Santonian Working Group
Subcommission on Cretaceous Stratigraphy, International Commission on Stratigraphy-International Union of Geological Sciences (IUGS)
Chairman: Marcos A. Lamolda

Report on the candidates of the base of the Santonian Stage GSSP

Introduction

During the Second International Symposium on Cretaceous Stage Boundaries, held at Brussels 8-16 September 1995, the Santonian Working Group (SWG) decided on the fossil markers of the Coniacian/Santonian boundary and selected three candidates as possible localities to establish the Santonian Global Stratotype Section and Point (GSSP). (Lamolda and Hancock, 1996).

The following text is a reproduction of some paragraphs of the referred paper, whose full version is available in the web site: http://www.ugr.es/~mlamolda/swg/bruselas.html

"Selected marker for the Coniacian-Santonian boundary

Primary marker: The lowest occurrence of *Cladoceramus undulatoplicatus* (Roemer). It is a taxon easily recognisable and widespread. It is known from N. America, Europe, Africa, Madagascar, and Central Asia.

Secondary marker: *Sigalia carpatica*. This planktonic foraminiferan is widespread in the Mediterranean Region of the Tethys.

Rejected: *Texanites* (*Texanites*)
Dicarinella asymetrica
Platyceramus siccensis
Sphenoceramus pachti

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). Prof. Lamolda would collate data and report to the Chairman.
2) Seaford Head (Sussex, England). Dr. Mortimore and Mr. Wood would collate data and report to the Chairman.
3) Ten Mile Creek (Dallas, Texas). Prof. Kauffman and Dr. Gale would collate data and report to the Chairman."

After the Brussels symposium the Santonian Working Group (SWG) met at Bilbao, September 14th-16th, 2002. A report about this meeting by the late Dr. Annie V. Dhondt is available at: http://www.ugr.es/~mlamolda/swg/report.html

In a keynote introductory talk, the late Professor Jake Hancock explained the somewhat unsatisfactory situation of the Texan outcrop at Ten Mile Creek near Dallas (see also Gale and Hancock, 2002, copy enclosed), and the problems with the outcrop at Seaford Head (Sussex) on the south coast of England.

"The last item on the scientific agenda concerned the suitability of Olazagutia as a possible boundary stratotype. Long discussions stressing positive and negative aspects of the quarry followed." (Dhondt's report)

No consensus was reached at the Bilbao meeting on a C/S boundary stratotype, although

"The participants finally agreed that the Olazagutia section should be chosen among the three possible candidates for the Coniacian-Santonian boundary stratotype designated in Brussels (1995)."

"It was stressed and agreed upon that beyond the agreement with the present quarry owners a complete protection of the geological site should be obtained if possible by the authorities of the region (Navarra)." (Dhondt's report)

Later, on September 21, 2002, Jake Hancock wrote a letter to Marcos Lamolda in which he gave his support to the Olazagutia section, remarking that it would be a permanent and accessible site for researchers. Other members of the SWG mailed to this Chairman their support for the Olazagutia section as the best GSSP for the base of the Santonian.

M. Lamolda subsequently contacted the Geological Survey of Spain (Instituto Geológico y Minero de España), the Navarran Regional Government and the owner of the Cantera de Margas, asking them to prepare an agreement that would enable preservation of the section on the eastern side of the quarry and allow access to it for research purposes. Eventually, all parties agreed to support both preservation and accessibility. The Director of the Olazagutia factory, Portland Valderrivas, sent a letter to this Chairman with the formal agreement of the quarry owner, on March 26th, 2007.

Results on the three candidates have been published in a special issue of Cretaceous Research "*Stratigraphy of the Coniacian–Santonian transition*", vol. 28 no. 1 (most of contributions had been completed in their final version in 2003), and a recent one is on line since late June in Acta Geological Polonica (see References for all of them).

The locality of Seaford Head, southern England, is no longer a candidate GSSP for the base of the Santonian. In fact, Hampton et al. (2007, p. 47) wrote:

"The Seaford Head sea-cliff section is being proposed herein as providing international reference sections in chalk facies for the basal boundaries of the Santonian and Campanian stages; these sections are not to be regarded as candidate GSSPs (Global Basal Boundary Stratotype sections and Points) for the two stages concerned."

Therefore, two candidates remain: Olazagutia (northern Spain) and Ten Mile Creek (Texas, USA). Recent details on them have been published (see References). Therefore, in the following paragraphs a comparison between them is made with special reference to relevant characteristics.

Observation: Ten Mile Creek (TMC-CS) is a composite section. The Ten Mile Creek s.s. (TMC) (Howe et al., 2007) is a part of the WalMart section (WM) (Gale et al., 2007).

Comparison between Olazagutia and TMC-CS

Outcrop nature and characteristics

TMC-CS: River side and floor. Thickness given by Howe et al. and Gale et al. are quite different, especially below the first occurrence (FO) of *Platyceramus undulatoplicatus*. It is a composite section, from 4 to 6 partial sections are necessary to have a complete idea of the scenario. The distance between the two groups of partial sections (Ten Mile Creek and Arbor Park) is 34.5 km (Howe et al.)

Thickness

WM: The candidate GSSP section (Walmart) extends through about 23.5 m, but only about 5 m above the FO of *Cladoceramus undulatoplicatus*. To investigate the full details of the Coniacian-Santonian boundary requires the use of a composite section (see Gale et al., 2007 for full details).

Olazagutia: A continuous section of approximately 320 m from the middle part of the Coniacian to beyond the Santonian/Campanian boundary. On the east side of the quarry at present a track obscures a short section the top of which is about 19 m below the FO of *P. undulatoplicatus*. On the west side the section is continuous, but currently less accessible since it is in the working part of the quarry

Thickness
The candidate GSSP section extends through about 160 m from the middle part of the Coniacian to the middle part of the Santonian. A more detailed study has been made in a 46 m thick section from 19 m below to 27 m above the FO of *P. undulatoplicatus*.

Structural complication

TMC-CS: a fault in one of the partial sections

Olazagutia: no complication

Continuity of sedimentation

TMC-CS: Correlation of partial sections above the TMC and WM, given by Howe et al., and Gale et al., respectively, is not reliable. There are several channels in the lower part (Gale et al., pp. 115, 120), and two possible unconformities in the middle part (Howe et al., p. 89, fig. 12).

Olazagutia: no evidence of discontinuities in sedimentation.
Howe et al. have suggested that the FO of *P. undulatoplicatus* is younger at Olazagutia than at TMC based on biostratigraphical criteria, e.g., the LO of *Whiteinella paradubia* at TMC 2 m below the FO of *P. undulatoplicatus*, but this species occurs at Olazagutia well above the FO of *P. undulatoplicatus* (sample 98-13, ~10.20 m above the FO of *P. undulatoplicatus*), and *Whiteinella* spp. occur throughout the section studied; therefore the LO of *W. paradubia* is not a good index for the upper part of the Coniacian. Their argument that the occurrence of *Dicarinella asymetrica* below the FO of *P. undulatoplicatus* at Olazagutia implies an early Santonian age for that event is not justified, as *D. asymetrica* occurs throughout the Olazagutia studied section, and is known even in the middle part of the Coniacian in Romania (Ion and Szasz, 1994). Therefore their inferred truncation of the lower part of the stratigraphical range of *P. undulatoplicatus* at Olazagutia is rejected.

Thickness of *Platyceramus undulatoplicatus* Zone

TMC-CS: around 14.5 m, but requires correlation with other local sections to establish the thickness.

Olazagutia: around 11.5 m

Paleoenvironment

TMC-CS: middle to outer shelf (Paul Sikora, pers. comm. on August 7, 2007).

Olazagutia: open outer shelf to upper bathyal
Howe et al. argued for palaeoecological control on the FO of *P. undulatoplicatus* at Olazagutia, but the same argument may be used on TMC, too (Howe et al., p. 86). Therefore, their proposal is inconsistent.

Fossils

- Type
    - TMC-CS: macro and microfossils. The primary marker *P. undulatoplicatus* is

recorded. The secondary marker *Sigalia carpatica* is not found.
  - Olazagutia: macro and microfossils. Both the primary and secondary markers are recorded.

- diversity and abundance
  - TMC-CS: high and abundant
  - Olazagutia: high and abundant

Biogeography

TMC-CS: temperate–boreal, somewhat restricted (southern border of the Western Interior Seaway)

Olazagutia: subtropical with temperate influence

Geochronometry

TMC-CS: some bentonite beds

Olazagutia: –

Stable isotope studies

TMC-CS: available (Gale et al., 2007)

Olazagutia: available (Lamolda and Paul, 2007)

<u>This part is confidential, including figures 1, 2 and 3</u> (Paul and Lamolda, in preparation)
Graphic correlation of stable isotope curves is used to assess how closely the primary boundary marker (*P. undulatoplicatus*) lies to the line of correlation (Figs. 1, 2 and 3), because the stable isotope data provide a much finer and more accurate timescale than biostratigraphic data do.

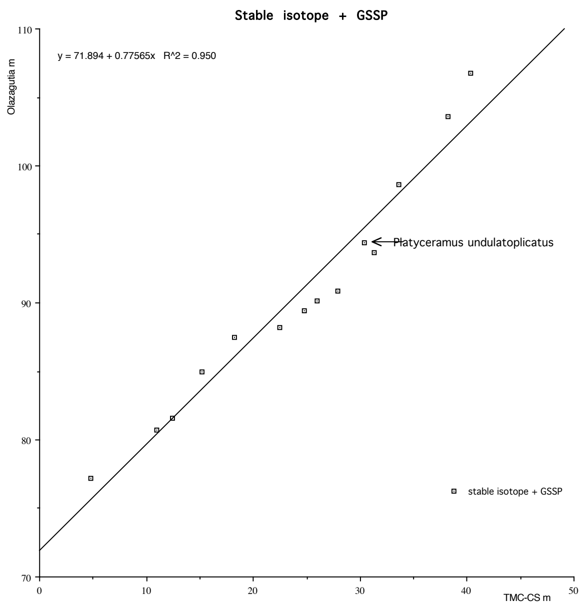

Figure 1

Figure 1 is a cross plot with δ ^{13}C values from TMC composite and Olazagutia sections (Gale et al., 2007, and Lamolda and Paul, 2007, respectively). Correlation is excellent, r^2= 0.950, and the FO of *P. undulatoplicatus* is close to the line of correlation, but below it. This suggests the bioevent occurs earlier in the Olazagutia section than it does in the TMC composite section, which is counter to the assertion of Howe et al. about the truncation of the stratigraphical range of *P. undulatoplicatus* at Olazagutia.

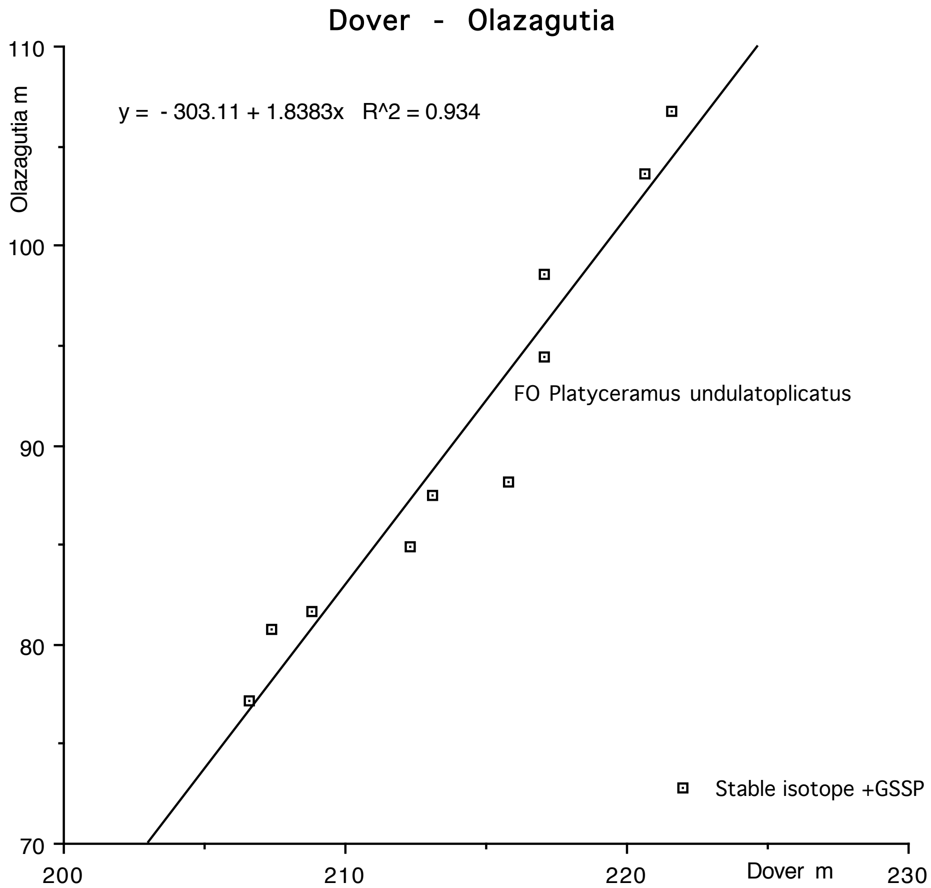

Figure 2

In Figures 2 and 3, Olazagutia section is correlated with Dover and Culver Cliff sections (data for Dover and Culver Cliff after Jarvis et al., 2006). In both cases correlation of δ ^{13}C and the FO of *P. undulatoplicatus* is also good: r^2=0.934 (Dover-Olazagutia), and r^2=0.902 (Culver-Olazagutia). The FO of *P. undulatoplicatus* lies very close to the correlation line confirming the excellence of this bioevent for correlation between different biogeoprovinces.

Bioevents (this section is confidential, including Figure 4; Paul and Lamolda, in preparation)

To check the accuracy of bioevents at both TMC-CS and Olazagutia sections, a cross plot with data on bioevent location has been drawn (Fig. 4).

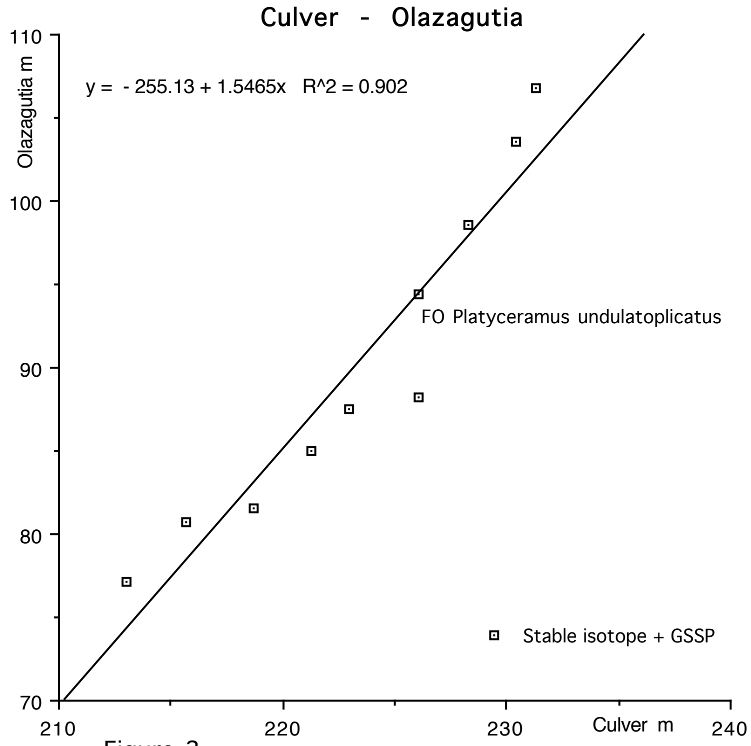

Figure 3

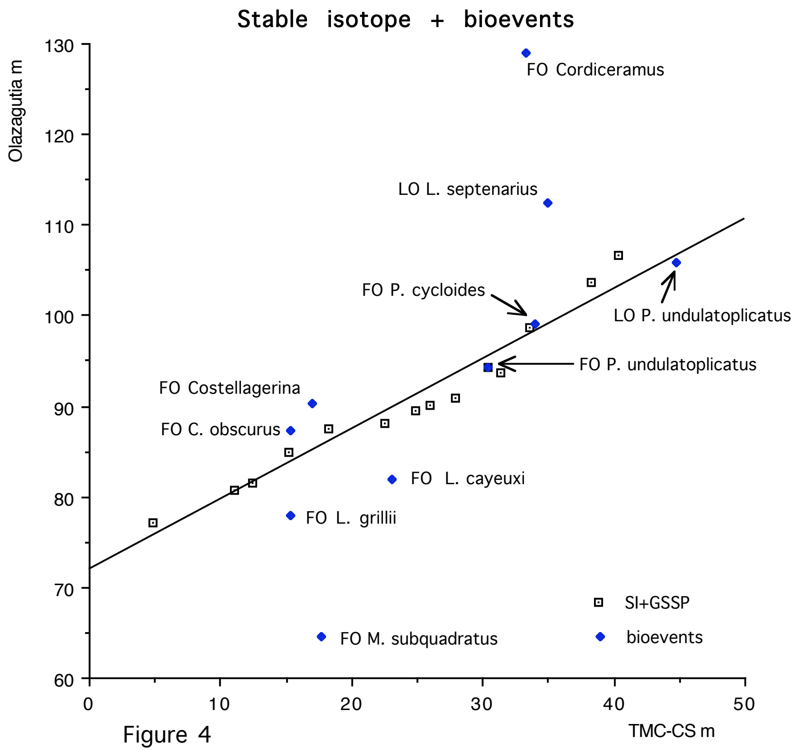

Figure 4

Depto. de Estratigrafía y Paleontología, Fac. de Ciencias, Univ. de Granada, Avda. de Fuenteneuva s/n, E-18002 Granada
http://www.ugr.es/~mlamolda/swg

Inoceramids

In both WM and Olazagutia sections the FO of *P. undulatoplicatus* lies between carbon isotope events K2 and Michel Dean. In particular, the bioevent is accompanied by a minimum just below the Michel Dean event. This bioevent is accurate.
The location of the FO of *P. undulatoplicatus* within biozones is not as appropriate, since the likely error of the bioevent is much smaller than those of any of the biozones involved.

The FO of *Platyceramus cycloides*.
It is detected at both WM and Olazagutia sections and is potentially an accurate bioevent.

The FO of *Magadiceramus subquadratus*
This species is known at Olazagutia from a single level and so is very poorly constrained. The level may well correlate better with the FO of *Magadiceramus subquadratus* at WM section.
The LO of *Magadiceramus* found at WM is not reliable at Olazagutia, and is inferred at Seaford Head (Hampton et al.).
Not a good bioevent.

Nannofossils

The FO of *Calculites obscurus* is recorded at both WM and Olazagutia sections and is potentially a reasonably accurate bioevent, but not close to the primary marker (see Melinte and Lamolda, 2002, for Olazagutia data).

The FOs of *Lucianorhabdus cayeuxi* and *Lithastrinus grillii*, and LO of *Lithatrinus septenarius* (=*L. moratus*) are recorded at both WM and Olazagutia sections but are inaccurate compared with the stable isotope best-fit line.

Planktonic foraminifers

The FO of *Costellagerina* is recorded at both WM and Olazagutia sections and potentially a reasonably accurate bioevent, but not close to the primary marker.

The LO of *Whiteinella*. This cannot be accurately located at Olazagutia as the genus ranges throughout the section studied. A very inaccurate bioevent. Best ignored.

The FO of *Heterohelix papula*.
This cannot be detected at either Olazagutia or Seaford Head.

Ammonites

The FO and LO of *Texanites gallicus*.
These cannot be detected at Olazagutia or Seaford Head and are poorly constrained in the WM section. The 50 % confidence interval on FO or LO is 2.5 m compared with a total range of 6 m (see other comments in Lamolda and Hancock, 1996, where *Texanites* was rejected).

In summary, Gale et al. proposed at TMC-CS 9 bioevents, in addition to the FO of *P. undulatoplicatus* and the Michel Dean isotope event. Of these, 3 cannot be detected at Olazagutia or Seaford Head. Of the remaining 6, 5 are inaccurate compared to the stable isotope best-fit line or not close to the primary marker. Thus only 1 bioevent is reasonable accurate: the FO of *Platyceramus cycloides*, and so could be used to strengthen the case for either Ten Mile Creek or Olazagutia.

Access

TMC-CS: Access has to be clarified for the several outcrops (this was one of the concerns of J. Hancock, see above). Exposures in its lower and middle parts (including WM section) are easily accessible during the dry season, only.

Olazagutia: Owner of the quarry has agreed to allow access for research (letter on April 26th, 2007).

Preservation of site

TMC-CS: Status uncertain. However, Walmart section alone is probably insufficient since it extends only a few metres into the Santonian. Would require other sections to be preserved as well to ensure future international correlation. TMC (WM) and other sections in the Dallas County, Texas, are in a growing urban area (another concern of J. Hancock).

Olazagutia: Owner of the quarry has agreed to preserve the non-active eastern border of the quarry where the section studied is located (letter on April 26th, 2007). This decision was supported by both the Navarran Regional Government, and the Instituto Geológico y Minero de España (Spanish Geological Survey).

Conclusions

The stable isotope curves are the most accurate means of correlation at present, especially between the expanded sections at Ten Mile Creek and Olazagutia (which has the thickest succession). All isotope points can be correlated, they plot close to a straight line, and the accuracy of correlation is much greater than with bioevents. Interestingly, the FO of *P. undulatoplicatus* plots about 1 m lower at Olazagutia than at Ten Mile Creek, which is close to the + or – 1 m precision imposed by sampling intervals. This correlation does not support Howe et al.'s conclusion that the FO of *P. undulatoplicatus* is higher at Olazagutia because the section is incomplete. The conclusion was based on other biostratigraphic criteria, which are likely to be as inaccurate as the majority of bioevents we can compare with the isotope correlation (Fig. 4).

Ten Mile Creek (Wall Mart) only extends about 5 m above the boundary. This is really not enough to encompass the changes that occur in the early Santonian. To make full sense of the Dallas sections requires at least the three used in the Gale et al. paper. Quite apart from the security of conservation of the proposed GSSP, other sites would need to be conserved to make the most of the section.

Both in structural complication and continuity of sedimentation the TMC-CS has problems. The biogeographical location of Olazagutia section gives a better representation of middle and low paleolatitude fossil assemblages, than the temperate-boreal and somewhat restricted TMC-CS. Furthermore, Olazagutia allows correlation with temperate-boreal regions by means of some benthic foraminifers, e.g., neoflabellinids (Lamolda and Hancock, 1996, Kopaevich et al., 2007, and Peryt and Lamolda, 2007).

Access and preservation of Olazagutia section is confirmed, whereas TMC-CS has uncertainties either in access or preservation.

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Marcos A. Lamolda
Chairman, Santonian Working Group