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Late Middle–early Late Albian ammonites from Ecuador

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Abstract

Ammonites of the Albian genera *Brancoceras*, *Dipoloceras*, *Mortoniceratoides* and *Neophlycticeras* are described and illustrated for the first time from Ecuador. Precise stratigraphic distribution in the Rio Misahuali field section allows delineation of the Middle/Upper Albian boundary in the Oriente of Ecuador through the recognition of the *Dipoloceras cristatum* Zone.

Keywords: Ammonites; Cretaceous; Albian; Ecuador; Subandean Zone

1. Introduction

The occurrence of Lower Cretaceous ammonites in Ecuador was first reported by Watson and Sinclair (1927) and Tschopp (1953) on the basis of faunas collected from the Napo Formation and identified respectively by J.B. Reeside Jr., and M. Breistroffer. Very few of these ammonites have been figured, and none described; some additional material was subsequently noted by Aspden and Ivimey-Cook (1992).

The aim of the present paper is to revise the descriptions and determinations of specimens previously identified by Breistroffer in Tschopp (1953) and document some interesting new finds made by one of us (EJ) during the course of a detailed field study of the Napo Group of the "Oriente" of Ecuador (Fig. 1). Emphasis is laid on cosmopolitan taxa that allow a correlation with the standard ammonite scales of Western Europe and the south-western USA. The remainder of the fauna (mainly *Oxytropidoceras* and engonoceratids) is only briefly mentioned in the stratigraphic description of the sections studied; they will be described elsewhere, together with their Peruvian and Colombian counterparts.

2. Geologic and stratigraphic setting

The area studied belongs to the Andean active margin that has experienced the subduction of the palaeo-Pacific oceanic plate since the Jurassic (Jaillard et al., 1990). During the Cretaceous Period, various palaeogeographic areas can be distinguished on this margin (Fig. 1).

One of these is the East Ecuadorian (or "Oriente") Basin that underlies large areas of eastern Ecuador to Brazil and extends towards Columbia in the north and Peru to the south. It was characterised by low subsidence rates and marine sedimentation during most of the Cretaceous (Canfield et al., 1982). Two different

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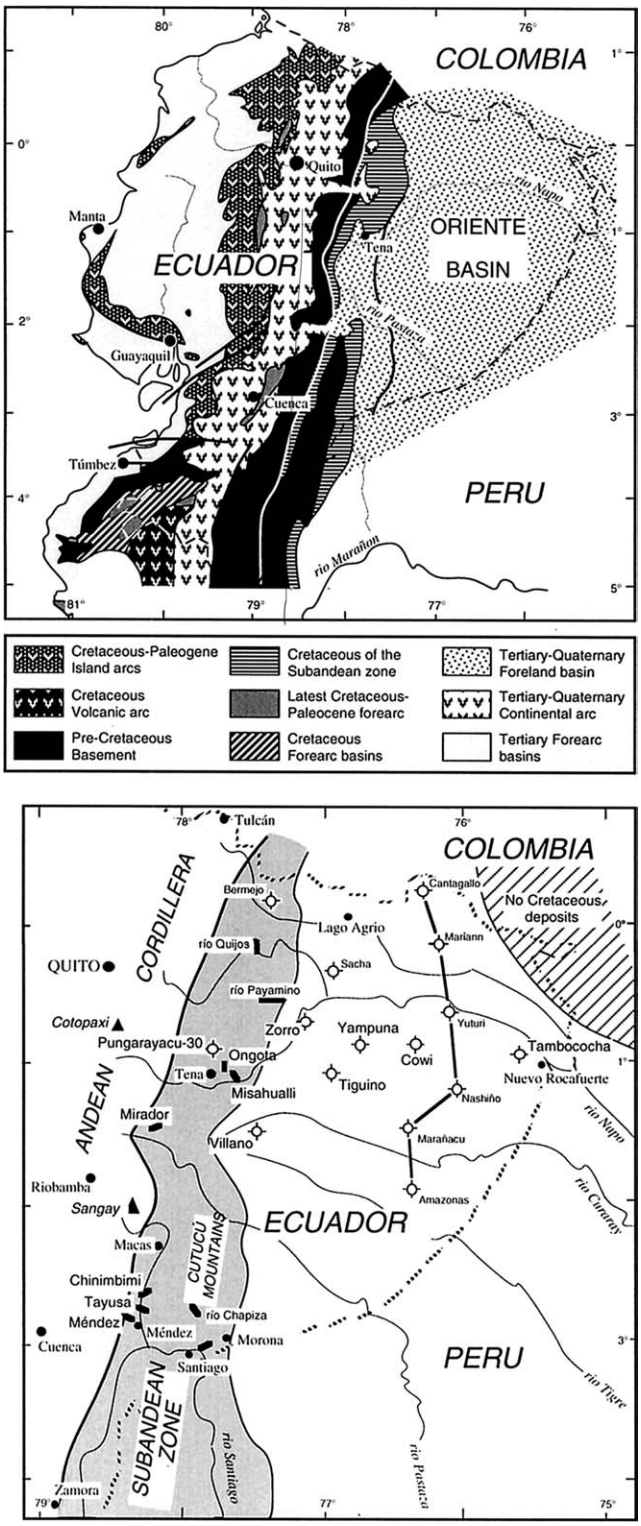

Fig. 1. Geological and palaeogeographical map of the South American Andean margin and location of the area studied.

zones can be distinguished: (1) the Subandean Zone where Mesozoic outcrops allow field study of the Cretaceous successions presented herein; (2) the Amazonian Zone where marine Cretaceous rocks are only known through well data.

The first survey of the Subandean Zone was carried out by Watson and Sinclair in the course of 1921 and their main geological results were published in 1927. The stratigraphic nomenclature of the area studied is still very much derived from their early work and subsequent syntheses by Shell geologists (Tschopp, 1953; see also discussion in Jaillard et al., 1997).

The ammonites described below were collected from the lower part of the Napo Group whose nomenclature has recently been refined by Jaillard et al. (1997, pp. 48–54, fig. 2). It rests on the sandstone of the Hollin Formation and is overlain unconformably by the basal conglomerates of the Tena Formation. As here understood, the Napo Group is subdivided into the Basal, Lower, Middle and Upper Napo formations. It ranges in age from the Late Early–Early Middle Albian to Early Coniacian (Jaillard et al., 1997).

Our material was collected from the Basal and Lower Napo formations. Two main areas have been studied in great detail; the Rio Misahuali and Chinimbimi sections where ammonites, bivalves, echinoids, microfaunas and microfloras have been collected bed by bed (Fig. 2). Preliminary results on the biostratigraphy of the Middle–Upper Albian of the Chinimbimi section were published by Robert et al. (1998, 2002). Because most of the significant specimens described herein were obtained at Rio Misahuali, we focus on that section.

3. Field section

The Rio Misahuali section is located south of the village Tena, and lies on the sides of the Misahuali river close to its confluence with the Napo River (Fig. 1). The exposures are good to excellent and quite easily accessible for the area. It provides a reference section for the northern part of the Subandean Zone.

No ammonites have been collected from the lowermost part (basal sandstones and "C" limestones) of the Basal Napo Formation. The oldest ammonites (sample M.94.9/10) were collected from the black laminated shales rich in crushed ammonites and bivalves that mark the base of the basal Napo Shales. Besides numerous *Brancoceras* (*Brancoceras*) sp., the fauna also includes rare *Venezoliceras* of the *venezolianum* group and many buchiids (*Aucellina* sp.). Comparison with equivalent faunas in Peru (Robert, 2002) and elsewhere in the world suggests a middle–late Middle Albian age. This view is also supported by the occurrence of numerous *Oxytropidoceras* (*O.*) *carbonarium* in the "C" limestones of the nearby Pungaracayu-30 well.

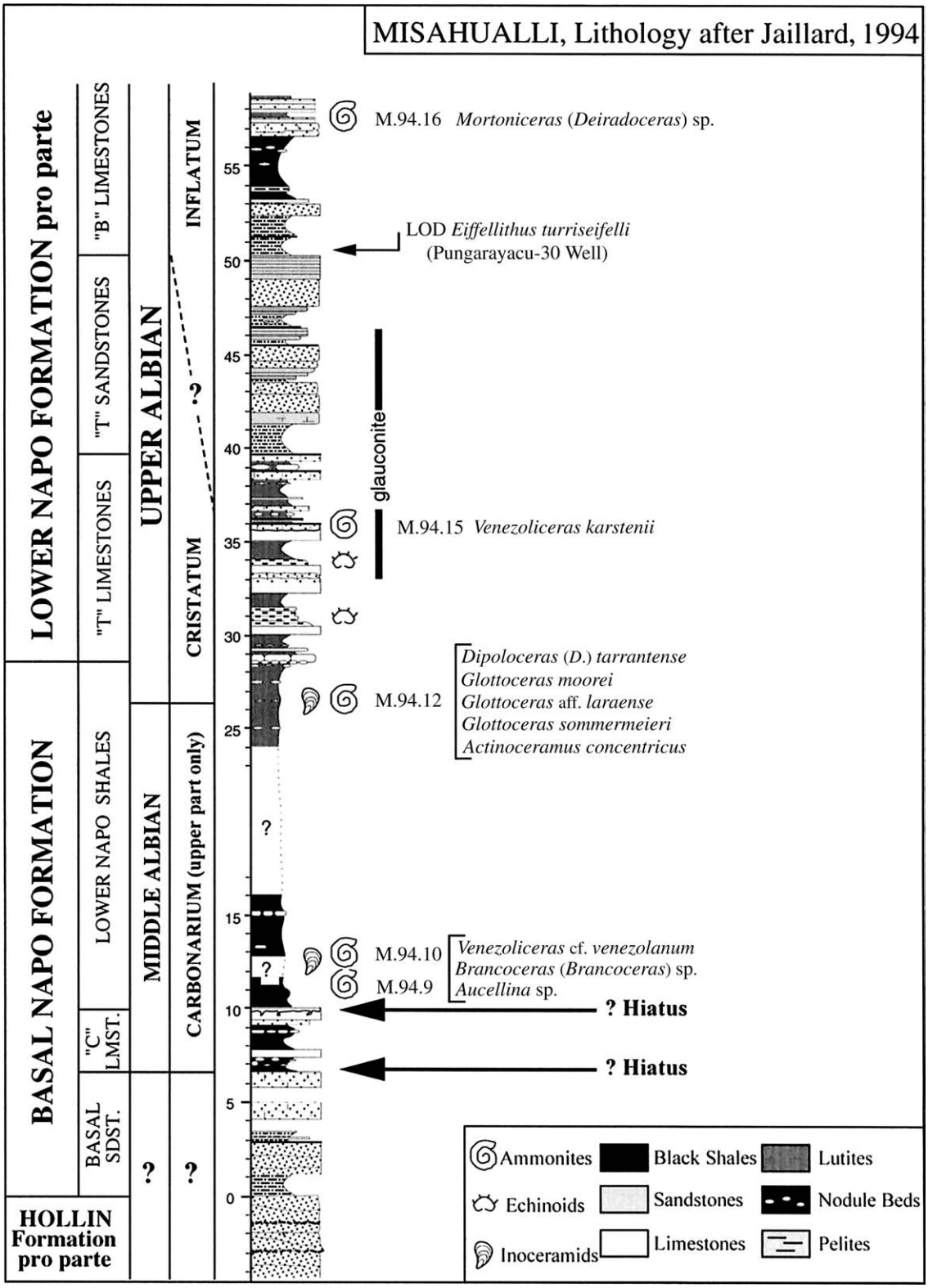

Fig. 2. Lithologic log and biostratigraphic interpretation of the Misahuali field section.

The most interesting ammonite fauna was collected from the nodule beds (M.94.12) at the top of the basal Napo shales. It includes *Dipoloceras* (*D.*) *tarrentense*, *D.* (*D.*) aff. *fredericksburgense* and species of *Glottoceras* such as *G. sommermeieri* and *G. moorei*. For the reason outlined below (see "Systematic palaeontology") this level is taken to mark the base of the Upper Albian (*Dipoloceras cristatum* Zone). The occurrence of

Actinoceramus concentricus (Parkinson) (determined by A. Dhont) at that level is also noteworthy.

Higher up the succession ammonites are scarce. A large fragment of *Oxytropidoceras* (*Benavidesites*) *karsteni* Stelier was collected from a hardground surface (M.94.15) in the middle of the "T" limestones. According to Renz (1968, 1982), this species is fairly common in the uppermost part of the La Puya Member of the Peñas Altas Formation of Western Venezuela, where it co-occurs with ammonites characteristic of the *Mortoniceras inflatum* Zone (*Hysteroceras orbignyi* Subzone according to Renz, 1982; *Hysteroceras varicosum* Subzone according to Owen, 1999).

The youngest Albian ammonites found at Misahuali are from lower part of the "B" limestones (Lower Napo Formation). Both specimens (M.94.16 and M.94.19a) are poorly preserved mortoniceratids, one of them showing close affinities with *Deiradoceras*. The lower part of the Lower Napo Formation therefore still belongs to the Upper Albian *Mortoniceras inflatum* Zone.

4. Systematic palaeontology

Repositories. The specimens mentioned below are housed in the following repositories: FSM, Faculté des Sciences, Marseille; BMNH, The Natural History Museum, London; MNHP, Museum National d'Histoire Naturelle, Paris.

Dimensions. All dimensions are given in millimetres. D, diameter; Wb, whorl breadth; Wh, whorl height; U, umbilicus. Figures in parentheses are dimensions as a percentage of diameter.

Order: Ammonoidea Zittel, 1884
Suborder: Ammonitina Hyatt, 1889
Superfamily: Acanthocerataceae de Grossouvre, 1894
Family: Brancoceratidae Spath, 1934
Subfamily: Mojsisovicziinae Hyatt, 1903
Genus and Subgenus *Dipoloceras* Hyatt, 1900

Type species. *Ammonites cristatus* Brongniart, 1822, p. 395, pl. 7, fig. 9, by original designation of Hyatt, 1900, p. 589.

Dipoloceras (*Dipoloceras*) *tarrantense* Scott, 1928
Figs. 3, 4

1928 *Dipoloceras tarrantense* Scott, p. 112, pl. 16, figs. 1, 2; text-fig. A3.
1928 *Dipoloceras tarrantense Scott;* Adkins, p. 224.
1931 *Dipoloceras tarrantense* Scott; Spath, p. 363; text-fig. 118a–c.
1994 *Dipoloceras tarrantense*; Emerson et al., table 48 on p. 117.
1999 *Dipoloceras* (*Dipoloceras*) *tarrantense* Scott, 1928; Kennedy in Kennedy et al., p. 1107, figs. 4.12–4.14, 7.1–7.7, 7.10–7.12, 10.7.

Type. The holotype, by monotypy, is the original of Scott, 1928, p. 112, pl. 16, figs, 1, 2; text-fig. A3, from the lower Upper Albian Goodland Limestone, 6.1 m (20 ft) below the top, 3.5 km (2 miles) north of a point where the White Settlement road crosses the Tarrant/Parker County line.

Material. FSM 94.12.1 is from bed M.94.12 (uppermost part of the Basal Napo Formation). Another less well-preserved specimen (FSM 94.12.3) was collected from the same bed.

Dimensions	D	Wb	Wh	Wh:Wh	U
FSM 94.12.1	126.0	46.9	43.6	1.08	56.0
	(100)	(37.2)	(34.6)		(44.4)
Costal dimensions	78.9	65.3	28.9	2.26	32.7
	(100)	(82.7)	(36.6)		(50)

Description. FSM 94.12.1 is a complete adult. Ornament of the adapertural 120° sector of the shell and the previous whorl are utterly distinctive. Prior to adult modification, the coiling is very evolute, with a wide, deep umbilicus. The umbilical wall is notched to accommodate the flared ribs of the previous whorl. The whorl section is very depressed oval in intercostal section; the costal whorl section is even more depressed, with a whorl breadth to height ratio of 2.26 through the flared ribs. There are nine massive flared horns per whorl at this stage of development. Each horn bears a strong narrow rib at the adapertural and adapical edge on the flanks and venter, which is deeply sunken between the flares. Between the flared horns are one or two low, narrow prorsiradiate primary ribs that sweep forwards across the ventrolateral shoulder to define a very obtuse chevron, interrupted by a coarse, blunt siphonal keel and flanking grooves. The last two flared horns are significantly weaker than the others on the outer whorl, and are separated by two coarse single ribs, with a third linked to the final flare. Adapertural of the last flare there are 13 strong, coarse, narrow ribs of variable strength and elevation. They are strongly prorsiradiate and markedly concave on the flanks, and directed backwards on the venter in a very obtuse chevron divided adapically; there is a coarse siphonal keel. A pair of ribs arise from the umbilical shoulder immediately adapical of the aperture. The sutures are not seen.

Discussion. The remarkable development of flared horns, occupying all of the flanks and rising above the venter, characterises the species. At this growth stage the specimen closely resembles in gross morphology the Texas example figured by Kennedy in Kennedy et al. (1999, fig. 4.12–4.14), differing only in the more

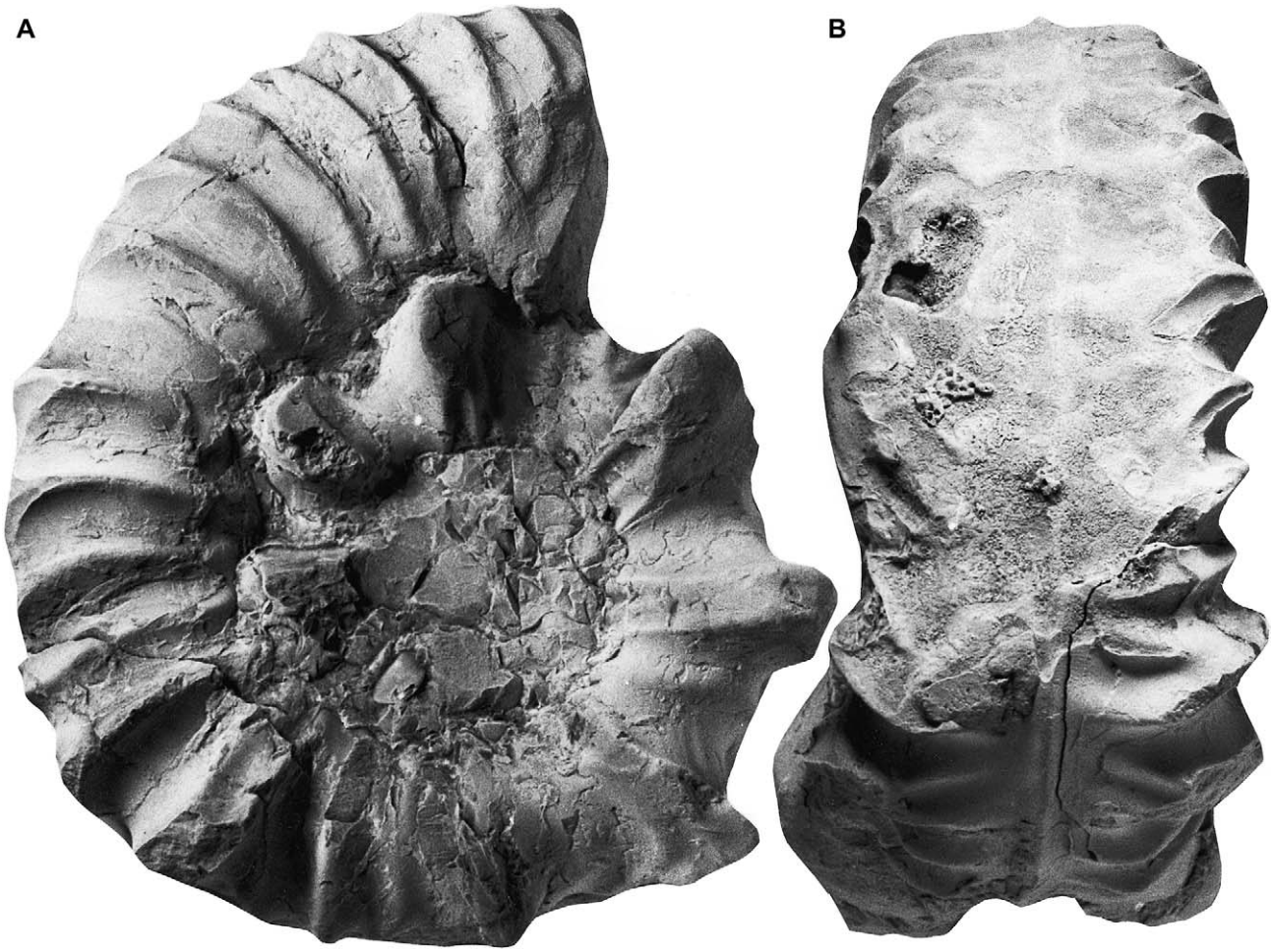

Fig. 3. A, B, *Dipoloceras* (*Dipoloceras*) *tarrantense* Scott, 1928. Side and ventral views of FSM M94.12.1; both ×1.

numerous (three versus one or two) ribs between flared horns. The dramatic change in ornament on the final 120° sector of the shell before the adult aperture is highly distinctive and shows the previously undescribed morphology of the adult shell.

Occurrence. *Dipoloceras tarrantense* was previously known only from the lower Upper Albian upper part of the Goodland/Comanche Peak Limestone in Tarrant and Parker Counties, Texas, where it co-occurs with *Dipoloceras cristatum*. In Ecuador, both specimens have been collected from the uppermost part (nodule beds) of the "Basal Napo Shales" (Napo Formation sensu Jaillard et al., 1997).

Subgenus *Rhytidoceras* van Hoepen, 1931

Type species. *Rhytidoceras elegans* van Hoepen, 1931, p. 43, text-figs. 4–7, by original designation of van Hoepen, 1931, p. 43.

Dipoloceras (*Rhytidoceras*) aff. *elegans* (van Hoepen, 1931)
Fig. 5

cf. 1931 *Rhytidoceras elegans* van Hoepen, p. 43, text-figs. 4–7.
cf. 1941 *Rhytidoceras elegans* van Hoepen; van Hoepen, p. 64, figs. 14–18.
cf. 1941 *Rhytidoceras crassicostatum* van Hoepen, p. 67, text-figs. 19, 20; pls. 9, 10.

Type. The holotype, by original designation, is the original of van Hoepen, 1931, text-fig. 4; 1941, text-fig. 17, from the lower Upper Albian of the Mzinene River, Zululand, South Africa.

Material. FSM KT.6.427, from Rio Longota (Misahuali) (Basal Napo Formation, exact horizon unknown).

Dimensions	D	Wb	Wh	Wb:Wh	U
FSM KT.6.427	160.0	43.2	50.0	0.84	67.0
	(100)	(27.0)	(31.3)		(41.0)

Description. Coiling is very evolute; the broad shallow umbilicus comprises 41.9% of the diameter. The low umbilical wall is feebly convex, the ventrolateral shoulders broadly rounded. The whorl section is compressed oval, with a whorl breadth to height ratio

Fig. 4. *Dipoloceras* (*Dipoloceras*) *tarrantense* Scott, 1928. Apertural view of FSM M94.12.1; ×1 (see also Fig. 3).

of 0.84, the greatest breadth just outside the umbilical shoulder. The inner and middle flanks are broadly convex, the outer flanks convergent, ventrolateral shoulders and venter broadly rounded. Thirty-six strong, narrow, crowded primary ribs arise on the umbilical wall and strengthen into feeble bullae, perched on the umbilical shoulder. The bullae give rise to ribs either singly or in pairs. The ribs are feebly prorsiradiate and weakly sinuous, concave on the inner to mid-flank, slightly concave on the outer flank and ventrolateral shoulder, and near-transverse on the venter. Although the surface of the mould is corroded, there are traces of weakly developed ventral bullae.

Discussion. The whorl proportions, coiling, density and style of ribbing are those of *Dipoloceras* (*Rhytidoceras*), particularly the type species, *D*. (*R*.) *elegans* (van Hoepen, 1931, p. 43, text-fig. 47; 1941, figs. 14–18). The specimen differs, however, in the very clearly developed ventral tubercles, whereas the ventral rib-endings of *D*. (*R*.) *elegans* are not so-differentiated. In this respect, the specimen is transitional to early Mortoniceratinae.

Occurrence. The most closely allied forms of *Dipoloceras* (*Rhytidoceras*) occur in the lower Upper Albian of Zululand, South Africa, where they first appear together with *Dipoloceras* (*D*.) *cristatum*, but range above. In Ecuador the one and only specimen was collected by Shell geologists and we lack detailed data on its precise stratigraphic position. Nevertheless, the preservation differs very much from most of the ammonites described herein, with the exception of *O*. (*B*.) *karsteni* from the "T" limestones (the worm surface is encrusted by serpulids and the matrix includes glauconite and phosphatic pebbles). We accordingly suggest that the specimen originates from one of the hardground surfaces that characterise the "T" limestones.

Subfamily: Brancoceratidae Spath, 1934
Genus and subgenus *Brancoceras* Steinmann, 1881

Type species. *Ammonites senequieri* d'Orbigny, 1841, p. 292, pl. 86, figs. 3–5, by subsequent designation of Hyatt, 1900, p. 590.

Brancoceras (*Brancoceras*) sp.
Fig. 6F

Material. FSM M.94.10.4, from bed M94-10 of the Mishahuali section (lowermost part of the Basal Napo Formation).

Description. The specimen is preserved as a crushed film, lacking shell, deformed into an ellipse with a major diameter of 26 mm. Coiling is very evolute, serpenticone, the wide umbilicus comprising an estimated 38% of the diameter. The whorls expand very slowly. Ribs arise either singly or in pairs from the umbilical shoulder, and appear to have been recti- to feebly rursiradiate, flexing backwards on the outer flank and thickening on the ventrolateral shoulder. There are an estimated 16 ribs on the outer half whorl of the specimen.

Discussion. Although poor, the specimen can be assigned to *Brancoceras* (*Brancoceras*), notably the type species *B*. (*B*.) *senequieri*, as represented by a suite of well-preserved specimens from the condensed Albian of Gourdon, Alpes-Maritimes, France, in the collections of the Université de Grenoble.

Occurrence. *Brancoceras* (*Brancoceras*) is a typical Early and Middle Albian genus. The present specimen and many other unlabelled juvenile specimens were collected from the lowermost part (black shales) of the "Basal Napo Shale" together with rare *Venezoliceras* gr. *venezolanum* Stieler. Because of its stratigraphic position

Fig. 5. A–C. *Dipoloceras* (*Rhytidoceras*) aff. *flexuosum* (van Hoepen, 1931). Apertural, side, and ventral views of FSM KT.6.427; ×1.

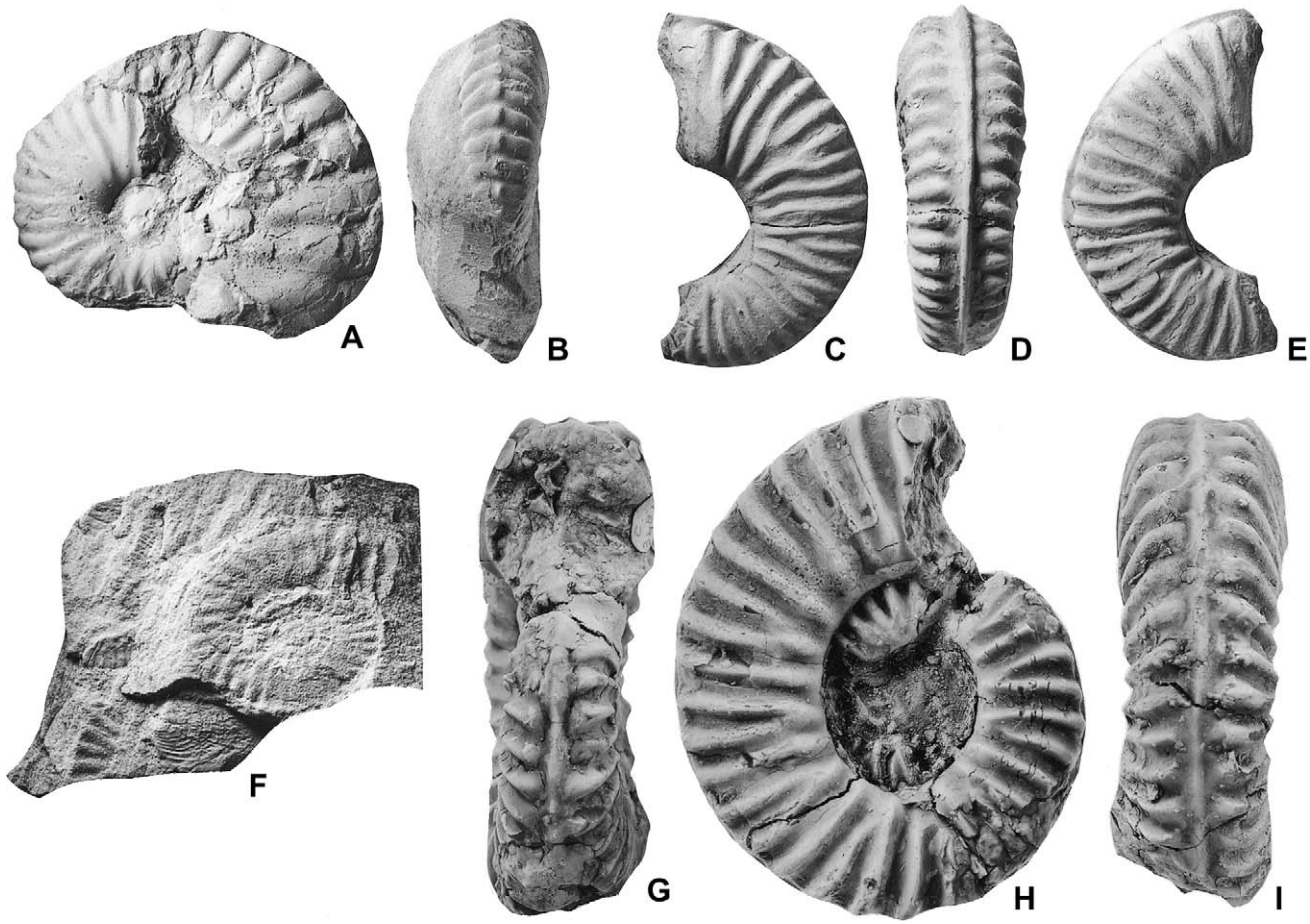

Fig. 6. A, B, *Neophlycticeras brottianum* (d'Orbigny, 1841), side and ventral views of FSM G350. C–E, G–I, *Mortoniceratoides rigidum* (Spath, 1933); C, E, side views, D, venter of FSM KTG 463; G–I, apertural, side and ventral views of the holotype, BMNH C. 34879. F, *Brancoceras* (*Brancoceras*) sp., side view of FSM M.9410.4. All ×1.

well below the level with *Dipoloceras* and association with *V*. gr. *venezolanum*, a middle–late Middle Albian age is indicated.

Genus *Mortoniceratoides* Cooper, 1982

Type species. *Mortoniceras* (*Pervinquieria*) *rigidum* Spath, 1933, p. 413, text-figs. 142, 144f, by original designation of Cooper, 1982, p. 296.

Mortoniceratoides rigidum (Spath, 1933)
Fig. 6C–E, G–I

1933 *Mortoniceras* (*Pervinquieria*) *rigidum* Spath, p. 413, text-figs. 142, 144f.
1982 *Mortoniceratoides rigidus* (Spath); Cooper, p. 296, text-fig. 13e, f.

Types. Holotype, BMNH C. 34879; paratype, BMNH C. 35929, from Bed 8, the *cristatum* nodule bed of the lower Middle Albian Gault Clay at Folkestone, Kent (Fig. 6G–I).

Material. FSM KTG 463 from the upper Rio Bueno (Basal Napo Formation, exact horizon unknown).

Dimensions	D	Wb	Wh	Wb:Wh	U
	47.2	17.4	20.0	0.87	14.6
	(100)	(36.9)	(42.4)		(30.9)

Description. FSM KTG 463 is a half whorl of body chamber with a maximum preserved diameter of 47.2 mm. Coiling is very evolute. The umbilicus comprises 30.9% of the diameter, and is of moderate depth, with a flattened, feebly convex wall. The umbilical shoulder is quite narrowly rounded. The whorl section is compressed trapezoidal in costal section, with the greatest breadth at the umbilical shoulder. Fourteen ribs arise at the umbilical seam, and strengthen across the umbilical wall and shoulder. They are strong, narrow, and prorsiradiate on the flanks. Single ribs are very feebly convex. Other ribs branch below mid-flank, with the adapical of the two secondary ribs either straight or with an initial

sinuosity, beyond which the two ribs of the pair are subparallel. The ribs strengthen across the ventrolateral shoulder, and are transverse on the venter, terminating in an incipient ventral bulla. There is a strong, continuous siphonal keel flanked by prominent grooves.

Discussion. The highly distinctive flank and ventral rib development of the fragment, notably the branching pattern and transverse ventral development, are identical to those of the holotype (Fig. 6G–I). This is rather more coarsely ribbed than the present specimen, which can be matched with topotypes.

Occurrence. Lower Upper Albian of southern England, associated with *Dipoloceras* (*D.*) *cristatum*. The precise horizon of the specimen described herein is unknown but its preservation suggests that it originates from nodule beds that occur at the top of the Basal Napo Shales sensu Jaillard et al. (1997). As a consequence, this suggests that, as in England, the Ecuadorian *Mortinoceratoides* occurs in the *Dipoloceras cristatum* Zone together with other *Dipoloceras* species.

Family: Lyelliceratidae Spath, 1921
Subfamily: Stoliczkaiinae Breistroffer, 1953
Genus and subgenus *Neophlycticeras* Spath, 1922

Type species. *Ammonites brottianus* d'Orbigny, 1841, p. 290, pl. 89, figs. 8–10, by original designation of Spath, 1922, p. 107.

Neophlycticeras (*Neophlycticeras*) *brottianum* (d'Orbigny, 1841)
Fig. 6A, B

1841 *Ammonites brottianus* d'Orbigny, p. 290, pl. 85, figs. 8–10.
1994 *Neophlycticeras brottianum* (d'Orbigny, 1841); Kennedy and Delamette, p. 7, text-figs. 3b–d, 5a–c, g–i, 6a–s; 7a–f; 8y, z (with full synonymy).
1998 *Neophlycticeras* (*Neophlycticeras*) *brottianum* (d'Orbigny, 1841): Matrion, Dubus and Touch, p. 19, pl. 1, figs. 1–3; pl. 2, figs. 1–5; text-figs. 3, 4.

Type. Holotype, by monotypy, MNHP5757, d'Orbigny Collection, the original of d'Orbigny, 1841, pl. 85, figs. 8–10, from the condensed Albian of Perte du Rhône, Ain, France.

Material. FSM G350-1 from Rio Coca (Basal Napo Shales, exact horizon unknown).

Description. FSM G350-1 is a partially crushed individual with a maximum preserved diameter of 47 mm. Coiling is very involute, with a small deep umbilicus. The whorl section is compressed, with the greatest breadth outside the umbilical shoulder, the inner flanks broadly convex, the outer flanks flattened and convergent, the venter fastigiate. At a diameter of 30 mm there are 17 low, broad, flexuous, prorsiradiate ribs per half whorl. Primary ribs arise at the umbilical seam, and strengthen across umbilical wall and shoulder. They are straight on the inner flank, feebly convex at mid-flank, flexed back and concave on the outer flank, and projected forwards and thickened across ventrolateral shoulders and venter, where they are near-transverse, with small, sharp siphonal clavi. Single intercalated ribs arise around mid-flank, and have comparable ventral and ventrolateral development to the primary ribs. The outer half whorl is crushed, but shows the ribs coarsening and broadening markedly.

Discussion. The present specimen differs in no significant respects from similarly compressed specimens of *N.* (*N.*) *brottianum* discussed by Kennedy and Delamette (1994) and Matrion et al. (1998).

Occurrence. Where well-dated, *N.* (*N.*) *brottianum* is early Late Albian in age, occurring in the *Dipoloceras cristatum* to low *Hysteroceras varicosum* subzones of the western European *Mortoniceras inflatum* Zone. The precise position of the specimen described herein is unknown but its preservation suggests that it originates from the nodule beds that occur at the top of the Basal Napo Shales sensu Jaillard et al. (1997). The geographic range is southern England, France, Switzerland, Tunisia, Morocco, Zululand (South Africa), Madagascar, and the present record from Ecuador.

5. Conclusions

The study of the Middle and Late Albian ammonite fauna of the lower part of the Napo Group of the "Oriente" Basin of Ecuador (Subandean Zone) sheds new light on the biostratigraphy and palaeobiogeography of the area. New field data show that the base of the Upper Albian lies at the top of the Basal Napo Shales sensu Jaillard et al. (1997) (Basal Napo Formation). The Upper Albian ranges up to the top of the "B" Limestones of the Lower Napo Formation. Nevertheless, our new collections do not provide any evidence for the uppermost part of the Albian (*Stoliczkaia dispar* Zone).

The fauna combines Andean (*Glottoceras* of the *sommermeieri* and *moorei* plexus) and cosmopolitan elements (mainly Mojsisovicziinae). Among the cosmopolitan taxa, some genera and species are reported and/or confirmed for the first time. These include *Neophlycticeras brottianum*, whose geographic range in the New World was hitherto restricted to Western

Venezuela. Noteworthy also is the occurrence of *Mortoniceratoides* and *Dipoloceras* (*D.*) *tarrantense*, previously only known, respectively, from southern England and Texas. Similarly, the subgenus *Rhytidoceras*, mainly known from Madagascar and South Africa, is reported from the first time in South America.

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