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Palynostratigraphy and palaeogeography of a Palaeozoic sequence in the Hassanakdar area, Central Alborz Range, northern Iran

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Abstract

A total of 129 samples from the Palaeozoic Lashkarak, Geirud and Dorud formations of the Hassanakdar area were examined palynologically in order to determine more precisely the stratigraphical age of these units. The study was also undertaken to assess the palaeogeographical relationships of the Alborz Ranges to Southern and Northern Hemispheres during the Palaeozoic interval represented by these formations. 90 palynomorph taxa were recorded including 58 acritarch, 24 spore and 8 pollen taxa, which permit the recognition of six ascending stratigraphic zones. Zones I–III represent the Lower Ordovician (Tremadoc–Arenig), Zones IV–V indicate the Upper Devonian (Frasnian) and Zone VI suggests a Lower Permian (Sakmarian) age. Two major "hiata" are recognised within the studied interval; the first "hiatus" appears between the Lashkarak Formation and Geirud Formation and extends from the Upper Ordovician through the Silurian and Lower–Middle Devonian, possibly equating with the Caledonian Orogeny. The second "hiatus" occurs between the Geirud Formation (Late Devonian) and Dorud Formation (Lower Permian) and spans the interval of Famennian, the entire Carboniferous and part of the Lower Permian. It possibly corresponds to the Hercynian Orogeny.

Diverse acritarch taxa in Lower Ordovician (Lashkarak Formation), Late Devonian (Geirud Formation) and Lower Permian (Dorud Formation) indicate a marine environment for each formation. Comparison of palynomorph taxa recorded in the Hassanakdar area with those reported from other parts of world indicates that the Alborz Ranges have been part of the Gondwanan Supercontinent during the Palaeozoic Era.

1. 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 (Kimyai, 1972, 1979) and Lower–Upper Palaeozoic strata (Ghavidel-Syooki, 1988, 1990).

This study is therefore directed toward developing the palynological information from the Palaeozoic sequence of Hassanakdar to aid in establishing the age relationships and correlation of the strata, resolution of some aspects of the palaeogeography, and depositional environments. The palaeogeography of the Lashkarak, Geirud and Dorud formations is important in relation to the central and southern parts of Iran as well as to the other parts of the world.

2. Previous studies

The study area, called the Hassanakdar area, is located approximately 60 km from the northern Iranian city of Karadj. The paved road from Karadj to Chalus is the main connection to the Hassanakdar area (Fig. 1). The Palaeozoic

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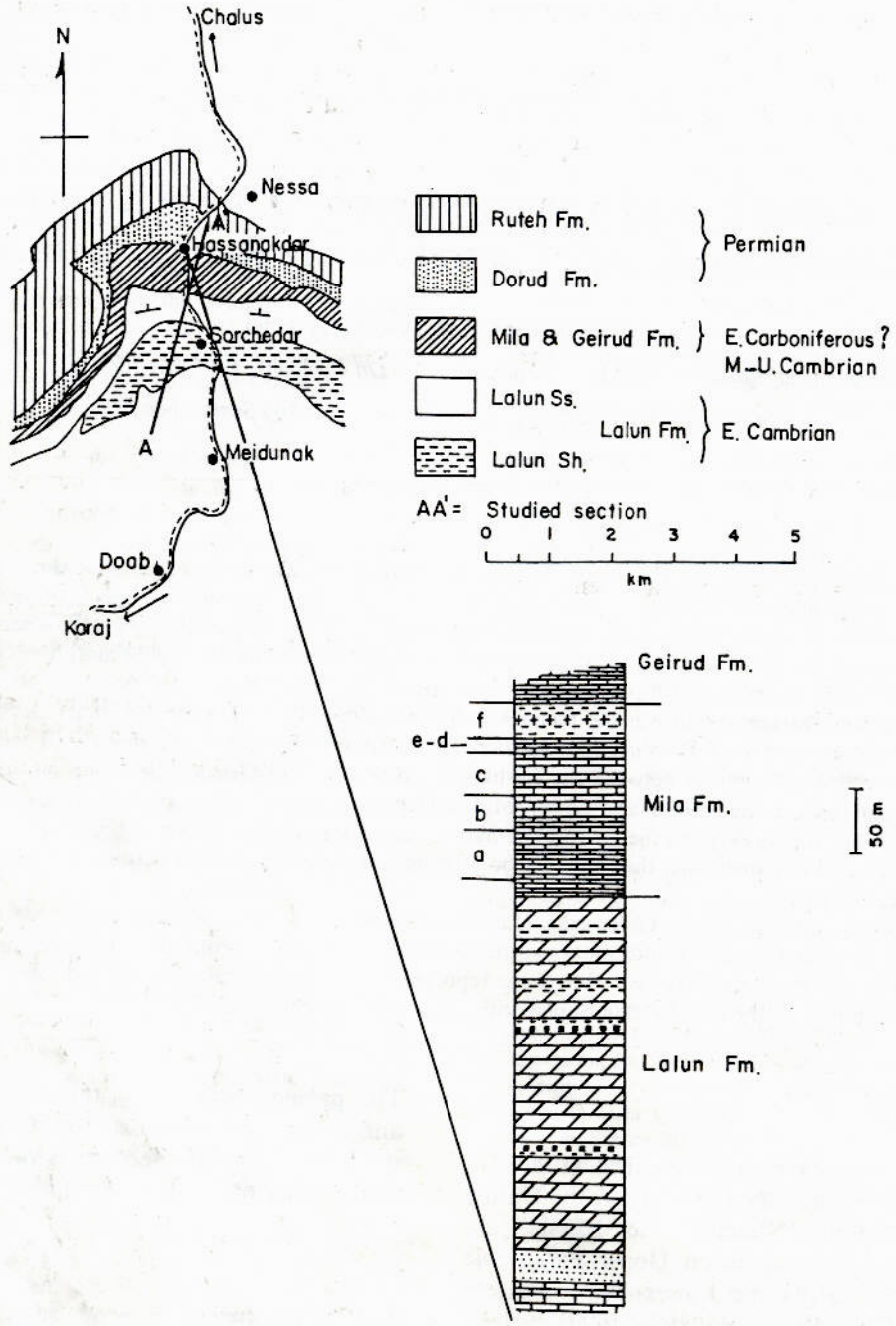


Fig. 1. Location, geographic map and stratigraphic column of the Hassanakdar region (after Lorenz, 1964; Kushan, 1978).

sequence in the study area has been divided in ascending order into the Lalun, Mila, Lashkarak, Geirud and Dorud-Ruteh formations. These rock units are well-exposed along the road from Karadj to Chalus near the village of Hassanakdar. The Lashkarak, the Geirud and the Dorud formations

were examined for palynological study from this section.

The field work was carried out in 1991. The measured and sampled stratigraphic section was chosen near the village of Hassanakdar where the total thickness of Lashkarak–Geirud-Dorud formations is 435 m; 35 out of the 435 m belongs to the Lashkarak Formation and the remainder to the Geirud and Dorud formations. The Hassanakdar area has previously been visited and studied by other geologists, e.g. Rivière (1934), Assereto (1963), Lorenz (1964), Gaetani (1965), Bozorgnia (1973), and Kimyai (1979).

The Lashkarak Formation is a very distinctive sedimentary facies which is easily separable from underlying and overlying formations (Fig. 2). The unit consists mainly of dark-grey silty shales, with an igneous sill in the middle part. One sample from the Lashkarak Formation has been studied palynologically and assigned to the Lower Ordovician.

The Geirud Formation was described by Assereto (1963) and is comprised of black, silty shales and sandy limestones with few brachiopods and corals. The stratigraphical age of the Geirud Formation has been the subject of major controversy. It has been assigned to Silurian–Devonian whilst on the basis of brachiopod species, Rivière (1934), Assereto (1963), Gaetani (1965), and Bozorgnia (1973) have suggested an Upper Devonian age, and Lorenz (1964) an Upper Devonian–Lower Carboniferous age. The palynomorphs of the Geirud Formation have also been studied by Kimyai (1979) who suggested a late Givetian–early Upper Devonian for this formation.

3. Laboratory techniques

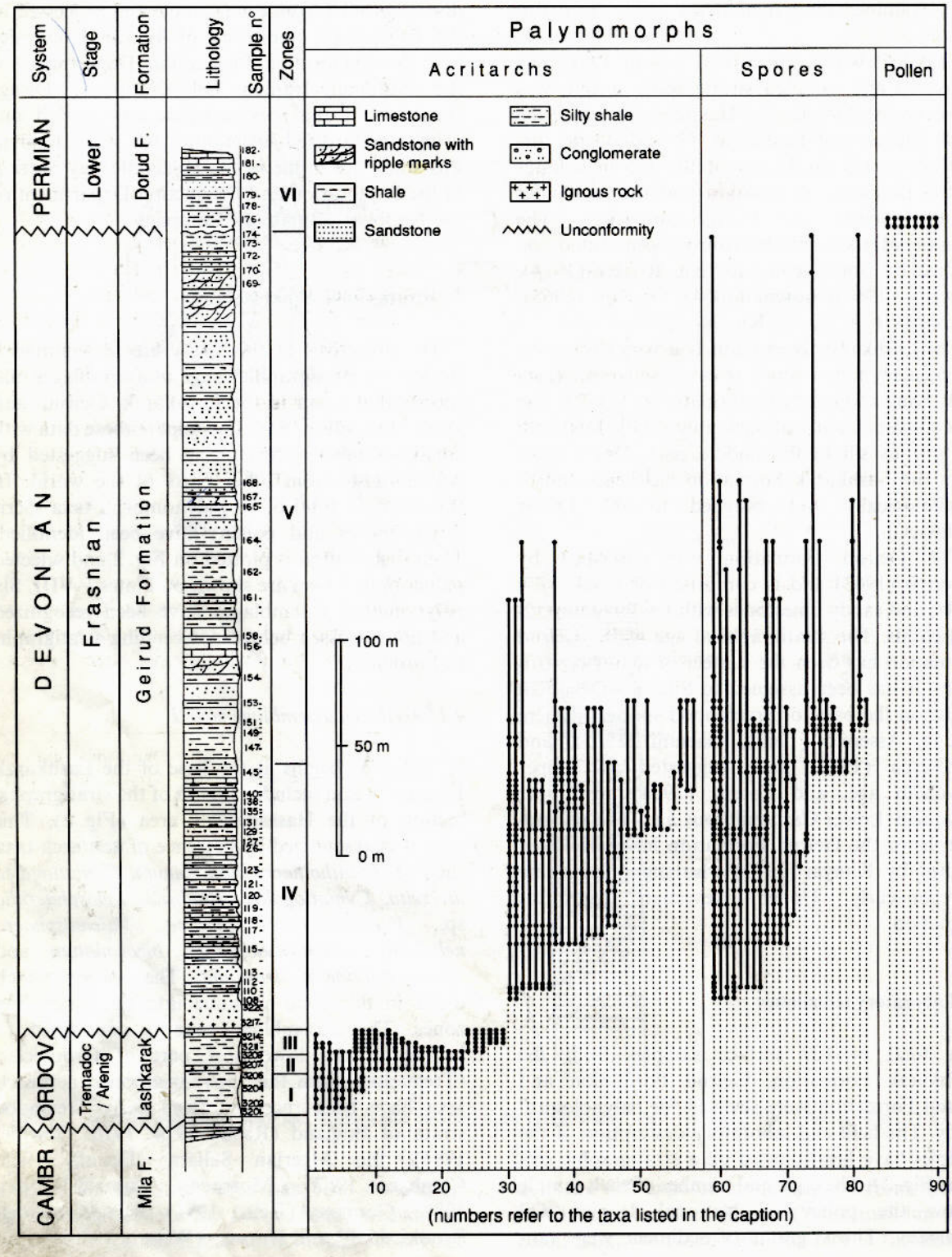
A total of 129 surface samples from the Lashkarak Formation, Geirud Formation and Dorud Formation were selected for palynological study. The field and laboratory description of the samples have been plotted on a stratigraphic section (Fig. 2). The code and number of each sample follow the policy of National Iranian Oil Company. Thirty grams of sediment were randomly selected from each sample and processed in the palynology laboratory of Tehran University and the Exploration Production Department of the National Iranian Oil Company. Disaggregation of the rock samples was carried out using standardized techniques. All slides used in this study are in file in the Palaeontology Section of the Exploration and Production Department of the National Iranian Oil Company.

4. Stratigraphical palynology

The objectives of this study are to summarize the known stratigraphic range of assemblages and species that occur in the Lashkarak, Geirud, and Dorud formations, and to compare these data with zonal assemblages that have been suggested by palynologists from other parts of the world. In this study, a total of 90 palynomorph taxa (acritarch, spores and pollen) have been identified. Their distribution is plotted on Fig. 2 and selected palynomorph taxa are shown on Plates I–VIII. Six palynomorph assemblages have been recognized and are discussed below in ascending stratigraphical order.

4.1 Acritarch assemblage zone I

This zone begins at the base of the Lashkarak Formation and includes 18.4 m of the stratigraphic section of the Hassanakdar area (Fig. 2). This zone is characterized by presence of acritarch taxa such as *Acanthodiacrodium spinum*, *Cymatiogalea diversita*, *Cymatiogalea cylindrata*, *Leiosphaeridia* sp., *Vulcanisphaera africana*, *Vulcanisphaera nebulosa*, *Acanthodiacrodium bicoronatum* and *Goniosphaeridium dentatum*. The species which occur in this zone continue into the succeeding zones. This assemblage zone is considered to belong to the lowermost part of Ordovician (Tremadoc) since the above-mentioned acritarch taxa have been recorded from early Tremadoc strata of England (Rasul, 1974, 1976; Downie, 1984), the Algerian Sahara (Deunff, 1966; Combaz, 1967), Morroco (Elaouad-Debbaj, 1988), Germany (Reitz, 1991), Iran (Ghavidel-Syooki, 1990) and Norway (Welsch, 1986).


System
Stage
Formation
Lithology
Sample n°
Zones
Palynomorphs
Acritarchs
Spores
Pollen
PERMIAN
DEVONIAN
CAMBR.-ORDOV.
Lower
Frasnian
Tremadoc / Arenig
Dorud F.
Geirud Formation
Lashkarak
Mila F.
VI
V
IV
III
II
I
Limestone
Silty shale
Sandstone with ripple marks
Conglomerate
Shale
Ignous rock
Sandstone
Unconformity
100 m
50 m
0 m
10
20
30
40
50
60
70
80
90
(numbers refer to the taxa listed in the caption)

4.2 Acritarch assemblage zone II

This zone is marked by appearance of additional acritarch taxa to supplement those reported in Zone I, e.g. *Priscotheca raia*, *Cymatiogalea cristata*, *Cymatiogalea bellicosa*, *Arbusculidium rommelaerei*, *Priscotheca tumida*, *Acanthodiacrodium complanatum*, *Goniosphaeridium sufflatum*, *Dasydiacrodium polarum*, *Goniosphaeridium tener*, *Lophosphaeridium* sp., *Saharidia downiei*, *Acanthodiacrodium zonaconstrictum*, *Acanthodiacrodium serotimum*, *Cymatiogalea membranispina* and *Arbusculidium filamentosum*. This Assemblage Zone occurs in 6 m of the Lashkarak Formation (Fig. 2). The acritarch taxa encountered in this zone indicate a Lower Ordovician (late Tremadoc–early Arenig age) by comparison with their previously recorded occurrence in Tremadoc strata from the Algerian Sahara (Deunff, 1966; Combaz, 1967), Morroco (Elaouad-Debbaj, 1988), England (Rasul, 1974; Downie, 1984), Norway (Welsch, 1986), Bohemia (Vavrdova, 1974), Russia (Timofeev, 1959), China (Li Jun, 1987), and Iran (Ghavidel-Syooki, 1990). Basaltic sills intruded into the Lashkarak Formation within sediments assigned to this zone have resulted in colour changes in the acritarch populations from orange to grey, reflecting local increases in the level of thermal maturity.

4.3 Acritarch assemblage zone III

This zone comprises 10.6 m of the Lashkarak Formation. It is marked by the presence of *Dactylofusa squama*, *Coryphidium elegans*, *Athabascaella rossii*, *Athabascaella penika*, *Acanthodiacrodium vavrdovae* and *Acanthodiacrodium tadlense*. Although some species of Zone I and II extend into this zone, a marked reduction in the number of species is obvious (Fig. 2). Based on the above-mentioned acritarch taxa, this zone is considered to belong to the uppermost part of the Lower Ordovician (Arenig). Acritarch taxa from this zone have been recorded in the Arenig strata of Morroco (Cramer et al. 1974a,b; Cramer and Diez, 1977) Canada (Martin, 1984), China (Martin and Yin, 1988), and Iran (Ghavidel-Syooki, 1990). Acritarch taxa from the Lashkarak Formation, including *Coryphidium elegans*, *Vulcanisphaera africana*, *Vulcanisphaera nebulosa*, *Acanthodiacrodium* spp., *Dasydiacrodium polarum*, *Priscotheca* spp. and *Arbusculidium filamentosum* are similar to those which have been recorded

Fig. 2. Stratigraphic distribution of palynomorph taxa in the Palaeozoic sequence of the Hassanakdar area, northern Iran. List or recorded taxa (numbers refer to the corresponding columns on Fig. 2): 1 = *Acanthodiacrodium spinum*; 2 = *Cymatiogalea diversita*; 3 = *Cymatiogalea cylindrata*; 4 = *Leiosphaeridia* sp.; 5 = *Vulcanisphaera africana*; 6 = *Vulcanisphaera nebulosa*; 7 = *Acanthodiacrodium bicoronatum*; 8 = *Goniosphaeridium dentatum*; 9 = *Priscotheca raia*; 10 = *Cymatiogalea cristata*; 11 = *Cymatiogalea bellicosa*; 12 = *Arbusculidium rommelaerei*; 13 = *Priscotheca tumida*; 14 = *Acanthodiacrodium complanatum*; 15 = *Goniosphaeridium sufflatum*; 16 = *Dasydiacrodium polarum*; 17 = *Goniospaeridium tener*; 18 = *Lophosphaeridium* sp.; 19 = *Saharidia downiei*; 20 = *Acanthodiacrodium zonaconstrictum*; 21 = *Acanthodiacrodium serotimum*; 22 = *Cymatiogalea membranispina*; 23 = *Arbusculidium filamentosum*; 24 = *Dactylofusa squama*; 25 = *Coryphidium elegans*; 26 = *Athabascaella penika*; 27 = *Acanthodiacrodium vavrdovae*; 28 = *Acanthodiacrodium tadlense*; 29 = *Athabascaella rossii*; 30 = *Gorgonisphaeridium discissum*; 31 = *Gorgonisphaeridium condensum*; 32 = *Navifusa exilis*; 33 = *Veryhachium downiei*; 34 = *Veryhachium colemanii*; 35 = *Veryhachium trispinosum*; 36 = *Veryhachium* sp.; 37 = *Papulogabata annulata*; 38 = *Duvernaysphaera tenuicingulata*; 39 = *Deltotosoma intonsum* 40 = *Dictyotidium granulatum*; 41 = *Gorgonisphaeridium carnarvonense*; 42 = *Tornacia sarjeantii*; 43 = *Tornacia stela*; 44 = *Palacanthus acutus*; 45 = *Chomotriletes vedugensis*; 46 = *Chomotriletes bistchoensis*; 47 = *Dictyotidium prolatum*; 48 = *Stellinium comptum*; 49 = *Stellinium octoaster*; 50 = *Tyligmasoma* sp.; 51 = *Melikeriopalla venulosa*; 52 = *Cymatiosphaera perimembrana*; 53 = *Cymatiosphaera hermosa*; 54 = *Cymatiosphaera turbinata*; 55 = *Unellium winslowae*; 56 = *Saharidia lusca*; 57 = *Tunisphaeridium flaccidum*; 58 = *Multiplicisphaeridium ramusculosum*; 59 = *Geminospora lemurata*; 60 = *Samarisporites triangulatus*; 61 = *Acinosporites salopiensis*; 62 = *Calamospora pannucea*; 63 = *Retusotriletes rotundus*; 64 = *Retusotriletes avonensis*; 65 = *Retusotriletes distinctus*; 66 = *Retusotriletes actinomorphus*; 67 = *Lagenicula minutus*; 68 = *Ancyrospora longispinosa*; 69 = *Dibolisporites turriculatus*; 70 = *Hystricosporites furcatus*; 71 = *Verrucosisporites* sp.; 72 = *Apiculiretusispora spicula*; 73 = *Cyclogranisporites isostictus*; 74 = *Dictyotriletes sphaericus*; 75 = *Grandispora megista*; 76 = *Vallatisporites devonicus*; 77 = *Calyptosporites stolidotus*; 78 = *Calyptosporites proximocavatus*; 79 = *Retusotriletes pychovii*; 80 = *Spinozonotriletes* sp.; 81 = *Diducites mucronatus*; 82 = *Geminospora* sp.; 83 = *Potonieisporites granulatus*; 84 = *Plicatipollenites indicus*; 85 = *Vittatina costabilis*; 86 = *Complexisporites polymorphus*; 87 = *Hamiapollenites perisporites*; 88 = *Striatopodocarpites cancellatus*; 89 = *Vesicaspora* sp.; 90 = *Nuskoisporites rotatus*.

from Zagros Basin of Iran, Belgium, France, England, China, Morroco, Algeria, Tunisia, Bulgaria, Czechoslovakia and Saudi Arabia. This similarity suggests the presence of a fairly homogeneous acritarch province that extends from east Newfoundland through the Mediterranean area to southern and northern Iran and China. The Iranian Platform appears, therefore, to have been part of Mediterranean acritarch province during the Lower Ordovician.

4.4 Acritarch and spore assemblage zone IV

The lower boundary of this zone is defined at the base of Geirud Formation and includes 123 m of that unit (Fig. 2). This zone is characterized by the appearance of Late Devonian index acritarch taxa including *Gorgonisphaeridium discissum*, *Navifusa exilis*, *Papulogobata annulata*, *Deltotosoma intonsum*, *Gorgonisphaeridium carnarvonense*, *Chomotriletes vedugensis*, *Chomotriletes*

PLATE I

All ×1000 (bar = 20 μm).
1. *Saharidia downiei* Combaz, 1967.
2. *Leiosphaeridia* sp.
3. *Vulcanisphaera africana* Deunff, 1961.
4. *Athabascaella penika* (Martin) Martin and Leiming, 1988.
5. *Cymatiogalea diversita* Deunff, 1961.
6. *Cymatiogalea membranispina* Deunff, 1961.
7. *Goniosphaeridium dentatum* (Timofeev) Cocchio, 1982.
8. *Coryphidium elegans* Cramer and Diez, 1974.
9. *Cymatiogalea cristata* (Downie) Rasul, 1974.
10. *Goniosphaeridium sufflatum* Welsch, 1986.
11. *Acanthodiacrodium tadlense* Cramer and Diez, 1977.
12. *Acanthodiacrodium zonaconstrictum* Welsch, 1986.
13. *Cymatiogalea bellicosa* Deunff, 1961.

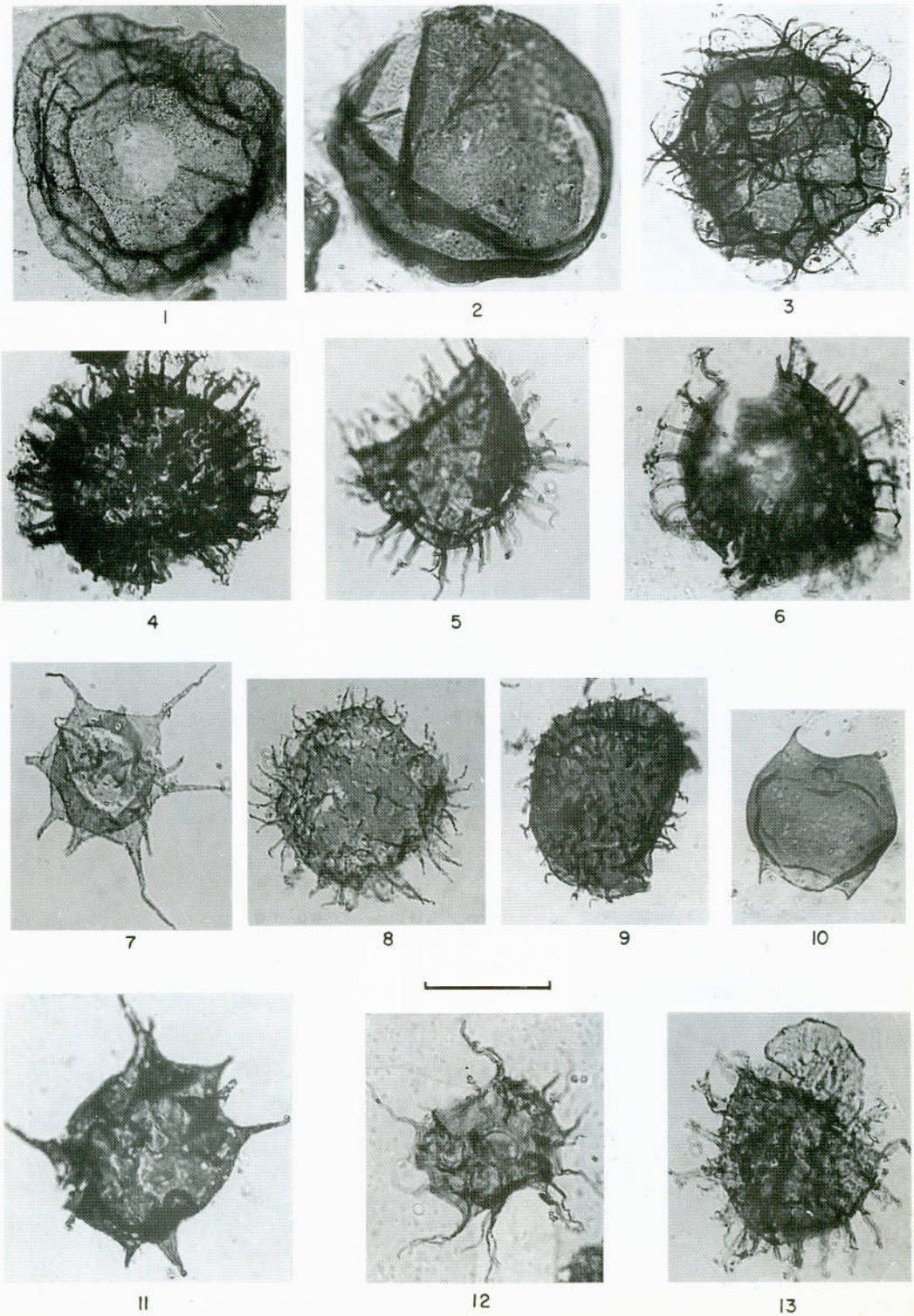
PLATE II (see p. 98)

All ×1000 (bar = 20 μm).
1. *Arbusculidium filamentosum* Vavrdova, 1972.
2. *Dasydiacrodium polarum* Jardiné et al., 1974.
3. *Priscotheca tumida* Deunff, 1961.
4. *Acanthodiacrodium vavrdovae* Cramer et Diez, 1977.
5. *Dactylofusa squama* (Deunff) Combaz, 1967.
6. *Athabascaella rossii* Martin, 1984.
7. *Vulcanisphaera nebulosa* Deunff, 1961.
8. *Goniosphaeridium tener* (Timofeev) Elaouad-Debbaj, 1988.

PLATE III (see p. 99)

All ×1000 (bar = 20 μm).
1. *Acanthodiacrodium serotimum* Timofeev, 1959.
2. *Acanthodiacrodium spinum* Rasul, 1976.
3. *Acanthodiacrodium bicoronatum* Welsch, 1986.
4. *Lophosphaeridium* sp.
5. *Cymatiogalea cylindrata* Rasul, 1974.
6. *Priscotheca raia* Deunff, 1961.
7. *Arbusculidium rammelaerei* Martin, 1981.

PLATE I



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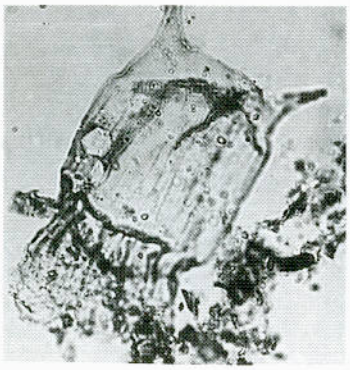

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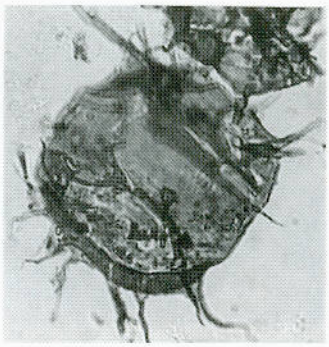

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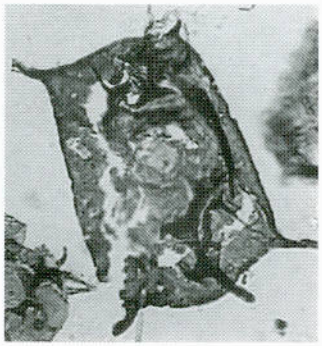

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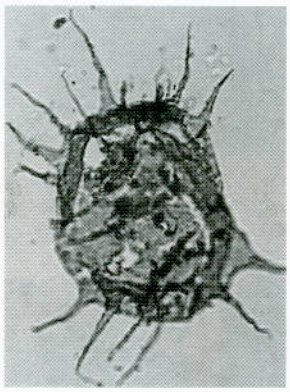

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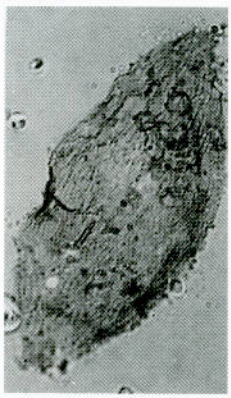

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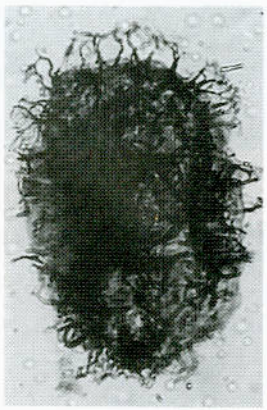

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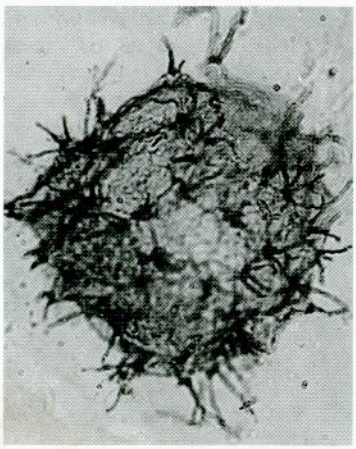

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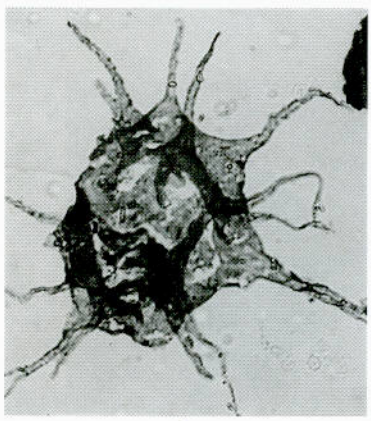

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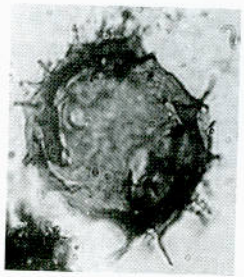
PLATE III



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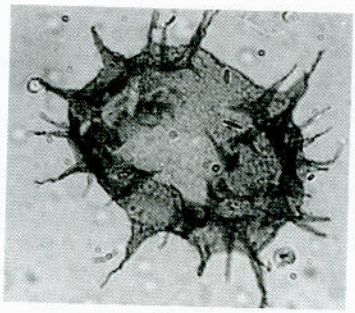

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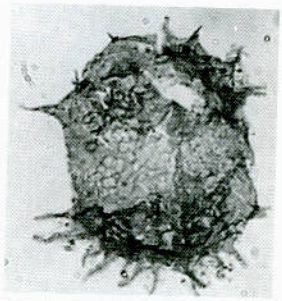

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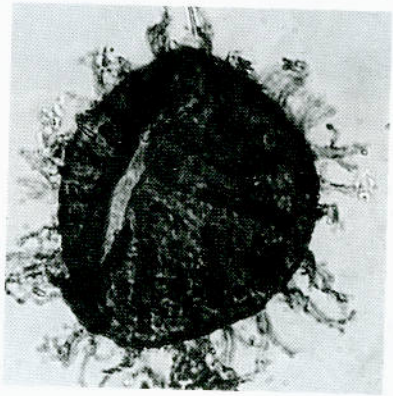

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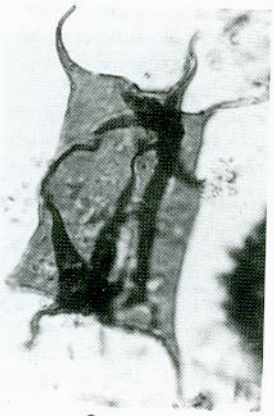

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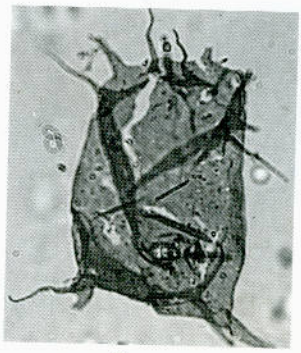

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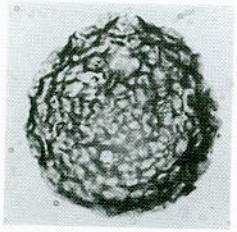
PLATE IV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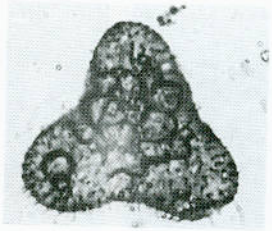
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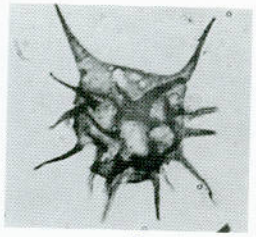
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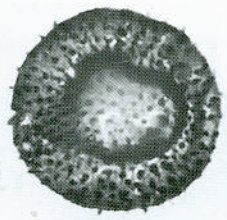
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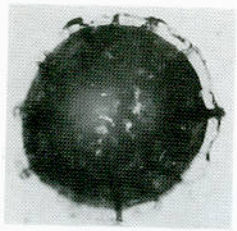
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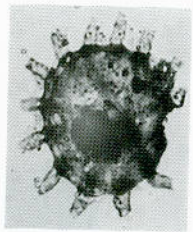
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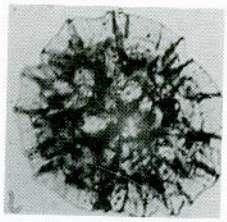
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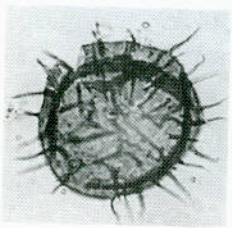
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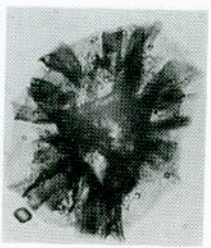
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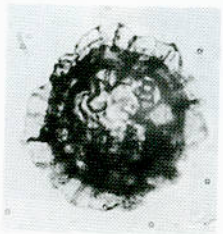
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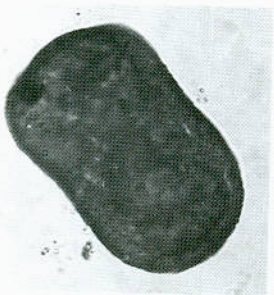
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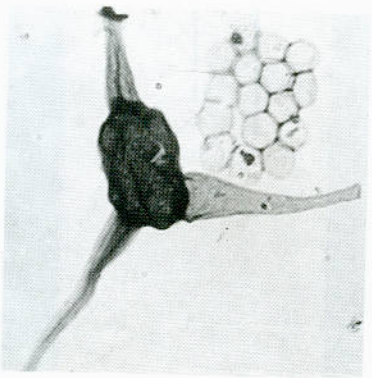
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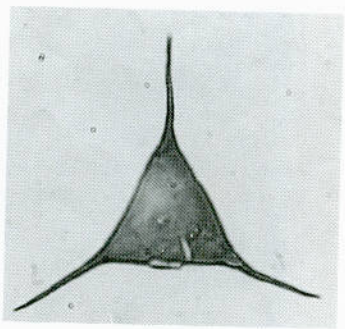
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bistchoensis, *Stellinium octoaster*, *Milkeriopalla venulosa*, *Saharidia lusca*, and *Tunisphaeridium flaccidum*. In addition to the above-mentioned index acritarch taxa, there are many index spore species in this zone, including *Geminospora lemurata*, *Samarisporites triangulatus*, *Lagenicula minutus*, *Dibolisporites turriculatus*, *Hystricosporites furcatus*, *Cyclogranisporites isostictus*, *Dictyotriletes sphaericus*, *Grandispora megista*, *Vallatisporites devonicus*, *Calyptosporites proximacavatus* and *Retusotriletes pychovii*. Several longer-ranging spore and acritarch taxa are also present in this zone. This assemblage zone is considered to be early Frasnian in age based on both the index spore and acritarch taxa mentioned above since palynomorph taxa such as *Chomotriletes vedugensis*, *Chomotriletes bistchoense*, and *Samarisporites triangulatus* have not been previously recorded from older or younger Devonian strata.

4.5 Acritarch and spore assemblage zone V

This zone is characterized by the presence of *Diducites mucronatus* which is associated with most of the acritarch and spore taxa of zone IV. The thickness of this zone in the Geirud Formation is 237 m (Fig. 2); it is considered to be of middle–late Frasnian age since many Frasnian index spores including *Geminospora lemurata*, *Samarisporites triangulatus*, *Cyclogranisporites isostictus*, *Dictyotriletes sphaericus*, *Diducites mucronatus* and *Spinozonotriletes* sp. are dominant components in the assemblages. Among 53 palynomorph taxa encountered in the Geirud Formation, most species are diagnostic of a Frasnian age whilst a small number are long-ranging forms common throughout the whole Devonian. Therefore, based on palynological evidence from Zones VI and V, the Geirud Formation has been assigned an early Upper Devonian (Frasnian) age. One of the most marked aspects of the spore assemblages of Zones IV and V is the occurrence of bifurcating spinose spore species such as *Hystricosporites furcatus* and *Ancyrospora longispinosa*. These two species have been recorded elsewhere from Middle Devonian strata, suggesting the possibility of a Middle Devonian age assignment for those zones. The numerous Upper Devonian index spore and acritarch taxa, especially, *Chomotriletes vedugensis*, *Chomotriletes bistchoensis*, *Saharidia lusca*, *Geminospora lemurata*, *Samarisporites triangulatus*, *Lagenicula minuta* (Wicander, 1974; Loboziak and Streel, 1980, 1981; McGregor, 1981; Playford, 1981; Wicander and Playford, 1985) limit the Geirud Formation to a Frasnian age since it must be assumed that bifurcate spinose spores are limited to the Upper Devonian in the Alborz Mountain Ranges. A similar pattern has been recorded by Hemer and Nygreen (1967) from the Frasnian deposits of Saudi-Arabia, the Zagros

PLATE IV

All ×1000 (bar = 20 μm).

1. *Dictyotidium prolatum* Playford, 1981.
2. *Deltotosoma intonsum* Playford, 1981.
3. *Unellium winslowae* Rauscher, 1969.
4. *Gorgonisphaeridium carnarvonense* Playford, 1981.
5. *Duvernaysphaera tenuicingulata* Staplin, 1961.
6. *Chomotriletes vedugensis* Naumova, 1953.
7. *Tornacia stela* Wicander, 1974.
8. *Cymatiosphaera hermosa* Cramer and Diez, 1976.
9. *Gorgonisphaeridium condensum* Playford, 1981.
10. *Cymatiosphaera turbinata* Wicander and Loeblich, 1977.
11. *Tunisphaeridium flaccidum* Playford, 1981.
12. *Cymatiosphaera perimembrana* Staplin, 1961.
13. *Navifusa exilis* Playford, 1981.
14. *Tyligmasoma* sp.
15. *Veryhachium downiei* Stockmans and Willière, 1962.

Basin of Iran (Ghavidel-Syooki, 1988), and Frasnian strata of Western Australia (Balme, 1962, 1988). There is a marked similarity between the spore taxa of the Geirud Formation with those recorded in southeastern Iran, Western Australia and the Arabian Peninsula. Some of the acritarch taxa identified from the Geirud Formation including *Chomotriletes vedugensis*, *Chomotriletes*

PLATE V

All ×1000 (bar = 20 μm).
1. *Stellinium comptum* Wicander and Loeblich, 1977.
2. *Veryhachium colemanii* Playford, 1981.
3. *Chomotriletes bischoensis* Staplin, 1961.
4. *Papulogabata annulata* Playford, 1981.
5. *Melikeriopalla venulosa* Playford, 1981.
6. *Dictyotidium granulatum* Playford, 1981.
7. *Saharidia lusca* Playford, 1981.
8. *Multiplicisphaeridium ramusculosum* (Deflandre) Lister, 1970.
9. *Veryhachium* sp.
10. *Stellinium octoaster* (Staplin) Jardiné et al., 1972.
11. *Palacanthus acutus* Wicander, 1974.
12. *Gorgonisphaeridium discissum* Playford, 1981.
13. *Tornacia sarjeantii* (Stockmans and Willière) Wicander, 1974.

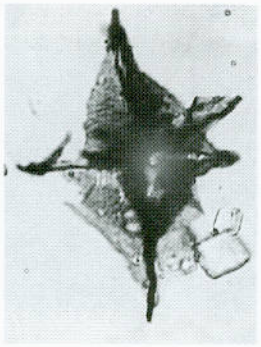
PLATE VI (see p. 104)

All ×1000 (bar = 20 μm).
1. *Cyclogranisporites isostictus* Balme, 1988.
2. *Retusotriletes distinctus* Richardson, 1965.
3. *Retusotriletes rotundus* (Streel) Streel, 1967.
4. *Calamospora pannucea* Richardson, 1965.
5, 9. *Retusotriletes actinomorphus* Chibrikova, 1962.
6. *Dibolisporites turriculatus* Balme, 1988.
7. *Geminospora lemurata* Balme, 1962.
8. *Retusotriletes avonensis* Playford, 1964.
10. *Diducites mucronatus* (Kedo) Van Veen, 1981.
11. *Retusotriletes pychovii* Naumova, 1953.
12. *Geminospora* sp.

PLATE VII (see p. 105)

All ×1000, except 4 (×290) and 7 (×625) (bar = 20 μm).
1. *Calyptosporites stolidotus* Balme, 1988.
2. *Acinosporites salopiensis* Richardson and Lister, 1969.
3. *Samarisporites triangulatus* Allen, 1965.
4. *Lagenicula minutus* Kimyai, 1979 (×290).
5. *Calyptosporites proximocavatus* Balme, 1988.
6. *Hystricosporites furcatus* Owens, 1971.
7. *Vallatisporites devonicus* Kimyai, 1979.
8. *Ancyrospora longispinosa* Richardson, 1962 (×750).
9. *Dictyotriletes sphaeridus* Kimyai, 1979.
10. *Grandispora megista* Balme, 1988.
11. *Verrucosisporites* sp.
12. *Apiculiretusispora spicula* Richardson and Lister, 1969.

PLATE V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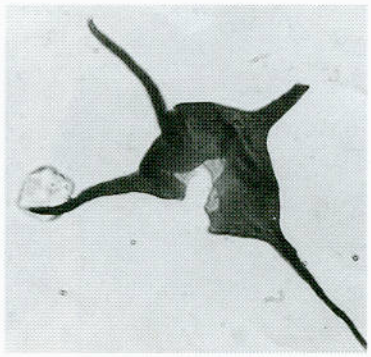
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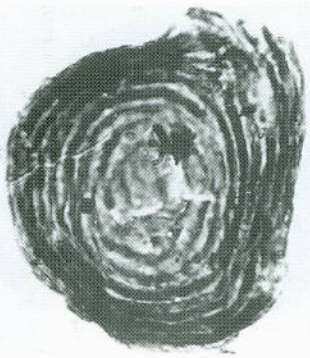
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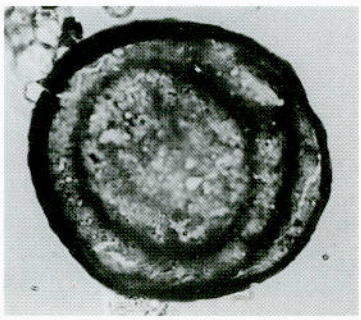
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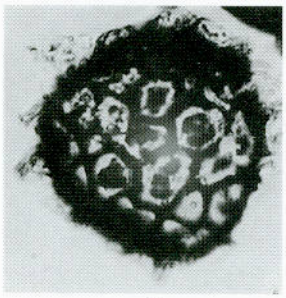
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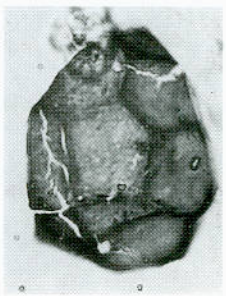
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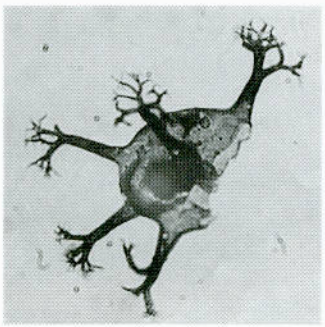
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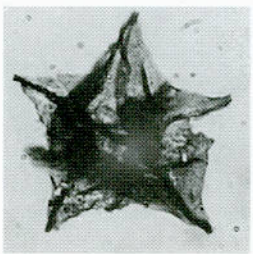
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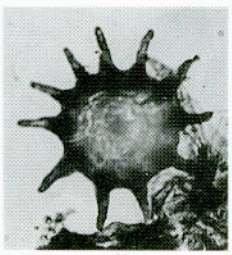
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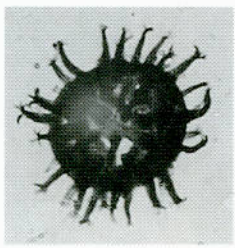
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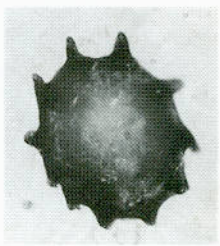
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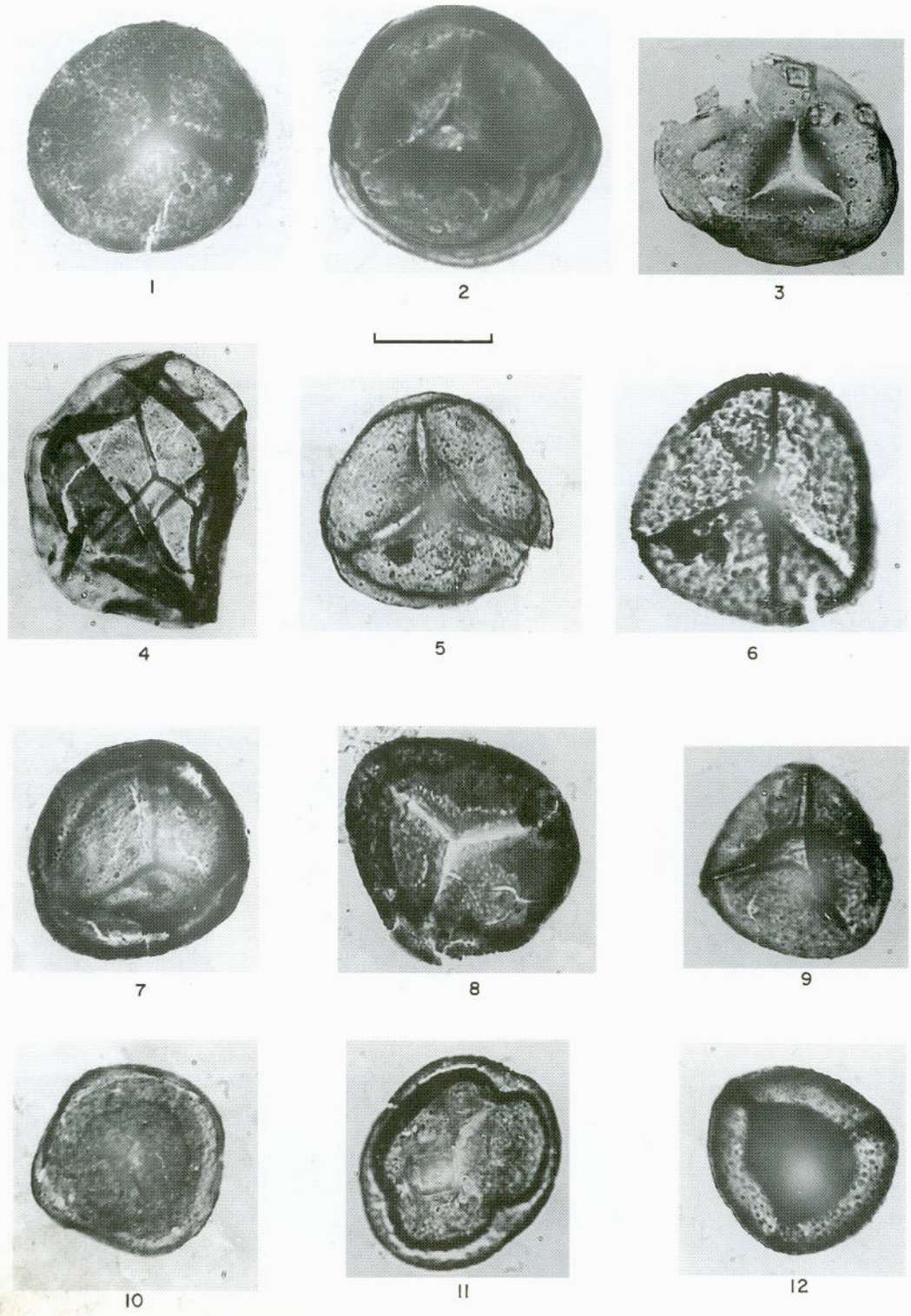
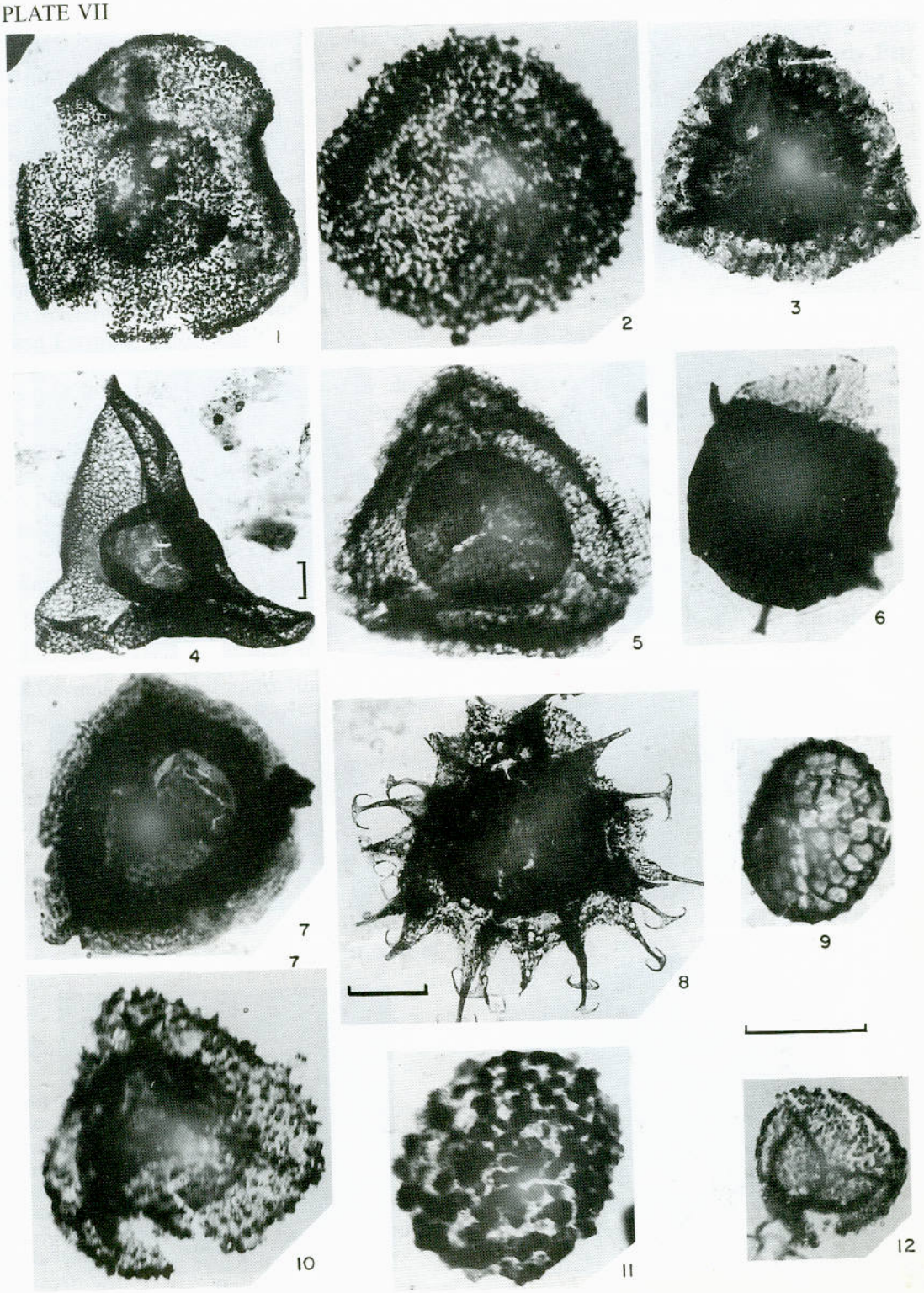
PLATE VI



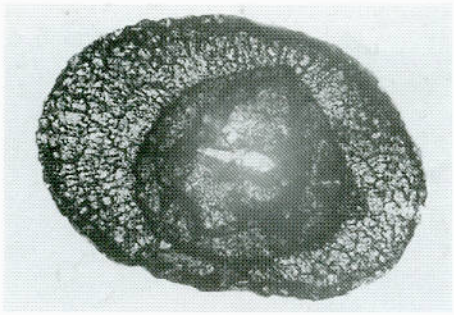
(for description see p. 102)

PLATE VII



(for description see p. 102)

PLATE VIII



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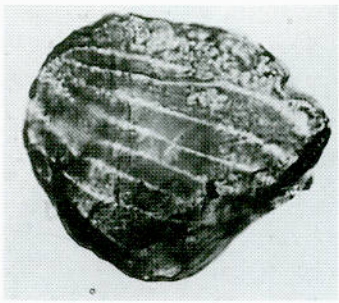

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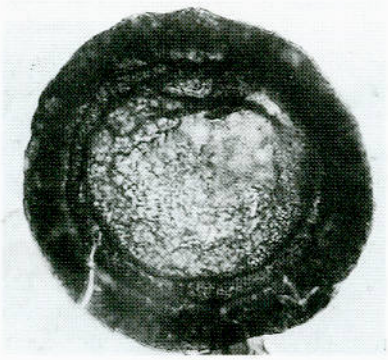

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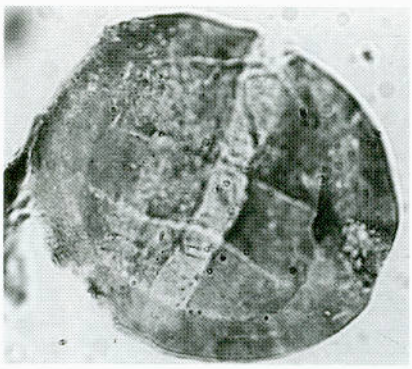

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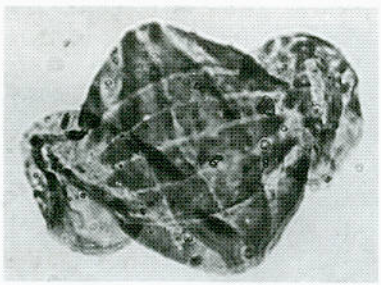

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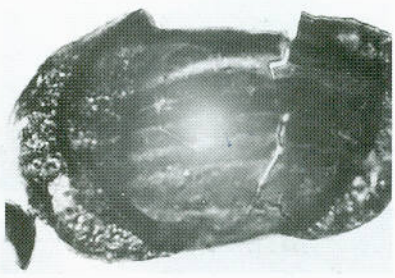

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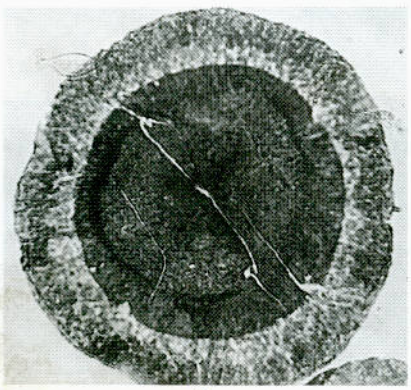

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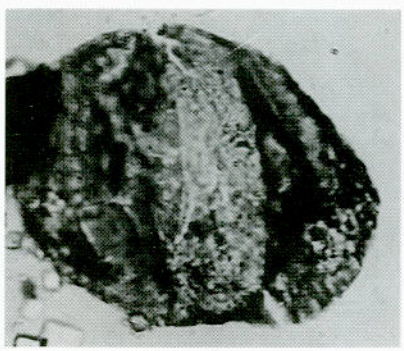

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bistchoensis, *Stellinium comptum*, *Stellinium octoaster*, *Cymatiosphaera perimembrana*, *Tyligmasoma* sp., and *Veryhachium* spp. are also known from Europe and North America. However, many other acritarch taxa of the Geirud Formation including *Deltotosoma intonsum*, *Papulogabata annulata*, *Navifusa exilis*, *Gorgonisphaeridium discissum*, *Melikeriopalla venulosa*, *Dictyotidium granulatum*, *Saharidia lusca*, *Gorgonisphaeridium carnarvonense*, *Gorgonisphaeridium condensum*, *Tunisphaeridium flaccidum* have also been recorded from Frasnian strata of Western Australia (Playford and Dring, 1981) and Frasnian deposits of the Zagros Basin in Iran (Ghavidel-Syooki, 1988). Based on these similarities it would be possible to consider that the Alborz Mountain Ranges, the Zagros Basin, the Arabian Peninsula, and Western Australia were at similar palaeolatitude along the southern shore of the Palaeo-Tethys Ocean during the Late Devonian (Frasnian).

4.6 Pollen assemblage zone VI

This zone extends over 40 m of the Dorud Formation (Fig. 2) and is marked by disappearance of Devonian taxa and appearance of Lower Permian index pollen species including *Potonieisporites granulatus*, *Plicatipollenites indicus*, *Vittatina costabilis*, *Complexisporites polymorphus*, *Hamiapollenites perisporites*, *Straitopodocarpites cancellatus*, *Vesicaspora* sp. and *Nuskoisporites rotatus*. Based on these species, the Dorud Formation was deposited during the Lower Permian (Sakmarian). The early Permian pollen species derived from the Dorud Formation are similar to those recorded from Lower Permian of the Faraghan Formation of the Zagros Ranges (Ghavidel-Syooki, 1988), the Lower Permian of Saudi Arabia (Hemer, 1965), the Early Permian of Africa (Bose and Kar 1966, 1967), the Lower Permian of Turkey (Akyole, 1975), and the Lower Permian of the USA (Wilson, 1962; Jizba, 1962; Tschudy and Kosanke, 1966).

5. Conclusions

90 palynomorph taxa were encountered from the Lashkarak, the Geirud and the Dorud formations. The local stratigraphic distribution of all known taxa is shown on Fig. 2. These species have been arranged in six ascending local stratigraphic assemblage zones. Zones I to III are present in the Lashkarak Formation, suggesting Lower Ordovician (Tremadoc–Arenig) age for this interval. Comparison of these Lower Ordovician acritarch assemblages with those from other parts of the world indicates broad similarity with those from the "Mediterranean Acritarch Province" elsewhere. This acritarch province includes southern Europe, northern Africa, southwestern China, Saudi Arabia and the Zagros Basin (Iran). The presence of Mediterranean acritarch taxa in the Lashkarak Formation of the Alborz Ranges, suggests that both southern and northern Iran were part of the Gondwanan palaeo-continent, possibly along the southern shore of the Palaeo-Tethys Ocean. Zones IV to V occur in the Geirud Formation and indicate an early Late Devonian (Frasnian) age for this interval. Likewise, comparison of known palynomorph taxa from the Geirud Formation reveals close similarity with those

PLATE VIII

All ×1000 (bar = 20 μm)

1. *Potonieisporites granulatus* Bose and Kar, 1966.
2. *Vittatina costabilis* (Wilson) Tschudy and Kosanke, 1966.
3. *Plicatipollenites indicus* Lele, 1964.
4. *Complexisporites polymorphus* Jizba, 1962.
5. *Hamiapollenites perisporites* (Jizba) Tschudy and Kosanke, 1966.
6. *Striatopodocarpites cancellatus* (Bharadwaj and Salujha) Balme, 1970.
7. *Nuskoisporites rotatus* Balme and Hennelly, 1965.
8. *Vesicospora* sp.

recorded from Western Australia, Arabian Peninsula and the Devonian of Zagros Basin in Iran. This similarity suggests that Iranian Platform and Western Australia have occupied the same palaeolatitude during the Late Devonian (Frasnian). Zone VI appears in the Dorud Formation and represents Lower Permian (Sakmarian). The recorded pollen flora from the Dorud Formation is similar to those from Lower Permian of Africa, Lower Permian of Zagros Basin, southern Iran and India. This similarity suggests that the Alborz Ranges and Zagros Basin were part of the super continent of Gondwana during the Lower Permian. Based on the palynological evidence two major "hiata" are recognised within the Palaeozoic sequence of Hassanakdar area. The first "hiatus" is present between the Lashkarak Formation and the Geirud Formation and extends from the Upper Ordovician through Silurian and Lower–Middle Devonian. The second "hiatus" is present between the Geirud and the Dorud formations and represents the period encompassed by the Famennian and the whole Carboniferous Period.

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