

**APPROACH TO THE SPANISH CONTINENTAL NEOGENE SYNTHESIS AND PALAEOCLIMATIC INTERPRETATION**

by

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*Introduction.* Integrated studies on Neogene geology have been scarce in Spain, but attempts 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 fossils provide an excellent basis for this kind of studies.

Advances in basin 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. Overlaid assemblage zones have been defined in the Teruel (WEERD, 1976; MEIN et al., 1983), Daroca (DAAMS et al., 1981), Vallés-Penedés (AGUSTÍ, 1981);



ALB	Alberca	LVF	Los Valles de Fuentidueña
ALG	Algora	MA	Manchones
ALM	Almendros	MB	Masia del Barbo
AR 1, 3	Aruillo 1, 3	MC	Moli Chalopa
AR 7	Armanes 7	ML	Mollaa de Aragón
ARB	Arbancón	MN	Moncalvillo
AT 3	Ateca 3	MD	Moratalfa
AU	Autol	MR 1	Marnota 1
BA	Bañón	MS	Molina Segura
BE	Bergasa	NA	Navarrete
BS	El Buste	ND	Nombrevilla
BU	Buciegas	OD	O'Donnell
C	Cetina	OL	Olmeda
C 1, 5, 6	Crevillente 1, 5, 6	OR	Orritos 1
CAL	Can Almirall	P	Pineda
CC	Casa del Acero	PA	Parralcs
CE 1, 3	Celadas 1, 3	PA 3, 5	Paracuellos 3, 5
CH	Chiolechcs	PE	Peñaguera
CJ	Can Joifresa	PER	Peralejos
CL	Can Lobateras	PI	Piera
CM	Can Martí Vell	PR	Priego
CN	Cenajo	PV	Pueblo de Valverde
CO	Córcoles	RA	Rambiar
CP	Casa de las Palomas	SC	Santa Cilia
CPO	Can Ponsic	SIM	Simancas
CR	Carretil	SJ	San Juan
CS	Ca Soria	SM	San Marnet
CT	Cendejas de la Torre	SO	Solera
CU	Cucalón	SQ	San Quirce
DH	La Dèhesa	SY	Savatón
E	Escobosa	TA	Tarazona
ES	Escamilla	TC	Torrent de Cinca
ESC	Escorihuela	TL	Tolosa
ER	El Rincón	TM 1, 5, 6	Torreormojón 1, 5, 6
F 7	Fraga 7	TO	Tortia
FP	Fuentepeñrida	TOA	Tortajada
G 1	Gea 1	TR	Torraiba de Ribota
H 1, 2	Henaes 1, 2	TU	Tudela
HI	Hijar	V 1	Vajadolid 1
HO	Huerta Obispalla	V 3	Valdeganga 3
IS	San Isidro	VA 1, 3	Valdemoros 1, 3
LA	Los Agudos	VAT 7	Valtorres
LB	Librilla	VC 2	Valverde Calatrava 2
LC	La Ciesma	VI	Villastar
LF	La Fortesa	VIC	Viladecabals
LG	La Galocha	VJ	Vallejo
LH	Las Higuercuelas	VL 2	Vilhateliche
LJ	Libros	VM	Venta del Moro
LJ	La Juliana	VR	Villarroya
LM	Los Mansuetos	VT	Valalto
LD	Loranca	YM	Yesos de Monteagudo
LP 4	Las Planas 4	ZZ	Zafra de Záncara
LPO	La Portera		

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 controverted correlation of marine and continental scales has been summarized by RÖGL et al. (1983), though the equivalence is not definitely established. 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 (BRUIN 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<sup>2</sup>. 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 detrital 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  $-5.7 \pm 0.3$  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 overlies 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  $-3.5 \pm 0.3$  Ma according to the volcanic event of Campo de Calatrava (Las Higuieruelas, 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 incrustated 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, comyids etc). Invertebrates are also good temperature indicators, and in some cases oxygen 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 Aagenian, 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  $\approx$  Late Aagenian), at -10 Ma (intra-Tortonian  $\approx$  Late Vallesian), at -7 Ma (intra-Messinian - Middle Turolian), and at -3 Ma (intra-Piacenzian  $\approx$  Early Villafranchian). Other ruptures appear also well-correlated, such as at -81 Ma (intra-Burdigalian  $\approx$  Middle Aragonian), at about -5,5 Ma (Mio/Pliocene limit  $\approx$  Upper Turolian) and at -1.8 Ma (Plio/Pleistocene limit  $\approx$  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 transgressive 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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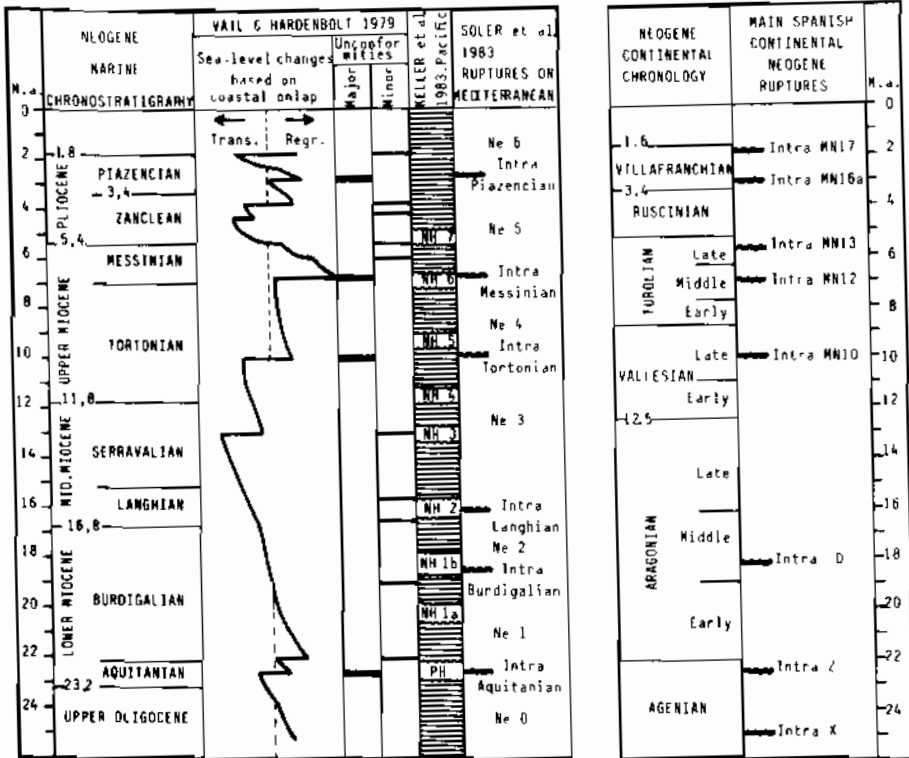


Fig. 2. Correlation of global changes in marine and continental Neogene. Note the position of the classic chronostratigraphic limits within the transgressive events, and the sedimentary ruptures within the stages

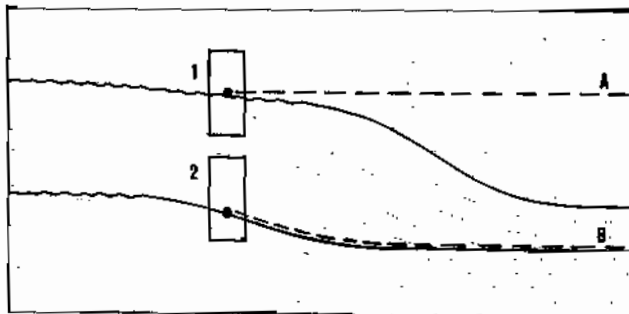


Fig. 3. Sketch representing several transgression—regression cycles with two ruptures dividing the record into three tecto-sedimentary units

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 possible stratotype, being the sedimentary rupture the chronostratigraphic limit (isocron B). It can be correlated by basin analysis and/or biostratigraphy

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