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SUBSURFACE OF ISRAEL

City University of New York

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PALYNOLOGICAL ASPECTS OF THE PERMO-TRIASSIC SEQUENCE
IN THE SUBSURFACE OF ISRAEL

by
YORAM ESHET

A dissertation submitted to the Graduate Faculty
in Earth and Environmental Sciences in partial
fulfillment of the requirements for the degree of
Doctor of Philosophy, The City University of New
York.

1987

This manuscript has been read and accepted for the Graduate Faculty
in Earth and Environmental Sciences in satisfaction of the disserta-
tion requirement for the degree of Doctor of Philosophy.

April 10, 1981
date

Donald C. Habel
Chairman of Examining Committee

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ABSTRACT

PALYNOLOGICAL ASPECTS OF THE PERMO-TRIASSIC SEQUENCE
IN THE SUBSURFACE OF ISRAEL

by

Yoram Eshet

Advisers: Professor Daniel Habib and Dr. Harold Cousminer.

A palynostratigraphic study of the Permo-Triassic sequence in the subsurface of Israel resulted in the identification of seven interval zones in the following ascending order:

- I. Potoniesporites novicus Zone (Early Permian)
- II. Lueckisporites virkkiae Zone (Late Permian)
- III. Endosporites papillatus Zone (Early Triassic)
- IV. Aratrisporites saturni Zone (Anisian)
- V. Podosporites amicus Zone (Ladinian)
- VI. Patinasporites densus Zone (Carnian)
- VII. Rhaetogonyaulax rhaetica Zone (Rhaeto-Norian)

Although a complete sequence of palynozones is found across the Permian-Triassic boundary in most of the boreholes, the occurrence of an hiatus is suggested by the pattern of extinctions and type of lithology at the transitional zone. A definite unconformity at the Permian-Triassic boundary has been identified in the Zuk Tamrur 1 well.

A study of the geographic distribution of selected taxa resulted in the definition of three discrete provinces

at different times during the Permo-Triassic. Provincialism in the south was found to be more prominent.

The content of reworked organic particles was found to be high in regressive intervals, while a low content characterizes the transgressive ones. This is offered as an efficient tool for the identification of transgressions and regressions.

A paleoclimatic model, used in this study, indicated a mixture of arid and humid niches during the Middle Triassic, and arid conditions in the Late Triassic (Carnian).

Rhythmic alternations in assemblage composition found in Early Permian intervals probably indicate rhythmic climatic or sedimentologic changes in depositional environments.

The entire Permo-Triassic sequence is within the oil window in northern Israel. In the south, the Upper Triassic is immature and only the older intervals are within the oil window. None of the studied boreholes has reached the over-mature zone. Kerogen is composed essentially of woody and other terrestrial particles. Only few samples were rich in amorphous algal organic matter.

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steps of this research, as the Head of the Mapping, Stratigraphy and Oil Division in the Geological Survey of Israel.

Drs. F. Hirsch, A. Parnes and M. Raab (Isr. Geol. Surv.) helped in giving me a better understanding of biostratigraphical problems in the Israeli Triassic. Dr. B. Derin (Isr. Inst. of Petroleum and Energy) provided important biostratigraphic data and shared with me his ideas on Permo-Triassic stratigraphy in Israel.

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INTRODUCTION

The purposes of this study are:

1. To create a palynozonation for the Permo-Triassic in the subsurface of Israel, and to establish correlation between the studied sections. This zonal scheme will also be used for correlation to other regions in the world.
2. To apply the palynological zonation to boundary problems and to other unresolved stratigraphic problems in the interval under consideration.
3. To contribute to the knowledge of Permo-Triassic paleoenvironments, paleoclimate and paleogeography.
4. To evaluate the source-rock potential of the Israeli Permo-Triassic in terms of its thermal maturation and type of kerogen.

The paleogeographic configuration in Israel during Permian and Triassic times was governed by the occurrence of the Arabian craton to the south and the Tethys ocean to the north. Transgressions appear to have generally invaded from the north; during regressions, continental clastics appear to have been carried from the continent in the south. Epeiric movements of the Arabian craton triggered the transgression/regression regime (Druckman, 1976; Goldberg & Friedman, 1974).

During most of the Permo-Triassic, sedimentation in the study area alternated between continental and nearshore marine conditions. In the Permian, continental conditions

were more prominent, resulting in the deposition of abundant clastic sediments. Marine conditions were more widespread in the Triassic and the major rock types are carbonates, shales and sandstones. Evaporites characterize the upper part of the section. Large sand-bodies occur in places. Unconformities occur at system boundaries. Lower Permian rocks unconformably overlies the Upper Precambrian Zenifim Formation. A hiatus was also encountered between Permian and Triassic sedimentary rocks in one of the boreholes. Lower Jurassic rocks unconformably overlies the Upper Triassic.

The Permo-Triassic section in Israel has been penetrated by several exploration wells. Triassic strata crop out in the south, at Makhtesh Ramon (Figure 1). No Permian rocks crop out in the study area and all palynological data of Permian age come from borehole samples.

The lithostratigraphy and depositional environments of the Permian and the nature of its lower contact were described by Weissbrod (1967, 1969, 1981). Zak (1957, 1963) produced the first lithostratigraphic framework for the Triassic in his study of outcrops in Makhtesh Ramon in southern Israel. Druckman (1974, 1976) established the currently used lithostratigraphic subdivisions of Triassic outcrops in southern Israel. He also was able to apply and extend the surface subdivisions to subsurface sections that were penetrated by oil wells. Of special interest for this research is the study of Karcz & Zak (1965) who studied

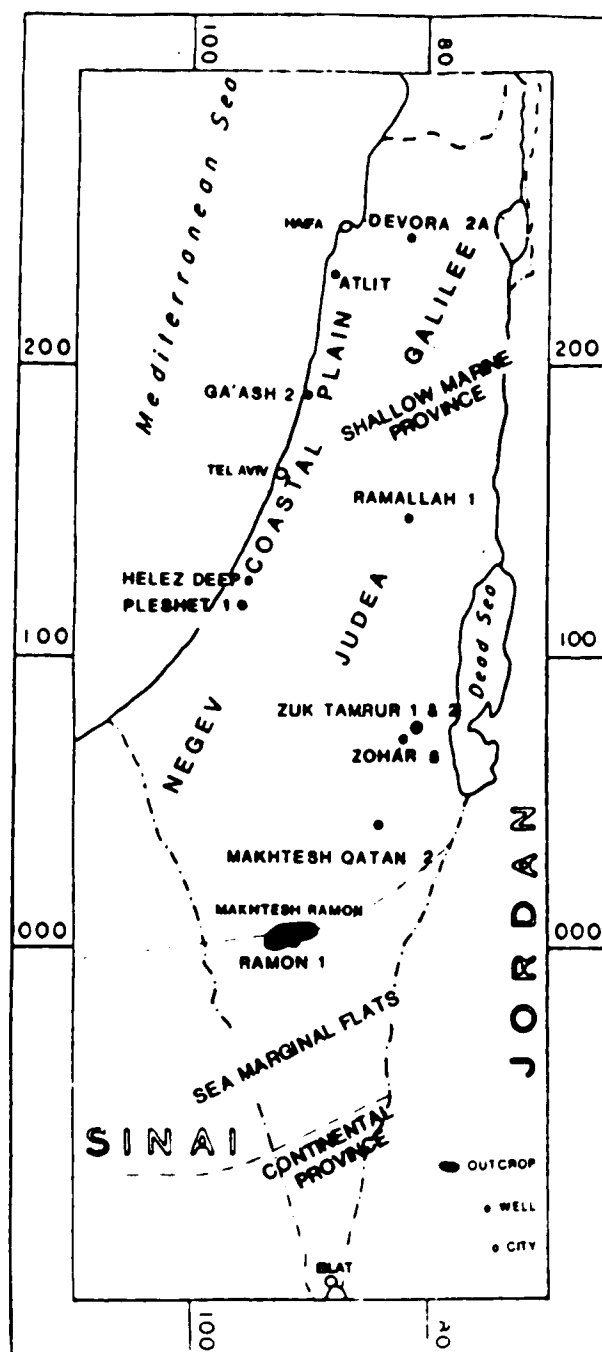


Figure 1.

Location of all wells studied in this research. Also includes the generalized distribution of the major Permo-Triassic depositional environments (modified from Druckman *et al.*, 1970) and from Goldberg & Friedman, 1964). Coordinates are according to the Israel Grid System

paleocurrent directions in Triassic sediments. Their results are used here to support some of the paleogeographic conclusions.

The Permo-Triassic succession in Israel, especially in the south, was the subject of several paleontological studies that served to define its chronostratigraphy. Gerry (1966, 1967) and Sohn (1963, 1968) described Permo-Triassic ostracodes. Hirsch & Gerry (1974) studied conodonts and ostracodes in the Israeli Triassic. Permo-Triassic ostracode biostratigraphy in the subsurface of Israel currently is being studied, but only preliminary results are available (Gerry & Honigstein, 1984). Hirsch (1972) studied Middle Triassic conodonts from Israel and compared them to those in southern France and Spain. He also described Early Triassic conodonts in southern Israel (Hirsch, 1975). Triassic conodonts were also studied by Huddle (1970). Foraminifers in the Triassic section were studied by Sohn & Reiss (1964) and Derin (in Derin & Gerry, 1981). Benjamini currently is working on the Triassic foraminiferal biostratigraphy in Israel, but only a small portion of his results have been published (Benjamini, 1984). A biostratigraphic framework of ostracode and foraminiferal biozones in the Permo-Triassic was published by Derin & Gerry (1981). Parnes discussed ammonite biostratigraphy for the Triassic section, in a series of studies (Parnes, 1962, 1975). This framework, although not covering the entire Triassic section, became

the basis for the standard chronostratigraphic subdivision of the Triassic. Later he revised parts of his ammonite biostratigraphy and changed the ages for some of the ammonite zones (in Parnes et al., 1985; Parnes, 1986).

Palynological research on the Israeli Permo-Triassic was begun by Glickson (1964) and by Gorni (1966), who studied core samples from the Makhtesh Qatan 2 well in the south (Figure 1). Horowitz (1970) suggested a palynozonal scheme for the Upper Permian and Triassic, based on his findings in Zohar 8 and Avdat 1 wells in southern Israel. Horowitz (1973) also described Triassic palynomorphs from the subsurface of Israel. Except for random samples studied by R. Dunay (unpublished report, Isr. Geol. Surv., 1974), all of the above studies were conducted before comprehensive publications on Permo-Triassic palynostratigraphy in the North Sea (Geiger & Hopping, 1968), England (Fisher, 1972), Ireland (Visscher, 1971), Switzerland (Scheuring, 1970), and Pakistan (Balme, 1970) were available for comparison. These studies demonstrated the need for a new study of the Permo-Triassic palynostratigraphy, especially since other paleontological disciplines have failed to establish a continuous zonal scheme without breaks. This failure raises questions as to the validity of some of the age determinations in this sequence. More recent work on Triassic palynostratigraphy in Israel was presented by the preliminary framework published by Cousminer (1981a), based on limited samples studied from

scattered intervals in the Triassic subsurface. In this research, I have used some of Cousminer's palynozones as a comparative standard.

Several major stratigraphic problems occur within the Permo-Triassic rocks of Israel. Both Druckman & Kashai (1981), and B. Derin & E. Gerry (written commun., 1986) found an unconformity in the Helez Deep well (Coastal Plain) between the Triassic and Precambrian rocks. This present study provides palynological evidence that suggests the presence of Lower Triassic rocks in that section. Based on the occurrence of Permian palynomorphs within the Zafir Formation, Horowitz (1970) proposed that the Permian-Triassic boundary be placed in this formation. This solution would raise the boundary by a considerable amount. The problem of the stratigraphic position of the Permo-Triassic boundary is discussed, in the light of new evidence from Pleshet 1, Zuk Tamrur 1 and Zohar 8 wells.

The drastic lithological differences between northern and southern Israel has made lithostratigraphic correlation between them unreliable. This study proposes a new north-south regional chronostratigraphic correlation. Another stratigraphic problem concerning the Triassic is the nature of its contact with the Jurassic. Despite the general agreement that the Norian is truncated, Cousminer (1981b) found the Norian to be represented by characteristic dinoflagellates in the Coastal Plain (Ga'ash 2 well). Similar conclu-

sions were reached by Derin & Gerry (1981) from foraminifers and ostracodes. The Permian-Triassic boundary appears to be barren of indicative fossils except for sporomorphs that are abundant in it. Although there have been discussions about an unconformity between the Permian and the Triassic, the contact was considered to be lithologically conformable (Weissbrod, 1981). However, in this research, detailed palynostratigraphic study of the Permian-Triassic transitional zone shows an unconformity at the boundary, in the Zuk Tamrur 1 well.

The Permo-Triassic assemblages in Israel have never been used in the past as paleoenvironmental indicators, although various models are available in the literature for their interpretation. A paleoenvironmental/paleoclimatological interpretation, together with the identification of various plant-communities in Israel, may shed new light on the understanding of geological events in this region.

Standard methods are available to define the location of the subsurface oil window and to evaluate source-rock potential (Tissot & Welte, 1978; Durand, 1980; Brooks, 1981). The TAI (Thermal Alteration Index) (Staplin, 1969, 1975) is a fast and inexpensive means for identifying the oil window, using the color of sporomorphs. Application of this method to rocks in Israel was first demonstrated by Gvirtzman, Cousminer and Feinstein (1981) who correlated TAI with values obtained by vitrinite reflectance. Some

discrepancies with the vitrinite reflectance values were found in a TAI study of palynomorphs in Makhtesh Qatan 2 (Eshet, 1983). This recent research includes a revision of the problematic interval, shedding new light on these discrepancies. TAI is usually an accurate method, although it can be subjective, depending on the operator. It allows a reliable definition of the thermal rank of a sample in terms of its hydrocarbon potential. Its advantage over other methods is that it makes use of in situ organic matter, rather than caved or reworked matter that is hard to eliminate in the vitrinite reflectance method. The major shortcoming of the TAI method is that only the general maturity ranks can be identified, while the vitrinite reflectance method defines all transitions from immature to over-mature ranks. In addition to thermal maturation studies, kerogen analysis is becoming a major means of source-rock evaluation (Brooks, 1981; Durand, 1980). It is routinely used by oil companies as demonstrated by Miller et al. (1979).

The boreholes studied in this research are within a 13,000 km² area in Israel. The region is located at the eastern edge of the Mediterranean Sea (Figure 1). Geographically, it is divided into the Negev desert at the south, Judea mountains along the center, the Galilee mountains at the north and the Coastal Plain along the Mediterranean. The Dead Sea rift system bounds the area at the east and forms a

deep elongated valley.

MATERIALS AND METHODS

SAMPLING

Selected sections

Six sections, penetrated by oil borings were selected for study (Figure 1). Each well represents a different depositional environment of the Permo-Triassic. Considering the size of the area and the purpose of study, these sections are considered to provide sufficient data to allow reliable palynostratigraphic results. The reasons for selecting the sections are as follows: the Zuk Tamrur (1 & 2) and the Zohar 8 wells are at the southern part of the area where lithostratigraphic control is good and electric-log correlation is reliable (Y. Druckman, 1974; Weissbrod, 1981). Useful previous palynological information is available from the studies of R. Dunay (written commun., 1974) and Eshet (1983, 1984). The Devora 2A well is at the northern part of the study area. It represents the northernmost Triassic section penetrated in Israel; the Devora 2A is a key section for correlating between northern and southern Israel. Lithostratigraphic correlation is not reliable in the north because of the different depositional setting from the south (Druckman, personal commun., 1985). The Helez Deep and Pleshet 1 wells are located in the Coastal Plain and

their palynologic study can contribute to the paleogeographic knowledge of the area. These two sections are only 10 km apart and yet they are very different from each other, which makes the palynologic study so important. Together with the detailed palynostratigraphic zonation available from Ga'ash 2 well (Cousminer, 1981b), a reliable palynostratigraphic correlation in the Coastal Plain might be established. The Ramallah 1 well (Judea Mountains) and Atlit well (northern Coastal Plain) were also sampled and processed. Since most of the samples were barren of palynomorphs, these sections are not included in this study, and only some results are mentioned.

Sampling procedures

The selected sections were sampled at intervals of about 25 m in most places. The total number of samples is 295. These are listed in Appendix 1, with reference to their stratigraphic location. The total thickness of the studied sections is about 7,500 m. Because of the technical problems in presenting the data on range charts, some of the very closely-spaced samples were grouped together.

Rock material was available from the Geological Survey of Israel, Jerusalem. Rock samples, consisting of 15-20 grams of crushed rock, were selected from a variety of lithologies, although black shale was preferred. Coarse clastic rocks were found to be barren in most samples,

probably due to oxidation and/or grain-size; thus coarsely clastic lithologies were rarely sampled. Samples were selected from both cores and cuttings, although cuttings were more frequently available. Because of their greater stratigraphic value cores, where available, were sampled more intensively than cuttings. Each sample was labelled by a P (pollen) number that was also used to mark the palynologic slides.

SAMPLE TREATMENT

Physical treatment

The first step in sample treatment was to crush the raw material into small pieces, not larger than 2-3 mm, and to water-wash them through a 250 micrometer sieve to eliminate contamination. The importance of waterwashing was stressed by Kuyl et al. (1965).

Chemical treatment

In this study, a combination of methods was used in order to perform palynostratigraphic, maturation and kerogen analyses on the same sample. Oxidizing agents were not utilized since they cause changes in kerogen color. Except for important intervals, all samples were treated chemically according to the following method (Figure 2):

- Dissolution of all carbonates in concentrated HCl (32%) for 1-2 days
- Treatment of the the remaining residue in HF (40%) for 1-2

days to eliminate the silicates. This step lasts 1-2 days. In some instances, the addition of HF before all the carbonates were removed, led to the precipitation of CaF_2 as a white jelly. It was dissolved by further addition of HCl.

SLIDE PREPARATION

In samples from nearshore marine and continental environments, palynomorphs are usually not found in high concentration. Artificial concentration of fossils is required for a satisfactory palynological slide. Concentration was achieved by sieving the samples through filters of different pore-sizes. This process fractionates the kerogen and results in a well dispersed palyniferous slide. As illustrated in Figure 2, the filters in use were of 150, 37 and 10 micrometer pore size. Two slides were prepared from the organic residue: a slide from the fraction >37 micrometer <150 micrometer, and another slide from the fraction >10 micrometer <37 micrometer. Palynomorphs were mounted in a synthetic permanent mount.

Following HF treatment, and before any sieving, a "raw slide" was prepared, to be used as a reference for kerogen and TAI analysis.

In addition, swirling was used as a method to eliminate heavy minerals and kerogen particles that were not removed by the chemical treatment (Doher, 1980). An ultra-sonic device was used occasionally to deflocculate some of the organic residue in order to help in the filtering process.

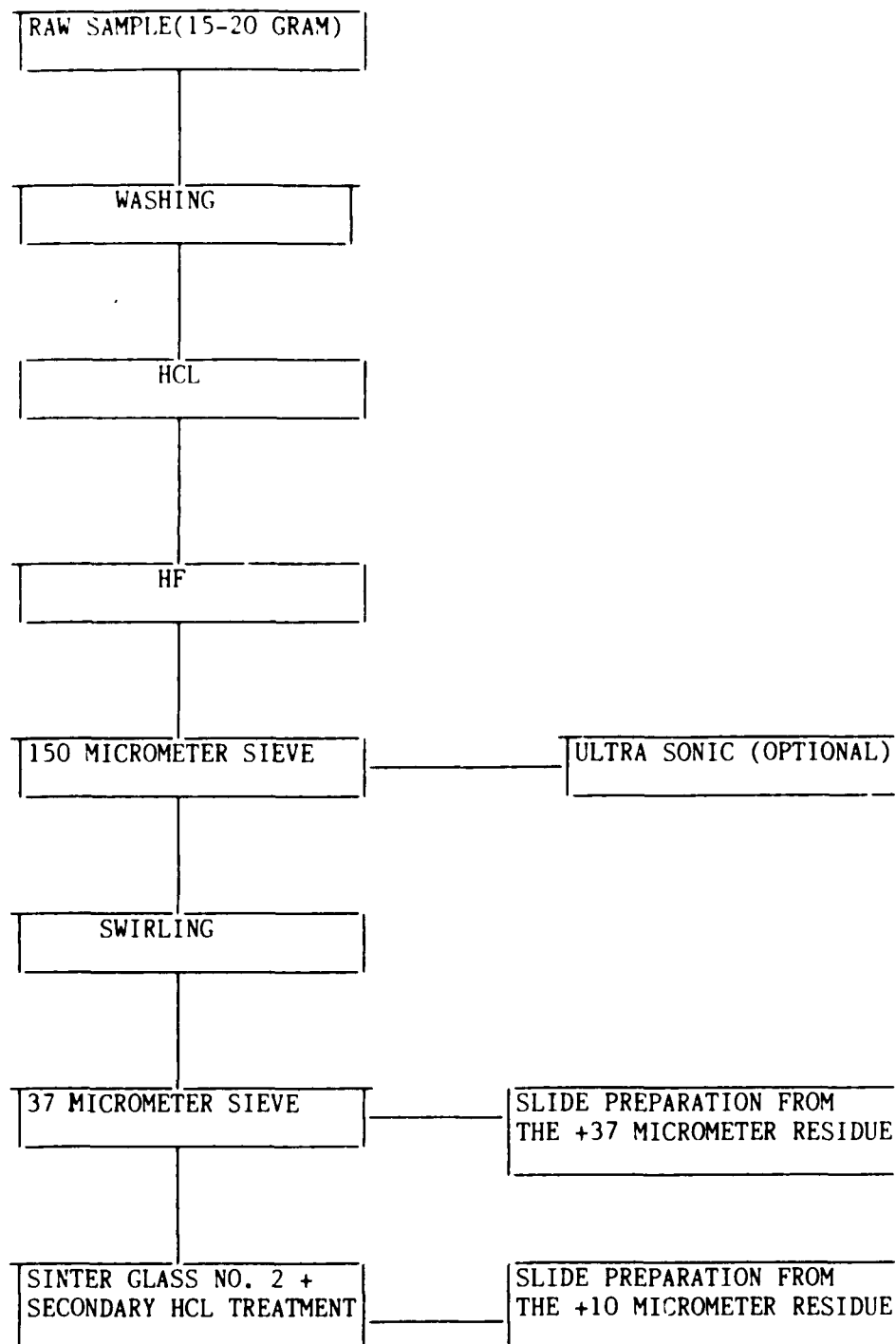


Figure 2. Physical and chemical steps in sample treatment
utilized in this study

Some reservations have been raised against the use of ultrasound because of its physical impact on palynomorphs (Tschudy, 1968). A test showed that for treatment of no more than 5-6 minutes, no physical damage was observed, while the residue deflocculated easily (Eshet, 1985). All samples and slides are stored in the Geological Survey of Israel, Jerusalem, in the Mapping, Stratigraphy and Oil Division.

MICROSCOPE STUDY

Slides were studied with a Zeiss transmitted light microscope. Study included the following:

- Identification and documentation of fossils
- Age determination of each sample.
- Thermal study of each sample and determination of its maturity rank by T.A.I. analysis.
- Kerogen type (organic facies) determination

Quantification of the organic matter and palynomorphs was made for each sample on a relative abundance basis. A key to the relative abundance of each group is given in each range chart). In stratigraphically important intervals or for special palynologic groups, counting of at least 100 specimens was used as a standard for statistical analyses.

GEOLOGICAL BACKGROUND

LITHOSTRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

The Permo-Triassic succession in the study area is composed of almost 1,500 m of nearshore to continental rocks in the south; it thickens considerably towards the north, where the base of the Triassic had never been reached. Triassic rocks in Israel are exposed in the Negev, in Makhtesh Ramon and Har Arif where the Middle and Upper Triassic crop out (Figure 1). The Permian occurs only in the subsurface and has never been penetrated outside of the Negev. About 12 drillholes have penetrated the Permo-Triassic section (Figure 1). Figure 3 shows that the Permo-Triassic succession unconformably overlies the Precambrian clastics of the Zenifim Formation (Weissbrod, 1981). The Triassic is unconformably overlain by the Jurassic succession (Goldberg & Friedman, 1974). An unconformity may occur at the Permo-Triassic boundary. Truncation of the lithologic column by the unconformity at the Triassic-Jurassic boundary is variable but a trend of a greater truncation in the south can be inferred from the presence of a larger hiatus there. In the north (Ga'ash 2 for example), the sequence is complete and includes the latest Triassic stages (Rhaetian and Norian) which are missing in the south (Cousminer, 1981b). An extremely large truncation occurs in the Helez Deep area, where Middle Triassic rocks overlie a Precambrian crystalline basement.

Permian lithostratigraphy was established by Weissbrod (1969, 1981). The Permian begins at the unconformity with Precambrian rocks and is composed of the following formations in ascending order (Figure 3):

- **Sa'ad Formation:** 80 m of primarily quartz arenite with anhydritic cement; coaly shales appear in places, as well as mud cracks and plant remains. A few layers of limestone and dolomite appear in places. The abundance of sandstone and plant remains suggest a fluviatile environment, with swamps in which the coaly material was deposited (Weissbrod, 1981). The formation was penetrated by several boreholes in the south only. Although the Sa'ad Formation was assigned in the past to the Carboniferous (Glickson, 1964), its age appears to be Early Permian (R. Dunay, written commun., 1974; Eshet, 1983)

Arqov Formation: This formation is composed of alternating sand, shale and carbonate units. Its thickness in the type section (Makhtesh Qatan 2) is 194 m and its inferred depositional environment is nearshore marine. Weissbrod (1981) suggested that in the Negev (Ramon 1, Boker 1 wells), a more open marine environment existed and therefore, a thicker section (of 232 m) accumulated there. Based on palynological and other paleontological evidence, Weissbrod (1981), Gerry (1967) and Derin and Gerry (1981) suggested a Late Permian age for this unit. Glickson (1964) had placed it within the Early Permian.

Yamin Formation: This formation is composed primarily of carbonates, although sand bodies occur at the top and bottom. Its thickness is 133 m in the type section (Makhtesh Qatan 2). It represents regressive conditions at the base, followed by a transgression and ending with another regression at the top. Weissbrod (1981) assigned this formation to the Late Permian based on scattered paleontological evidence. It seems that at least part of the Yamin Formation is of Triassic age and the Permian-Triassic boundary has to be placed in its lower part or in the uppermost Arqov Formation (Eshet, 1984). To summarize, the Permian is a sedimentary sequence that starts with continental conditions and ends with marine conditions.

The Triassic is reported to be represented by a continuous sequence from the Late Permian (Weissbrod, 1981). Its lithostratigraphy in outcrops and in the subsurface was established by Zak (1957, 1963) and Druckman (1974, 1976) from bottom to top as follows (Figure 3):

Zafir Formation: This formation is a shaly marine limestone, alternating with dolomite. Carbonates are abundant at the bottom, indicating transgression, while the abundance of clastics at the top indicates regression. Its environment is essentially shallow nearshore marine (Druckman, 1974), demonstrated by oolites in the formation. The Zafir Formation was penetrated by wells in all parts of the study area. A Scythian age was suggested by Hirsch (1975), Parnes (1975)

and Derin & Gerry (1981), which agrees with the palynological determinations in this study. Parnes et al. (1985) suggested that the upper part of the formation belongs to the Early Anisian .

Ra'af Formation: This marine formation is composed mostly of limestone. In outcrops (Har Arif, Ghebel Arif A Naqa) it also contains dolomite and shale. It represents a dominance of marine conditions after the regression of the upper Zafir Formation. Oncolites and oolites accumulated on a shallow shelf which may have been only a few meters deep. Only the upper part of the formation is exposed (25 m in Har Arif). In the subsurface, its thickness is 128 m (in Makhtesh Qatan 2). Parnes (1975) assigned it to the Early Anisian, based on the occurrence of the ammonites Beneckeia sp. and B. levantina which were defined in an equivalent lithostratigraphic unit in Wadi Hisban, Jordan. This age was later changed into Late Anisian (Parnes et al., 1985; Parnes, 1986).

Gevanim Formation: This formation is a clastic unit of 270 m thickness, composed mostly of sandstone and shale with some limestone. It appears to be a clastic wedge between two carbonate units: the Ra'af and Saharonim Formations. The Gevanim reflects a fluvial-controlled lateral migration of land during regression (Druckman, 1976). It is exposed in Makhtesh Ramon and was penetrated by boreholes in all parts of the study area. Of special interest for this study is the

northward wedging of this clastic unit, indicating transportation of clastics from the south. The presence of this clastic wedge is used later as part of the model suggested here for reworked material. The formation is assigned by all paleontological disciplines to the Late Anisian (Parnes et al., 1985; Gerry & Derin, 1981; Eshet & Cousminer, 1986).

Saharonim Formation: This formation is a marine unit (45 m in Makhtesh Ramon), composed essentially of limestone. It represents not only the largest transgression in the area but also almost complete cessation of clastic transportation. Evaporites at the top of the formation represent the beginning of a regression. The marine conditions are indicated by the occurrence of many cephalopods, echinoids and bivalves. Ammonites are the basis of a Ladinian age for most parts of the formation (Parnes, 1975, 1986; Parnes et al., 1985). The Ladinian/Carnian boundary is placed at the upper part of this unit (Gerry & Derin, 1981; Eshet & Cousminer, 1986). The Saharonim Formation crops out in Makhtesh Ramon and was penetrated by boreholes in all parts of the study area.

Mohilla Formation: This formation is an evaporitic unit, composed mostly of anhydrite, gypsum and dolomite. Its thickness is 202 m in outcrop in Makhtesh Ramon. Druckman (1974) suggested that this formation represents a time of regression. Lateral thickness and facies changes indicate tectonically-controlled differential subsidence that

resulted in the formation of evaporite basins separated by sills. The unit is thicker and of anhydritic composition in the basins, while along the sills it is thinner and dolomitic. Druckman (1976) offered a model of cyclical sedimentary events to explain the genesis of evaporites in the Mohilla Formation. The formation is devoid of ammonites and foraminifers in most parts of the area. A Carnian age was suggested by the finding of the conodont Metapolygnatus polygnathiformis Budurov & Stefanov near the top of the formation (Eicher & Mosher, 1974). The same age is also assigned by palynomorphs.

An unconformity marks the Triassic-Jurassic boundary in most of the boreholes. The variegated shales of the Liassic Mish'hor Formation overly the Triassic Mohilla Formation (Goldberg & Friedman, 1974). The uppermost Triassic, the Rhaeto-Norian interval., is truncated in most places. However, along the Coastal Plain some relicts that contain this time-interval are present (Ga'ash 2, Atlit, Helez Deep).

MAJOR TRENDS IN THE PERMO-TRIASSIC SEQUENCE OF ISRAEL

In addition to the lithostratigraphy described above, the Permo-Triassic succession in Israel is characterized by the following affinities, most of which are due to its paleogeographic location at the margins of the Arabian craton:

1. The sequence in the north is more marine than its equivalent units in the south. This is indicated by the occurrence

of thicker limestone intervals in the north, while towards the south the facies are of sea-marginal flats and sabkhas. These facies belts were shifting between times of transgression and regression. Figure 1 illustrates the facies distribution pattern during the Middle and Late Triassic.

2. Transportation of clastic material was, in most places, from the Arabian continent to the south (Karcz & Zak, 1965). As a result, the clastic fraction in the southern sections is more prominent than in the north and it decreases gradually northward. An example of these lateral changes is demonstrated by the north-south correlation between Devora 2A and Helez Deep sections. Along this line, the clastic Gevanim Formation thins northward while the calcareous Ra'af Formation thickens (Druckman & Kashai, 1981). Druckman (1974) demonstrated the same trend for the rest of the Triassic, especially for the transgressive parts. This trend forms the basis for some of the paleogeographic conclusions in this study which rely on the use of palynomorphs as detrital particles.

3. The Triassic lithostratigraphy in southern Israel reflects, at least, three sedimentary cycles of transgression and regression (Druckman, 1974, 1976) that resulted from epeirogenic movements of the Arabian craton. In this study, correlation between these cycles and the nature of the detrital organic matter agrees with the former conclusions.

PALYNOSTRATIGRAPHY

Various methods for plotting and presenting biostratigraphic data are described in the literature (Shaw, 1964; Eicher, 1976). The need to adapt the biostratigraphical method to the purpose and constraints of the study was stressed by Edwards (1982). Since the major goal of this research is stratigraphic and paleoenvironmental, the first objective must be to reconstruct, as accurately as possible, a complete sequence of palynozones in chronostratigraphic order. The nature of the available material, mostly from cuttings, dictates the biostratigraphic approaches adopted here for the designation of palynozones and ranges. (1) Ranges of palynomorphs are plotted according to their Last Appearance Datum (LAD), a method in which the effect of extending ranges due to caving is reduced. (2) Palynozones and age-determinations in this study are based on the definition of interval zones. The boundaries of each interval zone are determined by the stratigraphic last appearance of several marker fossils.

Major constraints on the results are twofold. One is derived from the materials available for study; another is due to the nature of the paleontological material. First, most of the samples are cuttings. This places constraints on the accuracy of the inferred age, because caving of younger fossils may cause misleading age determinations. However, the use of color-index sporomorphs (TAI) has been utilized

and helped to diminish this problem. The second problem, that of obtaining an older age than the true one, may arise from the occurrence of reworked organic matter. The TAI method is useful in approaching this problem as well.

Lithology may add a constraint to the size of organic remains. Black shales are found, generally, to be palyniferous, while most coarse clastics and many limestones are barren. Considering the scope and purpose of this study, black shale and silt were sampled much more intensively. Hence, lithological control on the accuracy of the results could not be studied in detail.

The degree of preservation of the recovered assemblages depends on many factors. It can be expressed in the biostratigraphical record by discontinuous ranges of fossils and by poor recovery. This implies that, unless the depositional environment is well understood, it is difficult to know whether an observed range is the true range of a fossil or whether it is due solely to depositional conditions. Aspects of the preservation of organisms in sediment were summarized by Curtis (1980) and Habib (1982) and are useful to interpret the effect of preservation on occurrence.

The palynostratigraphic framework established for the Permo-Triassic in Israel is composed of seven interval zones whose ages have been determined by correlation to ammonite, foraminifer, conodont and ostracode-bearing strata in Israel, as well as by comparison to well-dated palynological

zonations elsewhere in the world. These zones in ascending stratigraphic order are:

- I. Potoniesporites novicus Zone (Early Permian).
- II. Lueckisporites virkkiae Zone (Late Permian).
- III. Endosporites papillatus Zone (Early Triassic).
- IV. Aratrisporites saturni Zone (Anisian).
- V. Podosporites amicus Zone (Ladinian).
- VI. Patinasporites densus Zone (Carnian).
- VII. Rhaetogonyaulax rhaetica Zone (Rhaeto-Norian).

Reference sections for these zones are selected intervals in the Zuk Tamrur, Makhtesh Qatan 2 and Ga'ash 2 wells. For detailed palynozonation of each of the wells of this study see Appendices 2 to 13. The most age-significant taxa in each zone are listed in Table 1. All taxa defined in the study are listed, with reference to their authors, in Appendix 14. The morphology of selected species is described in Appendix 15.

The Permo-Triassic range zones in Israel are described here in ascending stratigraphic order (Figure 4).

ZONE I: POTONIESPORITES NOVICUS ZONE

Interval zone whose top is defined by the last appearance of P. novicus. The last appearances of Distriatites insolitus, Vittatina ovalis, V. costabilis, Laevigatosporites callosus and Pretricolpipollenites bharadwaji usually coincide with the zone's top. The following taxa also extend

STAGE	F O S S I L S	
RHAETO-NORIAN (VII *	RHAETOGONYAULAX RHAETICA NORICYSTA FIMBRIATA RHAETIPOLLIS GERMANICUS LIMBOSPORITES LUNDBLADII CLASSOPOLLIS TOROSUS STRIATISACCUS RHAETICUS	SUESSIA SWABIANA SVERDRUPIELLA SP. RICCISPORITES TUBERCULATUS GRANULOPERCULATIPOLLIS RUDIS KYRTOMISPORITES SPP.
CARNIAN (VI)	PATINASPORITES DENSUS DUPLICISPORITES GRANULATUS CAMEROSPORITES SECATUS LUNATISPORITES ACUTUS	PRaecIRCULINA GRANIFER PARACIRCULINA SCURRILIS OVALIPOLLIS OVALIS TRIADISPORA VERRUCATA
LADINIAN (V)	PODOSPORITES AMICUS EUCOMMIDITES MICROGRANULATUS TRIADISPORA PLICATA ANGUSTISULCITES KLAUSII MICROCACHRYDITES SITTLEI DUPLICISPORITES GRANULATUS	ECHINITOSPORITES ILIACOIDES RETISULCITES PERFORATUS TRIADISPORA CRASSA MICROCACHRYDITES DOUBINGERI PARACIRCULINA SCURRILIS LUNATISPORITES ACUTUS
ANISIAN (IV)	ARATKISPORITES SATURNI ARATRISPORITES PALETTAE BRACHYSACCUS OVALIS ALISPORITES GRAUVOGELI KEUPERISPORITES BACULATUS DENSOISPORITES NEJBURGII TRIADISPORA PLICATA SPINOTRILETES ECHINOIDES KUGLERINA MEIERI ANGUSTISULCITES KLAUSII PLATYSACCUS QUEENSLANDI	ARATRISPORITES CENTRATUS ARATRISPORITES FIMBRIATUS LUNATISPORITES PELLUCIDUS VOLTZIACEASPORITES HETEROMORPHUS RAISTRICKIA SP. B TRIADISPORA CRASSA CRISTIANISPORITES TRIANGULATUS ACRITARCHS MICROCACHRYDITES DOUBINGERI PLATYSACCUS LESCHICKII
SCYTHIAN (III)	LUNATISPORITES NOVIAULENSIS ACRITARCHS KRAEUSELISPORITES APICULATUS DENSOISPORITES PLAYFORDI	ENDOSPORITES PAPILLATUS KRAEUSELISPORITES CUSPIDUS KRAEUSELISPORITES SEPTATUS DENSOISPORITES NEJBURGII
THURING- IAN (II)	LUECKISPORITES VIRKKIAE STRIATOPODOCARPITES RARUS PROTOHAPLOXYPINUS DIAGONALIS PROTOHAPLOXYPINUS RICHTERI LIMITISPORITES MOERENSIS GUTHOERLISPORITES CANCELLOSUS	KLAUSIPOLLENITES SCHAUBERGERI PROTOHAPLOXYPINUS VARIUS PROTOHAPLOXYPINUS LIMPIDUS PROTOHAPLOXYPINUS MICROCORPUS FALCISPORITES ZAPFEI
AUTUNIAN (I)	DISTRIATITES INSOLITUS VITTATINA OVALIS PLICATIPOLLENITES INDICUS PUNCTATOSPORITES MINUTUS LOPHOTRILETES NOVICUS	POTONIESPORITES NOVICUS VITTATINA COSTABILIS PROTOHAPLOXYPINUS MICROCORPUS LAEVIGATOSPORITES CALLOSUS

Table 1. The most time-significant taxa in the Permo-Triassic (*) Modified from Cousminer (1981b)

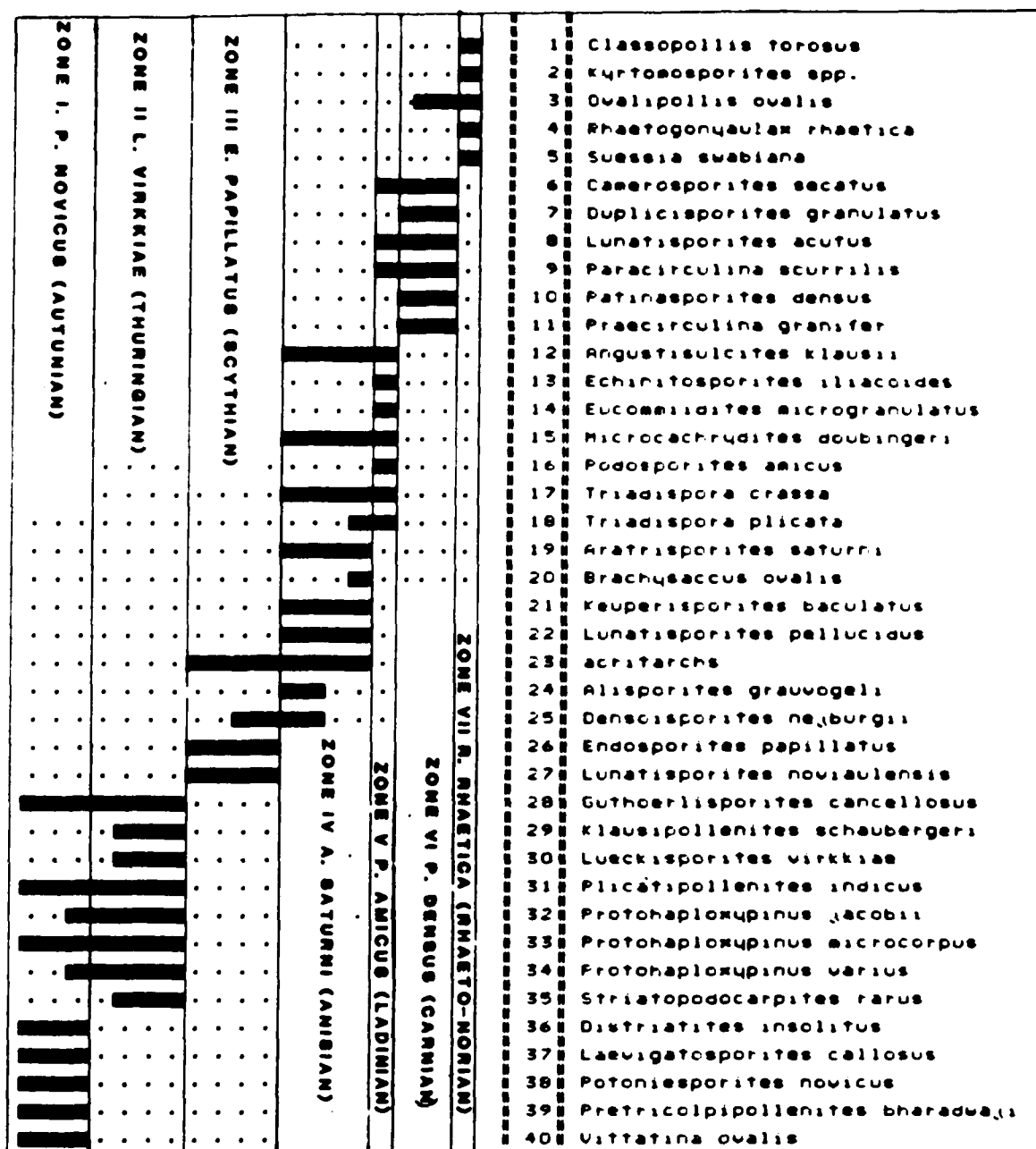


Figure 4. The Permo-Triassic palynozones of Israel.

only marker and selected short-range taxa are indicated. For complete details, see Appendices 4, 6, 8, 10, and 12.

into the overlying zone: Protohaploxylinus varius, P. microcorpus, P. jacobii, P. hartii, Plicatipollenites indicus and Guthoerlisporites cancellosus. The zone is named after P. novicus which is the most common sporomorph in it.

In addition to the abundance of P. novicus, Zone I contains many striate bisaccates, such as D. insolitus, Vittatina spp., and Protohaploxylinus microcorpus. Large rounded sporomorphs with trilete mark are common; these are Nuskoisporites dulhuntyi, Plicatipollenites indicus, Guthoerlisporites cancellosus and Endosporites hexareticulatus. In some intervals, Zone I was found to alternate with an assemblage of small trilete and monolete spores such as Reticuloidosporites warchianus, P. bharadwaji, Lophotriletes novicus and Punctatosporites minutus. In this alternation, the marker fossils continue to appear, but the dominant groups change. This phenomenon was observed in the Zuk Tamrur 1, Pleshet 1 and Zohar 8 wells. The alternations are believed to be environmentally controlled and are discussed separately.

The reference section for the P. novicus Zone is the Pleshet 1 well, interval 5036-5310 m. It was identified also in the Makhtesh Qatan 2, Zohar 8, Ramon 1 and Zuk Tamrur 1 wells, in the Negev and the southern Coastal Plain. The zone was not penetrated by any of the wells in northern Israel, due to its great depth of burial there. Its relatively homogenous composition at the Negev and Coastal Plain

probably reflects uniform conditions throughout the area.

This zone occurs within the Sa'ad Formation and part of the overlying Arqov Formation. Its upper boundary was placed at the lower Arqov Formation in the Makhtesh Qatan 2 and Zohar 8 wells. In the Zuk Tamrur 1 well, it occurs in the upper Arqov Formation. Its lower boundary contact, wherever penetrated, is at the unconformity with the Precambrian clastics of the Zenifim Formation. Its thickness ranges between 100 and 200 m. Variability in thickness seems to be controlled by the continental depositional environments that prevailed during most of Sa'ad and part of Arqov times.

Zone I is assigned to the Early Permian (Autunian Stage). A similar palynologic assemblage of Vittatina spp. and P. novicus was reported from Autunian strata in France and Germany (Doubinger, 1974). In their discussion of the Saxonian Stage, Visscher et al. (1974) assigned assemblages similar to Zone I to the Autunian. They used this evidence as an argument for discarding the Saxonian stage. An Early Permian age was assigned to some core samples from the Ramon 1 and Makhtesh Qatan 2 wells in southern Israel, which contained an assemblage identical in composition to Zone I (R. Dunay, written commun., 1974). With slight modification, the major components of Zone I occur in North and West Africa (Leschik, 1959; Jardine', 1974; Doubinger & Fabre, 1983) as well as in South Africa (Falcon, 1975), Pakistan (Balme, 1970), and India (Bharadwaj & Srivastava, 1969).

Early Permian assemblages, containing Vittatina spp. were reported from Canada (Jansonius, 1962). In his discussion of the Carboniferous-Permian boundary, Balme (1980) assigned assemblages dominated by Potoniesporites and Parasaccites to the Carboniferous, although they range also into the Early Permian. B. Balme (1985, pers. commun.) studied some of the samples from Zone I in Israel and confirmed their Early Permian age, based on similarity to equivalent assemblages in the Salt Range, Pakistan. Correlation of Zone I to the important sections throughout the world were discussed by Eshet (1983). Since this interval did not contain significant ammonites, foraminifers or ostracodes, age determination is based solely on palynologic evidence.

ZONE II: LUECKISPORITES VIRKKIAE ZONE

Interval zone whose top is defined by the last appearance of Lueckisporites virkkiae. Species of Protohaploxypinus (Protohaploxypinus varius, P. richteri, P. microcorpus and P. jacobii) are typical of the uppermost part of the zone. Klausipollenites schaubergeri, Plicatipollenites indicus and Striatopodocarpites rarus also have last occurrences at the top of the zone. Other taxa that are restricted to Zone II are Guthoerlisporites cancellosus and Falcisporites zapfei. As indicated by Figure 4, the top of this zone is marked by the disappearance of most of its significant taxa, none of which continues into the overlying zone. The following taxa

first appear in the underlying P. novicus Zone (Zone I): P. varius, P. microcorpus, P. hartii, P. indicus and G. cancellosus. The ranges of the rest of the fossils are restricted to this zone only.

Zone II is named after Lueckisporites virkkiae which is common in it and is considered to be a Late Permian marker fossil in Europe and Pakistan.

In most of the wells, the upper part of Zone II is characterized by an abundance of Protohaploxylinus spp. that occur in smaller numbers lower in the section. Reworked organic material is abundant in the upper part of the zone. Striate bisaccates form the most prominent palynologic group in this zone. Other taxa that occur in Zone II are Protohaploxylinus limpidus, P. diagonalis, Densoisporites complicatus and Limitisporites moerensis. Of special interest is the abundance of fungal spores in the Zohar 8 and Pleshet 1 wells, which may reflect provincialism of this group. In most of the sections, the upper limit of Zone II is marked by the last appearance of many taxa, although some fossils range also above the limit.

Reference sections for Zone II are in the Zohar 8 well (interval 2776-3076 m) and Makhtesh Qatan 2 well (interval 2051-2250 m). The zone was also identified in the Pleshet 1 and Ramon 1 wells in the Negev.

The L. virkkiae Zone occurs within part of the Arqov Formation and the lower Yamin Formation. Its upper boundary

is placed in the lower Yamin Formation in the Makhtesh Qatan 2 and Ramon 1 wells, and in the upper Yamin Formation in Zohar 8. It also occurs in the Yamin and part of the Zafir Formations in the Pleshet 1 well in a short interval of red beds.

Zone II is assigned to the Late Permian (Thuringian Stage). Age determination is based on the occurrence of L. Virkkiae, K. schaubergeri and P. varius, all of which are considered Late Permian markers in both Europe and Gondwana. Since only sparse fauna was found in these strata (Gerry & Derin, 1981), it is difficult to support this age by other paleontological evidence. However, in places where Late Permian fauna were found, they were in agreement with the palynological data, such as in Pleshet 1 well (B. Derin, 1986 written commun.).

Late Permian assemblages, almost identical to Zone II, were reported from the Serie de L'Agoula, Gabon (Jardine, 1974) and the Salt Range, Pakistan (Balme, 1970). In Europe, Klaus (1965) reported that in the Alpine realm, Late Permian strata are characterized by L. virkkiae, K. schaubergeri, and Falcisporites zapfei. The first two species were proposed as Late Permian markers in ammonite-controlled strata in Europe (Visscher & Brugman, 1981). Similar assemblages also were reported from England (Clark, 1965) and Ireland (Visscher, 1971). In the Germanic Facies of Central and Northern Europe, the Zechstein yielded assemblages similar

to Zone II (Geiger & Hopping, 1968; Dybova-Jachowicz, 1974). Correlations with Zone II throughout the world were described by Eshet (1983).

ZONE III: ENDOSPORITES PAPILLATUS ZONE

Interval zone whose top is defined by the last appearance of Endosporites papillatus. Lunatisporites noviaulensis usually last appears at the top of the zone. Species of Kraeuselisporites are common in Zone III. In addition, the base of the zone is marked by the first occurrence of acritarchs. The sporomorph species Falcisporites stabilis first appear in the underlying Zone II and continues to appear in Zone III.

Zone III is named after its marker and most common sporomorph E. papillatus, which is known from equivalent strata in Europe and the Southern Hemisphere.

The E. papillatus Zone contains a relatively low diversity of taxa. On the other hand, assemblages are homogenous, distinctive, and are dated easily by their well-dated markers. The most characteristic feature of the zone is the abundance of E. papillatus and L. noviaulensis. Kraeuselisporites septatus and K. cuspidus are common. Acritarchs are abundant and can reach to more than 70% of the assemblage. Compared to Zone II, Zone III is characterized by a sharp decrease in the striate bisaccate group (Figure 5). Other fossils that may occur in Zone III are Striatoabieites

multistriatus, Densoisporites playfordi, Lundbladispora brevica, Falcisporites stabilis, Densoisporites neiburgii, Alisporites opii, and Verrucosisporites thuringiacus.

The reference section for Zone III is the interval 1756-2051 m in the Makhtesh Qatan 2 well. It was identified also in the Devora 2A, Pleshet 1, Helez Deep, Zuk Tamrur 1, Zohar 8 and Ramon 1 wells. B. Derin (1986, written commun.) had argued that the Karmia Shale that contained the zone in the Helez Deep well, is an interval within an Anisian-Ladinian conglomerate (the Or Haner Conglomerate). If he is correct, then the Scythian assemblage in this well must be reworked.

Zone III occurs in a lithostratigraphic interval that ranges from the Yamin Formation to the upper part of the Zafir Formation. The thickness of the zone is about 200 m in the Negev (Makhtesh Qatan 2, Zohar 8 and Ramon 1 wells). It is thicker in the Zuk Tamrur 1, and thinner in the Pleshet 1 wells. In the Helez Deep well, the zone occurs in the Karmia Shale. This unit has been argued to be invalid and was included within the Or Haner Conglomerate by B. Derin (written commun., 1986). The lower boundary of Zone III was not penetrated in the Devora 2A well.

An Early Triassic (Scythian) age is assigned to Zone III. It is based on the studies of R. Dunay (written commun., 1974) and Visscher & Brugman (1981), who described E. papillatus as a Scythian marker species, as well as the

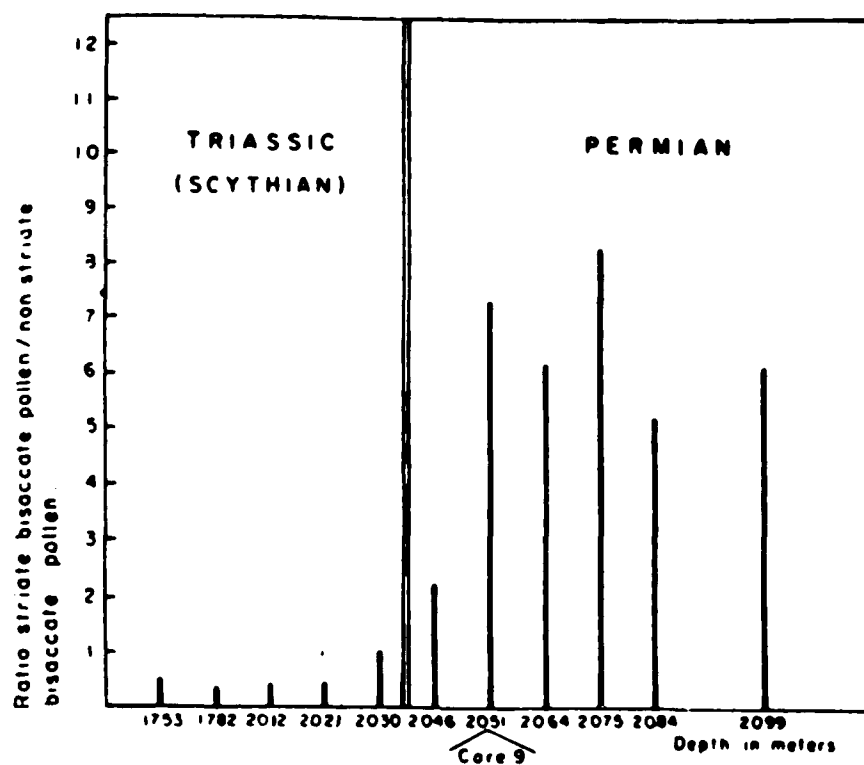


Figure 5. Changes in the striate/non striate bisaccate ratio across the Permian-Triassic boundary in the Makhtesh Qatan 2 well.

study of Geiger & Hopping (1968) that included L. noviaulensis among the markers for the Early Triassic. The age determination is supported by the Glomospira spp. and Meandrospira julia foraminifer zones, and by the "Monoceratina C" ostracode Zone of Derin & Gerry (1981).

Zone III is correlatable to sections in both Gondwana and Laurasia. In Australia, Early Triassic assemblages contain L. noviaulensis, Kraeuselisporites spp. and abundance of acritarchs (Balme, 1963; Dolby & Balme, 1976). L. noviaulensis and Kraeuselisporites spp. were also reported from the Salt Range, Pakistan (Balme, 1970).

In Laurasia, many sections contain assemblages which are similar to Zone III in their most prominent taxa. E. papillatus was reported from Lower Triassic strata in Ireland (Visscher, 1971). It occurs with L. noviaulensis in the Buntsandstein of Germany (Klaus, 1965; Reinhardt & Schon, 1964). The abundance and variety of acritarchs in the Early Triassic is reported both by Visscher & Brugman (1981) and Balme (1978). Early Triassic assemblages in Poland were identical to Zone III (Orlowska-Zwolinska, 1977). In North America, Early Triassic assemblages from the Peace River, Canada (Jansonius, 1962) and Arctic Canada (Fisher, 1979), show similarity to Zone III in Israel. These correlations between Early Triassic key sections throughout the world were discussed by Eshet (1983).

ZONE IV: ARATRISPORITES SATURNI ZONE

Interval zone whose top is defined by the last appearance of Brachysaccus ovalis, Cristianisporites triangulatus and Keuperisporites baculatus. These markers are not always found together at the top of the zone, but the last appearance of any of them can mark the upper boundary of Zone IV. Other age-significant taxa are Voltziaceasporites heteromorphus, Densoisporites nejburgii, Alisporites grauvogeli, Triadispora plicata, T. crassa and Angustisulcites klausii, most of which continue into the overlying Zone V. The last appearance of acritarchs marks the upper boundary of Zone IV. D. nejburgii and F. stabilis range from the underlying Zone III into this zone. The zone is named after its major component, A. saturni.

Zone IV is characterized by an abundance and diversity of species of Aratrisporites. A. saturni and A. centratus dominate, but A. fimbriatus, A. pallettae, A. major, and A. scabratus are also found. Brachysaccus ovalis, Alisporites grauvogeli and V. heteromorphus are other prominent components. At the base of this zone, the abundant Aratrisporites are replaced by Lunatisporites pellucidus which has its first appearance in that horizon. Keuperisporites baculatus occurs in a restricted province in Zohar 8-Zuk Tamrur-Ramon 1 area, where it is found in relatively high numbers. Acritarchs that begin in the underlying Zone III, continue to be abundant in Zone IV. They have their last appearance at the

top of the zone. In the Makhtesh Qatan 2 well, the interval containing A. saturni is subdivided into 3 zones (Eshet, 1983). That subdivision does not seem to be applicable to the other sections in this study and, therefore, may be of local significance only.

A high species diversity is another feature of Zone IV. Species diversity, which is very low in the underlying Scythian Zone III, increases here and continues to be high in the overlying zone. Other species which may occur in Zone IV are Cyclotriletes granulatus, C. oligogranifer, Platysaccus leschikii, Cycadopites coxii, Spinotriletes echinoides, Verrucosisporites thuringiatus, Raistrickia sp. B, Raistrickia sp. C, Lueckisporites singhii, Falcisporites stabilis, D. nejburgii, Micrhystridium spp., Veryhachium spp., Cristatisporites triangulatus, Platysaccus triassicus, P. queenslandi, Triadispora crassa, T. staplini, T. falcata, Vitreisporites pallidus, Kuglerina meieri, Dyupetallum spp., Parillinites vanus, Chordasporites singulichorda, Cristatisporites baculatus, Reticulatisporites nov. sp., Microcachrydites doubingeri, Microcachrydites sittleri, Cuneatisporites radialis, Angustisulcites klausii, Lunatisporites transversundatus, Sellaspora rugoverrucata, Aequitriradites minor, and Cristatisaccus margitatus.

The reference section for the A. saturni Zone is the Zuk Tamrur 2 well, interval 1631-1794 m. It also appears in the Makhtesh Qatan 2, Ramon 1, Zohar 8, Plesheth 1 and Devora

2A wells. Zone IV is missing only in the Helez Deep well, where some of its markers appear to be reworked within the Erez Conglomerate. The occurrence of the zone in the Devora 2A well helps to correlate between northern and southern Israel.

The A. saturni Zone was defined in most of the sections between the top of the Zafir Formation and the lower part of Saharonim Formation. In Makhtesh Qatan 2 well, its upper boundary was placed at the Gevanim/Saharonim boundary. Most of the zone is included within the Gevanim and Ra'af Formations.

Zone IV is assigned to the Anisian Stage. Although A. saturni also is known from younger strata, such as the Keuper in Germany (Madler, 1964), B. ovalis and L. pellucidus are primarily Anisian taxa (Madler, 1964; De Jersey, 1968a, 1968b accordingly). T. crassa and T. plicata have been reported from Anisian strata in the Netherlands (Visscher, 1966). Other taxa in this zone, such as Cristianisporites triangulatus and Keuperisporites baculatus are known from Anisian strata in Europe (Antonescu, 1970). Visscher & Brugman (1981) consider A. grauvogeli, V. heteromorphus and Dyupetallum spp. to be Anisian markers in the Alpine Triassic in Europe. The Anisian age is also supported by ammonites, foraminifers and ostracodes that occur in the same lithostratigraphic levels in outcrops (Parnes et al., 1985; Benjamini, 1984; Derin & Gerry 1981).

Zone IV can be correlated, with some modifications, to other Anisian key sections worldwide. In Europe, correlation is good to Muschelkalk strata (Madler, 1964; Geiger & Hopping, 1968; Klaus, 1964; Visscher, 1966). The abundance and variety of acritarchs in the Anisian was reported by Visscher & Brugman, (1981) from Europe, and by Sarjeant (1970) from the Salt Range, Pakistan. In England, Fisher (1972), recovered palynologic assemblages which were correlative to Zone IV from the Waterstones. Similar results were also obtained by other studies of the British Anisian (Clark, 1965; Elliot, 1961; Warrington, 1974). Assemblages from the Muschelkalk in the North Sea and France include Triadispora spp. A. grauvogeli, A. klausii, L. latus and C. triangulatus (Taugourdeau-Lanz, 1974; Geiger & Hopping, 1968). The Anisian in the Vicentinian Alps, Italy (Van der Eem, 1983), contained many of of Zone IV markers. Antonescu (1970) found in Romania an Anisian assemblage, identical to Zone IV. Anisian assemblages from Libya, contain A. saturni and A. centratus (Brugman (1985). Similarly, sections from Arctic Canada include assemblages similar to Zone IV (Fisher, 1979).

Sections in Gondwana also demonstrate good correlation with Zone IV. L. pellucidus and Aratrisporites spp. are important components in the Australian Anisian (De Jersey & Hamilton, 1969; Dolby & Balme, 1976; De Jersey, 1968a, 1968b). These palynologic correlations throughout the world

are discussed by Eshet (1983).

ZONE V: PODOSPORITES AMICUS ZONE

Interval zone whose top is defined by the last appearance of Podosporites amicus. The last appearance of Echinitorites iliacoides and Eucommiidites microgranulatus also coincides with the zone's top. Other age-significant sporomorphs that usually have their last appearance at the top of the zone are Triadispora plicata, T. crassa, Microcachrydites doubingeri and Kuglerina meieri. Zone V is named after Podosporites amicus, one of its age-significant taxa in ammonite-controlled strata in Europe.

The high species diversity found in Zone IV continues into Zone V. The two zones differ because Zone V is composed almost entirely of bisaccate pollen grains, whereas Zone IV also contains many spores. The following taxa are likely to be found in this zone: Triadispora modesta, T. plicata, Platysaccus reticulatus, P. papilionis, Pityosporites rutneri, A. klausii, Microcachrydites sittleri, Sellaspora rugoverrucata, Enzonalasporites vicens, Ellipsovelatisporites plicatus, Aratrisporites pallettae, Reticulatisporites sp., Cuneatisporites radialis, Lunatisporites transversundatus, L. pellucidus, Cristatitriletes baculatus, Platysaccus queenslandi, P. triassicus, Infernopollenites sulcatus, Lueckisporites singhii, Cyclotriletes oligogranifer, and Chordasporites singulichorda. Acritarchs, which were abundant in Zone IV, have their last appearance at the base of

Zone V, except for the Devora 2A well, where they continue to appear. Some of the important taxa in the overlying Zone VI, already have their first appearance in Zone V. Examples are Duplicisporites granulatus, Paracirculina scurrilis, Lunatisporites acutus and Camerosporites secatus.

The reference section for the P. amicus Zone is the Makhtesh Qatan 2 well, interval 1161-1345 m. It occurs in all the sections studied for this research, except for the Helez Deep well, where the time-interval covered by this zone is represented by the Erez Conglomerate. This conglomerate contains reworked palynomorphs from Zone V.

The P. amicus Zone occurs in most of the sections within the interval from lower to upper Saharonim Formation. In the Makhtesh Qatan 2 well its upper boundary had been placed at the Gevanim/Saharonim transition (Eshet & Cousminer, 1986).

A Ladinian age is assigned to Zone V. This age is based primarily on the Ladinian age assigned to Echinitosporites iliacoides from ammonite-controlled strata in Europe (Vischer & Brugman, 1981) and to P. amicus and E. microgranulatus in Switzerland (Scheuring, 1970). The stratigraphic interval from the lower to the upper Saharonim Formation, which contains Zone V, was dated to be Anisian in its outcrops by detailed ammonite zonation (Parnes *et al.*, 1985; Parnes, 1986); this dating is also supported by foraminiferal and ostracode age determinations (Derin & Gerry, 1981).

A reliable correlation of Zone V to important Ladinian sections worldwide can be made. In Europe, palynomorphs of this zone are reported from the Upper Muschelkalk, Lettenkohle, and Tonplatten Formations. In Switzerland and England, Scheuring (1970) and Eliot (1961) reported on assemblages identical to Zone V. Based on the occurrence of Carnian palynomorphs in Lettenkohle strata in France, Gradstein (1971) regarded it as Carnian in age, which appears unacceptable. Orłowska-Zwolinska (1977) found P. amicus to be a Ladinian marker in Upper Muschelkalk strata in Poland. Additional correlations were summarized by Eshet (1983).

ZONE VI: PATINASPORITES DENSUS ZONE

Interval zone whose top is defined by the last appearance of Patinasporites densus. Except for Ovalipollis ovalis, all of the age-significant taxa in this zone have their last appearance at its top.

The zone is named after Patinasporites densus which is a well-established marker fossil in the Northern Hemisphere.

The most striking feature of Zone VI is the abundance of taxa belonging to the Circumpolles subturmae. These are Paracirculina scurrilis, Praecirculina granifer, Duplicisporites granulatus, Camerosporites secatus and Spiritisorites spirabilis. P. densus is the only monosaccate in this zone. The most important bisaccate pollen are Lunatisporites acutus and O. ovalis. Other bisaccates are Striatoabieites

aytugii, Triadispora suspecta, T. obscura, T. stabilis, T. modesta, Platysaccus papilionis, Pityosporites ruttneri, Ellipsovelatisporites rugosus, Infernopollenites sulcatus, and Parillinites vanus. Other sporomorphs in Zone VI are Pseudoenzonalasporites summus, Reticulatisporites sp., Protodiploxypinus gracilis, Porcellispora londonensis, Enzonasporites vigens and Sellaspora rugoverrucata. In most samples, Circumpolles taxa form more than 60% of the assemblage. Many palynomorphs of this zone also occur in the underlying Zone V, which raises problems with the determination of the base of Zone VI. The top of the zone is often barren and is overlain unconformably by Jurassic strata.

The reference section for the P. densus Zone is the Makhtesh Qatan 2 well, interval 916-1161 m. The zone occurs throughout the study area where it is characterized by a relatively homogenous composition in most of the wells. It thickens northwards, to about 900 m in the Devora 2A well.

Zone VI occurs in most of the studied wells within the interval from the upper Saharonim Formation to the top of the Mohilla Formation. In the Ga'ash 2 well, this zone is overlain by the Norian Shefaiym Formation. In the remainder of the sections, it is overlain by the Early Jurassic Mish'hor Formation.

A Carnian age is assigned to Zone VI. The age determination is based primarily on sporomorphs; most of its evaporitic strata are devoid of ammonites and foraminifers. The

occurrence of the Carnian conodont Metapolygnatus polygnathiformis near the top of the Mohilla Formation in an outcrop in Makhtesh Ramon (Eicher & Mosher, 1974), helped to date this interval. However, the joint occurrence of Carnian fossils, coupled with the abundance of Circumpolles taxa, suggest a Carnian age. The stratigraphic position, between Ladinian ammonite zones (Parnes et al., 1985) and the Jurassic Mish'hor Formation, also support this age determination.

The Carnian assemblage of Israel shows close affinities with other Carnian assemblages described in the literature, especially in Laurasia. Among these are the Keuper Marl Facies in England (Fisher, 1972; Warrington, 1970) which contained an abundance of C. secatus and other Circumpolles taxa. Palynomorphs of Zone VI were reported from Switzerland (Scheuring, 1970), although bisaccates are more common there than in Israel. Cordevolian strata in Austria contained an assemblage identical to Zone VI. (Dunay & Fisher, 1978). The abundance of C. secatus and other Circumpolles taxa in ammonite-controlled strata in Sicily led Visscher & Krystyn (1978) to suggest the "Camerosporites Phase". This is equivalent to "Phase I" of the palynological sequence suggested by Schuurman (1977) for the Late Triassic-Early Jurassic transition. The "Camerosporites Phase", which is very similar in composition to Zone VI, is reported from many localities in the Northern Hemisphere: France (Boutet,

1980); Poland (Putsch, 1973); the North Sea (Geiger & Hopping, 1968) and North America (Cornet, 1977; Robbins, 1981). In the U.S.A., the Triassic section of the Newark Supergroup is composed of abundant bisaccates, while Circumpolles taxa can be relatively rare. An abundance in bisaccates with only rare Circumpolles taxa was also reported from Morocco (Cousminer & Manspeizer, 1976). On the other hand, the Gondwanian assemblages are somewhat different from Zone VI, although they contain P. densus and C. secatus (Dolby & Balme, 1976).

ZONE VII: RHAETOGONYAULAX RHAETICA ZONE

Interval zone whose top is defined by the last appearance of the dinoflagellate Rhaetogonyaulax rhaetica and other Triassic dinoflagellates. Its base is marked by the first appearance of post-Carnian sporomorphs, such as Classopollis torosus, Gliscopollis meyeriana and species of Kyrtomispories that extend into the overlying Jurassic strata. Other age-significant taxa are the dinoflagellates Noricysta spp., Suessia swabiana, Heibergella asymmetrica and Sverdrupiella sp. The zone is named after Rhaetogonyaulax rhaetica, a well-established marker throughout the world.

Zone VII occurs in the study area in two palynologic facies. The first includes the dinoflagellates, pollen and spores listed above as markers. It also includes Gliscopollis meyeriana, Classopollis torosus, Kyrtomispories laevi-

gatus and Striatissaccus rhaeticus. In the second palynologic facies, dinoflagellates are missing. The facies contains post-Carnian taxa such as Classopollis torosus, Granuloperculatipollis rudis and Kyrtomisorites spp.

The reference section for this zone is the Ga'ash 2 well, interval 4495-4860 m (Cousminer, 1981b). It has a very limited distribution in the study area, because of truncation at the Triassic/Jurassic transition. The zone is represented best along the Coastal Plain. Cousminer (1981b) recovered the only known Zone VII in the "dinoflagellates facies" from the Ga'ash 2 well. The Helez Deep and Zohar 8 wells contained components of the Zone VII in the "non-dinoflagellate facies," along with C. torosus and Kyrtomisorites spp. In these two wells, the identification of Zone VII may be questionable. Unfortunately, samples from the Atlit well in the Coastal Plain contained Rhaeto-Norian foraminifers (B. Derin, 1986, written commun.), but no palynomorphs.

Zone VII occurs in the Shefayim Formation in the Ga'ash 2 well. In the Helez Deep and Zohar 8 wells it occurs in the uppermost part of the Mohilla Formation.

A Rhaeto-Norian age is assigned to Zone VII. The age is based on the occurrence of R. rhaetica and Suessia swabiana, which are considered Rhaeto-Norian markers in ammonite-controlled strata in Europe (Visscher & Brugman, 1981). The same stratigraphic horizon that contained Zone VII in the

Ga'ash 2 well, contained a Rhaeto-Norian assemblage of foraminifers in the adjacent Atlit well (B. Derin, written commun., 1986).

Rhaeto-Norian assemblages have been reported from several localities in the Northern Hemisphere. Norian sections in Arctic Canada contain a diverse assemblage of dinoflagellates (Felix, 1975; Wiggins, 1973; Bujak & Fisher, 1976). Norian sections with dinoflagellates have been reported from England (Sarjeant, 1963; Fisher, 1972; Warrington, 1982). In the Rhaetian type-section, Kendelbachen Graben of Austria, Morbey (1975) was able to establish a palynozonation for the section. His Rhaetian zones included dinoflagellates such as Suessia swabiana, as well as pollen and spores such as those reported above for Zone VII in the Ga'ash 2 well.

Although the Ga'ash 2 well provides concrete evidence for the preservation of a Rhaeto-Norian interval along the Coastal Plain, much more detailed information from the subsurface is needed in order to establish conclusive age determinations and a palynologic zonation for this time-span.

COMPARISON WITH OTHER BIOZONATIONS IN ISRAEL

Various authors have established a biozonal framework to account for similarities and differences in the Permian-Triassic interval of the study area. Ammonite zones were established for only a minor part of the section, especially

for Middle Triassic marine strata. Unfortunately, the Late Triassic and Permian intervals are, so far, devoid of ammonites. Ammonite zonation was first established by Parnes (1975) and has been revised recently (Parnes et al., 1985; Parnes, 1986). Conodonts have been found in Lower Triassic strata in the Makhtesh Qatan 2 well (Hirsch, 1975). A regional zonation of foraminifers and ostracodes has been established by Derin & Gerry (1981). However, no foraminifers and ostracodes have been found in most of the latest Permian and lowermost Triassic strata; they also are absent in Carnian strata of southern Israel. Table 2 presents a regional synthesis showing a comparison between age determinations suggested by various paleontologic groups.

RELATIONSHIPS BETWEEN PALYNOZONES AND LITHOSTRATIGRAPHY

The palynozones of the Permo-Triassic sequence in Israel form a chronostratigraphic framework for this time-span. One can argue that these zones represent common palynologic associations that might be environmentally dependent and, hence, cannot serve as chronostratigraphic units. Because most sedimentary rock units reflect their depositional environment, and are environmentally dependent, the validity of the zone boundaries as time-lines could be tested by comparing them to the lithostratigraphic boundaries. This comparison is presented in Table 3, where the boundaries of each palynozone are plotted against the lithostratigraphic subdivision for the Permian (Weisbrod, 1981) and the Triassic

[illegible]

Table 2. Comparison of the major biozones in the
Permo- Triassic of Israel.

AGE	PALYNOZONE	FORMATION	LITHOLOGY (GENERALIZED)
RHAETO- NORIAN ?????????	RHAETOGONYAULAX RHAETIA SPP. (ZONE VII)	SHEFAIYM (in Ge'ash 2 well only)	CARBONATES WITH SOME SHALE
CARNIAN ////////	PATINASPORITES DENDUS (ZONE VI)	MOHILLA	MOSTLY GYPSUM, DOLOMITE AND ANHYDRITE; SOME MARL AND LIMESTONE
LADINIAN ////////	PODOSPORITES AMICUS (ZONE V)	SAHARONIM	MOSTLY LIMESTONE; SOME MARL ; DOLOMITE AND GYPSUM AT TOP
ANISIAN ////////	ARATRISPORITES SATURNI (ZONE IV)	GEVANIM	SANDSTONE; SILTSTONE; MINOR CLAY AND SHALE
SCYTHIAN ////////	ENDOSPORITES PAPILLATUS (ZONE III)	RA'AF	LIMESTONE AND SHALE
THURINGIAN ////////	LUECKISPORITES VIRIDIAE (ZONE II)	ZAFIR	CARBONATES AND SHALE; MORE CLASTICS IN UPPER PART
AUTUNIAN	POTONIESPORITES NOVICUS (ZONE I)	YAMIN	MOSTLY LIMESTONE
		ARQOV	LIMESTONE, DOLOMITE AND SHALE; SOME SANDSTONE HORIZONS
		SA'AD	MOSTLY SANDSTONE; SOME SHALE

Table 3. Relationships between litho- and
 chronostratigraphic units in the Permo-Triassic of
 Israel.

(Druckman, 1974). Table 3 shows that none of the palynozone boundaries coincides with formation boundaries: The top of Zone I (Early Permian) is found in most of the wells at the lower part of the Arqov Formation; it also includes the underlying Sa'ad Formation. Lithological changes from clastics to carbonates or shales within these formations are not followed by marked palynological changes. The top of Zone II (Late Permian) is found in the upper part of the Arqov or at the lower part of the Yamin Formations; variations in its lithostratigraphic position are believed to be a result of different lithostratigraphic interpretations. The top of Zone III (Early Triassic) is found in the upper part of the Zafir Formation; the associated assemblage does not seem to change with lithology within this formation. The top of Zone IV (Anisian), also, does not coincide with a formation boundary, but occurs in the lower part of the Saharonim Formation. Although it occurs in a variety of lithologies (carbonates of the Ra'af Formation, clastics of the Gevanim Formation) no marked palynological change could be traced across these lithological changes. The top of Zone V (Ladinian) is found in the upper part of the Saharonim Formation. The top of Zone VI (Carnian) occurs in most places at the top of the Mohilla Formation and is unconformably overlain by the Jurassic Mish'hor Formation. The fact that most of the zone boundaries do not match formation boundaries, and that major lithological changes within the column are not

associated with marked palynologic changes, suggest that the proposed palynozone boundaries are reliable time-lines. This is also supported by the good correlation between the palynological subdivision and the ammonite, foraminifer, conodont and ostracode-based subdivisions of the sequence (Table 2).

CORRELATION AND RELATIONS TO LITHOSTRATIGRAPHY

The palynozonation proposed for the Permo-Triassic in Israel allows a chronostratigraphic correlation to be made between the northern and southern parts of the region. Figure 6 shows that most of the palynozones have a relatively consistent occurrence throughout the area. Zone I (Early Permian) is found in all of the wells in the south. It has not been found in the north or the Coastal Plain, probably because no well was drilled deep enough to reach it. A similar distribution was found for Zone II (Late Permian), except that it is missing in the Zuk Tamrur 1 well, due to a possible hiatus. The Early Triassic Zone III is recognized in the south as well as in the north. Zones IV (Anisian), V (Ladinian) and VI (Carnian) are found throughout the study area, except for the Helez Deep well, where components of Zones IV and V occur as reworked particles in the Erez Conglomerate. Zone VII (Rhaeto-Norian) has a very limited distribution. It is definitely recognized in the Ga'ash 2 well (Cousminer, 1981b) but its occurrence in the Helez Deep and Zohar 8 wells is questionable.



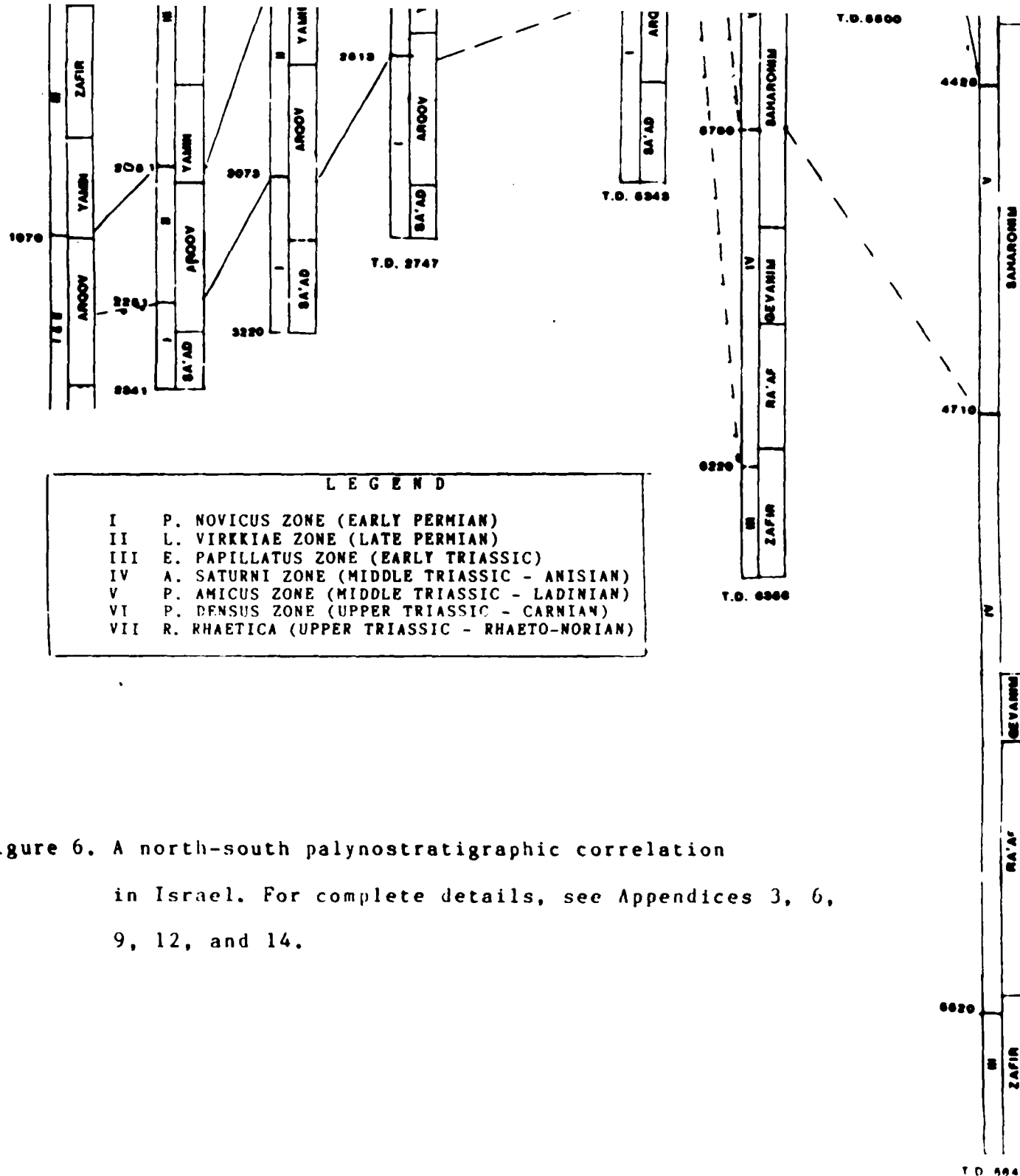


Figure 6. A north-south palynostratigraphic correlation in Israel. For complete details, see Appendices 3, 6, 9, 12, and 14.

During most of the Permo-Triassic southern Israel was a shelf or continental area, while deeper marine conditions prevailed in the north and in the Coastal Plain. As a result, thicker sedimentary sequences accumulated in the north and the Coastal Plain. This and the different depositional provinces between north and south makes lithostratigraphic correlation difficult and unreliable (Y. Druckman, Personal commun., 1985). These correlation problems were addressed by Druckman and Kashai (1981). The palynologic correlations (Figure 6) allow, for the first time, a refinement of the preliminary correlations of Druckman and Kashai (1981) and others.

Figure 6 shows the zones, their thickness, and their lithostratigraphic position in each of the wells. It is evident that the thicker sedimentary sequences in the north and Coastal Plain are also represented by thicker zones. For example, the Carnian Zone VI is about 1200 m thick in the northernmost well (Devora 2A) while it is only 240 m in the south (Ramon 1; Makhtesh Qatan 2). Also, the Ladinian Zone V is about 380 m thick in the north (Devora 2A) but only 130 m thick in the southernmost well (Ramon 1).

The correlation lines between the southern wells (Ramon 1, Makhtesh Qatan 2, Zohar 8, Zuk Tamrur) are relatively parallel, which suggests that the sedimentation rates were about the same. Figure 6 shows the same relationship between wells of the north and Coastal Plain (Devora 2A, Ga'ash 2,

Ramallah 1 and Helez Deep), although correlation is not as conclusive as it is for the south. Because most of the wells of this study were drilled in basins, changes in rates of sedimentation and thickness of palynozones as shown in Figure 6 cannot be related to changes in the regional tectonic regime.

BOUNDARY PROBLEMS

THE PERMIAN-TRIASSIC BOUNDARY

The stratigraphy and nature of the Permian-Triassic boundary has provided grounds for long-standing debates. Controversies have been fueled by incomplete sections, hiatuses, and by the provinciality of fossils. Debates have centered around the Late Permian (Waterhouse, 1976; Brugman, 1983). The Permian System itself presents a number of problems. So far, no definitely continuous sedimentary sequence across the Permian-Triassic boundary has been found (Sokratov, 1983). The result is that a complete biostratigraphic scale cannot be prepared for this part of the standard geologic column. The stratigraphic discontinuity has been interpreted as an almost world-wide regression of the sea during the time between the uppermost Permian and the lowermost Triassic zones. Such a regression is thought to have resulted in a "catastrophic" change of faunas at or near

the boundary. An Early Triassic ammonite zonation has been found to be reliable (Tozer, 1967), but some geologists argue that at least one more ammonite zone has to be added, between the earliest Triassic and latest Permian zones (B.E. Balme, 1985, personal commun.; Sokratov, 1983). The traditional placement of the boundary in Europe has been at the top of the Zechstein. This may be inaccurate on the basis of recent paleontological data (Brugman, 1983). The most continuous sections that contain the smallest hiatus at the boundary, occur in the Transcaucassia region of the Soviet Union (Sokratov, 1983) and in the Himalayan region (Gupta, 1983).

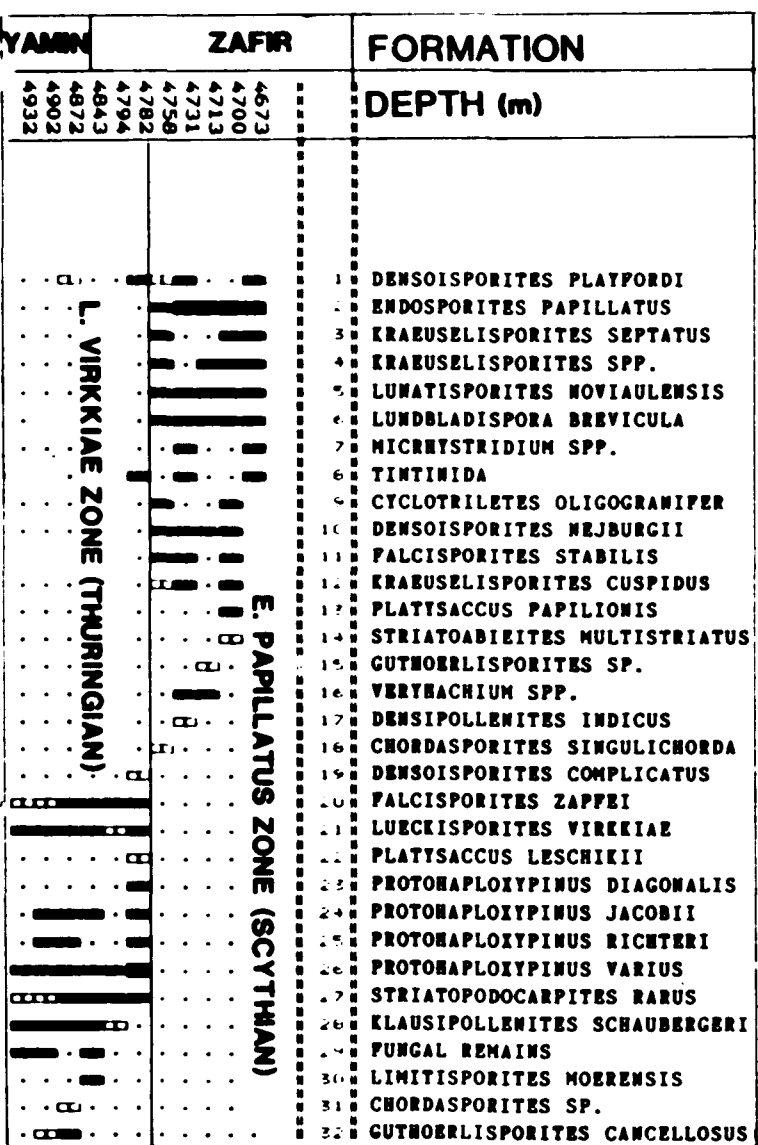
In Israel, the Permian-Triassic transition is known from the subsurface only; the succession is believed to represent a continuous sedimentation, with no obvious lithologic break (Weissbrod, 1981). However, red-bed rock samples from the recently-drilled borehole Pleshet 1 provide evidence for a local subaerial exposure at the boundary. Many problems in locating the exact stratigraphic position of the boundary in Israel are due to the subsurface origin of samples and to the lack of sufficient core samples. One of the major problems in locating the boundary is the fact that, except for palynomorphs, the transitional zone contains very few age-significant fossils. As indicated in Table 2, ammonites in Israel are not found before the Middle Triassic, and foraminifers and ostracodes are lacking in

most sections within the transitional zone. Palynomorphs, on the other hand, appear to delineate a continuous zonation across the Permian-Triassic boundary, which makes them useful for its determination.

Horowitz (1973) placed the Permian-Triassic boundary within the Zafir Formation in the Avdat 1 well, but at the contact between the Yamin and the overlying Zafir Formation in the Zohar 8 well. Eshet (1983, 1984), placed the boundary in the Makhtesh Qatan 2 well at the lower part of the Yamin Formation, based on the last appearance of a typical Late Permian (Thuringian) assemblage that contained Lueckisporites virkkiae, Klausipollenites schaubergeri, and many Protohaploxylinus spp. In that well, this assemblage was overlain by a definite Early Triassic (Scythian) assemblage dominated by Endosporites papillatus, Lunatisporites novialensis and Kraeuselisporites spp. A complete sequence of Late Permian and Early Triassic palynozones is identifiable in the Zohar 8 and Pleshet 1 wells, where many palynomorphs have a continuous range above and below the boundary, although many others become extinct at the boundary. Such transition at the Permian-Triassic boundary is best illustrated in Figure 7, from the Makhtesh Qatan 2 well. The figure shows that the boundary marks the last appearance of Thuringian (Late Permian) taxa such as L. virkkiae, K. schaubergeri and P. varius, as well the first appearance of Scythian (Early Triassic) forms such as E. papillatus, L.

noviaulensis and Kraeuselisporites spp. In the Pleshet 1 well, a complete sequence of palynozones occurs across the Permian-Triassic boundary, but almost all of the Permian sporomorphs become extinct there (Figure 8). These extinction, together with the red-bed lithology at the boundary suggest that part of the sequence might be missing due to either truncation or non-deposition.

A distinct unconformable contact can be seen in the Zuk Tamrur 1 well (Figure 9). In that section, a typical Autunian assemblage dominated by P. novicus, D. insolitus and many species of Protohaploxylinus and small trilete and monolete spores, is overlain by a well-dated Scythian assemblage of E. papillatus and L. noviaulensis; the Late Permian interval is not represented. Because this hiatus is unique in the studied sections, it is impossible at this point to correlate it with other localities. Table 4 summarizes the stratigraphic position of the Permian-Triassic boundary in different localities in Israel. It is clear that the boundary is located at different horizons throughout the study area. It is found in strata from the Arqov to the lower Zafir Formation. This inconsistency in stratigraphic position suggests that an irregular unconformity may mark the boundary, which resulted in the absence of parts of the Yamin or Arqov formations. The largest hiatus was identified in the Zuk Tamrur 1 well. The inconsistencies can also be the artificial result of different lithostratigraphic



WELL	FORMATION	DEPTH (m)
RAMON 1	ARQOV/YAMIN TRANSITION	1070
MAKHTESH QATAN 2	LOWER YAMIN	2051
ZOHAR 8	MIDDLE YAMIN	2776
ZUK TAMRUR 1	UPPER ARQOV	2513
PLESHET 1	LOWER ZAFIR	4782

Table 4. The stratigraphic position of the
Permian-Triassic boundary in the wells
studied for this research

interpretations, suggested by different authors (from the Pleshet 1 well, for example). Because paleontological resolution at the boundary provided by other fossil groups is not clear enough, it is impossible, at this point, to identify small-scale hiatuses by means of biostratigraphy. However, the evidence from the Pleshet 1 well indicates that subaerial exposure occurred at the Permian-Triassic boundary and led to the formation of red beds at least in that area.

THE TRIASSIC JURASSIC BOUNDARY AND THE RHAETO-NORIAN PROBLEM

The major problem with the concept of a transition from the Late Triassic to the Early Jurassic is the lack of type sections for the Norian and Rhaetian (For example, the section in the Kendelbachem Graben, Austria was established as a reference section only in 1975). The definition of the Rhaetian stage is based on the stratigraphic occurrence of either the ammonite Choristoceras marshi, or the pelecypod Rhaetavicula contorta. Weidman (1972) found the established Norian ammonite Rhabdoceras Suessi above Rhaetian strata containing R. contorta. Weidman et al. (1979) also found the Rhaetian C. marshi in Norian beds. Using palynomorphs, Fisher (1979) in Arctic Canada, and Smith (1982), in Svalbard, northwest Europe, showed that typical "Rhaetian" taxa such as Rhaetipollis, Chasmatosporites, Limbo-sporites, and Riccisporites, are present in Middle Norian strata in Canada and Early Norian strata (Kerri Zone) in Europe. This contradicting

evidence shed confusion on the ability to discern the uppermost part of the Late Triassic. Therefore, for the purposes of this study, the term "Rhaeto-Norian" is used for this time-interval. However, it must be stressed here, that despite such stratigraphic problems, Brugman (1983) was able to differentiate between Rhaetian and Norian strata based on their palynological composition, in the standard units established for the Late Triassic and Early Jurassic in Europe. The Triassic-Jurassic boundary is determined based on the occurrence of the ammonite Psiloceras planorbis (Tozer, 1967; 1974).

In southern Israel, the Triassic-Jurassic boundary is marked by the subaerial lateritic event that led to the deposition of variegated clays and flint clay of the Mish'hor Formation (Goldberg & Friedman, 1964). This formation is thought to have been deposited in a humid climate and records not only a large regression but also erosion and laterization of Upper Triassic strata. The weathering of earlier rocks may explain the occurrence of reworked Carnian palynomorphs in the Jurassic Mish'hor Formation in the Helez Deep well. The Mish'hor Formation is devoid of palynomorphs in most localities; the taxa that do occur have no chronostratigraphic importance, being mostly trilete spores and Classopollis torosus. Equivalents to this Early Jurassic lateritic zone, probably Liassic in age, occur all over Europe; they include the bauxite deposits of Greece. Goldberg

& Friedman (1964) and Druckman (1974; 1976) found that the Upper Triassic section in southern Israel is truncated in a diagonal manner by the erosional events at the Triassic-Jurassic boundary. Truncation appears to be gradually older and deeper southwards, until south of Makhtesh Ramon, the entire Triassic has been truncated. No Rhaeto-Norian intervals have been reported from southern wells; the question of whether the Late Triassic hiatus represents non-deposition or later truncation cannot be answered.

Cousminer (1981b) in his study of the Ga'ash 2 well and B. Derin (1986, written commun.) in his study of the Atlit well, were the first to provide convincing palynological and faunal evidence for the existence of Rhaeto-Norian sections in the Coastal Plain of Israel. In addition, Rhaeto-Norian relicts also were found in Zohar 8 (Cousminer, 1981a; this study) and in Helez Deep wells. These findings are consistent with the concept of deeper truncation of Triassic rocks to the south (Goldberg & Friedman, 1974). Because truncation is less to the north, Rhaeto-Norian strata should be preserved there. Figure 10 shows a hypothetical cross section, demonstrating this wedge out of the Rhaeto-Norian to the south. More subsurface information would aid in establishing a better paleogeographic view of the Rhaeto-Norian in Israel.

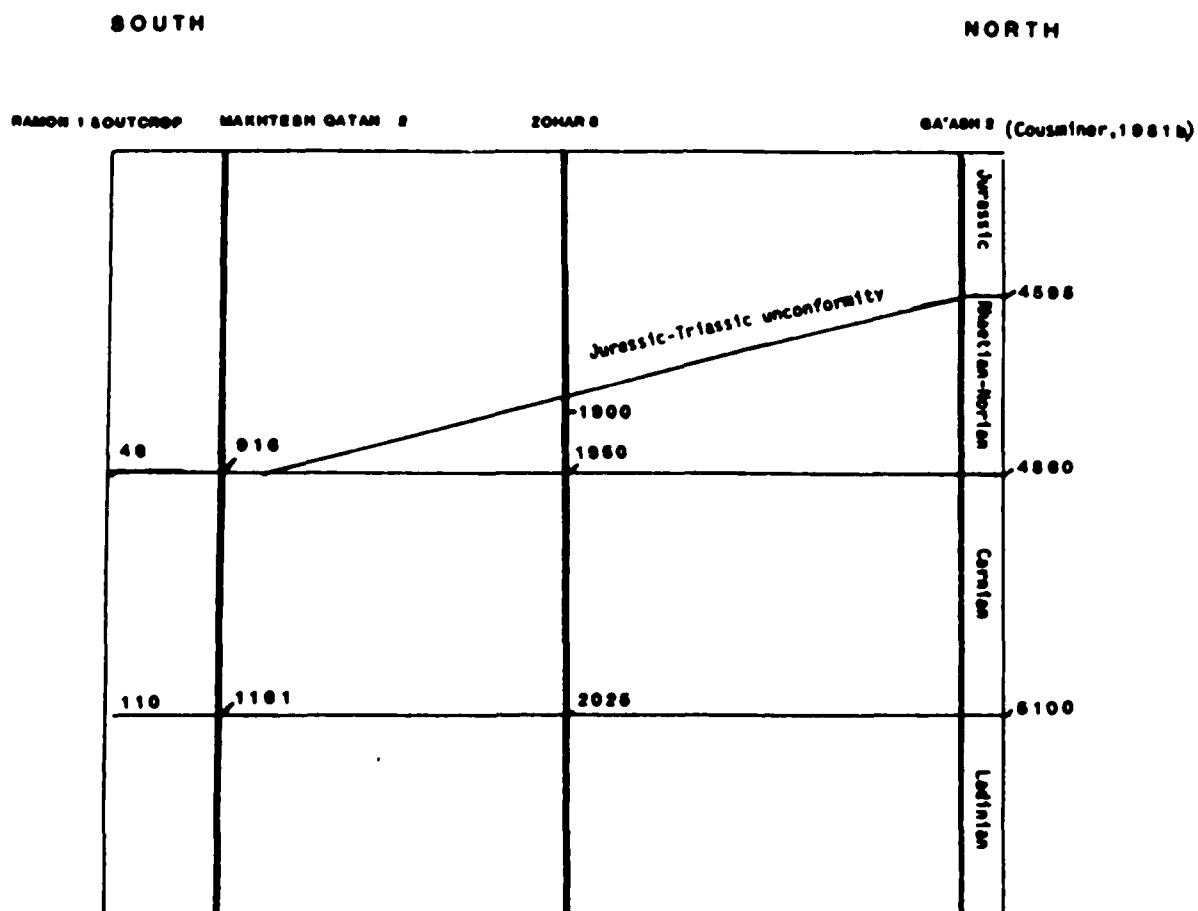


Figure 10. Diagrammatic north-south cross section explaining the possible position of the Rhaeto-Norian, Carnian, and Ladinian intervals below the Triassic-Jurassic unconformity. Note deeper truncation in the south. (Depths in meters).

INTERSTAGE BOUNDARIES IN THE PERMO-TRIASSIC

In addition to the major unconformities at the top and base of the Permo-Triassic sequence, and the possible unconformity at the Permian-Triassic boundary, interstage contacts throughout the study area have been reported to be lithologically conformable (Druckman, 1974; Weissbrod, 1981), with the exception of the unconformities involved with the Erez Conglomerate in the Helez Deep well. The palynozonal data appear to agree with the idea of conformable lithostratigraphic contacts, although the pattern of many extinctions at stage-boundaries may indicate small-scale hiatus. All of the interstage zones appear to be conformable with each other. Taxa range continuously from one zone to another. Appendix 4 demonstrates the continuity from the Anisian through the Carnian that is found in all the studied boreholes. Unconformities would have been expressed by many extinctions as is demonstrated for the Permo-Triassic boundary in Figure 9.

ORGANIC MATTER

An important application of palynology to petroleum research, hydrocarbon source-rock evaluation, and basin analysis is the classification of insoluble organic matter into different kerogen types. Both quantitative and qualitative information can be collected from palynological slides. A study of color changes in the organic residues can be used not only to determine the petroleum-generating capabilities of the rocks, but also to reconstruct the thermal history of the basin.

The petroleum industry has found that rocks with at least 0.5% weight organic carbon can be source rock if the kerogen is of the type that generates hydrocarbons (Hood et al., 1975; Tissot & Welte, 1978; Philp, 1986). These authors also indicate that there is a gradual enrichment in organic carbon and a decrease in volatiles associated with the generation of hydrocarbons; these are important because hydrocarbons are considered to be thermal products of organic matter.

Various methods of source rock evaluation have been developed during the last decade (Tissot & Welte, 1978; Durand, 1980; Brooks, 1981). This study applies two of the methods that give important source rock and depositional environment information: Thermal Alteration Index (TAI) and the kerogen facies analysis. Results from applying these

methods to the Permo-Triassic succession in the studied boreholes are presented here.

THERMAL ALTERATION INDEX

Staplin (1969, 1975), and Gray & Boucot (1975) have shown that in nature and experimentally, an increase in rock overburden is equivalent to the increase of temperature. The breakdown of organic matter as it is buried under thicker sections includes both the loss of volatiles and a consequent decrease in the ratios of H/C and O/C. Breakdown results in gradual changes in color of the organic matter from light transparent yellow, through orange and brown, and finally to opaque black. Because oil is considered to be a thermal product of the breakdown of organic matter, a correlation between the color of organic matter and its rank in terms of maturity can be made in order to define an oil window. Staplin (1969, 1975) first presented a color correlation chart, based on color changes of thin-walled pollen grains. He expressed the color values in vitrinite reflectance equivalents, thus making the subjective TAI method correlatable to more objective and independent methods. His and other data has shown that wells in which petroleum is actively being generated generally contain orange palynomorphs; the orange colors, therefore, are used to define the oil window. Yellow palynomorphs are typical of intervals that are above the oil window (immature), while below the oil

window, opaque black palynomorphs are characteristic of the overmature zone. Burial at depth is not the only parameter affecting the color changes of organics; others were described by Gray & Boucot (1975) and must be kept in mind when interpreting color changes.

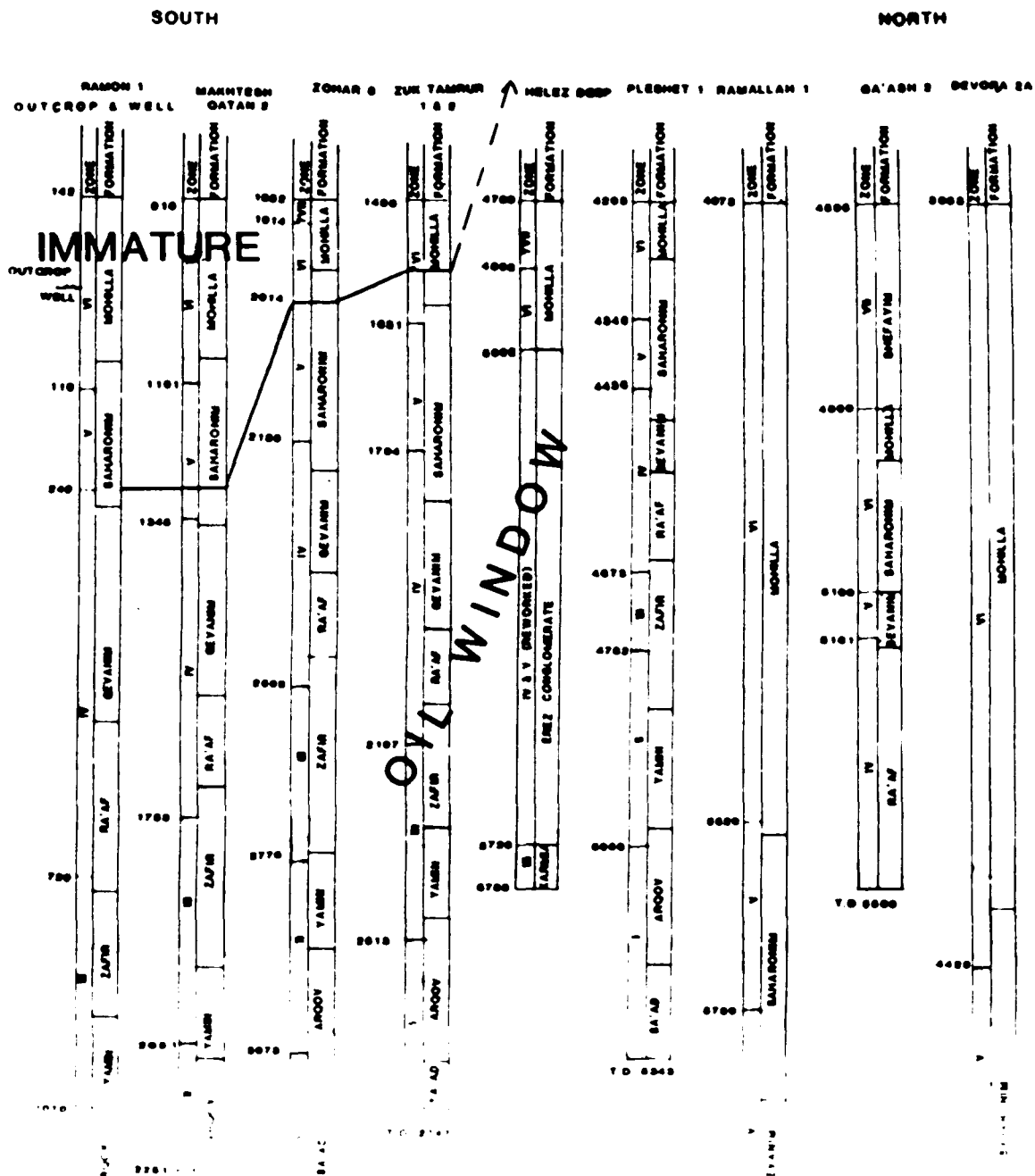
By observing fine details in color changes of palynomorphs in the Ga'ash 2 well, Gvirtzman et al. (1981) were able to show that TAI and vitrinite reflectance are correlatable methods. On the other hand, some discrepancies between TAI and vitrinite reflectance values were reported from the Makhtesh Qatan 2 well, southern Israel (Eshet, 1983). However, in the course of this study it was found that errors were made in TAI determinations by Eshet (1983). The major error was due to the abundance of black reworked material that gave the impression of overmature rank. Variation in color was observed for in situ sporomorphs of the same sample. These variations are probably due to differences in spore-wall thickness or composition, and to epigenetic processes such as corrosion and degradation.

In this study, maturation is determined by using a modification of the Munsell (1973) soil color chart. The modification is necessary because the chart lacks the orange colors typical of organic matter within the oil window. Maturation results, which were obtained by the TAI study, indicate that to the south, the Upper Triassic section is immature, while for rocks from the Middle Triassic and

older, the section is within the oil window (Figure 11). Overmature palynomorphs were encountered as reworked material only. In northern Israel (the Devora 2A well) and in the Coastal Plain (the Ga'ash 2 and Helez Deep wells), depths of burial are much greater for the Triassic section; therefore, the entire Permo-Triassic succession is within the oil window. These values are in general accordance with vitrinite reflectance results obtained for the same wells (Bein et al., 1984). A similar trend with a diachronous position of the oil window in Jurassic rocks was found by Conway (1984, personal commun.). He found that the Jurassic is immature in the south, but mature along the Coastal Plain and in the north.

KEROGEN TYPES

Many classifications of kerogen macerals are offered in the literature, most of which were summarized by Brooks (1980). The kerogen classification has to suit the purpose of study (Durand, 1980). By studying thermally immature samples from the North Atlantic, Habib (1979, 1982) established kerogen facies that are useful in characterizing changes in sea level and proximity to land during the Mesozoic. Porter & Robbins (1981) emphasized the significance of fecal pellets and amorphous kerogen in hydrocarbon exploration. The kerogen facies classification used in the present study reflects its purposes: to be useful for both paleoenvironmental and hydrocarbon exploration studies. Therefore, the



following kerogen facies are described here, following the classification used by the Geochem Laboratories Inc, Houston, Texas:

-Woody: Fusinite, wood tracheids, fibers and fiber-tracheids, all of terrestrial origin. The facies partially corresponds to the tracheal facies of Habib (1982).

-Herbaceous: Pollen, spores and plant-cuticles, all of terrestrial origin. This facies is identical to the exinitic facies of Habib (1982).

-Coaly: All black inertinites and micrinites, and black structured and structureless particles, most of which are believed to be of terrestrial origin. Some have argued that the micrinites may have formed in anoxic aquatic environments (Van Jizel, 1980; Curtis, 1980). This facies corresponds partially to the micrinitic facies of Habib (1982).

-Xenomorph: Structureless (amorphous) organic matter that is considered to be of aquatic algal origin and includes fecal pellets. It is identical to the xenomorphic facies of Habib (1982).

The woody and coaly kerogen types have a low H/C ratio and are gas prone; they are identical with kerogen type III (Tissot & Welte, 1978). The xenomorphic facies is characterized by its abundance of hydrogen and thus, considered the best source for petroleum; it partially corresponds to kerogen type I of Tissot & Welte (1978). The herbaceous facies has a potential for hydrocarbons which is intermediate

DEVORA 2A		HELEZ DEEP		FLESHET 1		ZEMAR 8		ZUR TAPUR 1		ZUR TAPUR 2	
DEPTH(m)	FORMATION AND KEROGEN	DEPTH(m)	FORMATION AND KEROGEN	DEPTH(m)	FORMATION AND KEROGEN	DEPTH(m)	FORMATION AND KEROGEN	DEPTH(m)	FORMATION AND KEROGEN	DEPTH(m)	FORMATION AND KEROGEN
3075	Mahilla C	4700-6	Nirta (lower)	4031	Arden	1893	Mish'har C/T	Core 1	Saharania	1470	Mish'har
3086	I	4713-18		4105		1899	Mahilla	1943	Gervania	1481	
3090		4721-4		4132	Y (fluid out)	1914		Core 2		1486	Mahilla
3107		4728-31		4203	Mahilla	1932-5				1496	
3128		4734		4233-6		1950				1514	
3133		4749-52		4270-3		1956				1532	
3162		4767-70	Mish'har	4293-6	Saharania	1956	Saharania	2000	Be'al	1532	
3179		4801-4		4346-9		1986		2044		1540	
3182		4843-47	Mahilla	4392		2014		2075		1562	
3202		4868-71		4436		2020		2076		1576	
3230-45		4898-901		4492	Gervania	2072		2123	Zafir	1595	
3240		4919-22		4509		2078		2165		1612	
3284		4946-9	Core 1	4627	Be'al	2124		2197		1631	Saharania
3338		4955-58		4648		2149		2245		1650	
3410		4973-6		4673	Zafir	2169		2270		1673	
3448		4988		4700		2224	Gervania	2312		1693	
3490		5006		4713		2257		2352	Yamla	1717	
3520		5032		4731		Core 8		2391		1736	
3540		5062		4758		Core 9		2425		1769	
3587		5121	Erse	4782		2420	Be'al	2476	Arqov	1784	
3633		5215		4796		2441		2513		1815	
3674		5236-9		4803		2448	Zafir	2536		1831	
3716		5286-9		4843	Yamla	2495		2595		1851	
3753		5325		4872		2537		2631	Se'al	1877	
3780		5384-7		4902		2563		2677		1927	
3843		5382		4932-5		2586		2708		1947	
3880		5407		4970		2620		2741		1967	
3912		5434		4986	Arqov	2625				1987	
3962		5482		5017		2651				2015	
3995		5494-39		5036		2676				2031	Lowermost Gerv.
4022		5507		5050		2696					
4074	Saharania	5534		5083-5		2727	Yamla				
4125		5559-62		5093		2746					
4181		5584-67		5120		2776					
4220-40		5595		5145		2797					
4239		Core 1		5160		2824					
4246		5657-60		5190	Se'al	2847					
4290		5678-81		5220		2869					
4335		5688		5240		2875	Arqov				
4405-25		5727		5259		2899					
4425		5733-36	Karnia	5285		2904					
4470		5745-6		5310		Core 11					
4485-45		5754		5343		2941					
4485-48		5757-41				2974					
4515		5764				3008					
4523-45		5770				3025					
4547		5783				3049					
4565-48						3076					
4579						3102	Se'al				
4630						3125					
4676						3148					
4710						3151					
4717						3178					
4730						Core 18					
4750						3188					

LEGEND
C COAL
E EUDYTIC
I EUDYTIC

Table 5. Kerogen type distribution in the studied wells

Table 5 (cont')

DEVORA 2A		ELEC DEEP		FLESHET 1		ZONAR 4		ZIR TABLE 1		ZIR TABLE 2	
DEPTH(m)	FORMATION AND LITHOLOGY	DEPTH(m)	FORMATION AND LITHOLOGY	DEPTH(m)	FORMATION AND LITHOLOGY	DEPTH(m)	FORMATION AND LITHOLOGY	DEPTH(m)	FORMATION AND LITHOLOGY	DEPTH(m)	FORMATION AND LITHOLOGY
4974	C										
4998	-										
5023	C/I										
5036	C/I										
5084	Gneiss										
5090	C										
5092	E										
5105	I										
5109-52	C										
5200	Re'af										
5248	I/C										
5288	-										
5337	I/C										
5359-65	I										
5383-9	C										
5417	-										
5448	C										
5469-72	Zafir										
5494	C/I										
5502-3	I										
5520	E										
5548-53	C										
5554	C/I										
5597-5600	-										
5625	-										
5633	C										

LITHO
 C ONLY
 E EXHIBIT
 I XENOMORPHIC

between that of the woody and the xenomorphic facies. The facies corresponds partially to kerogen type II of Tissot & Welte (1978). Table 5 shows the stratigraphic distribution of the kerogen types in the boreholes of this study. As can be seen, most of the Permo-Triassic succession in Israel, with the exception of small intervals containing xenomorphic or herbaceous remains, is classified within the coaly facies. Bein et al. (1984) also found that most of this interval belongs in kerogen type III, except for certain intervals in the Mohilla Formation that were assigned to type I, and for the Saharonim and Ra'af Formations that were assigned to type II.

PALAEENVIRONMENTAL ASPECTS

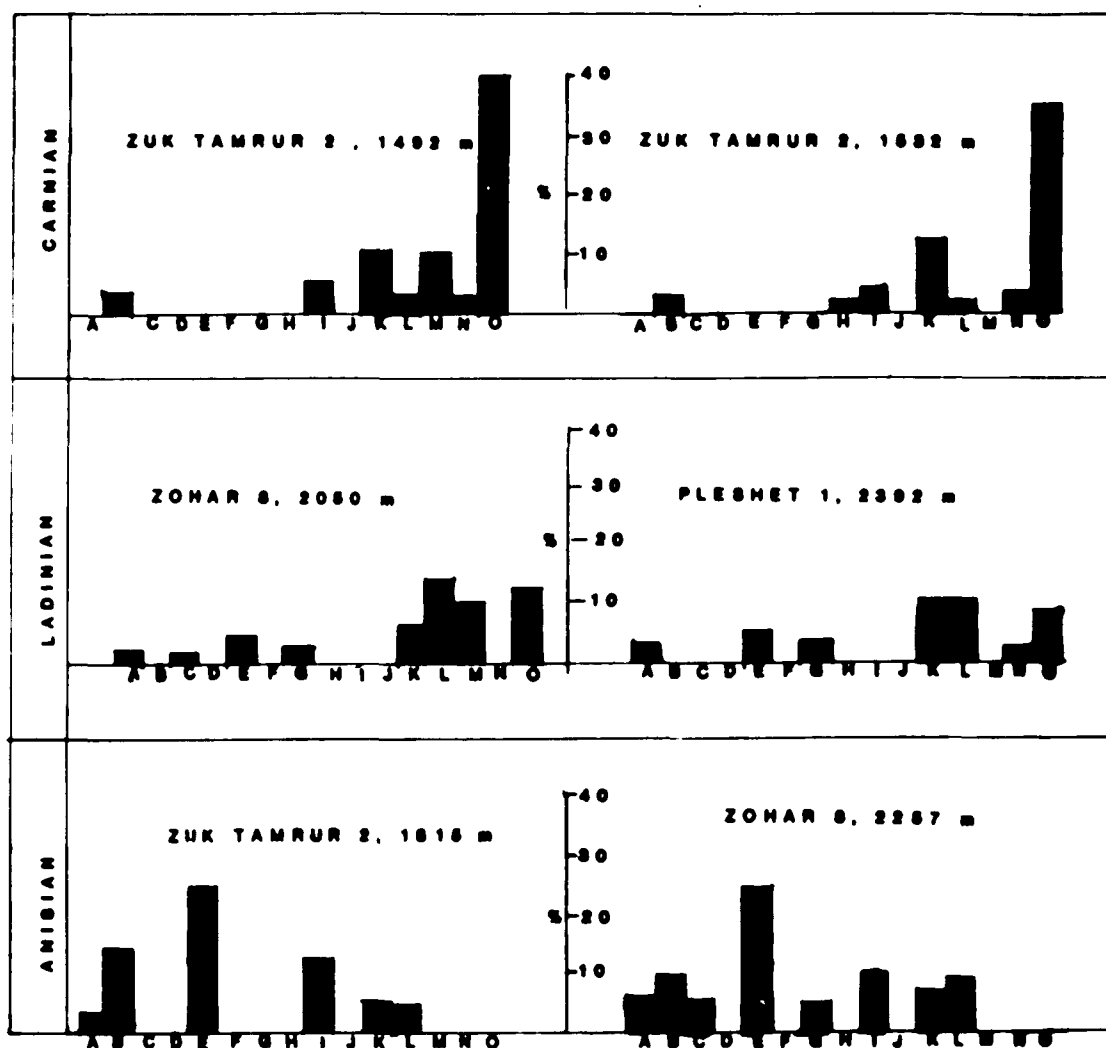
PALYNOMORPHS AS PALAECLIMATIC INDICATORS

Palynomorphs are known to add significant data for paleoclimatologic interpretations, particularly when they are used in concert with theoretical paleoclimatological models. Robinson (1973) suggested such a model for the Triassic based on paleogeographic configurations. This model suggests both decreasing precipitation towards the west in the Mediterranean region, as well as an arid belt along both sides of the paleoequator. Kremp (1977) utilized worldwide paleobotanical data to interpret global paleoclimates during the Late Paleozoic and Triassic times. He was able to estab-

lish paleobotanical belts or provinces that have a climatologic significance. Visscher and Van Der Zwan (1981) suggested a model for interpreting paleoclimates in the Triassic of the Mediterranean region based on statistical analyses of assemblages from coals that represent a humid environment and from evaporites that represent an arid environment. Any model that uses palynomorphs as paleoclimatologic indicators must assume that the vegetation in a locality is adapted to the climate in which it grows. With this assumption understood, paleoenvironments and paleoclimates can be inferred by applying statistical methods to the assemblages.

In order to evaluate Triassic paleoclimates in Israel, the model of Visscher and Van Der Zwan (1981) was applied to the assemblages recovered from the studied sections. To aid in the statistical analysis of assemblage compositions, the 15 palynologic groups suggested by Visscher and Van Der Zwan (1981) were utilized, wherever they were applicable to Israel. Only representative samples from selected intervals were analyzed statistically. Results are demonstrated by the histograms in Figure 12.

The results indicate that during the Anisian, the hygrophytic elements (essentially Aratrisporites - Group E - and some Cycadopites -Group A) predominate. Xerophytic elements such as Lunatisporites spp. (Group K) and Triadispora spp (Group L) are also present in smaller numbers. The inferred environment for the Anisian is humid, although some



HYGROPHYTIC ELEMENTS	A	MONOLETE SPORES
	B	TRILETE ACAVATE LAEVIGATE OR APICULATE SPORES
	C	TRILETE ACAVATE MURONATE SPORES
	D	TRILETE CINGULATE AND ZONOTRILETE SPORES
	E	ARATRISPORITES GROUP
	F	PORCELLISPORIA COMPLEX
	G	MONOSULCATE POLLEN GRAINS
	H	OVALIPOLLIS COMPLEX
	I	ALETE (PROTO) BISACCATE POLLEN GRAINS
	J	SAMAROPOLLENITES
XEROPHYTIC ELEMENTS	K	TAENIATE (PROTO) BISACCATE POLLEN GRAINS
	L	TRILETE (PROTO) BISACCATE POLLEN GRAINS
	M	VESICATE POLLEN GRAINS
	N	(PROTO) MONOSACCATE POLLEN GRAINS
	O	CIRCUMPOLLES GROUP

Figure 12. Application of Visscher & Van Der Zwan's (1981) paleoenvironmental model to the Triassic of Israel

xerophytes must have grown in dry niches. In the Ladinian, both xerophytic and hygrophytic elements occur. Although xerophytic elements predominate (Triadispora spp. - Group L -, Circumpolles taxa - Group O, Enzonasporites spp. - Group M, and Lunatisporites spp.), hygrophytic elements also are present, represented by Aratrisporites spp. (Group E) and Retitriletes perforites (Group G). The inferred climate of the Ladinian is arid, although humid vegetation grew in some niches. In the Carnian, the assemblages are composed almost entirely of xerophytic elements, most of them belonging to the Circumpolles subturmae (Group O). Other xerophytic elements are Patinasporites densus (Group N), Triadispora spp. (Group L), and Enzonasporites spp. (Group M). Hygrophytic elements such as Ovalipollis and Porcellispora occur in minor numbers. The inferred climate for the Carnian is arid, an interpretation which also is supported by evaporites that predominate in this time interval.

A regional distribution-analysis of the taxa occurring in the studied sections also enabled recognition of several palynologic provinces in the Permo-Triassic. A province is an area where specific taxon or taxa are prominent. A province based on sporomorphs does not necessarily represent the true geographic distribution of the plant. Boundaries of these provinces, plotted in Figure 13, are tentative due to the limited number of sections available for the analysis. The following provinces could be identified (see Figure 13):

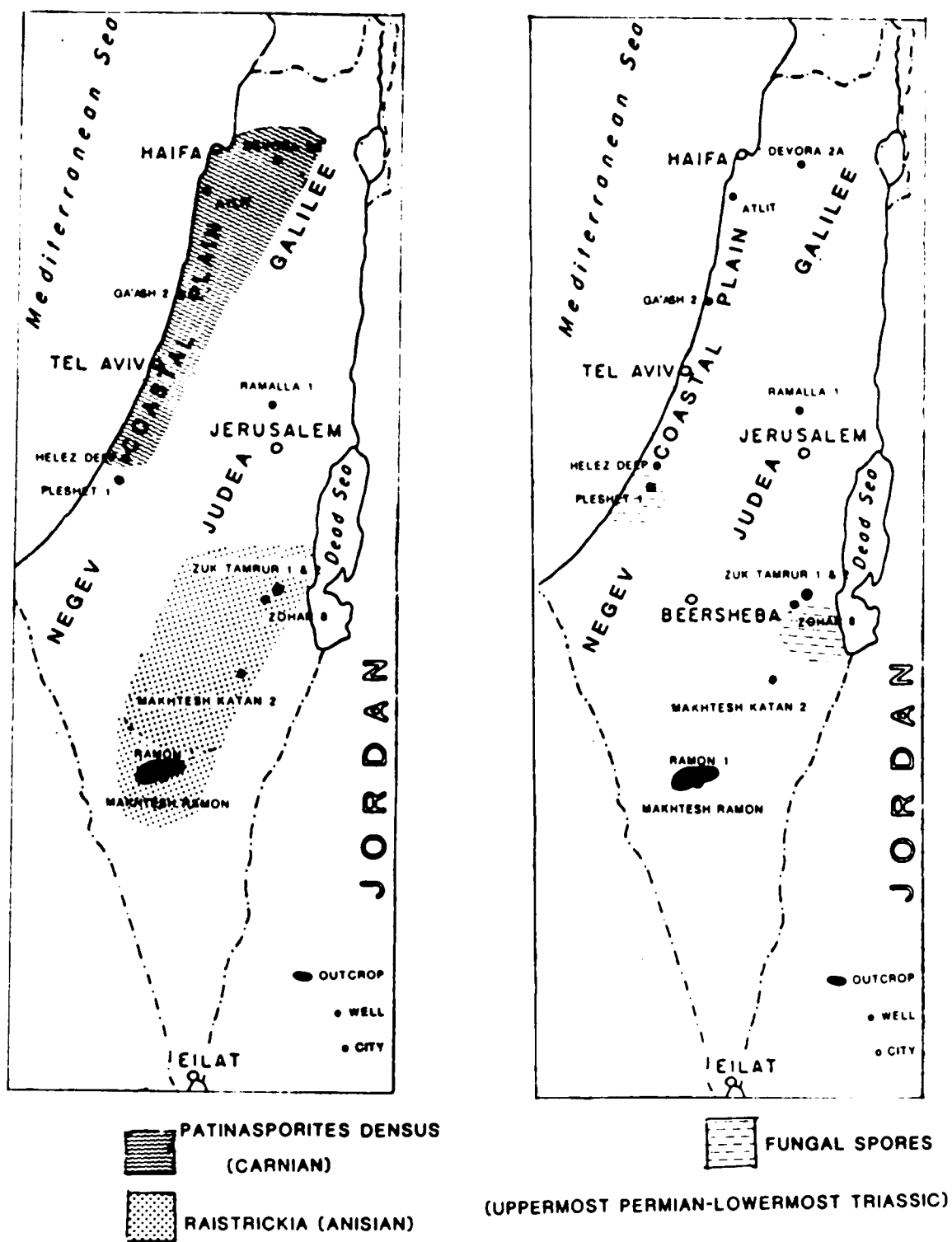


Figure 13. Three palynological provinces during the Permo-Triassic of Israel.

1. Raistrickia Province: The Anisian samples in Zuk Tamrur 2, Zohar 8, Makhtesh Qatan 2 and Ramon 1 wells, included significant numbers of Raistrickia spp. These taxa were found to be most abundant in the Zuk Tamrur area. They were not found in the northern part or the Coastal Plain of Israel.

2. Fungal spores Province: Uppermost Permian and lowermost Triassic samples from Zohar 8 and Pleshet 1 wells included abundance of fungal spores.

3. Patinasporites densus Province: Although P. densus is found during the Carnian all over Israel, it occurs in much greater numbers in the sections from central Israel (Ramallah 1), Coastal Plain (Helez Deep, Ga'ash 2) and northern Israel (Devora 2A). To the south (Makhtesh Qatan 2, Ramon 1, Zohar 8, Zuk Tamrur 2), this taxon is much less frequent.

These provinces are believed to be climatically-controlled, but more data from other sections are required for more conclusive interpretations. However, the relatively greater provincialism to the south is in accordance with the stronger continental influence known in that area during the Triassic (Druckman, 1974).

CLIMATICALLY OR SEDIMENTOLOGICALLY-CONTROLLED POPULATION DYNAMICS

IN THE LOWER PERMIAN

The characteristic assemblages of the Lower Permian (monosaccates such as Potoniesporites novicus, and bisaccates such as Distriatites insolitus) were found to alternate with assemblages dominated by small trilete or monolete spores such as Laevigatosporites callosus, Polypodiisporites mutabilis, Punctatosporites minutus, Reticuloidosporites warchianus, Marsupipollenites triradiatus, Pretricolpipolettites bharadwaji and Lophotriletes novicus. These alternations are marked by a sharp decrease in the abundance of the typical members of the P. novicus Zone, although they do not disappear completely. The alternations were found in all the sections that penetrated the Lower Permian (Pleshet 1, Zohar 8, Zuk Tamrur 1). They are best exemplified in Pleshet 1 well, below 5050 m (Figure 14). Because the Lower Permian represents a variety of continental environments, these vegetative alternations are likely to have been climatically or sedimentologically-controlled and reflect competition between different plant communities in the same area. These communities, represented by their spores and pollen, appear to be replacing each other as ecological niches shift during the course of a fluctuating climate or as the sedimentological setting changes. H. Visscher and P. Brugman (personal commun, 1986) suggested that the control for these alterna-

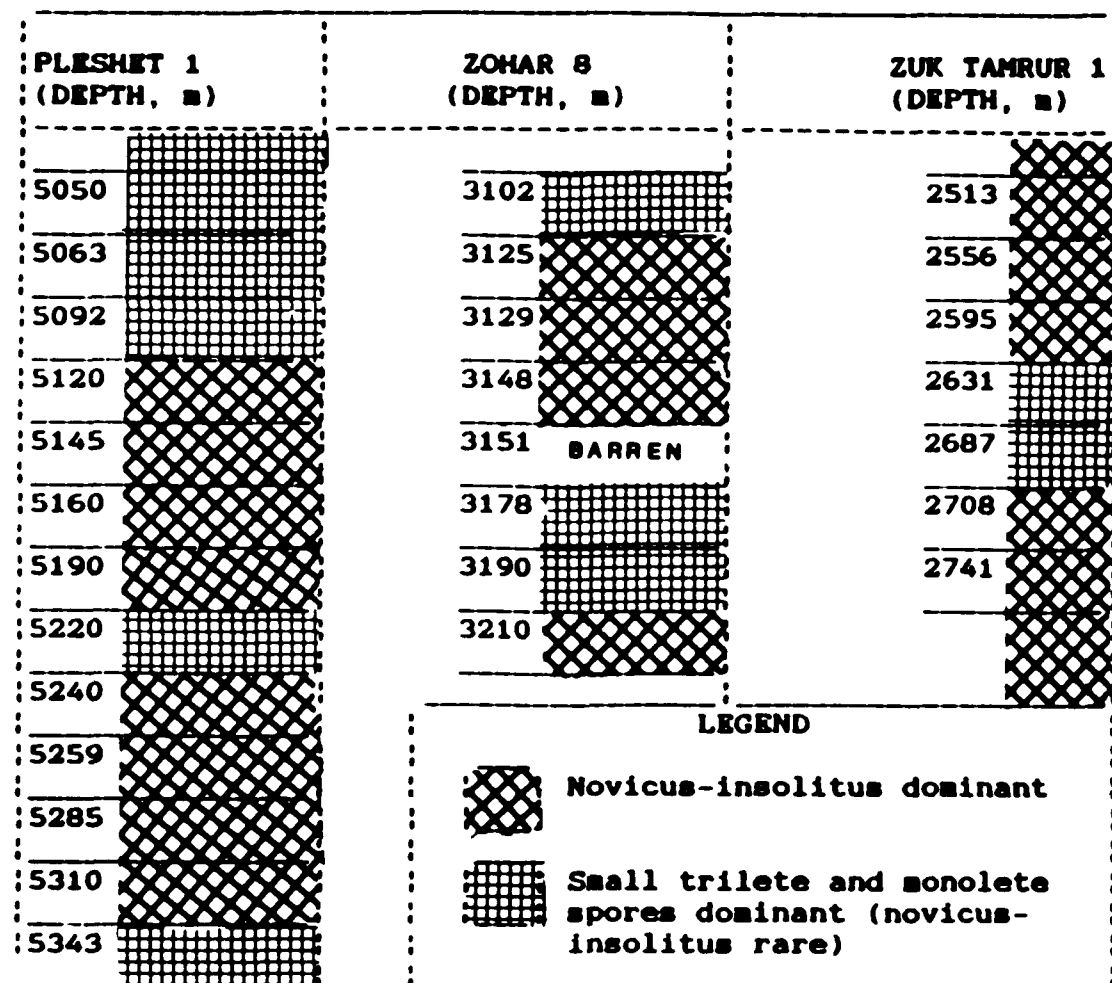


Figure 14. Climatologically or sedimentologically-controlled alternations of assemblages in the Lower Permian of Israel.

tions could have been shifting sedimentary environments in a fluvio-deltaic regime, in which plant communities are replacing each other with the dynamic changes in channels. Such a sedimentologic regime was offered for parts of the Jurassic sequence in Israel (Goldberg and Friedman, 1964). Figure 14 shows that the alternations are consistent throughout the entire area but data are insufficient to identify a definite number of climatic or sedimentary cycles in the Lower Permian. Better chronostratigraphic resolution and data from additional sections are required to further develop and test these hypotheses

PALYNOMORPHS AS INDICATORS OF THE SEDIMENTARY
ENVIRONMENT AND TRANSPORTATION REGIME

REWORKED MATERIAL

Palynomorphs are detrital particles that are carried to the environment of deposition by either wind or water currents. The size of most palynomorphs and vegetative debris falls within the silt size range. Therefore, some statistical parameters can be applied to the palynological assemblage to reach paleoenvironmental conclusions. The data of Kuyl et al. (1955) and Muller (1959) in western Venezuela, of Wall (1965) in England, and of Dale (1976) in Norway, strongly suggest that the sedimentary environment can be interpreted from statistical parameters, using palynological assemblages. In their important research in the Orinoco

delta, Scheihing and Pfefferkorn (1984) also studied burial and preservation processes of detrital land-plant debris in a deltaic depositional environment.

In nearshore or continental environments, detrital matter brought from land can be observed in considerable amounts. This detritus contains many types of reworked organic matter, all incorporated within the fine grain fraction. Reworked organic matter can be identified by its color, which is usually darker than the color of the in situ palynomorphs in the sample. Some palynomorphs can be identified to age, thereby supporting their reworked origin. The use of reworked palynomorphs for paleogeographic and paleoenvironmental studies had been described by Windle (1978) and LeGault and Norris (1981). Stanley (1966) offered some methods to isolate reworked palynomorphs from the rest of the palynologic fraction.

In this study, the percentage of the reworked palynological fraction was determined on the basis of a representative count of at least 10 traverses of the slide. Frequencies of reworked organics in three of the studied boreholes are plotted in Figure 15. This figure indicates that stratigraphic horizons of high or low reworked content can be distinguished, and they can be identified consistently throughout the study area. Interestingly, the peaks of high reworked organic matter in Figure 15 correspond to stratigraphic intervals that were interpreted as **regressive**

Figure 15. Distribution of reworked organic matter in the Permo-Triassic. Lithostratigraphy and geologic interpretations after Druckman (1974) and Weissbrod (1981). For details, see Figure 16.

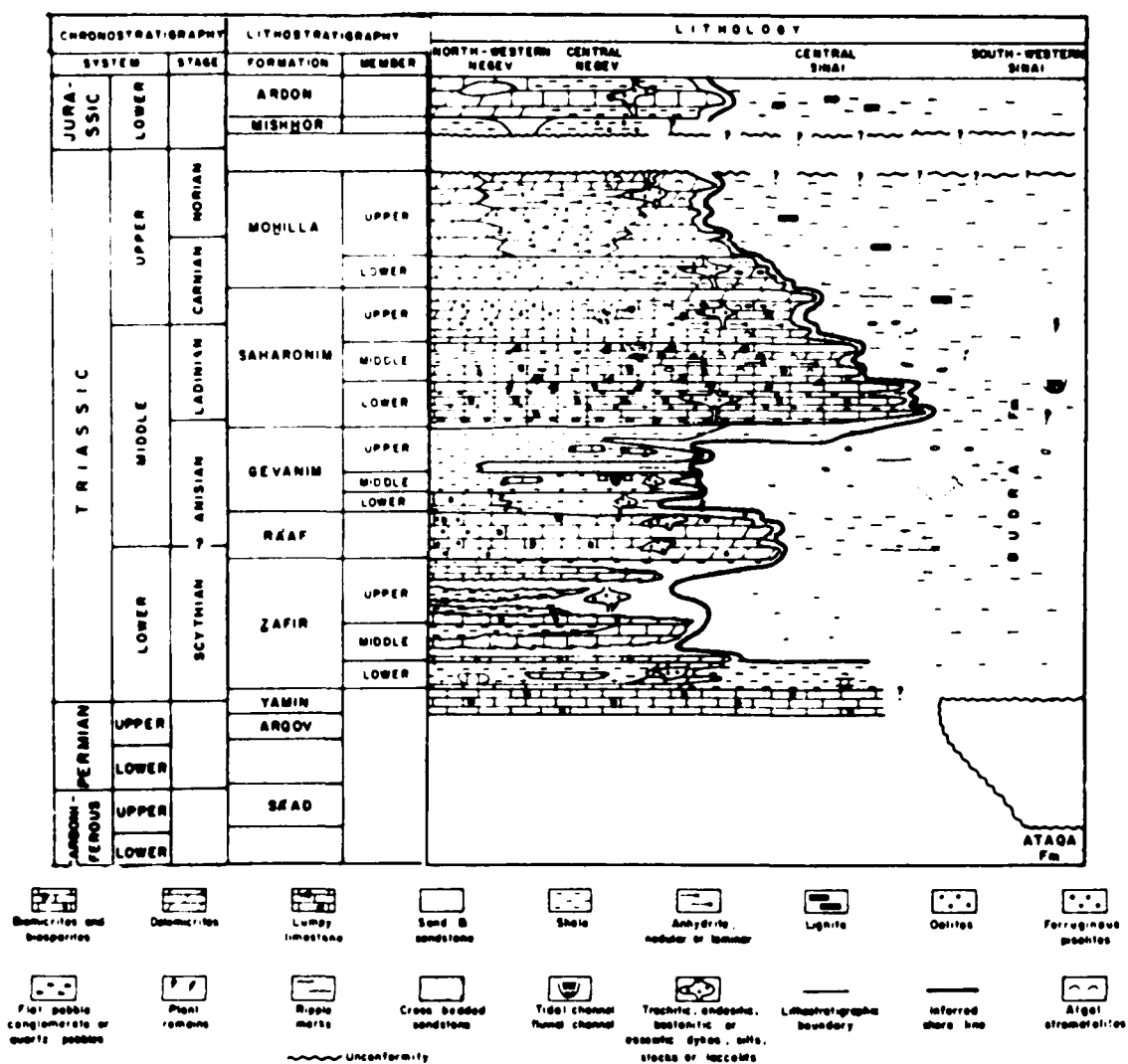


Figure 16. Transgressions and regressions in the Triassic of Israel (From Druckman, 1974).

(Druckman, 1974; Weissbrod, 1981, and Figure 16). They occur in the Sa'ad, upper Zafir, Gevanim, and Mohilla Formations. The intervals of low reworked material in Figure 15 correspond to the **transgressive** parts of the Permo-Triassic (Figure 16). Transgressive units include the Zafir Formation (except for its upper part) as well as the Ra'af, and Saharonim Formations. The correlation between transgressive intervals and low reworked content, and as well as the correlation between regressive intervals and high reworked content suggest that reworked palynomorphs are a useful tool that can be utilized to identify unknown transgressions and regressions in nearshore and shallow marine environments. The theoretical basis for such an interpretation is that during a regression, the increasing area of exposed land and older rocks, in concert with the development of a fluvial drainage system, lead to an increase in the total detritus content which also contains reworked palynomorphs. On the other hand, during transgressions, the amount of reworked material decreases as a result of the decrease in land area. It is suggested that this model is applicable to regions of low relief, which is typical of most shallow seas. In such a configuration, even small changes in sea level might leave evidence in the rock record. The Triassic sequence in Israel was deposited in such an environment and Druckman (1974) was able to distinguish 3 major sedimentologic cycles of transgression and regression in it (Figure 16). These cycles

seem to correspond to the peaks in reworked material of this study. Percentage of the reworked organics is generally greater in southern Israel. This agrees with the known paleogeographic configuration of the area, in which transgressions usually came from the north, whereas more continental conditions existed to the south.

Finally, the population of reworked palynomorphs provides some important indications about the source for some of the detritus. In the Makhtesh Qatan 2, Zuk Tamrur 1 and Zohar 8 wells, Silurian to Devonian chitinozoans, Silurian acritarchs and other Middle and Early Paleozoic palynomorphs are present in Triassic or Permian-Triassic boundary strata. No strata appear to have been deposited in Israel between the Cambrian and the Permian (Weissbrod, 1981). On the other hand, rocks of these time-intervals do occur in Saudi Arabia and Jordan. Therefore, the occurrence of reworked Paleozoic palynomorphs indicates that Silurian and Devonian rocks were exposed south and east of Israel during the Triassic and the Permian. These reworked palynomorphs appear to have been carried from their sources as clastic particles, which suggests a southeast-northwest direction of transportation. This direction is in accordance with that suggested by Karcz and Braun (1964) and Karcz and Zak (1965). Selected Paleozoic palynomorphs, found reworked into Triassic strata are shown in Plate 7.

ACRITARCHS

Acritarchs are abundant in most of the palyniferous samples of the Triassic interval. As shown in Plate D, most of them belong to the Veryhachium and Micrhystridium form genera. Some Leiofusa types also occur. Because many of these acritarchs resemble Paleozoic acritarchs, gross morphology may not be a useful criterion for systematic classification of acritarchs, at least in the Triassic. Habib and Knapp (1982) have found that microstructures are most significant in the identification and classification of acritarchs. However, no systematic study on the microornamentation of Triassic acritarchs is available, and only studies on the gross morphology of Triassic acritarchs have been done (Brosius & Bitterly, 1961; Sarjeant, 1970). Therefore, acritarchs are used here merely as environmental indicators.

Acritarchs are generally regarded as fossils of marine phytoplankton. Therefore, their occurrence is used to infer marine depositional environments. Their bouyancy appears to have been good and it is likely that high abundance of acritarchs may have been due to later concentration by marine currents.

Acritarchs characterize the Scythian and Anisian intervals in the study area. Their abundance is shown in Figure 17 from the Makhtesh Qatan 2 well. Surprisingly, acritarchs were abundant even in regressive intervals, such as in the Gevanim Formation. A more detailed study of acritarch

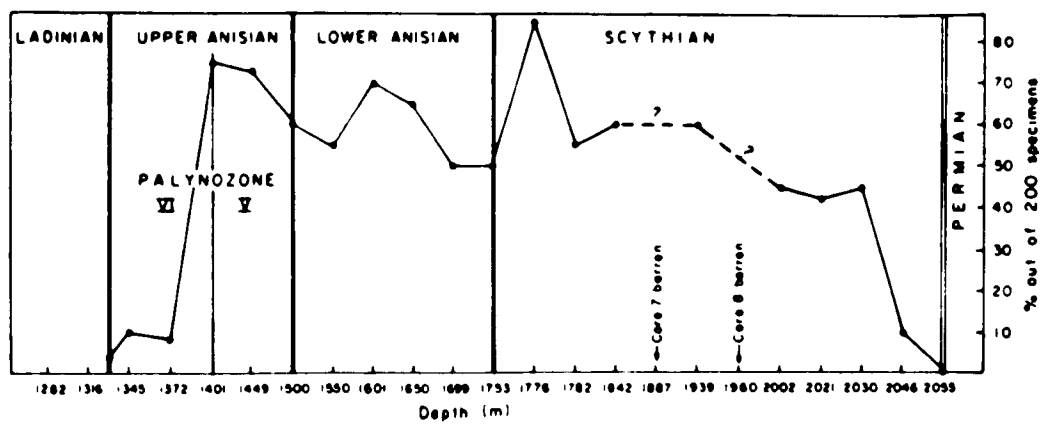


Figure 17. Abundance of acritarchs in the Scythian and Anisian intervals of the Makhtesh Qatan 2 well. Note absence in the Permian and the Ladinian.

distribution in adjacent regions outside of the study area might provide useful information about the location of shorelines and paleogeography during the Triassic.

The absence of acritarchs from intervals below the Triassic and above the Anisian stage appears to be stratigraphically important in Israel, although acritarchs are reported from Permian and Late Triassic sections in other parts of the world. It is noted here that in this study, acritarchs were found in the Ladinian interval of the Devora 2A well. This appears to indicate the more prominent marine conditions that prevailed in the north. The abundance of acritarchs during the Scythian was regarded as having a chronostratigraphic significance in Europe by Visscher and Brugman (1981). It was also reported from Pakistan (Balme, 1970) and Greenland (Balme, 1979). The "bloom" of acritarchs in the Early Triassic, after the worldwide regression of the Permian, suggests that acritarchs were a pioneering group of organisms that occupied the newly created marine environments at the beginning of the Triassic.

ORGANIC MATTER DEGRADATION

Palynomorphs from the Mohilla Formation in all the studied wells but especially in the Helez Deep and Devora 2A wells, contained a surprising amount of structurally degraded palynomorphs. Some of them are corroded to a degree that makes their identification impossible. A selection of degraded palynomorphs is demonstrated in Plate 8. Curtis (1980) and

Robbins & Traverse, 1980) suggested that degradation reflects either syngenetic conditions in the depositional environment, or thermal effects produced by the depth of burial. Hart (1986) discussed other factors that affect degradation and developed a classification scheme for degraded organic matter. In this study, heavily degraded palynomorphs have been observed in the Helez Deep and the Devora 2A wells, where depth of burial for the Triassic section exceeds 3 km. The depth can be compared with the 1,000-1,200 m depth for the equivalent units in the south. The heavily degraded zones are restricted to the evaporitic Mohilla Formation which is composed essentially of anhydrite, gypsum and dolomite. The alkaline content of water is known to promote degradation of palynomorphs and other organic debris (Burghardt, 1964; Richardson & Richardson, 1972; Robbins & Traverse, 1980). The depositional environment of the Mohilla Formation is one of hypersaline closed marine basins or sabkhas, in which evaporites precipitated. Hence, it is assumed that the degradation of palynomorphs in the Triassic of Israel is due to a combination of high salinity during the deposition of the Mohilla Formation, and a great depth of burial. Other factors that could affect preservation, such as the oxygen content at the base of a water body and the effect of various microorganisms could not be studied in this research.

THE NON-BISACCATE/BISACCATE RATIO

In the entire area, the transition from Ladinian to Carnian strata is characterized by a great decrease in the population of bisaccate pollen, while non-bisaccate pollen become abundant. The non-bisaccate group is composed essentially of Circumpolles palynomorphs such as Paracirculina, Praecirculina, Camerosporites and Duplicisporites. The majority of the bisaccate group is composed of Lunatisporites acutus. The non-bisaccate/bisaccate ratio in the Ladinian/Carnian transitional zone in three of the studied wells is shown in Figure 18. The ratio demonstrates decreasing abundance of bisaccates, and increasing abundance of non-bisaccates. Since bisaccate pollen grains were very common during the Carnian throughout the world, changes in the non-bisaccate/bisaccate ratio appears to reflect paleoenvironmental factors. The Ladinian/Carnian boundary in Israel also is marked by the beginning of a large regression which followed the transgression of the Ladinian.

The following model is proposed to explain the fluctuating non-bisaccate/bisaccate ratio. During the Ladinian, bisaccates, which are anamorphous palynomorphs (dispersed well by wind) were carried for long distances from the distant land in the south. During the Carnian of Israel, with the regression of the Mohilla Formation, the non-bisaccates became dominant because they originated from the xerophytic, probably halophytic, vegetation of the nearshore

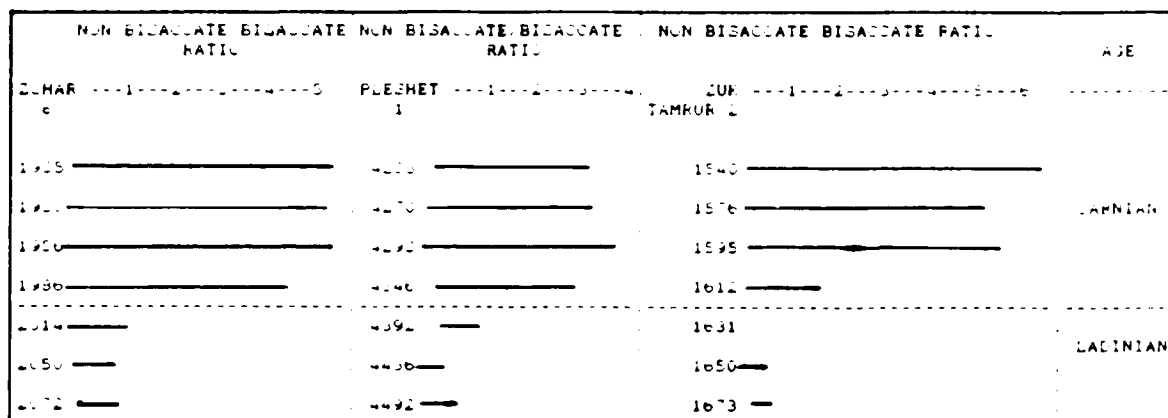


Figure 18. Changes in the non bisaccate/bisaccate pollen ratio in the Ladinian and Carnian. Note marked change across the Ladinian/Carnian boundary.

sabkhas. In areas where the Carnian environment was continental of high relief or lacustrine, bisaccates are found to be abundant, in Morocco (Cousminer & Manspeizer, 1976) and in the Newark rift system of Eastern U.S. (Cornet, 1977; Robbins, 1981). This model requires extensive correlation with results from modern analogs, such as the sabkhas along the Dead Sea rift valley, in order to be verified.

CONCLUSIONS

The Permo-Triassic succession in Israel, which was deposited at the margins of the Arabian craton, represents various sedimentary regimes. The depositional environments include shallow marine, marginal marine, and continental. The sequence represents cycles in sedimentation that are thought to have been the result of epeirogenic movements of the craton to the southeast. The top and base of the Permo-Triassic succession in Israel is distinguished by erosional unconformities.

A palynological study of assemblages recovered from boreholes in Israel resulted in the establishment of seven palynozones. The palynozones can be used to date and correlate different parts of the Permo-Triassic. The following formal palynozones are presented here, from the oldest to the youngest:

1. During the Early Permian (Artinskian), an assemblage of Potoniesporites novicus and Distriatites insolitus have been recovered from all of the sections that penetrated this time-interval. Striate bisaccate pollen grains are abundant in this zone. In some of the localities, the Early Permian assemblage is found to alternate with one of small trilete and monolete spores such as Pretricolpipoollenites bharadwaji, Punctatosporites minutus, Laevigatosporites callosus and Lophotriletes novicus. These alternations are interpreted as

representing climatically or sedimentologically-controlled changes in vegetation.

2. The Late Permian (Thuringian) palynozone contains Lueckisporites virkkiae, Klausipollenites schaubegeri and many Protohaploxylinus spp. as important markers.

3. The palynological assemblages of Early Triassic age are characterized by an abundance of Endosporites papillatus, Lunatisporites noviaulensis and many species of Kraeuselisporites, such as K. cuspidus and K. apiculatus. Acritarchs occur in large numbers in this zone.

4. With the exception of the Makhtesh Qatan 2 well, it is impossible to distinguish between the Early and Late Anisian. In the Makhtesh Qatan 2 well, the Early Anisian zone is composed of Alisporites grauvogeli, Voltziaceasporites heteromorphus, Platysaccus queenslandi, Cyclotriletes oligogranifer and an abundance of acritarchs. The Late Anisian in the Makhtesh Qatan 2 well included a complex of Aratrisporites spp. and Triadispora spp. In all the other boreholes, the Anisian as a whole is characterized by an abundance of Aratrisporites saturni and A. centratus, with some A. grauvogeli, Microcachrydites spp., Keuperisporites baculatus and Raistrickia spp. Lunatisporites pellucidus is dominant in the lower parts of the Anisian zone wherever it occurs. Furthermore, species diversity for the Anisian and the succeeding Ladinian stages is the highest recorded for the Permo-Triassic in Israel. Acritarchs also continue to be

abundant in the Anisian.

5. Echinitosporites iliacoides, Podosporites amicus and Eucommiidites microgranulatus are considered to be the best markers for the Ladinian interval. Most of the palynomorphs in this zone are bisaccate pollen. The peaking of bisaccate pollen may be explained by the fact that land became distant during the great Ladinian transgression in the Middle East, and only easily-dispersed palynomorphs, such as bisaccate pollen could reach the depositional sites. Acritarchs do not occur in the Ladinian intervals in most of the boreholes.

6. The Carnian palynozone is characterized by an abundance of Circumpolles palynomorphs such as Paracirculina scurrilis, Praecirculina granifer, Camerosporites secatus and Duplicisporites granulatus. Patinasporites densus is another marker fossil for this zone. Bisaccate pollen are sparse in most of the borehole samples.

7. The erosional unconformity at the Triassic/Jurassic boundary resulted in truncation of the latest Triassic (Rhaeto-Norian) in all of the boreholes in southern Israel. The Rhaeto-Norian interval can be distinguished palynologically only along the Coastal Plain, especially in the Ga'ash 2 well, where an assemblage of the dinoflagellates Rhaetogonyaulax rhaetica, Suessia spp., Noricysta fimbriata, Heiberella swabiana and Sverdrupiella spp. was found (Cousminer, 1981b). In other localities, such as the Helez Deep and Zuk Tamrur wells, an assemblage devoid of dinoflagellates but

including Classopollis torosus, Gliscopollis meyeriana, and Kyrtoisporites spp. may be assigned to the Rhaeto-Norian.

This palynozonation is found in most parts of the Permo-Triassic and enables a reliable dating and correlation of these time-intervals in different parts of Israel. This correlation could not be made accurately by means of lithostratigraphic correlation alone, due to the considerable lithofacies differences between northern and southern Israel.

A detailed palynostratigraphic study of age boundaries in the Permian and the Triassic revealed that the Late Permian and Early the Triassic palynozones are present at the Permian-Triassic boundary transitional zone in most localities. However, in the Zuk Tamrur 1 well, a palynologic discontinuity was evident where an Early Triassic assemblage overlies an Early Permian one. In the Pleshet 1 well, an unconformity might be indicated at the Permian-Triassic boundary by the extinction of all Late Permian taxa, as well as by a layer of red bed at the boundary. In the other boreholes, the Permian-Triassic boundary is characterized by a marked palynologic change and many extinctions. However, in those wells, the nature of the boundary is not clear enough. Boundaries between stages within the Permo-Triassic sequence appear to be conformable palynologically. At the top of the Triassic sequence, the Triassic-Jurassic boundary is characterized by an extinction of most Triassic taxa, suggesting unconformable relationship.

The Permo-Triassic zonation of Israel can be correlated to important sections in both Gondwana and Laurasia. This may reflect the changing paleogeographic position of Israel during this time-span between Gondwana and Laurasia.

A study of the thermal maturity of Permo-Triassic palynomorphs in boreholes in Israel reveals that in the south, the oil window extends from the top of the Ladinian to the base of the Lower Permian. The Upper Triassic interval in the south is, unfortunately, thermally immature for petroleum generation. In the north and along the Coastal Plain, the Permo-Triassic section was buried much deeper than that in the south. Consequently, the entire Triassic section in the northwest is within the oil window. No borehole information about the maturity of Permian strata from the northern and Coastal Plain of Israel is available. In the study area, the overmature zone has not been penetrated. Overmature palynomorphs occur as reworked particles only.

Kerogen types were studied in order to evaluate the potential of the Permo-Triassic strata for hydrocarbon generation. Most intervals were found to be rich in woody kerogen (type III), while xenomorphic (amorphous) kerogen, and exinitic kerogen were found in thin intervals only. These data imply a low potential for liquid hydrocarbon. The woody kerogen type, that indicates proximity to land, is especially dominant in the parts of the section that have been interpreted as regressive by their lithology and fossil

content. Woody kerogen is considered to be gas prone.

The geographic distribution of selected taxa has resulted in the recognition of some unique palynologic provinces that may reflect paleoclimatic and paleoenvironmental conditions. A latest Permian-earliest Triassic province of fungal spores occurs in the area between the Zohar 8 and Pleshet 1 wells. A Raistrickia spp. province existed in the area between the Zuk Tamrur, Makhtesh Qatan 2 and Ramon 1 boreholes during the Anisian. In the Carnian, a province of abundant Patinasporites densus occurs in the Coastal Plain and in northern Israel.

In order to use palynomorphs as paleoclimatologic indicators, a model established by Visscher and Van Der Zwan (1981) has been applied to the Triassic assemblages of Israel. This application suggests that during the Anisian, a mixture of hygrophytic and xerophytic elements existed. This suggests the co-occurrence of humid niches within the generally arid climate of the Triassic. Carnian samples include an abundance of xerophytic elements, indicating that a homogenous arid climate probably prevailed during that stage. Another kind of paleoenvironmental indication is provided by the rhythmical alternations found in Early Permian taxa. The P. novicus Zone alternates with a unique assemblage of small trilete and monolete spores. These alternations, which are found throughout the entire area, are believed to have been controlled by rhythmical changes in either the sedimentologic

regime or the climate of the continental or nearshore environments of the Early Permian.

Reworked palynomorphs occur in large numbers in many parts of the Permo-Triassic section. They apparently originated from a continent that existed to the south. Because Ordovician to Carboniferous strata are not recognized in the Paleozoic section of Israel, the occurrence of reworked palynomorphs of Silurian and Devonian age in the Triassic of Israel can be used as a useful indicator of a south or southeast paleocurrent regime. A quantitative analysis of the reworked population reveals an excellent correlation with known sedimentologic cycles; the transgressive intervals include very low reworked palynologic content, whereas in regressive intervals, the reworked material is abundant. Therefore, it is suggested that in regions where the geologic setting is similar to Israel, it is possible to identify transgressions and regressions by quantitative analysis of organic remains that include reworked particles.

The transition from the great transgression of the Saharonim Formation to the great regression of the Mohilla Formation is found to be associated with a remarkable decrease in the bisaccate population and a similar increase in the non-bisaccate (mostly Circumpolles) group. This change is found in most of the sections. Since bisaccate and non-bisaccate pollen have different modes of distribution, bisaccates by wind and non-bisaccates by currents, it is suggested

that a high bisaccate content occurs in the Carnian-Ladinian of Israel whenever land was far from the marine depositional sites and only easily-distributed taxa such as bisaccates pollen could reach it. Such conditions would occur during transgressions. On the other hand, during regressions, land would be closer to the depositional site, and non-bisaccates that have a short-range mode of distribution, could become dominant. A word of caution must be added to such an interpretation because the non-bisaccate/bisaccate ratio can be affected considerably by the regional transportation regime.

Strong degradation of organic matter is observed in samples from the Mohilla Formation (Carnian) in both the northern and Coastal Plain of Israel. In many studies, degradation has been found to be promoted by high salinity, great burial depths, and high temperatures. Because the Mohilla Formation was deposited in an hypersaline environment, and because the depth of burial was especially great in northern Israel and the Coastal Plain, a combination of syndepositional (high salinity), and diagenetic (high temperature) processes may have acted together to produce the degradation. Degradation of organic matter is not prominent in southern Israel where depth of burial was smaller.

Some affinities of the Permo-Triassic palynomorphs can be used as paleoenvironmental indicators. For example, assuming that most acritarchs are phytoplankton, their occurrence in Early and Middle Triassic strata can be used to

identify normal marine environments. Their first appearance in Israel immediately above the Permian-Triassic boundary supports the idea that acritarchs are pioneering populations that inhabit newly-made marine environments.

A P P E N D I C E S

DEVCRA 2A		WELZ DEEP		PLESHET 1		ZONAR 4		ZUK TAMBUR 1		ZUK TAMBUR 2	
DEPTH(m)	FORMATION	DEPTH(m)	FORMATION	DEPTH(m)	FORMATION	DEPTH(m)	FORMATION	DEPTH(m)	FORMATION	DEPTH(m)	FORMATION
3075	Mohilla	4700-6	Nirim (lower)	4031	Ardon	1893	Mish'hor	Core 1	Saharonim	1470	Mish'hor
3086		4713-18		4105		1899	Mohilla	1943	Gevanula	1481	
3090		4721-4		4152		1914		Core 2		1490	Mohilla
3107		4728-31		4203	Mohilla	1932-5		1973		1496	
3128		4734		4233-6		1950		1987		1514	
3133		4749-52		4270-3		1956		2020	Re'af	1532	
3162		4767-70	Mish'hor	4293-6	Saharonim	1986	Saharonim	2044		1540	
3179		4801-4		4346-9		2014		2075		1562	
3182		4843-47	Mohilla	4392		2090		2096		1576	
3202		4868-71		4436		2072		2123	Zafir	1595	
3230-45		4896-80		4492	Gevanula	2098		2165		1612	
3240		4919-22		4509		2124		2197		1631	
3264		4946-9		Core 1	Re'af	2169		2245		1650	Saharonim
3338		4955-58		4627		Core 7		2270		1673	
3410		4973-6		4646		2224		2311		1693	
3448		4986		4673	Zafir	2257	Gevanula	2352	Tamim	1717	
3490		5006		4700		Core 8		2391		1736	
3520		5032		4713		Core 9		2433		1769	
3540		5092		4731			Re'af	2476	Argov	1794	
3587		5121	Erez	4758		2420		2513		1815	
3633		5215		4782		2461		2556		1831	
3674		5236-9		4794		2485	Zafir	2595		Core 1	Gevanula
3716		5286-9		4843		Core		2631		Core 2	
3753		5294		4863	Tamim	2537		2687	Se'ad	1907	
3790		5325		4872		2563		2708		1927	
3843		5364-7		4902		2586		2741		1947	
3880		5382		4932-5		2600				1967	
3912		5407		4970		2625				Core 3	
3962		5434		4986		2651				2015	
3995		5456-59		5017	Argov	2678				2031	Lowermost Gev.
4022	Saharonim	5482		5036		2696					
4074		5507		5050		2727					
Core 7		5534		5063-5		2748	Tamim				
4125		5559-62		5093		2776					
4181		5584-87		5120		2797					
4239		5595		5145		2824					
4246		Core 1		5160		2847					
4290		5657-60		5190		2869					
4333		5678-81		5220	Se'ad	2875	Argov				
4385		5688		5240		2899					
4405-25		5727		5259		2901					
4425		5733-36	Karmia	5285		Core 11					
4470		5743		5310		2924					
4465-85		5745-8		5343		2941					
4485-905		5754				2974					
4515		5757-61				3001					
4525-45		5764				3025					
4547		5770				3049					
4565-85		5783				3076					
4629						3102	Se'ad				
4650						3125					
4676						Core 13					
4710						3148					
4717						3151					
4730						3178					
4750						Core 18					
4770						3198					
4790						3210					
4806											

Appendix 1. All samples and their lithostratigraphy

[illegible]

Appendix 2 PALYNOZONAL DESCRIPTION OF ALL WELLS IN THIS STUDY

I: THE ZUK TAMRUR 1 AND 2 WELLS

A. LOCATION AND LITHOSTRATIGRAPHY (Fig. 1; Appendix 3)

The Zuk Tamrur 1 and Zuk Tamrur 2 wells are located in the Judea Desert, to the west of the Dead Sea. The Zuk Tamrur 1 well is at coordinates 181.149/063.926 on the Israel grid. The Zuk Tamrur 2 is located nearby, at coordinates 180.689/064.232.

The lithostratigraphy, modified from the drilling log is presented in Appendix 3; also indicated are all sampling locations. The lithostratigraphy is typical of southern Israel and fits the lithological description of the type sections (Druckman, 1974; Weissbrod, 1981). Because the Zuk Tamrur 1 well penetrated the section down to the Lower Permian and the Zuk Tamrur 2 well only reached the base of the Gevanim Formation, the two wells were combined so that the upper part of the section, from the Triassic/Jurassic boundary (Mish'hor Formation) down to the base of Gevanim Formation (Anisian) was sampled from the Zuk Tamrur 2 well. The lower part of the section, from the top of Ra'af Formation down to the Sa'ad Formation (Lower Permian) was sampled from Zuk Tamrur 1 well. The proximity of these wells and the good lithostratigraphic control, allow the assumption that equivalent formations in both wells are of the same age.

B. PALYNOLOGICAL ZONATION (Appendix 4)

The palynological data from the two Zuk Tamrur wells are presented as range charts in Appendix 4. The following palynozones, each an interval zone, were identified in the studied sections from the oldest to the youngest:

P. novicus Zone

STRATIGRAPHIC OCCURRENCE: The zone appears in the Zuk Tamrur 1 well in the Sa'ad and part of the Arqov formations, interval 2513-2741 m. It was not penetrated to its base in this section.

PALYNOLOGIC DESCRIPTION (Appendix 4): The zone is characterized by a dominance of monosaccate palynomorphs, especially Potoniesporites novicus. The monosaccates Guthoerlisporites cancellosus, Plicatipollenites densus, and Nuskoisporites dulhuntyi also appear in the zone. Striate bisaccates and protobisaccates are common, among which Distriatites insolitus, Protohaploxylinus microcorpus and Vittatina spp. are the most prominent. Small trilete and monolete spores such as Laevigatosporites callosus, Punctatosporites minutus, Pretricolpipollenites bharadwaji and Lophotriletes novicus form a unique palynologic assemblage; they occur together with smaller numbers of large monosaccates and bisaccates (P. novicus, D. insolitus etc.) but have an inverse quantitative relationship with them. When the P. novicus assemblage is dominant, small trilete and monolete spores are

rare. When the latter is abundant, the P. novicus assemblage occurs in low percentages.

Because this zone was not penetrated to its base, the lower boundary cannot be defined here. The upper boundary is illustrated by the Last Appearance Datum of all the palynomorphs encountered in it; no palynomorph from this zone ranges above its upper boundary. Such a massive extinction suggests a possible hiatus (Shaw, 1964) at the top of this zone, and is discussed in more detail below.

AGE: Early Permian (Artinskian). It is not likely that the upper part of this palynozone extends into the Late Permian because it lacks the typical Late Permian palynomorphs (Lueckisporites virkkiae, Klausipollenites schaubergeri, Prototrapoxypinus varius and Striatopodocarpites rarus) that appear throughout the rest of the studied wells.

E. papillatus Zone

STRATIGRAPHIC OCCURRENCE: The base of this zone is in the uppermost part of the Arqov Formation, and its top is at the top of the Zafir Formation. Therefore, most of the zone is in the Zafir Formation. It occurs at the interval 2197-2513 m in Zuk Tamrur 1 well.

PALYNOLOGIC DESCRIPTION (Appendix 4):

Endosporites papillatus, Lunatisporites noviaulensis and Kraeuselisporites spp., are the marker species for this zone. Their local ranges coincide with the upper and lower boundary of the zone. It also is characterized by the abun-

dance of acritarchs (mostly Veryhachium and Micrhystridium). The acritarchs make their first appearance at the base of the zone, and continue upwards into the Middle Triassic. Other palynomorphs that occur at random are Densoisporites playfordi and Alisporites opii. A marked decrease in striate bisaccate pollen grains marks the transition from the underlying striate bisaccate-rich Permian to this zone. Assemblages in this interval are not very palyniferous but they contain enough well-established markers to allow a reliable age-determination.

AGE: Early Triassic (Scythian). The age is based on comparisons to the major key sections around the world.

REMARKS: The Early Triassic age assigned to this zone, suggests that Early Triassic directly overlies an Early Permian zone (P. novicus). This implies either an hiatus or another kind of unconformity at the Permian/Triassic boundary in Zuk Tamrur.

A. saturni Zone

STRATIGRAPHIC OCCURRENCE: This zone extends from the upper part of the Zafir Formation, through the Ra'af and Gevanim Formations, to the lower Saharonim Formation (1794-2197 m in Zuk Tamrur 1 and 2 wells (Appendix 3).

PALYNOLOGIC DESCRIPTION: The great abundance of Aratrisporites saturni is the most characteristic feature of this zone, whose upper boundary is determined by the LAD of this fossil. Species of Aratrisporites (A. pallettae, A. fimbria-

tus, A. centratus) also occur throughout most of this interval. In the lower part of the zone, it is partially replaced by Lunatisporites pellucidus and Cristatosaccus margitatus. Other significant palynomorphs whose last appearance marks the top of this zone are Brachysaccus ovalis, Cyclotriletes oligogranifer and Triadispora plicata. Acritarchs continue into the zone from the Early Triassic and have their Last Appearance Datum within it. Other significant fossils within this zone (some of them appear at random) are Spinotriletes echinoides, Voltziaceasporites heteromorphus, Alisporites grauvogeli, Cristianisporites triangulatus, Platysaccus triassicus, Triadispora crassa, Lunatisporites transversundatus, Microcachrydites doubingeri, M. sittleri, Platysaccus queenslandi and Angustisulcites klausii. The A. saturni Zone is generally characterized by a large variety of palynomorphs, most of which are bisaccates. Most samples are very palyniferous.

A unique element in this zone is the abundance of species of Raistrickia, that occur in relatively large numbers in this section and this zone only.

AGE: Anisian. Age determination based on comparisons with equivalent ammonoid-controlled strata in outcrops in Israel.

P. amicus Zone

STRATIGRAPHIC OCCURRENCE: This zone extends from 1631 to 1794 m in the Zuk Tamrur 2 well, and is within the Saharonim

Formation.

PALYNOLOGIC DESCRIPTION: As is common in the Anisian palynozone above, this zone is characterized by a large variety of palynomorphs. Bisaccate fossils form the majority of the assemblage, while non-bisaccates are rare. Species of Triadispora and Microcachrydites are frequent. The best markers for this zone are Podosporites amicus and Eucommiidite micrrogranulatus. They are restricted to this zone and their Last Appearance Datum is the best marker for its top. Other fossils that have their LAD at the top of this zone are Triadispora plicata, Sellaspora rugoverrucata, M. doubingeri, Cuneatisporites radialis and Chordasporites singulichorda. The range of many taxa, including Cristatitriletes baculatus, Platysaccus queenslandi, M. sittleri, Infernopolenites sulcatus, A. klausii, T. plicata, Platysaccus papilionis, Palaeospongiosporis europaeus, Triadispora suspecta, Lunatisporites acutus, Paracirculina scurrilis, Duplicisporites granulatus and Camerosporites secatus, continues above this zone.

AGE: Ladinian. Age is based on well-established marker palynomorphs elsewhere, as well as correlation to worldwide and local ammonite zonation.

P. densus Zone

STRATIGRAPHIC OCCURRENCE: The zone occurs within the upper Saharonim Formation and all of the Mohilla Formation (1496-1631 m in the Zuk Tamrur 2 well).

PALYNOLOGIC DESCRIPTION: This zone is characterized by a marked decrease in bisaccate taxa, followed by increase in non-bisaccates which form the major part of the assemblage. Most of the non-bisaccates belong to the Circumpolles Subturmæ. The best marker for this zone is Patinasporites densus whose range coincides with the boundaries of this interval. The upper boundary is designated by the Last Appearance Datum of D. granulatus, C. secatus, P. scurrilis and L. acutus, all of which had their First Appearance Datum in the previous zone. The LAD of many taxa at the top of this zone and the fact that none of its fossils continues above it, reflect the presence of an unconformity that is demonstrated by lithologic changes at the contact of the Mish'hor and Mohilla Formations (= Triassic/Jurassic boundary).

AGE: Carnian. The age determination is based essentially on palynologic markers, supported by random occurrence of other fossils.

II: ZOHAR 8 WELL

A. LOCATION AND LITHOSTRATIGRAPHY (Fig. 1, Appendix 5)

The Zohar 8 well is located in the Judea desert, west of the Dead Sea, at coordinates 170.979/069.737, about 10 km from the two Zuk Tamrur wells. Total depth was 3337 m (Fig. 1). The well penetrated the entire Permo-Triassic interval and also the underlying Precambrian Zenifim Formation (Appendix 5). The lithostratigraphy is typical of other sections

in southern Israel (Druckman, 1974; Weissbrod, 1981). Lithostratigraphy and sample locations are shown in Appendix 5.

B. PALYNOLOGICAL ZONATION (Appendix 7)

Appendix 7 summarizes the palynostratigraphic framework established for the Zohar 8 well. The following interval zones were designated in this well from the oldest to the youngest:

P. novicus Zone

STRATIGRAPHIC OCCURRENCE: The zone appears in the Sa'ad Formation and in the lower Arqov Formation, interval 3076 m-3210 m.

PALYNOLOGIC DESCRIPTION: The palynologic composition is generally similar to the same zone in Zuk Tamrur 1 well, with slight differences (see description above). The major difference between the zone in Zohar 8 and that in Zuk Tamrur 1 is in the upper contact of the zone: in Zuk Tamrur, a discontinuity of palynomorphs was interpreted as hiatus at the Permian/Triassic boundary, but in Zohar 8 a continuous transition into the overlying zone (Late Permian) is observed and the sequence shows no break in time. The continuity is illustrated by the range of Plicatipollenites indicus, Falcisporites nuthalensis, Protohaploxypinus microcorpus and Guthoerlisporites cancellosus. A unique element, found in this zone and continuing above its upper boundary is the abundance of fungal spores and other fungal remains. The upper boundary of the zone is illustrated by the same major

Last Appearance Datums as for Zuk Tamrur 1. The lower limit of the zone coincides with the Permian/Precambrian unconformity (Appendix 5).

AGE: Early Permian (Arturian).

L. virkkiae Zone

STRATIGRAPHIC OCCURRENCE: The zone appears in parts of the the Arqov and Yamin formations, interval 2776 m-3076 m.

PALYNOLOGIC DESCRIPTION: The abundance of striate bisaccates, mostly species of Protohaploxypinus, is a prominent feature of the zone. Its best markers are Klausipollenites schaubbergeri, Lueckisporites virkkiae and a variety of Protohaploxypinus spp., including P. varius, P. limpidus, P. richteri, P. jacobii and P. diagonalis. All these taxa, together with Limitisporites moerensis and Gardenasporites leonardii, have their last appearance at the the upper boundary of this zone. The LAD of many Protohaploxypinus spp. at the top of this zone seem to be of stratigraphic importance and is found in other sections. The occurrence of many taxa start in the underlying zone and continue in this zone (see the ranges of Falcisporites stabilis and Lundbladispora brevicula).

AGE: Late Permian (Thuringian). The age determination is based on the appearance of many well-established marker fossils.

E. papillatus Zone

STRATIGRAPHIC OCCURRENCE: This zone begins in the upper

Yamin Formation and extends upward to the upper part of the Zafir Formation (interval 2563-2776 m).

PALYNOLOGIC DESCRIPTION: The zone is composed of the same markers as its equivalent zone in Zuk Tamrur 1 well (see above), but recovery was better and assemblages are more palyniferous. In addition to L. noviaulensis, E. papillatus and Kraeuselisporites spp., whose last appearance marks the upper limit of the zone, the zone also is characterized by the occurrence of Lunatisporites pellucidus, Falcisporites stabilis, Cyclotriletes microgranifer, Densipollenites indicus, Hamiapollenites tractiferinus, Lundbladispora brevicula, Verrucosisporites thuringiacus, Densoisporites nejburgii, Spinotriletes echinoides and Lueckisporites singhii. Acritarchs, mostly Veryhachium and Micrhystridium begin to appear at the base of the zone and continue upwards.

AGE: Early Triassic (Scythian). The age is based on well-established palynologic markers.

A. saturni Zone

STRATIGRAPHIC OCCURRENCE: This zone extends from the upper Zafir Formation, through the Ra'af and Gevanim Formations, into the lower Saharonim Formation (interval 2178-2499 m).

PALYNOLOGIC DESCRIPTION: As already noted for Zuk Tamrur 1 well, a high species diversity is one of the most prominent characteristics of this zone. With slight changes, its palynologic composition is similar to what was found in the Zuk Tamrur 1. The same markers, A. saturni, B. ovalis and L. pellucidus are found in both wells, but they are less abundant than in the Zuk Tamrur wells. Also, A. saturni is rare at the base of the zone but becomes abundant later. Acritarchs continue from the underlying zone and their LAD is one of the markers for the upper limit of this assemblage. With slight differences, the rest of the palynologic composition is similar to Zuk Tamrur 1 well. Continuity of taxa across the upper and lower boundaries of this zone are observed. They indicate conformable contacts with the overlying and underlying palynozones.

AGE: Anisian. Age is based on comparison to equivalent ammonoid-controlled strata in outcrops.

P. amicus Zone

STRATIGRAPHIC OCCURRENCE: The zone occurs from the lower to the upper Saharonim Formation (interval 2014-2178 m)

PALYNOLOGIC DESCRIPTION: As for the Zuk Tamrur 2 well, E. microgranulatus, P. amicus and Echinitosporites iliacooides,

are the markers. With only minor differences, the rest of the palynologic description is similar to Zuk Tamrur 2 well. AGE: Ladinian. Age is based on comparison to equivalent ammonoid-controlled strata in outcrops.

P. densus Zone

STRATIGRAPHIC OCCURRENCE: From the upper Saharonim Formation to the upper part of the Mohilla Formation (interval 1914-2014 m).

PALYNOLOGIC DESCRIPTION: With minor changes, the composition is similar to the equivalent zone already described in Zuk Tamrur 2 well. Circumpolles pollen are abundant, and bisaccate pollen is rare. Many forms that begin in this zone continue higher into the succeeding zone.

AGE: Carnian.

A zone of trilete spores

STRATIGRAPHIC OCCURRENCE: The zone appears in the uppermost Mohilla Formation (interval 1893-1914 m).

PALYNOLOGIC DESCRIPTION: This zone contains mostly trilete spores such as Deltoidospora minor, D. toralis, Concavisporites crassexinus and Kyrtomisporites spp. Other important taxa are Gliscopollis meyeriana and C. torosa. The interval is very narrow and is found in two samples only.

AGE: ?Rhaeto-Norian. Kyrtomisporites was considered to be a typical post-Carnian genus by Schuurmaan (1979). Cousminer (1981a) studied a sample from 1899 m and suggested a Rhaeto-Norian age based on this fossil and other post Carnian taxa.

The problem with a Rhaeto-Norian age is that species of Kyrtomisorites were also reported from lower stratigraphic positions (Van Der Eem, 1983). C. torosa and G. meyeriana are known to be post Carnian in age. Therefore an accurate age for this small interval cannot be assigned with certainty; it may be Jurassic and contains reworked Kyrtomisorites, or it may be Rhaeto-Norian (and the Jurassic forms are cavings).

III: PLESHET 1 WELL

A. LOCATION AND LITHOSTRATIGRAPHY

The Pleshet 1 well is located in the southern coastal plain, at coordinates 120.844/100.611 on Israel grid (Fig. 1.) It was drilled in 1984, and total depth was 5343 m.

The lithostratigraphic subdivision of the Permo-Triassic interval (4200 to 5343 m) has been the subject of two different interpretations that reflect its proximity to both the Negev and the Coastal Plain. Accordingly, the lithostratigraphic interpretation made by the driller and by Grossman (1985), matched the well to the lithostratigraphic framework of the Negev wells, while Derin (1986, written commun.) matched it to the Helez Deep borehole. According to Grossman (1985), the lithostratigraphic "abnormalities" of Helez Deep, as represented by the Erez or Or Haner Conglomerates, do not appear in Pleshet 1 and it is a typical "Negev" sequence. The driller's lithostratigraphic subdivision and

sample locations are shown in the columnar section (Appendix 7).

B. PALYNOLOGICAL ZONATION (Appendix 8)

The palynozonal framework is illustrated in Appendix 8. The following zones from the oldest to the youngest were encountered:

P. novicus Zone

STRATIGRAPHIC OCCURRENCE: The zone is included within the Sa'ad Formation; its upper boundary is located at the upper part of this formation. Interval: 5050-5343 m.

PALYNOLOGIC DESCRIPTION: An assemblage of large monosaccates, including P. novicus and N. dulhuntyi is dominant in most of the samples. Together with these, a variety of small trilete and monolete spores, such as R. warchianus, P. minutus, L. callosus, P. mutabilis and others occur (Appendix 8). The overall composition, with minor differences, is similar to the Zuk Tamrur 1 and the Zohar 8 wells. Of interest here are the pronounced alternations between assemblages dominated by P. novicus and assemblages dominated by small trilete and monolete spores.

AGE: Early Permian. Age determination is based on marker palynomorphs.

L. virkkiae Zone

STRATIGRAPHIC OCCURRENCE: This zone appears from the lower Yamin Formation, through the Arqov Formation to the top of the Sa'ad Formation (interval 4782-5050m).

PALYNOLOGIC DESCRIPTION: Composition of this interval zone is similar to its equivalent zone in the Zohar 8 well. It is identical to Zone II of the Makhtesh Qatan 2 well (Eshet, 1983; Eshet & Cousminer, 1986). The zone is characterized by abundance of striate bisaccates (mostly Protohaploxylinus and Striatopodocarpites spp.) at its top. Other reliable markers are L. virkkiae and K. schaubergeri.

AGE: Late Permian (Thuringian).

E. papillatus Zone

STRATIGRAPHIC OCCURRENCE: Interval 4673-4782m (Zafir Formation). The short, 109 m-thick interval in this well is thinner than its equivalent zones in the Zohar 8 well (200 m) and in the Makhtesh Qatan 2 well (around 300 m).

PALYNOLOGIC DESCRIPTION: As in the previously-described wells, the zone is characterized by E. papillatus, L. noviaulensis and Kraeuselisporites spp. Acritarchs (mostly Veryhachium and Micrhystridium) have their first occurrence at the base of this zone and continue upward, into the overlying strata. The other characteristic fossils are shown in Appendix 8.

AGE: Early Triassic (Scythian).

A. saturni Zone

STRATIGRAPHIC OCCURRENCE: Interval 4436-4673 m (top Zafir to lower Saharonim Formations).

PALYNOLOGIC DESCRIPTION: As is described in the other wells, the zone is characterized by the abundance and variety of

Aratrisporites spp. (mostly A. saturni and A. centratus).

The best markers for the top are the last appearances of A. saturni, L. centratus, B. ovalis and Cristianisporites triangulatus. At the lower part of the zone, L. pellucidus is the characteristic fossil; A. saturni replaces it in abundance higher in the section. For more details, see Appendix 8.

AGE: Anisian.

P. amicus Zone

STRATIGRAPHIC OCCURRENCE: Interval 4346-4436 m (lower to upper Saharonim Formation).

PALYNOLOGIC DESCRIPTION: A large variety of taxa, mostly bisaccates, characterize this zone. Its top is marked by the last appearance of P. amicus, Triadispora plicata and Triadispora crassa. Species of Microcachrydites are common in this interval. Other Ladinian markers, such as Echinitosporites ilioides and Eucommiidites microgranulatus are missing. Continuity of ranges into the overlying and underlying zones was observed.

AGE: LADINIAN.

P. densus Zone

STRATIGRAPHIC OCCURRENCE: Interval 4203-4346 m (top Saharonim and the entire Mohilla Formations).

PALYNOLOGIC DESCRIPTION: With slight differences, this interval zone is similar to the Late Triassic assemblages described before from the Zuk Tamrur 2 and Zohar 8 wells.

Circumpolles palynomorphs are abundant, and bisaccates occur

in very low percentage. All of the markers described above also are found here, with slight variations in ranges. The top of this zone coincides with the base of the Jurassic Mish'hor Formation.

AGE: Carnian.

IV: HELEZ DEEP WELL

A. LOCATION AND LITHOSTRATIGRAPHY (Appendix 9 and Fig. 1)

The Helez Deep well is located in the southern coastal plain, about 10 km southeast of the Pleshet 1 well (Fig. 1). This is the only borehole in the coastal plain that penetrated the crystalline Precambrian basement. Therefore it is important for understanding both the paleogeographic position and geologic processes in this region. The lithostratigraphy was established by Druckman and Kashai (1981). An alternative lithostratigraphic subdivision was offered by B. Derin (written commun., 1986), who discarded the Karmia Formation and suggested the Or Haner Conglomerate, to replace the Erez Conglomerate of Druckman and Kashai. As had already been mentioned for the Pleshet 1 well, the marked lithologic difference between these two wells is of great paleogeographic significance.

B. PALYNOLOGICAL ZONATION (Appendix 10)

Palynologic data for the Helez Deep well is summarized in Appendix 10, where ranges and relative abundances of all

fossils are plotted. The following palynozones, from the oldest to the youngest were encountered:

E. papillatus Zone

STRATIGRAPHIC OCCURRENCE: The zone occurs in the the Karmia shale unit, from 5733 to 5783 m.

PALYNOLOGIC DESCRIPTION: The best markers for this zone are E. papillatus and L. noviaulensis. The zone contains few in situ palynomorphs and abundant reworked Permian and earlier Paleozoic taxa. Its upper boundary was placed at the top of Karmia Shale (5733 m). The same markers are found also as reworked particles in the lowermost part of the Erez Conglomerate. This zone overlies the Precambrian basement unconformably.

AGE: Scythian.

"The Erez Conglomerate Assemblage"

STRATIGRAPHIC OCCURRENCE: Erez Conglomerate (5092 m- 5733 m).

PALYNOLOGIC DESCRIPTION: The assemblage recovered from the Erez Conglomerate contains few palynomorphs and no definite assemblage could be established. Most palynomorphs appear to be reworked, and thus, cannot be classified into a significant interval zone. Among the reworked fraction, Late Permian fossils (e.g, L. virkkiae), Early Triassic (e.g., E. papillatus, L. noviaulensis, Krauselisporites spp.) and Anisian (A. saturni, L. pellucidus) are the most prominent palynomorphs.

AGE: Anisian to Ladinian. The fossils identified in this interval range from Late Permian to Anisian. Since they are reworked, the age of the assemblage, and of the conglomerate, cannot be older than Anisian. This interval probably accumulated during the end of the Anisian and the Ladinian.

P. densus Zone

STRATIGRAPHIC OCCURRENCE: This zone occurs in the Mohilla Formation, interval 4868-5092 m.

PALYNOLOGIC DESCRIPTION: The zone is characterized by the same markers as its equivalents in the other sections: C. secatus, P. scurrilis, P. granifer, P. densus, Ovalipollis ovalis, Duplicisporites granulatus, Striatoabieites aytugii, and Lunatisporites acutus. Circumpolles palynomorphs are abundant and bisaccate pollen is rare. The zone is located between two unconformities that probably represent subaerial erosional processes: it is overlain by the lateritic Mish'hor Formation, and is underlain by the Erez Conglomerate. Therefore, no taxon in this zone ranges above or below the zones' boundaries, which are characterized by extinctions of all taxa. Of special interest in this zone is the occurrence of P. densus in relatively large numbers, compared to its occurrence in the south. This phenomenon was also recorded in Devora 2A and Ga'ash 2 wells.

AGE: Carnian. Age is based on the palynologic composition as well as the stratigraphic position.

Kyrtonisporites spp. Zone

STRATIGRAPHIC OCCURRENCE: This zone occurs in the Mish'hor Formation and the lower part of the Nirim Formation, interval 4767-4868 m.

PALYNOLOGIC DESCRIPTION: Although this zone is generally poor in palynomorphs, species of Kyrtonisporites and Porcellispora longdonensis are found in some of the samples. The validity of this zone is questionable due to its low fossil content and to its stratigraphic position within the lateritic Mish'hor Formation. This zone also contained typical Carnian fossils such as C. secatus and P. densus. They are interpreted here to be taxa that "survived" the laterization event at the end of the Triassic and during the Liassic.

AGE: ?Rhaeto-Norian. Age-determination is based on the occurrence of P. longdonensis and Kyrtonisporites spp. from Rhaeto-Norian strata elsewhere (Morbey, 1975). It is noted that these fossils also are found in Carnian strata, which raise a question as to the accuracy of this age determination.

V: DEVORA 2A WELL

A. LOCATION AND LITHOSTRATIGRAPHY (Fig. 1; Appendix 11)

The Devora 2A well is located at the northern part of Israel, and at coordinates 1822.401/233.122 on the Israel grid. Drilling was completed in April, 7.1978 at a total depth of 5647 m.

The Triassic interval in this section unconformably underlies the Lower Jurassic Asher Volcanics (Gvirtzman & Steinitz, 1984). The section is much thicker and indicates more marine influence than its equivalents to the south (Appendix 11). The clastic formations, such as the Gevanim Formation, become thinner, while marine and evaporitic intervals (Ra'af, Saharonim and Mohilla Formations) are thicker than in the south. Sample locations are indicated in Appendix 11.

B. PALYNOLOGICAL ZONATION (Appendix 12)

Although most samples in Devora 2A well were not as productive as in the southern sections, recovery was good enough to allow a reliable palynozonation. The zonation is correlative to equivalent zones in the rest of Israel. The following palynozones were defined, from the oldest to the youngest, and are shown in Appendix 12):

E. papillatus Zone

STRATIGRAPHIC OCCURRENCE: This zone occurs from T.D. (Zafir Formation) to the upper part of this rock unit, interval 5520-5633 m. The lower part of the zone was not penetrated.

PALYNOLOGIC DESCRIPTION: The composition is similar to the

E. papillatus zone described in Zuk Tamrur 1, Zohar 8 and Pleshet 1 wells. It is characterized by the abundance of E. papillatus, L. noviaulensis and Kraeuselisporites spp. Acritarchs begin to appear in this zone. Reworked material is common. More details are plotted in Appendix 12 and.

AGE: Scythian.

A. saturni Zone

STRATIGRAPHIC OCCURRENCE: The zone extends from the upper Zafir Formation, through the Ra'af and Gevanim Formations to the lower part of the Saharonim Formation (interval 4710-5520 m).

PALYNOLOGIC DESCRIPTION: This zone is dominated at its upper part by A. saturni, whose last appearance is the best marker for the top of the zone. Other markers for the top are the last appearances of B. ovalis and A. klausii. At the lower portion of this zone, L. pellucidus becomes prominent, at the expense of A. saturni. The rest of the palynologic description, with slight differences, is similar to the equivalent zones in the other sections. More details are provided on Appendix 12).

AGE: Anisian.

P. amicus Zone

STRATIGRAPHIC OCCURRENCE: This zone is limited to the middle part of the Saharonim Formation, interval 4405-4710 m.

PALYNOLOGIC DESCRIPTION: The best markers for this zone are the last appearance of P. amicus and the abundance of Tria-

dispora spp. In contrast to the rest of the sections where acritarchs were absent from this zone, Microhystridium and Veryhachium occur in most samples. Other important taxa in this zone are Sellasporea rugoverrucata, Heliosaccus dimorphus, L. pellucidus, Kuglerina meieri, Platysaccus queenslandi, Microcachrydites doubingeri, A. klausii and Cuneatisporites radialis. As for the other sections, bisaccates are abundant. More details are provided in Appendix 12.

AGE: Ladinian.

P. densus Zone

STRATIGRAPHIC OCCURRENCE: The zone occurs in the upper Saharonim Formation and throughout the Mohilla Formation (interval 3075-4405 m. The zone is very thick, compared to its equivalents to the south that are in the order of 100 m in thickness.

PALYNOLOGIC DESCRIPTION: The common markers for this zone are P. scurrilis, P. densus, Duplicisporites granulatus, C. secatus and Praecirculina granifer. These have their last appearance at the top of this zone. Non-bisaccates, especially Circumpolles taxa are abundant, while bisaccate pollen is rare. Of special interest is the abundance of P. densus, which occurs in the equivalent zone in smaller numbers to the south. This species may have been "blooming" to the north and central Israel during this time. Many taxa of this zone first appear in the underlying Ladinian interval, which implies a conformable contact. The upper contact of this

zone coincides with the base of the Asher Volcanics that overlie the Triassic unconformably.

AGE: Carnian. No younger Rhaeto-Norian fossil have been found.

VI: GA'ASH 2, RAMALLAH 1, MAKHTESH QATAN 2, AND RAMON 1 WELLS

In addition to the five sections that have been studied and described palynologically above, results from other sections that have been studied over past years by various authors, were added to this study. These sections are described briefly here because some contain important information about the Permo-Triassic palynology of Israel. For location of these sections, refer to Figure 1. The palynostratigraphic data compiled for this chapter is summarized in Appendix 13.

A. GA'ASH 2 well:

The palynostratigraphy of the well was studied by Cousminer (1981b). It contains palynomorphs ranging in age from Anisian to Rhaeto-Norian. The Anisian interval includes, among others, Brachysaccus ovalis, Spinotriletes echinoides, Latosaccus latus, Protodiploxypinus acutus and P. potoniei.

These were also recorded in the sections studied for the present research. The Ladinian interval was poor in palynomorphs, and contained P. amicus, Triadispora stabilis, C. secatus and L. acutus. The Carnian interval was palynologically similar to all the other equivalent zones in Israel,

by having a dominance of Circumpolles taxa (C. secatus, P. scurrilis) together with Ovalopollis ovalis, Triadispora obscura, Infernopollenites spp., and L. acutus.

The Ga'ash well provides the best evidence for the existence of Rhaeto-Norian strata along the coastal Plain. Cousminer (1981b) reported from this interval some Rhaeto-Norian markers such as the dinoflagellate cysts Rhaetogonyaulax rhaetica, Suessia swabiana, Noricysta fimbriata, Heibergella assymetrica as well as the pollen and spores Rhaetipollis germanicus, Lunatisporites rhaeticus, Kyrtomispores laevigatus and Riccisporites tuberculatus.

B. RAMALLAH 1 well:

A preliminary study of samples from this well (Eshet, 1984a) revealed a distinct Anisian assemblage of A. saturni, Brachysaccus ovalis and L. pellucidus. Although the Zafir Formation appeared to have been penetrated, no fossils were found and it is not clear if an Early Triassic section is present. The Ladinian interval was composed of bisaccate pollen, especially Triadispora spp. and Microcachrydites spp. Although the well lacks markers that occurred in the other wells (E. ilioides, P. amicus), its age could be inferred from its stratigraphic position between Carnian and Anisian strata. The Carnian interval is represented by Circumpolles palynomorphs (mostly P. scurrilis and C. secatus) and relatively large numbers of P. densus. This zone is relatively thick, about 850 m. Recovery is generally poor,

but the palynological composition is distinct.

C. MAKHTESH QATAN 2 well:

This well was studied in detail by Eshet (1983). Nine palynozones, from Early Permian (Arturian) to Late Triassic (Carnian) were described. Those zones are used as a comparative standard for the present work. The Early Permian contained P. novicus, Vittatina spp., and D. insolitus. The Late Permian zone was composed of a variety of Protohaploxy-pinus spp. (P. varius, P. diagonalis, P. limpidus) along with K. schaubergeri and L. virkkiae. The dominant palynomorphs in the Early Triassic (Scythian) zone were E. papillatus, L. noviaulensis, Kraeuselisporites spp., and abundance of acritarchs. The Anisian interval was subdivided into a Lower Anisian zone, with Voltziaceasporites heteromorphus, Alisporites grauvogeli, C. oligogranifer and P. queenslandi, and two Late Anisian subzones: one with Latosaccus latus and A. saturni, overlain by Aratrisporites spp. complex. The Ladinian interval included the markers P. amicus, Echinitosporites iliacoides, Monosulcites perforatus, Triadispora stabilis and T. suspecta. The Carnian interval was similar to the P. densus zone in the rest of the wells of the present research.

D. RAMON 1 well:

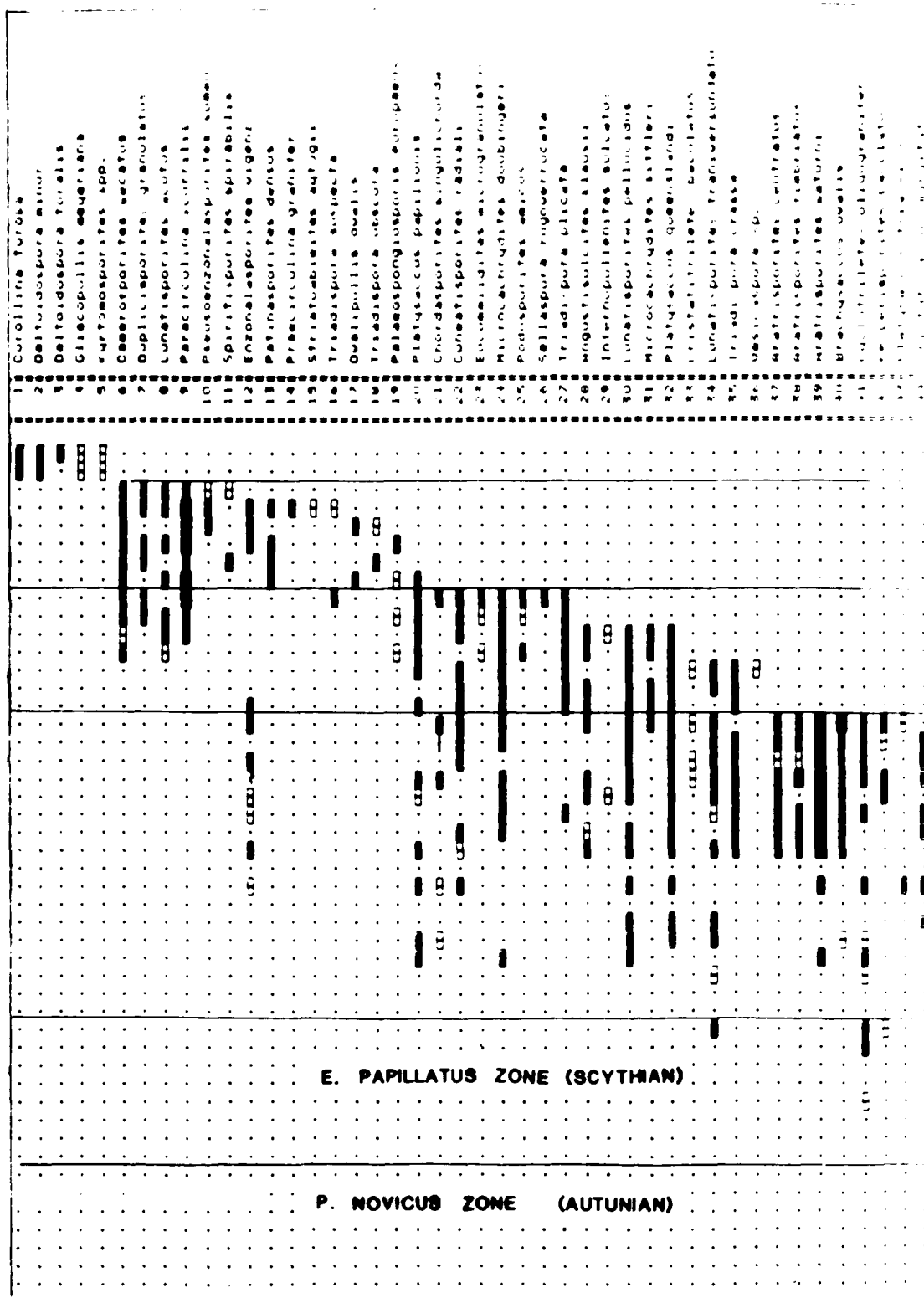
Preliminary results were presented by R. Dunay (1974, written commun.) and Eshet (1984a). This well penetrated the entire Permo-Triassic interval and reached the Precambrian

Zenifim Formation. The general palynological composition is similar to the Makhtesh Qatan 2 well. The Early and Late Permian intervals were composed of P. novicus and L. virkkiae zones, accordingly. The Scythian interval is represented by an E. papillatus zone, and the Anisian is represented by an A. saturni Zone. In the Ladinian interval, an assemblage of P. amicus, E. iliacoides and abundant bisaccate pollen were recovered. The Carnian is represented by an assemblage which is identical to the P. densus Zone described above.

PALYNOZONE	A. SATURNI					E. PAPILLATUS				
STAGE	ANISIAN					SCYTHIAN				
SYSTEM	T	R	I	A	S	S				
SAMPLES (m)	2044	2076	2086	2122	2166	2167	2248	2270	2312	2332
LITHOLOGY										
FORMATION	RA'AF					ZAFIR				

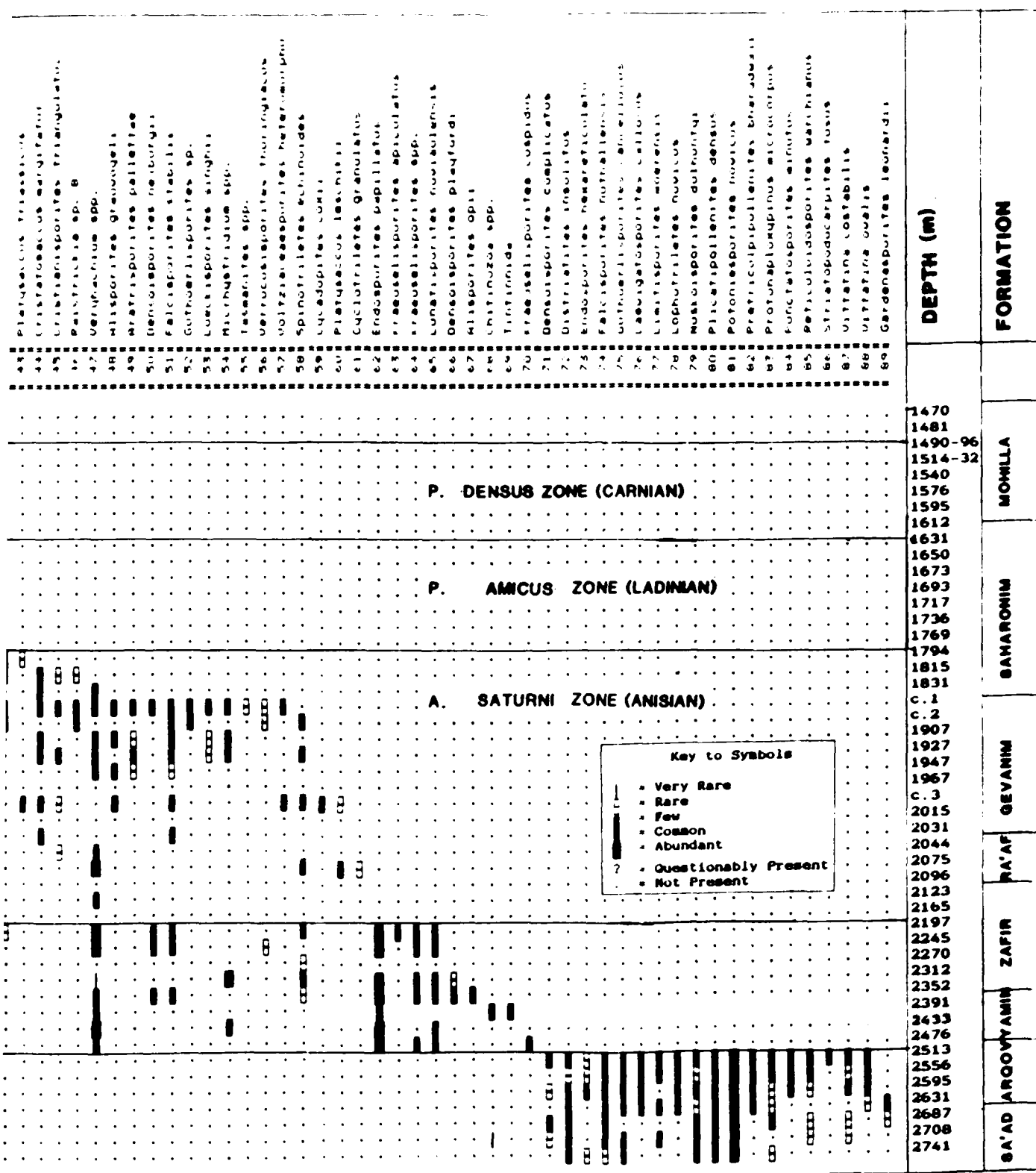
PALYNOZONE	P. DENSUS										P. AMICUS									
	STAGE	?	CARNIAN					LADINIAN												
SYSTEM		T					R					A					I		S	
SAMPLES (m)		1476	1484	1490	1614	1640	1676	1686	1612	1631	1680	1672	1686	1717	1736	1768	1784	1812		
CORE																				
LITHOLOGY																				
FORMATION	ARDON	MOHILLA					SAHARONI													

MISH'NOR



Appendix 4. Range chart

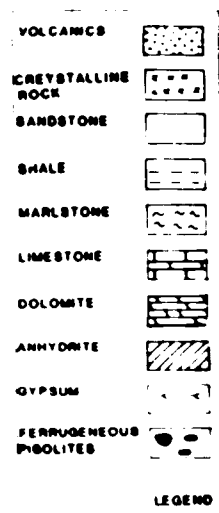
Tamrur 1 and 2 wells.



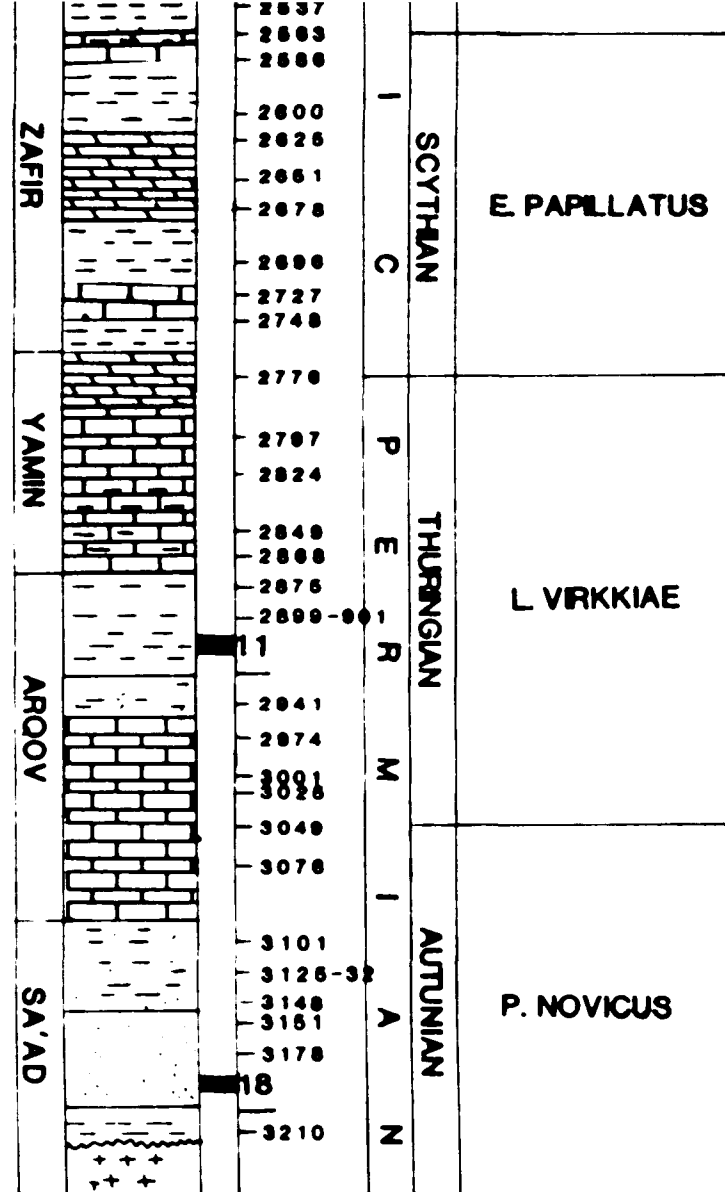
part of all taxa from the Zuk
 lls. For lithostratigraphy, see

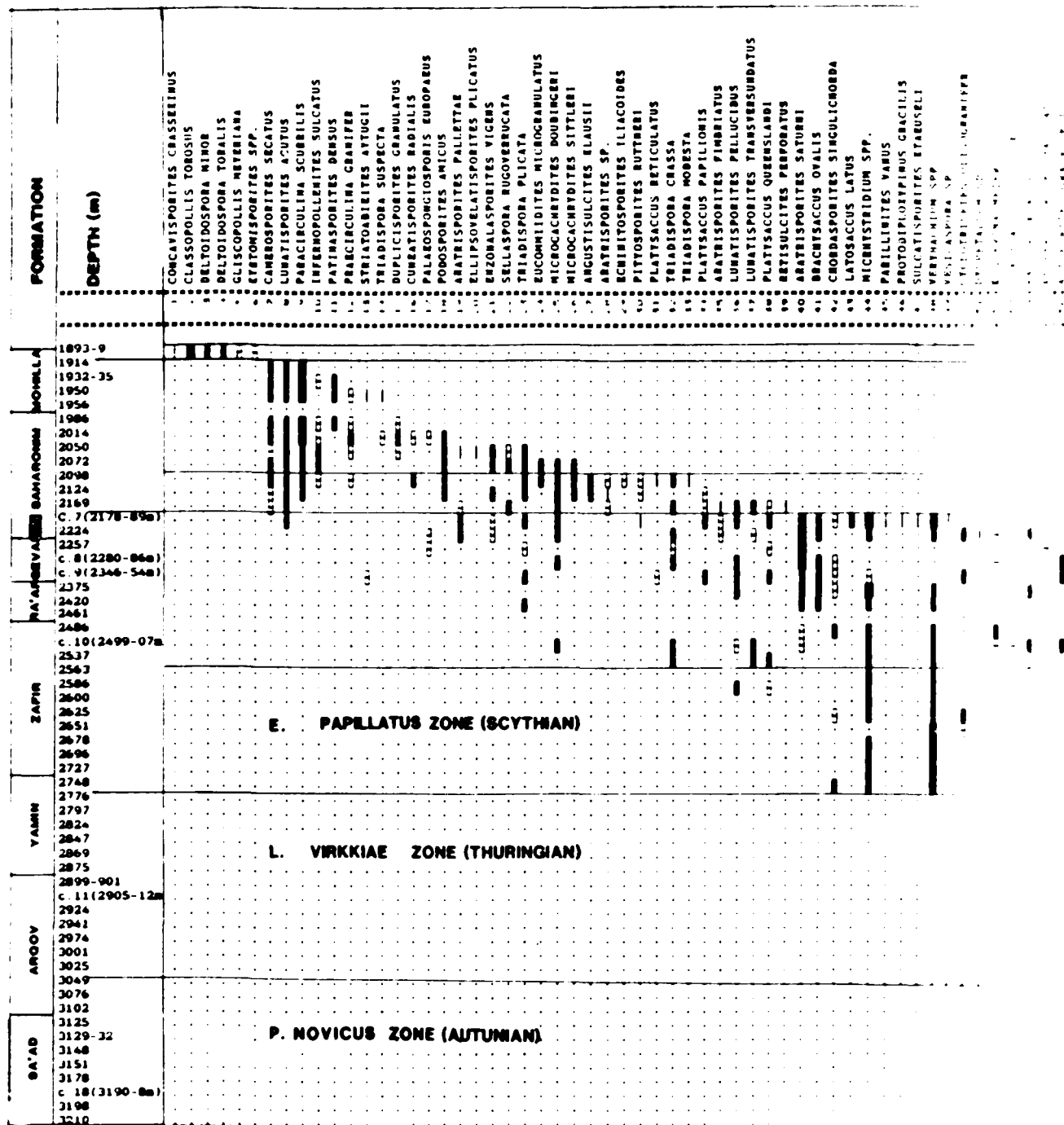
PALYNOZONE	TRILETE SPORES	P. DENSUS	P. AMICUS	A. SATURNI
STAGE	?	CARNIAN	LADINIAN	ANISIAN
SYSTEM		T	R	I A S S
SAMPLES (m)	1893-8 1914 1932-5	1980-8 1986 2014 2050 2072	2098 2124	2224 2267 2375 2420 2461 2486
CORE			7	8 9 10
LITHOLOGY				
FORMATION	MOHILLA	SAHARONIM	GEVANIM	RA'AF

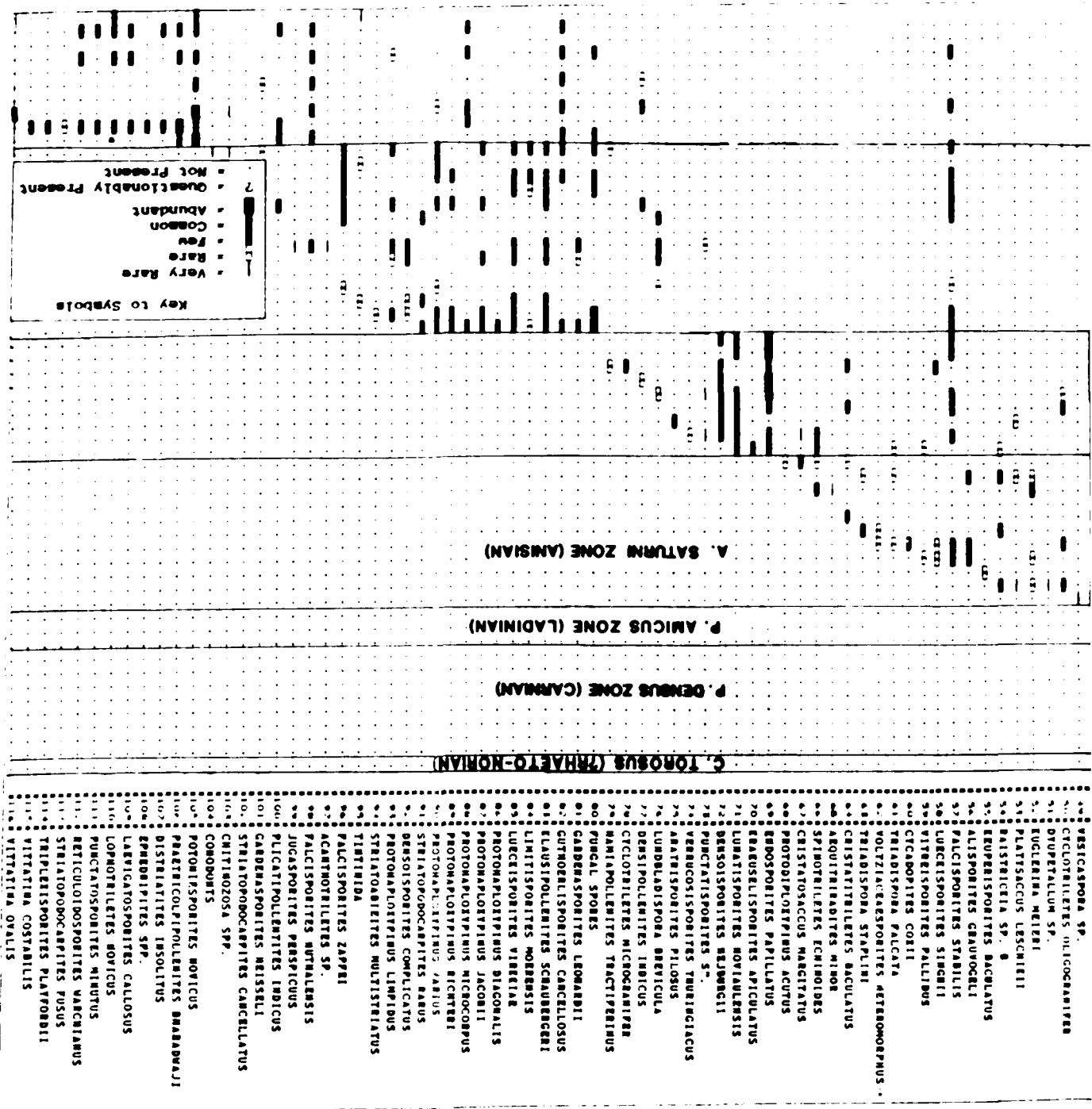
2537
2563
2586

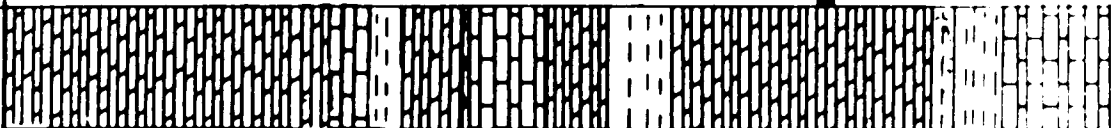


Appendix 5. Litho- and palynostratigraphy of the Zohar 8 well. Lithostratigraphy after Druckman, (1974)







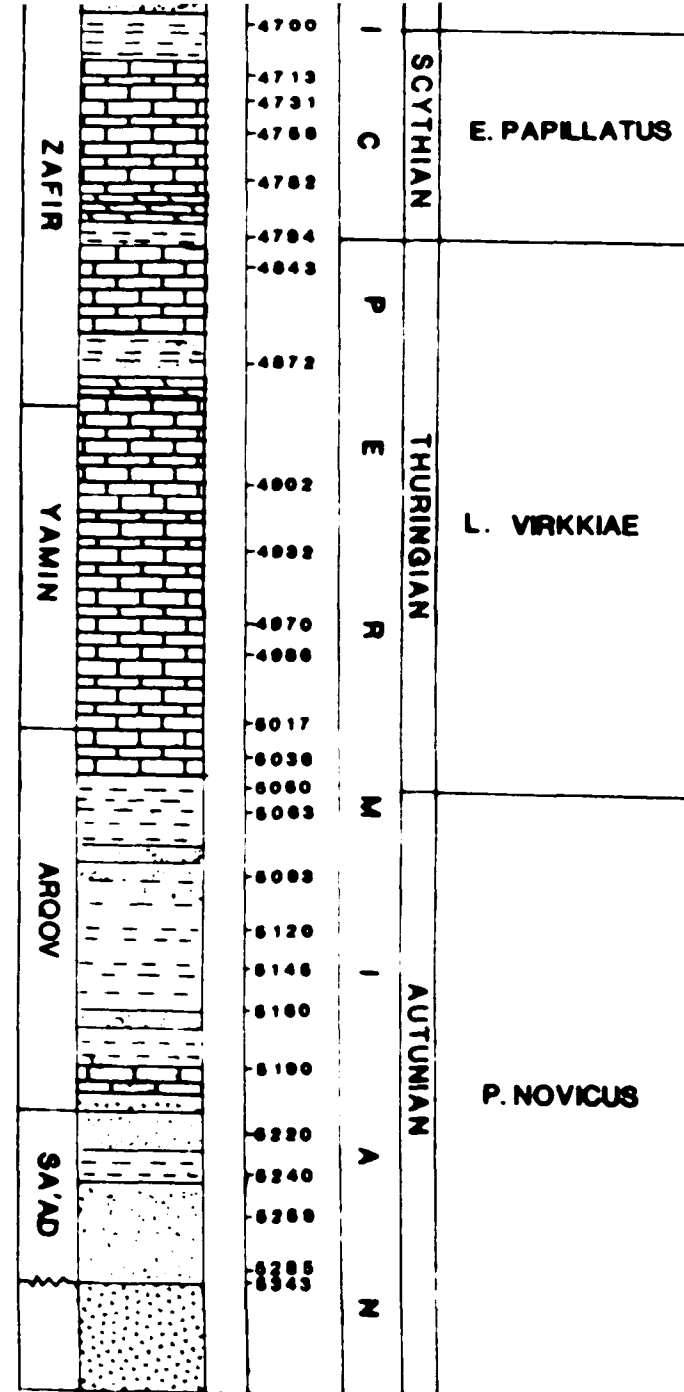
PALYNOZONE	P. DENSUS				P. AMICUS		A. SATURNI				E. PAPILLATUS					
STAGE	CARNIAN				LADINIAN		ANISIAN				SCYTHI.					
SYSTEM	T	R	I	A	S	S	I	C								
SAMPLES (m)	4208	4238	4270	4288	4348	4388	4438	4482	4608	4627	4648	4673	4700	4713	4731	4768
CORE	1															
LITHOLOGY																
FORMATION	MOHILLA		SAHARONIM				GEVANIM		RA'AF			Z/				

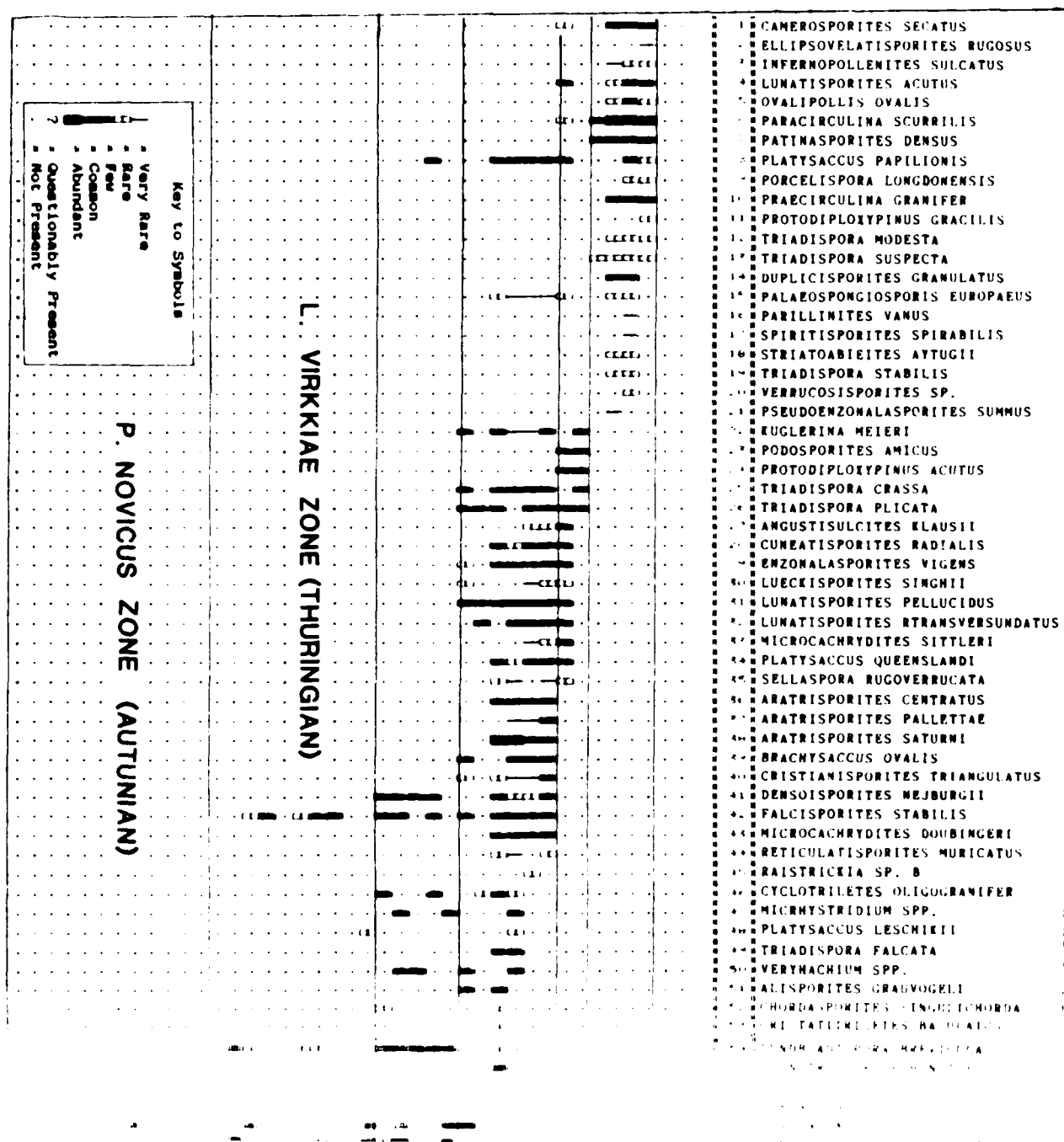
VOLCANICS	
CRYSTALLINE ROCK	
SANDSTONE	
SHALE	
MARLSTONE	
LIMESTONE	
DOLOMITE	
ANHYDRITE	
GYPHUM	
FERRUGINEOUS PHOLITES	
LEGEND	

ppendix 7

Litho- and palynostratigraphy
of the Pleshet 1 well.

Lithostratigraphy after the drilling log
(Oil Expl. Inv.)

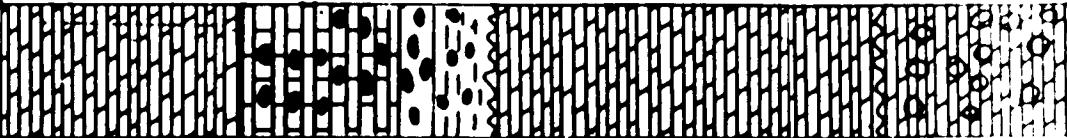


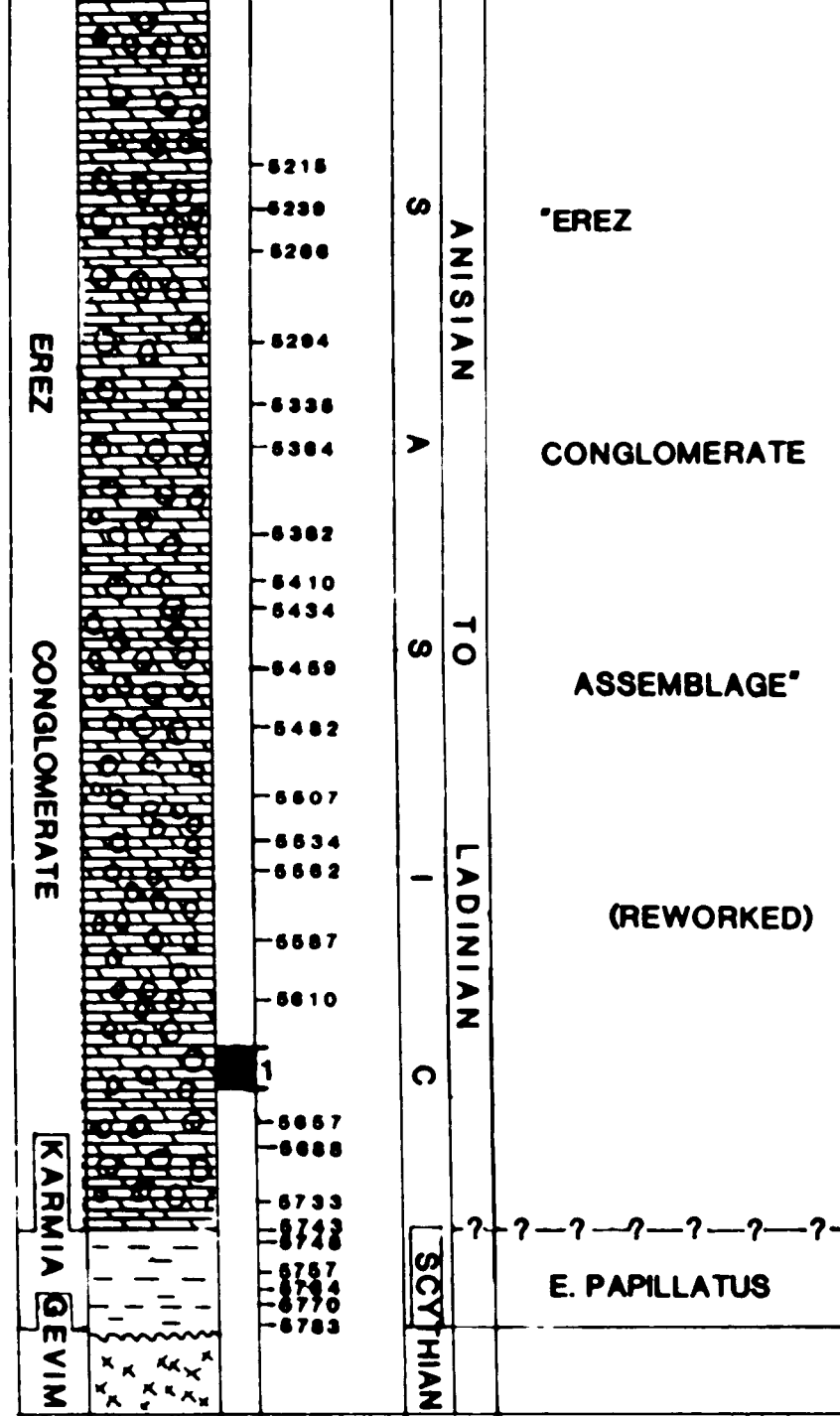
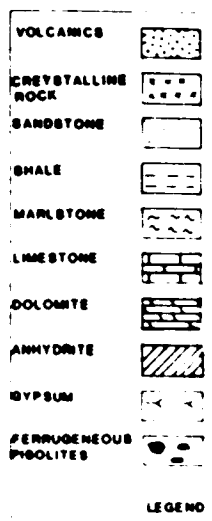


Appendix 8. Range chart of all fa

DEPTH	FORMATION
4105	
4152	
4203	
4233	MOMILTA
4270	
4293	
4346	BAHARONIM
4392	
4436	
4492	DEVANIM
4509	
C. 1 (4597-607)	
4627	
4648	
4673	
4700	
4713	
4731	
4758	
4782	
4794	
4843	
4872	
4902	
4932	
4970	
4986	
5017	
5036	
5050	
5063	
5093	
5120	
5145	
5160	
5190	
5220	
5240	
5259	
5285	
5310	

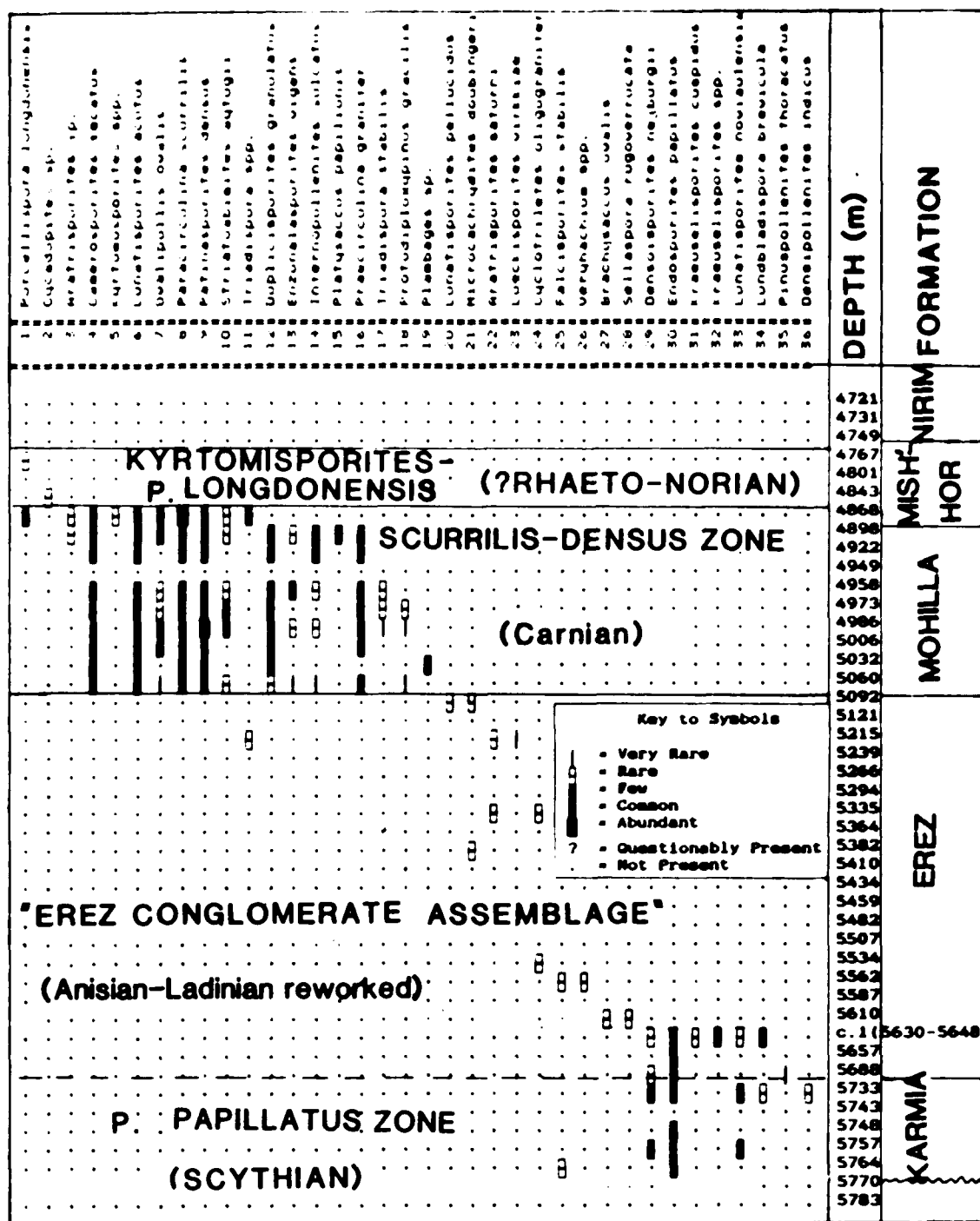
of all taxa in the Pleshet 1 well.

PALYNOZONE		KYRTOMISPORITES SPP.	P. DENSUS	
STAGE	LIASSIC	RHAETO-NORIAN?	CARNIAN	
SYSTEM	JURASSIC	T	R	I
SAMPLES (m)	4721 4731 4749 4767	4801	4843 4866 4886 4922 4949 4958	4973 4986 5006 5032 5060 5092 5121
CORE				
LITHOLOGY				
FORMATION	NIRIM	MISH'HOR	MOHILLA	

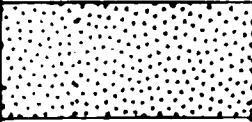
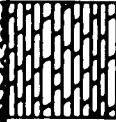
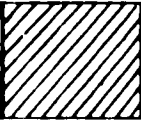
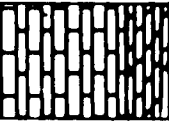
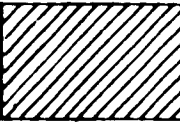
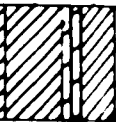


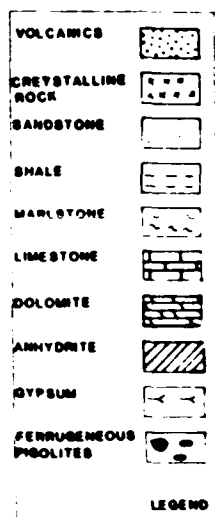
Appendix 9

Litho- and palynostratigraphy
 of the Helez Deep well
 (lithostratigraphy after Druckman
 & Kashai (1981))

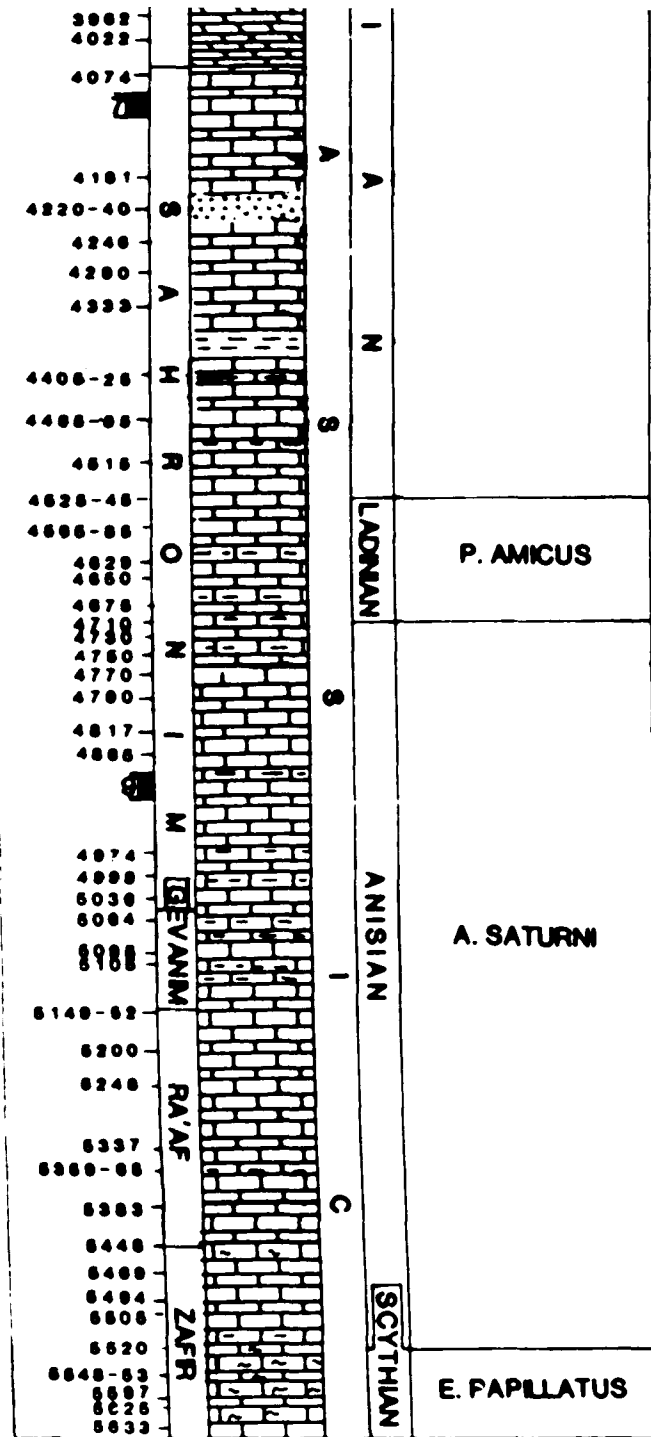


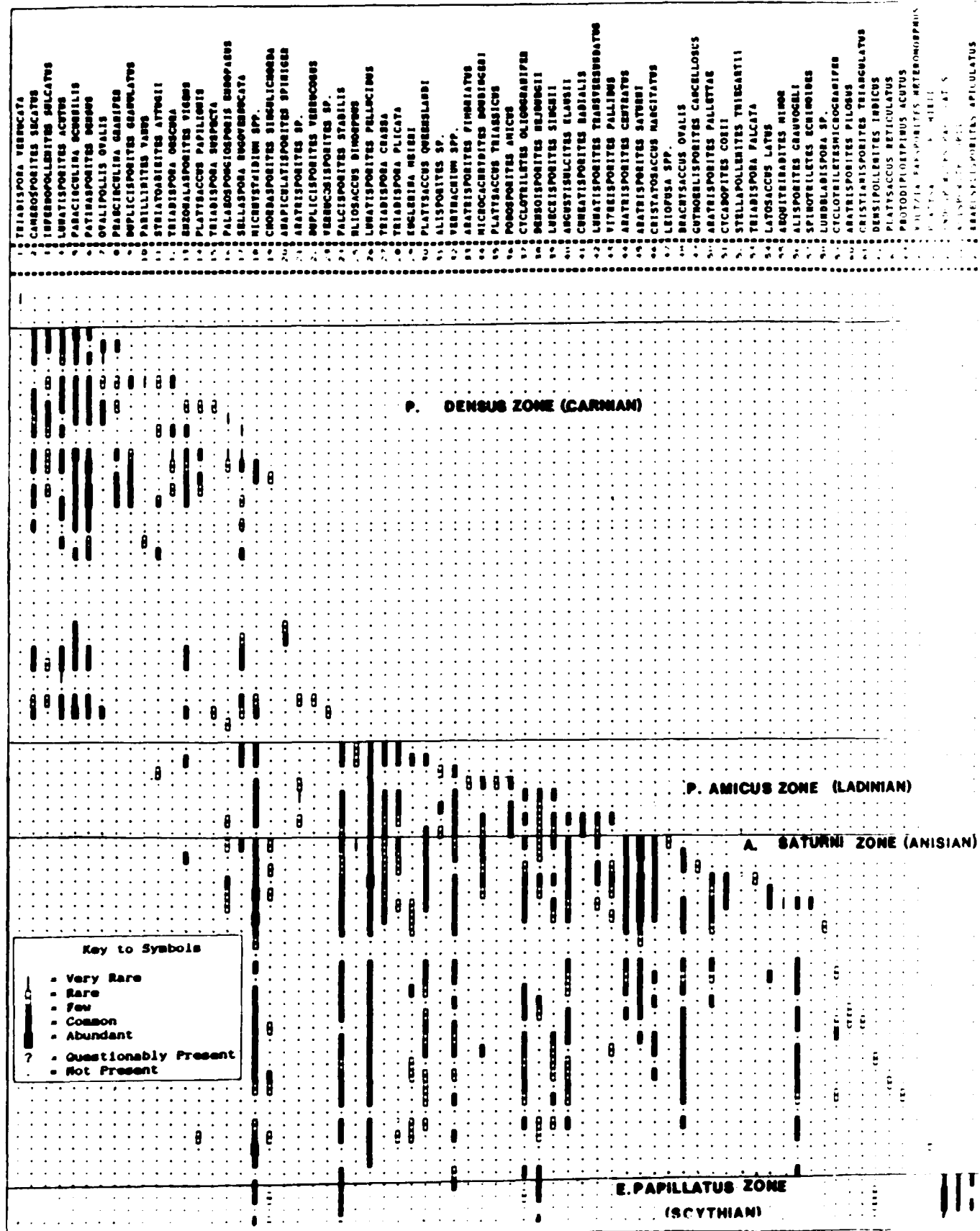
Appendix 10. Range chart of all taxa in the Helez Deep well.

PALYNOZONE		P. DENSUS																							
STAGE	LIASSIC	C A R N I																							
SYSTEM	JURASSIC	T R I																							
LITHOLOGY																									
FORMATION	ASHER	M	O	H	I	L	L	A																	
SAMPLES & CORES		3076	3133	3162	3182	3230	3264	3307	3388	3448	3490	3520	3540	3687	3838	3874	3718	3783	3790	3843	3880	3912	3962	4022	4074

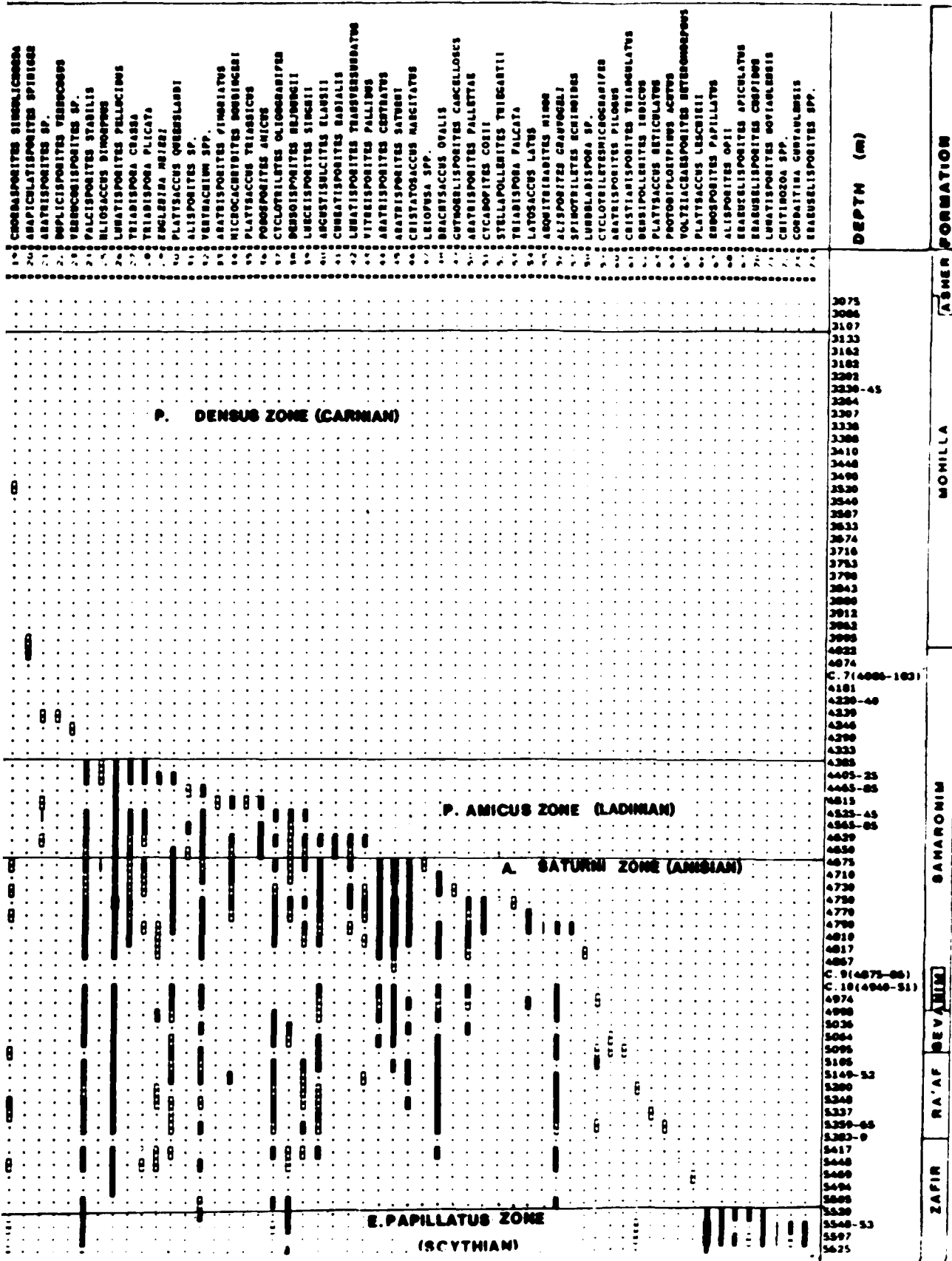


Appendix 11. Litho- and palynostratigraphy of the Devora 2A well. Lithostratigraphy after Druckman & Kashai (1981)





Appendix 12. Range chart of all taxa in the Devora 2A well
Lithostratigraphy after Druckman & Kashai (1981)



endix 12. Range chart of all taxa in the Devora 2A well

Lithostratigraphy after Druckman & Kashai (1981)

Ramon 1, Ramallah 1, and Ga'ash 2 wells (modified from Cousminer, 1981b and Eshet, 1984). For lithostratigraphy, see Figure 6.

APPENDIX 14

Taxonomic list of all taxa found in this study

- Aequitriradites minor Madler 1964
Alisporites grauvogeli Klaus 1964
Alisporites magnus Jain 1968
Alisporites opii Daugherty 1941
Anapiculatisporites spiniger (Leschik 1956) Reinhardt 1961
Angustisulcites klausii Freudenthal 1964) Visscher 1966
Aratrisporites centratus Leschik 1956
Aratrisporites fischeri (Klaus 1960) Balme 1970
Aratrisporites fimbriatus (Klaus 1960) Madler 1964
Aratrisporites major Madler 1964
Aratrisporites palletae Klaus 1960
Aratrisporites pilosus Madler 1964
Aratrisporites saturni (Thiegart) Madler 1964
Aratrisporites scabratus Klaus 1960
Brachysaccus ovalis Madler 1964
Camerosporites secatus Leschik 1955
Chordasporites magnus Klaus 1964
Chordasporites singulichorda Klaus 1960
Chordaitina gunyaulensis Pant & Srivastava
Classopollis torosus (Pflug 1953) Maljwagina 1949
Cristatisaccus margitatus Madler 1964
Cristianisporites triangulatus Antonescu 1969
Cuneatisporites radialis Leschik 1956

- Cycadopites coxii Visscher 1966
- Cyclotriletes granulatus Madler 1964
- Cyclotriletes microgranifer Madler 1964
- Cyclotriletes oligogranifer Madler 1964
- Densipollenites indicus Bharadwaj 1962
- Densoisporites complicatus Balme 1970
- Densoisporites nejburgii (Schulz 1965) Balme 1970
- Densoisporites playfordii (Balme 1963) Balme 1970
- Distriatites insolitus Bharadwaj & Salujha 1964
- Duplicisporites granulatus (Leschik 1956) Klaus 1960
- Duplicisporites verrucosus (Scheuring 1970
- Echinitosporites iliacoides Schulz & Krutzsch 1961
- Ellipsovelatisporites rugosus Scheuring 1970
- Endosporites papillatus Jansonius 1962
- Enzonasporites leschikii Madler 1964
- Enzonasporites vigena Leschik 1956
- Eucommiidites microgranulatus Scheuring 1970
- Falcisporites nuthalensis (Clarke 1965) Balme 1970
- Falcisporites stabilis Balme 1970
- Falcisporites zapfei Potonie' & Klaus 1954
- Gardenasporites heisseli Klaus 1963
- Gardenasporites leonardi Klaus 1963
- Gigantosporites hallstattensis Klaus 1963
- Gliscopollis meyeriana (Klaus 1960) Ventakachala et Go'cza'n 1964
- Guthoerlisporites cancellosus Playford & Dettman

- Hamiapollenites tractiferinus Jansonius 1962
- Heliosaccus dimorphus Madler 1964
- Indotriletes splendens Balme & Hennelly 1956
- Infernopollenites sulcatus (Putsch 1958) Scheuring 1970
- Jugasporites perspicuus Leschik 1956
- Keuperisporites baculatus Schulz 1965
- Klausipollenites schaubergeri (Potonie' & Klaus 1954)
Jansonius 1962
- Kraeuselisporites cuspidus Balme 1963
- Kraeuselisporites septatus Balme 1963
- Kraeuselisporites wargelensis Balme 1970
- Kuglerina meieri Scheuring 1978
- Laevigatosporites callosus Balme 1970
- Limitisporites moerensis Klaus 1963
- Lophotriletes novicus Singh 1964
- Lorisporites spectabilis Leschik 1955
- Lueckisporites singhi Balme 1970
- Lueckisporites virkkiae Potonie' & Klaus 1954
- Lunatisporites acutus Leschik 1955
- Lunatisporites noviaulensis Leschik 1956
- Lunatisporites pellucidus (Goubin) Balme 1970
- Lunatisporites transversundatus Jansonius 1962
- Lundbladispora brevicula Balme 1970
- Marsupipollenites triradiatus Balme & Hennelly 1956
- Microcachrydites doubingeri Klaus 1964
- Microcachrydites sittleri Klaus 1964

- Nuskoisporites dulhuntyi Potonie' & Klaus 1954
- Ovalipollis ovalis Krutzsch 1955
- Paracirculina scurrilis Scheuring 1970
- Parillinites vanus Scheuring 1970
- Patinasporites densus Leschik 1956
- Pinuspollenites thoracatus Balme 1970
- Pityosporites ruttneri Klaus 1960
- Plambages sp. Wetzell 1961
- Platysaccus leschikii Hart 1960
- Platysaccus papilionis Potonie' & Klaus 1954
- Platysaccus queenslandi De Jersey 1962
- Platysaccus reticulatus Madler 1964
- Platysaccus triassicus Madler 1964
- Plicatipollenites indicus Srivastava 1970
- Podosporites amicus Scheuring 1970
- Polypodiisporites mutabilis Balme 1970
- Porcelispora longdonensis (Clarke 1965) Scheuring 1970
- Potoniesporites novicus Bharadwaj 1954
- Praecirculina granifer (Leschik 1956) Klaus 1960
- Pretricolpipollenites bharadwaji Balme 1970
- Protodiploxypinus acutus Madler 1964
- Protodiploxypinus gracilis Scheuring 1970
- Protohaploxypinus diagonalis Balme 1970
- Protohaploxypinus jacobii (Jansonius 1962) Hart 1964
- Protohaploxypinus limpidus (Balme & Hennelly 1955) Balme & Hennelly 1958

- Protohaploxylinus microcorpus Schaarschmidt) Clarke 1965
- Protohaploxylinus richteri Jansonius 1962
- Protohaploxylinus varius (Bharadwaj 1964) Balme 1970
- Punctatosporites minutus Ibrahim
- Reticulatisporites n. sp.
- Reticuloidosporites varchianus Balme 1970
- Retisulcites perforatus (Madler 1964) Scheuring 1970
- Sellasporea rugoverrucata Van Der Eem 1983
- Spinotriletes echinoides Madler 1964
- Spiritisporites spirabilis Scheuring 1970
- Striatoabieites aytugii Visscher 1966
- Striatoabieites multistriatus (Balme & Hennelly) Hart 1964
- Striatopodocarpites cancellatus (Balme & Hennelly 1956) Balme 1970
- Striatopodocarpites fusus (Balme & Hennelly) Potonie' 1958
- Striatopodocarpites rarus (Bharadwaj & Salujha 1964) Balme 1970
- Triplexisporites playfordi De Jersey & Hamilton 1979
- Triadispora crassa Klaus 1964
- Triadispora falcata Klaus 1964
- Triadispora modesta Scheuring 1970
- Triadispora obscura Scheuring 1970
- Triadispora plicata Klaus 1964
- Triadispora stabilis Scheuring 1970
- Triadispora staplini (Jansonius 1962) Klaus 1964
- Triadispora suspecta Scheuring 1970

Triadispora verrucata (Schulz 1960) Scheuring 1970

Palaeospongiosporis europaeus Schulz 1965

Verrucosisporites thuringiacus Madler 1964

Vitreisporites pallidus (Reissinger) Wilson 1958

Vittatina costabilis Wilson 1962

Vittatina ovalis Klaus 1963

Voltziaceasporites heteromorphus Klaus 1964

Zonalasporites explanatus Leschik 1956

Appendix 15: TAXONOMY of selected taxa

This part of the study contains descriptions of selected stratigraphically-important taxa from the Permo-Triassic in Israel. A complete list of all taxa is given in Appendix 14.

1. Angustisulcites klausii (Freudenthal 1964) Visscher 1966 (Plate 3, Figure 4)

DISCUSSION: Similar to the emendation offered by Visscher (1966), describing a faint y-mark on the proximal side. Differs from Platysaccus in having small bladders and narrow deep distal sulcus. The observed size, 70-95 micrometers, suggests that it is slightly larger than the holotype.

AGE AND DISTRIBUTION: Restricted to Anisian strata in Europe (Brugman, 1983; Visscher, 1966). Ranges from Anisian to Ladinian in Israel.

Form genus Aratrisporites Klaus 1956

DISCUSSION: This genus is assigned to a variety of oval cavate monolete spores, with or without spines. Klaus assigned to Saturnisporites Klaus 1960 similar spores that are suggested here to be junior synonyms of Aratrisporites.

Aratrisporites scabratus Klaus and Aratrisporites fischeri are interpreted here to be synonyms of A. saturni. Folds along the monolete mark appear to have been used incorrectly to define Aratrisporites major Madler 1964. The most important Aratrisporites spp. in this study differ from each other as follows:

2. Aratrisporites saturni Madler 1964 (Plate 3, Figures 2, 3)

DISCUSSION: Specimens from Israel share characters with the original description. They differ from the other Aratrisporites specimens in having a narrow central body and in lacking spines. Spongy sexine. Monolete suture straight or undulating.

AGE AND DISTRIBUTION: Has been reported from England (Fisher, 1972) and from the Keuper in Germany (Madler, 1964). Brugman (1985) reported it from Anisian strata in Libya. Anisian age is also recorded in Israel.

DISCUSSION: A. palettae differs from A. saturni in having small spines scattered around the body. However, spines are easily removed during physical damage to the fossil. The presence and absence of spines lead to transitional forms between A. saturni, A. palettae, and A. fimbriatus.

AGE AND DISTRIBUTION: Reported from Carnian strata in the Alps (Klaus, 1960). Also found in the Anisian interval in Israel.

3. Aratrisporites fimbriatus Klaus 1960

DISCUSSION: Characterized by having a very densely arranged, hairy spines. Specimens of this species have been assigned incorrectly as dinoflagellates (Fensome & Sarjeant, 1982), an error later corrected by Conway & Cousminer (1983).

4. Brachysaccus ovalis Madler 1964 (Plate 3, Figure 7)

DISCUSSION: Rounded bisaccate pollen, 130-150 micrometers in size. Sacci do not protrude beyond the outline in polar view; almost circular outline; sacci are not connected equatorially; they are separated by a deep sulcus that usually widens near the equator.

AGE AND DISTRIBUTION: Occur in Anisian strata of Germany (Madler, 1964). In this study, they have the same age distribution.

5. Camerosporites secatus (Leschik 1955) Scheuring 1970
(Plate 5, Figure 4)

DISCUSSION: The coarse verrucae that form peripheral "rings" around the body in the original description are smaller in the specimens found in Israel. With such a reduction, the definition of C. secatus overlaps that of Camerosporites pseudoverrucatus. These two species may be synonyms. Preservation of the material in Israel is not particularly good. Observed size: 45-70 micrometers.

6. Cristianisporites sp. A (Plate 3, Figure 5)

DIAGNOSIS: Cavate spores. Amb triangular; strongly concave sides, forming an auriculate outline. Inner body very dark, covered by fine, infrareticulate sculpture. Trilete mark not clear. Observed dimensions: radius of inner body, 25-35 micrometers; total radius: 78-95 micrometers.

REMARKS: Very similar to C. triangulatus Antonescu 1969, but lacks the striations on inner body; also, the trilete mark

in C. triangulatus is more pronounced.

AGE AND DISTRIBUTION: Anisian strata in southern Israel, especially in the Zuk Tamrur area.

7. Densoisporites nejburgii (Schulz 1964) Balme 1970 (Plate 3, Figure 1)

DIAGNOSIS: Cavate trilete spores with circular to rounded outlines. Trilete scars distinct, extending almost to the equator; outer wall, 2-3 micrometers thick, with finely spongy ornamentation. Observed dimensions: 30-45 micrometers.

REMARKS: Densoisporites differs from Lundbladispora in having much smoother ornamentation. When only the inner body is present, it is difficult to differentiate between the two.

AGE AND DISTRIBUTION: Lower Triassic and Anisian strata in Europe (Brugman, 1983) and Pakistan (Balme, 1970). Similar ranges found in this study.

8. Distriatites insolitus Bharadwaj & Salujha 1964 (Plate 1, Figure 6; Plate 2, Figure 6) **DIAGNOSIS:** Weakly diploxylonoid bisaccate pollen. Corpus oval to almost circular. Cappa has 8-10 transverse taeniae. Cappa also dissected by 7-8 latitudinal furrows, which usually run the full breadth of the cappa. Sexine of cappa finely intrareticulate. Sacchi detached laterally with slight distal inclination. Observed dimensions: total breadth, 116 micrometers.

AGE AND DISTRIBUTION: This taxon is found in Lower Permian

strata of Gondwana: Salt Range (Balme, 1970), India (Bharadwaj & Salujha, 1964). The species is believed to be of Gondwanian origin.

REMARKS: Balme (1970) assigned this species to the genus Hamiapollenites. In this study, H. insolitus is transferred back to Distriatites insolitus.

9. Duplicisporites granulatus (Leschik 1956; Klaus 1960)
Scheuring 1970

DIAGNOSIS: A Circumpolles microspore with triangular to subtriangular outline in polar view. Trilete mark appears on the proximal side, the rays of which point to the corners of a triangle. Along the equator, an encircling thinning of the exine occurs, giving rise to a furrow around the body.

Differs from Paracirculina and Praecirculina in its triangular outline. Observed dimensions: 30-45 micrometers.

AGE AND DISTRIBUTION: D. granulatus is known in both Laurasia and Gondwana. In Europe it is reported from Ladinian and Upper Triassic strata (Brugman, 1983). Similar range recorded in Israel.

10. Echinitosporites iliacoides Schulz & Krutzsch 1961
(Plate 4, Figure 3)

DIAGNOSIS: Morphology agrees with the original description. Observed dimensions: 38-50 micrometers. Ricciisporites tuberculatus Lundblad has the same morphology but is larger in size (85-100 micrometers).

AGE AND DISTRIBUTION: E. iliacoides is a Laurasian taxon; it

is reported from Ladinian strata in Europe (Scheuring, 1970; Visscher & Brugman, 1981; Van Der Eem, 1983).

11. Endosporites papillatus Jansonius 1962 (Plate 2, Figure 1).

DIAGNOSIS: Rounded, triangular trilete cavate spores. Thin, laevigate sexine. Trilete mark distinct, rays equal to a half radius in length. Very clear 3 apical papillae. Observed dimensions: 65-70 micrometers.

REMARKS: The central body easily is detached and is found separately, which leads to incorrect descriptions of the taxon. In most cases, only the most resistant central bodies are found.

AGE AND DISTRIBUTION: E. papillatus is a distinct Laurasian taxon; it has never been reported from Gondwana. Found in large numbers in Scythian strata in Europe (Visscher & Brugman, 1981; Brugman, 1983). Has the same range and abundance in Israel.

12. Guthoerlisporites cancellosus Playford & Dettman 1965 (Plate 1, Figure 3)

DIAGNOSIS: Cavate, circular, usually distorted by folding. Trilete scar faint to distinct, rays extending to margins of intexine. Radial folds appear occasionally on exoexine. Observed dimensions: 92-107 micrometers.

REMARKS: G. cancellosus is difficult to separate from Endosporites velatus Leschik 1956, and Endosporites hexareticulatus Klaus 1960. E. velatus was described as granulate,

although this interpretation has been discarded by Potonie' (1958 p. 40), who reassigned the species to Guthoerlisporites. E. hexareticulatus can be distinguished from G. cancellosus by its slightly coarser exoexine and hexagonal lumina. Balme (1970) suggested that this taxon may be a pteridophyte.

AGE AND DISTRIBUTION: G. cancellosus has been reported from Upper Permian to Middle Triassic strata in the Salt Range (Balme, 1970). It is reported from other Gondwanan localities such as Tasmania (Playford & Dettman, 1965). In Israel, it ranges in the Permian.

13. Keuperisporites baculatus Schulz 1965 (Plate 4, Figures 5, 6)

DIAGNOSIS: Trilete microspore with subcircular amb. Exine moderately thick, distally, equatorially and in part proximally as well ornamented with verrucae or irregularly sinuous muri-like sculptural elements. Equatorially and in smaller amounts distally, scattered, isolated long baculate to conical sculptural processes often with branching tips. Trilete mark obscured by processes. Rays extend more or less to the equator. Observed dimensions: total diameter: 108-152 micrometers; exine: 2-3 micrometers; isolated baculae and branched processes: 6-20 micrometers.

AGE AND DISTRIBUTION: Common in Lower Keuper and other Ladinian strata in Europe (Schulz, 1965; Brugman, 1963). In Israel it is very common in Anisian strata in the Ramon-Zuk

Tamrur area.

14. Klausipollenites schaubergeri (Potonie' & Klaus 1954)

Jansonius 1962 (Plate 2, Figure 7)

DIAGNOSIS: Bisaccate pollen, usually without trilete mark; slightly diploxylonoid. Corpus oval to almost circular in polar view. Cappa finely intrareticulate. Sacci proximally attached near the equator. Equatorial outline smoothly oval; in equatorial view, slightly bean-shaped. Bladders between half crescent and half circular in shape.

AGE AND DISTRIBUTION: K. schaubergeri is known from Upper Permian strata in Gondwana and Laurasia.

15. Kraeuselisporites wargelensis Balme 1970 (Plate 1, Figures 1, 2)

DIAGNOSIS: Zonate, cavate trilete spore. Amb circular to subtriangular. Trilete scar extending to inner margin of zona. Exoexine has a fine spongy texture and is 1-2 micrometers thick. Zona is 7-10 micrometers wide, and is covered by small, scattered, spines on the distal side. Observed dimensions: (total diameter): 58-70 micrometers.

AGE AND DISTRIBUTION: This taxon is known from Upper Permian strata in the Salt Range (Balme, 1970). In Israel, it occurs in the Lower Permian in large quantities.

16. Laevigatosporites callosus Balme 1970

DIAGNOSIS: Acavate monolete spores. Broadly oval in shape; proximal face flattened. Monolete scar, extending about 2/3 of spore length. Exine smooth and structureless. Observed

dimensions (length): 52-60 micrometers, which makes it somewhat smaller than the holotype.

AGE AND DISTRIBUTION: L. callosus is found in Upper Permian strata in the Salt Range, Pakistan (Balme, 1970). It occurs in large numbers in the assemblages of small trilete and monolete spores in the Lower Permian of Israel.

17. Lueckisporites virkkiae Potonie' & Klaus 1954 (Plate 1, Figure 5)

DIAGNOSIS: Bisaccate, slightly diploxylonoidpollen. Corpus transversely elongate to oval in shape. Cappa divided in two by a wide transverse taeneae. Exoexine of cappa finely infrareticulated. Sacci almost hemispherical in polar view, with a strong distal inclination. Total length: 62-75 micrometers.

18. Lunatisporites acutus (Leschik 1956) Bharadwaj 1962 (Plate 5, Figures 2, 3)

DIAGNOSIS: Bisaccate pollen. Cappa oval, consisting of 2-6 taeniae that may be subdivided or branched. Sacci semicircular in shape.

REMARKS: In this study, the emendation of Bharadwaj (1962) is followed. He suggested that the holotype, named Taeniaesporites by Leschik (1956) is synonymous with Lunatisporites.

AGE AND DISTRIBUTION: L. acutus occurs in Carnian and Ladinian strata in most parts of the world, and also in Israel.

19. Lunatisporites noviaulensis Leschik 1956 (Plate 2, Figure 4)

DIAGNOSIS: Bisaccate pollen, slightly diploxytonoid. Corpus circular to transversely elongate. 2-6 taeniae between sacci. Sacci large with marked distal inclination. Observed dimensions (total length): 90-105 micrometers.

REMARKS: *Lunatisporites novimundi* Jansonius 1962 appears to be synonymous with L. noviaulensis.

AGE AND DISTRIBUTION: Upper Permian and Lower Triassic strata in Laurasia and Gondwana. In Israel, this taxon occurs in the Lower Triassic only.

20. Lunatisporites pellucidus Goubin 1965 (Plate 6, Figure 6)

DIAGNOSIS: This taxon differs from the other species of Lunatisporites in having undulating, long taeniae. Distal inclination of sacci is slight, giving rise to a relatively flat form, folded in many cases. Observed dimensions: total length: 102 micrometers; breadth: 15-25 micrometers.

AGE AND DISTRIBUTION: Common in Lower Triassic strata in Western Australia (Balme, 1963) and Queensland (Evans, 1966). It has been found in Lower to middle Triassic strata in the Salt Range (Balme, 1970). In Israel, it is common in Anisian strata but also occurs in the Scythian.

21. Microcachrydites doubingeri Klaus 1964 (Plate 4, Figure 2).

DIAGNOSIS: Medium-sized bisaccate pollen grains that resem-

ble the modern genus Microcachrys. Corpus oval and elongate, infrareticulated; corpus usually darker than sacci. A narrow furrow extends between the sacci and through the corpus. Sacci semicircular, distally attached. A marked distal inclination of sacci characterizes this taxon. Observed dimensions: 50-55 micrometers in length.

REMARKS: The form genus Microcachrydites resembles Protodiploxypinus (Madler 1964) Scheuring 1970. In Microcachrydites, the sacci are much smaller relative to the corpus.

AGE AND DISTRIBUTION: This species is found in Anisian and Ladinian strata in Europe (Antonescu, 1970; Geiger & Hopping, 1968) and Israel. It appears to be Laurasian in origin.

22. Retisulcites perforatus (Madler 1964) Scheuring 1970

DIAGNOSIS: Elongate oval to fusiform microspore, with an aperture shaped like a colpus or sulcus. Aperture runs the full length of the grain. Ektexine heavy, smooth, with large punctae of variable shapes, that are distributed over the whole spore, including the edges of the aperture. These holes give the spore the appearance of having a coarse reticulum. Observed dimensions: 25-45 micrometers in length.

REMARKS: Scheuring (1970) transferred Monosulcites perforatus Madler into R. perforatus, an emendation used in this study.

AGE AND DISTRIBUTION: R. perforatus is a Ladinian marker fossil in Europe (Brugman, 1983) and in the North Sea (Geiger & Hopping, 1968). It occurs in minor amounts in

Ladinian strata of Israel.

23. Paracirculina scurrilis Scheuring 1970 (Plate 6 Figures 2, 3)

DIAGNOSIS: Microspores oval to circular in polar view, and with faint trilete marks at proximal pole. Near the equator, a distinctly developed circular thinning of exine is developed, giving rise to a circular furrow which may be accompanied by circular folds in polar compressions. The two hemispheres that are formed by the circular furrow may be developed equally or differently in shape and size, depending on position and development of the furrow. Observed dimensions: 28-40 micrometers.

AGE AND DISTRIBUTION: Together with other members of the Circumpolles subturmae, P. scurrilis is known from Carnian and Ladinian strata in most regions of the world.

24. Patinasporites densus (Leschik 1956) Scheuring 1970 (Plate 5 Figures 6, 7)

DIAGNOSIS: Monosaccate microspore with approximately circular central bodies (in polar view). The monosaccus is attached proximally near the equator and protrudes beyond the outline of the central body. Cappa ectexine sculptured by rugulae or sinuous folds; these create a zig-zag pattern on the proximal side. The sculpture on the saccus becomes much denser and finer towards the margins. A thickened exinal ring is situated underneath the cappa, closing the saccus against the central cavity. Trilete marks were never seen.

Diameter of central body: 50-55 micrometers.

REMARKS: Enzonalasporites Leschik 1956 has finer and less pronounced proximal sculptural ridges than Patinasporites. Also, its central body is larger than Patinasporites.

AGE AND DISTRIBUTION: P. densus occurs in Carnian strata of both Laurasian and Gondwanian localities, although it appears to be more frequent in Laurasia.

25. Plicatipollenites indicus Lele 1964

DIAGNOSIS: Circular monosaccate pollen. Trilete scar distinct; laesurae extending almost to the proximal saccus roots. Corpus circular; exoexine of corpus intrareticulate; intexine very thin, with circumpolar folds developed below the distal saccus roots. These folds form a pronounced polygonal ring. Observed dimensions: total diameter: 90-110 micrometers; diameter of corpus: 65-77 micrometers; maximum width of saccus: 20-25 micrometers.

AGE AND DISTRIBUTION: Specimens of this taxon characterize Permian strata in Gondwanian localities (Foster, 1979; Balme, 1970). They also have been recorded from the Permian of Iraq (Singh, 1964). In Israel, they occur in Lower Permian strata.

26. Podosporites amicus (Rao 1943) Scheuring 1970

DIAGNOSIS: Bisaccate alete pollen with spherical or slightly longitudinally oval central body. Strong distal inclination of the small sacci. Corpus has strongly ornamented ectexine.

AGE AND DISTRIBUTION: P. amicus is found in Ladinian strata

in Europe. It has not been reported from any Gondwanian localities.

27. Potoniesporites novicus Bharadwaj 1955 (Plate 2, Figure 5)

DIAGNOSIS: Monosaccate, bilaterally symmetrical grains. Amb and corpus transversely oval. Proximal face bears a clearly defined straight or geniculate tetrad scar that usually has darkened margins. Exoexine of corpus finely intrareticulate. Exoexine of saccus finely intrareticulate. in many specimens, corpus is detached and only saccus is found. Observed dimensions: total length: 180-190 micrometers; corpus length: 124 micrometers; corpus breadth: 92 micrometers.

AGE AND DISTRIBUTION: P. novicus is known in Permian strata in both Laurasia and Gondwana. It is the most common fossil in the Lower Permian of Israel.

28. Praecirculina granifer (Leschik 1956) Klaus 1960 (Plate 5, Figure 1)

DIAGNOSIS: Circumpolles spores with circular outline and a very small trilete mark formed by short rays; rays commonly barely visible. An equatorial zone of exinal thinning occurs but not well developed; zone indicated by folding and by a polar tenuitas occasionally observed opposite the trilete mark. Sculpture smooth or granulate.

AGE AND DISTRIBUTION: P. granifer is known from Carnian strata in both Laurasia and Gondwana.

FORM GENUS Protohaploxypinus (Samoilovich) Hart 1964

GENUS DIAGNOSIS: Protohaploxylinus is used here as a form genus that includes bisaccate haploxylinoid pollen grains with thin intrareticulate cappa and more or less parallel-sided capula. Taeniae occur in all species of the genus. Protohaploxylinus is common in all Permian strata in Israel, especially in the Upper Permian.

29. Protohaploxylinus jacobii (Jansonius 1962) Hart 1964

DIAGNOSIS: Characterized by narrow offlapping sacci, broad capula, and a transversely oval corpus. These features distinguish it from P. amplus. However, P. amplus was not found to occur in association with P. jacobii by Clarke (1965) during his study of British Permian palynofloras. Geiger & Hopping's (1968) illustrations of P. jacobii, also from British assemblages suggests that P. amplus may be present. Therefore, these two species are maintained tentatively; further data from northern hemisphere assemblages may show that there is no advantage in distinguishing between them. Observed dimensions: total length: 100-110 micrometers; saccus length: 40 micrometers; corpus length: 48-57 micrometers.

AGE AND DISTRIBUTION: P. jacobii is common in Permian strata in Australia and other Gondwanian localities (Foster, 1979). It also is reported from Upper Permian and Lower Triassic strata in Europe (Clarke, 1965; Geiger & Hopping, 1968) and in Western Canada (Jansonius, 1962). This taxon is common in the Upper Permian of Israel.

30. Protohaploxylinus microcorpus (Schaarschmidt 1963) Clark 1965 (Plate 2, Figure 8)

DIAGNOSIS: Corpus longitudinally oval and elongate. Cappa dissected by 12-18 poorly-defined taeniae of uneven width; taeniae sometimes discontinuous and wedge-shaped. Exoexine of cappa intrareticulate. Sacci semicircular with strong distal inclination; they sometimes join equatorially. Observed dimensions: total length: 110-132 micrometers; width of corpus: 80-95 micrometers.

AGE AND DISTRIBUTION: Permian strata in both Laurasia and Gondwana, including Israel.

31. Protohaploxylinus richteri (Klaus 1963) Jansonius 1962

DIAGNOSIS: Central body very nearly circular, with tendency for the width to be greater than the length. Bladders hemispherical. Cappa darker in color but lighter lines separating the taeniae. Proximal face covered densely with approx. 18 taeniae (each about 3 micrometers) which may branch or be interrupted especially on the central area of the proximal face. Bladders have thick walls and coarse reticulation that is radially arranged near the saccus bases; distal bases of sacci distinct.

AGE AND DISTRIBUTION: Common in the Lower Triassic of western Canada (Jansonius, 1962) and the Permian of Australia (Foster, 1979). In Israel, common in the Upper Permian.

32. Protohaploxypinus varius (Bharadwaj 1962) Balme 1970
(Plate 1, Figure 4).

DIAGNOSIS: Corpus of pollen poorly defined. Grain circular to oval with a slight transverse longitudinal elongation. Exine of cappa intrareticulate. Cappa divided by 6-9 tae-niae. Sacci almost hemispherical in polar view. Cappula is parallel sided. Observed dimensions: total length: 92 micrometers; corpus length: 65 micrometers.

AGE AND DISTRIBUTION: Found in Permian strata in the Salt Range, Pakistan (Balme, 1970). It also occurs in the Upper Permian of Israel.

33. Raistrickia sp. B

DIAGNOSIS: Very large spores. Amb circular to oval; in most instances, specimens are compressed. Long baculae (3-5 micrometers each) cover the fossil densely on all sides. No sculpture can be observed. Trilete mark large, usually obscured by heavy baculae. Observed dimensions: 178-200 micrometers long; 85-90 micrometers wide.

AGE AND DISTRIBUTION: Anisian to Ladinian strata in southern Israel, especially in the Zuk Tamrur-Zohar area.

34. Reticulatisporites sp. A

DIAGNOSIS: Spores; amb circular to subcircular. Trilete mark on proximal side, reaching $\frac{2}{3}$ of radius. Thick ridges on the proximal side, 2-3 micrometers high, form a heavy and well pronounced reticulum. Specimens usually dark. Observed dimensions: total radius, 65-73 micrometers.

REMARKS: This species resembles Reticulatisporites sp. A of Upshaw & Creath, 1965, but differs from it by the size and density of reticulation.

AGE AND DISTRIBUTION: Ladinian to Anisian strata in southern Israel.

35. Spinotriletes echinoides Madler 1964

DIAGNOSIS: Trilete spores; amb circular to subtriangular.

Exine covered with closely spaced spines that have a broad basal cone and a pointed tip. Length of spines approximately equal each other. Sculpture more sparse in contact areas.

Trilete mark often not distinct; rays extend to equator.

Observed dimensions: diameter: 60-80 micrometers.

AGE AND DISTRIBUTION: S. echinoides appears in Middle Triassic strata in Europe. It is found in the upper part of the Anisian in Israel.

36. Striatopodocarpites rarus (Bharadwaj & Salujha 1964)

Balme 1970

DIAGNOSIS: Bisaccate, diploxytonoid pollen grains. Corpus circular. Cappa usually very dark, densely and finely structured, appearing intrapunctate in surface focus. Cappa divided by 5-9 taeniae which are usually continuous over the full breadth of the cappa. Sacci large and strongly inclined distally. Saccus exoexine intrareticulate. Observed dimensions: total length: 87-90 micrometers; corpus diameter: 40-45 micrometers.

AGE AND DISTRIBUTION: S. rarus is known from Permian strata

in India, Australia, Iraq (Singh, 1964), and Pakistan (Balme, 1970), and appears to be a Gondwanian fossil. In Israel it occurs in Upper Permian strata only.

37. Triadispora crassa Klaus 1964 (Plate 4, Figure 1)

DIAGNOSIS: Agrees with the holotype description of Klaus, although criteria for distinguishing between species of Triadispora are still not satisfactory.

AGE AND DISTRIBUTION: T. crassa is common in Middle Triassic strata in Europe but also is known from Gondwanian localities. Appears in the Ladinian and Anisian of Israel.

38. Vittatina ovalis Klaus 1963 (Plate 2, Figure 3)

DIAGNOSIS: Pollen with bilateral symmetry (planes of symmetry perpendicular to equatorial plane, through longitudinal and latitudinal axes). Proximal face with longitudinal ribs that run across the full length, but not joining, the equatorial rim. Continuous equatorial rim may be present and may appear as proximal ribs. Equatorial rim may or may not extend into distal face. At two ends of longitudinal axis appear more-or-less inflated bladderlike structures. Wall structure is difficult to analyze. This genus is somewhat similar to bisaccate striate genera in having a basic structure of proximal striation and distal bladders. However, it differs because the ribs are formed by thickening rather than inflation. Observed dimensions: 50-66 micrometers. 36-40 micrometers.

AGE AND DISTRIBUTION: Permian strata in both Gondwana and Laurasia. In Israel, appears in the Lower Permian only.

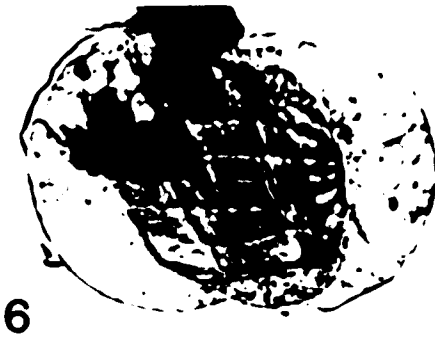
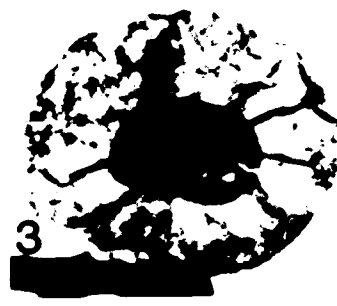
P L A T E S

Explanation of Plate 1

Magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

- 1, 2. Kraeuselisporites wargelensis. 1. Pleshet 1, 5285 m, sample 4149-a, O-17 (1). Proximal view.
2. Pleshet 1, 5343 m, sample 4151-a, proximal view.
3. Guthoerlisporites cancellosus. Zuk Tamrur 2, core 3 box 16, sample 3920-a. Proximal view. Slightly compressed specimen.
4. Protohaploxylinus varius. Makhtesh Qatan 2, core 9, resid-b. Distal view.
5. Lueckisporites virkkiae. Makhtesh Qatan 2, 2021 m, sample 2176-a, T-43. Distal view.
6. Distriatites insolitus. Makhtesh Qatan 2, core 14 box B, sample 1055-a. Proximal view.
7. Striatopodocarpites fusus. Makhtesh Qatan 2, core 14 box B, sample 1055-a, K-23. Proximal view.
8. Pretricolpipoollenites bharadwajii. Plashet 1, 5117 m, E-15 (3). Polar view.
9. Falcisporites zapfei. Makhtesh Qatan 2, 2059 m, sample 2194-b, N-33. Polar view.

Plate 1

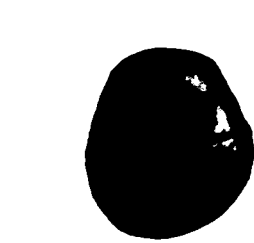


Explanation of Plate 2

All magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

1. Endosporites papillatus. Zohar 8, 2586 m, sample 534-b, M-43 (1), x 1250. Proximal view. Only inner body is preserved.
2. Marsupipollenites triradiatus. Pleshet 1, 5190 m, sample 4145-a, F-33 (1), x 1250. Proximal view.
3. Vittatina ovalis. Zohar 8, 3125 m, sample 544-c, L-35 (4).
4. Lunatisporites noviaulensis. Pleshet 1, 4731 m, sample 4076-a, L-26 (1). Proximal view.
5. Potoniesporites novicus. Makhtesh Qatan 2, core 15 box B, sample 1056-a, M-45, x 850. Proximal view. Geniculate tetrad scar.
6. Distriatites insolitus. Makhtesh Qatan 2, core 14 box B, sample 1055-b, K-25.
7. Klausipollenites schaubergeri. Makhtesh Qatan 2, core 9, resid-a, L-33. Oblique equatorial view.
8. Protohaploxypinus microcorpus. Makhtesh Qatan 2, core 15 box B, sample 1056-a, x 600, P-29. Polar view.

Plate 2



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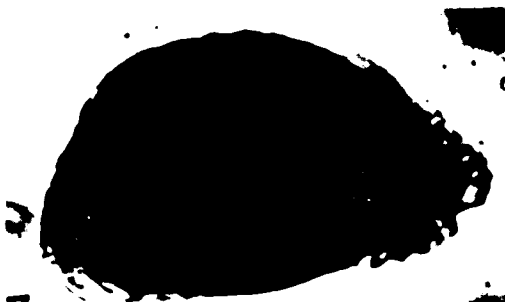
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Explanation of Plate 3

Magnifications may vary slightly, but, are approximately x 1000, unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

1. Densoisporites neiburgii. Makhtesh Qatan 2, 1550 m, sample 1015, Q-27. Proximal view.
- 2, 3. Aratrisporites saturni. 2. Zuk Tamrur 2, core 1, box 4. Proximal view.
3. Makhtesh Qatan 2, 1345 m-b. Oblique proximal view.
4. Angustisulcites klausii. Zuk Tamrur 2, 1736 m, sample 3903-a. Distal view.
5. Cristianisporites cf. C. triangulatus. Zuk Tamrur 2, core 1 box 16, sample 3804-a. Polar, probably distal view.
6. Lunatisporites pellucidus. Makhtesh Qatan 2, 1650 m, sample 1017. Polar view.
7. Brachysaccus ovalis. Zuk Tamrur 2 core 1 box 4, sample 3800-a, R-35 (3). Polar view.

Plate 3



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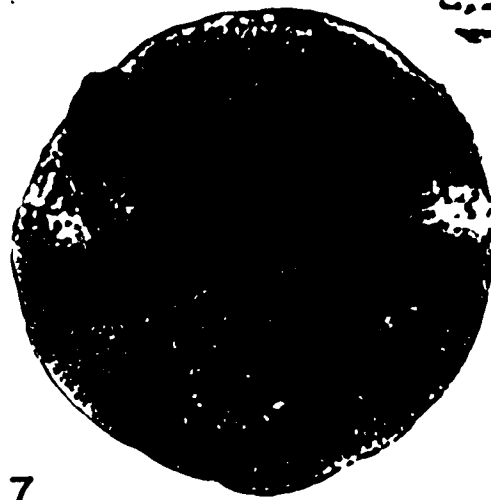
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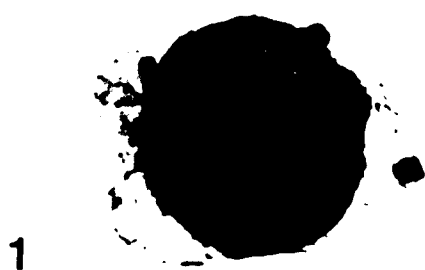
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Explanation of Plate 4

Magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

1. Triadispora crassa. Zohar 8, 2532 m, sample 533-a, N-41.
Proximal view.
2. Microcachrydites doubingeri. Makhtesh Qatan 2, 1345 m-b, P-59. Equatorial view. Strong distal inclination of sacci.
3. Echinitosporites iliacoides. Makhtesh Qatan 2, 1161 m, sample 3361-b, J-61. Upper right side of specimen distally folded.
4. Sellasporea rugoverrucata. Zuk Tamrur 2, 1631 m, sample 3900-b. Polar (probably distal) view).
- 5, 6. Keuperisporites baculatus. 5. Zuk Tamrur 2, core 1 box 12, sample 3806-a, x 800. Polar view.
6. Idem., focus on bifurcated processes, x 1250

Plate 4

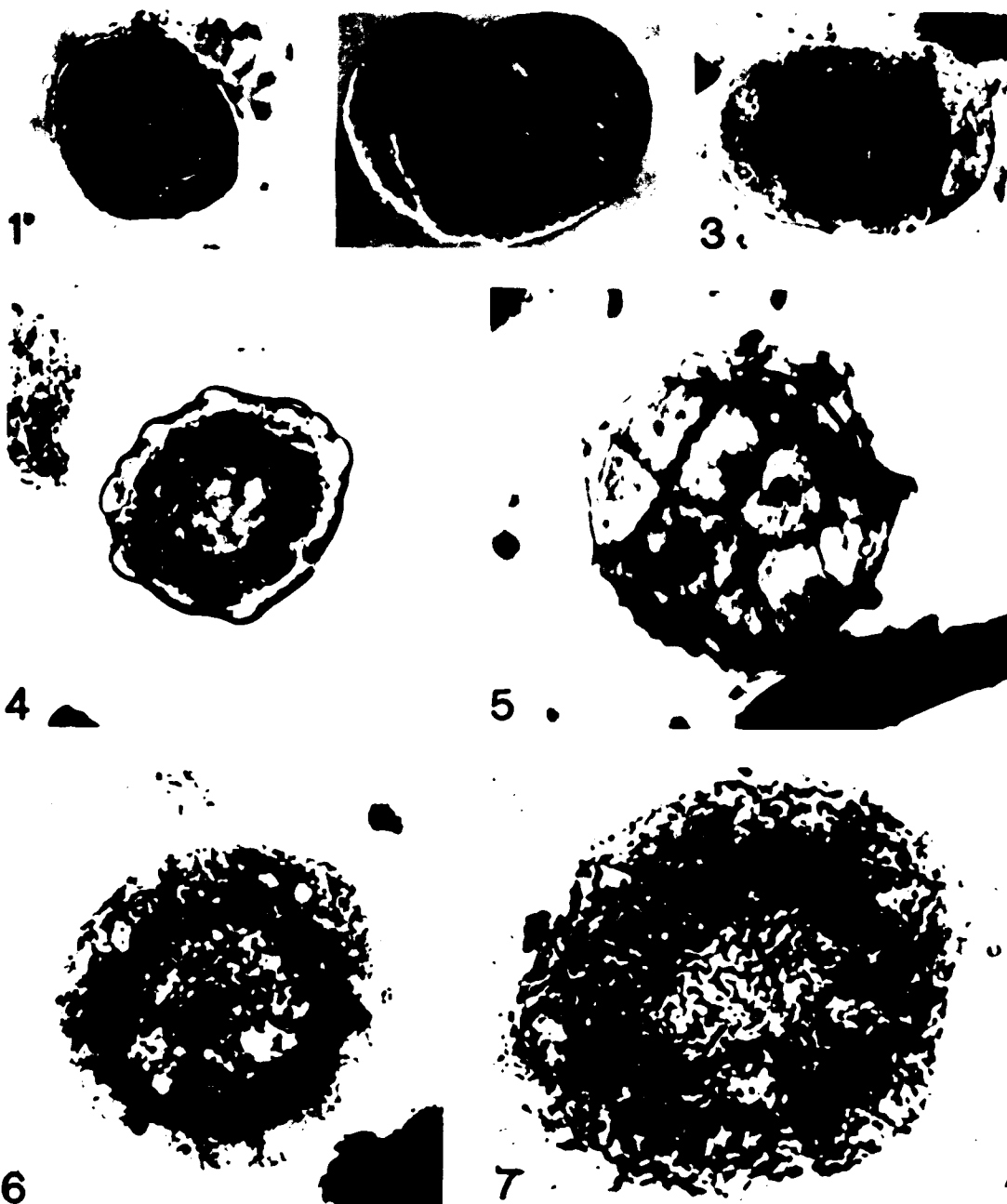


Explanation of Plate 5

All magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

1. Praecirculina granifer Makhtesh Qatan 2, 1081 m, sample 3358-b, P-67.
- 2, 3. Lunatisporites acutus. 2. Zohar 8, 2124 m, sample 525-a, T-41. Proximal view.
3. Zohar 8, 1986 m, sample 430-a, P-45. Proximal view.
4. Camerosporites secatus. Makhtesh Qatan 2, core 3 box B, K-34. Polar view.
5. Reticulatisporites sp. A. Zuk Tamrur 2, 1673 m, sample 3902-b. Distal view.
- 6, 7. Patinasporites densus. 6. Devora 2A, 3240 m, sample 3815-a, U-32 (1). Polar view.
7. Devora 2A, 3587 m, sample 3825-b, X-33 (1). Polar view.

Plate 5



Explanation of Plate 6

Magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

1. Classopollis torosus. Makhtesh Qatan 2, 892 m, sample 1635-a, D-28. Tetrad. One spore of the tetrad is missing.
- 2, 3. Paracirculina scurrilis. 2. Makhtesh Qatan 2, 1041 m, sample 3356-c, G-64. Polar view; oblique compression of specimen.
3. Zohar 8, 1950 m, sample 352-a, W-38. Polar view; polar compression of specimen.
4. Unidentified conodont. Zohar 8, 3049 m, sample 373-a, R-45 (3).
- 5, 6. Fungal spores. 5. Zohar 8, 3178 m, sample 896-b, W-39 (4), x 800.
6. Zohar 8, 3001 m, sample 887-a, X-39.
7. Micrhystriidium sp. Makhtesh Qatan 2, core 6 box G, sample 1030-b.
8. Leiofusa sp. Makhtesh Qatan 2, 1934 m, sample 1022.
9. Micrhystriidium sp. Makhtesh Qatan 2, 1550 m, sample 1015.
10. Unidentified foraminifer. Makhtesh Qatan 2, 892 m, sample 1635-a.
- 11, 12. Veryhachium. 11. Makhtesh Qatan 2, 1842 m, sample 1021, X 1250.
12. Makhtesh Qatan 2, 1449 m, sample 1013.

Plate 6



Explanation of Plate 7

Magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fossils are indicated by England Finder coordinates.

- 1, 3. Chitinozoan. Reworked from Middle Paleozoic into Permian strata. 1. Makhtesh Qatan 2 core 9, resid-b, W-37.
3. Zuk Tamrur 1, 2708 m, sample 3956-a.
2. Diexalophasis sp. Silurian acritarch, reworked into Permian strata. Makhtesh Qatan 2, core 9, resid-b.
4. Coaly organic facies. Zohar 8, 1899 m, x 250.
5. Exinitic organic facies of Potoniesporites novicus. Pleshet 1, 5240 m, sample 4147-a, H-12, x 250.

Plate 7

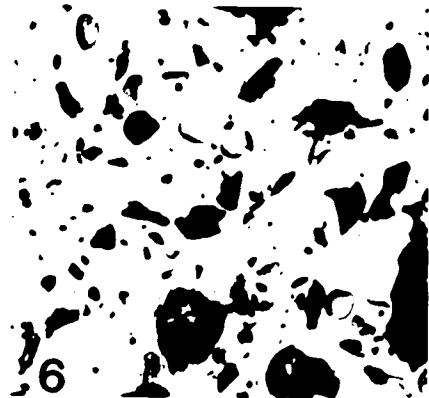
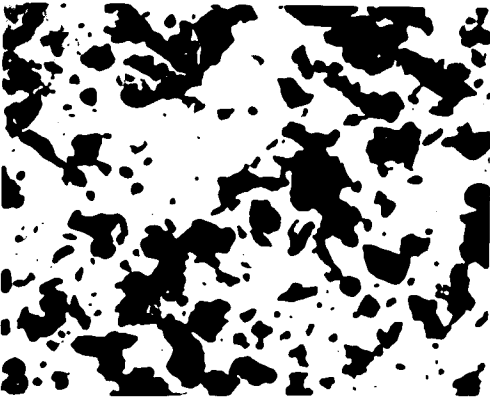


Explanation of Plate 8

Magnifications may vary slightly, but are approximately x 1000 unless otherwise indicated. Locations of fissils are indicated by England Finder coordinates.

1. Xenomorphic organic facies. Devora 2A, core 10 box 1, sample 3867-a, x 250.
2. Fecal pellet. Devora 2A, 4220-40 m, slide 3128.
3. Coaly organic facies. Pleshet 1, 4872 m, sample 4083-a, x 250. Sample taken from red bed at the Permian/Triassic boundary.
4. Unidentified bisaccate pollen grain undergone biodegradation. Devora 2A, 5494 m, sample 3884-c, x 600.
Original structures are lost in the process of biodegradation.
5. Pyritized bisaccate pollen grain. Helez Deep, 3240 m, sample 3815-a, x 600. Pyritization is believed to have been triggered by reducing bacteria.
6. Exinitic organic facies. Zohar 8, 3102 m, sample 376-a, x 250. Facies composed of small trilete and monolete spores of Early Permian age such as Laevigatosporites spp. and Punctatosporites spp.
7. Fungal spore. Zohar 8, 3178 m, sample 896-b.
8. Tracheid. Devora 2A, 5520 m, sample 3885-b, V-26, x 250.

Plate 8



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