Ammonite faunas and stratigraphy of the Lower Bajocian of Paso del Espinacito (Middle Jurassic, San Juan Province, Argentina)

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A b s t r a c t

The classical outcrop of the Paso del Espinacito (San Juan Province, Argentina), wherefrom Gottsche (1878) and Tornquist (1898) described many Early Bajocian ammonite species – some of them later became type species of new genera – was restudied by one of us (A. v. H.) in 1968. The newly collected ammonites sampled bed-by-bed are described and illustrated. The finds of many topotypes for most of the Gottsche and Tornquist taxa allows a reconstruction of their type horizons. The strata are subdivided in the standard chronozones of the Andean Province: the Puchenquia malarguensis Zone in the Aalenian and the Pseudotoites singularis and Chondromileia giebeli zones in the Lower Bajocian. The Singularis Zone is subdivided into two new subzones: the Fissilobiceras zitteli Subzone in the lower part with the *Pseudotoites singularis* horizon and the Sonninia altecostata Subzone in the upper part with the *Pseudotoites sphaeroceroides* horizon. The Giebeli Zone is subdivided into their standard subzones: the Chondromileia submicrostoma Subzone with the horizon of *Ch. submicrostoma* and the Emileia multiformis Subzone with the *Ch. giebeli* horizon. These zones and subzones of the Andean Province are tentatively correlated with the standard zones of the Northwest-European Province.

K e y w o r d s : Lower Bajocian, Singularis Zone, Giebeli Zone, ammonites, palaeobiogeography, Andean Province.

Z u s a m m e n f a s s u n g

Der klassische Fundpunkt Paso del Espinacito (Provinz San Juan, Argentinien), von dem Gottsche (1878) und Tornquist (1898) zahlreiche neue Arten von Ammoniten des Unter-Bajocium beschrieben haben – von denen einige sogar Typus-Art neuer Gattungen sind – wurde im Jahre 1968 von Hillebrandt neu untersucht. Die von ihm horizontiert aufgesammelten Ammoniten werden hiermit erstmals beschrieben und abgebildet. Mit Hilfe zahlreicher Topotypen kann der Typus-Horizont der meisten Gottsche- und Tornquist-Typen rekonstruiert werden. Die Schichten werden in die Standard-Chronozonen der Andinischen Provinz gegliedert: im Ober-Aalenium in die Zone der Puchenquia malarguensis; im Unter-Bajocium in die Zonen des Pseudotoites singularis und der Chondromileia giebeli. Die Singularis-Zone wird in zwei hier erstmals verwendete Subzonen unterteilt: in die untere Subzone des Fissilobiceras zitteli mit dem Horizont des *Pseudotoites singularis* und in eine obere Subzone der Sonninia altecostata mit dem Horizont des *Pseudotoites sphaeroceroides*. Die Giebeli-Zone kann in ihre Standard-Subzonen gegliedert werden: in die untere Subzone der Chondromileia submicrostoma mit dem Horizont der *Ch. submicrostoma* und in die Subzone der Emileia multiformis mit dem Horizont der *Ch. giebeli*. Diese Zonen und Subzonen der andinen Provinz werden mit den Standard-Zonen der Nordwesteuropäischen Faunenprovinz korreliert.

C o n t e n t s

1. Introduction

With the exception of some monographs (Gottsche 1878; Tornquist 1898; Westermann & Riccardi 1972, 1979; Westermann 1992) ammonites from the Lower Bajocian of Argentina have been rarely figured. Moreover, their exact stratigraphical provenience is often unknown. This is especially true for the type specimens of many taxa from the Paso del Espinacito site. In 1968, Hillebrandt collected topotypes for most taxa previously described from this locality. Most of this material is illustrated and described here for the first time.

The aims of this work are: (1) to describe the type horizons of most of the ammonite taxa from the Lower Bajocian Singularis and Giebeli zones of Paso del Espinacito described in the previous works of Gottsche (1878), Tornquist (1898), Arkell (in Arkell & Playford 1954), and Westermann & Riccardi (1972, 1979), (2) to describe the morphological variations of these taxa from their type locality and horizon, (3) to provide a biozonation for this important fossil site and for the Andean Province (Westermann & Riccardi 1979; Riccardi 1984; Riccardi & Westermann 1984; Westermann 1992; Hillebrandt 1970, 2001; Riccardi 2008), and (4) to improve the correlations between the Andean and the Northwest European bioprovinces.

The ammonites collected by Hillebrandt at the Paso del Espinacito are now stored in the collection of the La Plata Museum, Argentina.

Abbreviations

GMUG	Geowissenschaftliches Museum der Universität Göttingen, Germany
MLP	Museo de La Plata, Argentina
TUB vH	Technische Universität Berlin, Germany (ex coll. von Hillebrandt)
CT	Chorotype
HT	Holotype
PT	Paratype
TT	Topotype
var.	variety; used for morphological varieties of infrasubspecific rank

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2. Stratigraphy and ammonites from the Paso del Espinacito site

2.1. History of research

Giebel (1851) was the first who collected a Middle Jurassic ammonite "vom Gipfel der Cordilleren zwischen Mendoza und Auncagua in Chile", thus probably coming from the Paso del Espinacio itself or from a locality nearby. The investigations of the Middle Jurassic sedimentary succession at the Paso del Espinacito locality ("Espinazito-Pass") started in the second half of the 19th century. The fossils collected by Stelzner (1873) were sent to K. A. v. Zittel in Munich, Germany. Zittel assigned Gottsche (1878) with their description.

Later, Tornquist (1898) continued with a detailed research. He studied the rich and partly bed-by-bed collected material of Bodenbender and Güssfeldt. Bodenbender (1898) had collected – as far of interest – at the pass summit (= "Passhöhe"), and at the ridge (= "Grat"), called "Espinazito-Weg", a small pathway on a ridge starting at the pass summit. Güssfeldt's finds come from the ridge (= "Espinazito-Weg") and from another close locality called "Ramada-Abhang".

The Paso del Espinacito sections were also briefly mentioned in works of Moericke (1894), Schiller (1912), Groeber (1918, 1951), Jaworski (1926), and Stipanicic (1966) without providing any essential further data.

The bed-by-bed collections of Hillebrandt from 1968 are of special interest. Hillebrandt (1970) was the first modern researcher (see Groeber 1918; cf. Westermann & Riccardi 1972: 105) who subdivided biostratigraphically the Upper Aalenian and Lower Bajocian parts of the Paso del Espinacito sections.

Later, Westermann & Riccardi (1972, 1979 – with exact details of the type ammonites), Riccardi & Westermann (1984), Hillebrandt & Westermann (1985), Riccardi & Westermann (1991), Aguirre Urreta & Alvarez (1993), and Alvarez (1996) studied the ammonites and biostratigraphy of the Paso del Espinacito sections.

It is noticeable that the measured thicknesses of the beds given in Hillebrandt (1970) partly differ from those provided by Westermann & Riccardi (1979). These differences in thickness are apparent and probably due to the way the beds are exposed in relation to topography. Especially in the "Passhöhe" the section is almost horizontal and poorly exposed, and hence the measured sections in both publications are not strictly comparable. But this diminishes in no way the results in respect of the relative succession of the different ammonite taxa and the biostratigraphical results.

2.2. Pass summit (= Passhöhe)

On January 6th, 1968 Hillebrandt studied the section of the pass summit (4476 m altitude; Fig. 1). Ammonites were rare due to earlier collections, and the layers were found to be badly exposed. He labelled the ammonites as follows: year-month-day/bed (e. g. bed 1 of the pass summit: 680106/1).

Fig. 1. Geographical location of the Paso del Espinacito.

680106/1: Bedded sandstones (thickness of each bed 0.1–0.3 m) with intercalated sandy marls; bivalves ("*Lucina*" sp.) are common.
Ammonites: *Puchenquia malarguensis* (Burckhardt) (Fig. 2h)

On top, further bedded sandstones intercalated with sandy marlstones occur.

~5–7 m in top of 06/1: **680106/2**
Ammonites: *Fissilobiceras zitteli* (Gottsche) [incl. var. *argentinicum* (Tornquist) (Pl. 3, Fig. 1), var. *intumescens* (Tornquist), var. *andium* (Gottsche) (Pl. 3, Fig. 4a–b)]
Sonninia cf. *transiens* (Taylor) (= "*Sonninia (Euhoploceras) cf. adicra*" in Westermann & Riccardi 1972, pl. 11, figs. 1–2) (Pl. 1, Fig. 6; Pl. 2, Figs. 2–3: specimens of Westermann & Riccardi 1972)
Sonninia aff. *berckhemeri* Dorn (= "*Sonninia (Sonninia) ovalis*" in Westermann & Riccardi 1972, pl. 8, fig. 3) (Pl. 2, Fig. 1a–b: same specimen)
Slightly higher:
Pseudotoites argentinus Arkell (Pl. 1, Fig. 2a–b)
Ps. evolutus (Tornquist) (Pl. 1, Fig. 7) (considered as the corresponding microconch of *Ps. singularis*, see Westermann & Riccardi 1979).

On top, further bedded sandstones with intercalated sandy marlstones.

~4 m in top of 06/2: **680106/3**
Ammonites: *Pseudotoites sphaeroceroides* (Tornquist) (Pl. 4, Fig. 1a–b)
Ps. cf. *sphaeroceroides* (Tornquist) (Pl. 4, Fig. 2a–b)
Ps. evolutus (Tornquist)
Sonninia altecostata Tornquist (Pl. 4, Fig. 3; Pl. 5, Fig. 3)

Towards the north, a porphyrite had intruded. Furtheron the succession continues.

~5–7 m above the top of 06/3: **680106/4**
Ammonites: *Sonninia espinazitensis* Tornquist (Pl. 7, Fig. 3)
S. altecostata Tornquist (Pl. 7, Fig. 6)
Pseudotoites transatlanticus (Tornquist) (Pl. 6, Fig. 7)
Ps. aff. *evolutus* (Tornquist) (Pl. 6, Fig. 5)

Some meters above the top of 06/4: **680106/5**
The relative position of bed 680106/5 is unclear. Hillebrandt noted in his field book as a terminal note: "06/5 ?hangend oder liegend von 06/6, ev. = 06/7".
Ammonites: *Chondromileia giebeli* (Gottsche) (Pl. 8, Fig. 2a–b)
Fissilobiceras zitteli (Gottsche) var. *argentinicum* (Tornquist) (Pl. 9, Fig. 3)
Lytoceras subfrancisci posterum Gottsche (Fig. 3n)

~4–5 m in the top of 06/5: **680106/6**
Ammonites: *Sonninia* cf. *altecostata* Tornquist (Pl. 9, Fig. 2; Pl. 10, Fig. 1)
S. espinazitensis Tornquist (Pl. 10, Fig. 3)

~2–3 m in the top of 06/6: **680106/7**
Ammonites: *Chondromileia giebeli* (Gottsche) (Pl. 8, Fig. 7)

Subsequent finely bedded sandstones with marlstones.

~10 m in the top of 680106/7: *Reineckeia* sp. and *Gryphaea* sp.

2.3. Ridge (= Grat)

On January 7th, 1968 Hillebrandt studied the slopes of the ridge (~4300 m). The results were published by himself (Hillebrandt 1970) and by Westermann & Riccardi (1979) as part of their own work in the same area.

680107/1: Rare ammonites, bivalves are rather common (*Meleagrinella* sp., *Propeamussium andium* (Tornquist), *Trigonia stelzneri* Gottsche, *Vaugonia lycetti* (Gottsche), "*Lucina*" sp., *Astarte* cf. *andium* Gottsche, *Pleuromya* sp.).
Ammonites: ?*Puchenquia fascicostata* (Tornquist) (Fig. 2b–d)
?*Puchenquia* sp. (Fig. 2e–g)

~5–6 m in the top of 07/1: **680107/2**
Ammonites: *Fissilobiceras zitteli* (Gottsche) (Pl. 1, Fig. 5; Pl. 3, Fig. 3a–b) [incl. var. *argentinicum* (Tornquist), var. *intumescens* (Tornquist) (Pl. 3, Fig. 2)]

Sonninia cf. *transiens* (Taylor) (Pl. 1, Fig. 4)
Pseudotoites evolutus (Tornquist)
Ps. crassus Westermann & Riccardi
Phylloceras kunthi Neumayr *modestum* Tornquist (Fig. 3j–k)
Calliphylloceras aff. *disputabile* (Zittel) (Fig. 3e–f)

Some decimetres higher:
Pseudotoites singularis (Gottsche) (Pl. 1, Fig. 3a–b)
Ps. crassus Westermann & Riccardi (Pl. 1, Fig. 1a–b)
Ps. evolutus (Tornquist)

~2–3 m in the top of 07/2: **680107/3**
Ammonites: *Sonninia altecostata* Tornquist (Pl. 5, Fig. 2)
S. altecostata var. *gracilis* Tornquist (Pl. 5, Fig. 1)

~3–4 m in the top of 07/3: **680107/4**
Ammonites: *Sonninia espinazitensis* Tornquist (Pl. 7, Figs. 1–2, 4–5)
Phylloceras kunthi modestum Tornquist (Fig. 3l–m)
Holcophylloceras torulosum (Tornquist) (Fig. 3g–i)
Lytoceras adelae (d'Orbigny) (Fig. 3p–r)
L. subfrancisci posterum Gottsche (Fig. 3o)

~2 m in the top of 07/4: **680107/5**
Ammonites: *Emileia multiformis* (Gottsche) (Pl. 6, Figs. 4a–b, 6a–b)
Chondromileia submicrostoma (Gottsche) (Pl. 6, Figs. 1a–b, 3)
Sonninia modesta sensu Imlay (Pl. 7, Fig. 7)
Calliphylloceras achtalense (Redlich) (Fig. 3a–b)

~3–4 m in the top of 07/5: **680107/6**
Ammonites: *Emileia multiformis* (Gottsche) (Pl. 8, Fig. 3a–b)
Emileia ♂ sp. (Pl. 8, Fig. 6)
Chondromileia giebeli (Gotsche) (Pl. 8, Figs. 1a–b, 4a–b)
?*Pseudotoites* sp. (Pl. 8, Fig. 5)
S. aff. *espinazitensis* Tornquist (Pl. 9, Fig. 1a–b; Pl. 10, Fig. 2)
Calliphylloceras achtalense (Redlich) (Fig. 3c–d)
Strigoceras strigifer (Buckman) (Pl. 9, Fig. 4)

~5–6 m in the top of 07/06: Callovian

3. Stratigraphy

The beds are separated into standard chronstratigraphic zones and subzones (sensu Callomon 1985) of the Andean province. A standard chronostratigraphic unit is a member of a standard scale whose units are contiguous, without gaps or overlaps. Within this standard subzones we describe biostratigraphical unites, called faunal horizons or for short horizons. A faunal horizon is a bed or a series of beds, characterized by a fossil assemblage, within which no further stratigraphical differentiation of the fauna can be discerned (Callomon 1985). At the Paso del Espinacito we can recognise at the moment only one faunal horizon in each subzone. But it is clear from other sites in Argentina (e. g. Charahuilla area) and Chile (e. g. Manflas area), that there exist other faunal horizons, which will be described later.

3.1. Aalenian

3.1.1. Puchenquia malarguensis Zone (P. compressa or P. mendozana Subzone)

The Aalenian of the Southern Andes is separated into the Manflansensis, Groeberi and Malarguensis Zones (Westermann & Riccardi 1972, 1979, 1982; Riccardi & Westermann 1984; Hillebrandt & Westermann 1985; Westermann 1992; Riccardi 1992, 2008; Riccardi et al. 1994; Alvarez 1996). The Maubeugei Subzone, topmost Subzone of the Malarguensis Zone, extends probably into the Bajocian (Westermann 1992; Alvarez 1996; Riccardi 2008).

The scarce finds of *Puchenquia malarguensis* and ?*P. fascicostata* from Paso del Espinacito are less age-diagnostic, because *Puchenquia malarguensis* ranges throughout the Malarguensis Zone (Compressa, Mendozana and Maubeugei subzones; Hillebrandt & Westermann 1985). *Tmetoceras scissum* rarely co-occurs with *P.* aff. *malarguensis* in the same bed at Paso del Espinacito (Gottsche 1878; Tornquist 1898). The stratigraphical range of *Tmetoceras* in the Andean region is restricted to the Aalenian subzones of the Malarguensis Zone (Hillebrandt & Westermann 1985).

The beds 680106/1 from the pass summit ("Passhöhe") and 680107/1 from the ridge ("Grat") can be tentatively assigned to the Malarguensis Zone (Compressa or Mendozana Subzone) of the uppermost Aalenian (Hillebrandt 1970). However, since new specimens of *Tmetoceras* were not recorded from Bed 680106/1, and this bed is not necessarily the same where Stelzner had collected the assemblage described by Gottsche (1898), an earliest Bajocian age of these beds cannot be excluded.

3.2. Bajocian

3.2.1. Puchenquia malarguensis Zone (Podagrosiceras maubeugei Subzone)

The Bajocian of the Andean Province starts with the Maubeugei Subzone of the Malarguensis Zone. This subzone is not recorded yet from Paso del Espinacito.

3.2.2. Pseudotoites singularis Zone

This zone is characterized by *Pseudotoites singularis*, *Ps. sphaeroceroides* (Westermann & Riccardi 1979), together with early representatives of *Ps. crassus*, *Ps. trans-*

atlanticus, and *Ps. argentinus* (RICCARDI & WESTERMANN 1984). The latter three species range up into the lower part of the Giebeli Zone. Moreover, *Sonninia amosi*, *Fissilobiceras zitteli*, and *Sonninia altecostata* occur (WESTERMANN & RICCARDI 1979; RICCARDI 1992, 2008; WESTERMANN 1992; RICCARDI et al. 1994; ALVAREZ 1996). The stratotype of this zone is the Cerro Puchenque section in Argentina (RICCARDI 1992; WESTERMANN & RICCARDI 1979).

In Northern Chile HILLEBRANDT (2001) distinguished two ammonite faunal horizons which he included in this zone: a lower *Pseudotoites singularis* horizon (with *Pseudotoites singularis*, *Ps.* cf. *argentinus* and *Fissilobiceras zitteli*) and a higher *Ps. sphaeroceroides* horizon (with *Ps. sphaeroceroides*, *Ps.* spp., *Emileia* cf. *quenstedti*, and *S. altecostata*). Both horizons can be easily recognised also in the Paso del Espinacito sections. These horizons are recorded now both from Argentina and Northern Chile, so that a biostratigraphic subdivision into two subzones is necessary:

Fissilobiceras zitteli Subzone

The same names for zones and subzones should not be used in hierarchical stratigraphic systems – although this was often done in the past. To avoid any future confusion with the zonal index taxon *Pseudotoites singularis*, we select the typical and abundant *Fissilobiceras zitteli* (GOTTSCHE) as the index of this new Subzone. This subzone contains only a single horizon.

Horizon of *Pseudotoites singularis*

Bed 2 of the pass summit (680106/02) and the ridge (680107/02) comprises the *singularis* horizon of the Zitteli Subzone. The following ammonite taxa are recorded from Paso del Espinacito: *Fissilobiceras zitteli* (incl. var. *argentinicum*, var. *intumescens*, var. *andium*), *Sonninia* cf. *transiens*, *S.* aff. *berckhemeri*, *Pseudotoites singularis*, *Ps. argentinus*, *Ps. crassus*, *Ps. evolutus*, *Phylloceras kunthi modestum*, and *Calliphylloceras* aff. *disputabile*.

The differentiation of this horizon from the subjacent Maubeugei Subzone of the Malarguensis Zone is clear: *Pseudotoites*, *Sonninia* cf. *transiens,* and *Fissilobiceras zitteli* are new faunal elements of the *singularis* horizon of the Zitteli Subzone. The hammatoceratid genera *Puchenquia*, *Planammatoceras,* and *Eudmetoceras* as well as *Tmetoceras* (HILLEBRANDT & WESTERMANN 1985) have apparently disappeared.

Sonninia altecostata Subzone

To avoid any confusion with the index species of the *sphaeroceroides* horizon we use *Sonninia altecostata* TORNQUIST as the index of this new subzone. In the Paso del Espinacito area this subzone contains only a single horizon, that of *Pseudotoites sphaeroceroides*.

Horizon of *Pseudotoites sphaeroceroides*

This horizon lies in bed 3 of the pass summit (680106/03) and of the ridge (680107/3) sections. HILLEBRANDT collected *Pseudotoites sphaeroceroides*, *Ps.* cf. *sphaeroceroides*, *Ps. evolutus*, and S*onninia altecostata* (incl. var. *gracilis*) from this horizon.

The fauna of the *sphaeroceroides* horizon differs from that of the *singularis* horizon mainly in their different sonniniids: the strongly tuberculate *S.* cf. *transiens* group (morphogenus *Euhoploceras*) is replaced by the *S. altecostata* group (morphogenus *Papilliceras*). *Fissilobiceras zitteli*, which is a common element of the *singularis* horizon, is not recorded from the *sphaeroceroides* horizon. Ammonites of the genus *Pseudotoites* evolved to larger specimens of the *Ps. sphaeroceroides* morphology which is characterized by a broader whorl section.

3.2.3. Chondromileia giebeli Zone

The *Giebeli* Zone was originally introduced as an assemblage zone (WESTERMANN & RICCARDI 1979) with the *Dorsetensia blancoensis* faunule (?Assemblage Subzone) at the top, the *Emileia multiformis* Subzone (characterized by *E. multiformis*, *Chondromileia giebeli*, and rare *Stephanoceras* cf. *macrum*) in the middle, and the *Emileia submicrostoma* Assemblage Subzone (characterized by *Chondromiliea submicrostoma*, late representatives of *Pseudotoites* spp., and early representatives of *Emileia multiformis*) at the bottom. WESTERMANN (1992) raised the *Giebeli* Zone and the *Multiformis* and *Submicrostoma* Subzones to Andean standard. The selection of Carro Quebrado as being the stratotype of the Giebeli Zone is somewhat awkward, because the defined base of this zone at bed 149 is most probably a condensed or partly reworked layer (WESTERMANN & RICCARDI 1979: 97). In addition, TAYLOR (1988) gave zonal ranking for the *blancoensis* horizon.

From Northern Chile HILLEBRANDT (2001) described the horizon of *Emileia giebeli submicrostoma* (with *Emileia* cf. *brocchii*, *E. (Chondromiliea) giebeli submicrostoma*, *Euhoploceras* sp., *Papilliceras* sp., and *Fissilobiceras* (?) sp.) and the horizon of *Emileia giebeli giebeli* (with *E. (Ch.) giebeli giebeli*, *Sonninia espinazitensis*, *Euhoploceras* spp., and *Pseudotoites* cf. *sphaeroceroides*), overlain by a *Skirroceras* horizon. Neither the *Skirroceras* horizon nor the time-equivalent *Dorsetensia blancoensis* horizon have been recorded from the Paso del Espinacito sections.

Chondromileia submicrostoma Subzone

This subzone contains only a single horizon.

Horizon of *Chondromileia submicrostoma*

The beds 4 and 5 of the ridge (Grat) section and bed 4 (but not bed 5!) of the pass summit (Passhöhe) section yield the *submicrostoma* horizon of the Submicrostoma Subzone. The following ammonite taxa are recorded from this horizon: *Sonninia espinazitensis*, *S. altecostata*, *S. modesta* sensu Imlay, *Pseudotoites transatlanticus*, *Ps.* aff. *evolutus*, *Phylloceras kunthi modestum*, *Holcophylloceras torulosum*, *Lytoceras adelae*, *L. subfrancisci posterum*, *Calliphylloceras achtalense*, *Emileia multiformis*, and *Chondromileia submicrostoma*.

In bed 4 of the ridge section *Sonninia espinazitensis* is predominant. The holotype of this species has the same morphology and preservation as the new records. Therefore, we conclude that the *submicrostoma* horizon is the type horizon of this species. From bed 4 of the pass summit section only the four ammonites mentioned above have been recorded. We assign this bed also to the *submicrostoma* horizon, due to the occurrence of *S. espinazitensis*, which is still missing in the *sphaeroceroides* horizon below. Bed 5 of the ridge section yielded also the stratigraphically oldest known species of *Chondromileia*, *C. submicrostoma*, which we used here as the index of both the subzone and the faunal horizon. Moreover, the first *Emileia multiformis* appear in this bed.

The fauna of the *submicrostoma* horizon differs from that of the *sphaeroceroides* horizon below by the evolutionary replacement of the *Sonninia altecostata* group by the *S. espinazitensis* group. The genus *Pseudotoites* occurs only rarely in the *submicrostoma* horizon. The ammonite genera *Chondromileia* and *Emileia* have not been recorded yet from the *sphaeroceroides* horizon of the Paso del Espinacito. However, Hillebrandt (2001) mentioned a single specimen determined as *Emileia* cf. *quenstedti* from the *sphaeroceroides* horizon of Manflas in Northern Chile.

Multiformis Subzone

This subzone contains only a single horizon.

Horizon of *Chondromileia giebeli* (introduced by Hillebrandt 2001, as horizon of *Emileia giebeli giebeli*)

The beds 5–7 of the pass summit and the bed 6 of the ridge section are assigned to the *giebeli* horizon. At the Paso del Espinacito the ammonite fauna of this horizon includes *S. espinazitensis*, *S.* aff. *espinazitensis*, *S.* cf. *altecostata*, *Fissilobiceras zitteli* var. *argentinicum*, *Emileia multiformis*, *Chondromileia giebeli*, ?*Pseudotoites* sp., *Calliphylloceras achtalense*, *Lytoceras subfrancisci posterum*, and *Strigoceras strigifer*.

It is most likely that bed 5 of the pass summit is the same bed as bed 7 of the pass summit (this assumption was already noticed by Hillebrandt in his field-book). Both beds yielded typical, but small-sized specimens of *Ch. giebeli*. Also if bed 5 lies indeed below bed 6, we assign it to the *giebeli* horizon, due to a typical specimen of *Ch. giebeli*. In any case, bed 5 of the ridge and bed 5 of the pass summit cannot be coeval.

The *giebeli* horizon differs from the underlying *submicrostoma* horizon of the Paso del Espinacito section by a significant change within the *Sonninia* faunas, where now typical *S. espinazitensis* are just at the end, not in the centre of variation as in the *submicrostoma* horizon below. C*hondromiliea giebeli* occurs frequently, replacing the older chronospecies *C. submicrostoma*.

4. Short comments on the ammonite fauna

4.1. Sonniniidae Buckman, 1892

The hitherto stratigraphically oldest known sonniniid species – *Sonninia amosi* Westermann & Riccardi – occurs in South America already in the Upper Aalenian. This species still closely resembles the hammatoceratid ?*Puchenquia fascicostata* (Fig. 2a–f) from the Malarguensis Zone of Paso del Espinacito. At Paso del Espinacito the first sonniniids occur in the *singularis* horizon, with typical representatives of the morphogenus *Euhoploceras*. Westermann & Riccardi (1972, pl. 11, figs. 1–2) figured two ammonites collected by Hillebrandt from the *singularis* horizon of the pass summit as *Sonninia* cf. *adicra* (the specimen from pl. 11, fig. 1 was erroneously attributed to bed 680106/1, but its preservation and the original label clearly indicate that it comes from bed 680106/2). Taylor (1988) described some new species of *Sonninia* and *Euhoploceras* from the Aalenian/Bajocian boundary beds (Packardi and Tuberculatum Zones) of the Snowshoe Formation of Oregon (USA). These finds are slightly older than our finds from the Singularis Zone (Pl. 1, Figs. 4, 6; Pl. 2, Figs. 2–3), but some of them are morphologically very close to the ammonites from the Paso del Espinacito. The best fitting nominal species for the finds from the Paso del Espinacito is *Sonninia* cf. *transiens* (Taylor). In respect of this similarity and the stratigraphically earlier occurrence of such ammonites in Oregon it is possible that the sonniniids migrated from North America to South America during the interval of the Singularis Subzone. Alternatively (Westermann & Riccardi 1972, 1985) the Andean genus *Puchenquia* could be a probable ancestor of the Sonniniidae.

A rapid change within the sonniniids is recorded in the *sphaeroceroides* horizon, where the bulk of specimens belong to *S. altecostata* (Pl. 4, Fig. 3; Pl. 5, Figs. 1–3). *S. altecostata* is a representative of the morphogenus "*Papilliceras*". In the succeeding *submicrostoma* horizon *S. altecostata* has evolved to *S. espinazitensis*. Due to the obvious morphological differences it is unlikely that *S. transiens* of the *singularis* horizon is a direct ancestor of the *S. altecostata*/*espinazitensis* group. An independent immigration event of the latter group appears more reliable. A possible ancestral candidate is *Sonninia* (morphogenus *Papilliceras*) *burkei* Taylor from the Burkei Zone of Oregon, which can be correlated with most parts of the South American Singularis Zone (Taylor 1988). In Oregon *S. burkei* evolved to *S. grindstonensis*, which is very close to *S. espinazitensis*.

In the *submicrostoma* horizon only *S. espinazitensis* (Pl. 7, Figs. 1–5) occurs frequently.

The *Sonninia* fauna of the *giebeli* horizon at the Paso del Espinacito shows the highest morphological plasticity within this genus. Besides rare specimens of *S. espinazitensis* sensu stricto (Pl. 10, Fig. 3), *S.* aff. *espinazitensis* (Pl. 9, Fig. 1; Pl. 10, Fig. 2) occurs. These ammonites differ from typical *S. espinazitensis* by a broader whorl section and the absence of the typical projection of the ribbing from the ventral shoulder to the keel as seen in *S. espinazitensis*. Another group, again resembling *Euhoploceras*, is at present due to the scarce finds best labelled as *S.* cf. *altecostata* (Pl. 9, Fig. 2; Pl. 10, Fig. 1). Such ammonites occur also in the *giebeli* horizon of Manflas in Chile (coll. v. Hillebrandt).

4.2. Hammatoceratidae Buckman, 1887

At Paso del Espinacito Middle Jurassic hammatoceratids are represented by the genera *Puchenquia* in the

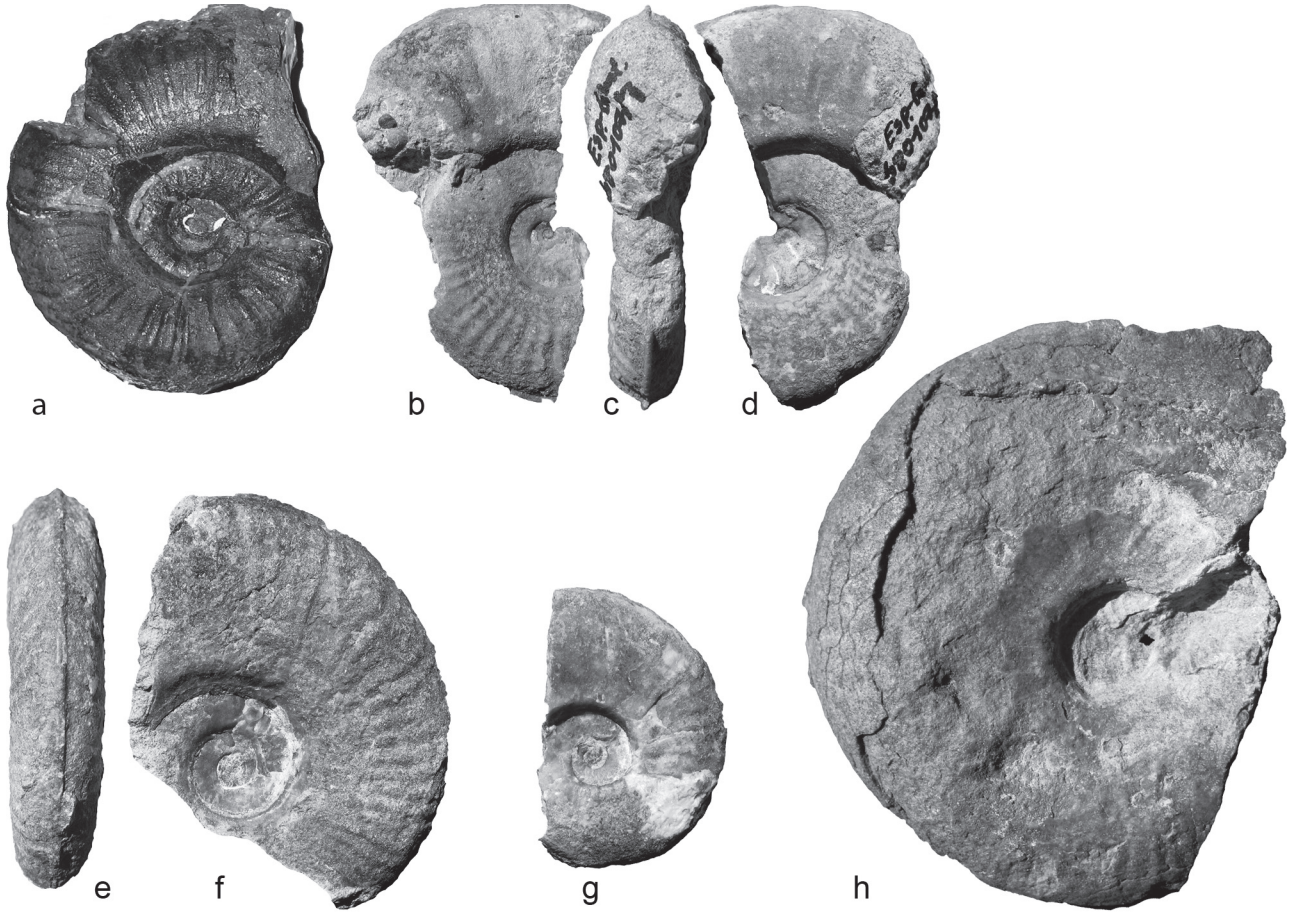


Fig. 2. Paso del Espinacito; Upper Aalenian, Malarguensis Zone, Compressa or Mendozana Subzone. – **a–d**. ?*Puchenquia fascicostata* (Tornquist). **a**. "*Sonninia*" *fascicostata* Tornquist, HT; Pass summit, probably bed 1; GMUG 496–31. **b–d**. MLP18750 [TT], Ridge, bed 1 (TUB vH 680107/1). **e–g**. ?*Puchenquia* sp.; Ridge, bed 1 (TUB vH 680107/1). **e–f**. Incomplete specimen, MLP18751. **g**. Nucleus; MLP18752. **h**. *Puchenquia malarguensis* (Buckhardt); Pass summit, bed 1 (TUB vH 680106/1); MLP18753. – All specimens in natural size.

Aalenian and *Fissilobiceras* in the Lower Bajocian part of the sections.

A reinvestigation of the Bodenbender collection in Göttingen showed that the type specimen of Tornquist's "*Sonninia*" *fascicostata* Tornquist exhibits an identical preservation as the ammonite illustrated by him as "*Harpoceras concavum*" (Tornquist 1898, pl. 1, fig. 2 = *Puchenquia malarguensis*). Both specimens are preserved with a black test, which is unknown from other specimens in the Bodenbender collection. Some of the specimens mentioned by Hillebrandt (1970) from bed 680107/1 of the ridge (Grat) as *Puchenquia* belong to ?*P. fascicostata* (Fig. 2a–f). *Sonninia amosi* Westermann & Riccardi differs by a compressed, but rounded whorl section and a usually spinose sculptural stage. The only ammonite collected by Hillebrandt from bed 680106/1 at the pass summit (Passhöhe) is a poorly preserved, but typical *Puchenquia malarguensis* (Fig. 2h). The *Sonninia* illustrated in Westermann & Riccardi (1972, pl. 11, fig. 1) was erroneously indicated as coming from bed 680106/1, in fact it comes from bed 680106/2 (see above).

The genus *Fissilobiceras* is most common in the *singularis* horizon. There it is represented by *F. zitteli* (Pl. 1, Fig. 5; Pl. 3, Figs. 1–4), but occurs also in the *giebeli* horizon with its variety *argentinicum* (Pl. 9, Fig. 3). The taxon shows a low variation. It was described under several names, which are considered now as varieties or junior synonyms of *F. zitteli* (Tab. 1). Like in Northwestern Europe this genus (represented there by *F. ovale* and *F. fissilobatum*) appears rather conservative in respect of its evolution. For a detailed discussion see Riccardi & Westermann (1972).

4.3. Strigoceratidae Buckman, 1924

A single specimen of *Strigoceras strigifer* (Pl. 9, Fig. 4) from the *giebeli* horizon is of special interest, because it is the first unequivocal record of this genus from South America (presumed forerunners are mentioned in Westermann & Riccardi 1985: 17). In the otherwise comprehensive revision of the ammonite genus *Strigoceras* by Schweigert et al. (2007) it was still stated as being unknown from South America. This Andean specimen matches well with European finds of the Laeviuscula and Sauzei Zones and thus affirms the correlation of the Multiforme Subzone with the lower and middle part of the Northwest European Sauzei Zone (see Tab. 2).

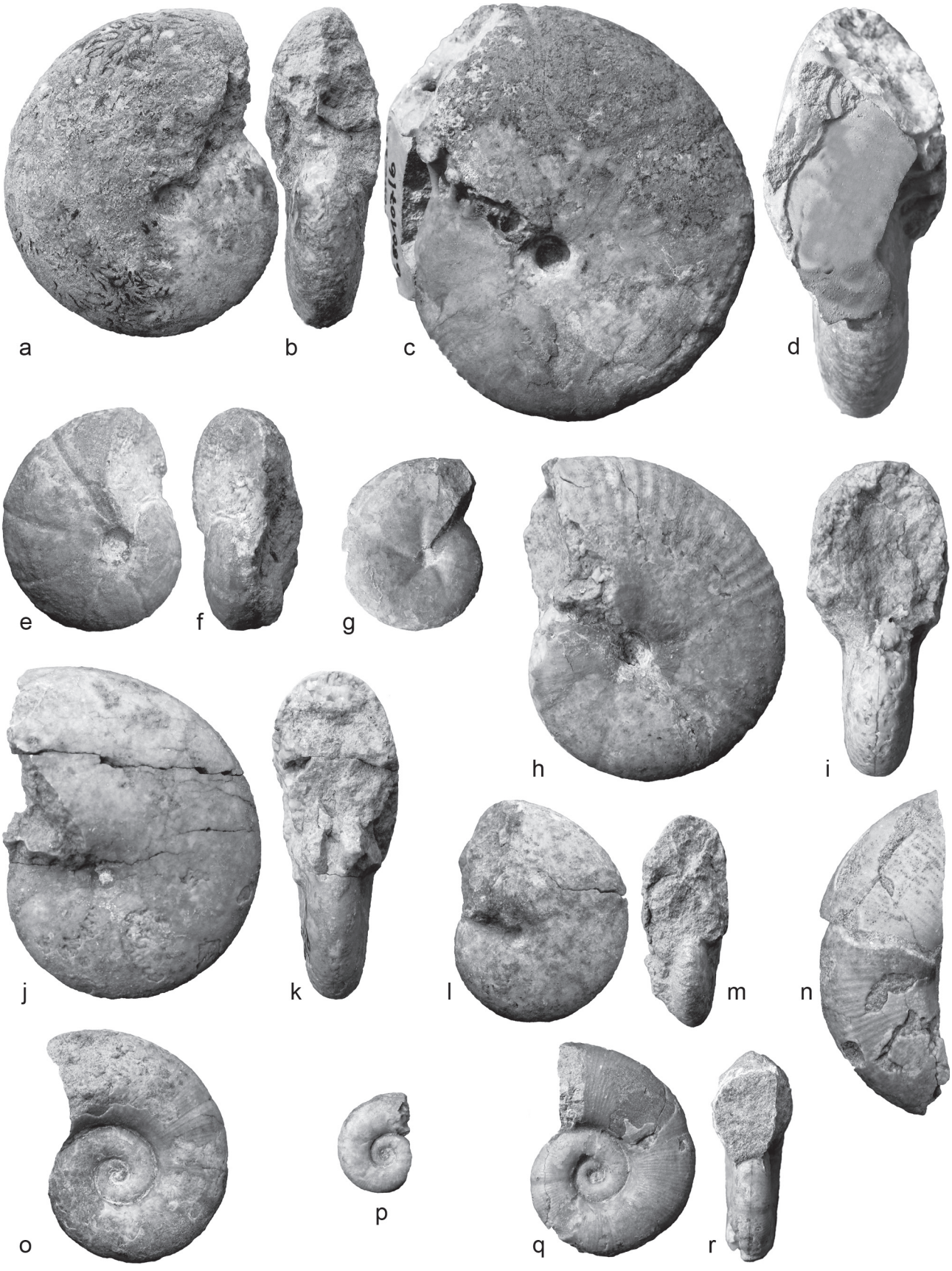
4.4. Otoitidae Mascke, 1907

The Otoitidae are represented at the Paso del Espinacito by the macroconch genera *Pseudotoites*, *Emileia*, *Chondromileia* and their microconch counterparts.

The "circum-pacific" genus *Pseudotoites* is a common faunal element of the Singularis Zone. In the older *singularis* horizon smaller specimens with an often rounded, ovale whorl section predominate. *Ps. argentinus* Arkell is a larger-sized modification (Pl. 1, Fig. 2) of *Ps. singularis* (Pl. 1, Fig. 3), ranging also up to higher horizons. *Ps. crassus* Westermann & Riccardi (Pl. 1, Fig. 1) is distinct by its inflated whorl section, resembling *Ps. sphaeroceroides* (Pl. 4, Figs. 1–2). The genus evolves in the *sphaeroceroides* horizon and younger strata of the Paso del Espinacito to larger specimens *(Ps. transatlanticus)* (Pl. 6, Fig. 7), often with a broad whorl section *(Ps. sphaeroceroides)* (Pl. 4, Figs. 1–2). All nominal species would belong to a single phyletic lineage, which shows an evolutionary trend to larger-sized, more compressed taxa in younger strata. In the Giebeli Zone the genus *Pseudotoites* (Pl. 8, Fig. 5) is only an accessory faunal element. *Pseudotoites* shows closest resemblance to the European genus *Parsemileites* of the Ovale and lower Laeviuscula Zones (Dietze & Chandler 2008), therefore it is very likely they have derived from a common ancestor in the Late Aalenian or earliest Bajocian.

The genus *Emiliea* is represented at the Paso del Espinacito by a single species, *E. multiformis* (Pl. 6, Figs. 4, 6; Pl. 8, Fig. 3). This species shows an extremely narrow umbilicus and a broad whorl section; it is strikingly similar to representatives of *Emileia* in the lower part of the

Fig. 3. Phylloceratids and lytoceratids from the Lower Bajocian of Paso del Espinacito. – **a–d**. *Calliphylloceras achtalense* (Redlich); Giebeli Zone. **a–b**. Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*, Ridge, bed 5 (TUB vH 680107/5); MLP18754. **c–d**. Multiformis Subzone, horizon of *Chondromileia giebeli*, Ridge, bed 6 (TUB vH 680107/6); MLP18755. **e–f**. *Calliphylloceras* aff. *disputabile* (Zittel); Singularis Zone, Zitteli Subzone, horizon of *Pseudotoites singularis*, Ridge, bed 2 (TUB vH 680107/2); MLP18756. **g–i**. *Holcophylloceras torulosum* (Tornquist); Giebeli Zone, Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*, Ridge, bed 4 (TUB vH 680107/4). **g**. Microconch; MLP18757 [TT]. **h–i**. Macroconch; MLP18758 [TT]. **j–m**. *Phylloceras kunthi modestum* Tornquist. **j–k**. Singularis Zone, Zitteli Subzone, horizon of *Pseudotoites singularis*, Ridge, bed 2 (TUB vH 680107/2); MLP18759. **l–m**. Giebeli zone, Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*, Ridge, bed 4 (TUB vH 680107/4); MLP18760. **n–o**. *Lytoceras subfrancisci posterum* Gottsche; Giebeli Zone; **n**. Multiformis Subzone, horizon of *Chondromileia giebeli*, Pass summit, bed 5 (TUB vH 680106/5); MLP18761. **o**. Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*, Ridge, bed 4 (TUB vH 680107/4); MLP18762. **p–r**. *Lytoceras adelae* (d'Orbigny); Giebeli Zone, Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*, Ridge, bed 4 (TUB vH 680107/4). **p**. MLP18763. **q–r**. MLP18764. – All specimens in natural size.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Sauzei Zone of Southern Germany (Dietze et al. 2008). In the latter, the morphospecies *E. quenstedti* Westermann marks the centre of variation. The rare microconchs (Pl. 8, Fig. 6) are here referred as *Emileia* ♂ sp.

The genus *Chondromileia* was sometimes only regarded as a subgenus of *Emileia* (Westermann & Riccardi 1979; Hillebrandt 2001). We here give *Chondromileia* full generic rank and keep the genus within the Otoitidae, although it is somehow transitional to the Sphaeroceratidae. The microconchs of *Chondromileia* and *Emileia* are almost undistinguishable from each other, the macroconchs can be easily separated. *Chondromileia* remains involute to the beginning of the body chamber, whereas *Emileia* opens the umbilicus earlier in its ontogeny and is less excentric. The newly collected material of *Ch. submicrostoma* (Pl. 6, Figs. 1, 3) from Paso del Espinacito consists only of phragmocones, so that we additionally illustrate a specimen with its preserved body chamber from the Bodenbender collection (Pl. 6, Fig. 2). As demonstrated from other localities, *Ch. submicostoma* is the older and *Ch. giebeli* the younger chronospecies (Westermann & Riccardi 1979; Hillebrandt 2001). Large-sized specimens and small-sized specimens co-occur in two distinct size classes of adults, as known from some North-west European Otoitidae (*Emileia – Emileites*). This phenomenon was recently interpreted as a possible developmental polymorphism (Dietze & Chandler 2008). This observation is still more evident in rich bed-by-bed collections of *Chondromileia* from the Submicrostoma and Multiformis Subzones of the Giebeli Zone at Charahuilla/Chacai-Co (Neuquén Basin, Argentina; coll. Volkheimer & Hillebrandt). The latter section was published by Volkheimer (1973), Hillebrandt (1973), and Westermann & Riccardi (1972, 1979).

4.5. Phylloceratidae Zittel, 1884

Phylloceras kunthi is recorded from the Upper Aalenian to the Upper Oxfordian of Europe, Eastern Africa (including Madagascar), Northern America and now South America. The subspecies *P. kunthi modestum* (Fig. 3j–m) is restricted to South America. *Calliphylloceras achtalense* (Fig. 3a–d) occurs in Europe, Asia, East Africa (Madagascar) and South America. It ranges from the Upper Aalenian to the Callovian. *Calliphylloceras disputabile* (Fig. 3e–f) occurs from the Bajocian to the Oxfordian of Europe, Asia, Eastern Africa (including Madagascar), ?North America (?Alaska), and South America (Fig. 3e–f). *Holcophylloceras torulosum* (Fig. 3g–i) is known from the Aalenian and Bajocian of Asia, South America, and questionably also from Europe. Joly & Fonters (2007, pl. 8, fig. 1; pl. 4, fig. 2) observed micro- and macroconchs within the genus *Holcophylloceras*. The microconch ("male-form") is *H. zignoidanum* s. str., the corresponding macroconch ("female-form") is *H. mediterraneum*. Similarly, we suppose that the specimens illustrated as Fig. 3g–i include both a microconch and a macroconch of *Holcophylloceras torulosum*.

In addition to this material, Westermann & Riccardi (1982) have described *Phylloceras* cf. *trifoliatum* (= *Phylloceras kunthi modestum*) and *Calliphylloceras disputabile* (= *Calliphylloceras achtalense*) from the Lower Bajocian of South America.

4.6. Lytoceratidae Neumayr, 1875

Lytoceras subfrancisci is recorded from the Aalenian and Lower Bajocian of Europe. The subspecies *L. subfrancisci posterum* (Fig. 3n–o) is only known from South America. *Lytoceras adelae* (Fig. 3p–r) occurs from the Lower Bajocian to the Upper Callovian of Europe and America. The largest known lytoceratids (diameter up to 0.7 m!) from South America were mentioned from Lower Bajocian strata (Hillebrandt 2001).

Phylloceratids and lytoceratids inhabited pelagic seas. Therefore, their rather common occurrence in the neritic deposits of Paso del Espinacito is somewhat surprising. The specimens may come from the Jurassic deep-ocean trench lying westwards. Obviously, there were connections of these faunas with the Tethyan Realm, probably through the Hispanic Corridor.

5. Correlations

The ammonite diversity in the Upper Aalenian and Lower Bajocian of the Paso del Espinacito at the western margin of Southern America is very low compared to that of North-western Europe, possibly due to the much smaller shelf along the Jurassic Palaeopacific coast in South America. There may have existed far less ecological niches compared to the expanded shelfs in the Jurassic of Europe (Hillebrandt 2001). However, a faunal exchange was possible in the Early Bajocian via the Hispanic Corridor in course of the beginning opening of the Atlantic (Westermann & Riccardi 1985; Westermann 1992; Gröschke & Hillebrandt 1993). This connection is reflected by the occurrence of the same ammonite genera in the Andean and in the Northwest European Province during the Early Bajocian: *Sonninia*, *Fissilobiceras*, *Emileia*, *Strigoceras*, *Stephanoceras*, and *Bradfordia*. The relatively common phylloceratids and lytoceratids indicate faunal connections to the Western Tethys. In contrast, the circum-pacific genus *Pseudotoites* and the genus *Chondromileia*, which is restricted to the western margin of the Americas, are, however, missing in the Northwest European Province, whereas vice versa Graphoceratidae

Tab. 1. Presumed type horizon and systematic/nomenclatorical status of the nominal ammonite taxa described by GOTTSCHE (1878), TORNQUIST (1898), ARKELL (in ARKELL & PLAYFORD 1954), and WESTERMANN & RICCARDI (1979) from Paso del Espinacito.

Taxon	**Type** [nomenclatorical status]	**Presumed type horizon**
?*Puchenquia fascicostata* (TORNQUIST)	TORNQUIST 1898: 20, pl. 2, fig. 2 [holotype by monotypy]	Malarguensis Zone (Upper Aalenian)
Fissilobiceras zitteli (GOTTSCHE)	GOTTSCHE 1878: 10, pl 1, fig. 4 [holotype, lost]	*singularis* horizon
Fissilobiceras proximum (GOTTSCHE)	GOTTSCHE 1878: 11, pl. 1, fig. 7 [holotype by monotypy, lost; variety of *F. zitteli*]	*singularis* horizon
Fissilobiceras andium (GOTTSCHE)	GOTTSCHE 1878: 11, pl. 1, fig. 8; pl. 2, fig. 1 [2 syntypes, syntype pl. 2, fig. 1 lost; variety of *F. zitteli*]	*singularis* horizon
Fissilobiceras intumescens (TORNQUIST)	TORNQUIST 1898: 18, pl. 2, fig. 2 [lectotype; junior synonym of *F. zitteli*]	*singularis* horizon
?*Fissilobiceras stelzneri* (GOTTSCHE)	GOTTSCHE 1878: 12, pl. 1, fig. 6 [lectotype; ?microconch of *F. zitteli*]	*singularis* horizon
Pseudotoites singularis (GOTTSCHE)	GOTTSCHE 1878: 13, pl. 3, fig. 2 [holotype by monotypy]	*singularis* horizon
Pseudotoites crassus WESTERMANN & RICCARDI	WESTERMANN & RICCARDI 1979: 144, pl. 15, fig. 2 [holotype, inflated variety of *Ps. singularis*]	*singularis* horizon
Pseudotoites evolutus (TORNQUIST)	TORNQUIST 1898: 27, pl. 4, fig. 5 [5 syntypes; microconch of *Ps. singularis*]	*singularis* horizon
Phylloceras kunthi NEUMAYR *modestum* TORNQUIST	TORNQUIST 1898: 19, pl. 5, fig. 2 [2 syntypes]	*singularis, sphaeroceroides* or *submicrostoma* horizon
Pseudotoites argentius ARKELL	ARKELL 1954: 592, pl. 40, fig. 1 [holotype; variety of *Ps. singularis*]	*singularis* or *sphaeroceroides* horizon
Pseudotoites sphaeroceroides TORNQUIST	TORNQUIST 1898: 25, pl. 6, fig. 2 [lectotype]	*sphaeroceroides* horizon
Sonninia altecostata TORNQUIST	TORNQUIST 1898: 13, pl. 3, fig. 1 [lectotype; forerunner of *S. espinazitensis*]	*sphaeroceroides* horizon
Sonninia gracilis TORNQUIST	TORNQUIST 1898: 21, pl. 4, fig. 4 [holotype by monotypy; variety or synonym of *S. altecostata*]	*sphaeroceroides* horizon
Sonninia curviplex TORNQUIST	TORNQUIST 1898: 22, pl. 4, fig. 3 [holotype, variety of *S. altecostata*]	*sphaeroceroides* horizon
Pseudotoites transantlanticus (TORNQUIST)	TORNQUIST 1898: 26, pl. 5, fig. 4 [holotype by monotypy]	*sphaeroceroides* or *submicrostoma* horizon
Chondromileia submicrostoma (GOTTSCHE)	GOTTSCHE 1878: 15, pl. 3, fig. 3 [lectotype]	*submicrostoma* horizon
Holcophylloceras torulosum TORNQUIST	TORNQUIST 1898: 29, pl. 5, figs. 3, 5 [3 syntypes]	*submicrostoma* horizon
Sonninia espinazitensis TORNQUIST	TORNQUIST 1898: 20, pl. 3, fig. 2 [holotype]	*submicrostoma* horizon
Lytoceras subfrancisci STURANI *posterum* GOTTSCHE	GOTTSCHE 1878: 9, pl. 1, fig. 2 [holotype by monotypy]	*submicrostoma* or *giebeli* horizon
Emileia multiformis (GOTTSCHE)	GOTTSCHE 1878: 14, pl. 2, fig. 7 [holotype, lost] [neotype: WESTERMANN & RICCARDI 1979: 123, pl. 3, fig. 2]	*giebeli* horizon *giebeli* horizon
Chondromileia giebeli (GOTTSCHE)	GOTTSCHE 1878: 15, pl. 4, fig. 1 [holotype by monotypy, lost; „Vom Gipfel der Cordillere W. von Mendoza“]	*giebeli* horizon
Fissilobiceras argentinicum (TORNQUIST)	TORNQUIST 1898: 17, pl. 1, fig. 1 [lectotype; variety of *F. zitteli*]	*giebeli* horizon
Phylloceras neogaeum GOTTSCHE	GOTTSCHE 1878: 9, pl. 1, fig. 3 [holotype by monotypy]	?
?*Sonninia subdeltafalcata* TORNQUIST	TORNQUIST 1898: 24, pl. 5, fig. 7 [lectotype; ?microconch of *S. espinazitensis*]	?
?*Sonninia bodenbenderi* TORNQUIST	TORNQUIST 1898: 24, pl. 5, fig. 9 [holotype by monotypy; ?microconch of *S. espinazitensis*]	?
Sonninia mirabilis TORNQUIST	TORNQUIST 1898: 23, pl. 4, fig. 4 [holotype by monotypy; ?variety of *S. altecostata*]	?

(Graphoceras, *Hyperlioceras)* do not occur in the Lower Bajocian of the Andean Province. The co-occurrence of *Pseudotoites* faunas in Argentina and Western Australia provides some additional correlation potential between these areas (Riding et al. 2010).

The Zitteli Subzone of the Singularis Zone in the Andean Province and the NW European Ovale Zone are both characterised by the hammatoceratid genus *Fissilobiceras*, which has a long stratigraphical range in both provinces. A direct evidence of this zone by the record of *F. ovale*, however, is impossible, because the ammonites determined and illustrated as "*Sonninia ovalis*" (Westermann & Riccardi 1972) do not belong to *Fissilobiceras*. The sonniniid fauna is dominated by the morphogenus "*Euhoploceras*" in both provinces.

In the Altecostata Subzone of the Singularis Zone (Andean Province) and the NW European Trigonalis Subzone of the Laeviuscula Zone the first *Sonninia* with lateral nodes ("papillae") occur. This character is typical of the artificial morphogenera "*Papilliceras*" and "*Prepapillites*".

Tab. 2. Correlation of the Upper Aalenian and Lower Bajocian between South America and Middle Europe.

	Zones, Subzones and faunal horizons in Argentina and Northern Chile (Westermann 1992, Hillebrandt 2001, Riccardi 2008, here)					NW European standard Zones and Subzones	
			Beds at Paso del Espinacito				
	Zones	Subzones faunal horizons	Ridge ("Grat")	Pass summit ("Passhöhe")		Zones	Subzones
Bajocian	Stephanoceras humphriesianum					Stephanoceras humphriesianum	
	Chondromileia giebeli	Dorsetensia blancoensis				Otoites sauzei	
		Emileia multiformis *Chondromileia giebeli*	680107/06	680106/07 680106/06 680106/05			
		Chondromileia submicrostoma *Chondromileia submicrostoma*	680107/05 680107/04	680106/04		Witchellia laeviuscula	Witchellia laeviuscula
	Pseudotoites singularis	Sonninia altecostata *Pseudotoites sphaeroceroides*	680107/03	680106/03			Shirbuirnia trigonalis
		Fissilobiceras zitteli *Pseudotoites singularis*	680107/02	680106/02		Fissilobiceras ovale	
	?					Hyperlioceras discites	
Aalenian	Puchenquia malarguensis	Podagrosiceras maubeugei				Graphoceras concavum	
		Puchenquia mendozana	680107/01	680106/01			
		Puchenquia compressa	680107/01	680106/01			

The Submicrostoma Subzone of the Giebeli Zone (Andean Province) yields involute, bulbose species of the genus *Emileia* together with papillae-bearing representatives of *Sonninia*. A similar fauna occurs in the Laeviuscula Subzone of the Northwest European Province.

In the Andean and in the Northwest European Province the Multiformis Subzone of the Giebeli Zone and the lower and middle part of the Sauzei Zone respectively, are overlain by beds containing large-sized, very evolute stephanoceratids (morphogenus "*Skirroceras*"). The Hebridica Subzone (sensu MORTON) partly overlaps with the Humphriesianum Zone auct. and is partly synonymous with the Pinguis Subzone, the basal subzone of the Humphriesianum Zone (see DIETZE et al. 2008).

For a comprehensive correlation chart see Tab. 2.

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Plate 1

Paso del Espinacito; Lower Bajocian, Singularis Zone, Zitteli Subzone, horizon of *Pseudotoites singularis*.

Fig. 1a–b. *Pseudotoites crassus* Westermann & Riccardi; Ridge, between beds 2 and 3 (TUB vH 680107/2-3); MLP18765 [PT, TT].

Fig. 2a–b. *Pseudotoites argentinus* Arkell; Pass summit, between beds 2 and 3 (TUB vH 680106/2-3); MLP18767 [TT].

Fig. 3a–b. *Pseudotoites singularis* (Gottsche); Ridge, between beds 2 and 3 (TUB vH 680107/2-3); MLP18766 [TT].

Fig. 4. *Sonninia* cf. *transiens* (Taylor); Ridge, bed 2 (TUB vH 680107/2); MLP18770.

Fig. 5. *Fissilobiceras zitteli* (Gottsche); Ridge, bed 2 (TUB vH 680107/2); MLP18771 [TT].

Fig. 6. *Sonninia* cf. *transiens* (Taylor); Pass summit, bed 2 (TUB vH 680106/2); MLP18769.

Fig. 7. *Pseudotoites evolutus* (Tornquist); Pass summit, between beds 2 and 3 (TUB vH 680106/2-3); MLP18768 [TT].

All specimens in natural size.


1a
1b
2a
3a
4
2b
3b
5
6
7

Plate 2

Paso del Espinacito, Pass summit, bed 2; Lower Bajocian, Singularis Zone, Zitteli Subzone, horizon of *Pseudotoites singularis*.

Fig. 1a–b. *Sonninia* aff. *berckhemeri* Dorn (= "*Sonninia (Sonninia) ovalis* (Quenstedt)" in Westermann & Riccardi 1972, pl. 8, fig. 3); (TUB vH 680106/2); MLP 18807.

Fig. 2–3. *Sonninia* cf. *transiens* (Taylor) (= "*Sonninia (Euhoploceras)* cf. *adicra* (Waagen)"in Westermann & Riccardi 1972, pl. 11, figs. 1–2); (TUB vH 680106/2). – **2**. MLP 18808. **3**. MLP 18809.

All specimens in natural size.


1a
1b
2a
2b
3a
3b

Plate 3

Paso del Espinacito; Lower Bajocian, Singularis Zone, Zitteli Subzone, horizon of *Pseudotoites singularis*.

Fig. 1. *Fissilobiceras zitteli* (Gottsche) var. *argentinicum* (Tornquist); Pass summit, bed 2 (TUB vH 680106/2); MLP18773 [TT].
Fig. 2. *Fissilobiceras zitteli* (Gottsche) var. *intumescens* (Tornquist); Ridge, bed 2 (TUB vH 680107/2); MLP18774 [TT].
Fig. 3a–b. *Fissilobiceras zitteli* (Gottsche); Ridge, bed 2 (TUB vH 680107/2); MLP18775 [TT].
Fig. 4a–b. *Fissilobiceras zitteli* (Gottsche) var. *andium* (Gottsche); Pass summit, bed 2 (TUB vH 680106/2); MLP18772 [TT].

All specimens in natural size.


1
2
3a
3b
4a
4b

Plate 4

Paso del Espinacito; Lower Bajocian, Singularis Zone, Altecostata Subzone, horizon of *Pseudotoites sphaeroceroides*.

Fig. 1a–b. *Pseudotoites sphaeroceroides* (Tornquist); Pass summit, bed 3 (TUB vH 680106/3); MLP18776 [TT].
Fig. 2a–b. *Pseudotoites* cf. *sphaeroceroides* (Tornquist); Pass summit, bed 3 (TUB vH 680106/3); MLP18777.
Fig. 3. *Sonninia altecostata* Tornquist; Pass summit, bed 3 (TUB vH 680107/3); MLP18778 [TT].

All specimens in natural size.


1a
1b
2b
3
2a

Plate 5

Paso del Espinacito; Lower Bajocian, Singularis Zone, Altecostata Subzone, horizon of *Pseudotoites sphaeroceroides*.

Fig. 1. *Sonninia altecostata* Tornquist var. *gracilis* Tornquist; Ridge, bed 3 (TUB vH 680107/3); MLP18779 [TT].
Fig. 2. *Sonninia altecostata* Tornquist; Ridge, bed 3 (TUB vH 680107/3); MLP18780 [TT].
Fig. 3. *Sonninia altecostata* Tornquist; Pass summit, bed 3 (TUB vH 680106/3); MLP18781 [TT].

All specimens in natural size.


1
2
3

Plate 6

Paso del Espinacito; Lower Bajocian, Giebeli Zone, Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*.

Figs. 1–3. *Chondromileia submicrostoma* (Gottsche). – **1a–b, 3**. Ridge, bed 5 (TUB vH 680107/5). **1a–b**. MLP18785 [TT]. **3**. MLP18784 [TT]. **2**. Espinazito-Pass, GMUG 496-70.

Fig. 4a–b. *Emileia multiformis* (Gottsche); Ridge, bed 5 (TUB vH 680107/5); MLP18787 [TT].

Fig. 5. *Pseudotoites* aff. *evolutus* (Tornquist); Pass summit, bed 4 (TUB vH 680106/4); MLP18783 [TT].

Fig. 6a–b. *Emileia multiformis* (Gottsche); Ridge, bed 5 (TUB vH 680107/5); MLP18786 [TT].

Fig. 7. *Pseudotoites transatlanticus* (Tornquist); Pass summit, bed 4 (TUB vH 680106/4); MLP18782 [TT].

All specimens in natural size.


1a
1b
2
3
4a
4b
5
6a
6b
7

Plate 7

Paso del Espinacito; Lower Bajocian, Giebeli Zone, Submicrostoma Subzone, horizon of *Chondromileia submicrostoma*.

Fig. 1–5. *Sonninia espinazitensis* Tornquist. – **1–2, 4–5**. Ridge, bed 4 (TUB vH 680107/4). **1**. MLP18788 [TT]. **2.** MLP18789 [TT]. **4**. MLP 18810 [TT]. **5.** MLP 18811 [TT]. **3**. Pass summit, bed 4 (TUB vH 680106/4); MLP18790 [TT].

Fig. 6. *Sonninia altecostata* Tornquist; Pass summit, bed 4 (TUB vH 680106/4); MLP18791.

Fig. 7. *Sonninia modesta* sensu Imlay; Ridge, bed 5 (TUB vH 680107/5); MLP18792.

All specimens in natural size.


1
2
3
4
5
6
7

Plate 8

Paso del Espinacito; Lower Bajocian, Giebeli Zone, Multiformis Subzone, horizon of *Chondromileia giebeli*.

Figs. 1–2. *Chondromileia giebeli* (Gottsche). – **1a–b**. Ridge, bed 6 (TUB vH 680107/6); MLP18793 [CT]. **2a–b**. Pass summit, bed 5 (TUB vH 680106/5); MLP18795 [CT].

Fig. 3a–b. *Emileia multiformis* (Gottsche); Ridge, bed 6 (TUB vH 680107/6); MLP18796.

Fig. 4a–b. *Chondromileia giebeli* (Gottsche); Ridge, bed 6 (TUB vH 680107/6); MLP18794 [CT].

Fig. 5. ?*Pseudotoites* sp.; Ridge, bed 6 (TUB vH 680107/6); MLP18799.

Fig. 6. *Emileia* ♂ sp.; Ridge, bed 6 (TUB vH 680107/6); MLP18797.

Fig. 7. *Chondromileia giebeli* (Gottsche); Pass summit, bed 7 (TUB vH 680106/7); MLP18800 [?CT].

All specimens in natural size.

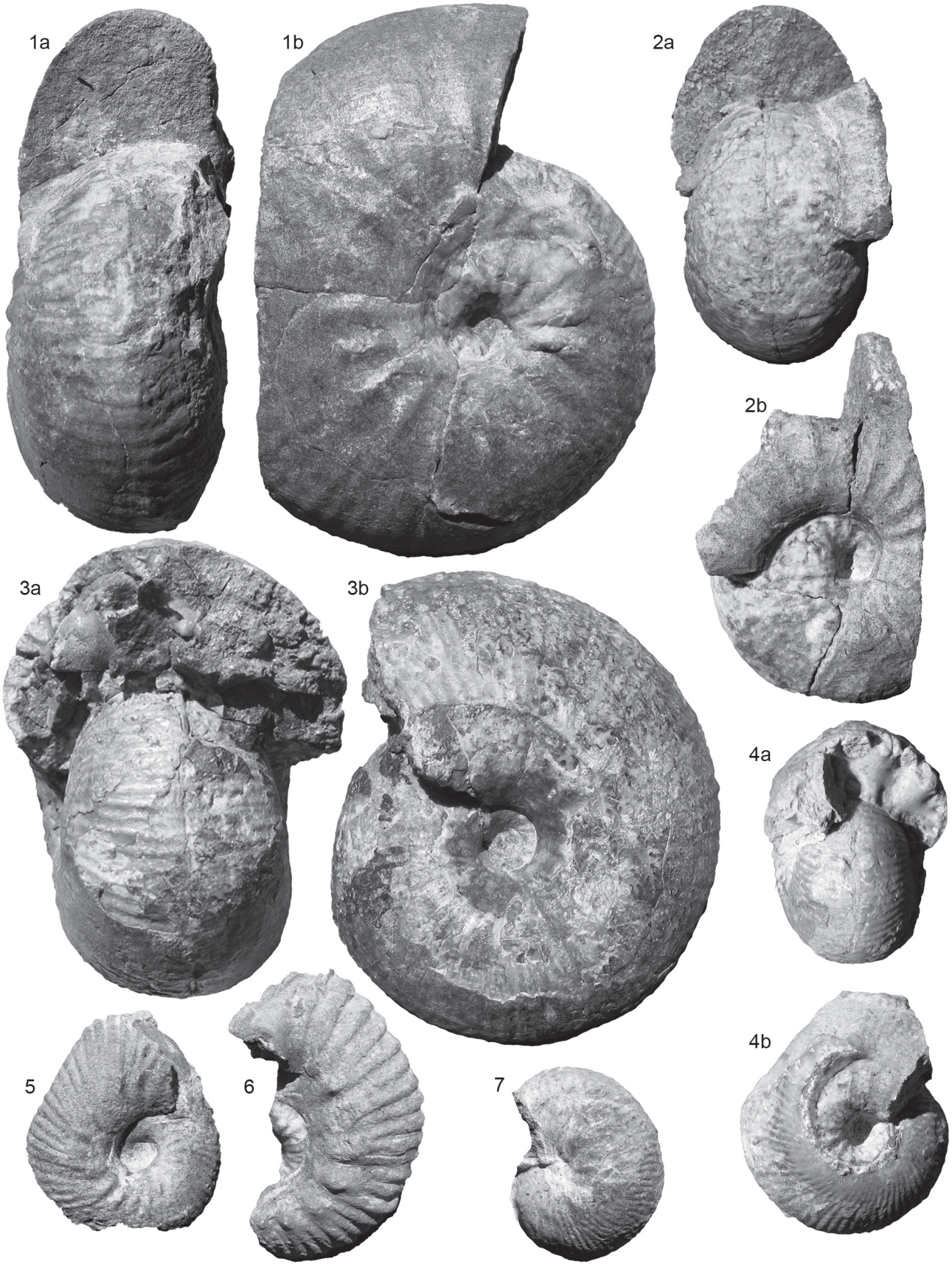
1a
1b
2a
2b
3a
3b
4a
4b
5
6
7

Plate 9

Paso del Espinacito; Lower Bajocian, Giebeli Zone, Multiformis Subzone, horizon of *Chondromileia giebeli*.

Fig. 1a–b. *Sonninia* aff. *espinazitensis* (Tornquist); Ridge, bed 6 (TUB vH 680107/6); MLP18804.
Fig. 2. *Sonninia* cf. *altecostata* (Tornquist); Pass summit, bed 6 (TUB vH 680106/6); MLP18801.
Fig. 3. *Fissilobiceras zitteli* (Gottsche) var. *argentinicum* (Tornquist); Pass summit, bed 5 or 7 (TUB vH 680106/5 or 7); MLP18805 [TT].
Fig. 4. *Strigoceras strigifer* (Buckman); Ridge, bed 6 (TUB vH 680107/6); MLP18798.

All specimens in natural size.


1a
2
1b
3
4

Plate 10

Paso del Espinacito; Lower Bajocian, Giebeli Zone, Multiformis Subzone, horizon of *Chondromileia giebeli*.

Fig. 1. *Sonninia* cf. *altecostata* Tornquist; Pass summit, bed 6 (TUB vH 680106/6); MLP18802.
Fig. 2. *Sonninia* aff. *espinazitensis* Tornquist; Ridge, bed 6 (TUB vH 680107/6); MLP18803.
Fig. 3. *Sonninia espinazitensis* Tornquist; Pass summit, bed 6 (TUB vH 680106/6); MLP18806.

All specimens in natural size.


1
2
3