

Tertiary basins of Spain the stratigraphic record of crustal kinematics

Edited by

PETER F. FRIEND AND CRISTINO J. DABRIO

(1996)



World and Regional Geology 6

CAMBRIDGE UNIVERSITY PRESS

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 **CAMBRIDGE**
UNIVERSITY PRESS

Published by the Press Syndicate of the University of Cambridge
The Pitt Building, Trumpington Street, Cambridge CB2 1RP
40 West 20th Street, New York, NY 10011-4211, USA
10 Stamford Road, Oakleigh, Melbourne 3166, Australia

© Cambridge University Press 1996

First published 1996

Printed in Great Britain at the University Press, Cambridge

A catalogue record for this book is available from the British Library

Library of Congress cataloguing in publication data

Tertiary basins of Spain : the stratigraphic record of crustal
kinematics / edited by Peter F. Friend and Cristino J. Dabrio.

p. cm. – (World and regional geology series)

Includes bibliographical references.

SBN 0 521 46171 5

1. Geology, Stratigraphic – Tertiary. 2. Geology, Structural –
Spain. 3. Basins (Geology) – Spain. I. Friend, P.F. II. Dabrio,
Cristino J. III. Series.

QE691.T465 1995

551.7'8'0946 – dc20 94-21724 CIP

ISBN 0 521 46171 5 hardback

Contents

<i>List of contributors</i>	ix		
<i>Preface</i> P.F. FRIEND and C.J. DABRIO	xiii		
<i>Dedication to Professor Oriol Riba I Arderiu</i> C. PUIGDEFÀBREGAS	xv		
<i>Memorial, Etienne Moissenet 1941–1994</i> P. ANADÓN, N. MOISSENET and O. RIBA	xvii		
PART G GENERAL			
G1. Tertiary stages and ages, and some distinctive stratigraphic approaches	3		
P.F. FRIEND			
G2. Cenozoic latitudes, positions and topography of the Iberian Peninsula	6		
A.G. SMITH			
G3. Tertiary tectonic framework of the Iberian Peninsula	9		
C.M. SANZ DE GALDEANO			
G4. Deep crustal expression of Tertiary basins in Spain	15		
E. BANDA			
G5. Oil and gas resources of the Tertiary basins of Spain	20		
F. MELÉNDEZ-HEVIA and E. ALVAREZ DE BUERGO			
G6. Mineral resources of the Tertiary deposits of Spain	26		
M.A. GARCÍA DEL CURA, C.J. DABRIO and S. ORDÓÑEZ			
PART E EAST			
E1. Geological setting of the Tertiary basins of Northeast Spain	43		
P. ANADÓN and E. ROCA			
E2. The lithosphere of the Valencia Trough: a brief review	49		
M. TORNÉ			
E3. Depositional sequences in the Gulf of Valencia Tertiary basin	55		
W. MARTÍNEZ DEL OLMO			
E4. Neogene basins in the Eastern Iberian Range	68		
P. ANADÓN and E. MOISSENET			
E5. The Tertiary of the Iberian margin of the Ebro basin: sequence stratigraphy	77		
J. VILLENA, G. PARDO, A. PÉREZ, A. MUÑOZ and A. GONZÁLEZ			
E6. Tertiary of the Iberian margin of the Ebro basin: paleogeography and tectonic control	83		
J. VILLENA, G. PARDO, A. PÉREZ, A. MUÑOZ and A. GONZÁLEZ			
E7. Stratigraphy of Paleogene deposits in the SE margin of the Catalan basin (St. Feliu de Codines–St. Llorenç del Munt sector, NE Ebro basin)	89		
J. CAPDEVILA, E. MAESTRO-MAIDEU, E. REMACHA and J. SERRA ROIG			
E8. Onshore Neogene record in NE Spain: Vallès–Penedès and El Camp half-grabens (NW Mediterranean)	97		
L. CABRERA and F. CALVET			
E9. The Paleogene basin of the Eastern Pyrenees	106		
J.M. COSTA, E. MAESTRO-MAIDEU and CH. BETZLER			
E10. The Neogene Cerdanya and Seu d'Urgell intramontane basins (Eastern Pyrenees)	114		
E. ROCA			
E11. Eocene-Oligocene thrusting and basin configuration in the eastern and central Pyrenees (Spain)	120		
J. VERGÉS and D.W. BURBANK			
E12. The Late Eocene – Early Oligocene deposits of the NE Ebro basin, west of the Segre River	134		
E. MAESTRO-MAIDEU and J. SERRA ROIG			
E13. Chronology of Eocene foreland basin evolution along the western oblique margin of the South–Central Pyrenees	144		
P. BENTHAM and D.W. BURBANK			
E14. Evolution of the Jaca piggyback basin and emergence of the External Sierra, southern Pyrenees	153		
P.J. HOGAN and D.W. BURBANK			
E15. Long-lived fluvial palaeovalleys sited on structural lineaments in the Tertiary of the Spanish Pyrenees	161		
S.J. VINCENT and T. ELLIOTT			
E16. Evolution of the central part of the northern Ebro basin margin, as indicated by its Tertiary fluvial sedimentary infill	166		
P.F. FRIEND, M.J. LLOYD, R. MCELROY, J. TURNER, A. VAN GELDER and S.J. VINCENT			
E17. The Rioja Area (westernmost Ebro basin): a ramp valley with neighbouring piggybacks	173		
M.J. JURADO and O. RIBA			
PART W WEST			
W1. The Duero Basin: a general overview	183		
J.I. SANTISTEBAN, R. MEDIAVILLA, A. MARTÍN-SERRANO and C.J. DABRIO			
W2. Alpine tectonic framework of south-western Duero basin	188		
J.I. SANTISTEBAN, R. MEDIAVILLA and A. MARTÍN-SERRANO			
W3. South-western Duero and Ciudad Rodrigo basins: infill and dissection of a Tertiary basin	196		
J.I. SANTISTEBAN, A. MARTÍN-SERRANO, R. MEDIAVILLA and C.J. DABRIO			
W4. Tectono-sedimentary evolution of the Almazán basin, NE Spain	203		
J. BOND			

W5. Tertiary basins and Alpine tectonics in the Cantabrian Mountains (NW Spain)	214	C8. Saline deposits associated with fluvial fans. Late Oligocene – Early Miocene, Loranca Basin, Central Spain	308
J.L. ALONSO, J.A. PULGAR, J.C. GARCÍA-RAMOS and P. BARBA		J. ARRIBAS and M. DÍAZ-MOLINA	
W6. Lacustrine Neogene systems of the Duero Basin: evolution and controls	228	C9. Shallow carbonate lacustrine depositional controls during the Late Oligocene – Early Miocene in the Loranca Basin (Cuenca Province, central Spain)	313
R. MEDIAVILLA, C.J. DABRIO, A. MARTÍN-SERRANO and J.I. SANTISTEBAN		M.E. ARRIBAS, R. MAS and M. DÍAZ-MOLINA	
W7. North-western Cainozoic record: present knowledge and the correlation problem	237		
A. MARTÍN-SERRANO, R. MEDIAVILLA and J.I. SANTISTEBAN		PART 5 SOUTH	
W8. Onshore Cenozoic strike-slip basins in NW Spain	247	S1. The Betic Neogene basins: introduction	321
L. CABRERA, B. FERRÚS, A. SÁEZ, P.F. SANTANACH and J. BACELAR		CH. MONTENAT	
W9. Tertiary of Central System basins	255	S2. Neogene palaeogeography of the Betic Cordillera: an attempt at reconstruction	323
A. MARTÍN-SERRANO, J.I. SANTISTEBAN and R. MEDIAVILLA		C.M. SANZ DE GALDEANO and J. RODRÍGUEZ-FERNÁNDEZ	
		S3. Depositional model of the Guadalquivir – Gulf of Cádiz Tertiary basin	330
PART 6 CENTRE		C. RIAZA and W. MARTÍNEZ DEL OLMO	
C1. Structure and Tertiary evolution of the Madrid basin	263	S4. Late Neogene depositional sequences in the foreland basin of Guadalquivir (SW Spain)	339
G. DE VICENTE, J.M. GONZÁLEZ-CASADO, A. MUÑOZ-MARTÍN, J. GINER and M.A. RODRÍGUEZ-PASCUA		F.J. SIERRO, J.A. GONZÁLEZ DELGADO, C.J. DABRIO, J.A. FLORES and J. CIVIS	
C2. Neogene tectono-sedimentary review of the Madrid basin	268	S5. Miocene basins of the eastern Prebetic Zone: some tectono-sedimentary aspects	346
G. DE VICENTE, J.P. CALVO and A. MUÑOZ-MARTÍN		CH. MONTENAT, P. OTT D'ESTEVOU and L. PIERSON D'AUTREY	
C3. Sedimentary evolution of lake systems through the Miocene of the Madrid Basin: paleoclimatic and paleohydrological constraints	272	S6. Stratigraphic architecture of the Neogene basins in the central sector of the Betic Cordillera (Spain): tectonic control and base-level changes	353
J.P. CALVO, A.M. ALONSO ZARZA, M.A. GARCÍA DEL CURA, S. ORDÓÑEZ, J.P. RODRÍGUEZ-ARANDA and M.E. SANZ-MONTERO		J. FERNÁNDEZ, J. SORIA and C. VISERAS	
C4. Paleomorphologic features of an intra-Vallesian paleokarst, Tertiary Madrid Basin: significance of paleokarstic surfaces in continental basin analysis	278	S7. Pliocene–Pleistocene continental infilling of the Granada and Guadix basins (Betic Cordillera, Spain): the influence of allocyclic and autocyclic processes on the resultant stratigraphic organization	366
J.C. CAÑAVÉRAS, J.P. CALVO, M. HOYOS and S. ORDÓÑEZ		J. FERNÁNDEZ, C. VISERAS and J. SORIA	
C5. Tectono-sedimentary analysis of the Loranca Basin (Upper Oligocene–Miocene, Central Spain): a 'non-sequenced' foreland basin	285	S8. Late Neogene basins evolving in the Eastern Betic transcurrent fault zone: an illustrated review	372
J.J. GÓMEZ FERNÁNDEZ, M. DÍAZ-MOLINA and A. LENDÍNEZ		CH. MONTENAT and P. OTT D'ESTEVOU	
C6. Paleocology and paleoclimatology of micromammal faunas from Upper Oligocene – Lower Miocene sediments in the Loranca Basin, Province of Cuenca, Spain	295	S9. Tectonic signals in the Messinian stratigraphy of the Sorbas basin (Almería, SE Spain)	387
R. DAAMS, M.A. ÁLVAREZ SIERRA, A.J. VAN DER MEULEN and P. PELÁEZ-CAMPOMANES		J.M. MARTÍN and J.C. BRAGA	
C7. Fluvial fans of the Loranca Basin, Late Oligocene – Early Miocene, central Spain	300	S10. Basinwide interpretation of seismic data in the Alborán Sea	392
M. DÍAZ-MOLINA and A. TORTOSA		C. DOCHERTY and E. BANDA	
		Index	399

W6 Lacustrine Neogene systems of the Duero Basin: evolution and controls

R. MEDIAVILLA, C.J. DABRIO, A. MARTÍN-SERRANO AND J.I. SANTISTEBAN

Abstract

Vertical aggradation of Neogene fluvial and lacustrine deposits occurred until the Late Neogene in central and northern areas of the Duero Basin, coeval with river incision in the south-western corner of the basin. The whole basin became exorheic in the Latest Neogene. We have differentiated five tectonosedimentary units (TSUs) of basinal extent, bounded by unconformities or breaks in the sedimentary record. Deposits in each TSU consist of alluvial-fan deposits in areas close to the active northern and eastern margins, and fluvial deposits along the western margin. These systems converged in the lower, subsiding areas of the basin occupied by carbonate–evaporite lacustrine systems.

Tectonics and climate controlled sedimentation. The main faults active from the Neogene to the Present reflect Late Hercynian basement fractures that were re-activated during the Alpine Orogeny, both fracturing blocks and modifying landscapes, and creating or modifying the areas of subsidence. Analysis of climatic variations during the Miocene shows that deposition of saline materials occurred in dry TSUs (1, 2) and, particularly, in humid TSUs (3, 4). Climate does not seem to have been a determining factor for the formation of evaporites. However, it was a very important factor in determining both the amount of water that reached the basin and, eventually, also the extent of the lacustrine systems.

Introduction

By the end of Oligocene times, the northern and southern margins of the Duero Basin experienced final compressional stresses and were uplifted by reverse faults above the Paleogene deposits of the basin (Barba, pers. commun., 1992; see also Chapter W2). During the Neogene, sedimentation took place in an extensional regime, with major vertical movements, which continue at present.

Gentle subsidence in the south-western margin during the Neogene favoured the headward erosion of the Atlantic fluvial network that began to be defined in Uppermost Oligocene–Early Neogene times (Martín-Serrano, 1991; see also Chapter W3). Coeval to river incision at this side of the basin, high subsidence rates in the central

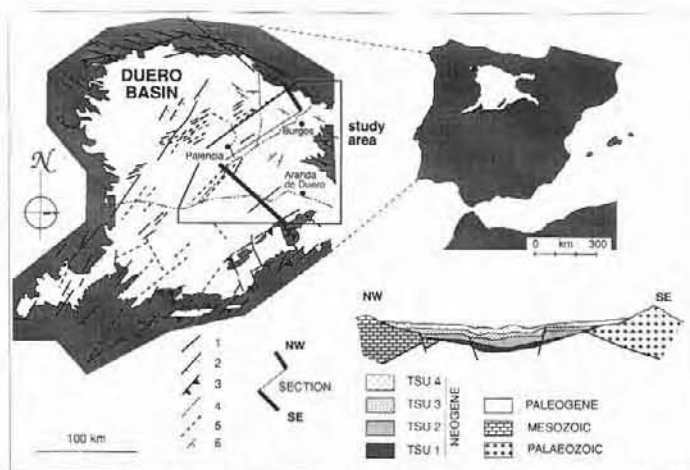


Fig. 1. Tectonic map of the Duero Basin (from Baena *et al.*, in press) and composite cross section of the central zone. 1: Fractures; 2: faults with indication of the sinking block; 3: overthrust; 4: fracture (supposed); 5: river; 6: strike and dip.

and northern areas of the basin (Fig. 1) caused vertical aggradation of Neogene fluvial and lacustrine deposits until the end of the Neogene when the whole basin became exorheic. We have differentiated five tectonosedimentary units (TSU, *sensu* Megias, 1982 and Pardo *et al.*, 1989) of basinal extent separated by unconformities or breaks in the sedimentary record (Figs. 2 and 3).

In general, each of these TSUs consists of alluvial-fan deposits in areas close to the active north and east margins, and fluvial deposits along the west margin. At that time, Paleogene arkoses formed the southern margin along the Honrubia–Pradales Range, which constituted a relatively passive area as suggested by the scarce development of alluvial deposits.

All these systems converge in the lower, subsiding areas of the basin (Fig. 2) occupied by the carbonate–evaporite lacustrine systems studied in this paper. There is an abundant literature concerning these deposits (e.g. Hernández-Pacheco, 1915; Royo Gómez, 1926; San Miguel de la Cámara, 1946; García del Cura, 1974; Ordóñez *et al.*, 1980; Ordóñez *et al.*, 1981; Portero *et al.*, 1982;

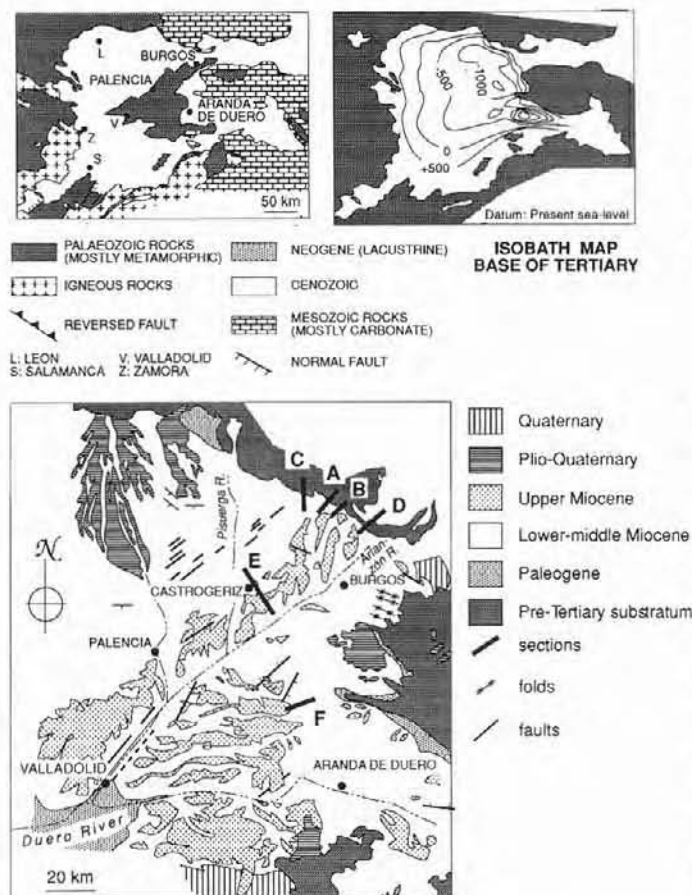


Fig. 2. Lacustrine Neogene deposits in the Duero Basin. A to F refer to cross-sections shown on Fig. 4.

Armenteros, 1986; Mediavilla & Dabrio, 1986, 1988, 1989a, 1989b; Corrochano & Armenteros, 1989; Pineda, in press; Pineda & Arce, in press; Mediavilla & Picart, in press; Piles & Picart, in press; López Olmedo & Enrile, in press; Nestares & Wouters, in press).

TSU 1

This reaches a maximum visible thickness of 50 m to the north of the study area (Fig. 3). Here it dips to the south-west. Near the Cantabrian and Iberian ranges it consists of alluvial gravels, sands and alluvial muds that rest unconformably upon Mesozoic and Paleogene deposits (Pineda & Arce, in press), (Fig. 4A). These coarse-grained sediments change to lacustrine carbonates and evaporites towards the south-west and north-east.

Lacustrine sediments crop out discontinuously in a NE-SW fringe parallel to the Pisuerga and Arlanzón river valleys. Maximum thicknesses are measured east of these rivers where evaporitic deposits (dolostones, microlenticular gypsum and gypsarenites) are best represented. There are also paludal fringes with carbonate sedimentation in positions laterally equivalent to these saline lakes (Fig. 8A).

As a whole, lacustrine sediments onlap Paleogene sediments in the southern margin (Fig. 5) and Mesozoic deposits of the Cantabrian Range in the north (Fig. 4B). Deposits of TSU 1 form an expansive and shallowing-upwards sequence topped by a major karstification profile (Pineda & Arce, in press). The deposition of TSU 1 records an important tectonic reactivation (basal unconformity) and the progressive infill of the basin under a delayed diastrophic regime.

TSU 2

This rests disconformably upon TSU 1 and covers the greatest area (Figs. 3, 4B and 4C). It crops out in the central Duero Basin with a maximum thickness of 60 m.

Near the margins of the basin, TSU 2 consists of coarse-grained siliciclastic sediments (conglomerate, sand, mud) of alluvial-fan and proximal fluvial systems flowing from source areas located to the north, north-east and east. These deposits fine out to more distal fluvial systems in the south. In the Valladolid-Palencia area, the siliciclastic sediments change to lacustrine limestones, dolostones and marls. Probably, these were formed in shallow lakes surrounded by paludal or swampy fringes (Fig. 8B). In the pattern suggested, fluvial systems flowed to topographically lower areas supposed to lie somewhere to the west of the central areas. However, there are no lacustrine Neogene deposits in these areas and we suggest that these fluvial systems drained outside the basin. The vertical stacking of the siliciclastic sediments is explained by a high rate of subsidence in the basin (Fig. 6).

Deposits of TSU 2 represent the progradation of fluvial over lacustrine facies with a coarsening-upwards trend that is thought to record tectonic movements in both the source areas and the basin. Mediavilla & Dabrio (1989) and Pineda & Arce, (in press) showed that NNW-SSE and WNW-ESE faults affected the sediments of TSU 2 along the northern margin (Fig. 4D). In the central areas there are fractures with block tilting, and also layers with palaeoseismites (Baena *et al.*, in press). The fractures observed at the surface are not really important, but they reflect the reactivation of the older, deeper Pisuerga scissors fault that lowered the NW block to the north-east and the SE block to the south-west, as demonstrated by careful thickness measurements.

In the central areas of the basin the unit is topped by dark layers of clay and limestone, interpreted as fluvio-paludal deposits. In other places these layers are paleosoils (Portero & del Olmo, 1982a, b, c; Mediavilla & Dabrio, 1986). These sediments form a continuous layer, of regional extent, considered as a marker level that indicates a sedimentary hiatus.

TSU 3

This unit rests unconformably upon TSU 2, and it onlaps the Mesozoic and Paleogene deposits of the northern and southern margins respectively (Figs. 4D and 5). The thickness is 25–45 m; the maximum thicknesses occur NE and SW of the Pisuerga River (Fig. 7). To the north-east there is a zone of subsidence with two maxima

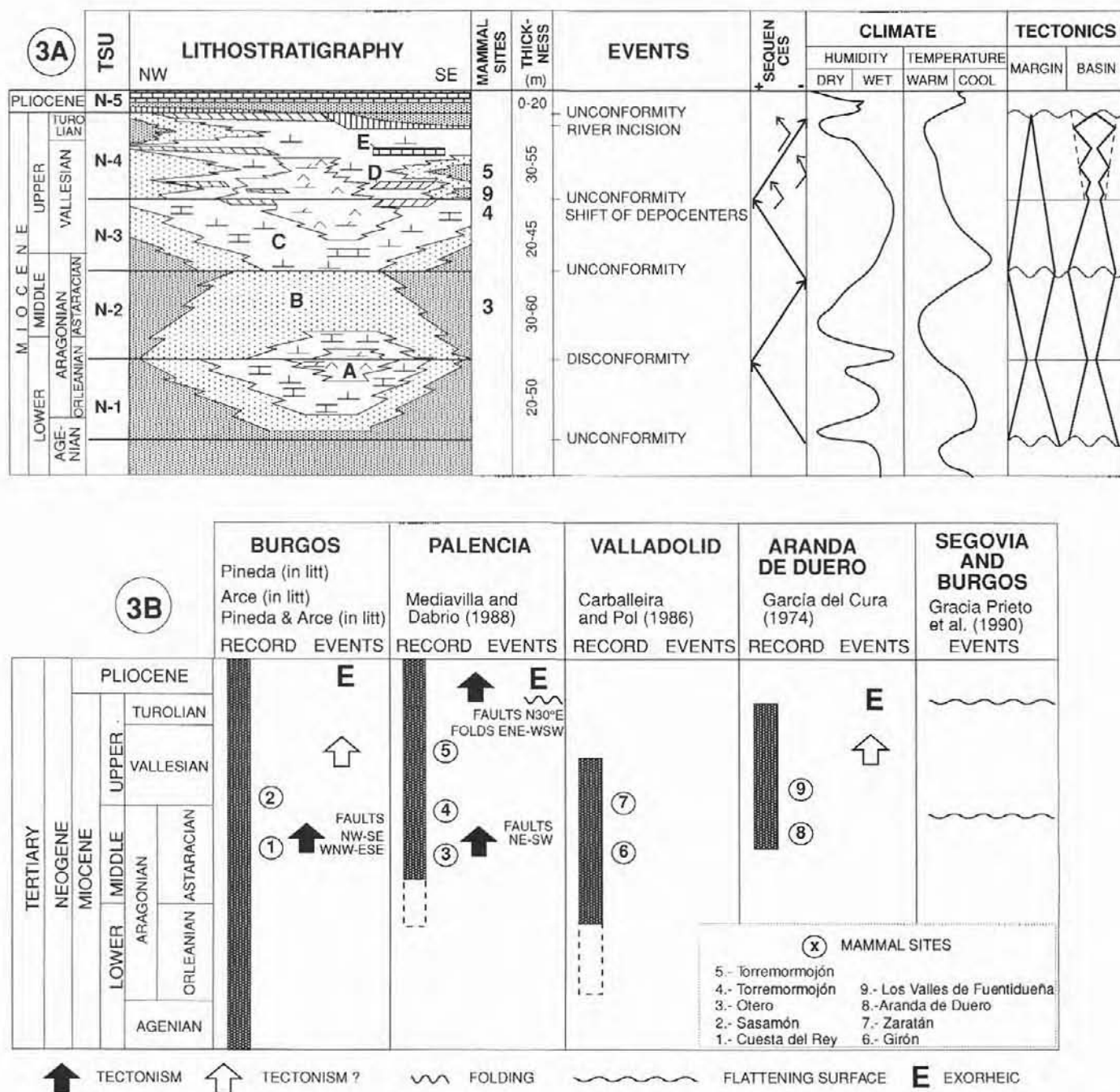


Fig. 3. Stratigraphic framework of the Neogene deposits of the Duero Basin, climatic and tectonic variations. Climatic curve after Lopez Martinez *et al.* (1985). Classic denominations: A, Facies Dueñas (Portero & Del Olmo, 1982); B, Tierra de Campos; C, Cuestas (Hernández Pacheco, 1915); D, Páramo 1; E, Páramo 2 (San Miguel de la Cámara, 1946). B, Sedimentary record, tectonic events and mammal sites in the Duero Basin. TSU – tectonosedimentary units.

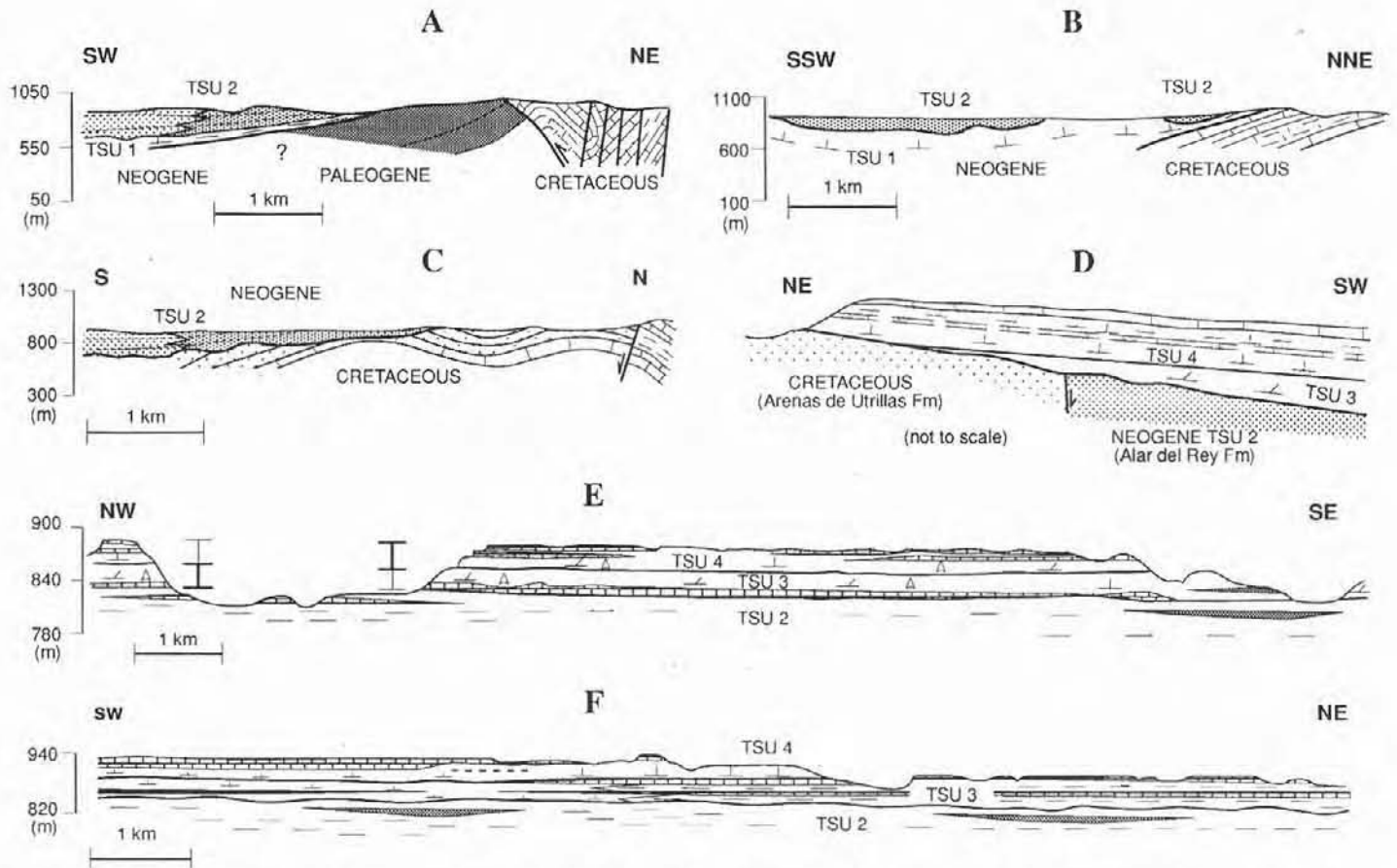


Fig. 4. Geologic cross-sections to show lateral relationships and changes of facies and thickness in the Neogene TSU of the Duero Basin. Location of sections indicated in Fig. 2. A, B, C and D: after Pineda (in press); E: after Pavón *et al.*, (in press); F: after López Olmedo *et al.*, (in press).

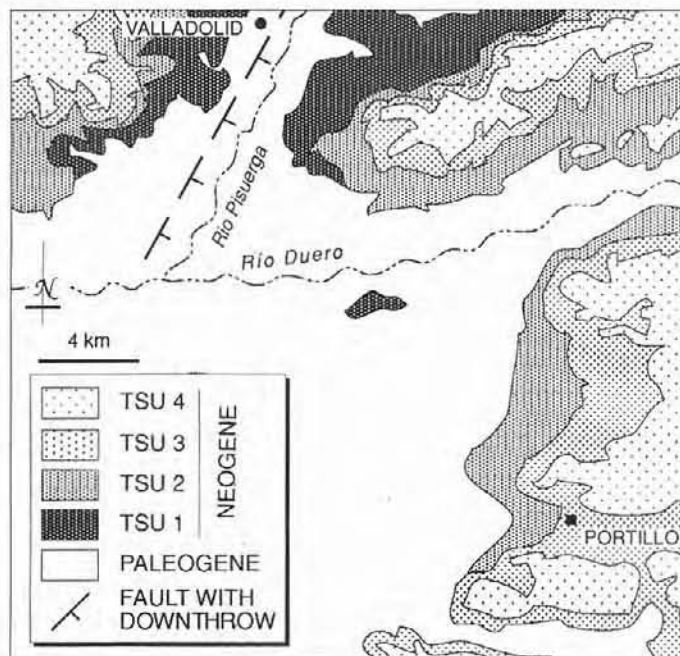


Fig. 5. Onlap of Neogene TSUs upon the Paleogene substratum in the area of Valladolid and Portillo. Modified from Portero and Del Olmo (1982), and Del Olmo and Portero (1982).

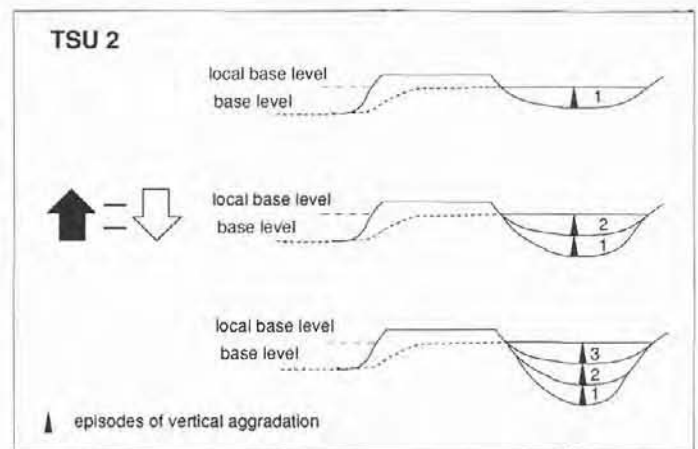


Fig. 6. Coeval dissection and vertical aggradation during the deposition of TSU 2 in central and south-western Duero Basin.

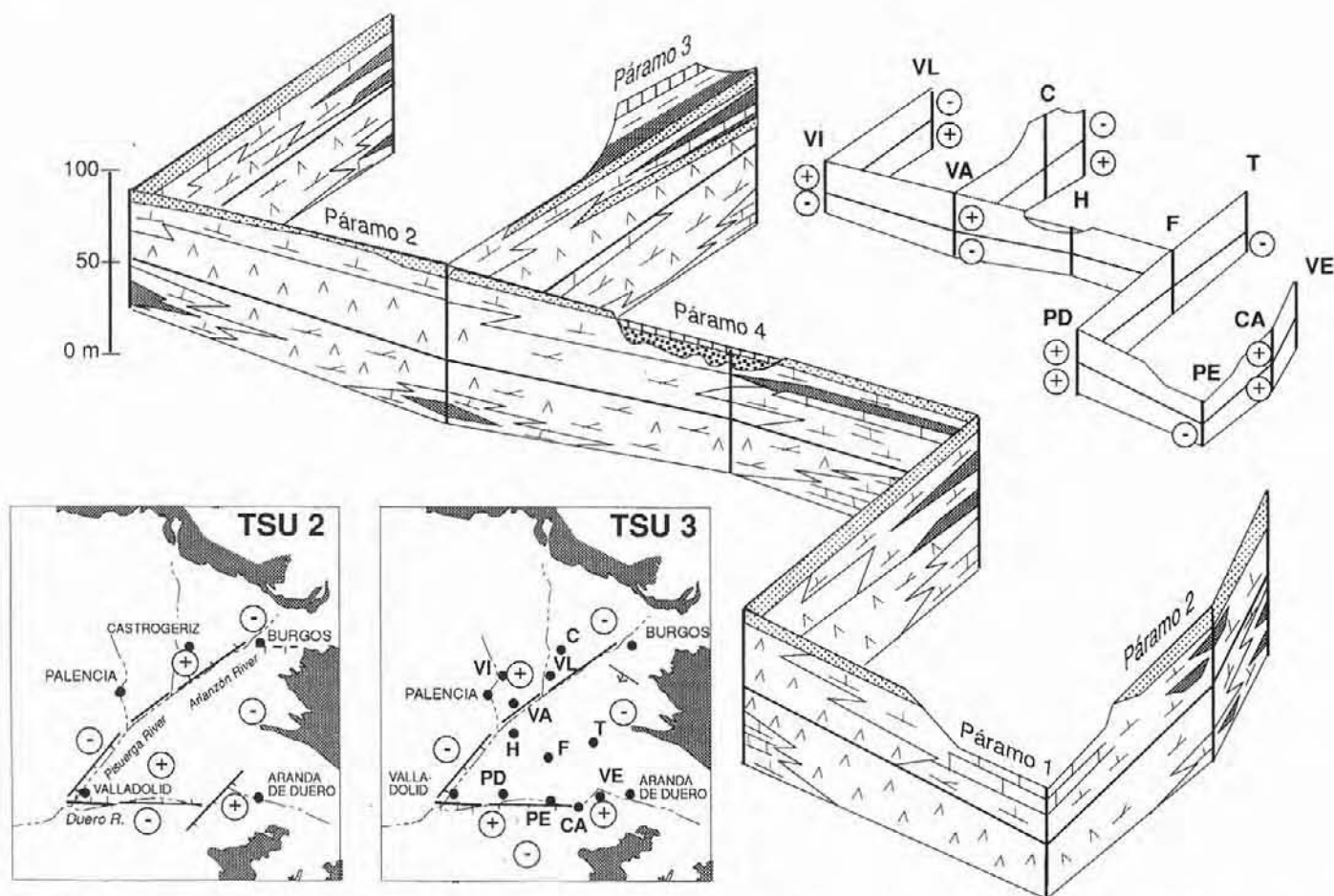


Fig. 7. Correlation panel for Neogene deposits in central Duero Basin. Same key as Figure 8 with the addition of: VL: Valbuena; VI: Villajimena; VA: Valdeolmillos; VE: Valdezate; H: Hontoria; F: Fombellido; T: Tórtoles de Esgueva; PD: Peñalba de Duero; PE: Peñañel; CA: Castrillo de Duero. (+) maximum thickness (subsidence) and (-) minimum thickness (subsidence) for lacustrine deposits. Location of sections indicated in palaeogeographic maps (compare with Fig. 1 for scale).

(Fig. 4E). To the south-east, the areas of maximum subsidence coincide with the E–W direction of the Duero River.

TSU 3 records one of the events of major lacustrine expansion and displacement of the fluvial systems towards the north-east border and towards the west.

The lacustrine systems include several subenvironments. In the shallow marginal areas (Figs. 4F and 7) sand to mud units related to the development of alluvial systems alternate with episodes of organic clays or paludal fossiliferous limestones.

Towards the central areas, far away from alluvial influence, chemical sedimentation increased. Facies associations are mainly of the carbonate–evaporite type (limestones, dolostones, primary microlenticular gypsum or gypsarenites with ripple cross-lamination). In some places there are also lenticular sand and mud bodies of deltaic origin.

The areal distribution of subenvironments (Fig. 8C, D) is governed by: 1. the existence of topographically lower, more strongly subsiding, areas controlled by fractures, which became depo-

centres; and 2. the supply of fresh water and siliciclastic sediments from source areas located to the north-west, north-east and south-east.

The deposits of TSU 3 generally form a shallowing-upwards sequence that reflects the expanding character of this unit (carbonate–evaporite deposits increasingly dominate upwards). This sequence records basin infill with a decreasing diastrophic regime.

The top of the unit is marked by a change in the sedimentary polarity, a displacement of the areas of maximum subsidence and depocentres (Fig. 7), and progradation of carbonate marginal lacustrine facies towards the central areas of lakes and widespread pedogenesis.

The paleosol formation does not necessarily imply an anomalous event. Periodic desiccation could have been a common feature. We assume that it was a basin-wide feature because of two facts: its occurrence in all the measured stratigraphic sections (despite the diversity of sedimentary environments involved), and the significant change in physical and chemical conditions of the basin,

environmental distribution and sedimentary processes detected just above this layer. Accordingly, we consider that this pedogenic episode indicates an extensive sedimentary discontinuity.

TSU 4

The thickness of TSU 4 is 35 to 55 m (Fig. 3) with the maximum located some distance to the south-east of the areas with thickest TSU 3 (Fig. 7). TSU 4 is a complex unit composed of three sedimentary cycles each recording a progradation of alluvial upon lacustrine deposits, later expansion of lacustrine facies and final progradation of carbonate marginal facies to the central parts of the lacustrine areas.

The facies architecture in the first two cycles is similar to TSU 3, although there was a shift of depocentres between these units, producing variations in the areal distribution of sedimentary environments (Fig. 8D). As in TSU 3, the facies pattern was controlled by: 1. location of fresh water and sediment supply that, by the end of the second, upper cycle, prevented the deposition of evaporitic facies; and 2. the existence of fault-related, subsiding areas that became depocentres.

The third cycle shows a similar pattern but there was no deposition of evaporites due to dilution of the lacustrine waters. At the top of this cycle, and in stratigraphic positions equivalent to the development of the lacustrine systems, there are fluvial systems, that drain to the west. The proximity of these systems to the south-western zones of the basin – which were the first to be captured by the exorheic Atlantic fluvial network – suggests that perhaps they were the first Neogene fluvial systems to be captured (Figs. 8E and 9). However, it is difficult to verify the equivalence of these isolated (encased) deposits or to confirm that they belong to the third cycle, because of the lack of connection of outcrops due to erosion.

The prograding character of the alluvial deposits inside each cycle, particularly in the two younger cycles, has been explained by successive tectonic reactivations (tectonic uplifts) of the basin margins (Portero *et al.*, 1982, in press; García del Cura, 1974; Pineda & Arce, in press). However, Pineda & Arce (in press) indicate that in the margins and neighbouring areas there is no evidence of deformation due to these tectonic movements. On the other hand, the sedimentary characteristics of fluvial deposits, even in locations close to the margins, indicate deposition by high-sinuosity fluvial systems in low-gradient zones (Pineda & Arce, in press; Armenteros, 1986). Moreover, the transition from alluvial to lacustrine facies is gradual (Fig. 3).

All these features lead us to conclude that the progradations of the fluvial systems resulted from oscillations of base level, perhaps related to 'pulses' of subsidence in the centre of the basin due to fluctuations of the rate of subsidence.

The unconformable nature of the lower boundary (unconformity recorded as a shift of depocentres with respect to those of the underlying TSU 3) and the upper boundary (unconformity due to a tectonic phase with faulting and folding related to adaptation to subsurface fractures) of this rock unit indicates that these three cycles form a single TSU.

TSU 5

This unit rests discordantly upon TSU 4 but in positions topographically lower than it. It is represented by alluvial-fan deposits (gravels) in the northern and southern borders, whereas in central areas, where it is located E of the Pisuegra River, it consists of 5 to 15 m of fluvial conglomerates changing vertically to floodplain muds, pedogenic crusts and paludal carbonates.

This TSU was previously interpreted as part of the basin infill (Mediavilla & Dabrio, 1989), but recent research (Mediavilla *et al.*, in press) has related it to basin emptying as the first terrace of this area.

Controls of sedimentation

Tectonics

The main faults active from the Neogene to the Present reflect Late Hercynian basement fractures that were reactivated, faulting the surface, modifying landscapes, and creating and modifying the previously established areas of subsidence.

The Neogene sedimentary record of the Duero Basin illustrates the relationships of tectonics and sedimentation. Tectonics controlled the sedimentation of all TSUs in different ways in the various areas, as recorded in the units described. Increase of activity in the margins (TSU 2) produced retraction of lacustrine environments, whereas decreasing activity favoured expansion of lacustrine deposits (TSUs 1, 2, 4). During deposition of unit TSU 4 there was a hybrid pattern with progradation of fluvial systems and expansion of lacustrine deposits. This was a result of accelerated diastrophic activity in the central areas (subsidence) that promoted progradation of alluvial systems but decreasing activity in the margins that allowed expansion units and covering of marginal areas.

Tectonics also influenced sedimentation by modifying paleogeographies, creating and moving the low areas that focused the drainage pattern. These modifications of the geometry of the basin, and of the areas of sediment and fresh-water supply produced a diversity of facies patterns in the sedimentary record of the basin.

Climate

Evaporites are one of the most popular criteria used in interior basins as climatic indicators.

Analysis of climatic variations during the Miocene (Fig. 3) shows that deposition of saline materials occurred both in dry periods (TSUs 1, 2) and humid periods (TSUs 3, 4). It is noteworthy that maximum development occurred particularly in humid periods. According to this, it seems clear that climate was not a determining factor for the generation of evaporites. In our opinion, the disappearance of saline lakes cannot be related to a particular climatic evolution because, in the Duero Basin, the end of evaporite deposition coincided with a climatic trend to more arid conditions (TSU 4). However, climate was a very important factor determining the amount of water that reached the basin and, eventually, also the

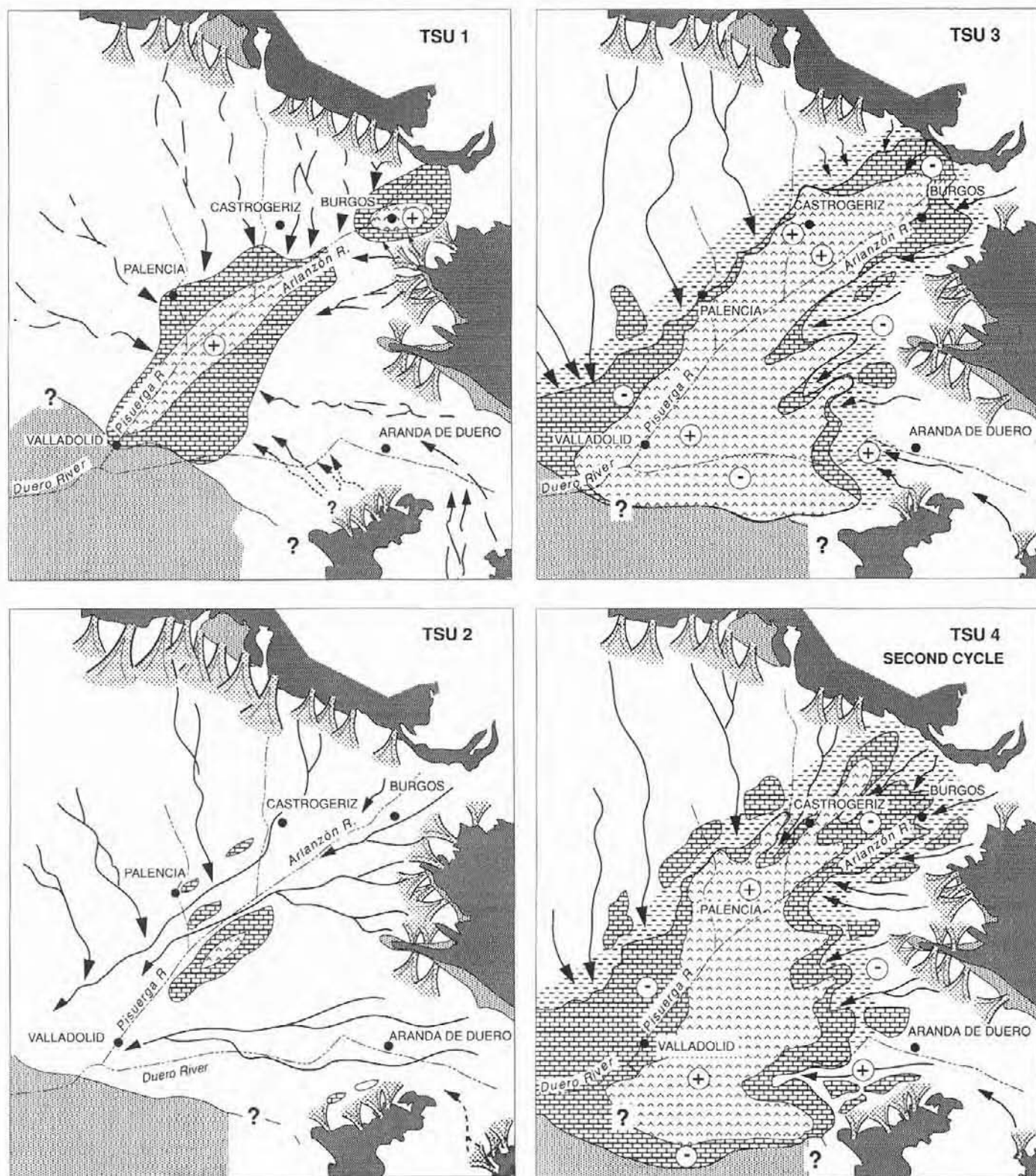


Fig. 8. Palaeogeographic maps for the Neogene TSU in the Duero Basin. Symbols as in Fig. 7. The areas with alluvial fans in exorheic regime are mapped with the present morphology in plan.

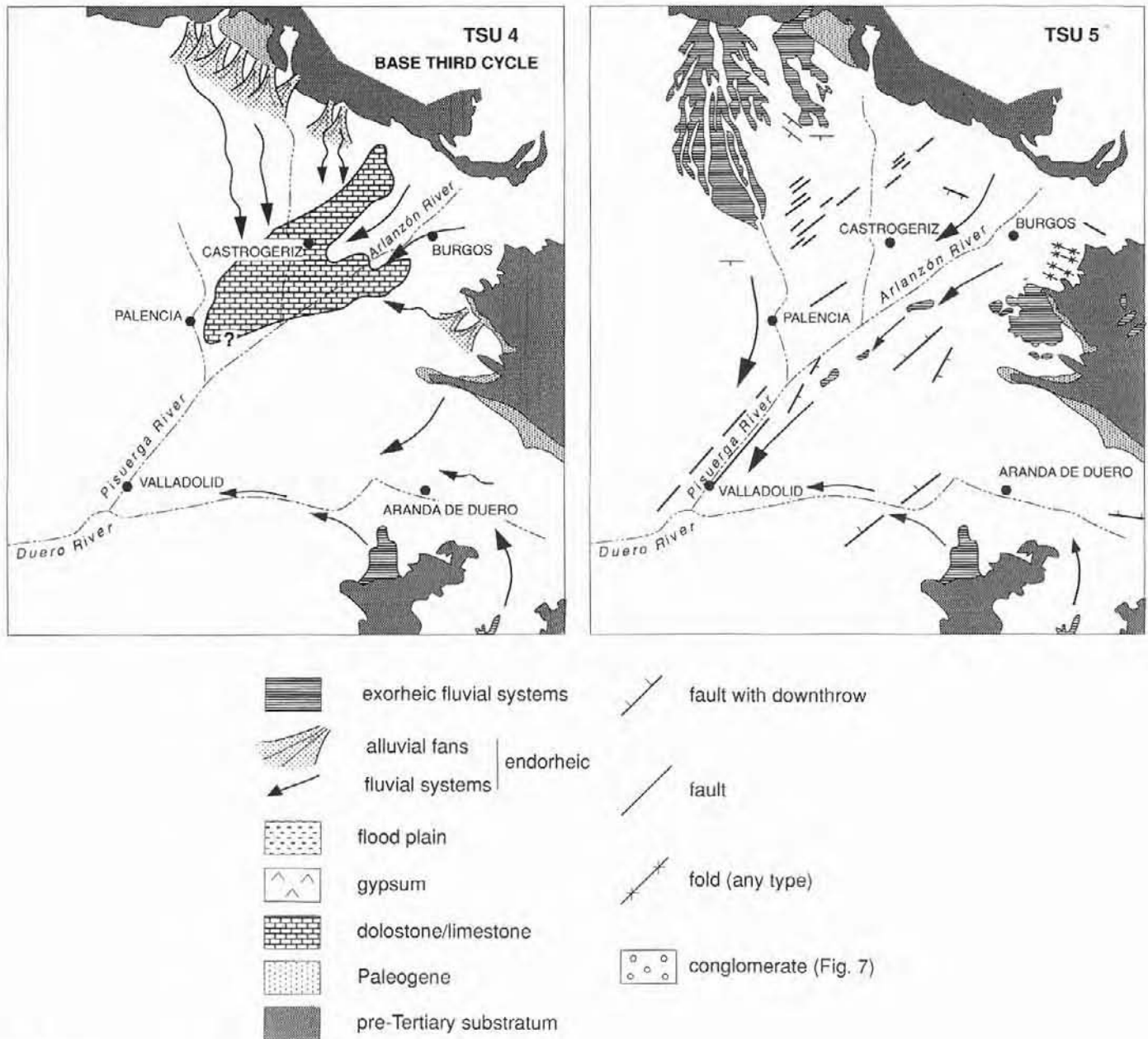
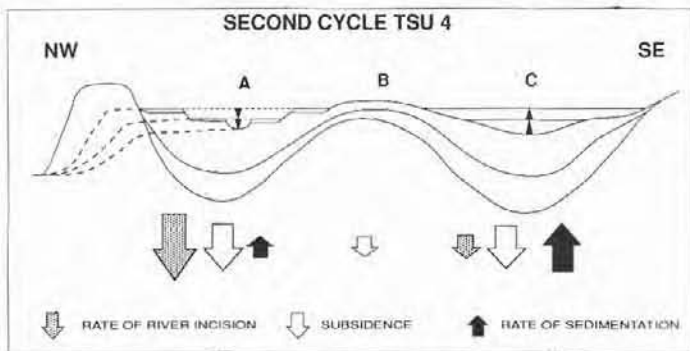
Fig. 8. *cont.*

Fig. 9. Schematic ideal cross-section in the south-eastern Duero Basin during the sedimentation of the second cycle of TSU 4, with coeval endorheic filling and exorheic regime. The variables subsidence, rate of sedimentation, and rate of river incision are mutually related.

extent of lacustrine systems. The extent of lacustrine deposits, particularly evaporites, during TSU 3 (Fig. 8A, C) is greater than during TSU 1. Although TSU 1 and 3 were influenced by greater diastrophism, TSU 3 coincided with a period of humid climate.

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