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ScienceDirect
Palaeogeography, Palaeoclimatology, Palaeoecology 254 (2007) 606–626
PALAEO
www.elsevier.com/locate/palaeo

Palaeogeography, facies and nomenclature of the Triassic units in the different domains of the Betic Cordillera (S Spain)

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Received 20 December 2006; received in revised form 24 July 2007; accepted 25 July 2007

Abstract

This paper reviews and discusses the different facies and nomenclature of the Triassic in the Betic Cordillera (S Spain). Emphasis is placed on problems encountered when studying Betic basin facies and palaeogeographic domains. In Triassic times, the Betic basin was positioned between the Iberian and Mesomediterranean Plates. We therefore propose the designations Southiberian Triassic and Mesomediterranean Triassic for the Triassic rocks that crop out in the External and Internal zones respectively of the Cordillera. Although facies types vary substantially, several similarities in their main stratigraphic features link the two palaeogeographic domains. Thus, Buntsandstein, Muschelkalk and Keuper facies can be currently distinguished in both domains of the External and the Internal Zones of the Betic Cordillera. Most rocks were coastal and shallow-marine sediments deposited across an extensive and varied palaeogeography, which defines the Sephardic domain. For some epochs, this last domain shows the influence of Alpine fauna and even palaeogeographically gives rise to subdomains characteristic of Alpine facies that today crop out in some Internal Zone units. This variety of facies makes the study of the Triassic in the Betic Cordillera all the more interesting.

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Keywords: Buntsandstein; Muschelkalk; Keuper; Triassic; Sephardic domain; Alpine facies; Betic Cordillera

1. Introduction

The Triassic system ("Trias") was defined by Alberti (1834) in Germany as a "formation" found between the Permian and the Jurassic. This author coined this "preliminary" name after the characteristic tripartition of the strata into "Bunter Sandstein, Muschelkalk and Keuper" (Bachmann, 1998). The Germanic Triassic has the rank of supergroup, comprising the three groups Buntsandstein, Muschelkalk and Keuper, each of which is subdivided into several formations (Bachmann, 1998). This division of the Triassic for the German epicontinental basin was adopted by the different regions of Europe in which this tripartition could be identified. Notwithstanding, these facies exhibit lithological and biostratigraphic variations according to their position in the different continental margins that formed around the Pangaea supercontinent during its extension stage. This stage of extension started in the Upper Carboniferous

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doi:10.1016/j.palaeo.2007.07.012

and continued during Permian times (e.g. López-Gómez et al., 2002). During the Lower Triassic, the generalised fragmentation of Pangaea gave rise to grabens, which harbour large amounts of detritic materials (e.g. Lucas, 1998). In the Middle Triassic, the expansion of the Tethys westwards flooded continental zones and locally covered Palaeozoic reliefs, with several transgression–regression cycles occurring up until the end of the Triassic (Aigner and Bachmann, 1998; Lucas, 1998). The most expansive stages took place in the Ladinian and Norian, leading to the deposition of carbonates on almost every European epicontinental platform. However, the uneven distribution of the deposits and facies variations indicate that sedimentation was often influenced by local or regional tectonic movements, besides sea level changes. Despite these variations, in all these basins it is possible to identify Buntsandstein, Muschelkalk and Keuper facies, albeit of different ages,

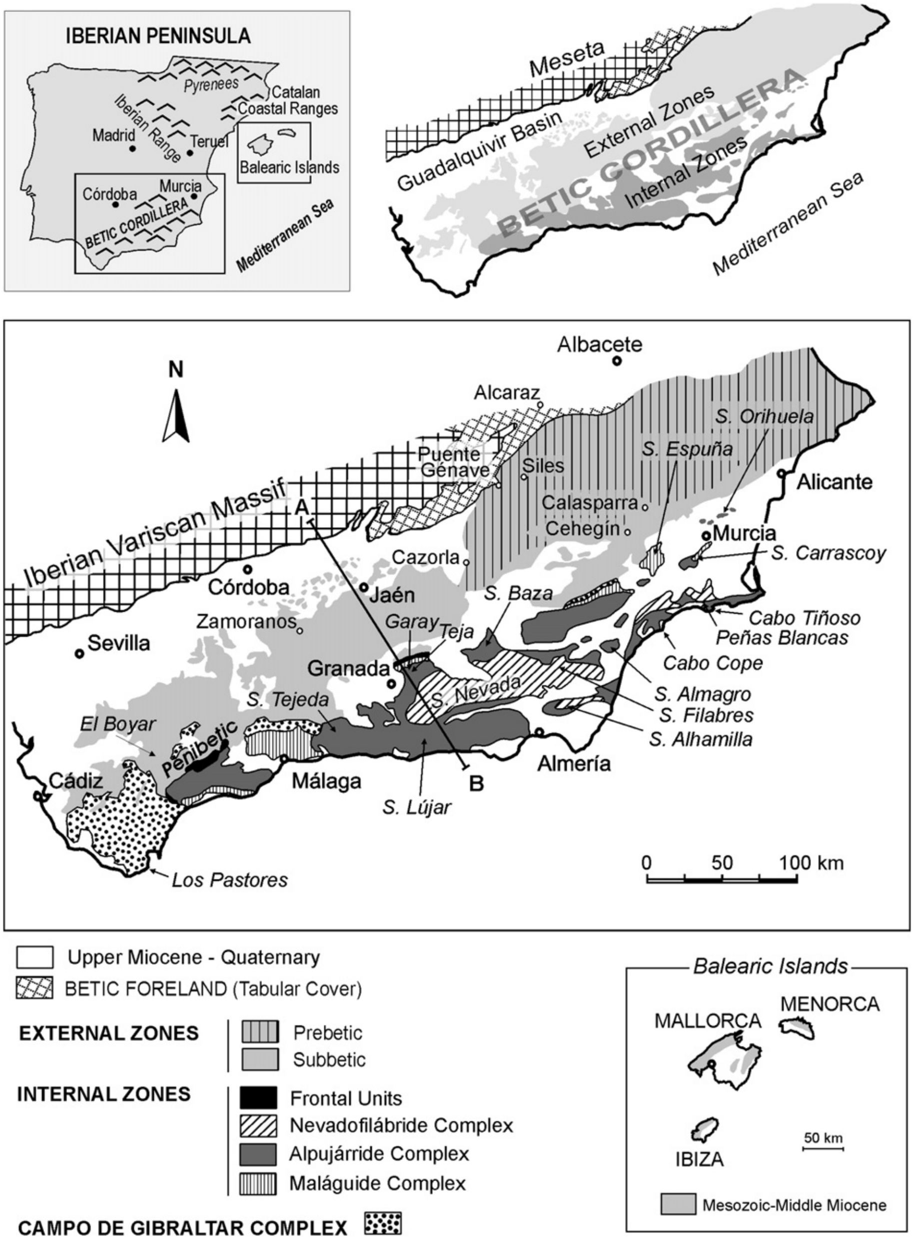

Fig. 1. Geological sketch map of the different tectonic units in the Betic Cordillera (S Spain). The localities (towns, villages and sierras (S.) –ranges–) mentioned in the text and the cross-section of the figure 2 are indicated.

and the units are extensive yet heterochronous (e.g. Virgili et al., 1977; López-Gómez et al., 2002).

Besides these Germanic facies, detritic deposits (redbeds) related to fluvial or alluvial systems have been described in western Europe. Deposits of a more marine nature than the Germanic facies have also been distinguished and defined as Alpine facies. In general terms, Germanic facies show shallow marine or even coastal deposits. In contrast, Alpine facies, although they also exhibit shallow platform facies, can also display deeper marine facies, reflecting their relationship with the Tethys. The basins of the Germanic and Alpine domain were considerably interconnected such that the shallow marine sediments of the epicontinental platform contributed to the deposits of the western Tethys margin and, towards submerged zones, they laterally passed to the alluvial deposits of continental facies.

In the Betic Cordillera (southern Spain), a wide variety of Triassic facies exists across the entire cordillera (e.g. Fallot, 1948; Fontboté, 1970). Over time, Germanic (Blumenthal, 1927; Schmidt, 1935; Busnardo, 1975) and Alpine (Simon and Kozur, 1977; Fontboté, 1986) facies have been identified, along with continental facies (Roep, 1972; Fernández, 1977). Among others, these published reports indicate the vast variety of facies existing in the different domains that can be distinguished in the Betic Cordillera, and even facies with characteristics intermediate to those of Germanic, continental and Alpine origin have been described. The problem arises when these types of facies are treated as if they belonged to very different or poorly-related contexts. Thus, some studies have been very limited and have sometimes even failed to consider the development of the other facies types, as if dealing with unconnected basins. Moreover, the studies performed to date have been mainly of a fairly local or regional nature such that the literature contains descriptions of formations and facies types for very specific regions or domains. It is also true that making regional correlations and defining a stratigraphy for the entire cordillera are difficult tasks because of the tectonic complexity (Figs. 1 and 2). This has led to certain confusion and ambiguity in terms of the designations used for the rocks of the Triassic in the Betic Cordillera.

The aim of the present paper is to provide a general picture of the stratigraphy of the Triassic of the Betic Cordillera. Our intention is not to resolve all aspects of correlations or palaeogeography, but rather to consider the facies similarities that exist to establish links among the different palaeogeographic domains that today appear as tectonic units. We propose that subsequent studies should consider the stratigraphic similarities amongst the Triassic facies of the entire cordillera in an effort to limit the terminology used up until now and apply the more appropriate nomenclature defined here.

Based on the regional stratigraphic study conducted by the present authors (Pérez-López, 1991; Pérez-Valera, 2005) and on previous works on this subject, we discuss

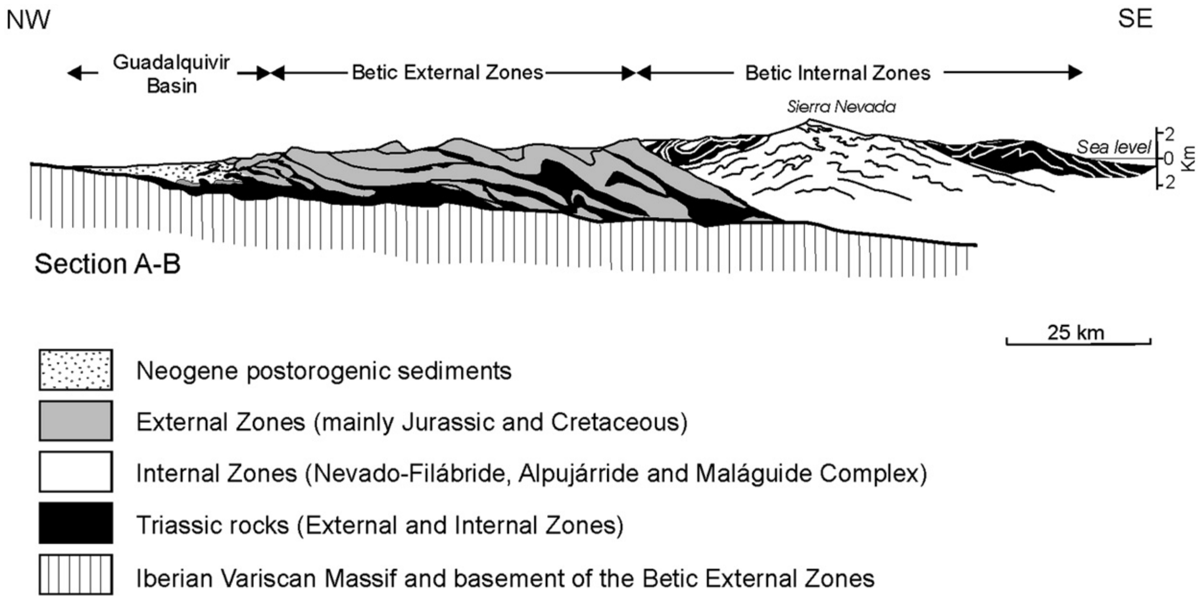

Fig. 2. Regional structural cross-section showing the present structure of the Betic Cordillera (Modified from Vera, 2001). The Triassic deposits constitute, in general, the main detachment level of the tectonic units. Triassic outcropping occurs in a notably displaced and fractured manner, and sometimes displays a mixture of different tectonic units.

the different terminology used for the Triassic deposits of the Betic Cordillera. Accordingly, we propose a simplified nomenclature scheme and the use of less local and confusing terminology, discussing the relationship between Triassic rocks and tectonic units and proposing a correlation scheme for the Triassic of the different units of the Cordillera, as well as correlations with the general palaeogeographic units of the Iberian Peninsula. Finally, based on the conclusions drawn and on data from previous studies (Márquez-Aliaga, et al., 1986; Decourt et al., 1993; Pérez-López et al., 2003; Martín-Algarra and Vera, 2004; Márquez, 2005), we present a palaeographic sketch of the western Tethys for the Middle Triassic, including the different bioprovinces and their possible connections. This sketch is designed to help the reader understand the relations between the different facies and units that are dealt with in this paper.

2. The Triassic in the Iberian Peninsula

In many regions of the Iberian Peninsula, Triassic sediments constitute the first deposits of the Alpine cycle. Following the Variscan orogeny and the first extensional episodes of the Permian, the Iberian Massif along with the currently-vanished Ebro block were the only emerged reliefs that formed the boundary and source area of the Triassic deposits that built up at its margins (Garrido-Megías and Villena-Morales, 1977; López-Gómez et al., 2002).

Within the Triassic outcrops of the Iberian Peninsula (Fig. 3), we can distinguish continental facies with the typical features of redbeds, which show lithofacies equivalent to Buntsandstein facies (Sopeña et al., 1983). However, the most common Triassic facies are the Germanic facies that comprise the Buntsandstein/

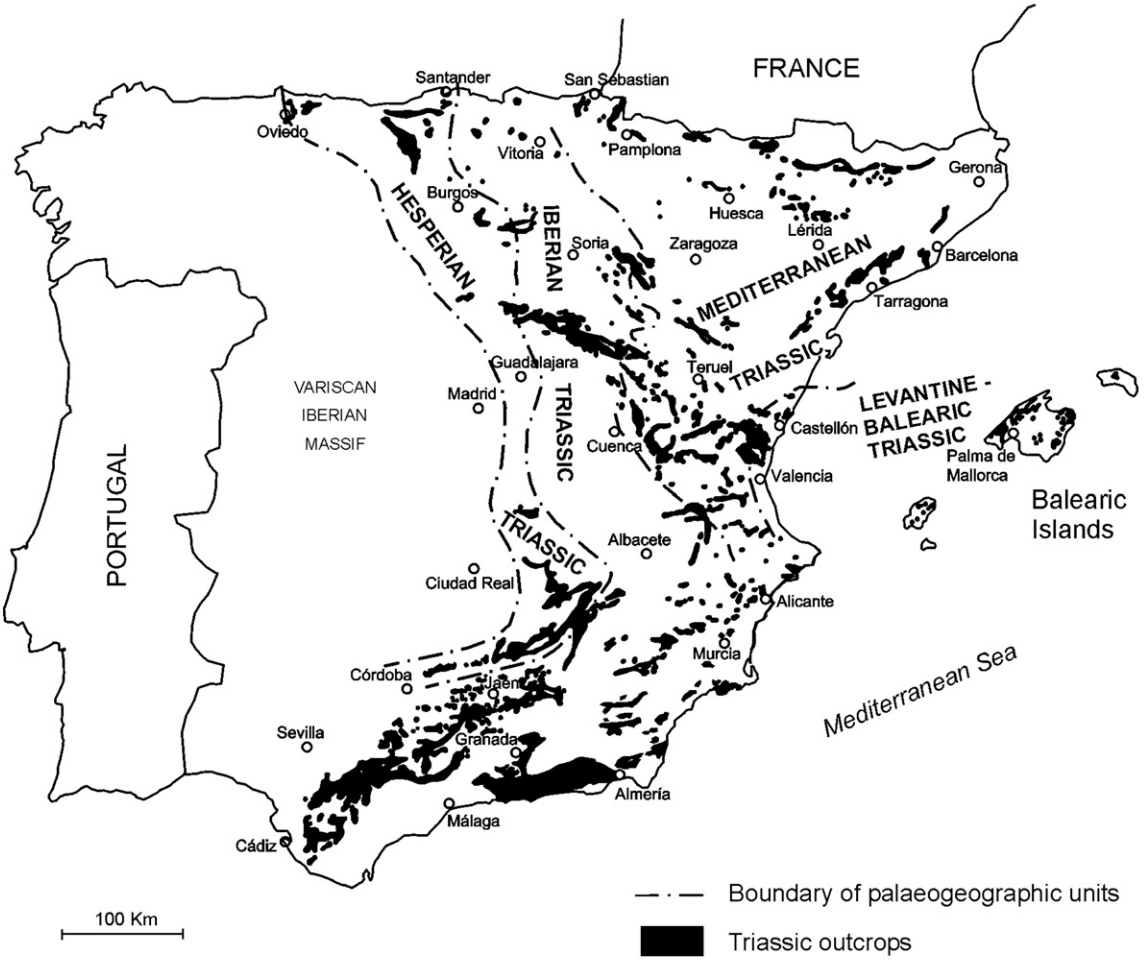

Fig. 3. Location of the Triassic outcrops in the Iberian Peninsula and Balearic Islands. The four different Triassic types are indicated (from López-Gómez et al., 1998).

Muschelkalk/Keuper trilogy. These are continental and, above all, epicontinental deposits, that is, shallow-marine and coastal sediments formed on an extending continental platform. In contrast, the least represented facies are Alpine facies related to an ocean basin. In southern Spain, Alpine facies have only really been identified in some of the outcrops of the Internal Zones of the Betic Cordillera. Occasionally these Alpine facies show relatively deeper marine facies than epicontinental marine facies, yet their ascription to Alpine facies is due, mainly, to the fact that they have been found to contain fossils of fauna from the Neotethys bioprovince.

Buntsandstein and Keuper facies display similar lithologies across the entire peninsula although their stratigraphies and thicknesses are extremely varied. In the Buntsandstein, different successions are described consisting of conglomerates, sandstones and clays. Nonetheless, it is most common to find conglomerates, sometimes locally, or pebbly sandstones at the base of successions such that their general sequences are fining-upward (e.g. Pérez-Arlucea and Sopeña, 1983; Ramos et al., 1986; López-Gómez and Arche, 1993). Keuper facies successions are even more varied, especially in terms of thickness. They exhibit clays, sandstones, marls, gypsums and carbonates alternating in different ways. Generally, clay beds appear most frequently, and those of gypsum usually predominate towards the tops of the successions (Ortí, 1974; Salvany and Ortí, 1987). On the contrary, the stratigraphy of the Muschelkalk carbonates of the Middle Triassic (Anisian–Ladinian or Ladinian), is more constant and displays a more even pattern of lithofacies development. Almost invariably, they consist of limestone and dolomite successions of greater or lesser marl contents with intercalated marly carbonate and marls. Successions are usually more marlaceous towards the top and show thinning-upward sequences. In the Catalan Coastal Ranges, centre and SE of the Iberian Ranges and some outcrops of the Pyrenees, these successions exhibit a red detritic section in the intermediate zone. This detritic section consists of clayey, evaporitic and sandy deposits, which have been dated as upper Anisian–lower Ladinian (López-Gómez et al., 1998).

Above the Keuper facies, in the carbonates of the Upper Triassic (Norian), which do not usually exceed a thickness of 50 m, we can discern limestones and bedded dolomites in almost every sector of the peninsula that have been denoted according to the region (Isábena Fm., Imón Fm., Zamoranos Fm.) (Goy and Yébenes, 1977; Arnal et al., 2002; Pérez-López et al., 1992).

In the Iberian Peninsula, several units have been described based on palaeogeographic differences among its Triassic deposits. The main criterion used for this classification has been the presence of Muschelkalk facies in the different outcrops, taking into account their thickness or whether the carbonate levels show detritic intercalations (Virgili et al., 1977; Sopeña et al., 1983; Virgili et al., 1983). The most recent classification scheme is that described by López-Gómez et al. (1998, 2002), who differentiate the following palaeogeographic units:

Hesperian Triassic. This unit is characterized by a lack of carbonate materials. It surrounds the entire Iberian Massif, from the Algarve to Asturias, and is exclusively made up of continental sediments, mainly clays and red sandstones. The unit corresponds to the continental facies or redbeds.

Iberian Triassic. The characteristic feature of this unit is the presence of a carbonate Muschelkalk (Ladinian) facies level underlying the Keuper facies and overlying the Buntsandstein facies. This domain includes the outcrops of the NW Iberian Ranges, a good part of the Pyrenees and the outcrops of the W Ebro.

Mediterranean Triassic: Characterized by the presence of two carbonate levels of Muschelkalk facies of Anisian and Ladinian age, respectively, and separated by an intercalation comprised of coastal facies (red clays, sandstones and gypsums). The unit includes the outcrops of the Catalan Coastal Range, the central zone of the Iberian Ranges, the E Ebro and the Masarac region of the Pyrenees.

Levantine–Balearic Triassic. This unit shows the presence of a single, thick carbonate level of Middle Anisian–Upper Ladinian age rendered by the disappearance of the detritic intercalation of the Mediterranean Triassic. This domain includes the outcrops of the regions Castellón, Valencia, Alicante and the Balearic Islands.

These divisions for the outcrops of the Triassic in the Iberian Peninsula have not been addressed in the Betic Cordillera. Hence, herein we propose assigning the Triassic of the different tectonic units of the Betic Cordillera to the general palaeogeographic units of the peninsula.

3. The Triassic in the Betic Cordillera

3.1. Tectonic units and domains

The Betic Cordillera forms part of a collisional mountain belt generated by convergence of the African and Iberian plates in Tertiary times (Fontboté and Vera, 1986; Martín-Algarra, 1987; Dewey et al., 1989; Comas et al., 1992; Sanz de Galdeano 1997; Vera, 2001). This large orographic, geological unit of the S and SE Iberian

Peninsula runs from the Gulf of Cádiz to the Balearic Islands (Fig. 1). Overlying the Betic orogen, extensive, thick successions of the Upper Miocene, Pliocene and Quaternary can be distinguished, forming part of the infill of the so-called postorogenic basins (Sanz de Galdeano and Vera, 1991; Vera and Martín-Algarra, 2004).

The Betic Cordillera is comprised of three main groups of geological units (Fig. 1): the External Zones, the Internal Zones and the flysch units of the Campo de Gibraltar Complex. These large groups of units are formed by complexes of allochthonous tectonic units (Fig. 2) derived from preexisting palaeogeographic domains that developed throughout the Mesozoic during the break-up of the Pangaean megacontinent and opening of the central Atlantic. These domains were narrow ocean basins and continental margins that opened at the borders of a series of ancient microcontinents or microplates that broke away from Pangaea: the palaeoplates of Iberia, Adria and the Mesomediterranean. This last, smallest plate was positioned between Iberia, Adria and Africa.

During the Triassic, sediments were deposited in the Betic basin on coastal, fluvial environments and, mainly, on an epicontinental platform, which was compartmentalised by a fault system that gradually developed during the rifting stage, conditioning the subsidence of the different grabens. From the Jurassic onwards, an oceanic crust appeared (Vera, 2001), defining the two continental margins that limited the Betic basin. These margins evolved differently and it is possible to distinguish them as the Southiberian and Mesomediterranean palaeomargin, respectively.

All these domains, generated in the Mesozoic, were destroyed throughout the Cenozoic and incorporated into the Alpine orogen as the European and African plates came together and collided with the Mesomediterranean crust terrain, located between the two plates (Martín-Algarra and Vera, 2004). By the end of the Miocene, the cordillera was structured into its External Zones and Internal Zones (Table 1 and Figs. 1 and 2).

The External Zones crop out extensively to the S and SE of the Iberian Variscan Massif and Guadalquivir basin and have been subdivided into two large tectonostratigraphic domains: the Prebetic and Subbetic. Both domains are comprised of successions of sedimentary rocks of Triassic to Miocene age, intensely deformed but only discretely affected or unaffected by Alpine metamorphism (Martín-Algarra and Vera, 2004). In both domains, deposited sediments were mainly marine, although in the Prebetic domain, facies are generally shallower because of their position closer to the continent.

The Internal Zones extend across the southernmost sector of the Betic Cordillera and represent the most intensely deformed region of the cordillera, frequently showing metamorphism. They are comprised of a complex of imbricated units, usually called Frontal Units, and numerous units that have been classified as three large tectonic complexes that currently form a large antiform nappe pile (e.g. Vera, 2004). From bottom to top, these complexes are: the Nevado–Filábride Complex, Alpujárride Complex and Maláguide Complex.

The Frontal Units have been described in the central and western sectors of the cordillera and are tectonically located between the External and Internal Zones. They are characterised by the presence of units formed by carbonate rocks of the Upper Triassic–Jurassic, although some units show red detritic successions, and sometimes more recent deposits (Martín-Algarra et al., 2004).

The Maláguide comprises a Palaeozoic basement and a Mesozoic and Tertiary cover intensely fragmented in places (Sanz de Galdeano, 1997). Triassic materials form part of this cover. They are mainly composed of red detritic facies although with carbonate intercalations, especially towards the top of the stratigraphic successions. Depending on the unit, metamorphism may be more or less notable, although it is generally scarcely developed.

The Alpujárride Complex is made up of numerous tectonic units, of which the lower ones show a lesser degree of metamorphism (Sanz de Galdeano, 1997). The successions are formed by schists at the base overlain by phylites, quartzites, sometimes bearing gypsums and igneous rocks, and thick beds of dolomites and limestones or dolomitic marbles and limestones at the top of the Triassic with metapelitic intercalations (Delgado et al., 1981).

The Nevado–Filábride Complex, as does the Alpujárride, shows a basement and a largely carbonated Triassic cover, although it may also harbour Jurassic and Cretaceous rocks (Tendero et al., 1993). It is the complex that presents the most difficulty in discerning its units because of its tectonics and intense metamorphism. Thus, the Triassic materials of this complex are very difficult to analyse and compare with those of other units.

Finally, we could mention the unfolded Mesocenozoic sediments that crop out in the northern region of the cordillera. Along with the underlying Variscan basement, these unfolded deposits constitute the Betic foreland (Fig. 1).

3.2. Triassic lithofacies and biofacies

In all the main tectonic units of the Betic Cordillera, rocks of the Triassic may be observed. Each tectonic

Table 1
Relationships among the different localities, Triassic deposits, Triassic facies types, tectonic units, and palaeogeographic domains of the Betic Cordillera

Tectonic units	Betic foreland	Betic Cordillera						
		External Zones			Internal Zones			
	Tabular Cover	Prebetic	Subbetic		Nevado–Filábride Complex	Alpujárride Complex	Intermediate units	Maláguide Complex
Localities mentioned in the text	Alcaraz Puente Génave	Cazorla Siles	Zamoranos Cehegín Calasparra	Penibetic El Boyar Los Pastores	(S. Filabres) (S. Alhamilla)	Almágride Complex S. Lújar S. Almagro S. Alhamilla (S. Espuña) S. Carrascoy S. Orihuela S. Baza S. Tejeda S.Filabres Cabo Tiñoso Peñas Blancas	Garay La Teja Cabo Cope	Saladilla Formation Sierra Espuña
General names of facies (previous authors)	Redbeds (Buntsandstein)	Germanic facies (Germano-Andaluz Trias)				Alpine facies		Continental facies
Triassic deposits	Continental	Coastal and marine			Coastal and marine (continental)			Coastal, marine and continental
Proposed Triassic facies	Continental facies	Germanic facies (Buntsandstein, Muschelkalk, Keuper)			German facies and Alpine facies			Germanic facies and continental facies
Regional context names	Southern Iberian palaeomargin → *Southern Triassic*				Mesomediterranean palaeomargin → *Mesomediterranean Triassic*			
Tectonic context and Triassic general type	Continental Triassic	Epicontinental basin (included coastal and slightly pelagic deposits) → *Epicontinental Triassic*						Continental Triassic Epicontinental Triassic
Correlations with the Iberian palaeogeographic units	Hesperian Triassiac	Iberian Triassic type			Mediterranean Triassic type Levantine–Balearic Ttriassic type Iberian Triassic type			Iberian Triassic type Hesperian Triassic
Palaeogeographic domain in the Anisian–Ladinian	Continental deposits	*Sepharadic domain* (included tethysian fauna influences)						*Sephardic domain* and continental deposits
Palaeogeographic domain in the Carnian–Norian	Continental deposits	Coastal deposits and *Tethys domain* in marine deposits						

The localities, formations or tectonic units indicated are only those mentioned in this paper. In the case of the Nevado–Filábride Complex the designations are very hypothetical.

unit features a different stratigraphy since, as mentioned above, each one has a different palaeogeographic origin, although at times it is not easy to distinguish because some units occupy intermediate palaeogeographic positions (e.g. Sanz de Galdeano et al., 2001).

3.2.1. Facies of the Betic foreland

Along the southeastern edge of the Iberian Variscan Massif, a belt of horizontal red beds crops out to form an unfolded sedimentary cover of the Meseta (Iberian Variscan Massif), or so-called "Tabular Cover" (Fig. 1). These continental facies denoted redbeds, crop out in the north of the central sector of the Betic Cordillera. These outcrops have been ascribed to the Hesperian Triassic defined by Sopeña et al. (1983) for the peninsula, comprising Buntsandstein facies and sometimes Keuper facies (Fig. 3). Specifically, at the SE border of the Meseta, these have been described as Buntsandstein-facies redbeds (Fernández and Dabrio, 1985), although the upper beds of the successions could be well correlated with Keuper facies (Fernández et al., 1994). These facies are composed of sandstones and red clays related to alluvial and fluvial sedimentary environments (Fernández, 1977; Fernández and Dabrio, 1985). The Hesperian Triassic is characterised by the absence of carbonate marine deposits and appears as a rim around the edges of the Iberian Massif (Sopeña et al., 1983; López-Gómez et al., 1998). In the Alcaraz sector (Albacete), where these redbed facies crop out extensively, dolomites can be distinguished at the higher levels and can be attributed to the carbonates of Norian age (Gil et al., 1987) correlatable with the Imón (Goy and Yébenes, 1977) and Zamoranos (Pérez-López et al., 1992) Formations. These Upper Triassic carbonates are thought to be the most expansive of the Betic Cordillera (Fernández et al., 1994).

3.2.2. Facies in the External Zones

Bundsandstein, Muschelkalk and Keuper facies have been described in the External Zones. Blumenthal (1927) identified Germanic facies in the Betic Cordillera, but with notable differences with respect to the rocks cropping out in the central zone of Europe. This author observed that in Andalucía (S Spain) multicoloured clays cropped out but with greater quantities of gypsum, this being one of the most outstanding features of this facies in the region. Hence, Blumenthal named the Triassic of the Betic Cordillera the "Germano–Andaluz Trias". Schmidt (1928, 1929) highlighted the presence of Buntsandstein facies beneath the carbonates of Muschelkalk facies, thus recognising the characteristic Germanic facies trilogy, which was to be later identified by other authors (Fallot, 1931; Alastrue, 1943; Felgueroso and Coma 1964). More recently, special emphasis has been placed on the stratigraphy of the Triassic rocks defining lithostratigraphic units (e.g. Foucault, 1971; López-Garrido, 1971; García-Rossell, 1973; Busnardo, 1975). Research efforts have continued to outline the stratigraphy of the Triassic in the central sector of the Betic Cordillera (e.g. Gil et al., 1987; López Chicano and Fernández, 1988; Pérez-López 1991) and its eastern sector (Pérez-Valera, 2005).

Although the development of the different stratigraphic successions of the External Zones differ in their detail, we could speak about a general stratigraphy for the Triassic including continental and epicontinental facies (Pérez-López, 1991, 1998; Pérez-Valera, 2005). The stratigraphy of the Triassic is not as varied as indicated in earlier works, at least if we consider the main formations (Fig. 4A, B and C). Thus, we can distinguish a siliciclastic unit attributable to the Buntsandstein facies, which essentially crops out in the Prebetic domain (Pérez-Valera et al., 2000; Pérez-Valera, 2005). The Muschelkalk facies carbonates overlie these detritic materials. These deposits of the Middle Triassic exhibit facies comprised of shallow-marine carbonates (Pérez-López, 1991; Pérez-Valera, 2005) that correspond to thickening-upward sequences: thick levels of dolomites and laminated limestones with bioturbated and bioclastic beds in the lower part, and marls and bedded marly limestones with abundant bivalves at the top. These carbonates are now defined by two formations (Fig. 4A and B): the Siles Fm. in the more northern zones and the Cehegín Fm. in the more southern zones (Pérez-Valera and Pérez-López, 2005; Pérez-Valera et al., 2005a). On top of these carbonates, always in truncated successions, appear the detritic–evaporitic Keuper units that form the Keuper Group of Jaén (Pérez-López, 1991, 1998): clays with thin beds of gypsum and sandstone in the lower part, thick levels of sandstone in the middle portion, and clay with sandstone intercalations in the upper section with a predominance of gypsums at the top. Overlying all these facies, we find the carbonate unit of the Upper Triassic (Norian), defined as the Zamoranos Fm. (Pérez-López et al., 1992).

All these formations also crop out in the most SW tectonic units of the Subbetic domain, in the so-called Penibetic zone (Fig. 1), although with different thicknesses and some different facies. For example, in the western Penibetic units, carbonates are the predominating lithofacies (Martín-Algarra, 1987). Marine influences are more obvious towards more southern successions as may be seen in the El Boyar (Martín-Algarra et al., 1995a) and Los Pastores sections,

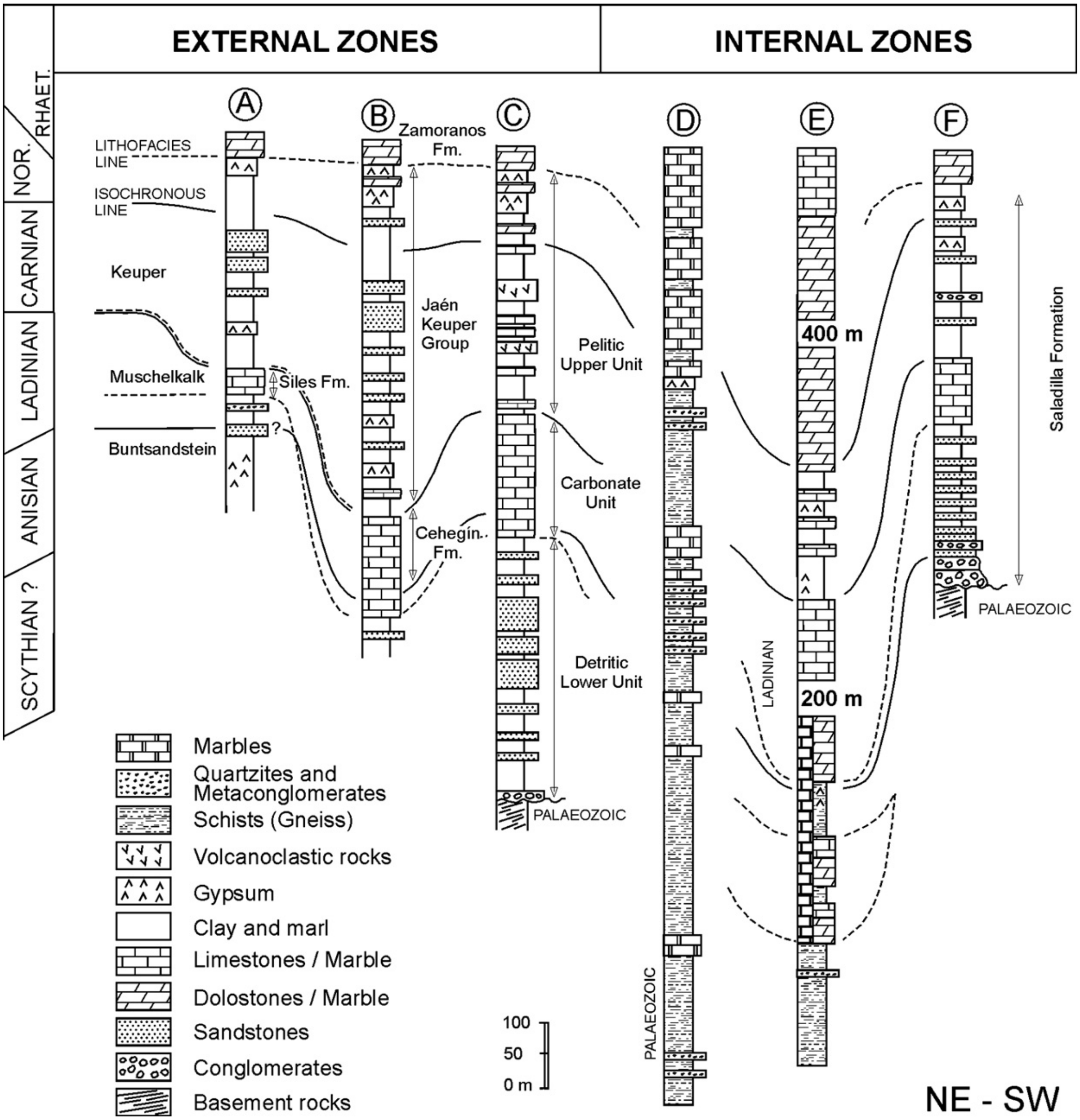

Fig. 4. Synthetic stratigraphic columns of the main tectonic units (modified from López-Gómez et al., 2002). A: Prebetic domain; B: Subbetic domain; C: Mallorca Island; D: Nevadofilábride Complex; E: Alpujárride Complex; F: Maláguide Complex.

although in the latter carbonates appear slightly more frequently (Martín-Algarra et al., 1993).

From a palaeontological viewpoint, we should mention the presence of bivalve fossils in the Triassic carbonates of the External Zones, corresponding to an autochthonous fauna and one from the Tethysian bioprovince, although some cosmopolitan species have been cited in the Germanic domain (Márquez-Aliaga and Ros, 2003). Hirsch (1977) defined the Sephardic domain, including endemic bivalve, ammonoid and conodont species, as a palaeogeographic domain spanning from Spain and North Africa to the Middle East that developed S and SW of the Tethys. Costamagna and Barca (2002) located the Sephardic domain across the whole N region of Africa and E of Spain as far as western Sardinia. This domain exhibits characteristic fossil assemblages that have been studied in numerous outcrops of S and E Spain (Márquez-Aliaga, 1985; Márquez-

Aliaga, et al., 1986; Márquez-Aliaga and Hirsch, 1988; Pérez-López et al., 1991; Pérez-Valera et al., 2005b). Some works also mention the presence of fossils characteristic of the Alpine bioprovince. Thus, Kozur et al. (1985) described Holothurian sclerites in the Subbetic Zone (Cehegín, Murcia) that are typical to the Dinaric and Austroalpine faunal provinces. Goy and Pérez-López (1996) found an outcrop containing ammonoids well-known in Alpine zones, and Pérez-López et al. (2005) identified foraminifera associations across the whole Subbetic Zone that are commonly observed in the Alpine bioprovince and even in the Upper Triassic carbonates defining the Zamoranos Fm. (Pérez-López et al., 1992). Also noted, is the presence of Tethysian fauna in the Upper Triassic carbonates of the more southern Subbetic units (Martín-Algarra, 1987). Martín-Algarra et al. (1995a) pointed out that there was evidence of closeness between these perimediterranean and Alpine platforms since some of the faunas of these outcrops resembled Alpine fauna.

3.2.3. Facies in Balearic Islands

The Betic Cordillera continues northeastwards towards the Balearic Islands. Its Mesozoic and younger rocks may be correlated with those of the Betic External Zones (Azañón et al., 2002). The Balearic Islands, from SW to NE, comprise the islands of Ibiza, Mallorca and Menorca (Fig. 1). Their Triassic stratigraphy can be partly correlated with that of the Subbetic Zone Triassic (López-Gómez et al., 2002). Buntsandstein, Muschelkalk and Keuper facies and Upper Triassic carbonates can be recognised in some outcrops of these islands.

The Buntsandstein is well-represented by sandstones, clays and the conglomerates that Rodríguez-Perea et al. (1987) defined as "the lower clastic unit" (Fig. 4C). This unit crops out in Mallorca and Menorca and is very similar to the Buntsantstein facies of the Iberian Ranges (Ramos, 1979).

Carbonates show Muschelkalk facies (e.g. Virgili, 1952; Llompart et al., 1987), although in this case, deep marine facies are more common and thicker than in the Subbetic Zone (López-Gómez et al., 2002). Rodríguez-Perea et al. (1987) defined these carbonates in Mallorca and Menorca as "the middle carbonate unit". This facies has provided many specimens of ammonoids or bivalves (*Daonella lommeli*). Palaeontologically, it seems that the influence of Tethysian fauna is greater than in the Subbetic domain. López-Gómez et al. (1998) suggest continuous carbonate sedimentation in Menorca during the Anisian–Ladinian period, represented by the marine epicontinental carbonates that correspond to the Levantine–Balearic Triassic (Fig. 3). In Mallorca, some authors (Colom, 1975; Rodríguez-Perea, et al., 1987) described these carbonates as a thin middle level of marls and red clays, a similar stratigraphic situation to the Catalan Basin, although this level could represent Keuper slices generated by tectonics (López-Gómez et al 2002). In Ibiza, the base of the Triassic succession is never exposed. Its first sediments correspond to dark dolomites and, towards the upper part, to bioturbated laminated limestones and marls. These Muschelkalk carbonates are attributed a Middle Triassic age (Gelabert and Sàbat, 2004).

In every island, at the top appear the clays and evaporites characteristic of the Keuper defined as "the upper silty unit" (Rodríguez-Perea et al., 1987), although this time there are no sandstones like those occurring in the Subbetic Zone (Pérez-López, 1991). Finally, overlying this unit we find the limestones and dolomites of the Norian (Boutet et al., 1982).

3.2.4. Facies in the Internal Zones

Within the Internal Zones, very interesting studies on Triassic facies can be undertaken at the Alpujárride and Maláguide Complexes (Fig. 1). This is more difficult in the Nevadofilábride Complex since there is substantial metamorphism, although very general interpretations can be made about their stratigraphy and palaeogeography. There is no doubt, however, that the Alpujárride Complex is the most interesting in palaeontological terms since fossil-containing carbonates are much more common.

In the Sierra de Baza, Sierra Tejeda or Sierra de Lújar (Fig. 1 and Table 1), the Triassic successions of the Alpujárride are comprised of thick limestone–dolomite complexes (Fig. 4E) with marl, quartzite and metapelite, and locally gypsum, intercalations (Delgado et al., 1981; Delgado et al., 2004). Gypsum layers can be as thick as 50 m in some eastern units of the Alpujárride (E Sierra de los Filabres). Considerable intercalations of subvolcanic rocks also exist. Massive dolostone marbles are common in the lower part of the successions, overlying metapelites and quartzites. The most bedded and marlaceous limestones occur in the middle part, with some metapelite levels. In the upper part, there is an abundance of massive marbles.

In these Alpujárride successions, according to the sectors and tectonic units there have been descriptions of a carbonate formation of Ladinian–Lower Carnian age (García Tortosa et al., 2000; García Tortosa, 2002) or two carbonate formations, one Ladinian and a thinner formation of Anisian age (Kozur et al, 1985; Martín and Braga, 1987; Sanz de Galdeano et al., 1995). Sometimes, only a single level of Anisian–Ladinian carbonates has been described (e.g. Delgado et al., 1981; Braga and Martín, 1987a). These Middle Triassic carbonates feature limestones, dolomites, marly limestones and marls, which have been interpreted as lagoon or barrier reef facies (e.g. Flügel et al., 1984; Martín and Braga 1987). In general, they are relatively shallow facies (Perconig, 1977), which are often fairly confined as indicated, for instance, in certain ostracod studies (Kozur et al., 1974).

Overlying these carbonates, we find layers of varying thickness of marls and lutites, which sometimes correspond to metapelites depending on the units. Towards the top, the successions contain hundreds of metres of Upper Triassic carbonates, which are characteristic of these Alpujárride units (e.g. Delgado et al., 1981; Braga and Martín 1987a). The most common facies are those of tidal plains and lagoons, sometimes harbouring some type of biostrome (e.g. Martín and Delgado, 1980; Braga and Martín, 1987b).

In terms of lithofacies, some of the Alpujárride units have revealed facies equivalent to the Muschelkalk facies of the External Zones (López-Garrido et al., 1997; García Tortosa, 2002), often with equivalent bivalve associations. Some units of the Almágride Complex (Simon, 1964), defined in the Sierra de Almagro (Table 1 and Fig. 1), were even ascribed to the Subbetic Zone, that is, they were fully identified with the External Zones (Besems and Simon, 1982; Simon, 1987), characterized by their Germanic facies. These same units have been subsequently incorporated in the Alpujárride Complex (Sanz de Galdeano, 1997; Sanz de Galdeano et al., 1997; García Tortosa et al., 2002). Whichever the case, it is evident that there are often many similarities between the Triassic of the External and Internal Zones. It should also be mentioned that the Alpujárride units also show detritic (lutites, phylites, etc.) and gypsum facies related to coastal settings typical of Keuper facies, although these are sometimes poorly developed such as in the External Zones. Nevertheless, in the E Sierra de los Filabres and Sierra de Almagro, there are many outcrops of metapelites with thin gypsum levels that are very difficult to assign to the Permian and could therefore correspond to metaphorphic Keuper facies. García Tortosa et al. (2000) indicate that the Alpujárride units of Cabo Tiñoso and Peñas Blancas bear detritic facies of Carnian age that clearly resemble those of the Maláguide Complex, which as indicated below show coastal facies equivalent to Keuper facies. Thus, in the Alpujárride units it is possible to recognise the Keuper facies.

From a palaeontological standpoint, it is in the Alpujárrride Complex that most similarities with the Tethys bioprovince have been found. Thus, on the basis of supposed affinities with the (Austro)–Alpine Triassic, the Triassic of the Alpujárride Complex is usually referred to as the Alpine Triassic (e.g. Almera and Sanz, 1958; Durand-Delga and Fontboté, 1960; Delgado et al., 1981, Martín-Algarra et al., 2004). Many of the fossils discovered (algae, foraminifera) originated in the Tethys domain (e.g. Braga and Martín, 1987a; López-López et al., 1988). However, in agreement with Simon (1987), it should be mentioned, that only portions of the faunal and floral assemblages show affinities to (Austro-) Alpine fossils. Indeed, some of the authors mentioned above also observed that associations of the bioconstructed facies of the Upper Triassic are not too typical of the Alpine Domain (Martín and Braga, 1987). These authors pointed out there was a separation during the Upper Triassic between the Alpujárride domain and the Tethys, which is reflected in the very specific peculiarities of the endemic fauna and differences in the types of bioconstruction in the Sierra de Baza and Sierra de Lújar. In contrast, in some sections of the Middle Triassic such as those appearing in the Sierras of Alhamilla, Carrascoy, Orihuela and Cabo Tiñoso, the fauna identified is very similar to that of the Muschelkalk carbonates of the External Zones. For example, *Costatoria kiliani* (Schmidt), *Gervilleia*cf. *joleaudi* Schmidt or *Placunopsis flabellum* Schmidt have been found in the Sierras of Almagro and Alhamilla (Boogaard and Simon, 1973), apart from the *Pseudofurnishius* conodonts that Boogaard and Simon (1973) described in the Alpujárride units and in Israel (Sephardic Domain). In Carrascoy (Murcia, SE Spain), Kampschuur (1972) described: *C. kiliani* (Schmidt), *Lyriomyophoria*cf. *sublaevis* (Schmidt) and *G.*cf. *joleaudi* Schmidt. These same fossils are those that Schimdt (1935) identified in the Ladinian carbonates of the External Zones.

In the Triassic rocks of the units of the Maláguide Complex (Fig. 4F) defined as the Saladilla Fm. (Roep, 1972), despite substantial continental deposits (redbeds facies), some levels of carbonates occur in the middle and upper part (Roep, 1972; Martín-Algarra et al., 1995b). We also find carbonates harbouring *Pseudofurnishius murcianus* (attributable to the Ladinian) with Muschelkalk facies in Sierra Espuña (Murcia, SE Spain). These outcrops of Sierra Espuña consist of a few conglomerates at the base, and sandstones and clays towards the top. Over these detritic levels, firstly laminated dolomites and secondly marly limestones with typical bioturbations of the Muschelkalk facies appear. Kozur et al. (1985) in the Maláguide W of Sierra Alamilla (Almeria, S Spain), besides these platforms of *Pseudofurnishius murcianus*, detected *Placunopsis* *flabellum* bivalves, which sometimes appear in the Lower Carnian of the Betic Cordillera (Simon and Kozur, 1977). Above these carbonates, clays with sandstone intercalations and gypsums occur. Hence, although the most characteristic feature of the Maláguide is its detritic deposits, it is significant that in some sections, shallow marine carbonates occur in the middle of a detritic succession. The result is a red detritic level, which shows a fining-upward sequence, a carbonate level, and a multicoloured lutite level with gypsum. This general pattern of facies resembles the Germanic trilogy: Buntsandstein, Muschelkalk and Keuper, respectively.

Thick carbonate levels have also been reported to occur at the top of the Triassic successions of the Maláguide Complex (e.g. Roep, 1972; Martín-Algarra et al., 1995b). These could be correlatable with the carbonates of Norian age existing in the Alpujárride Complex or in the Prebetic, Subbetic domains, despite their very different thickness.

Although is true that Triassic facies variation in the Maláguide Complex is intense and that Ladinian carbonate levels are not too thick, some of its successions are comparable to the general stratigraphy of the Triassic of the External Zones. It is clear there is more continental influence in the sediments of the lower part of the Maláguide Complex than in those of the External Zones. However, it should also be considered that the lack of Buntsandstein conglomerates in the External Zones could be because they are “stuck” to the basement and therefore unable to crop out.

In the intermediate tectonic units (Sanz de Galdeano et al., 2001) between the Maláguide and Alpujárride complexes (e.g. Garay and La Teja units, Fig. 1 and Table 1), it is even possible to find carbonates deposited in shallower or deeper seas, although almost always above the base level of storm waves. In some of these units, such as the Cabo Cope Unit, fossils related to the Alpine domain have been found including the bivalves *Daonnella lommeli* (Pérez-López et al., 2003), the same species that appears in the Catalan Basin (Virgili, 1958, Márquez-Aliaga, 1985), or *Anolcites* ammonoids (Goy et al., 2005). Links between these eastern units and the Tethys, although close to the continent, are evident. These same units show very similar facies to Keuper facies and contain lutites, sandstones and gypsums towards the top of some stratigraphic successions (Sanz de Galdeano et al., 2001).

Finally, the Frontal Units in the West of the cordillera (Fig. 1) have very varied facies that comprise fluvial (clays and sandstones) and coastal (lutites and gypsums) sediments. Some units exhibit thick successions of marine-platform carbonates and sometimes show deeper facies of Upper Carnian–Norian age, assigned to Alpine facies (Martín-Algarra et al., 2004). These units are not discussed here because they display incomplete stratigraphic successions and their palaeogeographic situation is not clear (e.g. Durand-Delga, 1972; Wildi, 1983; Martín-Algarra, 1987; Balanyá, 1991; Sanz de Galdeano, 1997).

4. Discussion

4.1. The sephardic domain related to Alpine and Germanic facies

The Triassic rocks of the Iberian Peninsula have traditionally been described by the different authors as those of Germanic facies. Referring to these outcrops of Germanic facies in the Iberian Peninsula, Virgili et al. (1977) specified that the Triassic displays a wide variety of lithofacies such that the stratigraphic sections of the Pyrenees and margins of the Central and Catalan Ranges differ more amongst themselves than with respect to some Alpine successions. In effect, the same could be said of the different outcrops of the Betic Cordillera. However, when referring to the Internal Zones of the latter, more has been said about their Alpine facies than about those of the remaining basins of the peninsula. This is probably the result of the marked thickness of the carbonate levels of the Alpujárride Complex. Nonetheless, its marine facies are not in many cases deeper than those of the peninsula’s other Triassic outcrops and neither is the development of its coral reefs, for example, as marked as those appearing in the Catalan Basin (Calvet et al., 1990), being even much less developed than those found in the Alps. Moreover, the stratigraphy of the different tectonic units is complicated by tectonics, although when explored in detail it is possible to recognize coastal Keuper facies in some of the Alpujárride units, as mentioned above. Thus, the carbonate levels of the Alpujárride Triassic are thick but the entire stratigraphic successions of the Triassic are clearly not solely comprised of carbonates.

Virgili et al. (1977) made another interesting observation when they mentioned that some of the fossils found in the Catalan Basin or in Valencia were typical of the Alpine Triassic, although autochthonous faunas also exist. At this point it is important we should bear in mind that all the epicontinental basins with Germanic facies in the Iberian Peninsula were at some time in their history connected to the Tethys, as demonstrated by the fossils found in the Muschelkalk carbonates of some sections (Fig. 5). Sopeña et al. (1983) observed in some of the Muschelkalk facies outcrops of

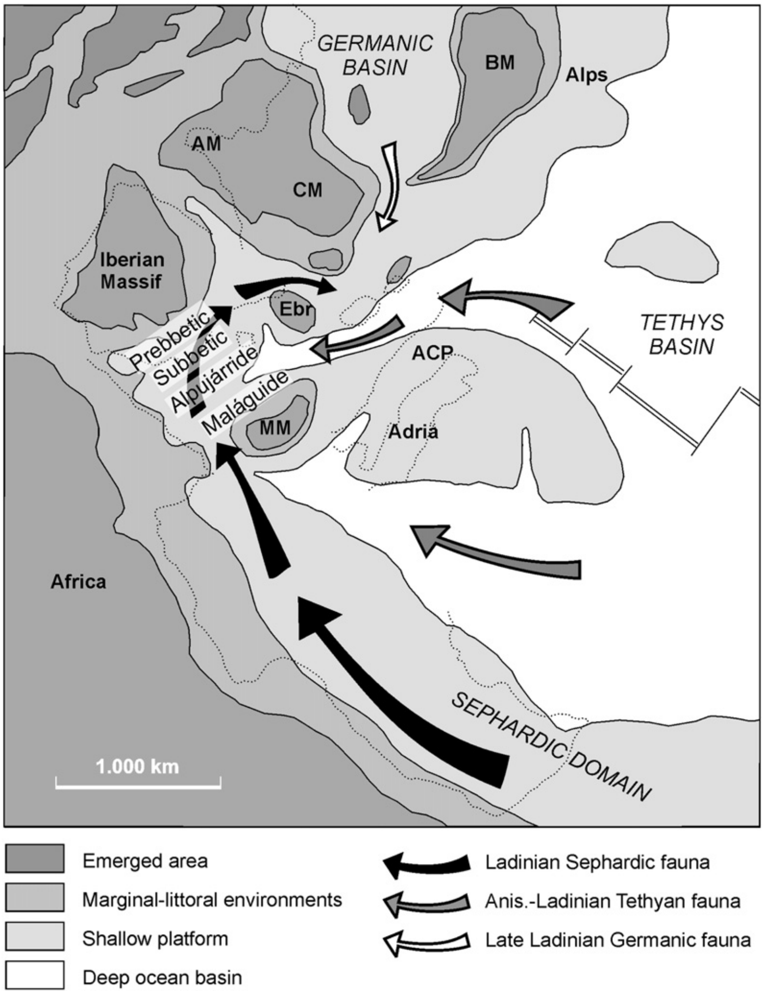

Fig. 5. Palaeogeographical reconstruction of the westernmost Tethys area for the Middle Triassic. Faunal movements are indicated with arrows. AM: Armorican Massif; BM: Mohemia Massif; CM: Central Massif; Ebr: Ebro Massif; MM: Mesomediterranean Massif; ACP: Apennine Carbonate Platform (main sources: Márquez-Aliaga et al., 1986; Decourt et al., 1993; Pérez-López et al., 2003; Martín-Algarra and Vera, 2004; Márquez, 2005).

Cataluña, Valencia, Castellón and Teruel, a particular biofacies other than the Germanic with Alpine influence. In effect, this is what Hirsch (1972,1975) had suggested some years earlier and coined the Sephardic domain. This author observed in many sectors of the peninsula and E Mediterranean (Hirsch, 1977) an "evolution autonomy" of species affecting a vast palaeogeographic area, independently of that of the Tethys but with some influence of its fauna.

Recently, Márquez (2005) indicated the presence in the NE Iberian Peninsula of some foraminifera of the Germanic bioprovince (e.g. *Dentalina gerkei*, Styk; *Spirillina oberhauseri,* Styk) in the top carbonate levels, but emphasized that Alpine foraminifera were the most common throughout the peninsula (Fig. 5). This author identified faunas with clear Tethyian affinities in Anisian carbonates, e.g. *Hoyenella sinensis* (Ho), *Endoteba kueperi* (Oberhauser), *Paulbronnimannia judicariensis* (Premoli–Silva) etc., and Ladinian carbonates, e.g. *Lamelliconus biconvexus* (Oberhauser), *Lamelliconus ventroplanus* (Oberhauser), *Lamelliconus multispirus* (Oberhauser), *Lamelliconus procerus* (Liebus), etc. The presence of these Involutinina species in the Lower Ladinian carbonates of the Betic Cordillera suggests the arrival of these fauna from similar assemblages of the Sephardic domain, which in Israel appear in levels dated as "Late Fassanian" (Early Ladinian) (Benjamini, 1988). Theses species were to became very important in Alpine basins of the late Ladinian (Márquez, 2005).

In a further study by Márquez-Aliaga and Ros (2003) on the bivalves of the peninsula's Triassic, among the fossils most extensively analysed in these Muschelkalk facies carbonates, 73% of the bivalve fossils of Spain were found in both Alpine and Germanic provinces, 12% of the species were purely Alpine (Tethysian) and the remaining species were considered native to the Iberian Peninsula. It is clear there is an autochthonous fauna, but with contributions by, or connections with, the Tethys that were considerable in some Triassic stages.

This influence is also patent in the Betic Cordillera especially in the Internal Zones. Effectively, it is because of the presence of Tethysian fauna that the Triassic rocks of many of the Internal Zone units have been assigned to the Alpine facies, although some units with Muschelkalk facies have also been described. In the External Zones, however, although some Tethysian fauna appear, the corresponding authors have never referred to Alpine facies since the presence of Muschelkalk along with Buntsandstein and Keuper facies is evident. At present, the overall influence of Tethysian fauna is clear and the presence of autochthonous fauna is also observed in all marine domains of the Betic Basin.

The faunal migration of bivalves was diachronic from the Middle East to the “circummediterranean terrains” (Hirsch and Márquez-Aliaga, 1988; Márquez, 2005). It seems reasonable to assume that the endemic fauna of the Sephardic domain reached the Iberian central-eastern platforms via the Betic basin during transgressive stages. Thus, the faunal assemblages of the shallow platforms of the Betic basin were probably not that different to each other. This has indeed been confirmed by the discovery of Ladinian fossils characteristic of the Sephardic Domain in the different Betic domains: Prebetic, Subbetic, Alpujárride and Maláguide. It was at the end of the Ladinian, when an extensive shallow platform had become established (Fig. 6A) but before the regressive stage that would give rise to the Keuper facies, that most intense spreading of bivalve faunas typical of the Sephardic Domain took place (Márquez-Aliaga and Ros, 2003), including: *Costatoria kiliani* (Schmidt), *Placunopsis teruelensis* Wurm, *Gervillia joleaudi* (Schmidt), among other species.

In addition, the contributions of Tethysian (Alpine) fauna became more or less significant depending on the palaeogeography, essentially on transgressive pulses (Pérez-López et al., 2005) especially in subdomains close to the Tethys basin proper. In transgressive stages, carbonate deposits were more extensive and abundant, and Alpine fauna spread to more domains. Thus, its influence took on a more significant role in the early and middle Ladinian (Márquez-Aliaga and Ros, 2003). However, the greatest influences of Alpine fauna, which are sometimes accompanied by deeper marine facies, appear in the Carnian–Norian of some of the Internal Zone units (Fig. 6B). In these regions that were less subsiding or closer to the continent, the tripartition stratigraphy of Germanic facies could have arisen, especially coastal facies, and only some zones of the Betic basin had a markedly marine or an oceanic influence of the Tethys.

Accordingly, fossils of Sephardic domain fauna appear both in Internal Zones of Ladinian age and External Zones with Tethysian influence. However, the influence of the Tethys gains importance in the Internal Zones of the upper Triassic. For this latter age, it is more appropriate to talk about Alpine influence in the Internal Zones, when carbonates predominated in the stratigraphic succession and a more Tethysian fauna is found.

4.2. Facies types and their designations in the different domains

In the Betic Cordillera, several Triassic stratigraphic successions crop out, whose lithofacies differ according to their corresponding palaeogeographic units. The palaeogeography of the Betic basin was conditioned by the grabens and continental areas emerging around it: the Iberian Variscan Massif and the Mesomediterranean microcontinent which, as already mentioned, was located on the plate situated between Iberia, Africa and Adria (Fig. 5) (Vera and Martín-Algarra, 2004).

The Triassic rocks that crop out in the Betic Cordillera eventually formed part of two main palaeogeographic domains, related to these two continental palaeomargins that developed from the Jurassic (Fig. 6C): the Southiberian palaeomargin (continental palaeomargin of S Iberia) and the Mesomediterranean palaeomargin (Durand-Delga and Fotboté, 1980). Since these two sets of materials currently constitute the External Zones and Internal Zones, respectively, we denote the Triassic of the External Zones the Southiberian Triassic (Pérez-López, 1991) and propose the generic designation of Mesomediterranean Triassic for the Triassic of the Internal Zones (Fig. 7). Evidently, these are regional names that refer to a given palaeogeographic situation, but they do not imply Triassic facies types.

Although the Southiberian Triassic shows redbed facies, which form part of the Tabular Cover, it mainly consists of epicontinental facies organised in a similar fashion to the Germanic facies corresponding to shallow-marine-coastal deposits. Hence, we suggest maintaining the designations Buntsandstein, Muschelkalk and Keuper facies for all outcrops in which this tripartion can be distinguished.

In the Mesomediterranean Triassic, more varied facies crop out than in the Southiberian Triassic, since

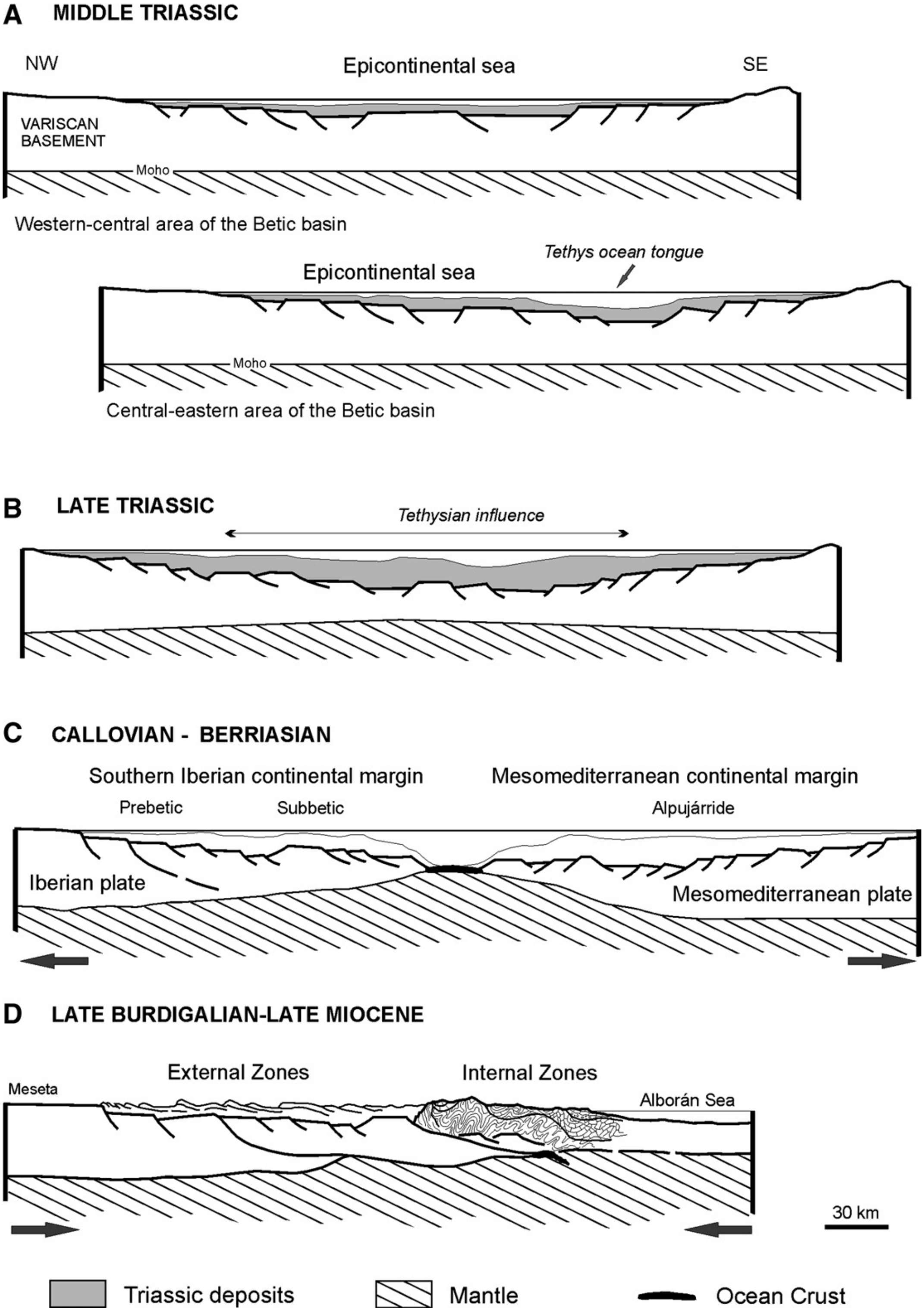

Fig. 6. Four stages in the development of the Betic basin. A: Initial rifting and sedimentation stage of the Triassic deposits on the epicontinental platform. B: Deposition of thick carbonate units showing major Tethysian influence. C: Differentiation of the two continental margins when the ocean crust appeared after the Triassic period. D: Formation of the Betic Cordillera during the Alpine orogeny. Some of the data were obtained from Vera (2001).

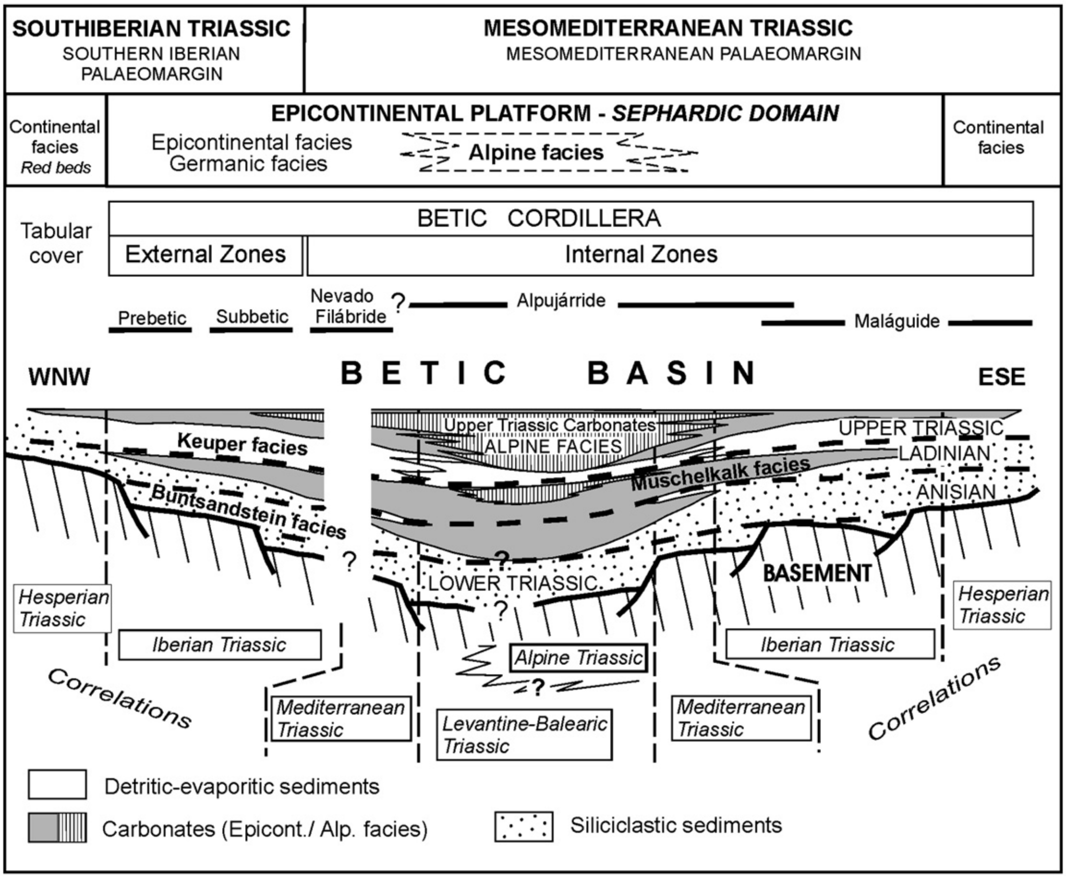

Fig. 7. Schematic cross section of the two continental margins of the Betic basin in which links between the palaeogeography and the domains, facies, tectonic units and names of the Triassic types are indicated. See also Fig. 1 for the location of the different domains.

their extension was greater and their evolution differed according to the zone.

The conglomerates, sandstones and clays, facies proper to Triassic base of the Maláguide Complex (Soediono, 1971; Roep, 1972; Martín-Algarra et al., 1995b), are not too comparable to the Buntsandstein of the External Zones, among other reasons, because they never crop out well and only some Buntsandstein upper levels of clays or sandstones are possible to observe in the External Zones, as occurs in Siles or Calasparra (Pérez-Valera et al., 2000). Nevertheless, the stratigraphy of the Maláguide Triassic has some resemblance to the Triassic stratigraphy of the Puente Génave–Siles area, which has been described by Gil et al. (1987) and Fernández et al. (1994). These authors determined the evolution of the facies of the Triassic rocks from the Prebetic Domain to the Tabular Cover. In this area, the Muschelkalk carbonates of the Prebetic domain are missing from the Tabular Cover (Edge of the Meseta) where the stratigraphic succession is predominantly comprised of red-coloured terrigenous deposits (redbeds). Thus, the Maláguide Triassic corresponds to several palaeogeographic domains and it is possible to recognize continental (redbeds) and epicontinental facies. We also propose the use of the Germanic facies designations for some of the Maláguide sections.

The Alpujárride Complex shows, on the one hand, Alpine facies linked to more open marine zones connected to the Tethys, which are characterised by displaying either continuous carbonate facies or a predominance of Tethysian fauna, and on the other, epicontinental facies, essentially characterised by the presence of Muschelkalk and Keuper facies. Accordingly, we should be cautious when dealing with the designations of the Triassic Alpine that are often used too loosely to refer to the Internal Zones (Mesomediterranean Triassic).

4.3. Links between facies and tectonic units

Because of the reasons described, a tectonic unit should not be directly related to a given type of Triassic facies, whether Alpine or Germanic. For example, it would be appropriate to refer to the rocks of the “Subbetic Triassic” or “Prebetic Triassic” only if we wanted to make reference to those rocks that crop out alongside these tectonic units with no intent to specify a particular type of facies. The differentiation between the Subbetic and the Prebetic domains corresponds to the Upper Liassic rocks (García-Hernández et al., 1980). Hence, the different Triassic facies are not related to these domains.

This situation is equivalent to that arising in the Internal Zones. Thus, the terms “Alpujárride Triassic” and “Maláguide Triassic” could be used to discuss the rocks cropping out in relation to these tectonic units without referring to a given facies type. However, because the stratigraphy of these complexes, including that of the Nevado–Filábride Complex, differ considerably, we consider the terms “Maláguide Triassic” or “Alpujárride Triassic” as regional names related to different vast palaeogeographical contexts, and they refer to several Triassic types within a given complex.

4.4. Correlations with the palaeogeographic units of the Iberian Peninsula

In early works that deal with the Triassic of the Iberian Peninsula, the Triassic rocks that crop out in the Betic Cordillera are referred to as belonging to the “Betic Trias” (Virgili et al., 1977). Clearly this term reflects the fact that very few studies had been conducted on the stratigraphy of the Triassic, therefore rendering few palaeogeographic interpretations. It may be noted in the discussion above that the types of Triassic facies cropping out in the Betic Cordillera are both numerous and widely variable. Accordingly, López-Gómez et al. (1998) propose that the different outcrops of the cordillera, or at least some of them, should be assigned to the palaeogeographic types defined for the rest of the peninsula.

Thus, the designation “Betic Triassic” should only be used as a loose, or generic, term to describe the Triassic age rocks that crop out in the Betic Cordillera, avoiding all facies connotations.

Notwithstanding, the diversity and complexity of the Triassic units in the Betic Cordillera have made it difficult to correlate these units with the general palaeogeographic types of the peninsula. The problem is that many of the tectonic units of the cordillera are currently superimposed and it is difficult to precisely define the Triassic stratigraphy of the different units, as indicated at the beginning of this paper. However, considering the present data, if we adopt the criteria of López-Gómez et al. (1998) to differentiate the outcrops of the peninsula’s Triassic, the Southiberian Triassic would be equivalent to the *Iberian Triassic* with one marine carbonate level of Ladinian age. In the Mesomediterranean Triassic, which is the most extended and varied of the Betic Cordillera, there are several situations. In the Maláguide Complex, when one carbonate level occurs, it could be correlated to the *Iberian Triassic*. In the Alpujárride Complex, the following situations arise: outcrops with two carbonate levels of Anisian–Ladinian age separated by a siliciclastic level (metapelites); and outcrops with only one substantial marine carbonate level of Middle Triassic age. These cases could be correlated to the Triassic types, respectively: *Mediterranean and Levantine–Balearic* (Fig. 7). Finally, the designation Alpine Triassic would be applicable when speaking about very thick carbonate successions or those more connected to the open sea harbouring fossils from the Tethys bioprovince.

According to these arguments, the Betic Cordillera may be viewed as a privileged setting in which we can observe the gradual change from the more marginal facies to the more marine ones linked to the ocean basin and containing larger amounts of carbonates.

5. Conclusions

The study of the stratigraphy and biostratigraphy of Triassic rocks in the Betic Cordillera is hindered by the tectonic complexity of the region and, in the Internal Zones, also by the existing metamorphism. Investigations to date have taken on an excessively focussed perspective and have failed to establish a general stratigraphy that could be coherent for the entire Cordillera. However, by reviewing the most recent studies and analysing many of the observations made by the earlier authors, it may be stated that almost all the palaeogeographic domains of the Betic basin are consistent with a stratigraphic scheme close to the Germanic type and proper to an epicontinental environment. The exception is its Norian deposits, which are mainly carbonate-marine in the Betic basin and essentially siliciclastic coastal-marine in the Germanic basin (Bachmann, 1998). It may be concluded that the epicontinental shelf of the Triassic eventually spanned almost the entire Betic basin, although with a highly variable and constantly changing palaeogeography due to a rifting tectonics and eustatic changes. The Triassic carbonates of the cordillera mainly exhibit extremely shallow to fairly shallow facies except in a few units in which they occupied areas close to the edge of the Tethys ocean basin.

The influx of fauna from the Tethysian domain occurred more or less as in other basins of the Iberian Peninsula, although in the Betic basin this was intense in some periods, especially during the most transgressive stages of the Upper Triassic. Our findings highlight the importance of considering that the domain characteristic of the Betic basin is the Sephardic domain proper to shallow platforms, in which emerging areas gave way to continental deposits and at the same time preserved their connections with the Tethys.

This simplified palaeogeographic overview and relationship among the different domains that today correspond to different tectonic units, allow for a more appropriate use of terminology and should help define the objectives of future studies. Thus, we propose the use of the terms Southiberian Triassic and Mesomediterranean Triassic to refer to the outcrops linked to the External Zones and Internal Zones, respectively. The terms Buntsandstein, Muschelkalk or Keuper facies can be used for any of the domains, since in large measure they all show epicontinental facies, especially characterized by Muschelkalk facies. In this way, more complex stratigraphic schemes could be avoided. In addition, the use of the term Alpine facies should be restricted to very thick carbonate successions with more oceanic facies, whose fauna is mainly derived from the Tethys bioprovince, that also lack coastal sediments in their stratigraphic successions.

This proposed nomenclature also allows for correlating the Triassic of the domains of the Betic Cordillera with the palaeogeographic units of the Iberian Peninsula. Hence, the Southiberian Triassic would correspond to the *Iberian Triassic*, and the Mesomediterranean Triassic would comprise the types *Mediterranean* and *Levantine–Balearic*.Accordingly, the Alpine Triassic proper is that cropping out in some of the Internal Zone units.

Finally, we would like to stress the considerable interest in exploring the Sephardic domain in the Triassic of the Betic Cordillera, given it harbours the Germanic facies that give rise to an Alpine facies.

Acknowledgements

The authors would like to thank their colleagues for their comments over these past few years. These discussions eventually prompted the study here described. They are also grateful to Ana Márquez-Aliaga (University of Valencia) and one anonymous reviewer for their constructive and thoughtful comments on the manuscript, and to Ana Burton for translating the original manuscript.

This study was supported by the Research Project grant CGL 2005-01520/BTE and by the research group of the Junta de Andalucía RNM 0163, and also forms part of the Project IGCP 467.

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