Fatka O. & Servais T. (eds.)
Acritarcha in Praha
1996

Acta Universitatis Carolinae
Geologica 40 (1996): 385-411
Editum 17. 4. 1997

Acritarch Biostratigraphy of the Palaeozoic Rock Units in the Zagros Basin, Southern Iran

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Accepted October 16, 1996

Abstract: A total of 1 000 surface and subsurface samples from the Palaeozoic Barut, Zaigun, Lalun, Mila, Ilebek, Zard-Kuh, Seyahou, Sarchahan, and Faraghan Formations were examined for palynomorph entities, in order to determine the stratigraphical age of these rock units. The study also undertaken to asses the palaeobiogeographical relationships of the Zagros Basin to Southern and Northern hemispheres during the Palaeozoic time, representing by these formations. Seventy diagnostic acritarch taxa were recorded that permit recognition of eleven acritarch assemblage zones. The zone C_1 is present in the Middle – Upper Cambrian, zone C_2 suggests the Cambrian - Ordovician, zones O_1 to O_6 reveal the Lower – Upper Ordovician, zones S_1 to S_2 indicate Lower Silurian, zone D_1 the Late Devonian (Frasnian) and zone P_1 indicates the Lower Permian. Three major hiata were recognized within the studied interval. The first hiatus appears between the Barut and Sarchahan Formations and extends from Lower Cambrian to Upper Ordovician. The second hiatus is present between the Sarchahan and Faraghan Formations and encompasses the Middle – Upper Silurian and part of Lower Devonian. The first and second hiata possibly correspond to the Caledonian Orogeny. The third hiatus occurs between the Zakeen Member and Chal-i-Sheh Member of the Faraghan Formation and extends the whole Carboniferous period and part of Late Devonian, possibly equating with Hercynian Orogeny. Comparison of the encountered acritarch taxa in the Zagros Basin with those reported from other parts of the world indicates that the Zagros Basin has been part of the Gondwanan supercontinent during the Palaeozoic era.

INTRODUCTION

Published records of palynological studies in Iran, in comparison to those in Europe, the United States of America, Canada, and Russia are restricted to a few papers on Upper Palaeozoic strata in the Alborz Mountain Ranges (Kimayai 1972, 1979; Ghavidel-syooki 1994a,b; 1995a,b). This study is therefore directed toward developing the palynological information from the Palaeozoic rock units of Zagros Basin to aid in establishing the age relationships and correlation of some Palaeozoic horizons which were previously poorly understood, misinterpreted or unknown, resolution of some aspects of the palaeogeography and depositional environments. The palaeogeography of the Zagros Basin is important in relation to central and northern parts of Iran as well as to other parts of the world. Since the establishment of various schemes of palynostratigraphical zonation in different parts of the world has already demonstrated the unique contributions that can be made by organic walled microfossils, not only in providing a key to stratigraphic correlation but also in the reconstructions of ancient landmasses. These reconstructions play an important role in certain important hydrocarbon provinces which were located at the margins of ancient supercontinents. The importance of these is nowhere better demonstrated than in the Zagros Basin which is located at the complex interface between many of plate units that made up Gondwana land to the south and more massive Euroamerican plate to the north. Both of these plate complexes were sufficiently and widely separated through much of the Palaeozoic time to allow the evolution of separate floral populations. Furthermore, hydrocarbon discoveries in the Palaeozoic strata of adjacent countries (Saudi Arabia, Oman, Abu-Dhabi, and Qatar) were resulted in establishing the project of palynostratigraphical zonation for the Palaeozoic rock units of Zagros Basin in order to obtain more information for future exploration requirements since it is difficult to differentiate one Palaeozoic rock unit from others in drilled deep-test wells based on trilobite, brachiopod, and graptolite fauna which are abundant in the Palaeozoic sediments. These Palaeozoic faunas are crushed and fragmented during drilling and their identification is not possible at the level of genera and species.

PREVIOUS STUDIES

The study region, called the Zagros Basin is located of southern parts of Iran. The Zagros Basin has been subdivided into the Lurestan, Khuzestan, Coastal Fars, and Interior Fars areas by Oil Service Company of Iran. The average thickness of Palaeozoic sediments is 5 000 meters in the Zagros Basin.

The Palaeozoic strata have been recognized both at surface exposures and deep-test explorations wells in the subdivisions of Zagros Basin. The surface exposures of the Palaeozoic time are well developed at the High Mountain Ranges of Zagros Basin, including Kuh-e-Dihar, Kuh-e-Gereh, Kuh-e-Lagin, Kuh-e-Sabzu, Zard-Kuh, Kuh-e-Surmeh, Chal-i-Sheh, Ushtoran-Kuh, Kuh-e-Gakhum, and Kuh-e-Faraghan (Fig. 1). Likewise, the Palaeozoic strata of Zagros Basin have been penetrated in some drilled deep-test wells, consisting of Finu-1, Namak-1, Dalan (1-2), Samand-1, Kuh-e-Siah-1, Kabir-kuh-1, Huleyan-1, Darang-1, Naura-1, Zirreh-1, and Well of G-3 (Fig. 1). The Palaeozoic sediments of the Zagros Basin have been divided in ascending order into the Barut, Zaigun, Lalun, Mila, Ilebek, Zard-Kuh, Seyahou, Sarchahan, Faraghan, and

Figure 1 Distribution of the Palaeozoic rock units in the Zagros Basin and the location of the studied areas to the Main Zagros Thrust (from Szabo and Kheradpir, 1978)

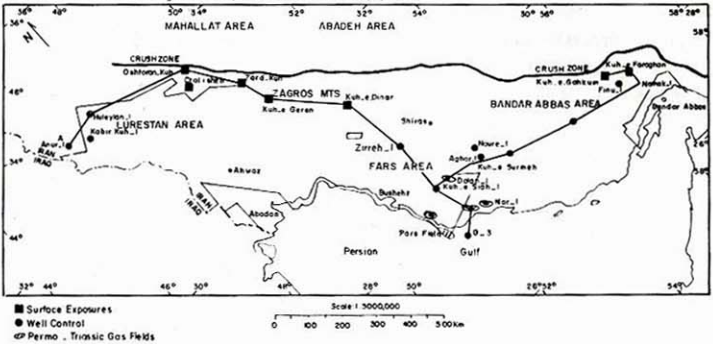

Fig. 1. Distribution of the Palaeozoic rock units in the Zagros Basin and the location of the studied areas to the Main Zagros Thrust (from Szabo and Kheradpir 1978).

Dalan Formations by Setudehnia (1975), Szabo and Kheradpir (1978), and Ghavidel-syooki and Khoshravi (1994). The names and descriptions of the above-mentioned Palaeozoic rock units have been submitted and accepted for the Zagros Basin by National Iranian Stratigraphic Committee (1975, 1978, 1994).

From the above-mentioned Palaeozoic rock units, the Barut, Zaigun, and Lalun Formations lack fauna, but based on stratigraphical position, they have been assigned to Lower Cambrian (Setudehnia 1975).

The Mila, Ibek, and Zard-Kuh Formations contain brachiopod, trilobite, and graptolite fauna. Thus they have been assigned to the Middle Cambrian – Lower Ordovician (Setudehnia 1975). The Seyahou and Sarchahan Formations also contain brachiopod, trilobite, and graptolite fauna and they have been assigned to Upper Ordovician and Lower Silurian respectively (Ghavidel-syooki and Khosravi 1994). The Faraghan Formation consists mainly of sandstones with intercalations of shale and limestone. This formation lacks fauna but it contains abundant acritarchs and spores. Therefore, based on palynological data, the Faraghan Formation has been assigned to Devonian and Lower Permian (Ghavidel-syooki 1988). The youngest Palaeozoic rock unit of Zagros Basin is the Dalan Formation which contains abundant microfauna and it has been assigned to the Upper Permian (Szabo and Kheradpir 1978).

LABORATORY TECHNIQUES

A total of 1 000 surface and cutting samples from the Barut, Zaigun, Lalun, Mila, Ilebek, Zard-Kuh, Seyahou, Sarchahan, and Faraghan Formations were selected for palynological study. The code and number of each sample follow the policy of National

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Iranian Oil Company. Thirty grams of sediments were randomly selected from each sample and processed in the palynological laboratory of the Exploration Department of the National Iranian Oil Company. Disintegration of the rock samples was carried out using standardized techniques.

All slide used in this study are in file in the palaeontological section of the National Iranian Oil Company.

ACRITARCH BIOSTRATIGRAPHY OF THE PALAEOZOIC STRATA IN THE ZAGROS BASIN

The objectives of this study are to summarize the known stratigraphic range of acritarch assemblages and species that occur in the Barut, Zaigun, Lalun, Ilebek, Zard-Kuh, Seyahou, Sarchahan, and Faraghan Formations and to compare these data with the zonal assemblages that have been recorded by palynologists from other parts of the world. This study revealed that the Barut, Zaigun, and Lalun Formations are barren in palynomorph entities, but the rest of Palaeozoic rock units of the Zagros Basin contain rich and well preserved acritarchs. In this study, total of 70 key acritarch species have been identified. Their zonal distribution is plotted on Fig. 2 and selected acritarch taxa are shown on plates 1-7. Twelve palynomorph assemblages have been recognized through the Palaeozoic rock units of Zagros Basin. One out of twelve is spore and pollen assemblage and the rest of them belong to the acritarchs. In this paper, the zonal acritarch assemblages are discussed below in ascending stratigraphical order:

Acritarch assemblage zone C_1 (*Ooidium – Timofeevia*)

This zone appears in the Mila Formation and extends through the whole stratigraphic sections of the Zagros Basin including surface exposures of Kuh-e-Dinar, Kuh-e-Gereh, Chl-i-sheh areas and deep-test wells of Darang-1 and Kabir-kuh-1. This zone is characterized by high frequencies of acritarch species such as:

Ooidium rossicum, *Timofeevia lancarae*, *Timofeevia phosphoritica*, *Timofeevia pentagonalis*, *Cristallinium cambriense*, *Cristallinium ovillense*, and algal clusters.

This assemblage zone is considered to belong to the Middle and Upper Cambrian since the above-mentioned acritarch species have been recorded from strata of this age of England (Downie 1981), Belgium (Vanguestaine 1978), Norway (Welsch 1986), Jordan (Keegan *et al.* 1990), and Turkey (Erkmen and Bozdogan 1981).

Acritarch assemblage zone C_2 (*Timofeevia – Vulcanisphaera*)

This zone occurs in the uppermost portion of the Mila Formation and basal part of the Ilebek Formation. This assemblage zone is marked by additional acritarch taxa to supplement those reported in the zone C_1, e.g.:

Vulcanisphaera africana, Vulcanisphaera cirrita, Cristallinium dentatum, Timofeevia lancarae, Timofeevia pentagonalis, Timofeevia phosphoritica, algal clusters, and a few chitinozoan taxa.

The reduction of algal clusters, *Timofeevia lancarae, Timofeevia phosphoritica, Timofeevia pentagonalis* and presence of chitinozoan species differentiates this assemblage zone (C_2) from underlying (C_1) and overlying (O_1) zones. This acritarch assemblage zone is suggested to belong to the Cambrian-Ordovician (Tremadocian) time since the acritarch species of this zone have been recorded from strata of this age of England (Downie 1981), Belgium (Vanguestaine 1978), Norway (Welsch 1986), Spain (Cramer and Díez 1972), Sweden (Bagnoli *et al.* 1988), Czech Republic (Vavrdová 1972), and Jordan (Keegan *et al.* 1990). Therefore, the boundary of Mila and Ilebek Formations is transitional in the studied sections of the Zagros Basin.

Acritarch assemblage zone O_1 (*Vulcanisphaera – Cymatiogalea*)

The zone O_1 is designated for the acritarch assemblage of the Ilebek Formation in the Zagros Basin. This acritarch assemblage zone is characterized by index acritarch species including:

Saharidia downiei, Saharidia fragile, Vulcanisphaera africana, Vulcanisphaera nebulosa, Cymatiogalea cuvillieri, Cymatiogalea membranispina, Stelliferidium cortinulum, Acanthodiacrodium simplex, Acanthodiacrodium spinum, Acanthodiacrodium unigerminum, Acanthodiacrodium echinatum, Acanthodiacrodium angustum, Acanthodiacrodium tumidum, Acanthodiacrodium bicoronatum, and *Acanthodiacrodium torum*.

Based on the above-mentioned acritarch taxa, this zone is considered to belong to the lower part of the Ordovician (Tremadocian). The acritarch species of this zone have been recorded from the Tremadocian sediments of Algeria (Deunff 1961; Combaz 1967; Jardiné *et al.* 1974; Deunff *et al.* 1974), China (Li 1983; Martin and Yin 1988), Europe (Vavrdová 1974), Norway (Welsch 1986), Saudi Arabia (Jachowicz 1995), Northern Iran (Ghavidel-syooki 1995a), England (Rasul 1974; Downie 1984), and France (Rauscher 1974). Based on this comparison, the Ilebek Formation is considered to be Lower Ordovician (Tremadocian) age.

Therefore, the age assignment of this formation to the Upper Cambrian is not correct.

Acritarch assemblage zone O_2 (*Arbusculidium – Acanthodaicrodium*)

This zone appears in the lower part of the Zard-Kuh Formation and extends through surface exposures of Zard-Kuh area and deep-test wells of Darang-1 and Kabir-Kuh-1. This acritarch assemblage zone is marked by presence of:

Arbusculidium filamentosum, Arbusculidium mamillosum, Arbusculidium bicuspidatum, Arbusculidium iranica, Acanthodiacrodium tasselii, Barakella felix, Acantho-

diacrodium complanata, *Acanthodiacrodium vavrdovae*, and also many acritarch species of the zone O_1.

The above-mentioned acritarch species have been recorded from the Arenigian sediments of Europe (Vavrdová 1974), Algeria (Jardiné *et al.* 1974), Morocco (Cramer and Díez 1977), Sweden (Ribecai and Tongiorgi 1995), England (Downie 1984), Saudi Arabia (Jachowicz 1995), and Northern and Southern Iran (Ghavidel-syooki 1990, 1993, 1995a).

Based upon this comparison, the Arenigian age is suggested for the lower part of the Zard-Kuh Formation.

Acritarch assemblage zone O_3 (*Striatotheca principalis*)

This acritarch assemblage zone appears in the middle part of the Zard-Kuh Formation and continues from the Zard-Kuh area into the deep-test wells of Darang-1 and Kabir-Kuh-1. This zone is marked by reduction in frequencies of acritarch species of the zone O_2 and predominant occurrence of following taxa:

Striatotheca principalis, *Striatotheca triangulata*, *Striatotheca transformata*, *Pirea dubia*, *Marrocanium simplex*, *Solisphaeridium solidispinosum*, and *Estiastra* sp.

This acritarch assemblage zone is considered to belong to Lower Ordovician (higher levels of Arenigian) since similar assemblages have been recorded from the Arenigian sediments of Morocco (Cramer and Díez 1977), Algeria (Jardiné *et al.* 1974), Argentina (Ottone *et al.* 1992), Europe (Vavrdová 1974), and Iran (Ghavidel-syooki 1990).

Based on comparison of the acritarch species of this zone, the Arenigian age is suggested from the middle part of the Zard-Kuh Formation.

Acritarch assemblage zone O_4 (*Coryphidium bohemicum*)

This acritarch assemblage zone encompasses the upper portion of the Zard-Kuh Formation. The zone O_4 is characterized by predominant occurrence of:

Coryphidium bohemicum, *Coryphidium elegans*, *Coryphidium persica*, *Acanthodiacrodium costatum*, *Dactylofusa crossii*, *Dactylofusa tagardii*, *Veryhachium lairdii*, *Veryhachium trispinosum*, *Dicrodiacrodium normale*, and a few species of the zone O_3, consisting of *Marrocanium simplex* and *Pirea dubia*.

This acritarch assemblage is considered to belong to the late Arenigian and Middle Ordovician, since the above-mentioned acritarch species have been recorded from equivalent strata of England (Downie 1984), Morocco (Cramer *et al.* 1974), Algeria (Jardiné *et al.* 1974), France (Rauscher 1974), Europe (Vavrdová 1974), and Saudi Arabia (Jachowicz 1995).

(Villosacapsula-Actinotodissus crassus)

Acritarch assemblage zone O_5 (~~Coryphidium bohemicum~~)

This acritarch assemblage zone appears in the basal part of the Seyahou Formation and extends from the Kuh-e-Faraghan area to the Zard-Kuh region and deep-test wells of Zirreh-1, Kuh-e-Siah-1, and Darang-1. This zone is marked by disappearance of Lower and Middle Ordovician index species and appearance of the Upper Ordovician acritarch taxa like:

Actinotodissus crassus, Actinotodissus longilateosus, Veryhachium reductum, Veryhachium subglobosum, Poikilofusa spinata, Villosacapsula setosapellicula, Gorgonisphaeridium antiquum, Leiosphaeridia tenuissima, Navifusa ancepsipunctata, Multiplicisphaeridium bifurcatum, Polygonium gracile, Baltisphaeridium longispinosum, Ordovicidium elegantulum, Diexallophasis granulatispinosum, Orthosphaeridium ternatum, Baltisphaeridium perclarum, and *Baltisphaeridium bystrenos.*

The most acritarchs species in this zone continue into the succeeding zone O_5. This assemblage zone is considered to belong to the early Late Ordovician (Caradocian) since the above-mentioned acritarch species have been recorded from the Caradocian sediments of England (Downie 1984; Turner 1984), the United States of America (Loeblich 1970; Loeblich and Tappan 1978), Libya (Molyneux and Paris 1985), Jordan (Keegan *et al.* 1990), Saudi Arabia (Jachowicz 1995; McClure 1988), Sweden (Gorka 1987), Morocco (Elaouad-Debbaj 1987), Europe (Vavrdová 1974), and Algeria (Jardiné *et al.* 1974).

Acritarch assemblage zone O_6 (*Orthosphaerdium inflatum/insculptum*)

This acritarch assemblage zone appears in the upper portion of the Seyahou Formation. This zone is distinguished from underlying (O_5) and overlying (S_1) zones by appearance and disapperance of:

Orthosphaeridoium inflatum, Orthosphaeridium insculptum, and *Armoricochitina nigerica.*

Likewise, some cryptospores species occur in this zone including:

Emphanisporites protohanus, Ambitisporites imperfectus, Tetrahedraletes medinensis, and *Dyadaspora murusdensa.*

This acritarch assemblage is considered to belong to the Ashgillian age since the above-mentioned acritarch and chitinozoan species have been recorded from the Ashgillian sediments of the United States of America (Loeblich and Tappan 1978), Canada (Jacobson and Achab 1985), Libya (Molyneux and Paris 1985), Morocco (Elaouad-Debbaj 1987), Algeria (Jardiné *et al.* 1974), Europe (Vavrdová 1974), Jordan (Keegan *et al.* 1990), Saudi Arabia (Jachowicz 1995), and Iran (Ghavidel-syooki 1990).

In addition to the type section area of Seyahou Formation (Kuh-e-Faraghan) the zone appears in the deep test wells of Zirreh-1, Darang-1, Kabir-kuh-1, Kuh-e-Siah-1, and surface exposure of Zard-Kuh Mountain Range.

Acritarch assemblage zone S_1 (*Dictyotidium faviformis*)

This acritarch assemblage S_1 is designated for the lower part of the Sarchahan Formation by presence of:

Dictyotidium faviformis, *Dictyotidium dictyotum*, *Leiosphaeridia laevigata*, *Evittia denticulata*, *Neoveryhachium carminae*, and *Neoveryhachium triangulata* n. sp. Likewise, the land plant miospores appear in this zone including *Ambitispirotes avitus* and *Ambitisporites dilutus*.

This assemblage zone is considered to belong to the Llandovery since the above-mentioned acritarchs species have been recorded from the lower Silurian strata of Saudi Arabia (McClure 1988), Jordan (Keegan *et al.* 1990), Libya (Hill *et al.* 1985), Sweden (Le Hérissé 1989), Norway (Smelror 1987), and Iran (Ghavidel-syooki 1995b).

Acritarch assemblage zone S_2 (*Dactylofusa estillis*)

This acritarch assemblage zone appears in the middle and upper parts of the Sarchahan Formation and continues through a thickness of 60 m in the Kuh-e-Gahkum and 40 m in the Kuh-e-Faraghan Formations. This assemblage zone is characterized by additional acritarch taxa to supplement those reported in the zone S_1, e.g. by:

Dactylofusa estilis, *Dactylofusa maranhensis*, *Dateriocradus monterossae*, *Tunisphaeridium tentaculiferum*, *Dilatisphaera laevigata*, *Onondagaella asymmetrica*, *Geron guirellerus*, *Helosphaeridium clavispinulosum*, *Dictyotidium perlucidum*, *Visbysphaera microspinosa*, *Visbysphaera oligofurcata*, and *Visbysphaera pirifera*.

This acritarch assemblage zone is considered to belong to the Llandovery since the acritarch taxa species have been recorded from the lower Silurian sediments of England (Downie 1984), Saudi Arabia (McClure 1988; Le Hérissé and Gourvennec 1995; Le Hérissé *et al.* 1995), Jordan (Keegan *et al.* 1990), the United States of America (Cramer and Díez 1972), Iran (Ghavidel-syooki and Khosravi 1994), and Libya (Hill *et al.* 1985).

Therefore, based on the acritarch assemblage zones S_1 and S_2, the middle and upper Silurian have been a non-depositional time in the Zagros Basin.

Acritarch assemblage zone D_1 (*Chomotriletes vedugensis*)

This acritarch assemblage zone occurs in the lower portion (Zakeen Member) of the Faraghan Formation. The zone D_1 is marked by appearance and disappearance of the Upper Devonian acritarch species consisting of:

Chomotriletes vedugensis, *Deltotosoma intonsum*, *Papulogobata annulata*, *Saharidia lusca*, *Stellinium micropolygonale*, *Pterospermella radiata*, *Unellum piriforme*, *Multi-*

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plicisphaeridium amitum, *Maranhites perplexus*, *Gorgonisphaeridium discissum*, *Horologinella quadrispina*, and *Ammonidium loriferum*.

This acritarch assemblage zone is considered to belong to Upper Devonian since the above-mentioned species have been recorded from equivalent strata of Western Australia (Playford and Dring 1981), Algeria (Jardiné *et al.* 1974; Moreau-Benoit *et al.* 1993), the United States of America (Wicander and Loeblich 1977; Wicander and Playford 1985), and Iran (Kimyai 1972, 1979; Ghavidel-syooki 1988, 1994a).

Pollen/Spore assemblage zone P_1 (*Hamiapollenites – Vittatina*)

The zone $\mathbf{P_1}$ is designated for the upper portion of the Faraghan Formation (Chali-Sheh Member). The zone $\mathbf{P_1}$ lacks acritarchs and it is characterized by presence of pollen and spore species, including:

Hamiapollenites perisporites, *Hamiapollenites saccatus*, *Corisaccites alutas*, *Vittatina costabillis*, *Fusacolpites fusus*, *Boutakofites elegans*, *Hoegiasaccites triangularis*, *Tiwariaspirotes flavatus*, *Punctatisporites gretensis*, and *Laevigatosporites vulgaris*.

This pollen/spore assemblage is considered to belong to lower Permian since the above-mentioned taxa have been recorded from the lower Permian sediments (Ghavidel-syooki 1988). Therefore, there is a hiatus within the Faraghan Formation that encompasses the whole Carboniferous period and part of the Upper Devonian.

CONCLUSIONS

The Palaeozoic rock units of Zagros Basin consist of Barut, Zaigun, Lalun, Mila, Ilebek, Zard-Kuh, Seyahou, Sarchahan, Faraghan, and Dalan Formations (Fig. 2). The above-mentioned rock units were studied for their palynological entities, in order to draw the real extension and age relationship of each rock unit through the Zagros Basin. From the Palaeozoic rock units of Zagros Basin, Barut, Zaigun, and Lalun Formations are barren, but the rest of them contain well-preserved and abundant palynomorph taxa. As a result of this study, eleven acritarch assemblage zones and one pollen/spore zone were established. All are useful for deep-test exploration wells in the Zagros Basin.

The local stratigraphic distribution of all palynomorph assemblage zones is shown in Fig. 2, the established palynomorph zones have been arranged in twelve ascending assemblage zones (Fig. 2). The zone C_1 is present in the Mila Formation, suggesting Middle and Upper Cambrian age for this interval. The zone C_2 occurs in the upper portion of Mila Formation and in the basal part of Ilebek Formation, indicating Cambrian-Ordovician age for this rock unit. The zone O_1 appears in the Ilebek Formation, suggesting Lower Ordovician (Tremadocian) age for this interval. The zones O_2 to O_4 are present in the Zard-Kuh Formation, indicating the Lower Ordovician (Arenigian) and Middle Ordovician ages. The zones O_5 to O_6 appear in the Seyahou Formation

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suggesting Upper Ordovician age for this rock unit. The zones $\mathbf{S_1}$ to $\mathbf{S_2}$ occur in the Sarchahan Formation, representing the lower Silurian for this interval. The zone $\mathbf{D_1}$ is present in the Zakeen Member of the Faraghan Formation, indicating Late Devonian (Frasnian) for this member. The zone $\mathbf{P_1}$ occurs in the Chal-i-Sheh Member of the Faraghan Formation, suggesting lower Permian for this interval.

Comparison of the Palaeozoic acritarch assemblages of Zagros Basin with those from other parts of the world indicates a broad similarity with those from the "Mediterranean acritarch Province" elsewhere. The presence of Mediterranean acritarch taxa in the Lower Palaeozoic sediments of the Zagros Basin suggests that the Zagros Basin was a part of the Gondwanan Palaeocontinent, possibly along the southern shore of the Palaeotethys Ocean. Likewise, comparison of the known palynomorph taxa of the zone $\mathbf{D_1}$ and Zone $\mathbf{P_1}$ reveal close similarity with those of Western Australia, North Africa, Arabian Peninsula, and the Alborz Mountain Range of Iran.

This similarity suggests that the Iranian Plate, Western Australia, African Plate, and Saudi Arabia have occupied the same palaeolatitude during the Devonian and Permian times.

On the other hand, based on the palynological evidence, three major hiata were recognized within the Palaeozoic sediments of the Zagros Mountains.

The first hiatus is present between the Barut and the Sarchahan Formations and extends from the Lower Cambrian through the Upper Ordovician. The second hiatus occurs between the Sarchahan and Faraghan Formation and encompasses the middle and upper Silurian. These two hiata possibly correspond to the Caledonian Orogeny. The third hiatus appears between the Zakeen Member and the Cal-i-Sheh Member of the Faraghan Formation. This hiatus encompasses the whole Carboniferous and a part of the Upper Devonian sediments, possibly equating with the Hercynian Orogeny.

REFERENCES

Bagnoli G., Stouge S., Tongiorgi M., 1988: Acritarchs and conodonts from the Cambro-Ordovician Furuhall (Köpingsklint) section (Öland, Sweden). *Rivista It. Paleont., Strat.* 94(2): 163-248.

Combaz A., 1967: Un microbios du Trémadocien dans un sondage d'Hassi-Messaoud. *Actes de la Societé Linneénne de Bordeaux* 104(29): 1-26.

Cramer F. H., Allam B., Kanes W. H., Díez M. d. C. R., 1974: Upper Arenigian to lower Llanvirnian acritarchs from subsurface of the Tadla Basin in Morocco. *Palaeontographica* Abt. B 146(3-6): 57-64.

Cramer F. H., Díez M. d. C. R., 1972: North American Silurian palynofacies and their spatial arrangement, acritarch. *Palaeontographica* Abt. B 138(5-6): 107-180.

Cramer F. H., Díez M. d. C. R., 1977: Late Arenigian (Ordovician) acritarchs from Cis-Saharan Morocco. *Micropaleontology* 23(3): 339-360.

Deunff J., 1961: Un microplancton à hystrichosphères dans le Tremadoc du Sahara. *Revue de Micropaléontologie* 4(1): 37-52.

Deunff J., Gorka H., Rauscher R., 1974: Observations nouvelles et precisions sur les acritarches à large ouverture polaire du Paléozoïque inférieur. *Geobios* 7(1): 5-18.

Downie C., 1981: Lower Cambrian acritarchs from Scotland, Norway, Greenland and Canada. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 72: 257-285.

Downie C., 1984: Acritarchs in British stratigraphy. *Geological Society of London*, Special Report 17: 1-26.

Erkmen U., Bozdogan N., 1981: Cambrian acritarchs from the Sosink Formation in southeast Turkey. *Revista Española de Micropaleontologia* 13(1): 47-60.

Elaouad-Debbaj Z., 1987: Acritarchs from the Upper Ordovician (Caradoc – Ashgill) of Anti-Atlas, Morocco. *Revue de Micropaléontologie* 30(4): 232-248.

Ghavidel-syooki M., 1988: Palynostratigraphy and paleoecology of Faraghan Formation of southeastern Iran. Ph.D. Dissertation, Michigan State University, 279 pp.

Ghavidel-syooki M., 1990: The encoutered acritarchs and chitinozoans from Mila, Ilebek, and Zard-Kuh Formations in Tang-i-Ilebek of Zard-Kuh region and their correlation with Palaeozoic sequence of Chal-i-sheh area in Zagros Basin, Iran. Proc. Symp. Diapirism with special reference to Iran. Geol. Surv. Iran, 1, pp. 141-218.

Ghavidel-syooki M., 1993: Palynological study of Palaeozoic sediments of the Chal-i-sheh area, southwestern Iran. *J. Sci. Islam Republic Iran* 4(1):32-46.

Ghavidel-syooki M., 1994a: Upper Devonian acritarchs and miospores from the Geirud Formation in Central Alborz Range, Northern Iran. *J. Sci. Islam Republic Iran* 5(3): 103-122.

Ghavidel-syooki M., 1994b: Palynological study and age determination of the Ordovician sediments and Faraghan Formation in Kuh-e-Surmeh, Southern Iran. *Geol. Surv. Iran, Geosciences, Scientific Quarterly Journal* 3(12): 28-35.

Ghavidel-syooki M., 1995a: Palynostratigraphy and palaeogeography of a Palaeozoic sequence in the Hassanakdar area Central Alborz Range, Northern Iran. *Review of Palaeobotany and Palynology* 86(1/2): 91-109.

Ghavidel-syooki M., 1995b: Palynostratigraphy of Sarchahan (lower Silurian) and Faraghan Formations (Devonian and Lower Permian) in Kuh-e-Gahkum, Zagros Basin. *Geol. Surv. Iran, Geosciences, Scientific Quarterly Journal* 4(14/16): 74-79.

Ghavidel-syooki M., Khosravi M. E., 1994: Investigation of Lower Palaeozoic sediments at Tang-e-Zakeen of Kuh-e-Faraghan, and introduction of Seyahou and Sarchahan Formations in the Zagros Basin. *Geol. Surv. Iran, Geosciences, Scientific Quarterly Journal* 4(14): 2-21.

Gorka H., 1987: Acritarches et prasinophyceae de l'Ordovicien Moyen (Viruen) du sondage de Smedsby Gard No. 1 (Gotland, Suède). *Review of Palaeobotany and Palynology* 89(1/2): 19-25.

Hill P. J., Paris F., Richardson J.B., 1985: Silurian palynomorphs, in: Thusu B. G., Owens B. (eds.), The palynostratigraphy of northeast Libya. *J. Micropalaeontology* 4(1): 27-43.

Jachowicz M., 1995: Ordovician acritarch assemblages from Central and Northwestern Saudi Arabia. *Review of Palaeobotany and Palynology* 89(1/2): 19-25.

Jacobson S. R., Achab A., 1985: Acritarch biostratigraphy of the Dicellograptus complanatus graptolite zone from the Vaureal Formation (Ashgillian) Anticosti Island, Quebec, Canada. *Palynology* 9: 165-198.

Jardiné S., Combaz A., Magloire L., Peniquel G., Vachey G., 1974: Distribution stratigraphique des acritarches dans le Paléozoïque du Sahara Algérien. *Review of Palaeobotany and Palynology* 18: 99-129.

Keegan J. B., Rasul S. M., Shaheen Y., 1990: Palynostratigraphy of the Lower Palaeozoic, Cambrian to Silurian sediments of the Hashemite Kingdom of Jordan. *Review of Palaeobotany and Palynology* 66:167-180.

Kimyai A., 1972: Devonian plant microfossils from the Central Alborz, Iran. *Pollen et spores* 14(2): 187-201.

Kimyai A., 1979: Devonian spores from the Hassanakdar area, Iran. *Pollen et Spores* 21(4): 481-498.

Le Hérissé A., 1989: Acritarches et kystes d'algues Prasinophycées du Silurien de Gotland, Suède. *Palaeontographia Italica* 76: 57-302.

Le Hérissé A., Al-Tayyar H., Van der Eem H., 1995: Stratigraphic and palaeogeographic significance of Silurian acritarchs from Saudi Arabia. *Review of Palaeobotany and Palynology* 89(1-2): 49-74.

Le Hérissé A., Gourvennec R., 1995: Biogeography of upper Llandovery and Wenlock acritarchs. *Review of Palaeobotany and Palynology* 86(1-2): 111-133.

Li J., 1983: Ordovician acritarchs from the Meitan Formation of Guizhou Province, South-west China. *Palaeontology* 30(3): 613-634.

Loeblich A. R., 1970: Morphology, Ultrastructure and Distribution of Paleozoic Acritarchs. Proc. North American Paleontologica Convention, 69, part G, pp. 705 -788.

Loeblich A. R., Tappan H., 1978: Some Middle and Late Ordovician microphytoplankton from central North America. *Journal of Paleontology* 52: 1233-1287.

McClure H. A., 1988: Chitinozoan and acritarch assemblages, stratigraphy and biogeography of the Early Paleozoic of Northwest Arabia. *Review of Palaeobotany and Palynology* 56: 41-60.

Martin F., Yin L., 1988: Early Ordovician acritarchs from southern Jilin Province, North-east China. *Palaeontology* 31(1): 109-127.

Molyneux S. G., Paris F., 1985: Late Ordovician palynomorphs, in: Thusu B. T., Owens B. (eds.), The palynostratigraphy of northeast Libya. *Journal of Micropalaeontology* 4(1): 11-26.

Moreau-Benoit A., Coquel R., Latreche S., 1993: Etude palynologique du Dévonien du bassin d'Illizi (Sahara Oriental Algerien) Approche biostratigraphie. *Geobios* 26(1): 3-31.

Ottone E. G., Toro B. A., Waisfeld B. G., 1992: Lower Ordovician palynomorphs from the Acoite Formation, North-western Argentina. *Palynology* 16: 93-116.

Playford G., Dring R. S., 1981: Late Devonian acritarchs from the Carnavon Basin, Western Australia. *Special Papers in Palaeontology* 27: 1-78.

Rasul S. M., 1974: The Lower Palaeozoic acritarchs *Priscogalea* and *Cymatiogalea*. *Palaeontology* 17(1): 41-63.

Rauscher R., 1974: Recherches micropaléontologiques et stratigraphiques dans l'Ordovicien et le Silurien de la France. *Université Louis Pasteur de Strasbourg, Sciences géologiques, Mémoire* 38: 1-224.

Ribecai C., Tongiorgi M., 1995: Arenigian acritarchs from Horns Udde (Öland, Sweden): a preliminary report. *Review of Palaeobotany and Palynology* 86(1/2): 1-11.

Smelror M., 1987: Early Silurian acritarchs and Prasinophycean algae from the Ringerike District, Oslo Region (Norway). *Review of Palaobotany and Palynology*. 52: 137-159.

Szabo F., Kheradpir A., 1978: Permian and Triassic stratigraphy, Zagros Basin, South-west Iran. *Journal of Petroleum Geology* 1(2): 57-82.

Setudehnia A., 1975: The Palaeozoic sequence at Kuh-e-Dinar and Zard-Kuh. *Iranian Petroleum Institute, Bulletin* 60: 16-33.

Turner R. E., 1984: Acritarchs from the type area of the Ordovician Caradoc Series, Shropshire, England. *Palaeontographica* Abt. B 190(4-6): 87-157.

Vanguestaine M., 1978: Critères palynostratigraphiques conduisant à la reconnaissance d'un pli couche Revinien dans le Sondage de Grand-Halleux. *Annales Soc. géol. Belgique* 100: 249-276.

Vavrdová M., 1972: Acritarchs from Klabava Shales (Arenig). *Věstník Ústředního ústavu geologického* 47(1): 79-86.

Vavrdová M., 1974: Geographical differentiation of Ordovician acritarch assemblages in Europe. *Review of Palaeobotany and Palynology* 18: 171-176.

Welsch M., 1986: The acritarchs of the upper Digermul Group, Middle Cambrian to Tremadoc, eastern Finnmark, northern Norway. *Palaeontographica* Abt. B 201: 1-109.

Wicander R., Loeblich A. R., 1977: Organic-walled microphytoplankton and its stratigraphic significance from the Upper Devonian Antrim Shale, Indiana, U.S.A. *Palaeontographica* Abt. B 160: 69-165.

Wicander R., Playford G., 1985: Acritarchs and spores from the Upper Devonian Lime Creek Formation, Iowa, U.S.A. *Micropaleontology* 31(2): 97-138.

VG

PLATE 1

All magnification × 1 200.

Fig. 1. *Acanthodiacrodium bicoronatum* Welsch 1986.

Fig. 2. *Arbusculidium mamillosum* Welsch 1986.

Fig. 3. *Acanthodiacrodium spinum* Rasul 1979.

Fig. 4. *Lophodiacrodium torum* Rasul 1979.

Fig. 5. *Acanthodiacrodium echinatum* (Timofeev 1959) Deflandre et Deflandre-Rigaud 1962.

Fig. 6. *Acanthodiacrodium unigerminum* (Timofeev 1959) Deflandre et Deflandre-Rigaud 1962.

Fig. 7. *Acanthodiacrodium tumidum* (Deunff) Eisenack *et al.* 1979.

Fig. 8. *Acanthodiacrodium simplex* Combaz 1967.

Fig. 9. *Acanthodiacrodium angustum* (Deflandre et Deflandre-Rigaud 1962) Combaz 1967.

Fig. 10. *Solisphaeridium solidispinosum* Cramer et Díez 1977.

Fig. 11. *Stelliferidium cortinulum* (Deunff) Deunff *et al.* 1974.

V4

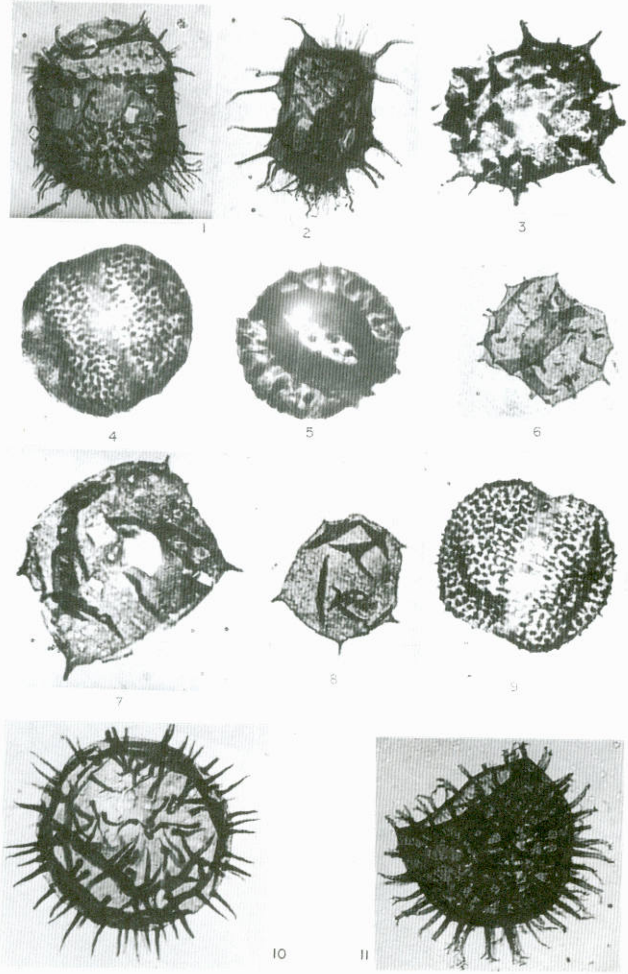
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PLATE 2

All magnification × 1200.

Figs 1, 4. *Vulcanisphaera africana* Deunff 1961.

Fig. 2. *Dactylofusa crossii* Ghavidel-syooki 1990.

Fig. 3. *Acanthodiacrodium complanatum* (Deunff) Cocchio 1982.

Fig. 5. *Pirea dubia* Vavrdová 1972.

Fig. 6. *Vulcanisphaera nebulosa* Deunff 1961.

Fig. 7. *Acanthodiacrodium vavrdovae* Cramer et Díez 1977.

Fig. 8. *Arbusculidium iranica* Ghavidel-syooki 1990.

Fig. 9. *Acanthodiacrodium tasselii* Martin 1969.

Fig. 10. *Barakella felix* Cramer et Díez 1977.

Fig. 11. *Cymatiogalea membranispina* Deunff 1961.

Fig. 12. *Cymatiogalea cuvillieri* (Deunff) Deunff *et al.* 1974.

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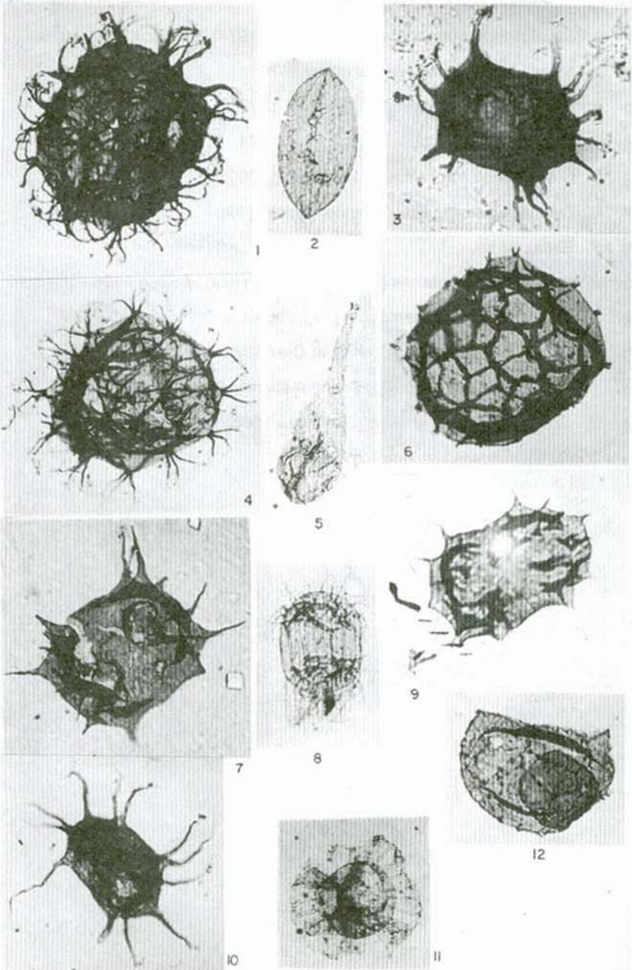

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PLATE 3

All magnification × 1200.

Fig. 1. *Striatotheca triangulata* (Cramer *et al.* 1974) Eisenack *et al.* 1976.

Fig. 2. *Striatotheca principalis* Burmann 1970.

Fig. 3. *Coryphidium bohemicum* Vavrdová 1972.

Fig. 4. *Marrocanium simplex* Cramer *et al.* 1974.

Fig. 5. *Striatotheca transformata* Burmann 1970.

Fig. 6. *Dactylofusa taggardii* Ghavidel-syooki 1990.

Fig. 7. *Estiastra* sp.

Fig. 8. *Cristallinium ovillense* (Cramer et Díez 1972) Welsch 1986.

Fig. 9. *Arbusculidum filamentosum* (Vavrdová 1965) Vavrdová 1972.

Fig. 10. *Timofeevia lancarae* (Cramer et Díez 1972) Vanguestaine 1978.

Fig. 11. *Timofeevia phosphoritica* (Vanguestaine 1974) Vanguestaine 1978.

Fig. 12. *Cristallinium cambriense* (Slavíková 1968) Vanguestaine 1978.

Fig. 13. *Ooidium rossicum* Timofeev 1957.

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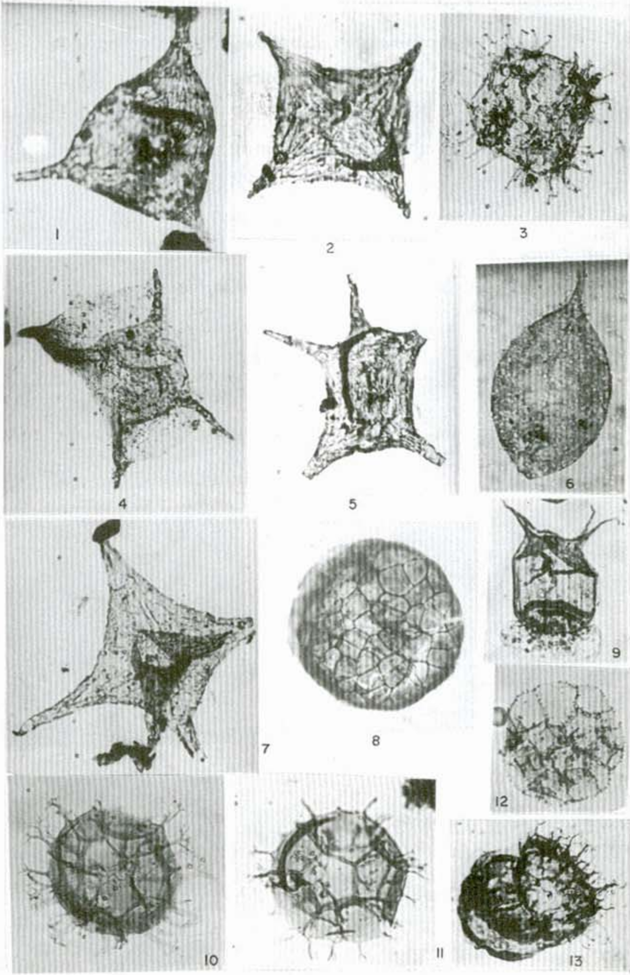
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PLATE 4

All magnification × 1200.

Fig. 1. *Diexallophasis granulatispinosum* (Downie 1963) Dorning 1981.

Fig. 2. *Baltisphaeridium longispinosum* Jardiné *et al.* 1974.

Fig. 3. *Polygonium gracile* Vavrdová 1966.

Fig. 4. *Veryhachium subglobosum* Jardiné *et al.* 1974.

Fig. 5. *Multiplicisphaeridium bifurcatum* Staplin *et al.* 1965.

Fig. 6. *Villosacapsula setosapellicula* Loeblich et Tappan 1976.

Fig. 7. *Ordovicidium elegantulum* Tappan et Loeblich 1971.

Fíg. 8. *Veryhachium reductum* (Deunff) Jekhowski 1961.

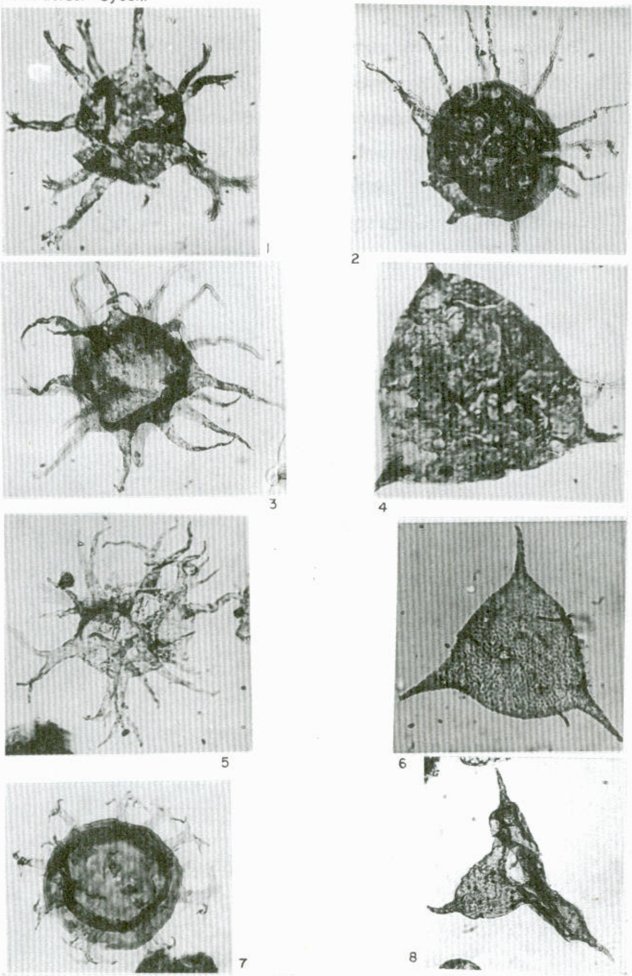
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PLATE 5

All magnification × 1200.

Fig. 1. *Baltisphaeridium perclarum* Loeblich et Tappan 1978.

Fig. 2. *Baltisphaeridium bystrenos* Loeblich et Tappan 1978.

Fig. 3. *Orthosphaeridium ternatum* (Burmann) Eisenack *et al.* 1976.

Fig. 4. *Orthosphaeridium inflatum* Loeblich 1969.

Fig. 5. *Orthosphaeridium inscupltum* Loeblich 1969.

Fig. 6. *Navifusa ancepsipuncta* Loeblich 1969.

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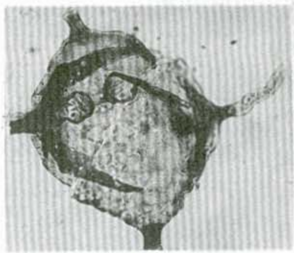

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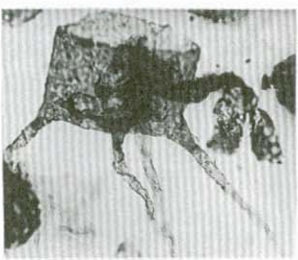

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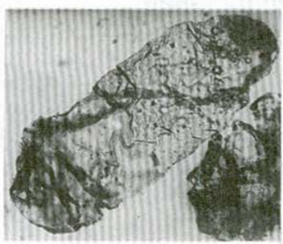

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PLATE 6

All magnification × 1200.

Fig. 1. *Actinotodissus longilateasus* Loeblich et Tappan 1978.

Fig. 2. *Neoveryhachium triangulata* n.sp. (MS)

Fig. 3. *Dateriocradus monterrosae* (Cramer) Dorning 1981.

Fig. 4. *Poikilofusa spinata* (Staplin *et al.* 1965) Combaz *et al.* 1967.

Fig. 5. *Actinotodissus crassus* Loeblich et Tappan 1978.

Fig. 6. *Dactylofusa estillis* Cramer et Díez 1972.

Fig. 7. *Dactylofusa maranhensis* Brito et Santos 1965.

Fig. 8. *Dictyotidium perlucidum* Le Hérissé 1989.

Fig. 9. *Visbysphaera microspinosa* (Eisenack) Hill 1974.

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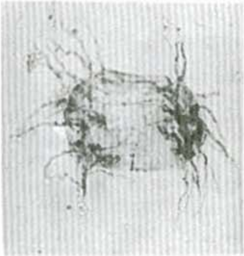
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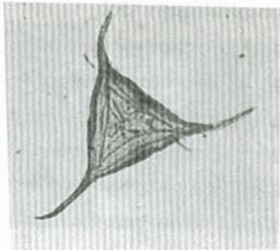
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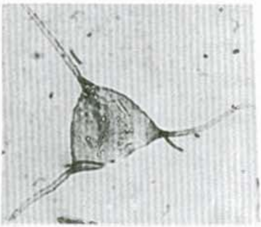
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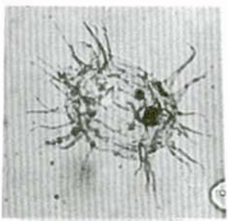
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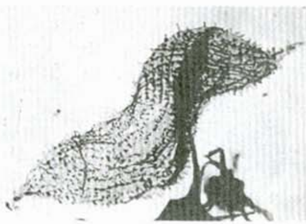
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PLATE 7

All magnification × 1200.

Fig. 1. *Horologinella quadrispina* Jardine *et al.* 1972.

Fig. 2. *Maranhites perplexus* Wicander et Playford 1985.

Fig. 3. *Deltotosoma intonsum* Playford 1981.

Fig. 4. *Papulogabata annulata* Playford 1981.

Fig. 5. *Multiplicisphaeridium amitum* Wicander et Loeblich 1977.

Fig. 6. Unellium piriforme Rauscher 1969.

Fig. 7. *Pterospermella radiata* Wicander 1974.

Fig. 8. *Ammonidium loriferum* (Deunff) Lister 1970.

Fig. 9. *Neoveryhachium carminae* (Cramer) Cramer 1970.

Fig. 10. *Chomotriletes vedugensis* Naumova 1953.

Figs 11, 12. *Stellinium micropolygonale* (Stockmans et Willière) Playford 1977.

Fig. 13. *Saharidia lusca* Playford 1981.

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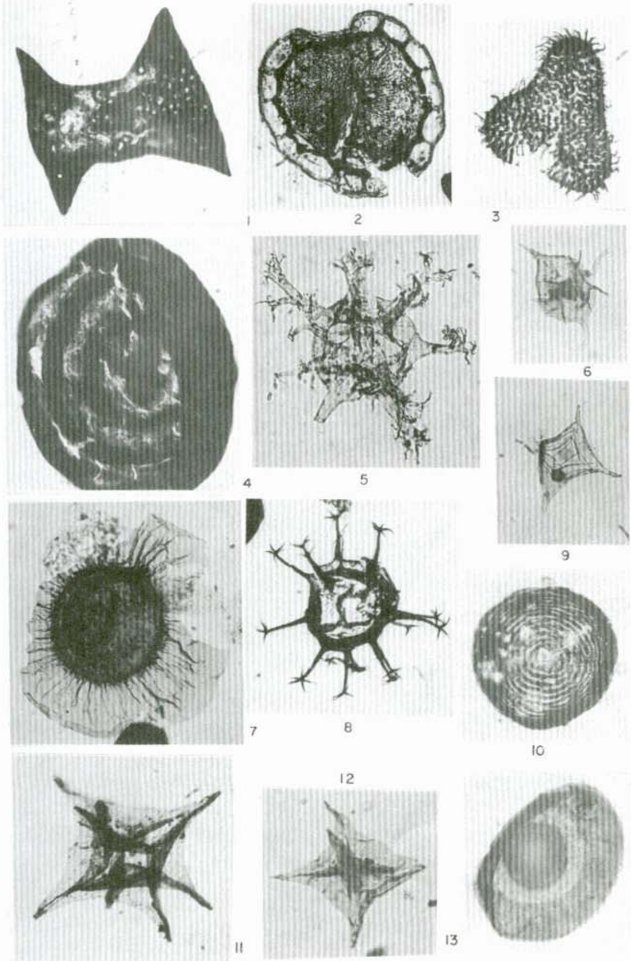
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Fig. 2. Palynological biofacies relationship of the Palaeozoic sedimentary rock units in the Zagros areas.