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The Upper Bajocian ammonite Strenoceras in Chile: first circum-Pacific record of the subfurcatum Zone

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with 1 plate and 1 figure

Abstract. The first *Strenoceras* [cf. *latisulcatum* (Qu.)] in the Americas – and the entire circum-Pacific – was found in the classical section of Caracoles in Antofagasta province, N. Chile. Its stratigraphic position is the boundary of the Torcazas and Mina Chica Formations, i. e. directly superjacent to the *'Stephanoceras* Beds' (with *S. chilense* etc.). Since *Strenoceras* has only been known from the *subfurcatum* Zone, basal Upper Bajocian, of Europe and N. W. Africa, this standard zone is now extended to the S. E. Pacific. The associated *Cadomites* aff. *deslongchampsi* also indicates post-Lower Bajocian age and Tethyan affinities.

Zusammenfassung. Das erste *Strenoceras* [cf. *latisulcatum* (Qu.)] Amerikas – und des gesamten circum-Pazifiks – wurde im klassischen Profil von Caracolas, Antofagasta Province, N. Chile, gefunden. Die stratigraphische Position ist an der Grenze der Torcazas- und Mina Chica-Formationen, d. h. direkt über den *'Stephanoceras*-Schichten' (mit *S. chilense* etc.). Da *Strenoceras* bislang nur von der *subfurcatum*-Zone, basales Ober-Bajocium, von Europa und Nordwest-Afrika bekannt ist, wird diese Standard-Zone nun bis zum Südost-Pazifik erweitert. Der assoziierte *Cadomites* aff. *deslongchampsi* weist auch auf post-Unter-Bajocian und Tethys hin.

Introduction

In September 1978 we re-examined the Middle Jurassic section of the classical Caracoles outcrops in Antofagasta province, Chile (Text-Fig. 1) (Westermann & Riccardi 1972–79). We are indebted to G. Chong D., Universidad del Norte in Antofagasta, for logistical support.

The Cerros de Caracoles have long been noted for their silver mines and the ammonites (caracoles = snails). The mountains, rising from the gently sloping desert to over 3000 m, are formed by uplifted blocks of Upper Triassic/Lower Jurassic volcanoclastics, overlain by Middle-Upper Jurassic marine sediments, and injected by Cretaceous diorites, andesites and Cenozoic porphyrites.

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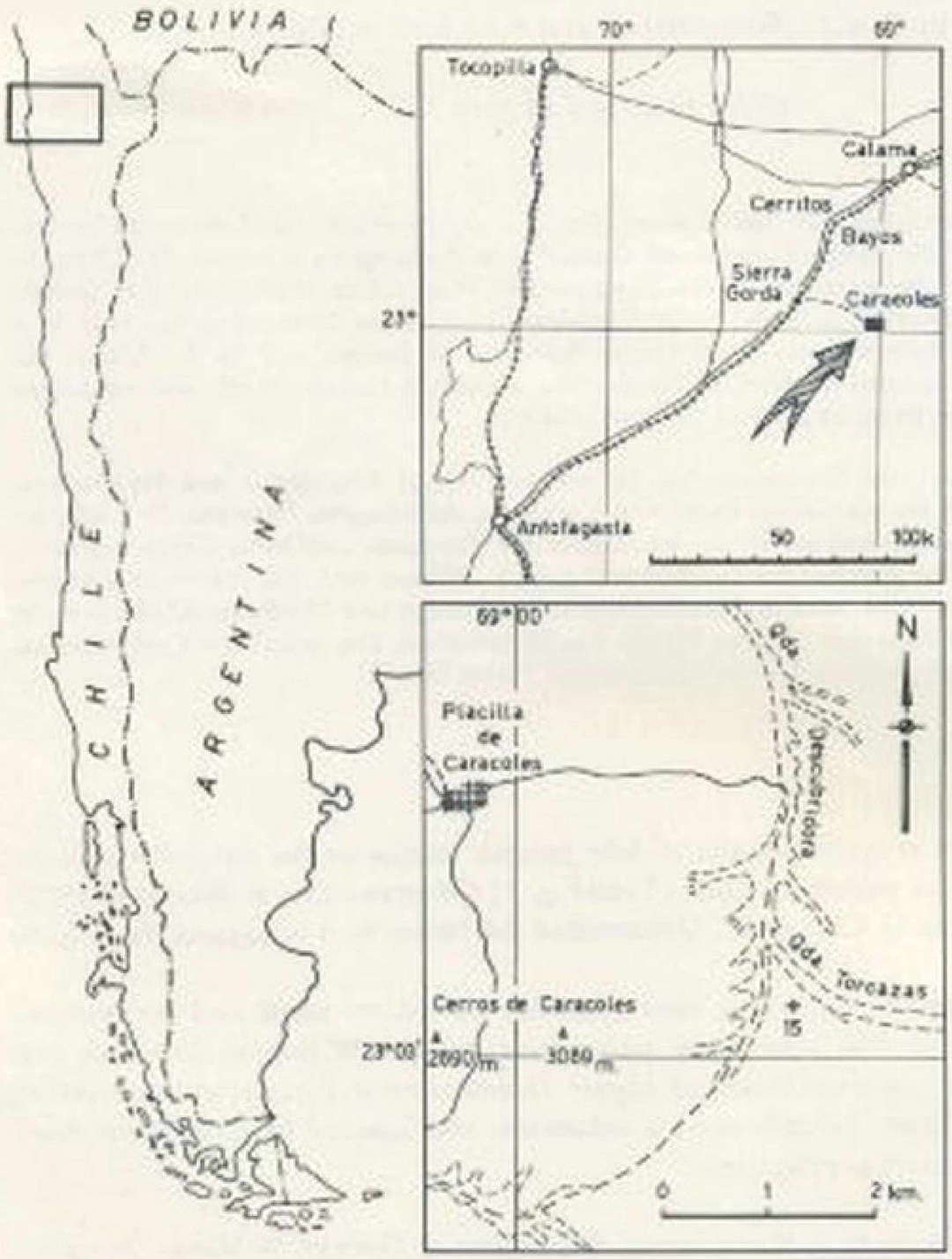
The rich Middle and Upper Jurassic (mainly Callovian) ammonite fauna became known from the descriptions by STEINMANN (1881). Topographic and stratigraphic data were lacking, however. The only undoubted Bajocian species, in a matrix of „yellow or light brown silicified rock", was the *„Stephanoceras humphriesianum"* or *„Coeloceras cosmopoliticum* MOERICKE", recently namend *S. chilense* HILLEBRANDT (1977). The geology and ammonite biostratigraphy was investigated by HARRINGTON (1961), but his fossils were listed only and later mostly lost. One of us (WESTERMANN) re-examined the Middle Jurassic outcrops in 1965, but was then unable to sample the complete Bajocian



Text-Fig. 1. Index maps to section 15 of the Quebrada Descubridora at the old Caracoles mine, Antofagasta Province, Chile.

section. This concerns particularly the boundary between the arenaceous Torcazas Formation with the superjacent argillaceous Mina Chica Formation, i. e. the boundary between Lower and Upper Bajocian. HARRINGTON's lithostratigraphic section together with our ammonite identifications has been described in part II of our monograph (WESTERMANN & RICCARDI 1979).

HILLEBRANDT (1970, 1973, 1977) and CHONG, D. (1977) have used the term „*subfurcatum* Zone" and other European standard zones in a chronologic sense, i. e. dronozone, beyond the geographic range of the typical faunal assemblage. They placed in, or dated with, this zone thick beds in the central Domeyko Range, about 200 km south of Caracoles bearing an association of Stephanoceratinae surviving from the Lower Bajocian and the typical Upper Bajocian *Spiroceras*, (?) *Megasphaeroceras*, and the „new" genus *Domeykoceras* HILLEBRANDT. The latter has been found to be synonymous with *Lupherites* IMLAY from the Middle/Upper Bajocian boundary beds of Oregon (WESTERMANN & RICCARDI 1979). From slightly higher up, HILLEBRANDT reported *Cadomites* and *Leptosphinctes* together with „*Megasphaeroceras*", but without Stephanoceratinae, which he tentatively placed in the uppermost *subfurcatum* Zone or in the *garantiana* Zone. In the absence, however, of the Parkinsoniidae, i. e. *Strenoceras*, *Caumontisphinctes*, *Garantiana* and *Parkinsonia*, on which the European zonation of the Upper Bajocian is based (cf. STURANI 1967, 1971), inter-continental correlation at the zonal level is difficult.

Stratigraphy

The Quebrada Descubridora-15 composite section is in the low hilly terrain between this large quebrada and the lower part of the tributary Quebrada Torcazas, about 1 km above the junction (Text-Fig. 1). The boundary beds of the Torcazas and Mina Chica Formations are as follows.

Formation	Bed	Thickness	
Mina Chica (part.)		> 10 m	Yellow marls with calcareous concretions
	J–I		Lower 7 m with *Reinecckeia* sp., *Eurycephalites* sp.
		26 m	Yellow and green siltstone and silty marl with calcareous concretions and some lenticular sandstone.
	H		In upper 1 m: *Xenocephalites* sp., Perisphinctidae, ?*Cadomites* sp.
	G		At 13–16 m from base: *Eurycephalites* sp., *Xenocephalites* sp.
	E, F		At 8–10 m from base: *E. cf. boesei*, Macrocephalitidae indet., bivalves and brachiopods.
		2 m	Silty and bituminous shale and mudstone with coquina bed.

Formation	Bed	Thickness	
	D		Near top: Poorly preserved, small and often fragmented *Lissoceras* cf. *oolithicum* (d'Orb.), Macrocephalitidae or Sphaeroceratidae, Perisphinctidae, *?Partschiceras* sp. and bivalves.
	C		Near base fragments of: *Strenoceras* cf. *latisulcatum* (Qu.) *Cadomites* n. sp. B aff. *deslongchampsi* (d'Orb.).
Tocazas		15–20 m	Intercalated siltstone and silty shale, yellow and light brownish weathering, some calcareous sandstone.
	B		2 m below top: *Stephanoceras (Stephanoceras)* cf. *chilense* Hillebrandt, *S. (S.?)* aff. *arcicostum* Imlay, Spaerocertidae indet.
A			10 m below top: *S. (S.) chilense, S. (Stemmatoceras)* cf. *dowlingi* (McLearn).
		> 10 m	Conglomeratic sandstone.

Our earlier collections from the uppermost Tocazas Formation included *Stephanoceras chilense* Hill, *S. (Stemmatoceras) allani* (Warren)?, *Teloceras* cf. *crickmayi chacayi* West. & Ricc. and *Lissoceras* cf. *oolithicum* (d'Orb.), indicating the *S. chilense* Subzone of the Upper *humphriesianum* Standard Zone (Westermann & Riccardi 1979).

The 2 m interval C–D contains fragmented specimens, at least in part of Upper Bajocian age, which appear to be reworked. This horizon may therefore be „condensed" including the *subfurcatum* Zone as documented by the *Strenoceras*. The superjacent 26 m interval E–H belongs already in the higher Bathonian to basal Callovian; while beds J–I with *Reineckeia* and *Eurycephalites* are clearly Lower Callovian. Most of the Upper Bajocian and the Bathonian are therefore either much reduced in thickness or absent.

This confirms our earlier conclusion (Westermann & Riccardi 1979) that the „*Stephanoceras* beds" of Caracoles are essentially restricted to the *humphriesianum* Zone. The several, probably Upper Bajocian ammonites reported by Hillebrandt (1977, p. 37) from Caracoles may be from the bed with *Stenoceras* at the base of the Mina Chica Formation.

Palaeontology

Class CEPHALOPODA Cuvier, 1978
Order AMMONOIDEA Agassiz, 1847
Superfamily Perisphinctaceae Steinmann, 1890
Family Parkinsoniidae Buckmann, 1920
Genus *Strenoceras* Hyatt, 1900

Taxonomy. The best known, and one of the two oldest species named is *S. subfurcatum* (Zieten 1830) (Schlotheim, MS name; cf. Parsons 1975). The lectotype from Auerbach, Bavaria, was designated by Arkell (1956, pl. 35, fig. 6; after Benitz 1928, pl. 14, fig. 1). *S. bajocense* (Defrance) of which the holotype was recently again illustrated by

ARKELL (1957, p. L 308) and which includes *S. niortense* (D'ORBIGNY 1846), has been regarded as conspecific with *S. subfurcatum* by some recent authors but as a distinct, sympatric species by others (cf. PAVIA 1971). While *S. bajocense* has mostly simple ribs, bifurcation is prevalent in *S. subfurcatum*. This distinction, however, appears spurious from the published illustrations (op cits.) and specific assignment certainly is not possible for a whorl fragment which may belong to the body chamber (PARSONS 1975).

An apparently small species, distinct from the *S. subfurcatum* group, is *S. apleurum* BUCKMAN (1921, pl. 239) from the *subfurcatum* Zone of England and the Venetian Alps (STURANI 1971, pl. 13, figs. 22–23). It resembles our specimen somewhat in the obsolescence of the secondaries and in the prominent tubercles or spines; these, however are much more widely spaced and more rounded, and the primaries also blunt to obsolete.

Strenoceras is probably not the microconch-dimorph to *Garantiana* MASCKE which, in some recent literature, has thus been included in *Strenoceras* (e. g. PARSONS 1975).

Vertical distribution. The vertical distribution of all previously known species of *Strenoceras* is probably restricted to the European middle and upper *subfurcatum* Standard Zone, i. e. the *polygyralis* and *baculatum* Subzones, best known from the Basses-Alpes (PAVIA 1971, STURANI 1971). The *polygyralis* and *baculatum* Subzones with *Strenoceras* ex gr. *subfurcatum* have also been identified in England (PARSONS 1976), while the *banksi* Subzone at the base is mostly absent in northwest Germany, with the probable exception of the thick shaly section near Bielefeld (BENTZ 1925, 1928, WESTERMANN 1969). In the Basses-Alpes, only *S. subfurcatum* (s. str.) ranges into the „*schroederi* Subzone" (PAVIA 1971).

The *schroederi* Subzone was introduced by KUMM (1952, „Zone der *Orthogarantiana schroederi*") and based on the succession of the Bielefeld clay pits (BENTZ, 1925, 1928, ALTHOFF, 1938, cf. WETZEL, 1954), supposedly containing *Strenoceras* spp., *Garantiana (Orthogarantiana)* spp., the last *G. baculata*, early *Parkinsonia* and *Spiroceras*. Recent work in the Basses-Alpes (above) and in Swabia (DIETL & HUGGER 1979), however, strongly indicate that the supposed *schroederi* Subzone does not exist outside northwestern Germany, and it cannot be verified even there anymore. The superjacent *Dichotoma* Subzone of the Garantiana Zone, also of KUMM (1952, „Zone der *Pseudogarantiana dichotoma*") yielded abundant *G. (Pseudogarantiana)* spp. throughout as well as the first supposed *G. (G.) garantiana*, while the index fossil was recorded only from its upper part; *Strenoceras subfurcatum* appears to be restricted to the lower part. The *Strenoceras* range zone, therefore, is not known to overlap with the *P. dichotoma* range zone which defines the *garantiana* Zone. Furthermore, the early „*G. garantiana*" of BENTZ is now known to be misidentified so that *G. garantiana* begins only well above the last occurrence of *Strenoceras* (DIETL, pers. comm.).

Geographic distribution. The previously known distribution of *Strenoceras* reaches from the Tellian Atlas in Algeria (ARKELL 1956, p. 278), over Portugal and Spain (e. g. FALLOT & BLANCHET 1923, MOUTERDE et al. 1971 b), to France, England (MOUTERDE et al. 1971 a, PARSONS 1975, 1976), north and south Germany, and the Swiss and Italian Alps (PAVIA 1971, BENTZ 1925, 1928, STURANI 1971) to the Caucasus (ZATVORUITSKY, fide

PAVIA 1971). Significantly, the genus seems to be missing in the coeval *Ermoceras* fauna, from the probably somewhat restricted basins of the North African margin, i. e. the Sahara Atlas of Algeria and the Arabian Peninsula (ARKELL 1952 a, 1956, IMLAY 1970).

Strenoceras cf. *latisculatum* (QUENSTEDT)

Plate 1, Figs. 1 a, b

Material. One 1/4 whorl fragment with remnant of previous whorl; shell and septation, if present, obliterated by silicification; from bed C of Quebrada Descubridora section 15 (McM. J 2500).

Description. At the reconstructed maximum diameter of 40 mm, the whorl section is strongly depressed subelliptical (W = 19 mm, H = 12 mm, intercostal measurements), with the almost vertical umbilical slope rounded into the narrow flanks which are continuous with the broadly curved venter. The ornament consists of moderately spaced, rectiradiate, thin and sharp primaries ending in large lateral nodes at about 3/5 whorl height, and of prominent ventro-lateral bullae, only one per primary. Lateral nodes and bullae are barely interconnected by obsolete secondaries. The mid-venter has a faint depression only and complete interruption of the ornament.

Comparison. While this is undoubtedly a true *Strenoceras*, no other species hitherto described apears to have quite as broad a whorl section. The best and oldest species with relatively broad whorl sections without marked ventral groove is *S. latisculatum* (QUENSTEDT 1866–87, pl. 70, fig. 2) from the *subfurcatum* Zone of the Swabian Jura, while *S. rotundum* BENTZ (1928, pl. 14, fig. 9) and *S. latidorsum* BENTZ (1925, pl. 4, figs. 9–12) from the *subfurcatum* Zone of Bielefeld and Goslar in northwest Germany, have a marked ventral groove. *S. latisculatum* has recently been reported from the *baculatum* Subzone of Swabia (DIETL & HUGGER, 1979) suggesting that our form belongs in the upper *subfurcatum* Zone.

Superfamily STEPHANOCERATACEAE NEUMAYR, 1875
Family STEPHANOCERATIDAE NEUMAYR, 1875
Subfamily CADOMITINAE WESTERMANN, 1956
Genus *Cadomites* MUNIER-CHALMES, 1892

Stratigraphic distribution. The *C. deslongchampsi* group ranges through the Upper Bajocian into the Lower Bathonian; the *C. daubenyi* (GEM.) group seems to appear as early but has its greatest abundance in the Bathonian and survives into the Lower Callovian, e. g. Moluccas (WESTERMANN et al. 1978).

The earliest, questionable *Cadomites* are planulate forms apparently transitory to *Stephanoceras* s. str., i. e. *C.* (?) *humphriesiformis* and *C.* (?) *lissajousi*, ROCHE spp., from the *bladgeni* Subzone, *humphriesianum* Standard Zone, and *subfurcatum* Standard Zone of France (PAVIA 1971, pl. 17, figs. 1–4, 6).

Plate 1

Figs. 1 a, b. Fragment of *Strenoceras* cf. *latisulcatum* (QUENSTEDT), bed C of Section 15, Quebreda Descubridora.

Fig. 2. Fragment of *Cadomites* n. sp. B aff. *C. deslongchampsi* (D'ORBIGNY) ♀, same bed and locality as Fig. 1.

The first undoubted *Cadomites* came from the basal Upper Bajocian of Normandy, i. e. *C. psilacanthus* (WERMBTER); the same species occurs more abundantly in the *parkinsoni* Zone of the Alps (cf. WESTERMANN & RIOULT 1975). Another early member of the group of *C. deslongchampsi* is the rare *C. bomalogaster* BUCKMAN (1925, pl. 543 a, b) from the „Stepheoceratan, *Leptosphinctes* hemera" of Dorset. The whorls are narrower and the secondaries finer (?obsolete) than in *C. deslongchampsi*.

An unnamed species, *C.* n. sp. A aff. *deslongchampsi*, occurs in the lower Upper Bajocian of Arroyo Blanco in Mendoza province, (?) Chacay Melehue in Neuquen province (WESTERMANN & RICCARDI 1979, p. 69) and of Sierra Domeyko in Antofagasta province (HILLEBRANDT 1977, p. 38). (We have reexamined the Quebrada del Profeta section and found the new species associated with *Lupherites* and *Spiroceras*).

Geographic distribution. Both, *Cadomites* gr. *deslongchampsi* and *C.* gr. *daubenyi* occur in northern Africa and Europe in relative abundance; the second, mostly younger group can be traced eastward all the way to Japan, the Moluccas and New Guinea: while the former, early group occurs disjunctively also in the Moluccas. The evidence for Upper Bajocian in the Indo-West Pacific (Indo-Malay) province, however, is meager so that distributional data have to be taken with extreme caution. The Andean record from Mendoza, (?) Neuquen and Antofagasta provinces is the only additional one.

In North Africa, the best record is from western Algeria (ELMI 1971), where *C.* cf. *deslongchampsi* occurs in the „*phaulus*" *{= polygyralis}* Subzone of the *subfurcatum* Zone and other species in the Lower and Middle Bathonian.

In western Europe, *Cadomites* is relatively abundant in the Mediterranean and Submediterranean provinces, e. g. Spain, France, northern Italy and Sicily (WENDT 1963, STURANI 1967, 1971, PAVIA 1971), but rare in south Germany (BUCK et al. 1966) and England (BUCKMAN 1925). The ages are mostly Upper Bajocian and (Lower) Bathonian.

The occurrences to the east of Poland (KOVIC 1974), i. e. Hungary, Romania, Asia Minor, Georgia, Iran, and to the south, i. e. Madagascar, appear to be entirely of Bathonian age, dating permitting (cf. ARKELL 1956, BREMER 1966, TSERETELI 1968, COLLIGNON 1958) (? except for Kenya, cf. WESTERMANN 1975). In the Moluccas, *C.* aff. *deslongchampsi* occurs together with *Leptosphinctes* sp. [„Caumontisphinctes"] in the upper Bajocian and *C.* cf. *daubenyi* in the basal Callovian (WESTERMANN et al. 1978). The only Asian Late Bajocian record of *Cadomites* is from Japan, where *C.* ex gr. *daubenyi* occurs in the same outcrop with *Leptosphinctes* (and very questionable „*Garantiana*" and „*Parkinsonia*"; TAKAHASHI 1969). The record from Irian Jaya is dubious (BOEHM 1913, pl. 3, fig. 1).

The previous Andean record (HILLEBRANDT 1977, WESTERMANN & RICCARDI 1979) consists of *C.* n. sp. A. aff. *C. deslongchampsi* in the lower Upper Bajocian of Arroyo Blanco in Mendoza Province, Chacay Melehue in Neuquen Province and the Cordillera Domeyko in Antofagasta Province, and of *C.* cf. *daubenyi* in the (?) Lower Bathonian of Chacay Melehue.

Cadomites n. sp. B. aff. *C. deslonchampsi* (D'ORBIGNY) ♀
Plate 1, Fig. 2

Material. One fragment of large shell with beginning of body chamber and parts of 2 previous whorls, preserved right side and venter only, silicified (with shell?); from Bed C of Quebrada Descubridora section 15 (McMJ 2501).

Description. The large shell had a phragmocone diameter of approximately 100 mm and a total reconstructed size of at least 160 mm. The outer three whorls are rather evolute and moderately depressed subelliptical to trapezoidal in section (W/H ≃ 1.3). The inner rounded flank reaches the umbilical seam with modest inclination. The maximum whorl width is well above mid-flank at about 3/5 whorl height and marked by a rounded margin, at least on the body chamber; the venter is broadly rounded. The ornament consists of extremely dense and somewhat curved, sharp primaries which end in small pointed tubercles on the lateral margin. On the outer whorl, the primaries become somewhat more widely spaced; they divide here mostly in 3 secondaries which cross the venter slightly convex. While, superficially, the ribs remain quite sharp up to the end, they become blunt on the internal mould.

Remnants of the last septal suture indicate that it has a radial saddle envelope, without retraction.

Comparison. Our specimen resembles *C. psilacanthus* (WERMBTER) (cf. WESTERMANN & RIOULT 1975) rather closely, except for its denser and longer primaries. The longer primaries resemble those of *C. deslongchampsi* (cf. ARKELL 1952 b, Textfigs. 21, cf. STURANI 1967, pl. 6, fig. 1) The Chilean specimen differs in the larger size and denser primaries. The *C.* n. sp. A. aff. *deslongchampsi* from Neuquen province (WESTERMANN & RICCARDI 1979) and Sierra Domeyko in Antofagasta province (unpublished) differ also in the coarser primaries.

Results

The presence in northern Chile of *Strenoceras*, the index fossil for the *subfurcatum* Zone, is the first clear evidence for (1) the extension of that Eurafrican Standard Zone into the Andean (sub-) province of the circum-Pacific area and (2) is also additional evidence for a direct marine connection during the Bajocian, through the „Central American" corridor. Significantly, this occurrence is near the northern limit of the well known Upper Bajocian outcrops of the Andes.

Just north of this corridor, the Upper Bajocian of southwest Mexico has closer Eurasian affinities than any other contemporaneous eastern Pacific ammonite fauna (WESTERMANN, in press). It is of interest that a relative of *Strenoceras*, i. e. *Parastrenoceras*, is abundant in Mexico and rare Mediterranean Europe, while *Strenoceras* has not yet been found in Mexico.

The Andean occurrence of early *Cadomites*, a genus arising at about the Lower/Upper Bajocian boundary, and its probable absence in the North American Cordillera, adds to the Tethyan affinity of the Andean fauna (WESTERMANN & RICCARDI 1976).

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