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Late Campanian polyptychoceratine ammonites from the Lehrte West Syncline, Hannover area, northwest Germany

John W.M. Jagt [a,*], Christian Neumann [b]

[a] *Natuurhistorisch Museum Maastricht, de Bosquetplein 6-7, NL-6211 KJ Maastricht, The Netherlands*
[b] *Museum für Naturkunde der Humboldt-Universität Berlin, Invalidenstraße 43, D-10115 Berlin, Germany*

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Abstract

Two faunules of heteromorph ammonites (Polyptychoceratinae) are recorded from the *vulgaris*/*stolleyi* and *minor*/*polyplocum* zones (mid/upper Campanian) as exposed at the Teutonia Nord (Teutonia AG) quarry near Misburg (Lehrte West Syncline, Hannover area, northwest Germany). Four taxa are recognised: *Oxybeloceras* aff. *crassum*, *Pseudoxybeloceras* (*Parasolenoceras*) ?*phaleratum*, *Solenoceras* aff. *texanum* and *Spiroxybeloceras*? *grande* sp. nov. Species of *Oxybeloceras*, *Solenoceras* and *Spiroxybeloceras* are widely distributed in the upper Campanian of the Western Interior and the Atlantic Seaboard of the USA, where their stratigraphic ranges are well known. Comparison of the new northwest German records with these ranges suggests polyptychoceratines are less well suited for strict zone-level correlations than are co-occurring nostoceratid and scaphitid ammonites.

Keywords: Ammonoidea; Diplomoceratidae; Polyptychoceratinae; Upper Cretaceous; Campanian; Northwest Germany; Comparisons; Western Interior; Atlantic Seaboard

1. Introduction

The lower and upper Campanian chalk/marl rhythmites exposed in a number of working quarries east of Hannover (Lehrte West Syncline, northwest Germany; Fig. 1) have yielded numerous heteromorph ammonite taxa, mostly baculitids, as well as scaphitids (genera *Scaphites*, *Trachyscaphites* and *Jeletzkytes*), diplomoceratids [species of *Glyptoxoceras*, *Lewyites*, *Neancyloceras*, *Neoglyptoxoceras*, *Neocrioceras* (*Schlueterella*) and *Scalarites*] and nostoceratids (Table 1; compare Zawischa and Schormann, 1992; Niebuhr, 1996, 2004; Niebuhr et al., 1997; Säbele, 2005). Species represented here compare well with records from elsewhere in northwest and central Europe (Błaszkiewicz, 1980; Wippich, 1995; Kaplan et al., 1996, in press; Kennedy and Kaplan, 1995, 1997; Hauschke et al., 1999; Kennedy and Summesberger, 1999, 2001; Summesberger and Kennedy, 2004).

Previous records of Polyptychoceratinae from this area are few; Niebuhr (2005, fig. 5) listed, but did not illustrate, *Solenoceras mortoni* from the middle *minor*/*polyplocum* Zone at the Teutonia Nord quarry, while Säbele (2005, p. 22, top left-hand figure) figured a specimen under the name of *Solenoceras* sp. from the same quarry, but failed to indicate its stratigraphic level. Although the illustration is too poor to determine this beyond doubt, this specimen appears to be closely related to, if not conspecific with, *Pseudoxybeloceras* (*Pseudoxybeloceras*) *kollmanni* Summesberger and Kennedy, 2004 (p. 182, pls. 8, 9), from the ?upper Campanian of the Gschliefgraben (Ultrahelvetic Nappe, Austria). Without having seen the actual specimen, we cannot comment further at this time.

Here, two lots are described from the Teutonia Nord quarry at Misburg (Fig. 1), one of the key localities in the Lehrte West Syncline (Ernst et al., 1997; Stratigraphische Kommission

* Corresponding author.
E-mail address: john.jagt@maastricht.nl (J.W.M. Jagt).

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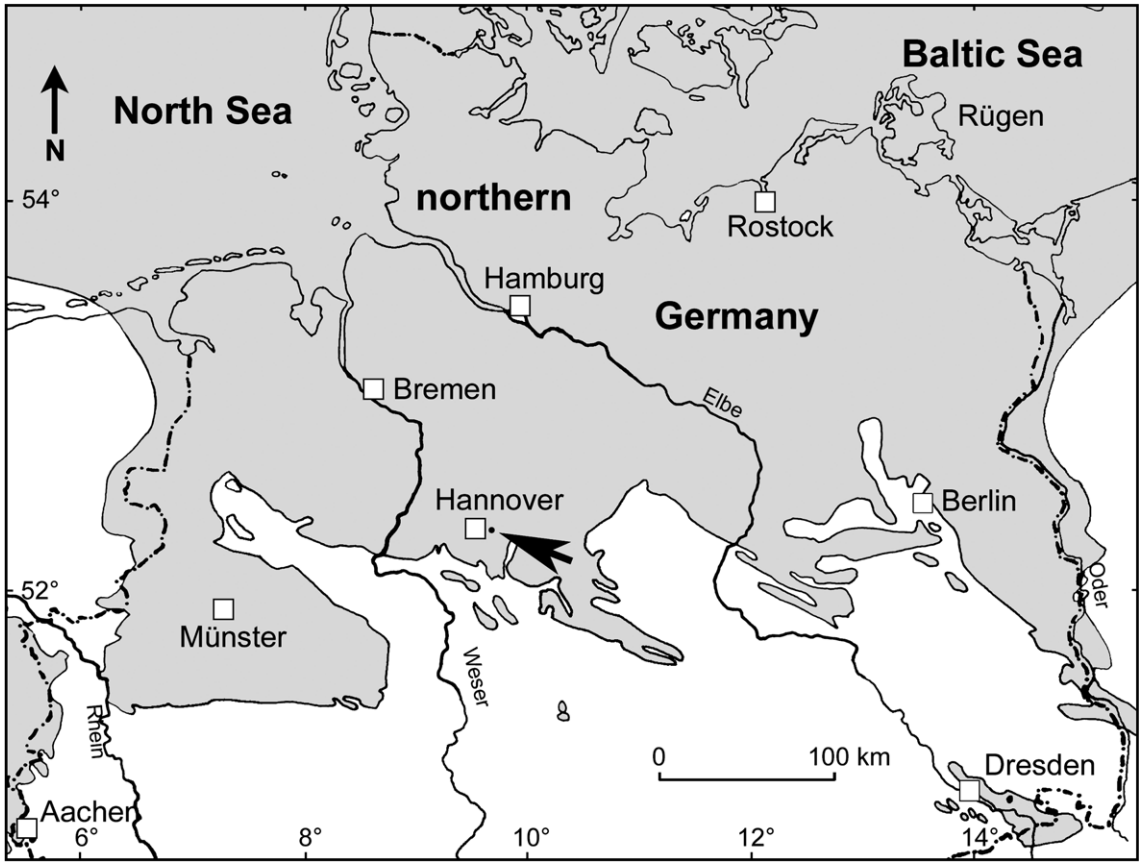

Fig. 1. Location (arrow) of the Teutonia Nord (Teutonia AG) quarry at Misburg (Lehrte West Syncline), east of Hannover, northern Germany; Cretaceous strata, both surface and subsurface, are shaded (modified after Niebuhr, 2004); see Niebuhr and Reich (2004) for a detailed map and a stratigraphic section of this quarry.

Deutschlands, 2000; Niebuhr and Reich, 2004). One of them is preserved in a matrix block, in an association reminiscent of material from the Pierre Shale of the Western Interior illustrated by Larson et al. (1997), and comprises two taxa. Unfortunately, this block was collected loose, but from information provided by the collectors it is here assumed to have originated from the *vulgaris*/*stolleyi* Zone (Table 2). Additional material, supplied by Berlin-based private collectors, is from the new easterly extension in the Teutonia Nord quarry, exposing the overlying *minor*/*polyplocum* Zone (see Niebuhr and Reich, 2004, fig. 2).

All specimens are preserved as fragmentary, diagenetically flattened and/or distorted composite moulds, which means that whorl breadth/whorl height ratios are difficult to determine. Consequently, generic and specific assignments are tentative at best, pending the discovery of more and better-preserved material. In general, species assignment within Diplomoceratidae (and Polyptychoceratinae) remains difficult (see Cooper, 1994), a view also expressed by Klinger and Kennedy (2003) in their treatment of Late Cretaceous nostoceratids and diplomoceratids from Zululand and Natal, South Africa.

In comparison to nostoceratid and scaphitid ammonites, on which transatlantic correlations have been based in recent literature, polyptychoceratine taxa appear less well suited for this purpose. Ranges of species of *Oxybeloceras*, *Solenoceras* and *Spiroxybeloceras* in the Western Interior and Atlantic Seaboard are well known, and suggest the new northwest German records the span the interval between the *Baculites scotti* Zone below and *B. reesidei* Zone (Table 3) above. However, the scaphitids *Trachyscaphites spiniger* and *T. pulcherrimus*, known from Europe as well as North America, provide much more reliable correlation tools (see Niebuhr and Reich, 2004, fig. 3).

Abbreviations. To denote the repositories of specimens referred to in the text, the following abbreviations are used: GPIG, Geologisch-Paläontologisches Institut und Museum der Georg-August Universität, Göttingen; MAB, Oertijdmuseum de Groene Poort, Boxtel (The Netherlands); MNB, Museum für Naturkunde, Humboldt Universität, Berlin; USNM, United States National Museum, Washington DC. Other abbreviations: Wb, whorl breadth; Wh, whorl height; RI, rib index.

2. Systematic palaeontology

Suborder: Ancyloceratina Wiedmann, 1966
Superfamily: Turrilitoidea Gill, 1871
Family: Diplomoceratidae Spath, 1926
Subfamily: Polyptychoceratinae Matsumoto, 1938
Genus *Oxybeloceras* Hyatt, 1900

Type species. *Ptychoceras crassum* Whitfield, 1877, by original designation.

Table 1
Heteromorph ammonite taxa recorded to date from the Campanian (*lingua*/*quadrata* to *bipunctatum*/*roemeri* zones; see Table 2) of the Lehrte West Syncline (after Niebuhr, 1996, 2004, 2005; Niebuhr et al., 1997; Säbele, 2005)

Diplomoceratidae
Lewyites elegans
Neancyloceras bipunctatum
**Oxybeloceras* aff. *crassum*
**Pseudoxybeloceras (Parasolenoceras) ?phaleratum*
Solenoceras mortoni
Solenoceras sp.
**Solenoceras* aff. *texanum*
**Spiroxybeloceras*? *grande*

Nostoceratidae
Nostoceras (Bostrychoceras) polyplocum
Nostoceras (Didymoceras) varium
Nostoceras (Didymoceras) postremum
Nostoceras ("Mobergoceras") junior

Baculitidae
various species, mostly indeterminate

Scaphitidae
Hoploscaphites greenlandicus
Jeletzkytes compressus
Scaphites (Scaphites) cobbani
Scaphites (Scaphites) gibbus
Scaphites (Scaphites) hippocrepis
Trachyscaphites pulcherrimus
Trachyscaphites spiniger spiniger
[possibly also *Hoploscaphites ikorfatensis*]

Species discussed in this paper are marked with an asterisk. Note: *Mobergoceras* Schmid and Ernst, 1975 was considered to be a junior synonym of *Nostoceras* by Kennedy and Christensen (1997).

Oxybeloceras aff. *crassum* (Whitfield, 1877)
Fig. 2A–C

compare

1877 *Ptychoceras crassum* Whitfield, p. 45.
1984 *Pseudoxybeloceras* (*Parasolenoceras*) *interruptum* (Schlüter, 1872); Kennedy and Summesberger, p. 167, pl. 9, figs. 5, 10, 11.
2000 *Pseudoxybeloceras* (*Parasolenoceras*) cf. *interruptum* (Schlüter); Küchler, pl. 12, figs. 9, 10 only.
2000c *Oxybeloceras crassum* (Whitfield, 1877); Kennedy et al., p. 65, figs. 51–54 (with synonymy).
2001 *Oxybeloceras* sp.; Kennedy and Odin, p. 481, pl. 2, fig. 17.

Type. Holotype, by monotypy, is USNM 12324, the original of Whitfield (1877, p. 46) and Whitfield (1880, p. 459, pl. 16, figs. 3–5), probably from the *Didymoceras stevensoni* Zone of Niobrara County, Wyoming.

Material. Two specimens, MAB 3290/a, b, probably from the *vulgaris*/*stolleyi* Zone at the Teutonia Nord quarry, Misburg.

Description. MAB 3290/a (Fig. 2C), preserved over most of its length as an external mould, attains an overall length of 85.5 mm, and consists of two straight, parallel limbs or shafts in tight contact, except for an elongate, tear-shaped opening associated with the curved sector; early whorls and aperture not preserved. Whorl section probably subcircular, but distorted to an ellipse. Ornament comprises strong, blunt (preservation induced?), straight ribs; RI 4 (-4.5); ?each rib with an inconspicuous bullate tubercle, of varying strength. Ribs prorsiradiate on smaller limb, rectiradiate on curved sector and rursiradiate on larger limb; weakening on venter; tubercles apparently connected by weak ribs. Constrictions lacking; sutures not seen.

As preserved, MAB 3290/b (Fig. 2B) is 38.5 mm long; closely comparable in size and general habitus to the other

Table 2
Biozonation of the Campanian of the Lägerdorf-Kronsmoor-Hemmoor (LKH) standard section, of the Münsterland Basin and of the Lehrte West Syncline (northwest Germany; after Kaplan et al., 1996, in press; Niebuhr, 2003, 2004; Niebuhr et al., 1997; see also Kennedy and Kaplan, 1997)

	LKH	Münsterland	Lehrte West Syncline
Campanian	*grimmensis*/*granulosus*		
	langei		*bipunctatum*/*roemeri*
	polyplocum	*polyplocum*	*minor*/*polyplocum*
	roemeri	*roemeri*	*vulgaris*/*stolleyi*
	basiplana/*spiniger*	*vulgaris*/*basiplana*	*vulgaris*/*basiplana*
	basiplana/*stobaei*	*basiplana*/*stobaei*	*stobaei*/*basiplana*
	conica/*mucronata*	*conica*/*mucronata*	*conica*/*mucronata*
	gracilis/*mucronata*	*gracilis*/*mucronata*	*gracilis*/*mucronata*
	conica/*papillosa*		*conica*/*papillosa*
	papillosa		*papillosa*
	senonensis	*quadrata*	*senonensis*
	pilula/*senonensis*		*pilula*/*senonensis*
	pilula		*pilula*
	lingua/*quadrata*		*lingua*/*quadrata*
	granulataquadrata		*granulataquadrata*

Table 3
Biozonation of the Campanian of the Western Interior, Gulf Coast and Atlantic Seaboard (USA; after Cobban and Kennedy, 1991a, 1992; Kennedy and Cobban, 1993b)

Campanian	*Baculites jenseni*
	Baculites reesidei
	Baculites cuneatus
	Baculites compressus
	Didymoceras cheyennense
	Exiteloceras jenneyi
	Didymoceras stevensoni
	Didymoceras nebrascense
	Baculites scotti
	Baculites reduncus
	Baculites gregoryensis
	Baculites perplexus
	Baculites sp. (smooth)
	Baculites asperiformis
	Baculites mclearni
	Baculites obtusus
	Baculites sp. (weak flank ribs)
	Baculites sp. (smooth)
	Scaphites hippocrepis III
	Scaphites hippocrepis II
	Scaphites hippocrepis I
	Scaphites leei III

specimen, but showing slightly denser ribbing (markedly rursiradiate and concave) on the lower portion of the larger limb, the result of an ?injury. Elbow diameters of ca. 18 and 15.5 mm, respectively, suggest that these specimens represent the larger (macroconch) of the dimorphs documented by Kennedy et al. (2000c). No constrictions; sutures not seen. In neither specimen is an impressed dorsal furrow in the larger limb, to accommodate the small limb, seen.

Discussion. These specimens are close to both *Oxybeloceras crassum* and *Spiroxybeloceras kimbroense* Kennedy and Cobban, 1999 (p. 74, pl. 1, figs. 1–18; pl. 5, figs. 1–10; text-figs. 5, 6), showing a comparable style of ribbing (and rib index; 3–5 for *O. crassum*, 3.5–5 for *Sp. kimbroense*) and general habitus. However, they differ from *O. crassum* (see revision by Kennedy et al., 2000c) in having a larger tear-shaped opening associated with the curved sector and, possibly, less closely spaced ribbing on the smaller limb, and less regular occurrence of tubercles at the edges of the venter. *Spiroxybeloceras kimbroense* also shows a large tear-shaped opening, yet has no impressed dorsal furrow on the dorsum of the larger limb, and appears to have much more regular ventral tuberculation (see Kennedy and Cobban, 1999). In addition, the older portion of the smaller shaft shows a tendency to curve into a broadly curved limb connecting to a loose criocone (see Kennedy and Cobban, 1999, fig. 5). This curvature of the smaller limb is not seen in the material from the Teutonia Nord quarry, which is why this is tentatively assigned to *O. crassum*. Coeval specimens here referred to *Spiroxybeloceras* (see below) have a different style of ribbing on the larger limb, and do show the curvature of the older portion of the smaller limb.

Küchler (2000, pl. 12, figs. 9, 10) illustrated a specimen from the upper Campanian (*Trachyscaphites pulcherrimus* Partial Range Zone) of the Barranca (Navarra, northeast Spain) under the name of *Pseudoxybeloceras* (*Parasolenoceras*) cf. *interruptum*. The fact that it shows two straight, closely adpressed shafts and a tear-shaped opening associated with the curved sector, means that it cannot be assigned to *Pseudoxybeloceras* (*Parasolenoceras*). The general habitus and style of ribbing and tuberculation show it to be conspecific with specimens from the Lehrte West Syncline here recorded as *Oxybeloceras* aff. *crassum*. The same holds true for specimens from the upper Campanian of the Gschliefgraben (Ultrahelvetic Nappe, Austria), illustrated by Kennedy and Summesberger (1984), as well as a single individual from the upper Campanian of Tercis les Bains, Landes (France; see Kennedy and Odin, 2001).

Occurrence. To date, the present form is known only from the upper Campanian (*vulgaris*/*stolleyi* Zone inferred) of the Lehrte West Syncline. The species with which it is here compared, *Oxybeloceras crassum*, has been recorded from numerous localities in Montana, Wyoming and Colorado, usually co-occurring with *Didymoceras stevensoni* and, less often, with *Exiteloceras jenneyi*, and possibly also from the Taylor Group of Williamson County, east-central Texas.

Genus *Pseudoxybeloceras* Wright and Matsumoto, 1954

Type species. *Hamites quadrispinosus* Jimbo, 1894, by original designation.

Subgenus *Parasolenoceras* Collignon, 1969

Type species. *Parasolenoceras splendens* Collignon, 1969, by original designation.

Discussion. Klinger and Kennedy (2003, p. 317) diagnosed the genus *Pseudoxybeloceras* as consisting primarily of straight or curved shafts connected by U-bends; ribbing may be bi- or quadrituberculate, and in some forms with major ribs on body chamber. Ribbing uniform throughout, and with initial ornament consisting of ventral tubercles on ribs only, but soon after changing to ventral and ventrolateral tubercles on every rib.

Pseudoxybeloceras (*Parasolenoceras*) ?*phaleratum* (Griepenkerl, 1889)
Fig. 2A, D–F

compare

1889 *Hamites phaleratus* Griepenkerl, p. 406, pl. 44, fig. 3; pl. 45, figs. 3, 4.
1980 *Neancyloceras phaleratum* (Griepenkerl, 1889); Błaszkiewicz, p. 28, pl. 11, figs. 1, 2, 4–8; pl. 12, figs. 1–4, 6–9.
1998 *Neancyloceras* (?) *phaleratum* (Griepenkerl, 1889); Kennedy and Jagt, p. 161, pl. 1, figs. 8–10.

Type. Lectotype, designated by Błaszkiewicz (1980, p. 28), is the original of Griepenkerl (1889, pl. 45, fig. 3), from the ‘‘Mucronaten-Schichten des Steindorenberges bei Lauingen’’; current whereabouts unknown.

Material. Three specimens, MAB 3290/c–e, probably from the *vulgaris*/*stolleyi* Zone at the Teutonia Nord quarry, Misburg, on the same matrix block with *Oxybeloceras* aff. *crassum* (MAB 3290/a, b).

Description. MAB 3290/c, d represent flattened composite moulds of two (near-)parallel limbs connected by a U-bend, of 49 and 58 mm in length (as preserved), respectively. Maximum preserved whorl heights in smaller and larger limbs are ca. 8–9 and 13.5 mm in costal section, respectively; original whorl section cannot be determined because of post-mortem crushing, but dorsum broadly rounded in costal and intercostal section, inner flanks feebly convex, outer flanks flattened and convergent; venter rounded in intercostal section and flattened in costal section. Ornament consists of coarse ribs with wider interspaces, weakening on dorsum, straight and prorsiradiate on flanks; on larger limb, almost all ribs have strong ventral clavi. On smaller limb,

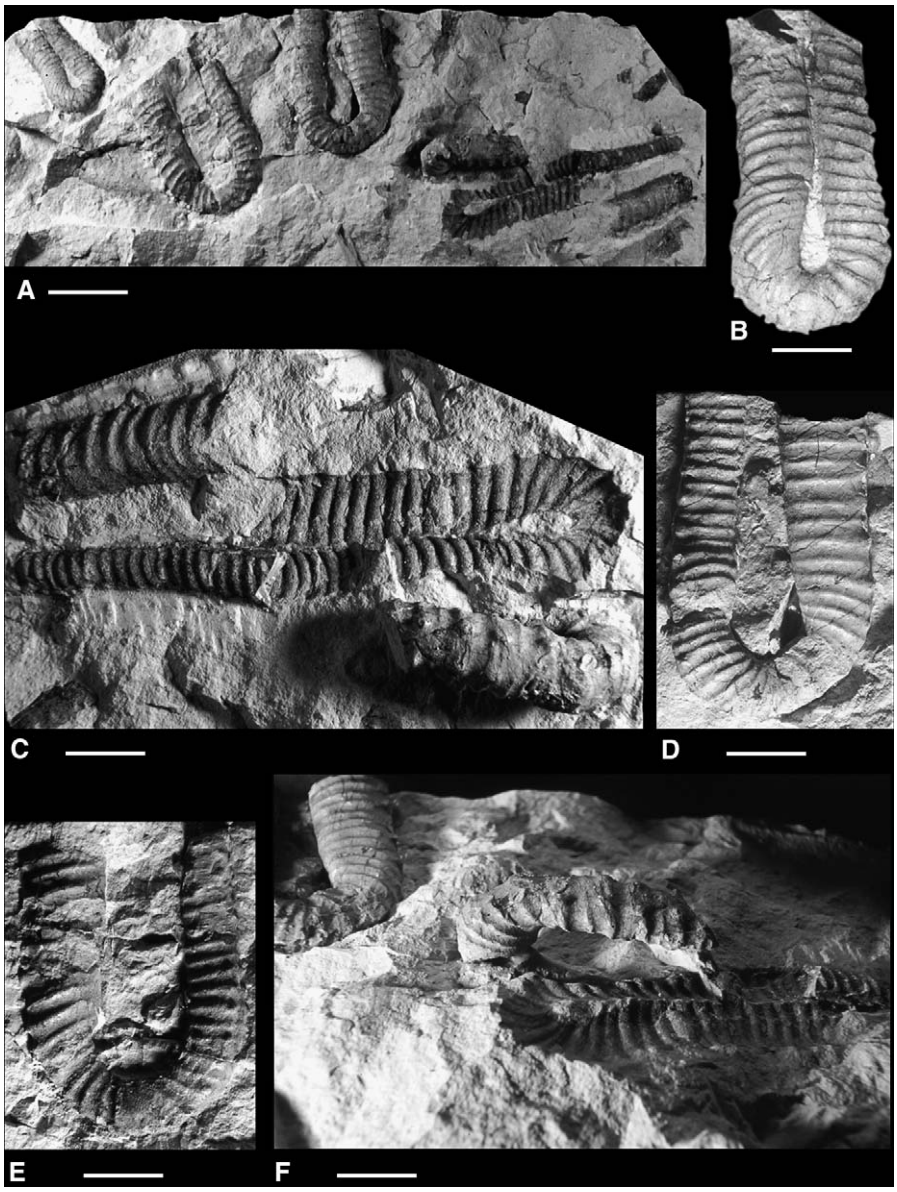

Fig. 2. MAB 3290 (leg. A. Visser), Teutonia Nord quarry, Misburg (Lehrte West Syncline), probably *vulgaris*/*stolleyi* Zone (mid/upper Campanian). A, view of entire block; scale bar represents 20 mm; other figures are enlargements of individual specimens preserved on this slab. B, C, *Oxybeloceras* aff. *crassum* (Whitfield, 1877), MAB 3290/a, b. D–F, *Pseudoxybeloceras* (*Parasolenoceras*) ?*phaleratum* (Griepenkerl, 1889), MAB 3290/c–e. Scale bars represent 10 mm.

tuberculate and nontuberculate ribs alternate, and on venter opposite clavi are joined by a coarse blunt single rib, or an incipiently split rib. On curved sector and lower portion of the larger limb, ribs are markedly rursiradiate, ending in strong ventral clavi. On the remainder of the larger limb, ribs are straight, or faintly rursiradiate, and show a tendency to join in pairs, linking to a single ventral clavus. MAB 3290/e is a poorly preserved fragment of the smaller limb and the curved sector, showing the same ornament of strong ventral clavi linked by a swelling with two incipient ribs on the venter, and alternation of nontuberculate and tuberculate ribs. Sutures not seen.

Discussion. At first, these specimens were compared to *Ps*. (*P*.) *interruptum* (Schlüter, 1872) (p. 105, pl. 32, figs. 8, 9; see also Klinger, 1982, pp. 230, 237, fig. 8f, g; Kennedy, 1986, p. 108, pl. 16, figs. 10, 11; 1993, p. 109, pl. 3, figs. 1–10, 17–19, 22, 23; Wright and Kennedy, 2002, p. 213, pl. 40, figs. 9, 10). Klinger (1982, p. 237, fig. 8f, g) traced the holotype, by monotypy, of *Hamites interruptus* (GPIG Orig. 65-13), and noted that it was still septate at the larger end, showing it not to be a body chamber hook but possibly to represent the early whorls of a type of conch comparable to *Exiteloceras jenneyi* (see Kennedy et al., 2000c, p. 51 and fig. 46D in particular). Kennedy (1993) recorded phosphatic internal moulds of *Ps*. (*P*.) *interruptum*, and noted a depressed oval whorl section, with Wb/Wh ratios of up to 1.25; ornament effacing on dorsum, but strengthening abruptly on dorsolateral margin into narrow, high, oblique straight flank ribs; rib index 3–5; ribs

prorsiradiate on small and rursiradiate on larger fragments; all ribs with small, sharp ventral tubercle on body chamber; flat-topped tubercles on phragmocone fragments, linked by narrow transverse rib, weaker than on flanks, across venter. Kennedy and Cobban (1994a) mentioned the recovery of a *Parasolenoceras* close to *P. interruptum* from the Wenonah Formation (mid- to upper Campanian) of New Jersey.

Although sutures cannot be seen, the present material is perhaps better interpreted as representing intermediate portions of much larger conchs with polyptychoceratid coiling, in which ribbing/tuberculation changes in an adapertural direction. The tendency of the ribs to become paired and linked to a single ventral clavi on the larger limb links these fragments to *Neancyloceras phaleratum* as interpreted by Błaszkiewicz (1980). Material listed by that author from the lower upper Campanian (*phaleratum* Zone) of central Poland and that recorded from coeval strata in northern Spain by Küchler (2000) and Küchler et al. (2001) is the best recorded to date, and the specimen on Błaszkiewicz's pl. 11, fig. 4 is close to the present material. The next curved portion would be comparable to the specimen from the lower upper Campanian of Liège (northeast Belgium) illustrated by Kennedy and Jagt (1998, pl. 1, figs. 8–10). If correctly interpreted, this also confirms Klinger's (1982) views about the (sub)generic assignment of this taxon.

Material from Tercis les Bains, illustrated by Küchler and Odin (2001, pl. 6, figs. 8–10) appears to belong to this form as well. Niebuhr (2005, fig. 5) recorded *Pseudoxybeloceras phaleratum* from a much lower level (*conica*/*papillosa* and *gracilis*/*mucronata* zones; upper lower Campanian) in the Lehrte West Syncline; without having seen the specimen(s) involved we can neither confirm nor reject her identification.

Lewyites elegans (Moberg, 1885), from the lower upper Campanian of southern Sweden, northern Germany, Aquitaine (France), southern Poland and the Maastrichtian type area, differs in style of ribbing, a higher rib index and lacks U-bends connecting parallel shafts (see Machalski et al. 2004, p. 459, pl. 5, figs. 6, 7; pl. 6, figs. 1–3; pl. 8, fig. 15; see also Kennedy et al., 2000a, pl. 1, fig. 28, for *L. oronensis*).

Parasolenoceras pulcher Cobban and Kennedy, 1991a (p. C4, pl. 1, figs. 7–9; see also Cobban and Kennedy, 1994, p. B7, pl. 7, figs. 13, 29), from the Coon Creek Tongue (Ripley Formation) of Tennessee, the Nacatoch Sand in Arkansas, and the *Baculites reesidei* Zone (Pierre Shale) of northern Colorado, is much smaller and has a compressed whorl section and delicate ribbing (RI 7–8).

Occurrence. Where well-dated, *Ps.* (*P.*) *phaleratum* appears to be confined to the lower upper Campanian, with definite records from northern Germany, Liège (northeast Belgium), northern Spain, southwest France and central Poland.

Genus *Solenoceras* Conrad, 1860

Type species. *Hamites annulifer* Morton, 1841 (see also Morton, 1842), by original designation.

Diagnosis. Small, consisting of two straight shafts in tight contact with the older shaft extending, straight or slightly curved, beyond aperture and arising from a minute ammonitella coil. With the exception of a very small, tear-shaped opening at the elbow, the younger shaft has a prominent impressed dorsal furrow resulting from growth of that shaft over dorsum of older shaft. Constrictions may or may not be present on both shafts, but the aperture is usually preceded by a conspicuous constriction bounded by high ribs. Ornament of narrow, straight, closely spaced ribs that are prorsiradiate on older shaft and rursiradiate on younger. Each rib ordinarily bearing a minute tubercle on each side of venter. Size dimorphism (Kennedy et al., 2000c) occurs. Differs from *Oxybeloceras* by having constrictions and with early growth stages in the form of a gently curved shaft originating from a tiny initial coil.

Solenoceras aff. *texanum* (Shumard, 1861)
Fig. 3A, B, G–I

compare

1861 *Ptychoceras texanus* Shumard, p. 189.
1991a *Solenoceras texanum* (Shumard, 1861); Cobban and Kennedy, p. C3, pl. 1, figs. 1–6.
1993c *Solenoceras* cf. *S. texanum* (Shumard, 1861); Kennedy and Cobban, p. 424.
1994 *Solenoceras texanum* (Shumard); Cobban and Kennedy, p. B6, pl. 7, figs. 10, 16, 17, 19–24, 26–28, 30, 31 (with additional synonymy).
1997 *Pseudoxybeloceras* (*Parasolenoceras*) *interruptum* (Schlüter 1872); Lommerzheim, p. 67, pl. 8, figs. 1, 2.
2000a *Solenoceras texanum* (Shumard, 1861): Kennedy et al., p. 14, pl. 1, figs. 10–16; pl. 4, figs. 1–7; text-fig. 11.

Type. Neotype is USNM 21092a, the original of Stephenson (1941, pl. 79, fig. 1), from the Nacatoch Sand of Navarro County, Texas.

Material. MB.C 3851, a single composite mould of a near-complete individual; two fragments (MB.C 3852-3853) may also belong here. All from the *minor*/*polyplocum* Zone at the Teutonia Nord quarry, Misburg.

Description. Shell comprising two parallel limbs (as preserved 43 mm long) in close contact, and expanding gradually; maximum preserved whorl height in the smaller and larger limbs are 3.9 and 6.9 mm, respectively; whorl section of smaller limb depressed and reniform, and compressed-ovate in larger limb. Tear-shaped opening between limbs in curved sector small. Ornament of smaller shaft consisting of fairly coarse, low, straight, prorsiradiate ribs, with interspaces of comparable width. Ribs bear small, slightly clavate ventral tubercles; periodic constrictions occur, preceded by a thickened rib. On curved sector, ribs are concave or rectiradiate and bear well-developed clavi linked across venter by a low rib. Ribs concave and markedly

rursiradiate on lower portion of larger limb, after that becoming rectiradiate to straight; RI 6; ribs becoming more widely spaced on final portion of larger limb, and with periodic constrictions/flared ribs; all ribs with clavi connected across venter by strong transverse ribs. Sutures not seen. Adult aperture slightly extended and preceded by a more or less smooth portion of shell.

Two flattened and distorted fragments (Fig. 3G–I) may also belong here; they show the same style of ribbing, with alternate tuberculate and nontuberculate ribs, ribs linked across the venter by a low, straight rib, at times barely visible, and with periodic constrictions.

Discussion. This material, and specimen MB.C 3851 in particular, is close to *Solenoceras texanum*, common in the Coon Creek fauna of McNairy County, Texas, and especially to specimen USNM 449425 (Cobban and Kennedy, 1994, pl. 7, figs. 22, 23), but differs in a higher rib index (6 vs 4–5 in *S. texanum*), and in a more regular pattern of constrictions with flared ribs. Moreover, the apical end of the larger shaft in MB.C 3851 shows concave portions bounded by thickened ribs. More material from the Teutonia Nord quarry is needed to determine whether or not these differences fall within the range of variation of *S. texanum*.

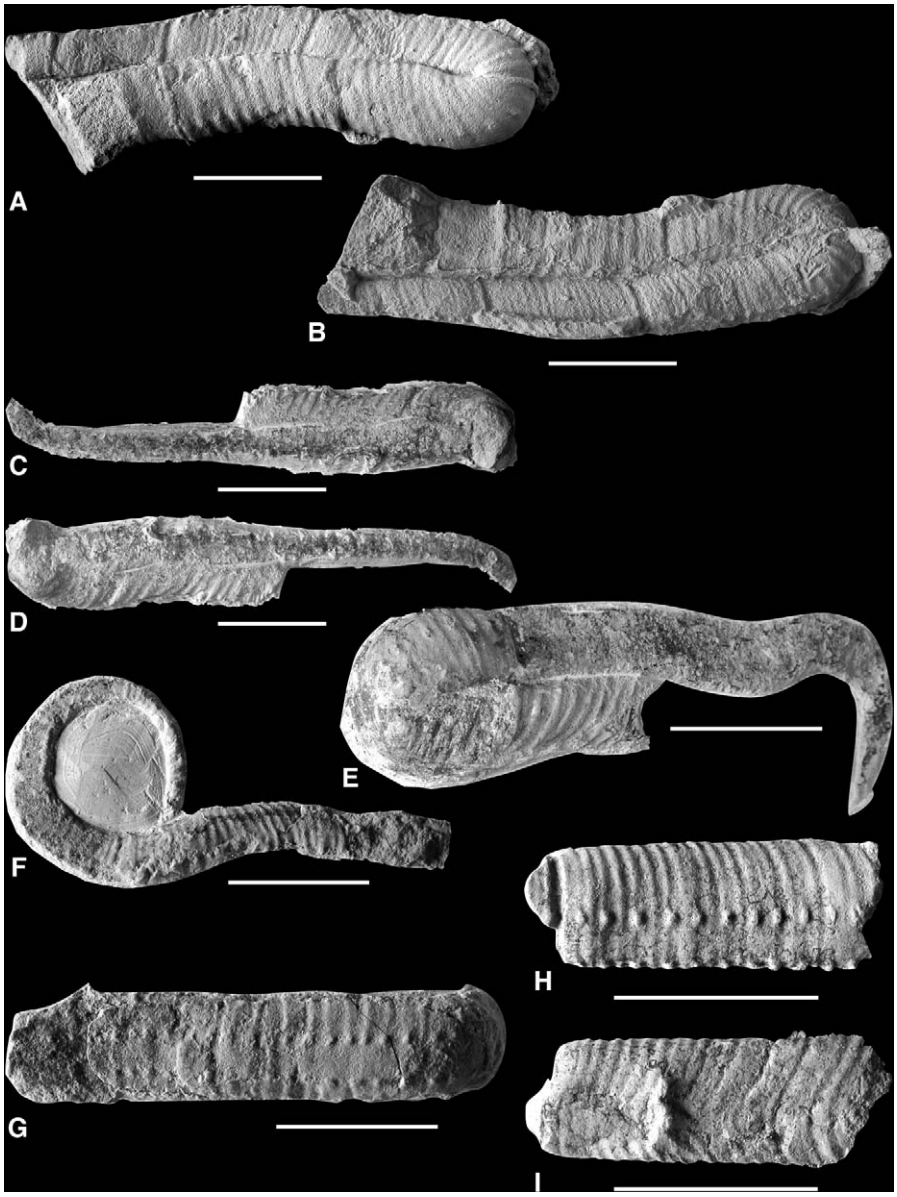

Fig. 3. All material from the Teutonia Nord quarry (Lehrte West Syncline), *minor*/*polyplocum* Zone, upper Campanian. A, B, G–I, *Solenoceras* aff. *texanum* (Shumard, 1861). A, B, MB.C 3851 (leg. Th. Rösner). G, MB.C 3852 (leg. H. Faustmann). H, I, MB.C 3853 (leg. H. Faustmann). C, D, *Spiroxybeloceras*? *grande* sp. nov.?, MB.C 3856 (leg. H. Faustmann). E, F, *Spiroxybeloceras*? *grande* sp. nov., MB.C 3854, holotype, and MB.C 3855, paratype, respectively (both leg. H. Faustmann). Scale bars represent 5 mm.

Lommerzheim (1995, p. 67, pl. 8, fig. 1) referred to nine specimens, all assigned by him to *Pseudoxybeloceras* (*Parasolenoceras*) *interruptum*, from the upper Campanian (*conica/mucronata* to *roemeri-polyplocum* zones interval) of the Coesfeld area of Münsterland. The single specimen figured from this lot is clearly conspecific with MB.C 3851, showing the same style of ribbing, constrictions and general habitus.

Solenoceras reesidei Stephenson, 1941 (p. 401, pl. 77, figs. 1–3) (see also Cobban and Kennedy, 1994, p. B6, pl. 7, figs. 1–9, 11, 12, 14, 15, 18, 25), from the Coon Creek Tongue (Ripley Formation) in Tennessee, the Neylandville Marl and Nacatoch Sand in northeast Texas, and the *Baculites compressus* and *B. reesidei* zones (Pierre Shale) in Colorado (Cobban et al., 1992), is a smaller species with a densely ribbed (RI 6) phragmocone, depressed to circular whorl section in smaller limb and a slightly compressed section in the larger (RI 6). Küchler and Odin (2001, p. 521, pl. 6, fig. 3) illustrated *Solenoceras reesidei* from the upper Campanian of Tercis les Bains, Landes, France, and the species is also known from the late Campanian Shinarish Formation of Djebel Sinjar, northwest Iraq, as demonstrated by Kennedy and Lunn (2000) (p. 469, figs. 4.16, 7.1–7.3, 7.5). Kennedy et al. (2000a, p. 15) recorded *S.* cf. *reesidei* from the Larimer Sandstone Member (Pierre Shale) of Colorado.

Solenoceras annulifer (Morton, 1842) (p. 109) (see also Reeside, 1962, p. 121, pl. 70, figs. 8–10), Kennedy and Cobban (1994b, p. 1295, figs. 11.1–11.11, 13.2) and Kennedy et al. (1995, pl. 5, figs. 17–19), from the Mount Laurel Sand of Delaware (Atlantic Seaboard), has a depressed reniform whorl section in the smaller and larger limbs, with fine, dense, concave ribs (RI 5–6), and Wb/Wh ratios of 0.8. This is closest to *S. reesidei* but that species has a compressed whorl section, constrictions on both shafts and nontuberculate ribs on the smaller limb.

Solenoceras multicostatum Stephenson, 1941 (p. 402, pl. 76, figs. 12–14), from the Nacatoch Sand of northeast Texas, is less depressed than *S. annulifer*, and very finely ribbed, while *S. nitidum* Cobban, 1974 (p. 83, figs. 1a–c, 2; see also Cobban and Kennedy, 1991a, p. C3, pl. 1, figs. 10–12) from the Nacatoch Sand of Texas, and the Maastrichtian *Nostoceras alternatum* Zone of southwest Arkansas (Cobban and Kennedy, 1991b, p. E4, pl. 2, figs. 1–4) lacks tubercles.

Solenoceras sp. (Kennedy, 1993, p. 107, pl. 2, figs. 10–12), from the so-called 'Poudingue de la Malogne' at Ciply-La Malogne, Mons Basin, but probably reworked from underlying Campanian strata, lacks tubercles and is very coarsely ribbed.

Solenoceras bearpawense Kennedy et al., 2000c (p. 73, figs. 58–60, 61G–Q, 62), from the entire *Didymoceras nebrascense* Zone (Montana, South Dakota and Colorado), Mesaverde Formation (Wyoming), Mancos Shale (Colorado) and Lewis Shale (San Juan Basin, New Mexico), is a slender species with periodic constrictions bounded by flared ribs on the smaller limb, weakened ornament or even loss of it on the curved portion elbow, and a finely ribbed larger limb.

Solenoceras larimerense Kennedy et al., 2000c (p. 77, figs. 61A–F, 63, 64), apparently confined to the upper Campanian *Exiteloceras jenneyi* Zone, from the Terry Sandstone Member (Pierre Shale) in northern Colorado and the Pierre Shale of Niobrara County, Wyoming, co-occurring with *E. j. jenneyi*, is much smaller than *S. bearpawense* and has slightly sparser ribbing (RI 3–4) and rare constrictions on both limbs.

Solenoceras elegans Kennedy et al., 2000c (p. 78, figs. 61R–HH, 65–67), from the Rock River Formation, associated with *Didymoceras stevensoni*, and ranging upwards into the *E. jenneyi* Zone in Colorado and Montana, is a long slender taxon with a few constrictions near the adapical end and at the aperture (not on the smaller limb), RI 5.

Finally, *Solenoceras mortoni* (Meek and Hayden, 1857) (see Kennedy et al., 2000b, p. 237, pl. 14, figs. 1–23; text-figs. 12, 13) from the *Baculites gregoryensis* and *B. scotti* zones in the US Western Interior, has a smaller limb with a circular cross section, a slightly compressed larger shaft, and delicate ribbing (RI 4–5).

In the literature, there are two more records of polyptychoceratines that may also be referred to *Solenoceras* rather than to *Pseudoxybeloceras* (*Parasolenoceras*). One is *Ps.* (*P.*) *wernickei* of Kennedy and Summesberger [1984, p. 166 (pars), pl. 9, figs. 6, 7 only], from the upper Campanian of the Gschliefgraben, Austria, the other *Ps.* (*P.*) ?*wernickei* of Küchler (2000, pl. 12, figs. 1–3) from the upper Campanian *Trachyscaphites pulcherrimus* Partial Range Zone of the Barranca, Navarra, northern Spain. Although much rarer than in the Western Interior and along the Gulf and Atlantic seaboards, there are thus representatives of *Solenoceras* in Campanian strata across Europe.

Occurrence. *Solenoceras* aff. *texanum*, as here understood, is known from the upper Campanian of the Lehrte West Syncline and Münsterland. In addition to occurrences referred to above, material closely related to or conspecific with *S. texanum* has also been recorded from the upper Campanian of Israel (Lewy, 1969) and the Maastrichtian of northeast Mexico (Ifrim et al., 2004).

Genus *Spiroxybeloceras* Kennedy and Cobban, 1999

Type species. *Ptychoceras meekanum* Whitfield, 1877, by original designation.

Diagnosis. Juvenile growth stage is a loosely coiled planispiral, followed by adult growth stage of two parallel shafts either tightly adpressed or barely in contact; ornament of narrow, sharp ribs with small, pointed tubercles on the venter; lacking constrictions.

Remarks. Klinger and Kennedy (2003, pp. 324, 325) have recently noted that there is some confusion about the validity of three polyptychoceratine genera with closely similar adult stages. *Solenoceras* consists of two straight, parallel limbs, closely adpressed for all of their length, and there are constrictions with associated flared ribs on both the body chamber and the phragmocone; in addition, tubercles are weaker than those in *Oxybeloceras*, and may even efface (see also Kennedy and Cobban, 1993b). *Spiroxybeloceras* is similar to *Solenoceras*,

but in early ontogeny shows a loose planispiral growth stage followed by two parallel shafts barely in contact; *Solenoceras* has an early ontogenetic stage of an ammonitella followed by a straight limb that is impressed in a second, parallel shaft.

Spiroxybeloceras? *grande* sp. nov.
Fig. 3E, F

Types. Holotype is MB.C 3854; paratype is MB.C 3855, both from the *minor*/*polyplocum* Zone (upper Campanian) as exposed at the Teutonia Nord quarry, Misburg.

Diagnosis. A small (estimated length 35 mm) species of *Spiroxybeloceras*? with a large initial coil, a median shaft with a concave and subsequent straight portion, narrowly rounded curved sector, parallel second limb, barely touching. Ornament of close-set prorsiradiate to markedly rursiradiate ribs; nontuberculate and tuberculate ribs alternate. No constrictions.

Derivation of name. Latin *grandis*, in allusion to the large initial coil.

Material. In addition to the types, there is a third specimen (Fig. 3C, D; MB.C 3856), which is comparable in size but differs in showing what appears to be a constriction on the larger limb (the preservation leaves much to be desired), in being more slender and in lacking the concave portion in the smaller shaft.

Description. The holotype, MB.C 3854, measures ca. 32 mm in length, but is incomplete; the initial coil is large, 13.5 mm in diameter; the outer whorl of the spiral is completely preserved, but earlier whorls are lacking; it leads into the smaller limb, which shows a concave portion. Earliest ribs visible are near-straight to feebly concave and rursiradiate, apparently all ending in a small ventral tubercle. Ribs narrow, equal to interspaces, changing to prorsiradiate on median portion of smaller shaft, and apparently with an alternation of nontuberculate and tuberculate ribs. Maximum preserved whorl height of smaller shaft 4.2 mm, and of initial portion of coil 1.9 mm. MB.C 3855 (Fig. 3E) shows a more poorly preserved initial coil, yet better preserved curved sector and larger limb than the holotype. Ribs straight and markedly prorsiradiate on lower portion of smaller limb, alternately tuberculate and nontuberculate, apparently recti- to rursiradiate on the curved sector, and convex and markedly rursiradiate on larger limb, where ribs are also stouter than on smaller limb. Limbs barely in contact along dorsum. Sutures and adult aperture not seen.

MB.C 3856, 39.7 mm long (as preserved; see Fig. 3C, D), shows a curvature in the upper end of the smaller limb, which suggests it originally had an initial coil, making placement in the genus *Spiroxybeloceras* likely. It shows a long small shaft, with ribbing closely comparable to the other two specimens, but lacks the concave portion between the initial coil and the small limb, and appears to have a single constriction on the lower part of the larger limb. *Spiroxybeloceras* was diagnosed as not having constrictions (Kennedy and Cobban, 1999).

Discussion. These specimens are referred to *Spiroxybeloceras* with a query, since the initial coil is extremely large in comparison to other species contained in the genus. Of this coil, only the later portions remain, since preservation was not conducive in the chalk/marl rhythmite facies of the Lehrte West Syncline.

Spiroxybeloceras meekanum (Whitfield, 1877) (see Kennedy and Cobban, 1994b, p. 1294, figs. 9.10–9.12, 11.11–11.13, 11.15–11.17, 12.1–12.13, 13.1; Kennedy et al., 1995, pl. 5, figs. 15, 16; 2000c, p. 71, figs. 55–57), seemingly confined to the *Didymoceras cheyennense* Zone (upper Campanian) in Montana, South Dakota, Wyoming, Nebraska, Colorado and New Mexico, and also known from the Mount Laurel Sand of Delaware, is a smaller species with an open planispiral coil and short body chamber; a short, broadly curved limb connects this coil with the body chamber. Ribbing is comparatively coarse, in particular on the larger limb. In comparison to the present material, *S. meekanum* has a much smaller initial coil, lacks the concave median portion of the smaller limb, and shows much coarser ribbing.

Spiroxybeloceras kimbroense Kennedy and Cobban, 1999 (p. 74, pl. 1, figs. 1–18; pl. 5, figs. 1–10; text-figs. 5, 6) (see also Kennedy et al., 2000b, p. 235, pl. 13, figs. 1, 3, 4; pl. 14, figs. 24–26; pl. 15, figs. 1–31; text-figs. 10b, 11), first appearing in the *Baculites gregoryensis* Zone, and well known from the Bergstrom Formation of Travis County (Texas), the Annona Chalk of southwest Arkansas (Kennedy and Cobban, 1993a), the ?Wenonah Formation of New Jersey, plus widespread in the *Baculites scotti* Zone of the Western Interior, closely resembles *Oxybeloceras crassum* in showing coarse ornament, but the latter has two limbs closely adpressed, leaving an impressed dorsal furrow on the body chamber. In addition, *O. crassum* grows to a larger size and lacks the loose planispire juvenile stage. In comparison to the present material, *S. kimbroense* shows more regular ventral tuberculation, coarser ribbing and a much larger opening between the limbs in the curved sector.

Spiroxybeloceras minimus (Basse, 1931), from the lower Maastrichtian of Madagascar and KwaZulu (Klinger and Kennedy, 2003, p. 325, fig. 64), is smaller, differs in habitus and shows fine, sharp-crested ribs with minute tubercles.

3. Stratigraphic implications

As noted above, it appears that polyptychoceratine ammonites are less well suited than co-occurring nostoceratids and scaphitids in transatlantic correlations, not only because of their rarity and general poor state of preservation in Europe, but also because species in the Western Interior and Gulf and Atlantic seaboards do not show any overlap in their ranges. Material recorded here from the Lehrte West Syncline is compared to North American taxa, which have been described in detail in recent years on the basis of rich

assemblages and whose stratigraphic ranges are well known. *Oxybeloceras crassum* is widely distributed in the *Didymoceras stevensoni* and *Exiteloceras jenneyi* zones, while *Solenoceras texanum* occurs higher in the upper Campanian, in the *Baculites cuneatus* and *B. reesidei* zones. North American species of *Pseudoxybeloceras* occur in the *Baculites scotti* and *Didymoceras cheyennense* zones, which makes it difficult to correlate on a zone-to-zone basis between the Western Interior and the Lehrte West Syncline, where congeneric species occur in the *vulgaris*/*stolleyi* and *minor*/*polyplocum* zones. The overlap in the ranges of the scaphitids *Trachyscaphites spiniger* and *T. pulcherrimus*, both also known from the USA, which is situated in these two zones, would be the best-fit correlative level in transatlantic correlation.

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