

## Late Albian (Early Cretaceous) ammonites from the Provincial Formation of central Cuba

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### ABSTRACT

A late Albian ammonite assemblage from the Provincial Formation of Villa Clara Province, Cuba is described. The Provincial Formation is a lithostratigraphic unit of Albian–Cenomanian age extensively exposed in central Cuba and formed within a part of the Caribbean Tethys that was volcanic during the Cretaceous. The formation is mainly composed of calcareous, terrigenous marine, and volcano-sedimentary deposits characterized by a series of micritic limestones intercalated with marls, sandstones, calcareous conglomerates, ash, and tuffaceous material. A rich assemblage of ammonites recovered from the calcareous biomicrites and marls is of late Albian (*Stoliczkaia dispar* Zone, *Mortoniceras rostratum* Subzone) age. The ammonite fauna shows a strong Tethyan affinity, and only a single hoplitid ammonite species was recorded. Although scarce, the first Cuban report of this and other boreal ammonite species now allows precise correlations to be made between Cuba and Albian sediments elsewhere in the world.

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### 1. Introduction

The geology of Cuba is among the most complex in the Caribbean region, and reconstructing its geological history is difficult (Iturralde-Vinent, 1997). The central part of Cuba is composed of volcanic deposits of Cretaceous (Berriasian–Maastrichtian) age (Furrazola-Bermúdez et al., 2003).

These volcanic sequences were initially studied by Rutten (1936) and Thiadens (1937), who used the name ‘Tuff Series’ to refer to these thick volcano-sedimentary units, with frequent intercalations of calcareo-terrigenous and terrigenous material.

The uppermost Albian and Cenomanian part of these thick volcano-sedimentary units is known as the Provincial Formation (Thiadens, 1937). The Albian part of the formation is fossiliferous in the Villa Clara Province of central Cuba, and has yielded a rich ammonite assemblage of late Albian (*Stoliczkaia* (S.) *dispar* Zone) age (Barragán-Manzo et al., 2008). The occurrence of Albian ammonites in this volcano-sedimentary unit had been mentioned in reports of the local geology compiled during the late 20th century, e.g. Kantchev et al. (1978), but these have not been widely published and discussed elsewhere. Late Albian to early Cenomanian ammonite faunas from the Gulf of Mexico region (Adkins, 1920; Mancini, 1979; Young, 1957, 1979, 1986; Kennedy, 2004; Kennedy et al., 2005) and more recently from the Caribbean

(Owen and Mutterlose, 2006) provide a context for the biostratigraphical discussion of the Cuban ammonite fauna presented here.

The ammonite fauna described here includes cosmopolitan taxa that have not been recorded for Cuba or in fact anywhere else in the Caribbean region. This is significant because it allows for correlation between sediments in Cuba and those elsewhere, notably the Mediterranean part of the Tethyan region.

Ammonite zonal schemes for the Gulf of Mexico region have been proposed for the upper Albian/lower Cenomanian successions (Young, 1979; Mancini, 1979) and discussed by Kennedy et al. (2005). However, in this paper the zonation outlined by Reboulet et al. (2009) is more useful because of the Tethyan affinity of the fauna described, in contrast to the other schemes based on more endemic Gulf region assemblages.

The current debate on Albian ammonite zonation (Kennedy, in Gale et al., 1996; Wiedmann and Owen, 2001), as documented by Kennedy and Latil (2007) and Scott (2009), means that defining the Aptian/Albian boundary remains uncertain. For our purposes we have chosen to use the standard ammonite zonation scheme proposed by the IUGS Lower Cretaceous Ammonite Working Group, informally known as the ‘Kilian Group’ (Reboulet et al., 2009).

### 2. Geographical and geological setting of the section studied

Fossiliferous outcrops of the upper Albian Provincial Formation are well exposed in the Province of Villa Clara, Central Cuba

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(Thiadens, 1937; Kantchev et al., 1978; Zelepuguin et al., 1986). There are extensive outcrops along the National Highway between kilometre posts 291 and 292, approximately 30 km southeast of Santa Clara (Fig. 1).

The section described here is located at 022°16' 36"N, 079°50'13"W on a small hill known as Las Nueces. It is part of a tectonostratigraphic unit that embraces the best-preserved fragments of the Cretaceous volcanic arc of the Caribbean Tethys (Díaz de Villalvilla, 1997; Furrazola-Bermúdez and Gil-González, 1997). Fig. 1 shows the location of the section and the relationship of the Cretaceous volcanic arc with other tectonostratigraphic units in the area.

### 3. Lithostratigraphy

The section consists of approximately 27 m of alternating beds of normal marine and volcano-sedimentary deposits. The marine beds are micritic and marly limestones, with intercalated beds of marls, sandstones, calcareous conglomerates, and ash and tuffaceous material attributed to flyschoid, relatively deep-water deposits of the Provincial Formation (*sensu* Thiadens, 1937).

Fig. 2 shows how the Provincial Formation fits into the stratigraphy of the volcanic arc sediments of this region (Villalvilla and García, 1994 in Díaz de Villalvilla, 1997). A distinctive feature of this particular section is the abundance of ammonites within the limestones and marly limestones. The ammonites occur in two distinctive horizons located in the middle (horizon I) and upper (horizon II) parts of the section.

### 4. Systematic palaeontology (O. Szives and R. Barragán)

The ammonites of the Provincial Formation are generally preserved as whole or fragmentary internal moulds, or else as shell impressions. The terminology used herein is that of the *Treatise on Invertebrate Paleontology* (Wright et al., 1996). Descriptions, synonyms, and references used for specific determinations are also included. In the descriptions, the following abbreviations are used for the measured parameters: *D* for shell diameter; *U* for diameter of the umbilicus; *Wh* for whorl height; and *Ww* for whorl width. All measurements are in millimetres.

All specimens are housed in the mollusc section of the invertebrate collection of the National Museum of Natural History of Cuba in La Havana under the catalogue numbers MNHNCu-92.001100–MNHNCu-92.001136 and MNHNCu-92.001269–MNHNCu-92.001270.

Suborder Lytoceratina Hyatt, 1889

Superfamily Tetragonitaceae Hyatt, 1900

Family Tetragonitidae Hyatt, 1900

Genus *Protetragonites* Hyatt, 1900

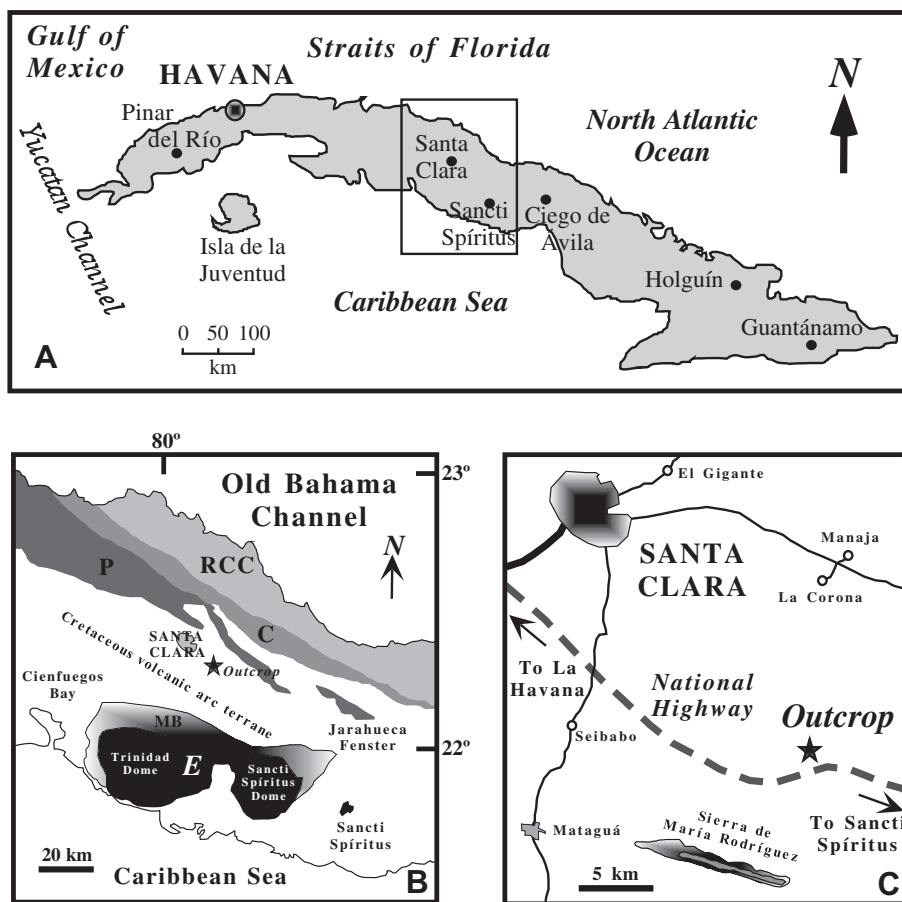
Type species. *Ammonites quadrisulcatus* d'Orbigny, 1840, p. 151, pl. 49, figs 1–3, by original designation.

*Protetragonites* cf. *aeolus* (d'Orbigny, 1850)

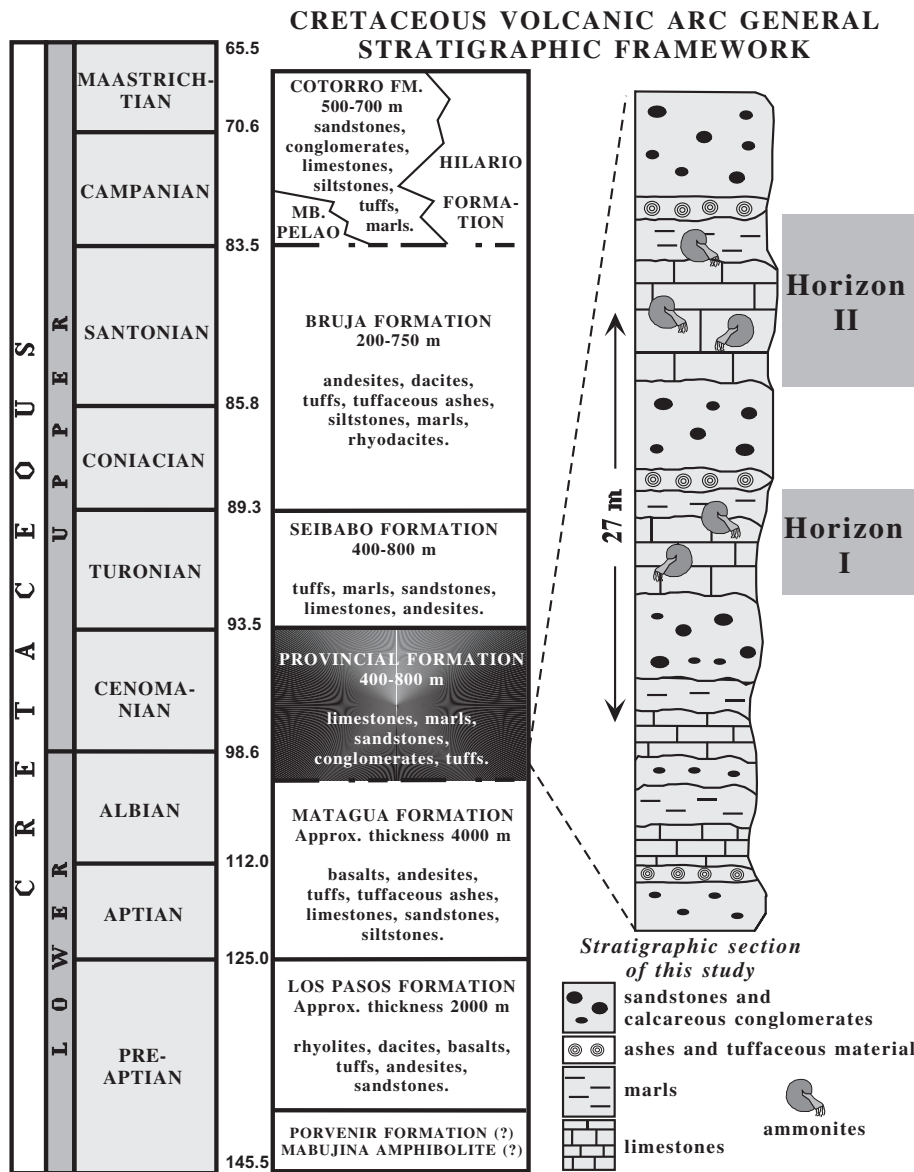
Fig. 3A

cf. 1850 *Ammonites Aeolus* d'Orbigny; p. 125.

cf. 1996 *Protetragonites aeolus aeolus* (d'Orbigny, 1850); Kennedy, in Gale et al., p. 544, figs. 13e, f [with additional synonymy].



**Fig. 1.** (A) General map of Cuba. (B) Location of the section studied, and the relationship between the Cretaceous volcanic arc and other local tectonostratigraphic units. P = Placetas Belt; C = Camajuani; RCC = Remedios–Cayo Coco–Canal Viejo. (C) Detail of the location of the outcrop along the National Highway between 291 km and 292 km in the segment between the cities of Santa Clara and Sancti Spiritus, approximately 30 km southeast of the former (modified from Cobiella-Reguera, 2008).



**Fig. 2.** Stratigraphic log of the section studied and its position within the stratigraphic framework of the Cretaceous volcanic arc of Cuba (modified from Villalvilla and García, 1994 in Díaz de Villalvilla, 1997). The section represents the upper Albian basal portion of the Provincial Formation. The ammonites occur in two distinctive horizons, I: in the middle, and II: in the upper parts of the section.

cf. 2001 *Protetragonites* cf. *aeolus aeolus* (d'Orbigny, 1850); Yazikova, p. 105, pl. 2, figs 18, 19.

**Material.** One specimen, MNHNCu-92.001100, collected from the horizon I.

**Dimensions of the figured specimen.**

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001100	10	5	3	—

**Description.** Very evolute ( $U/D=0.5$ ) slightly crushed and smooth internal mould lacking clearly visible ornamentation. The periodic constrictions of the shell typical of the genus are difficult to observe because of the poor state of preservation.

**Remarks.** The general appearance, including the highly evolute coiling and the presence of constrictions, are a diagnostic feature of the species. In this flattened, poor state of preservation, where the

exact position and form of the constrictions are poorly visible, apart from being less evolute, this specimen resembles *Zelandites* Marshall (1926).

**Occurrence.** The species has been reported from the Albian of southern France, Poland, and the Russian Far-East.

Suborder Ammonitina Hyatt, 1889

Superfamily Desmocerataceae Zittel, 1895

Family Desmoceratidae Zittel, 1895

Subfamily Desmoceratinae Zittel, 1895

Genus *Desmoceras* Zittel, 1884

Subgenus *Desmoceras* (*Desmoceras*) Zittel, 1895

Type species. *Ammonites latidorsatus* Michelin, 1838, p. 101, by subsequent designation.

*Desmoceras* (*Desmoceras*) cf. *latidorsatum* (Michelin, 1838)  
Fig. 3B

\*1838 *A. latidorsatus* Michelin, p. 101, pl. 12, fig. 9.

cf. 1979 *Desmoceras* (*Desmoceras*) *latidorsatum* (Michelin); Scholz, p. 61, fig. 18 [with cf. 1982 *Desmoceras* (*Desmoceras*) *latidorsatum latidorsatum* (Michelin); Renz, p. 37, pl. 5, figs. 3a, b, 4a, b, 5a, b, 7a, b, text-fig. 24b].

cf. 2000 *Desmoceras latidorsatum* (Michelin); Busnardo, in Monod et al., p. 386, fig. 5f.

**Material.** One specimen, MNHNCu-92.001101, collected from the horizon II.

*Dimensions of the figured specimen.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001101	22	6	8	–

**Description.** The specimen is rather involute ( $U/D = 0.27$ ). It is a small internal mould with flat, smooth, and wide flanks and a steep umbilical and ventrolateral edge.

**Remarks.** Only a single very poorly preserved specimen is referred to this species.

**Occurrence.** This species has been reported worldwide from rocks of mid-Aptian to late Cenomanian age.

Superfamily Hoplitaceae H. Douvillé, 1890

Family Hoplitidae H. Douvillé, 1890

Subfamily Hoplitinae H. Douvillé, 1890

Genus *Discohoplites* Spath, 1925b

**Type species.** *Ammonites coelonotus* Seeley, 1865, p. 237, by original designation.

?*Discohoplites* sp.

Fig. 3C

**Material.** One specimen, MNHNCu-92.001124, collected from the horizon I.

*Dimensions of the figured specimen.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001124	34	12	12	–

**Description.** Moderately involute ( $U/D = 0.35$ ) imprint of a cast with crowded, falcoid ribs. Slight, narrow umbilical bullae arise on the umbilical edge and give rise to crowded, fine, slightly falcoid ribs. There are approximately thirty ribs per half whorl, which become strongly prorsiradiate and sinuous. The ribs become plicate with growth, particularly on the outer quarter of the last whorl. The venter is not visible due to flattening.

**Remarks.** The genus *Discohoplites* Spath (1925b) is characterized by a compressed whorl section with moderately evolute style of coiling and grooved, but not flat, venter. *Discohoplites* is ornamented with falcoid ribs and umbilical tubercles. Based on the lateral ornamentation, the specimen MNHNCu-92.001124 is assigned to this genus. The determination is based mainly on the falcoid ribs because the venter is not visible, making it impossible to detect the ventral groove characteristic of *Discohoplites*. Significantly, the specimen also resembles lateral views of *Algericeras* Spath (1925a). However, all the reported specimens of *Algericeras* are smaller, and their ribs bifurcate from the umbilical bullae. Identification of this specimen as *Discohoplites* therefore remains likely but tentative.

Superfamily Acanthocerataceae de Grossouvre, 1894

Family Brancoceratidae Spath, 1934

Subfamily Mortoniceratinae Douvillé, 1912

Genus *Mortonicerases* Meek, 1876

**Type species.** *Ammonites vespertinus* Morton, 1834, p. 40, by original designation.

*Mortonicerases* sp.

Fig. 3D

**Material.** One specimen, MNHNCu-92.001102, collected from the horizon II.

*Dimensions of the figured specimen.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001102	–	23	22	15

**Description.** Compared to the other forms found at the same locality, this specimen is quite large. It is evolute with robust ornamentation. Strong primary ribs arise from the flattened umbilical seam; these ribs bear slight umbilical, lateral and ventral tubercles. Occasionally, intercalated ribs appear on the mid-flank. The venter seems to be keeled, but this feature is not clear.

**Remarks.** The genus *Mortonicerases* is characterized by an evolute style of coiling, robust trituberculate ribs, and a strongly keeled venter, as discussed by Kennedy and Latil (2007). The specimen assigned to this genus (MNHNCu-92.001102) is preserved such that the venter is not visible, and therefore it cannot be determined if it has a keel or not. However, the lateral view of this specimen is very similar to that of other specimens assigned to *Mortonicerases*. Nonetheless, because of the poor state of preservation identification to species level would be speculative at best.

**Occurrence.** The genus has been found in Albian deposits worldwide. Outside Cuba, its stratigraphic range does not reach the extreme top of the Albian stage (Wright et al., 1996, p. 142). However, in Cuba its occurrence alongside *Algerites* is remarkable, implying occurrence close to, but below, the Albian/Cenomanian boundary.

Genus *Cantabrigites* Spath, 1932

**Type species.** *Mortonicerases* (*Cantabrigites*) *cantabrigense* Spath, 1932, p. 380, by original designation.

*Cantabrigites spinosum* (Pervinquieré, 1907)

Fig. 3E–G

1907 *Mortonicerases inflatum* Sowerby var. *spinosa* Pervinquieré, p. 229, pl. 9, fig. 3.

2004 *C. spinosum* (Pervinquieré, 1907); Kennedy, p. 877, figs. 7A–E; 10A–K; 12H–W; 13 [with full synonymy].

2005 *C. spinosum* (Pervinquieré, 1907); Kennedy et al., p. 363, figs. 4F–J.

**Material.** Eight specimens, MNHNCu-92.001103–MNHNCu-92.001110, collected from the horizons I and II.

*Dimensions of the figured specimens.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001104	18	7	5	–
MNHNCu-92.001105	14	6	5	–
MNHNCu-92.001106	23	8	7	5

**Description.** Very evolute ( $U/D = 0.38$ ) internal moulds. From 20 to 22 coarse, spine-like tubercles along the umbilical shoulder. Each tubercle gives rise to a single non-branching rib that weakens in the



mid-lateral region, becoming stronger and coarser on the outer flank and ending in prominent tubercles at the ventrolateral edge. The ribs are more or less straight but become slightly prorsiradiate on the outer whorls. The venter is not visible in any specimen.

**Remarks.** The strong, coarse, and robust ribbing and the presence of umbilical inner and outer ventrolateral tubercles differentiate this species from *C. wenoensis* (Adkins, 1920).

**Occurrence.** The species has been reported from uppermost Albian of Texas (USA), Tunisia, Sardinia, Switzerland, France and Hungary.

*Cantabrigites wenoensis* (Adkins, 1920)

Fig. 3H–N

1920 *Schoenbachia wenoensis* Adkins, p. 89, pl. 1, fig. 14.

2004 *C. wenoensis* (Adkins, 1920); Kennedy, pp. 875–877, figs. 10 I–R, 11A, B, 12A–G [with full synonymy].

**Material.** Twelve specimens, MNHNCu-92.001111–MNHNCu-92.001122, collected from the horizons I and II.

*Dimensions of the figured specimens.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001115	18	7	5	–
MNHNCu-92.001116	27	11	10	–
MNHNCu-92.001117	25	9	8	–
MNHNCu-92.001118	28	11	11	–
MNHNCu-92.001120	17	6	6	–
MNHNCu-92.001121	22	9	9	–
MNHNCu-92.001122	34	12	12	–

**Description.** Very evolute ( $U/D = 0.38$ ) internal moulds. Weak umbilical but not spinate bullae arise along the umbilical shoulder. These umbilical bullae give rise to about sixteen to nineteen single, non-branching ribs per half whorl. Ribs weaken on the mid-flank and end in a prominent bulla at the ventral edge. With growth, the ribs become slightly plicate and prorsiradiate, and the ventrolateral tubercles become less rigid.

**Remarks.** According to Kennedy (2004, p. 879), “*C. spinosum* is easily separated from *C. wenoensis* on the basis of its coarse ornamentation with strong umbilical, inner and outer ventrolateral tubercles.” The Cuban material presented herein supports this opinion, because the specimens of *C. wenoensis* display less coarse and less rigid ribs as well as less prominent tubercles, compared to *C. spinosum*. Moreover, the Cuban specimens of *C. wenoensis* show a higher rib index and a more involute coiling than *C. spinosum*.

**Occurrence.** *C. wenoensis* (Adkins, 1920) is reported from the uppermost Albian of Texas (USA) and Tunisia.

*Cantabrigites cf. wenoensis* (Adkins, 1920).

Fig. 3O

**Material.** One specimen, MNHNCu-92.001123, collected from the horizon I.

*Dimensions of the figured specimen.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001123	15	5	4	–

**Description:** A rather evolute ( $U/D = 0.33$ ), flattened internal mould. Twelve to 14 bullae arise on the umbilical shoulder and give rise to sinuous ribs that are prorsiradiate across the flanks. Each of

these primary ribs end in a spiny bulla at the ventrolateral edge. The rib index is 12–15 ribs per half whorl. Between two umbilical bullae, slight secondary and non-tuberculate ribs are found. Both the primary and the secondary ribs become weaker and smoother on the mid-flank. A keel on the venter is observed on some parts of the mould (indicated by arrows in Fig. 3O).

**Remarks:** This specimen looks like a transitional form between *C. spinosum* (Pervinquier, 1907) and *C. wenoensis* (Adkins, 1920). The spiny, tuberculated primary ribs resemble those of *C. spinosum*. However, the finer ornamentation with sinuous primary ribs and non-tuberculate, weak secondaries are more similar to those of *C. wenoensis*.

**Occurrence:** As mentioned above, the species has been reported from the uppermost Albian of Texas (USA) and Tunisia. However, besides these two occurrences of the species, *Cantabrigites* spp. are known from England, Sardinia, Switzerland, France and Hungary.

Family Lyelliceratidae Spath, 1921

Subfamily Stoliczkaiainae Breistroffer, 1953

Genus *Stoliczkaia* Neumayr, 1875

Subgenus *Stoliczkaia* (*Stoliczkaia*) Neumayr, 1875

Type species. *Ammonites dispar* d’Orbigny, 1841, p. 142, by subsequent designation.

*Stoliczkaia* (*Stoliczkaia*) cf. *clavigera* (Neumayr, 1875)

Fig. 4A–C

cf. 1864 *A. dispar* Stoliczka, p. 85, pl. 45, fig. 1 only.

cf. 1875 *Stoliczkaia clavigera* Neumayr, p. 933.

cf. 1994 *Stoliczkaia* (*Stoliczkaia*) *clavigera* (Neumayr); Wright and Kennedy, p. 576, figs. 5b; 11k–m, q, r; 12e–h, k–n; 13a–c; 14a–c [with full synonymy].

**Material.** Five specimens, MNHNCu-92.001125–MNHNCu-92.001129, collected from the horizons I and II.

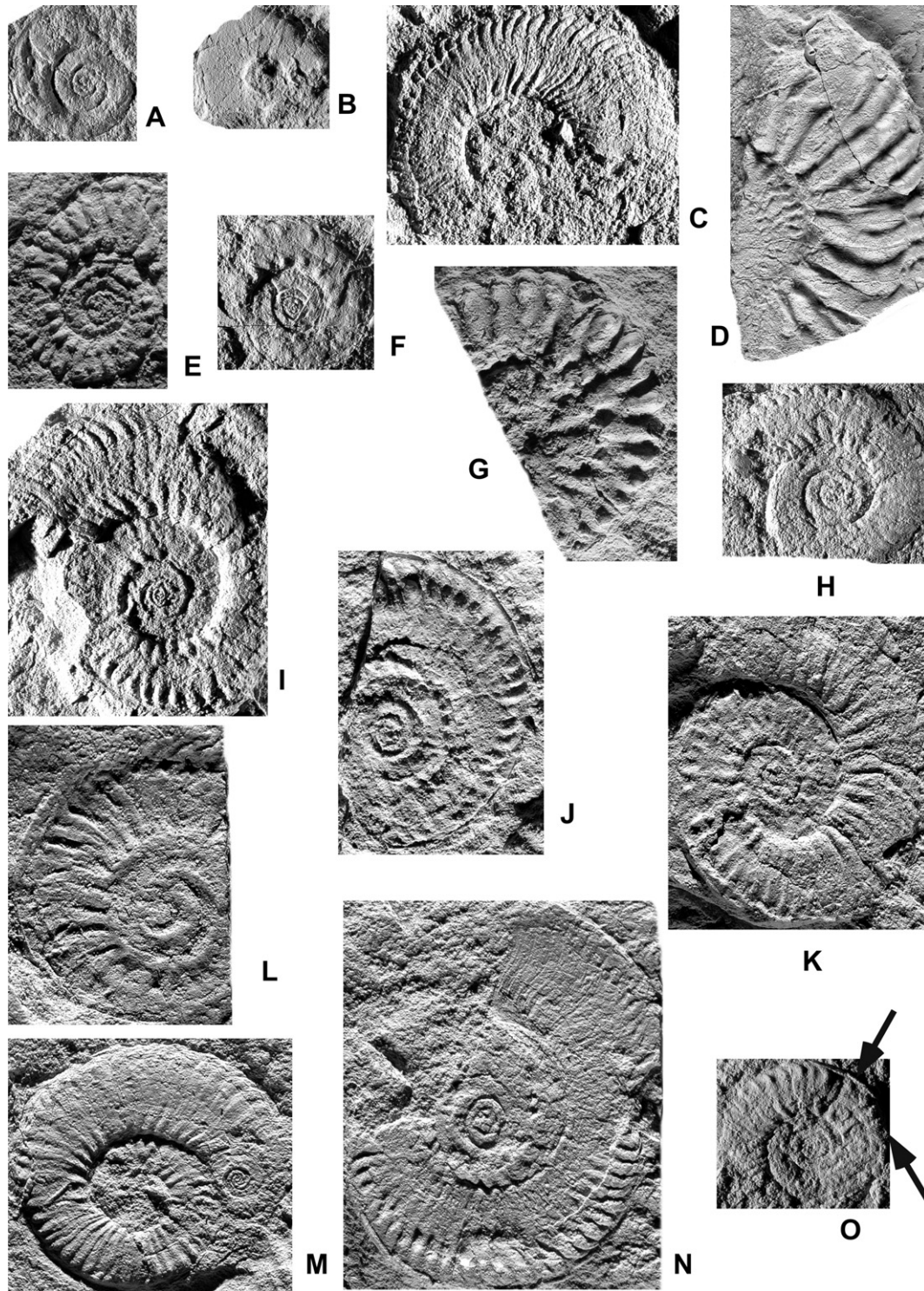
*Dimensions of the figured specimens.*

Specimen No.	D	U	Wh	Ww
MNHNCu-92.001127	62	10	21	–
MNHNCu-92.001128	45	7	23	–
MNHNCu-92.001129	63	12	22	–

**Description.** Slightly deformed involute ( $U/D = 0.16$ ) internal moulds. Weak bullae on the umbilical edge give rise to coarse and narrow primary ribs with finer ribs intercalated. In specimen MNHNCu-92.001128 (Fig. 4B), the ribs are crowded, narrow and persistent on the flank. The venter can be observed in this slightly deformed specimen, and the ribs seem to be angular and have weak tubercles on the ventral region. The rib index is more than 21 ribs per half whorl.

**Remarks.** The specimens assigned to *Stoliczkaia* superficially resemble *Stoliczkaia* (*Lamnayella*) *worthense* (Adkins, 1920), a species restricted to the upper Albian of Texas (USA). However, given Kennedy’s (2004, p. 882) analysis of hundreds of specimens of *S. (L.) worthense*, we conclude that the Cuban specimens display greater involution, stronger ornamentation, and distinct alternation of long and short ribs, and consequently believe that this material more resembles to *Stoliczkaia* (*Stoliczkaia*) cf. *clavigera* (Neumayr, 1875), which is also of late Albian age.

**Occurrence.** Although often considered to have Tethyan affinities, this cosmopolitan species has been reported from the



**Fig. 3.** Upper Albian ammonites of the Provincial Formation from the section studied. (A) *Protetragonites* cf. *aeolus* (d'Orbigny, 1850), MNHNCu-92.001100,  $\times 2$ . (B) *Desmoceras* (*Desmoceras*) cf. *latidorsatum* (Michelin), MNHNCu-92.001101,  $\times 1$ . (C) cf. *Discohoplites* sp., MNHNCu-92.001124,  $\times 2$ . (D) *Mortoniceras* sp., MNHNCu-92.001102,  $\times 1$ . (E–G) *C. spinosum* (Pervinqui re), all  $\times 2$ . (E) MNHNCu-92.001104. (F) MNHNCu-92.001105. (G) MNHNCu-92.001106. (H–N) *C. wenoensis* (Adkins). (H) MNHNCu-92.001115,  $\times 2$ . (I) MNHNCu-92.001116,  $\times 2$ . (J) MNHNCu-92.001117,  $\times 2$ . (K) MNHNCu-92.001118,  $\times 2$ . (L) MNHNCu-92.001120,  $\times 3$ . (M) MNHNCu-92.001121,  $\times 2$ . (N) MNHNCu-92.001122,  $\times 2$ . (O) *Cantabrigites* cf. *wenoensis*, MNHNCu-92.001123,  $\times 2$ .

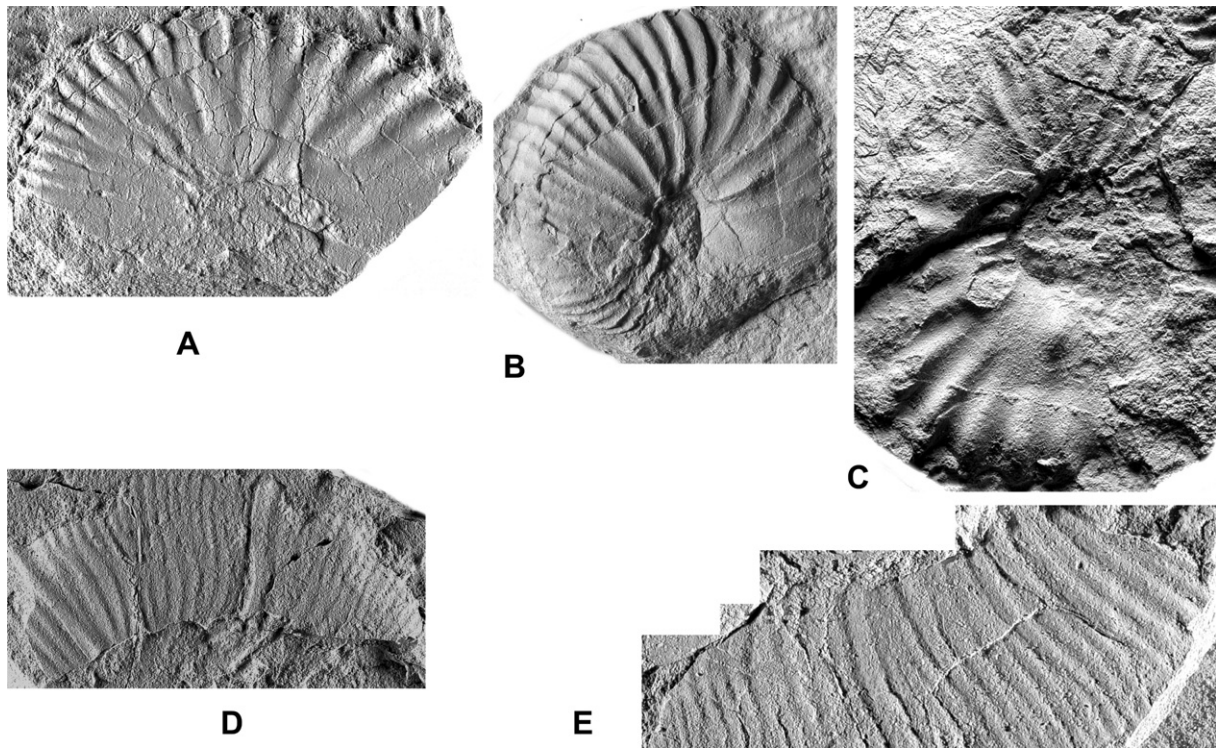
upper Albian of England, France, Switzerland, Romania, Hungary, Turkmenistan, Tunisia, Japan, Texas (USA) and South India.

Suborder Ancyloceratina Wiedmann, 1966  
Superfamily Turrilitaceae Gill, 1871

Family Anisoceratidae Hyatt, 1900  
Genus *Algerites* Pervinqui re, 1910

Type species. *Algerites sayni* Pervinqui re, 1910, p. 47, pl. 10 (1), figs. 21–25, by original designation.





**Fig. 4.** Upper Albian ammonites of the Provincial Formation from the section studied. (A–C) *Stoliczkaia* (*Stoliczkaia*) cf. *clavigera* (Neumayr), all  $\times 1$ . (A) MNHNCu-92.001127. (B) MNHNCu-92.001128. (C) MNHNCu-92.001129. (D–E) *Algerites* sp. (D) MNHNCu-92.001130,  $\times 1$ . (E) MNHNCu-92.001131,  $\times 2$ .

*Algerites* sp.

Fig. 4D–E

**Material.** Two moderately well-preserved internal mould fragments, MNHNCu-92.001130 and MNHNCu-92.001131, collected from the horizon II.

**Description.** Heteromorph ammonites with fine, narrow, slightly sinuous primary ribs that straighten and become wider towards the aperture. Between the primaries, intercalated ribs appear on the outer flank. Two shallow constrictions are present on the mould, each bordered with thickened collars. There are 11 primary ribs between these two constrictions. No tubercles are visible. The venter is not visible in any of the available specimens.

**Remarks.** Because of their constrictions, these specimens are best assigned to the heteromorph genus *Algerites*. This genus is definitely known from the early Cenomanian, although there are

also questionable reports from deposits of late Albian age. On the other hand, the two fragments also resemble *Anisoceras pseudoelegans* (Pictet and Campiche, 1861–1864), although they lack the tuberculation of that species and indeed of any other *Anisoceras*. In common with other *Algerites*, these specimens are superficially similar to contemporary *Idiohamites* Spath, 1925b, but the lack of constrictions, branched ribs, and uniform tuberculation distinguish *Idiohamites* from *Algerites* (Wright and Kennedy, 1995, p. 312).

Even so, *Algerites* is a poorly defined genus based on limited and fragmentary material, as discussed by Kennedy (1971, p. 14). Wright and Kennedy (1995, p. 312), whose work concerned *Algerites*, in the most recent and detailed study of the genus to date, assigned four species to *Algerites*: *A. sayni* (Pervinquière, 1910), *A. incertus* (Spath, 1939), *A. ellipticus* (Mantell, 1822) and *A. collignoni* (Föllmi, 1989), although the present authors consider the species described by Föllmi from Vorarlberg (Austria) to be a somewhat uncertain member of the genus. The Cuban specimens appear not to be identical with any of these species, but description of a new species will have to wait until more and better material is available.

**Occurrence.** These forms are found in the calcareous levels of the Provincial Formation exposed in the Province of Villa Clara, Cuba. Outside Cuba, the genus has been documented in the upper Albian *Stoliczkaia* (*S.*) *dispar* Zone of England, Austria and France; and from the lower Cenomanian *Mantelliceras mantelli* Zone, *Neostlingoceras carcitense* Subzone of France, Poland, England and Algeria.

## 5. Discussion and conclusions

Descriptions of the Cretaceous ammonite fauna of Cuba has been largely restricted to local reports not widely circulated outside the country, though the occurrence of Albian ammonites in the Provincial Formation has been mentioned in mapping reports, such as Kantchev et al. (1978).

SUBSTAGE	ZONES	SUBZONES	
		Owen, 1999	Reboullet et al., 2009
upper Albian	<i>Stoliczkaia</i> ( <i>S.</i> ) <i>dispar</i>	<i>biacensis</i>	<i>dispar</i>
		<i>perinflatum</i>	—?— —?—
		<i>rostratum</i>	<i>blancheti</i>
	<i>Mortoniceras inflatum</i>	4 subzones	unnamed
			<i>cristatum</i>

**Fig. 5.** Standard ammonite zonation of the upper Albian Substage (after Owen, 1999 and Reboullet et al., 2009). The section discussed in this paper is considered to be part of the upper Albian *Mortoniceras rostratum* Subzone (shaded area) of the *Stoliczkaia* (*Stoliczkaia*) *dispar* Zone, which in turn is approximately equivalent to the *Stoliczkaia* (*Stoliczkaia*) *blancheti* Subzone of the Mediterranean standard (Reboullet et al., 2009).

The ammonites in the micritic and marly limestones of the stratigraphic section studied show that the Provincial Formation that crops out at in the study area is of late, but not latest, Albian age. The presence of *Protetragonites* cf. *aeolus* (d'Orbigny), *Desmoceras* (*Desmoceras*) cf. *latidorsatum* (Michelin), cf. *Discohoplites* sp., *Mortoniceras* sp., *C. spinosum* (Pervinquière), *C. wenoensis* (Adkins), *Stoliczkaia* (*Stoliczkaia*) cf. *clavigera* (Neumayr), and *Algerites* sp. indicates a Tethyan assemblage typical of the uppermost Albian *Stoliczkaia* (*Stoliczkaia*) *dispar* Zone (Fig. 5). The presence of *Mortoniceras* suggests that the assemblage does not range up to the top of the Albian, though the co-occurrence of *Mortoniceras* with *Algerites* is remarkable due to the questionable late Albian record of the latter genus.

The ammonite fauna also reveals a strong Tethyan affinity, with boreal species underrepresented. Hoplitids are present, but scarce, and given the abundance of other ammonite fossils, this would seem to be a genuine reflection of their lack of importance within this ammonite fauna. This is important because the Albian was characterized by a division of northern hemisphere ammonite assemblages into distinct Tethyan, Boreal, and Arctic realms, a division that has been extensively discussed elsewhere (Owen, 1996, 1999, 2002; Owen and Mutterlose, 2006). Contemporaneous ammonite assemblages of the Arctic and Boreal realms differ greatly from those typical of the Tethyan Realm, particularly in the dominance of the genera *Anahoplites*, *Discohoplites* and *Callihoplites* in Boreal faunas compared with their absence from Tethyan ones.

Late Albian European ammonite faunas show “a general co-existence of Tethyan ammonites with the endemic hoplitid population” (Owen and Mutterlose, 2006, p. 722). In our study of the late Albian Cuban fauna, the same scenario would seem to exist, though more material is required to fully discuss and detail this phenomenon. Owen and Mutterlose (2006, p. 722) have published a revised scheme for the late Albian of Suriname relevant to the coeval ammonite assemblages of Venezuela and the South Atlantic region, but because they did not describe any ammonites from the *dispar* Zone of that area, contrasts cannot be made with the present discussion of the Provincial Formation ammonite fauna.

Kennedy (2004, p. 866) used the threefold zonation of Owen (1999) for the *dispar* Zone deposits of northeastern Texas. He reported *C. wenoensis*, *C. spinosum* and *S. (S.) clavigera* from the lower part of the Pawpaw Shale, which can be correlated with the *rostratum* Subzone of the European succession. We also regard our Cuban material as part of the *Mortoniceras rostratum* Subzone of the *dispar* Zone (sensu Owen, 1999 and Kennedy, 2004), which in turn is more or less equivalent to the *Stoliczkaia* (*Faraudiella*) *blancheti* Subzone of the Mediterranean standard (Reboulet et al., 2009) (Fig. 5).

Ammonite provincialism continued into the early Cenomanian but was less prominent, *Hyphoplites* rising to dominance, whereas *Schloenbachia* in the Boreal and Arctic realms became steadily less important (Wright et al., 1996).

Finally, the late Albian ammonite species presented here have not been reported from Cuba or any other Caribbean locality until now. Consequently these records shed new light on the paleobiogeographic distribution of these taxa and allow for the first time precise long-distance correlations between Cuba and other parts of the world using the “standard” Albian ammonite zonations.

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## References

- Adkins, W.S., 1920. The Weno and Pawpaw Formations of the Texas Comanchean. University of Texas Bulletin 1856, 1–172.
- Barragán-Manzo, R., Rojas-Consuegra, R., Szives, O., 2008. Upper Albian (Lower Cretaceous) ammonites from the Provincial Formation of central Cuba: biostratigraphic and Paleobiogeographic implications. Geological Society of America Annual Meeting, Houston, Texas, United States of America. Geological Society of America Abstracts with Programs 40 (6), 478.
- Breistroffer, M., 1953. Commentaires taxonomiques. In: Breistroffer, M., Villoutreysde, O. (Eds.), Les ammonites albiennes de Peille (Alpes-Maritimes). Travaux du Laboratoire de Géologie de la Faculté des Sciences de l'Université de Grenoble, vol. 30, pp. 69–74.
- Cobiella-Reguera, J., 2008. Palinspastic reconstruction of the Mesozoic North American paleomargin in west Cuba and the southeast Gulf of Mexico area. Implication for the evolution of the southeast portion of the Gulf of Mexico. Revista Mexicana de Ciencias Geológicas 25, 382–401 (in Spanish).
- Díaz de Villalvilla, L., 1997. Geological characterization of the volcanic and volcano-sedimentary formations in Central Cuba, Provinces of Cienfuegos, Villa Clara, Sancti Spiritus. In: Furrázola-Bermúdez, G.F., Núñez-Cambra, K.E. (Eds.), Studies About the Geology of Cuba. Centro Nacional de Información Geológica, Instituto de Geología y Paleontología, La Habana, pp. 325–344 (in Spanish).
- Douvillé, H., 1890. Sur la classification des Cératites de la Craie. Bulletin de la Société Géologique de France 3 (18), 275–292.
- Douvillé, H., 1912. Évolution et classification des Pulchelliidés. Bulletin de la Société Géologique de France 4 (11), 285–320.
- Föllmi, K.B., 1989. Beschreibung neugefundener Ammonoidea aus der Vorarlberger Garschella-Formation (Aptian-Albian). Jahrbuch der Geologischen Bundesanstalt 132 (1), 105–189.
- Furrázola-Bermúdez, G., Díaz-Otero, C., Rojas-Consuegra, R., García-Delgado, D., 2003. Biostratigraphic general aspects of the volcano-sedimentary formations of the Cretaceous Volcanic Arc and its cover, in central Cuba. In: Studies About the Volcanic Arcs in Cuba (CD ROM). Instituto de Geología y Paleontología, La Habana, Cuba. 10pp. (in Spanish).
- Furrázola-Bermúdez, G., Gil-González, S., 1997. A historic overview of the Cretaceous System. In: Furrázola-Bermúdez, G.F., Núñez-Cambra, K.E. (Eds.), Studies About the Geology of Cuba. Centro Nacional de Información Geológica, Instituto de Geología y Paleontología, La Habana, pp. 97–108 (in Spanish).
- Gale, A.S., Kennedy, W.J., Burnett, J.A., Caron, M., Kidd, B.E., 1996. The Late Albian to Early Cenomanian succession at Mont Risou near Rosans (Drôme, SE France): an integrated study (ammonites, inoceramids, planktonic foraminifera, nannofossils, oxygen and carbon isotopes). Cretaceous Research 17, 515–606.
- Gill, Th., 1871. Arrangement of the families of Mollusks. In: Smithsonian Miscellaneous Collections, vol. 227 1–49.
- de Grossouvre, A., 1894. Recherches sur la Craie supérieure. Deuxième partie: Paléontologie. Les ammonites de la Craie supérieure. Mémoires du Service de la Carte Géologique Détaillée de la France 264 89 figs., 39 pls.
- Hyatt, A., 1889. Genesis of the Arietitidae. In: Smithsonian Contributions to Knowledge 673, Washington, D.C., xi+238 pp., 14 pls.
- Hyatt, A., 1900. Cephalopoda (C.R. Eastman, Trans.). In: Zittel, K.A. (Ed.), Textbook of Palaeontology, first English ed. Macmillan, London & New York, pp. 502–592. figs. 1049–1235.
- Iturralde-Vinent, M., 1997. Introduction to the Geology of Cuba. In: Furrázola-Bermúdez, G.F., Núñez-Cambra, K.E. (Eds.), Studies About the Geology of Cuba. Centro Nacional de Información Geológica, Instituto de Geología y Paleontología, La Habana, pp. 35–68 (in Spanish).
- Kantchev, I.L., Boyanov, Y., Popov, N., Cabrera, R., Goranov, A.L., Iolkicev, N., Kana-zirski, M., Stancheva, M., 1978. Geology of the Province of Las Villas. Results of the geological studies and geologic mapping to the scale 1:250 000, carried out during the period 1969–1975. Cuban–Bulgarian Brigade. Instituto de Geología y Paleontología, Academia de Ciencias de Cuba, Oficina Nacional de Recursos Minerales. Ministerio de la Industria Básica, La Habana (Unpublished) (in Spanish).
- Kennedy, W.J., 1971. Cenomanian ammonites from southern England. In: Palaeontological Association, Special Papers in Palaeontology, vol. 8 pls. 1–641–133.
- Kennedy, W.J., 2004. Ammonites from the Pawpaw Shale (Upper Albian) in northeast Texas. Cretaceous Research 25, 865–905.



- Kennedy, W.J., Cobban, W.A., Hancock, J.M., Gale, A.S., 2005. Upper Albian and Lower Cenomanian ammonites from the Main Street Limestone, Grayson Marl and Del Rio Clay in northeast Texas. *Cretaceous Research* 26, 349–428.
- Kennedy, W.J., Latil, J.L., 2007. The Upper Albian ammonite succession in the Montlaur section, Hautes-Alpes, France. *Acta Geologica Polonica* 57, 453–478.
- Mancini, E.A., 1979. Late Albian and Early Cenomanian Grayson Ammonite biostratigraphy in north-central Texas. *Journal of Paleontology* 5, 1013–1022.
- Mantell, G.A., 1822. The Fossils of the South Downs, or Illustrations of the Geology of Sussex. L. Rolfe, London, xiv+328 pp., 3 figs., 43 pls.
- Marshall, P., 1926. The Upper Cretaceous ammonites of New Zealand. *Transactions and Proceedings of the New Zealand Institute* 56, 129–210.
- Meek, F.B., 1876. A report on the invertebrate Cretaceous and Tertiary fossils of the Upper Missouri Country. In: Hayden, F.V. (Ed.), Report of the United States Geological and Geographical Surveys of Territories 9, xiv+629 pp., 84 figs., 45 pls.
- Michelin, H., 1838. Note sur une argile dépendant du Gault observée au Gaty, commune de Gérodot, Département de l'Aube. *Mémoires de la Société Géologique de France*, 1e série 3, 97–103.
- Monod, O., Busnardo, R., Guerrero-Suástegui, M., 2000. Late Albian ammonites from the carbonate cover of the Teloloapan arc volcanic rocks (Guerrero State, Mexico). *Journal of South American Earth Sciences* 13, 377–388.
- Morton, S.G., 1834. Synopsis of the Organic Remains of the Cretaceous Group of the United States. Key & Biddle, Philadelphia, 88 pp. 1 fig., 19 pls.
- Neumayr, M., 1875. Über Kreideammonitiden. *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften, mathematisch-naturwissenschaftliche Classe* 71, 639–693.
- d'Orbigny, A., 1840–1842. Céphalopodes. In: *Paléontologie française. Terrains Crétacés*. I. Masson, Paris, 662 pp., 148 pls.
- d'Orbigny, A., 1850. Notes sur quelques nouvelles espèces remarquables d'Ammonites des étages Néocomien et Aptien de la France. *Journal de Conchyliologie*, Paris 1 196–201 8 pls.
- Owen, H.G., 1996. Boreal and Tethyan Late Aptian to Late Albian ammonite zonation and palaeobiogeography. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg* 77, 461–481.
- Owen, H.G., 1999. Correlation of Albian European and Tethyan ammonite zonation and the boundaries of the Albian stage and substages: some comments. *Scripta Geologica* 3, 129–149. Special Issue.
- Owen, H.G., 2002. The base of the Albian stage; comments on recent proposals. *Cretaceous Research* 23, 1–13.
- Owen, H.G., Mutterlose, J., 2006. Late Albian ammonites from offshore Suriname: implications for biostratigraphy and palaeobiogeography. *Cretaceous Research* 27, 717–727.
- Pervinquier, L., 1907. Études de paléontologie tunisienne. Céphalopodes des Terrains secondaires. Carte Géologique de la Tunisie, Rudeval, Paris, 438 pp. 158 figs., 27 pls., Atlas.
- Pervinquier, L., 1910. Sur quelques ammonites du crétacé algérien. *Mémoires de la Société Géologique de France, Paléontologie* 17 (2–3), 86. figs. 1–38, pls. 1–7.
- Pictet, F.-J., Campiche, G., 1861–1864. Description des fossiles du terrain Crétacé des environs de Sainte-Croix. Part 2. In: *Matériaux pour la Paléontologie Suisse* (series 3), pp. 1–752, pls. 44–98.
- Reboullet, S., Klein, J., Barragán, R., Company, M., González-Arreola, C., Lukeneder, A., Raisossadat, S.N., Sandoval, J., Szives, O., Tavera, J.M., Vašíček, Z., Vermeulen, J., 2009. Report on the 3rd International Meeting of the IUGS Lower Cretaceous Ammonite Working Group, the “Kilian Group” (Vienna, Austria, 15th April 2008). *Cretaceous Research* 30, 496–502.
- Renz, O., 1982. The Cretaceous Ammonites of Venezuela. *Petróleos de Venezuela, S.A., Maraven*, 132 pp., 40 pls.
- Rutten, M., 1936. Geology of the northern part of the Province Santa Clara, Cuba. *Geographische en Geologische Mededeelingen* 11, 1–60.
- Scholz, G., 1979. Die Ammoniten des Vracon (Oberalb, *dispar*-Zone) des Bakony-Gebirges (Westungarn) und eine Revision der wichtigsten Vracon-Arten der westmediterranen Faunenprovinz. *Palaeontographica* A165, 1–13.
- Scott, R.W., 2009. Uppermost Albian biostratigraphy and chronostratigraphy. *Carnets de Géologie/Notebooks on Geology* CG2009\_A03, 1–16.
- Seeley, H.G., 1865. On ammonites from the Cambridge Greensand. *Annals and Magazine of Natural History* 3 (16), 225–247.
- Spath, L.F., 1921. On Cretaceous Cephalopoda from Zululand. *Annals of the South African Museum* 12, 217–321.
- Spath, L.F., 1925a. A monograph of the Ammonoidea of the Gault. Part 2. *Monographs of the Palaeontographical Society*, London, 73–110. figs. 15–25, pls. 5–8.
- Spath, L.F., 1925b. On Upper Albian Ammonoidea from Portuguese East Africa, with an appendix on Upper Cretaceous ammonites from Maputoland. *Annals of the Transvaal Museum* 11, 179–200. 28–37 pls.
- Spath, L.F., 1932. A monograph of the Ammonoidea of the Gault. Part 9. *Monographs of the Palaeontographical Society*, London, 379–410. figs. 125–140, pls. 37–42.
- Spath, L.F., 1934. A monograph of the Ammonoidea of the Gault. Part 11. *Monographs of the Palaeontographical Society*, London, 443–496. figs. 153–173, pls. 49–56.
- Spath, L.F., 1939. A monograph of the Ammonoidea of the Gault. Part 13. *Monographs of the Palaeontographical Society*, London, 541–608. figs. 191–217, pls. 59–64.
- Stoliczka, F., 1864. Ammonitidae, with revision of the Nautilidae. In: Blanford, H.F., Stoliczka, F. (Eds.), *The Fossil Cephalopoda of the Cretaceous Rocks of Southern India. Memoirs of the Geological Survey of India, Palaeontologia Indica* 3 (1), 57–106, pls. 26–31.
- Thiaden, A., 1937. Geology of the southern part of the Province Santa Clara (Las Villas) Cuba. *Geographische en Geologische Mededeelingen* 12, 1–71.
- Wiedmann, J., 1966. Stammesgeschichte und System der posttriadischen Ammonoideen, ein Überblick. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 127, 13–81.
- Wiedmann, J., Owen, H.G., 2001. Late Albian ammonite biostratigraphy of the Kirchrode I borehole, Hannover, Germany. *Palaeogeography, Palaeoclimatology, Palaeoecology* 174, 161–180.
- Wright, C.W., Calloman, J.H., Howarth, M.K., 1996. Cretaceous Ammonoidea. In: *Treatise on Invertebrate Paleontology, Part L Mollusca* 4 Revised, vol. 4. The Geological Society of America Inc./The University of Kansas, 362 pp.
- Wright, C.W., Kennedy, W.J., 1994. Evolutionary relationship among *Stoliczkaia* (Cretaceous ammonites) with an account of some species from the English *Stoliczkaia dispar* Zone. *Cretaceous Research* 15, 547–582.
- Wright, C.W., Kennedy, W.J., 1995. The Ammonoidea of the Lower Chalk. Part 4. *Palaeontographical Society*, London, pp. 295–319, pls. 87–96.
- Young, K., 1957. Upper Albian (Cretaceous) Ammonoidea from Texas. *Journal of Paleontology* 31, 1–33.
- Young, K., 1979. Lower Cenomanian and Late Albian (Cretaceous) ammonites, especially *Lyelliceratidae*, of Texas and Mexico. *Texas Memorial Museum, Bulletin* 26, v+99.
- Young, K., 1986. The Albian–Cenomanian (Lower Cretaceous–Upper Cretaceous) boundary in Texas and northern Mexico. *Journal of Paleontology* 60, 1212–1219.
- Zelepuguin, V., Díaz de Villalvilla, L., Fonseca, E., Villa, M., Domínguez, E., Torres, M., 1986. Petrology of the vulcanogenic and vulcano-sedimentary rocks of Cuba. Report. Oficina Nacional de Recursos Minerales. Instituto de Geología y Paleontología (Unpublished) (in Spanish).
- Zittel, K.A., 1884. Cephalopoda. In: *Handbuch der Palaeontologie*, Abt. 2 pp. 329–522.
- Zittel, K.A., 1895. *Grundzüge der Palaeontologie*. Oldenbourg, Munich and Leipzig, vii+972 pp., 2048 figs.