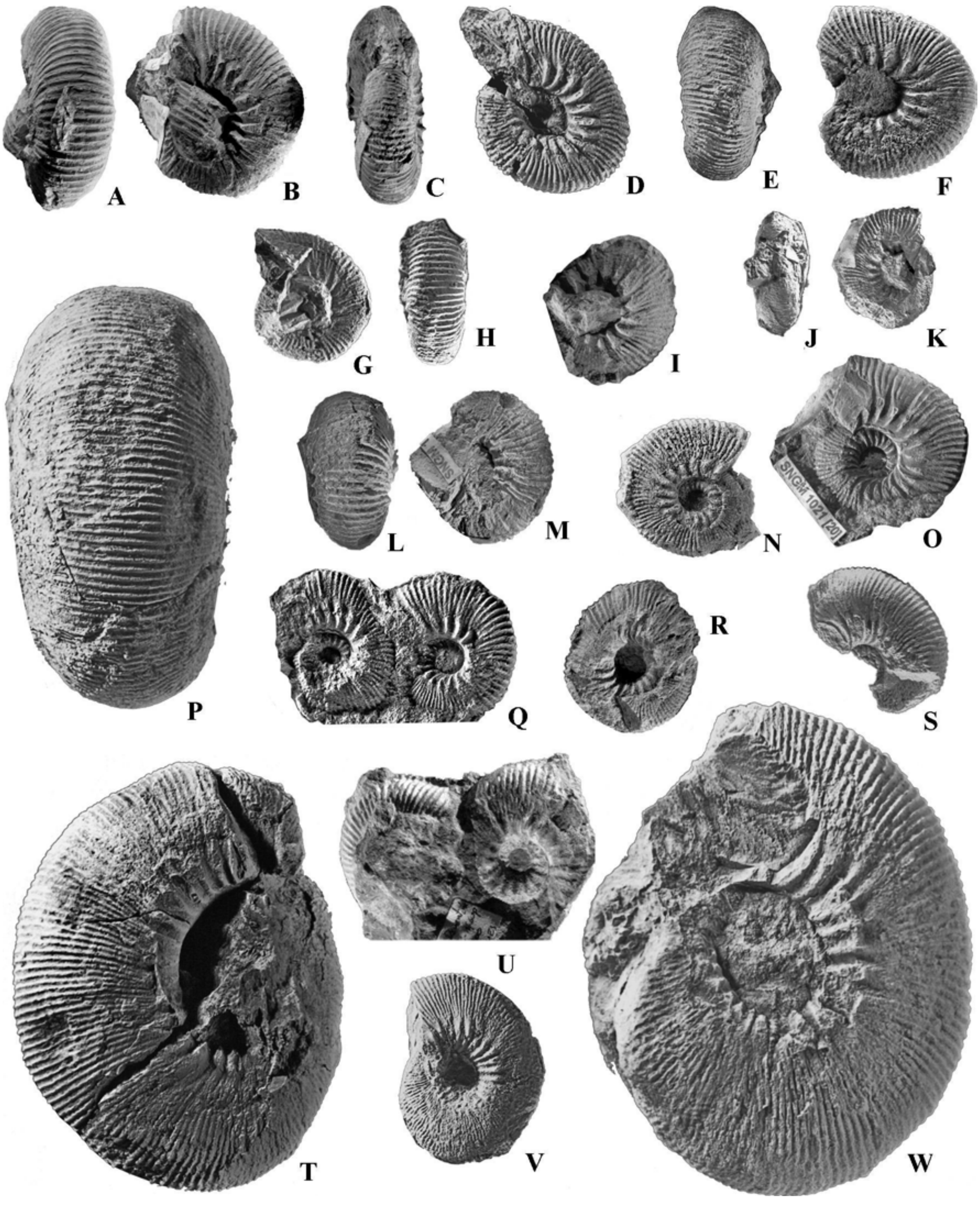

FIG. 5. *Olcostephanus* (*O.*) *atherstoni* (Sharpe, 1856). **A-B.** SNGM 1021-17; **C-D.** SNGM 1021-14; **E-F.** SNGM 1021-8; **G-H.** SNGM 1021-26; **I.** SNGM 1021-23; **J-K.** SNGM 1021-19; **L-M.** SNGM 1021-18; **N.** SNGM 1021-15; **O.** SNGM 1021-20; **P, T.** SNGM 1022-3; **Q, U.** SNGM 1021-10/11; **R.** SNGM 1021-29; **S.** SNGM 1021-16; **V.** SNGM 1022-15; **W.** SNGM 1022-4. All specimens from bed PC2 at Quebrada Los Algarrobos (Mourgues collection) except **E** and **F** from Quebrada Nantoco.

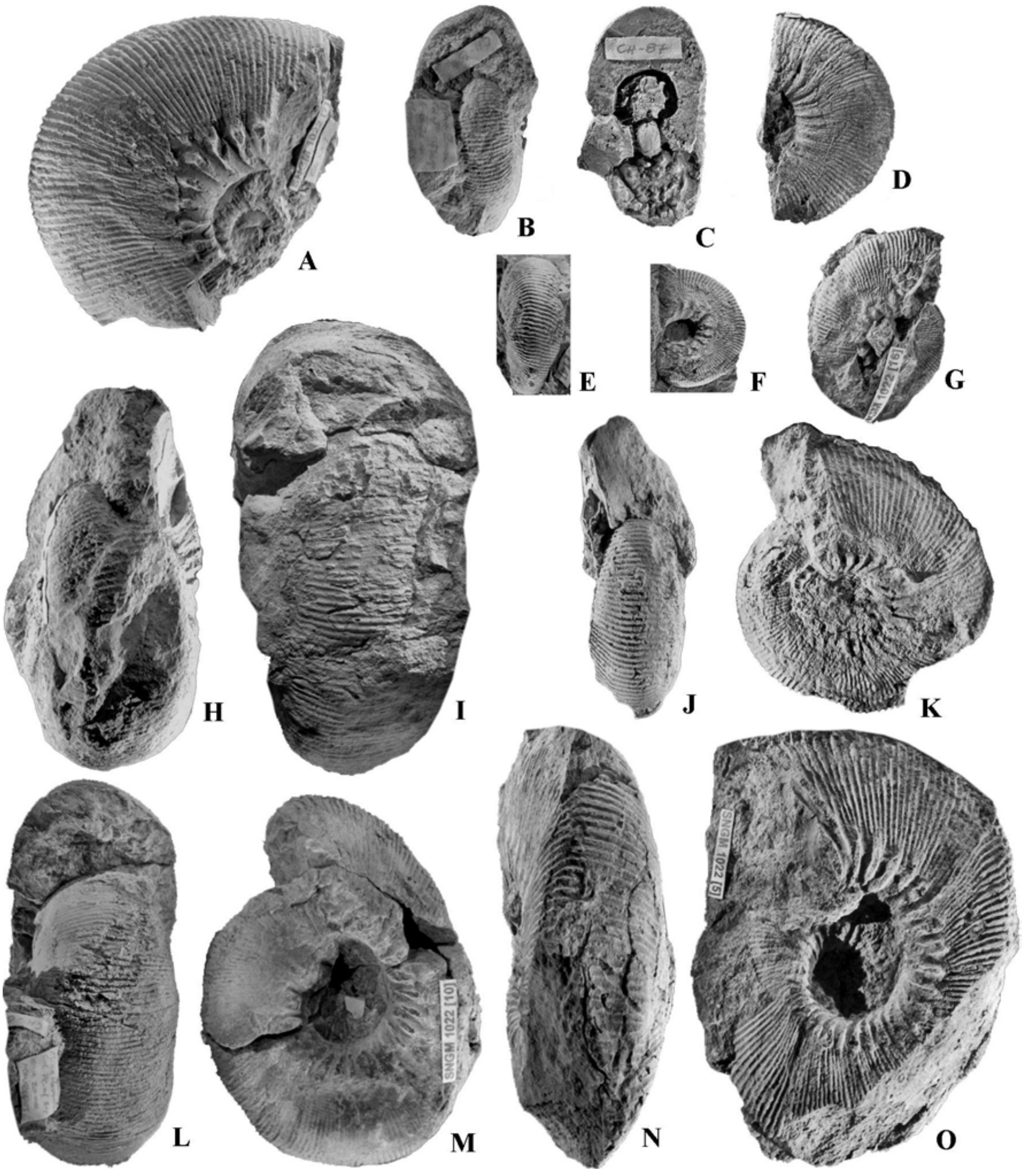

FIG. 6. *Olcostephanus* (*O.*) *atherstoni* (Sharpe, 1856). **A.** SNGM 1022-7; **B.** SNGM 1022-15; **C-D.** SNGM 1022-13; **E-F.** SNGM 1022-14; **G.** SNGM 1022-16; **H.** SNGM 1022-4; **I.** SNGM 1022-3; **J-K.** SNGM 1022-2; **L-M.** SNGM 1022-10; **N-O.** SNGM 1022-5 from bed PC2 at Quebrada Los Algarrobos (Mourgues collection). All specimens natural size except H (x 0.7).

are rounded. Maximum width of whorl at umbilical bullae. Rursiradiate primary ribs arise near the umbilical seam, progressively becoming prominent on the umbilical slope, and forming bullae-like tubercles on the upper part of the umbilical margin. There are 9-12 primary ribs per half-whorl. Bundles

TABLE 2. DIMENSIONS *OLCOSTEPHANUS* (*O.*) *ATHERSTONI* (SHARPE) MICROCONCH SPECIMENS.

Specimen	d	Wh	wh%d	wt	wt%d	wu	wu%d
SNGM 1021-20	27	11.5	43	-	-	6.6	24
SNGM 1021-12	30	12	40	-	-	6.6	22
SNGM 1021-25	27	11.4	42	-	-	7	26
SNGM 1021-24	25	9.3	37	-	-	5.4	22
SNGM 1021-18	24.6	10	41	-	-	6	24
SNGM 1021-23	27.5	14.3	52	-	-	6.4	23
SNGM 1021-10	29.6	12.2	41	10.9	37	7	24
SNGM 1021-11	27.1	12	44	11	41	6.2	23
SNGM 1021-13	36.1	18.6	52	17	47	10	28
SNGM 1021-14	30.4	12.2	40	13.2	43	8.4	28
SNGM 1021-16	28	13.5	48	11	39	8.7	31
SNGM 1021-17	36.6	15.4	42	15	41	10	27
SNGM 1021-19	20.5	9.5	46	8.5	41	5	24
SNGM 1021-26	24.6	8.8	36	11.8	48	5	20

TABLE 3. DIMENSIONS *OLCOSTEPHANUS* (*O.*) *ATHERSTONI* (SHARPE) MACROCONCH SPECIMENS.

Specimen	d	Wh	wh%d	wt	wt%d	wu	wu%d
SNGM 1022-10	57.8	23.4	40	29.5	51	10.4	18
SNGM 1022-13	37	11.8	32	-	-	9.6	26
SNGM 1022-15	37	18	49	-	-	6.7	18
SNGM 1022-03	73.3	33.3	45	43	59	21	29
SNGM 1022-04	59	24.3	41	34.3	58	16.1	27
SNGM 1022-05	75.2	32	43	-	-	18	24
SNGM 1022-14	21	10.3	49	10	48	3.7	18

of three to four (exceptionally 5) secondary ribs associated with each bulla, but an additional one or two may be intercalated between two bundles. There are 40-45 secondary ribs per half-whorl. No constrictions were observed our examples.

Macroconch [M]: the shell of the macroconch is moderately small with diameters between 70-85 mm. Some specimens are septate to at least 40-50 mm. The body chamber occupies at least ¾ of the last whorl. These forms are more involute than the microconchs, with the umbilicus (wu) reaching approximately a fifth of the shell diameter (d). The umbilical slope is steep with a rounded margin. Ribbing is finer and denser than in microconchs, and slightly rursiradiate. There are 13-15 primary ribs per half-whorl. Bundles of four to six secondary ribs are associated with each bulla, but an additional rib may be intercalated between two bundles. There are 55-70 secondary ribs per half-whorl. Neither constrictions nor parabolae was observed in our material.

Discussion: As already mentioned by Riccardi *et al.* (1971), Cooper (1981), Company (1987) and Bulot (1990a, 1992), the Olcostephanus of the atherstoni plexus are characterized by a marked dimorphism. The Chilean material also illustrates this feature (Fig. 7). The dimorphism clearly affects size, coiling and ribbing. The microconchs are more evolute, smaller and with coarser ribs than the macroconchs.

It should also be noted that the material from Atacama is closer to the population from the Mediterranean Tethys than to the one from South Africa and Argentina (Neuquén Basin). As a whole, our

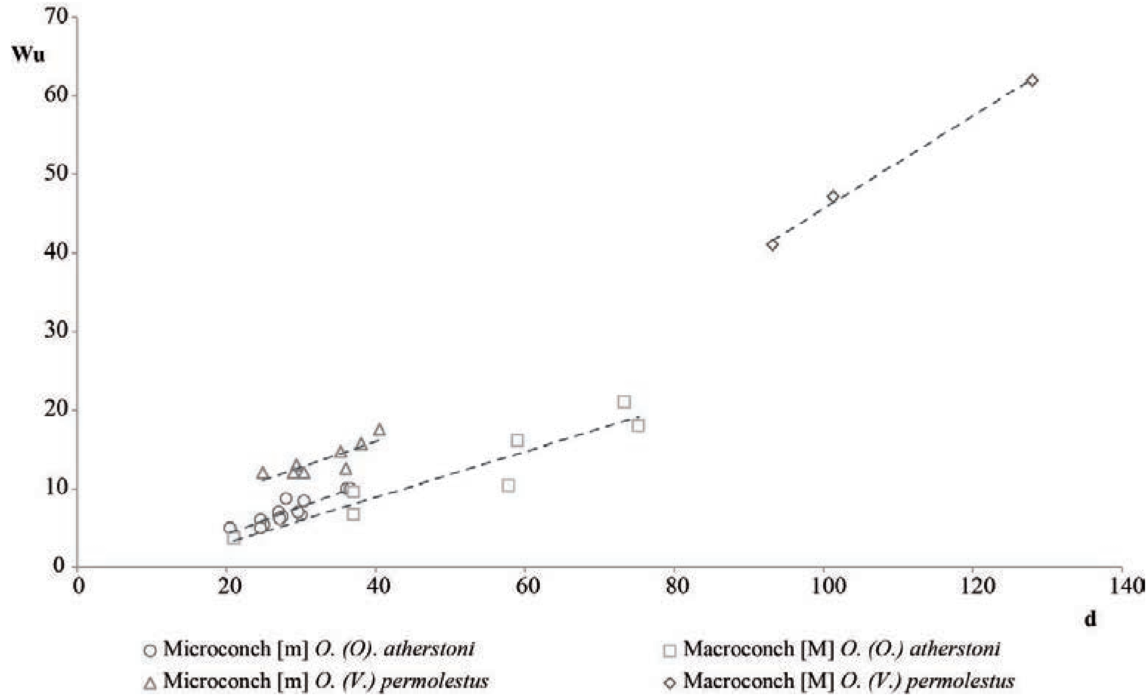

FIG. 7. Plot of umbilical width (**wu**) against shell diameter (**d**) for *Olcostephanus* (*O.*) *atherstoni* (Sharpe, 1856) and *O.* (*Viluceras*) *permolestus* (Leanza, 1957).

population is very similar to *O.* (*O.*) *guebhardi* and its morphotypes as defined by Bulot (1990a, 1992). This includes not only *O.* (*O.*) *guebhardi* s. str. but also *O.* (*O.*) *guebhardi* morphotype *querolensis* Bulot, the *O.* (*O.*) *densicostatus* (Wegner) in Company (1987, Pl. 15, Figs. 1-8, Pl. 19, Figs. 16, 17).

On the other hand, some of the South African microconchs figured by Cooper (1981, p. 265, Fig. 115, Fig. 129B) under *O.* (*O.*) *baini baini*, considered herein as a junior subjective synonym of *O.* (*O.*) *atherstoni*, hardly differ from the microconchs of *O.* (*O.*) *guebhardi*. Similarly, the larger macroconchs of *O.* (*O.*) *guebhardi* (morphotypes *querolensis* and *hollwedensis*) fall within the adult size of the smaller South African and Argentinean *O.* (*O.*) *atherstoni*. As a consequence, we cannot see any reason to keep *O.* (*O.*) *guebhardi* separate from *O.* (*O.*) *atherstoni*. Because of priority rules, *O.* (*O.*) *guebhardi* is a junior subjective synonym of *O.* (*O.*) *atherstoni*.

Nevertheless, it should be noted that in South-eastern France the oldest representatives of *O.* (*O.*) *atherstoni*, *O.* (*O.*) *guebhardi* 'forme primitive' *in* Bulot (1990a, 1992), first occur in the middle part of the *B. campylotoxus* Subzone (*B. subcampylotoxus* biohorizon *sensu* Bulot and Thieuloy, 1995). The acme of the species ranges from the upper part of the *B. campylotoxus* Subzone to the uppermost part of the *K. biassalense* Subzone (*B. campylotoxus* biohorizon to *K. inostranzewi* Zone *sensu* Bulot and Thieuloy, 1995). These forms, always cadicones, lose at the adult stage the sphaerocone morphology of the precursors. It is among those populations that the morphology is closer to the typical *O.* (*O.*) *atherstoni* from South Africa. They also include large numbers of typical *O.* (*O.*) *guebhardi*.

At the top of the *K. biassalense* Subzone, the populations are affected by a new morphological change that affects mainly the density of ribbing, while the general form of the shell remains unchanged. Bulot (1990a, 1992) introduced the name *querolensis* for this morphotype that shows its acme in the *S. verrucosum* Subzone and disappears at the top of the *K. pronecostatum* Subzone. Most of the Chilean macroconchs described herein clearly belong to this morphotype.

Similarly, Ettachfini (1991) showed that the morphotype succession identified in south-east of France is also represented in the Valanginian of the Essaouira basin (Morocco). In South-eastern Spain, *O.* (*O.*) *atherstoni* is represented only by the morphotype *querolensis*, which shows the same distribution as in France. The German morphotype *hollwedensis* Bulot (='*Proastieria*' *sensu* Stolley, 1937) is known only from the lower part of the *P. hollwedensis* Zone of the Lower Saxony and Yorkshire basins of Northern Europe (Kemper *et al.*, 1981). Similar forms also occur in the 'Marnes à *Astieria*' of the Jura platform in Switzerland (Bulot, 1992). This morphology is by far the closest to the typical *O. (O.) atherstoni* from South Africa. The time span of the *hollwedensis* morphotypes merely represents an equivalent of the uppermost *B. campylotoxus* and lower *K. biassalense* Subzones of the Mediterranean standard ammonite scale.

From the Neuquén basin, the species described by Leanza (1944), *O.* (*O.*) *auritus* and *O.* (*O.*) *midas*, correspond respectively to the macroconchs and microconchs of our *O.* (*O.*) *atherstoni*.

Subgenus *Viluceras* Aguirre-Urreta and Rawson, 1999

Type-species: *Simbirskites permolestus* Leanza, 1957, by original designation of Aguirre-Urreta and Rawson (1999, p. 351).

Diagnosis: An evolute to serpenticone subgenus of *Olcostephanus* characteristically with well-developed constrictions and flares, particularly in the adult growth stage.

Discussion: The relationships between *Viluceras*, *Simbirskites*, *Lemurostephanus* and *Olcostephanus* have been discussed at length by Aguirre-Urreta and Rawson (1999, p. 343 and 351-352) and we fully agree with those authors on the systematic position of *Viluceras* as a subgenus of *Olcostephanus*. As already mentioned above and for the reasons given by Aguirre-Urreta and Rawson (1999, p. 351-352), we also regard *Lemurostephanus* as a junior subjective synonym of *Olcostephanus s. str.*

Occurrence: Until the recognition of its occurrence in Chile (Mourgues, 2004), the subgenus was known only from the middle part of the Upper Valanginian of the Neuquén Basin in Argentina (Aguirre-Urreta and Rawson, 1999). The reported occurrence of O. (V.) permolestus from south-east France (Autran, 1993) is erroneous and will be discussed below.

***Olcostephanus* (*Viluceras*) *permolestus* (Leanza, 1957)**
Fig. 8

v 1957 *Simbirskites permolestus* Leanza, p. 16, Pl. 3, Fig. 1.
v 1963 '*Holcostephanus copiapoensis* nov. sp.': Corvalán *in* Segerstrom *et al.*, p. 10.
v 1974 '*Holcostephanus copiapoensis* nov. sp.': Corvalán, p. 19.
v 1980 *Olcostephanus* (*Lemurostephanus*) *permolestus* (Leanza): Leanza and Wiedmann, p. 949, Pl. 1, Fig. 2, Pl. 2, Fig. 1.
v 1993 *Olcostephanus* (*Lemurostephanus*) *permolestus* (Leanza): Aguirre-Urreta, Pl. 2, Fig. 4 (holotype refigured from opposite flank).
non 1993 *Olcostephanus (Lemurostephanus) permolestus* (Leanza): Autran, Pl. 4, Fig. 2.
v 1995 *Olcostephanus* (*Lemurostephanus*) *permolestus* (Leanza): Aguirre-Urreta and Rawson, Pl. 1g (re-illustration of Aguirre-Urreta, 1993, Pl. 2, Fig. 4).
v 1997 *Olcostephanus* (*Lemurostephanus*) *permolestus* (Leanza): Aguirre-Urreta and Rawson, Figs. 6a, b.
v 1999 *Olcostephanus* (*Lemurostephanus*) *permolestus* (Leanza): Aguirre-Urreta and Rawson, p. 352-353, Figs. 4e, f, I, j; Figs. 5a-n; Fig. 6; Figs. 7a-f, i, j.
v 2002 *Olcostephanus* (*V.*) *permolestus* (Leanza): Mourgues, p. 75.
v 2004 *Olcostephanus* (*Viluceras*) *permolestus* (Leanza): Mourgues, Fig. 5f.
2005 *Olcostephanus* (*Lemurostephanus*) *permolestus* (Leanza): Aguirre-Urreta *et al.*, Fig. 5b.
2007 *Olcostephanus* (*Viluceras*) *permolestus* (Leanza): Aguirre-Urreta *et al.*, Figs. 6D-E, Fig. 10I.

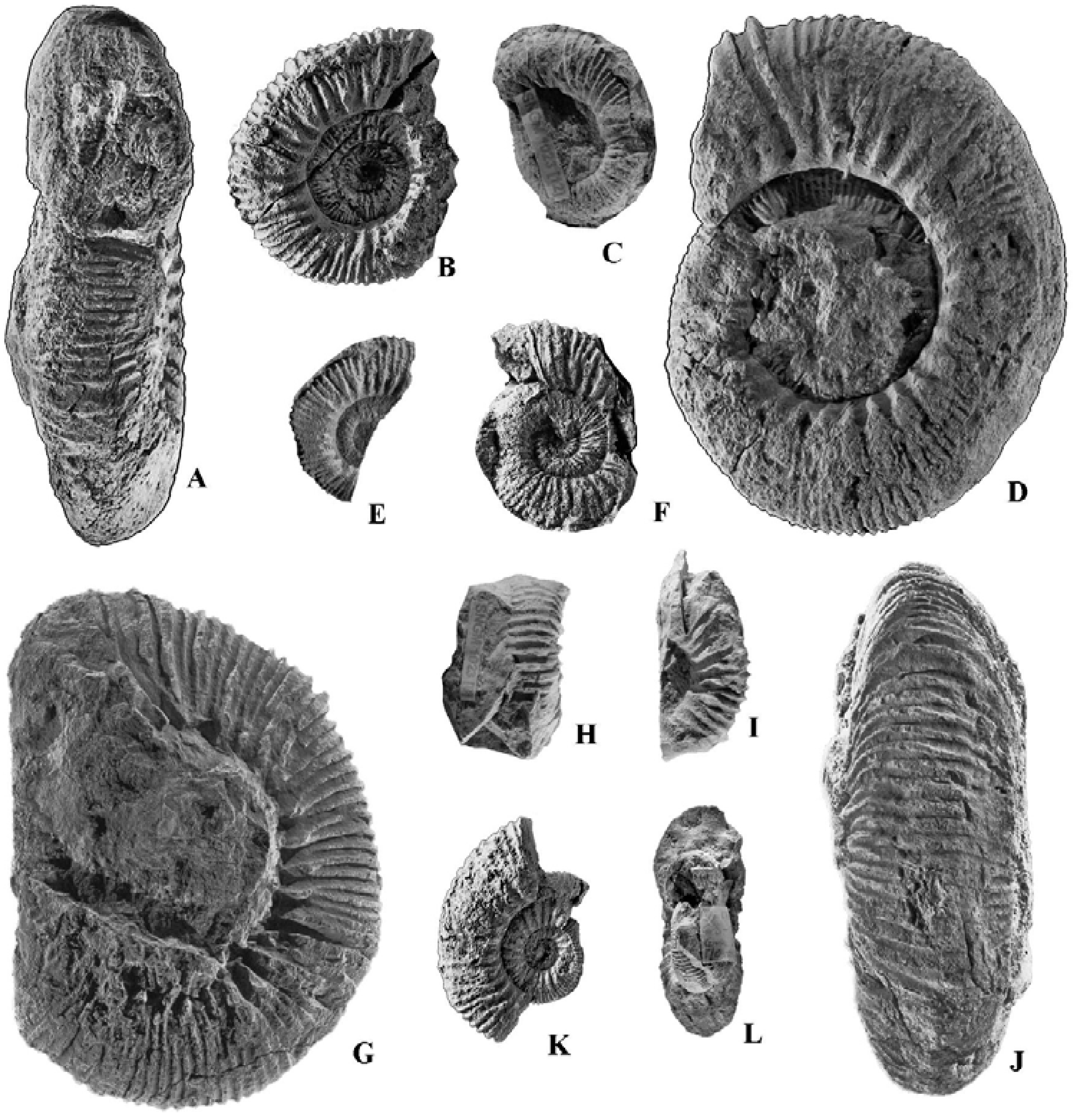

FIG. 8. *O.* (*Viluceras*) *permolestus* (Leanza, 1957). **A, G.** SNGM 1538-1; **B.** SNGM 1023-2; **C.** SNGM 1023-12; **D, J.** SNGM 1538-2; **E.** SNGM 1023-9; **F.** SNGM 1023-5; **H-I.** SNGM 1023-8; **K-L.** SNGM 1023-3. All specimens from bed G3-3 at Quebrada de Meléndez (Mourgues collection), except **A, G, D** and **J** (Corvalán collection).

Holotype: By original designation, the specimen figured by Leanza (1957, p. 16, Pl. 3, Fig. 1), from El Durazno hill, Central West Argentina. Universidad de Buenos Aires, CPBA 7018. Refigured by Aguirre-Urreta (1993, Pl. 2, Fig. 4) and Aguirre-Urreta and Rawson (1995, Pl. 1, Fig. g; 1999, p. 350, Fig. 5a).
Material: 19 specimens (table 4 and 5), from Quebrada de Meléndez (SNGM 1023 [1-17]; SNGM 1538 [1, 2], Corvalán collection).

Description: The examples are dimorphic in size. Small microconch of 35-45 mm diametre, serpenticone with a large umbilicus (wu=35-48% of d). The subcircular whorl section overlaps approximately a third of the preceding whorl. The umbilical slope is quite shallow and rounded and becomes moderately steep in the adult macroconch. The rectiradiate primary ribs are coarse, slightly concave, and form bullae-like tubercles on the upper part of the umbilical

TABLE 4. DIMENSIONS *O.* (*VILUCERAS*) *PERMOLESTUS* (LEANZA) MICROCONCH SPECIMENS.

Specimen	d	Wh	wh%d	wt	wt%d	wu	wu%d
SNGM 1023-2	40.5	13.2	33	17.2	42	17.5	43
SNGM 1023-3	36	13	36	15	42	12.5	35
SNGM 1023-3	30.4	10.7	35	12.2	40	12	39
SNGM 1023-9	29.4	10.1	34	10.3	35	13	44
SNGM 1023-5	38.1	13	34	11.8	31	15.7	41
SNGM 1023-11	35.3	12	34	10.6	30	14.7	42
SNGM 1023-12	24.9	10	34	11	37	12	41
SNGM 1023-14	29	10.5	36	9.3	32	12	41

TABLE 5. DIMENSIONS *O.* (*VILUCERAS*) *PERMOLESTUS* (LEANZA) MACROCONCH SPECIMENS

Specimen	d	Wh	wh%d	wt	wt%d	wu	wu%d
SNGM 1538-1	93.2	31	33	28.2	31	41	44
SNGM 1538-2	101.3	35.1	35	38	38	47.2	47
SNGM 1023-1	128	40	31	-	-	62	48

margin. From each bulla arise associated bundles of two to three (frequently two) secondary ribs, gently rursiradiate on the upper third of the whorl. An additional one may be intercalated between two bundles. Constrictions are frequent.

Remarks: Both our macroconchs and microconchs fall in the range of intraspecific variation accepted by Aguirre-Urreta and Rawson (1999) for this species (compare our Figs. 8B, E and K with their Figs. 5h, i and n). As in the Argentinean material, microconchs show a significant variation in rib density, degree of inflation, as well as in strength and frequency of constrictions and flares.

Outside southern South America, a single specimen was reported from south-east France by Autran (1993) as *O.* (*Lemurotephanus*) *permolestus*. As already noted by Bulot (1990a) and Aguirre-Urreta and Rawson (1999), this record is based on the misidentification of macroconch forms of *O.* (*O.*) *nicklesi*.

4. Biostratigraphic implications

As in the Neuquén Basin, the genus *Olcostephanus* occurs at two main distinct levels. The lower one is characterized by a monospecific assemblage of *O.* (*O.*) *atherstoni*, while the upper one is marked by the co-occurrence of *O.* (*V.*) *permolestus* with various Neocomitidae such as *N.* (*Neocomites*) *peregrinus*, *Neocomites* (*Sabbaiceras*) *beaumugnensis* and *Rodighieroites cardulus*.

Both *O.* (*O.*) *atherstoni* and *O.* (*V.*) *permolestus* were retained by Aguirre-Urreta and Rawson (1997, 1999) as index species for zones and subzones of the Valanginian of the Neuquén Basin (Fig. 9). As already pointed out by those authors, the lower and middle part of the *O.* (*O.*) *atherstoni* Zone, *O.* (*O.*) *atherstoni* and *Karakaschiceras attenuatum* subzones, span the Lower/Upper Valanginian boundary on evidence of ammonites common to Argentina and the Mediterranean Tethys.

Until now, *O.* (*O.*) *atherstoni* was considered by one of us (L.G.B.) as the southern hemisphere counterpart of the North Tethyan species *O.* (*O.*) *guebhardi*. As discussed above in the light of the Chilean material, we are now convinced that the two taxa should be considered as synonyms. For the reasons given in our discussion of the intraspecific variability of *O.* (*O.*) *atherstoni*, we therefore consider that the base of the Argentinean *O.* (*O.*) *atherstoni* Zone correlates with the middle part of the *B. campylotoxus* Zone of the Mediterranean zonal scheme (Fig. 9).

Even if the First Apparition Data (FAD) of *Karakaschiceras sensu* Bulot and Thieuloy (1995) and *Neohoploceras* Spath, 1939 occur at the base of the *K. biassalense* Subzone of the Mediterranean zonal

STAGES		CHAÑARCILLO BASIN (Zones)	NEUQUÉN BASIN (Zones / Subzones)		STANDARD MEDITERRANEAN (Zones / Subzones)	
VALANGINIAN	Upper		angulati-formis	*D. crassicostatus*	*C. furcillata*	*T. callidiscus*
				Ch. ornatum		*C. furcillata*
				P. angulatiformis	*N. peregrinus*	*O. (O.) nicklesi*
		O. (V.) permolestus	atherstoni	*O. (V.) permolestus*		*N. peregrinus*
				K. attenuatus	*S. verrucosum*	*K. pronecostatum*
		O. (O.) atherstoni		*O. (O.) atherstoni*		*S. verrucosum*
	Lower				*B. campylotoxus*	*K. biassalense*
		Lissonia	*L. riveroi*			*B. campylotoxus*
			N. wichmanni		*T. pertransiens*	
		Parandiceras				
BERRIASIAN	Upper				*S. boissieri*	*T. otopeta*
						T. alpillensis
		Malbosiceras				*B. picteti*
						M. paramimounum
	Middle				*S. occitanica*	*D. dalmasi*
						B. privasensis
						S. subalpina
	Low.				*B. jacobi*	

FIG. 9. Ammonite zonal scheme for the Chañarcillo Basin and proposed correlation with the Neuquén Basin (Aguirre-Urreta and Rawson, 1999; Rawson, 1999) and the West Mediterranean Province (Reboulet *et al.,* 2011).

scheme, we herein consider that the Argentinean *K. attenuatum* Subzone better correlates with the *K. pronecostatum* Subzone of the Mediterranean zonal scheme. This view is supported by the fact that *Neohoploceras arnoldi sensu* Aguirre-Urreta (1998) is closely allied, if not identical, to *Neohoploceras* gr. *depereti/schardti sensu* Bulot and Thieuloy (1995). Similarly, the general morphology of *K. attenuatum* (Behrensen, 1892) and *K. neumayri* (Behrensen, 1892) is closer to that of the group of *K. pronecostatum* Felix, 1891, including *K. quadristrangulatum* (Sayn, 1907), than to the late Lower Valanginian forms of the *K. biasselense/inostranzewi* plexus. As a consequence, the correlation proposed herein is slightly different from that formerly published by Rawson (1999, 2007) and Aguirre-Urreta *et al*. (2007).

So far, the Argentinean *O. (V.) permolestus* Subzone has been correlated with the *O.* (*O.*) *nicklesi* Subzone of the Mediterranean ammonite scale (Aguirre-Urreta and Rawson, 1999, p. 356; Aguirre-Urreta *et al.*, 2007; Rawson, 2007). As *Viluceras* is unknown outside southern South America, this view was mainly based on the co-occurrence *O.* (*O.*) *mingrammi* (Leanza), an evolute *Olcostephanus*, that shows some morphological affinities with the plexus of *O.* (*O.*) *nicklesi* Wiedmann and Dieni, 1968. Nevertheless, those authors also noted, that in south western Europe, the range of evolute *Olcostephanus s. str*. started in the *N. peregrinus* Subzone and carried on in the *C. furcillata* Subzone with such species as *O.* (*O.*) *detonii* (Rodighiero, 1919) and *O.* (*O.*) *mittreanus* (d'Orbigny, 1850). Our new material shows clearly that *O.* (*V.*) *permolestus* is associated with *Neocomites (N.) peregrinus* in Chile. We therefore suggest that the *O.* (*O.*) *permolestus* Subzone correlates with the *N. peregrinus* Subzone of the Mediterranean standard scale of Reboulet *et al.* (2011) (Fig. 9).

The stratigraphic record of the Chañarcillo Basin represents a bridge between the Neuquén Basin and the Tethys region, where the typical Andean faunas were documented in association with Tethysian ammonites which allows us to precise the former biostratigraphic long distance correlations, for the Valanginian ammonite biozones.

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