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Triassic of the Tethys Realm

Aspects of Middle and Late Triassic Palynology. 3. Palynology of the Hornos-Siles Formation (Prebetic Zone, Province of Jaén, Southern Spain), with Additional Information on the Macro- and Microfaunas

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3 Fgs., 3 Pls., 4 Tbs.

Abstract

The present paper provides palynological as well as macro- and microfaunal information from the Hornos-Siles Formation (Triassic of the Prebetic Zone, northeastern part of the province of Jaén, Spain).

The palynological assemblages found belong to the *Camerosporites secatus* phase, which indicate their Ladinian-Karnian age.

On the basis of the qualitative/quantitative distribution of xerophytic palynomorphs, so far known in southern Spain, as well as the faunal record, a more detailed subdivision on the substage-level has been attempted. The tectonic origin of the several carbonate intercalations of the so-called "Muschelkalk" facies of the Hornos-Siles Formation is demonstrated.

Zusammenfassung

Dieser Arbeit gibt neben palynologischen Daten auch makro- und mikrofaunistische Daten der Hornos-Siles Formation (Trias der Prebetischen Zone, im nordöstlichen Teil der Provinz Jaén, Spanien). Die gefundenen palynologischen Vergesellschaftungen gehören zur *Camerosporites secatus* Phase, und deuten daher auf ein Ladin-Karn Alter hin.

Sowohl auf Grund der qualitativen und quantitativen Verbreitung der xerophytischen Palynomorphen im südlichen Spanien, als auf Grund der faunistischen Angaben, wird eine mehr ausführliche Unterteilung des Unterstufen-Niveaus vorgestellt.

Ein tektonischer Ursprung der verschiedenen Kalkinterkalationen der „Muschelkalk"-Fazies der Hornos-Siles-Formation wird nachgewiesen.

Resumen

Este trabajo ofrece información tanto palinológica como sobre la macro- y microfauna de la Formación de Hornos-Siles (Triásico de la Zona Prebética, NE provincía de Jaén, España).

Las asociaciones palinológicas reconocidas son atribuidas a la fase de *Camerosporites secatus*, la cual refleja una edad Ladiniense-Karniense. Se ha realizado una subdivisión mas detallada, a nivel de sub-pisos, basada tanto en la distribución cualitativa y cuantitativa de las palinomorfas xerofíticas en el Sur de España, como en el contenido de fauna.

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Se demuestra el origen tectónico de las diversas intercalaciones de calizas de las facies denominada "Muschelkalk" de la Formación de Hornos-Siles.

Introduction

Since 1977 palynological investigations are carried out in the Triassic sequences of southern Spain by members of the Laboratory of Palaeobotany and Palynology of the State University of Utrecht, in collaboration with the Department of Structural Geology of Amsterdam. This project is further supported by the Departments of Stratigraphy and Sedimentology of the University of Granada (Spain).

The main objective of the palynological investigations is to establish chronostratigraphical interpretations of the Triassic strata in terms of formal standard stages of the Triassic System. The investigations are incorporated in the activities of the I.G.C.P. project No. 4, "The Triassic of the Tethys Realm".

In the Betic Corilleras, the Alpine fold-belt of southern Spain, two major tectonic Zones, viz. the External Zone and the Internal or Betic Zone, can be distinguished (see, e.g. EGELER and SIMON, 1969). Until now palynological investigations have been concentrated upon the non-metamorphic Triassic strata of the Prebetic and Subbetic Zones, structural complexes of the External Zone. They have resulted in a paper on the Triassic cover of the Spanish Meseta (BESEMS, 1981a) and a preliminary note on the Triassic of the Prebetic Zone (BESEMS, 1981b). The palynology of the Triassic of the Subbetic Zone is dealt with in BESEMS (1982) and BESEMS and SIMON (1982).

The lithological development of the Triassic sediments of the Prebetic and Subbetic Zones resembles that of the Germanic Basin of northwestern Europe. Therefore, they are usually considered to have a Germanic facies development; in geological literature they are also often referred to as the so-called Germanic-Andalusian facies.

Generally the traditional units of the Germanic Triassic, "Buntsandstein", "Muschelkalk" and "Keuper", have been applied to denote the relative superposition of specific lithological units within the Triassic of the Prebetic and Subbetic Zones.

Serious problems arise, however, in the practical application of these German units for the Triassic succession in the Prebetic Zone in the northeastern part of the province of Jaén.

The Triassic strata of this area have been formally described as the Hornos-Siles Formation by LOPEZ GARRIDO (1971). According to this author, the "Muschelkalk" consists of a, from place to place, varying number of carbonate intercalations within a sequence of predominantly red clastics. The "Buntsandstein" and "Keuper" were thought to be represented by the clastic sequences, below the lowermost and above the upermost carbonate intercalations, respectively. Because of this presumed varying number of carbonate intercalations, LOPEZ GARRIDO (1971) designated two reference sections to characterize the Hornos-Siles Formation, viz. the Hornos section and the Sombrero section(see also Fig. 1).

On the basis of palynological information and field observations, the present author (BESEMS, 1981b) concluded that the varying number of carbonate intercalations in the Hornos section has been caused by tectonic repetition of a single carbonate sequence, rather than representing an undisturbed stratigraphical suc-

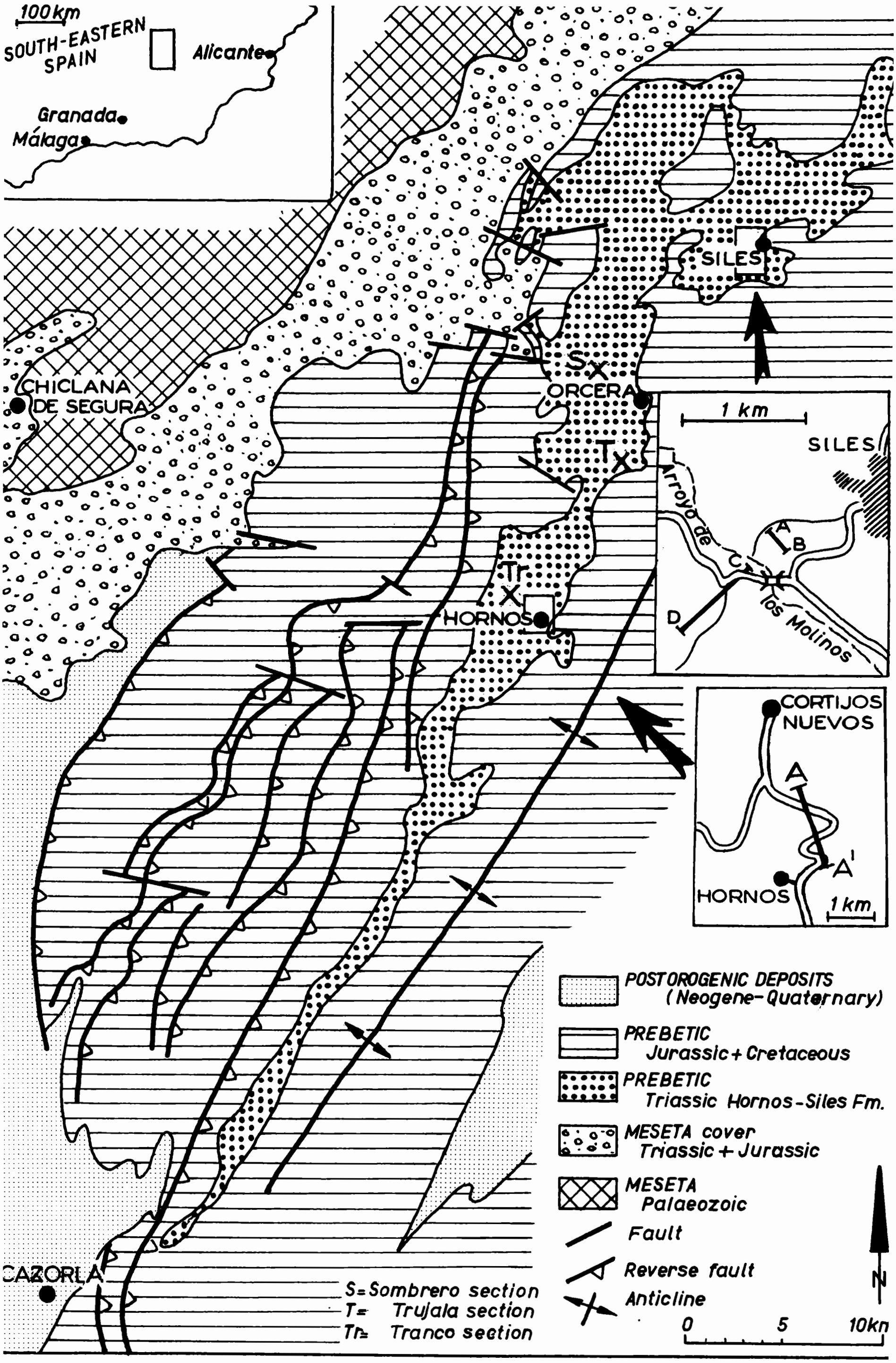


Fig. 1. Generalized structural map of the Siles-Cazorla region (after Lópe Garrido, 1971) with locations of the Siles and Hornos sections.

cession as assumed by LOPEZ GARRIDO (1971). This conclusion is in agreement with the observation by FOUCAULT (1971, p. 44) for the adjacent Cazorla region (Fig. 1).

The present paper provides the chronostratigraphical interpretation of the Hornos-Siles Formation near Siles on the basis of palynomorphs with some additional information on the macro- and microfaunas from carbonates of the so-called "Muschelkalk" facies. Furthermore, a chronostratigraphical re-interpretation has been made of the preliminarly described Hornos section (BESEMS, 1981 b) on the basis of new palynological information. A correlation between the Siles and Hornos sections has been established.

Lithostratigraphy

The Siles section is situated approximately 1 km. SW of the village of Siles (Fig. 1). In this section the Hornos-Siles Formation has a minimum thickness of approximately 145 m. It is composed of predominantly red mudstones and sandstones with gypsiferous intercalations (Table I). Within the upper part of the section a carbonate sequence of approximately 32 m occurs. The base of the section is marked by a NW-SE trending fault. Within the section some small faults have been observed. In the higher part of the Hornos-Siles Formation in this area, south of the Siles section (Fig. 1), only some scattered outcrops of variegated mudstone occur. Therefore, this part of the formation has not been incorporated in the section of Table I. The Hornos-Siles Formation is overlain by dolomites of Jurassic age (LOPEZ GARRIDO, 1971).

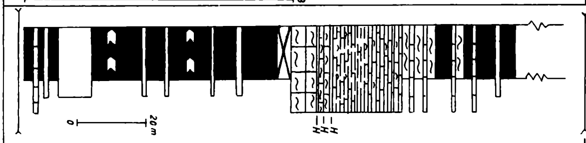
Three lithological units can be recognized within the Siles section (Table I):

(1) the lower unit (ca 78 m) consists of predominantly red mudstones with sandstone intercalations, sometimes with small scale X lamination. In the basal part of this unit a non-structured reddish sandstone of 10 m thickness is intercalated. In the middle part gypsiferous beds and yellowish calcareous sandstones occur. The grey colour is dominant in this part of the section. Towards the top of this unit the red colour becomes dominant; in this part of the section only mudstones are present. The contact with the overlying unit is not exposed.

(2) the middle unit (ca 32 m) comprises greyish carbonates. The lower 12 m is built up by beds from 30 cm up to 300 cm in thickness. Intercalated in this part are three hard grounds with a thickness of 15 to 30 cm. The overlying 20 m are composed of well-bedded carbonates from 5 cm up to 30 cm in thickness with intercalations of grey marly limestones. In this part of the section marine macrofossils commonly occur. The contact with the overlying unit is gradual.

(3) the upper unit (ca 33 m) is built up by variegated mudstones with intercalations of carbonate- and sandstonebeds from 5 cm up to 30 cm in thickness. The lower 8 m of this unit consists of an alternation of grey calcareous mudstones with grey carbonate beds. The overlying sediments become more reddish and carbonate intercalations are less frequent. In the upper part of this unit a sandstone-bed occurs.

Table I. Siles section.
Lithostratigraphy, lithology, position of samples, palynofloras, subphases, phases, age and quantitative/qualitative distribution of palynomorphs.
Palaeontological Samples:
75 = Si 80-075
16 = Si 77-016 = Si 80-068 and 069
15 = Si 77-015 = Si 80-067
14 = Si 77-014
12 = Si 77-012
J. = Jurassic

SILES SECTION	
LITHOSTRATIGRAPHY	Hornos-Siles Formation
COLOUR	g r gr y gr y r gr gr r g
PROFILE LINES (FIG.1)	A — B; C — D
LITHOLOGY	
LITHOLOGICAL UNITS Present paper	1 / 2 / 3
LITHOSTRATIGRAPHICAL UNITS (López Garrido,1971)	'Muschelkalk' / 'Keuper'
PALAEONTOLOGICAL SAMPLES	12, 14, 15, 16, 75
PALYNOLOGICAL SAMPLES	01, 02, 08, 12 / No information / 20, 24, 33, 27, 30
PALYNOLOGICAL ASSEMBLAGES	A / — / B
PALYNOFLORAS	2 / — / 3
SUBPHASES	secatus-meieri / — / secatus-densus
PHASE	Camerosporites secatus
AGE	LADINIAN (Langobardian) / KARNIAN (Cordevolian) / J.

Palynomorph	01	02	08	12	20	24	33	27	30
"Duplicisporites verrucosus"	o	.		.					
"Duplicisporites tenebrosus"	.	.		.					
"Partitisporites sp."	.	o		.					
Todisporites marginales	.	.		.					
Calamospora nathorstii	.	.			+	.			
indeterminable trilete spores	.	.	.	.	+	o	.		
Triadispora crassa	o	.	O	O	+	.	.	+	
"Duplicisporites granulatus"	o	O	o	.	+	.	.		.
alete (proto)bisaccate pollen grains	V	V	V	V	+	V	V	+	V
Convolutispora sp.A	.	.				.	.		.
Triadispora plicata	X	O	X	V	+	.	o	+	o
Ovalipollis pseudoalatus	o	o	.	.	+	X	X	+	O
"Duplicisporites scurrilis"	o	O	o	.	+	o	O		o
Camerosporites secatus	O	O			+			+	.
Convolutispora sp.B	.								o
Lunatisporites acutus	.				+	.	.	+	
Kuglerina cf. meieri	O		o				.	+	.
Aratrisporites spp.	O				+	X	o	+	V
Angustisulcites sp.	.	.				.	.		.
Todisporites cinctus		.			+	.	o	+	.
Staurosaccites quadrifidus		.			+	.	.		.
Praecirculina granifer					+	.	.	+	
Thompsonisporites sp.						.	.		
Striatoabietites aytugii					+	.			
Enzonalasporites vigens						o			
Distalanulisporites punctus									
Patinasporites densus								+	
Veryhachium sp.					+		.		
Micrhystridium sp.					+		.		
Dictyotidium reticulatum							.		.

Symbols

+ present
. 0-1.9% } Scarce
o 2-4.9%
O 5-14.9% } Common
X 15-24.9% } Abundant
V more 25%

r red
g green
gr grey
y yellow

fault
wavy bedding
small scale X lamination
gypsiferous
calcareous (20-40%)
H hardground

dolomite
limestone
marly limestone
mudstone
calcareous mudstone
sandstone

Palynology

DISTRIBUTION OF PALYNOMORPHS

Nine samples from the Siles section provided palynomorphs. With the exception of samples 20 and 27, all samples could be treated quantitatively (Table I). With respect to their palynological content two different assemblages can be designated: Assemblage A (samples 01, 02, 08 and 12) and Assemblage B (samples 20, 24, 33, 27 and 30).

In both assemblages alete (proto)bisaccate pollen grains, without specific age value, are predominant. A classification in terms of formgenera and species of these pollen grains has not been attempted. Since the main objective of the present investigations is the chronostratigraphical interpretation of the Hornos-Siles Formation by means of palynomorphs, a detailed discussion on the many taxonomic problems related to these formgenera is beyond the scope of this paper.

Assemblage A

This assemblage is characterized by:

(1) an abundance of *Triadispora plicata* KLAUS, 1964 emend. SCHEURING, 1979 (Plate I, Fig. 8, 10)

(2) occurrences up to 15%, of "*Duplicisporites scurrilis*" (SCHEURING, 1970) SCHEURING, 1979 (Plate I, Fig. 4; Plate II, Fig. 10), of other representatives of the "*Partitisporites-Duplicisporites*" complex sensu BESEMS, 1981 a (Plate II, Figs. 4—7 and 9), of *Triadispora crassa* KLAUS, 1964 (Plate I, Fig. 9), of *Ovalipollis pseudoalatus* (THIERGART, 1949) SCHUURMAN, 1976 (Plate I, Fig. 11), of *Camerosporites secatus* LESCHIK, 1956 emend. SCHEURING, 1979 (Plate I, Figs. 1—3), and of trilete spores

(3) the scarce occurrence of *Staurosaccites quadrifidus* DOLBY in DOLBY and BALME, 1976 (Plate II, Fig. 11) and taeniate pollen grains

(4) the presence of *Kuglerina* cf. *meieri* sensu BESEMS, 1981 a (Plate I, Figs. 5—7), which decreases toward the top of the section.

Camerosporites secatus is only present in samples 01 and 02. *Aratrisporites* spp. are only present in sample 01. The acritarch *Veryhachium* sp. (Plate II, Fig. 13) occurs in sample 02.

Assemblage B

This assemblage generally shows the following characteristics:

(1) a dominance of *Ovalipollis pseudoalatus* and *Aratrisporites* spp. (Plate II, Fig. 8)

(2) the common occurrence of „*Duplicisporites scurrilis*"

(3) the scarce presence of *Triadispora plicata*, *Camerosporites secatus*, trilete spores, representatives of the "*Partitisporites-Duplicisporites*" complex, *Staurosaccites quadrifidus* and taeniate pollen grains

(4) the very scarce presence of *Patinasporites densus* LESCHIK, 1956 emend. SCHEURING, 1970 (Plate II, Figs. 1—2) and *Enzonalasporites vigens* LESCHIK, 1956 (Plate II, Fig. 3)

Patinasporites densus has been recorded only in samples 27 and 30. *Enzonalasporites vigens* has been recorded in samples 24 and 30. Acritarchs occur in samples 20, 24, 33 and 30 (Plate II, Figs. 12, 13).

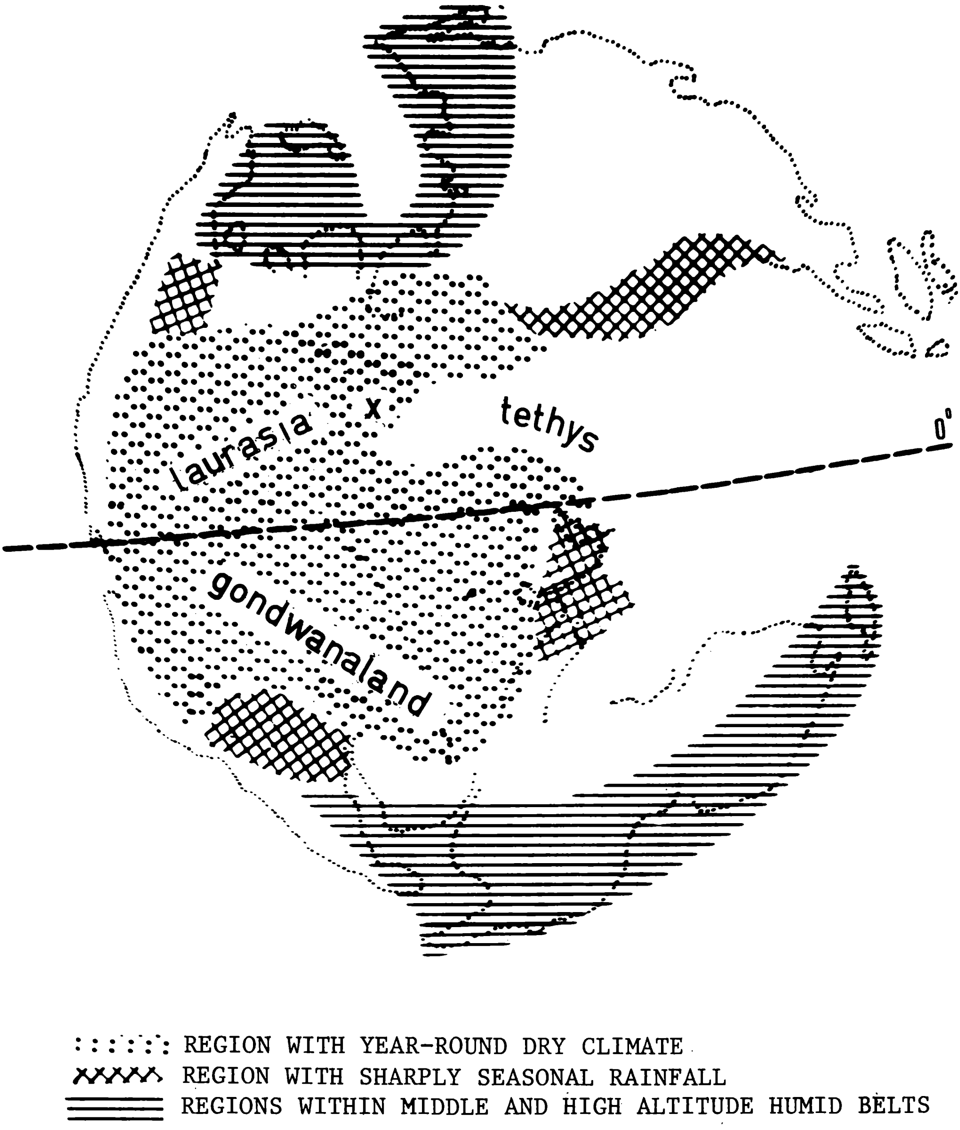


Fig. 2. Palaeo-geographical and climatological reconstruction of Karnian times (after Visscher and Van der Zwan, 1981)

THE PHASE CONCEPT, PHASES, SUBPHASES AND PALYNOFLORAS

In order to discuss the palynological information from the Hornos-Siles Formation, SCHUURMAN's (1977, 1979) *phase* concept has been applied. The principle of this concept (see also, VAN DER ZWAN, 1980, p. 104) is the recognition of a series of arbitrarily chosen steps (*phases*) in the (local, regional or interregional) gradual compositional development of successive palynological assemblages. *Phases* may be diagnosed on the basis of qualitative and/or quantitative compositional information. They may be named after characteristic species. The *phase* concept has been introduced for practical palynological correlation. Notably interregional *phases*, if biostratigraphically interpreted, may form the basis for the recognition of palynological assemblage Zones. However, they may also serve as a direct aid in the age-assessment of any reasonable preserved palynological assemblage, as well as its source strata, in terms of formal geochronological units. Of course, this can only be achieved when the corresponding chronostratigraphical units are sufficiently characterized on the basis of their palynological content.

Within an interregional *phase*, one may still observe a gradual change in composition. On a local or regional scale minor steps may be recognized, depending on the amount of palynological information available. Such local or regional minor steps may be termed *subphases*. Their compositional characteristics may vary from place to place, frequently due to environmental influences. For discussion purposes, the successive palynological assemblages constituting the *subphases* are here termed *palynofloras*.

Because of the presumed gradual character of the flora development in time, transitions between successive (*sub-*)*phases* and *palynofloras* are also gradual; the (*sub-*)*phases* and *palynofloras* are merely established to facilitate discussion. In general interpretations of transitions in terms of isochronic datumlevels should be considered carefully. Rapid interregional changes in the composition of the palynological content, however, may be extremely useful for diagnosing (not defining) boundaries between chronostratigraphical units (compare e. g. the Triassic-Jurassic boundary, SCHUURMANN, 1977, 1979; the Devonian-Carboniferous boundary, VAN VEEN, 1981).

THE *Camerosporites secatus* PHASE AND ITS SUBDIVISION

For discussing the information of the Hornos-Siles Formation only SCHUURMAN's (1977, 1979) phase 1, later termed the *Camerosporites secatus* phase by VISSCHER and KRYSTYN (1978) has to be taken into consideration. The *Camerosporites secatus* phase is characterized by the joint occurrence of *Camerosporites secatus*, *Ovalipollis pseudoalatus*, *Triadispora* spp. and representatives of the "*Partitisporites-Duplicisporites*" complex (BESEMS, 1981 a).

On the basis of additional taxa such as *Patinasporites densus*, *Enzonalasporites vigens* and *Vallasporites ignacii* LESCHIK, 1956, the younger part of the *Camerosporites secatus* phase as recognized in southern Spain is here designated as the *secatus-densus* subphase (= *secatus-densus* palynoflora, BESEMS, 1981 a). Because of the absence of these additional taxa and the common appearance of *Kuglerina* cf. *meieri*, the older part is here referred to as the *secatus-meieri* subphase.

With the palynological information from southern Spain, it is possible to trace the regional flora development within the *Camerosporites secatus* phase. It is obvious that this development strongly depends on palaeoclimatological conditions. The broad palaeoclimatological condition of southern Spain may be estimated from the world's palaeogeographical/palaeoclimatological reconstruction foı the Ladinian and especially the Karnian (compare, VISSCHER and VAN DER ZWAN, 1981). From this model it appears that southern Spain was situated in a wide equatorial arid belt (Fig. 2). The extreme western margin of the Tethys may well be regarded as one of the dryest areas in this belt. These conditions are indicated by red bed sequences and evaporite deposits.

The flora development in southern Spain is controlled by plants prefering such extreme dry and warm conditions. VISSCHER and VAN DER ZWAN (1981) discussed the xerophytic nature of the palynological assemblages from this area. Their overall composition is in strong contrast to that of coeval hygrophytic assemblages present in sediments deposited under humid environmental conditions.

The regional flora development within the *Camerosporites secatus* phase in southern Spain, is a reflection of the successive appearances and disappearances of xerophytic taxa, such as *Triadispora*, *Camerosporites*, representatives of the "*Partitisporites-Duplicisporites*" complex, *Patinasporites*. *Enzonalasporites* and *Vallasporites*.

A tentative scheme of successive xerophytic palynofloras within the *Camerosporites secatus* phase (Fig. 3) has been established on the basis of: (1) the qualitative and quantitative distribution of these xerophytic taxa; (2) the relative abundance of tetradal forms of representatives of the "*Partitisporites-Duplicisporites*" complex in youngest assemblages in this phase, which can be observed in several regions outside southern Spain (SCHEURING, 1970; BESEMS, 1981a); (3) the interregional decrease of *Triadispora* in Karnian assemblages (SCHEURING, 1970; VAN DER EEM, in prep.) and (4) the range charts of palynomorphs from the Alpine Triassic, recently compiled by VISSCHER and BRUGMAN (1981).

The validity of this scheme is regarded to be restricted to (semi-)arid areas only. A compilation of all information so far available from southern Spain (BESEMS, 1981a, b; BESEMS, 1982; BESEMS and SIMON, 1982) allow the recognition of the following general succession of xerophytic palynofloras:

Palynoflora 1

This palynoflora is characterized by the scarse presence of *Camerosporites secatus*, representatives of the "*Partitisporites-Duplicisporites*" complex, *Triadispora plicata* and *Triadispora crassa*. *Kuglerina* cf. *meieri* is a common element.

Palynoflora 2

This palynoflora is diagnosed by the dominance of *Triadispora plicata*, representatives of the "*Partitisporites-Duplicisporites*" complex and *Camerosporites secatus*. *Triadispora crassa* is common, while *Kuglerina* cf. *meieri* is scarse.

Palynoflora 3

This palynoflora is characterized by the scarse presence of *Patinasporites densus* and/or *Enzonalasporites vigens* and *Vallasporites ignacii*.

Dominant are representatives of the "*Partitisporites-Duplicisporites*" complex, *Camerosporites secatus* and *Triadispora plicata*.

Palynoflora 4

This palynoflora is dominated by *Patinasporites densus*, *Vallasporites ignacii* and *Enzonalasporites vigens*. Representatives of the "*Partitisporites-Duplicisporites*" complex and *Camerosporites secatus* frequently occur.

Triadispora plicata is common to scarse.

Palynoflora 5

This palynoflora is characterized by the dominance of *Patinasporites densus* and/or *Vallasporites ignacii* and *Enzonalasporites vigens*. *Camerosporites secatus* and representatives of the "*Partitisporites-Duplicisporites*" complex are scarse and mostly occur in tetradal form. *Triadispora plicata* may be present.

Palynofloras 1 and 2 constitute the *secatus-meieri* subphase; palynofloras 3—5 are characteristic of the *secatus-densus* subphase (Fig. 3).

<table>
<tr><th>PALYNOFLORAS</th><th>SUBPHASES</th><th>PHASE</th><th>AGE</th></tr>
<tr><td>5</td><td rowspan="3">secatus-densus</td><td rowspan="5">Camerosporites secatus</td><td>Tuvalian</td></tr>
<tr><td>4</td><td>Julian</td></tr>
<tr><td>3</td><td>Cordevolian</td></tr>
<tr><td>2</td><td rowspan="2">secatus-meieri</td><td>Langobardian</td></tr>
<tr><td>1</td><td>Fassanian</td></tr>
</table>

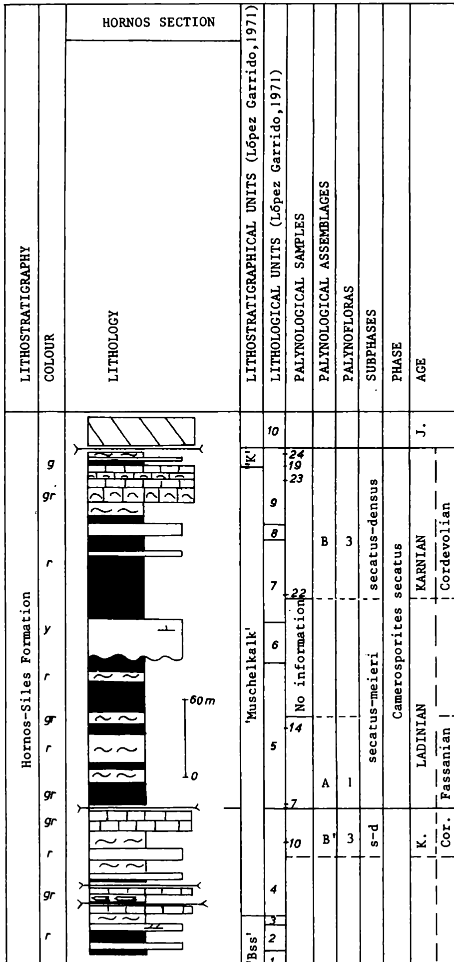
Fig. 3. Scheme of successive xerophytic palynofloras and subphases within the *Camerosporites secatus* phase and their age-interpretation.

Chronostratigraphical interpretation

The *Camerosporites secatus* phase can be recognized in sequences of Middle and Late Triassic age from all over the world (Visscher and Krystyn, 1978). A detailed age-assessment of this phase has been obtained from the Alps, where the standard stages of the Triassic System have now been palynologically characterized. Pending a detailed discussion on the palynology of the Ladinian and Cordevolian type-areas in the Dolomites (van der Eem, in prep.), palynological information from the Alpine Triassic, recently compiled by Visscher and Brugman (1981) is here used as a standard for chronostratigraphical interpretation of the *Camerosporites secatus* phase. From this compilation it appears that the *Camerosporites secatus* phase ranges from the middle part of the Fassanian through the Langobardian, Cordevolian, Julian up to the Tuvalian. According to the Alpine data, the older part of the *Camerosporites secatus* phase, reflected in southern Spain by the *secatus-meieri* subphase, can be regarded as having a strictly Ladinian (Fassanian and Langobardian) age. The younger part of this phase, the *secatus-densus* subphase, can be regarded as Karnian.

In contrast to the *secatus-meieri* subphase, the *secatus-densus* subphase has a strong interregional nature.

Because of the frequently restricted nature of xerophytic assemblages, it often remains difficult to locally recognize qualitative criteria necessary for age determinations on the substage-level. However, in southern Spain, within the *secatus-meieri* and *secatus-densus* subphases, one may suspect a gradual flora development, reflected by the succession of quantitatively determined palynofloras. Assuming that this local development is linked with time, these palynofloras may tentatively be regarded as the flora development within the specific substages of the Ladinian and Karnian. Thus, in southern Spain the Alpine substages nomenclature may be applied on the basis of quantitative information, even when characteristic species found in the Alpine type-areas are absent (Fig. 3).



Palynomorphs	10	7	14	22	23	19	24
Calamospora nathorstii		.					
Verrucosisporites morulae		.					
Plicatisaccus badius		.					
Cycadopites sp.		.					
Todisporites marginales		.	+				
Convolutispora sp.A		.	+				
Striatoabietites aytugii		.	+				
Todisporites cinctus		.	+		+		.
Microreticulatispora sp.		.					.
Convolutispora sp.B		o	+			+	.
Foveosporites visscheri		o	+			+	.
Ovalipollis pseudoalatus		o	+	+	+	+	o
Aratrisporites spp.	+	.	+			+	.
Triadispora plicata		o	+	+		+	v
Triadispora crassa	+	.				+	.
Angustisulcites sp.		.				+	.
alete (proto)bisaccate pollen grains	+	x		+		+	x
Staurosaccites quadrifidus	+	.	+		+		
Kuglerina cf. meieri	+	o				+	
"Duplicisporites granulatus"	+	.	+	+	+		.
"Duplicisporites verrucosus"		.					.
"Duplicisporites scurrilis"		.	+	+			o
Camerosporites secatus	+	.	+	+	+	+	o
"Partitisporites spp."				+			v
Patinasporites densus	+			+			.
cf. Triadispora verrucata							.
Patinasporites sp.							.
"Duplicisporites tenebrosus"	+						.
Thompsonisporites sp.							.
Dictyotidium reticulatum					+		

Table II. Hornos section.
Lithostratigraphy, lithology, position of samples, palynofloras, subphases, phases, age and quantitative/qualitative distribution of palynomorphs.

'Bss' = "Buntsandstein"
'K' = "Keuper"
K. = Karnian
Cor. = Cordevolian
J. = Jurassic
s-d = secatus-densus

Attribution of assemblages from the Hornos-Siles Formation to the scheme of successive palynofloras. Chronostratigraphical interpretation

Siles section

Assemblage A of the Siles section may be attributed to palynoflora 2, on the basis of the dominance of *Triadispora plicata*, representatives of the "*Partitisporites-Duplicisporites*" complex, *Camerosporites secatus*; the presence of *Kuglerina* cf. *meieri* and the absence of *Patinasporites densus*. The assemblage is considered to be of Langobardian age (Table I).

Assemblage B can be attributed to palynoflora 3, on the basis of the scarse presence of *Patinasporites densus* and *Enzonalasporites vigens* (Table I). A Cordevolian age is most plausible.

Hornos section

In a previous paper (Besems, 1981b), the assemblages of the Hornos section have been attributed to the Ladinian and Karnian, without any attempt to come to an age assessment on the substage-level. In view of the new information a more specific age determination may now be given.

Assemblage A of the Hornos section (Table II) is dominated by *Kuglerina* cf. *meieri* and trilete spores. Representatives of the "*Partitisporites-Duplicisporites*" complex, *Camerosporites secatus* and *Triadispora* sp. are relatively scarse. The distribution of xerophytic taxa matches that of palynoflora 1 and a Fassanian age for this assemblage is most plausible.

Assemblage B of the Hornus section (Table II) is dominated by *Triadispora plicata*, *Ovalipollis pseudoalatus*, *Camerosporites secatus* and representatives of the "*Partitisporites-Duplicisporites*" complex.

Patinasporites densus is scarse. In terms of successive palynofloras this assemblage can be designated to palynoflora 3 and a Cordevolian age is most likely.

Assemblage 'B' from below the base of the Hornos reference section sensu Besems (1981b) yielded thirteen palynomorphs. On the basis of the presence of *Patinasporites densus* this "assemblage" is assigned to palynoflora 3 and a Cordevolian age is assumed.

Biostratigraphy by Means of Marine Faunas

In order to provide additional biostratigraphical information from the carbonate ("Muschelkalk") sequence, as well as to check the palynologically founded age determinations, independent studies have been carried out on the macrofauna (O.J. Simon, Amsterdam), on the conodonts (M. van den Boogaard, Leiden; H. Kozur, Budapest) and on the holothurian sclirites (H. Kozur). The results will be briefly discussed.

Marine macrofaunas

In the higher part of the carbonate sequence of the Hornos-Siles Formation macrofaunas frequently occur. Schmidt (1930, 1935) recorded the following lamellibranchs: "*Placunopsis flabellum*, *P. teruelensis*, *Myophoria kiliani*, *Gervilleia joleaudi*, *G. goldfussi*, *Modiola* sp., *Avicula* cf. *caudata*, *Myoconcha jaensis*, *Macrodon* cf. *impressus*?, *Velopecten albertii*, *Pecten* (*Streblopteria*) sp., *P. discites* and *Neritaria* sp.".

In addition, HIRSCH (in LOPEZ GARRIDO, 1971, pp. 82—83) mentioned: "*Myophoria sublaevis*, *Myophoriopsis* cf. *subundata*, *Neoschizodus laevigatus*, *Modiola* cf. *minutaeformis*, *M.* cf. *myoconchaeformis*, *Pleuromya* sp. and *Nautilus* sp.".

Also two ammonoids were reported by this author. Later, these ammonoids have been identified as *Protrachyceras* cf. *hispanicum* and *Gevanites* (*Andalusites*) *hornosianus* (HIRSCH, 1977; p. 515).

FOUCAULT (1971, p. 45—46) recorded analogous faunas from carbonate rocks of the Prebetic Zone between Hornos and Cazorla (Fig. 1).

The age assessment on the basis of these faunas has been interpreted in different ways by the above-mentioned authors. According to SCHMIDT (1935) the macrofauna assemblage indicates the middle Langobardian. However, HIRSCH (in LOPEZ GARRIDO, 1971), after comparison with faunas from Israel, proposed an Early Ladinian age (see also HIRSCH, 1972). On the other hand FOUCAULT (1971) favoured a Cordevolian age.

Simular macrofaunas have been found in the "Muschelkalk" of the Subbetic Zone (e.g., SCHMIDT, 1930, 1935; FALLOT, 1945; GEYER, in HINKELBEIN, 1965; PAQUET, 1969; I. G. M. E., 1972 and BUSNARDO, 1975), as well as in the carbonates of the Internal or Betic Zone (e.g., FALLOT et al., 1945, pp. 28—29; FOUCAULT, 1971, p. 46; KAMPSCHUUR, 1972; KOZUR and SIMON, 1972, p. 146; KOZUR et al., 1974; SIMON and KOZUR, 1977; DELGADO, 1978 and DELGADO et al., in prep.).

In general, these macrofaunas are now considered to be of Cordevolian age. It should be noted, that such assessments are primarily based on the analyses of the accompanying microfaunas (ostracodes, conodonts and holothurian sclerites).

Conodonts

In the Hornos-Siles Formation conodonts have been found in the limestones of the Siles, Trujala and Tranco sections (Fig. 1). All conodont elements could be assigned to the form species *Pseudofurnishius murcianus* VAN DEN BOOGAARD, 1966. The presence of this species was already mentioned by HIRSCH (in LOPEZ GARRIDO, 1971). The conodont elements found in the Siles section (Table I) are listed in Table IV. The different elements of the skeletal apparatus of Pseudofurnishius murcianus conform to those described by RAMOVŠ, 1977 (Plate III, Figs. 1—3).

In the Subbetic Zone, *Pseudofurnishius murcianus* commonly occurs in faunas which can be dated as Cordevolian on the basis of the accompanying holothurian sclerites (H. KOZUR, pers. comm.). In the Betic Zone, *Pseudofurnishius murcianus* is a characteristic species in carbonates belonging to the *Mostlerella blumenthali* (ostracode) Zone, which can be attributed to the Cordevolian (KOZUR et al., 1974; SIMON and KOZUR, 1977). With the exception of a single specimen (sample Si 70-034, see VAN DEN BOOGAARD and SIMON, 1973; KOZUR et al., 1974), *Pseudofurnishius murcianus* has never been recorded in ostracode zones of Langobardian age.

Also outside southern Spain *Pseudofurnishius murcianus* has been recognized from strata classified as Langobardian and/or Cordevolian (e.g., EICHER and MOSHER, 1974; HIRSCH and GERRY, 1974; LUCAS, 1977; FORSTER and WEDDIGE, 1979; KOZUR, 1979; KOZUR, 1980; KOZUR et al., 1980; NICORA, in prep.). In the Alpine area, *Pseudofurnishius murcianus* has been reported from the Cordevolian part of the "Raibler Schichten" (NICORA, in prep.). It is also present in the Cordevolian part of the Vălani nappe of the Alpine-Carpathian area (KOZUR, 1979). Other occurrences in this realm are not well dated (RAMOVŠ, 1977).

The age of *Pseudofurnishius murcianus* is confined to the late Langobardian and the Cordevolian (KOZUR, 1980). In the Langobardian almost exclusively primitive representatives of this species occur. They possess platform rudiments or theeth on both sides of the blade. In the Cordevolian, however, highly evolved representatives of *Pseudofurnishius murcianus* are frequent. In these specimens, platform rudiments or teeth are only present on one side of the blade. Since such forms constitute the conodont faunas of the Hornos-Siles Formation (compare Table III; Plate III, Figs. 1 and 2), a Cordevolian age is most likely for the conodont-bearing carbonate sequences from the Hornos-Siles Formation.

	Sinistral P-element	Dextral P-element	Hi-element	Pr-element
Si 80 - 75	-	-	1	-
Si 80 - 68/69 = Si 77 - 16	8	8	1	-
Si 80 - 67 = Si 77 - 15	3	4	-	1
Si 77 - 14	1	1	-	-
Si 77 - 12	3	-	-	-

Table III. Elements of *Pseudofurnishius murcianus* from the Hornos-Siles Formation.

Holothurian sclerites

Holothurian sclerites have been found in the carbonates of the Siles section (samples Si 77-015 and Si 80-069, see Table I).

Theelia cf. *tubercula* (Plate III, Fig. 5) has been recorded in sample Si 77-015. *Theelia barkeyi* (Plate III, Fig. 4) and *Theelia* cf. *zankli* (Plate III, Fig. 6) have been found in sample Si 80-069.

Theelia tubercula, *Theelia barkeyi*, *Theelia* cf. *barkeyi* and *Theelia zankli* have been reported from the "Muschelkalk" of the Subbetic Zone in the province of Murcia (H. KOZUR, pers. comm.; BESEMS and SIMON, in prep.). In the Betic Zone, combinations of these taxa are known from equivalent Triassic carbonates of various tectonic units (KOZUR and SIMON, 1972; KOZUR et al., 1974; SIMON and KOZUR, 1977; KOZUR et al., 1980 and DELGADO et al., in prep.).

Assemblages with the above-mentioned holothurian sclerites have been interpreted in terms of a Cordevolian age, since some elements have been recorded in the Alpine Triassic (compare KOZUR and SIMON, 1972).

Theelia tubercula is a characteristic species in the *Theelia koeveskalensis* Zone, which has been recognized in Austria and Italy (MOSTLER, 1972). This Zone has been assigned to the Cordevolian (MOSTLER, 1971, pp. 737—738).

Consequently, the holothurian sclerites found in the carbonates of the Siles section are indicative of a Cordevolian age.

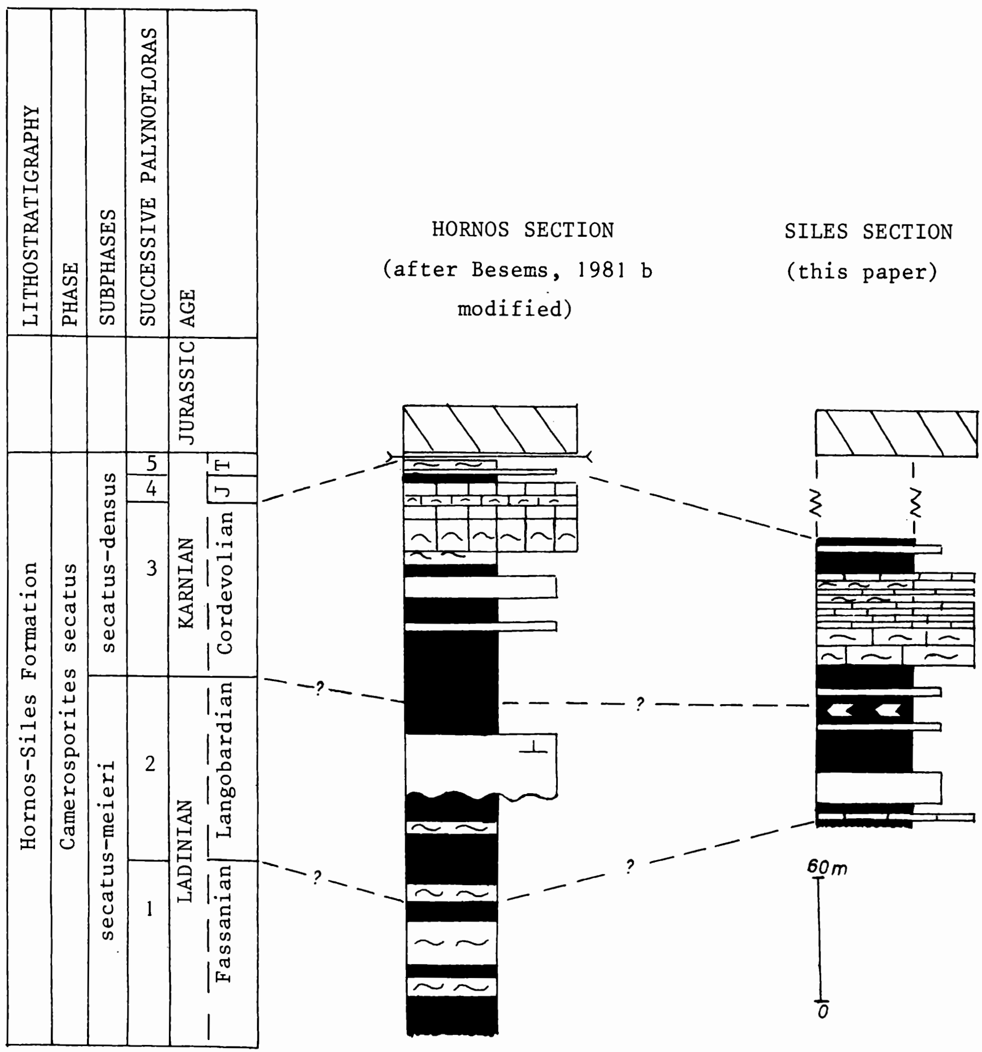


Table IV. Generalized correlation scheme of the Hornos and Siles section
J = Julian
T = Tuvalian

Correlation of the Siles and Hornos Sections

From the fore-going discussion it may be deduced that the palynological information from the Siles and Hornos sections is strongly in favour of the existance of both Ladinian and Karnian assemblages within the "Muschelkalk" facies of the Hornos-Siles Formation sensu LOPEZ GARRIDO (1971). Macro- and especially microfaunas indicate a Cordevolian age of the carbonates of this unit.

Because of (1) the repetition of Cordevolian palynological assemblages in the Hornos section (Table II); (2) the presence of a single carbonate sequence in the "Muschelkalk" of the Hornos-Cazorla region (FOUCAULT, 1971); (3) the tectonic systems in the adjacent areas (see Fig. 1) and (4) fieldobservations (compare BESEMS, 1981 b), it may be reasonable accepted that occurrences of more than one carbonate ("Muschelkalk") intercalation in sections of the Hornos-Siles Formation are due to a tectonic repetition of a single carbonate sequence.

On the basis of all evidence available, the Hornos-Siles Formation may now be diagrammatically represented in the form of a correlation of the Siles and Hornos sections as given in Table IV.

Environmental Interpretation of the Palynological Record

In order to explain differences in the distribution pattern of palynomorphs, the qualitative/quantitative information from the Siles and Hornos sections is discussed in relation to the lithological data. The analysis given hereafter clearly demonstrate the close relation between palynological assemblages and sedimentary environments.

Siles section (Table I)

(1) *Triadispora plicata*, representatives of the "*Partitisporites-Duplicisporites*" complex are predominant in the detritical part of the section (samples 01, 02, 08 and 12). This part of the section may represent an alluvial plain environment.

(2) *Camerosporites secatus* is relatively abundant in the lowermost samples of this red bed sequence (samples 01, 02).
In this part of the sequence no gypsiferous intercalations are present.

(3) *Triadispora crassa* is common in the part of the red bed sequence where such gypsiferous intercalations occur (samples 08 and 12). More arid conditions in the presumed alluvial plain environment may be suspected.

(4) *Ovalipollis pseudoalatus* and *Aratrisporites* spp. occur in abundancy in the carbonate part of the section (samples 24 and 33). This part of the section is considered to represent a shallow marine environment.

(5) The acritarchs *Dictyotidium reticulatum*, *Veryhachium* sp. and *Micrhystridium* sp. are present in the carbonate part of the section (samples 20, 24 and 33). They also occur in the detritical part of the section below (sample 02) and above these carbonates (samples 27 and 30). They are indicative of marine influence.

(6) *Aratrisporites* sp. are present in sample 01 and, together with the presence of *Camerosporites secatus*, may be indicative of relatively humid conditions during this part of the red bed deposition.

Hornos section (Table II)

(1) *Aratrisporites* spp. and trilete spores are relative abundant in sample 07 of

assemblage A. The red bed sequence is considered to represent an alluvial plain environment. Because of this abundancy of these hygrophytic taxa (compare VISSCHER & VAN DER ZWAN, 1981) a relatively humid environment in this part of the section may be deduced.

(2) The acritarch *Dictyotidium reticulatum* is present in the carbonates (sample 23) and indicates the marine nature of this deposit.

(3) *Triadispora plicata*, representatives of the "*Partitisporites-Duplicisporites*" complex, *Camerosporites secatus* and *Ovalipollis pseudoalatus* are dominant in the clastic beds above the carbonates (sample 24). This may be indicative of a relatively arid environment.

From the foregoing, the differences in distribution pattern from Cordevolian assemblages above the carbonate sequence of the Siles and Hornos sections may be interpreted as follows: after the deposition of shallow marine carbonates, the Siles region was still governed by marine conditions (acritarchs in samples 27 and 30, Table I). In the Hornos region, no such marine conditions were present; in this region continental conditions prevailed (sample 24).

Conclusions

(1) In the Hornos-Siles Formation of the Prebetic Zone, a succession of Ladinian and Early Karnian palynological assemblages has been recorded. Furthermore, in the Hornos section (Table II) an assemblage assignable to the Early Karnian (sample 10) has been obtained below a definite Ladinian assemblage (sample 07), indicating a tectonic repetition in this section.

(2) So far, no assemblages older than the Early Ladinian have been observed from this region.

(3) In the sections investigated the contact of the Hornos-Siles Formation and the overlying Jurassic rocks is either tectonical or not exposed. Additional samples from scattered localities of the upper most part of this formation did not provide palynological information. So far, no assemblages younger than the Early Karnian (Cordevolian) have been recorded.

(4) The *Camerosporites secatus* phase, reflecting the interregional Ladinian and Karnian flora development, can be subdivided into two subphases: the *secatus-meieri* subphase represents a regional Ladinian flora development, the *secatus-densus* subphase an interregional Karnian one.

(5) Within these subphases, one may assume a gradual change in the quantitative distribution of xerophytic taxa in successive palynofloras; these palynofloras are tentatively regarded as characteristic for the Ladinian and Karnian substages in southern Spain. The applicability of the scheme of palynofloras is confined to (semi-)arid areas and its interregional validity has to be checked.

(6) Independent of palynological considerations, biostratigraphical analyses of the macro- and especially the microfaunas indicate an Early Karnian age for the carbonate ("Muschelkalk") intercalations of the Hornos-Siles Formation.

(7) Within the detritical beds below and above the carbonate ("Muschelkalk") intercalation, marine influence has locally occurred in Late Ladinian and Early Karnian times.

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Explanation of Plates

Plate I (All Figures approximately 700 ×)

Figs. 1—3	*Camerosporites secatus*
	Figs. 1—2 proximally; Fig. 3 distally
Fig. 4	"*Duplicisporites scurrilis*", proximally
Figs. 5—7	*Kuglerina* cf. *meieri*
	Fig. 6 proximally; Fig. 7 distally
Fig. 8, 10	*Triadispora plicata*
	Fig. 8 proximal sexine structure; Fig. 10 trilete mark
Fig. 9	*Triadispora crassa*, proximally
Fig. 11	*Ovalipollis pseudoalatus*

Plate II (All Figures approximately 700 ×, except Fig. 11 approx. 350 ×)

Figs. 1—2	*Patinasporites densus*
	Fig. 1 proximally; Fig. 2 distally
Fig. 3	*Enzonalasporites vigens*
Fig. 4—5	"*Duplicisporites tenebrosus*"
	Fig. 4 proximally; Fig. 5 distally
Fig. 6	"*Duplicisporites granulatus*"
Fig. 7	"*Duplicisporites verrucosus*"
Fig. 8	*Aratrisporites* sp.
Fig. 9	"*Partitisporites* sp."
Fig. 10	"*Duplicisporites scurrilis*", laterally
Fig. 11	*Staurosaccites quadrifidus*
Fig. 12	*Dictyotidium reticulatum* SCHULZ, 1965
Fig. 13	*Veryhachium* sp.

Plate III (All Figures approximately 140 ×, except Fig. 4 approx. 350 ×)

Fig. 1	*Pseudofurnishius murcianus*, sinistral P-element
Fig. 2	*Pseudofurnishius murcianus*, dextral P-element
Fig. 3	*Pseudofurnishius murcianus*, dextral P-element
Fig. 4	*Theelia barkeyi*
Fig. 5	*Theelia tubercula*
Fig. 6	*Theelia zankli*

PLATE I

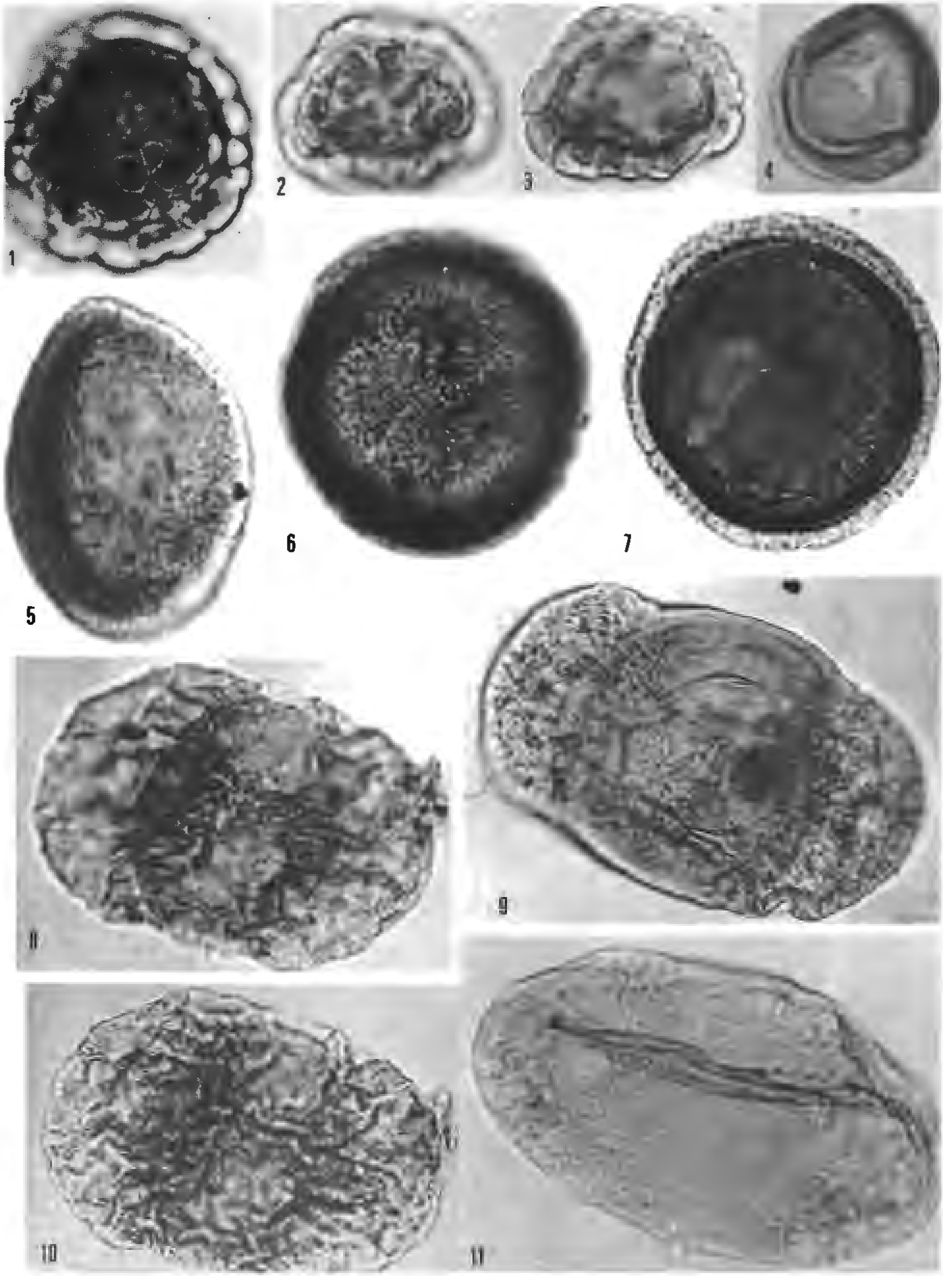

PLATE 11

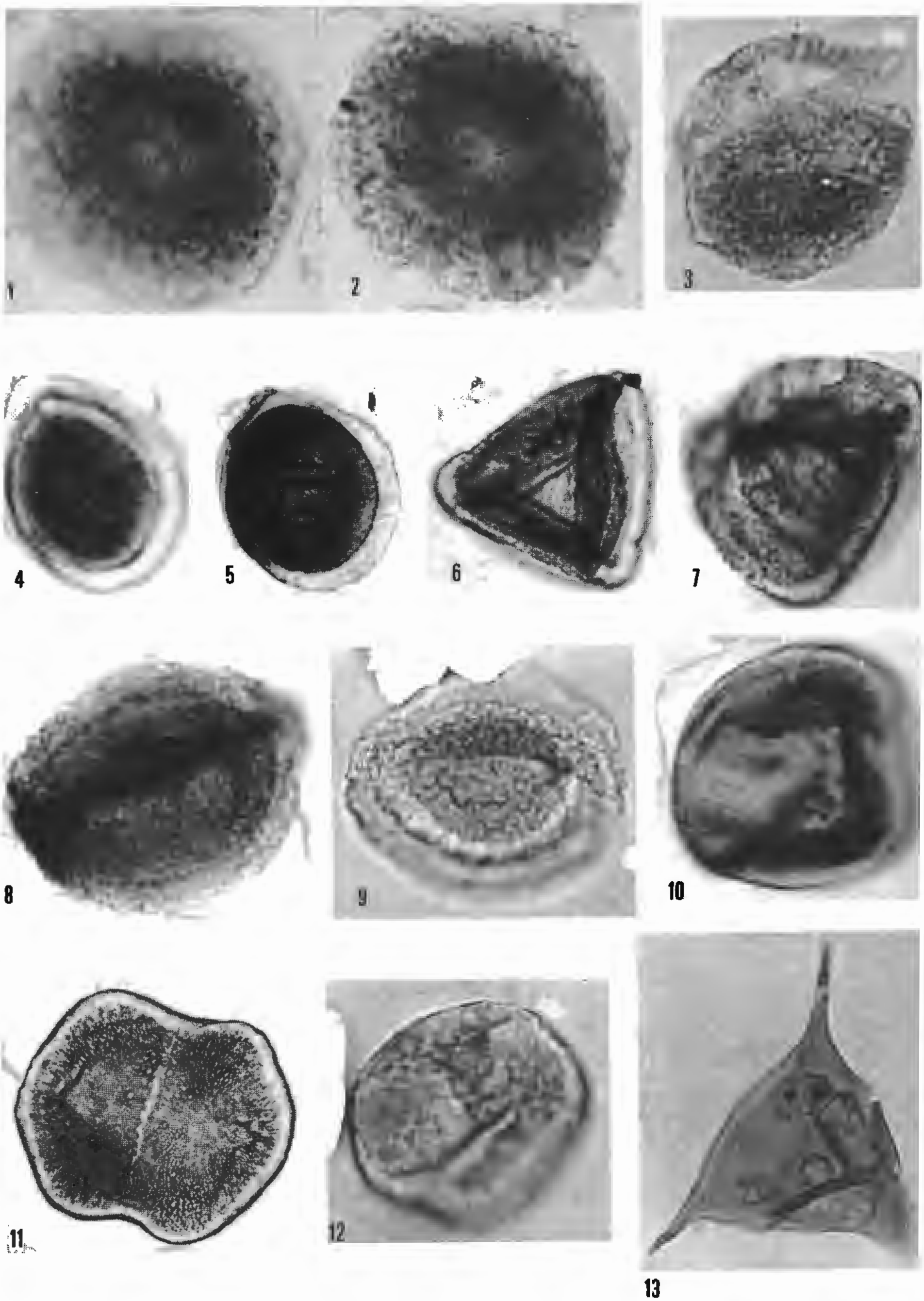

PLATE III