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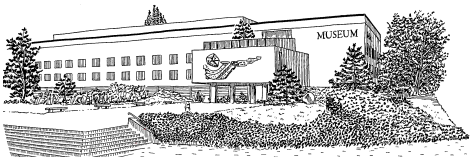

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Callovian (Middle Jurassic) ammonite faunas from the Bowser Lake Group, Northern Bowser Basin, British Columbia

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Abstract
Ammonites of late Early or early Middle Callovian age belonging to the genera *Cadoceras, C. (Stenocadoceras),* and *Indosphinctes* are described and figured. Both macroconch and corresponding microconch specimens have been recognized for each taxon. All the material described here came from a single sandstone bed in the Muskaboo Creek Assemblage of the Bowser Lake Group at a locality 1.2 km south east from the peak of Tsatia Mountain, close to the northern margin of the Bowser Basin in northwestern British Columbia, Canada. One new species of *Indosphinctes* SPATH, 1930 is recognized, with two varieties: *Indosphinctes tsatiaensis* var. *angustus* and *I. tsatiaensis* var. *latus,* apparently a unique occurrence of this Tethyan genus in North America.

Keywords
Callovian, ammonites, Bowser Basin, British Columbia.

INTRODUCTION

The Callovian ammonites described in this paper further document a poorly understood biostratigraphic level in western North America, and provide new information on a unique occurrence of Tethyan ammonites. They were collected during geological mapping projects in which ammonites have been important for our understanding of the stratigraphy and tectonic setting of this part of the Canadian western Cordillera (EVENCHICK & THORKELSEN, 2005; EVENCHICK *et al*., 2010).

The ammonites come from the Bowser Lake Group, close to the northern margin of the Bowser Basin in northwestern British Columbia (Fig. 1a). This unit is characterized by rapid facies variations, vertical repetition of similar lithologies, and structural complication, so that the ammonites have proved critical for its interpretation. This clastic sedimentary group in the Tsatia Mountain area (Fig. 1b) records the gradual cessation of Early Jurassic volcanism that produced the underlying Hazelton Group. Above the volcanics, Toarcian through Bajocian strata (Fig. 1c) of the upper Hazelton Group comprise a condensed deep-water package indicating probable thermal subsidence before the Bowser Lake Group was deposited (GAGNON *et al*., 2009). The latter is a thick, coarsening-upward sequence, from fine-grained deeper-water deposits at the base, through slope, deltaic and nonmarine coal-bearing strata at the top. The lower parts of the Bowser Lake Group, up to the Oxfordian, grade southward into more volcanic-rich strata that are included in the mainly older Hazelton Group, so that the mutual boundary between the two groups is diachronous, younger to the south (EVENCHICK *et al*., 2010).

The ammonites were collected in the lower part of the outer-shelf Muskaboo Creek Assemblage (Fig. 1d, 2-4), a diachronous series of narrow belts of siltstone and sandstone in coarsening-upward cycles, and with channeled conglomerate lenses. At Tsatia Mountain, each cycle is capped by a thin, resistant, fossiliferous brown-weathering sandstone with chert pebble beds at its top. The Muskaboo Creek Assemblage is time-transgressive, ranging from Late Bathonian in the north to earliest Cretaceous farther south, and from 300 m to more than 1500 m in thickness (EVENCHICK & THORKELSON, 2005).

The Bowser Basin was formed on top of the Hazelton volcanic arc complex, and the two constitute the bulk of Stikinia or Stikine exotic terrane, which lay on Panthalassa oceanic lithosphere off western Pangea. The basin was filled by a thick Middle Jurassic through Lower Cretaceous clastic sedimentary succession, which in the north and northeast (by modern directions; the terranes were rotated after their formation), was introduced from eroding uplifted Cache Creek oceanic mélange terrane with which Stikinia collided (Fig. 1c; EISBACHER, 1981 (as Atlin Terrane); GAGNON *et al*., 2009). There is much controversy regarding the location, timing and nature of amalgamation of the various exotic terranes with each other, and their accretion to the continent (e.g. MONGER & STRUIK, 2006). However, Middle to Late Jurassic development of an orogenic foredeep on the

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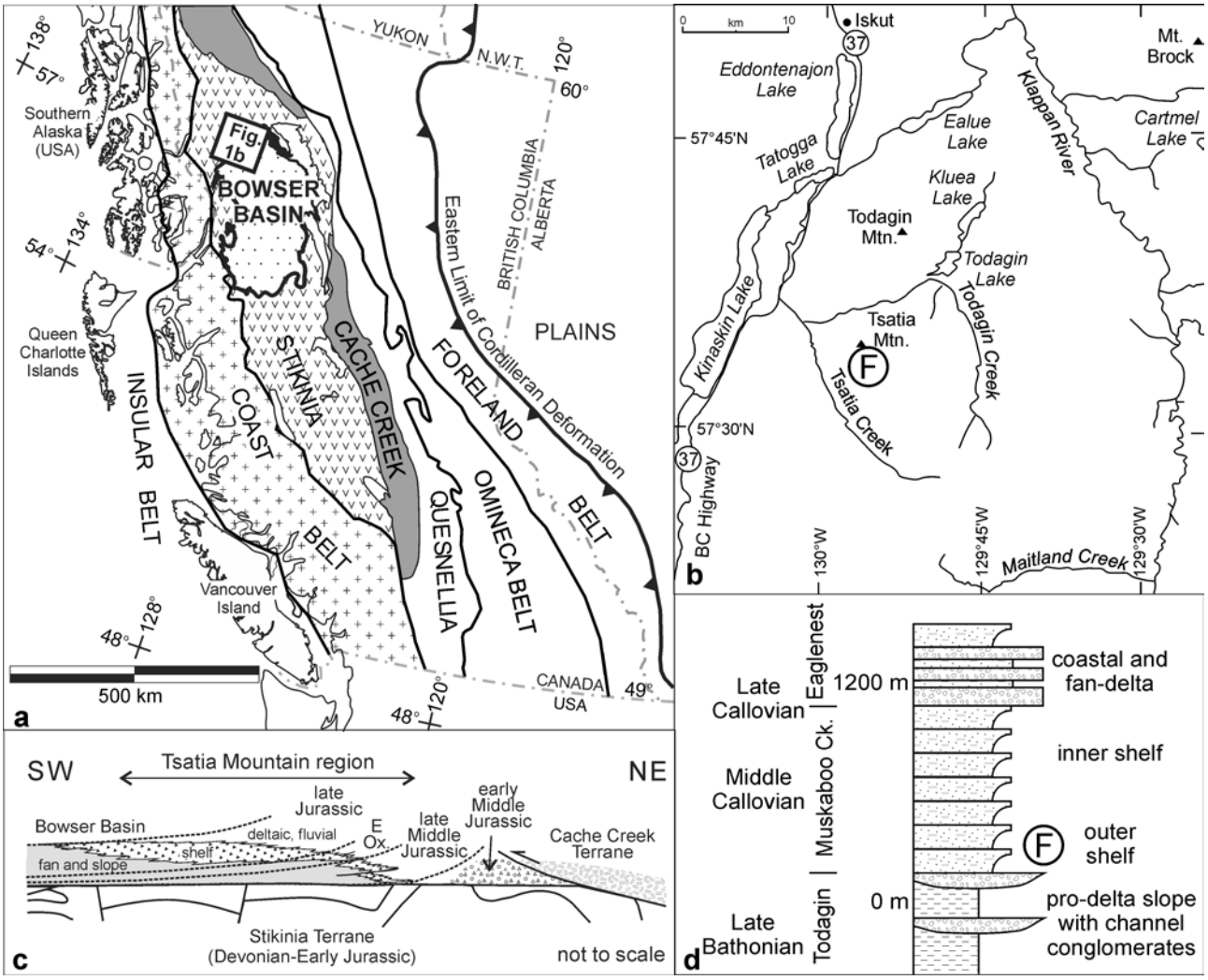


Fig. 1: **a**. Regional tectonic index map, British Columbia. **b**. Index map, Tsatia Mountain area, northwestern British Columbia. **c**. Conceptual cross-section illustrating facies assemblages in the Tsatia Mountain area and their supposed derivation from obducted Cache Creek source terrane to the northeast (modified from EVENCHICK & THORKELSON, 2005, fig. 8a). **d**. Generalized stratigraphic column, south side of Tsatia Mountain, modified from G. GREEN (1992; see also EVENCHICK & THORKELSON, 2005, fig. 48).

craton in eastern British Columbia and adjacent Alberta is consistent with accretions to the continent of western terranes such as Stikinia and Cache Creek about this time (e.g. EVENCHICK *et al*., 2010).

SYSTEMATICS

The Ammonite Faunas

Of nearly 300 identifiable ammonites collected at the primary locality (GSC Locality C-187052), 60% represent the Boreal subfamily Cadoceratinae (*Cadoceras, Stenocadoceras, Pseudocadoceras*), and 29% the Tethyan subfamily Pseudoperisphinctinae (*Indosphinctes, Elatmites*), all occurring as strongly dimorphic species. The closest affinities of the boreal components are with southern Alaska but similar forms occur elsewhere in western North America (e.g. TAYLOR *et al*., 1984), while the occurrences of the Tethyan forms in northern Bowser Basin are their only known record in North America. The association of Boreal and Tethyan elements is unusual for western Canadian Middle Jurassic faunas but its implications for terrane tectonics or paleo-oceanography are unclear. This interval is unknown on the coeval autochthonous craton. Additionally, *Adabofoloceras* comprises as much as 8% of the ammonite fauna. The abundance of this phylloceratid ammonite suggests open access to deep oceanic waters of the ancient Panthalassa/proto-Pacific Ocean, while the other ammonites most often occur with a variety of probable "shelf" faunas. The East Pacific eurycephalitinid ammonite *Lilloettia* apparently does not extend this high in the sequence and

Fig. 2: View of south east slopes of Tsatia Mountain. Cliff-forming channelled conglomerate lens with waterfall marks top of Todagin Assemblage. Ammonites described in this paper occur in double sandstone bed above and to the right of waterfall (GSC Localities C-175604 and C-187052; indicated by arrow), Muskaboo Creek Assemblage, Bowser Lake Group.

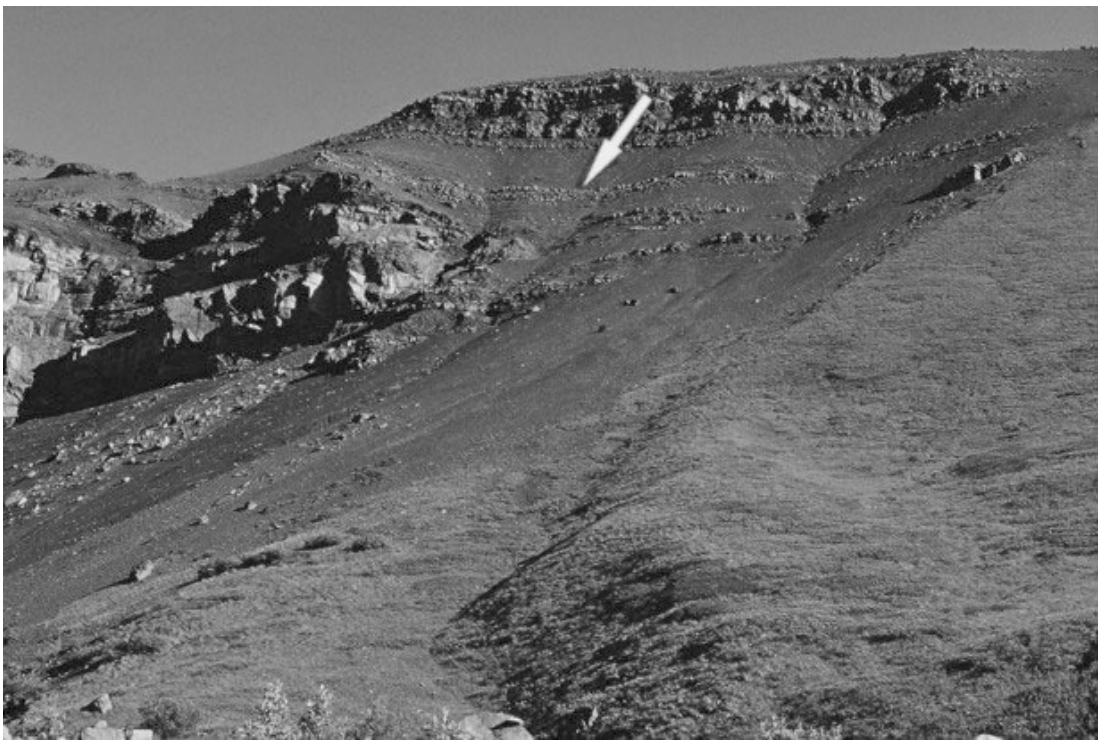


Fig. 3: View of collecting locality above base camp 1.1 km south east of peak of Tsatia Mountain, Bowser Basin. Lower scree slope and cliff-forming margin of conglomerate channel belong to Todagin Assemblage. Coarsening upwards cycles of siltstones and sandstones on scree slope above conglomerate belong to Muskaboo Creek Assemblage. Ammonites described in this paper come from sandstone bed marked with arrow (GSC Localities C-175604 and C-187052).

Fig. 4: Looking eastward, away from waterfall, along ammonite-bearing sandstone bed, Muskaboo Creek Assemblage (GSC Localities C-175604 and C-187052).

is no longer considered to occur in the Middle Callovian as first indicated by FREBOLD & TIPPER (1967). The Tsatia Mountain fossiliferous bed also contains a variety of bivalves, including *Pinna* in growth position and the distinctive trigoniid *Myophorella packardi* (CRICKMAY), another characteristic Lower and Middle Callovian guide fossil in western British Columbia. Some of these ammonites from northern Bowser Basin, including the first recognition of *Indosphinctes* in North America [as *Choffatia (Indosphinctes)* and *C. (Elatmites)*], were previously reported by POULTON *et al.* (1994, fig. 4), and most are listed in sequence in EVENCHICK *et al*. (2010, fig. 3B).

CALLOMON & WRIGHT (1989, p. 822-3) outlined some of the difficulties in treating the taxonomy of dimorphism in certain cardioceratid lineages, where a sequence of morphological changes seen in the evolution of macroconch genera appears not to be matched by the more conservative changes among the supposed corresponding microconchs. Proposed microconchs corresponding to all of *Arctocephalites*, *Arcticoceras*, and *Cadoceras* have usually been grouped into *Pseudocadoceras*, resulting in a stratigraphic range for this genus from the Middle Boreal Bathonian to the Upper Callovian. RAWSON (1982) separated as *Costacadoceras* some of these early microconch forms as dimorphic equivalents of the macroconch genus *Arctocephalites*. Since only two cardioceratid species occur in our fauna, *Cadoceras comma* and *C. (Stenocadoceras) stenoloboide*, and the morphology of their inner whorls can be closely compared with two microconch populations occurring in the same bed, we have chosen to recognize macroconch/microconch pairs under the same taxonomic name for these two species. We have treated dimorphism in *Indosphinctes* in the same way, although the amount of material for comparison is very limited; others (e.g. MANGOLD, 1971; COX, 1988) have treated microconchs of this genus as *Elatmites* SHEVYREV, 1960.

Age of the Fauna

While close taxonomic comparisons can be made with cadoceratids described from Alaska by IMLAY (1953), the faunal associations and stratigraphy of the Alaskan faunas remain poorly understood (CALLOMON, 1984), and there are unresolved problems with taxonomic definition of some older species names re-introduced by IMLAY. *Cadoceras* and *Indosphinctes* occur at various locations in Britain (COX, 1988), western Europe (MANGOLD, 1971) and European Russia (KISELEV, 2001) in rocks of Callovian age, but identification of our material with individual published European species, and correlation with the standard zonation scheme proposed for the Lower Callovian in Europe (see CALLOMON *et al.,* 1988) have been difficult. *Cadoceras, Pseudocadoceras,* and *Indosphinctes* occur together in European Russia in strata correlated with the Callovian Enodatum and Jason zones (KISELEV, 2001, p. 5, 6, and fig. 1), and therefore we propose correlation of the Bowser Basin

faunas with this interval. While KISELEV raised the Enodatum Subzone to zonal status (pp. 1, 17 and table 2) and made it the basal Zone for the Middle Callovian, this change has not been adopted subsequently by other Russian workers (KNYAZEV *et al.*, 2010). Evaluation of the taxonomy of cadoceratid and perisphinctid genera proposed in the rich and diverse faunas of European Russia and northern Siberia (KISELEV & ROGOV, 2007; KNYAZEV *et al.,* 2010; GULYAEV, 2011) is beyond the scope of this paper; our fauna is relatively species-poor in comparison, and occurs as a single horizon within a thick, poorly fossiliferous sequence.

Repository and field locations

All specimens are curated in the collections of the Geological Survey of Canada, Ottawa (prefixed GSC). Field localities are identified with six-digit grid references (eastings/northings) on the Kluea Lake 1:50 000 topographic map sheet (104 H/12), Edition 2, Zone 9, NAD 1927, published 1977.

Most of the ammonites described in this paper were collected in 1989 at GSC Locality C-187052 (Latitude 57°33'38"N, Longitude 129°56'18"W); Grid Reference 437799. This is the same locality as GSC Locality C-175604 where ammonites had been collected previously by C. EVENCHICK, who showed us the locality. The ammonites occur in the lower half of a 0.3 to 0.6 metre-thick sandstone bed, the lowest richly fossiliferous sandstone in a series of coarsening-upward, more or less recessive siltstone and more resistant, very fine grained sandstone cycles, some of which are hummocky cross-bedded in their upper part. The locality (Fig. 1b) is 1.2 km south-east of the peak of Tsatia Mountain, at an altitude of about 2000 m, 200 m east of a large waterfall formed over a thick conglomerate marking the top of the underlying Todagin Assemblage; it is approximately 52 metres stratigraphically above the top of this conspicuous conglomerate.

Suborder Ammonitina HYATT, 1889
Superfamily Stephanoceratacea NEUMAYR, 1875
Family Cardioceratidae SIEMIRADZKI, 1891
Subfamily Cadoceratinae HYATT, 1900
Genus *Cadoceras* FISCHER, 1882

Discussion: *Cadoceras* s. s. contains species that typically have a globose shell, strongly arched venter, deep umbilicus, and at least on the body chamber of macroconchs, a sharp umbilical edge. The adult body chamber is usually smooth, while on inner whorls the secondary ribs are directed forward over the venter, forming an angle. Several morphological groupings within the genus have been recognized, these usually being treated as subgenera; some of these are based on microconch specimens, while the taxonomic status of others remains dubious (IMLAY, 1953; CALLOMON, 1984). IMLAY (1953) identified some of his Alaskan material with taxa originally used by Russian workers; in doing so, he revived names whose status remains doubtful because their type specimens were either immature macroconchs, or microconchs (CALLOMON, 1984). It has seemed appropriate to us to continue using some of these taxa because of both morphological similarity and geographical proximity to Alaska.

At our locality, *Cadoceras (Stenocadoceras) stenoloboide* POMPECKJ is associated with abundant *Cadoceras comma* IMLAY, confirming the overlap of two faunas tentatively separated by CALLOMON (1984; his Faunas B8(e) and B9) and to which different ages were assigned.

Cadoceras comma IMLAY, 1953
Pl. I, figs. 1-17; Figs. 5.1-7

1953. *Cadoceras comma* IMLAY, p. 83, pl. 35, figs. 1-8, pl. 36, figs. 1-5 [holotype: figs. 1, 2].
1994. *Cadoceras comma* IMLAY; POULTON *et al.*, pl. 1, fig. 3 (macroconch), pl. 1, fig. 4 (microconch).

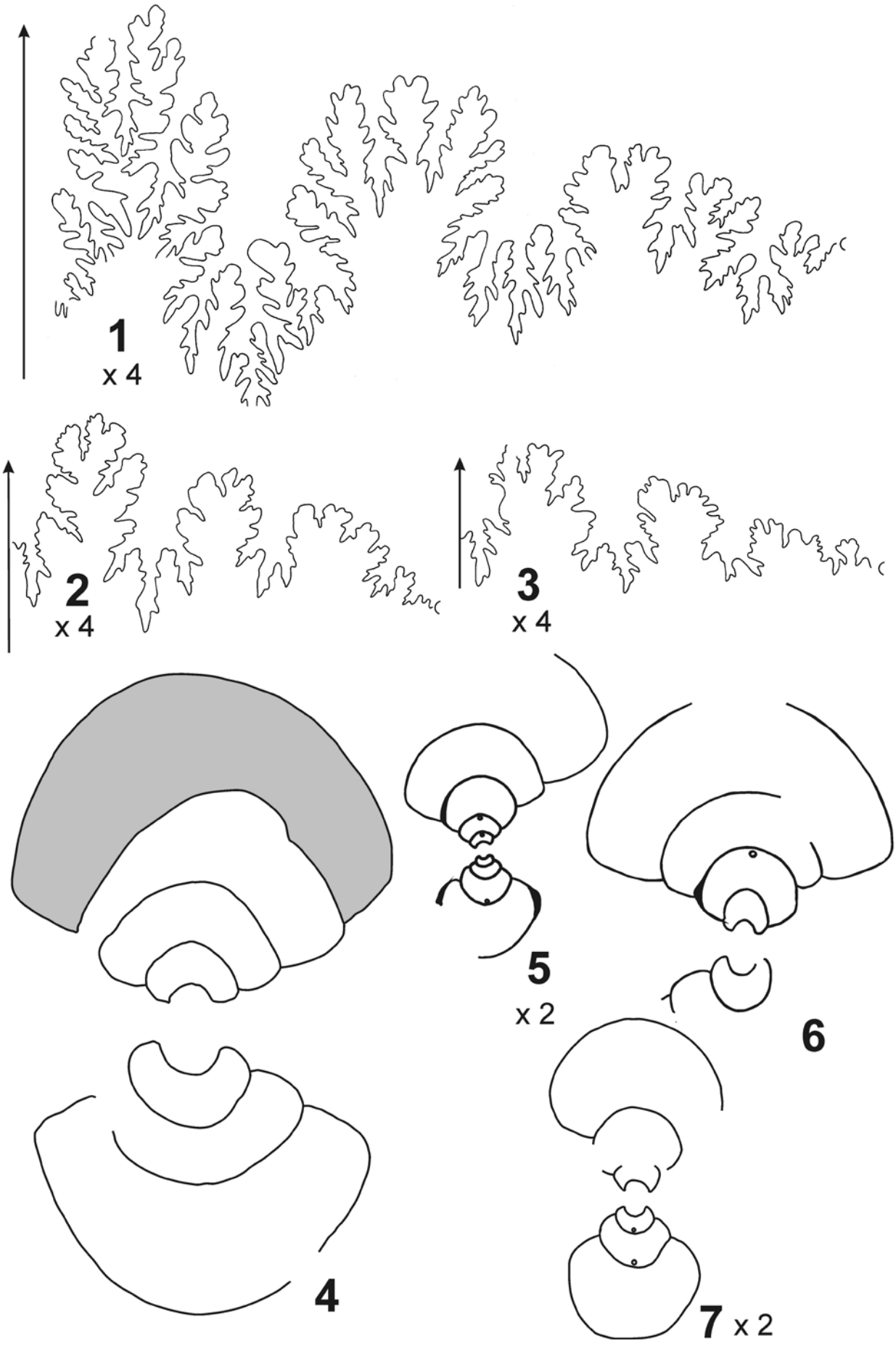
Description:

Macroconch: Involute, whorl section depressed at most growth stages, with very steep umbilical wall, umbilical margin abruptly rounded throughout later growth stages. Whorls wider than high (H/W = 0.5-0.8) on smallest preserved whorls (D < 10 mm), with steep, convex umbilical wall rounding gradually onto flanks, and with broadly arched venter; umbilicus represents 24-30% of shell diameter.

By shell diameters of 7.0 mm there are nine distinct, broad, primary ribs per half whorl, radial near the umbilical seam, curving strongly forward on upper parts of umbilical wall.

At D = 10-20 mm, venter becomes more narrowly arched, but whorls still wider than high (H/W = 0.6-0.8) with convex umbilical walls. Primary ribs very strong, 10-12 per half whorl, curving forward on upper part of umbilical wall; at, or just above, umbilical shoulder at about one third whorl height, most primaries swell and divide into two secondaries which cross almost straight over the venter where they are strongest and highest. Some primary ribs remain undivided and there are a few intercalated ribs arising a little higher than the branching point of other primaries, so there are approximately two secondaries to each primary; all ribs broad and rounded.

At larger diameters whorls remain depressed (H/W = 0.5-0.8), but umbilical wall becomes steeper and less convex, and venter is more broadly arched. Lower, vertical part of umbilical wall smooth, primary ribs appearing only on upper, convex part; 10-12 per half whorl. Ribs strong, curving forward across now more angular umbilical shoulder, where elongated swellings appear. These curve abruptly forward onto broad and flattened ventral region where secondary ribs arise both by bifurcation and intercalation. Secondary ribs only moderately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x 4
2
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4
5
x 2
6
7 x 2

strong, rounded, sweeping forward over the venter more markedly than on earlier whorls and outnumbering primaries by two or three to one.

Shell diameter of the last preserved septum on the five specimens ranges from 50 mm to just over 80 mm; however, it is not certain that the lower values are on mature specimens.

By end of phragmocone on two largest specimens umbilical walls much steeper, less convex, and almost entirely smooth, forming a deep, conical umbilicus which is only very slightly more open (U% = 28) than on earlier whorls. Ornamentation appears only as low, rounded, elongated nodes along fairly sharp umbilical shoulder, 13 or 14 per half whorl; nodes curve strongly forward onto ventral area, and a short distance beyond umbilical margin are reduced to low ribs or finer striations. Umbilical walls on body chamber remain very steep with fairly sharp shoulder, shell almost smooth except for very faint ribs crossing broad venter. Internal mold of GSC 134798 has aperture marked with a broad constriction.

Microconch (probable): Approximation of final sutures to indicate maturity cannot be seen on any of these specimens, nor is there any discernible uncoiling of the body chamber; we suggest they are microconchs because the ribs over the venter are increasingly projected forward. Whorls depressed (H/W = 0.6-0.8) and involute (U% = 22-32) throughout phragmocone, dimensions being identical with those of macroconchs at corresponding growth stages; last septum occurs at shell diameters of 25-30 mm. Unlike macroconchs, umbilical walls of body chamber remain convex, umbilical shoulder remains well rounded rather than becoming angular, and whorl cross section is less depressed (H/W = 0.7-0.9 *versus* 0.6-0.7 on macroconchs). Although aperture not preserved on any of our specimens, mature shells must have reached diameters of 40 mm, and final body chamber was two-thirds of a whorl in length.

At D < 3.0 mm, shell smooth. At D = 3.0-5.0 mm, primary ribs conspicuous, 9-11 per half whorl, but of variable strength and spacing: some thin and wiry with even spacing, others heavier and grouped in pairs. Ribs radial near umbilical seam where wall almost vertical, then slope forward approaching shoulder and recurve backwards on visible part of ventral shell. By diameters of 5.0 mm primary ribs very strong, 6-8 per half whorl, rounded, beginning low on umbilical wall, strongly prorsiradiate. Unlike macroconchs, ribbing remains very strong on body chamber with 9-12 primaries and 16-20 secondaries per half whorl. No evidence on internal molds of a swelling developed where ribs bifurcate at one third to one half whorl height; about one third of ribs remain simple and unbranched, and intercalated ribs are rare. Secondary ribs as strong as primaries, high, rounded, crossing venter with broad forward deflection on earlier parts of body chamber, this becoming more pronounced towards end of preserved specimen.

Remarks: Though some of IMLAY'S specimens from southern Alaska have denser ribbing with 16-19 sharp, concave, regularly spaced ribs per half whorl (his pl. 36, figs. 1, 4, 5), others have as few as 11 (his pl. 35, figs. 1, 6). Umbilical walls on our specimens slightly more convex than on IMLAY's material.

Of the other species in IMLAY'S (1953) Group 2, *C. catostoma* has coarser ribbing on later whorls than our specimens; the inner whorls of *C. glabrum* IMLAY have somewhat weaker and denser ribbing which becomes faint and almost obsolete before the end of the phragmocone; and *C. bathomphalum* IMLAY (based on a single specimen: IMLAY'S pl. 38, figs. 1, 5, 6) may be synonymous with *C. comma*, also having depressed whorls (H/W = 0.47-0.57) and obsolete ribbing on its body chamber, though its venter appears less strongly arched.

Macroconchs of *C. comma* differ from British Lower Callovian species of the genus, such as *C. tolype* BUCKMAN, 1923, and *C. sublaeve* (J. SOWERBY) in having convex rather than straight umbilical walls, a step-like rather than conical umbilical profile, a strongly rounded rather than sharp umbilical shoulder on intermediate and later whorls, and a failure to develop a globular cross section and such large size at maturity. In addition, our specimens have more deeply dissected sutural elements with an especially narrow E/L saddle, and deeper, narrower U_2 lobe with more lobules (Fig. 2.1).

Macroconchs of the associated species, *C. (Stenocadocers) stenoloboide*, differ from *C. comma* in having compressed whorls with narrowly arched venter except on the final part of the body chamber, a much shallower umbilicus with sloping umbilical walls, and flatter flanks, especially on inner whorls.

The close similarities in whorl dimensions, coiling, and ornamentation throughout much of the phragmocone support the dimorphic pairing proposed here. Middle Bathonian *Costacadoceras*, erected by RAWSON (1982) for microconch forms corresponding to the Arctic macroconch genus *Arcticoceras*, attains somewhat larger diameters at maturity (60 m), has more evolute coiling, and denser and sharper ribbing throughout than seen on microconchs of *C. comma*. Species of another microconch genus, *Pseudocadoceras* BUCKMAN, 1919,

Fig. 5: *Cadoceras comma* IMLAY, 1953. **1.** Macroconch suture line at D = 55 mm, GSC 134796; **2.** Macroconch suture line at D = 32 mm, GSC 134798; **3.** Microconch **s**uture line at D = 29 mm, GSC 134801; **4.** Macroconch cross section at D = 119 mm, GSC 134798; **5.** Macroconch cross section at D = 20.8 mm, shown x2 magnification, GSC 134797; **6.** Macroconch cross section, GSC 100713; **7.** Microconch cross section at D = 29 mm, shown x2 magnification, GSC 134801. All specimens natural size unless otherwise indicated; body chamber shaded.

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all have finer, denser, and more flexuous ribbing and compressed whorls with narrowly arched venter (IMLAY, 1953; CALLOMON & WRIGHT, 1989), whereas the present material has depressed whorl cross sections with broadly arched venters at all growth stages, with broad and rounded ribs. Even the most coarsely ribbed Alaskan species, *P. crassicostatum* IMLAY, has compressed body chamber whorls (1.1-1.2 *versus* 0.6-0.7 on ours), a much narrower venter and sharper ribbing.

Material: Five macroconch (including GSC 134798, 100713, 134797, and 134796) and three possible microconch (GSC 100714, 134800, and 134801) specimens, associated with *C. (Stenocadoceras) stenoloboide* and collected from a single bed at GSC Locality C-187052.

Subgenus *Stenocadoceras* IMLAY, 1953

Discussion: IMLAY introduced this name for one of seven morphological groups he distinguished within the genus *Cadoceras* FISCHER, 1882, designating *C. multicostatum* IMLAY (IMLAY, 1953, pp. 46, 90, pl. 44) as type species. He placed in *Stenocadoceras* those species having moderately large shells, compressed whorls, and a narrow umbilicus (U% = 14-23) with a rounded shoulder on inner whorls which becomes abrupt on the body chamber. Ribbing may become obsolete on the body chamber, and tubercles are weak or absent.

Four of the species erected by Imlay (*S. multicostatum, S. striatum, S. iniskinense,* and *S. bowserense*) are probably variants of a single bio-species, and synonyms of *S. stenoloboide* POMPECKJ (see discussion below under the last-named species). The remaining Alaskan species, *S. pomeroyense* IMLAY, belongs in *Longaeviceras* as already noted by CALLOMON (1984, p. 162). Of the Russian taxa included by IMLAY in *Stenocadoceras*, *S. stenolobum* (KEYSERLING) [type re-figured in SOKOLOV, 1912, pl. 1, fig. 4] and *S. nikitini* (SOKOLOV) [SOKOLOV, 1912, pl. 1, figs. 3b, c, d; *not* fig. 3a], both have a narrow venter, with ribs projected strongly forward across the flanks as seen in *Longaeviceras*. The body chamber on "*Stephanoceras*" *stenolobum* NIKITIN (1882, pl. 12, figs. 28-30) [= *Cadoceras stenolobum* var. *densicostata* SPATH] develops an umbilicus with a sharp margin, steep walls and conical profile typical of *Cadoceras* s. s. "*Stephanoceras*" *milaschevici* NIKITIN and "*S.*" *compressum* NIKITIN (1881, pl. 3, figs. 25, figs. 26, 27 respectively) are both based on juvenile specimens; their actual generic and/or subgeneric affinities cannot realistically be interpreted, though as CALLOMON (1984, p. 162) has noted, the outer whorls of *C. milaschevici* (as subsequently illustrated by SAZONOV, 1957) are again typical of *Cadoceras* s. s.

Cadoceras dubium SPATH (1932, p. 73, pl. 22, fig. 2) was based on a single small specimen which is entirely body chamber, so that it is either a juvenile macroconch or an almost-complete microconch. SPATH noted slight projection of secondary ribs on the venter near the end which would support the latter alternative, in which case it is a coarsely-ribbed species of *Pseudocadoceras*.

Cadoceras (Stenocadoceras) stenoloboide POMPECKJ, 1900
Pl. II, figs. 1 -18; Fig. 6.1-7

Macroconch:

1900. *Cadoceras stenoloboide* POMPECKJ, p. 255; pl. 7, figs. 2a-e, 3a, b.
1953. *Cadoceras (Stenocadoceras) stenoloboide* POMPECKJ; IMLAY, p. 92; pl. 46, fig. 3; pl. 47, figs. 1-15.
1985. *Stenocadoceras stenoloboide* (POMPECKJ); CALLOMON, p. 69, text-fig. 80 [holotype of *S. iniskinense* IMLAY actually figured].
1994. *Cadoceras (Stenocadoceras?) stenoloboide* POMPECKJ *sensu* IMLAY. POULTON *et al.*, pl. 1, fig. 1 (macroconch); pl.1, fig 2 (microconch).

Description:

Macroconch: Smallest observable whorls on macroconchs (D = 10-15 mm) compressed (H/W = 1.15), with shallow umbilicus, involute (U% = 19-25), walls rounding gradually from umbilical seam onto flattened flanks; venter narrowly arched. At this stage primary ribs arise a little above umbilical seam, 13 per half-whorl; moderately strong, evenly spaced and slightly concave forward as they cross flanks. At one third whorl height (just hidden by overlap of subsequent whorl) all ribs bifurcate without swellings or tubercles, there being few intercalatories or single ribs; secondary ribs, after slight backward curvature, bend forward on upper flanks with slightly accentuated projection over the venter.

Macroconchs show little change in whorl dimensions at diameters of 30-50 mm, except that lower flanks become more convex with steepening of umbilical wall, and some secondary ribs arise less obviously by bifurcation. These trends continue until end of phragmocone (last suture at diameters between 62 and 92 mm), where whorls are slightly wider than high (H/W = 0.80), umbilical wall becomes nearly vertical, rounding abruptly onto almost flat flanks which converge gradually towards strongly arched venter. Umbilical wall smooth, with primary ribs arising near its upper edge as short swellings directed strongly forward across umbilical edge; 13 per half-whorl. Secondary ribs arise by bifurcation and intercalation at about one-third whorl height, secondaries now outnumbering primaries by almost 3:1; they incline forward across flanks, are slightly flexuous, but cross straight over venter where they are strongest, rounded and very evenly spaced. Body chamber of macroconchs at least one volution in length, whorl slightly wider than high (H/W = 0.8), almost vertical umbilical wall with strongly rounded shoulder along which blunt swellings, 9 per half-whorl, extend forward onto lower flanks where, on internal molds, they fade quickly. Lower flanks almost smooth; faint secondaries (now outnumbering primaries

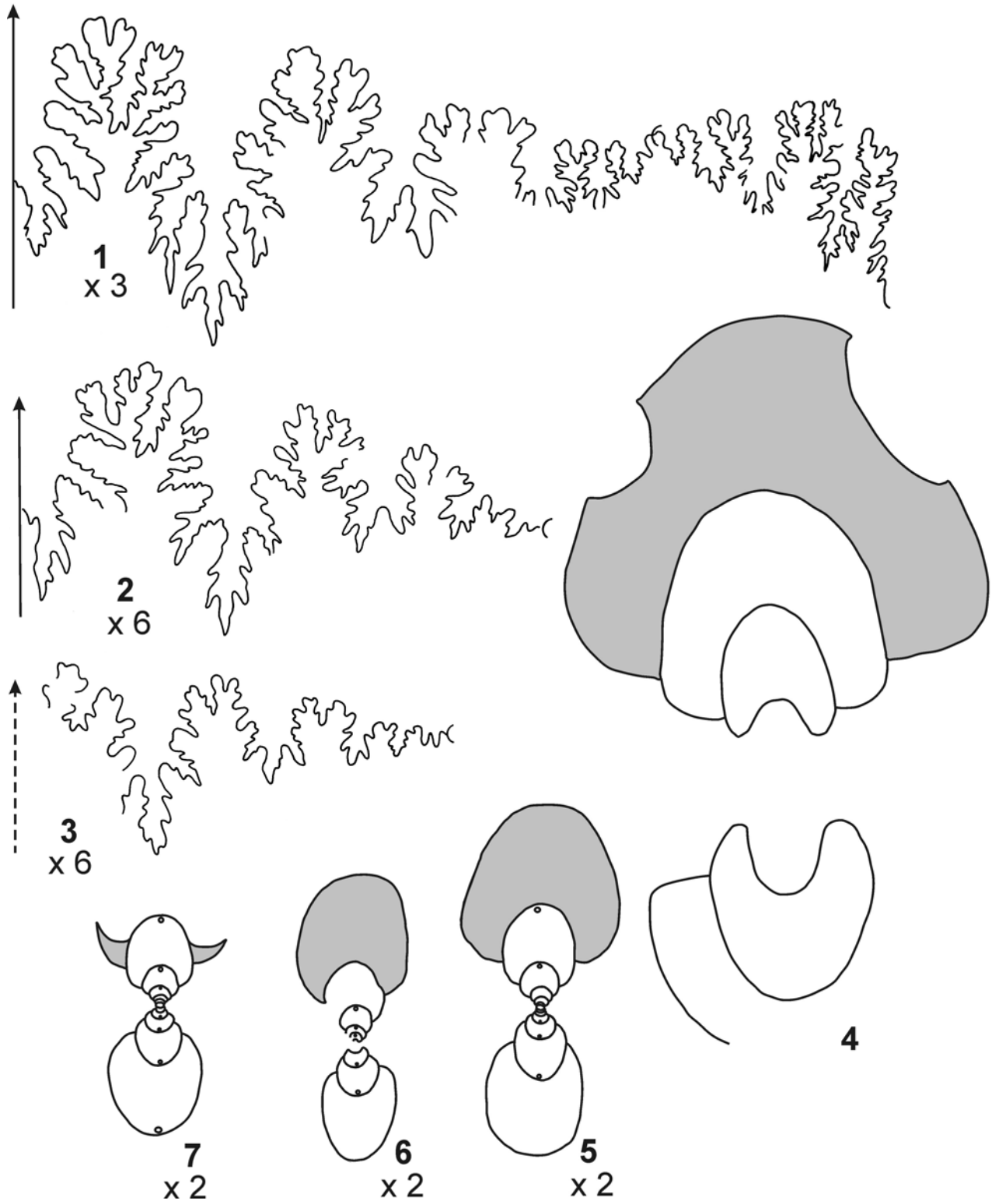


Fig. 6: *Cadoceras (Stenocadoceras) stenoloboide* (POMPECKJ, 1900). **1.** Macroconch suture at D = 61 mm, shown at x3 magnification, GSC 134803; **2.** macroconch suture at D = 29 mm, shown at x6 magnification, GSC 134802; **3.** microconch suture at D = 21 mm, shown at x6 magnification, GSC 134810; **4.** macroconch cross section at D = 170 mm (approx.), GSC 100711; **5.** microconch cross section at D = 30 mm, shown at x2 magnification, GSC 134811; **6.** microconch cross section at D = 24 mm, shown at x2 magnification, GSC 134812; **7.** microconch cross section, shown at x2 magnification, GSC 134813. All specimens natural size unless otherwise indicated; body chamber shaded.

by 3 or more to 1) arise higher on flanks, almost straight, but strongly directed forward across upper flanks, gaining strength approaching strongly arched venter.

Microconch: Nucleus of macroconch unknown; that of microconch is smooth, generally involute (U% = 18-42), whorls much wider than high (H/W = 0.55-0.70) with broadly arched venter, and highly convex flanks rounding continuously toward umbilical seam. Ornamentation appears at D = 4-6 mm as thin, unevenly developed primary ribs on flanks, very strongly concave forwards, with broader secondaries crossing straight over venter. Whorl cross-section changes to rounded and then slightly compressed by D = 10.0 mm (H/W changes correspondingly from 0.8 to 1.1).

Near end of phragmocone (last suture at D = 23-37 mm) shell remains involute (U% = 14 - 30), with compressed whorl section (H/W = 1.0-1.12) but slightly steeper umbilical wall. Twelve to sixteen primary ribs per half-whorl, strongly concave forward, but relatively fewer secondary ribs than on earlier stages, the ratio being from 2:1 to as low as 1.4:1; some primaries clearly bifurcate, others remain unbranched but alternate with secondaries arising by intercalation, while a few cross venter as simple ribs.

Body chamber of microconchs at least one half whorl in length (mature apertures not preserved), differing from macroconchs in retaining slightly compressed whorl section to the end (H/W = 1.0-1.1), with strong primary and secondary ribs, but swellings on umbilical margins absent; secondaries now strongest on venter where they arch forward to form rounded chevrons. Ribs quite variable in style, some clearly bifurcating, others with intercalated secondaries, and still others remaining simple.

Remarks: Macroconchs of this subgenus are unknown in Europe and East Greenland (CALLOMON, 1984). Here we follow IMLAY'S (1953) interpretation of POMPECKJ'S species which, as CALLOMON (1984) has pointed out, was based on four syntypes, all probably microconchs. Our specimens very closely resemble IMLAY's Alaskan macroconch specimens in whorl shape, involution, coiling, and style and density of ribbing, differing only in having a slightly less compressed body chamber. Of the other Alaskan species erected by IMLAY, *S. iniskinense* has slightly denser secondary ribbing (2.8 *versus* 2.2 per primary), but in all other features appears to be conspecific. *S. striatum* has more compressed whorls (H/W = 1.5-1.7 versus 1.2-1.3), is more involute (U% = 15 versus 19-25), and has finer and denser ribs (20 primaries per half-whorl versus 12-15 at similar diameters) which are reduced to faint striations even before the body chamber is attained. *S. multicostatum* has more compressed phragmocone whorls with a narrower venter, shallower umbilicus, and finer, denser ribs at all stages, which are reduced to striations prior to reaching the almost smooth body chamber. *S. bowserense* is more involute (U% = 16 versus 19-25) with finer and denser ribs. These four "species" are probably variants of a single bio-species showing intergradation in rib density, degree of involution and whorl compression. *S. stenoloboide* may be retained as a separate taxon on the basis of its less dense ribbing which is retained well onto the body chamber, although some of the forms illustrated by IMLAY (his pl. 47, figs. 11, 13) also have reduced ribbing on the body chamber. All of these "species" are associated at localities in the Chinitna (upper part of middle third and upper third) and Shelikof (middle member) formations of southern Alaska.

As no specimens with preserved apertures exist in our collections, establishing that smaller specimens preserved with at least some part of a body chamber whorl represent mature microconchs as opposed to immature macroconchs often proves difficult. Only the final two septa are slightly approximated, but not simplified, there is only slight egression over the last half-whorl, and the forward projection of ribs to form chevrons as they cross the venter is more strongly developed.

Microconchs for all subgenera of *Cadoceras* have been placed in *Pseudocadoceras* (CALLOMON, 1984, p. 150; CALLOMON & WRIGHT, 1989, p. 822), a genus initially characterised as being "like young *Cadoceras*, but not developing cadicone stage, only feeble inflation" (BUCKMAN, 1918, p. xiv). Separation of these forms from *Costacadoceras,* introduced by RAWSON (1982) for microconchs probably corresponding to the boreal Bathonian genus *Arcticoceras*, is not clearly established but, compared to our microconch material of *S. stenoloboide*, the only described species of *Costacadoceras* (*C. bluethgeni* RAWSON) has slightly denser primaries, with a lower secondary/primary ratio (1.5-1.7 *versus* 1.6-2.1 on ours) because of having more unbranched primaries, and is slightly more evolute on the body chamber (U% = 27-34 versus 19-31 on ours). Distinguishing between species of *Pseudocadoceras* over such a long vertical range is problematical, given their small size and fairly invariant morphology, especially as several morphological trends tend to be repeated or reversed within this interval (CALLOMON, 1985; CALLOMON & WRIGHT, 1989). Compared to our material, the holotype of the type species, *P. boreale* BUCKMAN (from the Koenigi Subzone, Calloviense Zone, of Yorkshire; CALLOMON & WRIGHT, 1989), is smaller at maturity, has a narrower umbilicus (U% = 14 - 21), and much narrower venter on which the secondary ribs form distinct V-shaped chevrons. Two other British species, *P. laminatum* BUCKMAN and *P. concinnum* BUCKMAN, are each based on laterally flattened holotypes which seem to be more evolute, but have more strongly projected secondary ribs on the venter of the body chamber than any of our material. *P. grewingki whithami* was proposed as a British geographic subspecies (CALLOMON & WRIGHT, 1989, pl. 94, figs. 7, 8), and compared with *P. grewingki* POMPECKJ as interpreted by IMLAY (1953) based on Alaskan material. This subspecies differs from both the Alaskan and Bowser Basin material placed in

Pseudocadoceras in having more numerous simple ribs which cross the venter without bifurcating or being associated with an intercalated rib; on the body chamber and final half-whorl of the phragmocone as many as 15 of the 22 primaries per half whorl exhibit this condition (sometimes occurring in groups of 2-3 adjacent ribs, with only one bifurcating rib between neighbouring bundles of simple ribs; see CALLOMON & WRIGHT, 1989, pl. 94, fig. 7a), resulting in a low secondary/primary ratio of 1.3 (compared to 1.8 to 2.0 on the Alaskan and Bowser Basin specimens). *P grewingki whithami* also has more numerous primary ribs (22 per half-whorl *versus* 13 - 17 on the Alaskan and Bowser Basin specimens), and is slightly more evolute (U% = 29 - 32 on the body chamber versus 24 on Alaskan specimens and 14-30 on Bowser Basin material). POMPECKJ'S original specimens (1900; pl. 6, figs. 1-3) also exhibit fewer primary ribs per half-whorl (13 versus 22) and fewer simple ribs, resulting in a secondary/primary ratio of 1.6-2.0 versus 1.3 on *P. grewingki whithami.*

Compared with proposed microconchs of *Cadoceras comma* IMLAY which occur in the same bed, microconchs of *C. (Stenocadoceras) stenoloboide* POMPECKJ have compressed rather than depressed whorls at all but the earliest stages (D < 6-7 mm), attain a larger size at maturity, develop steeper umbilical walls on the body chamber, have narrower, more densely spaced and strongly curved primaries and more flexuous secondaries. As well, a significant number of ribs on the body chamber remain simple and unbranched, a feature only occasionally seen on the probable microconchs of *C. comma* identified here.

Material: Macroconchs: GSC 134802, an undistorted macroconch with one complete whorl of body chamber preserved, collected by C. EVENCHICK at GSC Locality C-175604; GSC 100711, a fragmentary specimen with less than a quarter whorl of body chamber preserved, and GSC 134803 from the same locality; one specimen from Locality C-187055, from scree on south-east side of Tsatia Mountain, stratigraphically above Locality C-187052. Four immature macroconchs reach significantly larger sizes than known mature microconchs, but have non-approximated final septa, such as GSC 100712 and GSC 134828. **Microconchs:** Eleven specimens (including GSC 134806, 134807, 134808, and 134809), most relatively complete with at least part of body chamber preserved, and subtle approximation of final sutures. One additional specimen, GSC 134806 from GSC Locality C-175604.

Superfamily Perisphinctacea STEINMANN, 1890
Family Perisphinctidae STEINMANN, 1890
Subfamily Pseudoperisphinctinae SCHINDEWOLF, 1925
Genus *Indosphinctes* SPATH, 1930

Discussion: SPATH (1930, p. 36) introduced *Indosphinctes* for perisphinctids whose inner whorls were "irregularly ribbed, with primaries not prominent and often bundled, or confined to a blunt node at the umbilical edge" (SPATH, 1931, p. 325); he noted that such forms were closely related to both *Siemiradzkia* and *Procerites*, and included all three in his Subfamily Grossouvriinae. MANGOLD (1971) gave a detailed treatment of the genus, placing it in the Subfamily Zigzagiceratinae BUCKMAN because of the occurrence of a 'zigzag' stage of ornamentation on the inner whorls, and its complex suture line, with a trifid and asymmetrical lateral lobe, a strongly retracted suspensive lobe, and a narrow first lateral saddle; a tendency toward polychotomous or pseudovirgatoid ribbing on later whorls was also noted. He selected *Elatmites* SHEVYREV as the corresponding microconch genus, whereas COX (1988, p. 21) used *Indosphinctes* SPATH to accommodate both macro- and microconch forms. She added to the diagnosis the rursiradiate nature of the secondary ribbing often with ventral weakening, particularly near the end of microconch phragmocones, and the presence of both parabolic structures and weak constrictions.

Both macroconch and microconch specimens of *Indosphinctes* collected at this locality fall into broader- and narrower-whorled forms, but because of the small numbers of specimens available to us, we have chosen to recognize that distinction at the variety level.

Indosphinctes tsatiaensis n. sp.

Name derivation: "*tsatiaensis*" refers to Tsatia Mountain, on the southeast side of which this fauna was collected.

Diagnosis: The diagnosis and description for this species is the same as provided below, encompassing the characteristics of both narrow and inflated varieties *latus* and *angustus.*

Holotype: Macroconch holotype: GSC 134814, the same as for variety *latus.*

Indosphinctes tsatiaensis var. *latus* n. var.
Pl. III, figs. 1-6; Fig. 7.1, 3, 4, 5

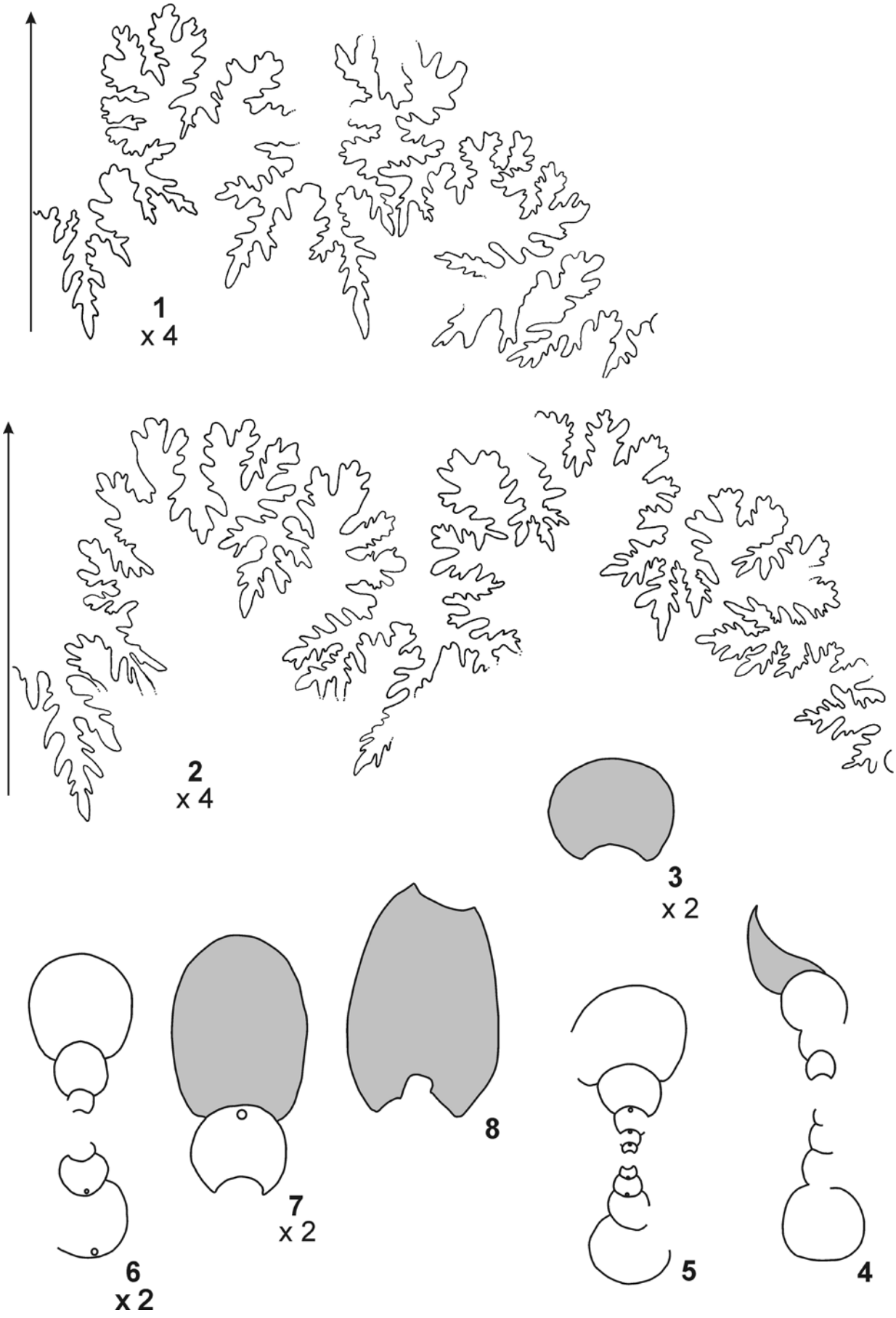
1994. *Choffatia* sp. POULTON *et al*., macroconch, pl. 1, fig. 5.

Name derivation: "*latus*", Latin for broad or wide, a reference to the relative whorl width of this variety.

Type specimens: Macroconch holotype: GSC 134814; microconch allotype: GSC 134817.

Description:

Macroconch: Specimens incomplete, inner whorls missing or crushed, three with half-whorl of body chamber; however, it is unknown whether any of these is mature. Coiling evolute throughout (U% = 38 - 54) with no consistent trend during ontogeny. Two macroconch specimens have depressed inner whorls (H/W = 0.65 - 0.80), the smallest whorls having a broadly rounded


1
x 4
2
x 4
3
x 2
8
7
x 2
6
x 2
5
4

venter with slightly flattened flanks; whorls become more rounded during ontogeny, with slightly compressed body chamber (H/W = 1.0 - 1.1).

Ribs on inner whorls quite strong, rounded in section, and almost rectiradiate; at irregular intervals two adjacent ribs are closely spaced and elevated to form broader whorl segment, with deeper and wider inter-costal space immediately adjacent to the pair. Rib divisions on these smaller whorls hidden by overlap of subsequent whorls. Occasional constrictions on some, but not all, specimens usually associated with simple ribs. Primaries on phragmocone whorls number 13-24 per half-whorl, decreasing to 11-13 on body chamber, and becoming heavy and blunt. Here the primary ribs begin just above umbilical seam, where they are highest, fading somewhat toward upper flanks; almost rectiradiate and widely spaced, except where two ribs are more closely spaced and usually more prorsiradiate to produce what appears to be a constriction between them. Occasional broad, deep and prorsiradiate constrictions also occur. Secondary ribs arise very high on flanks, some by branching but mostly by intercalation; slightly rursiradiate on venter where they fade, leaving a smooth, midventral band on internal molds; much weaker than primaries and outnumber them by 2-4:1. On some specimens there is occasional virgatotome ribbing. Nodes generally absent. Occasionally, paired, irregularly-swollen areas occur high on flanks or edge of ventral area, around which ribs are distorted and obsolescent; these occur more frequently near end of microconch phragmocone and often involve backward deflection of secondary ribs and growth lines.

Microconch: The single body chamber fragment (GSC 134817) representing the microconch of this species is almost 36 mm in diameter, and somewhat distorted. In those whorl dimensions that can be measured, and in the spacing, shape and irregularity of ribbing, it closely matches the proposed corresponding macroconch specimens from the same bed.

Remarks: Of the new macroconch species from Cutch described by SPATH (1931, p. 339, pl. 102, fig. 2), *Indosphinctes patiniformis* is closest to ours in also having strong, irregular primary ribs and a similar whorl section; however, on his species primaries are more rounded and branch lower on the flanks, while secondaries are coarser and less dense. *I. patina* (NEUMAYR, 1871, p. 41, pl. 13, fig. 2) has more regularly spaced primaries throughout, with finer and much longer secondaries than on our material. The coarser, more widely- and much more irregularly-spaced primary ribs, with secondaries appearing much higher on the flanks, all distinguish our material from any of the species illustrated by MANGOLD (1971).

Material: Seven fragmentary and incomplete macroconchs (including GSC 134814, 134815, and 134816) and a single microconch body chamber (GSC 134817) from GSC Locality 187052. Two additional specimens from GSC Locality C-175604.

Indosphinctes tsatiaensis var. *angustus* n. var.
Pl. III, figs. 7-13, Fig. 7.2, 6-8

1994. *Choffatia* sp. POULTON *et al*., microconch, pl. 1, fig. 6.

Name derivation: "*angustus*", Latin for narrow or slender, referring to the relatively compressed whorls on this variety.

Type specimens: Macroconch holotype: GSC 134828; microconch allotype: GSC 134825.

Description:

Macroconch: Diameter of larger specimen (GSC134820) after only one-third whorl of body chamber is 160 mm; coiling evolute (U% = 48-52), whorls rounded to slightly compressed with flattened flanks (H/W = 0.8-1.2). Primary ribs begin almost at umbilical seam, are long, rectiradiate to slightly prorsiradiate and rounded in cross section, 19-23 per half-whorl, fairly evenly spaced. Periodically on phragmocone whorls two narrower, sharper ribs are more closely spaced but without development of constrictions; on body chamber such bundling rarely seen. Secondary ribs arise both by branching without nodes, and by intercalation very high on flanks; less robust than primaries, outnumbering them 3:1, crossing straight over venter. Ribs persist at least onto first third of body chamber whorl, where both primaries and secondaries become broader but not fainter. Constrictions absent on phragmocone whorls, though a faint one developed on larger specimen at transition from phragmocone to body chamber.

Microconch: Small, reaching maximum diameters at maturity of 45-60 mm, with body chamber one half-whorl in length; diameter at end of phragmocone ranges between 35 and 40 mm. Mature aperture marked by narrow smooth band preceding relatively deep, narrow constriction, with short lateral lappets. Coiling throughout evolute (U% = 37-48) with little whorl overlap. Innermost whorls with smooth flanks up to D = 6.0 mm; at larger diameters primary ribs strong, rounded, increasing in strength across flanks, slightly flexuous, 10-12 per half

Fig. 7: *Indosphinctes tsatiaensis* var. *latus* n. sp. and subsp. **1.** Macroconch suture drawn at D = 75 mm, shown at x4 magnification, GSC134816; **3.** microconch cross section, shown at x2 magnification, GSC 134817; **4.** macroconch cross section, GSC 100715; **5.** microconch cross section, GSC 134819. *Indosphintes tsatiaensis* var. *angustus* n. sp. and subsp.; **2.** Macroconch suture, shown at x4 magnification, GSC 134820; **6.** microconch cross sections, shown at x2 magnification, GSC 134826; **7.** microconch cross section, shown at x2 magnification, GSC 134823; **8.** Macroconch cross section, GSC 134820. All specimens natural size unless otherwise indicated; body chamber shaded.

whorl. Ribs frequently irregular in spacing, with bundling of two or more finer and sharper ribs, usually associated with several faint striations and smoother, wider inter-rib space or occasionally shallow constriction separating adjacent more regular ribs. Rib density increases on body chamber to 18-24 per half whorl, flexuous to almost rectiradiate, weaker but more regularly spaced than on phragmocone. Secondary ribs appear very high on flanks, some by branching without nodes, some by intercalation; cross venter with broad, shallow, backward deflection. Secondaries here outnumber primaries 2:1.
Suture fairly deeply dissected, with several umbilical lobes strongly suspended.

Remarks: *Indosphinctes cesaredensis* MANGOLD (1971, pl. 13, fig. 1) and *I. choffati* (PARONA & BONARELLI, 1897, pl. 8, fig. 3; MANGOLD, 1971, pl. 11, figs. 1, 2), from the Lower Callovian Patina Zone (= Enodatum Subzone, topmost Calloviense Zone) from Savoie and Portugal, respectively, both resemble our material, but the former species has stronger and less densely-spaced primary ribs, especially on the last whorl, while on both species secondaries appear lower on the flanks than on ours.
Our microconchs are very similar to the group of *I. (Elatmites) calloviensis* (LOCZY), *I. (E.) anomala* (LOCZY) and *I. (E.) curvicosta* (OPPEL), described and illustrated by LOCZY (1915) as species of *Idoceras* or *Perisphinctes*, by SPATH (1931) as species of *Grossouvria*, and by MANGOLD (1971), who transferred all three to *Elatmites* as microconch forms corresponding to *Indosphinctes*. In France, all three species were said to come from the Lower Callovian Koenigi Zone (MANGOLD, 1971). Ours generally have finer and more strongly curved primary ribs on the body chamber, while on juvenile whorls the ribs are coarser, with more frequent grouping to produce irregular spacing and sudden changes in whorl width.
Microconch specimens of *I. patina* (NEUMAYR) figured by COX (1988, pl. 8, figs. 3, 4) from the Jason subzone of the Jason Zone in central England attain larger diameters at maturity (D = 90 mm), have more regular ribbing on their inner whorls, and a more compressed body chamber on which primary ribs are more distant and secondary ribs more numerous (outnumbering primaries 4:1). A microconch of *I. lobatus* (BUCKMAN) from the Koenigi subzone (Calloviense Zone, Dorset) illustrated by COX (1988, pl. 6, fig. 3) is very similar in size, coiling and ornamentation, but is more compressed, with straighter and more distantly-spaced primary ribs on the body chamber, less strongly rursiradiate secondary ribs, and more regular rib spacing on juvenile whorls than is seen on our specimens.
Our material also resembles *Grossouvria* SIEMIRADZKI [as discussed by SIEMIRADZKI (1898), MANGOLD (1971), and COX (1988), and now made the corresponding microconch to *Choffatia* SIEMIRADZKI], in having parabolae, constrictions and rursiradiate secondary ribbing, but differs in having less regularly-spaced primary ribs throughout. In particular, our material resembles the several subspecies of *Grossouvria kontkiewiczi* (SIEMIRADZKI) illustrated by MANGOLD (1971, pl. 8, figs. 3-6), but we question MANGOLD'S identification of his material with SIEMIRADZKI'S species; it could well belong in *Elatmites*.
Material: Macroconchs: Two specimens (GSC 134820, an external mold [remaining]; and GSC 134828 [holotype]) from GSC Locality C-187052. **Microconchs:** Seven specimens, including GSC 134823, 134824, 134825 [allotype], and 134826, more or less complete, several with lappets, from GSC Locality C-187052. Two additional microconchs from GSC Locality C-187054, grid reference 438801, Kluea Lake 1:50,000 topographic map sheet, 104 H/12.

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John CALLOMON was an important member of our Bowser Basin field party in 1989, where his enthusiasm, endurance, scientific knowledge, and general good cheer were much appreciated. He also contributed in a major way to our understanding of the taxonomy and biostratigraphy of these faunas, though the present authors are responsible for the final results published in this paper. We wish to dedicate this paper to our good friend and colleague, whose death last year was sad news for all who work on Jurassic rocks and fossils.
We also wish to acknowledge our gratitude to Carol EVENCHICK (Geological Survey of Canada, Vancouver) for inviting us to join field mapping parties in the

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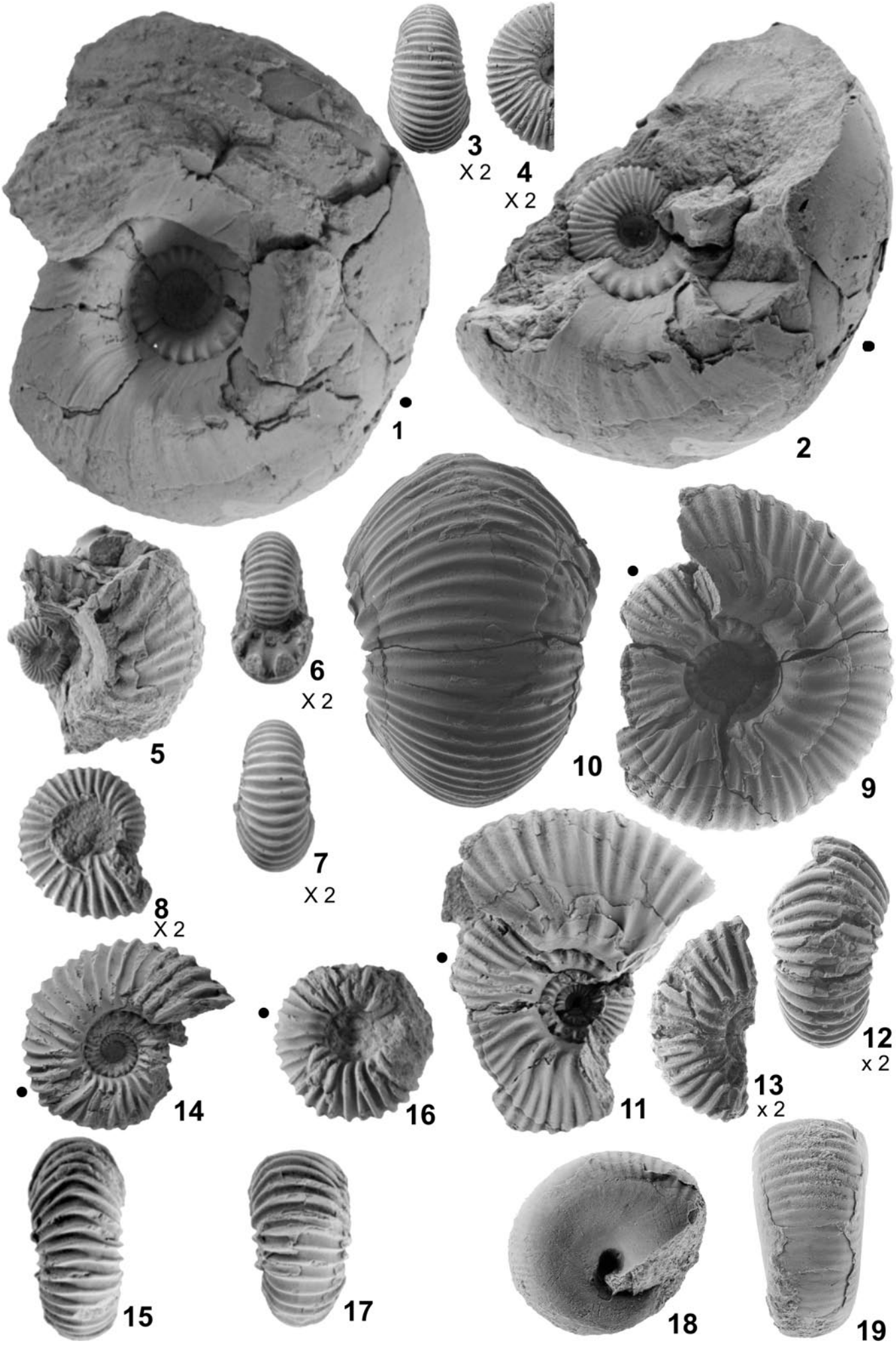
Plate I

1-17. *Cadoceras comma* IMLAY, 1953. Macroconch. **1-4.** GSC 100713, showing exposed and separated inner whorls for comparison with proposed microconchs; **3, 4.** inner whorls shown at x2 magnification; previously figured in POULTON *et al.,* 1994, pl. 1, fig. 3; **5-8.** GSC 134796; immature; **6, 7, 8.** inner whorls shown at x2 magnification; **9-13**. GSC 134797; immature; **12, 13.** inner whorls shown at x2 magnification. Microconch. **14, 15.** GSC 100714; previously figured in POULTON *et al.,* 1994, pl. 1, fig. 4; **16, 17.** GSC 134800. **18-19.** *Adabofoloceras* sp. **18, 19.** GSC 134827. All specimens natural size unless otherwise indicated; black dot indicates position of last suture.

Plate I



Bowser Basin in 1989 and 1990, and providing base camp, helicopter, and other logistical support. One of us (RLH) also thanks the following for access to type and other collections of British Callovian ammonites: B. COX and S. TUNNICLIFF (Geological Survey of Great Britain, Keyworth), K. PAGE (personal collections held in Sedgwick Museum, Cambridge), and to W. J. KENNEDY and P. POWELL for access to library, laboratory, office space and ammonite collections during a sabbatical study leave at the Oxford University Museum. Denise THEN prepared the line drawings.

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Plate II

Cadoceras (Stenocadoceras) stenoloboide (POMPECKJ, 1900). **1-11.** Macroconch. **1, 3.** GSC 134802; **2, 4.** GSC 134828, probably immature macroconch; **5-7.** GSC 134803, showing inner whorls for comparison with microconch; **8, 9.** GSC 100711, showing inner whorls for comparison with microconch; previously figured in POULTON *et al.,* 1994, pl. 1, fig. 1; **10, 11.** GSC 100712, immature; previously figured in POULTON *et al.,* 1994, pl. 1, fig. 2. **12-18**. Microconch. **12, 13.** GSC 134806; **14, 15.** GSC 134807; **16.** GSC 134808; **17, 18.** GSC 134809. All specimens natural size unless otherwise indicated; black dot indicates position of last suture.

Plate II

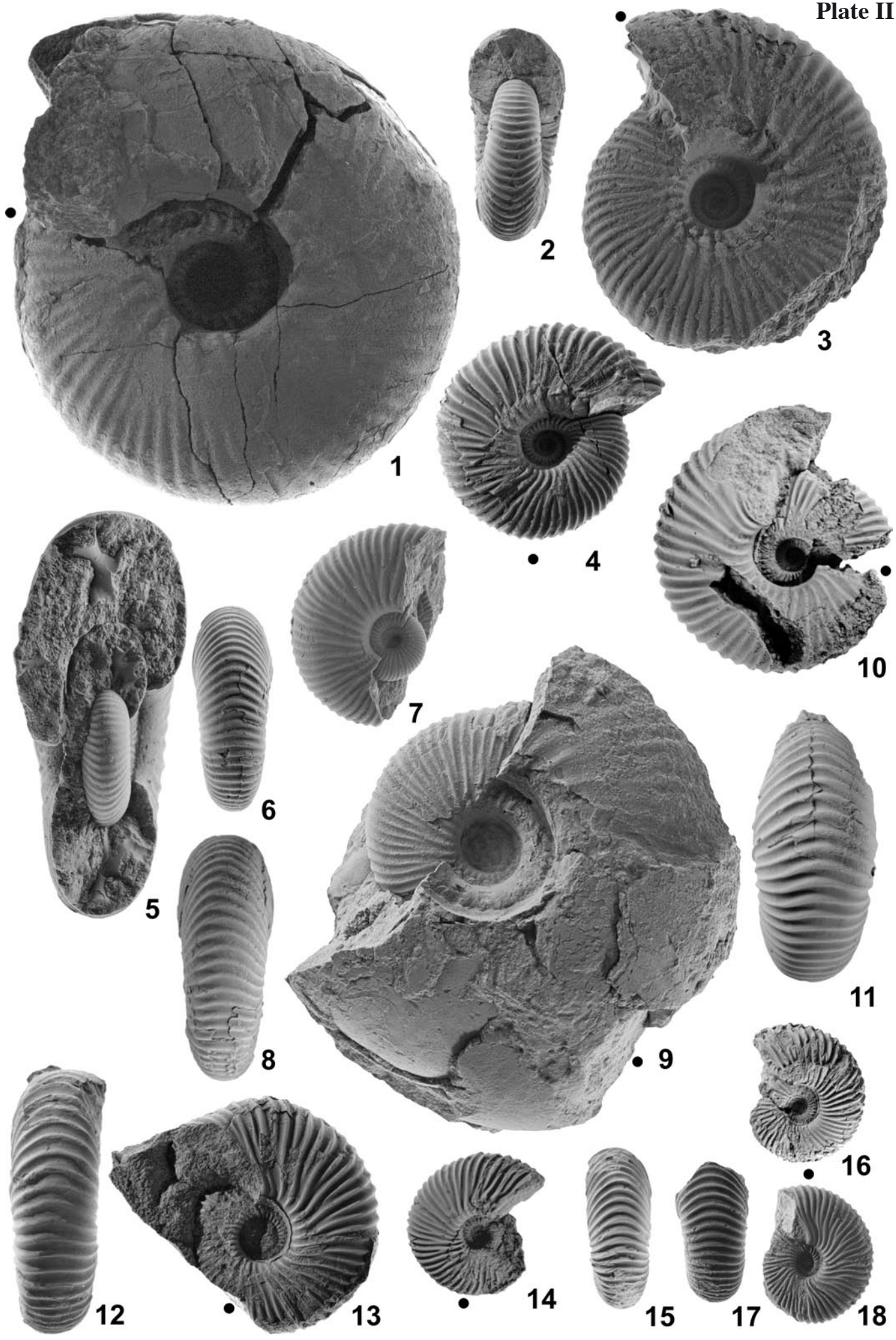

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Plate III

1-6. *Indosphinctes tsatiaensis* var**.** *latus***,** new sp. and subsp. Macroconch**. 1, 2.** GSC 134814 (holotype), specimen shown at 0.75 magnification; **3.** GSC 134815; Microconch. **4, 5.** GSC 134817 (allotype); **6.** GSC 100715; previously figured in POULTON *et al.,* 1994, pl. 1, fig. 5. **7-13.** *Indosphinctes tsatiaensis* var. *angustus,* n. sp. and subsp. Macroconch. **7, 8.** GSC 134828 (holotype). Microconch **9.** GSC 134823; **10, 11.** GSC 134824; **12, 13.** GSC 134825 (allotype). All specimens natural size unless otherwise indicated; black dot indicates position of last suture.

Plate III