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The Campanian Stage

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Abstract

The Campanian working party in Brussels did not wish to make a conclusive recommendation but there was a strong feeling that the base of the stage should be fixed at the extinction-level of the crinoid *Marsupites*. Other criteria discussed included ammonites, belemnites, foraminifera, calcareous nannofossils and magnetostratigraphy. Candidates for a boundary-stratotype occur in central Texas and south-east England. Until these sections have been described in detail, it will not be possible to choose a boundary-stratotype, and hence make a firm recommendation to the International Subcommission for the base of the stage.

It was felt that three substages should be used for the Campanian, but international correlations within the stage are still too uncertain to make recommendations for the definitions of these substages.

Key-words: Campanian, Upper Cretaceous, *Placenticeras*, *Submortoniceras*, *Gonioteuthis*, inoceramids, *Marsupites*, *Broinsonia*, *Dicarinella*, magnetostratigraphy.

Résumé

Le Groupe de Travail du Campanien n'a pas souhaité décider définitivement la position de la limite Santonien-Campanien mais un consensus s'est dégagé en faveur du tracé de la base de l'étage Campanien au niveau de l'extinction du crinoide *Marsupites*. D'autres critères discutés concernent, entre autres, les ammonites, les bélemnites, les foraminifères, les nannofossiles calcaires et la magnétostratigraphie. Des coupes retenues comme candidates pour le stratotype de la limite se trouvent au Texas central et dans le SE de l'Angleterre. Aussi longtemps que ces sections n'auront sont pas été décrites en détail, il sera impossible de choisir un stratotype de la limite, et donc de faire une recommendation formelle à la Sous-commision Internationale pour la base de l'étage.

Il a été considéré qu'une division en trois sous-étages serait utile pour le Campanien, mais les correlations internationales sont encore trop incertaines pour faire des recommendations concernant la définition de ces sous-étages.

Mots-clefs: Campanien, Crétacé supérieur, *Placenticeras, Submortoniceras, Gonioteuthis*, inoceramids, *Marsupites, Broinsonia, Dicarinella*, magnetostratigraphie.

Кампанский ярус.

Резюме.
Рабочая Группа Кампанского Яруса предпочла не определять окончательную позицию Сантоно-Кампанской границы; тем не менее, согласие было достигнуто о проведении основания Кампанского яруса на уровне протяжения морской лилии *Marsupites*. Другие затронутые критерии касаются, между прочим, аммонитов, белемнитов, фораминифер, известковых нанофоссилий и магнитостратиграфии. Отобранные в качестве возможных вариантов для стратотипа границы разрезы располагаются в центральном Тексасе и на юго-востоке Англии. Выбор стратотипа границы, а следовательно и формальные рекомендации для Международной Подкомиссии касательно основания яруса будут невозможны до тех пор пока эти разрезы не будут детально описаны.
Было принято во внимание, что разделение Кампанского яруса на 3 подъяруса может оказаться полезным, но глобальные корреляции являются на данный момент достаточно неопределёнными для того, чтобы давать какие-либо рекомендации, касающиеся определения подъярусов.

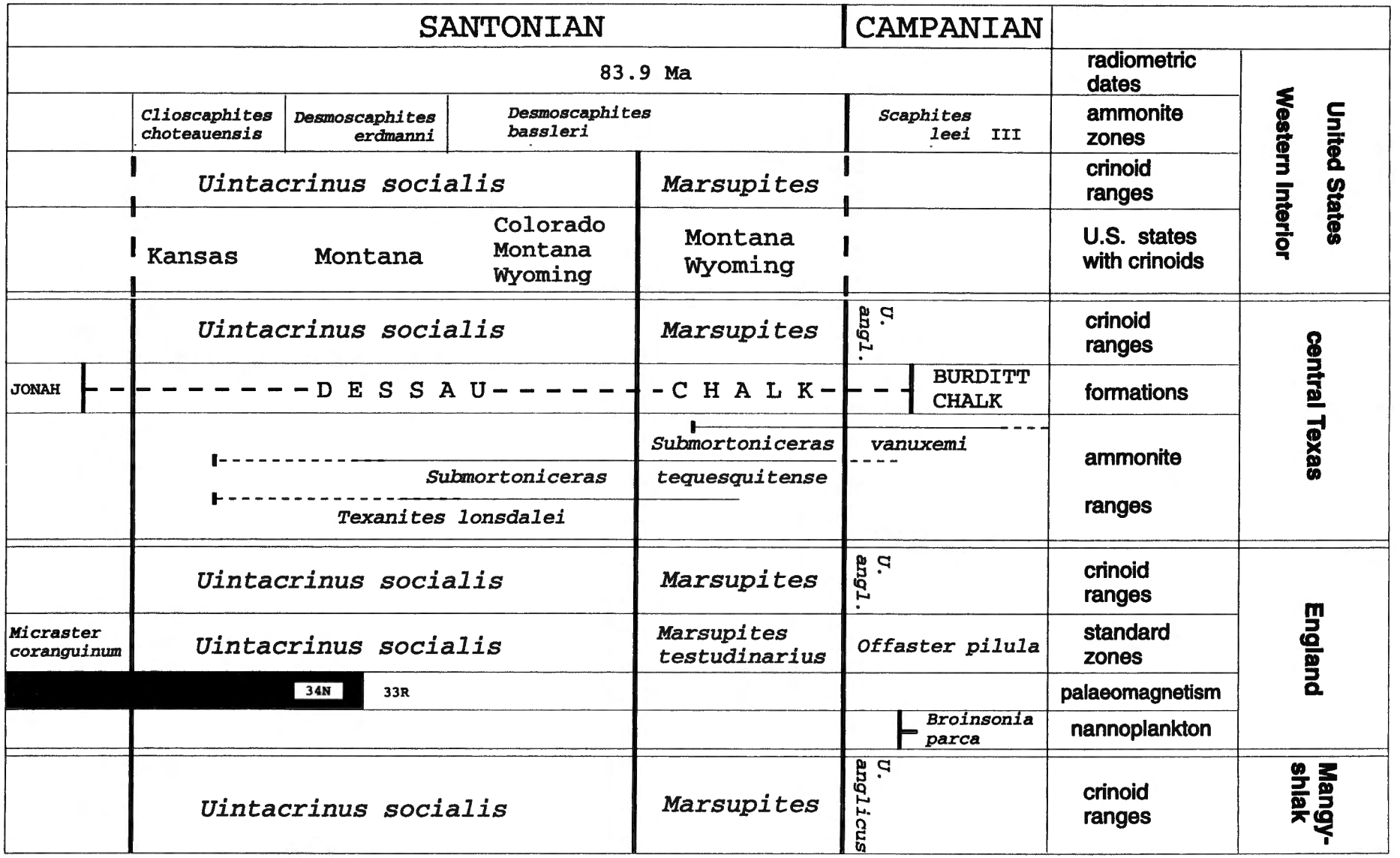
Ключевые слова: Кампанский ярус, верхний мел, *Placenticeras, Submortoniceras, Gonioteuthis*, иноцерамы, *Marsupites, Broinsonia, Dicarinella*, магнитостратиграфия.

Original concept

The Campanian stage was introduced by COQUAND (1857). It is generally agreed that it is the rock-succession in the hillsides of Grande Champagne near Aubeterre-sur-Dronne, some 45 km west-north-west of Périgueux in northern Aquitaine, France, which best represents what COQUAND had in mind out of all the sections which he mentioned. The sediments there are much burrowed shallow water limestones, rich in benthic foraminifera and bivalves (including scattered rudists); some beds contain cyclolitid corals and many polyzoa. Studies by SÉRONIE-VIVIEN (1972) and VAN HINTE (1979) have shown that there is no obvious base to the stage near Aubeterre. Earlier studies suggested that the top of the stage was reached, but even this is now known to be wrong (KENNEDY, 1986). With the near-absence of ammonites, rarity of planktic foraminifera, and presumably an incomplete representation of nannoplankton, the original stratotype no longer has even a potential value as an international standard.

Boundary Criteria

As usual, workers in different fields have got used to


SANTONIAN
CAMPANIAN
83.9 Ma
radiometric dates
United States Western Interior
Clioscaphites choteauensis
Desmoscaphites erdmanni
Desmoscaphites bassleri
Scaphites leei III
ammonite zones
Uintacrinus socialis
Marsupites
crinoid ranges
Kansas
Montana
Colorado Montana Wyoming
Montana Wyoming
U.S. states with crinoids
central Texas
U. angl.
JONAH
D E S S A U
C H A L K
BURDITT CHALK
formations
Submortoniceras
vanuxemi
Submortoniceras tequesquitense
Texanites lonsdalei
ammonite ranges
England
Micraster coranguinum
Marsupites testudinarius
Offaster pilula
standard zones
34N
33R
palaeomagnetism
Broinsonia parca
nannoplankton
Mangy-shlak
U. anglicus

different criteria for the Santonian-Campanian boundary. This has seldom been regarded as a problem because there has been little reason to believe that they differed significantly from one another. It is only the more recent requirements of sequence-stratigraphy and the possibilities of Milankovitch-rhythm stratigraphy that have raised the need to achieve correlations at resolutions better than 0.25 Ma. At this level of accuracy it is necessary to know how the various boundary standards stack up in relation to one another. There is now a valuable discussion of the boundary-criteria by GALE *et al.* (1996).

The possible boundary levels discussed at Copenhagen in 1983 (BIRKELUND *et al.*, 1984) and at Brussels in 1995 included the following.

AMMONITES

1) Since the survey by de GROSSOUVRE (1901) of Upper Cretaceous ammonite zonation, the most widely quoted base of the Campanian stage has been the Zone of *Placenticeras bidorsatum* (sometimes listed as *Diplacmoceras bidorsatum* or *Diplacomoceras bidorsatum*), e.g. HAUG (1911), WRIGHT in ARKELL *et al.* (1957). *P. bidorsatum* (Roemer) was originally described from north Germany (KENNEDY & KAPLAN, 1995) but it was Aquitaine which de GROSSOUVRE had in mind when introducing the zonal name. He listed the species from just three localities; no specimens have been found in modern times. The species is equally rare in north Germany (SCHMID, 1960). It probably evolved from *P. paraplanum* Wiedmann (ULBRICH, 1971; KENNEDY, 1984), but it is too rare to be able to know its true total range. At the Brussels meeting W. Jim Kennedy said that it was even difficult to find specimens in museum collections.

2) *Placenticeras bidorsatum* has not been recorded outside north-west Europe. Tethyan regions yield far richer assemblages of Campanian ammonites. Of the possible markers in places like Madagascar, South Africa and Texas, attention has been focussed on the genus *Submortoniceras*. Although it was stated to be Campanian when the name was introduced by SPATH (1926), he was being frankly speculative.

COLLIGNON (1948, p. 51) bracketed *Bevahites quadratus* and *Submortoniceras renniei* in a table as joint zonal indices for the bottom of the Campanian in Menabe on the western side of Madagascar, but in his text he indicated that *Bevahites* was the earlier Campanian genus. By 1960 he had abandoned *Submortoniceras* as a zonal index.

YOUNG (1963) found the genus to be a reliable index in Texas, taking *S. tequesquitense* Young as the zonal index, accompanied by two other species of *Submortoniceras*.

In South Africa also the genus *Submortoniceras* has been found to be a practical indicator for the base of the Campanian (KLINGER & KENNEDY, 1980; KENNEDY, 1984).

Should an ammonite standard be adopted as the boundary-criterion, the lowest *Submortoniceras* has much in its

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Fig. 1 — This table shows the correlation of four regions around the Santonian-Campanian boundary based on stratigraphical ranges of the crinoids *Uintacrinus* and *Marsupites*. The only tie-lines between the regions (printed in bold lines) are based on: the appearance of *Uintacrinus* (*U. socialis* GRINNELL, 1876); the highest *Uintacrinus socialis* and the lowest *Marsupites* [*M. testudinarius* (SCHLOTHEIM, 1820)], which are usually separated by less than one metre of sediment, and locally overlap; and the highest *Marsupites* (ornamented *M. testudinarius*), which is usually separated by less than one metre of sediment from the lowest *Uintacrinus anglicus* RASMUSSEN, 1961, where that species occurs. The occurrences of *Uintacrinus* and *Marsupites* in the Western Interior of the USA are based on COBBAN (1995) and HATTIN (1982). The ranges of these crinoids in the other three regions are based on collecting by ASG.

In the Western Interior of the USA the occurrence of these crinoids, particularly *Marsupites*, is sporadic, though it is known that both genera are to be found in the *bassleri* Zone in Wyoming and Montana. But the lower limit of *Uintacrinus* and the upper limit of *Marsupites* are still uncertain in the Western Interior. There is one reliable radiometric date of 83.91 0.43 Ma for the *Desmoscaphites bassleri* Zone by OBRADOVICH (1994); on the assumption that the Zone of *Scaphites leei* III is the lowest zone of the Campanian, he dates the base of the stage at 83.5 Ma.

In central Texas the ranges of the ammonites are based mainly on work by YOUNG (1963 and personal communication). There is no simple correlation with the ammonite zonation of the western interior seaway from Colorado to Montana. The crinoid ranges in central Texas are derived from sections at Brushy Creek, Hutto; Little Walnut Creek, Austin; and the Waxahachie Dam Spillway.

The crinoid ranges in England have long been known and form the basis of the standard zonation there for the higher Santonian; sections occur in the cliffs and on the shore between Foreness Point and White Ness in north-east Kent; and west of Seaford Head in Sussex. The boundary between Chron 34N and 33R is from MONTGOMERY in GALE *et al.* (1996). The appearance of *Broinsonia parca parca* STRADNER is based on work by J. BURNETT in the Isle of Wight.

Ranges of *Uintacrinus* and *Marsupites* in Mangyshlak are based on collecting at Emdy-Kurgan, about 100 km north of Aktau. Other macro-fossils are scarce in this section but are known from Shakh-Bogota, west of Tauchik (NAIDIN *et al.*, 1984, figs. 4 and 5).

The vertical ranges are not to scale, neither in years, nor in sediment thickness. The vertical range of *Uintacrinus socialis* occupies more space in the table than that of *Marsupites testudinarius* because *Uintacrinus* is known from more ammonite zones in the U.S. Western Interior. In the Chalk of Kent in England, the *Marsupites* Zone is nearly 15 m thick and the *Uintacrinus* Zone is only 10 m thick.

favour. As recognised by COLLIGNON, YOUNG, KLINGER and KENNEDY, it evolved from *Texanites*, a typically Santonian genus. In addition to being common in Madagascar, South Africa and Texas, it is known from Mexico and the Pacific coast of the United States, British Columbia and Spain.

3) There is a third ammonite candidate for the base of the stage. This is the lowest *Scaphites hippocrepis* III, the highest of three subspecies of *S. hippocrepis* (De Kay) (COBBAN, 1969). According to Cobban this is probably the same form as *Scaphites aquisgranensis* Schlüter of European writers. This is said to occur with *Placenticeras bidorsatum* in Germany. Although this scaphitid index has the advantage of occurring and being accurately placed in the ammonite rich succession of the Western Interior of the USA, as well as being known from the Atlantic and Gulf Coasts, and occurring in northern Aquitaine, north-west Germany, Belgium and the Netherlands, this possible boundary-criterion was not discussed at the Brussels meeting. The problem is that older scaphitids have now been found above the base of the *P. bidorsatum* Zone in Aquitaine (KENNEDY, 1986). COBBAN (1994) now places the base of the Campanian in the Western Interior at the base of the Zone of *Scaphites leei* III.

BELEMNITES

In north-west Germany the base of the Zone of *Gonioteuthis granulataquadrata* has been used for the base of the Campanian stage (SCHMID, 1956). However, at any one level there is variation in the morphology of guards in the *G. granulata* - *G. quadrata* lineage and one needs an assemblage of about ten specimens to fix the exact horizon (ERNST, 1964, 1968). Outside Germany there are rarely sufficient numbers of *Gonioteuthis* from around this level to make the necessary statistical analysis. Nevertheless, at both Copenhagen and Brussels the hope was expressed that whatever criterion were adopted, it would be desirable if it agreed with the German standard.

INOCERAMIDS

Inoceramids were not considered as possible boundary-criteria at either Copenhagen or Brussels. It has long been a popular idea that inoceramids of the group of *Inoceramus* (*Endocostea*) *balticus* Boehm characterise the Campanian e.g. ERNST *et al.* (1979), and that the appearance of this species should be close to the stage boundary, e.g. SCHULZ *et al.* (1984). In fact both SEITZ (1967) in Germany and KAUFFMAN *et al.* (1994) in the USA regard *I.* (*E.*) *balticus* s.s. as a species with a considerable range, easily straddling the Santonian-Campanian boundary, however it be defined.

There is undoubtedly a need for more figures of accurately recorded inoceramids from around these levels. SEITZ does record some actual ranges but it is not easy to work out the exact horizons of his figured specimens. Similarly, KAUFFMAN *et al.* subdivide their Lower Campanian into six (ammonite) zones, but the only modern figures are in the general survey by KAUFFMAN (1977) and a few accurately located specimens in general stratigraphy papers by COBBAN. In particular, there is a need for an accurate record of the inoceramids from the Austin Chalk group in Texas.

CRINOIDS

Once de GROSSOUVRE's concept of 1901 for the Santonian/Campanian boundary had become popular, his indication for its recognition in northern Europe, where ammonites are rare, namely the top of the Zone of *Marsupites testudinarius,* came to be used (de GROSSOUVRE, 1901). This criterion has been particularly favoured by British geologists because in the British Isles there are no ammonites around these levels, inoceramids for the most part are poorly preserved, and *Gonioteuthis* is uncommon except in Northern Ireland. In contrast, *Marsupites* is relatively common. *Marsupites* is geographically more widespread than any other recorded macrofossil boundary-marker, being known from British Columbia, Montana, Wyoming, Texas, Mississippi, Northern Ireland, England, northern France, Aquitaine, northern Germany, the Volga Basin, the Ukraine, Crimea, the Caucasus, the eastern slopes of the central Urals, Mangyshlak in north-west Kazakhstan, the Kopet Dagh in southern Turkmenistan, Algeria, Madagascar, southern India, and the Perth and Carnarvon Basins in Western Australia (COBBAN, 1995; GALE *et al.*, 1995).

Doubts were expressed in Brussels on the reliability of an extinction event as a boundary-criterion. There is some justification for this viewpoint for fine-scale correlation, that is at a resolution of less than one ammonite zone. At the Plymouth Bluff section in Mississippi the vertical range of *Marsupites* is only 0.1 m, with ammonites below this range which are known to occur with *Marsupites* in Texas, e.g. *Submortoniceras tequesquitense* and *Texanites lonsdalei* Young. However, there are two criteria which can be used to check when one has a *Marsupites* at or near its actual extinction level. First, there is a stratigraphical succession of distinct forms of the plates: this has been observed in Mangyshlak (D. P. Naidin, personal communication); southern England (ASG); and Texas (ASG). The strongly ornamented plates characterise the upper third of the Zone. Secondly, where the succession is complete the Zone of *Marsupites testudinarius* is overlain by a Zone of *Uintacrinus anglicus*. This was originally recognised in southern England by BRYDONE (1914), and is now also known in Yorkshire (MITCHELL, 1994), Mangyshlak (ASG), Texas (ASG) and Western Australia (ASG). Should the highest *Marsupites* be taken as the boundary-level for the base of the Campanian, the boundary-stratotype should be taken in one of these regions.

Foraminifera

There was discussion and disagreement at Brussels on ranges of foraminifera.

The lowest *Globotruncana arca* Cushman has been used as a criterion. Many workers, e.g. Sliter, 1989, believe this species appeared within the Santonian, but at the meeting both L.F. Kopaevich (Moscow) and J. Salaj (Bratislava) emphasised that true *G. arca* does not occur in the Santonian; the Santonian forms are phylogenetic ancestors.

The lowest *Globotruncana elevata* (Brotzen) which has been used as a marker, is now considered to appear in the Santonian. M. Apthorpe (Perth) reports it as going down into the Coniacian in Australia and DSDP cores.

The highest *Dicarinella asymetrica* (Sigal) (see Marks, 1984) and *D. concavata* are probably the most widely used foraminiferal criteria for the stage boundary. Although mainly a tethyan species, *D. concavata* is known as far north as southern England (Bailey & Hart, 1979). Nobody raised strong objections in Brussels to the use of these species as secondary criteria.

M. B. Hart (Plymouth) pointed out that the lowest occurrence of the benthic foraminifera of the *Bolivinoides* group and *Stensioina* can be used as a link with the succession of both planktic foraminifera and the crinoid zones.

Calcareous Nannofossils

Discussion at Brussels was concentrated on the appearance of the coccolith *Broinsonia parca parca* (Stradner).

J. A. Burnett (London) pointed out that where one places this horizon depends on how the species is studied. This view was supported by S. Gardin (Firenze) who gave an elegant presentation which showed that it was essential to use specimens of all sizes because there are stratigraphical changes in size; there is a precise series of 'subspecies' with which one can distinguish fine subdivisions. The true *B. parca parca* comes in well above the base of the Campanian defined on the extinction level of *Marsupites*. In Culver Cliff, Isle of Wight in southern England this nannofossil level is 10 m up in the Campanian.

Magnetostratigraphy

The long Cretaceous Quiet Zone extends from the Aptian to the Santonian. It is often assumed that the reversed Magnetochron 33R above this starts at the Santonian/Campanian boundary or within the Lower Campanian. This has usually been based on the succession at Gubbio in Umbria (Italy) where the base of 33R is 1 m below the lowest *Globotruncana elevata* (Premoli Silva, 1977). Montgomery (in Gale *et al.*, 1996) has now shown that in southern England the start of Chron 33R lies in the middle of the Zone of *Uintacrinus socialis*, i.e. well below the top of the Santonian on the crinoid scale.

Carbon Isotope Stratigraphy

This criterion was not discussed at Brussels but a small $\delta^{13}C$ positive excursion has been found at the top of the range of *Marsupites* in the counties of Kent and Sussex in England (Jenkins, *et al.*, 1994), and at Lägerdorf in north Germany (Schönfeld, *et al.*, 1991).

Recommendations

Boundary-Criterion

D. P. Naidin (Papulov & Naidin, 1979) and G. Ernst (Ernst, 1963) both pressed for the use of the extinction level of *Marsupites* as the boundary-criterion. Whilst this was the general sympathy at the meeting of the working group in Brussels, it was felt that a fuller investigation of relative stratigraphical levels of the various distinctive features should be made before making a definite decision. Accordingly, the following motion was put to the meeting -

1. The definition of the base of the Campanian stage should be compatible with the classic definition by de Grossouvre, that is the lowest level with *Placenticeras bidorsatum*.
2. This corresponds to the extinction-level of *Marsupites testudinarius* (Schlotheim), which we recommend provisionally as the boundary-marker for the base of the Campanian stage.
3. This datum-level should be linked to:
(a) extinctions in the planktonic foraminiferal group of *Dicarinella concavata*;
(b) nannofossil data, including the lineage of *Broinsonia parca*;
(c) and directly or indirectly to the 33R/34N palaeomagnetic boundary.
4. We invite reports on correlation of these events from members of the working group.

The vote for this motion was: 23 for, none against and no abstentions.

Boundary-Stratotype

It was further agreed, without a formal vote being taken, that should the crinoid standard eventually be adopted, there were candidate boundary-stratotypes in Texas and southern England. Accordingly, reports should be prepared on the sections in England at Seaford Head, Sussex (and possibly Foreness Point, Kent) by R. Mortimore, C. J. Wood and A. S. Gale, and in north-central Texas at the

Waxahachie dam-spillway by A. S. Gale, J. M. Hancock and K. Young.

Substages of the Campanian stage

By a vote of 17 to 2 (with 4 abstentions) it was agreed that the working group should endeavour to subdivide the Campanian into three sub-stages, Lower, Middle and Upper (though a small number of people felt that the stage was so long that an attempt should be made to divide it into four sub-stages). If possible, each sub-stage should be of approximately equal duration. It was not possible at this time to make any formal proposals on definitions of the bases of the Middle and Upper Campanian.

Postscript

Several correspondents have emphasised that even *Marsupites* is not found everywhere in the world. For this reason it is going to be exceptionally important to develop the use of secondary criteria for the boundary, which must be accurately related stratigraphically to the primary criterion, i.e. the extinction level of *Marsupites*.

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