A reappraisal of the position of Chron C25n in the Campo section (Huesca province, south-central Pyrenees)

Reevaluación de la posición del Cron C25n en la sección de Campo (provincia de Huesca, Pirineos centro-meridionales)

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ABSTRACT

Upper Thanetian strata of the Campo section, in the southern Pyrenees, were assigned by previous authors to geomagnetic Chron C25r. Such attribution, however, is rendered obsolete by the discovery of Discoaster multiradiatus in beds situated 35 m below the Thanetian-Ilerdian boundary, since this calcareous nannofossil first appeared within C25n. Further, a biometric study shows that these D. multiradiatus have a chronostratigraphic position well above the base of Chron C24r. Therefore, magneto-biostratigraphic calibrations based on former interpretations must be revised. A new magnetostratigraphic study has found a previously undetected interval with normal magnetic polarities beneath the beds with D. multiradiatus, which presumably represents Chron C25n. However, more data will be necessary to substantiate that option.

Key words: *Campo section, Pyrenees, Thanetian, Magnetostratigraphy, Calcareous Nannofossils*

RESUMEN

El intervalo del Tanetiense superior de la sección de Campo, en los Pirineos meridionales, ha sido atribuido por autores previos al Cron geomagnético C25r (inverso). Tal atribución, sin embargo, queda obsoleta por el descubrimiento de Discoaster multiradiatus en capas situadas más de 30 m por debajo del límite Thanetiense-Ilerdiense, dado que este nannofósil calcáreo apareció por primera vez en el Cron 25n (normal). Además, un análisis biométrico indica que dichos D. multiradiatus tienen una posición cronoestratigráfica relativamente alta dentro del Cron C24r. En consecuencia, calibraciones magneto-biostratigráficas basadas en previas interpretaciones deben ser revisadas. Un nuevo estudio magnetoestratigráfico ha puesto de manifiesto un nuevo intervalo con polaridad normal por debajo de las capas con D. multiradiatus, que puede verosímilmente representar el Cron 25n. No obstante, son necesarios más datos para confirmar tal posibilidad.

Palabras clave: *Sección de Campo, Pirineos, Thanetiense, Magnetoestratigrafía, Nannofósiles calcáreos*

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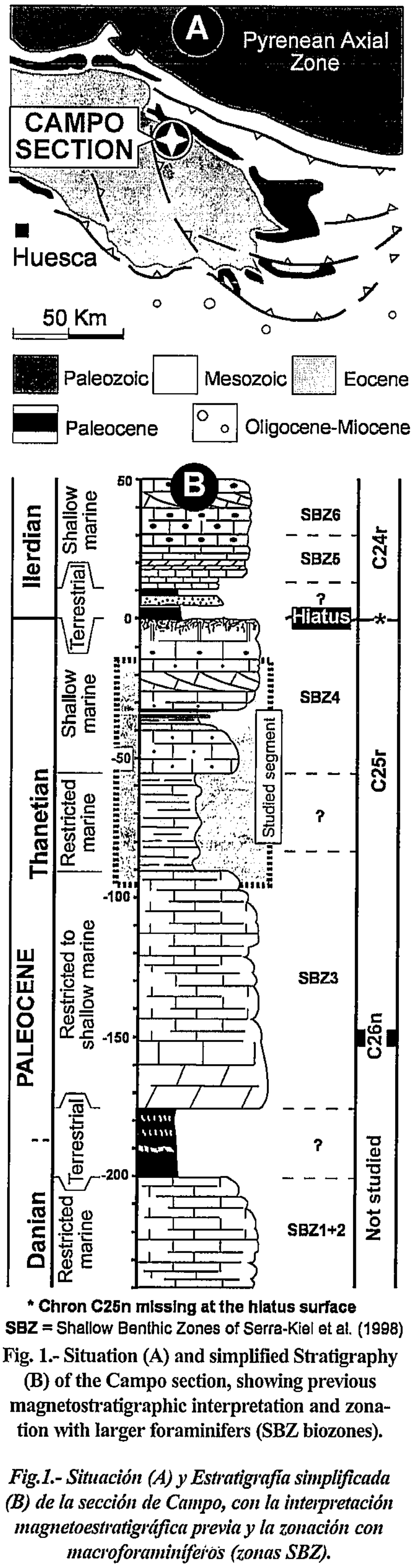
Introduction

Reversals of the Earth magnetic field are known to be synchronous global events and, if properly identified and calibrated, are ideal tools to correlate widely separated stratigraphic sequences, particularly during geological periods typified by relatively short-lived geomagnetic chrons. This is the case, for instance, of the late Paleocene-earliest Eocene interval, when normal polarity episodes were relatively few and of short duration (i.e., Chrons C24n.3n to C27n), separated by much longer reverse intervals (Berggren et al, 1995). Of these normal episodes, Chron C25n is perhaps the most interesting, because it marks the lower limit of the so-called Paleocene/ Eocene boundary interval, during which important climatic changes led to a dramatic turnover of the biosphere. For this reason, we designed a plan to locate Chron C25n in both deep-water and shallow-water marine successions of the Pyrenean area. The analysis of a deep-water section was successfully completed at Zumaia, in the Basque basin (Dinarès-Turell et al, 2002); the study of several shallow marine sections is still in progress. Here we report the results obtained in one of them (Campo), discussing previous ideas about the position of Chron C25n and the biochronologic implications of the new findings.

The lower Paleogene of the Campo section: setting and prior studies

Campo is an important reference section in the Pyrenean geology (Fig. 1A). Among other things, it is the parastratotype of the Ilerdian (Schaub, 1969), an stage whose relevance has greatly increased after confirmation that its base essentially coincides with the newly defined Paleocene-Eocene Epoch boundary (Orue-Etxebarria *et al.*, 2001, Pujalte *et al.*, 2003). The section has therefore been the object of numerous studies, those dealing with the stratigraphy of the Paleocene-lower Ilerdian interval being summarized by Payros *et al.* (2000). That interval is



* Chron C25n missing at the hiatus surface
SBZ = Shallow Benthic Zones of Serra-Kiel et al. (1998)

Fig. 1.- Situation (A) and simplified Stratigraphy (B) of the Campo section, showing previous magnetostratigraphic interpretation and zonation with larger foraminifers (SBZ biozones).

Fig.1.- Situación (A) y Estratigrafía simplificada (B) de la sección de Campo, con la interpretación magnetoestratigráfica previa y la zonación con macroforaminíferos (zonas SBZ).

mainly composed of littoral and shallow marine carbonate deposits alternating with lesser amounts of restricted marine and terrestrial deposits (Fig. 1B). The most significant fossils in the marine carbonates are larger foraminifers, which have been used to zone the section (Fig. 1B; Serra-Kiel *et al.*, 1994, 1998; Molina *et al.*, 1992).

Magnetostratigraphic studies were carried out by Pascual and Parés (in Molina *et al.*, 1992) and Dinarès-Turell and Pascual (in Serra-Kiel *et al.*, 1994). They found that most of the Paleocene-middle Ilerdian segment of the Campo section was characterized by reversed polarities, except for two short normal intervals. The oldest one (2 directions) was located 27 m above the base of the Thanetian carbonates, the younger one (3 directions) at the base of the middle Ilerdian Puebla Formation. Based on available biochronology, they were respectively assigned to C26n and C24n.2n. More important for the purposes of this paper, the authors above interpreted that Chron C25n was missing at the sharp discontinuity surface with *Microcodium* remains that caps the Thanetian carbonates, which was thus considered to represent a hiatus of ca. 500 kyr. Consequently, the upper part of the Thanetian succession was assigned to Chron C25r (Fig. 1B) and, based on that assumption, Serra-Kiel *et al.* (1998) calibrated their Shallow Benthic Zone (SBZ) 4 to this reversed chron (Fig. 1B).

Finding of *Discoaster multiradiatus* in Campo, and its relevance

The calcareous plankton of the upper Paleocene to middle Ilerdian segment of Campo was recently revised by Orue-Etxebarria *et al.* (2001). They found that, in Paleocene strata, autochthonous calcareous nannofossils were generally absent or very poorly preserved. However, some samples collected in the interval between -15 and -35 m down from the top of the Paleocene carbonates yielded an association that, among other species, contained *Discoaster multiradiatus*, whose first appearance (FA) was used by Martini (1971) to define the base of the calcareous nannofossils biozone NP9 (Fig. 2A). Such finding is here relevant because it is firmly established that *D. multiradiatus* first appeared in Chron C25n, a fact reconfirmed at the Zumaia section (Dinarès-Turell *et al.*, 2002; Bernaola, 2002). Therefore, upper Thanetian beds of Campo containing *D. multiradiatus* can either pertain to C25n or to younger chrons, but not to C25r as interpreted by previous authors. The chronostratigraphic position of these beds can in fact be further constrained. In effect, as demonstrated by Wei (1992), the mean number rays of *D. multiradiatus* decreases progressively from about 30 near the base of Chron C24r (close to its FA) to about 17 rays within NP10 (Fig.2), a decrease that according to Wei (1992) was virtually synchronous in different oceans and thus has chronostratigraphic applicability. Consequently, we have carried out a biometric analysis of all well-preserved *D. multiradiatus* specimens of the lowermost sample containing this species (CpE1, situated at -35 m in Fig. 3C). The number of rays of *D. multiradiatus* in this sample range between 16 and 25, and average 19 (Fig. 2B), a result that strongly suggests a chronostratigraphic position well above the base of C24r, in the upper part of the NP9 biozone (Fig 2C).

New magnetostratigraphic data

The data above prove that Chron C25n cannot be missing at the Thanetian-Ilerdian boundary, and its position in the Campo section remains to be fixed. A new attempt to locate it has therefore been carried out, resampling an interval about 60 m thick of the Thanetian succession (Figs. 1B and 3C). Paleomagnetic samples were collected from 59 different stratigraphic levels using a gasoline-powered drill (including a few hand-samples) (Fig. 3C). Natural remanent magnetisation (NRM) and remanence through all demagnetisation stages were measured using a 2G-Enterprises high-resolution (45 mm diameter) pass-through cryogenic magnetometer equipped with DC-squids and operating in a shielded room at the Istituto Nazionale di Geofisica e Vulcanologia in Rome, Italy. This magnetometer has a noise level of 10^{-12} Am^2. Alternating field (AF) demagnetisation was performed with three orthogonal coils installed inline with the magnetometer. A shielded Pyrex furnace was used for thermal demagnetisation. Each sample provided several specimens and a total of 117 of them were subjected to either thermal or alternating field (AF) stepwise demagnetisation. Thermal demagnetization up to 480°C included 11 steps with intervals of 30-50°. AF demagnetization up to 100 mT employed 14 steps at 5-20 mT intervals. The characteristic remanent magnetization (ChRM) is defined as the linear segment trending towards the origin of the demagnetization diagram. The mean declination and inclination of the ChRM components for each sample has been used to derive the latitude of the virtual geomagnetic pole (VGP).

Example vector component diagrams of both thermal and AF demagnetisation behaviours are presented in Fig 3A. After removal of a low coercivity and low temperature component (L) unblocked between 100°C and 240-280°C (or 5 mT and 15-20mT), a ChRM component with variable unblocking temperature (but always below 100 mT) is isolated. Component L conforms to the present geomagnetic field in in-situ coordinates and is therefore a secondary recent overprint. The ChRM component presents both reverse (Fig. 3A, a, b, d, g and h) and normal polarities (Fig. 3A, d,e and f). For a suite of samples, mostly located in the interval from -71 m to -64 m, the ChRM component is unblocked rapidly between 310°C and 340°C suggesting that the magnetic carrier is an iron-sulphide. However, the ChRM component for the majority of samples is mostly removed above 340°C indicating a magnetite-like mineralogy in those cases. For magnetostratigraphic purposes we have retained unreliable the iron-sulphide components because both polarities can coexist in close stratigraphic levels and, although pre-tilting in origin, they probably originate as secondary diagenetic overprints (Dinarès-Turell and Dekkers, 1999). With the exclusion of those samples, and other non measurable low NRM intensity samples, the reliable directions indicate that the studied section is indeed mostly reverse, but it includes two normal zones. The younger of them spans at least from -44 to -49 m, aproximately 10 m below the beds with *D. multiradiatus*, while the older one was found around -86 m (Fig. 3C). All reliable ChRM directions do not correspond to the present geomagnetic field in in-situ coordinates and show a regional clockwise rotation of about 25° when corrected for bedding attitude (Fig 3B), which is compatible with previous studies (Dinarès-Turell *et al.*, 1992, Serra-Kiel *et al.*, 1994). All these directions are pre-tilting and interpreted to be the primary directions at (or close) the time of deposition. The normal zone between -44 and -49 m is represented by 5 samples from 2 stratigraphic levels, and is considered a good candidate to represent Chron C25n (Fig. 3C). It must be pointed out however that, at Zumaia, Chron C25n is 10 m thick and has an estimated duration between 441 to 483 kyr (Dinarès-Turell *et al.*, 2002). Therefore, since sedimentation rate in Campo nearly doubled that of Zumaia, the thickness of Chron C25 should expected to be greater in the former than in the latter section, rather than the reverse. The normal zone at around -86 m is even narrower, and might represent a criptochron.

Concluding discussion

A first conclusion of this study is a negative one: namely, that the Campo section is probably unsuitable to establish the magnetostratigraphy of shallow-water Paleocene strata of the Pyrenees. In effect, both previous studies and the one presented here, conclusively show that: (i) the Thanetian succession mainly records reversed polarities; (ii) zones with normal polarities, candidates to represent Chrons C26n (Fig. 1B) and C25n (Fig. 3C), are shorter than expected and cannot be unambiguously calibrated with biostratigraphy, and (iii) there exist intervals with unclear magnetostratigraphic signals (e.g., between -64/-71 m, and around -86 m in Fig. 3C).

However, our study provides clear guidelines for future attempts to locate Chron C25n in other Pyrenean shallow sections: clearly, this chron must be sought within the Thanetian strata, rather than near the Thanetian-Ilerdian boundary, as earlier postulated. We prognosticate that it will be eventually found either at the lower part of biozone SBZ-4, or near the boundary between SBZ-3 and 4. Other implications of our data are that (i) the magnetostratigraphic calibration of Thanetian and early Ilerdian zones SBZ-3, 4 and 5 proposed by Serra-Kiel *et al.* (1998) must be revised and (ii) the extent of ca. 500 kyr assigned by Molina *et al.* (1992) and Serra-Kiel *et al.* (1994) to the hiatal surface at the top of the Thanetian carbonates (Fig. 1B) is grossly overestimated.

As noted by several previous authors (e.g., Schaub, 1969, Serra-Kiel *et al.*, 1994) Thanetian and Ilerdian carbonates are characterized by very distinct associations of larger foraminifers. Should a large hiatus be involved at their boundary, these differences could be explained by a slow evolution during the missing time interval. Instead, our data indicate that the extent of the hiatus was comparatively small and the dissimilarities in Thanetian and Ilerdian larger foraminifers reflect an important turnover of these shallow water benthic organisms.

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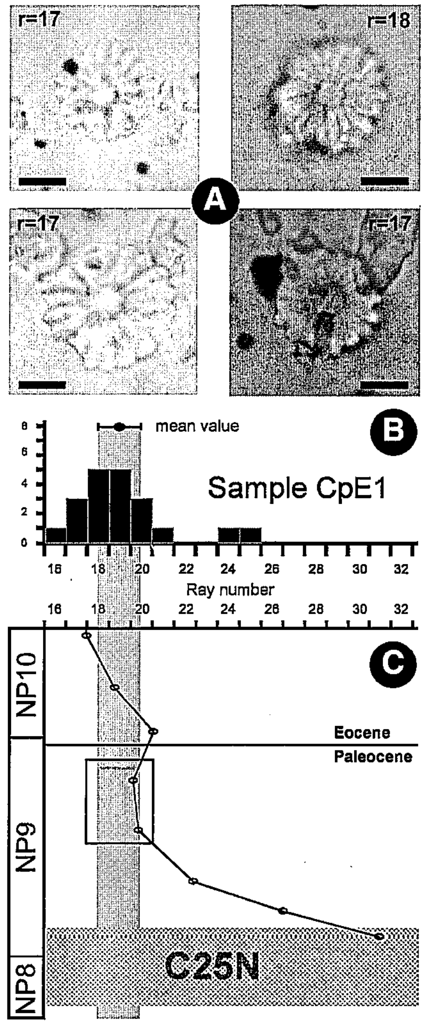

Fig. 2.- A and B: Microphotos of *Discoaster multiradiatus* specimens (scale bars = 5 mµ) and histogram of their number of rays from sample CpE1. C: Plot of decreasing ray number of *D. multiradiatus* during the late Paleocene and early Eocene (after Wei, 1992): according to this diagram, and the ray counting above (histogram), sample CpE1 must pertain to the upper part of NP9 (boxed interval).

Fig. 2.- A y B: Microfotos de ejemplares de* Discoaster multiradiatus *de la muestra CpE1 (barras escala = 5 mµ), con histograma de su número de radios. C: Gráfica del número de radios decreciente de* D. multiradiatus *durante el Paleoceno superior-Eoceno inferior (según Wei, 1992): de acuerdo con esta gráfica, y el contaje de radios (histograma), la muestra CpE1 debe pertenecer a la parte superior de NP9 (intervalo recuadrado)

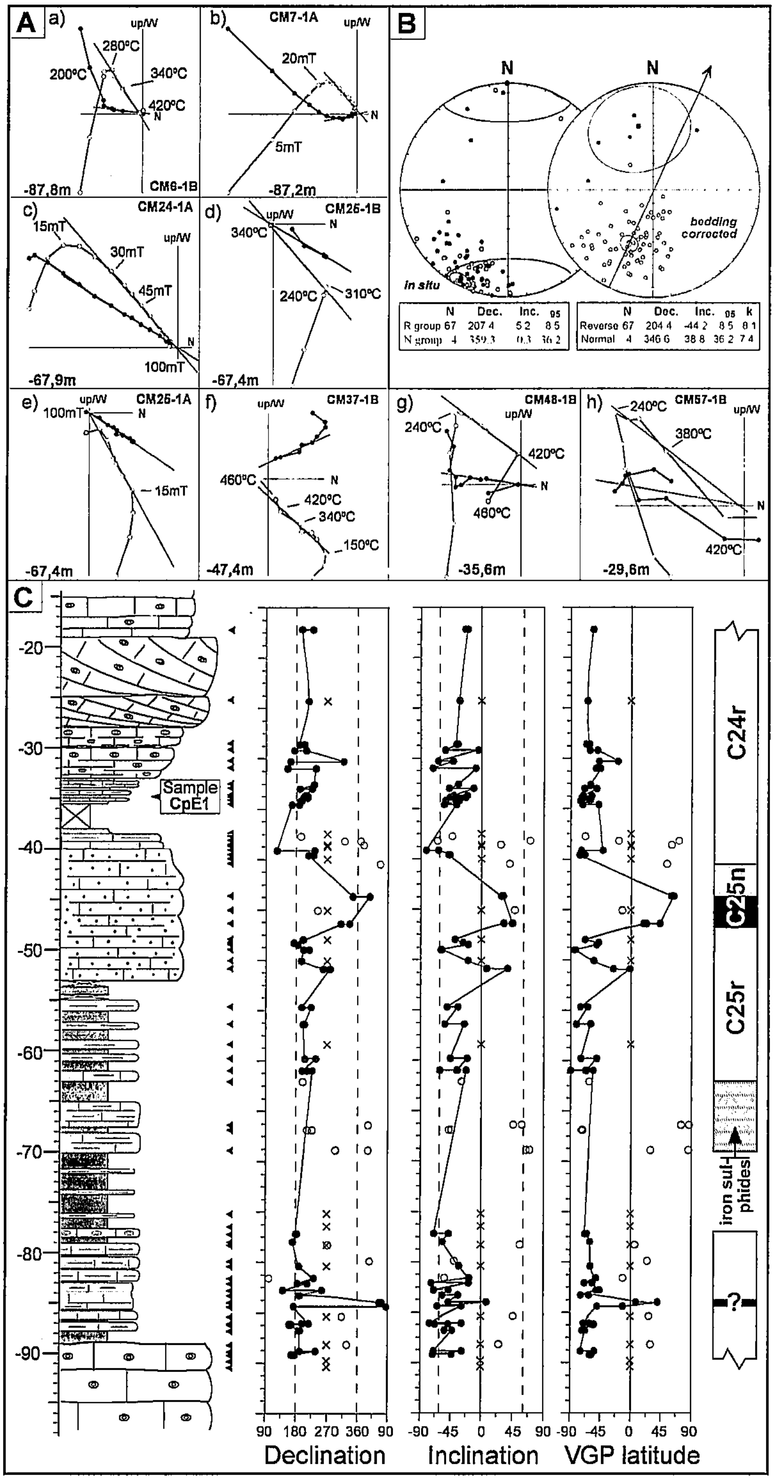

Fig. 3.- (A) Bedding-corrected orthogonal plots of thermal and alternating field demagnetisation data from representative specimens, showing their fitted ChRM direction and stratigraphic level in meters. Solid (open) symbols = projections onto the horizontal (vertical) plane. (B) Equal area projections of the ChRM directions, with 95% confidence ellipses (N, number of samples; Dec., declination; Inc., inclination; k, Fisher's precision parameter; a_{95}, radius of the 95% confidence cone). (C) Stratigraphic variations of declination, inclination of the ChRM vectors and virtual geomagnetic pole (VGP) latitude. Closed (open) circles = reliable (unreliable) data; crosses = samples providing no data.

Fig. 3.- (A) Gráficos ortogonales abatidos de datos de desmagnetización térmica y por campos alternantes de muestras representativas, mostrando sus direcciones características (ChRM) y posición estratigráfica en metros. Círculos negros (blancos) = proyecciones en el plano horizontal (vertical). (B) Proyección estereográfica de direcciones ChRM, con elipses de 95% de confianza (N, número de muestras; Dec., declinación; Inc., inclinación; k, parámetro de precisión de Fisher; a_{95}, radio del cono de 95% de confianza). (C) Variación estratigráfica de la declinación, inclinación de los vectores ChRM y latitud del polo geomagnético virtual (VGP). Círculos negros (blancos) = datos fiables (dudosos); cruces = muestras sin datos.

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