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Autor(en): **Mettraux, Monique / Mohr, Barbara**

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Stratigraphy of the Triassic/Jurassic boundary in the "Préalpes Médianes" nappe: Facies and palynology

By Monique Mettraux[1]) and Barbara Mohr[2])

ABSTRACT

Late Triassic to early Jurassic sediments, now outcropping in the alpine front ranges of western Switzerland, were deposited on the northern flank of the Briançonnais paleogeographic realm. Primary sedimentary structures show storm deposits with different associations. The first association is composed of alternating layers of marls and bioclastic limestones; the second is dominated by arenites or siltites and marls. Sporomorphs can be assigned to zones ("phases") 4 and 5 of Schuurman, and show diachronous progradation of the siliciclastic facies of over 50 km from North to South between latest Triassic (late Rhaetian) and early Jurassic (early Hettangian). The sporomorph/dinocyst ratios of the samples fluctuate widely, reflecting occasional terrestrial input by storm events and short transgressional phases. This cyclic pattern is superimposed by a general trend toward more marine conditions indicated by higher percentages of dinocysts and acritarchs, especially evident in the early Jurassic.

RÉSUMÉ

Les sédiments étudiés (du Trias supérieur au Lias inférieur) appartiennent à la Nappe des Préalpes Médianes (Suisse romande). Les dépôts de tempêtes y sont caractéristiques et sont représentés par deux associations de faciès. La première association est composée principalement d'une alternance de marnes et calcaires bioclastiques, alors que les grès et marnes dominent la seconde association. Ces faciès ont été datés grâce aux méthodes palynologiques. Les résultats permettent de déceler une diachronie marquée des faciès siliciclastiques, précédemment datés du Jurassique inférieur (Hettangien). Ces niveaux détritiques (alternance de grès et de marnes) progradent sur 50 kilomètres dans le temps du Rhétien supérieur à l'Hettangien inférieur. Les sporomorphes peuvent être assignées aux zones («phases») 4 et 5 de Schuurman, qui correspondent à l'intervalle du Trias supérieur au Jurassique inférieur (Rhétien supérieur à l'Hettangien basal). Les proportions en sporomorphes/dinocystes des échantillons varient considérablement, et reflètent également un mélange de matériel terrestre et marin provoqué par des tempêtes occasionnelles. Ce caractère cyclique est superposé à une tendance générale de conditions marines comme l'indiquent les pourcentages élevés de dinoflagellés et acritarches, spécialement dans le Jurassique inférieur.

ZUSAMMENFASSUNG

Obertriassische bis unterjurassische Sedimente, die heute in der Klippen-Decke der Westschweiz (Préalpes Médianes) aufgeschlossen sind, wurden am Nordrand des Briançonnais abgelagert. Aufgrund primärer Sedimentstrukturen können Sturmablagerungen mit unterschiedlichen Assoziationen nachgewiesen werden. Die erste Assoziation ist aus alternierenden Lagen von Mergeln und bioklastischen Kalken zusammengesetzt; die zweite wird von Areniten oder Siltiten und Mergeln dominiert. Die Sporomorphen in diesen Schichten können den Zonen («phases») 4 und 5 von Schuurman zugeordnet werden und zeigen eine diachrone Progradation der siliziklastischen Fa-

[1]) Institut de Géologie, Pérolles, CH–1700 Fribourg; present address: Université Louis Pasteur de Strasbourg, Laboratoire de géodynamique sédimentaire, 1, rue Blessig, F–67084 Strasbourg Cedex (France).

[2]) Eidg. Techn. Hochschule, Institut für Geologie, Sonneggstr. 5, CH–8092 Zürich.

zies im Bereich von 50 Kilometern von Nord nach Süd zwischen spätester Trias und frühestem Jura (spätes Rhaet bis frühes Hettangium). Das Verhältnis von Sporomorphen/Dinoflagellaten-Zysten variiert stark und reflektiert die gelegentlich verstärkte Zufuhr von terrestrischem Material durch Sturmereignisse und kurze transgressive Phasen. Diese zyklischen Änderungen werden besonders im frühen Jura von einem zunehmenden marinen Einfluss überlagert, der durch generell höhere Anteile von Dinozysten/Acritarchen angezeigt wird.

1. Introduction

Tethyan history, as far as the segment preserved in the western Alps is concerned, began with rifting and associated alkaline volkanism in the Permian (TRÜMPY 1982). The subtle interplay of subsidence and sealevel change led to marine transgression in the Triassic and sea floor spreading produced ocean crust in the mid-Jurassic (FONTIGNIE et al. 1980). These events are generally considered to be related to the opening of the central Atlantic ocean. In late Triassic and early Jurassic times, extensional half graben basins of the North-Tethyan margin accumulated sediments within a variety of depositional environments at very shallow to intermediate depth. They are storm deposits (with different associated facies) of Rhaetian to Toarcian age. Upper Triassic hurricanes and intense winter storms (MARSAGLIA & KLEIN 1983) reworked mixed carbonate/clastic sediments across a shallow platform with emergent sand- and mudflats. The storm sequences are both subtidal and supratidal (METTRAUX 1987). Siliciclastics became progressively more important at the Triassic/Jurassic boundary. These latter storm deposits were only subtidal, but fairly shallow, and are graded layers with ripple marks at the top. They are similar to the sequences described by AIGNER (1985) in the Muschelkalk of Germany. Provenance of the well sorted quartz grains was studied by cathodoluminescence (METTRAUX 1989). The monocrystaline grains have a characteristic brown luminescence which indicates metamorphic source rocks (MATTER & RAMSEYER 1985). These clastics were eroded from the Variscan basement and recycled from Lower Triassic continental sediments. After winnowing by wind on the Northern coast of the Tethys, they were finally distributed across nearshore platforms by major storms. Here the focus is on dating of these storm deposits and their different facies.

2. Geographical and geological setting

The Médiane Nappe of the Swiss Préalpes is a decollement nappe of the Pennine belt of Western Switzerland, located between Lake Leman and Lake of Thun. Two sections have been studied: Plan Falcon (Geological Atlas of Switzerland, 1:25000, No. 17. Topographic maps of Switzerland, map. No. 1264, Montreux, 1:25000, coordinates: 565.275/135.325, 1700 m) and Agreblierai (Geological Atlas of Switzerland, 1:25000, No. 99; topographic map No. 1244. Châtel-St-Denis, coordinates: 563.220/149.300, 1310 m), see Fig. 1.

3. Storm associated facies and sedimentology

Two storm facies types have been identified in each of the two sections (Fig. 2). The first storm associated facies is an alternating sequence of marls and upwards thickening bioclastic limestones (Fig. 2, lithologic unit A). These have an erosive base followed by

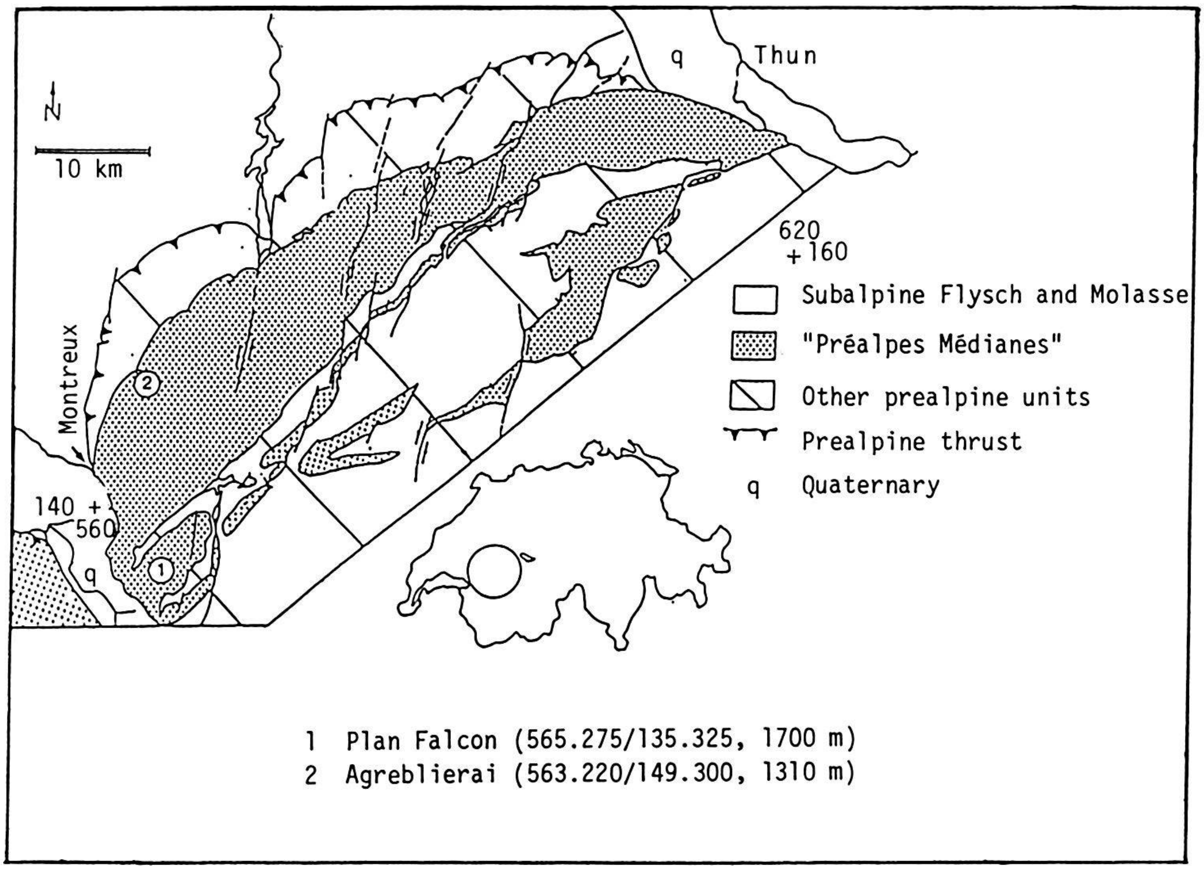


Fig. 1. Schematic map of the Préalpes Médianes with main geological units. Inset shows location of study area within Switzerland (circle).

layers with parallel lamination and smallscale low angle cross lamination. Intercalated dolomites frequently show mud cracks. The fauna is composed of relatively few taxa of benthic foraminifera, corals, bivalves, brachiopods, gastropods, ostracods, echinoderms and vertebrates. Their remains are often broken and accumulated in different facies types.

The second storm associated facies is composed of alternating marls and arenites or siltites, with erosive bases and occasional gutter casts (Fig. 2, lithologic unit B). Internal laminations also show graded layers and wave ripples at the top. The dominant constituents are monocrystaline quartz grains of subangular to subrounded shape, 0.016 to 0.250 mm in diameter. Minor components are mica, feldspar and glauconites. Ichnofossils are represented by *Thalassinoides* and *Rhizocorallium.* The fauna is mainly composed of oysters and other bivalve groups. The lithologic unit C (Fig. 2, Plan Falcon) is composed of bioclastic limestones, mainly wackestones with a micritic matrix and 40 to 50% shell fragments and dolomitic limestones with stromatolithic laminations and mud cracks. Unit D (Fig. 2, Agreblierai) mainly consists of oolithic limestones with a high amount of lamellibranchiate shells (Mettraux 1989).

Figure 3 shows a reconstruction of the northern Tethyan continental margin at late Triassic and earliest Jurassic times. From the NW to the SE these depositional environments changed from supra- to intertidal (A, B, C, D, I), mostly located in the inter- to subtidal zone (D, E, F, G). From the area of abrasion, during storm events terrestrial

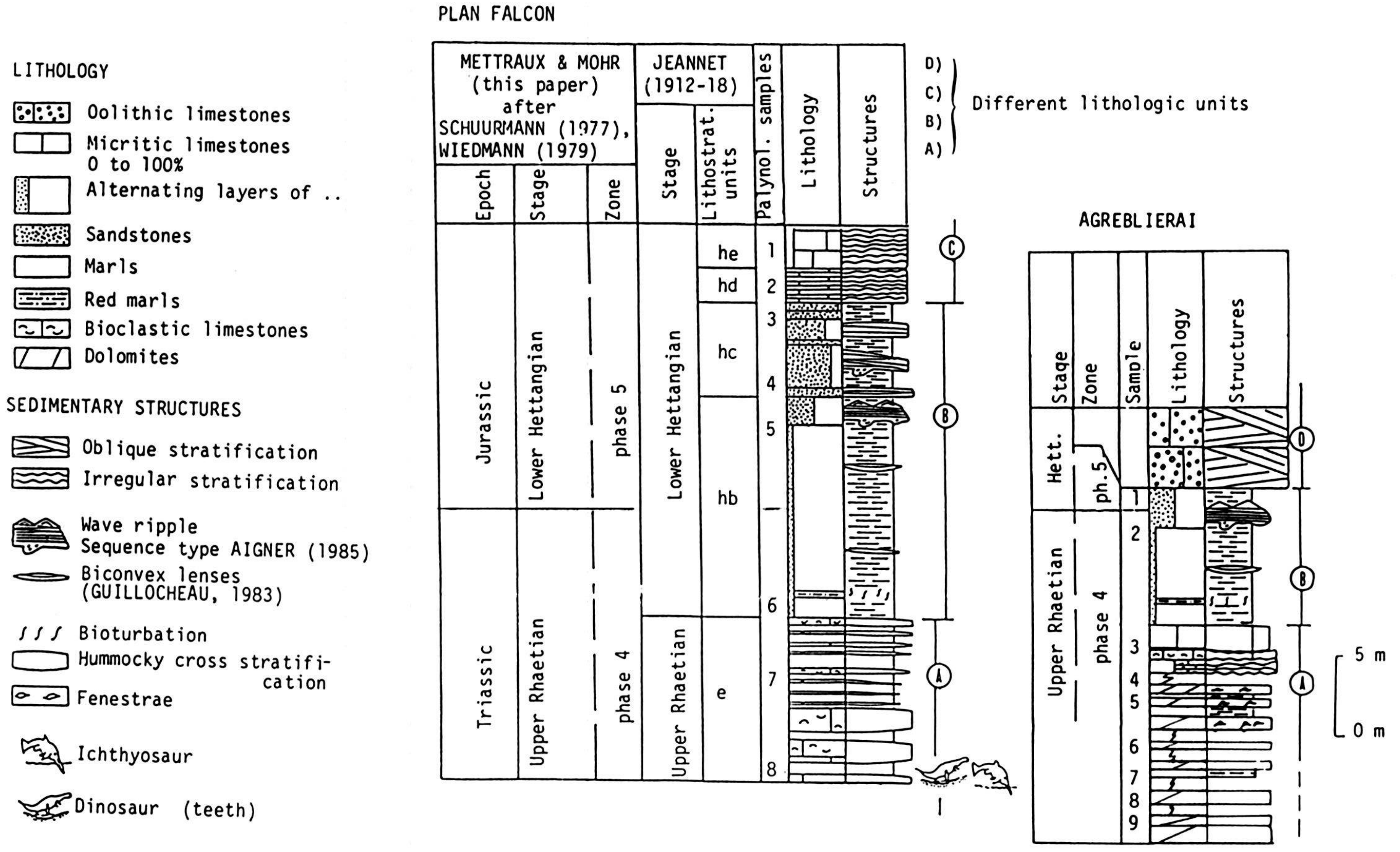


Fig. 2. Summary of Plan Falcon and Agreblierai stratigraphic sections. Ages are based on sporomorph stratigraphy as discussed in text. Lithologic units A to D represent different storm associated facies, as discussed in the text.

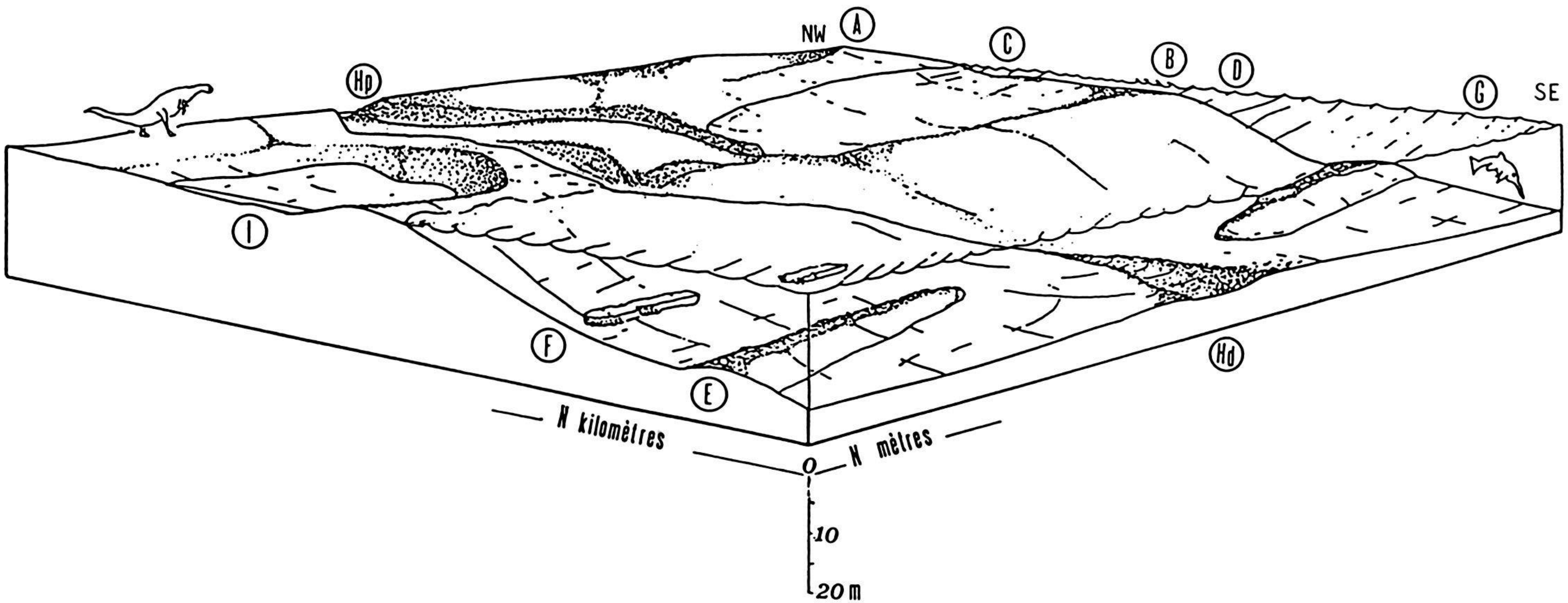


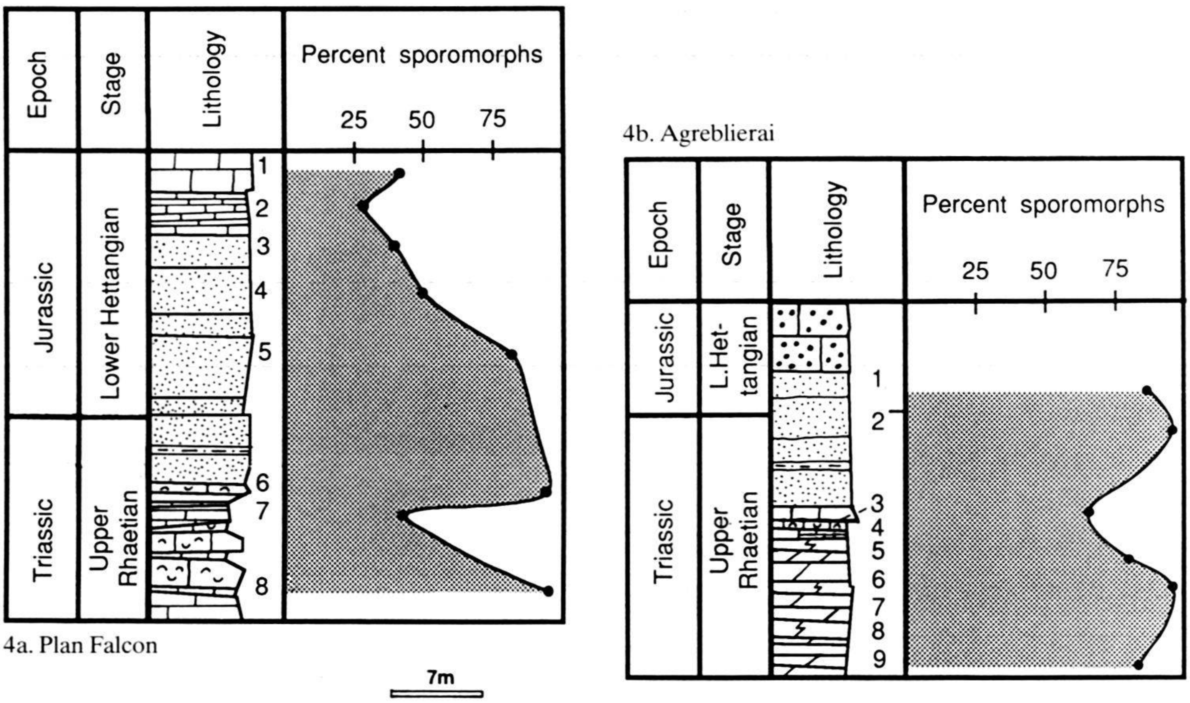
Fig. 3. Reconstruction of latest Triassic to earliest Jurassic landscape in the Briançonnais realm, northern part of the Tethyan continental margin. From NW to SE environments changed from inter- to supratidal (A, B, C, D, I) until inter- to subtidal (D, E, F, G). In the emergent part channels (Hp) drained storm tidal flats, flowing SE (Hd). Patch reefs were located in the subtidal (F) part and bioclastic banks with low relief (E) were mobilised during storm events (Mettraux 1989).

material was carried through channels (Hp) to the tidal flats (Hd) in the SE. In the subtidal zone (F), small coral reefs (patch reefs) were located and bioclastic banks with low relief (E) were mobilised during storm events. The letters A through I of Figure 3 refer also to the lithologic units shown in Figure 2 (A through D) and to additional facies (E through I), found in different sections of the Préalpes Médianes area and described by Mettraux (1987 and 1989) in detail.

JEANNET (1913) used paleontological criteria, mainly based on bivalves, and lithological differences, to subdivide the sections (stages e to he, Fig. 2) and to define the Triassic/Jurassic boundary. But he recognised the difficulties of dating these sequences. Seventy years later, new micropaleontological criteria provide greater precision in dating these sedimentary rocks. Palynology has proved to be particularly useful, as discussed below.

4. Material and methods

About thirty samples from the Préalpes médianes region were processed and examined for palynomorphs. Eight samples from the Plan Falcon section and nine from the Agreblierai section were analyzed in detail (Figs. 2 and 4). Samples were processed using standard preparation techniques (VAN ERVE 1977) and were sieved with a 15 µm sieve; in general, about six smear slides were made from each sample, in addition to some single grain slides. From every sample about 150 sporomorphs, dinocysts, acritarchs and tapeta of benthic foraminifera were counted to evaluate the terrestrial/marine ratios (Fig. 4). The slides are deposited under the registration numbers 100–128 IZ at the Geological Institute of the ETH Zürich.



Figs. 4a and b. Percent sporomorphs in the total palynomorph assemblage in samples from the (a) Plan Falcon section and (b) Agreblierai sections. Sample numbers are shown adjacent to lithology columns. Counting methods described in text. Lithologic symbols defined in Fig. 2.

5. The Plan Falcon section

a. Palynomorphs of the Plan Falcon section

About 25 taxa of palynomorphs have been recognized, comprizing 9 taxa of spores, 9 taxa of pollen grains and 7 microplankton taxa.

Taxonomy of the sporomorphs is mainly based on publications by SCHULZ (1967), LUND (1977), SCHUURMAN (1977), ACHILLES (1981) and BRENNER (1986). For specific identification of the dinoflagellate cysts the Index of LENTIN & WILLIAMS (1985) was consulted. Papers cited in this Index are not included in our reference list.

Spores

Anapiculatisporites spiniger (LESCHIK 1955) REINHARDT 1962
Concavisporites sp.
Deltoidospora sp.
Heliosporites altmarkensis SCHULZ 1962
Iraquispora laevigata (MÄDLER 1964) LUND 1977
Leptolepidites major COUPER 1958
Trachysporites sp.
Triancoraesporites ancorae (REINHARDT 1962) SCHULZ 1967
Zebrasporites laevigatus (SCHULZ 1962) SCHULZ 1967

Pollen

Alisporites radialis (LESCHIK 1955) LUND 1977
Alisporites robustus NILSSON 1958
Corollina sp.
Lunatisporites rhaeticus (SCHULZ 1967) WARRINGTON 1974
Ovalipollis pseudoalatus (THIERGART 1949) SCHUURMAN 1976
Pinuspollenites sp.
Rhaetipollis germanicus SCHULZ 1967
Ricciisporites tuberculatus LUNDBLAD 1954
Vitreisporites pallidus (REISSINGER 1950) NILSSON 1958

Dinoflagellate cysts and acritarchs

Dapcodinium priscum EVITT 1961
Rhaetogonyaulax uncinata FISHER & VAN HELDEN 1979
Dinoflag. indet.
Baltisphaeridium sp.

b. Occurrence of palynomorphs in the Plan Falcon section

All samples contain acritarchs and occasionally the tapeta of foraminifera (e.g. Table 1). Samples 6b–8 from the base of the section include dinocysts. In sample 7 cysts are more abundant than sporomorphs.

PLAN FALCON	Upper Triassic				Lower Jurassic				
	Upper Rhaetian				Lower Hettangian				
Sample number / Species	8	7	6b	6a	5	4	3	2	1
Alisporites sp. 1		x		x	x		x		
Alisporites sp. 2				x	x				
Deltoidospora				x	x	x	x	x	x
Ovalipollis		x	x	x	(x)				
Corollina	x	x	x	x	x	x	x		
Trachysporites		x	x	x	x		x		
Pinuspollenites		x	x	x	x		x		x
Riccisporites		x	x	x					
Rhaetipollis	x	x							
Lunatisporites				x					
Anapiculatisporites					x	x			
Heliosporites					x	x	x	x	
Concavisporites				x					
Zebrasporites				x					
Triancoraesporites				x					
Iraquispora				x					
Leptolepidites				x					
Dapcodinium				x					
Rhaetogonyaulax		x		x					
Baltisphaeridium	x	x	x	x	x	x	x	x	x

Table 1: Palynomorph ranges in the Plan Falcon section.

Samples 1–5 from the top of the section contain the (fern)-spores *Deltoidospora, Trachysporites, Anapiculatisporites spiniger,* and *Heliosporites reissingeri.* Species of *Alisporites* – and *Pinuspollenites* and *Corollina* document the presence of conifers in this flora. Sporomorphs that are considered to be typical for a Rhaetian assemblage, such as *Rhaetipollis* and *Ovalipollis,* are missing. *Ovalipollis* was observed very rarely in sample 5 and was also extremely poorly preserved. Because of this reason and because of the lack of other "Rhaetian elements", seen in the lower part of the section, these grains are interpreted as reworked.

In samples 6a to 8 *Ricciisporites, Triancoraesporites, Lunatisporites rhaeticus* and *Zebrasporites* occur. In sample 6b to 8, *Ovalipollis* is abundant. The genus *Rhaetipollis* forms a minor component in samples 7 to 8 (1–2%) of the assemblage.

c. *Palynofacies*

A palynofacies analysis (Combaz 1980) of the Plan Falcon section (samples No. 1–8) was carried out. These samples contain about 10% to 20% of amorphous material (matière organique grumuleuse), partly of probable algal (marine) origin; the structured fraction contains a high amount of shredded and degraded sporomorphs (10–20%) and high percentages of wood and cuticles (30–50%). Fusite comprises about 20% of the total organic matter. Thus the palynofacies belongs to the exinitic facies sensu Habib's (1978) classification scheme. Identifiable sporomorphs are generally rare. The amount of wood and fusite particles is somewhat higher in sample 6 than in the other samples, and the organic debris and sporomorphs are not degraded in this sample.

The ratios between sporomorphs (spores and pollen grains) and marine organisms (dinocysts, acritarchs and tapeta of foraminifera) vary widely (see Fig. 3a). The highest amount of terrestrial input was found in samples 6 (94%) and 8 (95%), whereas the highest percentages of marine organisms is seen in the uppermost part of the section (sample 2, 73%). The strongly varying terrestrial/marine ratio curve (Fig. 4a) reflects occasional storm events with high amounts of terrestrial input, which is overimposed by a general trend towards more marine conditions, especially in the lower Jurassic.

The Thermal Alteration Index (TAI) is determined as being 2.6–2.8 (Traverse 1988) in the transition zone from immature to mature. These sediments were heated to about 400–430 °C. Some of the wood – and cuticle-remains still show well preserved structures, although some parts are vitrinised. This vitrinised material is interpreted to be partly recycled from older strata.

Rock-Eval analyses were carried out on ten samples from the lower part of the section (Mettraux 1989). According to the literature (Espitalie et al. 1985–86), kerogens are mainly type III in origin, with Total Organic Matter (TOC) between 0.17 to 0.62% and a maximum temperature up to 455° C. A relative low content of residual organic matter may be explained by diagenetic processes in the sulphate reduction zone where organic matter has been consumed to form pyrite. This mineral is also responsible for the black colour of the marls.

d. *Age and environment*

When compared to the zonation scheme of Schuurman (1977) for the Rhaetian/Liassic transition, samples 1–5 correlate with his Hettangien zone ("phase 5"), and samples 6–8 correlate with his upper Rhaetian zone ("phase 4"), (Schuurman, 1979).

According to Brenner (1986) the "phase 4" zone can also be correlated with the *Ricciisporites/Polypodiisporites* zone proposed by Lund (1977).

The depositional environment definitely can be characterized as marine, as shown by findings of bivalves and a disarticulated ichthyosaur skeleton (FURRER, in prep.), but rather nearshore (dinoflagellate cysts are only common in a few samples). Because of the preponderance of land derived particles in most samples, and also because of the poor preservation of the sporomorphs and the kerogen, deposition was most likely in a high energy nearshore environment. A short transgression probably occurred during the deposition of sample 7, as indicated by the high number of dinoflagellate cysts.

6. The Agreblierai section

a. Palynomorphs

The diversity of identifiable spore- and pollen taxa was found to be very high in comparison to the Plan Falcon section, especially within sample 2. In all, 33 spore taxa, 19 pollen taxa and 5 microplankton forms were identified. Identification was carried out as described above.

Spores

Acanthotriletes varius NILSSON 1958
Anapiculatisporites spiniger (LESCHIK 1956) REINHARDT 1961
Annulispora folliculosa (ROGALSKA 1954) DE JERSEY 1959
Apiculatisporites plicatus VISSCHER 1967
Asseretospora gyrata (PLAYFORD & DETTMANN 1965) SCHUURMAN 1977
Calamospora sp.
Camarozonosporites rudis (LESCHIK 1956) KLAUS 1960
Carnisporites granulatus SCHULZ 1967
Cirratriradites cf. saturni (IBRAHIM 1932) WILSON & BENTALL 1944
Concavisporites sp.
Convolutispora microfoveolata SCHULZ 1967
C. microrugulata SCHULZ 1967
C. cf. klukiforma (NILSSON 1958) SCHULZ 1967
Deltoidospora mesozoica (THIERGART 1949) SCHUURMAN 1977
Deltoidospora sp.
Densosporites fissus (REINHARDT 1964) SCHULZ 1967
Heliosporites altmarkensis SCHULZ 1962
Iraquispora laevigata (MÄDLER 1964) LUND 1977
Leptolepidites sp.
Limbosporites lundbladii NILSSON 1958
Lycopodiacidites infragranulatus MÄDLER 1964
Lycopodiumsporites austroclavatidites (COOKSON 1953) POTONIÉ 1956
Polycingulatisporites circulus SIMONCSICS & KEDVES 1961
Polypodiisporites polymicroferatus (ORLOWSKA-ZWOLINSKA 1966) LUND 1977
Retusotriletes hercynicus (MÄDLER 1964) SCHUURMAN 1977
Rogalskaisporites cicatricosus (ROGALSKA 1954) DANZÉ-CORSIN et LAVAINE 1963
Semiretisporis gothae REINHARDT 1962
Stereisporites sp.

Thuringiasporites laevigatus SCHULZ 1962
Trachysporites sp.
Triancoraesporites ancorae (REINHARDT 1961) SCHULZ 1967
T. reticulatus SCHULZ 1962
Zebrasporites interscriptus (THIERGART 1949) KLAUS 1960

Pollen

Alisporites radialis (LESCHIK 1955) LUND 1977
A. robustus NILSSON 1958
A. thomasii (COUPER 1958) POCOCK 1962
A. sp.
Corollina sp.
Cycadopites andrewsii CORNET & TRAVERSE 1975
C. deterius POCOCK 1970
C. follicularis WILSON & WEBSTER 1946
Cyadopites sp. 1
C. sp. 2
Lunatisporites rhaeticus (SCHULZ 1967) WARRINGTON 1974
Ovalipollis pseudoalatus (THIERGART 1949) SCHUURMAN 1976
Perinopollenites sp.
Pinuspollenites minimus (COUPER 1958) KEMP 1960
Quadraeculina anellaeformis MALJAVKINA 1949
Ricciisporites tuberculatus LUNDBLAD 1954
Rhaetipollis germanicus SCHULZ 1967
Vitreisporites pallidus (REISSINGER 1950) NILSSON 1958
V. bjuvensis NILSSON 1958

Dinoflagellate cysts and acritarchs

Rhaetogonyaulax rhaetica (SARJEANT 1963) LOEBLICH & LOEBLICH 1968
Rhaetogonyaulax uncinata FISCHER & VAN HELDEN 1979
Baltisphaeridium sp.
Micrhystridium sp.
Botryococcus

c. Taxonomic notes on selected pollen species

Genus *Cycadopites* WODEHOUSE 1933 ex WILSON & WEBSTER 1946

In the descriptive literature on Triassic and Jurassic sporomorphs there are obvious discrepancies in the nomenclature of monosulcate cycadophytic pollen. In the material studied, several species of this pollen group were found. These are briefly discussed in the following section. We agree with the opinion of CORNET & TRAVERSE (1975) about the definition of the genus *Cycadopites.* According to these authors a differentiation of the genera on the basis of the sulcus is very vague, because of the secondary alterations of this area (folding by compression, orientation of the pollen on the slide). Therefore all smooth and reticulate monosulcate forms are placed here into the genus *"Cycadopites"*.

Cycadopites follicularis WILSON & WEBSTER 1946
Pl. 2, Fig. 5

The specimens in this material are between 50 and 60 μm long and are thus larger than the specimens (39–42 μm) described by WILSON & WEBSTER (1946). However, because all the other diagnostic features agree very well with those of *C. follicularis* (length approximately twice the width, furrow extending the total length of grain, exine smooth to scabrate), our specimens are assigned to this species.

Cycadopites deterius (BALME 1957) POCOCK 1970
Pl. 2, Fig. 6

Thin walled, one-layered monosulcate pollen, smaller than *C. follicularis* (38 μm) oval shaped.

Cycadopites andrewsii CORNET & TRAVERSE 1975
Pl. 2, Fig. 7

As in the original description of the species by CORNET & TRAVERSE (1975), the single specimen found here has a double layered exine and an external pseudoreticulum.

Cycadopites sp. 1
Pl. 2, Fig. 8

The single pollen found in our samples generally resembles *C. andrewsii* CORNET & TRAVERSE 1975. The grain is rather large (45 μm long and 30 μm wide), but is still in the size range of *C. andrewsii*. Differences, however, inlcude the thickness of the wall (1.0 μm for the ektexine) and the coarseness of the pseudoreticulum. The lumina can reach a diameter of 0.7 μm. This pollen is also similar to *C. stonei*, recently described by HELBY (1987) from the late Triassic of Australia, but differs in being considerably smaller.

d. Occurrence of the palynomorphs in the Agreblierai section

Sample 1 contains a sporomorph assemblage which can be correlated with the samples 1–5 of the Plan Falcon section (see Fig. 1 and Table 2). The samples 2, 3, 6 and 9 show the typical "*Rhaetipollis germanicus* assemblage" (SCHUURMAN 1979) with the genera *Ovalipollis*, *Rhaetipollis* and *Ricciisporites*. In particular, the assemblage found in sample 2 which includes *Asseretospora gyrata*, *Iraquispora laevigata* and *Triancoraesporites triancorae* is indicative for the late Rhaetian, as discussed below.

e. Palynofacies

Samples 1 and 2 of the Agreblierai section contain between 80% to 90% of land derived sporomorphs (see Fig. 4b). Sample 3 contains a fair amount of identifiable

AGREBLIERAI	Upper Triassic								Lower Jurass.
	Upper Rhaetian								Hett.
Sample number / Species	9	8	7	6	5	4	3	2	1
Alisporites sp. 1	x								x
Alisporites sp. 2									
Deltoidospora							x	x	x
Ovalipollis	x				x		x	x	
Corollina	x			x	x		x		x
Trachysporites	x						x		x
Pinuspollenites	x						x	x	
Ricciisporites				x	x		x	x	
Rhaetipollis							x	x	
Lunatisporites							x	x	
Lycopodiacidites							x	x	
Stereisporites								x	
Concavisporites								x	
Cycadopites								x	
Zebrasporites								x	
Triancoraesporites								x	
Iraquispora								x	
Asseretospora								x	
Anapiculatisporis								x	x
Polypodiisporites								x	
Baculatisporites									x
other								x	
Rhaetogonyaulax								x	
other								x	
Baltisphaeridium	x							x	

Table 2: Palynomorph ranges in the Agreblierai section.

marine material (dinoflagellate cysts and acritarchs, about 40%), but mainly land derived kerogen. Especially in sample 2 the land derived organic matter consists partly of undegraded sporomorphs and of well preserved wood and cuticle particles.

Samples 5 and 6 are completely different in their composition of the organic debris. 90% of these debris consist of small, extremely shredded dark woody pieces (less than 40 μm in diameter), which show no internal structures. The composition of the organic matter is comparable with the "restricted marine palynofacies" of BATTEN (1982).

Samples 7 to 9 of the Agreblierai section consist almost exclusively of sporomorphs, sample 9 mainly of bisaccate pollen grains (5–8%) or protosaccate forms (*Ovalipollis*, ca. 90%) which are very degraded. The kerogen type II (herbaceous material) is dominant by far. But there are also well preserved, relatively large pieces of wood (ca. 20% of the total kerogen).

In summary, samples 1, 5, 6 and 9 were probably deposited in a nearshore region in turbulent water. In contrast, samples 2 and 3 were fossilized in a low energy environment. Sample 3 is thought to represent a lagoonal environment (BATTEN 1982), which is consistent with the observed sedimentary structures, such as mud cracks (lithological Unit A, see Fig. 2). Samples 2, 7 and 9 are much more terrestrially influenced with direct connections to fresh water, evidenced also by the occurrence of the fresh water alga *Botryococcus* in sample 2.

A tremendous increase of marine organisms at the level of sample 3 within the Agreblierai section can be correlated with the negative spike of terrestrial input at the level of sample 7 within the Plan Falcon section (see Fig. 4a and b). This pattern probably can be explained by a short transgressional event.

f. Age and Environment

According to the sporomorphs in the Agreblierai section, only sample 1 can be attributed to the early Liassic. All the other samples can be assigned to the latest Triassic, because of the occurrence of *Ovalipollis*, which exceeds 80% in sample 9. In other samples *Ricciisporites* is also relatively common (5–10%). According to SCHUURMAN (1977, Table 1), *Asseretospora gyrata* seems to be a good marker, as it does not appear before the upper Rhaetian. Another good marker is *Iraquispora* which does not occur before the lithological member of the "Preplanorbis Beds" (KARLE 1984). In sharp contrast to the zonational scheme by SCHUURMAN (1979) and LUND (1977), but in accordance with the stratigraphic propositions of WIEDMANN et al. (1979), KARLE places these beds in the Liassic (see BRENNER 1986). According to VISSCHER & BRUGMAN (1981), several species, including *Triancoraesporites triancorae* range from the middle Rhaetian to the upper Rhaetian, and thus do not cross the Rhaetian/Liassic boundary.

The diversity of sporomorphs is by far higher in the Agreblierai section than in the Plan Falcon section. This pattern fits with the more northerly location of the Agreblierai section, which is closer to the paleoshore.

Like in the more southerly Plan Falcon section, in the Agreblierai section the Rhaetic/Liassic boundary is placed in lithological Unit B (see Fig. 2). In the Agreblierai section the sedimentation style changes only a few meters above the boundary, where oolithic limestones of early Hettangian age (METTRAUX 1989) are found. We conclude, that in the lowermost Jurassic in the south (Plan Falcon section) siliciclastic sedimentation was still going on, whereas in the North (Agreblierai section) oolithic limestones were deposited, indicative of a high energy environment and a depth of 2 m to 15 m (Milliman et al. 1974).

7. Final remarks

During the last years several publications on Rhaetian palynomorph assemblages (Morbey 1975) and Rhaetian/Liassic boundary sequences (Schuurman 1979, Karle 1984) in the Eastern Alpine area were published. These sporomorph assemblages are comparable with the Plan Falcon and Agreblierai sections, which show each two different sporomorph spectra. Both spectra are remarkably similar to those described by Karle (1984) from the Fonsjoch (Achensee, Eastern Alpine area) of the Upper Rhaetian and the "Preplanorbis Beds". Karle subdivides the "Preplanorbis Beds" (Unit 3) in two subunits (3a and 3b), based on two different sporomorph spectra, which the author places both into the Liassic according to the zonation scheme of Wiedman et al. (1979). We follow here, however, the proposed ranges and zonation of sporomorphs for the Rhaetian/Liassic boundary of Visscher & Brugman (1981). According to these authors the taxa *Ovalipollis, Camerozonosporites rudis, Rhaetipollis germanicus, Quadraeculina anellaeformis,* and *Rhaetogoniaulax rhaetica* have their last occurrence at the end of the Rhaetian. Therefore, we propose to place the Rhaetian/Liassic boundary within the Unit hb of Jeannet (1912–1918), between our samples 6 and 5 in the Plan Falcon section and between samples 2 and 1 at the Agreblierai section (see Fig. 2) where the boundary is marked by the last occurrence of the above mentioned taxa and the first occurrence of *Heliosporites altmarkensis.*

The dating of the siliciclastic facies gives a better understanding of the dynamics of this part of the northern Tethys margin. Shortly after the Rhaetian/Liassic boundary time interval the sedimentation of clastic facies became restricted to the south, where it was deposited during major storm events, on a wide shallow platform (Fig. 3). Tectonic activity certainly played the most important role in general for the geometry of the basin and therefore the distribution of the sediments during the Triassic and Jurassic. However, just at the turn of the uppermost Rhaetian to the basal Hettangian, tectonic activity was less important than eustatic sea level changes (Mettraux, 1989).

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Plate 1

Palynomorphs of the Rhaetian and Hettangien of the Plan Falcon and Agreblierai sections.
Magnifications × 900; coordinates refer to the Nikon microscope Mikrophot FX, No. 590968

Fig 1. *Densosporites* sp.
Agreblierai, sample 3, 7, 27/99,5

Fig. 2. *Lycopodiacidites* sp.
Agreblierai, sample 3, 7a, 24,5/94

Fig. 3. *Thuringiasporites laevigatus* SCHULZ 1962
Agreblierai, sample 2, S 2, 41,2/95

Fig. 4. *Zebrasporites interscriptus* (THIERGART 1949) KLAUS 1960
Agreblierai, sample 2 S 2, 46,5/98,2

Fig. 5. *Anapiculatisporites spiniger* (LESCHIK 1956a) REINHARDT 1961
Agreblierai, sample 2, 8, 25/86

Fig. 6. *Quadraeculina anellaeformis* MALJAVKINA 1949
Agreblierai, sample 2, S 5, 36,1/90,8

Fig. 7. *Rogalskaisporites cicatricosus* (ROGALSKA 1954) DANZÉ-CORSIN & LAVAINE 1963
Agreblierai, sample 2, S 2, 45,5/98

Fig. 8. *Asseretospora gyrata* (PLAYFORD & DETTMANN 1965); SCHUURMAN 1977
Agreblierai, sample 2, S 2, 37,2/96,4

Fig. 9. *Annulispora folliculosa* (ROGALSKA 1954) DE JERSEY 1959
Agreblierai, sample 2, S 5, 38,5/89

Fig. 10. *Platyptera trilingua* (HORST 1943) SCHULZ 1967
Agreblierai, sample 2, 8, 50,5/90,5

Fig. 11. *Triancoraesporites ancorae* (REINHARDT 1961) SCHULZ 1967
Agreblierai, sample 8, 2, 34/93,8

Fig. 12. *Triancoraesporites reticulatus* SCHULZ 1962
Plan Falcon, sample 6, S 1, 44/93,2

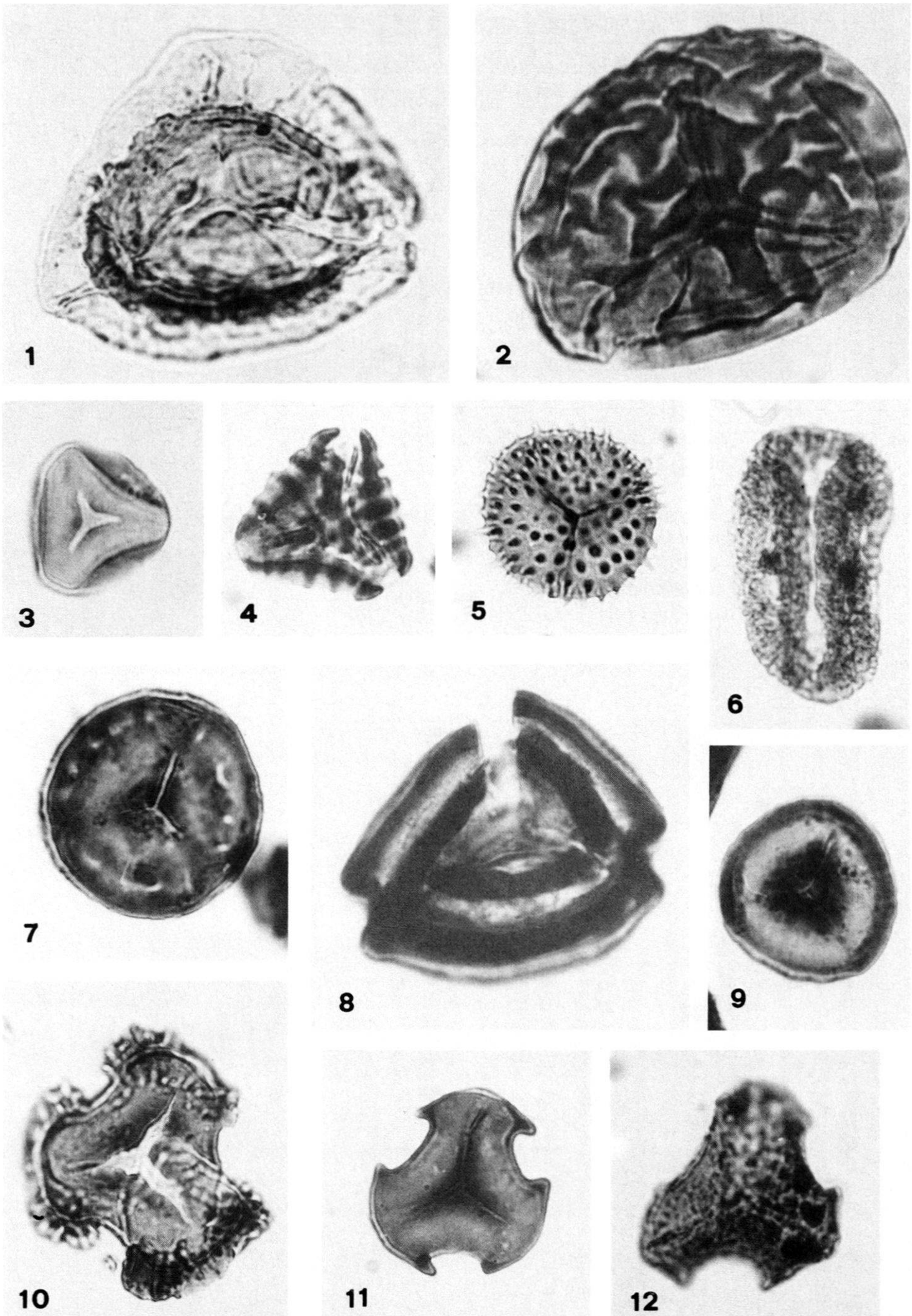
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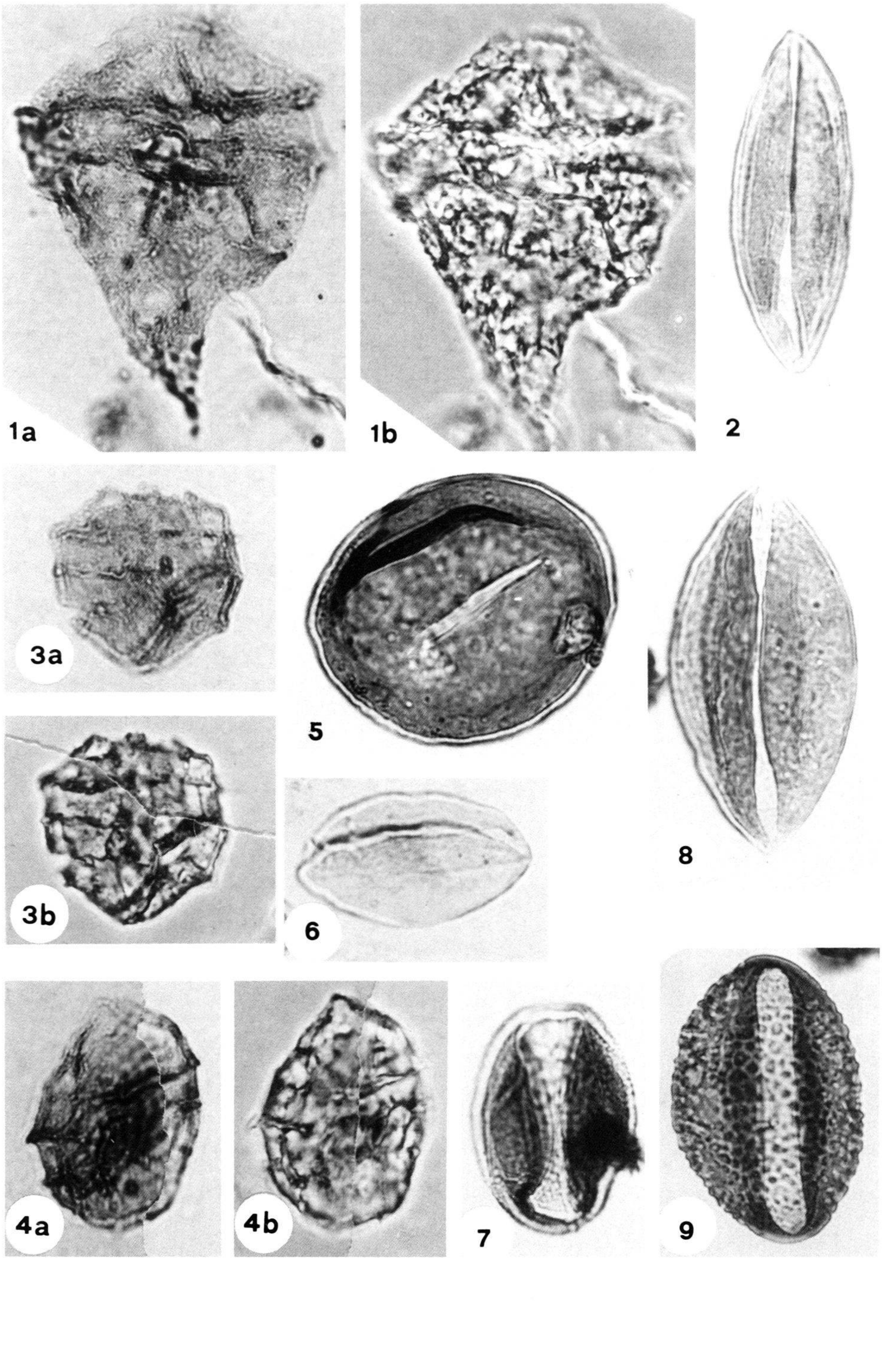
Plate 2

Palynomorphs of the Rhaetian and Hettangien of the Agreblierai and Plan Falcon sections.
Magnifications × 900; coordinates refer to the Nikon microscope Mikrophot FX, No. 590968

Fig. 1a, b.	*Rhaetogonyaulax rhaetica* (SARJEANT 1963) LOEBLICH & LOEBLICH 1968 Plan Falcon, sample 6, S A, 42/85,8
Fig. 2.	*Cycadopites follicularis* WILSON & WEBSTER 1946 Agreblierai, sample 2, S 7, 32,7/86,8
Fig. 3a, b.	*Dapcodinium priscum* EVITT 1961 Plan Falcon, sample 6, S B, 46/89
Fig. 4a, b.	*Dapcodinium priscum* EVITT 1961 Agreblierai, sample 6, S C, 46,5/101,3
Fig. 5.	*Cycadopites follicularis* WILSON & WEBSTER 1946 Agreblierai, sample 2, S 8, 26,2/87
Fig. 6.	*Cycadopites deterius* POCOCK 1970 Agreblierai, sample 3, S 1, 41/86
Fig. 7.	*Cycadopites andrewsii* CORNET & TRAVERSE 1975 Agreblierai, sample 2, S 2, 37/97,5
Fig. 8.	*Cycadopites* sp. 1 Agreblierai, sample 2, S 1, 38/98,5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