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The Santonian Stage and substages

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Abstract

The recognition of the Coniacian-Santonian boundary is easy with good correlation of macro- and microfossil evidence. The Santonian Working Group (SWG) recommends the lowest occurrence of *Cladoceramus undulatoplicatus* (Roemer) as the marker for the Coniacian-Santonian boundary. As yet, the SWG cannot make a formal proposal for a Boundary Stratotype Section, because the biostratigraphy must be better known and integrated first. Three candidates for Boundary Stratotype Section, Olazagutia Quarry (Navarra, Spain), Seaford Head (Sussex, England) and Ten Mile Creek (Dallas, Texas, USA) were selected for further decision. To achieve a useful subdivision of the Santonian into substages a better understanding of taxa ranges and correlation through different biogeographic realms is needed. Formal proposals for subdivision would be premature at present, but a three-fold division is favoured.

Key-words: Santonian, Upper Cretaceous, stratotypes, chronostratigraphy, biostratigraphy, ammonites, belemnites, crinoids, foraminifera, inoceramids, nannofossils.

Résumé

La reconnaissance de la limite Coniacien-Santonien se fait aisément grâce à une bonne correlation sur base des marqueurs macro- et microfossiles.

Le Groupe de Travail du Santonien (SWG) a recommandé la première apparition de *Cladoceramus undulatoplicatus* (Roemer) comme marqueur de la limite Coniacien-Santonien. Le SWG considère qu'une proposition formelle pour un stratotype de la limite ne peut pas encore être faite car la biostratigraphie est encore insuffisamment connue et doit être mieux intégrée. Trois propositions de stratotypes de la limite ont été sélectionnées, la carrière Olazagutia (Navarre, Espagne), Seaford Head (Sussex, Angleterre) et Ten Mile Creek (Dallas, Texas, USA), pour des recherches plus approfondies.

La subdivision du Santonien en sous-étages nécessite une meilleur compréhension des extensions des taxa et une corrélation dans différentes régions biogéographiques. Des propositions formelles pour la subdivision de l'étage seraient encore prématurées, mais une division en trois sous-étages paraît préférable.

Mots-clefs: Santonien, Crétacé supérieur, stratotypes, chronostratigraphie, biostratigraphie, ammonites, bélemnites, crinoides, foraminifères, inocéramidés, nannofossiles.

Сантонский ярус и подъярусы: рекомендации Рабочей группы Сантонского яруса.

Резюме.
Граница Коньяка и Сантона легко опознаётся благодаря существующей корреляции индекс-видов макро- и микрофоссилий.

Рабочая группа Сантонского яруса рекомендует считать первое появление *Cladoceramus undulatoplicatus* (Roemer) как индекс-вид для Коньяко-Сантона. Рабочая группа Сантонского Яруса считает, что, на данный момент, формальное предложение для стратотипа границы не может быть сформулировано, так как биостратиграфия ещё не достаточно известна и должна быть лучше интегрирована. Для проведения более подробных опытов были отобраны 3 предложения стратотипа: карьер Olazagutia (Navarra, Испания), Seaford Head (Sussex, Англия) и Ten Mile Creek (Dallas, Texas, США).
Разделение Сантона на подъярусы требует лучшего понимания распространения таксонов и корреляции разных биогеографических районов. Формальные предложения по разделению яруса являются преждевременными; тем не менее, разделение на три подъяруса кажется предпочтительным.

Ключевые слова: Сантонский ярус, верхний мел, стратотипы, хроностратиграфия, биостратиграфия, аммониты, белемниты, *Crinoida*, фораминиферы, иноцерамы, нанофоссилии.

Historical

The Santonian Stage was proposed by COQUAND (1857), presumably named after the town of Saintes in south-west France. One of the localities which Coquand mentioned was Javrezac, a village on the north-west side of Cognac. The boundary there was drawn on a hardground of glauconitic, nodular limestone, with many "*Exogyra*", of the Coniacian below, and soft micaceous chalk of the Santonian above.

At the First Symposium on Cretaceous Stage Boundaries (BIRKELUND *et al.*, 1984) the consensus was that the first appearance of *Texanites (Texanites)* and of *Cladoceramus undulatoplicatus* (Roemer) are the two best boundary criteria. *Texanites (Texanites)* has been used over a wide area, although in classic regions of north-west Europe this subgenus is far too rare to be a practical marker (HANCOCK, 1991). *Cladoceramus undulatoplicatus* is widespread, and owing to its characteristic form and sculpture is easy to identify. The appearance of *Platyceramus siccensis* (Pervinquière) is well known in north Africa associated with *Texanites*, and it could be another possible marker for the base of the Santonian.

In the Santonian Working Group report to the Second Symposium on Cretaceous Stage Boundaries (Brussels, September 1995), other macro- and microfossils were mentioned as possible indices for the Coniacian-Santonian Boundary.

Thus, the lowest occurrence of the ammonite *Placenticeras polyopsis* (Dujardin) is relatively close to lower *Texanites (Texanites)*. Similarly, the entry of the *Sphenoceramus pachti-cardissoides* group is a possible marker for this boundary, associated with *Texanites* and *Cladoceramus undulatoplicatus*. Further discussion on macrofossil criteria were reported by KENNEDY (1995).

Published calcareous nannofossil events do not precisely define the Coniacian-Santonian boundary, which SISSINGH (1977) placed in CC 14 [above the first occurrence (F.O.) of *Micula staurophora* (Gardet) Stradner]: e.g., the lowest occurrence of *Reinhardtites anthophorus* (Deflandre) Perch-Nielsen is unreliable (WAGREICH, 1992), and recent studies (e.g., at Ten Mile Creek in Dallas, Texas; J. A. Burnett, written comm.) show that the Coniacian-Santonian boundary actually lies above the F.O. of *Reinhardtites anthophorus* (i.e. in CC 15 of SISSINGH, 1977). Nannofossil events which approximate the boundary are (from stratigraphically old to young): F.O. of *Lithastrinus grillii* Stradner, last occurrence (L.O.) of *Quadrum gartneri* Prins & Perch-Nielsen, L.O. of *Flabellites oblongus* (Bukry) Crux (all below the boundary) and the L.O. of *Lithastrinus septenarius* Forchheimer above the boundary. All these events fall within CC 15. Other nannofossil events, such as the L.O. of *Eprolithus floralis* (Stradner) Strover, and F.O. of *Micula concava* (Stradner) Verbeek occur later or earlier than entries of *Texanites* and *Cladoceramus undulatoplicatus*. Nevertheless, FLORES *et al.* (1987) commented that *Micula concava* and *Lithastrinus grillii* are present in greater abundances in the Santonian than in the Coniacian, and this may serve as a general guide, although nannofossil abundance is related to ecological and taphonomical factors which are generally not cosmopolitan in their extent.

First occurrences of the planktonic foraminiferan *Sigalia deflaensis* (Sigal) and *S. carpathica* Salaj have been used as markers of the latest Coniacian and the Coniacian-Santonian Boundary (SALAJ, 1975; SIGAL, 1977, respectively). Also, the first occurrence of *Dicarinella asymetrica* (Sigal), belonging to the *D. concavata* group, dates early Santonian, since it post-dated lower *Texanites* and *Cladoceramus undulatoplicatus*. Successive occurrences of these three taxa are very promising for correlation with macrofaunal ranges, and a definition of the Coniacian-Santonian Boundary.

Boundary criteria proposed at Copenhagen, and other ones commented in the Working Group reports, were discussed at Brussels during the Second Symposium in 1995.

Discussion

AMMONITES

Once it had been concluded that the species *Texanites texanus* (Roemer) does not occur in the Aquitaine Basin, nor in other European localities, (BIRKELUND *et al.*, 1984) pointed out the first appearance of the subgenus *Texanites (Texanites)* could still be a good marker of the Coniacian-Santonian boundary. Nevertheless, *Texanites (Texanites)* is rare in many areas where other indices occur, only in Zululand (South Africa), Madagascar and Texas is the subgenus common (reported by KENNEDY, 1995).

In the Anglo-Paris Basin, Texanitidae are rare, although in a hard-ground level in the Craie de Villedieu, France, *Texanites gallicus* Collignon occurs with *Placenticeras polyopsis* (Dujardin) and *Inoceramus (Cladoceramus)* (JARVIS & GALE, 1984). In Sussex in S. England, *Texanites* has not been found, but *Spinaptychus*, an aptychus associated with *Texanites*, is recorded below and close to the *Cladoceramus undulatoplicatus* event (BAILEY *et al.*, 1983, p. 34; see below in the inoceramid chapter).

KENNEDY (1995) cited Germany as a region where there are well documented co-occurrences of *Texanites* and *Cladoceramus undulatoplicatus* (Roemer), particularly the species *Texanites (T.) pseudotexanus* de Groussouvre (= *Texanites texanus* auct.). SEITZ (1961) cited in the shaft Ewald Section the coexistence of *T. texanum* (= *T. (T.) pseudotexanus*) and *Inoceramus pachti* (Arkhanguelsky) (*fide* Tröger, written comm.; see below inoceramid chapter).

In the Gosau Group, in Austria, TRÖGER & SUMMESBERGER (1994), have reported that *Texanites quinquenodosus* (Redtenbacher) co-occurs with *Sphenoceramus cardissoides* (Goldfuss) and *Parapuzosia daubreei* (de Groussouvre). This assemblage is several metres below the first occurrence of *Cladoceramus undulatoplicatus*, and above the Coniacian inoceramid *Volviceramus involutus* (J. de C. Sowerby). Such a sequence is well correlated with TRÖGER's (1989) inoceramid biostratigraphy. WAGREICH (1992) correlated lower Santonian localities in Austria (Gosau Valley and Bad Ischl-Nussensee) with *Texanites quinquenodosus*, associated with the first occurrences of the planktonic foraminifera *Sigalia deflaensis* and *Dicarinella asymetrica*. Also, those assemblages were directly correlated with the *Cladoceramus undulatoplicatus*-bed in the Brandenberg area.

In the Pyrenees *Texanites (T.)* occurs at several levels in the Santonian. In north Spain (MARTINEZ *et al.*, 1996) *Texanites (T. hispanicus* Collignon, *T.* cf. *quinquenodosus*, *T. gallicus)* occurs in several sections. These species have an irregular distribution, but *T. gallicus* and *Texanites* sp. are sometimes found below *Cladoceramus undulatoplicatus*: more than 40 m in the Oteo section (Lopez, written comm.). In Tunisia, also a Tethyan area, at Djebl Fguira Salah, *Texanites (T.) olivetti* (= *T. quinquenodosus)* occurs in the lowermost Santonian levels, with *Platyceramus siccensis* (Pervinquière) (*fide* BIRKELUND *et* *al.*, 1984; SALAJ, 1980, p. 91). In the Corbières, S.E. France, *Texanites soutoni* (Baily), *T. quinquenodosus* and *T. gallicus* occur in "Middle" Santonian but not in the Lower Santonian *Nowakites carezi* Subzone (KENNEDY *et al.*, 1996); as in the Craie de Villedieu, *T. gallicus* co-occurs with *Placenticeras polyopsis*. Although no texanitids have been found immediately above a distinctive Upper Coniacian *Paratexanites serratomarginatus* Zone, with *Protexanites* spp. , there is otherwise a macrofaunal turnover, whose species belong to the genera *Muniericeras, Texasia, Pseudoschloenbachia, Nowakites*, etc., which mark the base of the Santonian (KENNEDY *et al.*, 1996).

Near Austin in Texas the *Texanites stangeri densicostatus* Zone, as understood by K. Young, begins some distance (but probably 2 m) below the lowest *Cladoceramus undulatoplicatus* (YOUNG, 1963, particularly fig. 4); moreover, its main abundance is near the top of the *T. stangeri densicostatus* Zone. In the Dallas area of north central Texas there is a record of *Texanites* (LARSON *et al.*, 1991, fig. 10.6) in a bed which A. S. Gale and J. M. Hancock found to be at least 12 m below the lowest *Cl. undulatoplicatus* (Hancock, written comm.). This figure agrees with data from northern Spain. Therefore the lowest *Texanites* cannot be used as an accurate and absolute standard for the base of the Santonian stage.

At Amakusa, in S.W. Japan, the Coniacian-Santonian boundary is marked by the occurrence of *T. collignoni* Klinger and Kennedy (= *T. olivetti* auct.) which is associated with *Inoceramus amakusensis* Nagao and Matsumoto (UEDA, 1962; T. Matsumoto, written comm.), whereas in the Haboro area, N.W. Hokkaido, *I. amakusensis* occurs below *T. collignoni* (TOSHIMITSU *et al.*, 1995, fig. 2, p. 24), but just above the Coniacian species *I. mihoensis* Matsumoto.

The first appearance of *Texanites*, particularly *T. (Plesiotexanites) kawasakii* (Kawada) and *Inoceramus amakusensis* are the two best criteria for the Coniacian-Santonian boundary in Sakhalin. Both species lie above *Peroniceras* sp. and *Inoceramus mihoensis* (E.A. Yazykova, written comm., YAZYKOVA, 1996) (Figure 1).

INOCERAMIDS

Three species have been used to define the Coniacian-Santonian boundary: the widespread species *Cladoceramus undulatoplicatus*, the north Temperate *Sphenoceramus pachti-cardissoides* group and the north African *Platyceramus siccensis*.

The last species, possibly related to the *Pl. cycloides* group, was cited in Algeria (SIGAL, 1952) and Tunisia associated with *Sigalia carpathica* Salaj; both occurrences are above the late Coniacian species *S. deflaensis* (Sigal) (SALAJ, 1980). No occurrence is known outside north Africa.

Cladoceramus undulatoplicatus is an almost worldwide species, whose appearance has been used to define the Coniacian-Santonian boundary. It is associated with *Sphenoceramus* in North Temperate areas, and lies above *Magadiceramus subquadratus* (Schlüter) in the Northern Hemisphere (DHONDT, 1992; LOPEZ *et al.*, 1992).

In the Western Interior of N. America, KAUFFMAN *et al.* (1994) reported the co-occurrence of *Cladoceramus undulatoplicatus* s.s., *Sphenoceramus pachti*? and *Platyceramus cycloides* (Wegner) at the base of the Santonian, which are associated with *Cordiceramus cordiformis* (J. de C. Sowerby) in overlying beds. Near Austin, Texas, the lowest *Cladoceramus undulatoplicatus* occurs at an uncertain distance above the base of the Zone of *Texanites stangeri densicostatus* (for details, see above in "Ammonites").

In the north German-Polish Basin it is common to find the succession of uppermost Coniacian *Magadiceramus subquadratus* [TRÖGER, 1989's Zone 24] and lowermost Santonian *Sphenoceramus pachti* and *Sph. cardissoides* (TRÖGER (1989)'s Zone 25). They are followed (TRÖGER, 1989) by occurrences of *Cladoceramus undulatoplicatus*. SEITZ (1961, fig. 2, p. 19) cited, in the Ewald shaft section, the coexistence of *Sphenoceramus pachti* and *Texanites texanum* (Roemer) [= *Texanites (T.) pseudotexanus*], and SEITZ (1965) mentioned occurrences of *Cl. undulatoplicatus* cf. *michaeli* (Heinz) with *Texanites* sp. ;

Magadiceramus subquadratus	*	*	*			north-central Texas
Cladoceramus undulatoplicatus				*	*	
Texanites stangeri densicostatus			*	*	*	
Texanites		*	*	*	*	
Volviceramus involutus	*					Gosau Group Austria
Spenoceramus cardissoides		*				
Cladoceramus undulatoplicatus				*	*	
Texanites quinquenodosus		*	*	*		
Sigalia deflaensis			*	*	*	
Dicarinella asymetrica			*	*	*	
Lucianorhabdus cayeuxii				*	*	
Magadiceramus subquadratus	*	*				Germany
Cladoceramus undulatoplicatus				*	*	
Sphenoceramus pachti			*			
Sphenoceramus cardissoides			*			
Texanites pseudotexanus			*	*	*	
Magadiceramus subquadratus	*	*	*			north Spain
Cladoceramus undulatoplicatus				*	*	
Texanites gallicus		*	*	*	*	
Texanites	*	*	*	*	*	
Sigalia carpathica				*		
Inceramus mihoensis	*					Japan
Inceramus amakusensis		*	*			
Platyceramus mantelli	*	*	*	*	*	
Texanites collignoni			*	*	*	
	CONIACIAN			SANTONIAN		

Fig. 1 — Distribution of possible markers for the Coniacian-Santonian boundary in different palaeobiogeographic provinces.

he also cited the sequence of *Sph. cardissoides* subsp. ind. and *Sph. pachti* followed by *Texanites pseudotexanus* at Recklinghausen (*fide* K. A. Tröger, written comm.).

In England there is a double *Cladoceramus* event, which can also be traced throughout the Anglo-Paris Basin, N.W. Germany (BAILEY *et al.*, 1984) and north Spain. Below these levels, in S. England there are no occurrences of sphenoceramids: the lower occurrence of *Sphenoceramus cardissoides* was collected above the double *Cladoceramus* event (BAILEY *et al.*, 1983; C. J. Wood, written comm.). Recent field work by A. S. Gale in the Isle of Thanet (S.E. England) has demonstrated that in addition to the two main *Cladoceramus* events, there are three additional minor *Cladoceramus* occurrences in the overlying succession. This total known range of *Cladoceramus* matches occurrences of *Spinaptychus*. There is no evidence in S. England for the existence of a *Sphenoceramus pachti-cardissoides* group Zone below the *Cl. undulatoplicatus* Zone (C. J. Wood, written comm.).

In both France and north Spain, inoceramid assemblages are good markers for the Coniacian-Santonian boundary. *Magadiceramus subquadratus* (Schlüter) followed by *Cl. undulatoplicatus* characterise the uppermost Coniacian and lowermost Santonian, respectively (LOPEZ *et al.*, 1992). Lower Santonian assemblages, in north Spain, are rich and diverse. In addition to *Cl. undulatoplicatus* other divergent rib species are found: *Platyceramus cycloides wegneri* (Boehm) and *Cordiceramus cordiinitialis ickernensis* (Seitz) (MARTINEZ *et al.*, 1996). Sphenoceramids have not been found in Spain, and therefore Zone 25 of TRÖGER (1989) is not recognisable (see below).

In Austria, in the Gosau basin, assemblage sequences are similar to other Tethyan localities, but with north temperate affinities, e.g., *Actaeonella laevis* (J. de C. Sowerby) and *Volviceramus involutus* in the Upper Coniacian, and *Texanites quinquenodosus*, *Parapuzosia daubreei*, *Sphenoceramus cardissoides*, *Platyceramus cycloides cycloides* (Wegner) and *Cladoceramus undulatoplicatus* in the Lower Santonian are recorded (TRÖGER & SUMMESBERGER, 1994). According to these authors there is no clear evidence of TRÖGER's inoceramid zones 24 (uppermost Coniacian) and 25 (lowermost Santonian). *Sphenoceramus pachti* has also been found in Austria by K.A. Tröger & H. Summesberger (K. A. Tröger, written comm.). The occurrences of the genus *Magadiceramus* in Tyrol (SEITZ, 1970; KAUFFMAN, *in* HERM *et al.*, 1979) are doubtful according to TRÖGER & SUMMESBERGER (1994, p. 179). However, it seems that *Cl. undulatoplicatus* and *Texanites quinquenodosus* co-occur in the Mühlbach Section (TRÖGER & SUMMESBERGER, 1994: p. 184).

In the Caucasus Region and central Asia (Turkmenia; MOSKVIN, 1986) the Coniacian-Santonian transition shows an upper Coniacian with *Volviceramus involutus* overlain by *Cl. undulatoplicatus*, and sometimes *Sphenoceramus cardissoides.*

In far-east Asia (Japan, Sakhalin) *Inoceramus amakusensis* Nagao and Matsumoto is a well known marker for the base of the Santonian, associated with *Texanites (T.) collignoni* or *T. (Plesiotexanites) kawasakii* (Kawada). The succession of *Inoceramus mihoensis* overlain by *I. amakusensis* characterises the Coniacian-Santonian Boundary in the Haboro area (Hokkaido; TOSHIMITSU *et al.*, 1995), and Sakhalin (E. A. Yazykova, written comm.). Some Coniacian inoceramid species, in Europe, may have higher occurrences in far-east Asia, since *Platyceramus mantelli* (de Mercey) is known in the Upper Coniacian and also "Santonian" together with *I. amakusensis* (T. Matsumoto, written comm.). The species *Cladoceramus undulatoplicatus* is unknown in far-east Russia.

Sphenoceramids are widespread, but occur only rarely in the Tethyan Realm. The species *Sphenoceramus pachti* and *Sph. cardissoides* characterise the lowermost Santonian (TRÖGER's Zone 25, 1989), but this zone is only well recognised in the north German-Polish Basin, where both species are associated with *Sph. bornholmensis?* (Tröger & Christensen), and *Platyceramus cycloides ahsenensis* (Seitz) (TRÖGER, 1989). Nonetheless, either *Sph. pachti* and *Sph. cardissoides*, mainly the latter, are recorded at many localities from the Northern Temperate Realm (DHONDT, 1992; LOPEZ *et al.*, 1992), overlying Coniacian volvoceramids or *Magadiceramus* assemblages, and underlying *Cladoceramus undulatoplicatus* and *Platyceramus cycloides wegneri* (Boehm) assemblages.

Even in the Gosau Basin, a Tethyan locality, *Sph. cardissoides* is recorded close to *Cl. undulatoplicatus* (see: TRÖGER & SUMMESBERGER, 1994), but probably underlying it. Sphenoceramids have also been recorded in the Charente, S.W. France (DHONDT, 1992), on a northern border of the Tethyan Realm. In contrast, in other Tethyan localities, e.g., Crimea and Caucasus (DOBROV & PAVLOVA, 1959), *Sph. cardissoides* is associated with *Cl. undulatoplicatus.*

Up till now, no sphenoceramids have been found in north Spain, but the species *Pl. cycloides ahsenensis* is common and is associated with *Cl. undulatoplicatus*, as in the north German-Polish Basin. In consequence, it is possible to make a good correlation between Lower Santonian rocks belonging to the Northern Temperate and Tethyan Realms (see LOPEZ *et al.*, 1992, for additional common species between north Germany and north Spain) (Figure 1).

FORAMINIFERA AND NANNOFOSSILS

This group shows different assemblages controlled by biogeography. In general, low and middle latitudes have good occurrences of planktonic foraminifera, whereas in the Temperate Realm benthic foraminiferal assemblages characterise the Coniacian-Santonian boundary.

In the Mediterranean area of the Tethys, the succession of species *Sigalia deflaensis* (Sigal), *S. carpathica* Salaj and *Dicarinella asymetrica* (Sigal) characterise the Coniacian-Santonian transition. *S. deflaensis* has a widespread occurrence in the Tethyan Realm (see MASTER, 1977), but *S. carpathica* is only known from the Mediterranean Region and, like *D. asymetrica*, was also rare in shallow water facies. Nevertheless, as the lower occurrence of *S. carpathica* is associated with *Cl. undulatoplicatus* and *Texanites (T.)* spp. in north Spain MARTINEZ *et al.*, 1996), or with *Platyceramus siccensis* in north Africa (SALAJ, 1980), it is a good regional index (SIGAL, 1977) which should be checked throughout the Tethyan Realm, where both *S. deflaensis* and *D. asymetrica* associated with inoceramids and texanitids occur. Both species *S. deflaensis* (= *S. carpathica*; M. Wagreich, written comm.) and *D. asymetrica*, with *D. concavata* (Brotzen), were cited by WAGREICH (1992) in Austria, as markers of the Coniacian- Santonian Boundary. Especially, in the Bad Ischl-Nussensee section successive occurrences of *S. deflaensis, D. asymetrica* and *S. decoratissima* (de Klasz) are similar to Tunisian localities.

Nannofossil occurrences in these levels are similar to other boundary sections, e.g., rare upper *Eprolithus floralis* (Stradner) Strover, *Lithastrinus septenarius* Forchheimer and *Quadrum gartneri* Prins & Perch-Nielsen, associated with lower occurrences of *L. grillii* Stradner and *Micula decussata* Vekshina [= *M. staurophora* (Gardet) Stradner], in upper Coniacian beds. All these entries lie below *Lucianorhabdus cayeuxii* Deflandre (WAGREICH, 1992), an early Santonian species.

The species *Stensioina polonica* Witwicka used to be a good marker of the Coniacian-Santonian boundary in the North Temperate Region, from England to eastern Europe. In S.E. England *St. polonica* occurs with lower *Cladoceramus undulatoplicatus*, which marks a significant macrofaunal and microfaunal turnover (C. J. Wood, written comm.). In eastern Temperate Europe the F.O. of *Stensioina exsculpta exsculpta* (Reuss) is a very convenient marker for the Coniacian-Santonian boundary (L. F. Kopaevich, written comm.). Other benthic species, such as *Neoflabellina gibbera* (Wedekind), occur in north Africa and western Carpathia, and its stratigraphical range is similar to *Sigalia carpathica* (SALAJ, 1980). Furthermore, this author correlated the *S. carpathica* Zone from western Carpathia with the lower part of the *Anomalina (A.) infrasantonica* Zone (VASILENKO, 1961), allowing a correlation of western Tethys with its eastern European areas.

Criteria proposed for the Coniacian-Santonian boundary

1) FO of *Texanites (Texanites)*
2) FO of *Sigalia carpathica*
3) FO of *Dicarinella asymetrica*
4) FO of *Platyceramus siccensis*
5) FO of *Cladoceramus undulatoplicatus*
6) FO of *Sphenoceramus pachti*

No nannofossil event is suitable for the Coniacian-Santonian boundary

Selected marker for the Coniacian-Santonian boundary

Primary marker: The lowest occurrence of *Cladoceramus undulatoplicatus.* It is a taxon easily recognisable and widespread. It is known from N. America, Europe, Africa, Madagascar, and central Asia.
This proposal was supported by a majority at Brussels. (Yes = 23; No = 1; Abstentions= 2)
Postal vote: 20 votes (out of 39 WG members) were returned (Yes = 17; No = 1; Abstentions = 2).

Secondary marker: *Sigalia carpathica.* This planktonic foraminiferan is widespread in the Mediterranean Region of the Tethys. It is associated with *Inoceramus siccensis* and *Texanites* in Tunisia. In north Spain (Navarra) it is very close to the lowest occurrence of *Cladoceramus undulatoplicatus*.
This secondary marker has been supported by a postal ballot (Yes = 10; No = 3; Abstentions = 7).
Some voting members have emphasised the usefulness of other planktonic foraminifera (D. Herm) and the convenience of benthic forms as secondary markers in the Temperate Realm (L. Kopaevich).

Rejected

Texanites (Texanites). Its first occurrence is below the lowest *Cladoceramus undulatoplicatus.* It has been cited in assemblages with inoceramids normally regarded as Coniacian.
Dicarinella asymetrica. Its first appearance is above the lowest *Sigalia carpathica*, and therefore is not suitable to characterise the Coniacian-Santonian boundary. Moreover it is restricted to basinal facies.
Platyceramus siccensis. Only known from north Africa, although it may be correlated with other areas through the lowest *Sigalia carpathica.*
Sphenoceramus pachti. It is a temperate species, rare at middle latitudes and unknown in palaeotropics (Tethys).

Boundary Stratotype Section

As yet, we cannot make a formal proposal, because we need to know and integrate the biostratigraphy better.
We have selected three candidates:
1) Olazagutia Quarry (Navarra, Spain). M. Lamolda would collate data and report to the Chairman.
2) Seaford Head (Sussex, England). R. Mortimore and C.J. Wood would collate data and report to the Chairman.
3) Ten Mile Creek (Dallas, Texas). E. G. Kauffman and A. S. Gale would collate data and report to the Chairman.

This proposal was approved UNANIMOUSLY
(Yes = 34; No = 0; Abstentions = 0)
The postal ballot also supported this proposal (Yes = 18; No = 1; Abstention = 1).
J. Salaj (Bratislava) has sent a new proposal to the chairman for the C/S boundary stratotype in the El Kef Area, Tunisia, whose fossil content is cited above. C. J. Collom (Calgary) has sent a proposal for this boundary in the Cold Temperate Province; several sections are located at the Smoky River, Bad Heart River and Tipper's Coulee, all of them in west-central Alberta (Canada), having a very rich fossil content. L. F. Kopaevich (Moscow) has proposed a section at Emdy-Kurgan, Mangyshlak (Kazakhstan), which is being studied by D. P. Naidin, L.F. Kopaevich and A. S. Gale.

Substages of the Santonian Stage

Criteria for the subdivision of the Santonian Stage have been changeable since de GROUSSOUVRE (1901) proposed two zones in the Corbières, a lower Santonian *Mortoniceras texanum* Zone and an upper Santonian *Placenticeras syrtale* Zone. Both indices are American species and unknown in France (HANCOCK, 1991). In Europe, both *Texanites gallicus* and *T. quinquenodosus* are common in the Lower Santonian, but they are not recorded in the Corbières (KENNEDY & WRIGHT, 1983; see above Ammonite chapter). For the upper Santonian several indices have been used, thus *Placenticeras paraplanum* Wiedmann seems to characterise the top Santonian (HANCOCK, 1991; KENNEDY, 1995), whereas in north Spain the index could be *Eupachydiscus isculensis* (Redtenbacher) (MARTINEZ *et al.*,1996).

Results outside Europe are also confusing and show endemic zonations, whose correlations up till now are not suitable. It is possible to distinguish two to five subdivisions, according to the literature.

Inoceramids show a similar picture. A detailed zonation in the north German-Polish Basin (TRÖGER, 1989) is not recognised everywhere (see Inoceramid chapter for the lowermost Santonian Tröger's Zone 25).

Thus, in north Spain (MARTINEZ *et al.*, 1996) 4 or 5 subdivisions are recognisable, but most of them are quite different from TRÖGER's zones, because cold temperate taxa - mainly the genus *Sphenoceramus* - have not been found in Spain; except for the lower Santonian *Cladoceramus undulatoplicatus* Zone, which is very common worldwide. KENNEDY (1995) suggested the first occurrence of the cosmopolitan species *Inoceramus (Cordiceramus) cordiformis* (J. de C. Sowerby) as the base of the Middle Santonian.

KENNEDY (1995) favoured the first appearance of the cosmopolitan *Uintacrinus socialis* Grinnell as the base of the Upper Santonian (see also GALE *et al.*, 1995). Nevertheless LEAHY & LERBEKMO (1995) have shown that the appearance of the crinoid *Uintacrinus socialis* (and *Marsupites*) in the Western Interior of N. America should be time transgressive relative to its appearance in Europe, according to its correlation with the base of Chron 33r.

The Santonian of N.W. Europe is subdivided into five *Gonioteuthis* zones, whereas the Santonian of the Russian Platform is subdivided into only two zones (CHRISTENSEN, 1990). Nevertheless, the base of the Santonian cannot be defined on the basis of belemnites, because *Gonioteuthis* is extremely rare in the lower Lower Santonian. The L.O. of *Cladoceramus undulatoplicatus* may be identical with/or very close to the base of the *coranguinum/ westfalica* Zone, and *Gonioteuthis granulata* (Blainville) appears slightly later than *Uintacrinus socialis* (W. K. Christensen, written comm.). Russian workers favoured a two fold division of the Santonian in cold temperate regions (L. F. Kopaevich and E. A. Yazykova, written communication).

Recent research on planktonic foraminifera has changed known occurrences (ROBASZYNSKI *et al.*, 1984) for both *Globotruncanita elevata* (Brotzen) and *Gl. stuartiformis* (Dalbiez). The first occurrence of *Gl. elevata* is younger (see PREMOLI SILVA & SLITER, 1994, fig. 2) and probably suitable to correlate the basal 'upper' Santonian. Both J. Salaj and L. F. Kopaevich disagreed with Santonian occurrences of *Gl. arca* (Cushman), because those stratigraphically younger specimens actually belong to ancestral species in the phylogeny of *G. arca*. Lamolda supports that opinion: he used to find (unpublished data) *Gl. convexa* Sandidge in north Spain in 'upper' Santonian rocks, but not *Gl. arca* s.s. First occurrences of *Gl. convexa* and *Gl. manaurensis* Gandolfi had been cited by SIGAL (1977) as upper Santonian markers in the Mediterranean Region (also, see SALAJ, 1980). The status and ranges of all these species should be cleared but they are interesting for Santonian subdivision.

Nannofossils present several problems related to preservation of the genera *Calculites* and *Lucianorhabdus*. Nevertheless, *Calculites obscurus* (Deflandre) Prins & Sissingh used to be a marker of the 'upper' Santonian and *Lucianorhabdus cayeuxii* Deflandre for 'middle' Santonian (WAGREICH, 1992). The first occurrence of *Amphizygus minimus* Bukry was reported by BURNETT (1996) close to the lowest *Uintacrinus socialis* Grinnell. In the Bottaccione Section, GARDIN *et al.* (in press) have found a similar sequence of nannofossil events - successive occurrences of *L. cayeuxii* followed by *A. minimus* - to those in England (S. Gardin, written comm.). Therefore, it will be necessary to check other sections to contrast correlations of these indices, especially the relative horizons of *L. cayeuxii, A. minimus, Uintacrinus socialis*, and *C. obscurus*.

After discussion this motion was put:
1) A threefold division should be used for the Santonian;
2) Formal proposals are premature at present;
3) A possible datum for the base of the Middle Santonian is the extinction point of *Cladoceramus undulatoplicatus*.

4) A possible datum for the base of the Upper Santonian is the first occurrence of *Uintacrinus socialis*.
The WG voted: Yes = 15; No = 0; Abstentions = 6.
The postal ballot supported the motion by a majority: Yes = 12; No = 5; Abstentions = 3.

Substage boundary stratotypes

At present, the WG has no proposals for the substage boundary stratotypes. Possible boundary sections in Texas, along the Channel Coast, in Germany and Mangyshlak were discussed. Integration of macro-, micro-, nannofossil datum-levels, stable isotope-ratios and palaeomagnetism, is necessary before further progress is possible.

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