# PALYNOSTRATIGRAPHY AND PALAEOBIOGEOGRAPHY OF LOWER PALAEOZOIC STRATA IN THE GHELLI AREA, NORTHEASTERN ALBORZ RANGE OF IRAN (KOPET-DAGH REGION)

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## Abstract

Acritarchs from the Lashkarak, Ghelli and Niur formations of the western part of Kuh-e-Saluk were examined to more precisely determine the stratigraphical age. This study was also undertaken to assess the palaeogeographic relationships of the northeastern Alborz Range to the Southern and Northern Hemispheres during the Palaeozoic interval represented by these formations. A total of 78 acritarch taxa were encountered. Four new species together with two species in open nomenclature are described: *Multiplicisphaeridium iranicum*, *Multiplicisphaeridium* sp., *Veryhachium membranispinum*, *Stelliferidium persicum*, *Leiofusa* sp., and *Estiastra iranicum*. The encountered acritarch species have been arranged in six ascending local stratigraphic Zones. Zones I-II occur in the Lashkarak Formation, suggesting an Early Ordovician age (Tremadoc-Arenig). Zones III-V are present in the Ghelli Formation, indicating a Mid and Late Ordovician age. Zone VI appears in the lower part of Niur Formation and suggests the Early Silurian age (Llandovery). The Early Ordovician acritarchs of the Lashkarak Formation were compared with those from other parts of world. This comparison indicates a broad similarity with those of the same age in northern Africa, southern Europe and southwestern China. This similarity suggests that the northeastern Alborz Ranges were part of the Peri-Gondwanan supercontinent during the Early Ordovician. The Mid to Late Ordovician and Early Silurian acritarch taxa were also compared with those of the same age from elsewhere. This comparison indicates a broad similarity with those of northern Africa, southern Europe, the Middle East and the United States. This similarity suggests that the Peri-Gondwanan palaeocontinent began to move toward the Northern Hemisphere palaeocontinent during the Mid and Late Ordovician and by the Silurian formed the supercontinent of Pangea. Diverse acritarch taxa in the Early Ordovician (Lashkarak Fm.), Mid and Late Ordovician (Ghelli Fm.) and Early Silurian strata (Niur Fm.) reveal a marine environment for each formation.

**Keywords:** Acritarchs; Biostratigraphy; Palaeobiogeography; Ordovician; Early Silurian; Kopet-Dagh region; Alborz Ranges; Northeastern Iran

## Introduction

A lower Palaeozoic sequence in the Ghelli area, northeastern Alborz Range (Kopet-Dagh region) yielded diverse and well-preserved acritarch assemblages. This study is directed toward developing palynological information from the Ordovician (Lashkarak and Ghelli formations) and Silurian sediments (Niur Formation) from the northeastern Alborz Range of Iran to aid in establishing the age relationships of the Lower Palaeozoic strata and resolve aspects of palaeogeography and

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depositional environments.

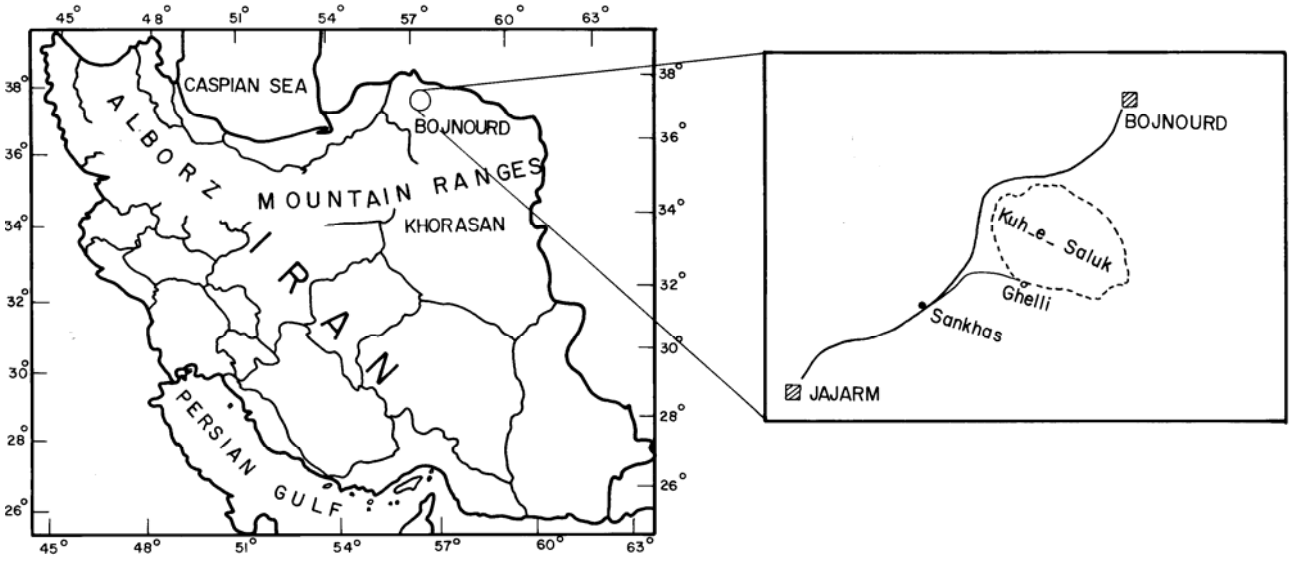
**Previous Studies**

The studied locality is called the Ghelli area which is located at the western part of Kuh-e-Saluk, approximately 55 km southwest of Bojnourd city (Text-Fig. 1). The road from Jajarm to Bojnourd is the main connection to the study area. The lower Palaeozoic strata in Kuh-e-Saluk have been divided in ascending order into the Mila, Lashkarak, Ghelli and Niur formations [1]. The studied area is part of northeastern Alborz range (Kopet-Dagh region) where these rock units extend towards southern and eastern parts of the Caspian Sea. The total thickness of the Lower Palaeozoic strata is 2141 m. The Mila Formation mainly consists of limestones with poorly preserved brachiopods and trilobite fragments. Based on stratigraphic position, it has been assigned to the Middle and Late Cambrian [1].

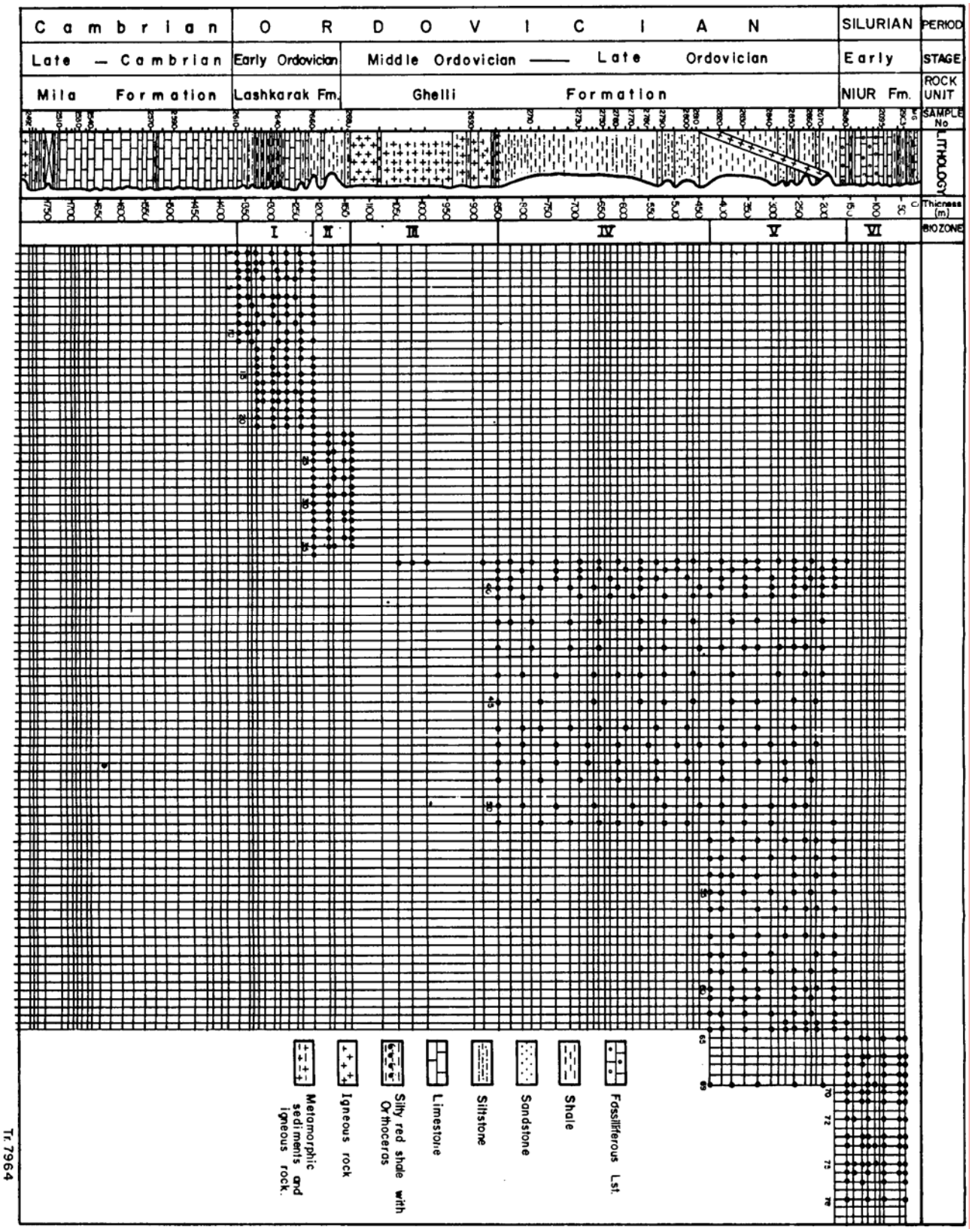
The lower contact of this formation is not clear, but its upper contact is conformable with the Lashkarak Formation. The Lashkarak Formation is 250 m thick and it consists of olive-grey shales and rubbly limestones. Both the lower and upper contacts of this formation are conformable with underlying and overlying formations. The Ghelli Formation has a thickness of 1140 m in the Ghelli area (type section). This formation mainly consists of dark-grey shales and grey-cream siltstones and sandstones. The basal and upper parts of this formation have been intruded by igneous rocks (sills and dikes). The lower and upper contacts of this formation are conformable with the Lashkarak Formation below and with the Niur Formation above. The Ghelli Formation contains Orthoceras, brachiopod fauna and trace fossils in some intervals (text-fig. 2), but no attention has been made to identify these. However, this formation has been assigned to the Late Ordovician based upon palynomorph taxa from a few samples near the top of formation [1]. The Niur formation is the youngest Lower Palaeozoic rock unit in the studied area and consists of fossiliferous limestones and shales (text-fig. 2). This formation has been assigned to the Silurian based on some brachiopod and coral species.

**Laboratory Techniques**

This palynological study was carried out on 200 surface samples from the Lashkarak, Ghelli and Niur formations. The field and laboratory descriptions of the samples have been plotted on a stratigraphic section (text-fig. 2). The code and number of each sample follows the policy of the National Iranian Oil Company. Fifty grams of sediments were randomly selected from each sample and treated in the palynological laboratory of the Exploration Department of the National Iranian Oil Company. Disaggregation of the rock samples was conducted using standard techniques. All slides used in this study are in the palaeontological collection of the Exploration Department of the National Iranian Oil Company, under sample numbers of MG-2611 to MG-2903.




**Text-Figure 1.** Location map of studied area.




**Text-Figure 2.** Stratigraphic distribution of selected acritarch taxa in the Lower Palaeozoic strata of Ghelli area, northeastern Iran (Kopet Dagh Region). List of recorded taxa (numbers refer to the corresponding columns on text-figure 2):

**Text-Figure 2. Continued**
1=*Ooidium rossicum*; 2=*Saharidia downiei*; 3=*Multiplicisphaeridium cervinacornium*; 4=*Michrystridium shinetonense*; 5=*Leiofusa simplex*; 6=*Datylofusa squama*; 7=*Vulcanisphaera cirrita*; 8=*Vulcanisphaera africana*; 9=*Vulcanisphaera britannica*; 10=*Acanthodiacrodium raia*; 11=*Lophosphaeridium torum*; 12=*Acanthodiacrodium angustum*; 13=*Baltisphaeridium crinitum*; 14=*Baltisphaeridium verutum*; 15=*Stelliferidium striatulum*; 16=*Goniosphaeridium piliferum*; 17=*Cymatiogalea elgassiensis*; 18=*Stelliferidium cortinulum*; 19=*Cymatiogalea bellicosa*; 20=*Stelliferidium persicum n. sp.*; 21=*Multiplicisphaeridium iranicum n. sp.*; 22=*Pirea dubia*; 23=*Athabascaella playfordii*; 24=*Pirea baculifera*; 25=*Peteinosphaeridium angustilaminae*; 26=*Ropaliophora palmata*; 27=*Cymatiogalea deunffii*; 28=*Peteinosphaeridium robustiramosum*; 29=*Peteinosphaeridium armatum*; 30=*Arbusculidium sp. aff A. filamentosum*; 31=*Marrocanium simplex*; 32=*Coryphidium bohemicum*; 33=*Coryphidium minutum*; 34=*Striatotheca principalis*; 35=*Acanthodiacrodium vavrdovae*; 36=*Arkonia virgata*; 37=*Veryhachium reductum*; 38=*Ordovicidium elegantulum*; 39=*Actinotodissus crassus*; 40=*Multiplicisphaeridium irregulare*; 41=*Multiplicisphaeridium bifurcatum*; 42=*Frankea hamulata*; 43=*Baltisphaeridium perclarum*; 44=*Baltisphaeridium longispinosum subsp. delicatum*; 45=*Dactylofusa spinata*; 46=*Navifusa ancepsipuncta*; 47=*Orthosphaeridium ternatum*; 48=*Orthosphaeridium octospinosum*; 49=*Orthosphaeridium chondrododora*; 50=*Orthosphaeridium insculptum*; 51=*Orthosphaeridium inflatum*; 52=*Dactylofusa anolota*; 53=*Leiofusa litotes*; 54=*Dactylofusa ctenista*; 55=*Disparifusa perryii*; 56=*Dactylofusa striata*; 57=*Leiofusa sp.*; 58=*Villosacapsula setosapellicula*; 59=*Veryhachium subglobosum*; 60=*Veryhachium hamii*; 61=*Multiplicisphaeridium* sp.; 62=*Veryhachium membranispinum n. sp.*; 63=*Eastiastra iranicum n. sp.*; 64=*Tunisphaeridium eisenackii*; 65=*Multiplicisphaeridium arbusculum*; 66=*Dactylofusa striatifera*; 67=*Leiofusa blanca*; 68=*Diexallophasis denticulata*; 69=*Tunisphaeridium tentaculiferum*; 70=*Leiofusa bispinosoides*; 71=*Dilatisphaera willierae*; 72=*Tunisphaeridium caudatum*; 73=*Visbysphaera brevifurcata*; 74=*Geron guerillerus*; 75=*Dactylofusa estillis*; 76=*Visbysphaera microspinosa*; 77=*Helosphaeridium clavispinulosum*; 78=*Multiplicisphaeridium neaghae*.

**Systematic Palaeontology**

In the systematic part of this paper new acritarch species are described only when a minimum 20 specimens are available. The new species and those in open nomenclature are alphabetically arranged under the informal Incertae Sedis group Acritarcha Evitt, 1963.

Group Acritarcha Evitt, 1963
Genus *Estiastra* Eisenack, 1959
Type species: *Estiastra magna* Eisenack, 1959.

*Estiastra iranicum* n. sp.
Pl. 5, Fig. 1

Derivation of name: Named from Iran, where this species was found.

Type stratum: *Estiastra iranicum* n. sp. From surface materials of Ghelli Formation with Ashgill age.

Holotype: MG-2872, (2872, slide 1), Pl. 5, Fig. 1.

Description. Cyst is stellate in outline. Maximum diameter from process tip to process tip is 77 µm. Vesicle 52 µm in length and they differ from one to another in length and width. Surface of processes are smooth with freely connection to vesicle.

Remark: *Estiastra iranicum* n. sp. is very similar to *Estiastra stellata* Loeblich (1970) from the Middle Silurian Maplewood Shale of the United States, but it differs from *E. stellata* in its larger size and lack of grana ornamentation on the surface of processes. *Estiastra iranicum* n. sp. is also similar to *Estiastra granulata* of Downie (1963) from the Middle Silurian of England, but differs from *E. granulata* in the number of processes and lack of grana on the surface of processes. This new species is only found in the Late Ordovician sediments of Iran where it is common on the upper part of Ghelli Formation.

Genus *Leiofusa* Eisenack, 1938.
Type species: *Leiofusa fusiformis* Eisenack, 1934 ex Eisenack, 1938 a
*Leiofusa* sp.
Pl. 4, Fig. 4.

Description. Cyst is fusiform in outline with one long spine at one pole and two short spines at the other pole. Total length 172.5 µm and width of 6 µm. Vesicle is smooth. The species is rare and it is confined to the Late Ordovician strata (Ghelli Formation) in the studied area.

Genus *Multiplicisphaeridium* Staplin, emend. Staplin *et al.*, 1965.
Type species: *Multiplicisphaeridium ramispinosum* Staplin, 1961
P. 411, Pl. 48, Figs. 23A-E.
*Multiplicisphaeridium iranicum* n. sp.
Pl. 1, Figs. 2 and 6.

Derivation of name: Named from Iran, where this species is found.

Type stratum: *Multiplicisphaeridium iranicum* n. sp. From surface samples of lower part of Lashkarak Formation, northeastern Alborz Range of Iran.

Holotype: Sample number of MG-2615, Lashkarak Fm., Pl. 1, Figs. 2&6

Description. Vesicle is circular to subcircular in outline with diameter of 22 µm. Processes are homomorphic, hollow with free connection to vesicle

and total length of 10 µm. The bases of processes are broad and distally branched two times. Excystment structure is not evident.

Remark: *Multiplicisphaeridium iranicum* n. sp. is very similar to *multiplicis phaeridium* sp. 1. recorded from the Early Ordovician sediments of Algerian Sahara (Vecoli, 1996).

The Iranian new species differs from that of the Algerian Sahara in having a smaller size and number of processes. The species of *Multiplicisphaeridium iranicum* n. sp. is also similar to *Multiplicisphaeridium radicosum* of the Sylvan Shale of the United States (Loeblich Jr., 1969) but the Iranian new species differs from *M. radicosum* in having smaller size and smaller number of processes. This species is common in the lower part of Lashkarak Formation (Early Ordovician) in the studied area.

*Multiplicisphaeridium* sp.
Pl. 5, Fig. 10

Description. Vesicle is triangular in outline with diameter of 35 µm; vesicle is smooth with convex sides; three long processes are freely connected to vesicle and form a dense tree-like crown. Total length of each process is 23 µm. This species is very rare and it is confined to the upper part of Ghelli Formation (Late Ordovician).

Genus *Stelliferidium* Deunff, Gorka & Rauscher, 1974.
Type species: *Stelliferidium striatulum* (Vavrdova) Deunff, Gorka & Rauscher, 1974.

*Stelliferidium persicum* n. sp.
Pl. 1, Fig. 4

Derivation of name: Named derived from Persia, the ancient name of Iran.

Type stratum: Surface materials from the Lashkarak Formation of northeastern Alborz Range of Iran.

Holotype: MG-2666, Lashkarak Fm., Pl. 1, Fig. 4.

Description. Vesicle is spherical to subspherical shape with 35-40 µm diameter and large polar opening. Eighty homomorphic processes with total length of 6 µm.

The processes are slender and distributed on the whole vesicle surface; each process divides at distal end into two equal parts. This species is abundant and it is confined to the Lashkarak Formation.

Remark: This species is very similar to *Stelliferidium* sp. 2. from the Early Ordovician strata in NE Germany (Servias & Molyneux, 1997), but it differs from *Stelliferidium* sp. 2. of NE Germany in having more processes.

Genus *Veryhachium* Deunff ex Downie, 1959.
Type species: *Veryhachium trisulcum* (Deunff 1951) Deunff, 1959.

*Veryhachium membranispinum* n. sp.
Pl. 3, Figs. 10 & 14.

Derivation of name: Name derived from the translucent membrane.

Type stratum: Surface materials from type section of Ghelli Formation in northeastern Alborz Range of Iran.

Holotype: MG-2850, Ghelli Formation, Pl 3, Figs. 10 & 14.

Description. Vesicle is subquadratic shape in outline with concave sides. A translucent membrane covers the vesicle. In some specimens, the membrane is removed during the laboratory preparation. Four simple, long processes arise from the vesicle corners and taper distally; the processes have broad bases and merge from the vesicle without sharp contact; no exystment opening was observed. This species is similar to *Veryhachium triangulatum* Le Herisse, *et al.* (1995) but the Iranian new species differs from the latter in having a translucent membrane.

**Stratigraphical Palynology**

The objectives of this study are to summarize the stratigraphical range of assemblages and species that occur in the Lashkarak, Ghelli and Niur formations and to compare these data with zonal assemblages that have been recorded from other parts of the world. A total of 78 acritarch taxa were encountered and their distribution is plotted on text fig. 2, and selected acritarch species are shown on plates 1-6. Six local acritarch assemblages were established and are discussed below in ascending stratigraphic order.

**Acritarch Assemblage Zone I**

This zone begins at the lowermost part of the Lashkarak Formation and extends through a thickness of 170 m of this rock unit (text-fig. 2). This zone is characterized by presence of diagnostic acritarch taxa, including *Ooidium rossicum, Saharidia downiei, Multiplicisphaeridium cervinacornuum, Michrystridium shinetonense, Leiofusa simplex, Dactylofusa squama, Vulcanisphaera cirrita, Vulcanisphaera africana, Vulcanisphaera Britannica, Acanthodiacrodium raia, Lophosphaeridium torum, Acanthodiacrodium angustum, Baltisphaeridium crinitum, Baltisphaeridium verutum, Stelliferidium striatulum, Goniosphaeridium piliferum, Cymatiogalea elgassiensis, Stelliferidium cortinulum, Cymatiogalea bellicosa, Stelliferidium persicum* and *Multiplicisphaeridium iranicum.*

This acritarch assemblage zone is considered to belong to the Early Ordovician (Tremadoc) based on

their stratigraphic occurrence in England [13,50], France [51], Belgium [42], Germany [52,55], Norway [62], Czech Republic [60], Algeria [4,5,11,28,61], Sweden [2], Morocco [17], Jordan [30], Argentina [47] and northern and southern Iran [19-22].

**Acritarch Assemblage Zone II**

This zone occurs in the upper part of Lashkarak Formation and extends through a thickness of 80 m (text-fig. 2). This one is marked by appearance of *Pirea dubia, Athabascaella playfordii, Pirea baculifera, Peteinosphaeridium angustilaminae, Ropaliophora palmata, Cymatiogalea deunffii, Peteinosphaeridium robustiramosum, Peteinosphaeridium armatum, Arbusculidium sp. aff A. filamentosum, Marrocanium simplex, Coryphidium bohemicum, Coryphidium minutum, Striatitheca principalis, Acanthodiacrodium vavrdovae* and *Arkonia virgata*. The acritarch species of this assemblage zone indicate the recorded so far from the Arenigian strata in Europe [3,13,15,16,55,60] China [34,39,58], Argentina [47], Algeria [28], Morocco [8-10] and northern and southern Iran [19,21,22].

**Acritarch Assemblage Zone III**

This zone corresponds to the beds which are barren or poor from palynomorph taxa. This zone is made of igneous rock (sills) which is associated with sedimentary layers (text-fig. 2). This interval of Ghelli Formation is 350 m thick. All sedimentary layers of this thickness contain brachiopod fauna which have been identified at species level, but from palynomorph species, only *Veryhachium reductun* were identified.

This species continues into the succeeding zones. This part of Ghelli Formation has been assigned to Middle Ordovician based on brachiopod species [1] and stratigraphical position.

**Acritarch Assemblage Zone IV**

This zone includes a thickness of 480 m from the Ghelli Formation. The basal part of this zone is marked by one meter of red shale with abundant Orthoceras (text-fig. 2).

This acritarch assemblage zone is characterized by occurrence of *Ordovicidium elegantulum, Actinotodissus crassus, Multiplicisphaeridium irregulare, Multiplicisphaeridium bifurcatum, Frankea hamulata, Baltisphaeridium perclarum, Baltisphaeridium longispinosum subsp. delicatum, Dactylofusa spinata, Navifusa ancepsipuncta, Orthosphaeridium ternatum, Orthosphaeridium octospinosum, Orthosphaeridium chondrododora, Orthosphaeridium insculptum* and *Orthosphaeridium inflatum*. All acritarch species which appear in this zone continue into the succeeding zone (text-fig. 2). The above-mentioned acritarch taxa have been recorded from the Late Ordovician sediments in the United States [37-39], England [46,49,59], Morocco [17], Algeria [28], Libya [45] southern Iran [22], Jordan [30] and Saudi Arabia [26]. Therefore, based on palynological evidence, this part of Ghelli Formation is assigned to the Late Ordovician (Caradoc) age.

**Acritarch Assemblage Zone V**

This zone is marked by appearance of additional Late Ordovician acritarch taxa to supplement those recorded in Zone IV, e.g. *Dactylofusa anolota, Leiofusa litotes, Dactylofusa ctenista, Disparifusa perryi, Dactylofusa striata, Leiofusa sp., Villosacapsula setosapellicula, Veryhachium subglobosum, Veryhachium hamii, Multiplicisphaeridium sp., Veryhachium membranispinum, Estiastra iranicum, Tunisphaeridium eisenackii*, and *Diexallophasis denticulata*. This acritarch assemblage zone occurs in the upper part of Ghelli Formation and extends through a thickness of 310 m (text-fig. 2). The acritarch taxa encountered in this zone indicate the Late Ordovician (Ashgill age), by comparison with their previously recorded occurrence from the United States [37-39], Canada [27], Libya [45], Jordan [30], southern Iran [22], Saudi Arabia [26], southern Europe [59,60], Morocco, Algeria [28] and Sweden [31].

**Acritarch Assemblage Zone VI**

This zone begins at the base of Niur Formation and extends through a thickness of 85 m (text-fig. 2). This zone is characterized by presence of the Early Silurian index acritarch taxa, consisting of *Multiplicisphaeridium arbusculum, Dactylofusa striatifera, Leiofusa blanca, Tunisphaeridium tentaculiferum, Leiofusa bispinosoides, Dilatisphaera willierae, Tunisphaeridium caudatum, Visbysphaera brevifurcata, Geron guerillerus, Visbysphaera microspinosa, Helosphaeridium clavispinulosum, Multiplicisphaeridium neaghae* and *Dactylofusa estillis*. This acritarch assemblage zone is considered to be Early Silurian (Llandovery). This is based on acritarch taxa which have been recorded from the Llandovery strata in the United States [6,44], England [13,25], Norway [56], Sweden [33], Algeria [28], Libya [45], Jordan [30], Saudi Arabia [26] and southern Iran [22]. In this study, the basal part of Niur Formation and the uppermost part of Ghelli Formation (Late Ordovician) were investigated for changes of acritarch populations at the boundary of Late Ordovician and Early Silurian strata. The investigation indicates that all Ordovician acritarch taxa disappear in the boundary of Ghelli Formation (Late Ordovician) and new acritarch species appear in the Niur Formation (Early Silurian).

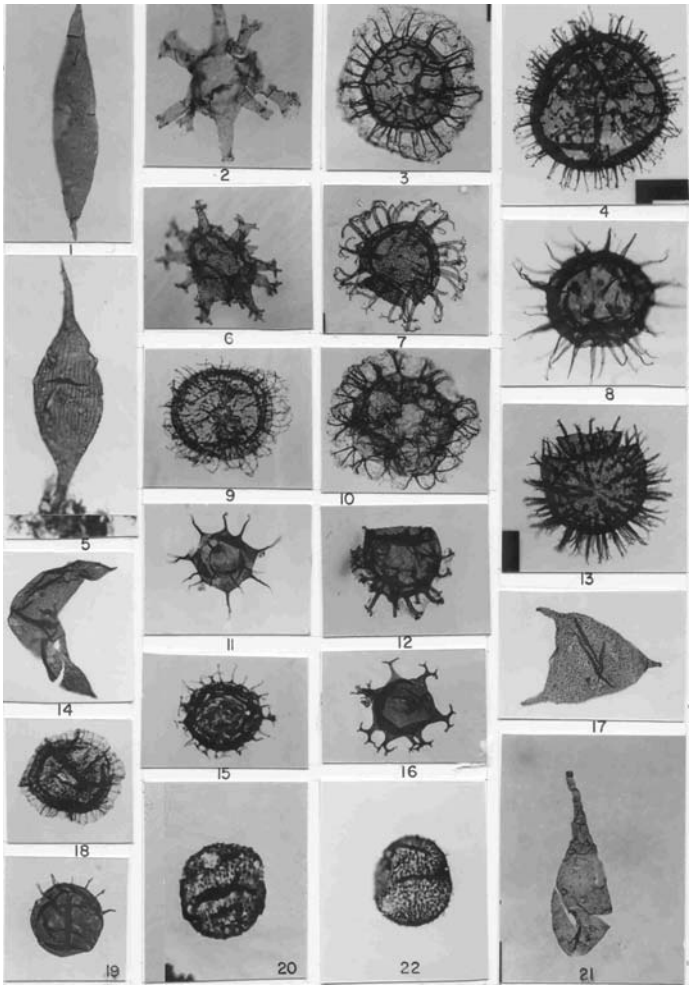



**Plate 1** (All figures magnified ×1000)
Fig. 1. *Leiofusa simplex* (Combaz, 1967). Martin, 1975
Fig. 2. *Multiplicisphaeridium iranicum n. sp.*
Fig. 3. *Vulcanisphaera cirrita* Rasul, 1976.
Fig. 4. *Stelliferidium persicum* n. sp.
Fig. 5. *Dactylofusa squama* (Deunff, 1961) Combaz, Lange and Pansart, 1967.
Fig. 6. *Multiplicisphaeridium iranicum* n. sp.
Fig. 7. *Stelliferidium striatulum* (Vavrdova, 1970) Deunff, Gorka and Rauscher, 1974.
Fig. 8. *Baltisphaeridium verutum* Vecoli, 1996.
Fig. 9. *Baltisphaeridium crinitum* Martin, 1978.
Fig. 10. *Vulcanisphaera africana* Deunff, 1961.
Fig. 11. *Micrhystridium shinetonese* Downie, 1958.
Fig. 12. *Cymatiogalea bellicosa* Deunff, 1961.
Fig. 13. *Stelliferidium cortinulum* (Deunff, 1961) Deunff, Gorka and Rauscher, 1974.
Fig. 14. *Dactylofusa squama* (Deunff, 1961) Comaz, Lange and Pansart, 1967.
Fig. 15. *Vulcanisphaera britannica* Rasul, 1974.
Fig. 16. *Multiplicisphaeridium cervinacornuum* Welsch, 1986.
Fig. 17. *Goniosphaeridium piliferum* (Martin, 1966) Eisenack, Cramer and Diez, 1973.
Fig. 18. *Cymatiogalea elgassiensis* Deunff, 1961.
Fig. 19. Ooidium rossicum Timofeev, 1957.
Fig. 20. *Lophosphaeridium torum* Rasul, 1979.
Fig. 21. *Pirea dubia* Vavrdova, 1972.
Fig. 22. *Acanthodiacrodium angustum* (Downie, 1958) Combaz, 1967.

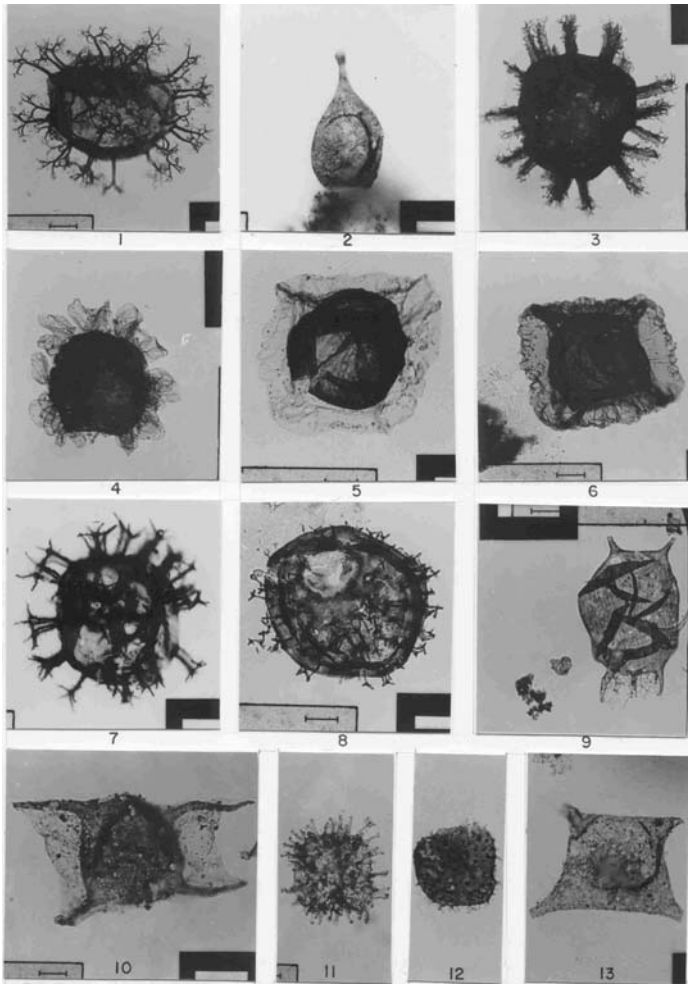



**Plate 2** (All figures magnified ×1000)
Fig. 1. *Athabascaella playfordii* Martin, 1984.
Fig. 2. *Pirea baculifera* Tongiorgi, Yin, Lei-Ming and Di Milia, 1995.
Fig. 3. *Peteinosphaeridium angustilamirae* Playford, Rebecai and Tongiorgi, 1995.
Fig. 4. *Ropaliophora palmata* (Combaz and Peniguel) emend. Playford and Martin, 1984.
Fig. 5 and 6. *Cymatiogalea deunffii* Jardine, Combaz, Magloire, Peniguel and Vachey, 1974.
Fig. 7. *Peteinosphaeridium robustiramosum* Tongiorgi, Yin, Lei-ming and Di Milia, 1995.
Fig. 8. *Peteinosphaeridium armatum* Tongiorgi, Yin, Lei-ming and Di Milia, 1995.
Fig. 9. *Arbusculidium* sp. aff. *A. filamentosum* (Vavrdova, 1965) Vavrdova, 1972.
Fig. 10. *Marrocanium simplex* Cramer, Kanes, Diez and Christopher, 1974.
Fig. 11. *Coryphidium bohemicum* Vavrdova, 1972.
Fig. 12. *Coryphidium minutum* Cramer and Diez, 1976.
Fig. 13. *Striatotheca principalis* Burmann, 1970.

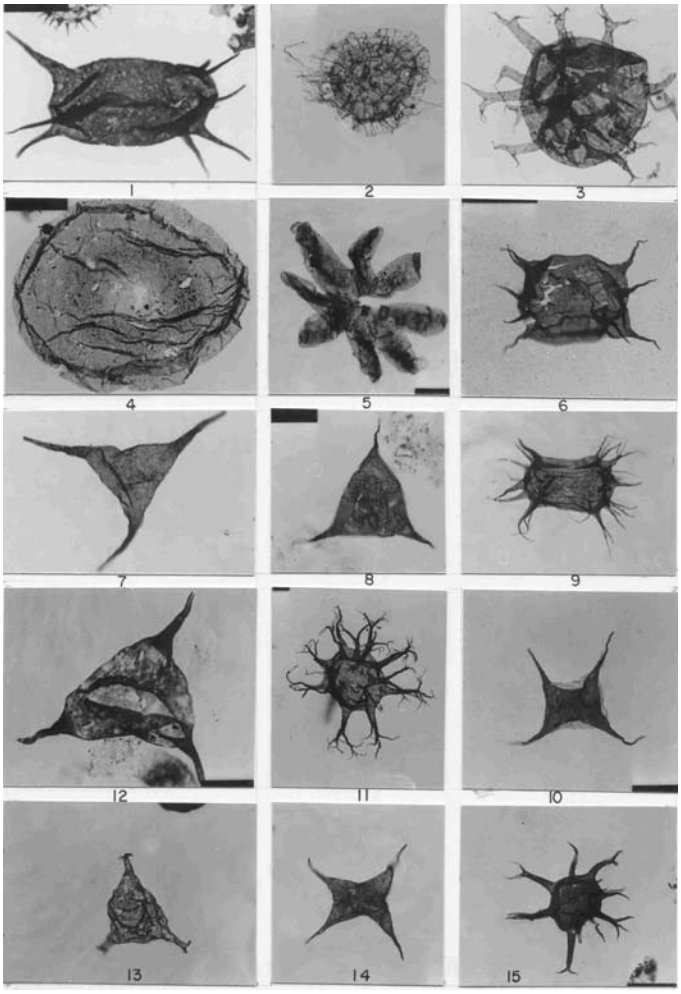



**Plate 3** (All figures magnified ×1000)
Fig. 1. *Acanthodiacrodium raia* (Deunff, 1961) Eisenack, Cramer and Diez, 1979.
Fig. 2. *Tunisphaeridium eisenackii* Loeblich Jr. and Tappan, 1978.
Fig. 3. *Ordovicidium elegantulum* Tappan and Loeblich Jr., 1971.
Fig. 4. *Saharidia downiei* Combaz, 1967.
Fig. 5. *Loebate coenobium* Wood and Miller, 1997.
Fig. 6. *Acanthodiacrodium vavrdovae* Cramer and Diez, 1977.
Fig. 7. *Arkonia virgata* Burmann, 1970.
Fig. 8. *Villosacapsula setosapellicula* (Loeblich Jr., 1970) Loeblich Jr. and Tappan, 1976.
Fig. 9. *Actinotodissus crassus* Loeblich Jr. and Tappan, 1976.
Fig. 10. *Veryhachium membranispinum* n. sp.
Fig. 11. *Multiplicisphaeridium irregulare* Staplin, Jansonius and Pocock, 1965.
Fig. 12. *Veryhachium reductum* (Deunff, 1959) Jekhowsky, 1961.
Fig. 13. *Frankea hamulata* Burmann, 1970.
Fig. 14. *Veryhachium membranispinum* n. sp.
Fig. 15. *Multiplicisphaeridium bifurcatum* Staplin, Jansonius and Pocock, 1965.

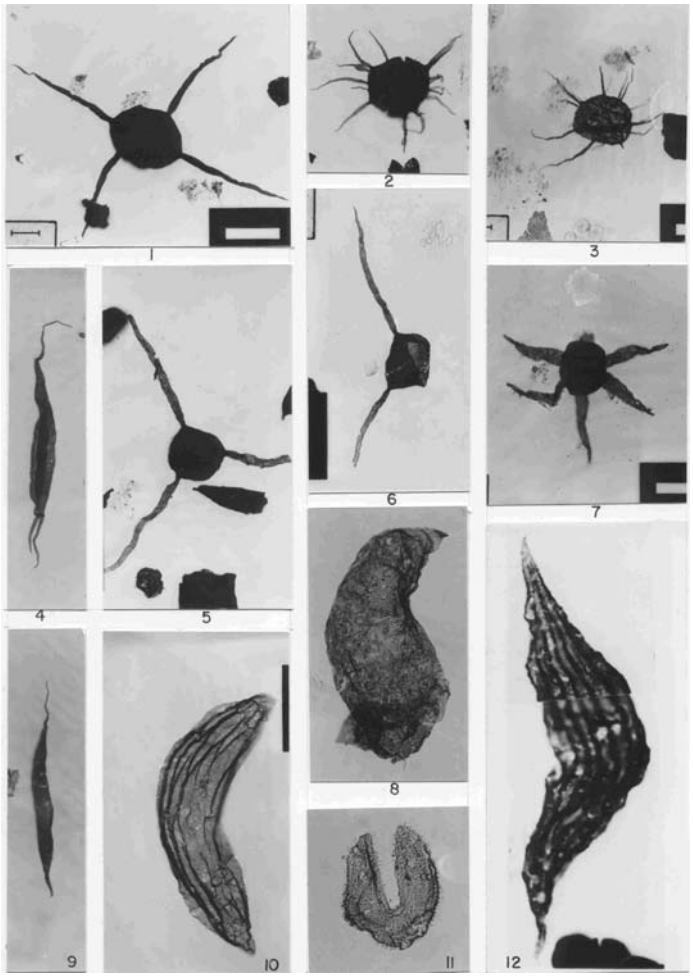



**Plate 4** (All figures magnified ×350 except where stated)
Fig. 1. *Orthosphaeridium chondrododora* Loeblich Jr. and Tappan, 1971.
Fig. 2. *Orthosphaeridium insculptum* Loeblich Jr., 1970.
Fig. 3. *Baltisphaeridium longispinosum subsp. delicatum* Turner, 1984.
Fig. 4. *Leiofusa* sp.
Fig. 5. *Orthosphaeridium ternatum* (Burmann, 1970) Eisenack, Cramer and Diez, 1976.
Fig. 6. *Orthosphaeridium inflatum* Loeblich Jr., 1970.
Fig. 7. *Baltisphaeridium perclarum* Loeblich Jr. and Tappan, 1976.
Fig. 8. *Dactylofusa sp.* aff. *D. anolota* (Loeblich Jr. and Tappan, 1976) Fensome, Williams, Barss, Freeman and Hill, 1990. ×1000.
Fig. 9. *Leiofusa litotes* Loeblich Jr. and Tappan, 1976. ×1000.
Fig. 10. *Dactylofusa ctenista* (Loeblich Jr. and Tappan, 1976) Fensome, Barss, Freeman and Hill, 1990. ×1000.
Fig. 11. *Disparifusa perryi* Loeblich Jr. and Tappan, 1976. ×1000.
Fig. 12. *Dactylofusa striata* (Staplin, Jansonius and Pocock, 1965) Fensome, Williams, Barss, Freeman and Hill, 1990. ×1000.

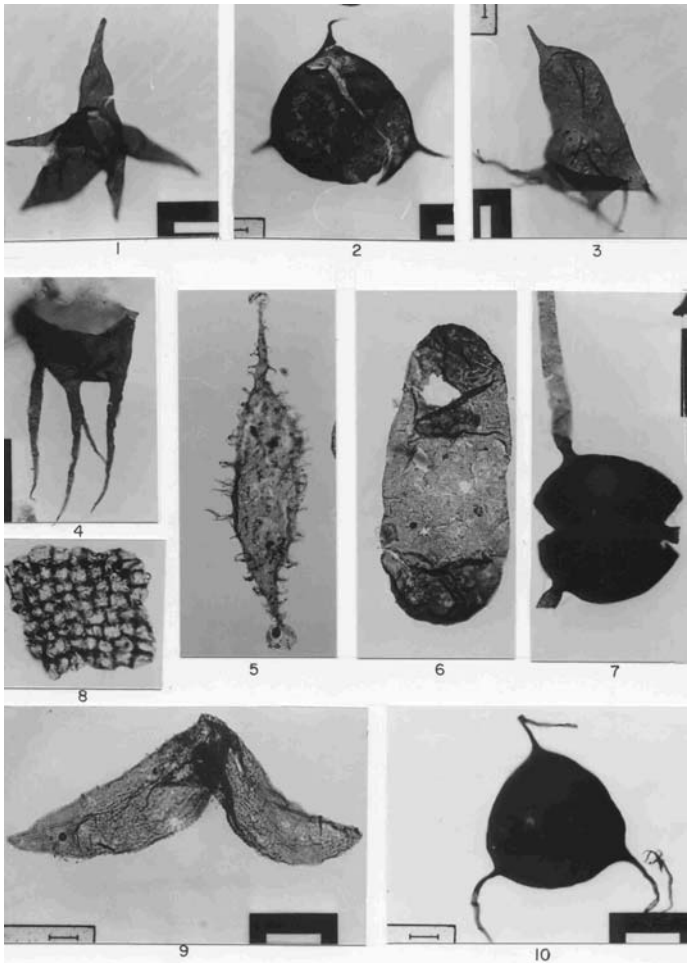



**Plate 5** (All figures magnified ×1000 except where stated)
Fig. 1. *Estiastra iranicum* n. sp.
Fig. 2. *Veryhachium subglobosum* Jardine, Combaz, Magloire, Peniguel and Vachey, 1974.
Fig. 3. *Veryhachium hamii* Loeblich Jr., 1970.
Fig. 4. *Orthosphaeridium octospinosum* Eisenack, 1968. ×350.
Fig. 5. *Dactylofusa spinata* (Staplin, Jansonius, Pocock, 1965) Fensome, Williams, Barss, Freeman and Hill, 1990.
Fig. 6. *Navifusa ancepsipuncta* Loeblich., 1970.
Fig. 7. *Orthosphaeridium ternatum* (Burmann, 1970), Eisenack, Cramer and Diez, 1976. ×350.
Fig. 8. *Planar coenobium* Wood and Miller, 1997.
Fig. 9. *Disprifusa perryi* Loeblich Jr. and Tapan, 1976.
Fig. 10. *Multiplicisphaeridium* sp.

## Conclusions

The Lashkarak, Ghelli and Niur formations yielded 78 acritarch taxa. These species have been arranged in six ascending local stratigraphic assemblage zones. Zones I-II are present in the Lashkarak Formation and suggest an early Ordovician (Tremadoc-Arenig) age for this rock unit. Zones III-V occur in the Ghelli formation and indicate a Mid and Late Ordovician age. Zone VI is present in the Niur Formation and reveals an Early Silurian (Llandovery) age for basal part of this Formation. Comparison of the Early Ordovician acritarch species indicates broad similarity with those of the same age from southern Europe, North Africa, southwestern China, Saudi Arabia and southern Iran. This similarity suggests that both northeastern and southern Iran were part of Peri-Gondwanan palaeo-continent, possibly positioned along the southern shore of Palaeo-Tethys Ocean. The acritarch taxa from the

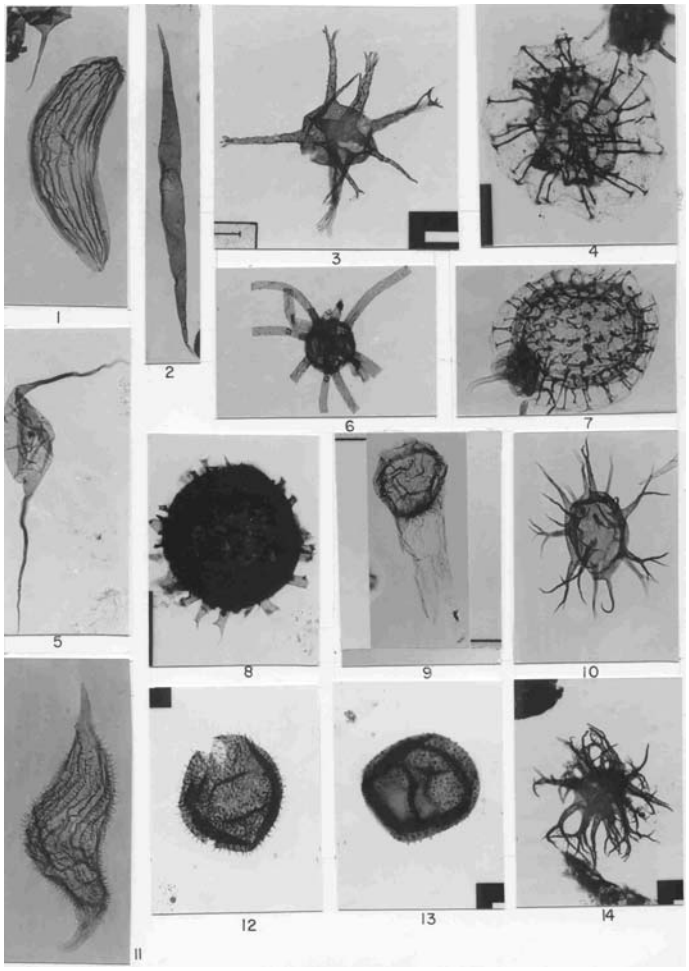



**Plate 6** (All figures magnified ×1000 except where stated)
Fig. 1. *Dactylofusa striatifera* (Cramer and Diez, 1972) Fensome, Williams, Barss, Freeman and Hill, 1990.
Fig. 2. *Leiofusa blanca* Cramer, 1964 (with striate microstructure). ×350.
Fig. 3. *Diexallophasis denticulata* (Stockmans and Wiliere) Loeblich Jr., 1970.
Fig. 4. *Tunisphaeridium tentaculiferum* (Martin, 1967) Cramer, 1970.
Fig. 5. *Leiofusa bispinosoides* Brito and Santos, 1965.
Fig. 6. *Dilatisphaera willierae* (Martin) Lister, 1970.
Fig. 7. *Tunisphaeridium caudatum* Deunff and Evitt, 1963.
Fig. 8. *Visbysphaera brevifurcata* (Eisenack) Le Herisse, 1989.
Fig. 9. *Geron guerillerus* (Cramer, 1967) emend. Cramer, 1969.
Fig. 10. *Multiplicisphaeridium arbusculum* Dorning, 1981.
Fig. 11. *Dactylofusa estillis* Cramer and Diez, 1972.
Fig. 12. *Visbysphaera microspinosa* (Eisenack) Hill, 1974.
Fig. 13. *Helosphaeridium clavispinulosum* Lister, 1970.
Fig.14. Multiplicisphaeridium neaghae Cramer, 1970.

Late Ordovician strata (Ghelli Fm.) reveal a similarity with those of Libya, Morocco, Algeria, Jordan, Saudi Arabia, southern Iran, Sweden, Germany, England and the United States. This supports the opinion that peri-Gondwanan palaeo-continent and the United States have occupied a similar palaeolatitude during the Late Ordovician. Likewise, the Early Silurian acritarch species have a very close similarity with those of the same age from the United States, North Africa and southern Europe. This similarity suggests that peri-Gondwanan palaeocontinent began to move towards the Baltic palaeocontinent during the Late Ordovician and by the Early Silurian formed part of the supercontinent of Pangea.

## Acknowledgements

The author expresses his sincere appreciation to the management of the National Iranian Oil Company for permission to publish this paper.

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