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ON THE TRIASSIC OF THE BETIC CORDILLERAS (SOUTHERN SPAIN)

POR

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ABSTRACT

With the aid of microfossils a number of detailed lithostratigraphic columns of the Triassic of the External and Internal Zones of the Betic Cordilleras, the alpine foldbelt of southern Spain could be established.

The Triassic of the External Zone (Prebetic and Subbetic) is characterised by two clastic-evaporitic sequences, separated by a carbonate sequence. The Triassic of the Almagride Complex very strongly resembles that of the Subbetic, implying deposition of the Triassic sediments of both complexes in a single major paleogeographic domain. The Almagride Complex belongs to the External Zone and represents the southern continuation of the Subbetic below the tectonic complexes of the Internal Zone. Carbonate sedimentation started in the Late Ladinian in the Almagride-Subbetic domain and is essentially of Early Karnian age in the more external parts of the Prebetic Zone. In the Triassic of the Meseta cover only redbeds of Early Ladinian-Norian age are present. The Late Triassic upper clastic-evaporitic sequence is overlain by a dolomite sequence, which is thought to be at least partly of Norian age.

The Triassic of the Internal Zone is quite different from that of the External Zone. It is characterised by a clastic sequence, with intercalations of carbonates and evaporites in its upper part, and an overlying carbonate sequence. The onset of the carbonate sedimenta-

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tion in the various tectonic units was not synchronous, and it may be concluded that large areas of the Internal Zone were affected by normal faulting in Triassic time. The Alpujarride domain was situated between the Malaguide-Dorsale domain (in the south) and the Nevado-Filabride domain (in the north). The northern part of the Nevado-Filabride domain (Veleta domain) is thought to represent a highland in Triassic time, situated between the Mulhacén and Almagride domains, resp. to the south and to the north.

RESUMEN

Se presenta una sinopsis del Triásico de las Zonas Externa e Interna de las Cordilleras Béticas, la cadena alpina del Sur de España. Han podido establecerse algunas columnas litoestratigráficas detalladas de varias partes del orógeno, con ayuda de microfósiles.

El Triásico de la Zona Externa (Prebético y Subbético) se caracteriza por poseer dos secuencias clástico-evaporíticas, separadas por una secuencia carbonatada. El Triásico del Complejo Almágride presenta un extremado parecido al del Subbético, lo que implica un depósito de los sedimentos triásicos de ambos complejos en un único dominio paleogeográfico. El complejo Almágride representa pues la continuación meridional del Subbético bajo los complejos tectónicos de la Zona Interna y debe ser considerado como la parte más meridional de la Zona Externa. La sedimentación carbonatada se inició, en el dominio Subbético-Almágride, en el Ladiniense Superior y es esencialmente de edad Karniense Inferior en las partes más externas de la Zona Prebética. En la Cobertera Triásica de la Meseta sólo están presentes capas rojas de edad Ladiniense Inferior-Noriense. Sobre la secuencia clástico-evaporítica del Triásico Superior reposa una secuencia dolomítica, la cual se presume que es, al menos parcialmente, de edad Noriense.

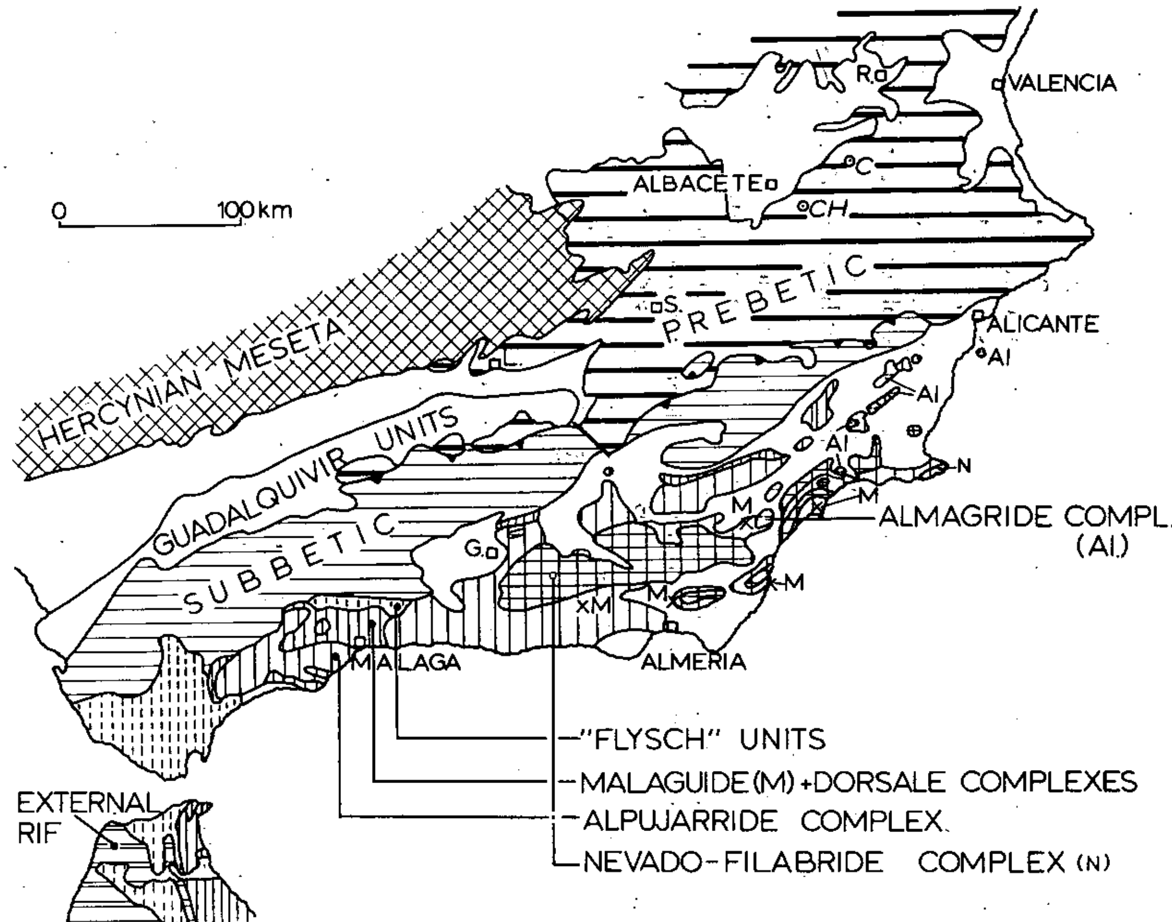
El Triásico de la Zona Interna es bastante diferente del de la Zona Externa. Se caracteriza por una secuencia clástica, con intercalaciones de carbonatos y evaporitas en su parte superior, y una secuencia carbonatada suprayacente. El comienzo de la sedimentación carbonatada en las diferentes unidades tectónicas no fue sincrónico, y se puede concluir que amplias áreas de la Zona Interna fueron afectadas por la actuación de fallas normales en el Triásico. El dominio Alpujárride estuvo situado entre el Dominio Maláguide-Dorsal (en el Sur) y el dominio Nevado-Filábride (en el N). La parte septentrional del dominio Nevado-Filábride (dominio Veleta) se piensa que representa un área emergida durante el Triásico, situada entre los dominios Mulhacén y Almágride, al Sur y al N respectivamente.

INTRODUCTION

At the occasion of the first «Congreso Pérmico-Triásico de España», held in October 1976, a sypnosis has been given of the Triassic of the Internal Zone of the Betic Cordilleras of southern Spain (SIMON and KOZUR, 1977). In the last decade many new data have become available on the precise age, stratigraphy and mode of deposition of the Triassic rock sequences. Furthermore, detailed mapping of large parts of southern Spain, strongly stimulated by the MAGNA-project, and studies of the metamorphic history and tectonic evolution have considerably contributed to a better knowledge of the Betic geology. This has enabled us to present a paper in which a number of detailed Triassic sections of various parts of the orogen has been given (KOZUR *et al.*, 1985). On the basis of these columns and additional data from other regions, a summary will be given of the Triassic of the Betic Cordilleras.

The Betic Cordilleras represent the westernmost part of the peri-Mediterranean Alpine orogenic system. It comprises an External and an Internal Zone. In the External Zone non-metamorphic Triassic and younger rocks, which have been deposited on the southern continental margin of the Iberian Block, are exposed. The External Zone is usually subdivided in the Prebetic and Subbetic Zones on the basis of marked differences in the development of the Middle Jurassic and younger sequences (HERMES, 1978; GARCIA-HERNANDEZ *et al.*, 1980; Figs. 1 and 2). In the region to the south of Albacete and Valencia the northern part of the Prebetic gradually passes into the southern spurs of the Iberian Chain. In the Cazorla-Siles region the contact between the Prebetic and the autochtonous cover of the Hercynian Meseta is of tectonic nature (cf. BAENA PEREZ and JEREZ MIR, 1982). Between the Prebetic and Subbetic so-called «Intermediate Units», which are thought to comprise rocks deposited in a paleogeographic realm between the Prebetic and Subbetic domains, are currently) differentiated (HERMES, 1978; GARCIA-HERNANDEZ *et al.*, 1980). Final emplacement of the Subbetic upon the Prebetic and «Intermediate Units» —with a minimum displacement in the order of several tens of kilometres— took place around the Middle/Late Miocene boundary, and is thought to be synchronous with the shortening of the cover of the Prebetic and Intermediate «units» in the order of some 60 kilometres along the Siles-Cazorla transversal.

The Internal Zone of the Betic Cordilleras is characterised by the superposition of a number of overthrust masses and by polyphase deformation and plurifacial metamorphism during the Alpine orogeny. The Internal Zone is essentially built up by low-to medium-grade sediments of Triassic and older age. On the basis of lithostratigraphic


0
100 km
HERCYNIAN MESETA
GUADALQUIVIR UNITS
SUBBETIC
PREBETIC
VALENCIA
R.
C
CH
ALBACETE
S.
ALICANTE
Al
N
M
ALMAGRIDE COMPL.
(Al.)
G.
MALAGA
ALMERIA
EXTERNAL
RIF
"FLYSCH" UNITS
MALAGUIDE (M) + DORSALE COMPLEXES
ALPUJARRIDE COMPLEX.
NEVADO-FILABRIDE COMPLEX (N)

development of the Triassic sequences and tectono-metamorphic evolution, the overthrust masses are usually grouped into three major tectonic complexes. They are, in ascending order, (1) the Nevado-Filabride Complex in which a bipartite subdivision can be made into a Veleta Complex and an overlying Mulhacén Complex; (2) the Alpujarride Complex and (3) the Malaguide Complex (including the Dorsale Complex) (EGELER and SIMON, 1969; PUGA and DIAZ DE FEDERICO, 1978; MAKEL, 1985). In the western Internal Zone and locally also to the east of the Granada transversal, Mesozoic and Early Miocene sediments of the so-called «Flysch» units tectonically overlie Alpujarride and Malaguide rocks.

In the northeastern Internal Zone the Almagride Complex has recently been differentiated. It consists of (very) low grade Triassic rocks with a stratigraphy that very strongly resembles the Subbetic Triassic in the Murcia province (BESEMS and SIMON, 1982; SIMON and VISSCHER, 1983). This complex is thought to represent the southern to southeastern continuation o the Subbetic below the afore-mentioned nappe complexes of the Internal Zone (KOZUR *et al.*, 1985). The rocks of the Almagride Complex and parts of the Alpujarride Complex have been previously incorporated in the Ballabona-Cucharón Complex. This complex was thought to have an intermediate position between the Nevado-Filabride and Alpujarride Complexes (EGELER and SIMON, 1969).

Nowadays most authors favour a northern (= external) position of the Nevado-Filabride domain with regard to the Alpujarride-Malaguide domain, whereas the sediments of the «Flysch» units are thought to have been deposited between the Malaguide-Dorsale and External Rif domains (MAKEL, 1985). The paleogeographic relationship between the Nevado-Filabride domain and the Almagride-Subbetic domain is still unclear.

First Alpine compressional movements in the Internal Zone, accompanied by high pressure metamorphism in the Nevado-Filabride Complex (NIJHUIS, 1964; PUGA and DIAZ DE FEDERICO, 1978), started probably in Late Cretaceous time. An important orogenic phase —related with the rise of ultramafic mantle diapirs— took place in Early Miocene (and Oligocene ?) time. Alpujarride and Malaguide nappes (and possibly also the Nevado-Filabride nappes) were emplaced to-

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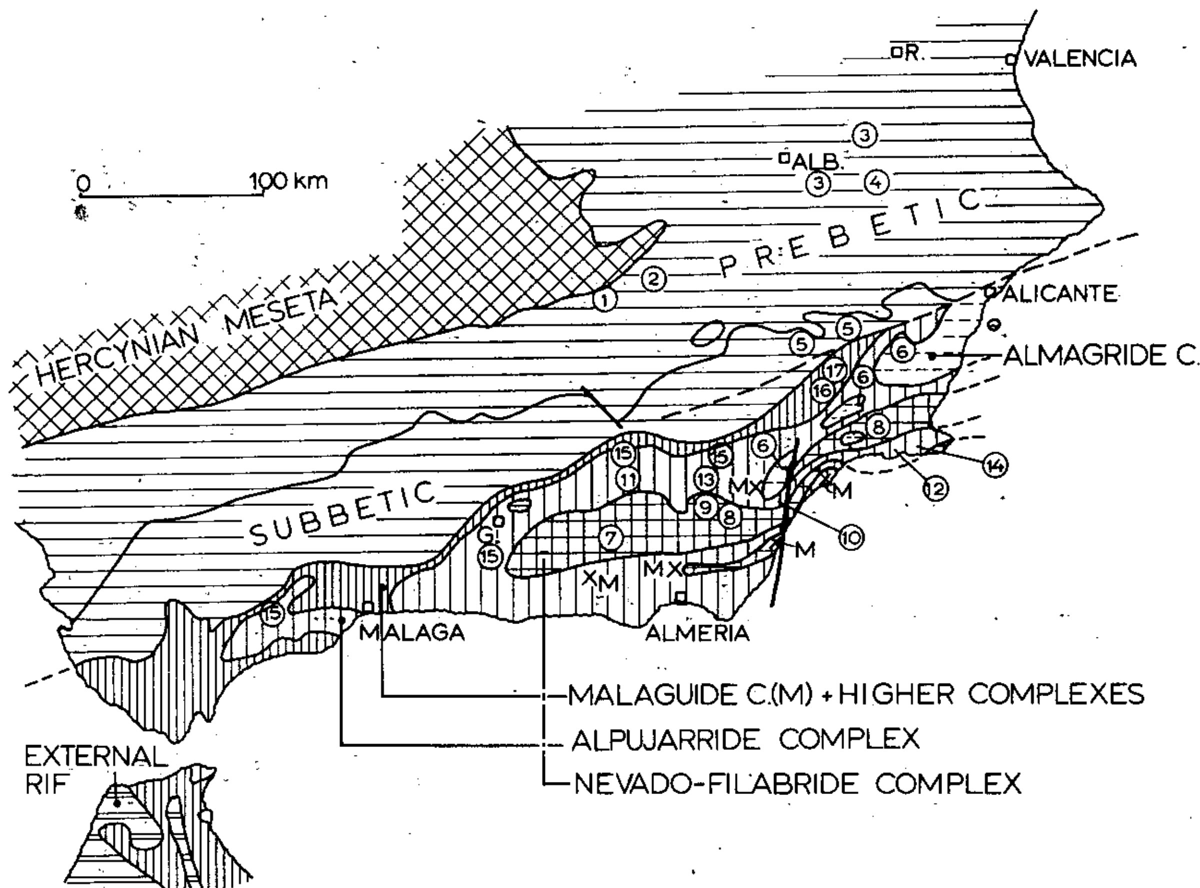
FIG. 1.—*Tectonic map of the Betic Cordilleras. C: Carcelén; CH: Chinchilla de Monte Aragón; G: Granada; L: Linares; R: Requena; S: Siles; The «Intermediate Units» have been incorporated in the Prebetic.*

Mapa tectónico de las Cordilleras Béticas. C: Carcelén; CH: Chinchilla de Monte Aragón; G: Granada; L: Linares; R: Requena; S: Siles. Se han incorporado a las «Unidades Intermedias» al Prebético.



R.
VALENCIA
ALB.
0
100 km
PREBETIC
HERCYNIAN MESETA
ALICANTE
ALMAGRIDE C.
SUBBETIC
G.
MX
M
XM
MALAGA
ALMERIA
MALAGUIDE C.(M) + HIGHER COMPLEXES
ALPUJARRIDE COMPLEX
NEVADO-FILABRIDE COMPLEX
EXTERNAL RIF

wards the Iberian foreland and upon the Almagride Complex. Tectonic activity in the Internal Zone continued during the deposition of post-nappes sediments of (Late ?) Burdigalian and Middle Miocene age, and culminated in a major compressional tectonic phase around the Middle/Late Miocene boundary.

The Triassic is the only period for which sediments are known from all complexes in the Betic Cordilleras. Therefore, a comparison of the Triassic columnar sections is of essential importance for the reconstruction of the Betic paleogeography in Early Mesozoic (EGELER *et al.*, 1971).

Dating of the Triassic sequences has been done by means of microfaunas (ostracods, conodonts, holothurian sclerites, foraminifera, etc.) and by (micro)floras (pollen, spores, algae) and sometimes on the basis of macrofaunas. For a correlation of microfloras, microfaunas and macrofaunas in the Ladinian and Karnian of the Betic Cordilleras, the reader is referred to KOZUR *et al.* (1985, table 3).

This paper is a contribution to the I.G.C.P. Project no. 203 «Permo-Triassic events of the Eastern Tethys and their intercontinental correlation», involving the whole Tethys, Gondwana and Circum-Pacific Realms with emphasis on the organic evolution and tectonic development» and to the «Proyecto Mixto Hispano-Holandés: El Triásico de la Cordillera Bética».

TRIASSIC OF THE EXTERNAL ZONE AND OF THE ALMAGRIDE COMPLEX

The Triassic of the External Zone comprises two clastic (-evaporitic) sequences with an intercalated shallow marine carbonate sequence. This threefold subdivision is well-known in literature as the germanic or germanic-andalusian Triassic. The lower and upper clastic (-evaporitic) sequences are usually referred to as resp. «Buntsandstein» and «Keuper», whereas the carbonate sequence is commonly designated as «Muschelkalk». As stated by VISSCHER (1974), these traditional lithological classification units are often incorrectly used in a chronostratigraphical sense. In the Betic Cordilleras the use of these terms has often led to significant chronostratigraphical, lithostratigraphical and tectonic misinterpretation (BESEM and SIMON, 1982). Therefore, it is recommended to avoid the use of such terms

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FIG. 2.—*Simplifed tectonic map of the Betic Cordilleras. The numbers in the map refer to the columnar sections of Figs. 3 and 4.*

Mapa tectónico simplificado de las Cordilleras Béticas. Los números indican los cortes representados en las figs. 3 y 4.

for indicating stratigraphical units as well as facies units. With regard to the chronostratigraphical classification of the Betic Triassic, it should be attempted to interpret biostratigraphical information in

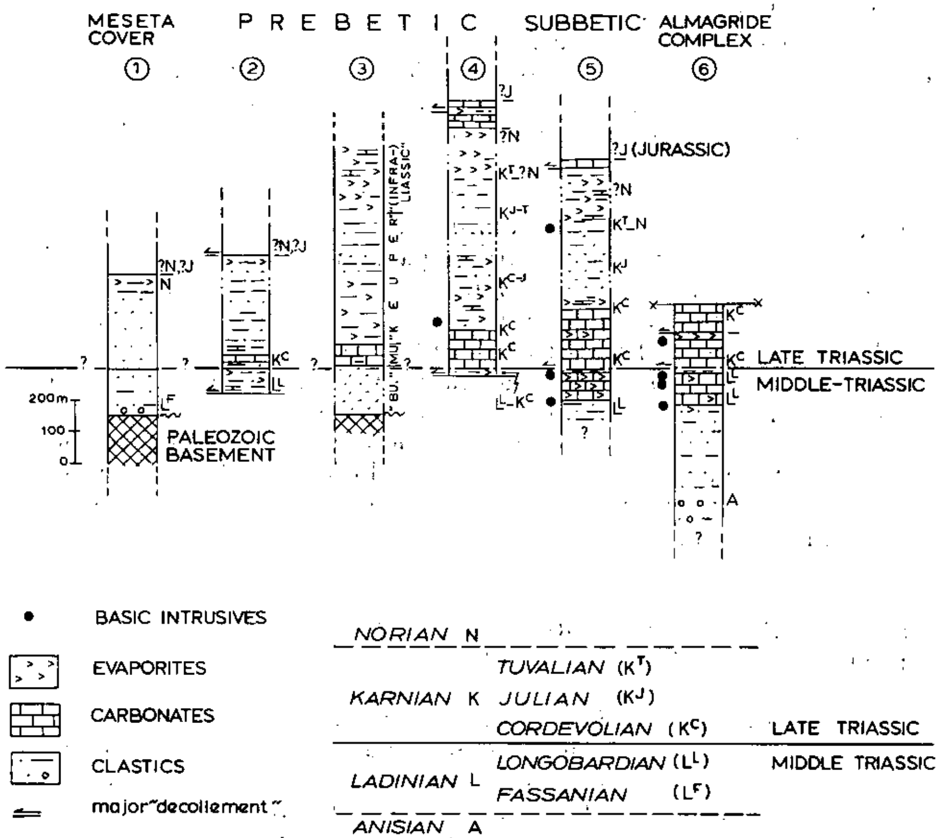


FIG. 3.—*Columnar sections of the Triassic of the External Zone of the Betic Cordilleras (incl. Almagride Complex). For the location, see Fig. 2. Column 1: after BESEMS (1981); column 2: after BESEMS (1983, Siles section). In the Hornos section the lower clastic-evaporitic sequence also contains Early Ladinian (Fassanian) sediments; column 3: after unpubl. rep. of ENPENSA (Carcelén-1, 1967) and TENNECO (Chinchilla, 1973); column 4: after VAN DEN BERGH et al. (1983) and HAAN et al. (1984); columns 5 and 6: after KOZUR et al. (1985).*

Cortes del Triásico de la Zona Externa de las Cordilleras Béticas (incluido el Complejo Almágride). Localización en la fig. 2. Corte 1, según BESEMS (1981): corte 2, según BESEMS (1983, corte de Siles). La secuencia clástico-evaporítica del corte de Hornos comprende también sedimentos del Ladiniense inferior (Fassaniense); corte 3, según informe inédito de ENPENSA (Carcelén 1, 1967); corte 4, según VAN DER BERG et al. (1983) y HAAN et al. (1984); cortes 5 y 6, según KOZUR et al. (1985).

terms of the Alpine standard stages and, if possible, substages (BESEMS, 1981).

The carbonate sequence decreases in thickness from SE (Almagride Complex) towards NW (Cazorla-Siles zone of the Prebetic) (see Fig. 3). It is absent in the Chiclana de Segura Formation of the Meseta cover (LOPEZ GARRIDO, 1971), in which only Early Ladinian to Norian redbeds are present (BESEM, 1981; Fig. 3, column 1). The onset of the carbonate sedimentation was Late Ladinian in the Subbetic-Almagride domain (BESEMS and SIMON, 1982). In the Alpera-Montealegre del Castillo region (Fig. 3, column 4), the oldest rocks of the carbonate sequence must be latest Ladinian or earliest Karnian in view of the age of the underlying clastic-evaporitic deposits (HAAN *et al.*, 1984). The precise age of the carbonate sequence in the Cazorla-Siles zone (Fig. 3, column 2) poses some problems. According to BESEM (1983) only a single carbonate sequence is present in the Triassic Hornos-Siles Formation in the Siles and Hornos areas; occurrences of more than one carbonate sequence are due to a tectonic repetition. On the basis of microfaunas and palynomorphs an Early Karnian age has been attributed to this carbonate sequence (BESEMS, 1983, tables 1-3). According to GIL *et al.* (1985) in the eastern part of the Hornos-Siles zone three carbonate intercalations are present, whereas in the more western part only a single carbonate intercalation (the uppermost) can be recognized. In the middle carbonate intercalation the ammonite *Protrachyceras hispanicum*, indicating a Late Ladinian age, has been found (PARNES *et al.*, 1985; HIRSCH, pers. com.). Therefore, the possibility must be envisaged that in the more eastern part of the Siles-Hornos zone carbonate sedimentation started in the Late Ladinian and in the more western part in the Early Karnian.

The Triassic sequences of the Almagride Complex and the Subbetic very closely resemble each other. This becomes evident if we compare the following lithological units of both complexes (BESEMS and SIMON, 1982; KOZUR *et al.*, 1985).

(1) Green Slate member (Almagride Complex) and «mudstone sequence» (Subbetic). In both complexes this unit comprises greenish and purple to reddish mudstones of latest Ladinian to earliest Karnian age, with a common thickness in the order of several metres. At least part of these mudstones represent tuffaceous deposits.

(2) Tres Bancos member (Almagride Complex) and «lower limestone-dolomite sequence» (Subbetic). SEYFRIED (1978, p. 17) recognized for the first time the conspicuous resemblance between both sequences. In both complexes this unit, which rests upon the aforementioned unit, has a thickness between 30 and 40 metres. It consists

of three pronounced carbonate beds, separated by thinbedded (marly) limestones (SIMON, 1963, plate e; KAMPSCHUUR, 1972, fig. 4). Iron mineralisations are of common occurrence, especially in the lower part of the unit. At least part of the mineralisations are thought to be of sedimentary origin (ARANA CASTILLO, 1973).

(3) Variegated Carbonate member (Almagride Complex) and lower part of the «upper limestone-dolomite sequence» (Subbetic). This unit stratigraphically overlies the unit mentioned sub (2). In both sequences a number of identical «keybeds» can be recognized (e.g. Almagride Complex: KAMPSCHUUR, 1972; KOZUR *et al.*, 1974). In the Subbetic the «keybeds» can be observed in the Cehegin-Bullas region and in the southern Sierra del Oro and in the Cabezas Negras area to the south of Cieza. In the lowermost «keybed» in both complexes the lamellibranchs *Costatoria kiliani* and *Gervilleia joleaudi* are of common occurrence.

(4) Basic intrusives. In both complexes basic intrusives (in litterature usually referred to as «ophites») are of frequent occurrence. They mainly occur as discontinuous bodies between the Green Slate member/«mudstone sequence» and the underlying carbonate sequence. From a petrographical point of view they closely resemble each other (cf. SIMON, 1963; KAMPSCHUUR, 1972; GOLZ, 1978). In the Almagride Complex the basic intrusives contain newly-formed pumpellyite, amphiboles and minerals of the glaucophane group. Pumpellyite has also been described from Subbetic «ophites» (GOLZ, 1978). Intrusion most probably took place around the Triassic-Jurassic boundary (BESEMS and SIMON, 1982, p. 46; see also KAMPSCHUUR, 1972, p. 42).

On the basis of this comparison it can be concluded that during Triassic time the Almagride and Subbetic sediments have been deposited in a single major paleogeographic domain, in which the Almagride domain occupied a more southern (i.e. internal) position with respect to the Subbetic domain. Until now the Almagride Complex has been incorporated in the Internal Zone. As follows from the foregoing, we are of the opinion that this complex belongs to the External Zone. This view is also supported by its tectonic position below all complexes of the Internal Zone.

In the Antequera-Archidona region, 80 km to the WSW of Granada, extensive outcrops of Triassic rocks are present. They occur just to the north of the boundary between the Internal and External Zones, and are currently incorporated in the Subbetic Zone. The «Antequera Trias» comprises sandstones, mudstones, evaporites and carbonate rocks. According to PEYRE (1974), pp. 402-406) and PUGA *et al.* (1983) the «Antequera Trias» also contains «blocks» of low-grade mudstones and carbonates. Basic volcanics («ophites») are of common occurrence. «Ophites» from the Archidona area contain newly-formed minerals, e.g. pumpellyite, chlorite, amphiboles and crossite (PUGA *et al.*, 1983).

Due to the strong tectonisation, stratigraphic successions have generally been totally disordered in the «Antequera Trias». On the basis of the descriptions by PEYRE (1974, pp. 392-397) and reconnaissance by the present author, it can be concluded that at least part of the carbonate rocks represent the «lower limestone-dolomite sequence» or Tres Bancos member. Most authors (e.g. CRUZ-SANJULIAN, 1976) are of the opinion that the rocks of the «Antequera Trias» have been deposited to the south of the Internal Subbetic realm and have been thrusted towards the north upon rocks of the Subbetic Zone s.s. This implies that the rocks of the «Antequera Trias» have been deposited in an analogous paleogeographic position as those of the Almagride Complex.

The upper clastic-evaporitic sequences of the Prebetic and of the Subbetic show great affinities to each other and are characterised by a subdivision in five distinct lithological units. Unit 1 comprises gypsiferous deposits with intercalations of mudstones and carbonates. Unit 2 is built up by variegated sandstones and mudstones with some intercalations of evaporites and carbonates. Unit 3 consists of reddish mudstones. Units 4 and 5 are respectively built up by reddish and white evaporites. An analogous subdivision has been established by ORTI (1974) in the «Keuper» of the Levant.

Palynomorphs from the units 1 and 2, and from the lower part of unit 3 of the Prebetic and Subbetic indicate the Karnian (Cordevolian, Julian and Tuvalian). It could be established that throughout the eastern External Zone the lithological boundaries between units 1, 2 and 3 do not coincide with time boundaries (VAN DEN BERGH *et al.*, 1983; HAAN *et al.*, 1984). For a discussion on the mode of deposition of the rocks of the upper clastic-evaporitic sequence, the reader is referred to ORTI CABO (1974).

The upper clastic-evaporitic sequence is generally overlain by a sequence that essentially consists of greyish dolomites with intercalations of clastics and evaporites. This sequence is usually referred to as «Supra-Keuper», «Infra-Liassic» or Imón Formation (e.g. GOY and YEBENES, 1977). It is probably at least partly of Norian age (cf. BOUTET *et al.*, 1982).

In the Almagride Complex the upper clastic-evaporitic sequence is absent. It is uncertain whether this is due to non-deposition or tectonic causes.

Formation of important detachment planes took place in the incompetent mudstones within the carbonate sequence of the Almagride Complex and of the Subbetic, in the upper parts of the clastic-evaporitic sequences and in the incompetent mudstone and evaporite intercalations of the Imón Formation. In many areas this led to the emplacement of the competent rocks of the carbonate sequence upon the upper clastic-evaporitic sequence. In view of its actual position, the latter sequence is often erroneously indicated in litterature as «Buntsandstein» (e.g. clastic-evaporitic rocks in the Agost region near Alicante; SCHMIDT, 1937; LECLERC, 1971).

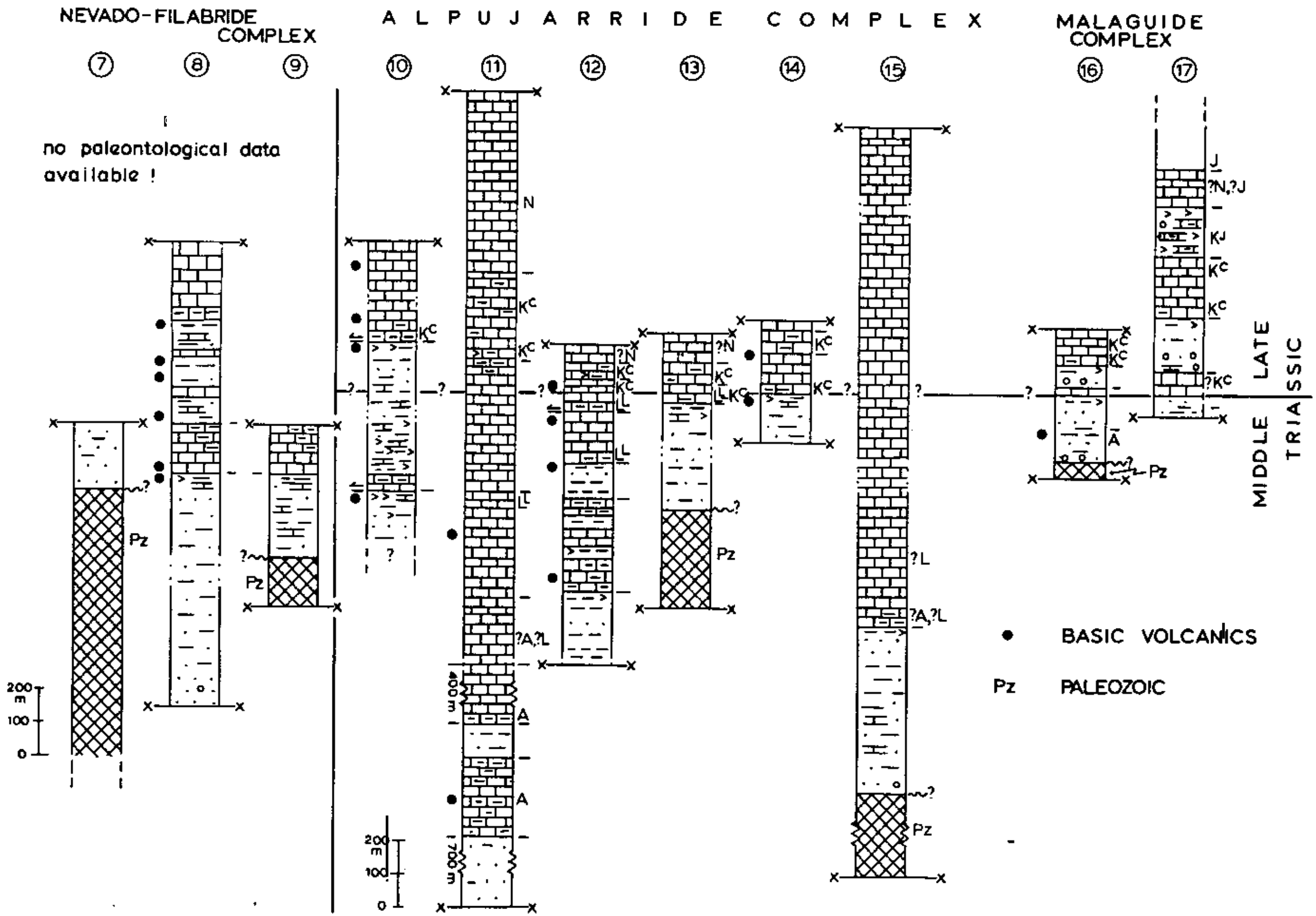
TRIASSIC OF THE INTERNAL ZONE

The Triassic of the Internal Zone has a different lithostratigraphic development with respect to that of the External Zone and the Almagride Complex (cf. Figs. 3 and 4). The Triassic sequences of the Nevado-Filabride, Alpujarride and Malaguide Complexes show marked similarities. The idealised columnar section consists of a clastic sequence and an overlying carbonate sequence (up to more than 2 km in some Alpujarride units). In the upper part of the clastic sequence discontinuous carbonate intercalations, up to 250 metres, and evaporites are of common occurrence. Evaporites are also present amidst Early Karnian rocks of the carbonate sequence.

The clastic sequence comprises continental sediments in its lower part and shallow marine deposits in its upper part. The precise age of the basal part of this sequence in the Nevado-Filabride and Alpujarride Complexes is unknown (SIMON and VISSCHER, 1983).

FIG. 4.—*Columnar sections of the Triassic of the Internal Zone of the Betic Cordilleras. For the location, see Fig. 2. For legend, see Fig. 3. Column 7: Veleta Complex, after DIAZ DE FEDERICO (1980); columns 8 and 9: Mulhacén Complex, resp. Nevado-Lubrín and Macael units, after BAKKER and DE JONG (1985); column 10: Almanzora unit, after BLOEMENDAAL (1982); column 11: Barbara unit, after DELGADO (1978) and DELGADO et al. (1981); column 12: San Gines unit, after KOZUR et al. (1985); column 13: Partaloa unit, after AKKERMAN et al. (1980); column 14: Portman unit, after KOZUR et al. (1985); column 15: composite columnar section of the Oria unit (AKKERMAN et al., 1980), Blanquizares unit (DELGADO, 1978), Trevenque and Nieves units (DELGADO et al., 1981). Post-Triassic sediments in the Nieves unit have been omitted; columns 16 and 17 resp. of Lower and Higher Malaguide units, after MÄKEL (1985).*

Cortes del Triásico de la cara interna de las Cordilleras Béticas. Localización en la fig. 2 y leyenda en la fig. 3. Corte 7: Complejo del Veleta, según DIAZ DE FEDERICO (1980); cortes 8 y 9: Complejo del Mulhacén, resp. Unidades Nevado-Lubrín y Macael; corte 10: Unidad Almanzora, según BLOEMENDHAL (1982); corte 11: Unidad Bárbara, según DEGADO (1978) y DELGADO et al. (1981); corte 12: Unidad San Ginés, según KOZUR et al. (1985); corte 13: Unidad Partaloa según AKKERMAN et al. (1980); corte 14: Unidad Portman, según KOZUR et al. (1985); corte 15: corte compuesto de la unidad Oria (AKKERMAN et al., 1980), Unidad Blanquizares (DELGADO, 1978), Unidad Trevenque y Unidad Nieves; corte 16 y 17: resp. de las Unidades Maláguides Inferior y Superior, según MÄKEL (1985).


NEVADO-FILABRIDE COMPLEX
ALPUJARRIDE COMPLEX
MALAGUIDE COMPLEX
⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮ ⑯ ⑰
no paleontological data available !
MIDDLE
LATE
TRIASSIC
● BASIC VOLCANICS
Pz PALEOZOIC
200 m
100
0
400 m
700 m

In the Malaguide Complex the age of the oldest clastics is most probably Anisian (or Early Triassic) and the presence of Permian rocks is very unlikely (MAKEL, 1985; see also SIMON and VISSCHER, 1983).

The rocks of the carbonate sequence have been deposited in a shallow marine, partially hypersaline, sea with water depths less than 100-150 metres and generally in the order of 0-30 metres, including intertidal conditions (SIMON and KOZUR, 1977). For further information on the mode of deposition of the Triassic rock sequences of the Internal Zone, the reader is referred to ROEP (1972), MARTIN (1980), MARTIN and DELGADO (1980), MARTIN and TORRES-RUIZ (1982), FLUGEL *et al.* (1984) and MAKEL (1985).

For a discussion on the correlation and grouping of the Alpujarride units, one is referred to KOZUR *et al.* (1985, see especially table 4). Column 15 (Fig. 4) represents a composite, schematic, columnar section of a group of units which tectonically overlies the Portman unit (column 14) and correlatable units. Above this group of units a highest group of Alpujarride units can be differentiated, comprising e.g. the Montroy unit (AKKERMAN *et al.*, 1980), Hernán-Valle, La Plata, Guájares and Benamocarra units (ALDAYA *et al.*, 1979) and the Casares unit (MAKEL, 1985). These units are mainly built up by Paleozoic rocks with a thin Triassic cover, and have generally been severely tectonised and influenced by metamorphism. In litterature no reliable lithostratigraphic sections of the Triassic of these units are available.

On the basis of supposed affinities with the (austro)-alpine Triassic, the Triassic of the Alpujarride Complex is usually referred to as the Alpine Triassic. It should be mentioned, however, that only part of the faunas and floras shows affinities with the (austro-) alpine fossils. Most of the fossils represent endemic faunas and floras.

On the basis of lithostratigraphic development, especially of the carbonate sequence —in combination with tectono-metamorphic evolution and geometric position in the pile of tectonic units— several tectonic complexes, each comprising a number of nappes, can be distinguished (e.g. EGELER and SIMON, 1969; ALDAYA *et al.*, 1979; KOZUR *et al.*, 1985). In Fig. 4 the columns of the tectonic complexes and units have been placed from left to right in ascending tectonic order. This order is also supposed to represent the succession of paleogeographic domains from north to south (i.e. from more external to more internal).

It is generally assumed that the onset of the carbonate sedimentation was synchronous in all complexes and nappes of the Internal Zone. Our investigations have revealed, however, that this is not the case. As can be concluded from figure 4, carbonate sedimentation started in some nappes in the early Middle Triassic, whereas it began in the early Late Triassic in other ones. From the differences in timing of onset of carbonate sedimentation, combined with significant differences in thickness of the Triassic sequences, it may be concluded that the Internal Domain was affected by normal faulting in an extensional tectonic regime (cf. MAKEL, 1985). Such a regime also explains the occurrence of basic volcanics and of sedimentary breccias in part of the Triassic sequences.

CONCLUDING REMARKS

Many authors advocated, or still advocate, a paleogeographic relationship between the Subbetic and Malaguide domains, especially on the basis of supposed resemblances between the Triassic sequences of both complexes (e.g. PAQUET, 1969; JEREZ MIR, 1981). Our investigations have revealed that the Subbetic Triassic differs considerably from that of the Malaguide Triassic and the same holds good for the post-Triassic sequences (MAKEL, 1985, pp. 183-185, fig. 3-9). Comparison of the lithostratigraphic development of the Malaguide sequences with that of other complexes in the Betic-Rif orogen —and other, geometric, arguments— indicate a paleogeographic position of the Malaguide domain between that of the Alpujarride domain in the north (i.e. more external) and the Dorsale/Flysch domain in the south (i.e. more internal) (MAKEL, 1985).

The Triassic of the higher tectonic nappes of the Nevado-Filabride Complex (=Mulhacén Complex) shows great resemblance with that of the lowermost Alpujarride Almanzora nappe (cf. columns 8, 9 and 10 of Fig. 4), and has no obvious affinities with that of the «germanic» Triassic of the External Zone as proposed by TRUMPY (1983). The paleogeographic position of the Nevado-Filabride domain and especially that of its most external part, i.e. the Veleta domain, with respect to that of the Almagride-Subbetic domain is uncertain in view of the absence of reliable paleomagnetic data which enable a reconstruction of the Betic paleogeographic in Early Mesozoic time (cf. MAKEL, 1985). For the time being, we favour the hypothesis that the Veleta realm represented a highland in Triassic time, on which only some continental sediments were deposited (Fig. 4, column 7), and that supplied the terrigeneous detritus for the Mulhacén and Almagride domains, situated resp. to the south and to the north (see also MAKEL, 1985, figs. 5-3 and 5-4).

The widths of the paleogeographic domains of the Betic Cordilleras are uncertain. On the basis of geometrical aspects of the tectonic units, we arrive at a minimum width of some 270 kilometres for the External Domain (including the Almagride domain) and of some 500 kilometres for the Internal Domain, assuming a North-South arrangement of the Nevado-Filabride, Alpujarride and Malaguide domains (cf. FALLOT, 1932; MAKEL, 1985). Due to the Alpine orogenesis these domains have been shortened to resp. 145 and 100 kilometres.

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