Iranian Int. J. Sci. ***4****(2), 2003, p. 181-207*

Palynostratigraphy and Paleogeoraphy of Lower Paleozoic Strata at Kuh-e-Boghou, Southwest of Kashmar City, at Eastern Central Iran

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(received: 3/6/2003 ; accepted: 16/9/2003)

Abstract

Acritarchs from the Shirgesht, Ghelli and Niur formations were used to determine the age of these rock units and to assess their paleogeographic importance. These formations yielded 55 palynomorph taxa (54 acritarch species and 1 cryptospore species) permitting the recognition of eight biozones (palynozones). The zones I - III represent the Early Ordovician (Tremadocian-Arenigian), zones IV-VI indicate Middle-Late Ordovician (Llanvirian-Ashgillian) and zone VII suggests the Early-Middle Silurian (Llandoverian- early Wenlockian). The presence of genera such as Arbusculidium, Striatotheca and Coryphidium in the Early Ordovician sediments of the Shirgesht Formation from the eastern Central Iran suggest, that the Iranian Platform was part of Peri-Gondwanan Paleo-continent, possibly along the southern shore of the Paleo- Tethys Ocean during the Early Ordovician .

Comparison of acritarch taxa from the Ghelli (Middle-Late Ordovician) and Niur (Early-Middle Silurian) formations with those from other parts of the world indicate broad similarity with those of the United States, Europe, North Africa and China. This similarity suggests that the Peri-Gondwanan Paleo-continent began moving northward during the Middle-Late Ordovician and by the Silurian formed part of the supercontinent Pangea. The diverse palynomorph taxa (acritarchs, chitinozoans and scolecodonts) in the Early Ordovician (Shirgesht Formation), Middle-Late Ordovician (Ghelli Formation) and Early-Middle Silurian (Niur Formation) strata indicate a marine depositional environment.

Keywords: *Acritarchs; Biostratigraphy; Palaeobiogeography; Ordovician; Silurian; Eastern Central Iran; Kashmar city; Kuh-e-Boghou*

Introduction

A lower Palaeozoic sequence in the eastern Iranian Platform yielded diverse and well-preserved acritarch assemblage. This study is directed toward developing palynological information from the Ordovician (Shirgesht and Ghelli formations) and Silurian (Niur Formation) strata, to aid establishing the age relationships of these rock units and resolve aspects of paleogeography of Shirgesht, Ghelli and Niur formations .

The paleogeography of these rock units is important to northern and southern Iran as well as to the other parts of the world .

Previous Works

The study area is called Kuh-e-Boghou, approximately 46 km southwest of Kashmar city at the eastern Central Iran (Fig. 1). The road from Mashhad to Kashmar is the main route into the region. This Palaeozoic sequence is 2230 m thick , and it was assigned to the Devonian period by Eftekhar-nejad, et al., 1976. Later on, this sequence was assigned to the Ordovician-Silurian periods based on palynological data by Ghavidel-Syooki's students (Alavi, 1996; Esmaili-suvary,1996; and Ruhizadeh, 1996). As a result, this sequence was divided, in ascending stratigraphic order into the Shirgesht, Ghelli and Niur formations by Ghavidel-Syooki (1998).

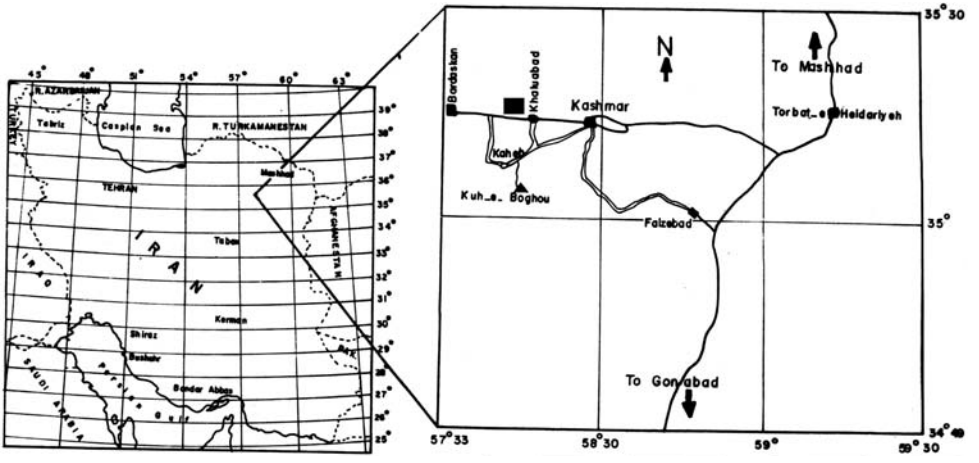

Figure 1 - Location map of Iranian major cities and connection of Kashmar city to the studied area.

The Shirgesht Formation is 700m thick and has a very distinctive sedimentary facies in eastern Central Iranian Basin. This formation consists mainly of dark-gray shales, siltstones and fine-grained sandstones (Fig. 2). In the study area, the Shirgesht Formation lacks marine fauna, but it contains abundant and well-preserved palynomorph taxa (acritarchs and chitinozoans). Therefore, based on palynomorph taxa, it has been assigned to the Early Ordovician (Ghavidel-Syooki, 1998). The Ghelli Formation has a thickness of 500m and consists mainly of olive-gray shale, micaceous siltstones, fine-grained sandstone, a limestone bed and a basaltic sill at the middle part .

A red silty shale with straight orthoceras occurs near the basal part of Ghelli Formation, but the rest of formation lacks macrofauna. Therefore, based on palynological data, it has been assigned to Middle-Late Ordovician (Alavi,1996; Ghavidel-Syooki,1998).

The Niur Formation is well-developed in Kuh-e-Boghou where is 1030m thick. This formation comprises fossiliferous limestones, white quartzite sandstones and dark-gray shales. The Niur Formation is separated from the Ghelli Formation by a 4 m pebbly conglomerate (Fig. 2). The uppermost part of this formation is reefal limestone and its upper contact is easily separatable from the Padeha Formation (Fig. 2). The macrofauna of the Niur Formation has not been studied yet, but, based on palynological data, it has been assigned to Early and Middle Silurian (Esmaili-Suvayri,1996; Ruhizadeh, 1996 ; Ghavidel-Syooki,1998).

Materials and Methods

Palynological study was carried out on 450 surface samples (MG-6839 to MG-7287) from the Shirgesht, Ghelli and Niur formations. The field and laboratory descriptions of the surface samples have been plotted on the stratigraphic column in Figure 2. The code and number of each sample follow the policy of the National Iranian Oil Company. The palynomorphs were extracted from shale, siltstone, fine-grained sandstone and limestone by standard palynological procedures, including treatment of the residues of each sample with 30ml of saturated zinc bromide in order to separate the organic residues from the inorganic materials and screening of the organic residues through 20 microns nylon mesh sieves. Extensive Scanning Electron and Transmitted Light microscopic examinations were carried out on selected specimens . All microscopic slides and SEM's stubs which were used in this study are in file in the palaeontological collections of the Exploration Directorate of the National Iranian Oil Company, under sample numbers of MG-6839 to MG-7287.

Stratigraphic Palynology

The objectives of this study are to summarize the stratigraphic range of assemblages and species that occur in the Shirgesht, Ghelli and Niur formations and to compare these data with zonal assemblages that have been reported from the other parts of the world. A total of 54 acritarch taxa and one cryptospore species were identified and their distribution is plotted on Figure 2.

The selected palynomorph taxa are illustrated in plates 1- 7. Eight acritarch assemblages have been recognized and are discussed below in ascending stratigraphical order:

Acritarch assemblage zone I (Fig. 2, nos. 1-9)

Assemblage zone I begins in the lower part of Shirgesht Formation and extends through a thickness of 250m of the studied stratigraphic column (Fig. 2). This zone is characterized by presence of acritarch taxa such as *Acanthodiacrodium simplex, Cymatiogalea multarea, Cymatiogalea cuvillieri, Acanthodiacrodium tremadocum, Cymatiogalea barbara, Stelliferidium simplex, Stelliferidium striatulum, Stelliferidium cortinulum* and *Athabascaella penika.* This

assemblage zone is considered to be Early Ordovician (Early Tremadoc) based on the stratigraphic occurrence of the acritarchs in England (Rasul,1974; Downie,1984; Connery and Higgs, 1999, Lister, 1970) , France (Rauscher,1974), Spain (Cramer,1964), Norway (Welsch,1986), Germany (Servais & Molyneux, 1997), Russia (Umnova,1975), Sweden (Bagnoli, et al., 1988), North Africa (Combaz, 1967; Deunff, 1964; Deunff, et al., 1974; Deunff, 1961; Elaouad-Debbaj, 1988; Jardiné, et at., 1974; Vecoli , 1999), Czech Republic (Vavrdova, 1974), China (Lu, 1987; Martin & Yin Lei-Ming, 1988) and northern and southern Iran (Ghavidel-Syooki,1995, 1997, 1998, 2001).

Acritarch assemblage zone II (Fig. 2, nos. 10-16)

This zone occurs immediately above zone I and includes a thickness of 300m. The zone II is marked by the first appearance of *Athabascaella playfordii, Arybollomorpha grooteri, Rhapaliomorpha mamilliformis, Lua edaopuziana, Acanthodiacrodium hirsutum, Stelliferidium furcatum and Dasydiacrodium longicornatum* (Fig. 2). The above-mentioned acritarch assemblage is assigned to the Early Ordovician (Tremadocian - Arenigian) by comparison to their occurrence in strata from China (Tongiorgi, et al., 1995), North Africa (Martin and Yin Leiming, 1988; Jardiné, et al., 1974; Deunff, 1961; Vecoli, 1999), England (Downie, 1984), Sweden (Bagnoli, et al., 1988) and northern and southern Iran (Ghavidel-Syooki, 1995, 1997, 1998, 2001).

Acritarch assemblage zone III (Fig. 2, nos. 17-23)

This zone comprises 150m of the Shirgesht Formation. It is characterized by presence of *Arbusculidium filamentosum, Acanthodiacrodium tadlense, Barakella fortunata, Acanthodiacrodium vavrdovae, Coryphidium elegans, Coryphidium australe, Striatotheca principalis* and *Striatotheca quieta* (Fig. 2). This zone is considered to be the Early Ordovician (Arenigian) since the above-mentioned acritarch species have been recorded from the Arenigian strata of Europe (Vavrdova, 1972, 1974; Rauscher, 1974; Burmann, 1968, 1970; Molyneux, 1987; Downie, 1984), North Africa (Cramer, et al., 1974; Cramer & Diez, 1977; Jardiné, et at, 1974;

Vecoli , l999), China (Lu, 1987; Martin & Yin Lei-Ming, 1988; Tongiorgi, et at, 1995), Argentina (Rubinstein, et al, 1999) and southern and northern Iran (Ghavidel-Syooki, 1995, 1997, 1998, 2001). This assemblage zone contains typical Mediterranian acritarch taxa, including *Coryphidium, Striatotheca* and *Arbusculidium,* which have been recorded from the Arenigian of Peri-Gondwanan (Mediterranian) acritarch paleo- province (Vavrdova, 1972,1974). The occurrence of Mediterranian acritarch species and *Rhopaliophora* and *Arybollomorpha* in the Shirgesht Formation indicates that the Iranian Platform and China were in close proximity and about the same paleolatitude along the southern shore of the Paleo-Tethys Ocean.

Acritarch assemblage zone IV (Fig. 2, nos. 24-32)

This zone begins in the lower part of Ghelli Formation and extends through a thickness of 200m (Fig. 2). The zone IV is marked by absence of Early Ordovician and appearance of the Middle and Late Ordovician acritarch species, consisting of *Stellechinatum uncinatum, Acanthodiacrodium costatum, Ordovicidium elegantulum, Baltisphaeridium latiradiatum, Multiplicisphaeridium dikranon, Actinotodissus longilateosus and Baltisphaeridium longispinosum.* The acritarch taxa of this zone suggest the Middle-Late Ordovician (Llanvirnian-Caradocian) age for this part of the Ghelli Formation. Since the above-mentioned acritarch taxa have been recorded from the Middle-Late Ordovician of the United States (Loeblich, 1970; Tappan & Loeblich,1971; Loeblich and Tappan, 1978; Gorka,1987), England (Turner, 1984; Downie, 1984), Sweden (Kjellström, 1971), North Africa (Elaouad-Debbaj, 1988; Jardiné, et al., 1974) and Iran (Ghavidel-Syooki, 1977, 1998, 2001).

Acritarch assemblage zone V (Fig. 2, nos. 29-34)

This zone occurs in the middle part of Ghelli Formation and extends through a thichkness of 200m. This assemblage is characterized by the first occurrence of *Goniosphaeridium uncinatum, Actinotodissus crassus, Baltisphaeridium onniense,* and *Orthosphaeridium octospinosum.* This zone is assigned to the Late Ordovician (Caradocian- Ashgillian).So far, the acritarch species of this zone have been recorded from Late Ordovician strata in the United States

(Loeblich & Tappan, 1978; Gorka ,1987; Fensome,et al.,1999), Sweden (Kjellström,I971), England (Downie, 1984; Turner, 1984), North Africa (Jardiné, et al., 1974; Elaouad Debbag, 1988; Vecoli, 1999), France (Rauscher, 1974) and Iran (Ghavidel-Syooki, 1997, 1998, 2001).

Acritarch assemblage zone VI (Fig. 2, nos. 35-42)

This zone has a thickness of l00m and includes the upper part of the Ghelli Formation. This zone is marked by presence of acritarch taxa, consisting of *Orthosphaeridium inflatum, Orthosphaeridium insculptum, Dactylofusa platynetrella, Veryhachium irrorata, Veryhachium oklahomense, Multiplicisphaeridium bifurcatum, Multiplicisphaeridium ramispinosum* and *Villosacapsulla setosapellicula.* This assemblage zone is considered to be Late Ordovician (Ashgillian) since the above-mentioned acritarch taxa have been recorded from the Ashgillian strata in the United States (Loeblich, 1970; Loeblich & Tappan, 1978 ;Fensome,et al.,1999), North Africa (Jardiné, *et al.,* 1974; Elaouad-Debbaj, 1988), Europe (Vavrdova, 1974;Eisenack,1968; Kjellström, 1971;Eisenack,Cramer and Diez 1973,1976,1979) and Iran (Ghavidel-Syooki, 1997,1998,2001).

Acritarch assemblage zone VII (Fig. 2, nos. 43-55)

This zone begins above the basal conglomerate of Niur Formation and extends through a thickness of 700m (Fig. 2). This zone is characterized by complete absence of Late Ordovician acritarchs and the first appearance of Silurian taxa, such as*, Visbysphaera brevifurcata, Leiofusa estrecha, Visbysphaera pirifera, Visbysphaera oligofurcata, Oppilatala singularis, Evittia denticulata denticulata, Dictyotidium stel1atum, Ammonidium microcladum, Visbysphaera erratica, Dictyotidium dictyotum, Visbysphaera connexa, Visbysphaera meson* and abundant cryptospore species of *Tetrahedraletes medinensis* (it should be mentioned that two Late Ordovician acritarch species are found with the Silurian taxa, these might have been reworked from the Ghelli Formation into the Niur Formation, namely *Vil1osacapsulla setosapellicula and Veryhachium irrorata).*

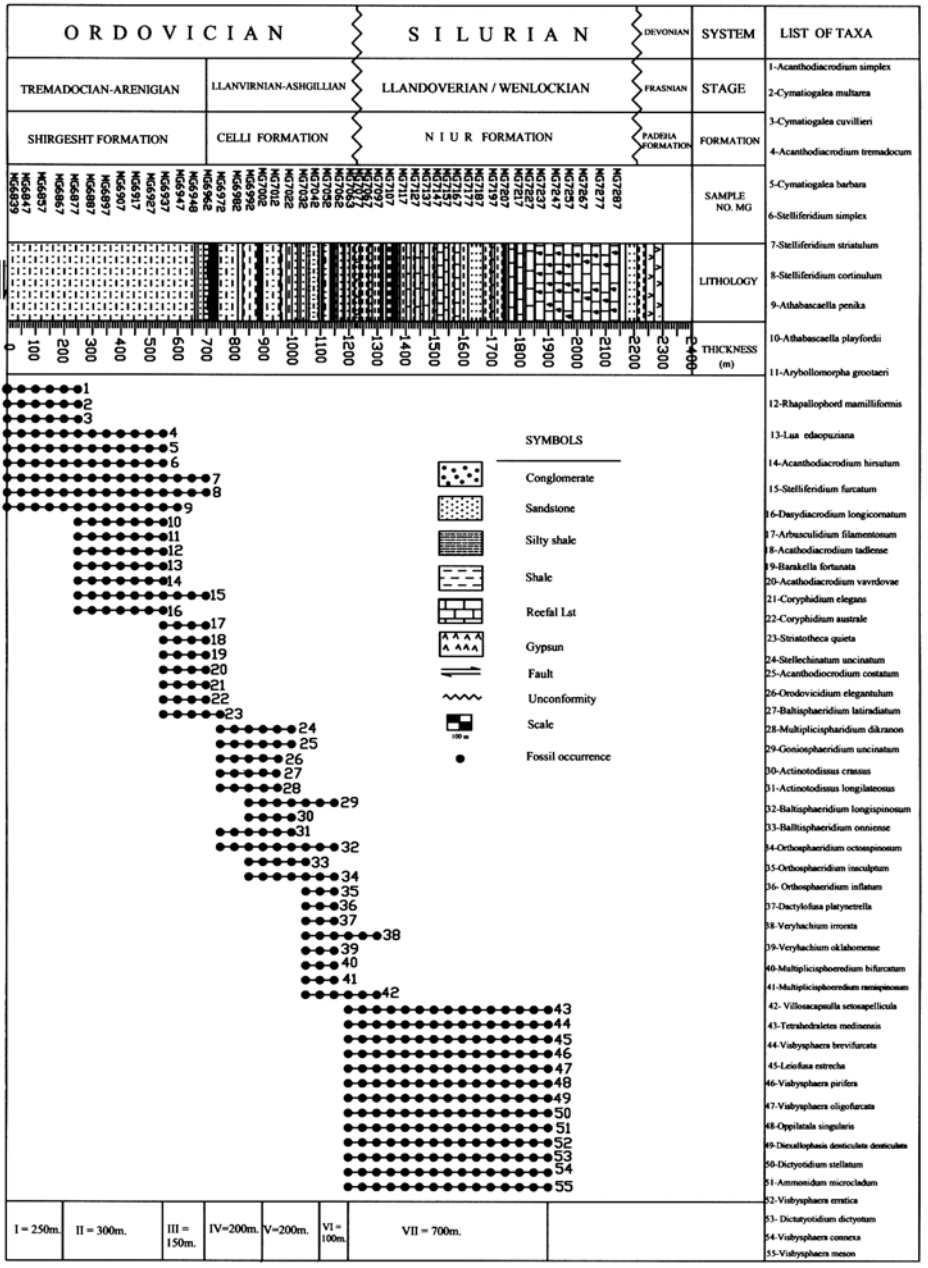

Figure 2 – Stratigraphic distribution of selected acritarch taxa through Lower Paleozoic strata of southwestern Kashmar city, eastern central Iran

This assemblage zone is considered to be Early and Middle Silurian (Llandoverian-early Wenloekian) based on comparison of acritarch taxa which have been recorded from Early-Middle Silurian strata from the United States (Cramer, 1970; Strother & Traverse, 1979), England (Downie, 1984), Sweden (Le Hérissé, 1989) and Iran (Ghavidel-Syooki, 1997,1998, 2001).

Conclusions

The Shirgesht, Ghelli and Niur formations yielded 55 palynomorph taxa. The local stratigraphic distribution of acritarchs is shown in Figure 2. Zones I-III are present in the Shirgesht Formation and suggest an Early Ordovician (Tremadoc-Arenig.) age for this formation. Comparison of these Early Ordovician acritarch assemblages with acritarch taxa from other parts of the world indicates broad similarity with those from the Mediterranian acritarch province.

This acritarch province includes southern Europe, North Africa, southwestern China, Saudia Arabia and southern and northern Iran. The presence of Mediterranian acritarch taxa (e.g. Arbusculidium ,Striatotheca and Coryphidium) in the Shirgesht Formation of eastern Central Iran suggests that this part of Iranian Platform has also been in domain of the Peri-Gondwanan Paleo-continent, possibly positioned along the southern shore of the Paleo-Tethys Ocean. Zones IV-VI occur in the Ghelli Formation and indicate a Middle and Late Ordovician age. The acritarch species from Ghelli Formation suggest a similarity with those recorded from Middle and Upper Ordovician strata in the United States, North Africa and Europe. This supports the opinion that the Peri-Gondwanan Paleo-continent have probably occupied a similar paleolatitude during the Middle and Late Ordovician. Zone VII occurs in the Niur Formation and the acritarch assemblage suggests the Early and Middle Silurian age. Comparison of the Silurian acritarch taxa with those of the other parts of the world indicates broad similarity with those from the United States, North Africa and Europe. This suggests that the Peri-Gondwanan (Mediterranian) Paleo-continent probably began to move up toward the Baltic Paleo-continent in the Middle and Late Ordovician and by the Silurian formed the supercontinent of Pangea.

Acknowledgments

The author expresses his sincere appreciation to the management of the National Iranian Oil Company for permission to publish this paper. I am grateful to my wife Fatemeh and my daughters Hedieh and Mona for many kindnesses.

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Plate 1

Fig.1. *Acanthodiacrodium costatum* Burmann, 1968 [X 4000].

Fig.2. *Striatotheca quieta* (Martin) Eisenack, Cramer & Diez,1973 [X4000].

Fig.3. *Acanthodiacrodium vavrdovae* Cramer & Diez 1977 [X2500].

Fig.4. *Coryphidium elegans* Cramer, Allam, Knaes & Diez,1974 [X 4000].

Fig.5. *Striatotheca principiis* Burmann,1970 [X3000].

Fig.6. *Acanthodiacrodium tremadocum* Gorka,1967 [X3000].

Fig. 7. *Acanthodiacrodium tadlense* Cramer&Diez, 1977 [X3000].

Fig.8. *Dasydiacrodium longicornatum* Gorka,1967 [X3000].

Fig.9. *Acanthodiacrodium simplex* Combaz, 1967 [X4000].

Fig.10. *Barakella fortunata* Cramer & Diez, 1977 [X3000].

Fig.11. *Arbusculidium filamentosum* (Vavrdova) Vavrdova, 1972 [X4000].

Fig.12. *Copyphidium elegans* Cramer, AIlam, Kanes & Diez 1974 [X3000].

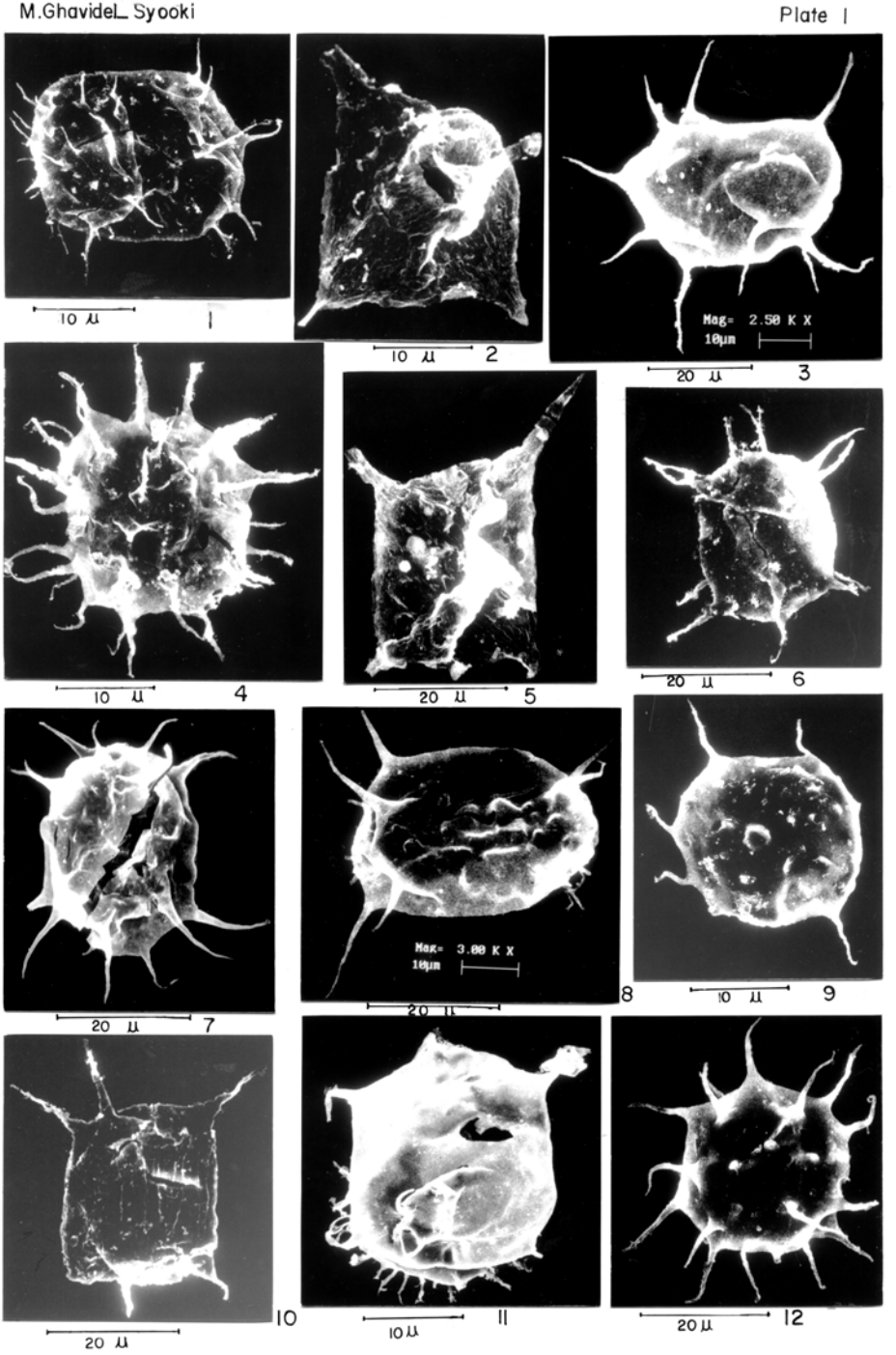
M.Ghavidel_ Syooki
Plate I
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Plate 2

Fig.l. *Acanthodiacrodium tadlense* Cramer & Diez,1977 [X4000].

Fig.2.*Coryphidium elegans* Cramer,AIlam, Kanes & Diez,1974 [X3000].

Fig.3. *Athabascaella penika* Martin & Yin Lei-Ming,1988 [X4000].

Fig.4. *Stellechinatum uncinatum* (Downie)Molyneux, 1987 [X4000]

Fig.5.*Sculptural elements* of Fig.6. [X5000].

Fig.6. *Rhopaliophora mamilliformis* Lu Li Chang,1987 [X3000].

Fig. 7. *Lua erdaopuziana* Martin & Yin, Lei-Ming,1988 [X4000].

Fig.8.*Stelliferidium cortinulum* (Deunff) Deunff, Gorka & Rauscher, 1974 [X3000].

Fig.9. *Athabascaella playfordii* Martin, 1984. [X4000]

Fig.10. *Athabascaella playfordii* Martin, 1984 [X2500]

Fig.ll. Sculplural elements of Fig.l0 [X6000].

Fig.12. *Aryballomorpha grootaerii* (Martin) Martin & Yin Lei-Ming, 1988 [X2500].

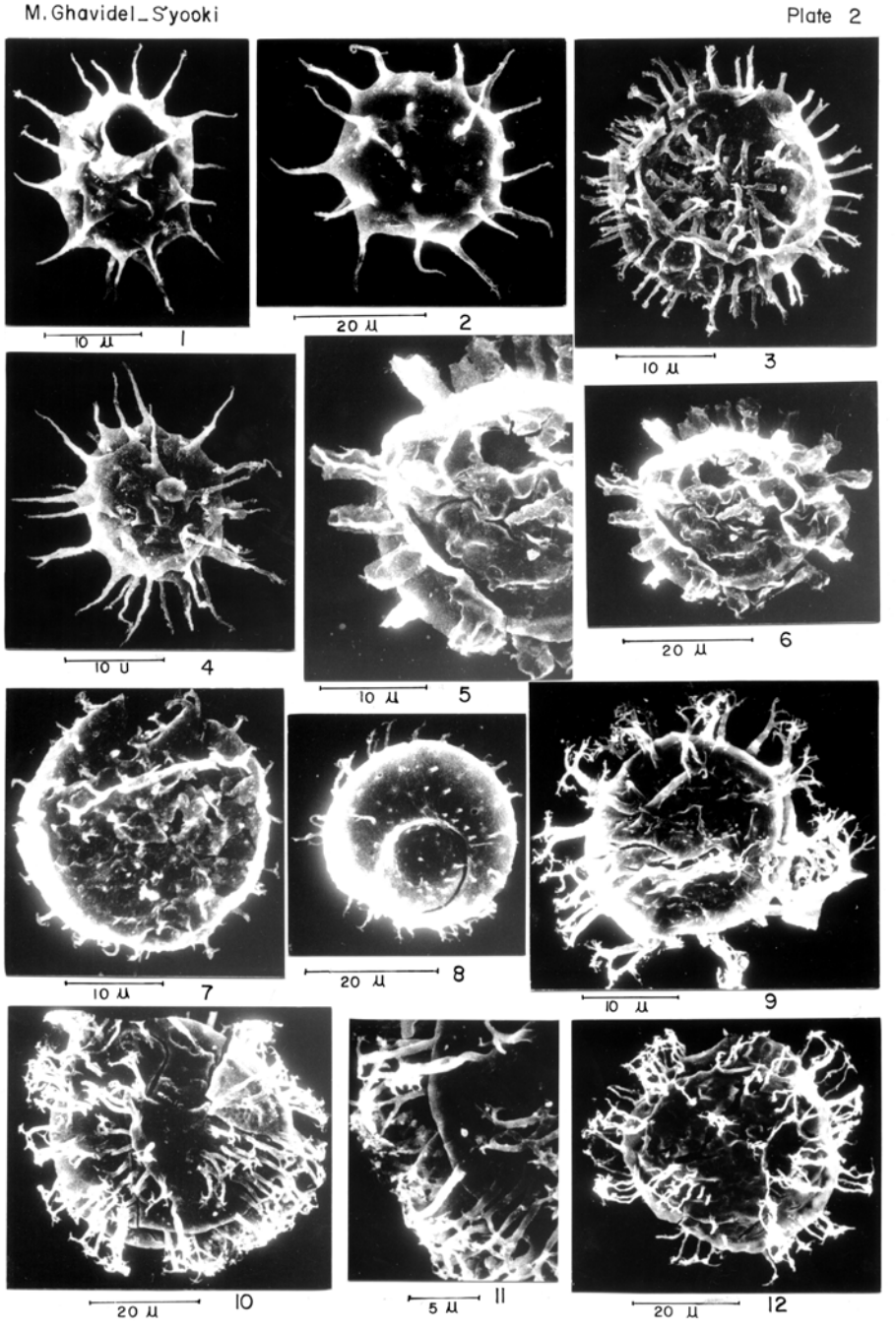
M. Ghavidel_S'yooki
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***Plate* 3**

Fig.l. *Cymatiogalea barbara* (Deunft) Deunff, Gorka & Rauscher,1974 [X4000].

Fig.2. *Cymatogalea barbara* (Deunft) Deunff, Gorka & Rauscher,1974 [X4000).

Fig.3. *Stelliferidium furcatum* (Deunff) Deunff, Gorka & Rauscher,1974 [X3000].

Fig.4. *Stelliferidium furcatum* (Deunft) Deunff, Gorka & Rauscher,1974 [X3000].

Fig.5. *Copyphidium australe* Cramer & Diez, 1976 [X3000].

Fig.6. *Stelliferidium striatulum* (Vavrdova) Deunff, Gorka & Rauscher, 1974 [X4000].

Fig.7. *Stelliferidium striatulum* (Vavrdova) Deunff, Gorka & Rauscher, 1974 [X4000].

Fig.8. *Stelliferidium simplex* (Deunft) Deunff, Gorka & Rauscher, 1974 [X3000].

Fig.9. *Cymatiogalea cuvillieri* (Deunft) Deunff, 1964 [X4000].

Fig.10. *Cymatiogalea multarea*. (Deunff) Eisenack, Cramer & Diez, 1973. [X4000].

Fig.ll. *Goniosphaeridium uncinatum* (Downie)Kjellstrom,1971 [X3000].

Fig.12. *Stelliferidium cortinulum* (Deunft) Deunff, Gorka & Rauscher, 1974 [X4000].

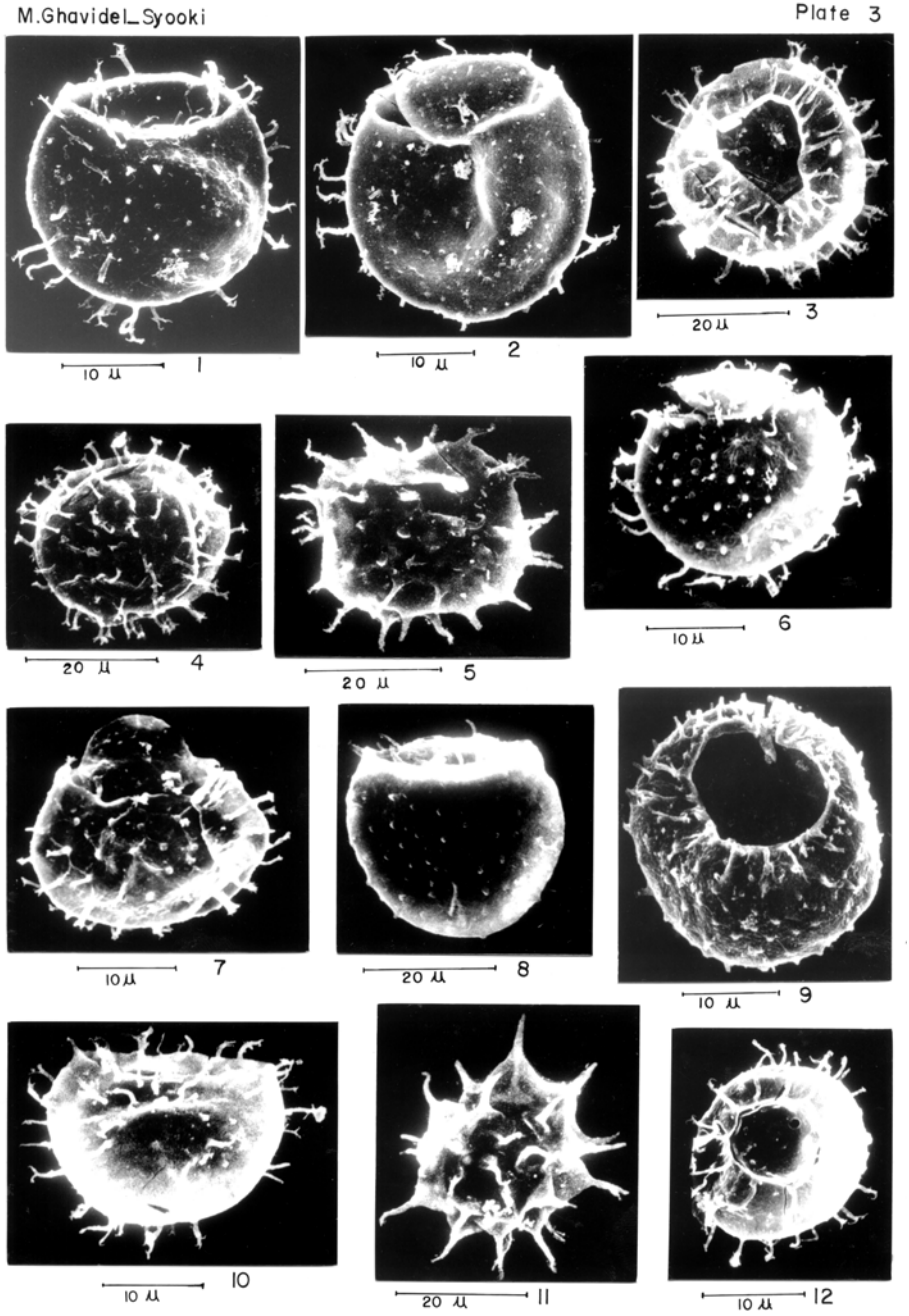
M.Ghavidel_Syooki
Plate 3
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Plate 4

Fig.1. *Orthosphaeridium octospinosum* Eisenack, 1968 [X2000].

Fig.2. *Baltisphaeridium latiradiatum* (Eisenack) Eisenack, Cramer & Diez, 1973 [X2000].

Fig.3. *Multiplicisphaeridiu dikranon* Vecoli, 1999 [X3000] .

Fig.4. *Veryhachium irrorata* (Loeblich & Tappan) Fensome, et at., 1999. [X2000].

Fig.5. *Orthosphaeridium inflatum* Loeblich Jr., 1970 [X1000],

Fig.6. *Dactylofusa platynetrella* (Loeblich & Tappan) Fensome, Williams, Barss, Freeman & Hill,1990 [X2000].

Fig. 7. *Baltisphaeridium longispinosum* Turner 1984 [X2000].

Fig.8. *Ordovicidium elegantulum* Tappan & Loeblich Jr.,1971 [X3000].

Fig.9. *Actinotodissus longitaleosus* Loeblich & Tappan,1978 [X3000].

Fig.l0. *Orthosphaeridium insculptum* Loeblich Jr,1971 [XI000].

Fig.11. *Actinotodissus crassus* Loeblich & Tappan, 1978 [X3000].

Fig.12. *Actinotodissus longitaleosus* Loeblich & Tappan 1978, [X3000].

Fig.13. *Orthosphaeridium inflatum* Loeblich Jr., 1970 [X1000],

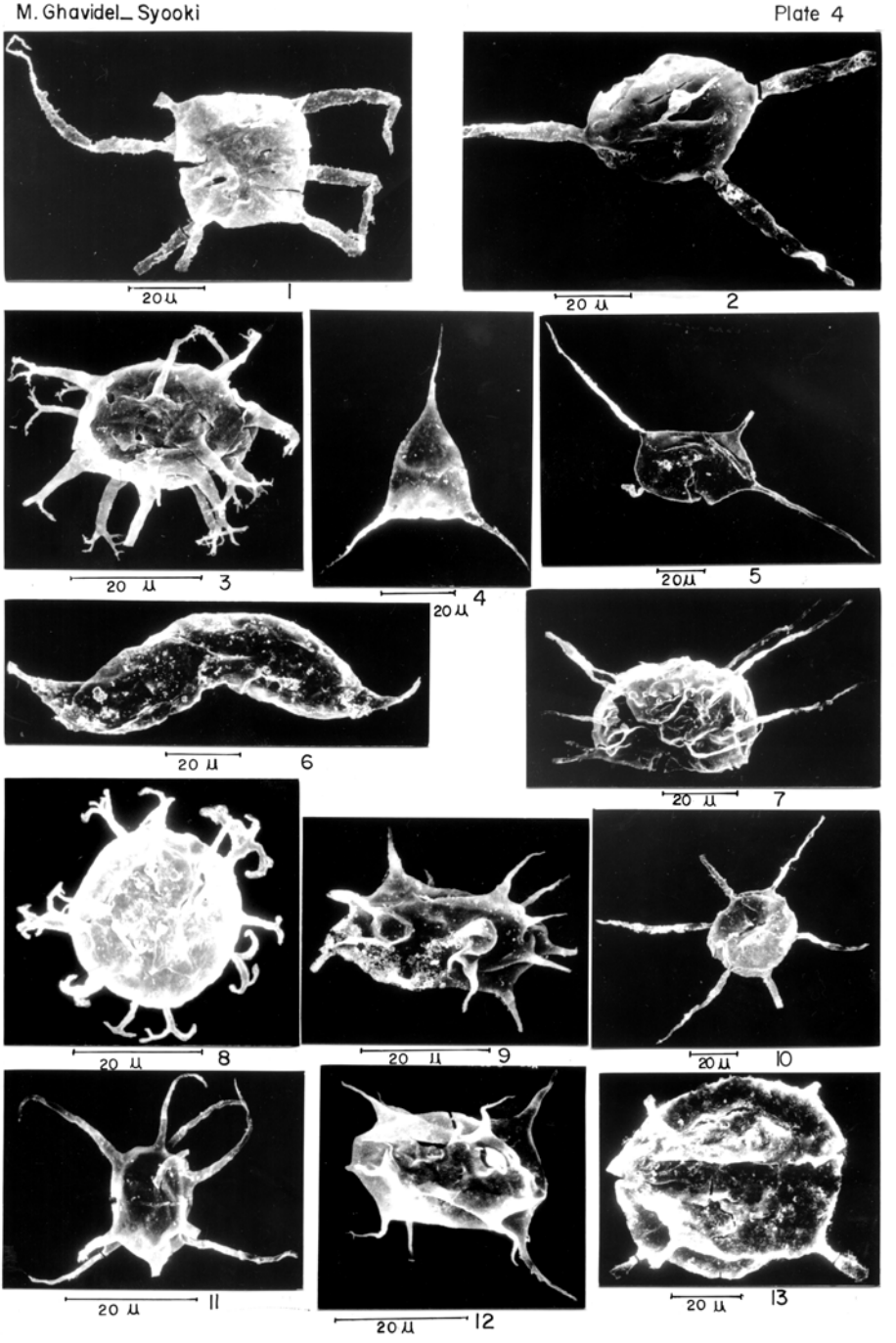
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Plate 5

Fig.l. *Veryhachium oklahomense* Loeblich, 1970 [X3000].

Fig.2. *Detailed sculptured elements* of Fig.3 [X6000].

Fig.3. *Villosacapsula setosapellicula* (LoebIich) LoebIich & Tappan, 1976 [X4000).

Fig.4. *Veryhachium oklahomense* Loeblich, 1970. [X3000].

Fig.5. *Villosacapsula setosapellicula* (Loeblich) Loeblich & Tappan,1976 [X3000].

Fig.6. *Tetrahedraletes medinensis* Strother & Traverse, 1979 [X3000].

Fig. 7. *Baltisphaeridium onniense* Turner, 1984 [X2000].

Fig.8. *Multiplicisphaeridium ramispinosum* Staplin,1965 [X3000J.

Fig.9. *Acanthodiacrodium hirsutum* Gorka, 1967 [X4000].

Fig.10. *Villosacapsula setosapellicula* (Loeblich & Tappan) Fensome et al., 1990 [X3500].

Fig.ll. Detailed sculptural elements of Fig.lO [X7000].

Fig.12. A general view from the Early Ordovician acrirachs of studied area. [X2000].

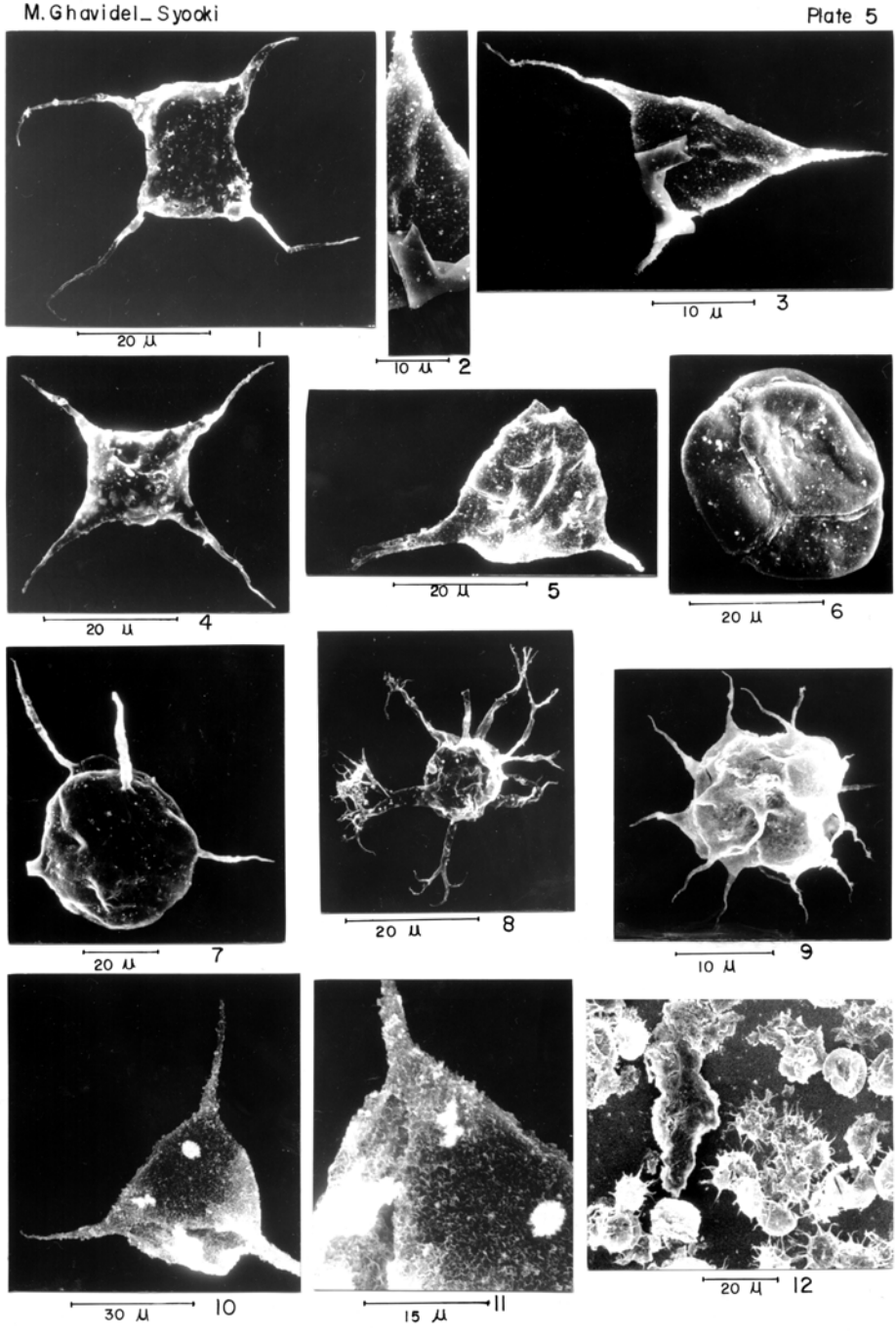
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Plate 6

Fig.1. *Visbysphaera connexa* Le Hérissé, 1989 [X3000].

Fig.2. *Visbysphaera meson* (Eisenack) Lister, 1970 [X3000].

Fig.3. *Leiofusa estrecha* Cramer, 1964 [X800].

Fig.4. *Visbysphaera brevifurcata* (Eisenack) Le Hérissé, 1989 [X3000].

Fig.5. Detailed sculptural elements of Fig.4 [X600].

Fig.6. *Visbysphaera erratica* (Eisenack) Lister ,1970 [X3000]

Fig. 7. *Visbysphaera brevifurcata* (Eisenack) Le Hérissé, 1989 (X3000].

Fig.8. *Multiplicisphaeridium bifurcatum* Staplin, Jansonius & Pocock , 1965 [X3000].

Fig.9. *Multiplicisphaeridium bifurcatum* Staplin , Jansonius & Pocock, 1965 [X3000].

Fig.10. *Ammonidium microcladum* (Downie) Lister, 1970. [X3000].

Fig.11. *Visbysphaera oligofurcata* (Eisenack) Lister, 1970 [X3000].

Fig.12. *Visbysphaera pirifera* (Eisenack) Lister, 1970 [X3000].

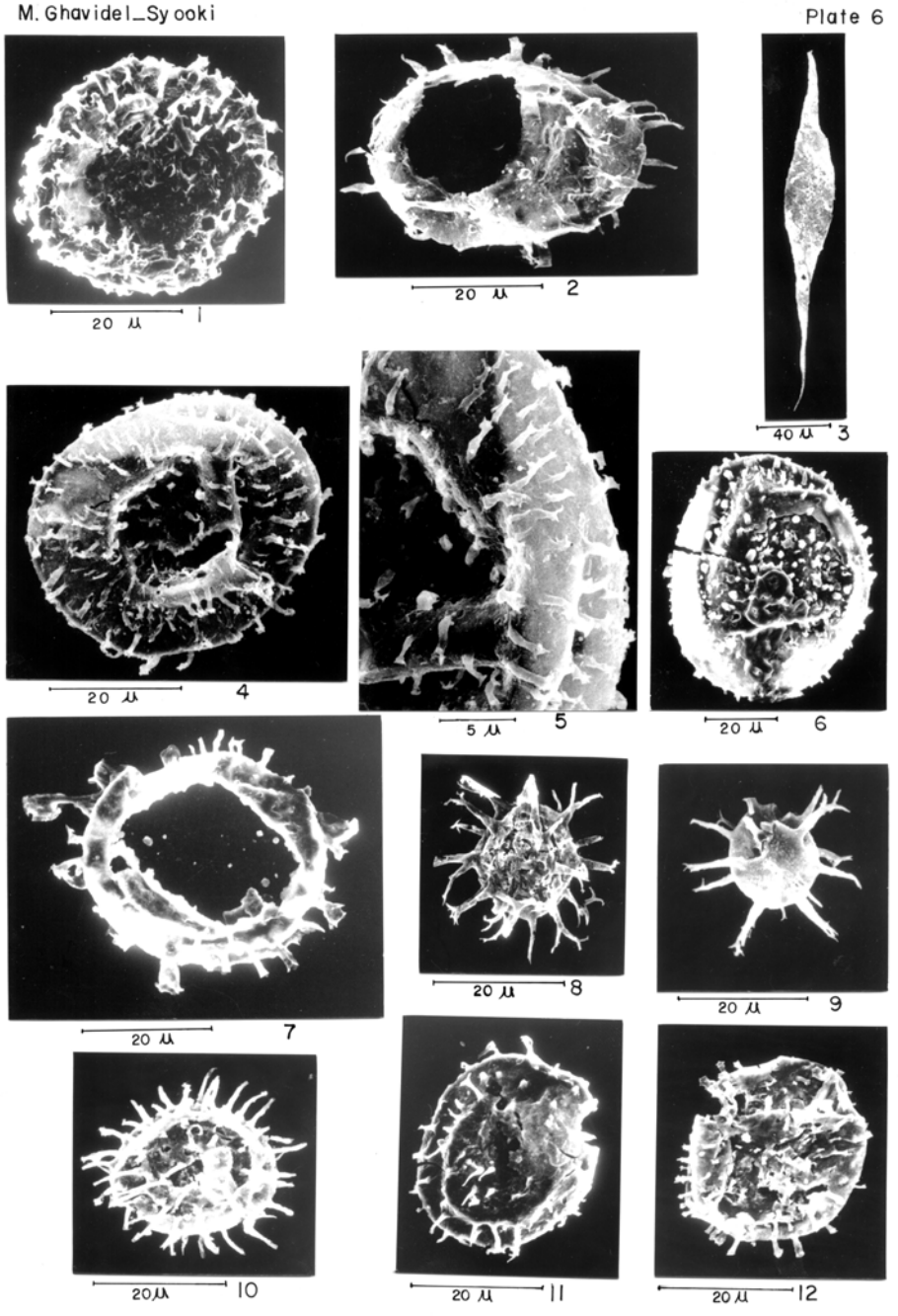
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Plate 7

Fig.l. *Dictyotidium dictyotum* (Eisenack) Eisenack, 1955 [X3000].

Fig.2. *Dictyotidium stellatum* Le Hérissé, 1989 [X3000].

Fig.3. *Detailed sculptural* elements of Fig.2 [X6000].

Fig.4. *Oppilatala singularis* Le Hérissé , 1989 [X3000].

Fig.5. *Oppilatala singularis* Le Hérissé, 1989 [X3000].

Fig.6. Detailed sculptural elements of Fig.5 [X6000].

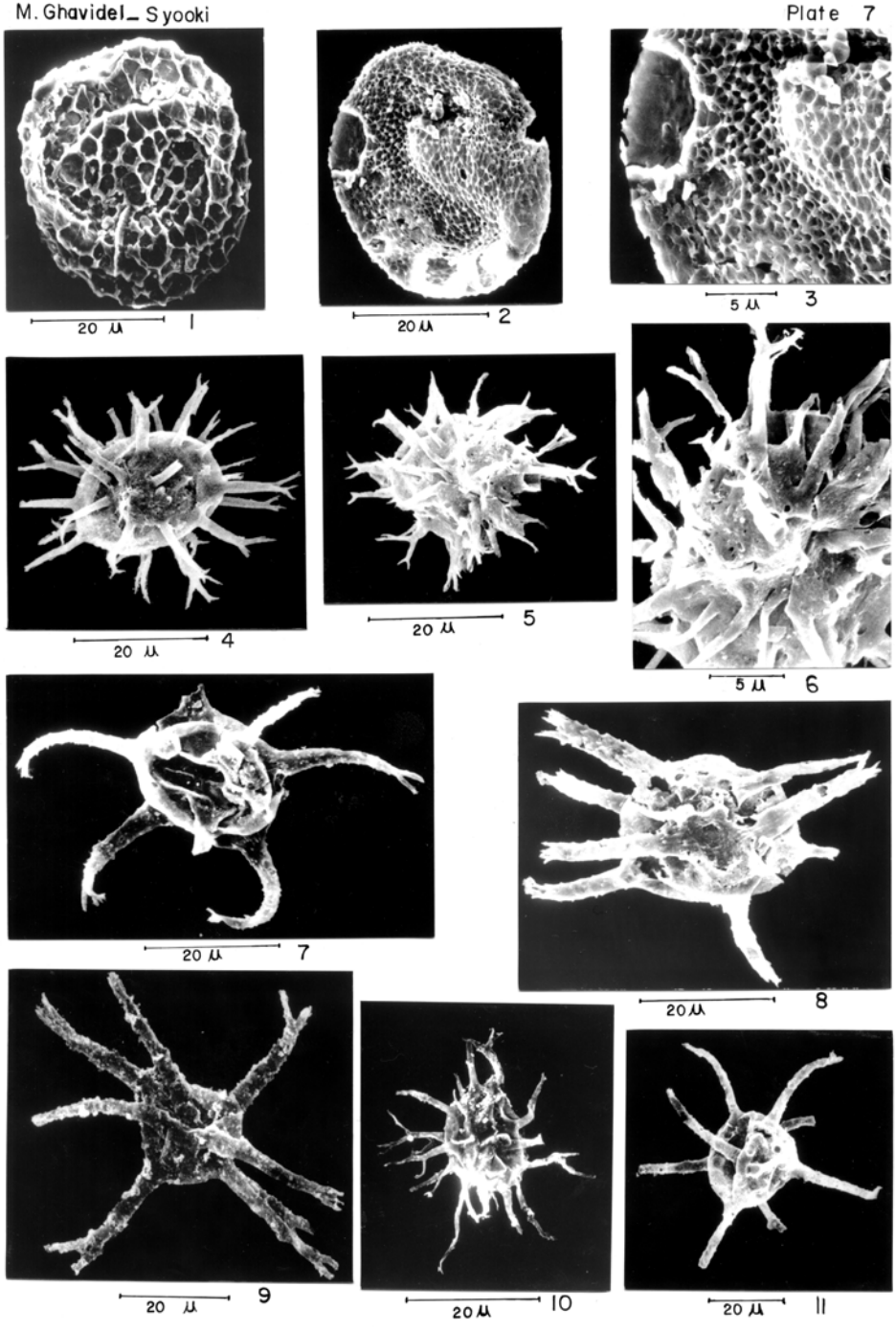
Fig. 7. *Evittia denticulata denticulata* (Cramer) Le Hérissé, 1989 [X3000].

Fig.8. *Evittia denticulata denticulata* (Cramer) Le Hérissé, 1989 [X3000].

Fig.9. *Evittia denticulata denticulata* (Cramer) Le Hérissé, 1989 [X2500].

Fig.10. *Multiplicisphaeridium bifurcatum* Staplin , Jansonius and Pocock, 1965 [X3000].

Fig.11. *Evittia denticulata denticulata* (Cramer) Le Hérissé ,1989 [X2000].


M. Ghavidel_ Syooki
Plate 7
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