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APPROACH TO THE SPANISH CONTINENTAL NEOGENE SYNTHESIS AND PALAEOCLIMATIC INTERPRETATION

by

N. Lopez-Martinez, J. Agustí, L. Cabrera, J. P. Calvo, J. Civis, A. Corrochano, R. Daams, M. Diaz, E. Elizaga, M. Hoyos, J. Martinez, J. Morales, J. M. Portero, F. Robles, C. Santisteban and T. Torres

Introduction. Integrated studies on Neogene geology have been scarce in Spain, but attemps to stratigraphic and sedimentological analysis of continental Tertiary basins have increased considerably lately. The large extent of Neogene basins in Spain, the good quality of the outcrops and the abundance of fossil provide an excellent basis for this kind of studies.

Advances in basis analysis, supported by the achievement of 10 national meetings of sedimentology, continental biostratigraphy programs and regional mapping projects sponsored by public funding, enable us to present this approach assuming that it adequately reflects the present day knowledge about the continental Neogene in Spain.

Previous synthesis on this topic have been outlined by Vertebrate palaeontologists specially (Aguirre, 1974; Alberdi et al., 1975; Aguirre, 1975; Crusafont et al., 1975) but the stratigraphic background has barely been taken into account. Numerous regional works have provided extensive information which has made possible the present synthesis. It is supported by a considerable amount of data, and proposed to be tested and compared with other synthetic attempts on Mediterranean Neogene geology.

Basin analysis. Constructing a sketch summarizing the information on different basins (Fig. 1) needs previous discussion and data selection. Stratigraphic units have been distinguished in the simplified logs representing to the basin sedimentary successions. The method used in this paper approaches the infill unit of continental basins to the tectosedimentary unit (TSU) defined by Megias (1973, 1982). The depositional sequence defined by Mitchum et al. (1977) for marine sediments are geometrically similar to the TSU, but they propose an essentially eustatic control in their model. This makes difficult its conceptual use in continental basins with their own base level, and where the control of the depositional units is considered mainly tectonic.

The limits between the stratigraphic units (Fig. 1) are sedimentary discontinuities or ruptures of basinal range. Their origin and identification criteria were discussed by Megias (1973, 1982). In this paper the ruptures limiting stratigraphical units have been recognized in the field as hiatuses (with or without karstification), erosions, unconformities (and their relative conformities), horizontal and vertical changes of polarity during the depositional processes and boundaries between megasequences. Not all co-authors of this paper have identical view on the work method; data have been selected according to the accepted criteria given above.

Biostratigraphy and marine—continental correlations. Regional biozonation based on Micromammal assemblage zones have been used for biostratigraphic correlations. Overlied assemblage zones have been defined in the Teruel (Weerd, 1976; Mein et al., 1983), Daroca (Daams et al., 1981), Vallés-Penedés (Agustí, 1981;

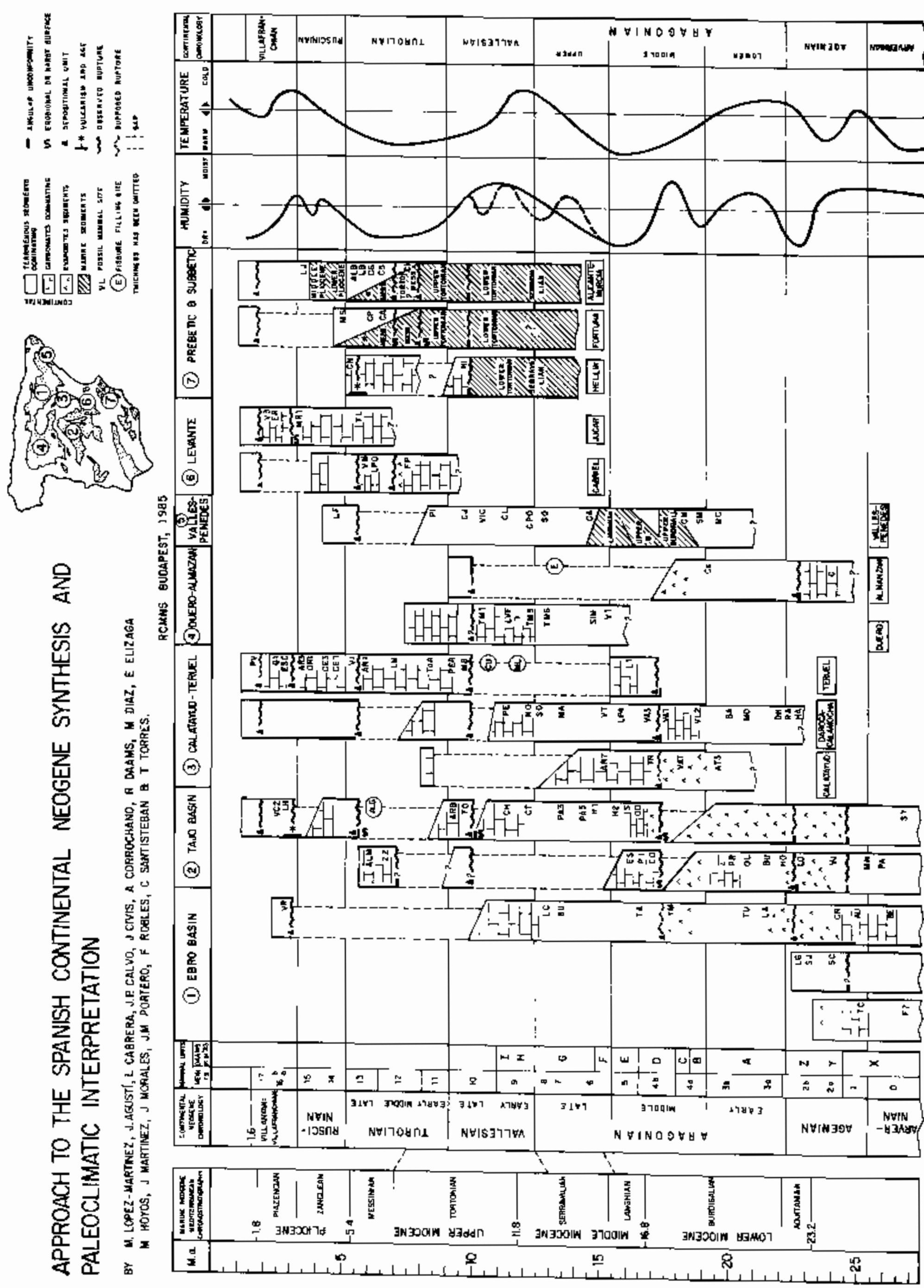

Fig. 1. Correlations of the Spanish continental Neogene sedimentary sequences. Sedimentary units and ruptures have been dated on the basis of Micromammals fossil sites; several of them are coded on the logs

ALB — Alberca
ALG — Algora
ALM — Almendros
AR 1, 3 — Arquillo 1, 3
AR 7 — Armantes 7
ARB — Arbancón
AT 3 — Ateca 3
AU — Autol
BA — Bañón
BE — Bergasa
BS — El Buste
BU — Buciegas
C — Cetina
C 1, 5, 6 — Crevillente 1, 5, 6
CAL — Can Almirall
CC — Casa del Acero
CE 1, 3 — Celadas 1, 3
CH — Chiloeches
CJ — Can Jofressa
CL — Can Llobateras
CM — Can Martí Vell
CN — Cenajo
CO — Córcoles
CP — Casa de las Palomas
CPO — Can Ponsic
CR — Carretil
CS — Ca Soria
CT — Cendejas de la Torre
CU — Cucalón
DH — La Dehesa
E — Escobosa
ES — Escamilla
ESC — Escorihuela
ER — El Rincón
F 7 — Fraga 7
FP — Fuentepodrida
G 1 — Gea 1
H 1, 2 — Henares 1, 2
HI — Hijar
HO — Huerta Obispalía
IS — San Isidro
LA — Los Agudos
LB — Librilla
LC — La Ciesma
LF — La Fortesa
LG — La Galocha
LH — Las Higueruelas
LI — Libros
LJ — La Juliana
LM — Los Mansuetos
LD — Loranca
LP 4 — Las Planas 4
LPO — La Portera
LVF — Los Valles de Fuentidueña
MA — Manchones
MB — Masía del Barbo
MC — Molí Calopa
ML — Molina de Aragón
MN — Moncalvillo
MD — Moratilla
MR 1 — Marmota 1
MS — Molina Segura
NA — Navarrete
ND — Nombrevilla
OD — O'Donnell
OL — Olmeda
OR — Orrios 1
P — Pineda
PA — Parrales
PA 3, 5 — Paracuellos 3, 5
PE — Pedregueras
PER — Peralejos
PI — Piera
PR — Priego
PV — Puebla de Valverde
RA — Ramblar
SC — Santa Cilia
SIM — Simancas
SJ — San Juan
SM — San Mamet
SO — Solera
SQ — San Quirce
SY — Sayatón
TA — Tarazona
TC — Torrent de Cinca
TL — Tolosa
TM 1, 5, 6 — Torremormojón *1*, 5, 6
TO — Torija
TOA — Tortajada
TR — Torralba de Ribota
TU — Tudela
V 1 — Valladolid 1
V 3 — Valdeganga 3
VA *1*, 3 — Valdemoros *1*, 3
VAT — Valtorres
VC 2 — Valverde Calatrava 2
VI — Villastar
VIC — Viladecabals
VJ — Vallejo
VL 2 — Villafeliche
VM — Venta del Moro
VR — Villarroya
VT — Valalto
YM — Yesos de Monteagudo
ZZ — Zafra de Záncara

AGUSTÍ et al., 1984 a) and Duero (ALVAREZ et al., 1985) basins. The biochronological scale of MEIN (1975) has been used together with that of DAAMS et al. (1984), more adequate for the Spanish fauna. The migration events of Large Mammals, traditionally used to define Mammal Ages, occur within the Micromammal zones. Changes in the composition of Mammal fauna seems controlled by environmental and climatic changes, because each assemblage has a different ecological meaning. The entry of immigrants is related also to palaeogeographic changes of intercontinental range.

Sedimentary ruptures have been dated according to the age of the oldest overlying bed or the youngest underlying bed. Ruptures do not coincide with faunal changes. All the eight dated generalized ruptures occur within biozones. No wonder, since sedimentary ruptures are mainly related to tectonics, while faunal changes to climate.

The controversed correlation of marine and continental scales has been summarized by RÖGL et al. (1983), though the equivalence is not definitely stablished. We have used their results but we propose to change it at three points (see Fig. 1):

a Late Aragonian—Langhian; this is a first order correlation in Vallés-Penedés basin (AGUSTÍ et al., 1984 a).

b Early Vallesian—Serravallian; the oldest *Hipparion* was calibrated in Europe at—12.5 Ma., and a first order correlation has been indicated by MEIN (1985).

c Middle Turolian—Messinian; in the Levante basins a second order correlation is pointed out in Crevillente 5 and Casa del Acero (BRUIJN et al., 1975; AGUSTÍ et al., 1975; AGUSTÍ et al., 1981, 1984). Many of the marine-continental correlation problems derive from the criteria of marine stage boundaries, as arbitrary historical boundaries cannot be translated to continental basins only biostratigraphic correlations are possible (see Fig. 3).

Summary of the Spanish continental Neogene. Spanish continental Neogene basins cover more than 100 000 km^2. Eastern basins show marine interbedded sediments, but in northern and central basins only Neogene continental sediments have been indicated. Thickness can reach more than 1000 m. Lithologies are varied, according to the origin of the materials but the amount of evaporites is striking.

Simplified logs of each area (Fig. 1) are the results of careful lithostratigraphic and sedimentologic analysis, sampling and correlation of fossil sites, biostratigraphic and basin analysis and the integration of both kind studies. The discontinuities, both stratigraphical and palaeontological are the rule; but when a sedimentary rupture has been well-dated, the underlying and overlying fauna showed the same composition. An intra-biozone position has been verified for most of the major ruptures indicated in Fig. 1.

1 An *Early Agenian* rupture is revealed in Ebro and Tajo basins as a change from well-developed fluvial system sedimentation to a mud-flat, playa-lake and lacustrine deposits. *Rhodanomys* faunas are present both below and above the rupture. This event corresponds probably to the Upper Oligocene.

2 A sedimentary rupture in *Late Agenian* or *Early Aragonian* has been recognized in the Ebro, Tajo and Duero (Almazán) basins. This rupture appears as an angular unconformity on the margins of the basin and a change of sedimentary polarity in its centre of it. *Ligerimys* (one species), *Anchitherium* and *Gomphotherium* are recorded both below and above this rupture. A possible correlation may be suggested with the Aquitanian based on marine—continental interbedded deposits in Lisboa R—1 (ANTUNES et al., 1973).

3 A *Middle Aragonian* sedimentary rupture seems to affect each of the studied basins. Some of them display angular unconformities; others have "cannibalistic" autophagic detritical sediments, and finally others seem to have formed at this moment. *Hispanotherium*, recorded above this rupture, and other faunistic criteria indicate increased aridity, coinciding with sepiolite deposits in the Tajo basin. The marine-continental interbedding in Vallés-Penedés basin allows to correlate this rupture with the Upper Burdigalian (AGUSTÍ et al., 1984).

A minor sedimentary rupture within the Late Aragonian deposits has been detected in Madrid basin. It has not been marked in the sketch because it is not clearly observed in other basins.

4 A *Late Vallesian* rupture is commonly located as a palaeokarst on the top of a structural folded surface of a carbonate depositional unit in most of the basins. The overlying unit is a complex deposit of terrigenous sediments and peculiar palustrine carbonates. *Hipparion* and *Progonomys* are present both below and above this rupture. A correlation with the Lower Tortonian has been verified in the Prebetic basins (CALVO et al., 1978).

5 A *Middle Turolian* rupture is well-characterized in most of the basins. *Parapodemus* are recorded both below and above this rupture. A correlation with marine deposits can be established in the Fortuna and Alicante basins. The Middle Turolian site of Casa del Acero overlies shallow open marine deposits of Messinian age (with *Globigerinoides elongatus* and *G. extermus*) and an evaporite diatomitic unit with *Globorotalia mediterranea*. Between this evaporite unit and the overlying terminal complex (evaporites, reefs and associated continental deposits), a major rupture can be correlated with the intra-Messinian regional rupture (SANTISTEBAN, 1981; MEGIAS et al., 1983; AGUSTÍ et al., 1984 b).

6 A *Late Turolian* sedimentary rupture appearing as a major progradation of terrigenous over chemical sediments is recorded in many basins. This rupture has a probable absolute age of about -5.7 ± 0.3 Ma dated at the Monagrillo volcanic event (BELLON et al., 1981). *Apodemus* faunas are recorded both below and above this rupture.

7 A *Late Ruscinian* or *Early Villafranchian* rupture is well-known in the Ebro, Tajo, Júcar and Teruel basins. A new depositional unit with terrigenous and carbonated sediments overlie a folded and karstified surface. *Mimomys* aff. *cappettai* (sensu WEERD, 1976) has been recorded both below and above this rupture (MARTINEZ and ESTEBAN, 1985). This absolute age is near -3.5 ± 0.3 Ma according to the volcanic event of Campo de Calatrava (Las Higueruelas, ALBERDI et al., 1984).

8 A *Late Villafranchian* rupture can be distinguished prior to the recent fluvial system incision. A large conglomeratic unit overlies an erosional incrusted surface. *Equus* and *Mammuthus* faunas occur below and above this rupture.

Other basins which have not yet been studied can be used to test this model. For example, the Guadix-Baza basin studied by AGUSTÍ et al., (1985) corroborates the Late Villafranchian rupture in a different geographic and geologic framework.

Palaeoclimatology. The palaeoclimatic interpretation of this synthesis is mainly based on faunal data, because the palaeobotanical data so far are scarce. The interpretation is based on the criteria proposed by WEERD et al. (1978) and DAAMS et al., (1984), who use percentages of Micromammal climatic indicators (glirids, castorids, eomyids etc). Invertebrates are also good temperature indicators, and in some cases oxigen isotopes in shells have been measured (ALBERDI et al., 1982). Organisms are more sensible to the variations in climate than sediments, which reveal to be more controlled by other factors. Several examples of the Spanish Neogene sediments show that sedimentological criteria are ambiguous as climatic indicators;

a the contemporaneous deposition of both types, arid alluvial fan and wet fluvial fan in the same basin;

b alluvial fan deposits where sedimentary facies are mainly mass transport deposits, having a fan radius longitude similar to those of the wet fluvial fan models (SCHUMM, 1977); these examples would indicate that all drainage system variables (SCHUMM, 1981) and not only climate, have to be considered;

c evaporitic deposits do not always correlate with warmer and drier intervals but can be associated to moister and colder times in Tajo basin (Fig. 1) where, on the basis of field criteria, a control of the source area lithology can be demonstrated.

Deduced climatic changes should be attributed either to humidity oscillations or temperature variations. Temperature changes were more difficult to detect. Four relative cooling phase have been recognized in Late Oligocene (X-zone), Early Miocene (Z—A zones). Aragonian/Vallesian limit and Ruscinian/Villafranchian limit. The last three of them may be roughly related to those outlined by KEIGWIN et al. (1979) and MULLER (1983) at —23 Ma, —12 Ma and —3 Ma in the marine Neogene.

Relative humidity changes can be detected easier than temperature variations. The Neogene faunas in Spain seem to indicate a more arid climate than that of the areas located north of it. Relative increases in humidity are recognized during the Middle Agenian, Early Aragonian, Early Vallesian, Early Ruscinian and Late Ruscinian. Other humidity oscillations in the Late Aragonian and Vallesian of the Tajo and Vallés-Penedés basins have been detected.

Chronostratigraphy and global events. Global ruptures have been recognized in marine sedimentary successions by VAIL et al., 1979 (changes of sea-level based on coastal onlap, and unconformities), KELLER et al., 1983 (hiatuses) and SOLER et al., 1983 (regional tecto-sedimentary ruptures). Based on marine-continental biostratigraphic correlations, we have verified that most of the ruptures in both marine and continental series coincide chronologically (Fig. 2). The major ruptures are at —22,5 Ma (intra-Aquitanian ≃ Late Agenian), al —10 Ma (intra-Tortorian ≃ Late Vallesian), al —7 Ma (intra-Messinian — Middle Turolian), and at —3 Ma (intra-Piazencian ≃ Early Villafranchian). Other ruptures appear also well-correlated, such as at —81 Ma (intra-Burdigalian ≃ Middle Aragonian), at about —5,5 Ma (Mio/Pliocene limit ≃ Upper Turolian) and at —1.8 Ma (Plio/Pleistocene limit ≃ Upper Villafranchian).

Sedimentary ruptures divide the Neogene into tecto-sedimentary units with a chronostratigraphic significance (as indicated by MEGIAS, 1973, 1982; MITCHUM et al., 1977; VAIL et al., 1982). Most of the global ruptures do not coincide with classic chronostratigraphic limits. Boundaries between stages, defined from stratotypes, are located within the TSU (Fig. 2) because of the methodology of the classic stages definition. They are based on stratigraphic record (stratotypes) of transgresive events that usually correspond to the terminal episodes of coastal onlap (Fig. 3). For this reason, stages boundaries only can be correlated on the basis of biostratigraphic successions. On the contrary, sedimentary ruptures can be correlated by means of basin analysis and biostratigraphy, even between marine and continental successions; therefore they are a better reference for chronostratigraphic limits.

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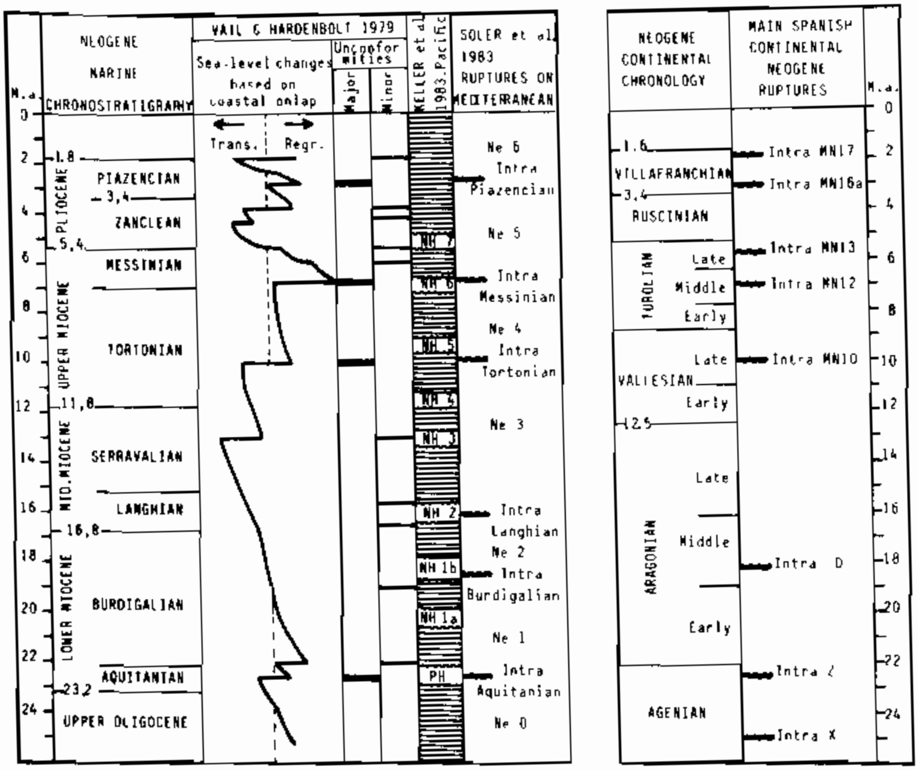

Fig. 2. Correlation of global changes in marine and continental Neogene. Note the position of the classic chronostratigraphic limits within the transgressive events, and the sedimentary ruptures within the stages

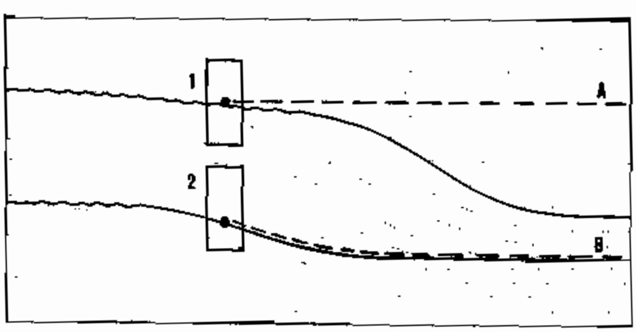

Fig. 3. Sketch representing several transgression—regression cycles with two ruptures dividing the record into three tecto-sedimentary units

1 Situation of the classic stratotypes on the coastal onlap episodes. The transgression event is diachronous, so the chronostratigraphic limit is defined on the basis of the transgression in the stratotype (isocron A). It can only be correlated biostratigraphically. *2* situation of a posible stratotype, being the sedimentary rupture the chronostratigraphic limit (isocron B). It can be correlated by basin analysis and/or biostratigraphy

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Synthesis authors: **NIEVES LOPEZ-MARTINEZ[1], JORGE AGUSTI[2], LUIS CABRERA[3], JOSÉ PEDRO CALVO[1], JORGE CIVIS[4], ANGEL CORROCHANO[4], REMMERT DAAMS[5], MARGARITA DIAZ[1], EMILIO ELIZAGA[6], MANUEL HOYOS[7], JAVIER MARTINEZ[1], JORGE MORALES[7], JOSÉ MANUEL PORTERO[6], FERNANDO ROBLES,[9] CARLOS SANTISTEBAN[9], TRINIDAD TORRES[10]**

Analysis authors: **Mª TERESA ALBERDI[7], Mª ANGELES ALVAREZ[1], MARGARITA BELINCHON[9], JESÚS CARBALLEIRA[4], GLORIA CUENCA[11], MATIJS FREUDENTHAL[12], EDUARDO GARCIA[1], JOSÉ GIBERT[2], ANGEL GONZALEZ[4], FERNANDO JUNCO[10], JOSÉ IGNACIO LACOMBA[9], ANA V. MAZO[7], ALBERT VAN DER MEULEN[13], SALVADOR MOYA[2], ALFONSO OLIVE[8], SALVADOR ORDOÑEZ[1], MIGUEL DE RENZI[9], Mª ANGELES SACRISTAN[1], CARMEN SESE[7] Mª DOLORES SORIA[7], JUAN USERA[9], MARIA VALLE[4], JOSÉ LUIS ZAPATA[10]**

(1) Facultad de C. Geológicas. Univ. Complutense. 28040 MADRID.
(2) Inst. de Paleontología. C. Escuela Ind. 23. SABADELL (Barcelona).
(3) Facultad de C. Geológicas. Univ. Central. 08007 BARCELONA.
(4) Facultad de Ciencias, Univ. de Salamanca. 37000 SALAMANCA.
(5) Geologish Inst. Rijksuniversiteit, Melkweg, 1, GRONINGEN. NL.
(6) Inst. Geológico y Minero de España. C. Rios Rosas 23.28003 MADRID.
(7) Museo Nacional de Ciencias Naturales. CSIC.C. José Gutierrez Abascal, 2.28006 MADRID.
(8) Compañía General de Sondeos. C. San Roque, 3. MAJADAHONDA (Madrid).
(9) Facultad de C. Biológicas. Universidad Literaria, C. Dr. Moliner s/n. BURJASOT (Valencia).
(10) Empresa Nacional del Uranio, Santiago Rusiñol 12. 28040 Madrid. 28008 MADRID.
(11) Facultad de Ciencias, Univ. de Zaragoza. 50001 ZARAGOZA.
(12) Rijksmuseum Geologie Min., Hooglandse Kerkgracht, 17. LEIDEN, NL.
(13) Instituut voor Aardwetenschappen, Budapestlaan 4,3508 TA UTRECHT, NL.