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UPPER DEVONIAN ACRITARCHS AND MIOSPORES FROM THE GEIRUD FORMATION IN CENTRAL ALBORZ RANGE, NORTHERN IRAN

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Abstract

The Geirud Formation consists mainly of clastic sediments which are interbedded with limestone stringers. This rock unit is well-exposed along the Central Alborz Range in northern Iran. The Geirud Formation rests unconformably on the Mila Formation (Upper Cambrian) and is conformably overlain by the Mobarak Formation (Lower Carboniferous). This study was undertaken to determine the geological age of the Geirud Formation, to interpret the depositional sites, and to reconstruct the palaeogeographic relationships between the Central Alborz Range and the southern and northern hemispheres during the Upper Devonian epoch. A total of 59 palynomorph species were described in this study, including 27 acritarch species (21 genera) and 32 miospore species (21 genera). In ascending stratigraphic order, these have been arranged in four miospore and three acritarch assemblages. The assemblage zones I through III represent Upper Devonian (Frasnian-Famennian) and zone IV suggests Lower Tournaisian. A major hiatus which includes Ordovician, Silurian, and Lower-Middle Devonian was recognized between the Geirud and Mila formations. This hiatus possibly coincides with the Hercynian orogeny which resulted in the emergence of the Central Alborz Range. In terms of relative frequency, the acritarchs and miospores comprise 48% and 52%, respectively. The presence of acritarchs in the Geirud Formation suggests a shallow marine environment which covered the Central Alborz Range during the Upper Devonian epoch. On the other hand, the presence of miospores in the Geirud Formation shows that spore-bearing plants grew on the adjacent land masses that were transported into the shallow marine basin. Among the encountered morphotype species of the Geirud Formation *Archaeo-perisaccus scabratus* and *Retispora lepidophyta* are more important than the

Keywords: Upper Devonian-Lower Carboniferous; Acritarchs; Miospores; Palynology; Biostratigraphy

others, since they suggest a tropical condition for the Geirud Formation around the palaeoequatorial belt which stretched from Timan in Western Russia through the islands of the Arctic archipelago of Canada to Alaska. Moreover, some acritarch species have been recorded, only from Upper Devonian of North Africa, Western Australia, and southern Iran, including *Papulogabata annulata, Deltotosoma intonsum, Gorgonisphaeridium discissum, Dictyotidium granulatum, Elektoriskos tenuis, Horologinella horologia, Horologinella quadrispina* and *Crassiangulina tessellita*. The presence of the above-mentioned taxa in the Geirud Formation shows that southern and northern Iran, North Africa and Western Australia were at a similar palaeolatitude, along the southern shore of the Tethys Sea, during the Upper Devonian epoch.

Introduction and Stratigraphy

The locality studied is called Imam-Zadeh Hashem region. It is located approximately 75 km northeast of Tehran, on the Central Alborz Range, northern Iran (Fig. 1). In ascending order, the stratigraphic sequence of the studied area has been divided into the Lalun, Mila, Geirud, Mobarak and Ruteh Formations. Based on fossil evidence, the Lalun and Mila Formations have been assigned to the Cambrian, but the Geirud, Mobarak and Ruteh Formations are thought to belong to the Upper Devonian, Lower Carboniferous, and Upper Permian, respectively [25].

The Upper Devonian sediments of the Central Alborz Range are referred to as the Geirud Formation after the village of Geirud, 60 kilometres west of the studied area [2]. The Geirud Formation is subject to considerable lateral variations and great reductions in thickness in most places of the Central Alborz Range. The Formation is 230 metres thick in the type locality (Geirud village) and consists mainly of dark calcareous shale, siltstone, sandstone and fossiliferous limestone.

The brachiopods of the Geirud Formation were collected and studied by Lorenz [26] and Gaetani [11]. Based on genera and species of brachiopods, the age Upper Devonian-Lower Carboniferous is suggested for this rock unit. Moreover, the only work on the palynology of the Geirud Formation is that of Kimyai [23] who identified 18 miospore species (15 genera) and suggested Upper Devonian for this rock unit. The Geirud Formation is well-exposed north of the village of Mobarak in the Imam-Zadeh Hashem area where its thickness is 281 metres and consists of dark calcareous shale, siltstone, sandstone and limestone (Fig. 1). In the Imam-Zadeh Hashem area, the invertebrate fossils are not encountered in the Geirud Formation, whereas the Mobarak Formation contains brachiopods, corals and faunal microfossils. Thus, the Geirud Formation has tentatively been assigned to the Upper Devonian. In this area, the Geirud Formation unconformably overlies the Mila Formation (Upper Cambrian) and is conformably overlain by the Mobarak Formation (Lower Carboniferous). The thickness of the Mobarak Formation is 450 metres with 50 metres of dark-calcareous and fossiliferous shale at the base (Fig. 1) and 400 metres of dark fossiliferous limestone. Based on brachiopods, corals, and foraminifers, the Mobarak Formation has been assigned to the Lower Carboniferous in age [26, 11, 6].

The purpose of this investigation can be summarized in the following objectives:

1- To identify, describe and illustrate the diagnostic acritarch and miospore species of the Geirud and Mobarak Formations.

2- To establish the Frasnian-Famennian and Famennian-Tournaisian boundaries.

3- To determine the diagnostic acritarch and miospore taxa which are useful for interpretation of palaeogeographic relationships of Iran with other parts of the world.

4- To resolve the age relationships of the Geirud Formation with underlying and overlying formations.

Materials and Methods

The Geirud Formation in the Imam-Zadeh Hashem area is 281 metres thick. It consists of shale, siltstone, sandstone, and limestone. The Geirud Formation rests unconformably on the Mila Formation (Upper Cambrian) and is overlain by the Mobarak Formation (Lower Carboniferous). The Palaeozoic sequence of the Imam-Zadeh Hashem area was measured and sampled by the author in 1991. A total of 40 samples were selected from the whole thickness of the Geirud Formation and the basal part of the Mobarak Formation. Standard preparation techniques were employed by using hydrochloric and hydroflouric

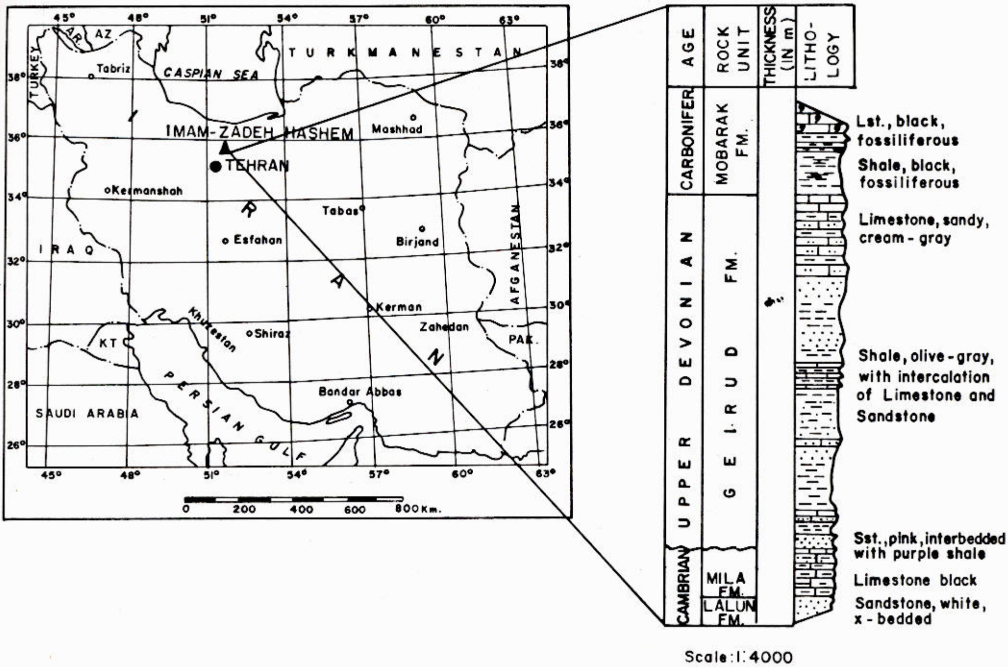

Figure 1. Location map and stratigraphic sequence of studied area

acids to remove the carbonate and silicate contents of the samples. The samples were sieved through a 15 μm mesh screen to separate palynomorph contents from unwanted materials. About 30 ml zinc chlorite (s. g. 1.95) was put into a clean centrifuge tube. The residues were then added to the centrifuge tube, in order to separate palynomorphs from inorganic materials, and treated with cold sodium hypochlorite (trade name: clorox) to bleach the palynomorph contents.

Three slides per samples were then prepared by using Adams Hystoclad as the mounting medium. The diagnostic acritarch and miospore species were photographed using the Leitz Automatic Microscope System. Developing and printing was carried out at the existing facilities of the laboratories of the Palaeontology Department of the National Iranian Oil Company. Identification of various palynomorph taxa was accomplished by comparing them to those described and illustrated in the available literature on the Palaeozoic era. All palynological slides are housed in the palaeontological collections of the National Iranian Oil Company.

Qualitative and Quantitative Variations of Palynomorph Taxa in the Geirud Formation

The Geirud Formation is well-exposed along the Central Alborz Range. It contains invertebrate fauna such as brachiopods and corals in the type locality (Geirud village). In the type locality, the invertebrate fauna of the Geirud Formation were studied by Lorenz [26] and Gaetani [11]. On the basis of the brachiopods, the Upper Devonian epoch and Lower Carboniferous subperiod were assigned for the Geirud Formation by these authors.

In the studied area, the Geirud Formation lacks invertebrate fauna and comprises of dark-grey calcareous shale, siltstone, sandstone and sandy limestone. Samples from all types of sediments were treated for palynomorph entities including miospores, acritarchs, chitinozoans and scolecodonts. Except for one sample, (MG-3032), which is barren, the rest of the samples contain well-preserved and abundant palynomorph taxa. Some miospores such as

Table 1. Percentage of known miospore taxa in the studied samples from the Geirud Formation in the Imam-Zadeh Hashem area, northern Iran

No.	List of encountered miospore taxa	Total grains in studied samples	%
1	*Retispora lepidophyta*	247	14.5
2	*Geminospora lemurata*	156	9.2
3	*Diducites mucronatus*	149	8.8
4	*Grandispora cornuta*	134	7.9
5	*Retusotriletes rotundus*	101	5.9
6	*Retusotriletes distinctus*	98	5.7
7	*Hymenozonotriletes perplexa*	97	5.7
8	*Lagenicula minutus*	97	5.6
9	*Spelaeotriletes crustatus*	91	5.4
10	*Grandispora echinata*	68	4.0
11	*Verrucosisporites nitidus*	55	3.2
12	*Emphanisporites rotatus*	46	2.7
13	*Hymenozonotriletes famenensis*	44	2.6
14	*Hystricosporites grandis*	40	2.3
15	*Hymenozonotriletes explanatus*	39	2.3
16	*Archaeozonotriletes* sp.	38	2.2
17	*Knoxisporites literatus*	35	2.1
18	*Vallatisporites pusillites*	32	1.9
19	*Diducites poljessicus*	26	1.5
20	*Raistrickia corynoges*	19	1.1
21	*Hystricosporites multifurcatus*	18	1.0
22	*Retusotriletes phillipsii*	14	0.9
23	*Archaeoperisaccus scabratus*	12	0.7
24	*Hymenozonotriletes commutatus*	12	0.7
25	*Lophozonotriletes malevkensis*	12	0.7
26	*Ancyrospora* sp.	10	0.6
27	*Punctatisporites glabrimarginatus*	4	0.2
28	*Retispora cassiculus*	4	0.2
29	*Leiotriletes liebigensis*	3	0.2
30	*Cymbosporites* sp.	3	0.2
		1697	100%

Hystricosporites and *Ancyrospora* are black in colour. This may indicate that these two genera were oxidized on the adjacent land masses of the sedimentary basin.

In terms of relative frequencies, acritarchs and miospores are common or abundant, but chitinozoans and scolecodonts are rare or very rare in all samples. However, the relative frequency of acritarch and miospore taxa changes from one sample to another. This may have been controlled, to some extent, by depositional conditions (such as winnowing), or local changes in plant distribution on the adjacent land masses. The known miospore and acritarch taxa were counted and their total percentages calculated in all samples (Tables 1 and 2). In this study, the relative

Table 2. Percentage of known acritarch taxa in the studied samples from the Geirud Formation in the Imam-Zadeh Hashem area, northern Iran

No.	List of known acritarch taxa	Total grains in studied samples	%
1	*Gorgonisphaeridium ohioense*	860	54.8
2	*Gorgonisphaeridium discissum*	252	16.0
3	*Veryhachium trispinosum*	85	5.4
4	*Stellinium micropolygonale*	67	4.3
5	*Maranhites perplexus*	48	3.1
6	*Navifusa exilis*	37	2.4
7	*Chomotriletes vedugensis*	36	2.3
8	*Deltotosoma intonsum*	31	2.0
9	*Ammonidium loriferum*	29	1.8
10	*Daillydium pentaster*	18	1.1
11	*Papulogabata annulata*	17	1.1
12	*Cymatiosphaera perimembrana*	15	0.9
13	*Dictyotidium granulatum*	14	0.8
14	*Tunisphaeridium flaccidum*	7	0.4
15	*Polyedryxium ambitum*	7	0.4
16	*Tyligmasoma alargada*	6	0.4
17	*Horologinella horologia*	6	0.4
18	*Hologinella quadrispina*	6	0.4
19	*Crassiangulina tessellita*	6	0.4
20	*Pterospermella radiata*	4	0.3
21	*Polyedryxium pharaonis*	4	0.3
22	*Multiplisphaeridium amitum*	4	0.3
23	*Elektoriskos tenuis*	2	0.1
24	*Umbellaspheridium* sp.	2	0.1
25	*Cymatiosphaera adaiochorata*	2	0.1
26	*Veryhachium pannuceum*	2	0.1
27	*Polyedryxium embudum*	2	0.1
		1568	100%

frequency of each taxa is indicated by quantifiers, such as very rare (< 1%), rare (1% - 2%), common (3% - 5%) and abundant (> 5%). Based on the total number of specimens, the acritarchs and miospores represent 48% and 52%, respectively. The presence of a high percentage of marine palynomorph taxa in the Geirud Formation suggests a shallow-marine sea, which covered most of the Central Alborz Range during the Upper Devonian time. On the other hand, the associated miospores with acritarchs indicate that a variety of spore-bearing plants grew on the adjacent land masses or islands of a shallow-water sea.

Biostratigraphy and Age Relationship of the Geirud Formation

A total of 40 surface samples were selected for miospore and acritarch taxa from the Geirud Formation. Fifty-nine morphotype species are identified from the studied samples that include 32 miospores (21 genera) and 27 acritarchs (21 genera). These have been plotted in Figure 2 and arranged in four spore and three acritarch assemblages. In

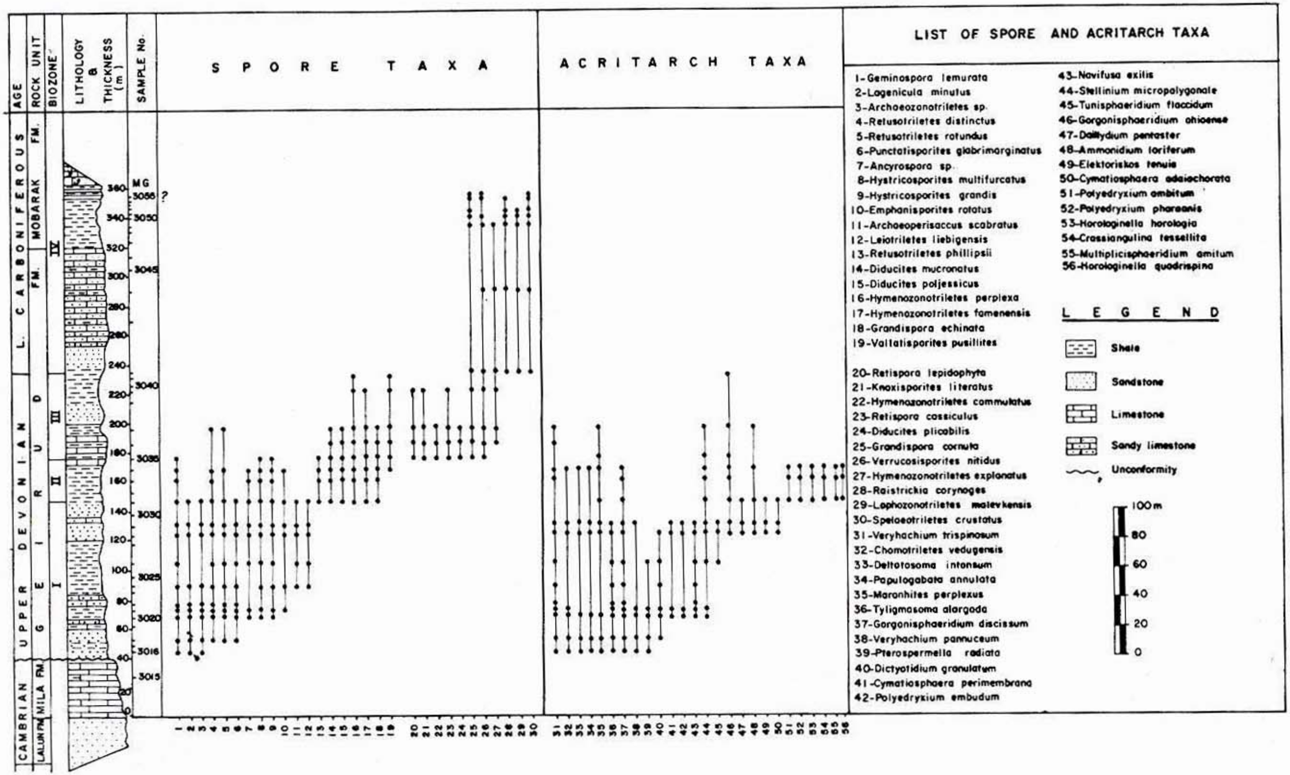

Figure 2. Stratigraphical distribution of spore and acritarch taxa in the Geirud Formation in the Imam-Zadeh Hashem area, northern Iran

(Author: M. Ghavidel-Syooki, 1993)

ascending stratigraphic order these are:

Miospore and Acritarch Assemblage Zone I

This assemblage appears in the lower part of the Geirud Formation and includes 106 metres of this rock unit (Fig. 2). Thirty-two morphotype species make their first appearance in this assemblage zone some of which are restricted to only the lower part of the Geirud Formation and others continue into the succeeding assemblage zones. This zone is marked by the appearance and disappearance of *Lagenicula minutus, Archaeoperisaccus scabratus, Archaeozonotriletes* sp., *Leiotriletes liebegensis, Tyligmasoma alargada, Veryhachium pannuceum, Pterospermella radiata, Cymatiosphaera perimembrana, Dictyotidium granulatum, Navifusa exilis, Tunisphaeridium flaccidum, Daillydium pentaster* and *Elektoriskos tenuis*. Other stratigraphically significant species are present in this assemblage zone and consist of *Geminospora lemurata, Chomotriletes vedugensis, Deltotosoma intonsum, Papulogabata annulata, Maranhites perplexus, Gorgonisphaeridium discissum, Hystricosporites multifurcatus* and *Stellinium micropolygonale*. The above-mentioned acritarch and miospore taxa suggest the Frasnian age for the lower part of the Geirud Formation. The strongest miospore and acritarch evidence for the Frasnian age comes from the association of *Chomotriletes vedugensis, Cymatiosphaera perimembrana, Daillydium pentaster, Elektoriskos tenuis, Maranhites perplexus, Stellinium micropolygonale, Deltotosoma intonsum, Papulogabata annulata, Tunisphaeridium flaccdium, Navifusa exilis, Gorgonisphaeridium discissum, Lagenicula minutus, Archaeoperisaccus scabratus, Archaeozonotriletes* sp., and *Hystricosporites multifucatus*. So far, the above-mentioned acritarch and miospore species have been recorded from Frasnian deposits of Western Australia [3, 35], Frasnian of Saudi Arabia [17], Frasnian of southern and northern Iran [23, 14, 15], Frasnian of Russia [30], Frasnian of North America [39, 46] and Frasnian of North Africa [9, 36, 28].

Miospore and Acritarch Assemblage Zone II

The assemblage zone II occurs just above zone I and represents a thickness of 30 metres of the Geirud Formation. This assemblage is characterized by the presence of some acritarch species such as *Polyedryxium ambitum, Polyedryxium pharaonis, Horologinella horologia, Horologinella quadrispina, Crassiangulina tessellita* and *Multiplicisphaeridium amitum*. Some miospore species also make their first appearance in this zone including: *Diducites mucronatus, Diducites poljessicus, Hymenozonotriletes perplexa, Hymenozonotriletes famenensis, Grandispora echinata* and *Retusotriletes phillipsii*. This assemblage zone has a number of morphotype species in common with the assemblage zone I especially, *Chomotriletes vedugensis, Deltotosoma intonsum*, and *Papulogabata annulata* (Fig. 2). Based on the above-mentioned miospore and acritarch species, the Late Frasnian-Early Famennian is suggested for this thickness of the Geirud Formation. Since both Frasnian and Famennian species are present in this interval, this assemblage probably indicates a transitional zone between the Frasnian and Famennian stages. The strongest miospore and acritarch evidence for the Late Frasnian-Early Famennian age comes from the association of *Horologinella horologia, Horologinella quadrispina, Crassiangulina tessellita, Chomotriletes vedugensis, Diducites mucronatus, Diducites poljessicus, Hymenozonotriletes perplexa*, and *Grandispore echinata*. So far, these have been recorded from Late Frasnian-Early Famennian of North Africa [19, 20, 33] Late Frasnian-Early Famennian of Western Australia [34] and Late Frasnian-Early Famennian of Iran [8, 14, 15]. The age assignment of this assemblage is the same as the brachiopod zone *Ptychomaletoechia elburzensis* that suggests Late Frasnian-Early Famennian for a part of the lower Geirud Formation [26].

Miospore and Acritarch Assemblage Zone III

This assemblage immediately begins above zone II and covers a thickness of 60 metres of the Geirud Formation. This zone is recognized by the appearance and disappearance of a number of distinctive species such as *Retispora lepidophyta, Knoxisporites literatus, Vallatisporites pusillites, Hymenozonotriletes commutatus, Retispora cassiculus (H. cassiculus)* and *Diducites plicabilis*. This assemblage has some species in common with succeeding zones (Fig. 2). Based on the above-mentioned miospore species, the Late Famennian (Strunian) is suggested for this interval of the Geirud Formation. The strongest miospore evidence for the Late Famennian age comes from the association of *Retispora lepidophyta, Vallatisporites pusillites, Grandispora echinata, Retispora cassiculus, Grandispore cornuta*, and *Hymenozonotriletes explanatus*. So far, these have been recorded from the Late Famennian strata of Western Australia [34], Late Famennian of Europe [18, 22, 40], Late Famennian of Iran [8, 14, 15], Late Famennian of North Africa [33, 9, 36, 28] and Late Famennian of Russia [30]. This assemblage zone is equivalent to the brachiopod zone *Productella* sp., which suggests Late Famennian for this part of the Geirud Formation in the type section area [26].

Miospore Assemblage Zone IV

This assemblage includes 48 metres of the upper part of the Geirud Formation and continues into the basal part of the Mobarak Formation (Fig. 2). It is marked by the appearance of *Raistrickia corynoges, Lophozonotriletes malevkensis* and *Spelaeotriletes crustatus*. The above-mentioned species are associated with *Hymenozonotriletes explanatus, Verrucosisporites nitidus,* and *Grandispora cornuta*, which make their first appearance in the assemblage zone III (Fig. 2). Based on these species, the Lower Tournaisian is suggested for the upper part of the Geirud and basal part of the Mobarak Formations. The strongest evidence for the Lower Tournaisian comes from the miospore species of *Lophozonotriletes malevkensis, Raistrickia corynoges, Spelaeotriletes crustatus*, and associated forms. These have been recorded so far from the Lower Tournaisian of Europe [18, 22, 41, 42], Lower Tournaisian of Western Australia [34], Lower Tournaisian of North Africa [33, 9, 36, 28] and Lower Tournaisian of Iran [8, 15]. This miospore assemblage zone is equivalent to the brachiopod zone *Rossirhynchus adamantinus* which suggests the Lower Tournaisian age for the upper part of the Geirud Formation in the type section area (Geirud village) in Central Alborz Range.

Discussion of Palynological Data

In the last decades, considerable attention has been given to the Upper Devonian-Lower Carboniferous deposits for palynological data. This has resulted in numerous publications introducing palynomorph assemblages from the Upper Devonian-Lower Carboniferous strata. From amongst these publications, those which were in close agreement with assemblages of the Geirud Formation were selected and a comparison was carried out, the results of which are documented in Tables 3 and 4. As has been shown in Table 3, most of the acritarch species of the Geirud Formation are the same as those of the Upper Devonian of North America [39, 44, 46], the Upper Devonian of Western Australia [35] and the Upper Devonian of North Africa [33, 9, 36, 28]. This implies an appreciable degree of cosmopolitanism for the acritarch taxa. The cosmopolitan acritarch species consists of *Chomotriletes vedugensis, Cymatiosphaera perimembrana, Cymatiosphaera adaiachorata, Veryhachium trispinosum, Stellinium micropolygonale, Veryhachium pannuceum, Multiplicisphaeridium amitum, Maranhites perplexus, Pterospermella radiata, Polyedryxium pharaonis, Polyedryxium embudum, Polyedryxium ambitum,* and *Daillydium pentaster*. In addition to the above-mentioned acritarch taxa, the following acritarch species have been recorded only from the Upper Devonian of Western Australia, southern and northern Iran and North Africa: *Papulogabata annulata, Deltotosoma intonsum, Gorgonisphaeridium discissum, Dictyotidium granulatum, Elektoriskos tenuis, Hologinella horologia, Horologinella quadrispina,* and *Crassiangulina tessellita*. Among the above-mentioned acritarch taxa, the three species *Horologinella horologia, Horologinella quadrispina,* and *Crassiangulina tessellita* have been recorded only from North Africa, the rest of them can be found in Iran and Australia also. The presence of these species in the Geirud Formation reveals that northern and southern Iran, North Africa and Western Australia along the southern shore of the Tethys Sea were probably at a similar palaeolatitude during the Upper Devonian time.

Likewise, the spore assemblages of the Geirud Formation were compared with those of Upper Devonian-Lower Carboniferous of northern and southern Iran [23, 8, 14, 15], Upper Devonian of Western Australia [3, 5, 34], Upper Devonian-Lower Carboniferous of North Africa [33, 9, 36, 28], and Upper Devonian-Lower Carboniferous of Europe [27, 42, 41, 22, 18, 40]. As documented in Table 4, except for species *Lagenicula minutus* which is only found in the Geirud Formation, the rest of the miospore species have been recorded from Western Australia, North America, North Africa and Europe. From Table 4, which shows the comparison of miospores, the spore assemblages of the Geirud Formation are more similar to those of the Upper Devonian-Lower Carboniferous of Europe and North Africa than North America and Western Australia. The similarities and differences may be simply due to either a lack of described Upper Devonian-Lower Carboniferous miospore assemblages or the use of a different nomenclature for the same species by the palynologists of North America and Western Australia. However, among the miospores of the Geirud Formation, two miospore species are more important than the others, these are *Archaeoperisaccus scabratus* and *Retispora lepidophyta*. The species *Archaeoperisaccus scabratus* is restricted to the Frasnian stage of a number of localities around the palaeoequatorial belt of the southern and northern hemispheres. Likewise, the species *Retispora lepidophyta* has been recorded, only from the Famennian stage, and is distributed around the palaeoequatorial belt. This belt stretches from Timan

Table 3. Comparison of Geirud Formation acritarch assemblages with other published Upper Devonian acritarch assemblages

List of acritarch taxa in this study	S & N Iran	Australia	N. Africa	N. America	Europe
	Kimyai, 1972, 1979 Coquel *et al.*, 1977 Ghavidel-Syooki, 1988, 1992	Playford & Dring, 1981 Playford, 1981	Vauguestaine, 1985 Coquel & Moreau-Benoit, 1986 Rahmani-Antari, 1990 Moreau-Benoit *et al.*, 1993	Staplin, 1961 Wicander & Loeblich, 1977 Wicander & Wood, 1981 Wicander & Playford, 1985	Downie, 1984
G. ohioense	+	-	+	-	-
G. discissum	+	+	-	-	-
V. trispinosum	+	+	+	+	+
S. micropolygonale	+	+	+	+	+
M. perplexus	-	-	-	+	-
N. exilis	+	+	-	-	-
C. vedugensis	+	+	+		+
D. intonsum	+	+	+	+	-
A. loriferum	+	-	-	-	+
D. pentaster	-	+	+	-	+
P. annulata	+	+	+	+	-
C. perimembrana	+	+	+	-	+
D. granulatum	+	+	-	+	-
T. flaccidum	+	+	-	-	-
P. ambitum	+	+	-	-	+
T. alargada	-	+	+	+	-
H. horologia	-	-	+	+	-
H. quadrispina	-	-	+	-	-
C. tessellita	+	-	+	-	-
P. radiata	-	-	-	-	-
P. pharaonis	+	+	+	+	-
M. amitum	+	-	-	+	-
E. tenuis	-	+	+	+	-
U. sp.	-	-	+	-	-
C. adaiochorata	-	-	-	-	-
V. pannuceum	+	-	-	+	-
P. embudum	+	+	+	+	-
				+	-

in Western Russia through the islands of the Arctic archipelago of Canada to Alaska. The presence of these two cosmopolitan species in the Geirud Formation suggests a warm condition for the Central Alborz Range around the palaeoequatorial belt during the Upper Devonian time, since they have been recorded only from the lower palaeolatitude in the southern and northern hemispheres.

All morphotype species of the Geirud Formation are shown for their relative frequencies in Tables 1 and 2. As shown in these tables, 25 species are very rare, 8 species rare and 27 species range from being common to abundant. Based on the total count of specimens, the acritarchs and the miospores comprise 48% and 52%, respectively. The high percentage of acritarchs in the Geirud Formation suggests a shallow

Table 4. Comparison of Geirud Formation miospore assemblages with other published Upper Devonian-Lower Carboniferous assemblages

List of miospore taxa in this paper	S & N Iran	Australia	N. Africa	N. America	Europe
	Kimyai, 1972, 1979 Coquel *et al.*, 1977 Ghavidel-Syooki, 1988, 1992	Balme, 1962, 1992 Balme & Hassel, 1962 Playford, 1976	Streel, 1985 Coquel & Moreau-Benoit, 1986 Rahmani-Antari, 1990 Moreau-Benoit *et al.*, 1993	Winslow, 1962 McGregor, 1967, 1970, 1980 Chi & Hills, 1976 Wicander & Playford, 1985	Kiggs, 1975 Turner *et al.*, 1989 Keegan, 1977 Van Veen, 1980 Kohoziak & Streel, 1980, 1981 Van der Zwan, 1980
R. lepidophyta	+	+	+	+	+
G. lemurata	+	+	+	+	+
D. mucronatus	-	-	-	-	+
G. cornuta	-	-	-	-	+
R. rotundus	+	+	+	+	+
R. distinctus	+	+	+	+	+
H. perplexa	+	+	-	-	-
L. minutus	+	-	-	-	-
S. crustatus	-	-	+	-	+
G. echinata	-	-	+	-	+
V. nitidus	-	+	+	-	+
E. rotatus	+	+	+	+	+
H. famenensis	-	-	+	-	+
H. grandis	-	-	-	+	+
H. explanatus	+	+	+	-	+
A. sp.	+	+	+	+	+
K. literatus	+	+	+	-	+
V. pusillites	+	+	+	-	+
D. poljessicus	-	-	-	-	+
R. corynoges	-	-	=	-	+
H. multifurcatus	-	-	-	-	+
R. phillipsii	+	-	-	+	-
A. scabratus	-	-	-	+	-
H. commutatus	-	-	-	-	+
L. malevkensis	-	-	-	-	+
A. sp.	+	+	+	+	+
P. glabrimarginatus	+	+	+	+	-
R. cassiculus	-	-	+	-	+
L. liebigensis	-	+	-	-	-
C. sp.	+	+	+	+	+

marine environment which covered the Central Alborz Range during the Upper Devonian epoch. On the other hand, the high amount of miospores in the Geirud Formation indicates that a variety of spore-bearing plants grew on the adjacent land masses and were transported into the shallow-marine basin.

Conclusion

The following results can be derived from the palynological study of the Geirud Formation in the Imam-Zadeh Hashem area, Central Alborz Range, northern Iran.

a) There is close similarity between the acritarchs and miospores of the Geirud Formation and those reported from North Africa, Western Australia, North America, and Europe. This may indicate the use of Upper Devonian morphotype species for intercontinental correlation.

b) Four miospore and three acritarch assemblages were established in the Geirud Formation. Zones I

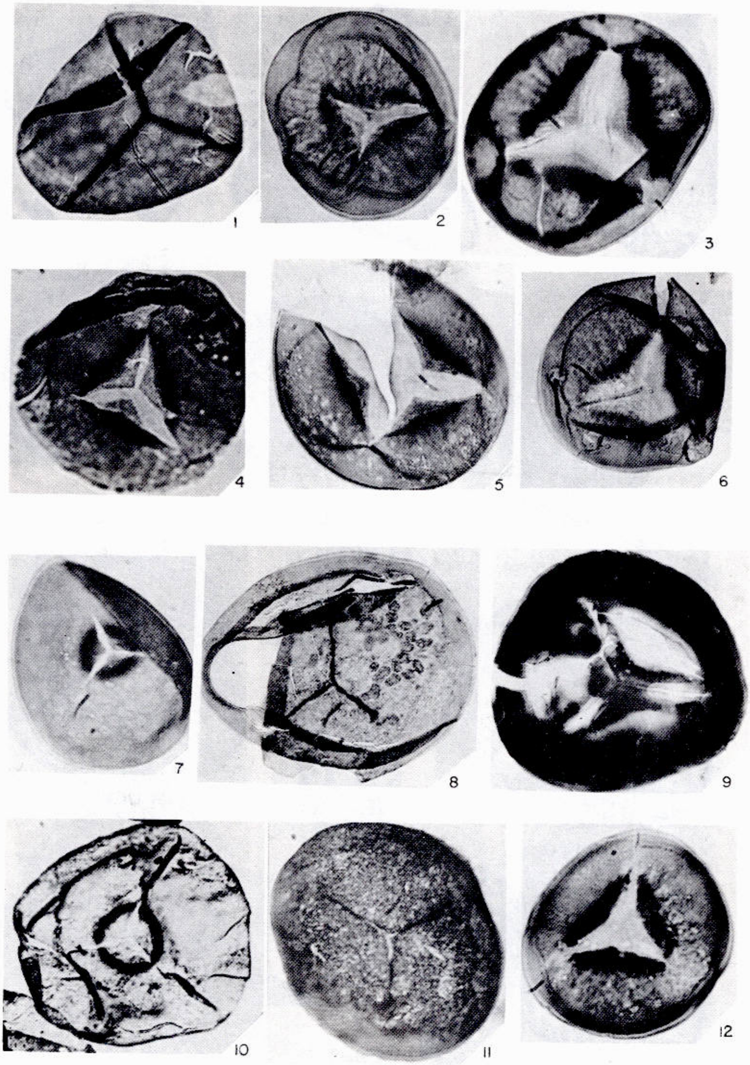

Plate 1
Magnifications: Figs. 1-6 & 8-12, 1200x and Fig. 7, 750X

Fig. 1. *Leiotriletes liebigensis* Hodjson, 1968.
Figs. 2-3. *Retusotriletes phillipsii* Clendening, Eames & Wood, 1980.
Figs. 4-6. *Retusotriletes distinctus* Richardson, 1965.
Figs. 7, 10&12. *Retusotriletes rotundus* Streel (Streel), 1967.
Fig. 8. *Punctatisporites glabrimarginatus* Owens, 1971.
Fig. 9. *Knoxisporites literatus* (Waltz), Playford, 1963.
Fig. 11. *Geminospora lemurata* Blame, 1962.

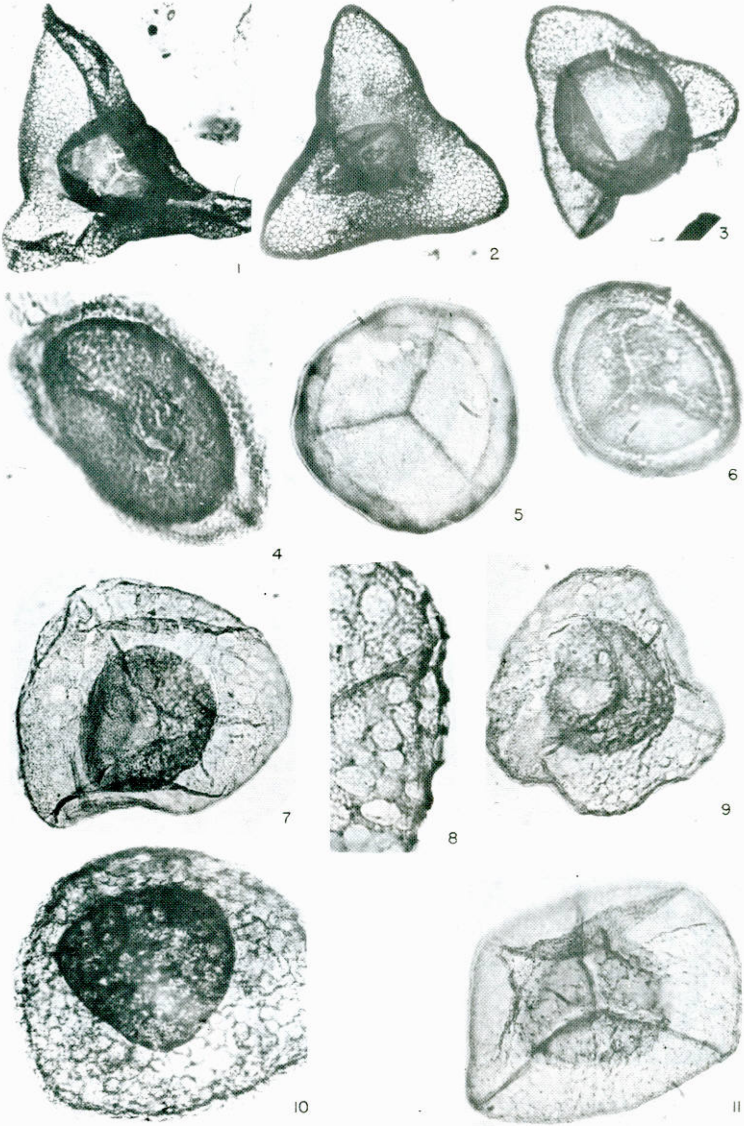

Plate 2
Magnifications: Figs. 1-3 x350 and Figs. 4-11, 1200X

Figs. 1-3. *Lagenicula minutus* Kimyai, 1979.
Fig. 4. *Archaeoperisaccus scabratus* Owens, 1971.
Figs. 5-6. *Geminospora lemurata* Balme, 1962.
Figs. 7,9 & 11. *Retispora lepidophyta* (Kedo) Playford, 1967.
Fig. 8. Sculptural detail of *Retispora lepidophyta*.
Fig. 10. *Retispora cassiculus* (Higgs, 1975) Comb. nov.

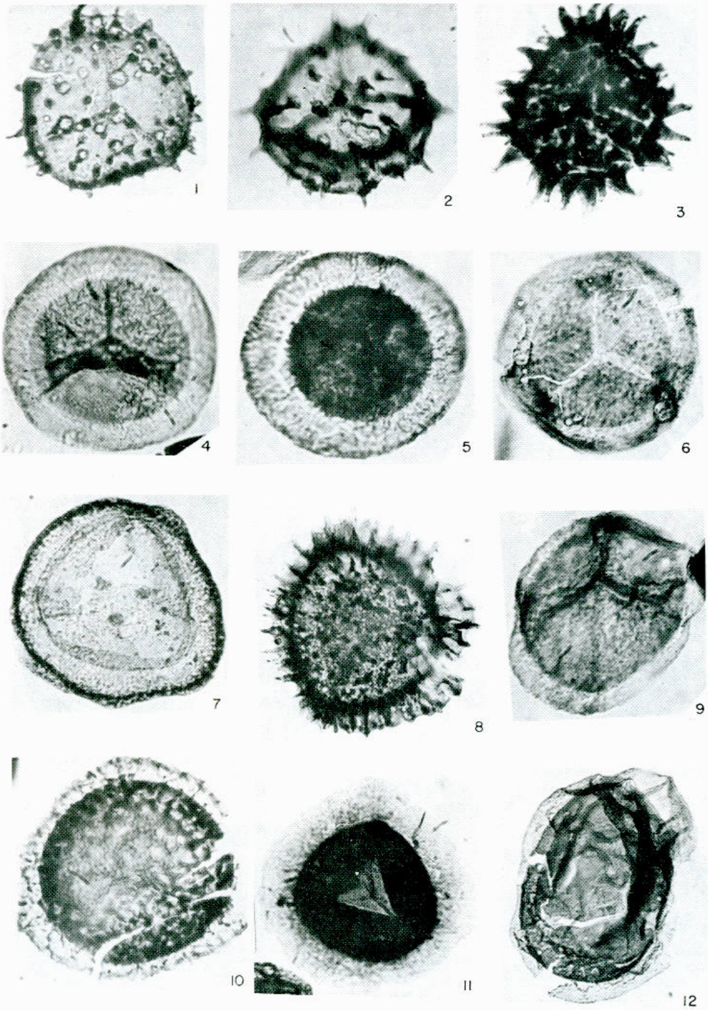

Plate 3
All magnification, 1200X

Figs. 1-2. *Grandispora cornuta* Higgs, 1975.
Fig. 3. *Raistrickia corynoges* Sullivan, 1964.
Figs. 4-5. *Diducites mucronatus* (Kedo) Van Veen, 1981.
Figs. 6-7. *Diducites poljessicus* (Kedo) Van Veen, 1981.
Fig. 8. *Hymenozonotriletes explanatus* (Luber) Kedo, 1963.
Fig. 9. *Diducites plicabilis* (Kedo) Van Veen, 1981.
Fig. 10. *Grandispora* sp.
Fig. 11. *Hymenozonotriletes commutatus* Naumova, 1953.
Fig. 12. *Hymenozonotriletes perplexa* Balme & Hassel, 1962.

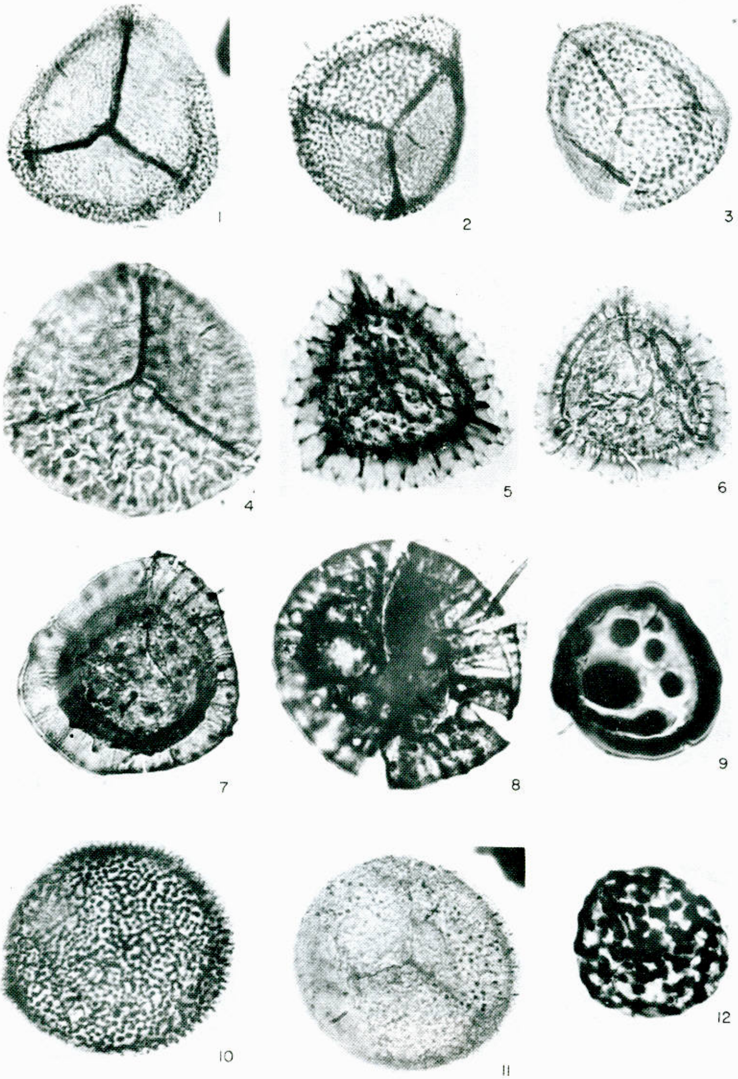

Plate 4
All magnification, 1200X

Figs. 1-3. *Spelaeotriletes crustatus* Higgs, 1975.
Fig. 4. *Hymenozonotriletes famenensis* Naumova, 1953.
Figs. 5-6. *Vallatisporites pusillites* (Kedo) Dolby & Neves, 1970.
Fig. 7. *Grandispora echinata* Hacquebard, 1957.
Fig. 8. *Emphanisporites rotatus* McGregor, 1961.
Fig. 9. *Lophozonotriletes malevkensis* Naumova, 1953.
Figs. 10-11. *Cymbosporites* sp.
Fig. 12. *Verrucosisporites nitidus* (Naumova) Playford, 1964.

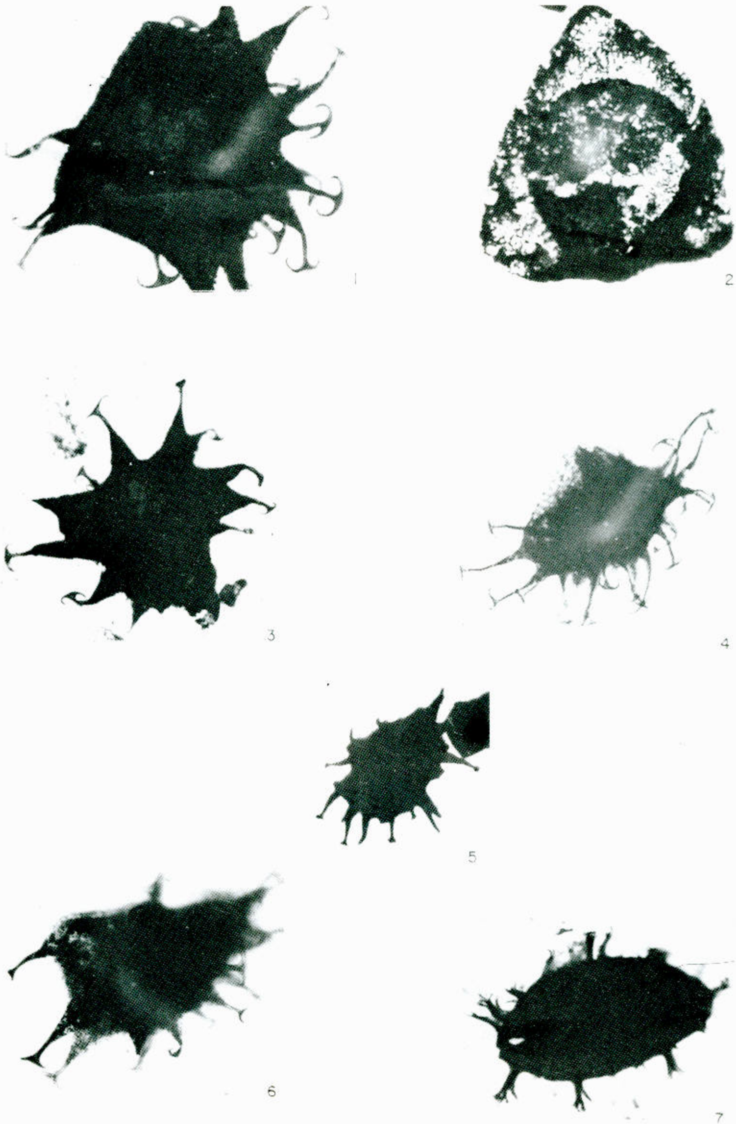

Plate 5

Magnifications: Figs. 1 & 3-6, 750X and Figs. 2 & 7, 1200X

Fig. 1. *Hystricosporites grandis* Owens, 1971.
Fig. 2. *Archaeozonotriletes* sp.
Figs. 3 & 4. *Hystricosporites grandis* Owens, 1971.
Fig. 5. *Hystricosporites multifurcatus* (Winslow) Mortimer & Chaloner, 1967.
Fig. 6. *Ancyrospora* sp.
Fig. 7. *Umbellasphaeridium* sp.

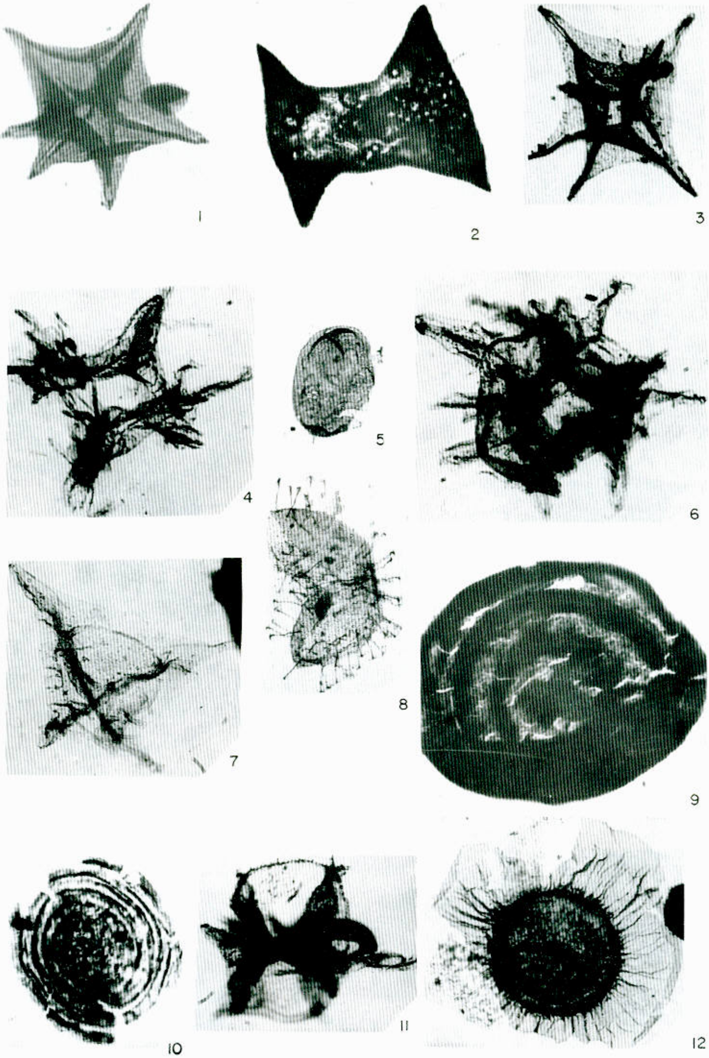

Plate 6
All magnification 1200X

Figs. 1 & 3. *Stellinium micropolygonale* (Stockmans & Williere) Playford, 1977.
Fig. 2. *Horologinella quadrispina* Jardine *et al.*, 1972.
Fig. 4. *Polyedryxium embudum* Cramer, 1964.
Fig. 5. *Navifusa exilis* Playford, 1981.
Fig. 6. *Polyedryxium ambitum* Wicander & Wood, 1981.
Figs. 7 & 11. *Polyedryxium pharaonis* Deunff, 1954.
Fig. 8. *Tunisphaeridium flaccidum* Playford, 1981.
Fig. 9. *Papulogabata annulata* Playford, 1981.
Fig. 10. *Chomotriletes vedugensis* Naumova, 1953.
Fig. 12. *Pterospermella radiata* Wicander, 1974.

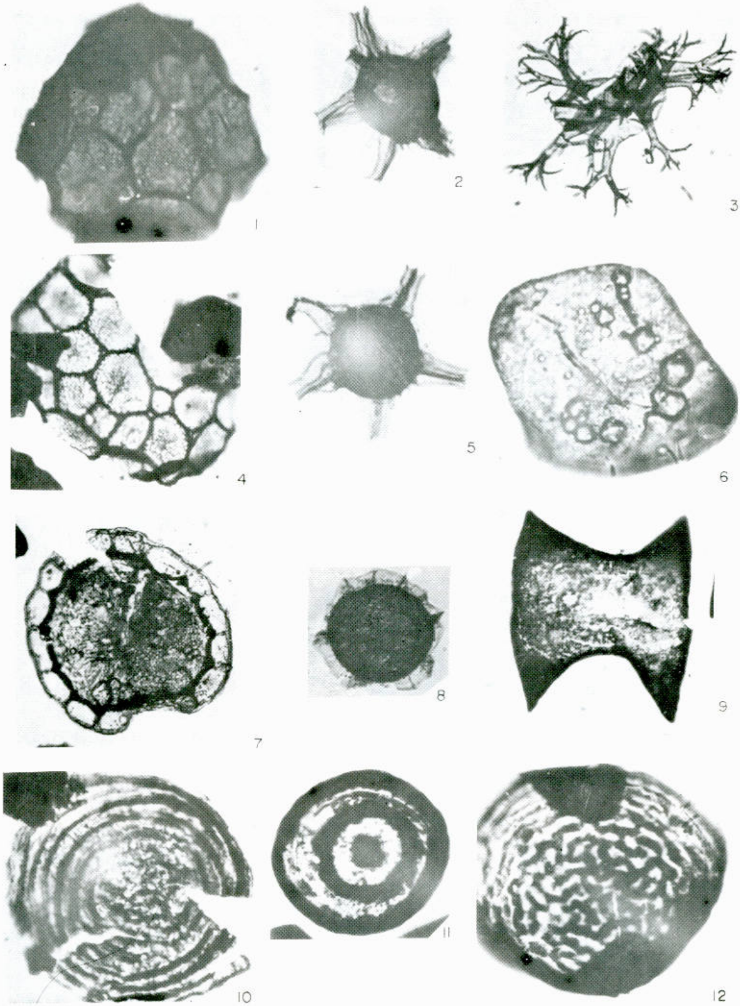

Plate 7
All magnification 1200X

Fig. 1. *Dictyotidium granulatum* Playford, 1981.
Figs. 2 & 5. *Daillydium pentaster* (Staplin) Playford, 1981.
Fig. 3. *Multiplicisphaeridium amitum* Wicander & Loeblich, 1977.
Fig. 4. *Cymatiosphaera adaiochorata* Wicander, 1974.
Fig. 6. *Horologinella horologia* (Staplin) Jardine *et al.*, 1972.
Fig. 7. *Maranhites perplexus* Wicander & Playford, 1985.
Fig. 8. *Cymatiosphaera perimembrana* Staplin, 1962.
Figs. 10 & 12. *Chomotriletes vedugensis* Naumova, 1953.
Fig. 11. *Papulogabata annulata* Playford, 1981.

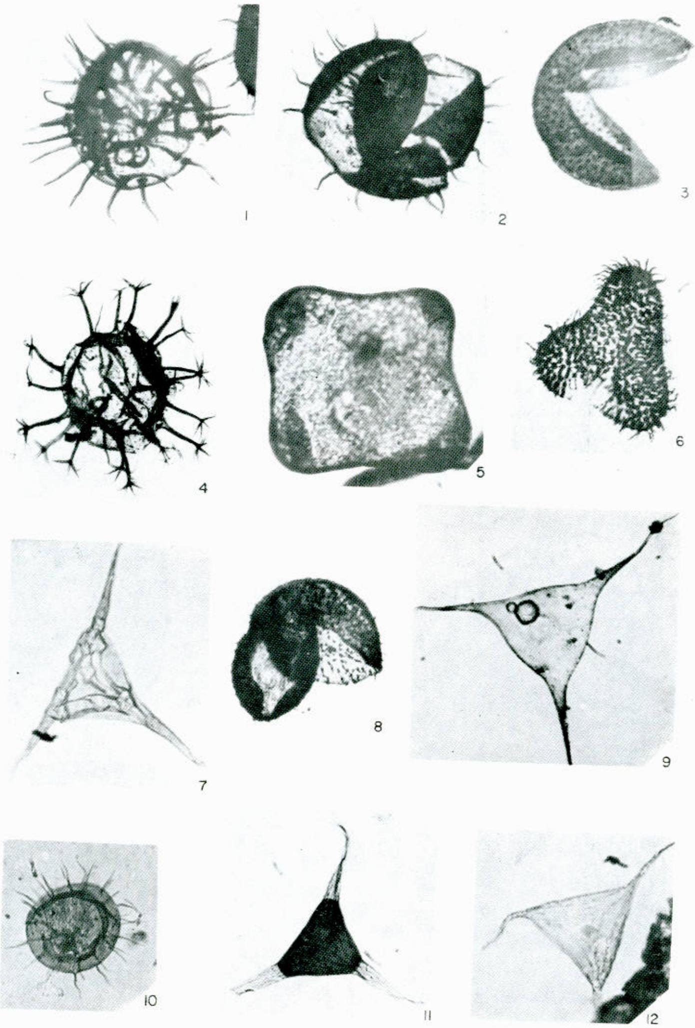

Plate 8
All magnification 1200X

Figs. 1-2. *Gorgonisphaeridium ohioense* (Winslow) Wicander, 1974.
Figs. 3 & 8. *Gorgonisphaeridium discissum* Playford, 1981.
Fig. 4. *Ammonidium loriferum* (Deunff) Lister, 1970.
Fig. 5. *Crassiangulina tessellita* Jardine *et al.*, 1972.
Fig. 6. *Deltotosoma intonsum* Playford, 1981.
Figs. 7 & 12. *Veryhachium pannuceum* Wicander & Loeblich, 1977.
Fig. 9. *Veryhachium trispinosum* (Eisenack) Deunff, 1964.
Fig. 10. *Elektoriskos tenuis*, Playford, 1981.
Fig. 11. *Tyligmasoma alargada* (Cramer) Playford, 1977.

through III represent Upper Devonian (Frasnian-Famennian) for the lower and middle part of the Geirud Formation. Zone IV suggests Lower Tournaisian for the upper part of the Geirud Formation and basal part of the Mobarak Formation. This is consistent with age assignment of the Geirud Formation in the type locality (Geirud village), based on brachiopods.

c) Among the acritarch taxa of the Geirud Formation, the following species have been reported only from North Africa, Western Australia and southern and northern Iran: *Deltotosoma intonsum, Papulogabata annulata, Elektoriskos tenuis, Horologinella horologia, Horologinella quadrispina* and *Crassiangulina tessellita.* The presence of the above-mentioned taxa suggests that Africa, Australia and Iran along the southern shore of the Tethys sea were at similar palaeolatitude during the Upper Devonian epoch.

d) The presence of abundant acritarch in the Geirud Formation reveals a shallow-marine environment which covered the Central Alborz Range during the Upper Devonian epoch. On the other hand, the presence of abundant miospores in the Geirud Formation indicates that a variety of spore-bearing plants grew in the vicinity of the shallow-marine basin.

e) The presence of *Archaeoperisaccus* and *Retispora* in the Geirud Formation indicates a warm tropical condition for the Upper Devonian of Iran. This suggests that Iran was located around the palaeoequatorial belt which stretched from Timan in Western Russia through the Arctic archipelago of Canada to Alaska.

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References

1. Allen, K. C. Lower and Middle Devonian spores of North and Central Vestspitsbergen. *Palaeontology,* **8**, (4), 687-748, (1965).
2. Assereto, R. Paleozoic Formations in Central Elburz, Iran (preliminary note). *Rev. Ital. Pal. Strat, LXIX*, 4, 503-543, (1963).
3. Balme, B. E. Upper Devonian (Frasnian) spores from the Carnarvon Basin, Western Australia. *Palaeobotanist*, **9**, (1-2), 1-10, (1962).
4. Balme, B. E. and Hassell, C. W. Upper Devonian spores from the Canning Basin, Western Australia. *Micropaleontology,* **8**, (1) 1-28, (1962).
5. Balme, B. E. Miospores from the Late Devonian (Early Frasnian) strata, Carnarvon Basin, Western Australia. *Palaeontolographica Abt. B.*, **209**, 109-166, (1988).
6. Bozorgnia, F. *Paleozoic foraminifera biostratigraphy of Central and East Alborz Mountains, Iran.* National Iranian Oil Company, Geological Laboratories Publication, (4), 167 pp., (1973).
7. Clendening, J. A. Eames, L. E. and Wood, G. D., *Retusotriletes phillipsii* n. sp., A potential Upper Devonian guide palynomorph. *Palynology,* **4**, 15-22, (1980).
8. Coquel, R. *et al.* Palynologie du Devonien superiur et du Carbonifere Inferieur dans Elburz Oriental. *Rev. de Micropaleontologie*, **20**, (2), 59-71, (1977).
9. Coquel, R. et Moreau-Bonoit, A. Strunian and Tournaisian spores of Western Libya. *Ibid.,* **29**, (1), 17-43, (1986).
10. Dolby, G. and Neves, R. Palynological evidence concerning the Devonian-Carboniferous boundary in the Mendips, England. Cogr. Internat. Strat. Geol. Carb., 6th. Sheffield (1967), C. R., **2**, 631-646, (1970).
11. Gaetani, M. The geology of the Upper Jajrud and Lar valleys, North Iran. II *Palaeontology Riv. Ital. Pal. Strat.*, **73**, (3), 679-770, (1965).
12. Ghavidel-Syooki, M. Palynological study and age determination of the Faraghan Formation of southeastern Iran. *Journal of Science*, University of Tehran, **21**, (3/4), 41-56, (1984).
13. Ghavidel-Syooki, M. Palynological study of Faraghan Formation in Kuh-e-Gahkum, southeastern Iran. *Ibid.*, **15**, (1-2), 11-28, (1986).
14. Ghavidel-Syooki, M. Palynostratigraphy and palaeoecology of the Faraghan Formation of southeastern Iran. Ph.D. dissertation, Michigan State University U. S. A., 279 pp., (1988).
15. Ghavidel-Syooki, M. First palynological record from Devonian Strata in eastern Alborz Range. 8th International Palynological Congress, Aix-en-Province, Abstract book, p. 52, (1992).
16. Hacquebard, P. A., Plant spores in coal from the Horton group (Mississipian) of Nova Scotia. *Micropaleontology,* **3**, (4), 301-324, (1957).
17. Hemer, D. O. and Nygreen, P. W. Devonian palynology of Saudi Arabia. *Rev. Palaeobot. Palynol.*, **5**, (1/4), 51-61, (1967).
18. Higgs, K. Upper Devonian and Lower Carboniferous miospore assemblage from Hook-Head country, Wexford Ireland. *Micropaleontology,* **21**, (4), 393-416, (1975).
19. Jardine, S. *et al.*, Acritarchs du Silurien terminal et du

Devonien du Sahara algerien. Comptes, Rendus du 7e Congres International de Stratigraphie et de Geologie du Carbonifere, **1**, 295-310, (1972).

20. Jardine, S. *et al.*, Distribution stratigraphique des acritarches dans le paleozoic du Sahara algerien. *Rev. Palaeobot. Palynol.*, **18**, (1-2), 99-129, (1974).
21. Kedo, G. I. Spores of the Tournaisian stage of the Pripiat Depression and their stratigraphical significance. *Akad. Nauk. Belorusskoi S. S. R. Inst. Geol. Nauk. Palaeontologiyai Stratigrafiya B. S. S. R.*, **4**, 3-131, (1963).
22. Keegan, J. B. Late Devonian and Early Carboniferous miospores from the Gallery Head-Leap Harbour region of southwest Ireland. *Pollen et Spores*, **19**, (4), 545-573, (1977).
23. Kimyai, A. Devonian plant microfossils from Central Elburz, Iran. *Ibid.*, **14**, (2), 187-201, (1972).
24. Kimyai, A. Devonian spores from Hassanakdar area, Iran. *Ibid.*, **21**, (4), 481-498, (1979).
25. Kushan, B. *Stratigraphy and trilobites fauna of the Mila Formation (Middle Cambrian-Ordovician) of the Alborz Range, North Iran.* Geol. Survey of Iran, Publication No. 46, 79 pp., (1978).
26. Lorenz, C. Die geologie des oberen Karadj-Tales (Zentral Alborz) Iran. Thesis, University of Zurich, 113 pp., (1964).
27. Loboziak, S. and Streel, M. Miospores in the middle-upper Frasnian to Famennian sediments, partly dated by conodonts (Boulonias France). *Rev. Palaeobot. Palynol.*, **34**, (1), 49-66, (1981).
28. Moreau-Benoit, A., Coquel, R. and Latreche, S. Etude palynologique du Devonien du Bassin d'Illizi (Sahara Orental Algerien). Approache biostratigraphique. *Geobios, Paleont. Stratig. Paleoecol.*, **26**, (fasc. 1), 1-31, (1993).
29. Mortimer, M. G. and Chaloner, W. G. Devonian megaspores from the Wyboston borehole, Bedfordshire, England. *Palaeontology*, **10**, (2), 189-213, (1967).
30. Naumova, S. N. Spores and pollen assemblage from the Upper Devonian of Russian platform and their stratigraphic significance. *TR. Inst. Geol Nauk. Akad. Nauk. U. S. S. R., Geol. Ser.*, **143**, (60), 1-204, (1953).
31. Owens, B. Miospores from the Middle and Early Upper Devonian rocks of the Western Queen Elizabeth Islands, Arctic archipelago. *Surv. Can.*, Paper 70-38, 1-157, (1971).
32. Owens, B., Gueinn, K. J. and Cameron, I. B. A Tournaisian miospore assemblage from the Altagoan Formation (Upper Calciferous Sandstone) Draperstown, Northern Ireland. *Pollen et Spores*, **19**, (2), 313-324, (1977).
33. Paris, F., Richardson, J. B., Riegel, W., Streel, M. and Vanguestaine, M. Devonian (Emsian-Famennian) palynomorphs from North-East Libya. *J. Micropalaeontology*, **4**, (1), 42-82, (1985).
34. Playford, G. Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin, Western Australia. *Palaeontographica Abt. B.*, **158**, 1-103, (1976).
35. Playford, G. and Dring, R. S. Late Devonian acritarchs from the Carnarvon Basin, Western Australia, Palaeont. A. S. S. special paper in palaeontology, No. 27, 41-63, (1981).
36. Rahmani-Antari, K. Etude palynologique et evaluation de l'indice d'alternation thermique du Paleozoique du forange Dot. 1 (bassin des Doukkala Centre-Quest marocain). *Rev. Palaeobot. Palynol.*, **66**, (3/4), 211-227, (1990).
37. Richardson, J. B. Middle Old Red Sandstone spore asssemblage from the Orcadian Basin, northeastern Scotland. *Palaeontol.*, **7**, (4), 559-605, (1965).
38. Sullivan, H. J. Tournaisian spore flora from the Cementstone group of Ayrshire Scotland. *Ibid.*, **11**, (1), 116-131, (1968).
39. Staplin, F. L. Reef-controlled distribution of Devonian microplankton in Alberta. *Ibid.*, **4**, 392-424, (1961).
40. Turner, N., Spinner, E. and Soanes, C. Further studies on the palynology of Upper Devonian-Lower Carboniferous transition strata of Burrington Combe, Somerset, England. *Pollen et Spores*, **31**, (3/4), 289-315, (1989).
41. Van Veen, P. M. Aspects of Late Devonian and Early Carboniferous palynology of southern Ireland. V. The change in composition of palynological assemblages at the Devonian-Carboniferous boundary. *Rev. Palaeobot. Palynol.*, **34**, (1), 67-97, (1981).
42. Van der Zwan, C. J. Aspects of Late Devonian and Early Carboniferous palynology of southern Ireland, III. Palynology of Devonian-Carboniferous transition sequences with special reference to the Bantry Bay area, Co. Cork. *Rev. Palaeobot. Palynol.*, **30**, (3/4), 165-286, (1980).
43. Wicander, E. R. Upper Devonian-Lower Mississipian acritarchs and Prasinophycean algae from Ohio, U. S. A. *Palaeontographica Abt. B.*, **148**, 2-43, (1974).
44. Wicander, E. R. and Loeblich, A. R. Organic-walled microphytoplankton and its stratigraphic significance from the Upper Devonian Antrim Shale, Indiana, U. S. A. *Ibid.*, **160**, 129-165, (1977).
45. Wicander, E. R. and Wood, G. D. Systematics and biostratigraphy of organic-walled microplankton from the Middle Devonian (Givetian) Silica Formation Ohio, U. S. A. *Am. Ass. Strat. Palynol.*, Contribution Series, **8**, 1-137, (1981).
46. Wicander, E. R. and Playford, G. Acritarchs and spores from the Upper Devonian Lime Creek Formation, Iowa, U. S. A. *Micropaleontology*, **3**, (2), 97-138, (1985).