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PALYNOSTRATIGRAPHY AND PALAEOGEOGRAPHY OF EARLY PERMIAN STRATA IN THE ZAGROS BASIN, SOUTHEAST-SOUTHWEST IRAN

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Abstract

A total of 500 Early Permian samples from the Chal-i-Sheh Formation in the Zagros Basin were examined palynologically in order to determine the stratigraphical age of the formation and to assess the palaeogeographical relationships of this basin to the Southern and Northern Hemispheres during the Early Permian. Fifty-eight taxa were recorded including 46 pollen, 10 spore and 2 acritarch species, which permitted the establishment of the age of the formation. Quantitatively, pollen contributed 98 percent, spores 1.5 percent, and acritarchs 0.5 percent of the total assemblages. The high relative percentage of gymnospermous pollen taxa suggests a relatively cold condition which was in favor of gymnospermous plants at the beginning of the Early Permian. Comparison of the taxa recorded from the Early Permian strata of the Zagros Basin with those reported from other parts of the world indicates that the Zagros Basin was part of the Gondwanan Supercontinent located on the southern shore of the Tethys sea during the Permian period.

Introduction

During the past decade, the writer has carried out a detailed palynological study on the Palaeozoic sequences (Barut, Zaigun, Lalun, Mila, Ilebeck, Zard-Kuh, Seyahou, Sarchahan and "Faraghan" Formations) in the Zagros Basin (Fig. 2). The Zagros Basin includes the southeastern part of Iran and most of the adjacent Persian Gulf, forming a SE-NW trending linear belt, approximately 1400 km long and 250 km wide, which is separated from the Central Iranian Basin by the 5-10 km wide Main Zagros Thrust or Crush Zone (Fig. 1).

Among the Palaeozoic rock units of this basin, the "Faraghan" Formation has received minimal biostratigraphic interest since it lacks marine fauna. However, based on its stratigraphic position and some plant remains, it has been assigned to the Early Permian [62] or the Permo-Carboniferous period [57]. The writer's palynological investigations have, however, revealed that part of the "Faraghan" Formation was deposited in the Devonian period and another part during the Early Permain [26]. Therefore, the carboniferous strata are apparently unrepresented in the Zagros Basin.

As a result of these studies, the use of the term "Faraghan" Formation was discontinued and, with the approval of the National Iranian Stratigraphic Committee, was replaced with the terms Zakeen Formation (of

Keywords: Chal-i-Sheh formation; Early Permian; Miospores; Palaeogeography; Zagros Basin

Devonian age) and Chal-i-Sheh Formation (of Permian age). This paper aims to demonstrate some diagnostic palynomorph taxa from the Chal-i-Sheh Formation in order to resolve aspects of palaeogeographic relationships of the Zagros Basin during the Early Permian. The palaeogeography of the Zagros Basin is important at this geological time since the palynological data are able to make clear the relationships of this basin to central and northern parts of Iran as well as to other parts of the world.

Previous Studies

The Zagros Basin encompasses the southeastern part of Iran and most of the Persian Gulf and has been a major center of oil exploration. Most of the formation nomenclature for the sedimentary sequence of the Zagros Basin was established by petroleum geologists (J.V. Harrison, 1930, unpublished company report). Setudehnia [57] described the Palaeozoic strata in parts of the Zagros Basin such as Zard-Kuh, Kuh-e-Gereh, Kuh-e-Dinar and Oshtoran-Kuh areas (Fig. 1). As a result of field studies, the Pre-Triassic sediments of the Zagros Basin were named by Szabo and Kheradpir [62] and their rock units approved by the National Iranian Stratigraphic Committee in that year. Although Szabo and Kheradpir's paper is the most complete documentation for the Palaeozoic rock units in the Zagros Basin, the age assignments of some of them are still incomplete or in premature stages due to a lack of diagnostic biostratigraphical evidence. With the exception of the Zakeen and Chal-i-Sheh Formations, which lack marine funa, the rest of the Palaeozoic rock units in the basin contain well-preserved and abundant faunas consisting of trilobite, coral, brachiopod, graptolite and fusulinid, providing reliable age controls. The studied sequence was originally referred to as Carboniferous Sandstones or Permo-Carboniferous Sandstones by Setudehnia [57], but later was named the Faraghan Formation by Szabo and Kheradpir [62] and assigned to the Lower Permian. The age assignment of the sequence either by Setudehnia [57], or Szabo and Kheradpir [62], was based on Seward's work [58] which identified plant remains as *Sigillaria persica* and suggested an Upper Carboniferous (Stephanian), or Lower Permian age.

The writer's preliminary research focused on palynological characteristics of the sequence (Faraghan Formation) in the Gahkum-Faraghan areas (Fig. 1). The study revealed that 200 out of 245 m of the Faraghan Formation in both Kuh-e-Faraghan and Kuh-e-Gahkum have been deposited during the Devonian period and the remainder laid down during the Early Permian [26]. This resulted in the subdivision of the Faraghan Formation into the Zakeen Formation (Devonian) and the Chal-i-Sheh Formation (Early Permian) by the National Iranian Stratigraphic Committee in 1996. This paper is concerned with the palynological characteristics of the Chal-i-Sheh Formation (Fig. 2) and those of the Zakeen formation will be published in another paper.

Stratigraphy

The name Chal-i-Sheh Formation is given to the Early Permian part of the succession formerly known as the Faraghan Formation. This rock unit is well-developed in all of the high mountain ranges in the Zagros Basin, from northwest to southeast parts of Iran (Fig. 1).

The Chal-i-Sheh Formation was named as one of the best developed outcrop sections in the Chal-e-Sheh area [30]. Its thickness varies from a minimum of a few meters at Kuh-e-Dinar to 500 meters in the type locality area (Fig. 2). The formation mainly consists of sandstone, siltstone, shale and a few limestone beds.

The Chal-i-Sheh Formation lacks marine fauna but contains abundant plant remains at one horizon in the type locality area (Fig. 2). The plant remains were collected by J.V. Harrison in 1930 and identified by Seward [58] as *Sigillaria persica* suggesting a Late Carboniferous (Stephanian), or Early Permian age. The upper contact of the Chal-i-Sheh Formation is gradational with the Dalan Formation (Upper Permian) at all surface and subsurface sections (Fig. 2) and is marked by a transition from interbedded sandstones to limestone beds. The Lower contact is characterized by a major hiatus, the magnitude of which increases in a SE-NW direction in the Zagros Basin with the lowest beds of the Chal-i-Sheh Formation resting on a variety of older strata (Fig. 2).

Laboratory Techniques

A total of 500 surface and subsurface samples from the Chal-i-Sheh Formation were selected for palynological study. Digestion of the samples was carried out using standardized techniques. All slides are housed in the Palaeontological Section of the Exploration Department of the National Iranian Oil Company.

List of Taxa Identified

In this study, no attempt was made to establish systematic description for the known morphotypes of the Chal-i-Sheh Formation based on conventional suprageneric classification, instead, they were arranged under their probable parent plant groups. This informal scheme has already been used for Australian morphotypes by Gilby and Foster [31] who attributed the Permian morphotypes to the categories of articulates, pterophytes, lycopods and gymnosperms. In the list of taxa given below, plate and figure numbers given in brackets refer to the illustrations in this paper.

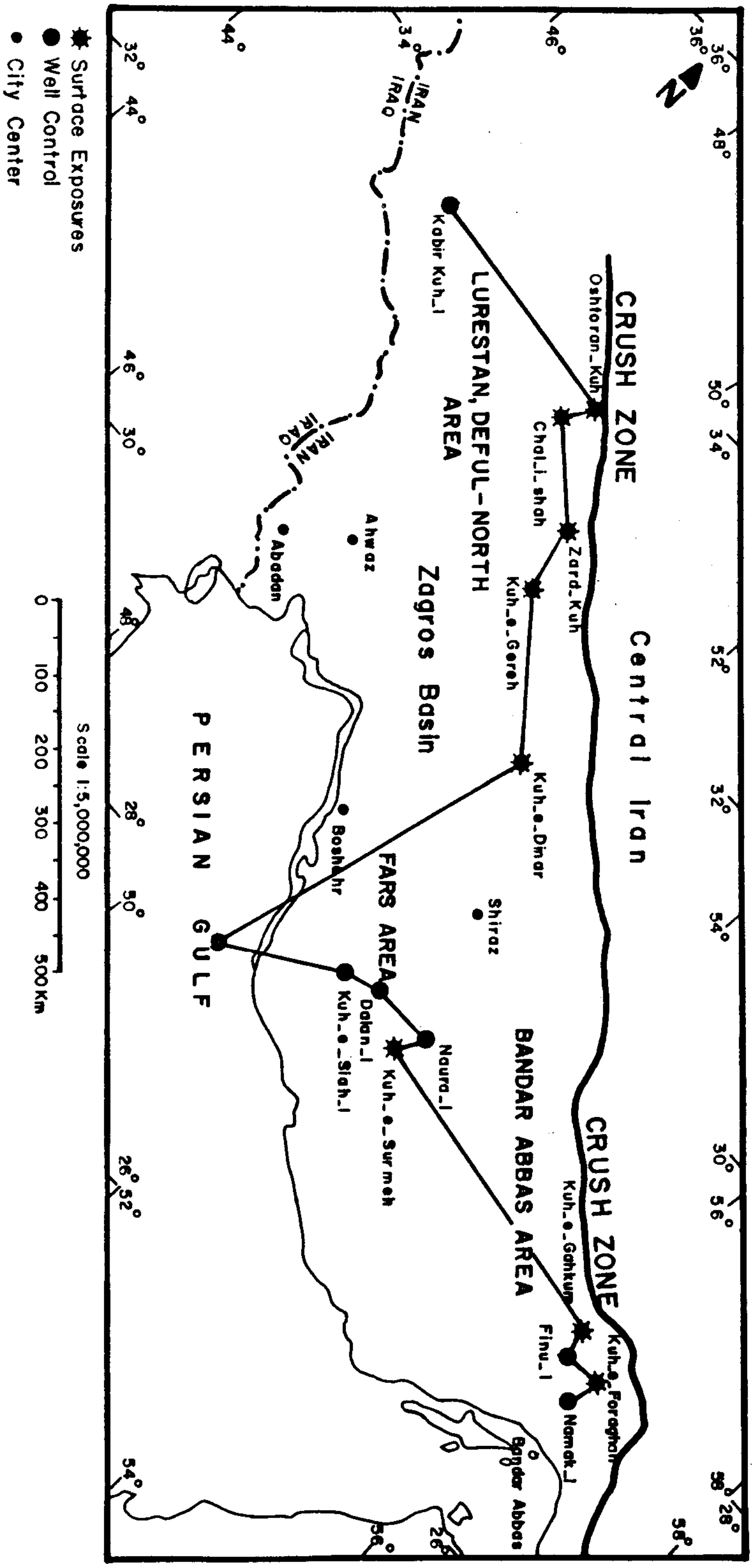


Figure 1. Distribution of the Chal-i-Sheh Formation in the Zagros Basin and the locations of the study area to the main Zagros Thrust, Southern Iran

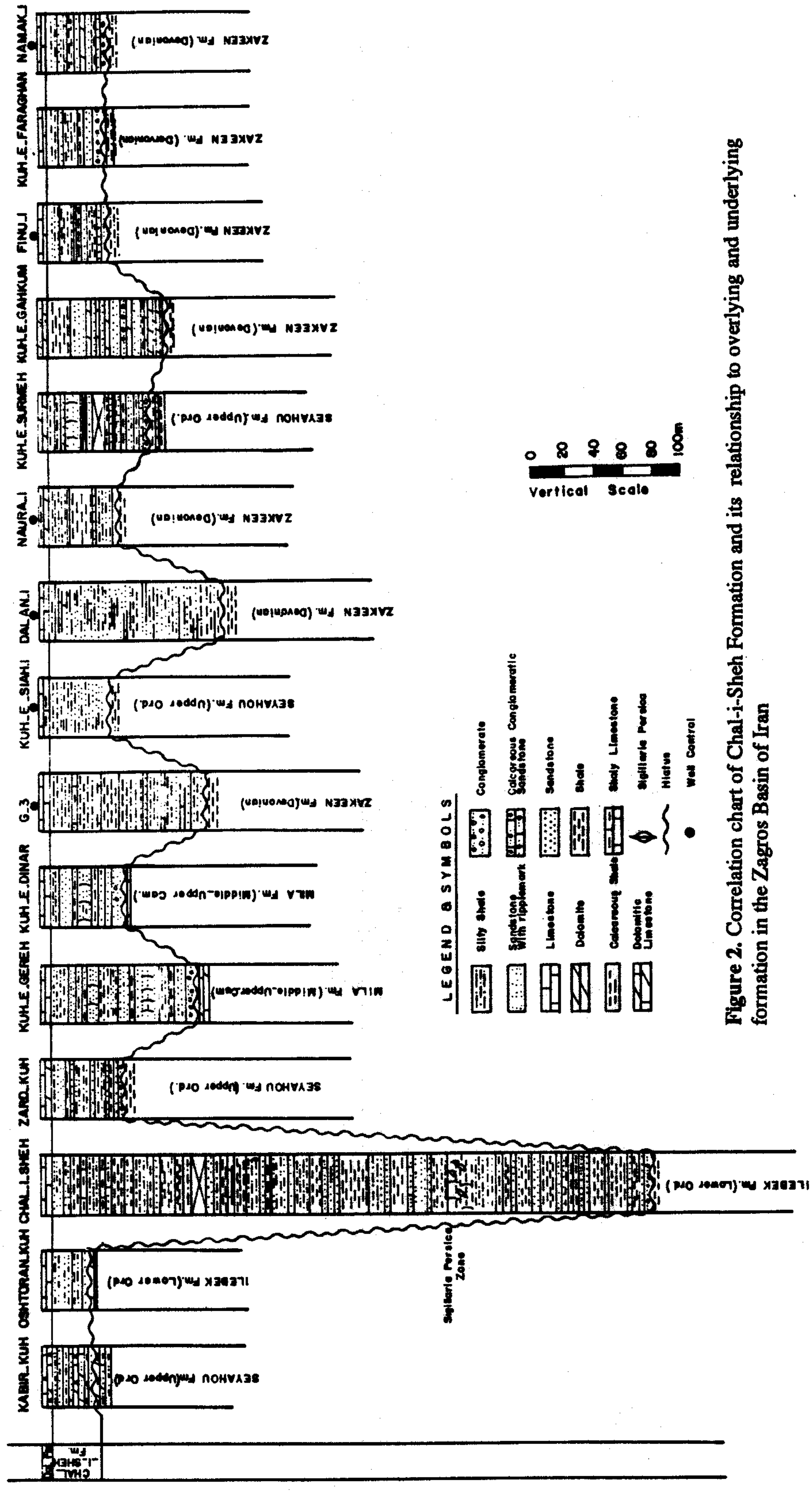


Figure 2. Correlation chart of Chal-i-Sheh Formation and its relationship to overlying and underlying formation in the Zagros Basin of Iran

Articulates

Punctatisporites gretensis, Balme and Hennelly, 1965 (Pl. I, Fig. 5).

Pterophytes

Horriditriletes ramosus, (Balme and Hennelly) Bharadwaj and Salujha, 1964 (Pl. I, Figs. 2 & 6).
Laevigatosporites colliensis, (Bharadwaj and Hennelly) Venkatachala and Kar, 1968 (Pl. I, Fig. 10).
Leiotriletes virkkii, Tiwari, 1965 (Pl. I, Fig. 9).
Lophotriletes scotinus, Segroves, 1970 (Pl. I, Fig. 1).
Pseudoreticulatispora pseudoreticulata, (Balme and Hennelly) Bharadwaj and Srivastava 1969 (Pl. I, Fig. 4).
Verrucosisporites andersonii, (Anderson) Backhouse, 1988 (Pl. I, Fig. 8).

Lycopods

Densoisporites solidus, Segroves, 1970 (Pl. I, Fig. 7).
Jayantisporites variabilis, (Anderson) Backhouse, 1991 (Pl. I, Fig. 3).
Kraeuselisporites niger, Segroves, 1970 (Pl. I, Fig. 12).

Gymnospermous Pollen
Monosaccate Pollen

Bascanisporites undosus, Balme and Hennelly, 1956 (Pl. III, Fig. 4).
Nuskoisporites triangularis, Potonié and Lele, 1961 (Pl. II, Fig. 7).
Plicatipollenites densus, Srivastava, 1970 (Pl. II, Fig. 9).
Plicatipollenites indicus, Lele, 1964 (Pl. V, Fig. 12).
Potonieisporites granulatus, Bose and Kar, 1966 (Pl. II, Fig. 12).
Potonieisporites neglectus, Potonié and Lele, 196*l* (Pl. II, Fig. 6).
Rugasaccites orbiculatus, Lele and Maithy, 1969 (Pl. II, Fig. 5).

Disaccate Non-Taeniate

Alisporites nuthallensis, Clarke, 1965 (Pl. II, Fig. 2).
Caheniasaccites ellipticus, Bose and Maheshwari, 1968 (Pl. II, Fig. 1).
Caheniasaccites indicus, Srivastava, 1970 (Pl. II, Fig. 10).
Falcisporites, sp., (Pl. II, Fig. 8).
Klausipollenites schaubergeri (Potonié and Klaus) Jansonius, 1962 (Pl. II, Fig. 11).
Walikalesaccites ellipticus, Bose and Kar, 1966 (Pl. V, Fig. 2).

Colpate Pollen

Cycadopites cymbatus, (Balme and Hennelly) Segroves, 1969 (Pl. III, Fig. 6).
Praecolpatites sinuosus, (Balme and Hennelly) Bharadwaj and Srivastava, 1969 (Pl. II, Fig. 3).

Taeniate Pollen

Boutakoffites elongatus, Bose and Kar, 1966 (Pl. IV, Fig. 3).
Complexisporites polymorphus, Jizba, 1962 (Pl. VI, Figs. 1 & 12).
Corisaccites alutas, Venkatachala and Kar, 1966 (Pl. V, Fig. 10).
Costapollenites ellipticus, Tschudy and Kosanke, 1966 (Pl. IV, Fig. 6).
Crustaesporites globosus, Leschik, 1956 (Pl. III, Fig. 7).
Decussatisporites circularis, Sinha, 1970 (Pl. III, Fig. 10).
Distriamonocolpites ovalis, Bharadwaj and Sinha, 1969 (Pl. III, Fig. 11).
Fusacolpites fusus, Bose and Kar, 1966 (Pl. IV, Fig. 12).
Fusacolpites ovatus, Bose and Kar, 1966 (Pl. IV, Fig. 8).
Hamiapollenites karrooensis, (Hart) Hart, 1964 (Pl. VI, Fig. 7).
Hamiapollenites saccatus, Wilson, 1962 (Pl. V, Fig. 1).
Lueckisporites virkkiae, (Potonié and Klaus) Clarke, 1965 (Pl. VI, Fig. 3).
Mabuitasaccites ovatus, Bose and Kar, 1966 (Pl. IV, Fig. 11).
Marsupipollenites striatus, (Balme and Hennelly) Foster, 1979 (Pl. IV, Fig. 1).
Protohaploxypinus bharadwajii, Foster, 1979 (Pl. VI, Fig. 2).
Protohaploxypinus limpidus, (Balme and Hennelly) Balme and Playford, 1967 (Pl. VI, Fig. 6).
Striatoabieites multistriatus, (Balme and Hennelly) Hart, 1964 (Pl. V, Figs. 7 & 8).
Striatopodocarpites cancellatus, (Balme and Hennelly) Hart, 1963 (Pl. VI, Figs. 9 & 11).
Striatopodocarpites fusus, (Balme and Hennelly) Potonié, 1956 (Pl. VI, Fig. 5).
Striatopodocarpites raniganjensis, (Bharadwaj) Hart, 1964 (Pl. VI, Fig. 10).
Striomonosaccites brevis, Bose and Kar, 1966 (Pl. III, Fig. 3).
Striomonosaccites cicatricosus, Archangelsky and Gamerro, 1979 (Pl. III, Fig. 1).
Striomonosaccites triangularis, Maheshwari, 1967 (Pl. III, Fig. 2).
Tiwariasporis flavatus, Maheshwari and Kar, 1967 (Pl. III, Fig. 12).
Tiwariasporis gondwanensis, (Tiwari) Maheshwari and Kar, 1967 (Pl. IV, Fig. 4).
Trochosporites sp., (Pl. III, Fig. 5).
Tuberisaccites sp., (Pl. II, Fig. 4).
Vittatina costabilis, Wilson, 1962 (Pl. V, Fig. 3).
Vittatina subsaccata, Samoilovich, 1953 (Pl. V, Fig. 5).
Vittatina verrucosa, Tiwari, 1968 (Pl. V, Fig. 4).
Weylandites magnus, (Bose and Kar) Backhouse, 1991

Plate I
All x 1000 (bar = 20um)

Figure 1. *Lophotriletes scotinus*, Segroves, 1970.
Figure 2. *Horriditriletes ramosus*, (Balme and Hennelly) Bharadwaj and Salujha,196.
Figure 3. *Jayantisporites variabilis*, (Anderson) Backhouse, 1997.
Figure 4. *Pseudoreticulatispora pseudoreticulata*, (Balme and Hennelly) Bharadwaj and Srivastava, 1969.
Figure 5. *Punctatisporites gretensis*, Balme and Hennelly, 1956.
Figure 6. *Horriditriletes ramosus*, (Balme and Hennelly) Bharadwaj and Salujha, 1964.
Figure 7. *Densoisporites solidus*, Segroves, 1970.
Figure 8. *Verrucosisporites andersonii*, (Anderson) Backhouse, 1988.
Figure 9. *Leiotriletes virkkii*, Tiwari, 1965.
Figure 10. *Laevigatosporites colliensis*, (Bharadwaj and Hennelly) Venkatachala and Kar, 1968.
Figure 11. *Brazilea* sp.
Figure 12. *Kraeuselisporites niger*, Segroves, 1970.

Plate II
All x 1000 (bar = 20um)

Figure 1. *Caheniasaccites ellipticus*, Maheshwari and Bose, 1968.
Figure 2. *Alisporites nuthallensis*, Clarke, 1965.
Figure 3. *Praecolpatites ovatus*, (Anderson) Backhouse, 1991.
Figure 4. *Tuberisaccites* sp.
Figure 5. *Rugasaccites orbiculatus*, Lele and Maithy, 1969.
Figure 6. *Potonieisporties neglectus*, Potonié and Lele, 1959.
Figure 7. *Nuskoisporites triangularis*, Potonié and Lele, 1959.
Figure 8. *Falcisporites* sp.
Figure 9. *Plicatipollenites densus*, Srivastava, 1970.
Figure 10. *Caheniasaccites indicus*, Srivastava, 1970.
Figure 11. *Klausipollenites schaubergeri*, (Potonié and Klaus) Jansonius, 1962.
Figure 12. *Potonieisporites granulatus*, Bose and Kar, 1966.

Plate III
All x 1000 (bar = 20um)

Figure 1. *Striomonosaccites cicatricosus*, Archangelsky and Gamerro, 1979.
Figure 2. *Striomonosaccites triangularis*, Maheshwari, 1967.
Figure 3. *Striomonosaccites brevis*, Bose and Kar, 1966.
Figure 4. *Bascanisporites undosus*, Balme and Hennelly, 1956.
Figure 5. *Trochosporite sp.*
Figure 6. *Cycadopites cymbatus*, (Balme and Hennelly) Segroves, 1969.
Figure 7. *Crustaesporites globosus*, Leschik, 1956.
Figure 8. *Crustaesporites globosus*, Leschik, 1956.
Figure 9. *Weylandites magnus*, (Bose and Kar) Backhouse, 1991.
Figure 10. *Decussatisporites circularis*, Sinha, 1970.
Figure 11. *Distriamonocolpites ovalis*, Bharadwaj and Sinha, 1969.
Figure 12. *Tiwariasporis flavatus*, Maheshwari and Kar, 1967.

Plate IV
All x 1000 (ba r= 20um)

Figure 1. *Marsupipollenites striatus*, (Balme and Hennelly) Foster, 1979.
Figure 2. *Tiwariasporis flavatus*, Maheshwari and Kar, 1967.
Figure 3. *Doutakoffites elongatus*, Bose and Kar, 1966.
Figure 4. *Tiwariasporis gondwanensis*, (Tiwari) Maheshwari and Kar, 1967.
Figure 5. *Mabuitasaccites ovatus*, Bose and Kar, 1966.
Figure 6. *Costapollenites ellipticus*, Tschudy and Kosanke, 1966.
Figure 7. *Mabuitasaccites ovatus*, Bose and Kar, 1966.
Figure 8. *Fusacolpites ovatus*, Bose and Kar, 1966.
Figure 9. *Decussatisporites circularis*, Sinha, 1970.
Figure 10. *Boutakoffites elongatus*, Bose and Kar, 1966.
Figure 11. *Mabuitasaccites ovatus*, Bose and Kar, 1966.
Figure 12. *Fusacolpites fusus*, Bose and Kar, 1966.

(Pl. III, Fig. 9).

Acritarchs
Brazilea sp., (Pl. I, Fig. 11).
Gorgonisphaeridium sp., (Pl. V, Fig. 11).

Stratigraphic Palynology

This study was undertaken to determine the geological age of the formation, to make an interpretation of the depositional site, and to reconstruct the palaeogeographic relationships of the Zagros Basin to Gondwana and Laurasia Supercontinents during the time interval represented by these strata. A total of 58 species are identified, including 46 pollen (32 genera), 10 spore (10 genera) and 2 acritarch (2 genera) species. The distribution of the taxa are shown on Table I and selected morphotype species are illustrated in Plates I-VI.

A detailed microscopic study of the palynological

Plate I

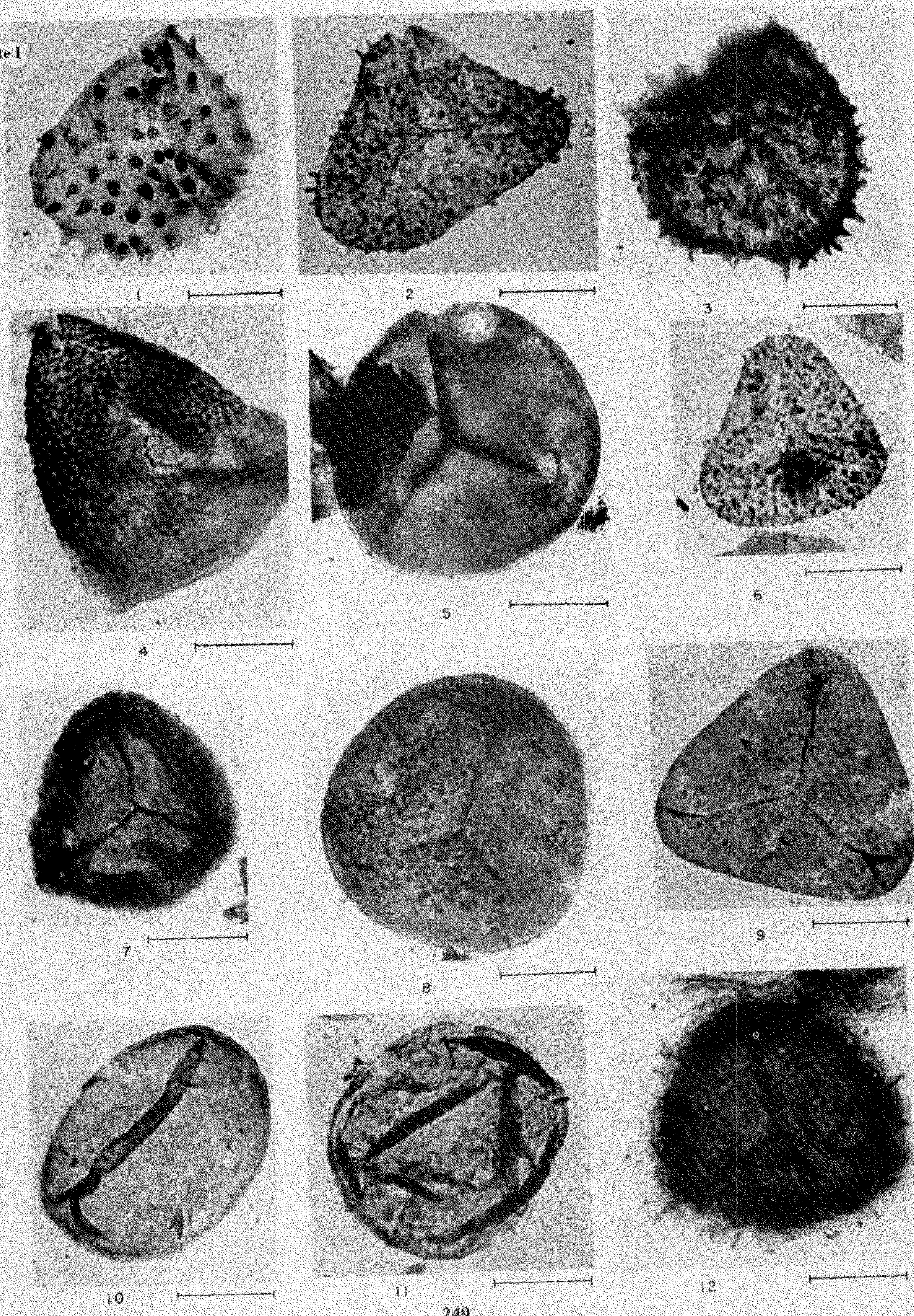
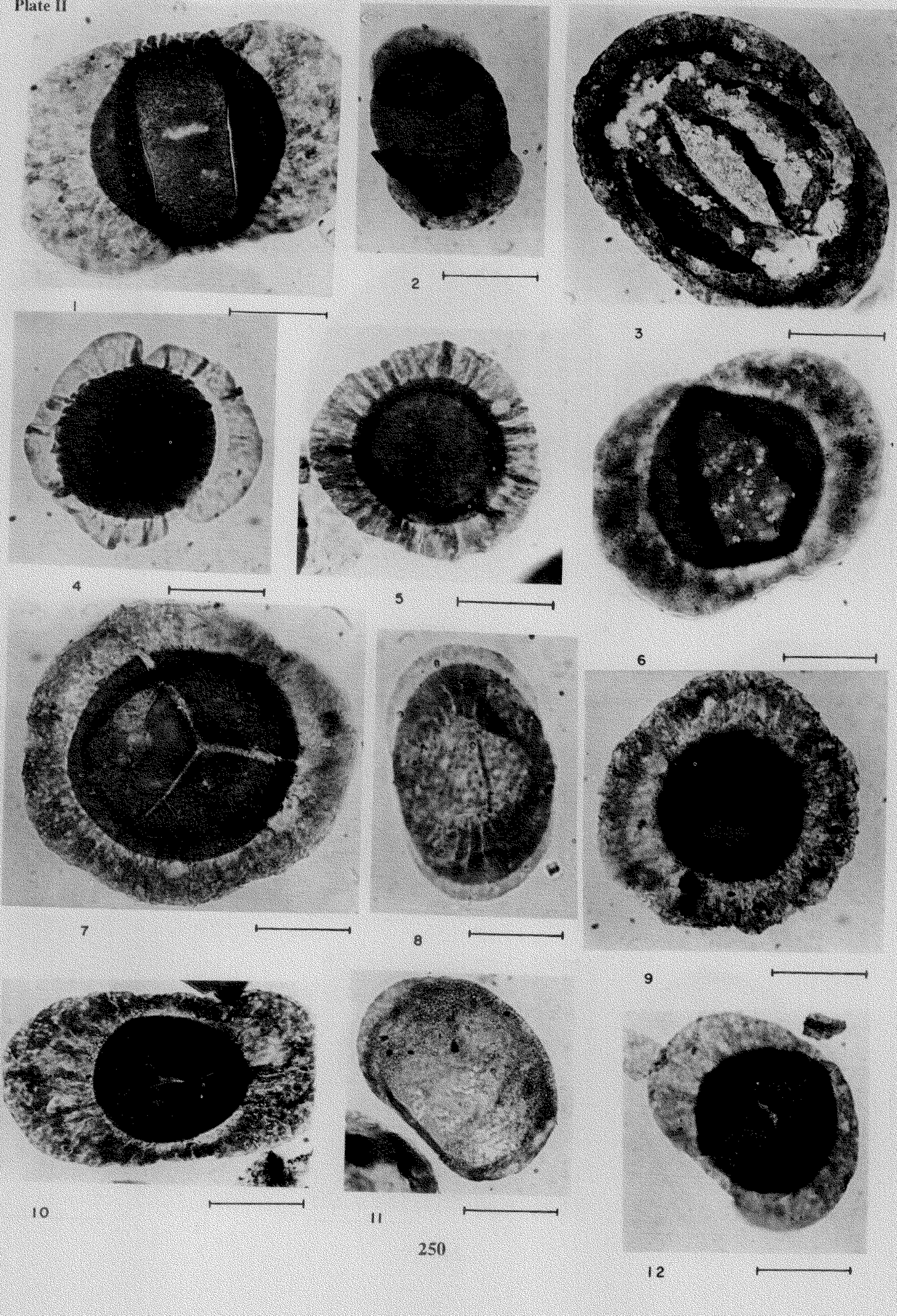


Plate II



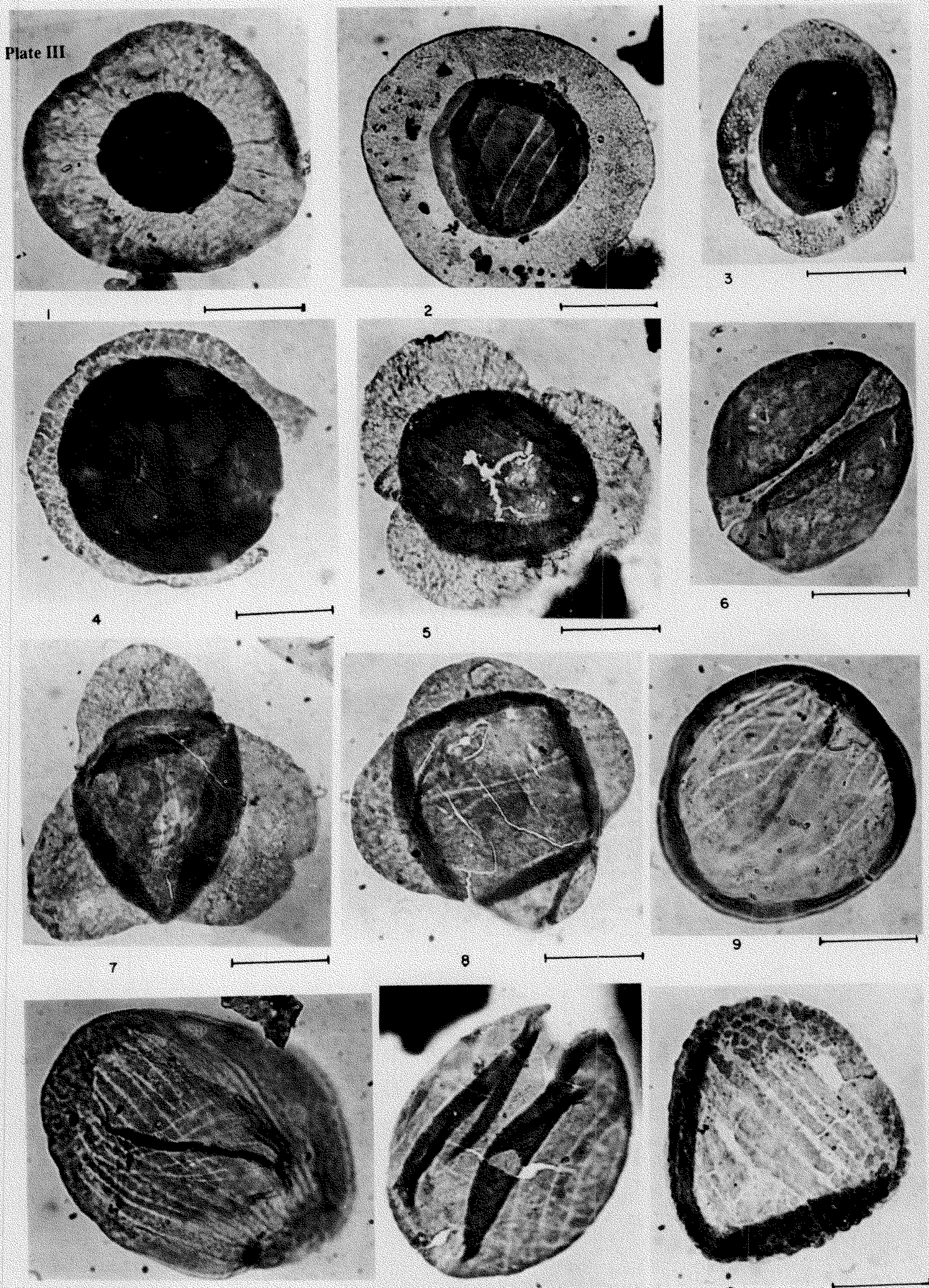


Plate III
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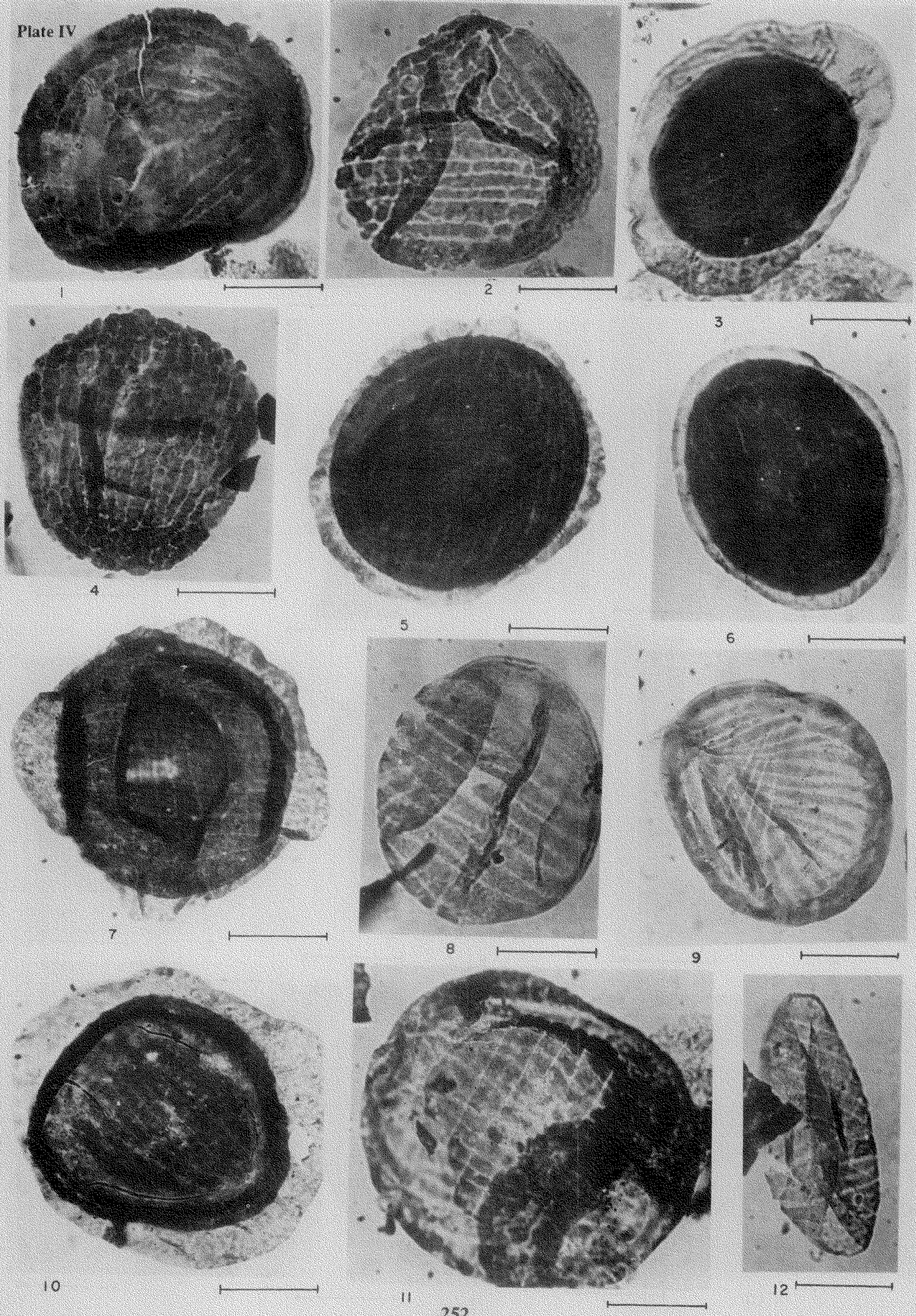
Plate IV



samples of the Chal-i-Sheh Formation reveals that the base of this rock unit coincides with the appearance of abundant gymnospermous pollen taxa in all studied sections including:

Vittatina costabilis, Costapollenites ellipticus, Hamiapollenites karrooensis,
Potonieisporites granulatus, Potonieisporites neglectus, Nuskoisporites triangularis,
Plicatipollenites densus, Plicatipollenites indicus, Rugasaccites orbiculatus,
Klausipollenites schaubergeri, Falcisporites flexuosa and *Alisporites nuthalensis*

Diversity within this rock unit rapidly increases with the occurrence of other pollen species including:

Caheniasaccites ellipticus, Caheniasaccites indicus, Fusacolpites fusus, Fusacolpites ovatus,
Boutakoffites elongatus, Mabuitasaccites ovatus, Cycadopites cymbatus,
Marsupipollenites striatus, Tiwariasporis flavatus, Tiwariasporis gondwanensis,
Decussatisporites circularis, Distriamonocolpites ovalis, Weylandites magnus,
Bascanisporites undosus, Vittatina subsaccata, Vittatina verrucosa,
Walikalesaccites ellipticus, Striatoabieites multistriatus, Striatopodocarpites fusus,
Striatopodocarpites raniganjensis, Striatopodocarpites cancellatus, Lueckisporites virkkiae,
Protohaploxypinus limpidus, Protohaploxypinus bharadwajii and *Praecolpatites ovatus.*

In addition to the pollen taxa, there are several spore species in this rock unit including:

Laevigatosporites colliensis, Leiotriletes virkkii, Punctatisporites gretensis,
Lophotriletes scotinus, Densoisporites solidus, Horriditriletes ramosus,
Kraeuselisporites niger, Pseudoreticulatispora pseudoreticulata, Verrucosisporites andersonii and *Jayantisporites variabilis*

The relative percentage of each morphotype was calculated based on counts of two hundred grains per sample and the sum total resulted in 98% pollen, 1.5% acritarchs and scolecodonts.

Some of the components of this rock unit are found in the Early Permian Dorud Formation of northern Iran [19, 29] and the Early Permian of Turkey [1], but the majority of species of Chal-i-Sheh Formation are recorded in the Early Permian strata of Pakistan [68, 69, 70, 6], India [14, 68, 70, 59], Africa [32, 36, 15, 17, 2], Australia [55, 56, 31, 4] and a few species in the Early Permian sediments of the United States of America [38, 66]. This indicates that the index species of Early Permian are:

Hamiapollenites karrooensis, Vittatina costabilis, Vittatina subsaccata, Vittatina verrucosa,
Costapollenites ellipticus, Fusacolpites fusus, Fusacolpites ovatus,
Boutakoffites elongatus, Mabuitasaccites ovatus, Walikalesaccites ellipticus,
Corisaccites alutas, Nuskoisporites triangularis, Striomonosaccites brevis,
Striomonosaccites triangularis, Cycadopites cymbatus, Weylandites magnus,
Potonieisporites granulatus, Potonieisporites neglectus, Plicatipollenites densus,
Plicatipollenites gondwanensis, Decussatisporites circularis, Distriamonocolptes ovalis,
Tiwariasporis flavatus, Tiwariasporis gondwanensis, Striatopodocarpites fusus,
Leiotriletes virkkii, Verrucosisporites andersonii, Densoisporites solidus, and other species are long-ranging during the Permian period (Table 1). Based on the abovementioned species, an Early Permian (Sakmarian-Artinskian) age is suggested for the Chal-i-Sheh Formation in the Zagros Basin.

From the point of view of lithology and age relationship, the Chal-i-Sheh Formation is possibly equivalent to the Unayzah Formation in the southern part of the Persian Gulf (Saudi Arabia). The Upper Carboniferous age assignment to the Chal-i-Sheh Formation, based on the presence of the megafossil plant *Sigillaria persica* of Seward [58], is therefore rejected and the Carboniferous is represented by an hiatus in the Zagros Basin which possibly equates with the Hercynian Orogeny.

A small number of acritarch taxa and scolecodonts, which contribute 0.5 percent of the total assemblages, are associated with the miospore assemblages of the Chal-i-Sheh Formation. In all samples, the pollen diversity is high-masking the contributions of acritarchs, scolecodonts and spores. This phenomenon might be explained in terms of the close proximity of the depositional site to the parent plant source. Another interpretation would be that the Late Carboniferous Gondwana glaciation retreated and gave rise to relatively cold conditions at the beginning of the Permian period. This situation favored the gymnospermous plant community and inhibited the development of spore-bearing plants as well as acritarchs and marine annelid worms in the depositional environment. In summary, the Chal-i-Sheh Formation was deposited in a shallow marine environment.

Palaeogeography

The 58 morphotype species identified from the Early Permian sediments (Chal-i-Sheh Formation) of the Zagros

Plate V
All x 1000 (bar = 20um)

Figure 1. *Hamiapollenites saccatus*, Wilson, 1962.
Figure 2. *Walikalesaccites ellipticus*, Bose and Kar, 1966.
Figure 3. *Vittatina costabilis*, Wilson, 1962.
Figure 4. *Vittatina verrucosa*, Tiwari, 1965.
Figure 5. *Vittatina subsaccata*, Samoilovitch, 1953.
Figure 6. *Vittatina subsaccata*, Samoilovitch, 1953.
Figure 7. *Striatoabieites multistriatus*, (Blame and Hennelly) Hart, 1964.
Figure 8. *Striatoabietites multistriatus*, (Balme and Hennelly) Hart, 1964.
Figure 9. *Vittatina costabilis*, Wilson, 1962.
Figure 10. *Corisaccites alutas*, Venkatachala and Kar, 1966.
Figure 11. *Gorgonisphaeridium* sp.
Figure 12. *Plicatipollenites indicus*, Lele, 1964.

Plate VI
All x 1000 (ba r= 20 um)

Figures 1&2. *Complexisporites polymorphus*, Jizba, 1962.
Figure 2. *Protohaploxypinus bharadwajii*, Foster, 1979.
Figure 3. *Lueckisporites virkkiae*, (Potonié and Klaus) Clarke, 1965.
Figure 4. *Striatopodocarpites raniganjensis*, (Bharadwaj) Hart, 1964.
Figure 5. *Striatopodocarpites fusus*, (Balme and Hennelly) Potonié, 1956.
Figure 6. *Protohaploxypinus limpidus*, (Balme and Hennelly) Balme and Playford, 1967.
Figure 7. *Hamiapollenites karrooensis*, (Hart) Hart, 1964.
Figure 8. *Hamiapollenites saccatus*, Wilson, 1962.
Figures 9 & 11. *Striatopodocarpites cancellatus*, (Balme and Hennelly) Hart, 1963.
Figure 10. *Striatopodocarpites raniganjensis*, (Bharadwaj) Hart, 1964.

Basin are considered to be sufficiently distinct and of potential value in reconstructing the palaeogeography of the Zagros Basin during the Early Permian. These species were compared with those of almost coeval strata in Africa [36, 15, 48, 17, 41, 67, 2], Australia [55, 56, 31, 4], India and Pakistan [14, 63, 69, 13, 6, 10], South America [22, 3, 45], Turkey [1], Europe and North America [38, 66, 21, 37]. This comparison indicates that from the 58 Early Permian species of the Zagros Basin, 40 species are common with Australia, 30 species with India and Pakistan, 47 species with Africa, 28 species with South America, 11 species with Europe and North America and three species with Turkey (Table 2). Comparison of the palynological data suggests a closer relation to those of Gondwanan countries than with those of Europe, North America and Turkey (Table 2). However, the Early Permian assemblage of the Zagros Basin appears to be most similar to those of African countries (Table 2). It would be reasonable, therefore, to suggest that the Zagros Basin and African Plate were not distant from one another and they were at about the same latitude along the southern shore of the Tethys sea during the Permian period.

Conclusions

The Early Permian sediments of the Zagros Basin are called the Chal-i-Sheh Formation, which is well-developed from SE-NW of this basin. The surface and subsurface samples of this rock unit were investigated for palynomorph entities. All samples contain well-preseved and abundant palynomorph taxa, which permit determination of the stratigraphic age of this formation.

A detailed microscopic study of the Chal-i-Sheh Formation reveals that the lower most part of the formation coincides with the appearance of abundant gymnospermous pollen taxa whose diversities increase toward the top of this rock unit. Among the miospore species of this rock unit, a few species have been recorded from the whole Permian period in other parts of the world, and most of them belong to the Early Permian (Table 1). Therefore, based on palynological data, there is a major hiatus between the Chal-i-Sheh Formation and older rock units and its magnitude increases from SE-NW of the Zagros Basin (Fig. 2). Likewise, the miospore species of this rock unit were compared with those of coeval strata elsewhere (Table 2). The comparison indicates that from 56 miospore species of Chal-i-Sheh Formation, 40 species are common with Australia, 47 species with Africa, 30 species with India and Pakistan, 28 species with South America, and three species with Turkey. Therefore, the Early Permian assemblage of Zagros Basin appears most similar to those of African countries. This similarity suggests that the Iranian platform and African plate were at about the same palaeolatitude along the southern shore of the Palaeo-Tethys Ocean during the Early Permian.

On the other hand, a cold limnic condition prevailed over the vegetation of the Zagros Basin during the Early Permian. This is indicated by the remnants of a Carboniferous forest (including *Sigillaria persica*) in the Chal-i-Sheh area and coal seams in Kuh-e-Gareh and Zard-Kuh area.

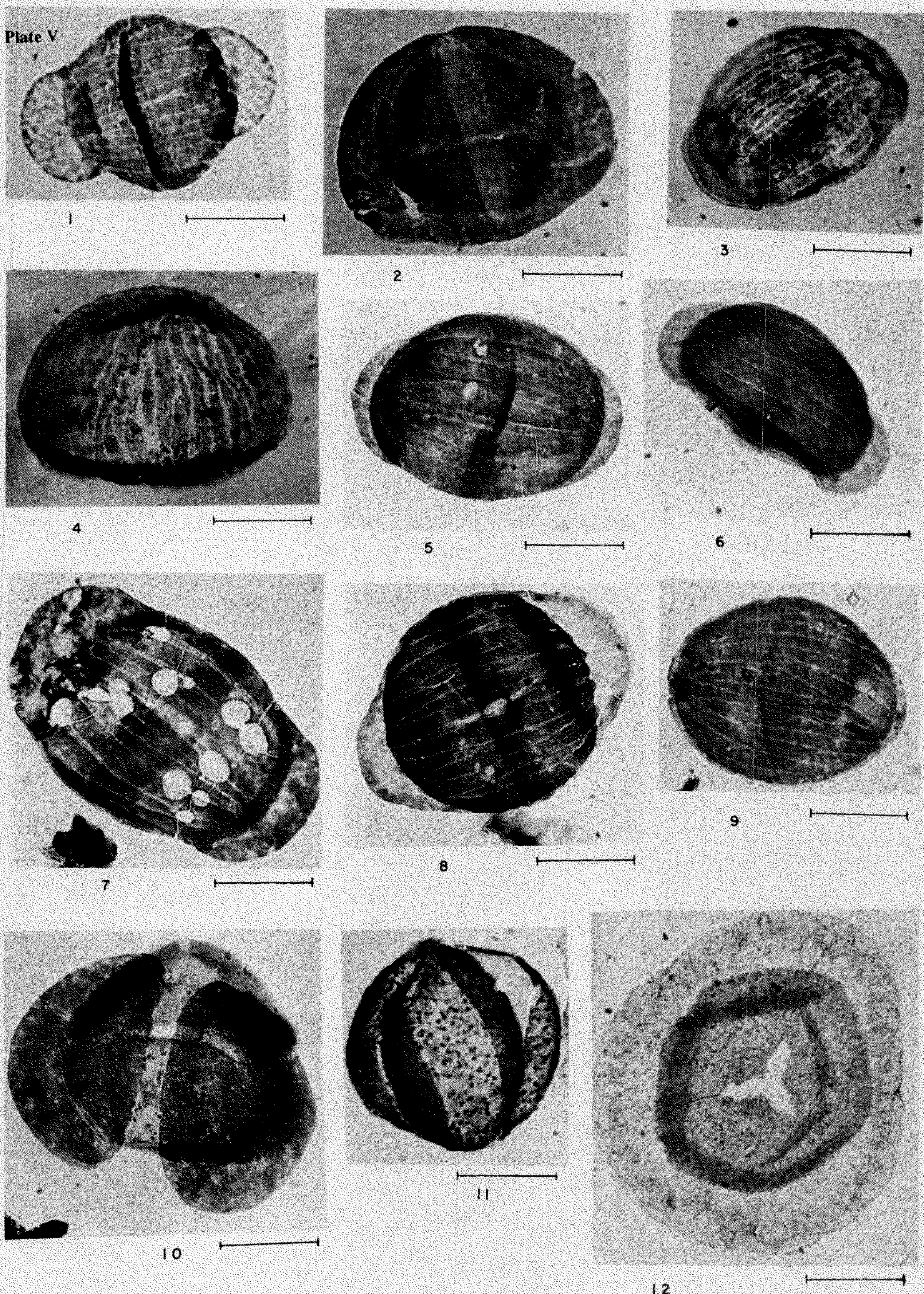


Plate V
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Plate VI

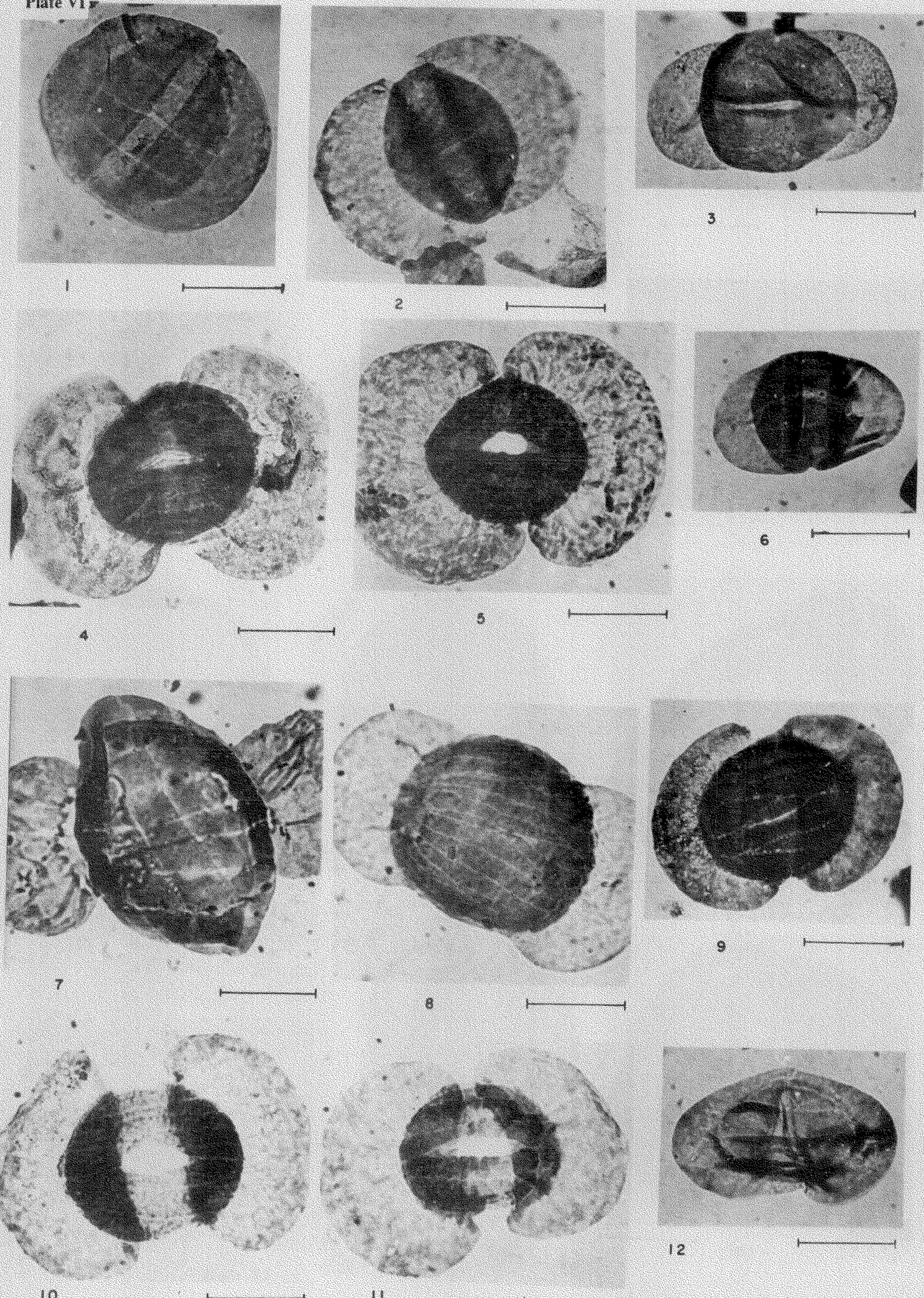

Table I. Stratigraphic range chart of palynomorph taxa from the Early Permian strata in the Zagros Basin, of the Islamic Republic of Iran

LIST OF MORPHOTYPE SPECIES	U.Car bonif erous	Early Permian			Late Permian		
	Stephanian	Asselian	Sakmarian	Artinskian	Kungurian	Kazanian	Tatarian
Hamiapollenites saccatus		—	—	—	—	—	
Horriditriletes ramosus		—	—	—	—	—	
Fusacolpites ovatus		—	—	—	—		
Fusacolpites fusus		—	—	—	—		
Pseudoreticulatispora pseudoreticulata		—	—	—	—		
Punctatisporites gretensis		—	—	—	—		
Potonieisporites neglectus		—	—	—			
Boutakoffites elongatus		—	—	—			
Mabuitasaccites ovatus		—	—	—			
Costapollenites ellipticus		—	—	—			
Walikalesaccites ellipticus		—	—	—			
Vittatina costabilis		—	—	—			
Vittatina verrucosa		—	—	—			
Nuskoisporites triangularis		—	—	—			
Plicatipollenites densus		—	—	—			
Potonieisporites granulatus		—	—	—			
Striomonosaccites cicatricosus		—	—	—			
Striomonosaccites triangularis		—	—	—			
Striomonosaccites brevis		—	—	—			
Cycadopites cymbatus		—	—	—			
Vittatina subsaccata		—	—	—			
Plicatipollenites indicus		—	—	—			
Complexisporites polymorphus		—	—	—			
Hamiapollenites karrooensis		—	—	—			
Protohaploxypinus bharadwajii			—	—	—	—	—
Striatopodocarpites fusus			—	—	—	—	—
Striatopodocarpites cancellatus			—	—	—	—	—
Laevigatosporites colliensis			—	—	—	—	
Praecolpatites ovatus			—	—	—	—	
Crustaesporites globosus			—	—	—	—	
Striatoabieites multistriatus			—	—	—	—	
Trochosporites sp.			—	—	—	—	
Verrucosisporites andersonii			—	—	—		
Leiotriletes virkkii			—	—	—		
Kraeuselisporites niger			—	—	—		
Marsupipollenites striatus			—	—	—		
Jayantisporites variabilis			—	—	—		
Corisaccites alutas			—	—	—		
Striatopodocarpites raniganjensis			—	—	—		
Protohaploxypinuus limpidus			—	—	—		
Caheniasaccites ellipticus			—	—			
Tuberisaccites sp.			—	—			
Rugasaccites orbiculatus			—	—			
Caheniasaccites indicus			—	—			
Weylandites magnus			—	—			
Decussatisporites circularis			—	—			
Distriamonocolpites ovalis			—	—			
Lophotriletes scotinus			—	—			
Densoisporites solidus			—	—			
Alisporites nuthallensis				—	—	—	
Klausipollenites schaubergeri				—	—	—	
Bascanisporites undosus				—	—		
Lueckisporites virkkiae				—	—		
Tiwariasporis flavatus				—			
Tiwariasporis gondwanensis				—			

Table II. Palaeogeographic distribution of palynomorph taxa from the Early Permian Strata in the Zagros Basin of the Islamic Republic of Iran

LIST OF PALYNOMORPH TAXA FOUND IN THIS STUDY	*Turkey*	*Europe & North America*	*South America*	*Africa*	*India & Pakistan*	*Australia*
Lophotriletes scotinus	-	-	+	+	+	+
Horriditriletes ramosus	-	-	+	+	+	+
Jayantisporites variabilis	+	-	+	+	-	+
Pseudoreticulatispora pseudoreticulata	-	-	+	+	+	+
Punctatisorites gretensis	+	-	+	+	+	+
Densoisporites solidus	-	-	-	+	-	+
Verrucosisporites andersonii	+	+	+	+	+	+
Leiotriletes virkkii	-	-	-	+	+	+
Laevigatosporites colliensis	-	-	+	+	+	+
Kraeuselisporites niger	-	-	-	+	+	+
Caheniasaccites ellipticus	-	-	+	+	+	+
Alisporites nuthallensis	-	-	-	+	+	+
Praecolpatites ovatus	-	-	+	+	+	+
Tuberisaccites sp.	-	-	+	-	+	-
Rugasaccites orbiculatus	-	-	-	+	-	+
Potonieisporites neglectus	-	-	+	+	+	+
Nuskoisporites triangularis	-	-	-	-	+	-
Falcisporites sp.	-	-	-	-	-	-
Plicatipollenites densus	-	-	+	+	+	+
Caheniasaccites indicus	-	-	-	+	+	+
Klausipollenites schaubergeri	-	+	-	+	+	+
Potonieisporites granulatus	-	-	+	+	+	-
Striomonosaccites cicatricosus	-	-	+	-	-	-
Striomonosaccites triangularis	-	-	-	-	+	-
Striomonosaccites brevis	-	-	-	+	-	+
Bascanisporites undosus	-	-	+	-	-	+
Trochosporites sp.	-	+	-	+	-	-
Cycadopites cymbatus	-	-	+	+	+	+
Crustaesporites globosus	-	+	-	+	-	+
Weylandites magnus	-	-	+	+	+	+
Decussatisporites circularis	-	-	-	+	-	+
Distriamonocolpites ovalis	-	-	-	+	+	-
Tiwariasporis flavatus	-	-	+	+	+	+
Marsupipollenites striatus	-	-	+	+	-	+
Boutakoffites elongatus	-	-	-	+	+	+
Tiwariasporis gondwanensis	-	-	-	+	+	+
Mabuitasaccites ovatus	-	-	-	+	-	-
Costapollenites ellipticus	-	+	-	+	-	-
Fusacolpites ovatus	-	-	-	+	+	-
Fusacolpites fusus		-	-	+	+	-
Hamiapollenites saccatus	+	+	-	-	+	+
Walikalesaccites ellipticus	-	-	-	+	-	-
Vittatina costabilis	-	+	-	+	-	-
Vittatina verrucosa	-	-	-	+	+	-
Vittatina subsaccata	-	+	-	+	+	-
Striatoabieites multistriatus	-	-	+	+	-	+
Corisaccites alutas	-	-	+	+	+	+
Plicatipollenites indicus	-	-	+	+	+	+
Complexisporites polymorphus	-	+	-	-	+	-
Protohaploxypinus bharadwajii	-	-	+	+	+	+
Lueckisporites virkkiae	-	-	+	+	-	+
Striatopodocarpites raniganjensis	-	-	-	+	+	+
Striatopodocarpites fusus	-	+	+	-	-	+
Protohaploxypinus limpidus	-	-	+	+	+	+
Hamiapollenites karrooensis	-	+	-	+	-	-
Striatopodocarpites cancellatus	-	+	+	+	+	+
Brazilea sp.	-	-	+	-	-	+
Gorgonisphaeridium sp.	-	-	+	-	+	+

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