Palaeogeography, Palaeoclimatology, Palaeoecology 471 (2017) 157–180

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Triassic evaporites of Iberia: Sedimentological and palaeogeographical implications for the western Neotethys evolution during the Middle Triassic–Earliest Jurassic

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ARTICLE INFO

Article history:
Received 8 August 2016
Received in revised form 14 January 2017
Accepted 17 January 2017
Available online 24 January 2017

Keywords:
Evaporites
Sedimentation
Palaeogeography
Triassic
Iberian platform

ABSTRACT

This paper deals with the Middle Triassic-to-earliest Jurassic evaporite sedimentation in the epicontinental, eastern Iberian platform. This deposition occurred under extensional regime during the westwards migration of the Neotethys Ocean at the start of the Pangea break-up. Although attention is focused on the evaporitic episodes recorded in the Epicontinental (Germanic) Triassic of the platform, the evaporite units in the carbonatic Alpine Triassic are also considered. In the Epicontinental Triassic, up to six evaporitic episodes, which alternated with three carbonatic episodes and a siliciclastic one, occurred between the Anisian and the Lower Hettangian. The evaporitic episodes may be divided into two groups. The stratigraphic units of the older group have similar characteristics in salinity and facies, and were formed in chloride-rich, evaporitic mudflats. In the younger group, the salinity and depositional features display considerable differences and the environments evolved from evaporitic mudflats to extensive salterns. The different evolutive trends in the evaporites of the two groups suggest major re-structuration of the platform after the sedimentation of the siliciclastic units of the middle Keuper (Carnian Humide Episode). Progressive marine influence in the assemblage of the six evaporitic episodes is deduced from the changing nature of the evaporites and their host sediment. All the evaporite units accumulated as transgressive and highstand systems tracts. The close relationship between evaporite units and thick accumulation suggests that the structural control played a major role in the sedimentation. In the Alpine Triassic, the presence of evaporites interbedded in the allochthonous carbonate units is documented. Lateral correlation of the evaporite units of the Epicontinental and the Alpine types of Triassic allows us to reconstruct the facies continuum across the original Iberian platform. Such a west-to-east transect illustrates the palaeogeography, structural evolution, and major depositional controls in the platform during the period under study. The deduced evaporitic pattern could be applied to other Triassic platforms which acted as epeiric seaways for the westward advance of the Neotethys.

1. Introduction

The Triassic was a period during which the Earth underwent important structural, sedimentologic, climatic, and biotic changes (Simms et al., 1994). These changes were associated with the break-up of the Pangea supercontinent and the westwards migration of the Neotethys Ocean under extensional (rifting) regime (Ziegler, 1982, 1988). Many of these changes have been documented in different sectors of the western margin of the Neotethys. In this margin, the evolution of the Triassic rifting resulted in the differentiation of three broad, structural regions: the North Atlantic continental-margin basins, the German-British-Paris Basin continental shelf, and the Italian-Carpathian Alps (Simms and Ruffell, 1989).

Areas of predominant siliciclastic, evaporitic, and carbonatic materials occurred in the structural region of the German-British-Paris Basin continental shelf and in its southern parts, i.e. some Triassic basins in south France (the Aquitaine and the Southeastern basins) (Delfaud, 1980) and Spain (the Ebro and the Iberian basins). In this structural region, evaporites formed in inner (proximal) zones of the platforms and also filled some subsident basins during the Middle–Upper Triassic, and carbonates occurred in distal (external) platform positions during the Middle Triassic and especially during the Upper Triassic (Simms and Ruffell, 1989; Stefani et al., 2010). As a whole, the Triassic sedimentation in western-central Europe may be considered as a lateral, eastwards

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http://dx.doi.org/10.1016/j.palaeo.2017.01.025
0031-0182/

gradation from (a) coastal and continental fluvial to playa environments (Keuper facies of the German-British-Paris Basin continental shelf) to (b) carbonate facies bearing evaporites along the Neotethys margin (Alpine facies of the Italian-Carpathian Alps) (Berra et al., 2010). However, the lateral correlation of the Triassic evaporites in the two structural regions is not always well established.

Climate conditions during the Triassic period were predominantly warm, and arid to semiarid (Preto et al., 2010; Sellwood and Valdes, 2006). Nevertheless, some humid phases occurred which markedly affected the sedimentation and biota distribution (Ruffell et al., 2016). These climatic changes were probably due to a variety of factors such as tectonism, which resulted in great palaeogeographic re-structurations of the platforms, or volcanism, which caused modifications in the gas composition of the atmosphere and its mass circulation (Simms et al., 1994; Preto et al., 2010). As regards the biotic changes during the Triassic, this period represents one of the most important episodes of biotic turnovers, with well-documented, massive extinctions. These biotic episodes occurred at the start of the period (Permian–Triassic boundary extinction) and towards its end (Triassic–Jurassic boundary extinction) (Hallam, 1981; Benton, 1986; Clark, 1987). In the middle of the period, however, extinctions of variable intensity such as that of the Carnian (Benton, 1986) also occurred.

In this geodynamic and climatic context, two features may help us to better understand the palaeogeographic and sedimentologic evolution of the platforms in the western margin of the Neotethys Ocean. One is the evaporite record, i.e. the successive episodes of aridity, their variable geographical distribution, and the different rates of evaporite accumulation on the platforms. The other feature concerns the stratigraphic relationships and mutual lateral gradations between the evaporites and the coeval carbonatic units across the platforms.

These two features can be documented in the Iberian platform (the eastern platform adjacent to the emerged Iberian Massif) during the Triassic. On the one hand, numerous evaporitic episodes occurred in the autochthonous, inner zones of the platform, i.e. the continental and transitional facies of the Epicontinental Triassic, showing a wide distribution and considerable sediment thickness. On the other hand, the platform has preserved in its Betic domain (Fig. 1) an assemblage of allochthonous evaporite-bearing carbonate formations, i.e. the Alpine Triassic, which originated in the distalmost zones of the platform. These formations are currently in structural contact with the siliciclastic-evaporitic formations of the inner zones. Such a close juxtaposition of autochthonous and allochthonous evaporite units is uncommon in the Triassic platforms of the western Neotethys. Accordingly, the present paper is focused on the Iberian platform during the Middle–Upper Triassic. The major aim is the comprehensive study of the multiepisodic evaporite record in the Epicontinental Triassic between the Anisian and the Lower Hettangian. Such a prolonged record is rarely found in other coeval platforms in western-central Europe and the circum-Mediterranean area. Another aim is to document in the original platform the evaporitic sedimentation of the Alpine Triassic (Betic Cordillera) and its correlation with that of the Epicontinental Triassic.

The selected example offers fresh insight into the controls over sedimentation in evaporitic platforms, in general. Many observations in the case under study could be applied to the mosaic of structural plates and microplates which evolved under extensional (rifting) regime in the contact band between the European plate in the north and the African plate in the south during the Triassic. Some features in this paper are noteworthy: (1) the most common platform settings of the evaporitic precipitation are characterised; (2) the 3th-order depositional sequences bearing evaporites are commented upon; (3) the climatic, structural, and eustatic controls over this sedimentation are discussed; and (4) the significance of the evaporitic sedimentation in the evolution of the western Neotethys is highlighted. Because this paper is focused on sedimentology and palaeogeography, other important phenomena such as tectonism, diapirism or magmatism which affected these Triassic evaporites are not considered.

2. Evaporite record in the Iberian platform: geological and stratigraphical setting

Evaporites in extensional regime are mainly associated with rifting processes at local or regional scales, or are linked to supercontinent break-up at much broader scales (Warren, 2006). The Late Permian–Late Triassic rifting led (a) to the propagation of the Neotethys rift system towards the west and of the Arctic-North Atlantic rift system towards the south (Preto et al., 2010; Berra et al., 2010; Stefani et al., 2010; Mutti and Weissert, 1995; Rigo et al., 2007; Tomasso et al., 2008), and (b) to the separation of a number of structural plates and microplates (Ziegler, 1982, 1988). One of these plates was Iberia (Manspeizer, 1988; López-Gómez et al., 2002; Sopeña et al., 2009; Salas et al., 2001), whose palaeolatitude during the Triassic and Early Jurassic period was between 25° and 30° N. This subtropical position was associated with long arid to semiarid periods, although this generally dry framework was punctuated by episodes of moister climate (Gaetani et al., 2000; Thierry, 2000; Strampfli et al., 2001).

Several extensional (rifting) systems interacted in the platform of Iberia during this period, resulting in the creation of inner basins or troughs such as the Prebetic–Subbetic, Iberian, Catalan, Ebro, Basque-Cantabrian, and Pyrenean basins (Arche and López-Gómez, 1996) (Fig. 1A). The sedimentary fill of these platform basins continued throughout the Mesozoic. During the Cenozoic, the convergence of the European, African and Iberian plates resulted in the deformation of the Mesozoic basins and their structuration as Alpine ranges (Betic Cordillera; Iberian, Pyrenean, and Catalan ranges) (Vegas and Banda, 1982; Sopeña et al., 1988; Salas et al., 2001) (Fig. 1A).

The Iberian platform has preserved one of the best examples of Triassic marine evaporites. The outcrop assemblage of these evaporites in Spain is excellent (Fig. 1B), and the available subsurface data (deep boreholes and seismic profiles), although not exhaustive, seem to be adequate for an approach to the study of the evaporitic phenomenon as a whole. This record is arranged in six evaporitic episodes, all showing wider regional extent progressively (Ortí, 2004). The stratigraphic units derived from these episodes vary in thickness, from tens of metres to one thousand metres. The mobilisation of the thickest salt deposits in these units during the Alpine cycle resulted in diapiric provinces, which are common in the Pyrenees, the Basque-Cantabrian Zone, and the eastern Betic Cordillera (Serrano and Martínez del Olmo, 1990; Klimowitz et al., 1999; Martínez del Olmo et al., 2015). As regards the marine carbonates of the distal zones of the platform, the dolomitic formations of the Betic Cordillera are grouped into several structural units, each one bearing specific associations with evaporites.

Three types of Triassic successions have been distinguished in the deposits of the Iberian platform on the basis of facies, palaeogeography, and tectonics (Virgili et al., 1977; Sopeña et al., 1988; López-Gómez et al., 1998) (Fig. 1B): Hesperian Triassic, which corresponds to a poorly differentiated assemblage of non-marine siliciclastic materials deposited along the western margin of the Iberian Massif (Stable Meseta); Epicontinental (Germanic-type) Triassic, which represents the classic non-marine to marine trilogy made up of siliciclastics at the base (Buntsandstein facies), carbonates in the middle (Muschelkalk facies), and evaporites at the top (Keuper facies); and Alpine Triassic, which is formed by marine carbonates in allochthonous units. In the Epicontinental Triassic, a distinction is made between sectors with one carbonate Muschelkalk unit (Iberian Triassic) or two (Mediterranean Triassic).

3. Evaporites in the Epicontinental (Germanic-type) Triassic

This section summarises important characteristics of the stratigraphy and regional distribution of the Middle Triassic to the earliest Jurassic evaporites in the Epicontinental (autochthonous) Triassic of the Iberian platform (Fig. 2). The Triassic evaporitic succession in the southern sectors of the Iberian basin (València and La Mancha sectors) is taken as reference for this basin and also for the other basins in the

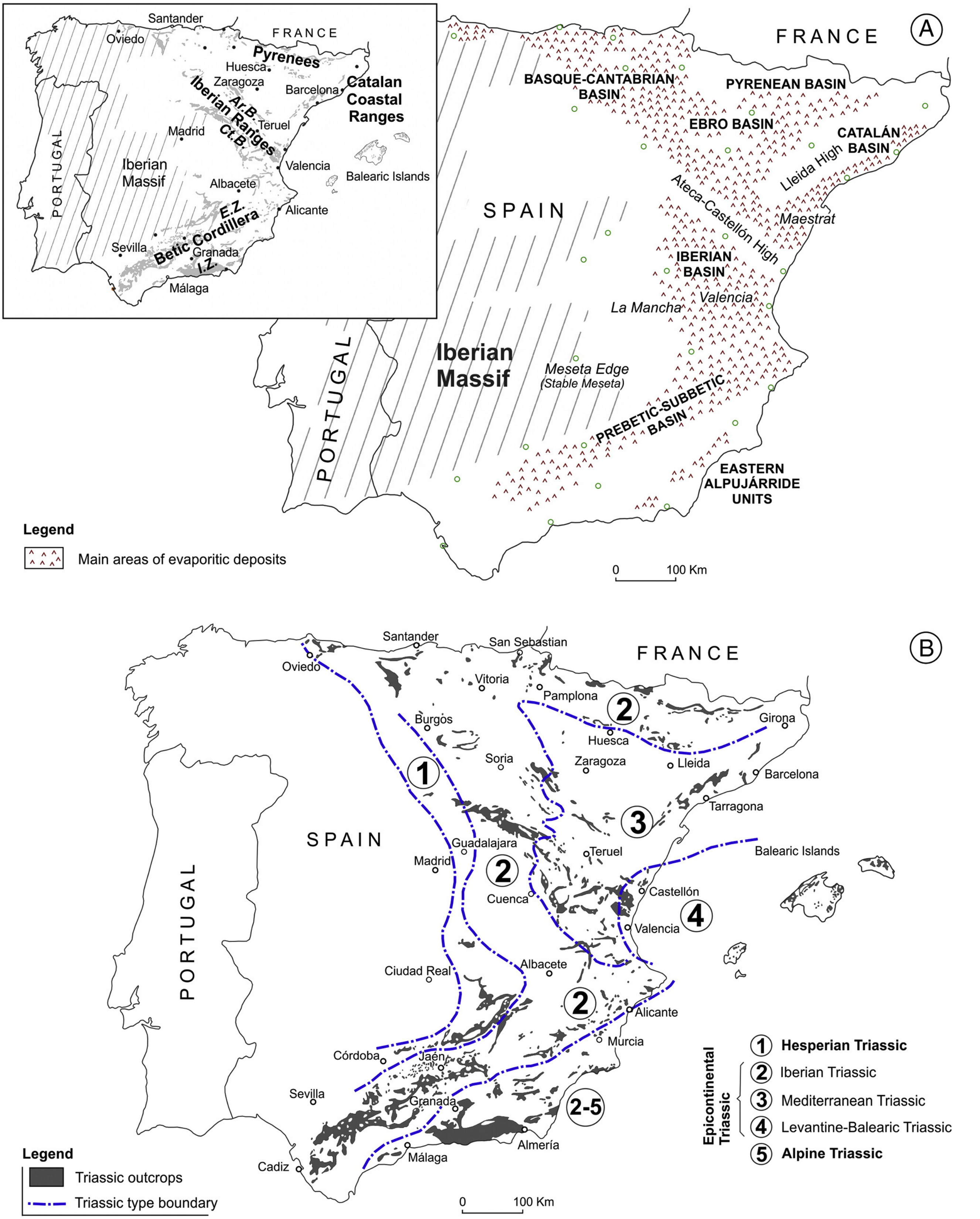


Fig. 1. Location maps in the Iberian Peninsula. (A) Geographic distribution of Triassic platform basins, basin sectors (in italics), paleohighs, and main areas of evaporite deposition in Spain. A location map of the main Alpine ranges is shown (Ar.B., Aragonese Branch of the Iberian Ranges; Ct.B., Castillian Branch; E.Z., External Zones of the Betic Cordillera; I.Z., Internal Zones). (B) Triassic outcrops and types of Triassic successions (1 to 5) in Spain. In the Betic Cordillera, the Epicontinental Triassic succession bearing gypsum is mainly present in the Prebetic–Subbetic basin (2), but also in some of the eastern Alpujárride units (2–5).

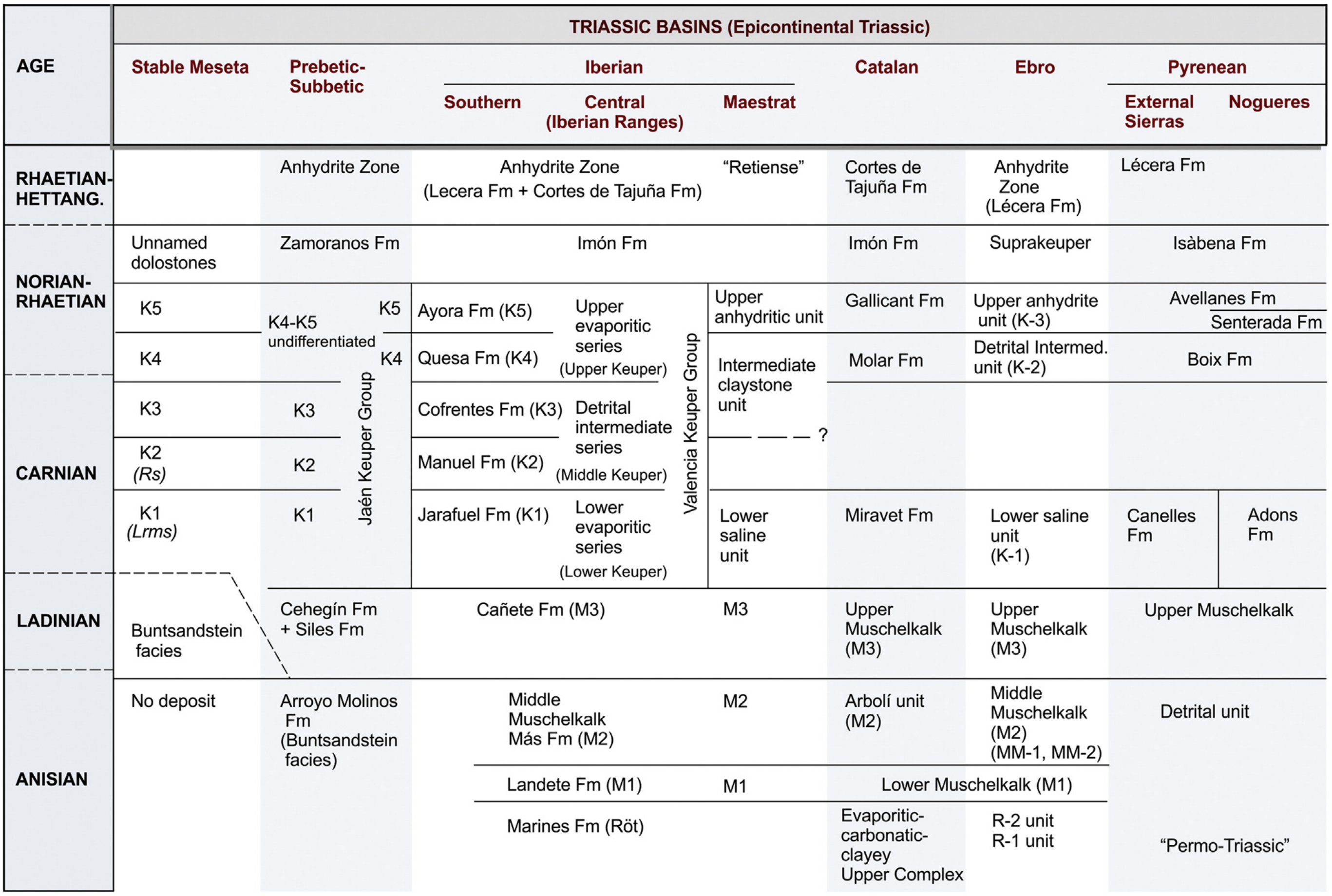


Fig. 2. Distribution of the stratigraphic units forming the Middle Triassic to earliest Jurassic successions in the basins of the Iberian platform (Epicontinental Triassic). Sectors are indicated only in the Iberian and Pyrenean basins. Symbols in the Stable Meseta (after Arche and López-Gómez, 2014): Rs, Red sandstones unit; Lrms, Lower red mudstones and sandstones unit.

Iberian platform (Figs. 2 and 3). For the sake of brevity, the successions of the Iberian basin are given below, but those of the other basins are summarised in Tables 1 and 2. Moreover, the depositional interpretations (literature) of the evaporitic successions in the Iberian basin are included in Table 1 and those of the other basins are given in Tables 1 and 2. Our own interpretations of all these evaporitic successions, units, and depositional settings are included in Sections 6 and 7 of this paper. The marine origin of all these Triassic evaporites is based on the isotopic compositions of sulfur, oxygen, and strontium ($\delta^{34}S_{CDT}$, $\delta^{18}O_{SMOW}$, $^{87}Sr/^{86}Sr$) in sulfates (Utrilla et al., 1992; Ortí et al., 2014), and on the bromine content in chlorides (Ortí et al., 1996).

Only vestiges of the Röt evaporites remain in the outcrops of the València sector (Fig. 1A) of the Iberian basin. The middle Muschelkalk evaporites were identified by Suárez Alba (2007) at the subsurface of the La Mancha sector (Fig. 1A) as a 20 to 60 m thick, clastic-evaporitic unit ('M2') overlying the Buntsandstein facies (Fig. 3). This author also identified the unit in the easternmost sector of the Iberian basin (Jaraco-1 borehole) as a thick anhydrite-carbonate interval underlying the carbonates of the upper Muschelkalk unit (Fig. 3). The outcrops in the eastern sector of the basin (Alt Palància area) suggest the presence in this unit of a 'lower grey unit' made up of alternations of laminated gypsum beds and claystone beds, and an 'upper red unit' dominated by red claystones and nodular sulfates (Ortí and Guimerà, 2015). At the subsurface of the Maestrat sector (Fig. 1A), the unit reaches up to 600 m in thickness (Bartrina and Hernández, 1990; Lanaja, 1987). In it, two evaporitic subunits were distinguished by Nebot and Guimerà (2016a, 2016b).

The lower Keuper unit (K1) is characterised by monotonous alternations of laminated gypsum beds and claystone beds on the outcrops of the València sector. These alternations, which are over one hundred metres thick, also show layers of sandstones, marls, and carbonates (Ortí, 1974). At the subsurface of the La Mancha sector, Suárez Alba (2007) described the K1 unit as a bedded halite unit formed by 4th- or 5th-order shallowing upwards sequences of about 5–25 m thick, with a total thickness of 40 to 380 m (Fig. 3). Stratigraphic details of the unit were provided by Suárez Alba (2007) at the Carcelén-1 borehole (Fig. 4A) and the Santa Bárbara-1 borehole. In these boreholes, clay-halite cycles at metre-scale can be observed, and the possible existence of these cycles at decametre-scale can be deduced. Little sulfate is observed in all these cycles. At the subsurface of the Maestrat sector, three units with a total thickness of 280 m were distinguished by Bartrina and Hernández (1990) in the Keuper succession (Fig. 2): lower saline unit, intermediate claystone unit, and upper anhydritic unit (without salt). The lower saline unit probably correlates with the K1 unit in the other sectors of the Iberian basin.

The upper Keuper evaporites in the Iberian basin comprise the K4 and the K5 units (Fig. 2). The K4 unit forms the lower part of the upper Keuper succession in the València sector. This unit, which is 60–70 m thick on outcrop, is a poorly stratified assemblage of massive, red claystones bearing abundant nodular gypsum. At the subsurface of the La Mancha sector, Suárez Alba (2007) divided this unit into three subunits (Fig. 3): basal (K4a) and top (K4c) subunits, which are formed by claystone and anhydrite layers; and a central (K4b) subunit, which is mainly composed of salt. These subunits show metre- and decametre-scale cycles, which are of clay-halite in the K4a and K4b subunits, and of clay-anhydrite in the K4c subunit (these two cycles are similar to those in the Zuera-1 borehole of the Ebro basin, Fig. 4A). The K5 unit forms the upper part of the upper Keuper succession. This unit, 30–

50 m thick, is characterised by white, bedded gypsum, although some claystone and carbonate beds are intercalated locally. At the subsurface of the Maestrat sector, the intermediate claystone unit probably corresponds to the K4 unit, and the upper anhydritic one to the K5 unit (Bartrina and Hernández, 1990) (Fig. 2).

The Anhydrite Zone (Lécera Fm of Gómez and Goy, 1998) is well developed at the subsurface of the La Mancha sector in the Iberian basin, where it consists of a thick (up to 1000 m) alternation of anhydrite beds and dolomite beds (Suárez Alba, 2007). Locally, however, this unit shows a basal alternation of anhydrite and halite beds (Fig. 3). Suárez Alba (2007) divided this unit into four subunits, all of which are arranged in cycles at metre- and decametre-scale (Fig. 3). An example of the basal halite subunit (Lower Salt Zone) is shown in the Gabaldón-1 borehole (Fig. 4B). The anhydrite-halite cycles forming this subunit differ from the clay-halite cycles characterising the other Triassic halite units (Fig. 4A) in which sulfate is practically absent. An example of the (halite-free) carbonate-anhydrite alternation forming the other subunits of the Anhydrite Zone is the Salobral-1 borehole (Fig. 4B). At the subsurface of the Maestrat sector, Bartrina and Hernández (1990) identified a 100–200 m thick dolostone-sulfate unit ('Retiense'), which probably corresponds to the Anhydrite Zone (Fig. 2). In the Aragonese Branch of the Iberian Ranges (Fig. 1A, ArB), the Lécera Fm (Anhydrite Zone) was first studied on the outcrops of the Sierra de Arcos by Gómez and Goy (1998). At the subsurface of the Sierra de Arcos, Ortí and Salvany (2004) described the anhydrite lithofacies as formed by laminated and bedded anhydrite, by anhydrite pseudomorphs of both selenitic gypsum and interstitial gypsum crystals, and by nodular and massive anhydrite (the Alacón borehole). The thick evaporites of the Lécera Fm grade laterally and vertically into the carbonates of the 'Cortes de Tajuña Fm', which crop out extensively in the NE of Iberia with a thickness exceeding one hundred metres (Fig. 2). The sulfates of the Lécera Fm occur in central positions in the basins, whereas the carbonates of the Cortes de Tajuña Fm are often present in marginal positions (Bordonaba and Aurell, 2002).

4. Evaporites in the Alpine Triassic

The palaeogeographic reconstruction of the western Neotethys during the Triassic shows the location of the Iberian platform between the Iberian plate and the Mesomediterranean microplate (Fig. 5A). The enlarged area of the Iberian platform includes the estimated location of the structural units of the Betic domain (Fig. 5B). The Alpine Triassic is developed in the today's Betic Cordillera (Fig. 1). This chain consists of three structural and palaeogeographical zones: the External Zones (EZ), the Internal Zones (IZ), and the flysch deposits of the Campo de Gibraltar Complex (Fig. 6A). The External Zones are formed by the units of the relatively autochthonous (Prebetic) domain and the para-autochthonous (Subbetic) domain. The Internal Zones are formed by allochthonous, tectonic units derived from different Mesozoic palaeogeographic domains along the borders of the ancient plates mentioned above (Iberia, Adria, Mesomediterranean) (Fig. 5B). These were plates which broke away from the Pangea supercontinent (Martín-Algarra and Vera, 2004). The Triassic of the External Zones is of the Epicontinental type (Prebetic-Subbetic basin), while the Triassic of the Internal Zones, located further to the east, is of the Alpine type. In the Internal Zones, however, Muschelkalk facies are also present, providing evidence of continuity across the platform between the two Triassic types (López-Garrido et al., 1997; Pérez-López and Pérez-Valera, 2007). The Internal Zones comprise several allochthonous complexes such as the Nevado-Filábride Complex, which consists of Paleozoic or older rocks (Gómez-Pugnaire et al., 2012), the Alpujárride Complex, and the Maláguide Complex. The two last complexes are formed by Palaeozoic basement, Triassic materials, and thin successions of post-Triassic rocks (Fig. 6A).

The Maláguide Complex consists of lithostratigraphic units that were originally located in the southeasternmost zone of the platform, close to the Mesomediterranean emerged area (Durand-Delga and Fontboté, 1980; Martín-Algarra et al., 1992; Guerrera et al., 1993) (Fig. 5B). Although in this complex the Triassic facies vary considerably, some of the successions resemble those of the Epicontinental Triassic (Pérez-López and Pérez-Valera, 2007). Moreover, this complex shows locally gypsiferous marl and laminated gypsum beds (Fig. 7), mainly of Carnian age, which are similar to those of the Keuper facies (Pérez-López and Pérez-Valera, 2007). The continental influence is clear because the lower parts of these units are formed by redbeds with "Pseudoverrucano-like facies" (Perrone et al., 2006), which are present at the base of the Alpine orogenic cycle.

The Alpujárride Complex (Fig. 5B) is formed by carbonate units that are always thicker than those in the External Zones, especially for the Norian units (Fig. 7). Some units in this complex are equivalent to the Muschelkalk facies of the External Zones and include similar bivalve associations (López-Garrido et al., 1997; García-Tortosa, 2002). Other units show evaporite facies formed by gypsiferous marls (and phyllites) and laminated gypsum beds which resemble the Keuper facies in the External Zones (Sanz de Galdeano and García-Tortosa, 2002; Pérez-López and Pérez-Valera, 2007). These evaporite units are up to 20 m thick in the Almagro Sierra section and up to 60 m thick in the Lubrín outcrop (Fig. 7). Many of these units are attributed to the Carnian or Carnian-Norian, but those which underlie the Ladinian or the Anisian carbonates are assigned to the Middle Triassic (Fig. 7). The carbonate and the evaporite units of this complex can be correlated with those units located in the northwestern areas (Epicontinental Triassic), indicating lateral continuity in the original platform (Fig. 6B). This complex has similarities with the Tethys bioprovince and is usually referred to as the 'Alpine Triassic' in the literature (Durand-Delga and Fontboté, 1960; Delgado et al., 1981, Martín-Algarra et al., 2004).

The lithofacies gradation from carbonate units to claystone and gypsum units across the initial basin of the Betic Cordillera allows us to interpret an extensive platform or shelf (the epicontinental Iberian platform) during the Triassic. In this platform continuum, the palaeogeography often changed due to rifting tectonics and sea-level oscillations. The evaporite environments, mainly gypsum salinas or lagoons, were prevalent in the western or inner zones of the platform. These salinas changed laterally into carbonate lagoons or tidal flats in the eastern and southern parts of the platform. The most marine carbonate sediments (Alpine facies) were deposited on distal, subsident sub-basins and received Tethysian or Sephardic faunal influences (Pérez-López and Pérez-Valera, 2007). During the last transgressive pulse of the Triassic, the salinas were interconnected throughout the platform forming the K5-type deposits (Fig. 6B). Subsequently, these deposits were overlain by the Norian carbonates throughout the entire Betic domain. In the External Zones, these transgressive carbonates are represented by the Zamoranos Fm (Epicontinental Triassic) (Fig. 2). This unit probably correlates with the upper part of the Norian Alpujárride carbonates (Fig. 6B).

5. Palynological dating of the evaporites

Age attributions of the Middle–Upper Triassic evaporites in the Iberian platform have been based almost exclusively on palynological associations of some units in the Epicontinental Triassic, and this has resulted in some contradictory dating. Most of the available analyses refer to the Keuper facies and very few to the other Triassic evaporite formations (Table 3). For the Keuper units, the majority of palynological determinations in the Prebetic–Subbetic, Iberian, Catalan, and Ebro basins indicate Latest Ladinian to Carnian ages. The K1 unit (Jarafuel Fm) has been dated as Latest Ladinian–Early Carnian in the SE margin of the Iberian Massif by Arche and López-Gómez (2014) (Fig. 2). In the southwest sector of the Iberian basin, these authors have dated the K1 unit also as Latest Ladinian–Early Carnian, and the overlying K2 unit (Manuel Fm) as Early–Middle Carnian. In the València sector, a similar palynofloral assemblage was found in the K1, K2 and K5 Keuper units

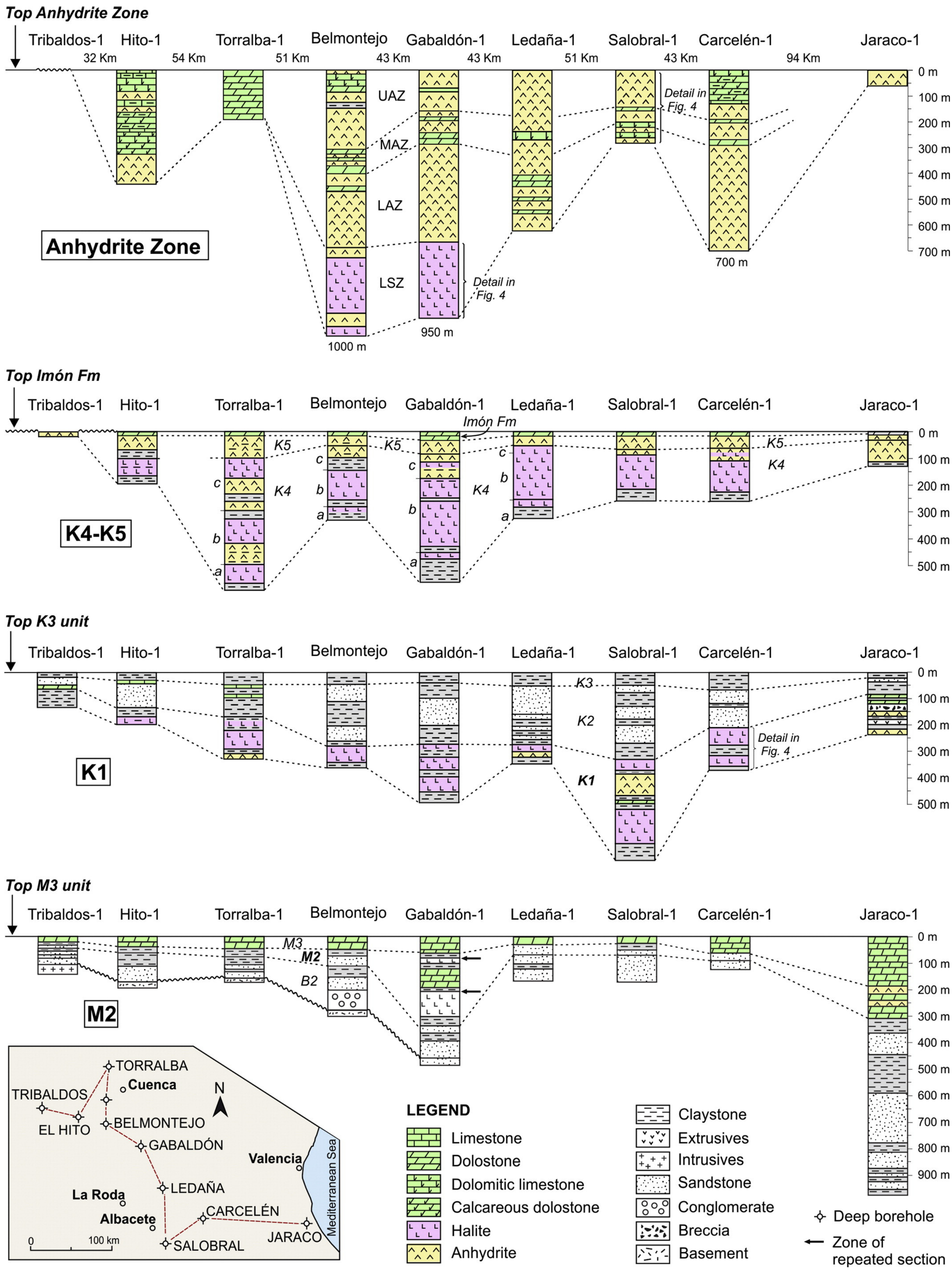

Top Anhydrite Zone
Tribaldos-1
Hito-1
Torralba-1
Belmontejo
Gabaldón-1
Ledaña-1
Salobral-1
Carcelén-1
Jaraco-1
32 Km
54 Km
51 Km
43 Km
43 Km
51 Km
43 Km
94 Km
UAZ
MAZ
LAZ
LSZ
Detail in Fig. 4
Detail in Fig. 4
1000 m
950 m
700 m
Anhydrite Zone
0 m
100 m
200 m
300 m
400 m
500 m
600 m
700 m
Top Imón Fm
Imón Fm
K5
K4
a
b
c
K4-K5
0 m
100 m
200 m
300 m
400 m
500 m
Top K3 unit
K3
K2
K1
Detail in Fig. 4
K1
0 m
100 m
200 m
300 m
400 m
500 m
Top M3 unit
M3
M2
B2
M2
0 m
100 m
200 m
300 m
400 m
500 m
600 m
700 m
800 m
900 m
TORRALBA
Cuenca
TRIBALDOS
EL HITO
BELMONTEJO
GABALDÓN
N
Valencia
Mediterranean Sea
LEDAÑA
La Roda
Albacete
CARCELÉN
JARACO
SALOBRAL
0
100 km
LEGEND
Limestone
Dolostone
Dolomitic limestone
Calcareous dolostone
Halite
Anhydrite
Claystone
Extrusives
Intrusives
Sandstone
Conglomerate
Breccia
Basement
Deep borehole
Zone of repeated section

Table 1
Descriptions and depositional interpretations (literature) of the evaporite units (older group of evaporitic episodes) in the Epicontinental Triassic of the Iberian platform (Anisian to Lower Carnian). Lithostratigraphic units in Fig. 2.

Iberian Basin. Depositional interpretations.

- Middle Muschelkalk: The clastic-evaporitic unit (M2) of the La Mancha sector was interpreted as 'deposited in tidal environments' (Suárez Alba, 2007).
- Lower Keuper: The gypsum sediments of the K1 unit 'were deposited in a brackish, shallow lagoon, in which also halite could have formed sporadically' (Ortí, 1974). According to Suárez Alba (2007), the K1 unit 'was deposited under arid conditions in low subaqueous, coastal salinas forming evaporitic 4th- or 5th-order shallowing upwards sequences, about 5–25 m thick. Some of the sequences exhibit top stages of sabkha'.
- Upper Keuper: In the València sector, the K4 unit was interpreted as 'an anhydrite sabkha developed on the red clayey, distal plain of the K3 unit', and the K5 unit as 'accumulated on an evaporitic, coastal lagoon formed subsequently to the K4 sabkha' (Ortí, 1982–83). In the La Mancha sector, the three K4 subunits were interpreted as 'initially a sulfate sabkha bearing some halite ponds (K4a subunit), then a great halite pond (K4b subunit), and finally a gradational setting (K4c subunit) towards the generalised sulfate environment of the K5 unit' (Suárez Alba, 2007).
- Anhydrite Zone: The anhydrite lithofacies of the Lécera Fm (Alacón borehole in Sierra de Arcos) were interpreted as 'derived from the precipitation of fine-grained laminated and bedded gypsum together with selenitic beds and interstitial gypsum crystals in shallow coastal salinas or lagoons; these gypsum lithofacies alternated with nodular and massive anhydrite; this anhydrite was grown interstitially in final sabkha stages of the salinas resulting in metre-scale, salina-sabkha cycles of carbonates and sulfates' (Ortí and Salvany, 2004). Also in Sierra de Arcos, the following depositional environments have been interpreted for the carbonate lithofacies of the Cortes de Tajuña Fm by Bordonaba and Aurell (2002): 'the porous massive dolostones ('carniolas') were accumulated in zones under some evaporitic influence; the carbonate mudstones bearing anhydrite nodules were formed in sabkhas under more intense evaporitic influence; and the carbonate collapse-breccias were generated by total or partial evaporite dissolution of the former lithofacies'. There is, however, some controversy in the interpretation of the timing for the collapso-breccia generation in the assemblage of the Cortes de Tajuña Fm, and not only in the Iberian basin but also in the basins of northeast Iberia. Morillo Velarde and Meléndez Hevia (1979) argued that 'the collapse-breccias were formed in deep burial during late diagenesis'; Gómez and Goy (1998) interpreted them 'as formed in late diagenesis during surface exposure'; and Bordonaba and Aurell (2002) considered that 'they originated during early diagenesis or under shallow burial conditions'.

Other basins. Descriptions and interpretations

Röt facies

- Ebro Basin. The Röt facies has a marked evaporitic character. The 50 m thick Röt facies identified at the subsurface by Jurado (1989, 1990) comprises a basal 'lutitic Unit (R-1)' formed by red claystones with gypsum nodules, and an upper 'evaporitic Unit (R-2)' made up of halite in the depocenter and anhydrite on the basin margins.
- Catalan basin. The Röt facies has only a weak evaporitic character. The 'evaporitic-carbonatic-clayey Upper Complex' described on outcrop by Marzo (1980) exhibits gypsum nodules locally.

Middle Muschelkalk evaporites

- Catalan basin. The middle Muschelkalk succession, which is 50–115 m thick, exhibits siliciclastic facies in the northern sector of the basin and evaporites (Arbolí unit) in the southern one (Castelltort, 1986). A thick gypsum unit is present at the base of the succession in the Baix Ebre area, which is overlain by a red gypsiferous siliciclastic unit (Castelltort, 1986).
  Interpretation. The middle Muschelkalk evaporites in the Catalan basin were interpreted as 'deposited in clayey-evaporitic supralitoral plains and sabkha settings' (Calvet and Marzo, 1994).
- Ebro Basin. At the subsurface of this basin, Jurado (1989, 1990) distinguished a 'lower halite unit' (MM-1) and an 'upper halite unit'(MM-2; halite bearing claystone intercalations) in the middle Muschelkalk succession (M2).

Lower Keuper (K1) evaporites

- SE Margin of the Iberian Massif. The 'Lower red mudstones and sandstones unit' has been defined by Arche and López-Gómez (2014) as an equivalent to the upper part of the marine Jarafuel Fm (K1) of Ortí (1974) and its age is Latest Longobardian–Early Cordevolian (Early Carnian). This unit lies unconformably on the Paleozoic basement in the Alcaraz-Chiclana de Segura region and was deposited along the complete southern border of the Iberian Massif. It has been subdivided into five subunits (Lrmsa to Lrsme) by Arche and López-Gómez (2014).
  Interpretation. The Lower red mudstones and sandstones unit 'was deposited in marginal marine to distal fluvial environments during a series of minor transgressive--regressive cycles punctuating the transgressive part of a third-order eustatic cycle' (Arche and López-Gómez, 2014).
- Prebetic-Subbetic basin. The K1 unit is a 'multi-colored clayey series with thin intercalations of carbonates, gypsum, and fine-grained sandstones'. Some oolitic beds are present. In the outcrops of the eastern sector of the basin (Murcia and Alicante provinces), the unit is formed by gypsum and claystone beds with minor carbonates and sandstones (Peréz-López, 1996; Pérez-Valera, 2005).
  Interpretation. The K1 unit was deposited 'on a fluvial-coastal plain system feeded by siliciclastic materials from the Iberian Massif, with broad development of lagoons or salt pans with variable salinity. On this plain, the sandstone layers represent channel-fill deposits of poorly confined, extensive braided systems' (Peréz-López, 1996).
- Catalan basin. The Miravet Gypsum Fm, which is up to 90–100 m thick, comprises an alternation of gypsum beds (laminated and nodular gypsum) and grey claystone beds. In some paleohighs, however, only thin successions of claystone, marl, and carbonate are present. A gypsum package bearing carbonates with ripple structures is present at the top of the unit locally. This formation was correlated with the K1 unit of the Iberian basin (Salvany and Ortí, 1987).
  Interpretation. The Miravet Gypsum Fm 'was formed in sabkhas and coastal salinas located on an evaporitic supratidal mudflat. The central sector of the basin, where marginal facies (stromatolites, anhydrite nodules) are recorded, behaved as a paleogeographic high during the accumulation of the Miravet Fm' (Salvany and Ortí, 1987).
- Ebro basin. The base of the Keuper succession is formed by the 'Lower Saline Unit (K-1)', which is composed of halite with interbedded clay and anhydrite (Jurado, 1989, 1990). At the Zuera-1 deep borehole, this halite unit is 413 m thick, although the uppermost 100 m thick interval is formed by clay-anhydrite cycles (Fig. 4A). This K-1 unit correlates with the K1 unit (Iberian basin) and the Miravet Fm (Catalan basin).
- Pyrenean basin. The Canelles Gypsum Fm (External Sierras) is formed by laminated gypsum beds with some intercalated carbonate beds. The Adons Clay and Carbonate Fm (Nogueres Unit) consists of green claystone layers and carbonate beds grading upward into variegated, red claystones and minor carbonate. These two units of the lower Keuper were correlated with the Miravet Gypsum Fm (Catalan basin) and the K1 unit (Iberian basin) by Salvany and Bastida (2004).
  Interpretation. The Canelles Gypsum Fm (Sierras Marginales) 'was formed in evaporitic lagoons and in carbonate tidal flats, and the Adons Clay and Carbonate Fm was deposited on an evaporitic tidal flat' (Salvany and Bastida, 2004).
- Basque-Cantabrian basin. The Aguilar de Campoo and Reinosa outcrops show clay-gypsum alternations similar to those of the K1 unit (Iberian basin). In Aguilar de Campoo, halite beds are intercalated in these alternations (Santalucia mine) (Calvet et al., 1993).

by Solé de Porta and Ortí (1982) and De Torres (1990). This assemblage dates the Middle–Late Carnian according to Besems (1981a, 1981b). However, some palynological assemblages of the upper Keuper units in domains located to the west and to the southwest of the Iberian basin have been dated as Norian, as in the NE Central System (Hernando, 1977) and in the K5 unit of the Stable Meseta (Besems, 1981a, 1981b). Thus, in the Prebetic–Subbetic and the Iberian basins it is commonly assumed that the K1, K2 and K3 units are of Carnian age, and that the K4 and K5 units are of Norian age (Pérez-López et al., 1991; Arche and López-Gómez, 2014). The palynological association of the Anhydrite Zone in the València sector has been assigned to the Rhaetian (Pérez-López et al., 1996) (Table 3).

In the Catalan basin, the palynological assemblage found in the lower Keuper unit (Miravet Fm) (Fig. 2) was assigned to the Carnian by Solé de Porta et al. (1987). In the Ebro basin, the Röt facies with anhydrite nodules was assigned to the Anisian (Ballobar-1 borehole) and

Fig. 3. Stratigraphical units (Middle Muschelkalk unit, M2; Keuper units; Anhydrite Zone unit) and borehole correlations in the Middle Triassic to earliest Jurassic succession at the subsurface of the La Mancha sector of the Iberian basin (Epicontinental Triassic). Adapted from several figures of Suárez Alba (2007). Subunits in the Anhydrite Zone: LSZ, Lower Salt Zone; LAZ, Lower Anhydrite Zone; MAZ, Middle Anhydrite Zone; UAZ, Upper Anhydrite Zone. Keuper units: K1 to K5 (subunits a, b, c, in the K4 unit).

Table 2
Descriptions and depositional interpretations (literature) of the evaporite units (younger group of evaporitic episodes) in the Epicontinental Triassic of the Iberian platform (Upper Carnian to Lower Hettangian). Lithostratigrapic units in Fig. 2.

Upper Keuper evaporites (K4 and K5 units)

- Prebetic-Subbetic basin. A clear distinction between the K4 and K5 units is not always possible. Peréz-López (1996) referred to these units as the 'K4–K5 assemblage' in some sectors. Along the northern boundary of this basin, the K4 unit is extensively developed and may rest directly on the Paleozoic materials of the Stable Meseta, and the K5 unit extends to the west reaching the Alcazar de San Juán area (Fernández et al., 1994; Sopeña et al., 1990). Many outcrops in the eastern diapiric province of Pinoso-Jumilla provide evidence of the presence of the K4 and K5 units.
  Interpretation. The K4–K5 assemblage 'was accumulated on a restricted coastal setting hosting salt marshes, salt pans, and saline lagoons' (Peréz-López, 1996).
- Catalan basin. Overlying the Miravet Fm, Salvany and Ortí (1987) distinguished the Molar Gypsum and Clay Fm, and the Gallicant Carbonate and Clay Fm. The Molar Fm is characterised by abundant gypsum layers (mainly laminated gypsum but nodular also) bearing red claystones. The Gallicant Fm is made up of claystones, carbonates and minor gypsum. Salvany and Ortí (1987) correlated the Molar Fm and the Gallicant Fm with the K4 and K5 units of the Iberian basin, respectively.
- Ebro basin. The K-2 unit was defined by Jurado (1989, 1990) as a claystone unit with a thickness of 50–125 m. Anhydrite beds, however, are abundant in all the boreholes where this unit was differentiated. In some of them, the anhydrite beds clearly predominate over the claystone ones either through the entire unit (Ebro-1 borehole) or only at the upper part (La Zaida-1 borehole). This unit is equivalent to the K4 unit (Iberian basin) and to the Molar Fm (Catalan basin) (Jurado, 1989; Salvany, 1990), although its correlation with the K2 unit of the Iberian basin was proposed by Arche and López-Gómez (2014). The upper evaporite unit (K-3) of Jurado (1989) is a 40–50 m thick anhydrite unit. This unit is equivalent to the K5 unit (Iberian basin) and to the Gallicant Fm (Catalan basin) (Jurado, 1990).
- Pyrenean basin. The Boix Gypsum Fm was distinguished by Salvany and Bastida (2004) in the outcrops of the External Sierras and the Nogueres structural units. The Boix Fm is characterised by red to variegated claystones, laminated gypsum beds, and reddish masses of gypsum breccias. At the subsurface, the thick salt masses present in some boreholes –of the 'Evaporitic unit' distinguished by Klimowitz and Torrescusa (1990)– were assigned to the Boix Fm by Salvany and Bastida (2004). The Senterada Gypsum Fm (Les Nogueres) is a monotonous succession of laminated gypsum bearing some carbonate beds, with a total thickness over 250 m locally.
  Interpretation. In the External Sierras, the 'Boix Fm was deposited in a subsident evaporitic setting receiving distal alluvial fine sediments (clays), and the Avellanes Fm (Fig. 2) was accumulated on a carbonate inter-supratidal mud flat' (Salvany and Bastida, 2004). The Senterada Fm represents a 'stable lagunar setting of fluctuating salinity and alternating deposition of gypsum and carbonate' (Salvany and Bastida, 2004).
- Basque-Cantabrian basin. At the Poza de la Sal diapir, the K4 and K5 units crop out with features similar to those present in other basins. In other diapirs of this basin, some gypsum workings also suggest the presence of the K5 unit.

Anhydrite Zone

- Prebetic–Subbetic basin. Few gypsum-carbonate outcrops can be attributed to the Anhydrite Zone. This is the case of the Almansa outcrop (Albacete), which is located close to the boundary with the Iberian basin. Dolostone beds and nodular gypsum is the common facies association on this outcrop (Ortí and Pérez-López, 1994).
- Ebro basin. At the subsurface of this basin, the Triassic–Jurassic boundary is included in the 'Anhydrite Unit' of Jurado (1989, 1990), which is an anhydrite unit bearing dolomitic interbeds with a total thickness of 200–450 m. The cyclic character of this unit (Lécera Fm) has been documented in several deep boreholes by Gómez et al. (2007).
- Pyrenean basin. The Lécera Fm crops out near Camarasa with gypsum layers and total thickness of 300 m (Gómez et al., 2007).
- Basque-Cantabrian basin. At the Asturias sector, the Cantavieyo and Vilorteo deep boreholes have been described by Gómez et al. (2007). These boreholes cut an assemblage of carbonates, evaporites and claystones arranged in shallowing-upwards sequences. Carbonate breccias are present at these boreholes, which are considered to be the lateral equivalent to the Lécera Fm.
  Interpretation. The sulfates of the Barzana Mb (Lécera Fm) 'were formed in playa to sabkha settings, and the very shallow-water interbedded carbonates probably formed in more or less extensive but ephemeral ponds' (Gómez et al., 2007). These authors have interpreted the claystone-bearing, shallowing-upwards sequences of this unit as follows: 'subtidal to intertidal settings for the lower carbonates; subtidal to supratidal sabkha for the intermediate banded anhydrite and gypsum; and distal alluvial settings for the upper claystones'.

the base of the K-1 unit of the Keuper succession was attributed to the Late Ladinian (La Zaida-1 borehole) in Jurado (1989) (Table 3). The Anhydrite Zone in the Ebro basin was dated as Rhaeto-Hettangian by Castillo Herrador (1974). The palynological assemblages in the Pyrenean basin, however, seem to be younger according to Calvet et al. (1993) (Table 3). In the Nogueres and the External Sierras structural units of this basin (Fig. 2), the assemblages of the transition from the upper Muschelkalk unit to the Keuper unit have been assigned to the Carnian; the assemblages of several Keuper units, including the basal one, have been attributed to the Norian; and the uppermost Keuper unit has been attributed to the Rhaetian. The palynological assemblages in the Basque-Cantabrian basin also appear to be younger than in the other basins. The assemblages of the lower Keuper unit in some localities (Reinosa, Aguilar de Campoo, Estella) have been assigned to the Norian (Calvet et al., 1993), and those of the upper units (K4, K5) in Poza de la Sal were dated as Rhaetian by N. Solé de Porta (pers. comm., Table 3). These data suggest that the Carnian is not sufficiently characterised in the northern basins of Iberia, and that the Keuper units could be younger than in the other Triassic basins (Calvet et al., 1993).

6. Evaporitic environments: characterisation

This section characterises and interprets the most relevant evaporitic settings in the Iberian platform during the Triassic on the basis of outcrop and borehole observations done or summarised by us mainly in the Epicontinental Triassic for the present paper. For the case under study, the terms used probably have a more general applicability than those that up to now have been employed in the literature, which often are ambiguous or not sufficiently precise (Tables 1 and 2). The term 'pond' for chlorides, and 'salina' and 'lagoon' for sulfates are used here for perennial to semi-perennial standing brine bodies, and 'sabkha' is employed for exposed settings precipitating interstitial evaporites (Figs. 8, 9). The main sulfate minerals in the various environments were primary gypsum and early diagenetic anhydrite. The primary gypsum underwent a complete diagenetic cycle at depth in all the basins: it was transformed into anhydrite in burial diagenesis, and this anhydrite together with the early diagenetic one were rehydrated into secondary gypsum near the surface during exhumation.

Sulfate salinas refer to standing bodies of calcium sulfate brines in which the most significant precipitate was fine-grained gypsum (Fig. 8). Some types are distinguished. *Clay-gypsum alternation salina* refers to shallow-water settings whose sediments were characterised by very regular alternations (cycles), at the metre- and the decametre-scale, which are formed by laminated gypsum beds and claystone beds. Some carbonate and some nodular gypsum beds may accompany the laminated gypsum. Thin halite layers may be found sporadically interbedded with the laminated gypsum. The cycles are piled up in successions reaching thicknesses between several tens and over one hundred metres. The gypsum laminae may show irregular morphologies resembling microbial mats (planar stromatolites). The claystone beds are grey, green or dark in color. These salinas occupied very variable positions on the evaporitic platforms. An example of these salinas is found in the upper interval of the K-1 unit at the Zuera-1 borehole (Fig. 4A). *Clayey gypsum salina* refers to shallow-water settings whose sediments were characterised by irregular alternations of laminated gypsum beds and red to variegated gypsiferous claystone beds. The gypsum beds are always predominant over the gypsiferous claystone beds. The sediment thickness accumulated in these salinas may exceed one hundred metres. Some bedded or interstitial halite may be present in the boreholes in association with the gypsum beds; the term *clayey gypsum/halite salina* is used in these cases.

Sulfate lagoon refers to shallow- to moderately deeper-water bodies (Fig. 8). These bodies probably developed at scales broader than those in the sulfate salinas, and were also richer in sulfate. The sulfate units that derived from these lagoons varied in thickness from tens to some hundreds of metres, and the carbonate content varies from very scarce to abundant. Different types of ripple associations suggest tidal influence. The size of the original gypsum crystals oscillated from very fine-grained to centimetric (selenitic). Some claystones can also be found interbedded with sulfates. The cyclicity varies from weakly developed in the small lagoons to very well developed in the big ones, where metre- and decametre-scale cycles of carbonate-sulfate are common. These lagoons occupied platform positions closer to the sea shore in comparison with those of the sulfate salinas. The sulfate proportion in these lagoons was higher in the depocenters; along the margins, however, the carbonate content increased, especially in the direction of the sea shore. Examples of sulfate lagoons are found in some K5 sections of different basins and in the Anhydrite Zone of the Salobral-1 borehole (Fig. 4B).

Chloride pond refers to shallow-water settings whose main sediment was bedded halite forming metre- and decametre-scale cycles (Fig. 8). These deposits attain thicknesses from tens to some hundreds of metres. Two types of ponds are distinguished: halite pond and anhydrite-halite pond. In the *halite pond*, which is the most common type, halite beds alternate cyclically with claystone beds. Sulfate in these cycles can be absent or present only in a low proportion. Examples of this pond are found in the K1 unit of the Carcelén-1 borehole and in the K-1 unit of the Zuera-1 borehole (Fig. 4A). In the less common *anhydrite-halite pond*, halite beds and anhydrite beds (originally gypsum beds) alternate. An example is found in the Lower Salt Zone of the Gabaldón-1 borehole (Fig. 4B). The two types of ponds occupied variable positions on the platform, but they were preferentially located further from the sea shore with respect to the coeval sulfate salinas as deduced from the borehole correlation in the La Mancha sector of the Iberian basin (Fig. 3). Vertical gradations from chloride ponds to clay-gypsum alternation salinas are observed in some borehole logs (Zuera-1 borehole, Fig. 4A), and lateral gradations between these settings can be interpreted from the borehole profiles in some basins.

Sabkha refers to exposed, peripheral areas or flats that were adjacent to the standing brine bodies, in which different evaporite minerals grew within an abundant host matrix in the vadose-capillary zone or at the top of the phreatic zone (Fig. 8). Cycles are not so well developed as in the adjacent salinas, lagoons or ponds. Two main types of sabkhas are distinguished: (a) *clayey sabkha*, in which various minerals and textures such as halite crystals, poikilitic masses of gypsum, and anhydrite nodules grew interstitially within a claystone matrix. The host claystone can be grey or green, and variegated or reddish in tone; and (b) *carbonate-anhydrite sabkha*, in which nodular anhydrite grew within dolomitic mudstone in exposed or supratidal flats. This type of sabkha graded laterally into carbonate or evaporite-carbonate platforms, and into sulfate lagoons.

7. Evolution of the evaporitic sedimentation (Epicontinental Triassic)

The present paper uses 'evaporitic mudflat', 'saltern', and 'epeiric evaporitic seaway' (Warren, 2006) for the largest environments, at platform scale, characterising the evaporitic episodes under study (Fig. 9). In these large-scale settings, the mentioned above ponds, salinas, lagoons and sabkhas were located. *Evaporitic mudflat* is used when claystone, either grey/green or red, is an abundant host material of the evaporites, and *saltern* is employed when the host material, less abundant, is carbonate or mixed (carbonate, marl, claystone). In the evaporitic mudflat, the settings were shallower and more variable, and the marine influence was limited. In the saltern, the settings were more homogeneous and deeper, and the marine influence was higher.

Two groups of Triassic evaporitic episodes can be differentiated in the Iberian platform on the basis of the sedimentological and regional characteristics described above and summarised in Tables 1 and 2. The older group (Anisian to Early Carnian) is formed by the Röt, the middle Muschelkalk, and the lower Keuper episodes. The depositional units derived from these episodes resemble one another in lithologies and facies (Fig. 8). This group is separated from the younger one by the middle Keuper siliciclastic episode (Middle Carnian). The younger group is formed by the two upper Keuper episodes (Late Carnian–Norian) and the Anhydrite Zone episode (Rhaetian–Hettangian). The units derived from these three evaporitic episodes, however, differ from one another and also from the units of the older group (Fig. 8). In this study, the metre-scale cycles in all these units are interpreted as 5th-order cycles and the decametre-scale ones as 4th-order cycles. As in the Triassic basins of central Europe (Reinhardt and Ricken, 2000), the probable origin of these high-frequency cycles (Fig. 4) is astronomic.

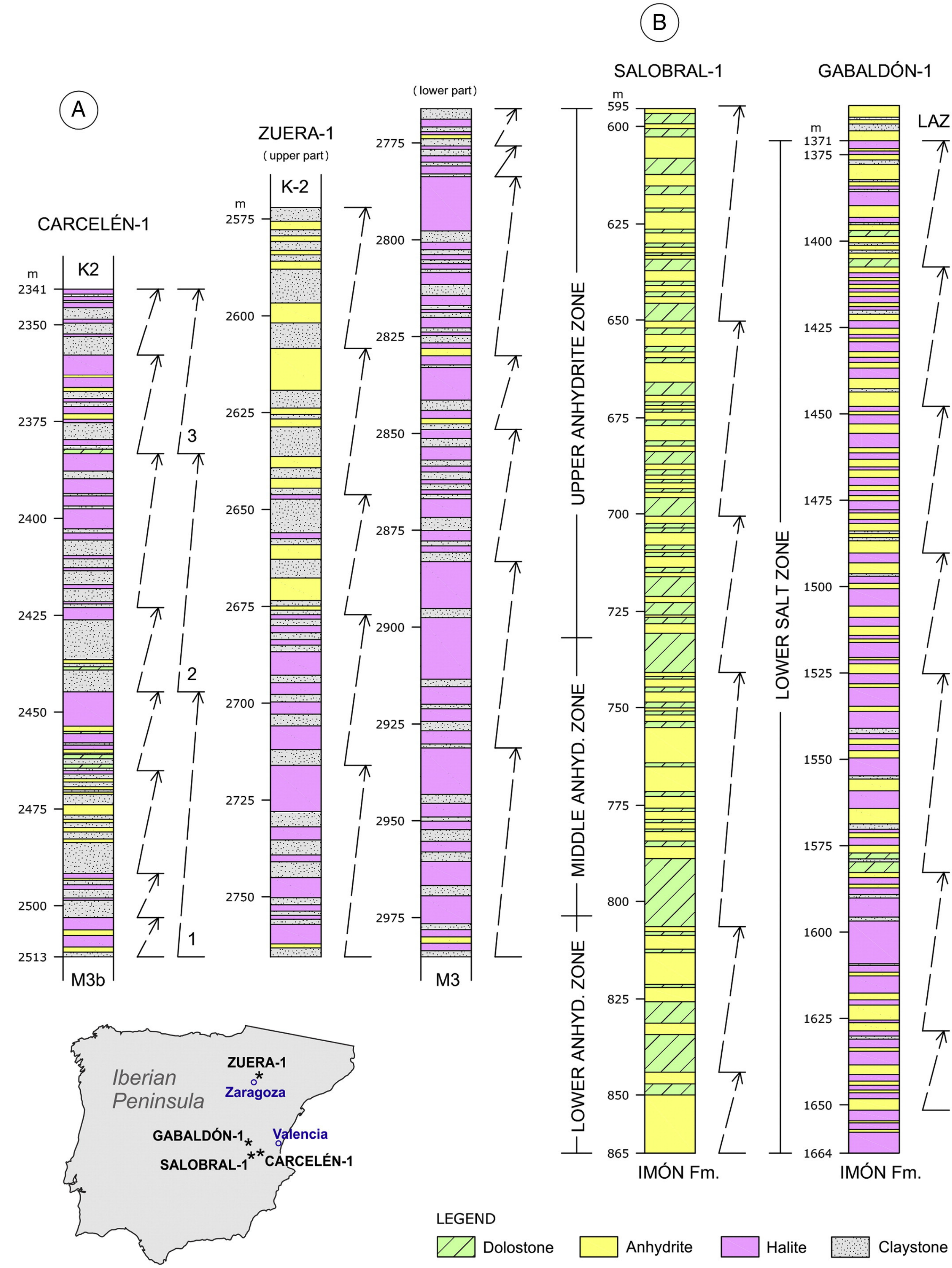
7.1. Initial detrital-evaporitic platform: Röt episode (Anisian)

The Röt evaporites are limited to the northeast of the Iberian platform, where they covered the non-marine, siliciclastic sediments of the Buntsandstein facies (Table 1). In the Ebro basin, salt and sulfates were deposited in halite ponds. The scarce sulfate present in the Catalan basin was formed in small, clayey sabkhas of anhydrite. The global setting of all these precipitates is envisaged as a narrow siliciclastic platform colonised by evaporites. This initial episode marks the first incursion of the Neotethys Ocean into Iberia during the Triassic and was characterised by transgressive evaporites. Overlying these evaporites, the carbonates of the lower Muschelkalk unit (Anisian) accumulated in the eastern areas of the Iberian platform (Fig. 2). These carbonates, which are relatively homogeneous in thickness (100–150 m), expanded further to the west than the underlying Röt evaporites.

7.2. Detrital-evaporitic platform: Middle Muschelkalk episode (Anisian)

These evaporites, of Anisian age (Escudero-Mozo et al., 2015), are limited to the northeastern and eastern parts of the Iberian platform and are associated with a siliciclastic host material - claystones in reddish or grey tones and sandstones - that is abundant in the Catalan basin (Table 1). Halite ponds were formed in the Ebro basin and in the eastern sectors of the Iberian basin (Fig. 9). These ponds were filled with clay-halite cycles, at least in the Ebro basin. The presence at the subsurface of these two basins of abundant anhydrite intervals and of claystone intervals bearing interstitial halite suggests that poor fractionation between chlorides and sulfates occurred in the ponds. On outcrop, sediments of clay-gypsum alternation salinas are observed in the lower grey unit of the successions, while sediments of clayey gypsum salinas and clayey sabkhas are present in the upper red unit (Iberian and Catalan basins). Sulfate lagoons are identified at the base of the succession in the Catalan basin (Fig. 8, M2 episode).

The middle Muschelkalk evaporitic episode represents a restriction of the preexistent lower Muschelkalk carbonate platform. However, these evaporites advanced further westwards than the underlying carbonates. This evaporitic platform was a chloride-rich, *evaporitic mudflat* in which a mosaic of shallow evaporitic settings was developed. The platform was affected by differential subsidence allowing the accumulation of thick successions of evaporites in some basins (450 m in the Iberian basin; 600 m in the Ebro basin) for the first time (Fig. 9). Sharp lateral gradations from evaporites into siliciclastics, which are recorded in several basins, suggest proximity to exposed Paleozoic highs. These highs favoured an irregular distribution of the evaporitic settings throughout the platform. Moreover, the scarcity of carbonate suggests considerable distance from the sea shore eastwards. In the Maestrat



A
B
CARCELÉN-1
K2
M3b
m
2341
2350
2375
2400
2425
2450
2475
2500
2513
3
2
1
ZUERA-1
(upper part)
K-2
2575
2600
2625
2650
2675
2700
2725
2750
(lower part)
2775
2800
2825
2850
2875
2900
2925
2950
2975
M3
UPPER ANHYDRITE ZONE
MIDDLE ANHYD. ZONE
LOWER ANHYD. ZONE
SALOBRAL-1
595
600
625
650
675
700
725
750
775
800
825
850
865
IMÓN Fm.
LOWER SALT ZONE
GABALDÓN-1
LAZ
1371
1375
1400
1425
1450
1475
1500
1525
1550
1575
1600
1625
1650
1664
IMÓN Fm.
Iberian Peninsula
ZUERA-1
Zaragoza
GABALDÓN-1
Valencia
SALOBRAL-1
CARCELÉN-1
LEGEND
Dolostone
Anhydrite
Halite
Claystone

sector of the Iberian basin, Nebot and Guimerà (2016a, 2016b) based the division into two subunits on their different depositional geometry, which indicates a higher rifting activity in the lower subunit, and a decrease in the upper one together with an expansive trend. The carbonate platform of the upper Muschelkalk unit (Ladinian) was developed after this detrital-evaporitic episode. These carbonates shifted westwards further than the underlying evaporites - they reached the Bilbao-San Sebastián area in northern Spain; Sopeña et al. (2009) - and display a homogeneous thickness (100–200 m).

7.3. Generalised evaporitic platform: Lower Keuper episode (Uppermost Ladinian–Lower Carnian)

The unit of this episode was considerably extended over the carbonates of the upper Muschelkalk unit (Table 1). The evaporite platform occupied the whole study area reaching the Prebetic–Subbetic basin. The marginal siliciclastics covered the Paleozoic substratum at several points along the SE margin of the Iberian Massif (Table 1). The facies that characterised this evaporitic episode were varied and the associated clayey host sediment was grey or green in color. Inputs of fluvial sandstones occurred only in the basins located close to the Iberian Massif, being absent in the others. The presence of large halite ponds and clay-gypsum alternation salinas was generalised, and they two changed laterally into clayey sabkhas of nodular anhydrite (Figs. 8, 9). The predominance in the ponds of clay-halite cycles at metre- and decametre-scales provides evidence of the first occurrence of efficient fractionation between chlorides and sulfates. On outcrop, the predominance of clay-gypsum alternations indicates that these salinas graded laterally into the halite ponds. Some features of these alternations suggest shallow-water and variable salinity in the precipitating brines together with reducing conditions underneath the water-sediment interface. These features are marked by: (1) the predominance of fine-grained laminated lithofacies, which commonly show irregular morphology resembling microbial laminae; (2) the prevalence of grey, green or dark tones in the clayey host sediment of the sulfates; and (3) the absence of selenitic gypsum and gypsum laminites. Broad sulfate lagoons (Canelles Fm) as well as marly-calcareous tidal flats (Adons Fm) formed in the Pyrenean basin (Figs. 8, 9, respectively). Some of the clayey sabkhas in this episode occupied paleohighs in which thin successions of nodular sulfates, claystones, marls, vuggy carbonates, and stromatolites were formed (Catalan and Prebetic–Subbetic basins) (Fig. 8).

The lower Keuper evaporitic platform is regarded as a widespread chloride-rich *evaporitic mudflat* extending at least from the Jaén sector in the Prebetic–Subbetic basin to the Catalan, Ebro, Pyrenean, and Basque-Cantabrian basins in the north, i.e. approximately one thousand kilometres. The considerable thickness of these evaporites in several basins indicates tectonic control over the sedimentation. Despite the diversity of materials composing this evaporitic mudflat in the various basins, the evaporitic facies and settings are relatively similar. These settings represent a mosaic of relatively shallow halite ponds and clay-gypsum alternation salinas. Chloride brines could not be drained off and were retained in the more subsident troughs of the platform. However, the characteristics of the evaporite units in the Pyrenean basin, i.e. thin successions and large sulfate lagoons that were more influenced by seawater proximity, suggest positions closer to the sea shore northwards. Differentiated distribution of halite ponds and clay-gypsum alternation salinas together with efficient sulfate depletion in the halite ponds suggest that salinity gradients occurred at large scale on the platform. Thus, the central sector of the today's Iberian Range, where the lower Keuper successions are thinner and richer in sulfate, would have originally supplied heavy brines to the adjacent, subsident chloride ponds (southern sector of the Iberian basin and central sector of the Ebro basin) (Fig. 9).

7.4. Interruption of the evaporitic platform: Middle Keuper detrital episode (Middle–Upper Carnian)

In the Iberian basin, the end of arid to semiarid conditions in the wide evaporitic mudflat of the lower Keuper episode was marked by the invasion of red siliciclastic facies from the Iberian Massif to the west. This facies is formed by the Manuel Sandstone Fm, or K2 unit (Ortí, 1974), of early Carnian/Julian age (Arche and López-Gómez, 2014), and by the Cofrentes Claystone Fm, or K3 unit (Fig. 2). A succession of claystones and channelled fluvial sediments of up to 280 m in thickness forms the K2 unit in the southern and western sectors of the basin (Suárez Alba, 2007) (Fig. 9). Overlying this unit, the red-colored, massive claystones of the K3 unit were sedimented as distal alluvial facies on a wide coastal plain (Peréz-López, 1996). In this relatively thin unit (50–80 m), only some thin beds of carbonate were formed. The K2 and K3 units are also present in the Prebetic–Subbetic basin (Peréz-López, 1996). Here, however, some fluvial sandstones are still interbedded in the K3 unit, suggesting more continuous siliciclastics supplies from the adjacent Iberian Massif. Nevertheless, the sandstones of the K2 unit are not present in the other Triassic basins (Salvany and Ortí, 1987; Arche and López-Gómez, 2014). Moreover, the red claystones of the K3 unit are variably represented. For instance, the K3 unit in the Poza de la Sal diapir is about 50 m thick (Salvany, 1990), but red claystones cannot be recognised as an independent unit in other sectors of the Basque-Cantabrian basin. In this paper, it is assumed that not only the K2 unit but also the K3 unit are absent in the Ebro, Catalan, and Pyrenean basins owing to non-deposition or to subsequent erosion (stratigraphic gap). This suggests a structural control over the platform, which selectively limited the clastic accumulation of the Middle–Upper Carnian to some basins. The palaeoclimatic significance of the Middle–Upper Carnian clastic episode has been documented by Arche and López-Gómez (2014) as a short-lived (>1 Ma) humid event (the 'Carnian Pluvial Event').

7.5. The renewed evaporitic platform: Lower episode of the upper Keuper (Carnian?–Norian)

Significant structural reactivation had taken place in the Iberian platform at the start of the sedimentation of the lower unit of the upper Keuper (K4 unit and equivalent units). The re-established evaporite

Fig. 4. Subsurface evaporite stratigraphy (deep boreholes) in the Iberian platform (Epicontinental Triassic). Examples from the Iberian basin (Carcelén-1, Salobral-1 and Gabaldón-1 boreholes) and the Ebro basin (Zuera-1 borehole). (A) Lower Keuper in the La Mancha sector of the Iberian basin (K1 unit: Carcelén-1 borehole; adapted from Suárez Alba, 2007, Figs. 5 and 6) and in the Ebro basin (K-1 unit: Zuera-1 borehole; adapted from Jurado, 1989). Same scale for the two boreholes. To the right of the logs, arrows numbered 1 to 3 at the Carcelén-1 borehole correspond to the 'three main cycles' distinguished by Suárez Alba (2007) in the K1 succession. The thickness of the K1 unit at the Carcelén-1 borehole is 172 m. Also to the right of the logs, the non-numbered arrows (interpreted in this work) at the Carcelén-1 and the Zuera-1 boreholes suggest the presence of decametre-scale cycles. Carcelén-1 borehole: Cycles 2 and 3 in this succession correspond to a halite pond. A predominance of clay-halite cycles at the metre- and the decametre-scale is observed, although some clay-anhydrite cycles are present towards the base of the succession. In the suggested (this work) decametre-scale cycles, 8 cycles are distinguished with average thickness of 26.8 m. Zuera-1 borehole: This succession shows a sharp change from a predominant halite pond to a clay-gypsum alternation salina (the 106 m thick, anhydrite interval forming the upper part of the succession). In the suggested (this work) decametre-scale cycles, 12 cycles are distinguished with average thickness of 38.5 m. (B) Anhydrite Zone in the La Mancha sector of the Iberian basin. Anhydrite-halite cycles forming the 'Lower Salt Zone' (LSZ) are shown at the Gabaldón-1 borehole. The carbonate-anhydrite cycles forming the other units are shown at the Salobral-1 borehole. Note slight difference in the two scales. Adapted from Suárez Alba (2007, Figs. 12 and 13). At the right of the boreholes, arrows indicate the suggested (this work) presence of decametre-scale cycles. Salobral-1 borehole: This succession corresponds to a sulfate lagoon. The six suggested decametre-scale cycles of carbonate-anhydrite have individual thicknesses between 22 and 66 m with average thickness of 41.6 m. At the top of the unit, however, such a distinction becomes tentative. Gabaldón-1 borehole: This succession corresponds to an anhydrite-halite pond. The seven suggested (this work) decametre-scale cycles of anhydrite-halite have individual thickness from 23 to 58 m with average thickness of 41.1 m. Two of them show carbonate at the base.

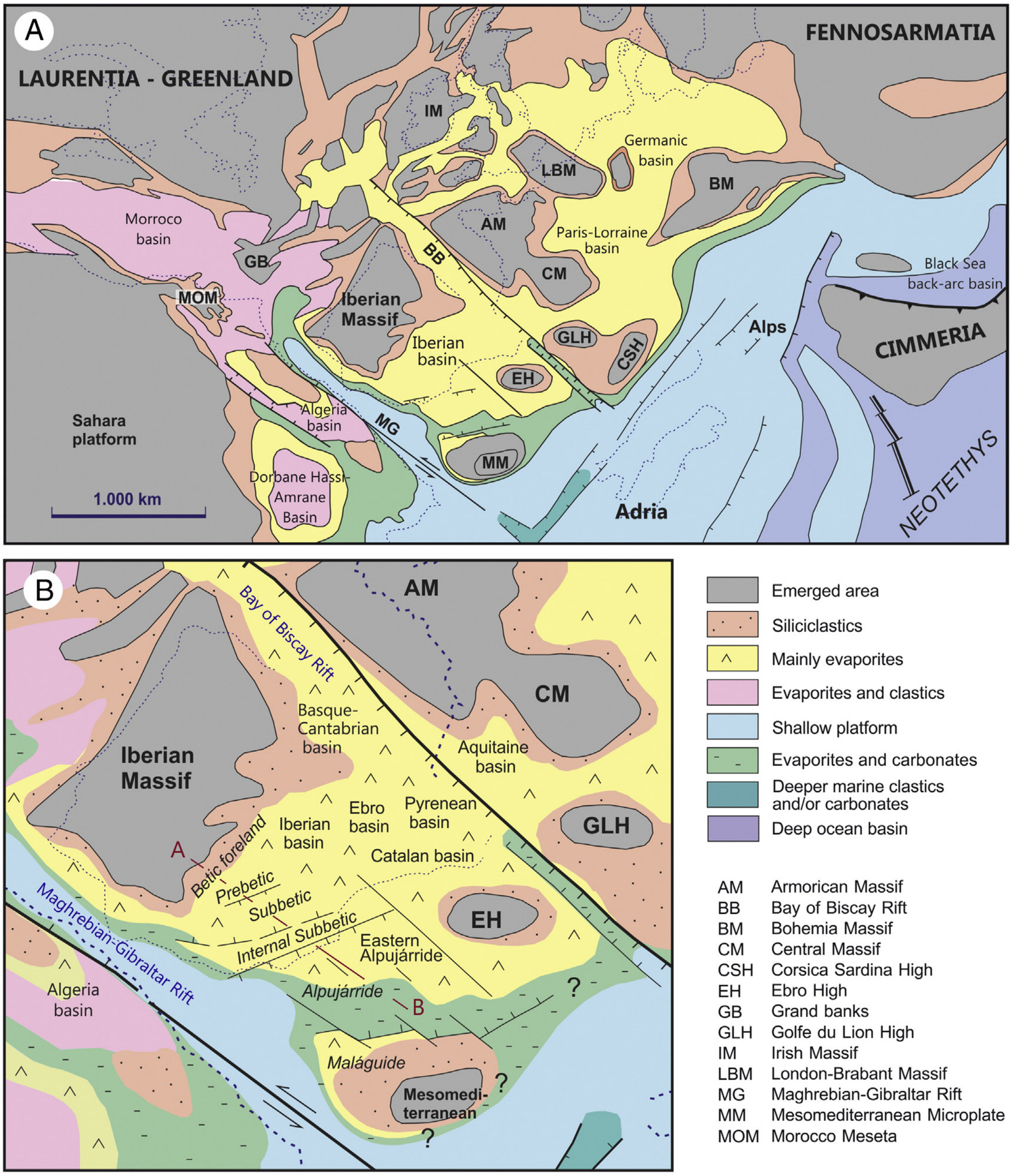


Fig. 5. Palaeogeographical reconstruction of the westernmost Neotethys area for the Late Triassic. (A) The westwards rift propagation produced numerous evaporitic basins in western-central Europe. These basins received clastic influx from the emerged lands when Cimmeria was further deformed and the Black Sea back-arc ocean continued to close (Adapted from Manspeizer, 1988, with data from Sanz de Galdeano et al., 2001, and Martín-Algarra and Vera, 2004). (B) The southern-central Europe and the Neotethys Sea were connected through the Maghrebian-Gibraltar and the Bay of Biscay rift systems. The Triassic Betic Basin (including the Prebetic–Subbetic sub-basin and the Alpine domain) was an extensive shallow platform with abundant evaporites in the western (inner) zone. The Neotethyan influence was significant in some subsident sub-basins of the Alpujarride domain (distal zone of the platform). The (A–B) section is shown in Fig. 6. For interpretation of the legend colors see the web version of this article.

platform was characterised by the red claystone matrix of the evaporites (Fig. 8). In fact, red to variegated gypsiferous claystone was the most important bulk sediment in the lower evaporitic episode of the upper Keuper in all the platform basins (Fig. 9). These evaporites, however, differ considerably from those of the older episodes with regard to the areal distribution, the precipitates and their host sediments, and the sedimentary thickness of the successions in the different basins and in the basin sectors. These evaporites migrated further westwards than those of the older group of episodes, and they currently rest on the Paleozoic basement on the SE margin of the Stable Meseta. Halite ponds were extensively developed in the K4 unit and equivalent units (Fig. 8). Clayey sabkhas were abundant in the Iberian and the Prebetic–Subbetic basins, whereas clayey gypsum salinas held a sway in the Catalan basin and in the K-2 unit of the Ebro basin, and clayey gypsum/halite salinas predominated in the Pyrenean basin (Fig. 9).

All these characteristics allow us to interpret the lower evaporitic episode of the upper Keuper as a new, broad *evaporitic mudflat* of a chloride character. In this new evaporitic platform, the K4 unit accumulated on a coastal plain formed by red claystones. A mosaic of shallow, standing brine bodies surrounded by clayey sabkhas was present. Halite ponds, however, were probably not ubiquitous: they seem to be absent or barely developed in the Ebro and the Catalan basins, and in the Maestrat sector of the Iberian basin (Fig. 9). The absence of sulfate in the clay-halite cycles of the K4 unit (Ebro and Iberian basins) suggests

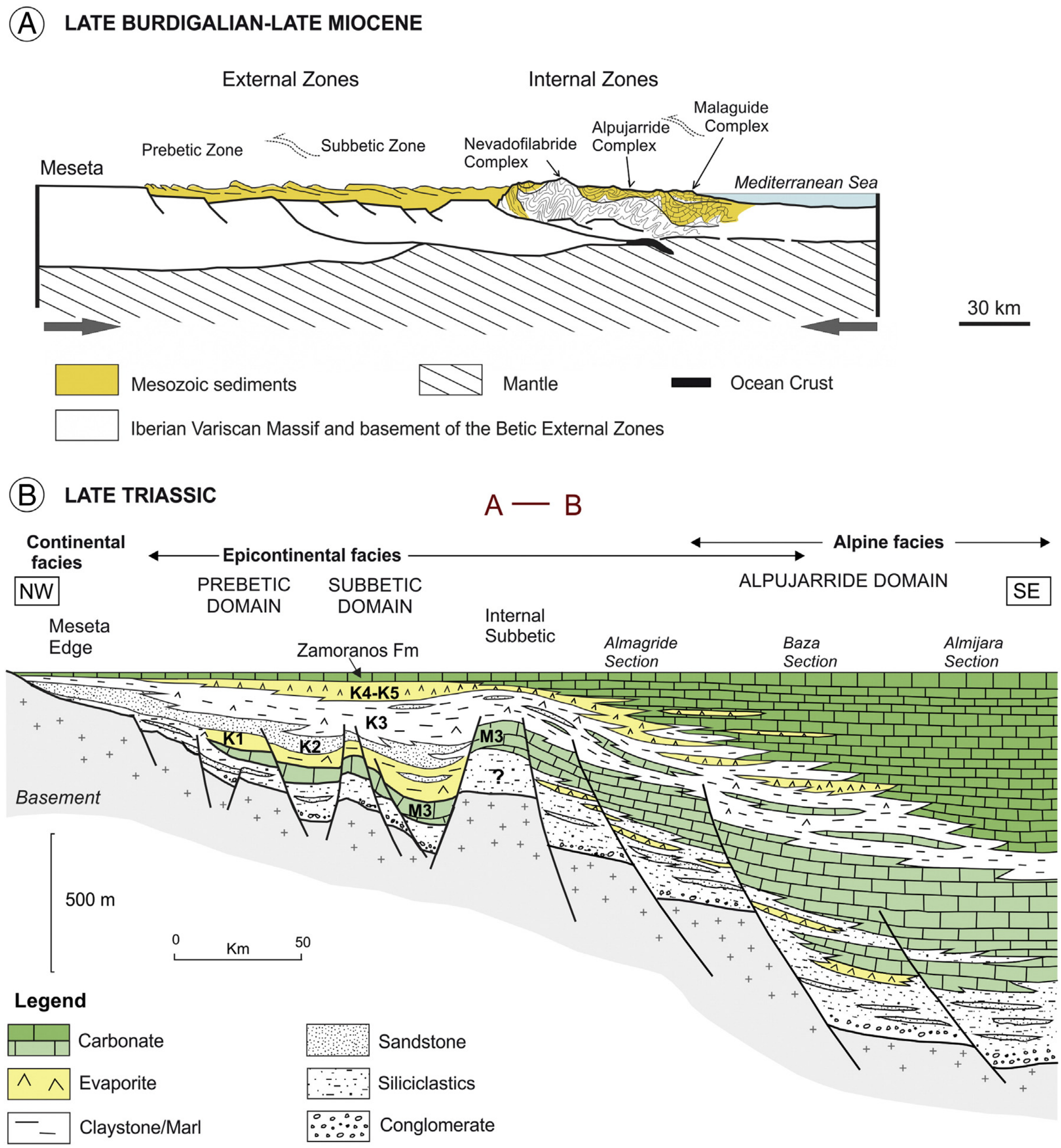


Fig. 6. Interpretative distribution of depositional units in the Betic domains of the Iberian platform during the Late Triassic. (A): Cross-section during the Late Miocene showing the structure of the Betic Cordillera with the main tectonic units (after Pérez-Valera and Pérez-López, 2008; Modified from Vera, 2001). (B): Cross-section of the syn-rift depositional system showing the lateral transition from the evaporite units in the Epicontinental Triassic (External Zones) to the thick carbonate units bearing evaporites in the Alpine Triassic (Internal Zones). Note that all the domains (Prebetic, Subbetic, Alpujárride) of the Betic Cordillera formed part of the same platform originally. The Maláguide Domain would be located to the right of the figure. Cross-section (A–B) location in Fig. 5B. For the indicated sections in (B), see Fig. 7.

that sulfate-depleted brines were supplied to the central halite ponds from peripheral salinas and sabkhas. Subsidence was high during the K4 episode in the southern sectors of the Iberian basin, where the successions attained several hundreds of metres, and also locally in the External Sierras of the Pyrenean basin, but was low in other sectors of these basins and in the other basins (Fig. 9).

7.6. The renewed evaporitic platform: Upper episode of the upper Keuper (Norian)

The evaporites of the upper episode of the upper Keuper (K5 and equivalent units) show areal distribution similar to that of the lower evaporitic episode, although their presence in the basins is somewhat irregular (Fig. 9). The main facies of these evaporites is white, bedded gypsum. The gypsum deposits of the K5 correspond to sulfate lagoons, in which some thin beds of carbonates and grey claystones may be intercalated in the gypsum layers. Two different areas of lagoons, (a) and (b), are distinguished: (a) The widest area extended irregularly through the Prebetic–Subbetic, Iberian, and Ebro basins. The thickness of the gypsum units in this area is <50 m, in general. The carbonate accompanying the sulfates suggests some influence of the marine environments to the east. In the lagoons of this wide area, sulfates occurred as fine-grained gypsum crystals forming beds and, in a minor proportion, as beds of nodular anhydrite. Metre-order sabkha cycles are observed locally. Some paleohighs bearing scarce sulfate are recorded, which correspond to marl-carbonate sabkhas bearing anhydrite nodules (e.g., the Gallicant Fm, Catalan basin; Fig. 2); and (b) The other lagoonal area, which is smaller, is the Senterada Fm of the

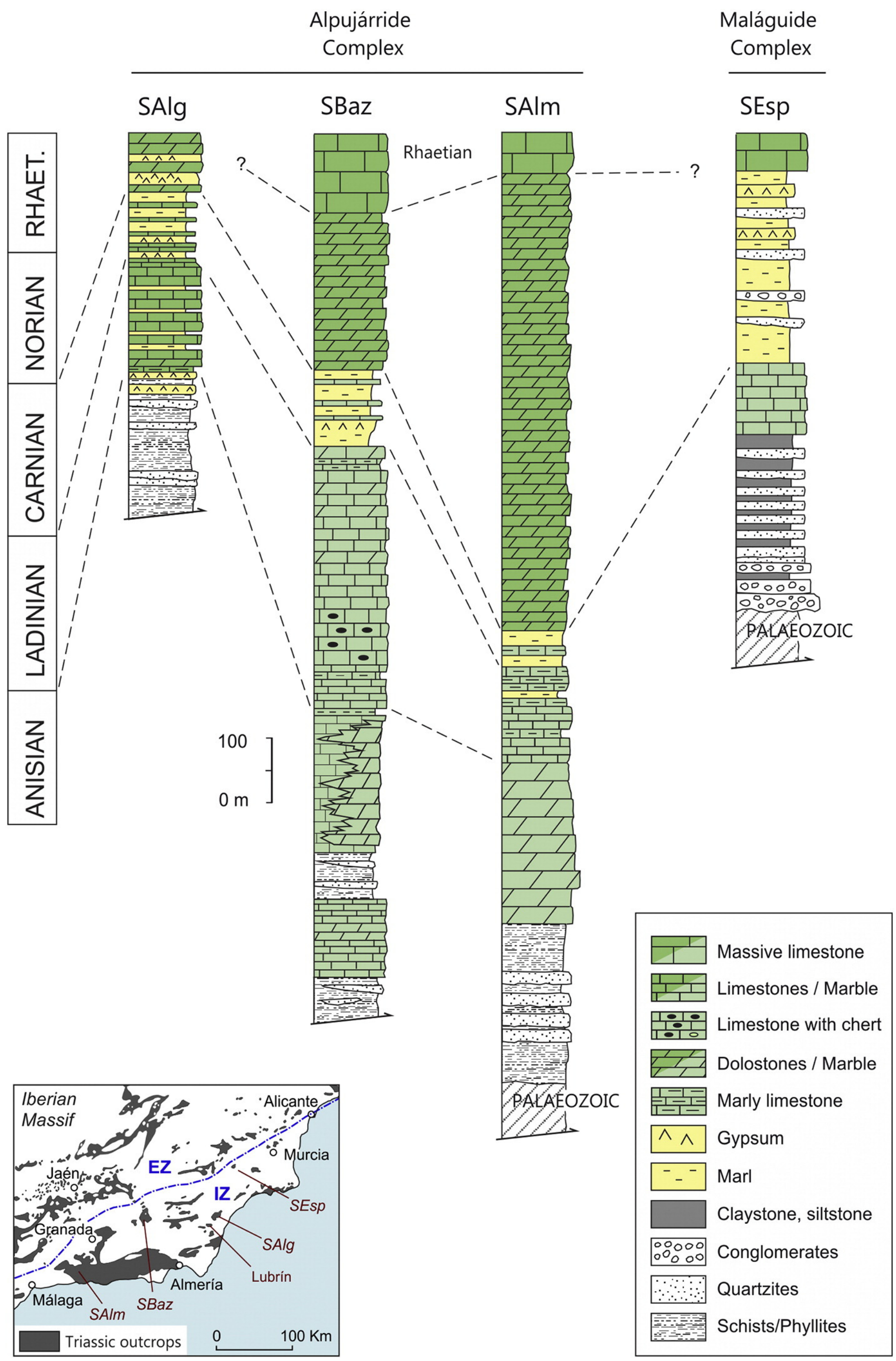


Fig. 7. Synthetic stratigraphic sections and tentative correlation of the Alpine Triassic in the Internal Zones of the Betic Cordillera (Alpujárride Complex, Maláguide Complex). SAlg: Sierra of Almagride; SBaz: Sierra of Baza; SAlm: Sierra of Almijara; SEsp: Sierra of Espuña. EZ: External Zones; IZ: Internal Zones. Estimated palaeogeographic location of the sections in Fig. 6B.

Pyrenean basin (Nogueres Unit), whose deposits attain a thickness over 250 m (Fig. 9). The carbonate associated with this unit is abundant and is arranged in beds thicker (up to > 1 m) than in the southern area. Sulfate in this northern lagoon occurred as fine-grained gypsum, and also as thicker beds. Nodular anhydrite, however, was absent. All these features suggest that this lagoon was deeper than the southern one.

In general, the evaporites of this upper episode correspond to a sulfate saltern at platform scale. An irregular distribution of small, shallow-water lagoons characterised the wide, less subsident, southern sector. In contrast, a single, deeper-water lagoon occupied a very subsident area in the Pyrenean basin (Nogueres Unit). The location of the latter lagoon was closer to the sea shore than the lagoons in the southern area. In several paleohighs, clayey sabkhas graded laterally and vertically into the lagoonal sulfates (Fig. 8).

The evaporites of the two episodes of the upper Keuper show a wider areal distribution - from the Prebetic–Subbetic basin and the Stable Meseta in the SW to the Pyrenean basin in the NE - advancing further westwards than those of the lower Keuper episode. Moreover, they underwent a marked change from the lower episode (chloride-rich evaporites, hosted by red, fine siliciclastics) to the upper episode (sulfate-rich evaporites, hosted by grey, mixed carbonate-fine siliciclastic sediments). Subsidence also behaved differently in the two episodes: during the lower episode (chloride ponds) the more subsident areas were located in the Iberian basin and the External

Table 3
Palynology of some evaporite units in Triassic basins of Iberia (Epicontinental Triassic).

Palynologic assemblage of Keuper units in the SE margin of the Stable Meseta, eastern sector of the Prebetic–Subbetic basin, and Iberian basin (València sector and Castillian Branch of the Iberian Ranges). In De Torres (1990). Age: Carnian (determinations: V. Horvat)

- Jarafuel Claystone and Gypsum Fm (K1 unit): *Alisporites* sp., *Camerosporites pseudoverrucatus*, *Camerosporites secatus*, *Camerosporites verrucatus*, *Cycadopites* sp., *Duplicisporites granulatus*, *Duplicisporites* sp., *Enzonalasporites tenuis*, *Enzonalasporites* sp., *Lunatisporites acutus*, *Microcachryidites fastidioides*, *Ovalipollis cultus*, *Ovalipollis minimus*, *Ovalipollis ovalis*, *Ovalipollis pseudoalatus*, *Paracirculina granifer*, *Paracirculinaquadriplicis*, *Paracirculina scurrilis*, *Paracirculina* sp., *Patinasporites densus*, *Patinasporites iustus*, *Patinasporites toralis*, *Patinasporites* sp., *Pityosporites* sp., *Praecirculina granifer*, *Protodiploxypinusgracilis*, *Protodiploxypinus* sp., *Pseudoenzonalasporites sumus*, *Pseudoenzonalasporites* sp., *Punctatisporites* sp., *Striatoabietites aytugii*, *Striatoabietites* sp., *Triadispora aurea*, *Triadispora stabilis*, *Triadospora suspecta*, *Triadospora* sp., *Vallasporites ignacii*.
- Manuel Sandstone Fm (K2 unit): *Alisporites* sp., *Camerosporites pseudoverrucatus*, *Camerosporitessecatus*, *Enzonalasporites* sp., *Patinasporites densus*, *Patinasporites toralis*, *Patinasporites* sp., *Praecirculina granifer*, *Pseudoenzonalasporites sumus*, *Punctatisporites* sp., *Triadospora suspecta*, *Triadospora* sp., *Vallasporites ignacii*.
- Ayora Gypsum Fm (K5 unit): *Alisporites* sp., *Camerosporites pseudoverrucatus*, *Camerosporites secatus*, *Duplicisporites granulatus*, *Enzonalasporites tenuis*, *Ovalipollis cultus*, *Ovalipollis minimus*, *Ovalipollis ovalis*, *Ovalipollis pseudoalatus*, *Paracirculina scurrilis*, *Paracirculina tenebrosa*, *Paracirculina* sp., *Patinasporites densus*, *Patinasporites tenuis*, *Patinasporites toralis*, *Patinasporites* sp., *Pityosporites* sp., *Praecirculina granifer*, *Protodiploxypinus* sp., *Pseudoenzonalasporites sumus*, *Pseudoenzonalasporites* sp., *Triadispora aurea*, *Triadospora suspecta*, *Triadospora* sp., *Vallasporites ignacii*.

All these assemblages are characterised by: *Camerosporites secatus* accompanied by *Vallasporites ignacii*, *Pseudoenzonalasporites summus*, and the genus *Paracirculina*. This palynological association belongs to the "*Camerosporites secatus* phase" of Visscher and Krystyn (1978), and more specifically to the *secatus-densus* palynological zone, which dates the Middle–Late Carnian according to Besems (1981a, 1981b).

Palynologic assemblage of the Anhydrite Zone in the southern sector of the Iberian basin. In Pérez-López et al. (1996). Age: Rhaetian (determinations: N. Solé de Porta)
Deltoidospora sp., *Ovalipollis ovalis*, *Classopollis* sp., *Classopollis torosus*, *Cerebropollenitespseudomassulae*, *Monosulcites* sp.

Palynologic assemblage of Keuper units in the Pyrenean basin. Nogueres-Cadí Unit. In Calvet et al. (1993). Age: Carnian to Rhaetian (determinations: N. Solé de Porta)

- Transit zone between the Muschelkalk and the Keuper facies (Odèn, Cadí area). Age: Carnian, possibly Middle–Upper Carnian: *Patinasporites densus*, *Partitisporites quadruplicis*, *Staurosaccitesquadrifidus*
- Grey Lutite and Carbonate unit (equivalent to the K1 unit of the Iberian basin) (Noguera de Tor and Adons outcrops). Age: Lower and Middle parts of the unit, possibly Carnian; upper part of the unit, Lower–Middle Norian: *Triadispora* sp., *Triadispora crassa*, *Alisporites* sp., *Ovalipollis ovalis*, *Ovalipollis* cf. *cultus*, *Classopollis* sp., *Cycadopites* sp., *Granuloperculatipollis rudis*
- Green Lutite and Carbonate unit (equivalent to the K5 unit of the Iberian basin) (La Nou outcrop). Age: middle part of the unit, possibly Rhaetian: cf. *Deltoidospora*, cf. *Classopollis*, cf. *Taeniaesporites*

Palynologic assemblage of Keuper units in the Basque-Cantabrian basin. In Calvet et al. (1993) (determinations: N. Solé de Porta)

- Undetermined Keuper (assigned to the basal Keuper unit in Calvet et al., 1993), Reinosa outcrop. Age: Norian, possibly Lower–Middle Norian: *Alisporites* sp., *Ovalipollis ovalis*, *Praecirculina granifer*, *Duplicisporitres granulatus*, *Classopollis* sp., *Granuloperculatipollis rudis*.
- Lower Keuper unit, Aguilar de Campoo, Santalucía mine (considered as basal? Keuper unit in Calvet et al., 1993; also assigned to the K1 unit in the present work). Age: Norian: *Triadispora* sp., *Ovalipollis ovalis*, *Praecirculina granifer*, *Duplicisporitres granulatus*, *Patinaspores densus*, *Camerosporites secatus*, *Classopollis* sp., *Granuloperculatipollis rudis*.

Palynologic assemblage of Keuper units in the Basque-Cantabrian basin: Poza de la Sal diapir. Source: INYPSA Company (internal report). Age: Rhaetian (determinations: N. Solé de Porta):

- K4 and K5 Keuper units: *Ovalipollis ovalis*, *Triadispora* sp., *Alisporites* sp., *Classopollis* sp., *Granuloperculatipollis rudis*, *Rhaetipollis germanicus*, *Cerebropollenites psuedomassulae*, *Quadraeculina anellaeformis*

Palynologic assemblage in the Ebro basin. In Jurado (1989) (determinations: N. Solé de Porta)

- Transition between upper Muschekalk and Keuper (base of the K-1 unit; sample 15), La Zaida-1 borehole. Age: Late Ladinian: *Triadispora crassa*, *Triadispora* cf. *plicata*, *Triadispora staplini*, *Triadispora* sp., *Alisporites* sp., *Ovalipollis ovalis*, *Ovallipolis cultus*, *Bisaccate indet*., *Kuglerina meieri*, *Duplicisporites granulatus*, *Duplicisporites scurrilis*, *Praecirculina granifer*.
- Röt facies (samples 28 and 29, Ballobar-1 borehole). Age: Anisian: *Stellapollenites thiergartii*, *Triadispora crassa*, *Triadispora falcata*, *Triadispora suspecta*, *Lunatisporites* sp., *Lunatisporites acutus*, *Alisporites grauvolegi*, *Klugerina meieri*, *Praecirculina granifer*, *Cycadopites* sp.

Sierras of the Pyrenean basin, whereas only the Nogueres sector of the Pyrenean basin underwent marked subsidence during the upper episode (sulfate lagoon). This global evolution shows a decreasing salinity trend, from chlorides to sulfates. The evaporites of the upper episode, which are relatively similar to those of the next episode (Anhydrite Zone), mark a change in the evaporite sedimentation at the end of the Triassic.

The upper episode of the upper Keuper was followed by the marine carbonates of the Imón Fm and equivalent units (again, transgressive evaporites preceding carbonates) (Fig. 2). These carbonates, of Upper Norian–Rhaetian age, migrated further westwards than the underlying upper Keuper units, reaching the Asturias sector in northern Iberia (Sopeña et al., 2009). The thickness of these carbonate units is limited to some tens of metres (commonly < 70 m), and the carbonate facies suggest that restricted or hypersaline conditions were common (laminated mudstones with very scarce bioturbation structures; Arnal et al., 2002).

7.7. Final evaporitic episode: The Anhydrite Zone (Rhaetian–Hettangian)

The evaporitic episode of the Anhydrite Zone shows lithological and depositional features that differ from those in many of the former episodes (Fig. 9). The Anhydrite Zone is developed from the eastern Prebetic domain to the Asturias sector in NE Iberia. It is absent in the Catalan basin and its presence in some areas of the Subbetic domain is uncertain owing to tectonic complexity. Sedimentation occurred mainly in two subsident sulfate lagoons, northern and southern, and in a less subsident central evaporite-carbonate platform. The southern sulfate lagoon occupied the eastern Prebetic sector and the southern sectors of the Iberian basin, while the northern one extended through the Ebro and the Basque-Cantabrian basins reaching the Asturias sector in the northwest. The central evaporite-carbonate platform occupied the present sector of the Iberian Range, and graded laterally into the sulfate lagoons (Fig. 9). Currently the lagoons correspond to the Lécera Fm and the central platform to the Cortes de Tajuña Fm (Fig. 2). The sulfate lagoons, which are characterised by metre- and decametre-scale cycles of carbonate and sulfate beds (Fig. 4B), reflect uniformity in the facies. Originally these cycles were formed by fine-grained laminated to bedded gypsum, selenitic gypsum, and nodular anhydrite in the sulfate beds, and by dolomitic mudstones in the carbonate ones. Sulfates predominated over carbonates in the depocenter of the sulfate lagoons, but the carbonate proportion increased towards the central evaporite-carbonate platform. The considerable thickness attained by the carbonate-sulfate cycles in these lagoons indicates an aggrading mechanism of accumulation. The central evaporite-carbonate platform, of 100–150 m in thickness in the Iberian Range, was characterised by shallow-water to inter-supratidal carbonates, which laterally graded into local carbonate-anhydrite sabkhas (Fig. 9). This platform probably

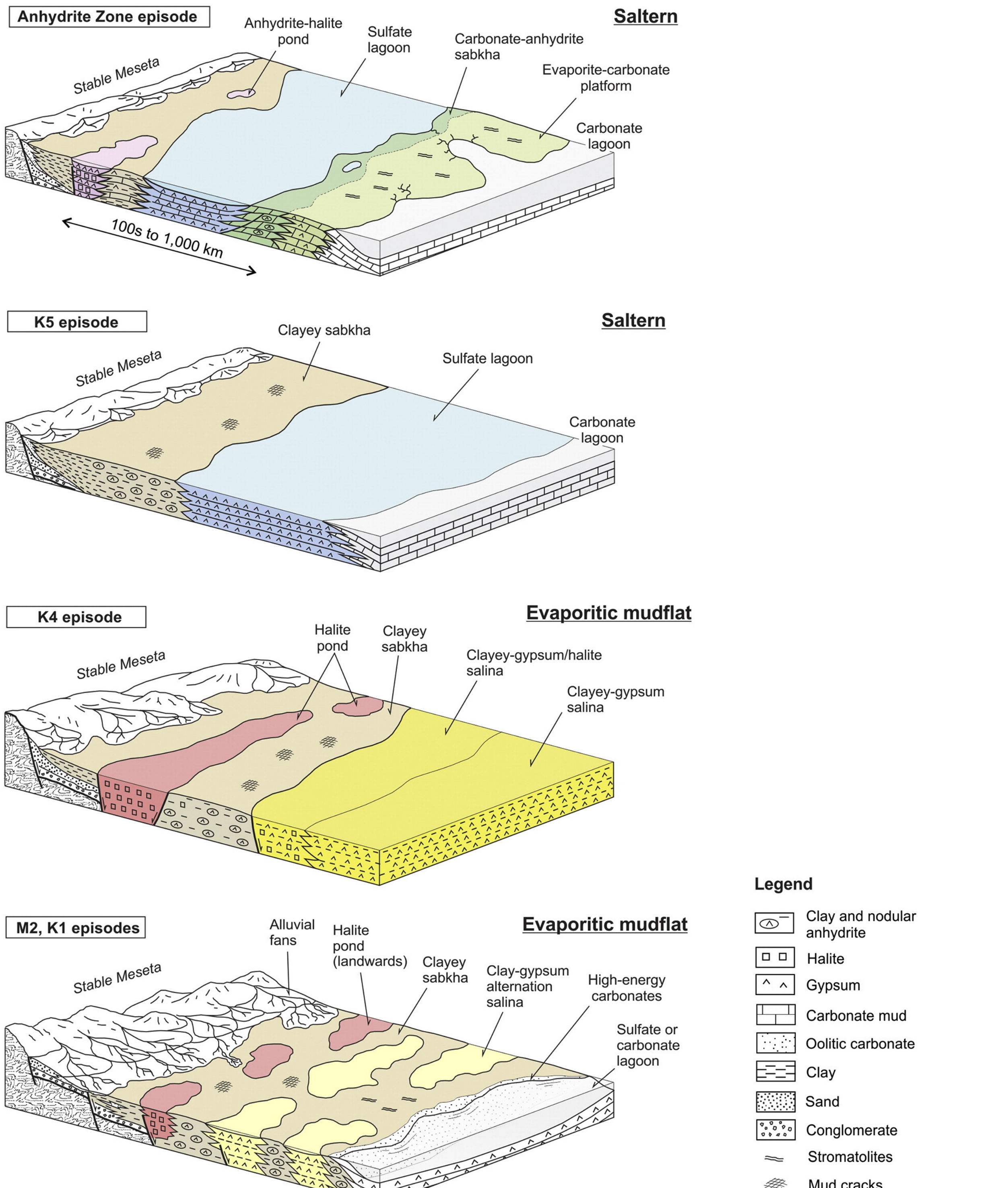


Fig. 8. Schemes of the evaporitic settings developed in the Iberian platform (Epicontinental Triassic) between the Middle Triassic (M2) and the earliest Jurassic (Anhydrite Zone) episodes. The same scheme is valid for the M2 and K1 units. The scheme for the Anhydrite Zone episode only refers to the southern sulfate lagoon ('sulfate lagoon' refers to the Lécera Fm; 'evaporite-carbonate platform' refers to the Cortes de Tajuña Fm).

occupied a position that was on land higher than that of the sulfate lagoons. The evaporites were soon affected by dissolution, and the carbonates by hypersaline dolomitization resulting in vuggy carbonates and collapse-breccias.

The two sulfate lagoons (Lécera Fm) and the central evaporite-carbonate platform (Cortes de Tajuña Fm) define a broad, clay-poor, subaqueous *saltern* at scale of the Iberian platform. Considerable subsidence in the sulfate lagoons resulted in depositional thicknesses between 500 and 1000 m in the Iberian basin (La Mancha sector) and up to several hundred metres in the Ebro, Pyrenean, and Basque-Cantabrian basins. However, subsidence in the central evaporite-carbonate platform was limited. The abundant carbonate production associated with sulfates strongly suggests close proximity to the sea shore. The general trend of

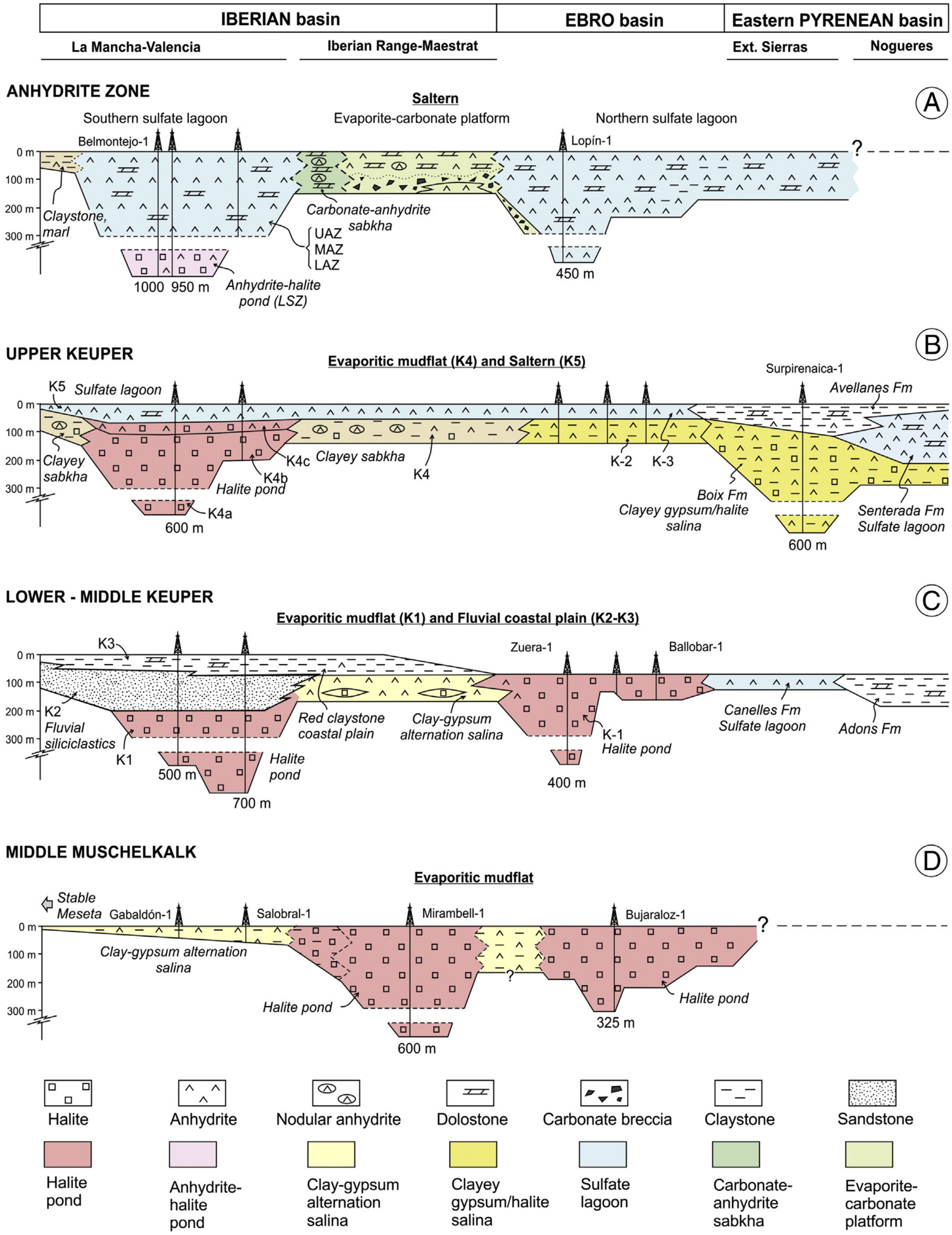


Fig. 9. Interpretative sections, out of scale, across the Iberian, Ebro, and Pyrenean basins of the Iberian platform (Epicontinental Triassic) during the evaporitic episodes between the Middle Triassic and the earliest Jurassic. The schemes show the evaporitic settings and the maximum thickness of the units in the basins. Symbols of stratigraphical units and subunits in the Iberian basin: K1 to K5, Keuper units; K4a to K4c, subunits of the K4 unit; LSZ to VAZ, subunits of the Anhydrite Zone. Symbols of units in the Ebro basin: K-1 to K-3, Keuper units.

salinity decreased upwards, evolving from local chlorides (La Mancha sector, Iberian basin) to generalised sulfates, which were progressively richer in carbonate (Fig. 3). The carbonate unit overlying the Anhydrite Zone in the basins of eastern Iberia, the Cuevas Labradas Fm (Sinemurian), was the first non-evaporitic, wholly marine Jurassic unit (Cortés et al., 2009).

8. Discussion

The preceding sections show that, between the Middle Triassic and the earliest Jurassic, the evaporite units in the inner zones of the Iberian platform (Epicontinental facies) alternated with siliciclastic and carbonatic units, recorded individual thicknesses up to one thousand metres, and graded laterally into distal carbonate units bearing evaporites (Alpine facies). This section reviews the controls of this multiepisodic evaporitic sedimentation, which participated from different 3rd-order depositional sequences and maintained close relationships with reactivation rifting phases. This section also briefly compares the Triassic successions in the Iberian platform with those in other platforms of the western Neotethys realm.

8.1. Climatic control. Humid episodes

The Triassic has been considered a "hot-house" period in a greenhouse climatic mode. This period was characterised by ice-free poles, temperate warm conditions without major climate oscillations, and by a non-zonal pattern controlled by a strong global monsoon system (Robinson, 1973; Kutzbach and Gallimore, 1989; Dubiel et al., 1991; Preto et al., 2010). The Triassic seawater was in the "aragonite sea" mode derived from a Mg/Ca ratio <2 (Stanley and Hardie, 1998; Stanley, 2008) together with the acidification of the oceans' mixed layer in equilibrium with high atmospheric pCO_2 (Retallack, 2001; Berner, 2006; Royer, 2006). This period, however, was also marked by numerous oscillations to humid conditions at least in the Neotethys realm, where the climate underwent changes even in time intervals considered to be stable (Wang, 2009).

During the Early Triassic, harsh hot-house climatic conditions inherited from the Late Permian were probably maintained (Hallam, 1981; Dickins, 1993). However, considerable climatic changes occurred during this period (Preto et al., 2010; Galfetti et al., 2007). During the Middle Triassic, the existence of a dry, arid equatorial climate is evidenced by macrofloras and palynomorphs (Visscher and Van der Zwan, 1981; Ziegler et al., 1993), and also by the terrestrial successions in Europe and North America, which have often been considered to record arid and semi-arid environments (Van der Zwan and Spaak, 1992; Ziegler et al., 1993; Simms et al., 1994). Humid periods, however, have been observed in the Middle Triassic of the western Neotethys, as in the Upper Anisian successions of the Southern Alps and Hungary (Brugman, 1986; Kustatscher et al., 2010) or in the uppermost Ladinian ones of the Alps (Mutti and Weissert, 1995). A 'Fassanian–Longobardian humid episode' has also been recorded in England, the Germanic Basin, and the Southern Alps (Szulc, 1999; Houslow and Ruffell, 2006).

A maximum expression of monsoon climate probably occurred during the Late Triassic, with non-latitudinal distribution of climate zones (Robinson, 1973; Wang, 2009; Sellwood and Valdes, 2006; Preto et al., 2010). The semiarid and warm climate model proposed for this period in Pangea corresponds to dry equatorial and continental regions, and to humid belts at higher latitudes and around the Neotethys Ocean (Parrish, 1993; Fawcett et al., 1994; Tanner et al., 2004). The Late Triassic, however, was also interrupted by an important episode of humid conditions in the Middle Carnian, the 'Carnian Humid Episode' (Ruffell et al., 2016). In the western Neotethys, this episode was characterised by exceptional inputs of coarse siliciclastics and by the demise of rimmed carbonate platforms (Simms and Ruffell, 1989; Simms et al., 1994; Gianolla et al., 1998; Preto and Hinnov, 2003; Rigo et al., 2007). Subsequently, the Upper Carnian and Norian times were represented by monotonous successions of dolomitized peritidal carbonates in the Southern Alps, which have been interpreted as deposited under a generally hot and semi-arid climate (Berra et al., 2010; Stefani et al., 2010; Haas and Demény, 2002). At the start of the Rhaetian, however, several features indicate intense weathering in a hot, humid climate. These features are as follows: replacement of gypsiferous red-beds by plant-rich and coal-bearing paralic sediments; high kaolinite proportion in mudrocks; and development of palaeosoils in Central Europe (Ahlberg et al., 2002; Preto et al., 2010).

Some of the former humid episodes have also been documented in the Epicontinental Triassic of the Iberian platform. The most important one corresponds to the 'Carnian Pluvial Event' of Arche and López-Gómez (2014) (Carnian Humid Episode of Ruffell et al., 2016), as evidenced by the Manuel Sandstone Fm. Following this formation, absolute dominance of red claystones occurs in the Cofrentes Claystone Fm (K3 unit), and a reddish clayey matrix of the evaporites prevails in the overlying K4 units in all the platform basins. Other humid episodes are the following: Gómez et al. (2007) reported a humid phase at the Rhaetian–Hettangian boundary in the Asturias sector on the basis of an increase in the proportion of miospores from hygrophytic plants; and Suárez Alba (2007) also suggested the presence of a humid phase in the lower part of the Hettangian (Iberian basin) on the basis of a thick carbonate intercalation (MAZ) within the Anhydrite Zone in the La Mancha sector (Fig. 3).

8.2. Triassic evaporites and depositional sequences in the Iberian platform

A number of studies have investigated (a) the 3th-order sequences (between fifty and several hundred metres in thickness) forming the Epicontinental Triassic of the Iberian platform (Calvet and Marzo, 1994; López-Gómez and Arche, 1994; Peréz-López, 1996, Pérez-López, 2000; Pérez-López et al., 2005; Suárez Alba, 2007; Haas et al., 2010; Escudero-Mozo et al., 2015; among others), and (b) the relationships of these sequences with the eustatic oscillations of the oceanic level and the associated depositional systems tracts (Exxon cycle chart; Haq et al., 1987, 1988). All these studies reflects some interpretative discrepancies, and this is partly because of the difficulty of identifying discontinuities in the basin depocenters using only seismic profiles and geophysical logging at deep boreholes. It is also possible that some discontinuities have not been recorded in all the basins of the Iberian platform owing to their different subsidence and tectonic activities. The two marine transgressive (eustatic) sequences of the Middle Triassic involving basal evaporites and top carbonates, i.e. the Röt-lower Muschelkalk sequence and the middle Muschelkalk–upper Muschelkalk sequence, are reported in the literature (Fig. 10). In some interpretations, however, the boundary between these depositional sequences is located in the middle of the units, not at the base or the top (TR1–TR2 in Escudero-Mozo et al., 2015; SB4–SB5 in Calvet and Marzo, 1994). Different interpretations exist for the Late Triassic and the Anhydrite Zone sequences. Some of these interpretations are shown in Fig. 10: (a) the long K1-Imón Fm sequence of López-Gómez and Arche (1994) has been divided into two separate sequences by Suárez Alba (2007). These are the K1–K3 sequence, which involves a break at the K1–K2 boundary, and the K4-Imón Fm ('K6 unit') sequence; (b) the Imón Fm has been separated as a single sequence (Calvet and Marzo, 1994) or only its lower part has been considered the top of the K2-Imón Fm sequence (Peréz-López, 1996; Pérez-López, 2000); and (c) the Anhydrite Zone has been considered as a single sequence (Vargas et al., 2009; Bordonaba and Aurell, 2002) or as a double sequence (Suárez Alba, 2007).

Not all the eustatic sea-level oscillations documented in sequential stratigraphy at a global scale (Haq et al., 1987, 1988; Haq, 2014; Embry, 1997; Haq and Al-Qahtani, 2005; Tomasso et al., 2008; Ruban, 2014; Stefani et al., 2010; among others) can be identified with certainty in the Triassic successions of the Iberian platform. This is because of the intense tectonism that affected this platform during that period, and because of the inaccuracy of the chronostratigraphic dating of the evaporite units in this platform (Fig. 11). Recently, Ruban (2014) discussed the long-term eustatic cycles of the Triassic, which are mostly based on geophysical criteria (Haq, 2014). Ruban (2014) has noted the difficulty of plotting a global curve by comparing the eustatic reconstructions of Embry (1997) and of Haq and Al-Qahtani (2005). However, it does not seem impossible to correlate most of the sea-level falls distinguished by Embry (1997) with the major discontinuities in the Triassic of the Iberian platform or with the boundaries between their stratigraphic units (Fig. 11). For the Anisian–Ladinian interval, the sea-level falls distinguished by Embry (1997) approximately correspond to the bases of the two transgressive sequences of the Middle Triassic (sequence boundaries according to Escudero-Mozo et al., 2015; Fig. 11). For the Carnian–Norian interval, in which several falls of different

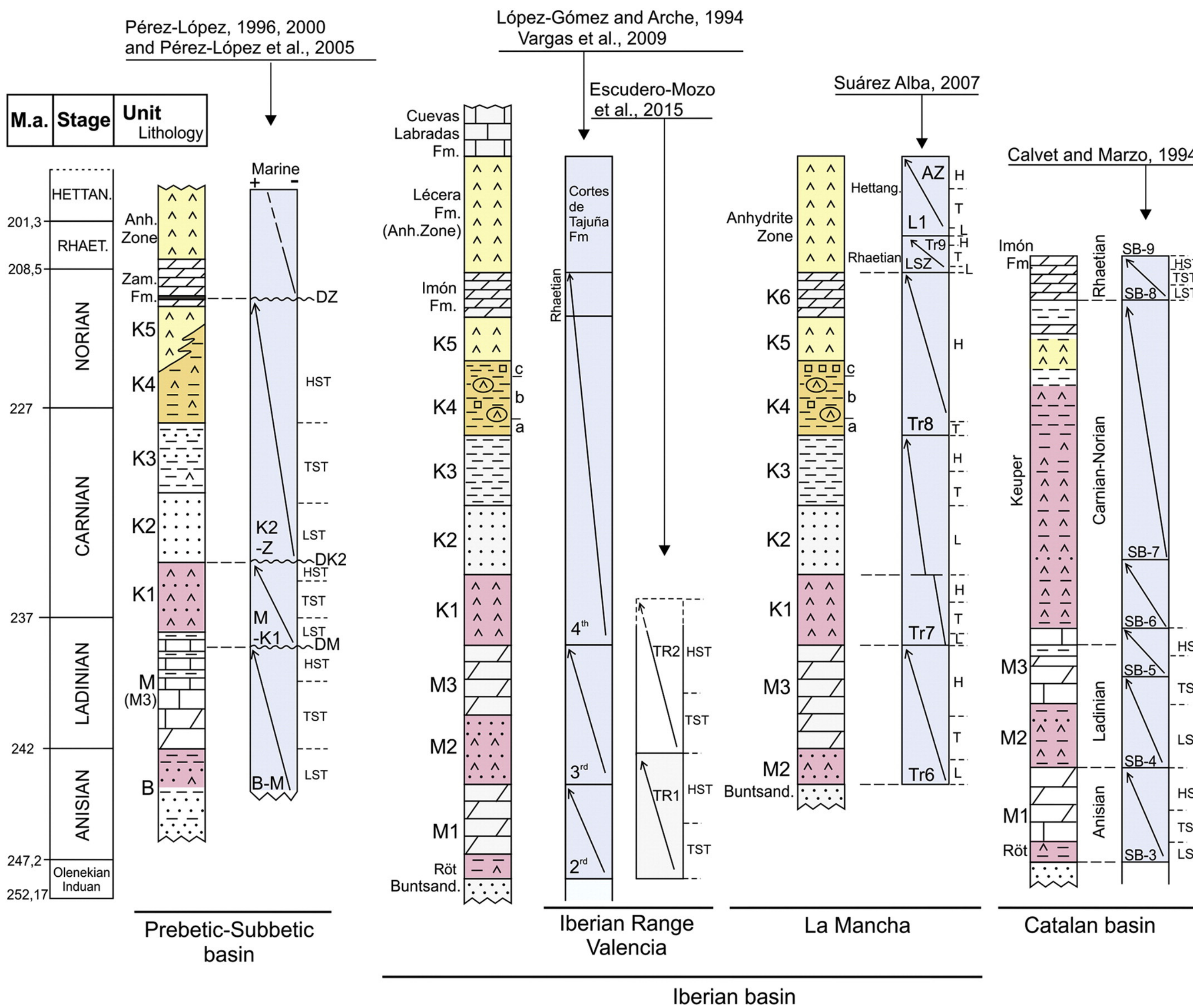


Fig. 10. Interpretations of the 3th-order depositional sequences in the Middle Triassic to earliest Jurassic successions in the Iberian platform (Epicontinental Triassic). The successions, out of scale, are arranged by basins: Prebetic–Subbetic basin, Iberian basin (southern sector of València and Castillian Branch of the Iberian Ranges; southern sector of the La Mancha), and Catalan basin. The ages assigned to some units may vary in the different sources. One representative lithologic column is shown for each basin succession. On the right of these columns, the arrow columns indicate the depositional sequences and the system tracts in some cases. Stratigraphical symbols: B, Buntsandstein; M, Muschelkalk; K, Keuper; LSZ, Lower Salt Zone; L1, Lower Liassic. Symbols of depositional sequences: B-M, M-K1, K2-Z, Tr, TR, SB. Symbols of systems tracts: LST, (L), lowstand systems tract; TST, (T), transgressive systems tract; HST, (H), highstand systems tract. Symbols of major unconformities in the Prebetic-Subbetic succession: DM, DK2, DZ.

intensities are indicated in the curve by Embry (1997), the correlation becomes tentative. Falls 1 to 5 - numbers arbitrarily introduced by us in this curve - in Fig. 11 could be roughly coincident with the bases of the K1 to K5 units of the Keuper succession, and fall 6 with the base of the Anhydrite Zone. From this perspective, an eustatic control over the evaporite deposition in the Iberian platform seems to be justifed.

8.3. Triassic evaporites and rifting pulses in the Iberian platform

Some authors have studied the major rifting cycles during the Mesozoic in the Epicontinental Triassic of the Iberian platform. The papers by Salas et al. (2001, 2010) have shown that several pulses of high and low extensional activity occurred during the long Late Permian–Triassic rifting cycle. Other authors have calculated the subsidence rates for the Iberian and the Ebro basins during this period (Suárez Alba, 2007; Vargas et al., 2009). According to Vargas et al. (2009), the Late Permian–Triassic long-term rifting cycle was punctuated by repeated, short-lived (1–2 Ma) synrift and postrift phases.

All thickness values of the sedimentary units reported in the present study indicate that (1) subsidence was high during most of the evaporitic episodes suggesting coeval pulses of rifting reactivation, (2) this subsidence was markedly differentiated not only in the basins but also in the different basin sectors, and (3) some type of alternation seems to be present in these values. Accordingly, a new approach to the relationships between extensional pulses and sediment accumulation may be proposed when a distinction between ‘thick units’ (>250 m) and ‘thin units’ (<250 m) is made in the successions of the Middle Triassic to the earliest Jurassic in the Iberian platform (Fig. 11). The maximum values of the thick units, between 250 and 1000 m, in the Iberian, Ebro and Pyrenean basins are specified in Figs. 9 and 11. As regards the thin units, the maximum thicknesses are limited to about 150–200 m for the three carbonate units, to about 50 m for the K3 claystone unit of the basins surrounding the Iberian Massif, and to about 50 m for

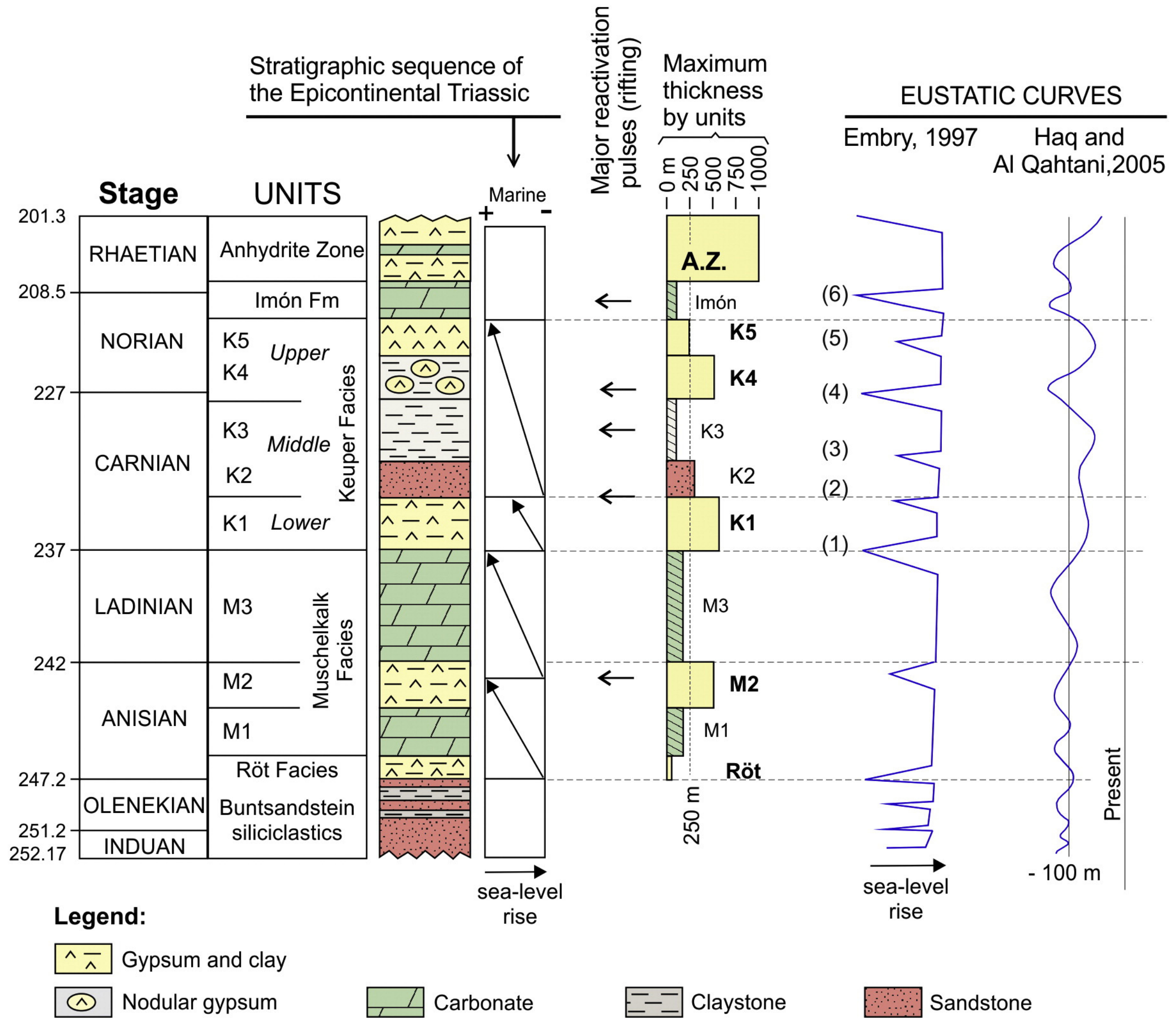


Fig. 11. Comparison of the sea-level (eustatic) oscillation curves to global scale by Embry (1997) and by Haq and Al-Qahtani (2005) with the 3rd-order depositional sequences of the representative Middle–Upper Triassic succession in the Iberian platform (Epicontinental Triassic). For the Carnian–Rhaetian interval, numbers 1 to 6 in the curve by Embry (1997) were introduced (arbitrarily in the present study) to facilitate the comparison. In the column of "Maximum thickness by units", the value of 250 m separates 'thin' from 'thick' units. The top sequence boundary of Escudero-Mozo et al. (2015) is used for the Anisian.

the K5 evaporite unit in many basins. From these values, an alternation of thick and thin units can be deduced (Fig. 11), which suggests a similar alternation of reactivation and deceleration rifting pulses. Local anomalies in this alternation are the K2 unit in the Iberian basin, which is considered to be a thick unit, and the K5 unit in the Nogueres sector of the Pyrenean basin, which behaves as a thick unit (Fig. 9). This alternation, which provides evidence for a structural control, seems to be also related to the sea-level falls as reflected in the boundaries between the Keuper units (Fig. 11). From the foregoing, it seems reasonable to assume that a concomitance of extensional pulses and sea-level falls could have controlled the evaporite sedimentation in the Iberian platform during the period under study.

8.4. Comparison with other Triassic evaporitic records in the western Neotethys

The most generalised depositional sequence of the Triassic–Lower Jurassic rifting in the structural region of the North Atlantic continental-margin basins was early established by Evans (1978). Evans's sequence consisted of (a) basal detrital facies, generally fluvial, lacustrine, and eolian red beds; (b) intermediate thick evaporites, mainly salt, and marly-dolomitic units; and (c) upper carbonate and shale facies of shallow-water normal marine environment. Stages (a) and (b) correspond to the continental (initial) stage of rifting, whereas stage (c) corresponds to the final oceanic transgression. This interpretation of the Triassic evaporites as a 'rifting facies' is also valid for the structural region of the German-British-Paris basin continental shelf including its southern sectors (Iberia, south France).

Our Fig. 12, which is based on the paper by Simms et al. (1994; Fig. 21.1), is a summary of some Triassic successions bearing evaporites (East North Atlantic, Southern North Sea-Germany, France-Germany, Aquitaine basin in S France, Ebro basin in N Spain, Alpine facies of the Betic domain in S Spain, Italy (Lombardia), Atlasic domain (Tunisia), Israel-Jordan, western Anatolia; see Fig. 12 caption) in the structural regions of the western Neotethys. Three main evaporitic intervals can be distinguished in these representative sections, although their correlation in the different basins cannot be proposed accurately. Except for the brief event of the Carnian Humid Episode, the Carnian–Norian is the interval with the widest evaporite distribution and the maximum accumulation of chloride-dominated sequences, over one thousand metres in thickness in several platform basins. An older interval of evaporite deposition, although not so regularly distributed, is that of the Anisian–Ladinian. A younger interval, albeit more local, occurred during the Rhaetian–Hettangian, with anhydrite-dominated sequences up to one thousand metres thick.

The concurrence in the northern part of the Iberian platform (Fig. 9) of the three main intervals of evaporite accumulation is significant. They are represented by the assemblage of the older and younger groups of

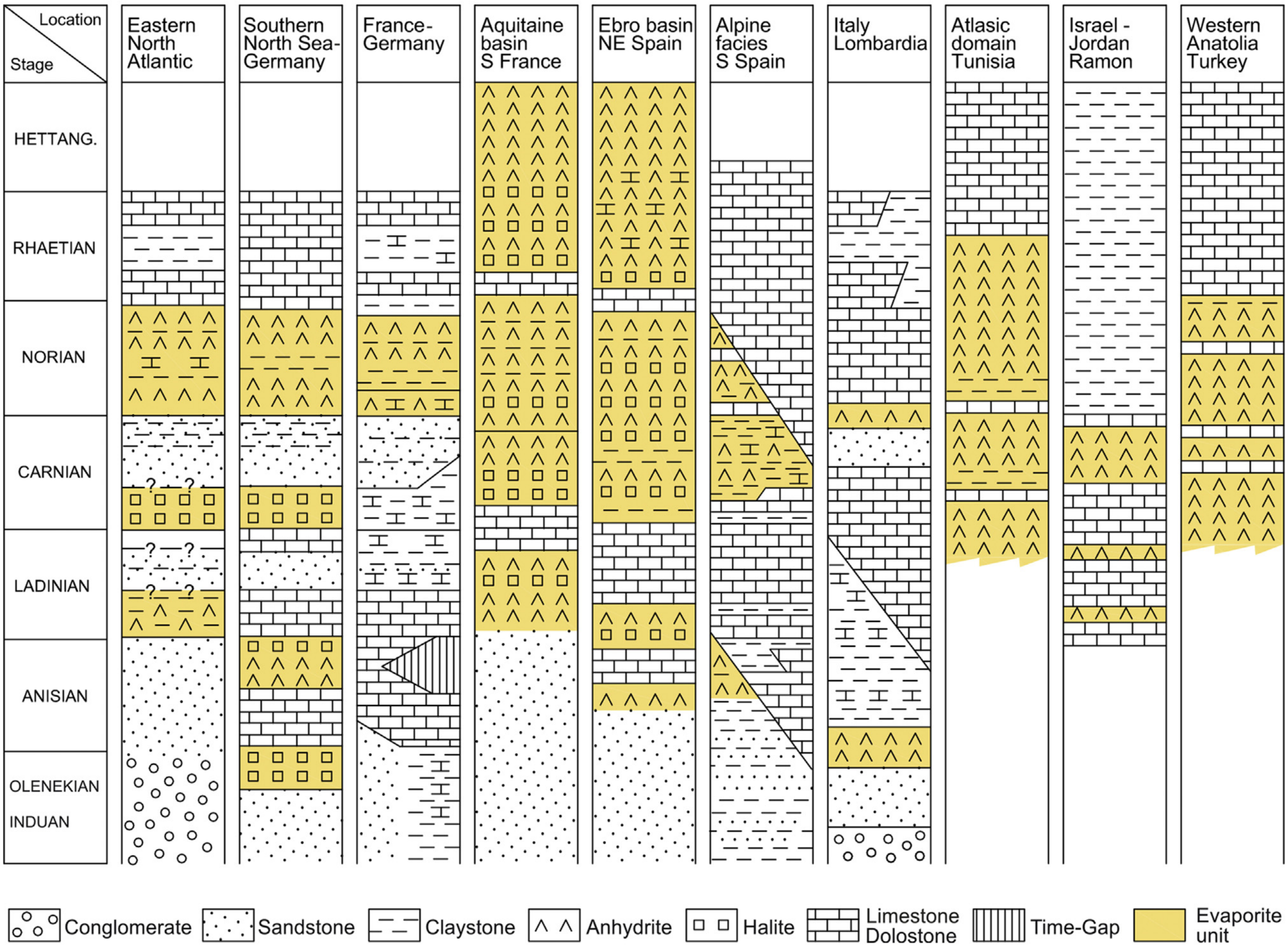


Fig. 12. Summary of evaporite stratigraphy in Triassic basins of the western Neotethys realm. The successions of the Eastern North Atlantic, Southern North Sea-Germany, France-Germany, and Italy (Lombardia) are taken from Simms et al. (1994; Fig. 21.1). The other successions are summarised from the following sources: Aquitaine basin (Stévaux, 1971; Stévaux and Winnock, 1974); Ebro basin (this paper); Alpine facies, Betic Chain, S Spain (this paper); Atlasic domain (Courel et al., 2003); Israel-Jordan (Bialik et al., 2012); western Anatolia, Turkey (Gündoğan et al., 2008). The evaporites in the Aquitaine basin are included in the following units: saliferous and anhydritic variegated clay unit of 363 m thick at the base of the Muschelkalk facies (Middle Triassic); lower saliferous series (several hundred metres thick) and upper saliferous series (50–100 m thick) in the 'lower Keuper facies' (Upper Triassic) (Stévaux, 1971; Stévaux and Winnock, 1974). The evaporites in the Atlasic domain are included in the following units: evaporites and carbonates of the megasequence 1 (evaporitic interval of about 200 m thick) of Ladinian–Carnian age; evaporites and top carbonates of the megasequence 3 (evaporitic interval of about 200 m thick) of Carnian age; and evaporites and top carbonates of megasequence 4 (evaporitic interval of about 100 m thick) of Norian–Rhaetian age (Courel et al., 2003). The evaporites in Israel–Jordan are included in the following units: evaporites of the Saharonian Fm of Ladinain age; evaporites and carbonates of the M2 Member of the Mohilla Fm in Israel (about 95 m thick), and of the Ruweis Fm in Jordan (Bialik et al., 2012). The evaporites in Turkey are included in the gypsum bearing Kaleboğazı Fm (gypsum interval of about 200–300 m thick) of Late Triassic age (Gündoğan et al., 2008).

evaporitic episodes in the Epicontinental Triassic. This multiepisodic evaporite sequence has a counterpart in the Aquitaine basin (Fig. 12), where thicknesses over 350 m for the (Anisian)–Ladinian evaporites, over one thousand metres of Carnian-Norian chlorides, and up to 800 m of Hettangian sulfates were also recorded in the southern part of the basin (Stévaux and Winnock, 1974). Probably these two areas originally formed part of the same platform developed between the Iberian Massif and the Central Massif in France (Fig. 5B). This platform could have served as a wide evaporitic seaway for the westward migration of the Neotethys Ocean during some periods between the Anisian and the Hettangian. Carbonates and siliciclastics were the time-equivalent deposits in other areas of central-western Europe.

In the Iberian platform, the relationships between the Epicontinental Triassic and the Alpine Triassic (Fig. 12) suggests that at least the Carnian–Norian was a time interval of generalised evaporite deposition throughout the platform, although much more intense in the inner zones (Epicontinental facies) that in the distalmost ones (Alpine facies). These relationships also suggest that the precipitation of evaporites and the accumulation of carbonates occurred coevally as lateral facies gradations. This seems to be corroborated by the fact that biological or physical barriers separating the depositional settings of the two facies have not been documented up to now. The transect in the southern (Betic) zone of the Iberian platform from carbonates, which attained thicknesses of 500–1000 m, to evaporites (Figs. 6, 5, 12) help us to better understand the palaeogeography and tectonic controls in other Triassic platforms of the western Tethys. For instance, this could be the case of the Dolomites in the Triassic of Italy (Lombardia), where evaporite units are interbedded with the predominant, shallow-water carbonates (Stefani et al., 2010; Berra et al., 2010) (Fig. 12).

9. Conclusions

Under arid to semiarid climate conditions, the sedimentation of marine evaporites in the western Neotethys during the Triassic may be regarded as a stage of the rifting process ('rifting facies'). In the Iberian platform, considerable sedimentation of evaporites occurred between the Middle Triassic and the earliest Jurassic in extensional regime. This sedimentation occurred not only in the inner zones of the platform (Epicontinental Triassic) but also in the more distal zones in association with the prevailing marine carbonates (Alpine Triassic, Betic domain).

In the inner zones of the platform, an assemblage of six evaporitic episodes, three carbonate episodes, and one detrital episode occurred during this period. The stratigraphic units derived from the evaporitic episodes are arranged in two groups, each one with differentiated characteristics. These evaporite units are heterogeneous and display variable thickness attaining up to 1000 m locally. In contrast, the carbonate units which alternate with the evaporites are relatively homogeneous and thin (<200, in general). All of these units progressively expanded towards the Iberian Massif. The six evaporitic episodes were the result of multiple controls. Together with the sea-level (eustatic) oscillations at global scale, the structural factor (pulses of rifting reactivation) played a major role in the evaporite formation leading to repeated episodes of restriction and to high sedimentary thickness in some basins and sectors of the platform. An upwards decrease in the salinity trend is recorded for the assemblage of the six episodes. The evaporites were formed as transgressive systems tracts or as combinations of transgressive and highstand systems tracts. The different evolutive trends in the evaporites of the two groups suggest major re-structuration of the platform after the sedimentation of the siliciclastic units of the middle Keuper (Carnian Humide Episode). The great thickness of the evaporite units suggests high subsidence rates in the platform, which behaved as an evaporite trap first for chlorides and lately for sulfates. The alternation of thick units (mainly evaporites) and thin units (mainly carbonates) reflects a combination of sea-level fluctuations and pulses of rifting activation-deceleration.

The age of the evaporitic episodes in the allochthonous units of the Alpine Triassic not always is unequivocal. However, evaporites associated with the carbonates of the Alpine facies can be reported in the Carnian–Norian and the Anisian intervals. As far the carbonate units in the Epicontinental Triassic, those of Ladinian age (upper Muschelkalk unit) and Norian–Rhaetian age (Zamoranos Fm) can be correlated with the carbonate units in the Alpine Triassic, or with parts of these units bearing evaporites. All these evaporites interbedded within the Alpine carbonates provide evidence of lateral gradations from the Epicontinental Triassic to the Alpine Triassic across the Iberian platform. Probably factors such as tectonic pulses, sea-level oscillations, and palaeogeographic modifications controlled the facies distribution across the original platform more effectively than local climatic variations.

Many of the sedimentological and palaeogeographic findings in this paper concerning the evaporite record in the Iberian platform could be applied to the mosaic of structural plates and platforms which evolved in the western Neotethys during the Triassic. It is also feasible that some of the platforms could have behaved as epeiric, evaporitic seaways for the westward migration of the Neotethys Ocean at the time.

Acknowledgements

This study was supported by research projects CGL2009-11096, CGL2014–52699–P, and CGL2015-66835-P of the Spanish Government (Ministerio de Ciencia e Innovación), by project 2009GR1451 of the Catalan Government (Departament d'Innovació, Universitats i Empresa), and by a fund from the research group "Stratigraphic discontinuities" of the Junta de Andalucía RNM 208. We thank M.J. Jurado for allowing the publication of palynological data in her Ph.D. Thesis, and to INYPSA for allowing the publication of some palynological data. Review comments by José López-Gómez and Tadeusz Peryt, and Editor Thierry Corrège, considerably improved the manuscript.

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