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Biostratigraphy of the upper Bajocian–middle Callovian (Middle Jurassic), South America

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Abstract—The biostratigraphic division of the upper Bajocian-middle Callovian of South America is based on ammonites from different sections of the following provinces and regions: Neuquén, Mendoza, and San Juan in Argentina; Malleco, Linares, Talca, Atacama, Antofagasta, and Tarapacá in Chile. The complete upper Bajocian-middle Callovian succession includes the following biostratigraphic units: the *Megasphaeroceras magnum* assemblage zone, lowermost upper Bajocian; the Cadomites-Tulitidae mixed assemblage, (?lower) middle and upper Bathonian; the Steinmanni zone, index *Lilloettia steinmanni* (Spath), uppermost Bathonian, with two local horizons — *Stehnocephalites gerthi* horizon (Argentina) and *Choffatia jupiter* horizon (northern Chile); the Vergarensis zone, index *Eurycephalites vergarensis* (Burck.), near the Bathonian-Callovian boundary; the Bodenbenderi zone, index *Neuqueniceras (Frickites) bodenbenderi* (Tornq.), lower Callovian; the Proximum zone, index *Hecticoceras proximum* Elmi, uppermost lower Callovian; and the *Rehmannia (Loczyceras) patagoniensis* horizon, middle Callovian.

Resumen—La división bioestratigráfica del Bajociano superior-Caloviano inferior de América del Sur está basada en la fauna de amonites proveniente de diferentes secciones de las provincias/regiones de Neuquén, Mendoza, San Juan (Argentina), Malleco, Linares, Talca, Atacama, Antofagasta, y Tarapacá (Chile). La sucesión del Bajociano superior-Caloviano medio incluye las siguientes unidades bioestratigráficas: zona de asociación de *Megasphaeroceras magnum*, Bajociano superior bajo; asociación de mezcla de Cadomites-Tulitidae, Bathoniano (?inferior) medio y superior; zona de Steinmanni, fósil guía *Lilloettia steinmanni* (Spath), Bathoniano superior alto, con dos horizontes locales — horizonte con *Stehnocephalites gerthi* (Argentina) y horizonte con *Choffatia jupiter* (norte de Chile); zona de Vergarensis, fósil guía *Eurycephalites vergarensis* (Burck.), aproximadamente límite Bathoniano-Caloviano; zona de Bodenbenderi, fósil guía *Neuqueniceras (Frickites) bodenbenderi* (Tornq.), Caloviano inferior; zona de Proximum, fósil guía *Hecticoceras proximum* Elmi, Caloviano inferior alto; horizonte con *Rehmannia (Loczyceras) patagoniensis*, Caloviano medio.

INTRODUCTION

FOR THE LAST 25 years, two of us (ACR and GEGW) have conducted field and laboratory research on the Middle Jurassic of South America. These studies have resulted in a number of publications dealing with Aalenian-Callovian ammonite faunas and biostratigraphic zonation and correlation throughout Argentina, Chile, and Peru. Either ACR or ACR and GEGW have studied most of the sections. Additional information and/or material on these sections has been contributed by G. Chong, C. Cornejo, V. Covacevich, J. Davidson, C. Gulisano, A. Hillebrandt, A. Jensen, J. Muñoz, E. Pérez d'A., L. A. Quinzio, R. Vicencio, and J.-C. Vicente. As a result, a formal zonal succession has been developed for the Aalenian-Callovian (Westermann and Riccardi, 1979; Riccardi, 1984b) of the region. Additional information on the Aalenian was provided by Hillebrandt and Westermann (1985). All other ammonite stratigraphy described in this region (*e.g.*, Groeber *et al.*, 1953; Stipanicic, 1966, 1969; Hillebrandt, 1970; Bogdanic and Chong, 1985) is referred to European standard zones.

The first Bathonian-Callovian zonation (Riccardi, 1984b) was based primarily on Eurycephalitinae distribution in the Chacay Melehue section, Neuquén Province, Argentina. Despite similar ammonites of other areas studied by different authors (Gottsche, 1878; Steinmann, 1881; Tornquist, 1898; Burckhardt, 1900a,b, 1903; Stipanicic, 1966; Cornejo *et al.*, 1982), the rich fauna described by Stehn (1923) from that locality represents the most complete Eurycephalitinae succession of the entire Andes. Analysis of the whole assemblage resulted in the delineation of several assemblages (Riccardi, 1984b), even if restriction of this subfamily to the east Pacific subrealm renders it almost useless for correlation with European standard zones. Evidence provided by relatively rare pandemic representatives of the oppeliids and perisphinctids from Chacay Melehue, supplemented by similar faunas found at Caracoles, Antofagasta, Chile, were subsequently used by Riccardi *et al.* (1988a,b, 1990) to propose the validity of most of these biostratigraphic units throughout the Andes.

Recently, the Bajocian-Callovian Eurycephalitinae and Reineckeiidae have been revised taxonomically and chronologically (Riccardi and Westermann, 1991a,b) by examining all available speci-

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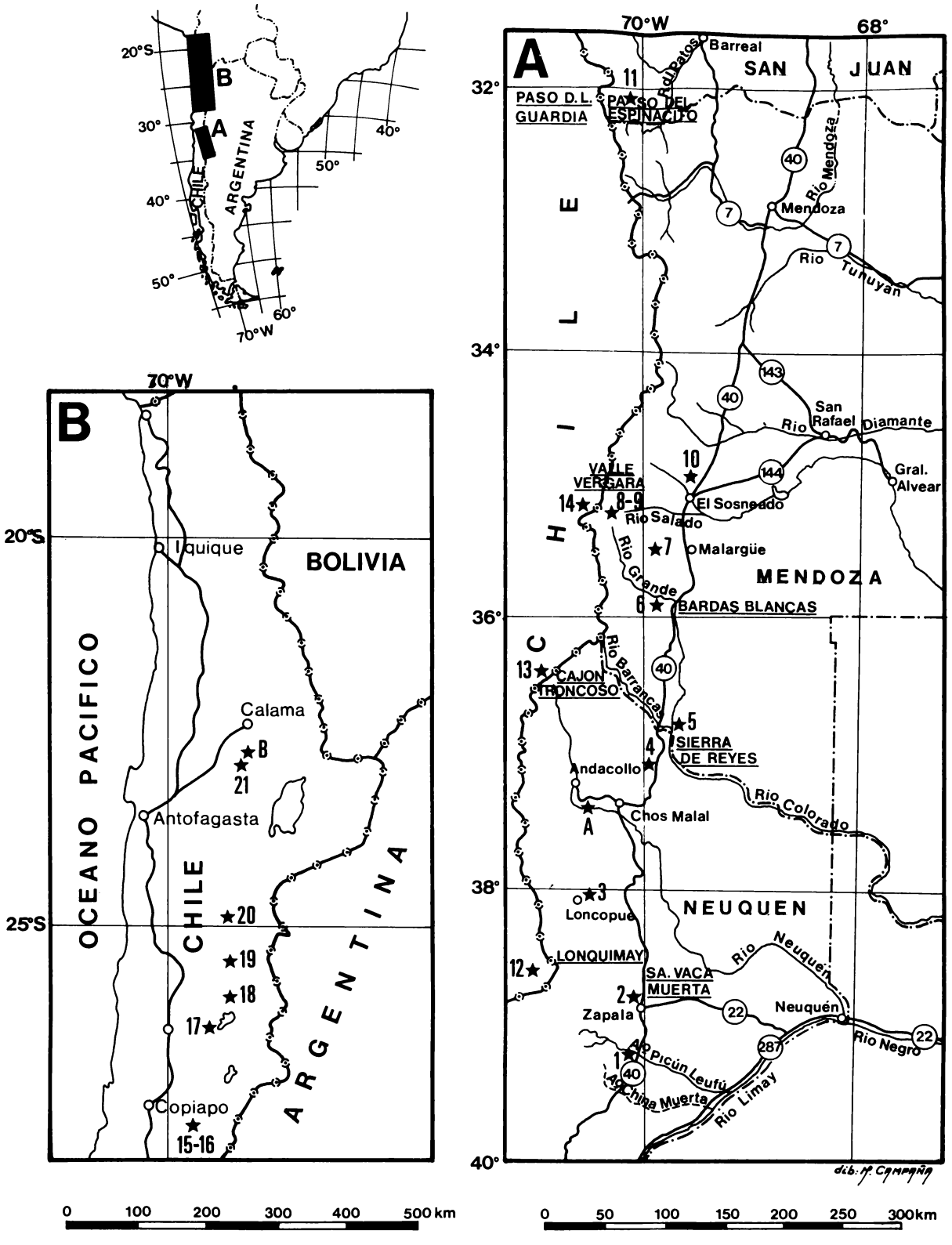

Fig. 1. Index map for the upper Bajocian-middle Callovian ammonoid localities in the Argentine-Chilean Andes. In Argentina, Neuquén province: 1) Picun Leufú, 2) Arroyo Mulichinco, 3) Arroyo Agua Fria, 4) Vega de la Veranada; Mendoza province: 5) Sierra de Reyes (La Estrechura, Quebrada Remoredo, Quebrada de la Buitrera, Aguada de la Mula, Agua del Ñaco), 6) Arroyo de la Vaina, 7) Cerro Puchenque, 8) Arroyo La Bajada, 9) Cerro de Las Yeseras, 10) Arroyo Blanco; San Juan province: 11) Paso del Espinacito. In Chile, Malleco province, 12) Lonquimay; Linares province, 13) Cajón Troncoso; Talca province, 14) Valle Vergara; Atacama region, 15) Quebrada Calquis, 16) Manflas, 17) Salar de Pedernales, 18) Quebrada de los Burros; Antofagasta province, 19) Quebrada Incahuasi, 20) Quebrada El Profeta, 21) Quebrada San Pedro; Tarapacá region, 22) Iquique.

mens, most types, and many new localities in the provinces/regions of Neuquen, Mendoza, and San Juan in Argentina, and of Malleco, Linares, Talca, Atacama, Antofagasta, and Tarapacá in Chile. These studies support and improve the previous zonal scheme.

Three levels of stratigraphic units are distinguished in classifying the Andean fossiliferous succession based on its ammonites (Riccardi *et al.*, 1990). The lowest level comprises the "faunal horizon," the next level is the "assemblage zone," and the third level of classification is the "standard chronozone."

Fossil specimens shown here are in the collections of the La Plata Museum, Argentina (MLP) and the Geologisch-Paläontologisches Institut, Georg August Universität, Göttingen, Germany (GAUG).

BIOSTRATIGRAPHY

Key Sections

Chacay Melehue, Argentina. The Jurassic of the Chacay Melehue area (Fig. 1A) has been described by Keidel (1910), Jaworski (1914, 1925), Groeber (1918), Stehn (1923), Leanza (1945, 1946, 1947), Groeber *et al.* (1953), Stipanicic (1966), Zöllner and Amos (1973), and Rosenfeld and Volkheimer (1980).

Aalenian-Bajocian biostratigraphy and the Hildocerataceae and Stephanocerataceae of this section have been dealt with by Westermann and Riccardi (1972, 1979). More recently, the stratigraphy and ammonoids of the supposed Kimmeridgian beds were studied by Riccardi and Westermann (in Dellape *et al.*, 1979), who reassigned them to the Callovian-Oxfordian. Lower Jurassic stratigraphy and bivalves have been studied by Damborenea (1987). Upper Bajocian-Callovian stratigraphy and eurycephalitine systematics have been discussed by Westermann (1981), Riccardi (1983, 1984a,b 1985), and Westermann and Riccardi (1985), and have been revised by Riccardi and Westermann (1991a).

The fossiliferous sucession consists of about 1300-1400 meters of marine sediments ranging in age from Pliensbachian to Oxfordian. The upper Bajocian-lower Callovian is about 990 meters thick. The Pliensbachian-Callovian succession includes about 30 tuffaceous levels. Samples from these levels collected by ACR, together with S. Damborenea, M. Manceñido, and S. Ballent, are undergoing radiometric analysis.

Caracoles, Chile. Jurassic fossils from Caracoles (Fig. 1B) were discovered over a century ago (Gottsche, 1878); they were systematically described by Steinmann (1881; also Stehn, 1923), but without information on stratigraphy and locality. The stratigraphy was described by Harrington (1961), and the biostratigraphy by Westermann and Riccardi (1979), Riccardi *et al.* (1988a,b, 1990), and Riccardi and Westermann (1991a,b). The main section examined for this study is south and east of an old cemetery associated with a mine. This excellent outcrop exposes about 55-60 meters of upper Bathonian-lower Callovian shales with fossiliferous limestone concretions. Other sections were studied at Quebrada Descubridora, Quebrada Torcazas, and Quebrada Honda.

Additional Sections

Bajocian-Callovian ammonite stratigraphy and Eurycephalitinae and Reineckeiidae taxonomy have also been studied in the Neuquen, Mendoza, and San Juan provinces in Argentina and in the following provinces/regions in Chile: Malleco, Linares, Talca, Atacama, Antofagasta, and Tarapacá (Fig. 1). These are also described or discussed in Riccardi and Westermann (1991a,b).

AMMONITE ASSEMBLAGES, BIOZONES, AND STANDARD ZONES

Megasphaeroceras magnum Assemblage Zone

This zone is introduced for the "*(?)Megasphaeroceras rotundum* assemblage zone" of Westermann and Riccardi (1979; see also Riccardi and Westermann, 1984; Riccardi, 1984b; Riccardi *et al.*, 1988a,b, 1990). The *M. rotundum* assemblage zone was formally introduced by Hall and Westermann (1980) for North America, and it was tentatively recognized in the Andes by Westermann and Riccardi (1979) on the basis of a fossil assemblage in which they identified *Megasphaeroceras* aff. *rotundum* (Imlay). The material has now been ascribed to *M. magnum* by Riccardi and Westerman (1991a,b).

This zone is represented at Chacay Melehue by about 60 meters of sediments with *Teloceras crickmayi chacayi* West. & Ricc., *Duashnoceras* aff. *andinense* (Hill.), *Cadomites* n.sp., *Megasphaeroceras magnum* Ricc. & West. (Fig. 3, no. 1a-b), *Lissoceras* cf. *oolithicum* (Orb.), *Oppelia* cf. *pulchra* Buck., *Strenoceras* or *Parastrenoceras* sp.juv., *Leptosphinctes* (*L.*) *coronarius* Buck. n.subsp., and *Lobosphinctes intersertus* Buck.

A very similar assemblage is present in the Cordillera Domeyko (Quebrada El Profeta, Quebrada San Pedro), northern Chile, with *Megasphaeroceras magnum*, *Teloceras*, *Cadomites* n.sp., and *Leptosphinctes*, as well as *Spiroceras* and rare ?*Orthogarantiana*. A single *Strenoceras* was found at Caracoles (Westermann and Riccardi, 1980). Below, in the same area, another assemblage occurs (Hillebrandt, 1977), with *Lupherites dehmi* (Hill.), *S.* (*Stemmatoceras*) spp., inflated *Stephanoceras* ex gr. *umblicum* (Quenstedt), and *Teloceras* spp. On the basis of this assemblage, Westermann and Riccardi (1979) introduced the *Lupherites dehmi* assemblage subzone; it is apparently time equivalent to the Banksii subzone (Riccardi *et al.*, 1990).

The zonal index has also been recorded in Sierra de Reyes (Quebrada Remoredo, ?Quebrada de la Buitrera) and Cerro de las Yeseras, Mendoza province, Argentina; and in Quebrada Calquis and

Manflas, Atacama province, Chile (Fig. 1, loc. 5, 9, 15-16).

This assemblage supports correlation with the Subfurcatum (Niortense) standard zone, mainly the Baculatum subzone (Fig. 2). The large *Lobosphinctes intersertus* Buck. found at Chacay Melehue occurs typically in the English Parkinsoni zone. We have therefore assumed that the upper Bajocian at Chacay Melehue is strongly condensed.

Cadomites-Tulitidae Mixed Assemblage

This assemblage was introduced by Riccardi *et al.* (1988a,b, 1990) for the "Cadomites Faunula" defined by Riccardi (1984b) in the Chacay Melehue area. The beds there are about 50 meters thick and are characterized by rather abundant *Cadomites* of the group *C. orbignyi* (Gross.) and *C. bremeri* Tsereteli, preserved in impure sandstone and mudstone. They occur close to *Tulites*? (*Rugiferites*?) cf. *davaiacensis* (Liss.), clearly indicating middle Bathonian. Rare *Bullatimorphites* (*Kheraiceras*) cf. *bullatus* (d'Orb.) and *Bomburites* cf. *microstoma* (d'Orb.), which indicate upper Bathonian, occur in an argillaceous matrix and may also have come from this interval or from an even slightly lower one. Such an admixture of faunas of different ages may have been caused by the reworking as olistostromes (turbiditic breccias) of the arenaceous rocks that yielded most or all of the *Cadomites*, whereas the late Bathonian species came from the autochthonous shales.

Locally abundant *Cadomites bremeri* indicate the Bremeri zone at the top of the middle Bathonian in Europe (Westermann and Callomon, 1988). Although closely similar forms appear already in the uppermost Bajocian, the main European-North African distribution of the *C. bremeri-orbignyi* group is in the middle Bathonian. Mangold (1985) has clearly placed the level of *Cadomites bremeri* at the top of the middle Bathonian. In the Cordillera Domeyko of northern Chile, similar *Cadomites* occur at a similar level and sometimes even together with *Epistrenoceras*, indicating the upper Bathonian Retrocostatum zone (A. Hillenbrandt, pers. commun. to GEGW).

At Chacay Melehue, this association is separated from the *Megasphaeroceras magnum* zone by approximately 150 meters of poorly fossiliferous shales from which middle Bathonian *Tulites* (*Rugiferites*?) aff. *sofanus* (Boehm) was collected. Similar forms occur in the lower Subcontractus zone of Spain — *i.e.*, the Sofanus zone of Sandoval (1983), which also include early *Cadomites bremeri*. This interval at Chacay Melehue therefore seems to represent part of the upper Bathonian, while containing resedimented earlier Bathonian fauna (Fig. 2).

Steinmanni Standard Zone

This zone was introduced by Riccardi *et al.* (1984b) for the "*Lilloettia* Assemblage Zone" of Riccardi (1984b). It is composed of about 110 meters of thick shales at Chacay Melehue. The base of the zone was defined where the first *Iniskinites* occur, below the first appearance of the index species; the top was defined by the base of the overlying Vergarensis zone. The fauna contains *Lilloettia steinmanni* (Spath) (Fig. 3. no. 3), *Iniskinites crassus* Ricc. & West., *I. gulisanoi* Ricc. & West., *Xenocephalites neuquensis* (Stehn), *Neuqueniceras* (*N.*) *biscissum* (Stehn); it is characterized, near the base, by *Choffatia* aff. *aequalis* (Roem.) and, in the upper part, by *Neuqueniceras (N.) steinmanni* Stehn, *Choffatia* gr. *jupiter* (Stein.), and *C. suborion* (Burck.).

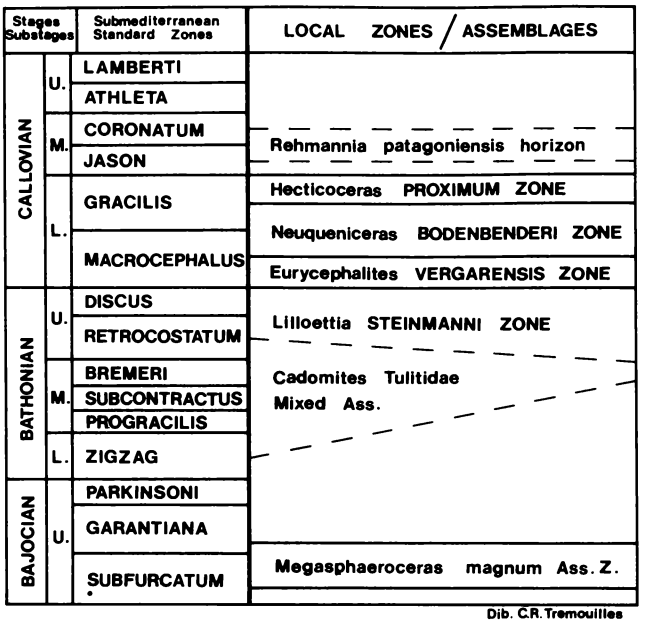

Fig. 2. Correlation of regional ammonite assemblages and zones with the standard chronostratigraphic scale.

In the cemetery section at Caracoles, Chile, this zone consists of at least 17 meters of shales and limestones (base not exposed). The fossiliferous limestone in the middle of this interval yields the index species together with abundant *Choffatia jupiter*, which marks an easily recognizable horizon in the Cordillera Domeyko. Below *L. steinmanni* occurs associated with *Hecticoceras* (*Prohecticoceras*) *blanazense* Elmi and *Eohecticoceras* sp., indicating in the Mediterranean the basal upper Bathonian Blanazense subzone of the Retrocostatum zone. Therefore the age of this zone is late Bathonian — Retrocostatum zone and Discus zone (Fig. 2).

This zone is represented at Arroyo Mulichinco, Arroyo Agua Fria, Sierra de Reyes, and Cerro Puchenque in Argentina, and at Lonquimay and Cordillera Domeyko (Quebrada El Profeta, ?Quebrada San Pedro, Caracoles) in Chile (Fig. 1, loc. 2, 3, 5, 7, 12, 20, 21). At Cualac, Mexico, the Steinmanni standard zone includes at its base *Epistrenoceras histricoides* (Roll.), marking the Retrocostatum zone in the Mediterranean (Sandoval *et al.*, 1990).

Stehnocephalites gerthi Horizon. This is the "*Indocephalites*" *gerthi* assemblage zone or subzone proposed by Riccardi (1984b) and Riccardi *et al.*

(1988a,b) (see Riccardi *et al.*, 1990). About 40 meters of shales in the Chacay Melehue section yield an abundant fauna dominated by *S. gerthi* (Spath) in the uppermost part of the Steinmanni zone. Ancillary species belong to the group of *Choffatia jupiter* (Stein.) and *suborion* (Burck.) and to *Ch.* cf. *gottschei* (Stein.). *Stehnocephalites* appears to be strictly endemic in the Neuquén Basin and has been found only within about a 100-(250?) km radius of the type locality at Chacay Melehue — *i.e.*, Arroyo Mulichinco, Arroyo Agua Fria, Sierra de Reyes (La Estrechura, ?Quebrada Remoredo, Agua del Ñaco), and ?Cerro Puchenque (Fig. 1, loc. 2, 3, 5, 7).

Choffatia jupiter Horizon. The interval of the *Choffatia jupiter* horizon at Caracoles and in the Cordillera Domeyko, northern Chile, may be coeval with the *S. gerthi* horizon of Chacay Melehue bearing similar species of *Choffatia*. In the Cordillera Domeyko, *Epistrenoceras* and *Hecticoceras* (*Prohecticoceras*) *retrocostatum*, marking the upper Retrocostatum zone in Europe, have been found mainly below this horizon, but at one locality it also occurs with abundant *Ch. jupiter* (Gröschke and Hillebrandt, 1985, p. 153).

Both horizons are probably still latest Bathonian, and the *Ch. jupiter* horizon appears to be somewhat diachronous within the upper Retrocostatum and Discus zones.

Vergarensis Standard Zone

This zone was based on the *Eurycephalites vergarensis* subzone of the "*Eurycephalites* Assemblage Zone" of Riccardi (1984b; see Riccardi *et al.*, 1988a,b, 1990); it is about 30 meters thick at Chacay Melehue. This assemblage is characterized by the macroconchiate index species *E. vergarensis* (Burck.) (Fig. 3, no. 2a-b) together with the microconchiate *Xenocephalites gottscheri* (Tornq.), both of which range throughout the zone, and by late *Neuqueniceras steinmanni* Stehn and *N.* (*N.*) *biscissum* (Stehn). The last *Stehnocephalites*, *Lilloettia*, and *Xenocephalites* cf. *araucanus* (Burck.) also occur here.

The index species has also been recorded from Arroyo Mulichinco and ?Arroyo La Bajada in Argentina, and from Valle Vergara, Quebrada Incahuasi, and Quebrada San Pedro in Chile (Fig. 1, loc. 2, 8, 14, 19, 21). This standard zone has also been recognized at Cualac, Mexico, on the basis of rare *Eurycephalites* cf. *vergarensis* (Burck.) (Sandoval *et al.*, 1990).

Bodenbenderi Standard Zone

This zone was based on the "*Eurycephalites rotundus* Subzone" of the "*Eurycephalites* Assemblage Zone" of Riccardi (1984b; see Riccardi *et al.*, 1988a,b, 1990). It is characterized by *Neuqueniceras* (*Frickites*) *bodenbenderi* (Tornq.) (Fig. 4, no. 1a-b), *Eurycephalites rotundus* (Tornq.) (Fig. 3, no. 4a-b), *E.* cf. *extremus* (Tornq.), and the two microconchs *Xenocephalites stipanicici* Ricc. *et al.* and *X.? involutus* Ricc. & West. *N.* (*F.*) cf. *antipodum* (Gott.) occur in the upper part. In the cemetery section at Caracoles, Chile, this zone is made up of abundant *Neuqueniceras* (*Frickites*) *bodenbenderi*, together with *N.* (*F.*) *antipodum* (Gott.), *Oxycerites* (*Alcidellus*) *obsoletoides* Ricc. *et al.*, and *Rehmannia* (*R.*) *douvillei* (Stein.).

The zone has also been recorded at Arroyo Mulichinco, Arroyo Agua Fria, Vega de la Veranada, Sierra de Reyes (La Estrechura, Quebrada Remoredo), Arroyo de la Vaina, Cerro Puchenque, and Arroyo La Bajada in Argentina, and at Cajón Troncoso and Cordillera Domeyko (Quebrada San Pedro) in Chile (Fig. 1, loc. 2, 4-8, 13, 21). The Bodenbenderi standard zone has been recognized in southern Mexico, where the upper part has yielded *Rehmannia* gr. *rehmanni* (Oppel), indicating the basal Gracilis zone of the standard sub-Mediterranean zonation (Sandoval *et al.*, 1990).

Proximum Standard Zone

This zone was introduced by Riccardi *et al.* (1988a,b, 1990) for the uppermost shales, approximately 60 meters thick, in the Chacay Melehue section. The assemblage is characterized by *Hecticoceras* (*H.*) *proximum* Elmi (Fig. 4, no. 2), *H.* (*H.*) cf. *hecticum* (Rein.), *H.* (*H.*) cf. *boginense* (Pet.), *H.* (*Chanasia*) *navense* Roman, and *H.* (*Ch.*) *ardescicum* Elmi, as well as by some other poorly known hecticoceratids. This association of Tethyan species can be clearly dated as late Callovian or Gracilis chronozone (Enodatum and Patina subzones, respectively), or latest early Callovian (Fig. 2). The last, rare eurycephalitids, including the large microconch *Xenocephalites stipanicici* Ricc. *et al.*, are associated with this zone. In the Andes, some reineckeiids pass from the Bodenbenderi zone into this zone, including *Neuqueniceras* (*Frickites*) *antipodum* (Góttsche), *Rehmannia* (*R.*) *douvillei* (Steinmann), *and R.* (*R.*) cf. *paucicostata* (Tornq.). *Rehmannia* (*R.*) *brancoi* (Steinmann) and *R.* (*R.*) *stehni* (Zeiss) are characteristic of the uppermost part of the zone. Both species probably pass into the lower-middle Callovian boundary. In Europe, *Hecticoceras* (*H.*) *proximum* marks the top horizon of the lower Callovian in France (Cariou, 1980). A similar species, *Hecticoceras* (*H.*) *boginense*, has been identified for the uppermost part of the Cualac section in Mexico, above the *Rehmannia* gr. *rehmanni* association (Sandoval *et al.*, 1990).

Rehmannia (*Loczyceras*) *patagoniensis Horizon*

This horizon is introduced by Riccardi and Westermann (1991a,b) on the basis of a 3-meter-thick interval with *Rehmannia* (*Loczyceras*) *patagoniensis* (Weaver) (Fig. 4, no. 3a-b). It appears to be widely distributed in west-central Argentina, from Picún Leufú, Neuquén province, to Sierra de Reyes, Mendoza province (Fig. 1). This horizon appears to yield the youngest Andean reineckeiids. Stratigraphic and

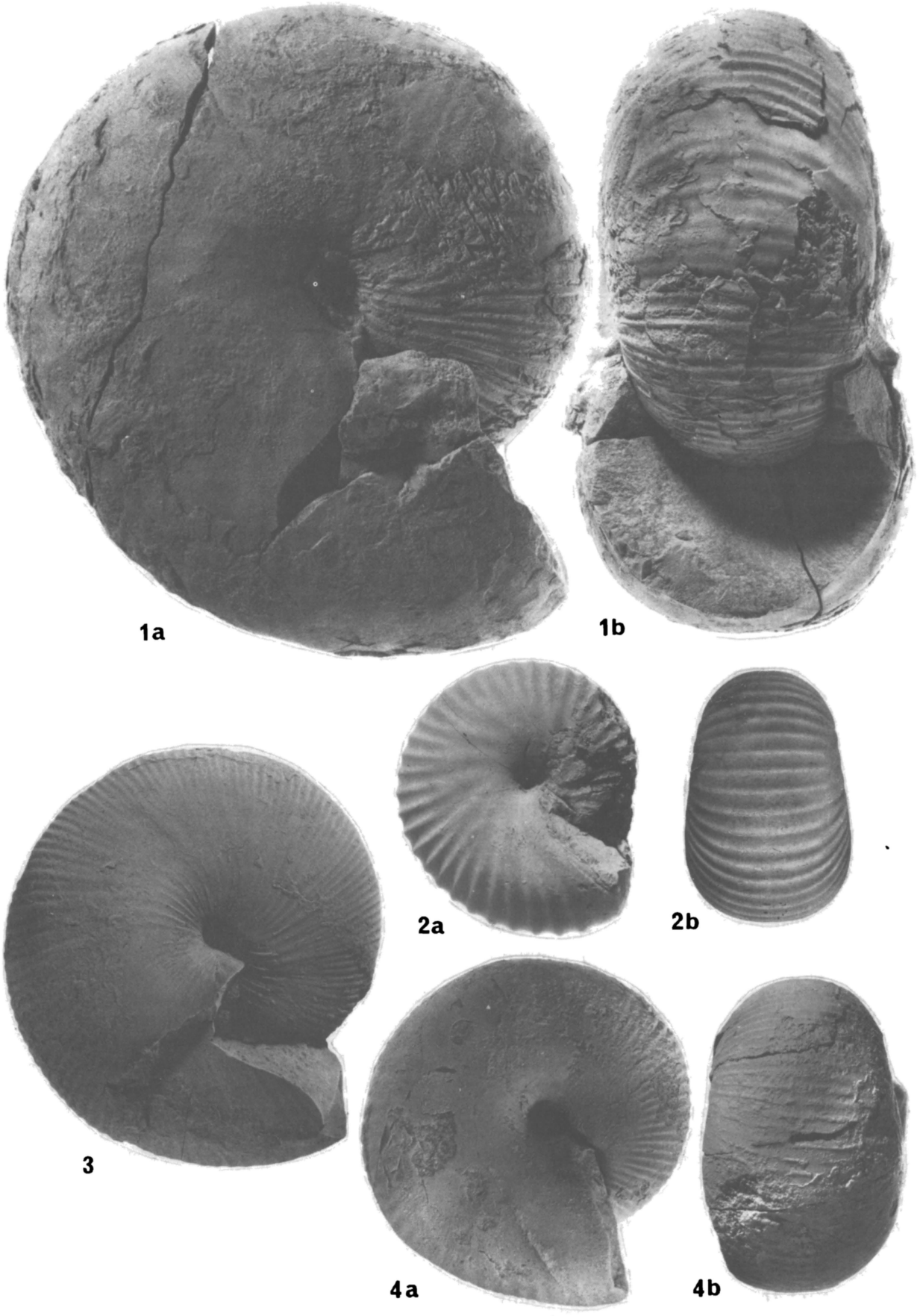

Fig. 3. Numbers 1-3 of the figured fossils are from Chacay Melehue, Argentina; number 4 is from Paso del Espinacito, Argentina. All are in the collections of the Museo La Plata (MLP) or Geologisch-Paläontologisches Institut, Georg August Universität, Göttingen, Germany (GAUG). All were photographed at ×1, but the illustration has been slightly reduced for publication: 1a-b, *Megasphaeroceras magnum* Riccardi and Westermann (MLP 23931); 2a-b, *Eurycephalites vergarensis* (Burckhardt) (MLP 12664); 3, *Lilloettia steinmanni* (Spath) (MLP 12704); 4a-b, *Eurycephalites rotundus* (Tornquist) (GAUG 496-440).

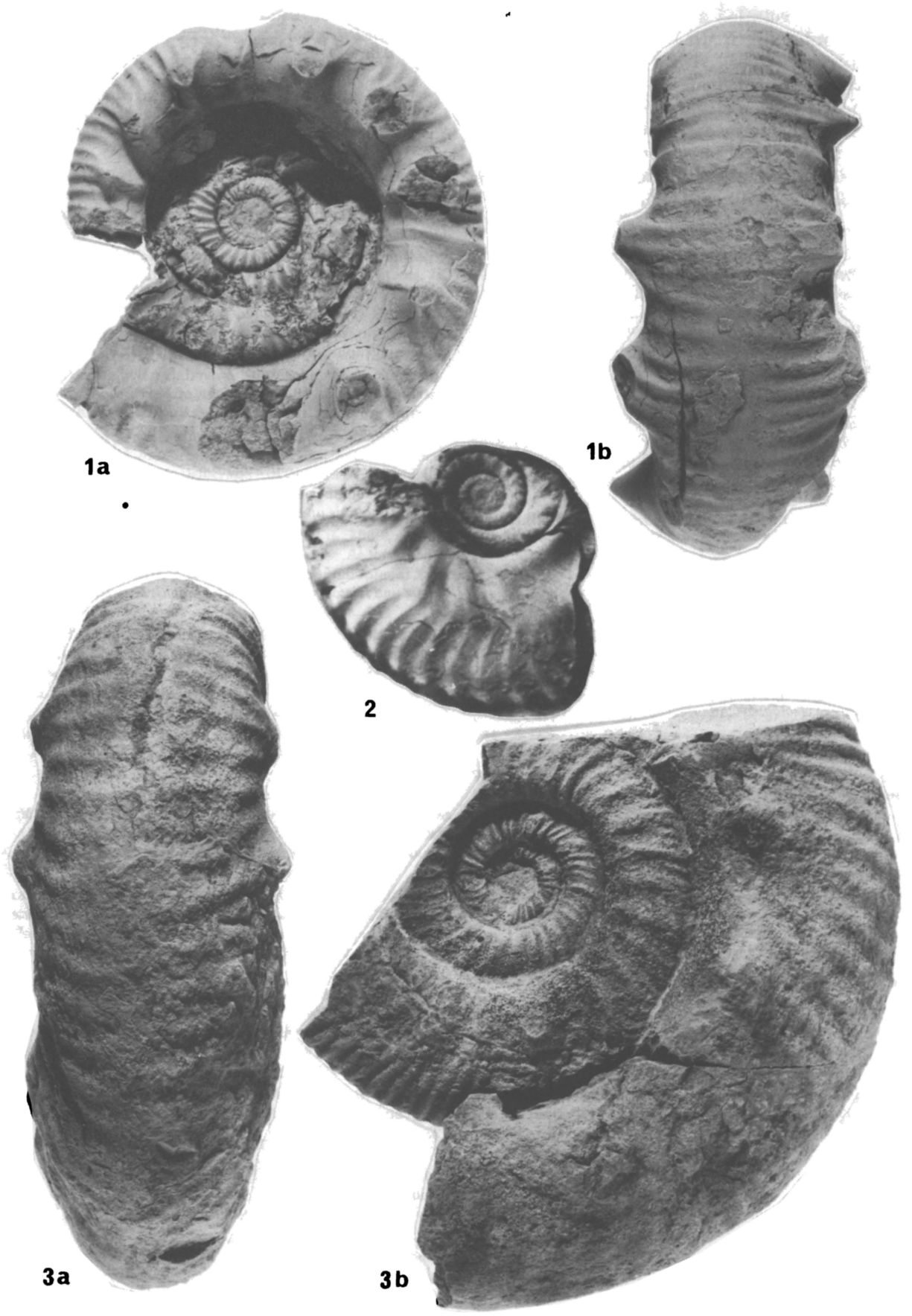

Fig. 4. Numbers 1-2 of the figured fossils are from Chacay Melehue, Argentina; number 3 is from Aguada de la Mula, Sierra de Reyes, Argentina. All are in the collections of the Museo La Plata (MLP). All were photographed at ×1, but the illustration has been slightly reduced for publication: 1a-b, *Neuqueniceras* (*Frickites*) *bodenbenderi* (Tornquist) (MLP 23997); 2, *Hecticoceras* (*H.*) *proximum* Elmi (MLP 12808); 3a-b, *Reineckeia* (*Loczyceras*) *patagoniensis* (Weaver) (MLP 23984).

paleogeographic evolution indicate that it is younger than levels containing *R.* (*R.*) *brancoi* (Steinmann) and *R.* (*R.*) *stehni* (Zeiss). The genus *Rehmannia* is widely distributed throughout the Tethys. The nominal subgenus is present from the upper part of the Macrocephalus zone to the top of the lower Callovian, whereas *R. (Loczyceras)* is present in the Jason to Athleta zones. This and systematic affinities indicate that the horizon is middle Callovian (see Fig. 2).

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