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Coilopoceras inflatum Cobban and Hook, 1980, a United States Western Interior ammonite from the Upper Turonian of the southern Corbières, Aude, France

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ABSTRACT:

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A newly discovered ammonite faunule from the Padern region of the southern Corbières in southern France includes representatives of typical northwest European Upper Turonian species *Subprionocyclus* cf. *neptuni* (Geinitz, 1850) and *Lewesiceras* cf. *woodi* Wright 1979, tethyan/ northwestern Pacific species *Phyllopachyceras* cf. *ezoense* (Yokoyama, 1890), *Anagaudryceras involvulum* (Stoliczka, 1865) and, *Desmoceras* (*Pseudouhligella*) sp., together with *Coilopoceras inflatum* Cobban and Hook, 1980, a species previously known only from New Mexico in the United States, where it is regarded as Middle Turonian. The faunule occurs above one with *Romaniceras* (*R.*) *mexicanum* Jones, 1938 and *Coilopoceras springeri* Hyatt, 1903, also originally described from New Mexico and northern Mexico, and recently described from the Uchaux massif in Vaucluse in southern France. The records suggest that the base of the Upper Turonian may be drawn at different, higher level in the United States Western Interior than in Europe. The coming together of these mixed faunal elements may be a result of high sea levels, and changing oceanic circulation patterns.

Key words: Ammonites; biostratigraphy; Turonian; Cretaceous; France.

INTRODUCTION

We recently revised the then known Turonian ammonites from the southern Corbières in Aude, France (Kennedy *et al*. 2015). Three faunas were recognized, in a sequence interpreted in terms of three transgressive-regressive cycles. The oldest fauna came from the basal glauconitic unit of the first cycle, and was assigned to the Lower Turonian *Mammites nodosoides* Zone (and, possibly, the underlying *Fagesia catinus* Zone). The succeeding fauna came from the basal glauconitic unit of the second cycle, and was assigned to the *Romaniceras* (*Yubariceras*) *ornatissimum* and *Romaniceras* (*Romaniceras*) *mexicanum* Zones of the Middle Turonian.

The youngest fauna came from the external platform sequence of Marnes supérieurs de Saint Louis of the Saint Louis syncline, and although slight: *Subprionocyclus* sp., *Prionocyclus* sp., and *Worthoc-*

eras cf. *rochatianum* (d'Orbigny, 1850), suggested the lower Upper Turonian *Subprionocyclus bravaisianus* Zone.

One of the most interesting elements of the faunas was the recognition of *Romaniceras* (*R.*) *mexicanum* Jones, 1938, and *Coilopoceras springeri* Hyatt, 1903, in the Middle Turonian. These species were originally described from Coahuila Province in northern Mexico and New Mexico in the United States respectively, and remained unknown outside North America until Robaszynski *et al*. (2014) documented their presence in the Uchaux Massif in Vaucluse, and interpreted this occurrence as a result of a transgressive event or sea level high at that time (as discussed elsewhere in this volume: Amédro *et al*. 2016).

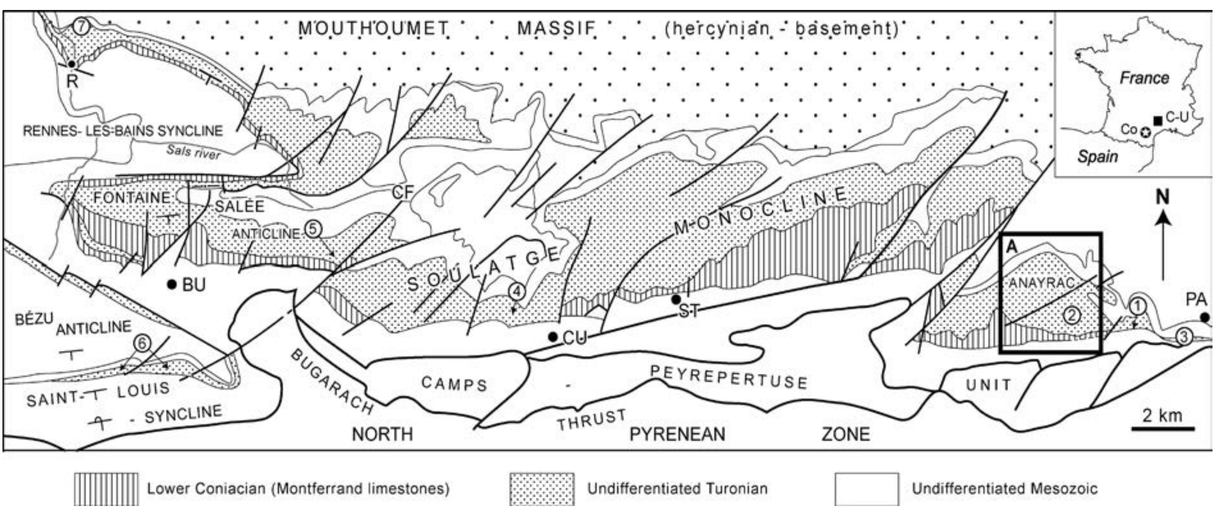
Recent fieldwork in the southern Corbières by one of us (PM) has extended the Turonian ammonite record, and revealed the presence of a further migrant from the United States Western Interior: *Coilopoceras inflatum* Cobban and Hook, 1980, a species originally described from, and restricted to, New Mexico. It occurs in a faunule associated with typically Boreal *Subprionocyclus* and typically Tethyan *Phyllopachyceras* and *Anagaudryceras* that forms the basis of this account.

REGIONAL GEOLOGY

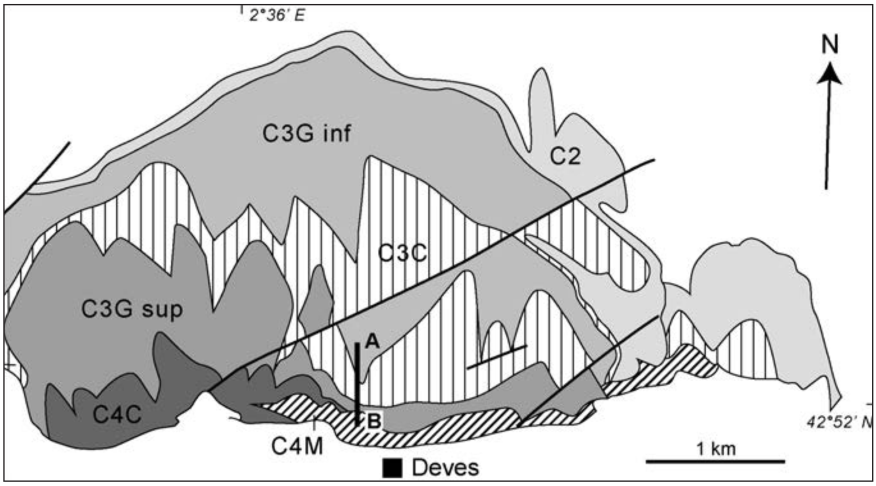
In the southern Corbières, the Turonian is represented, in the north, by inner and mid-platform deposits made up of interdigitating bioconstructional and terrigenous clastic units. To the south, in the Saint Louis syncline (Text-fig. 1), the sequence is of outer shelf deposits, the Marnes supérieurs de Saint Louis, as discussed previously (Kennedy *et al.* 2015). As noted above, only the last named could be demonstrated to extend into the Upper Turonian on the basis of ammonites, the dating of the higher parts of the sequence in the inner and middle platform deposits remained uncertain. This is now resolved on the basis of the present records from west of Padern (Text-figs 1, 2).

LITHOSTRATIGRAPHY

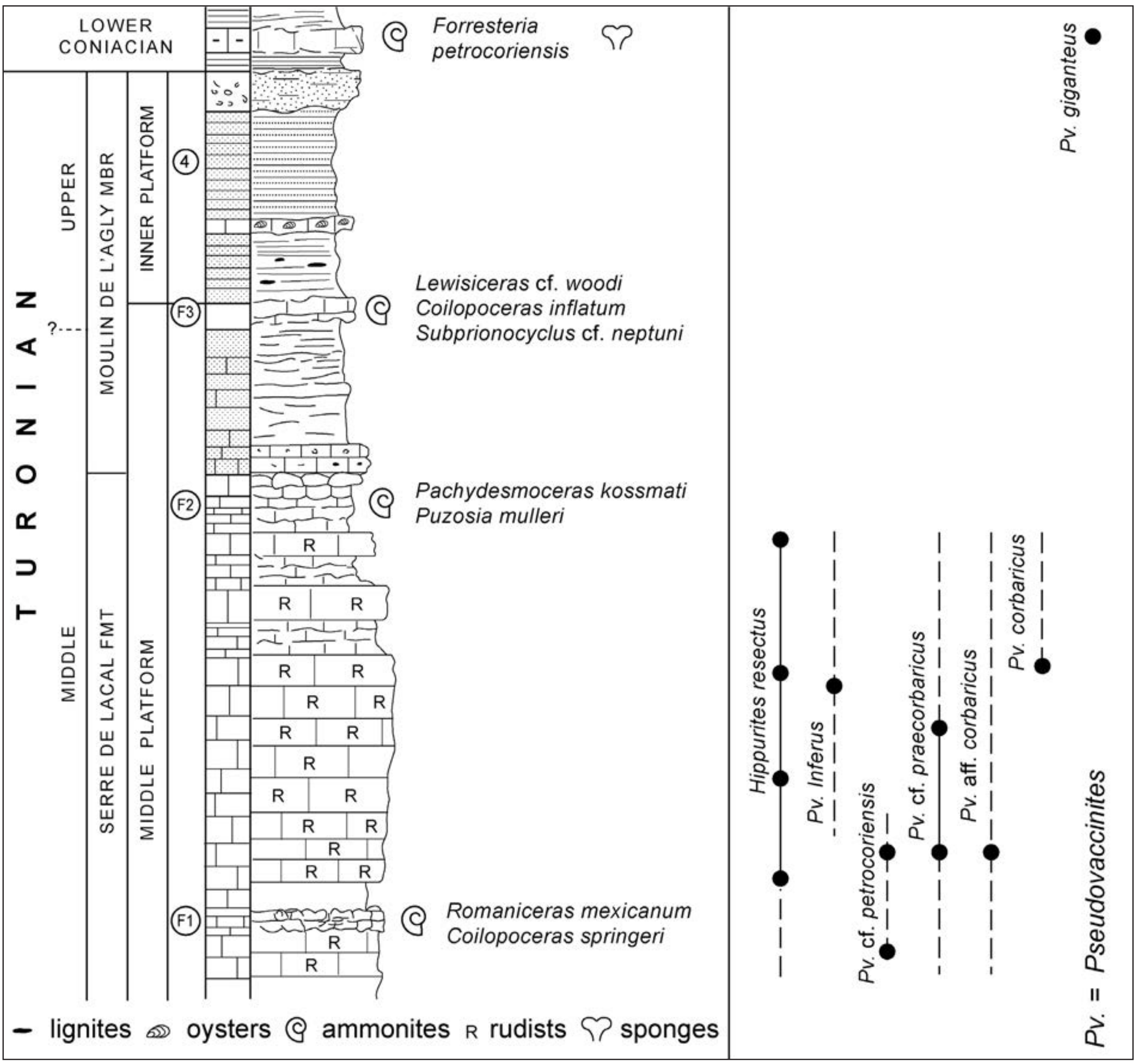
In our previous account of the Padern region (Kennedy *et al*. 2015, text-fig. 3), the source of the early ammonite records of Roussel (1895) we recognised a Lower Turonian ammonite association that included *Mammites nodosoides* in glauconitic marly limestones overlying the Tartières Limestones (La Ferrière etc.). To the west the nodular facies of the Tartières Limestones come to dominate the lower part of the sequence (côte 261 in Kennedy *et a*l. 2015, text-fig. 3); above, they are progressively replaced by the rudist limestones of the Serre de Lacal Formation in the collines de l' Anayrac, Devès and Roc de Redounel (Text-figs 2–4). Terrigenous influences become increasingly important above these rudist limestones (the distribution of the principal species present is shown in Text-fig. 3, and examples in 4B–D), with a sequence of limestones with a minor terrigenous component through to calcareous sandstones, a



Text-fig. 1. Simplified geological map showing the distribution of the main ammonite-bearing Turonian outcrops on the southern limb of the Mouthoumet Massif in the southern Corbières. 1 – Padern (historic outcrop); 2 – Marsa; 3 – La Ferrière; 4 – Baillesats; 5 – Les Capitaines-Le Linas; 6 – Montplaisir-Parahou; 7 – Rennes-les-Bains. BU – Bugarach; CU – Cubières; PA – Padern; R – Rennes-les-Bains; ST – Soulatgé; CF – Capitaines fault. Box **A** indicates the location of Text-fig. 2



Text-fig. 2. Locality map indicating the position of the colline de Redounel section (**A–B**) as shown in Text-fig. 3. C2 – Cenomanian. C3G inf – Lower Turonian sandstones. C3C Turonian limestones. C3G sup – Upper Turonian sandstones. C4C – Lower Coniacian Montferrand Limestones. C4M – Coniacian marls



Text-fig. 3. Synthetic section of the Middle Turonian to Lower Coniacian sequence between Devès and Redounel passage represented in the Moulin de l'Agly Member. The ammonites described below come from a sequenceof one to two metre thick brown limestones with abundant solitary corals, succeeded by marls, silts and sandstones (Text-fig.3) forming the upper part of the Moulin de l'Agly Member. These include numerous limonitic nodules and units rich in plant debris (lignites), and are interpreted as having accumulated in estuarine environments with intermittent marine and terrestrial influences, represented by carbonate units rich in small oysters and fluviatile sandstones respectively.

Text-fig. 4. A – view of the Turonian succession on the east flank of the Colline de Redounel. R – rudistid limestones; F2 position of association of *Pachydesmoceas kossmati* and *Puzosia muller*i shown in Text-fig. 3. B – *Pseudovaccinites corbaricus*; C – *Pseudovaccinites inferus*; D – *Hippurites resectus*; E – outcrop of the ferruginous limestones that yielded fauna F1 (Text-fig. 3): *Romaniceras* (*R.*) *mexicanum* and *Coilopoceras springeri*. F, G – lignitic marls and fine-grained sandstones of the Upper Turonian tidal facies

LOCALITY DETAILS

The succession described below is a composite, based on outcrops in the Collines du Dèves and de Redounel (Text-fig. 2). The Lower and Middle Turonian are relatively well-exposed here, in spite of the extensive cover of evergreen shrubs (Maquis). The log (Text-fig. 3) shows the relative position of the ammonite assemblages recognised previously, and the new faunule. Assemblage F1 comes from an interval of ferruginous limestones (Text-fig. 4E) which divides the rudist bioconstructional sequence in two. It yielded *Romaniceras* (*R.*) *mexicanum* (Kennedy *et al.* 2015, text-fig. 15o, p) and *Coilopoceras springeri* (*ibid*, text-fig. 28h, i). Assemblage F2 comes from immediately above the highest rudist limestone, and yielded *Pachydesmoceras kossmati* Matsumoto, 1987 (Kennedy *et al.* 2015, text-fig. 10a, c, e) and *Puzosia* (*Puzosia*) *mulleri* de Grossouvre, 1894 (FSIT D53: *ibid*, p. 447)

The third assemblage comes from the highest marine interval in the Moulin del'Agly Member. Above, the regressive estuarine sequence is terminated by renewed transgression that deposited the Lower Coniacian marls rich in sponges that have yielded *Forresteria* (*Harleites*) *petrocoriensis* (Coquand, 1859) elsewhere in the region.

REPOSITORIES OF SPECIMENS

BMNH: The Natural History Museum, London.

FSIT DSE: Patrice Melchior Collection, held in the reserves of the service commun d'Etudes et de Conservation des Collections Patrimoniales de la Faculté des Sciences et Ingénierie de Toulouse.

USNM: US National Museum of Natural History, Washington D. C..

SYSTEMATIC PALAEONTOLOGY
(W. J. Kennedy)

Order Ammonoidea Zittel, 1884
Suborder Phylloceratina Arkell, 1950
Superfamily Phylloceratoidea Zittel, 1884
Subfamily Phylloceratinae Zittel, 1884
Genus *Phyllopachyceras* Spath, 1925

TYPE SPECIES: *Ammonites infundibulum* d'Orbigny, 1841, p. 131, pl. 39, figs 4, 5, by the original designation of Spath 1925, p. 101.

Phyllopachyceras cf. *ezoense* (Yokoyama, 1890)
(Text-fig. 5D–F)

Compare:
1890. *Phylloceras ezoense* Yokoyama, p. 178, pl. 19, fig. 2.
2009. *Phyllopachyceras ezoense* (Yokoyama, 1890); Klein *et al.*, p. 59 (with full synonymy).

TYPE: The holotype is the original of Yokoyama 1890, p. 178, pl. 19, fig. 2, from the Yezo Group of the Urakawa area in central Hokkaido, Japan.

MATERIAL: FSIT DSE24.

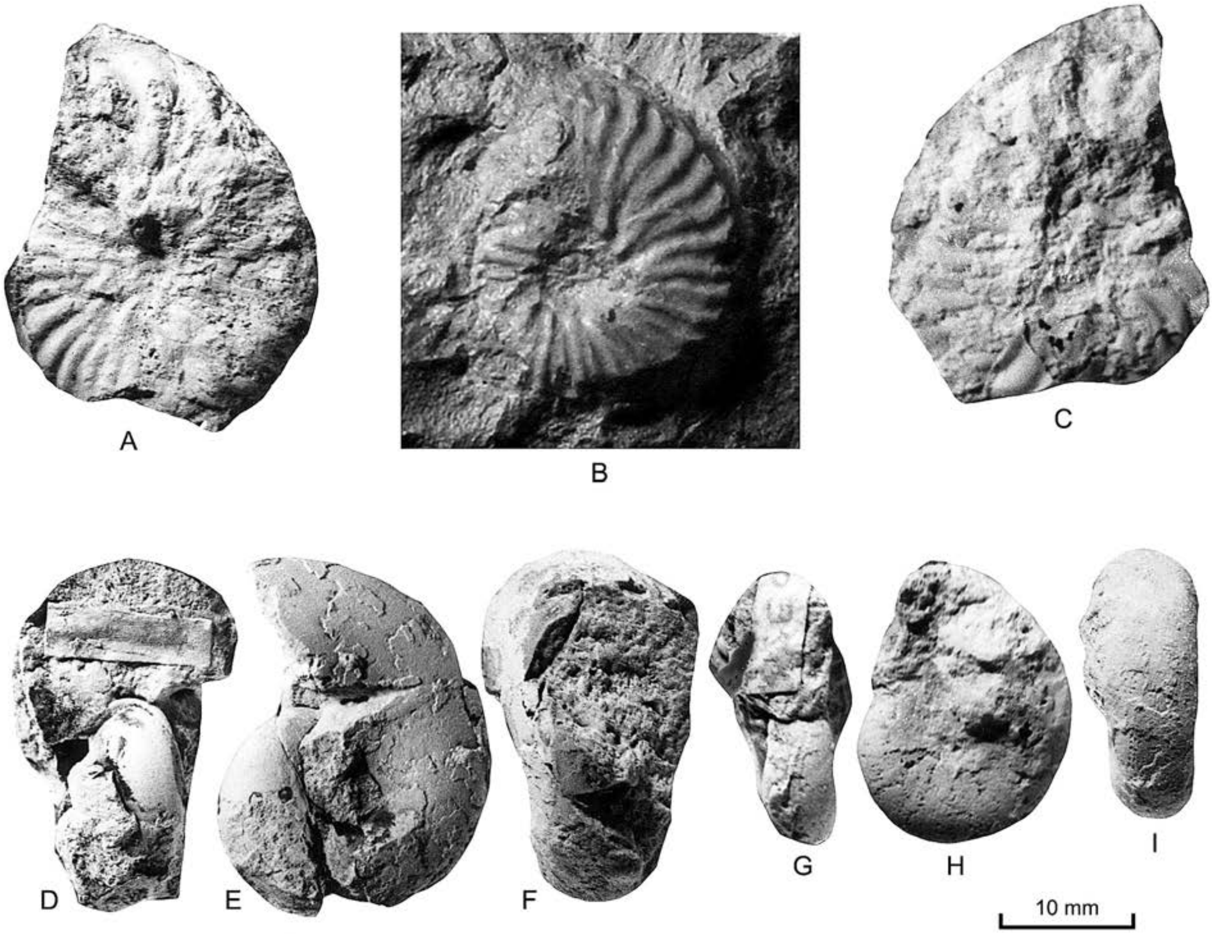
DESCRIPTION: The specimen is a phragmocone 28 mm in diameter, retaining replaced shell on the adapical part of the outer whorl, but exfoliated replaced shell material elsewhere. Coiling is very involute, the umbilicus comprising 10% or less of the diameter, the umbilical wall inclined outward and passing into the broadly rounded umbilical shoulder. The whorl section is depressed reniform, with broadly rounded flanks, ventrolateral shoulders and venter. The surface of the shell is ornamented by delicate lirae, with individual widely separated lirae slightly strengthened. They are near-straight and transverse over the venter. There is no trace of ornament on the exfoliated surface. The sutures, visible in places through the replaced shell, have deeply incised elements, the external lobe elongate.

DISCUSSION: Whorl proportions, ornament, and such as is visible of the suture line are compatible with assignation to *Phyllopachyceras*, and correspond to those of *P. ezoense*, to which the specimen is compared.

OCCURRRENCE: *Phyllopachyceras ezoense* ranges from Turonian to Lower Campanian according to Toshimitsu and Hirano (2000). The geographic distribution extends from Hokkaido in Japan to southern Sakhalin, together with the present possible record from the southern Corbières.

Suborder Lytoceratina Hyatt, 1889
Superfamily Tetragonitoidea Hyatt, 1900
Family Gaudryceratidae Spath, 1927
Genus *Anagaudryceras* Shimizu, 1934

TYPE SPECIES: *Ammonites sacya* Forbes, 1846, p. 113, pl. 14, fig. 9, by the original designation of Shimizu 1934, p. 67.



Text-fig. 5. A, C – *Subprionocyclus* cf. *neptuni* (Geinitz,1850). FSIT DSE321. B – *Subprionocyclus neptuni* (Geinitz,1850), the lectotype, SaK 10032, in the collections of the Staatlichen Museum für Mineralogie and Geologie, Dresded, the original of Geinitz 1850, pl. 3, fig. 3, and from the Upper Turonian Plänerkalk of Strehlen, Saxony, Germany. D-F – *Phyllopachyceras* cf. *ezoense* (Yokoyama, 1890), FSIT DSE24. G-I – *Desmoceras* (*Pseudouhligella*) sp., FSIT DSE9. All figures are × 2.

Anagaudryceras involvulum
(Stoliczka, 1865)
(Text-fig. 6)

1865. *Ammonites involvulus* Stoliczka, p. 150, pl. 75, fig. 1 [*involutus* in the explanation of the plate].
2009. *Anagaudryceras involvulum* (Stoliczka, 1865); Klein *et al*., p. 159 (with full synonymy).

TYPE: The holotype, by monotypy, is the original of Stoliczka 1865, p. 150, pl. 75. fig. 1, from the Utatur group of Odium, South India.

MATERIAL: FSIT DSE14.

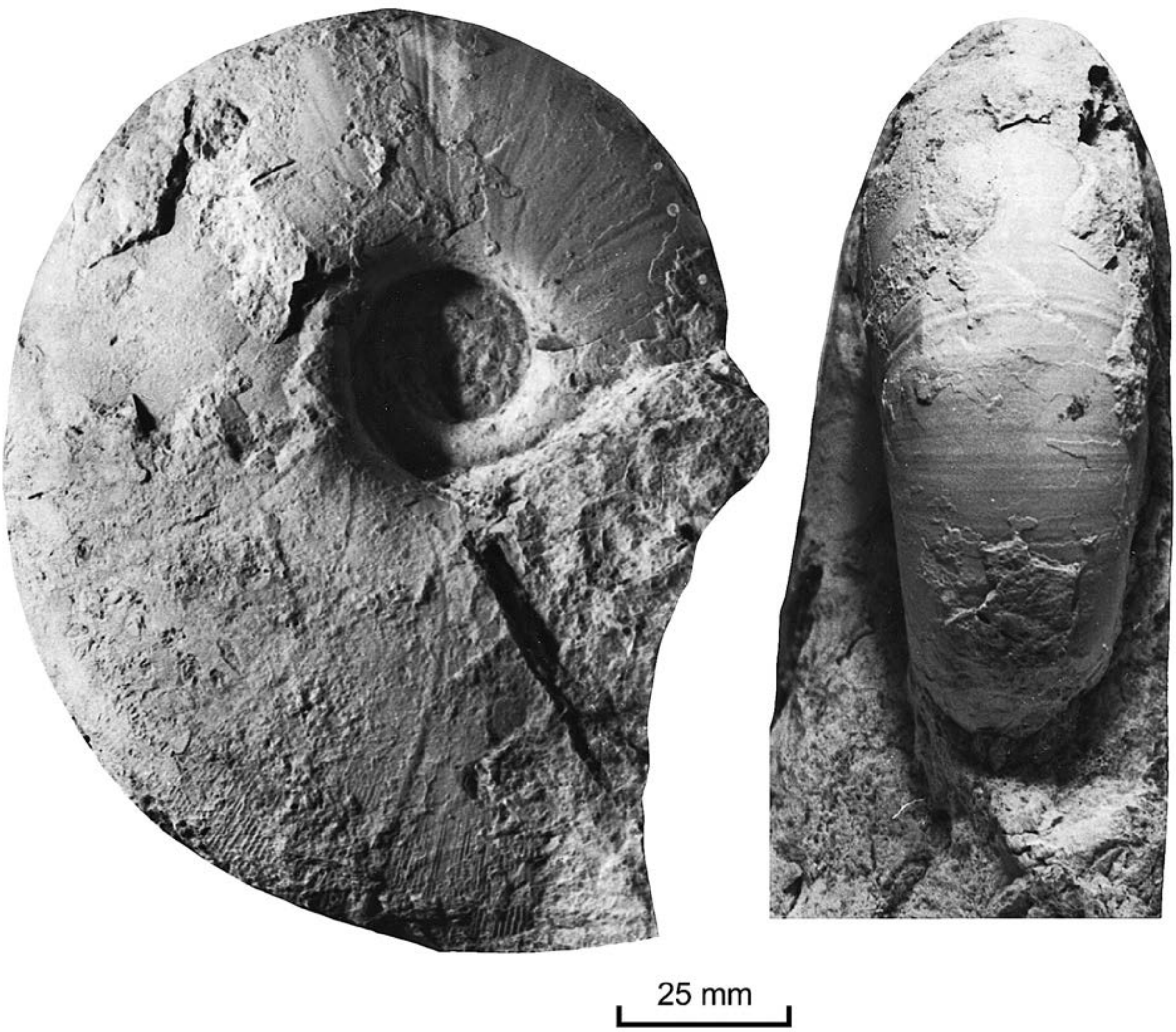
DIMENSIONS:

	D	Wb	Wh	Wb:Wh	U
FSIT DSE14	125 (100)	-(-)	67.3 (53.8)	-	26.7 (21.4)

DESCRIPTION: The specimen retains extensive areas of replaced shell; a septal face is visible at a whorl height of 42 mm, and may mark the end of the phragmocone. Coiling is involute, the umbilicus comprising 21.4% of the diameter, of moderate depth, with a very feebly convex wall and quite broadly rounded umbilical shoulder. The whorl section is compressed, with a whorl breadth to height ratio of 0.86, the flanks very feebly convex, subparallel, with the greatest breadth below mid-flank, the ventrolateral shoulders and venter broadly and evenly rounded. The partially exfoliated shell of what is presumed to be the adapertural part of the phragmocone preserves the course of the ornament of the outer surface of the shell, which is preserved on the adapertural part of the specimen. It consists of delicate lirae that are prorsiradiate and convex across the inner flank, flexing back, straight and rursiradiate on the outer flank, and passing straight across the venter. There are widely separated collar ribs, well preserved on the adapertural part of the specimen; on the partially exfoliated adapertural part they are seen to mark the position of narrow constrictions, here associated with both adapical and adapertural collar-ribs.

DISCUSSION: The holotype (Stoliczka, 1865, pl. 75, fig. 1) is 44 mm in diameter, and shows constrictions that follow the same course and occur at the same spacing as in the present specimen. The figure shows a smooth shell, but Stoliczka noted (p. 150) that: "on the well-preserved surface covered with numerous transverse flexuous striae; where these are not preserved, the shell appears smooth, without any sulci or furrows." Subsequent authors have interpreted the original of Stoliczka's pl. 76, fig. 3 as a further example of the species (it was originally referred to *Ammonites sacya* Forbes, 1846, by Stoliczka). It is a phragmocone 120 mm in diameter, with whorl proportions, lirae, and collar ribs are as in the present specimen

DISCUSSION: *Anagaudryceras involvulum* is readily distinguished from most other species of *Anagaudryceras* in that it does not, so far as is known, developing fold-like major ribs in the later ontogenetic stages, as in other species of the genus described by Kennedy and Klinger (1979) and Matsumoto (1995). The latter referred *Anagaudryceras involvulum* of Howarth (1966, p. 219, pl. 1, figs 1, 2), from the mid-Turonian of Angola to his new species, *Anagaudryceras howarthi* Matsumoto, 1995 (p. 46, text-figs 22–24), based on material from the Turonian of Hokkaido, Japan. It too develops major fold-like ribs on the body chamber.



Text-fig. 6. *Anagaudryceras involvulum* (Stoliczka), 1865. FSIT DSE14. The figures are × 1.

OCCURRENCE: The species ranges from Lower Cenomanian to Lower Coniacian, with records from southern India, Japan, Nigeria, Angola, Haute Normandie and Aude in France (the present record), and southern England.

Suborder Ammonitina Hyatt, 1889
Superfamily Desmoceratoidea Zittel, 1895
Family Desmoceratidae Zittel, 1895
Subfamily Desmoceratinae Zittel, 1895
Genus *Desmoceras* Genus Zittel, 1884

TYPE SPECIES: *Ammonites latidorsatus* Michelin, 1838, p. 101, pl.12, fig.9, by the subsequent designation of Böhm, 1895, p. 364.

Subgenus *Pseudouhligella* Matsumoto, 1938

TYPE SPECIES: *Desmoceras dawsoni* var. *japonica* Yabe, 1904, p. 35, pl. 5, fig. 3, by the subsequent designation of Matsumoto, 1938, p.22.

Desmoceras (*Pseudouhligella*) sp.
(Text-fig. 5G–I)

MATERIAL: FSIT DSE9.

DESCRIPTION and DISCUSSION: The specimen is a phragmocone retaining extensive areas of recrystallised shell; the maximum preserved diameter is 21.6 mm. Coiling is very involute, the umbilicus tiny. The whorl section is compressed, with flattened subparallel flanks, broadly rounded ventrolateral shoulders and a feebly convex venter. There is no ornament. The specimen is referred to *Pseudouhligella* on the basis of the whorl proportions and coiling.

OCCURRENCE: As for material.

Family Pachydiscidae Spath, 1922
Genus *Lewesiceras* Spath, 1939

TYPE SPECIES: *Ammonites peramplus* Mantell, 1822, p.200, by original designation by Spath 1939, p. 296.

Lewesiceras cf. *woodi* Wright, 1979
(Text-fig. 7)

Compare:
1973. *Pseudopuzosia* sp. Birkelund, p. 141, pl. 12.
1979. *Lewesiceras woodi* Wright, p. 312, pl.3, fig. 21; pl. 6, fig. 6.
2015. *Lewesiceras woodi* Wright, 1979; Kennedy and Gale, p. 514, text-fig. 5d, n.

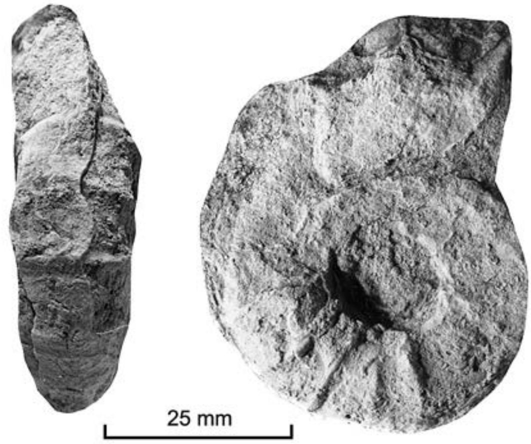
TYPES: The holotype is BMNH C79509, the original of Wright 1979, pl. 3, fig. 21, from the Upper Turonian *Subprionocyclus neptuni* Zone fauna of the Chalk Rock at Hitch Wood, near Hitchin, Hertfordshire. There are four paratypes.

MATERIAL: FSIT DSE8.

DESCRIPTION: The specimen is a partially crushed individual with a maximum preserved diameter of 42 mm. Coiling is moderately involute, the umbilicus comprising an estimated 24% of the diameter. The whorl section is compressed reniform, with the greatest breadth below mid-flank, the flanks convex, and converging to the broadly rounded ventrolateral shoulders and feebly convex venter. Five ribs, four of them primaries, are preserved on a 90° sector of the specimen They arise on the umbilical wall, are strong, narrow, straight and prorsiradiate on the flanks, and cross the venter near-straight. Two of the ribs are preceded by a constriction, and there is a single long intercalated rib.

DISCUSSION: The present poorly preserved specimen is compared to *Lewsiceras woodi* on the basis of the pattern and spacing of the ribs, it which respect it matches well with the holotype.

OCCURRENCE: Upper Turonian, *Subprionocyclus neptuni* Zone, southern England, Haute-Normandie and Aude in France and Särdal, Sweden.



Text-fig. 7. *Lewesicas* cf. *woodi* Wright, 1979. FSIT DSE8. The figures are × 1.

Superfamily Acanthoceratoidea de Grossouvre, 1894
Family Collignoniceratidae Wright and Wright, 1951
Subfamily Collignoniceratinae Wright and Wright, 1951
Genus *Subprionocyclus* Shimizu, 1932

TYPE SPECIES: *Prionocyclus hitchinensis* Billinghurst, 1927, p. 516, pl. 16, figs 1, 2, by the original designation of Shimizu 1932, p. 2.

Subprionocyclus cf. *neptuni* (Geinitz, 1850)
(Text-fig. 5A, C)

Compare:
1850. *Ammonites neptuni* Geinitz, p. 114, pl. 3, fig. 3.
2014. *Subprionocyclus neptuni*, (Geinitz, 1849); Wilmsen and Nagm, p. 224, text-fig. 13a, c, d.

TYPE: The lectotype, by the subsequent designation of Matsumoto 1959, p. 112, is the original of Geinitz 1850, pl. 3, fig. 3, SaK 10032, housed in the collections of the Staatlichen Museum für Mineralogie und Geologie, Dresden, and from the Upper Turonian Plänerkalk of Strehlen, Saxony, Germany. It is figured here as Text-fig. 5B.

MATERIAL: FSIT DSE321.

DESCRIPTION: The specimen is a crushed individual retaining replaced shell; the maximum preserved diameter is 29 mm. Coiling is involute, with a small umbilicus; the original whorl proportions and section cannot be established. Primary ribs arise in pairs from well-developed umbilical bullae and are straight and prorsirsdiate on the inner flank and concave on the outer flank, sweeping forwards and strengthening into prorsirsdiate ventrolateral bullae. There are traces of an undulose siphonal keel.

DISCUSSION: Poor as the specimen is there is sufficient ornament preserved as to indicate it to be a *Subprionocyclus*. The proportions and ornament compare well with that of the lectotype of *Subprionocyclus neptuni* (Text-fig. 3B), with which it is compared. Amédro and Devalque (in Robaszynski *et al*. 2014, p. 156) regarded *neptuni* as a junior synonym of *bravaisianus* of d'Orbigny (1841, p. 308, pl. 91, figs 3, 4). We believe them to be distinct; *neptuni* is more involute, the whorls higher, the rib density lower, the ribs coarser, and the umbilical bullae stronger.

OCCURRENCE: *Subprionocyclus neptuni* is index of the eponymous lower Upper Turonian zone in northwest Europe, with a geographic distribution that extends from southern England to northern France, possibly northern Spain and the Corbières in southern France, Germany, Poland, ?Austria, the Czech Republic, ?Bulgaria, Kazakhstan, Tunisia, Madagascar, Japan, and California and Oregon in the United States.

Family Coilopoceratidae Hyatt, 1903
Genus *Coilopoceras* Hyatt, 1903

TYPE SPECIES: *Coilopoceras colleti* Hyatt, 1903, p. 91, pl. 10, figs 5–21; pl. 11, fig. 1, by the original designation of Hyatt 1903, p. 91.

Coilopoceras inflatum Cobban and Hook, 1980
(Text-fig. 8A–F)

1980. *Coilopoceras inflatum* Cobban and Hook, p. 19, pl. 1, figs 9–11; pl. 11, fig. 2; pls 12–17; pl. 18, figs 1–3, 11–13; pls 20, 21; text-figs 14, 15.

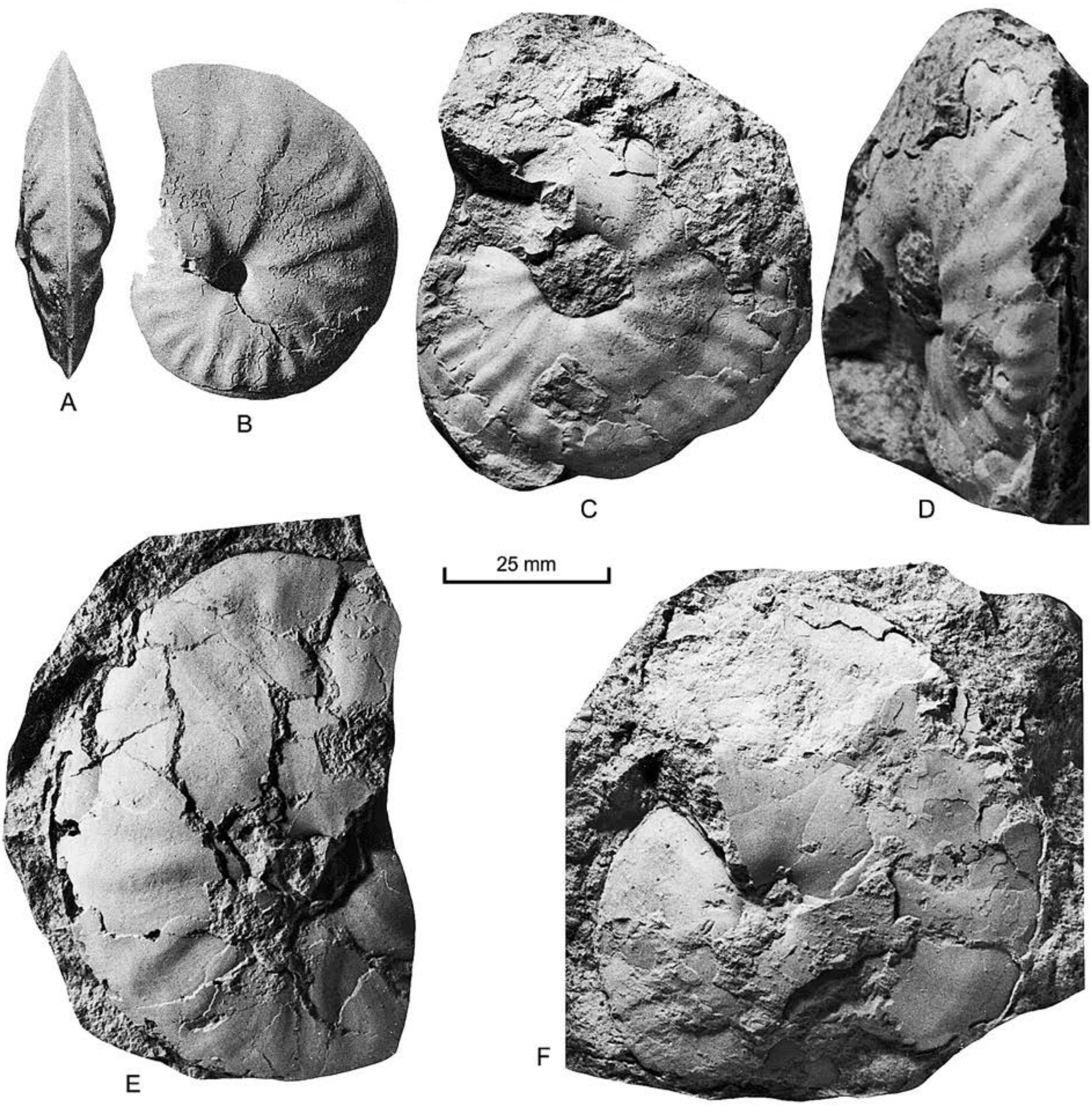
TYPE The holotype is USNM 275920, from the basal 3 meters of the D-Cross tongue of the Mancos Shale, *Prionocyclus wyomingensis*/ *Scaphites warreni* Zone at USGS Mesozoic locality D2005 in Valencia County, New Mexico. There are numerous paratypes (Cobban and Hook 1980, p. 22).

MATERIAL: FSIT DSE17, 21, and 27.

DESCRIPTION: FSIT DSE17 (Text-fig. 8C, D), a phragmocone, has one flank and the ventral region well-preserved, and retains replaced shell; the maximum preserved diameter is 72 mm approximately. Coiling is very involute, oxycone, the umbilicus comprising an estimate 15% of the diameter. The inner flanks are very feebly convex, the outer flanks flattened and convergent, the venter acute, with a sharp keel. Six primary ribs per half whorl arise on the umbilical wall, and strengthen into blunt, narrow umbilical bullae that give rise to pairs of ribs, one of which is in some cases only weakly linked to the bulla; there are additional long and short intercalated ribs to give a total of 16 ribs per whorl at the ventrolateral shoulder. The ribs are straight on the inner flank, broaden progressively, flex forwards on the ventrolateral shoulder, and strengthen into blunt ventrolateral bullae. FSIT DSE27 (Text-fig. 8E), a phragmocone 84 mm in diameter, has blunt ornament, and feeble ventrolateral bullae present to the greatest preserved diameter. FSIT DSE21 (Text-fig. 8F), is a very feebly ornament variant, also 84 mm in diameter.

DISCUSSION: We refer these specimens to *Coilopoceras inflatum* on the basis of the coarser ornamented individuals, notably the presence of distinct ventrolateral tubercles, and the course of the ribbing, which matches that of paratype USNM 275927, figured here for comparison (Text-fig. 6A–C).

OCCURRENCE: In New Mexico, the species occurs in the *Prionocyclus macombi* Zone and the succeeding *Prionocyclus wyomingensis*/*Scaphites warreni* Zone, and is regarded as upper Middle Turonian. The Corbières record is regarded as lower Upper Turonian.



Text-fig. 8. *Coilopoceras inflatum* Cobban and Hook, 1980. A, B– paratype USNM275927, the original of Cobban and Hook 1980, pl. 18, figs 1–3, from sandstone concretions at the top of the Tres Hermanos Sandstone Member of the Mancos Shale in Lincon County, New Mexico. C, D– FSIT DSE17; E–FSIT DSE27; F–FSIT DSE21. All figures are × 1.

AGE AND AFFINITIES OF THE FAUNULE

Age

Text-fig. 9 shows the Middle and Upper Turonian zonal scheme for southern Europe proposed by Robaszynski and Amédro in Robaszynski *et al.* (2014), with the relative positions of *Coilopoceras springeri* (based on occurrences in the Uchaux Massif and the southern Corbières) and *C. inflatum* (the present record), and the zonal scheme and occurrence data for the United States Western Interior (based on Cobban and Hook 1980 and Cobban *et al.* 2006). The faunule is assigned to the lower Upper Turonian on the basis of the presence of *Subprionocyclus* cf. *neptuni* and *Lewesiceras* cf. *woodi*. These are elements of the classic *neptuni* Zone fauna of the Chalk Rock of southern England and its correlatives in northern Eu-

	ZONE	SUBSTAGE
	Forresteria petrocoriensis	LOWER CONIACIAN
	Prionocyclus germari	UPPER TURONIAN
Coilpopoceras inflatum →	*Subprionocyclus bravaisianus*	
	Romaniceras deverianum	
Romaniceras (R.) mexicanum → *Coilopoceras springeri* →	*Romaniceras mexicanum*	MIDDLE TURONIAN
	Romaniceras ornatissimum	
	Romaniceras kallesi	
	Kamerunoceras turoniense	

	ZONE	SUBSTAGE
	Prionocyclus germari	UPPER TURONIAN
	Prionocyclus novimexicanus	
Coilpopoceras inflatum →	*Prionocyclus wyomingenesis*	MIDDLE TURONIAN
Coilpopoceras inflatum →	*Prionocyclus macombi*	
Romaniceras (R.) mexicanum → *Coilopoceras springeri* →	*Prionocyclus hyatti*	
	Collignoniceras praecox	
	Collignoniceras cwoollgari	

Text-fig. 9. Middle and Upper Turonian zonal schemes for and southern Europe (above, based on Robaszynski *et al.* 2014) and the United States Western Interior (below, based on Cobban *et al.* 2006, table 1) rope, where they co-occur with elements of the *bravaisianus* Zone fauna of Robaszynski *et al.* (2014), including *Subprionocyclus brannneri* (Anderson, 1902), *S. hitchinensis* (Billinghurst, 1927), and *Hyphantoceras reussianum* (d'Orbigny, 1850).

It will be seen from Text-fig. 9 that *C. springeri* and *C. inflatum* occur in the same order in both the southern Corbières and the United States Western Interior, but that *inflatum* appears to come from a significantly higher level in the Corbières: lower Upper, rather than upper Middle Turonian. There are two possible explanations:

1. The Middle/Upper Turonian boundary may be drawn at a higher level in the Western Interior than in southern Europe; this cannot be tested on the basis of the known ammonite record, as there are no diagnostic taxa common to the *deverianum* and *bravaisianus*/*neptuni* zones of southern Europe and the U. S. sequence.
2. The U.S. record represents only the lower part of the total range of *C. inflatum*, which survived to a higher level in Europe than in the U.S.

The solution to this paradox proposed here is that the base of the Upper Turonian is drawn at a higher level in the U. S. Western Interior than Europe and that the U.S. *hyatti* Zone and the southern European *mexicanum* Zone are coeval, based on the common occurrence of *Coilopoceras springeri* and *R.* (*R.*) *mexicanum* and *P. hyatti* in these zones.

To resolve this problem, the inoceramid bivalves may provide clues, for which we thank Irek Walaszczyk (see also Walaszczyk and Cobban 2000). The *Prionocyclus macombi* and *P. wyomingensis* ammonite zones, which yield *C. inflatum* in the Western Interior, correspond to the *Inoceramus dimidius* Zone; none of the marker species for this zone occur in Western Europe. The *Prionocyclus novimexicanus* Zone yields *Inoceramus perplexus* Whitfield, 1877. This species occurs in Western Europe, and is the *Inoceramus costellatus* of authors, *non* Woods, 1896 (Walaszczyk and Wood 1999; Walaszczyk and Cobban 2000, p. 34), and occurs the *neptuni* Zone (Keller 1982; Walaszczyk 1988, p. 56, text-fig. 2; Walaszczyk 1992, table 18).

Affinities

With only seven specimens, speculation on the affinities of the fauna is perhaps foolhardy. Robaszynski *et al.* (2014) and Amédro *et al.* (2016) suggested that the occurrence of *Romaniceras* (*R.*) *mexicanum*, *Prionocyclus hyatti* (Stanton, 1894) and *Coilopoceras* cf. *colleti* in the upper Middle Turonian of the Uchaux massif recorded a transgressive event or a short sea-level high at that time. The occurrence of *C. inflatum* at a higher level in the southern Corbières may record a second such event. The occurrence of *Subprionocyclus* cf. *neptuni* and *Lewesiceras* cf. *woodi* is unexceptional, as they occur in northern Europe (Wright 1979; Kennedy and Gale 2015). In contrast, *Anagaudryceras involvulum* and *Phyllopachyceras* cf. *ezoense* lend an exotic touch to the association; these are classic leiostraca more typical of Tethyan or northwestern Pacific associations, as in Japan and southern Sakhalin. Again, high sea levels, and changing oceanic circulation patterns may provide an explanation for the coming together of the disparate elements of the faunule.

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