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The Global Boundary Stratotype Section and Point (GSSP) for the base of the Cenomanian Stage, Mont Risou, Hautes-Alpes, France

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Following the unanimous recommendation of the International Commission on Stratigraphy, the Global boundary Stratotype Section and Point (GSSP) for the base of the Cenomanian Stage is defined at a level 36 metres below the top of the Marnes Bleues Formation, a level that corresponds to the first appearance of the planktonic foraminiferan Rotalipora globotruncanoides Sigal, 1948, on the south side of Mont Risou, east of Rosans, Haute-Alpes, France, where it can be placed in the context of a series of secondary marker levels based on nannofossils, planktonic foraminifera, ammonites, and an ornate δ¹³C curve.

Introduction

The present document defining a Global boundary Stratotype Section and Point (GSSP) for the base of the Cenomanian Stage of the Upper Cretaceous arises from the recommendations of the Cenomanian Working Group of the Subcommission on Cretaceous Stratigraphy at its meetings during the Second International Symposium on Cretaceous Stage Boundaries held in Brussels from September 8–15, 1995.

The proposal was subsequently submitted to the Subcommission of Cretaceous Stratigraphy, which voted 18 yes, abstain 2. A revised proposal was submitted to the International Commission on Stratigraphy, which voted unanimously in favour of the proposal. The International Union of Geological Sciences was requested to ratify this decision; the proposal was finally ratified on 10 December 2001.

Historical background

When Alcide d’Orbigny began to divide up the Cretaceous system into stages, he at first recognized only two in what is now known as the Upper Cretaceous: the Turonian and Senonian (Paléontologie française, Terrains Crétacés, II Gastropodes, pp. 403–406). With respect to the Turonian, his words are: “je propose de désigner à l’avenir l’étage qui m’occupe sous le nom de terrain Turonien, de la Ville de Tours (Turonien) ou de la Touraine (Turonia), situées sur ces terrains” (d’Orbigny, 1842-1843, p. 405), defining the Turonian as equivalent to the Craie Chloritée, Craie tuffeau, Glauciony creyouse, Grès Vert Supérieur etc., and taking the name from Touraine (Roman Turonia). Five years later, he realized that two distinct ammonite and rudist faunas were present, and he restricted the term Turonian to beds corresponding to his third zone of rudists, yielding “Ammonites levesiensis, peramplus, Vielbancii, Woolgari, Fleuri-ausianus, Deverianus etc.”, “le plus beau type côtier étant très prononcé dans toute la Touraine, et nous donnerons à la partie inférieure le nom d’étage Cénomanien, le Mans (Cenomanum), en montrant à la fois le type sous-marin” (d’Orbigny, 1848–1851, p. 270).

In the second volume of Prodrome d’Orbigny (1850) listed 809 species as characteristic of the Cenomanian, 46 of them ammonites, of which 10 were specifically cited from Sarthe, in which Le Mans lies. Localities mentioned are Saint-Calais, Le Flèche, Cérans, Ecommoy, Grand Lucé, Coudrecieux, Vibraye, Lamnay and La Ferté-Bernard.

Faunas from the Cenomanian of Sarthe were described by Guéranger (1867) in his Album paléontologique du département de la Sarthe, one of the earliest publications with photographs of fossils, and the stratigraphy was investigated in particular by Guillier (1886). The ammonites were then neglected for almost 100 years, until Hancock (1960) listed all the stratigraphically localized Cenomanian ammonites he was able to trace in the Le Mans and Paris Collections, as well as new material collected by him, a total of 161 specimens. This work forms the basis of all subsequent studies.


From these works it has become recognized that the paucity of exposure in the environs of Le Mans makes it unlikely that a boundary section could ever be designated in the historical type area of the stage.

The Global boundary Stratotype Section and Point for the base of the Cenomanian Stage

Location

The GSSP is located on the western flanks of Mont Risou (1183 m), in NE-SW trending gullies in badlands, 3.15 km east of the centre of the town of Rosans, Hautes-Alpes, France (Figures 1–3),
around a point 5° 30’ 43” E, 44° 23’ 33” N (Lambert II Zone coordinates 852.725; 1937.625), on the 1:25,000 French Série Bleue 1:25,000 Sheet 3239 Ouest, Rosans (Gale et al. 1996).

The boundary lies 36 m below the top of a thick sequence of constantly eroding marls, the Marnes Bleues of French workers, but can be located in the field in relation to the first limestone that defines the base of the overlying, unnamed unit of limestone-marl alternations (Figures 3, 4) (this limestone marker bed was taken as the base of the Cenomanian by Moullade (1966), and Porthault (1974, 1978) in their classic studies of the Cretaceous of the Vocontian Basin).

Access

The GSSP can be reached by taking the D994 road east from Rosans, and turning south on the D949 (signpost: St. André-de-Rosans). Beyond the buildings at Notre Dame, the road describes a hairpin bend, and crosses the Lidane stream. Just east of the 668 m spot height a track leads left (NNE) up the lower slopes of Mont Risou: the gullies that encompass the GSSP are easily accessible on foot.

Figure 1 Locality map for Mont Risou, Hautes-Alpes, France.

Figure 2 Locality map for the Global boundary Stratotype Section and Point for the base of the Cenomanian Stage, on the western slopes of Mont Risou, east of Rosans, Hautes-Alpes, France.

Description of the GSSP

The Global boundary Stratotype Section and Point for the base of the Cenomanian Stage is the level 36 m below the top of the Marnes Bleues that corresponds to the first occurrence (FO) of the planktonic foraminifer *Rotalipora globotruncanoides* Sigal, 1948, in the Marnes Bleues Formation. This can be most readily located in the field by measuring down from the base of the lowest limestone of the overlying unnamed limestone-marl unit of Cenomanian age (Figure 3). A detailed log of the sequence is shown in Figure 4.

The GSSP succession in the top 136 m of the Marnes Bleues Formation is of marls with varying carbonate and organic carbon content. Levels with higher carbonate content weather out as slightly more resistant levels, as indicated on the logs. Levels of higher organic carbon content are frequently laminated, and are again slightly more resistant to weathering. Bréhéret (1988a, 1988b, 1997) has recognised a series of such levels in the Marnes Bleues of the Vocontian Basin, and assigned names to the more important. The highest of these marker beds, the Niveau Breistroffer (Breistroffer Level) occurs 135 to 124 m below the top of the GSSP, and is the only prominent marker in the section below the zero datum at the base of the unnamed formation that overlies the Marnes Bleues.

The Niveau Breistroffer is well exposed immediately beneath a stream junction. It comprises decimeter- to meter-scale alternations of marls with varying carbonate and organic carbon content.
of more or less calcareous, dark grey bioturbated marl, and five beds of dark, laminated marl that are relatively organic-rich. The second laminated layer is 0.5 m in thickness, and contains a diverse ammonite fauna and infrequent bivalves. A similar, but slightly less abundant ammonite fauna is found in the third and fourth laminated layers.

Above the Niveau Breistroffer are 12 m of grey, bioturbated, poorly fossiliferous marls (−123 to −135 m) containing an impersistent bed of barytes — cemented concretions. The overlying 31 m of marls (−92 to −123 m) are rhythmically bedded on a meter scale, and limited macrofaunas were collected. At −80 m is a bed containing abundant ammonites, notably heteromorphs.

The boundary level: primary and auxiliary biostratigraphic markers

Three groups provide the principal biostratigraphic markers for the boundary interval: ammonites, planktonic foraminifera, and nannofossils, with inoceramid bivalves (which are poorly represented in the Marnes Bleues) as a further group. Figure 5 shows the occurrence data for ammonites in the sequence, Figure 6 the data for planktonic foraminifera, and Figure 7 the nannofossil data.

The distribution of key faunal and floral events across the Albien-Cenomanian boundary in the Marnes Bleues succession at the Mont Risou GSSP are plotted in Figure 10, and are, from oldest to youngest:
Base of the Niveau Breistroffer: −135 m.

- The last occurrence of the planktonic foraminiferan *Rotalipora subticinensis* at −132 m.
- The last occurrence of the planktonic foraminiferan *Hayesites albiensis*, also at −132 m.
- The last occurrence of species of the ammonite genera *Mortoniceras* (Durnovarites) and *Cantabrigites*, also at −132 m.
- The first occurrence of the planktonic foraminiferan *Planomalina buxtorfi* at −116 m.
- The last occurrence of the planktonic foraminiferan *Costellicagerina libyca* at −112 m.
- The last occurrence of the planktonic foraminiferan *Arkhangelskiella antecessor* at −80 m.
- The first occurrence of the planktonic foraminiferan *Rotalipora tehamaensis* at −48 m.
- The last occurrence of the planktonic foraminiferan *Rotalipora ticinensis* at −40 m.

Top of the Breistroffer Level: −124 m.

- The first occurrences of the nannofossils *Gartnerago chiasta* and *Crucicribrium anglicum* at −124 m, (local events).
- The last occurrence of the planktonic foraminiferan *Planomalina buxtorfi* at −116 m.
- The last occurrence of the planktonic foraminiferan *Costellicagerina libyca* at −112 m.
- The last occurrence of the planktonic foraminiferan *Arkhangelskiella antecessor* at −80 m.
- The first occurrence of the planktonic foraminiferan *Rotalipora tehamaensis* at −48 m.
- The last occurrence of the planktonic foraminiferan *Rotalipora ticinensis* at −40 m.

March 2004
The major faunal change in the ammonite fauna occurs between −30 and −32 m, with the disappearance of typical Albian taxa at −32 m and the appearance of typical Cenomanian taxa at −30 m. Nine ammonite taxa pass across the boundary; they are long-ranging desmoceratids, puzosiids, phylloceratids and gaudryceratids of typically Tethyan aspect. There is no lithological break or change in the assemblages of ammonites, nannofossils, and planktonic foraminifera in the transitional intervals in which the new species arose.

In a broader context, the *Ticinella praeticianensis*-Rotalipora subtichiensis–R. ticinensis–R. globotruncanoides–R. greenhornensis* lineage is of great value in Upper Albian to Upper Cenomanian biostratigraphy, showing gradual progressive changes, a feature that strengthens the case for the selection of the first occurrence of *R. tehamensis* as the key biostratigraphic marker for the base of the Cenomanian stage. These two lineages are readily traced in the present successions on the basis of a series of intermediate forms, marked by an asterisk in Figure 6, which occur in the transitional intervals in which the new species arose.

The gradual evolution of the polyphyletic *Rotalipora* group (cf. Gonzalez Donoso in Robaszyski et al., 1994, p. 428) can be followed through the interval studied. Two lineages that arose during the late Albian are present at the base of the section. The first, represented by *Rotalipora subtichiensis*, arose from *Ticinella praeticianensis* by acquisition of a peripheral keel, giving rise to *Rotalipora subtichiensis*, which gave rise in turn to *R. ticinensis*. This last named gave rise, in turn, to *R. tehamensis* (−48 m), and *R. globotruncanoides* (−36 m). The second lineage arose from *Ticinella raynaudi*, and is represented by *Rotalipora appenninica* and *R. gandolfi* (−40 m).

These two lineages are readily traced in the present successions on the basis of a series of intermediate forms, marked by an asterisk in Figure 6, which occur in the transitional intervals in which the new species arose.
Figure 7 Distribution of calcareous nannofossils in the top 136 m of the Marnes Bleues Formation at the Global boundary Stratotype Section for the base of the Cenomanian Stage on the western flanks of Mont Risou, east of Rosans, Hautes-Alpes, France.
### Key:
- **Nannofloral abundance (qualitative):**
  - H = High
  - M = Moderate

- **Nannofloral preservation:**
  - M = Moderate (identification of specimens with the light microscope not hampered by diagenetic etching and overgrowth of calcite).

- **Taxon abundance:**
  - A = Abundant (> 10 specimens/field of view)
  - C = Common (1–10 specimens/field of view)
  - F = Few (> 3 specimens/traverse)
  - R = Rare (1–2 specimens/traverse)

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**SAMPLE**

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<th>Nannofloral preservation</th>
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Figure 8  Key planktonic foraminiferal taxa from the Global boundary Stratotype Section for the base of the Cenomanian Stage on the western flanks of Mont Risou, east of Rosans, Hautes-Alpes, France.

1–3, Rotalipora appenninica (Renz), BMNH, −136 m;
4–6, Rotalipora gandolfii Luterbacher & Premoli-Silva, BMNH, −38 m;
7–9, Rotalipora tehamaensis Marianos & Zingula, BMNH, −27 m;
10–12, Rotalipora globotruncanoides Sigal, BMNH, −36 m;
13–15, Rotalipora globotruncanoides Sigal, BMNH, −23 m;
16–18, Rotalipora ticinensis (Gandolfii), BMNH, −136 m.  
(Bar scale is 100 microns)
Carbon and oxygen stable isotope stratigraphy of the boundary interval

Oxygen isotopes

The $\delta^{18}O$ curve for the Mont Risou section (Figure 9) shows small-scale variation of the order of 0.3‰ for much of the lower, Albian, part of the succession, values mostly falling between $-3.8\%e$ and $-4.1\%e$. In the Cenomanian part of the section above, values rise to a maximum of $-3.5\%e$. The possibility that these values have been altered by the addition of isotopically light cement during burial diagenesis has to be considered, because the Marnes Bleues in the Vocontian Basin have been buried to a depth of up to several kilometers. The primary nature of these results is supported by several lines of evidence. SEM inspection of broken surfaces of various lithologies reveals little obvious cement; foraminiferan tests are empty, for example. The $\delta^{18}O$ values translate to give sea water surface temperatures of 26–27°C, using the equation of Anderson & Arthur (1983 SMOW 1.2‰) which are reasonable for this latitude in the Late Albian to Early Cenomanian interval (cf. Jenkyns, Gale & Corfield 1994). There is no correlation between lithology and $\delta^{18}O$ values; indeed, the highest part of the succession contains carbonate cemented beds, yet yields heavier oxygen isotope values — opposite to the predicted diagentic trend. Finally, the very low level of variance is itself suggestive of a primary signal, because significantly altered successions are generally noisy as a result of the patchy distribution of cement. The oxygen isotope data thus indicates a slight cooling of about 1°C, beginning during the earliest Cenomanian.

Carbon isotopes

$\delta^{13}C$ in carbonate sediments is relatively stable and more likely to survive the effects of burial diagenesis than are oxygen isotopes. However, the bacterial degradation of organic matter can have a marked effect on the $\delta^{13}C$ ratios of the dissolved bicarbonate reservoir, and may result in the formation of cements enriched in $\delta^{12}C$ (Scholle & Arthur 1980; Marshall 1992). Such cements are relatively common in deeper water organic-rich mudrocks (Marshall 1992) and are potentially important in interpretation of the $\delta^{13}C$ data from Mont Risou, because the deep-water marls at this locality contain up to 50% clay and have TOC values of 1–2% (Bréhéret & Delamette 1989, Fig. 2). The Niveau Breistroffer (containing laminated horizons) has the highest TOC values in the succession studied, and registers $\delta^{13}C$ values of the order of 1.5–1.9‰, which are not significantly lighter than values from coeval carbonate successions (e.g. Jenkyns et al. 1994). Additional evidence for a primary $\delta^{13}C$ signal in the Mont Risou section comes from the lack of correlation between lithology and carbon isotope values.

The carbon curve (Figures 9, 10) registers a broad overall peak (maximum values of 2.3 % at −104 m) through much of the Mont Risou section, broken into four discrete peaks (lettered A, B, C, D in Figure 10) by sharp, short-lived falls of $\delta^{13}C$ of up to 0.8‰. These peaks and troughs do not correspond to lithological changes, are defined by numerous points, and thus probably represent secular change (see above). Peak B registers the highest values which pro-
gressively fall through C and D. However, to demonstrate convincingly the primary nature of the Risou δ13C signature, it is necessary to find similar curves elsewhere (Scholle & Arthur 1980; Gale et al. 1996) compared carbon cases based on bulk carbonate analyses across Albian-Cenomanian boundary sections for Gubbio, Umbria Marche, Italy, (Jenkyns et al. 1994, Fig. 10) and for Speeton, Yorkshire, England (Mitchell & Paul 1994, Fig. 1) both based on whole-rock analyses. The Gubbio curve shows a small but discrete positive δ13C spike including four minor peaks straddling the Albian-Cenomanian boundary as defined there by planktonic foraminifera. The Speeton curve shows a broad peak over 3–3.5 m of succession in unit RC2 of Mitchell & Paul (1994), made up of four individual sharp peaks and falls, with a total variance of about 0.8‰. The second peak is largest and reaches about 1.75‰; the two succeeding peaks are smaller. Mitchell & Paul place the Albian-Cenomanian boundary immediately beneath the highest of the four peaks, on evidence from calcitic macrofossils and calcitic and arenaceous microfossils.

The Speeton curve is very similar in overall shape, detail of ornament and variation range to that from Mont Risou. The Albian-Cenomanian boundary at Speeton falls in an identical position to that in Mont Risou. The Albian-Cenomanian boundary immediately beneath the fourth minor δ13C peak. Such a result is in line with data from the Cenomanian-Turonian boundary (Gale et al. 1993) where intricate details of the δ13C spike can be interpolated with faunal and floral events and correlated on an intercontinental scale. However, the similarity between the Mont Risou and Speeton curves is perhaps even more remarkable because the thicknesses of the two sections differ by two orders of magnitude. The apparent lack of ornament on the Gubbio curve may be a result of the widely spaced sample intervals of 1 m taken by Jenkyns et al. (1994) from what is a thin succession. We conclude that the ornate δ13C curve across the Albian-Cenomanian boundary established at Mont Risou provides a further secondary marker for the base of the Cenomanian Stage, which lies between peaks C and D of the curve. Figure 10 summarizes the sequence of lithostratigraphic, biostratigraphic, and stable isotope markers across the boundary section.

Conclusions

The Global boundary Stratotype Section and Point for the base of the Cenomanian Stage at Mont Risou, near Rosans fulfils the following requirements set out by Remane et al. (1996):

There is exposure over an adequate thickness, and a sufficient time interval is represented by the section so that the boundary can also be determined by interpretation, using auxiliary markers close to the boundary. There is continuous sedimentation across the boundary interval, with no evidence of sedimentary breaks or condensation. The sedimentation rate was high, and successive events that straddle the boundary are widely separated. The boundary interval is not disturbed by synsedimentary and significant tectonic disturbances. The Risou GSSP is terminated at its lower limit by a fault 100 m below the boundary level, and there is evidence of synsedimentary deformation 130 m above the boundary. The intervening interval includes minor faults with small displacements, in part of recent origin, but the boundary is not so disturbed. There is no metamorphism, nor a strong diagenetic signal. Well-preserved (if crushed) macrofossils, especially ammonites occur throughout the sequence, as do well-preserved and abundant micro- and nanofossils. There are no vertical facies changes for 36 m above the boundary, and for more than 80 m below the boundary. The pelagic facies, with cosmopolitan ammonite taxa, plus abundant planktonic micro- and nanofossils represents a favourable facies for long-distance correlation, as does the palaeogeographic setting of the GSSP, in the passage zone between the European Boreal and Tethyan Realms.

The GSSP preserves an excellent δ13C and δ18O record that provides an auxiliary marker of potential global application in the marine pelagic realm. The GSSP is readily accessible by road, with free access. The GSSP does not include potential chronometers for radiometric dating.

We lack a magnetostratigraphic profile for the GSSP, but note that the Albian-Cenomanian boundary falls within the Cretaceous Magnetic Quiet Zone.

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Appendix I

Cretaceous Subcommission—Cenomanian Working Group Membership as at 31/3/97

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Appendix II

Ammonites. A full account of the ammonite fauna of the sequence is given by Kennedy in Gale et al. 1996. Nanofossils. The nanofossil sequence is described by Burnett in Gale et al. 1996. The revised nomenclature of Burnett (1998) is used here. Planktonic foraminifera. Taxonomic notes on key species (Figure 8) are as follows:

*Rotalipora tehamensis* Mariano & Zingula, 1966: this species (Figure 8: 7–9) was identified in Tunisia by Gonzales-Donoso in Rosaswzynski et al. 1994, pp. 432, 457, illustrated in their pl. 20, Fig. 1, the stratigraphic range given in their text-fig. 36. This species differs from *R. ticinensis* (Figure 8: 16–18) in having a higher trochospire, a narrow umbilicus with peribulbar flanges on all chambers. It differs from *R. greenhornensis* by the absence of curved sutures on the spiral and umbilical faces.

*Rotalipora gadolphi* Luterbacher & Premoli-Silva, 1962: validly adopted by Rosaswzynski et al. 1979, pp. 81–84. This species (Figure 8: 4–6) evolved from *R. appenninica* (Figure 8: 1–3) by the development of a peribulbar flange and a more inflated umbilical face to the last two chambers. *Rotalipora globotruncanoides* Sigal, 1948 (Figure 8: 10–12): a synonymy was published by Gonzalez-Donoso in Rosaswzynski et
al., 1994, p. 456. Caron herein, and in Gale et al., 1996 adopted a similar interpretation.

The taxonomy of *R. globotruncanoides* is complex, as summarised below.

- Sigal, 1948: two genera, *Rotalipora* Brotzen, 1942, and *Thalmaninella* gen. nov. recognised, as were two new species, *Rotalipora globotruncanoides* Sigal, 1948, and *Thalmaninella brotzeni* Sigal, 1948.
- Brönnimann & Brown, 1948: maintained *Thalmaninella* and *Rotalipora* as separate genera on the basis of the presence of a characteristic cover plate in *Thalmaninella*.
- Bolli, 1957: treated *Thalmaninella* as a junior synonym of *Rotalipora*.
- Sigal, 1958: *Thalmaninella* also regarded as a junior synonym of *Rotalipora*.
- Robaszynski & Caron, 1979; Caron, 1985; Loeblich & Tappan, 1988: only *Rotalipora* recognised.
- Gonzalez-Donoso in Robaszynski et al., 1994 returned to the distinction of three phylectic groups within the rotaliporids, as recognised by Wonders (1978), which he referred to *Rotalipora*, with *Thalmaninella* and *Pseudothalmaninella* as junior synonyms. He also (p. 456), referred to *brotzeni* Sigal, 1948, as a “synonyme subjectif postérieur” of *globotruncanoides* because Sigal (1948) introduced the name *globotruncanoides* on p. 100, and *brotzeni* on p. 102 of the same work. The term “synonym subjectif postérieur” does not appear in the fourth edition of the International Code of Zoological Nomenclature, while the names *globotruncanoides* and *brotzeni* are deemed to have been published simultaneously under the Rules (Article 24.2.2). The act of listing *brotzeni* Sigal, 1948, as a synonym of *globotruncanoides* Sigal, 1948, makes Gonzalez-Donoso (in Robaszynski et al., 1994, p. 456) “First Reviser” under the terms of Article 24.2.1 of the Code, and for those who believe *brotzeni* and *globotruncanoides* to be synonymous, the specific name *globotruncanoides* takes precedence.
- Robaszynski & Caron, 1995: recognised the genus *Rotalipora* only, accepted the act of Gonzalez-Donoso (1994), and afforded *globotruncanoides* precedence over *brotzeni*. This is the position adopted here.

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