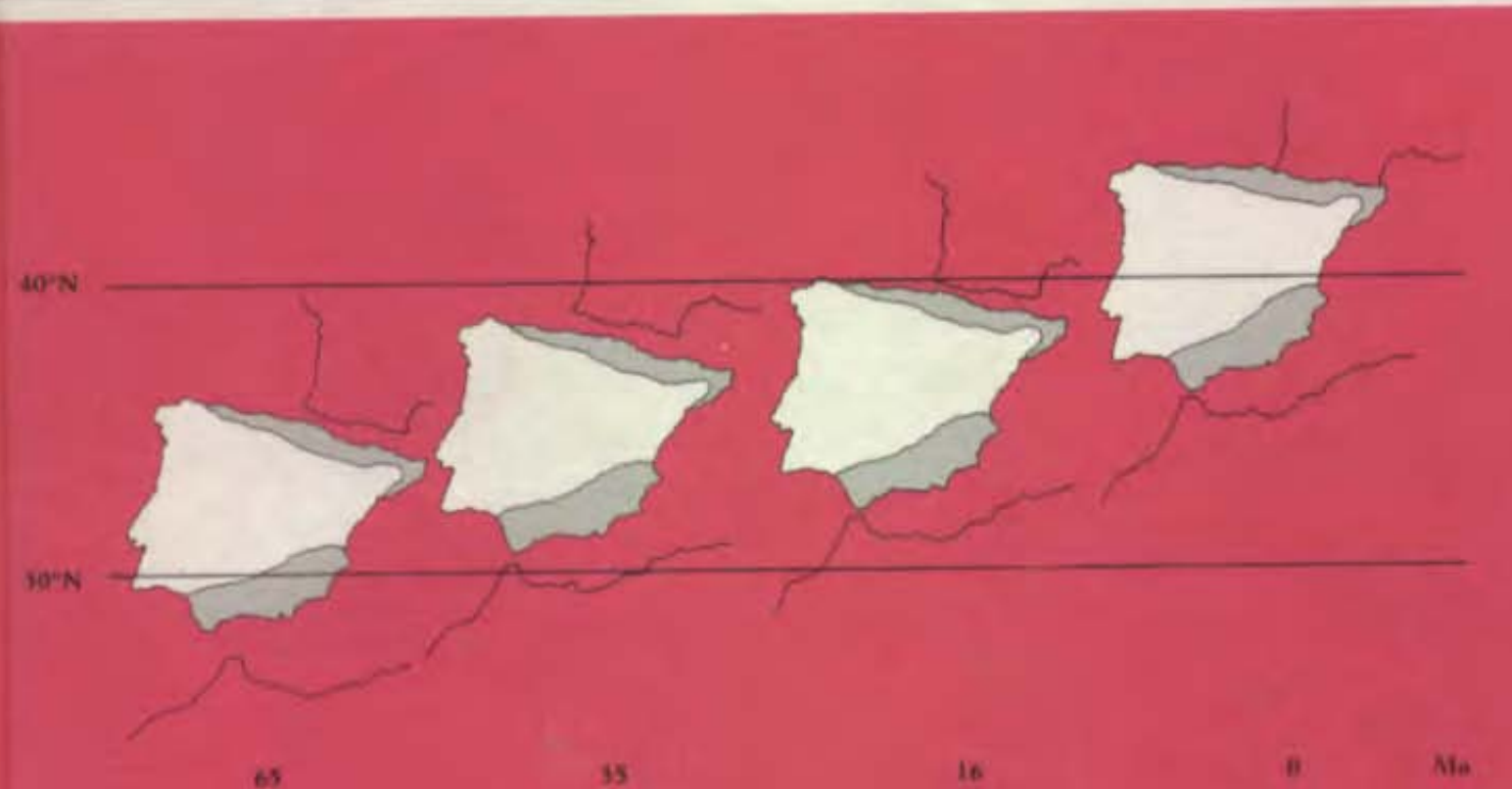


Tertiary basins of Spain the stratigraphic record of crustal kinematics

Edited by

PETER F. FRIEND AND CRISTINO J. DABRIO

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W1 The Duero Basin: a general overview

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

Abstract

The Duero basin occupies a large area in the north-west of the Iberian Peninsula. It has an approximately quadrangular shape, and three of its four corners are the sites of distinctive sub-basins that extend outwards from the main basin. The different margins of the sub-basins and the main basin tend to have distinctive histories of tectonic and sedimentary evolution.

Introduction

The Duero Basin is the largest Cenozoic basin in Spain with a surface area of almost 50 000 km². It occupies the major part of the north-west Iberian Peninsula. High-relief mountains composed of igneous and metamorphic rocks of Paleozoic age (mainly to the south and west) and siliciclastic and carbonate rocks of Mesozoic age (mainly to the east) bound the basin (Fig. 1). These borders formed during the Alpine Orogeny and played an important role in the geodynamic evolution of the basin.

The roughly quadrangular basin extends into three relatively narrow basins protruding near the corners (Fig. 1).

- The Ciudad Rodrigo Basin, in the south-western corner, is a half-graben oriented NE-SW that penetrates south-westerly into the Hercynic Massif. Its sedimentary record consists mainly of Paleogene deposits, although no Early Paleogene deposits have been found so far.
- The Almazán Basin is a complex area that extends to the east between the Iberian Range and the Central System. It was filled by siliciclastic and carbonate sediments, along with some rare evaporites, of Paleogene and Neogene age.
- La Bureba Corridor, in the north-eastern corner, is a narrow basin separating the Cantabrian Mountains from the Iberian Range. This Corridor acts as a linking area between the Ebro and Duero basins.

The Alpine structure of the Duero Basin

The Late-Hercynian structure of north-western Spain strongly influenced the structure of the Duero Basin. The main structural lineaments of the basement reacted under the new tectonic conditions imposed by the Alpine Orogeny, but new fault lines also appeared. However, the borders of the basin tended to evolve independently, and this fact is clear in the sedimentary record of the Duero Basin. It is necessary therefore to deal, at least briefly, with the structural features of the basin borders before describing the sedimentary record.

The present northern boundary consists of low-angle thrusts (a more detailed description can be seen in Chapter W5). These thrusts moved several kilometres towards the south, over the Duero Basin fill. They must be backthrust related to the subduction zone further north, where the Cantabrian Sea crust moves under the Iberian Plate (Boillot, 1984; Boillot & Malod, 1988). Sediments, ranging from Upper Cretaceous (Garumnian facies) to Oligocene, occur below these large thrusts. Neogene sediments onlap this structure.

The eastern border is a tectonic massif bounded by reverse faults with small horizontal displacements. Sediments affected by these faults range from Cretaceous to Oligocene in age. As in the northern border, Neogene sediments onlap the earlier structures.

Most of the southern boundary consists of reverse faults that affect Paleogene and Mesozoic sediments. Fault surfaces are relatively vertical in outcrop, but the fault dips decrease with depth. Neogene sediments usually onlap this border, but in some places they are affected by normal faults. There are also strike-slip faults along this border; their magnitude increases to the west.

The western border has mainly been passive, but some north to north-east trending faults acted during the Tertiary, modifying the disposition of the sediments.

The tectonic record of the internal parts of the Duero Basin is much poorer because Paleogene sediments do not crop out; thus, the record is limited to Neogene times. Here, the movements of basement faults decrease upwards and are hardly apparent at the surface. The only effect of the largest faults was to produce differential subsidence or to induce families of small faults.

Three major tectonic periods (Fig. 2) can be recognized in the

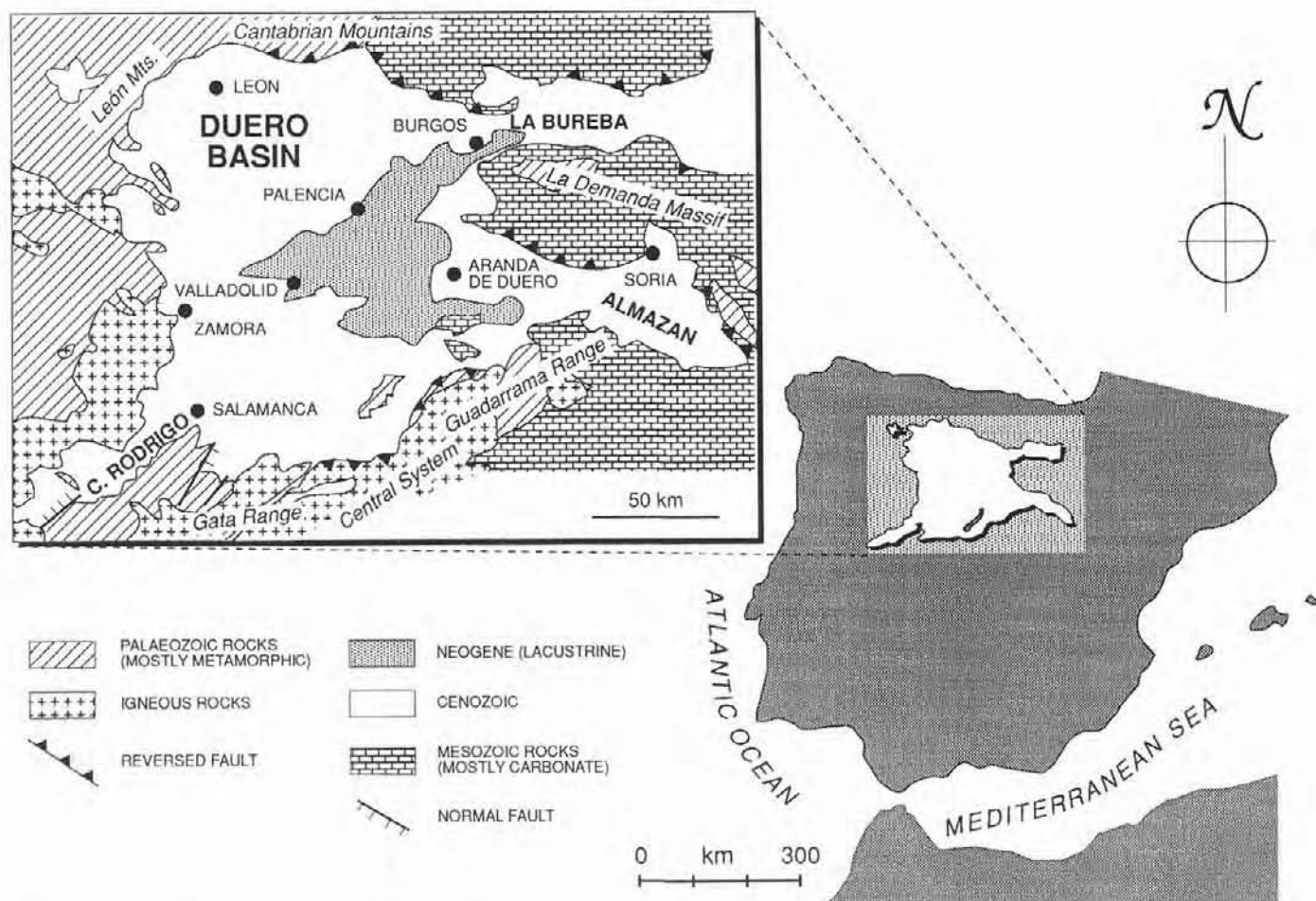


Fig. 1. Location map of the Duero Basin in the Iberian Peninsula.

Duero Basin. Activity during Upper Cretaceous to Paleocene times relates to the Mesozoic extensional regime. Activity during the Eocene and Oligocene reflects the compressional regime caused in Iberia by convergence of tectonic plates. The period from Miocene to Recent represents a new extensional stage with adjustments of the relief.

The sedimentary record of the Duero Basin

The stratigraphic framework of the Duero Basin has been studied and described since the nineteenth century (Botella, 1877, 1884; Dantin Cereceda, 1912; Ezquerro, 1837, 1845; among many others). The ideas of one of them, Eduardo Hernández-Pacheco, still remain the basis of present-day stratigraphical research. In the first third of the twentieth century, Hernández-Pacheco (1914, 1915, 1921, 1930) studied the stratigraphy, 'sedimentology' (of a rudimentary sort, but including the first description and interpretation of fossil point bar deposits published in the world), paleontology and tectonics of a large part of the basin.

Most of the sedimentary fill of the basin was deposited in

terrestrial sedimentary environments. A great variety of lithofacies crop out.

Siliciclastic sediments are widespread. They range from gravels to muds, with a well-marked dependence on their source areas. The composition of sediments derived from the north and east is lithic, whereas those coming from the south and southwest are arkosic to lithic.

Carbonates are also well represented, but their largest volumes occur near the present basin centre.

Evaporites occur only in the eastern half of the basin, and mainly towards the centre and north-east.

One of the more remarkable results of previous works was the generation of an abundant nomenclature, rich in local names (for a general overview the reader is referred to Portero *et al.*, 1982, and Jiménez *et al.*, 1983). As a consequence, attempts to establish valid general stratigraphical frameworks for the whole basin were only partial, because it is very difficult to trace particular stratigraphical units across the basin. In general, the proposed frameworks rested upon lithostratigraphy, with little or no detailed tectonic analysis, and poor understanding of the importance of weathering processes. The resulting basin models showed a bull's-eye facies distribution.

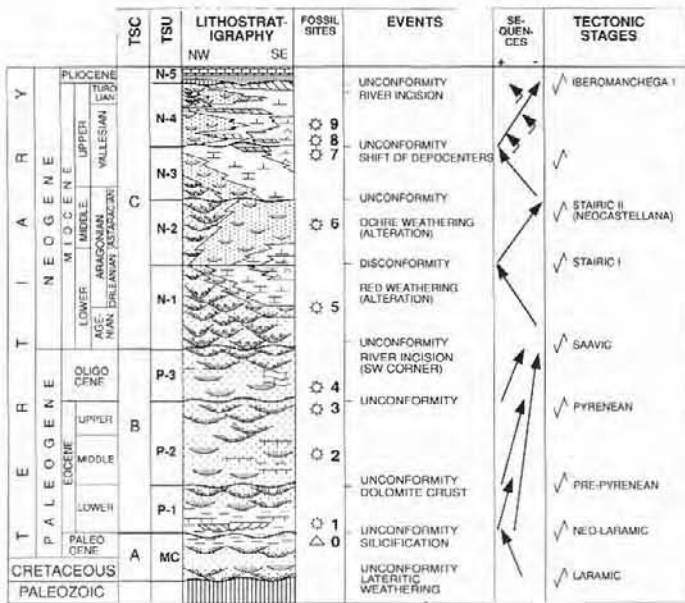


Fig. 2. Tertiary units of Duero Basin. TSC: tectonosedimentary complexes; TSU: tectonosedimentary units (*sensu* Megias, 1982). Fossil sites, 0: Absolute age (Kr/Ar) 58 Ma (Blanco *et al.*, 1982), 1: Sanzoles and Avedillo (Zamora), 2: Teso de la Flecha (Salamanca) and Corrales II (Zamora), 3: Molino del Pico and San Morales (Salamanca), 4: Camino Fuentes and El Molino (Ciudad Rodrigo Basin), 5: El Guijo (Salamanca), 6: Otero (Palencia), 7: Torremormojón (Palencia), 8: Los Valles de Fuentidueña (Segovia), 9: Torremormojón (Palencia). (Modified from Santisteban *et al.*, Chapter W2; Mediavilla *et al.*, Chapter W6).

with alluvial fans along the periphery and lacustrine environments in the centre. These models interpret the Duero Basin as an endorheic basin until Plio-Quaternary times.

A new era of research began, following systematic application of modern approaches to basin analyses. These studies include detailed work on tectonics, sedimentology, geomorphology and weathering profiles (García del Cura, 1974; Ordóñez *et al.*, 1980, 1981; Armenteros, 1986; Pozo, 1987; Martín-Serrano, 1988a, b, 1989, 1991; Mediavilla, 1985, 1986–87; Mediavilla & Dabrio, 1986, 1988; Mediavilla *et al.*, Chapter W6; Santisteban *et al.*, 1991a, 1991b, (Chapters W2 and W3; Bond, Chapter W4).

From a general point of view, we have divided the sedimentary record of the Duero Basin into three tectonosedimentary complexes (TSCs), composed, in their turn, of several tectonosedimentary units (TSUs *sensu* Megias, 1982). Each one of these complexes relates to a stage of basin evolution (Figs. 2 and 3):

TSC A, also referred to as the 'preorogenic complex', is of Upper Cretaceous to Paleocene age. This unit consists of siliciclastic, carbonate, and evaporitic deposits arranged in a fining-upwards (FU) sequence. Outcrops occur only in some areas along the margins of the basin, but they are not continuous laterally due to intense faulting. There are also outcrops in down-thrown fault blocks of the mountains surrounding the basin (Central System, Galicia basins; see Chapters W7 and W9). The deposits of TSC A usually occur in stratigraphical continuity with the Upper Creta-

ceous in the north, east and south-east borders. In other places (west and south-west borders) they rest unconformably upon a thick lateritic weathering profile that affects the Paleozoic basement. In these places, the rocks forming TSC A underwent a strong episode of silicification that increased towards the top. This TSC is interpreted as having been deposited in environments ranging from terrestrial (towards the west) to marine (towards the east): this pattern still reflects the Late Mesozoic palaeogeography.

TSC B, also referred to as the 'synorogenic complex', is Eocene to Oligocene in age. It consists of mainly siliciclastic sediments, along with scarce carbonates (except in the Almazán Basin where carbonates reach considerable thicknesses), which form a generally coarsening-upwards (CU) sequence. During this time preservation of weathering profiles was very poor. The deposits of TSC B form a fringe near the borders of the basin, where they rest unconformably upon both rocks of the TSC A and the pre-Tertiary basement. TSC B splits into several TSUs bounded by unconformities (an example is the S and W borders in Fig. 2). Some of these unconformities are of the progressive type (*sensu* Riba, 1976a, b), also referred to as cumulative wedging systems, related to movements of reverse faults or thrusts along the borders of the basin. Most of the deposits of TSC B were laid down in terrestrial environments (alluvial fan, fluvial); marine deposits occur only in the basin of Villarcayo, in the north-east corner (Montes *et al.*, 1989).

TSC C, also referred to as the 'postorogenic complex' (not implying lack of tectonic activity), is of Miocene to Recent age. It consists of siliciclastic, carbonate and evaporite deposits that form a fining-upwards (FU) sequence. It is best represented in the central and north-western parts of the basin, covering the previous deposits. TSC C consists of several TSUs (Fig. 2) which progressively onlap previous units and the borders. These rocks formed in terrestrial environments (alluvial fan, fluvial and lacustrine), which filled a basin with a shape roughly similar to the present Duero basin. Tectonic stability favoured the development of weathering profiles during the deposition of TSC C, both in the basin margins and the borders (red and ochre Mediterranean soils).

Gravel sheets (the so-called *raña*, plural *rañas*) covered large areas of the Hesperic Massif, the borders of the basin, and large areas of the basin. Many authors have considered these deposits as having time significance, but we must stress that they lack specific chronological meaning because 'raña' has formed in the basin at a number of different times since the Oligocene–Miocene, following episodes of fluvial incision (Martín Serrano, 1991).

Cenozoic evolution of the Duero Basin

During Mesozoic times, the area occupied at present by the Duero Basin was a marine and terrestrial area, open to the north and east, under an extensional regime. To the west and south, the neighbouring, emergent Hesperic Massif supplied sediments to these basins. The emergent Hesperic Massif underwent intense weathering under a tropical climate that generated lateritic profiles, tens of metres deep.

At the end of the Paleocene the compressional phase of the

TSC	AGE	NORTHERN BORDER	EASTERN BORDER		ALMAZAN BASIN		SOUTHERN BORDER		S.W. DUERO BASIN	BASIN CENTER					
			2	3	4	5	6	7							
C	NEOGENE	Pliocene-Vallesian	second cycle	Upper Nebreda, Retuerta, and Cueva Burgos systems	Jalón Group	TSU T5	Ochre Series	Ochre Series	TSU N5 TSU N4 TSU N3 TSU N2						
		Astaracian								Modino, Quintana de la Peña, Puente Almuhey, Polygenic Aviñante, Upper Cuevas and Upper Candanedo systems	TSU T6	TSU T4	Red Series	Red Series	TSU N1
		Agenian-Orleanian													
B	PALEOGENE	Oligocene	first cycle	Lower Nebreda, and Lower Covarrubias systems Rio Arlanza system	Henar Group	TSU T2	Polymictic sediments	Red Series	TSU P3 TSU P2 TSU P1						
		Upper Eocene								Upper Vegaquemada complex	TSU T4	TSU T3	TSU T1		
		Middle Eocene												TSU T2	?
		Lower Eocene													
A		Paleocene	Lower Vegaquemada complex	TSU T1		Siliciclastic sediments	Siliceous gravels, sands, and clays	TSU MC							
		Cretaceous													

Fig. 3. Tentative correlation of units in the Duero Basin resulting from the reinterpretation of data. 1: Colmenero *et al.*, 1982; García Ramos *et al.*, 1982; 2: Pol & Carballeira, 1982; 3: Pol & Carballeira, 1986; 4: Bond, W4; 5: Armenteros *et al.*, 1989; 6: Del Olmo & Martínez-Salanova, 1989; 7: Martín-Serrano & Del Olmo, 1990; Martín-Serrano, 1988b; 8: Santisteban *et al.*, Chapter W2; 9: Mediavilla *et al.*, Chapter W6.

Alpine Orogeny began causing uplift of the borders of the basin, and retreat of the marine environments towards the east and north-east. This phase induced progradation of alluvial systems towards the basin centre. Progressive uplifting along the margins of the basin caused the deformation of alluvial deposits. Major changes in paleogeography took place, changing from a smooth landscape, with small tectonic-induced highs, to a well-differentiated basin. Tectonic instability at this time prevented good development of weathering profiles. Tectonic movements resulted in the opening of several small basins in the Central System and Galicia, and the basin of Ciudad Rodrigo. All these basins share a similar record of sedimentation and weathering (see Chapters W3, W7 and W9).

The Early Neogene landscape of the basin was approximately similar to the present-day landscape. However, a long-lasting modification then began to take place, when the Atlantic fluvial network captured some of the endorheic fluvial systems in the south-eastern corner of the basin (Chapter W2). The resulting incision of these new exorheic rivers initiated the process of draining the basin and evacuating enormous volumes of sediment to the Atlantic Ocean, as the area connected to the exorheic drainage grew progressively larger.

In the meantime, subsidence related to faulting favoured the continuity of lacustrine deposition in the still endorheic central and north-eastern realms of the basin. Here, marginal alluvial fans fed

fluvial systems connected to central lakes; tectonic stability in the basin (which does not imply absence or lack of tectonism or diastrophism) allowed the development and preservation of thick Mediterranean weathering profiles. The fill of the basin overlapped the eroded borders of the basin.

The coexistence of the ever-growing fluvial network in the south-western areas and the more-or-less restricted lacustrine realms on the opposite side, continued until the drainage of the whole basin was captured. At that point, the whole basin was connected to the Atlantic Ocean base level through the ancestral Duero River, and the last lacustrine environments had disappeared from the basin (see Chapter W6).

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