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A North American ammonite fauna from the late Middle Turonian of Vaucluse and Gard, southern France: the *Romaniceras mexicanum, Prionocyclus hyatti* and *Coilopoceras* cf. *springeri* association

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ABSTRACT:

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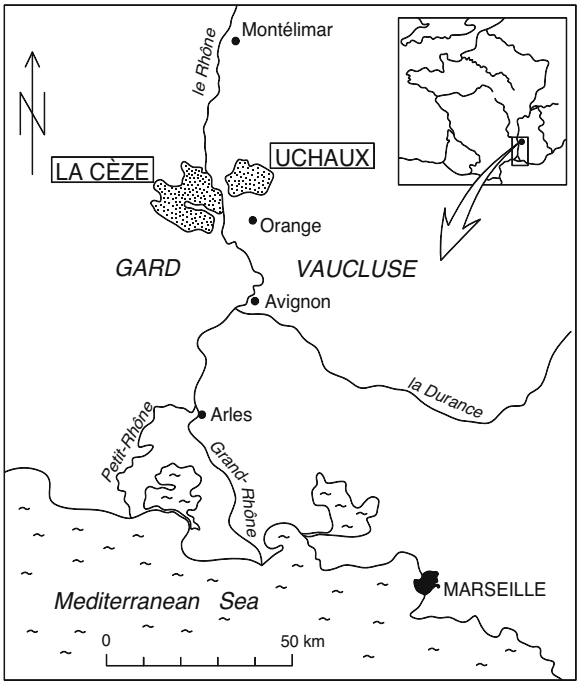
An unusual, exotic, ammonite fauna including *Romaniceras mexicanum* Jones, 1938, *Prionocyclus hyatti* (Stanton, 1894) and *Coilopoceras* cf. *springeri* Hyatt, 1903 is recorded from the late Middle Turonian of Vaucluse and Gard, southern France. It is the first record of this ammonite association outside the Gulf Coast region and the Western Interior of the United States of North America. Up to present, these species were considered as endemic to the Western Interior sea-way. The migration of numerous ammonites from North America to western Europe during the late Middle Turonian suggests it is linked to a transgressive event or to a short sea-level high.

Key words: Cretaceous; Turonian; Ammonites; Transgressive event; Migration; North America; Southern France.

PREFACE

This paper renders a tribute to Bill Cobban (1916–2015) who devoted his life to the study of Cretaceous ammonite faunas of North America and especially those of the Western Interior of the United States. His works and his scientific contributions are considerable. To take just two examples, he was one of the first to show the intraspecific morphological variability of Cretaceous ammonites through the remarkable study of the Upper Albian *Neogastroplites* of the Western Interior of the United States and of Canada (Reeside and Cobban 1960). More recently, his studies carried out with Jim Kennedy near Pueblo, in Colorado, allowed the fixing of the GSSP – Global boundary Stratotype Section and Point – of the base

of the Turonian stage (Kennedy, Walaszczyk and Cobban 2000). For this goal they used the rich assemblages of fossils collected by Bill over many decades in the Western Interior. We refer to these works when, on several occasions, in northern Africa as in western Europe, one of us (F.A.) found unusual and exotic ammonites known until then only in the Western Interior: *Prionocyclus novimexicanus* (Marcou, 1858) in the Upper Turonian of Central Tunisia (Amédro in Robaszynski *et al.* 1990), *Acanthoceras amphibolum* Morrow, 1935 and *Paraconlinoceras* aff. *barcusi* (Jones, 1938) in the Middle Cenomanian of Central Tunisia (Amédro in Robaszynski *et al.* 1994), *Metengonoceras teigenense* Cobban and Kennedy, 1989 in the Lower Cenomanian of Normandy, France (Amédro *et al.* 2002) and, lastly, the association being the subject of the present paper, with *Romaniceras mexicanum* Jones, 1938, *Prionocyclus hyatti* (Stanton, 1894) and *Coilopoceras* cf. *springeri* Hyatt, 1903, in the late Middle Turonian of south-east France (Amédro and Devalque in Robaszynski *et al.* 2014). On each of these occasions Bill Cobban in Denver and Jim Kennedy in Oxford welcomed them and agreed to examine representative specimens of these ammonites, and discuss their determinations, even sending casts of the types of North American species for comparison with our material. Thank you Bill, thank you Jim!



Text-fig. 1. Geographical map of southern France, including the location of the Uchaux massif on the left bank of the Rhône (Vaucluse) and the la Cèze massif on the right bank (Gard)

INTRODUCTION

Situated in the south-east of France, the Uchaux and la Cèze massifs (Text-fig. 1) have been known all over the world since the 19th century through the works of Alcide d'Orbigny (1840-1842, 1852). This fame is due to the presence in the Uchaux red sandstones of an exceptionally rich and diversified Upper Turonian ammonite fauna, described firstly by d'Orbigny, then by Roman and Mazeran (1913) and recently revised by Wright (1979), Kennedy *et al.* (1980), Kennedy (1984), Kennedy and Wright (1984) and finally by Amédro and Devalque (in Robaszynski *et al.* 2014). The types of six ammonite species come from these Uchaux sandstones: *Scalarites gracilis* (d'Orbigny, 1841), *Baculites undulatus* (d'Orbigny, 1850), *Worthoceras rochatianum* (d'Orbigny, 1850), *Coilopoceras requienianum* (d'Orbigny, 1841), especially *Romaniceras deverianum* (d'Orbigny, 1841) and *Subprionocyclus bravaisianus* (d'Orbigny, 1841) [= *S. neptuni* (Geinitz, 1850)] which are the index species of the current two first ammonite zones of the Upper Turonian, following the recommendations expressed during the Colloquium on the Turonian held in Paris in 1981 (Robaszynski 1983).

The interest of the Uchaux and la Cèze massifs is not limited to the Upper Turonian as it concerns also the Middle Turonian. The methodical collecting of ammonites in the two massifs by one of us (C.D.) during four decades led the amassing of about 2 000 specimens, of which 200 came from the Middle Turonian and were sufficiently diverse to allow us to distinguish four successive zones in that substage (Text-fig. 2), of *Kamerunoceras turoniense* (Tm1), *Romaniceras kallesi* (Tm2), *Romaniceras ornatissimum* (Tm3) and *Romaniceras mexicanum* (Tm4). The last of these zones is new, previously unknown in western Europe, and marked by the presence of species considered endemic and restricted to the Gulf Coast region and the Western Interior.

Below is a short account of the main litho-and palaeontological aspects of the Uchaux and la Cèze massifs. Details of the successions measured and described during the field work progressively and intermittently carried out from 1980 to 2010 are recorded in the memoir of 197 pages, 46 figures and 48 plates, recently published by the Belgian Academy of Sciences (Robaszynski *et al.* 2014). This gives all particularities and characteristics relative to the sections, their correlation, their palaeontological content, the systematic position of the ammonites species collected etc. Some of the illustrations of the present paper are taken from the memoir, with permission, and adapted to a new text.

THE TURONIAN OF THE UCHAUX MASSIF

The geographical location of the Uchaux and la Cèze massifs, north of the city of Orange, on both sides of the river Rhône is given on Text-fig. 1. The succession of strata exposed in the Uchaux massif, in the Department of Vaucluse, was studied repeatedly, particularly by Hébert and Toucas (1875), Mennessier (1950), Devalque *et al.* (1983), and more recently by Robaszynski *et al.* (2014), where Amédro and Devalque proposed a revision of ammonite and rudist faunas with all specimens placed on measured lithological logs. The main results of this last work are summarised on Text-fig. 2. Three formations can be recognized in the Uchaux massif, from base to top:

1. The Roustan Formation (Lower Turonian to Middle Turonian *pro parte*), units 1 to 3, composed of white sandstones resting on a conglomeratic level and overlain by an alternation of sandstone tempestites and silty sandstones, 250–300 m thick, they contain very few fossils;
2. The Massillan Formation (Middle Turonian *p.p.* to Upper Turonian *p.p.*), units 4 to 9, succession of sandstones and sandy limestones, 150 to 180 m thick, with fossiliferous layers;
3. The Montmout Formation (late Upper Turonian), units 10 and 11, about 300 m thick, mainly composed of sands with sandstone layers showing cross-stratification; fossils are very rare.

Each of these formations is divided into members subdivided further into several lithologic units numbered from 1 to 11. The typical "Uchaux red sandstones" containing silicified fossils correspond to units 7 and 8. The Uchaux sandstones *sensu lato* correspond to units 6 to 9.

The distribution chart (Text-fig. 2) shows well Upper Turonian succession of two zones corresponding to two associations: the *Romaniceras deverianum* Zone (units 6 and 7) followed by the *Subprionocyclus bravaisianus* Zone (units 8 to 10). In the lower half of the Middle Turonian, the *Kamerunoceras turoniense* and the *Romaniceras kallesi* Zones are not clearly identified when it is the contrary into the sequence in the la Cèze massif where the two zones are well represented. Higher in the sequence, the *Romaniceras ornatissimum* Zone is characterized by the presence of the index species, but one of the major interests of the chart is to reveal the existence, between the *R. ornatissimum* and the *R. deverianum* Zones, of a new zone, not previously recognised in Europe : the *Romaniceras mexicanum* Zone (from the top of unit 3 to units 4 and 5). In total, 205 ammonites were collected in the *R. mexicanum* interval: *Puzosia* cf. *mayoriana* (d'Orbigny, 1841) (four specimens), *Lewesiceras peramplum* (Mantell, 1822) (18 specimens), *Romaniceras (Romaniceras) mexicanum* Jones, 1938 (69 specimens), *Masiaposites kennedyi* Amédro and Devalque, 2014 (14 specimens), *Prionocyclus hyatti* (Stanton, 1894) (eight specimens), *Collignoniceras woollgari regulare* (Haas, 1946) (49 specimens), *Collignoniceras uchauxiense* Amédro and Devalque, 2014 (33 specimens) and *Coilopoceras* cf. *springeri* Hyatt, 1903 (10 specimens).

THE TURONIAN OF THE LA CÈZE MASSIF

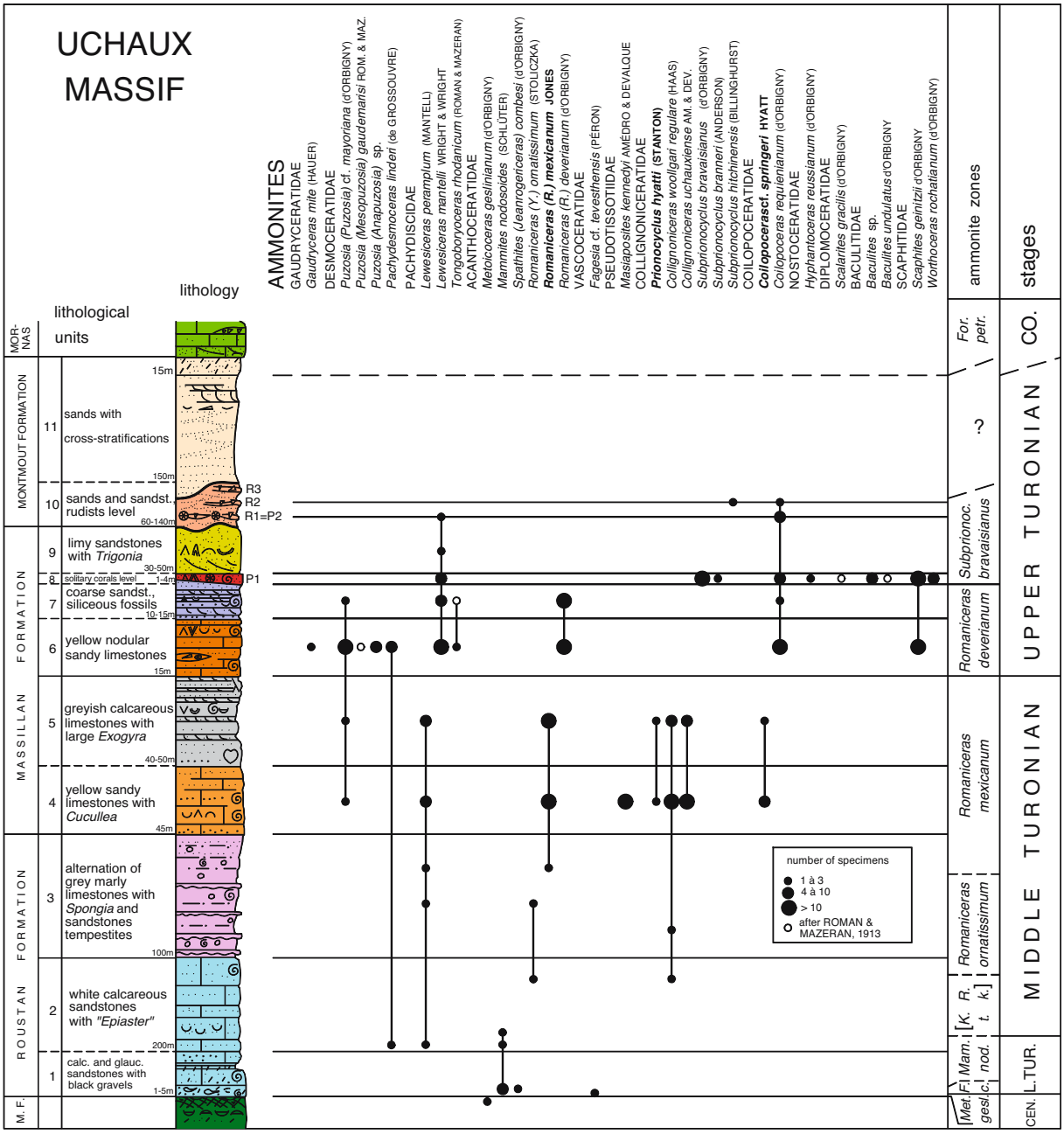
The la Cèze massif is situated in the Department of Gard, about 15 km south-east of the Uchaux Massif, on the right bank of the Rhône. During Turonian times, the la Cèze area was in a very marginal environment where the deposits were principally sandy. The stratigraphical succession was studied in the past especially by Hébert and Toucas (1875), Sornay (1950) and more recently by Robaszynski *et al.* (2014). As sedimentation was affected by rapid lateral facies variations, it is very difficult in the field to define and to follow lithological units as was possible on the other side of the Rhône. So, it seemed not pertinent to draw a synthetic lithological log nor a distribution chart for the area. Nevertheless, the Lower Turonian and the lower half of the Middle Turonian are very well exposed, and yielded rich ammonite faunas (more than 1 000 specimens) from the *Fagesia catinus* Zone to the *Romaniceras kallesi* Zone. Above, the outcrops are generally covered with vegetation. Only one area, localized near the Signal de Pignet, on the northern side of the la Cèze Massif, yielded three species of the *Romaniceras mexicanum* Zone: *R. mexicanum, C. woollgari regulare* and *P. hyatti.*

THE *ROMANICERAS MEXICANUM, PRIONOCYCLUS HYATTI* AND *COILOPOCERAS* CF. *SPRINGERI* FAUNA: A MIGRANT ASSOCIATION ORIGINATED FROM NORTH-AMERICA

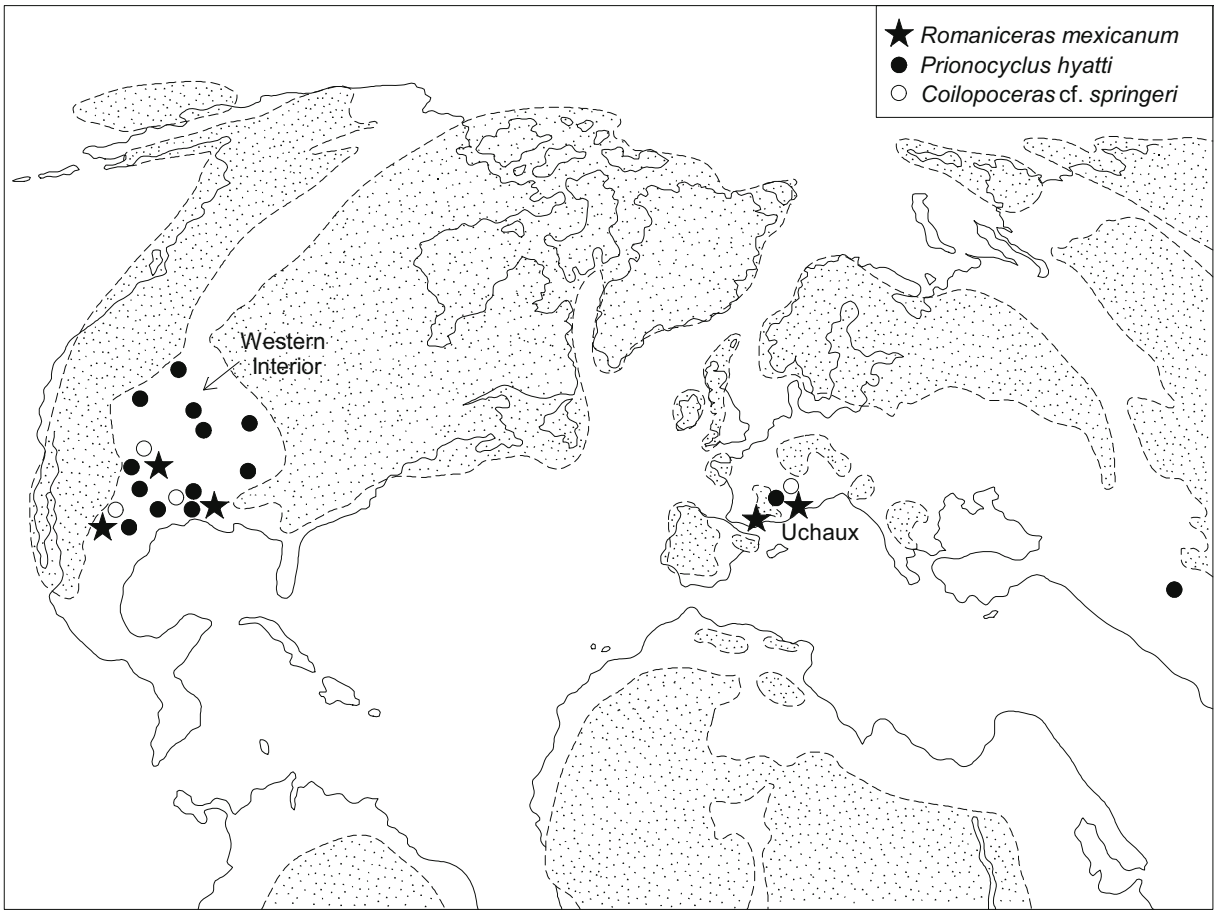
The collecting of 89 specimens of *Romaniceras mexicanum, Prionocyclus hyatti* and *Coilopoceras* cf. *springeri* (see Plates 1–3) at the top of the Middle Turonian in the Uchaux and la Cèze massifs in south-east France is especially interesting in so far as this association was until now known only in northern America. The palaeogeographic reconstructions of North America during Turonian times given by William and Stelck (1975), Smith *et alii* (1994) and Roberts and Kirschbaum (1995) shows a wide interior sea in the Western Interior of the United States linked to the south with the Gulf of Mexico. During the Middle and Upper Turonian, the am-

monites living in the Western Interior were essentially endemic and show the presence of five successive associations with *Prionocyclus* and *Coilopoceras* (Cobban and Hook 1979; Cobban 1984; Kennedy *et al.* 2001). The first association is characterized by the species *Prionocyclus hyatti* linked to *Coilopoceras springeri* and to *Romaniceras* (*Romaniceras*) *mexicanum.*

Text-fig. 3 illustrates the geographic range of the three species on the Turonian palaeogeographical map. The spreading of *P. hyatti* covers all the Western Interior sea and extends to the south to the Gulf of Mexico but that of *R. mexicanum* and *C. springeri* seem restricted to the south part of the Western Interior and to the Gulf Coast region (Cobban and Hook 1980; Kennedy and Cobban 1988 a, b; Kennedy *et al.* 1989). Outside the Western Interior, the only occurrences of the species concerned are these described in southern France, at first in the Uchaux and la Cèze massifs (Amédro and Devalque in Robaszynski *et al.* 2014) and then in the Corbières (Kennedy *et al.* 2015), excepted for *Prionocyclus hyatti* for which only one quotation was given in Kazakhstan (Marcinowski *et al.* 1996).



Text-fig. 2. Generalized succession of the Turonian formations in the Uchaux massif (Vaucluse, southern France) and ammonite ranges and zonation

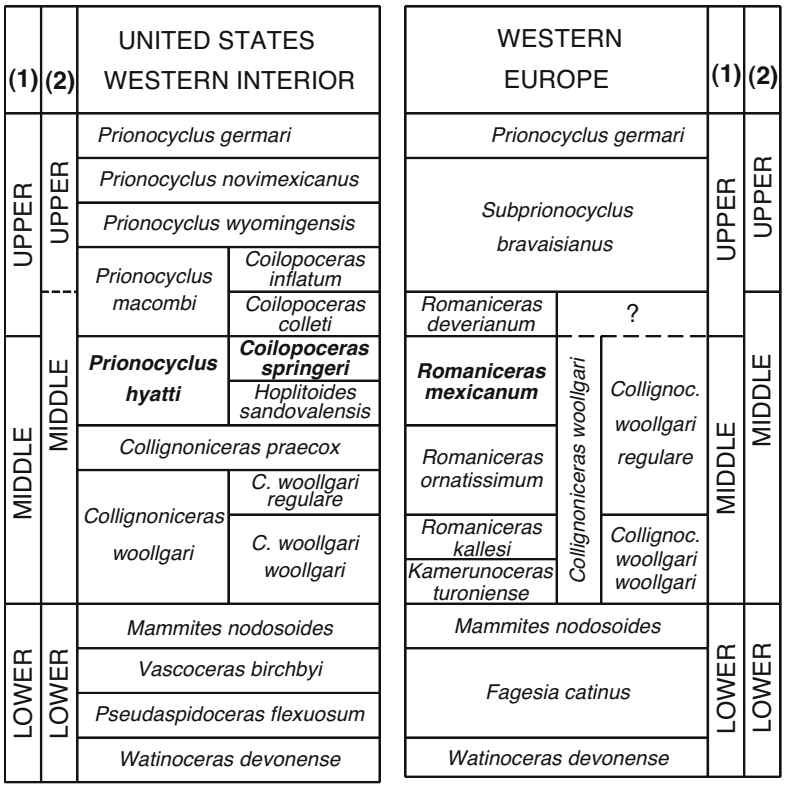


Text-fig. 3. Turonian sketch of North America and western Europe with the palaeogeographical extension of *Romaniceras mexicanum, Prionocyclus hyatti* and *Coilopoceras springeri.* During the late Middle Turonian, the ammonite faunas of the Western Interior were endemic. The discovery of numerous *R. mexicanum, P. hyatti* and *C.* cf. *springeri* in southern France suggest a transgressive event and a migration between the two areas

The finding of numerous specimens of *P. hyatti, R. mexicanum* and *C.* cf. *springeri* in association in the high Middle Turonian of the Uchaux and la Cèze massifs allows for the first time the establishment of a direct correlation line between North America and Europe, and more particularly between the *P. hyatti* Zone of the Western Interior and the *R. mexicanum* Zone of south-eastern France (Text-fig. 4). On the one hand, if the base of the Upper Turonian is defined by the first appearance of the ammonite *Romaniceras* (*R.*) *deverianum* (d'Orbigny, 1841) as recommended during the Colloquium on the Turonian stage held in Paris in 1981 (Robaszynski 1983), the boundary between Middle and Upper Turonian has to be placed at the top of the *Prionocyclus hyatti* Zone in North America, in agreement with the proposal by Hancock *et al.* (1993). On the other hand, if we follow our British colleagues and the appearance of the ammonite species *Subprionocyclus bravaisianus* (d'Orbigny, 1841) [of which *S. neptuni* (Geinitz, 1850) is a junior synonym, see discussion in Robaszynski *et al.* 2014] to place the boundary, the base of the Upper Turonian Substage could coincide with the base of the *Prionocyclus wyomingensis* Zone or even be within the *Prionocyclus macombi* Zone (as about twenty *S. bravaisianus* were collected 100 m below the base of the *Prionocyclus novimexicanus* Zone and 33 m below the occurrence of a *P.* cf. *wyomingensis* – determination confirmed par W.J. Kennedy – in marls of the Kef Formation in Central Tunisia; cf. Amédro in Robaszynski *et al.* 2000).

It remains now to understand the circumstances and events that permitted the migration of numerous *Romaniceras mexicanum, Prionocyclus hyatti* and *Coilopoceras* cf. *springeri* from the U.S. Western Interior as far as southern France towards the end of Middle Turonian times.

Isolated specimens of ammonites originating from North America and belonging to the genera *Borissiakoceras, Budaiceras, Metengonoceras,* etc., had already been found in the Cenomanian of the Paris Basin (Kennedy and Juignet 1973, 1984; Kennedy *et al.* 1990;



Text-fig. 4. Correlation of the Turonian ammonite successions between the western Interior of the United States and western Europe. The co-occurence of *Romaniceras mexicanum, Prionocyclus hyatti* and *Coilopoceras* cf. *springeri* supports a precise correlation between the two areas during the late Middle Turonian. Two views prevail to define the middle-upper Turonian boundary: (1) the FO of *Romaniceras deverianum* (this work and as recommended during the Colloquium on the Turonian stage held in Paris in 1981; cf. Robaszynski compiler, 1983) and (2) the FO of *Subprionocyclus bravaisianus* (d'Orbigny, 1841) [= *S. neptuni* (Geinitz, 1850)]

Amédro *et al.* 2002). The rarity of these finds in the field suggests that they are probably empty, drifted shells conveyed, *post-mortem*, by oceanic surface currents (Kennedy and Cobban 1976). Nevertheless, it is interesting to note that most of the arrivals of "exotic" ammonites in Europe during the Cenomanian coincided with transgressive intervals of 3rd order sequences, corresponding to temporary elevations of sea-level (Amédro *et al.* 2002). At the end of the Middle Turonian, the migration of an abundant population of *Romaniceras*, *Prionocyclus* and *Coilopoceras* appears to correspond to a comparable eustatic context. The sequence interpretations of the Turonian in Central Tunisia, in the Anglo-Paris Basin and in north-western Europe, as proposed recently by Robaszynski *et al.* (1990), Gale (1996), Hardenbol *et al.* (1998) and Miller *et al.* (2005) all support the view that the uppermost levels of the Middle Turonian correspond to the end of a transgressive interval of a 3rd order eustatic cycle, indeed the beginning of a highstand systems tract. Thus, when there is a temporary eustatic sea-level rise, one can imagine that a part of the ammonite population living in the Western Interior sea might pass in the Gulf of Mexico and be swept along by oceanic currents of the Proto-Atlantic for several thousands of kilometres to Europe (Luyendyk *et al.* 1972). If we are right, it is not impossible that future collecting in the Turonian of northern Africa or in the Iberian Peninsula may reveal the same "exotic" association as found in the Uchaux – la Cèze massifs.

CONCLUSIONS

The collecting of nearly one hundred specimens of *Romaniceras mexicanum, Prionocyclus hyatti* and *Coilopoceras* cf. *springeri* in the Turonian sandstone formations of the Uchaux and la Cèze massifs in the south-east of France is very interesting from four points of view:

1. Till now, this association was known only in the U.S. Western Interior and in the Gulf Coastal region and was considered as endemic;
2. A new *Romaniceras mexicanum* ammonite Zone is recognised at the end of the Middle Turonian in north-west Europe between the *Romaniceras ornatissimum* Zone below and the *Romaniceras deverianum* Zone above;
3. For the first time a direct correlation becomes possible between the Middle Turonian of the United States of America and Western Europe;
4. Finally, it is suggested that the migration of this ammonite population from northern America to Europe could be the consequence of an eustatic event linked to a transgressive or a highstand systems tract near the end of the Middle Turonian.

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PLATES 1–3

PLATE 1

Prionocyclus hyatti (Stanton, 1894)

A, B – from SE Chapus, lithological unit UL 4 ; C, D – from W_1 Chapus, UL 4 ; Tm4, *Romaniceras mexicanum* Zone. (scale bar = 2 cm). Field localities and full descriptions of sections referred in the plates are given in Robaszynski *et al.* (2014).

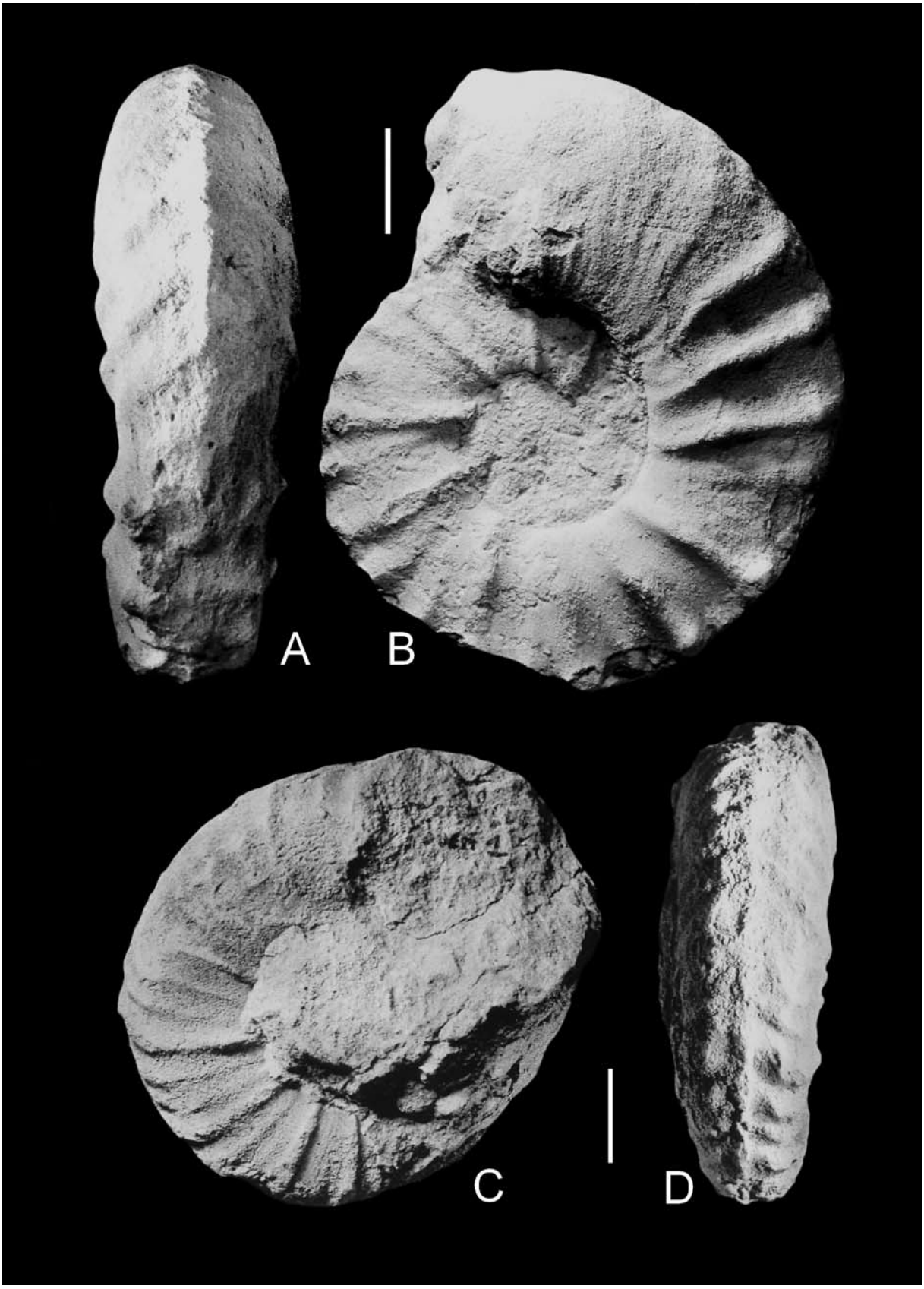
A
B
C
D

PLATE 2

Romaniceras (Romaniceras) mexicanum Jones, 1938

A, B – from E_2 Chansiergue, UL 5; C, D – from SE Peyras, UL 4 ; Tm4, *Romaniceras. mexicanum* Zone (scale bar = 2 cm). Field localities and full descriptions of sections referred in the plates are given in Robaszynski *et al.* (2014).

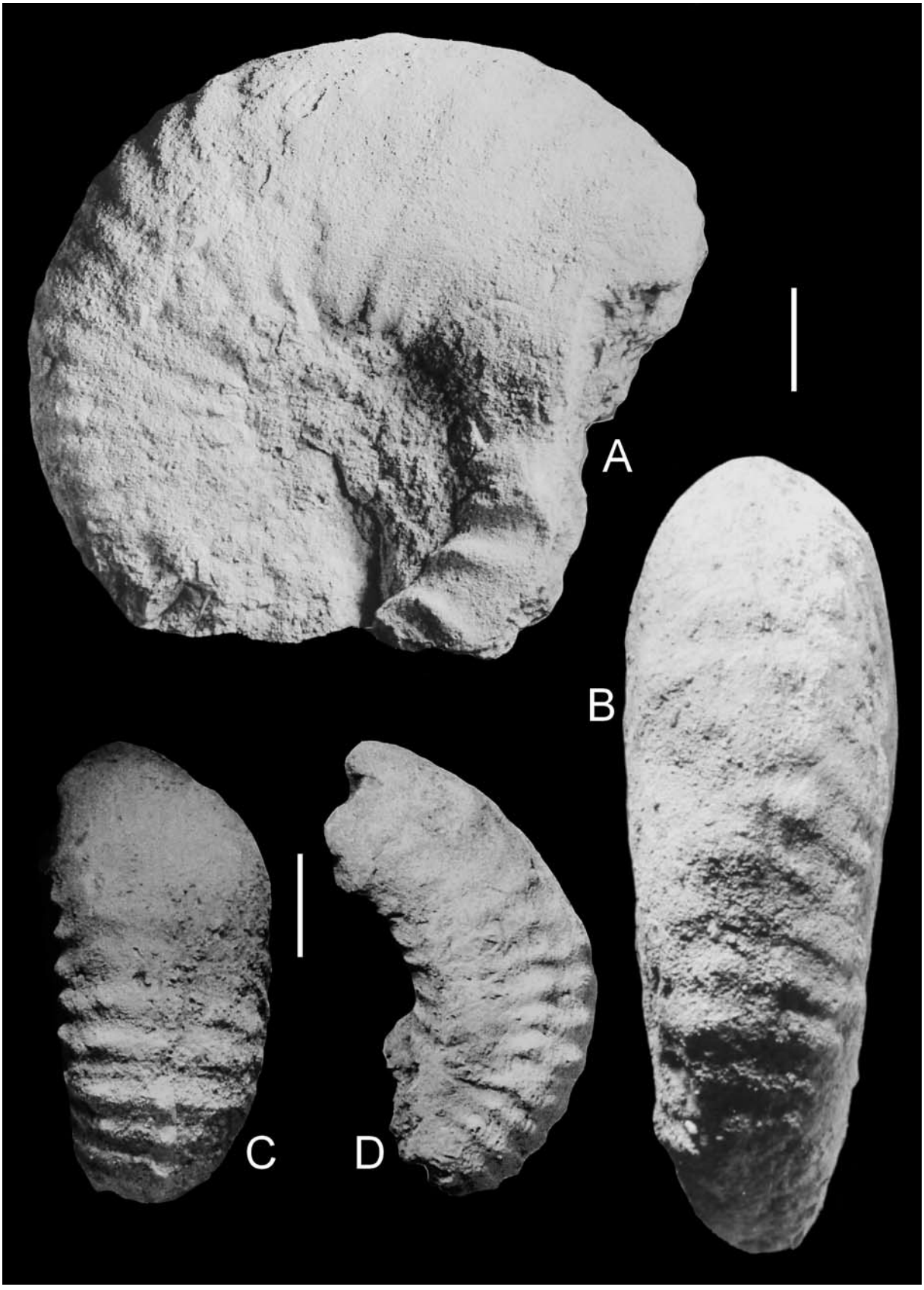
A
B
C
D

PLATE 3

A, B – *Coilopoceras* cf. *springeri* Hyatt, 1903, from S Peyras, UL 4, Tm4, *Romaniceras mexicanum* Zone.
C, D – *Romaniceras (Romaniceras) mexicanum* Jones, 1938, from SE Peyras, UL 4, Tm4, *Romaniceras mexicanum* Zone (scale bar = 2 cm).

Field localities and full descriptions of sections referred in the plates are given in Robaszynski *et al.* (2014)


A
B
C
D