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Original article

Palynostratigraphy and palaeogeography of the Padeha, Khoshyeilagh, and Mobarak formations in the eastern Alborz Range (Kopet-Dagh region), northeastern Iran

Palynostratigraphie et paléogéographie des formations de Padeha, Khoshyeilagh and Mobarak dans l'est de l'Alborz (région de Kopet-Dagh), nord-est de l'Iran

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Abstract

A total of 113 surface samples collected from the Padeha, Khoshyeilagh, and Mobarak formations of Kuh-e-Ozum, northeast of Jajarm town were processed for palynomorphs, in order to determine age relationships. Well-preserved and abundant palynomorphs dominated by organic-walled-marine microphytoplankton (acritarchs and prasinophyte phycomata), miospores and subordinate chitinozoans, and scolecodonts were recovered. Seven species of prasinophyte phycomata (four genera), 19 acritarch species (14 genera), one species of chitinozoa, and 26 miospore species (19 genera) were recorded and assigned to eight local Assemblage Zones. Assemblage Zones I–IV occur in the Padeha Formation and suggest an Early Late Devonian (Frasnian) age whilst assemblages zones V–VII are present in the Khoshyeilagh Formation and indicate Late Devonian (Famennian) ages. Assemblage zone VIII, which occurs in the basal part of Mobarak Formation, suggests a Lower Mississippian (Tournaisian) age for this formation. Many of the palynomorph groups encountered are closely comparable with coeval assemblages recorded from Western Australia, southwest Ireland, England, Turkey, Saudi Arabia, North Africa, and South America, indicating the close relationship of the Iranian Platform to other parts of the northern Gondwana Domain during the time interval represented by these strata. The presence of marine palynomorphs (acritarchs/prasinophyte phycomata, chitinozoans, and scolecodonts), and shelly macrofauna (brachiopods, gastropods, and corals) in Member c of the Padeha Formation (as well as the Khoshyeilagh and Mobarak formations), together with associated miospores, indicate an open marine (moderately nearshore) depositional environment for the Upper Devonian and Lower Carboniferous deposits in northeastern Alborz Range (Kopet-Dagh region) of Iran.

Résumé

Un total de 113 échantillons palynologiques récoltés à l'affleurement dans les formations de Padeha, Khoshyeilagh et Mobarak, à Kuh-e-Ozum, au nord-est de la ville de Jajarm, ont été analysés afin de préciser leurs relations chronostratigraphiques avec la succession sus-jacente. Des palynomorphes abondants et bien conservés ont été recueillis. Les assemblages, dominés par les acritarches, les phycomata de prasinophytes (microphytoplancton) et par les spores, contiennent aussi quelques chitinozoaires et scolécodontes. Sept espèces de phycomata de prasinophytes (quatre genres), 19 espèces d'acritarches (14 genres), 26 espèces de miospores (19 genres) et une espèce de chitinozoaires ont été répertoriées. Elles ont été réparties en huit zones locales d'assemblage. Les Zones d'Assemblage I–IV se trouvent dans la Formation de Padeha et suggèrent un âge Dévonien Supérieur précoce (Frasnien). Les Zones d'Assemblage V–VII concernent la Formation de Khoshyeilagh et indiquent le Dévonien Tardif (Famennien). La Zone d'Assemblage VIII se place dans la partie basale de la Formation de Mobarak et suggère un âge Mississippien

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Précoce (Tournaisien). Nombre des palynomorphes observés sont très proches de ceux des assemblages contemporains de l'Ouest de l'Australie, du Sud-ouest de l'Irlande, d'Angleterre, de Turquie, d'Arabie Saoudite, d'Afrique du Nord et d'Amérique du Sud. Ils indiquent les bonnes affinités de la plateforme iranienne et les autres régions du Domaine nord gondwanien à cette époque.

Keywords: Devonian; Miospores; Acritarchs; Palynostratigraphy; Palaeogeography; Eastern Alborz Range (NE Iran)

Mots clés : Dévonien ; Miospores ; Acritarches ; Palynostratigraphy ; Palaeogeography ; Est de l'Alborz (NE Iran)

1. Introduction

Palaeozoic strata are well exposed in Kuh-e-Ozum, which is located northeast of Jajarm town, approximately 180 km northeast of Shahrud city, northern Iran. The road from Shahrud to Jajarm is the principle link to the studied area (Fig. 1). This Palaeozoic sequence has been divided in ascending stratigraphical order into the Padeha, Khoshyeilagh and Mobarak formations. The Padeha Formation has always been the subject of major controversy since it lacks any diagnostic faunal evidence regarding its age at both its type locality and in other sections (Alavi-naini, 1972; Ghavidel-syooki, 1992, 1994, 2001; Rafighei-oskuei, 1992). The same is true for the Khoshyeilagh Formation since there is no agreement on the age relationships of this formation (Bozorgnia, 1973; Alavi-naini, 1972; Coquel et al., 1977; Ghavidel-syooki, 1994). Sections of both formations were therefore measured and sampled in order to determine their age relationships in the Kopet-Dagh region. The palynological data recovered will enable reconstruction of the relationship of these formations of the Kopet-Dagh region with those in the Central and Western Alborz Ranges as well as other parts of the world.

2. Stratigraphy

The Palaeozoic sequence of Kuh-e-Ozum is 854 m thick (only 622 m was investigated in this study) and it has been divided in ascending stratigraphical order into the Padeha, Khoshyeilagh and Mobarak formations (Afshar-harb, 1979).

The Padeha Formation is 492 m thick at its type locality in Ozbak-Kuh, but it is only 340 m thick in the studied area. The lower contact of this formation is disconformable with the Niur Formation in its type locality (Ozbak-Kuh), but this contact is not clear in the studied area where it is cut by a thrust fault. The upper contact of this formation is graditional with the Khoshyeilagh Formation (Fig. 2) in the studied area. The Padeha Formation consists of variably colored shales, sandstones, siltstones, dolomites, and gypsum. Using lithological criteria, the Padeha Formation has been divided into four members (a, b, c and d). Member a consists of purple shales and sandy siltstones (Afshar-harb, 1979) and is 205 m thick in the type locality (Ozbak-Kuh), but it is not exposed in the study area (Kuh-e-Ozum) since this member and older Palaeozoic rock units have been cut out by a fault. Member b, which comprises alternations of gypsum, dolomite and olive-gray shale, is 70 m thick in its type locality (Ozbak-Kuh), but increases to 202 m in thickness in the Kuh-e-Ozum study area. Member c is 49 m thick in Kuh-e-Ozum and consists mainly of fossiliferous limestones with brachiopods and corals. This member is 120 m thick in its type locality (Ozbak-Kuh) where it consists of alternations of dolomite and sandstone. Member d is 89 m thick in the study area (Kuh-e-Ozum) compared to a thickness of 80 m in its type locality (Ozbak-Kuh), where it is represented by gypsum and thinly-bedded gray shales. The Padeha Formation has its best development in Kuh-e-Ozum, where Member c of this formation contains important macrofauna (Afshar-harb, 1979). The Padeha Formation lacks any diagnostic macrofossils at its type locality (Ozbak-Kuh) and based largely on its stratigraphical position,

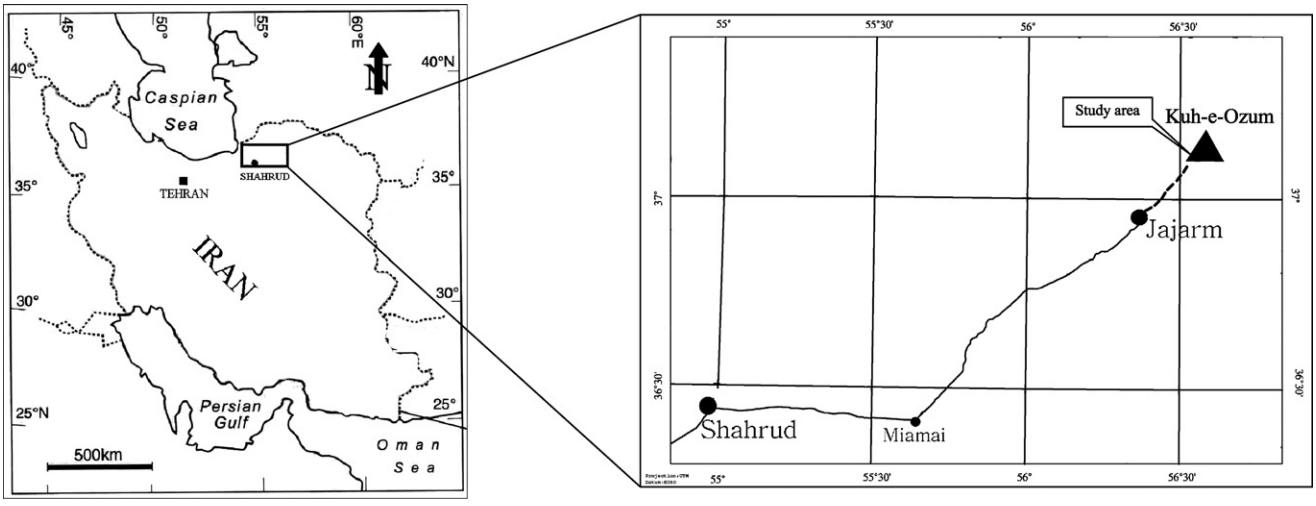

Fig. 1. Location map of studied area in the Kopet-Dagh region, northeastern Iran.
Fig. 1. Carte de localisation du secteur étudié dans la région de Kopet-Dagh, Nord-est de l'Iran.

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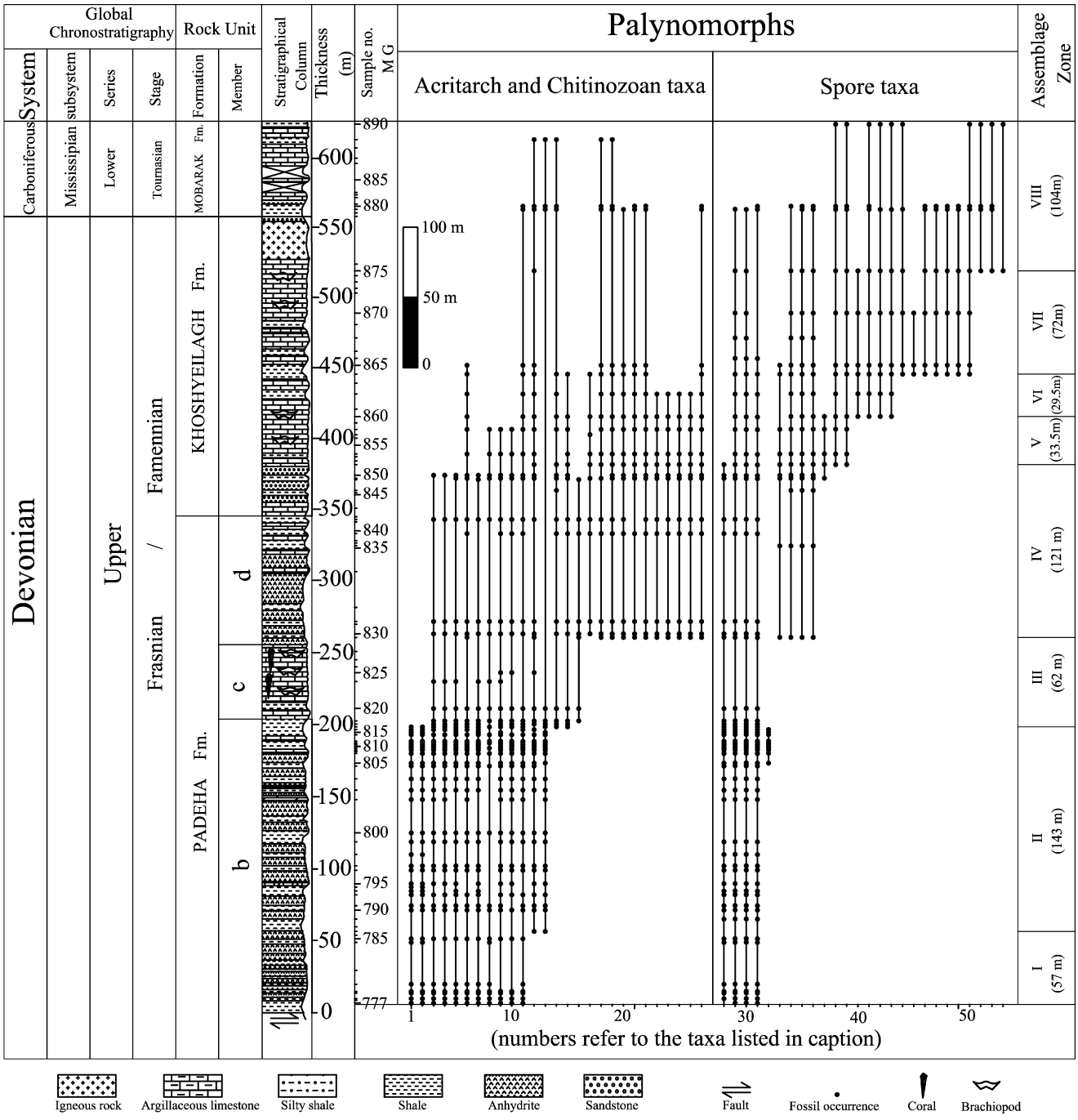

Fig. 2. Stratigraphic distribution of all known palynomorph taxa in the Padeha and Khoshyeilagh Formation of Kuh-e-Ozum, eastern Alborz Mountain Range (Kopet-Dagh region) Iran. **1**. *Chomotriletes vedugensis*, **2**. *Papulogabata annulata*, **3**. *Lophosphaeridium segregum*, **4**. *Helosphaeridium guttatum*, **5**. *Gorgonisphaeridium plerispinosum*, **6**. *Gorgonisphaeridium discissum*, **7**. *Dictyotidium torosum*, **8**. *Cymatiosphaera perimembrana*, **9**. *Solisphaeridium inaffectum*, **10**. *Solisphaeridium spinoglobosum*, **11**. *Dictyotidium araiomegronium*, **12**. *Gorgonisphaeridium abstrusum*, **13**. *Stellinium comptum*, **14**. *Veryhachium pannuceum*, **15**. *Multiplicisphaeridium ramispinosum*, **16**. *Angochitina devonica*, **17**. *Daillyidium pentaster*, **18**. *Gorgonisphaeridium ohioensis*, **19**. *Deltotosoma intonsum*, **20**. *Ammonidium loriferum*, **21**. *Dictyotidium craticulum*, **22**. *Dictyotidium litum*, **23**. *Crassiangulina tessellita*, **24**. *Cymatiosphaera melikera*, **25**. *Striatostellula sparsa*, **26**. *Polyedryxium pharaonis*, **27**. *Maranhites perplexus*, **28**. *Emphanisporites rotatus*, **29**. *Retusotriletes rotundus*, **30**. *Retusotriletes distinctus*, **31**. *Geminospora lemurata*, **32**. *Ancyrospora ampulla*, **33**. *Hystricosporites porrectus*, **34**. *Auroraspora torquata*, **35**. *Grandispora gracilis*, **36**. *Densosporites rotatus*, **37**. *Retusotriletes phillipsii*, **38**. *Rugospora flexuosa*, **39**. *Grandispora cornuta*, **40**. *Retispora lepidophyta*, **41**. *Vallatisporites pusillites*, **42**. *Indotriradites explanatus*, **43**. *Hymenozonotriletes (Diaphanospora) perplexa*, **44**. *Diducites mucronatus*, **45**. *Retispora macroreticulata*, **46**. *Verruciretusispora loboziakii*, **47**. *Raistrickia variabilis*, **48**. *Apiculiretusispora fructicosa*, **49**. *Grandispora echinata*, **50**. *Verrucosisporites nitidus*, **51**. *Vallatisporites verrucosus*, **52**. *Retusotriletes incohatus*, **53**. *Dictyotriletes submarginatus*.

Fig. 2. Répartition stratigraphique de tous les taxons de palynomorphes reconnus dans les formations de Padeha et de Khoshyeilagh de Kuh-e-Ozum, chaîne de l'Alborz oriental (région de Kopet-Dagh), Iran.

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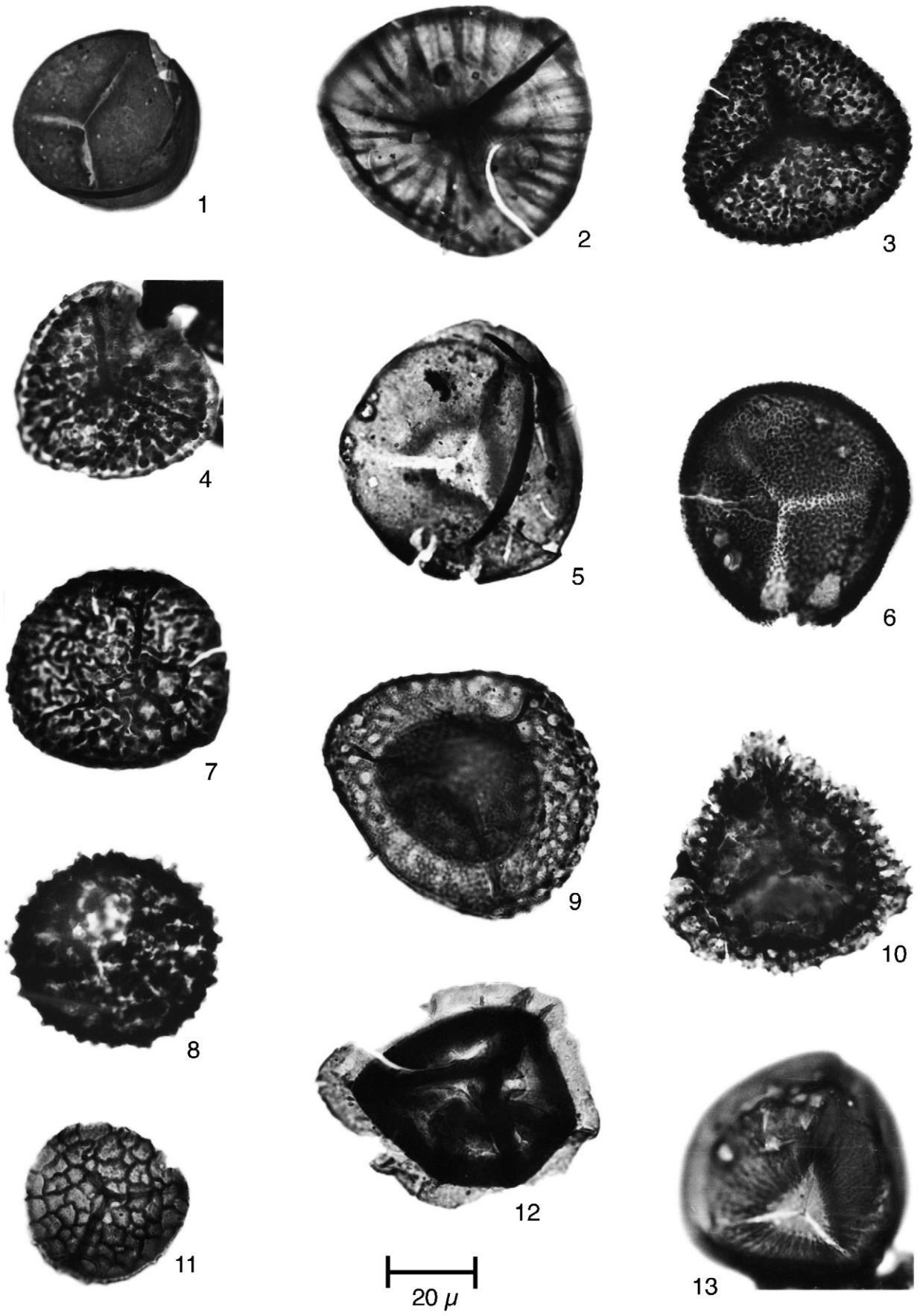

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has been assigned to the Early Devonian (Alavi-naini, 1972). The macrofauna from Member c of Padeha Formation in the study area contains brachiopods and corals that have been investigated by Ahmadzadeh-heravi (in Afshar-harb, 1979). Previous palynological investigations have been undertaken on outcrop sections of this formation by several workers (Ghavidel-syooki, 1992, 1994, 2001; Rafighei-oskuei, 1992) who have assigned it to a Late Devonian age.

The Khoshyeilagh Formation is 1350 m thick in its type locality (Khoshyeilagh area) but the thickness of this formation varies from place to place and it only 209 m thick in Kuh-e-Ozum. The lower and upper contacts of Khoshyeilagh Formation are gradational with the underlying Padeha Formation and the overlying Mobarak Formation. The formation, which consists of fossiliferous limestones, shales, and sandstones (Assereto and Gaetani, 1964; Bozorgnia, 1973), contains brachiopod faunas that have been assigned to the Middle and Late Devonian (Brice in Bozorgnia, 1973). The Khoshyeilagh Formation was investigated for brachiopod and conodont faunas in its type locality by Ahmadzadeh-heravi (1975) and Brice et al. (1974) who assigned them an Early–Late Devonian age. Palynological studies have also been previously undertaken on this formation by Coquel et al. (1977) and Ghavidel-syooki (1994) who have assigned a broad Late Devonian age. The brachiopods of the Khoshyeilagh Formation have more recently been re-investigated by Brice (1999) and Zaman (2001) and he has assigned the basal part of this formation to the Early Late Devonian (Early Frasnian).

The Mobarak Formation is 450 m thick at its type locality but it is only 306 m in the Kuh-e-Ozum study area with only 104 m of that section investigated during the present study. This formation consists mainly of limestones with some shale intercalations, which contain both macro and micro faunas that indicate an Early Carboniferous age (Stepanov, 1971; Bozorgnia, 1973; Afshar-harb, 1979). The Mobarak Formation is disconformably overlain by the Elika Formation of Early Triassic age. Biostratigraphical data therefore indicate that there is a major hiatus between the Mobarak and Elika formations, which accounts for the Middle–Late Carboniferous and entire Permian interval.

3. Materials and methods

One hundred and thirteen surface samples from the Padeha, Khoshyeilagh, and Mobarak formations at Kuh-e-Ozum were processed and analyzed for palynomorphs. The palynomorphs were extracted from shales, siltstones, fine-grained sandstones, and argillaceous limestones by standard palynological procedures, including the use of saturated zinc bromide to separate the organic residues from the inorganic materials and the screening of the organic residues through 20 μm nylon mesh sieves. Extensive scanning electron and transmitted light microscopic examinations were carried out on selected specimens throughout the study. All microscopic slides used in this study are housed in the Palaeontological Collections of the Exploration Directorate of the National Iranian Oil Company under sample numbers MG-777 to MG-890. Most samples contain well-preserved and abundant palynomorph taxa (acritarchs, miospores, scolecodonts, and chitinozoans), which permit the recognition of eight ascending stratigraphical assemblage zones within the succession examined. The palynomorphs and organic debris range in color from yellow to orange brown, which indicates a good thermal maturity for the organic materials of Upper Devonian and Carboniferous strata in this part of the Alborz Ranges. Routine oxidation of the residues during sample preparation prevented any detailed palynofacies investigations being undertaken.

4. Biostratigraphy

The objectives of this study are to summarize the stratigraphic range of assemblages and species that occur within the Padeha and Khoshyeilagh formations in the Kopet-Dagh region and to compare these data with zonal assemblages that have been reported from other parts of the world. In this study, we have defined a number of "assemblage zones" to facilitate palynological subdivision of the succession. The base of each assemblage zone being defined by the first appearance of two or more diagnostic species and its top being marked by the base of the succeeding assemblage zone. Ghavidel-syooki (1994, 1995) has previously established comparable local sequences of assemblage zones in the Devonian successions of the Zagros/Alborz and Hassenakdar regions of Iran. Lithological and facies differences between these regions and the Kopet-Dagh succession prevent detailed comparisons and correlations being attempted between these different series of assemblage zones at the present time. A total of 53 miospore, acritarch, and chitinozoan taxa were identified in the Kopet-Dagh succession and their distributions are plotted on Fig. 2. Selected miospore and acritarch taxa are illustrated on Plates 1–6. The eight assemblage zones, which have been established throughout the Devonian–Lower Carboniferous sequence (Padeha and Khoshyeilagh formations as well as the basal part of Mobarak Formation) of the studied area, are described below in ascending stratigraphic order.

Plate 1. **Fig. 1**. *Retusotriletes incohatus* Dolby and Neves, 1970. Sample MG-875, Khoshyeilagh Formation. **Fig. 2**. *Emphanisporites rotatus* McGregor, 1961. Sample MG-815, Member b of Padeha Formation. **Fig. 3**. *Apiculiretusispora fructicosa* Higgs, 1975. Sample MG-864, Khoshyeilagh Formation. **Fig. 4**. *Vallatisporites verrucosus* Hacquebard, 1957. Sample MG-875, Khoshyeilagh Formation. **Fig. 5**. *Retusotriletes rotundus* (Streel) Streel, 1967. Sample MG-812, Member b of Padeha Formation. **Fig. 6**. *Geminospora lemurata* Balme emend. Playford, 1983. Sample MG-812, Member b of Padeha Formation. **Fig. 7**. *Rugospora flexuosa* (Jushko) Streel in Becker et al., 1974. Sample MG-850, Khoshyeilagh Formation. **Fig. 8**. *Raistrickia variabilis* Dolby and Neves, 1970. Sample MG-850, Khoshyeilagh Formation. **Fig. 9**. *Retispora lepidophyta* (Kedo) Playford, 1976. Sample MG-864, Khoshyeilagh Formation. **Fig. 10**. *Vallatisporites pusillites* (Kedo) Dolby and Neves, 1970. Sample MG-864, Khoshyeilagh Formation. **Fig. 11**. *Dictyotriletes submarginatus* Playford, 1976. Sample MG-875, Khoshyeilagh Formation. **Fig. 12**. *Hymenozonotriletes perplexa* Balme and Hassell, 1962. Sample MG-864, Khoshyeilagh Formation. **Fig. 13**. *Retusotriletes phillipsii* Clendening, Eames and Wood, 1980. Sample MG-853, Khoshyeilagh Formation.
Planche 1. Fig. 1, 3, 4, 7–13 : spores de la Formation de Khoshyeilagh; Fig. 2, 5, 6 : miospores du Membre b de la Formation de Padeha.

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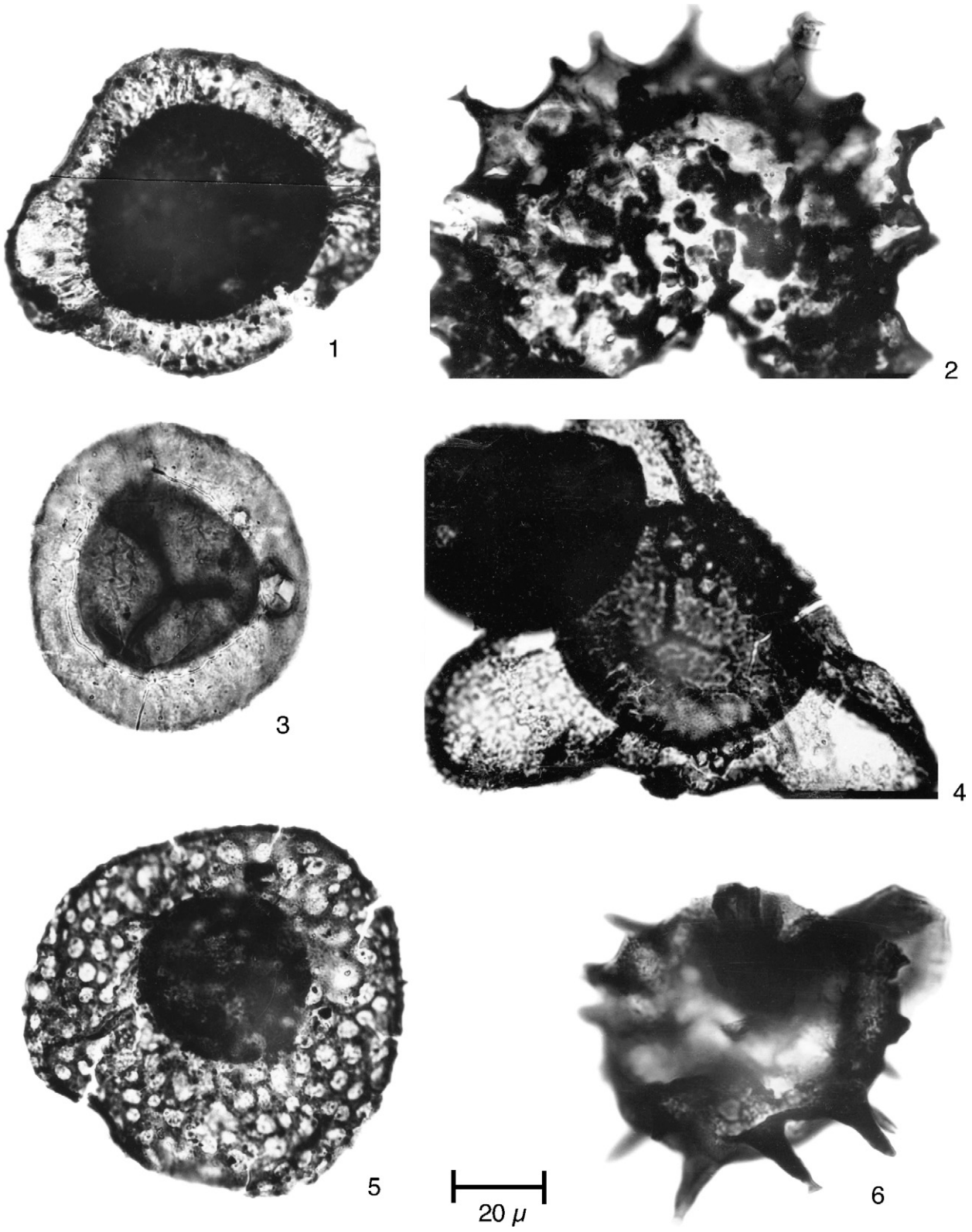

Plate 2. **Fig. 1**. *Indotriradites explanatus* (Luber) Playford, 1991. Sample MG-860, Khoshyeilagh Formation. **Fig. 2**. *Ancyrospora ampulla* Owens, 1971. Sample MG-815, Member b of Padeha Formation. **Fig. 3**. *Diducites mucronatus* (Kedo) Van Veen, 1981. Sample MG-864, Khoshyeilagh Formation. **Fig. 4**. *Auroraspora torquata* Higgs, 1975. Sample MG-830, Member d of Padeha Formation. **Fig. 5**. *Retispora macroreticulata* (Kedo) Byvscheva, 1985. Sample MG-864, Khoshyeilagh Formation. **Fig. 6**. *Hystricosporites porrectus* (Balme and Hassell) Allen, 1965. Sample MG-830, Member d of Padeha Formation.
Planche 2. Fig. 1, 3 et 5 : spores de la Formation de Khoshyeilagh ; Fig. 2 : spore du Membre b de la Formation de Padeha ; Fig. 4 et 6 : spores du Membre d de la Formation de Padeha.

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4.1. Acritarch/spore assemblage zone I

This assemblage zone occurs in the lowermost part of Member b of the Padeha Formation and extends through a thickness of 57 m (Fig. 2), composed mainly of alternations of shale and gypsum. This assemblage zone is characterized by the first occurrence of acritarch taxa, including *Chomotriletes vedugensis*, *Papulogabata annulata*, *Lophosphaeridium segregum*, *Helosphaeridium guttatum*, *Gorgonisphaeridium plerispinosum*, *Gorgonisphaeridium discissum*, *Dictyotidium torosum*, *Cymatiosphaera perimembrana*, *Solisphaeridium inaffectum*, *S. spinoglobosum*, and *Dictyotidium araiomegronium*. Amongst this association, the acritarch taxa, *Chomotriletes vedugensis* and *Papulogabata annulata* are confined to assemblage zone I and the remainder continue into the succeeding assemblage zones (Fig. 2). Amongst the acritarch species of this assemblage zone, the phytoplankton species *Chomotriletes vedugensis* is more noteworthy than the others for the age determination of this part of Padeha Formation. This species has been previously recorded as being not older than Frasnian in age. *Chomotriletes vedugensis* has been recorded from Frasnian sediments in Australia (Balme, 1962; Playford and Dring, 1981; Playford, 1981), Frasnian–Famennian sediments of Argentina (Ottone, 1996), the United States (Wicander and Playford, 1985), Russia (Naumova, 1953), Saudi Arabia (Hemer and Nygreen, 1967), and Iran (Kimyai, 1972; Ghavidel-syooki, 1988, 1992, 1994, 1999, 2001, 2003).

Several of the microphytoplankton species recorded with *Chomotriletes vedugensis*, including *Lophosphaeridium segregum*, *Helosphaeridium guttatum*, *Gorgonisphaeridium plerispinosum*, *Gorgonisphaeridium discissum*, *Dictyotidium torosum*, *Cymatiosphaera perimembrana*, *Solisphaeridium inaffectum*, *S. spinoglobosum*, *Dictyotidium araiomegronium* and *Papulogabata annulata*, have also been reported from the Late Devonian (Frasnian–Famennian), or Frasnian deposits elsewhere (Le Hérissé et al., 2000). Therefore, based on the previous occurrences of *Chomotriletes vedugensis*, *Papulogabata annulata*, and other acritarch species, this assemblage zone from Member b of the Padeha Formation is assigned a Frasnian age.

In addition to acritarch taxa, there are also miospores and a small number of scolecodonts in the productive samples from this part of Padeha Formation. The miospore species within this assemblage zone include *Emphanisporites rotatus*, *Retusotriletes distinctus*, *R. rotundus*, and *Geminospora lemurata* but all extend stratigraphically into the succeeding zones (Fig. 2). *Emphanisporites rotatus* and *Retusotriletes rotundus* have been recorded from sections throughout most of the Devonian (Clayton et al., 1977), *Retusotriletes distinctus* has been previously recorded from the Middle and Early Late Devonian (Frasnian) in Western Australia (Balme, 1988) whilst *Geminospora lemurata* has a worldwide Givetian–Late Frasnian distribution (Balme, 1988).

4.2. Acritarch/spore assemblage zone II

This assemblage zone II is also present in Member b of Padeha Formation and extends through a thickness of 143 m. This interval of the formation consists mainly of alternations of shale and gypsum with a few dolomite stringers (Fig. 2). This assemblage is marked by the first appearance of acritarch species such as *Gorgonisphaeridium abstrusum* and *Stellinium comptum*, which are also accompanied by miospore and acritarch taxa characteristic of underlying assemblage zone I. *Gorgonisphaeridium abstrusum* has been previously recorded from Early Frasnian deposits of Western Australia (Playford and Dring, 1981; Playford, 1981) and Frasnian sediments of Iran (Hashemi and Playford, 1998; Ghavidel-syooki, 2003). *Stellinium comptum* has also been reported from Late Frasnian sediments in the United States (Wicander and Loeblich, 1977; Wicander and Playford, 1985), Early Late Devonian deposits of Iran (Hashemi and Playford, 1998; Ghavidel-syooki, 1988, 1992, 1994, 2001) and Late Devonian and Early Carboniferous deposits of Turkey (Higgs et al., 2002). Near to the top of this assemblage zone, the miospore *Ancyrospora ampulla* is present and continues into the succeeding assemblage zone. This species has been recorded from the Frasnian sediments of both Canada (Owens, 1971) and Iran (Ghavidel-syooki, 2003). Therefore, based on presence of the above acritarch taxa and the miospore taxa, this interval of Member b is also assigned to the Frasnian.

4.3. Acritarch/spore assemblage zone III

This assemblage zone occurs in the uppermost part of Member b and the whole of Member c of the Padeha Formation and includes a thickness of 62 m of sediments consisting mainly of shales and fossiliferous limestones. This assemblage zone is characterized by the first appearance of the acritarch species *Veryhachium pannuceum*, *Daillyidium pentaster*, and *Multiplicisphaeridium ramispinosum*. *Veryhachium pannuceum* has been previously recorded from the Upper Devonian including the Antrim Shale of the United States (Wicander and Loeblich, 1977) and in Libya (Vanguestainé in Paris et al., 1985). In general, this species is confined to the Frasnian–Famennian interval (Le Hérissé et al., 2000). *Daillyidium pentaster* is widely distributed in the Upper Givetian–Upper Famennian strata of both northern and southern hemispheres. This species has recorded from the Frasnian–Famennian strata of Canada (Staplin, 1961), Givetian–Upper Devonian deposits of the Algerian Sahara (Jardiné et al., 1972), the Middle Devonian Cedar Valley Formation of Iowa (Wicander and Wood, 1997), Early Late Devonian sediments of Western Australia (Playford and Dring, 1981; Playford, 1981), Upper Frasnian–Lower Famennian deposits of the Brabant Massif of Belgium (Kimpe et al., 1978), and the Upper Devonian Shishtu Formation of Iran (Hashemi and Playford, 1998). *Multiplicisphaeridium ramispinosum* is widely distributed in the Lower and Upper Devonian rocks in both the northern and southern hemispheres, especially within the Givetian through Famennian interval (Colbath, 1990). Shelly faunas (brachiopod and coral specimens) were collected from some horizons within Member c of the Padeha Formation during this study. The brachiopods were studied by Prof. Mohammad-Ali Jafari of Esfahan University who identified species including *Sucatospirifer iranicus* Brice, (*Cyrtospirifer syringothyriformis* Golshani et al., 1973), *Spinatrypa* sp., and *Athyris* aff. *sulcifer*

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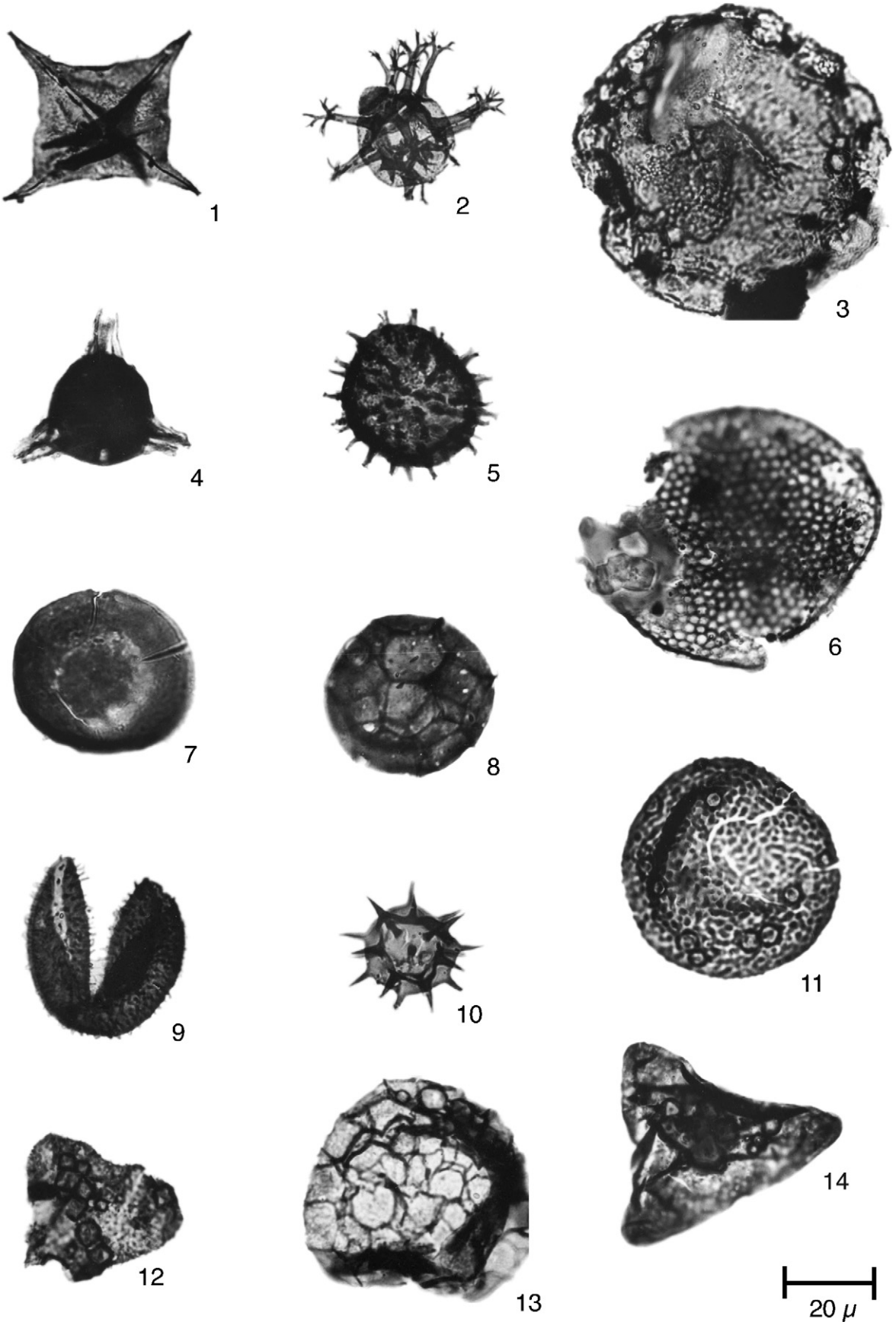

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Reed, suggesting an uppermost Frasnian or lowermost Famennian age. Therefore, based on both acritarch and brachiopod evidence, this interval of the Padeha Formation is assigned to the uppermost Frasnian and lowermost Famennian.

4.4. Acritarch/spore assemblage zone IV

This assemblage zone is present in Member d of Padeha Formation and the basal part of Khoshyeilagh Formation and represents a thickness of 121 m of sediment. This Member of the Padeha Formation consists mainly of alternations of shale and gypsum in the lower part but changes to alternations of shale and limestone in the upper part (Fig. 2). The basal part of Khoshyeilagh Formation consists of an alternation of fossiliferous limestone, sandstone and shale. This assemblage zone is marked by the first appearance of several miospore species including *Hystricosporites porrectus*, *Auroraspora torquata* (=*Teichertospora torquata* McGregor and Playford, 1992), *Grandispora gracilis*, and *Densosporites rotatus*. These species are diagnostic of the Late Devonian and have previously been recorded from the Famennian deposits of southern Ireland (Higgs, 1975; Higgs et al., 1988), the Late Devonian strata of Australia (Balme and Hassell, 1962; Balme, 1988; Playford, 1991), and Lower Famennian sediments of Euramerica (Richardson and McGregor, 1986), the Upper Devonian Geirud Formation of Iran (Kimyai, 1972, 1979) and Lower and Middle Devonian of Vestspitsbergen (Allen, 1965). Amongst the miospore species from Member d of Padeha Formation and basal part of Khoshyeilagh Formation, *Auroraspora torquata* and *Grandispora gracilis* suggest an assignment to Richardson and McGregor's *Auroraspora torquata–Grandispora gracilis* assemblage zone which is recognized in the latest Frasnian and Early Famennian strata in Europe, Australia and Canada (Richardson and McGregor, 1986; McGregor and Playford, 1992; Streel and Loboziak, 1996).

In addition to the miospore species, some acritarch and prasinophyte species including *Gorgonisphaeridium ohioensis*, *Deltotosoma intonsum*, *Ammonidium loriferum*, *Dictyotidium craticulum*, *Dictyotidium litum*, *Crassiangulina tessellita*, *Cymatiosphaera melikera*, *Striatostellula sparsa*, *Polyedryxium pharaonis* and *Maranhites perplexus* have their first occurrence in the uppermost part of Member d of the Padeha Formation and extend into the succeeding assemblage zones. With the exception of *Polyedryxium pharaonis*, which has been previously recorded from Lower–Upper Devonian sediments elsewhere (Wicander and Wood, 1997), the remainder of these marine phytoplankton species in this assemblage zone have been recorded from the Late Devonian sediments in the United States (Wicander and Loeblich, 1977; Wicander and Playford, 1985), North Africa (Paris et al., 1985; Jardiné et al., 1972; Streel et al., 1988), Australia (Playford and Dring, 1981; Playford, 1981), Middle–Upper Frasnian to Famennian sediments at Boulonnais of France (Loboziak and Streel, 1981), and Iran (Coquel et al., 1977; Ghavidel-syooki, 1988, 1992, 1994, 1995, 2001, 2003; Hashemi and Playford, 1998). It should be noted, however, that *Deltotosoma intonsum* has only previously been reported from Frasnian deposits (Le Hérissé et al., 2000), whereas in the present study it is interpreted to occur within the Famennian. The prasinophyte species *Dictyotidium litum* and *Dictyotidium craticulum* have also reported from Frasnian sediments of Iran (Hashemi and Playford, 1998; Ghavidel-syooki, 2003), but they extend into the Famennian interval of the Padeha Formation in the Jajarm area. The chitinozoan *Angochitina devonica* is also present in this member and continues into the succeeding zones. This species have been recorded from the Late Devonian deposits of Alberta, Canada (Staplin, 1961) and Middle Devonian strata of the United States (Wicander and Wood, 1997). Based on the marine and nonmarine phytoplankton taxa recorded, a latest Frasnian and Early Famennian age (Belgian unit of Fa2a) is suggested for Member d of the Padeha Formation and basal part of the Khoshyeilagh Formation in the Jajarm area, northeastern Iran. It should be noted that the brachiopod fauna of the basal part of Khoshyeilagh Formation in its type section has recently been re-investigated and suggests a Late Devonian age for this part of formation (Zaman, 2001).

4.5. Acritarch/spore assemblage zone V

This assemblage zone occurs in the Khoshyeilagh Formation and extends through a thickness of 33.5 m, consisting of limestones and shales (Fig. 2). The assemblage zone is distinguished by the presence of miospore species such as *Retusotriletes phillipsii*, *Rugospora flexuosa*, and *Grandispora cornuta*, which are associated with marine phytoplankton and miospore species from the preceding, older assemblage zones. *Retusotriletes phillipsii* has been previously recorded from Famennian sediments in the United States (Clendening et al., 1980) and

Plate 3. **Fig. 1**. *Stellinium comptum* Wicander and Loeblich, 1977. Sample MG-812, Member b of Padeha Formation. **Fig. 2**. *Multiplicisphaeridium ramispinosum* Staplin, 1961. Sample MG-812, Member b of Padeha Formation. **Fig. 3**. *Maranhites perplexus* Wicander and Playford, 1985. Sample MG-830, Member d of Padeha Formation. **Fig. 4**. *Daillyidium pentaster* (Staplin) Playford, comb. nov., emend. in Playford and Dring, 1981. Sample MG-812, Member b of Padeha Formation. **Fig. 5**. *Gorgonisphaeridium discissum* Playford in Playford and Dring, 1981. Sample MG-812, Member b of Padeha Formation. **Fig. 6**. *Cymatiosphaera melikera* Wicander and Loeblich, 1977. Sample MG-835, Member d of Padeha Formation. **Fig. 7**. *Papulogabata annulata* Playford in Playford and Dring, 1981. Sample MG-785, Member b of Padeha Formation. **Fig. 8**. *Dictyotidium araiomegronium* Hashemi and Playford, 1998. Sample MG-785, Member b of Padeha Formation. **Fig. 9**. *Gorgonisphaeridium plerispinosum* Wicander, 1974. Sample MG-830, Member d of Padeha Formation. **Fig. 10**. *Solisphaeridium inaffectum* Playford in Playford and Dring, 1981. Sample MG-812, Member b of Padeha Formation. **Fig. 11**. *Lophosphaeridium segregum* Playford in Playford and Dring, 1981. Sample MG-785, Member b of Padeha Formation. **Fig. 12**. *Deltotosoma intonsum* Playford in Playford and Dring, 1981. Sample MG-850, Member d of Padeha Formation. **Fig. 13**. *Dictyotidium craticulum* (Wicander and Loeblich) Wicander and Playford, 1985. Sample MG-850, Member d of Padeha Formation. **Fig. 14**. *Crassiangulina tessellita* Jardiné et al., 1974. Sample MG-830, Member d of Padeha Formation.
Planche 3. Fig. 1, 2, 4, 5, 7, 8, 10, 11 : acritarches du Membre b de la Formation de Padeha. Fig. 3 , 6, 9, 12–14 : acritarches du Membre d de la Formation de Padeha.

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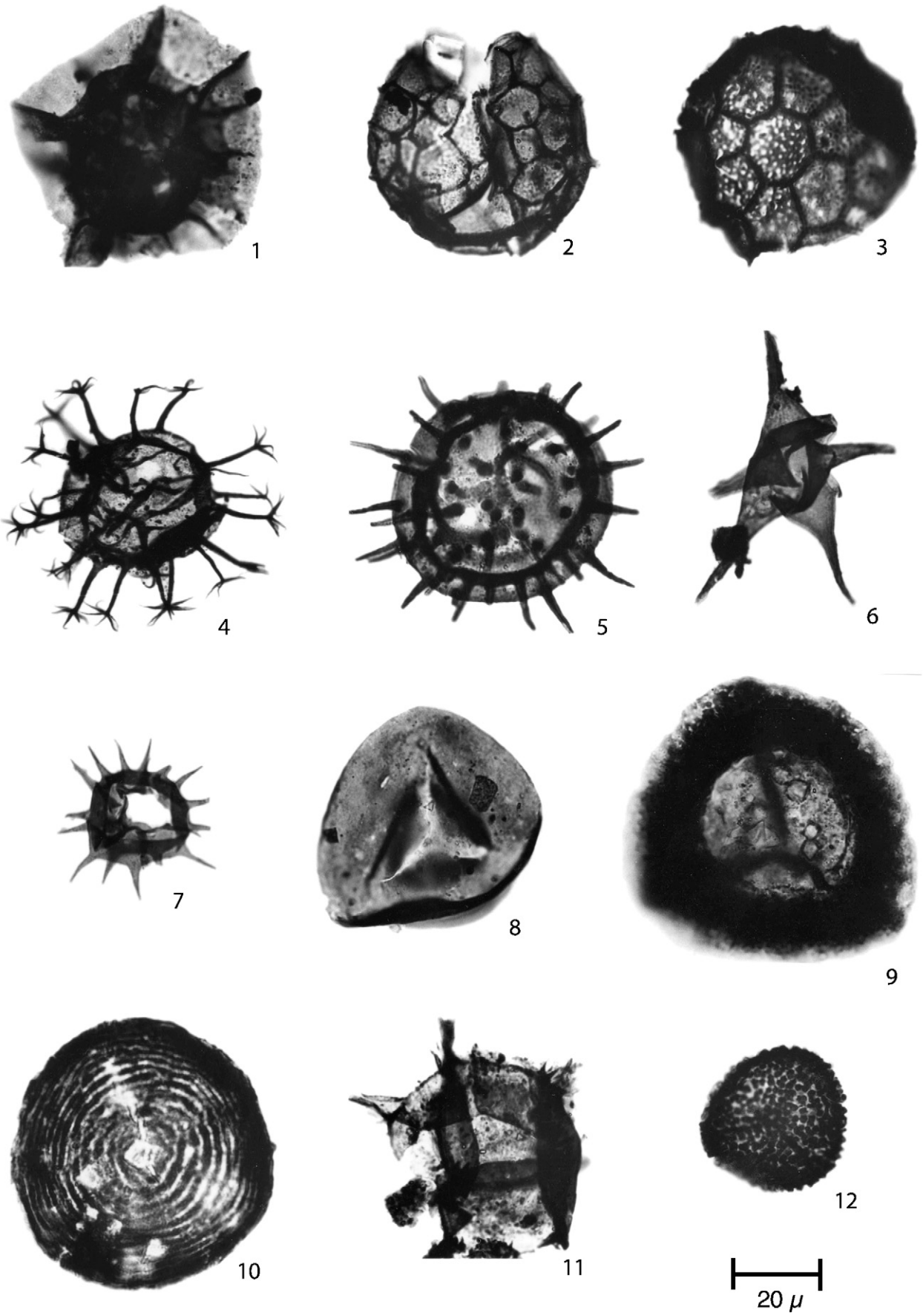

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Famennian strata in Belgium (Becker et al., 1974; Clayton et al., 1977). This species has a stratigraphical range in the Belgian sequence of F2a to F2b (Richardson and McGregor, 1986), but not in unit F2c (Becker et al., 1974). *Rugospora flexuosa* and *Grandispora cornuta* are diagnostic taxa of an assemblage zone between the *Auroraspora torquata–Grandispora gracilis* and the *Vallatisporites pusillites–Retispora lepidophyta* assemblage zones of Euramerica (Richardson and McGregor, 1986). This assemblage zone is also equivalent to the *Rugospora radiata–Grandispora cornuta* assemblage zone of Famennian age in Australia and Canada (McGregor and Playford, 1992).

4.6. Miospore assemblage zone VI

This assemblage zone is developed in the upper part of Khoshyeilagh Formation and extends through a thickness of 29.5 m, consisting of alternations of shale and fossiliferous limestones (Fig. 2). This interval is marked by the first appearance of abundant *Retispora lepidophyta*, common *Vallatisporites pusillites*, *Indotriradites explanatus*, *Hymenozonotriletes (Diaphanospora) perplexa*, and infrequent *Diducites mucronatus*. These miospore species are abundant in this interval of the Khoshyeilagh Formation and appear immediately above the upper limit of assemblage zone VI. The association has previously been recorded from the Late Famennian of England (Dolby, 1970; Dolby and Neves, 1970; Clayton et al., 1978; Turner et al., 1989), southern Ireland (Higgs, 1975; Keegan, 1977; Van Der Zwan and Van Veen, 1978; Van Veen, 1981; Higgs et al., 1988), Belgium (Kimpe et al., 1978; Streel et al., 1987; Maziane et al., 2002), Russia (Naumova, 1953; Byvscheva et al., 1984; Avkhimovitch et al., 1989), Canada and Australia (McGregor and Playford, 1992), Euramerica (Richardson and McGregor, 1986), Turkey (Higgs et al., 2002), North Africa (Paris et al., 1985), Western Australia, North Africa, Belgium, Germany, Canada and Russia (Owens and Streel, 1967), Saudi Arabia (Clayton et al., 2000), Algerian Sahara (Coquel and Latreche, 1989), and Iran (Coquel et al., 1977; Kimyai, 1972, 1979). This association is characteristic of the *Vallatisporites pusillites–Retispora lepidophyta* (PL) Zone of Clayton et al. (1978), the *Retispora–Diducites* group of Turner et al. (1989), the LE Subzone of Higgs et al. (1988) and the Belgian F2d and earliest Tn1 units of Becker et al. (1974).

Late Devonian acritarch species, including *Deltotosoma intonsum*, *Ammonidium loriferum*, *Crassiangulina tessellita*, *Striatostellula sparsa*, *Gorgonisphaeridium ohioensis*, *Gorgonisphaeridium abstrusum*, and *Maranhites perplexus* are also present but relatively rare.

4.7. Miospore assemblage zone VII

This assemblage zone occurs in a thickness of 72 m of fossiliferous limestones and shales in the uppermost part of Khoshyeilagh Formation (Fig. 2). In the study area, the upper contact of this formation and the lower contact of the overlying Mobarak Formation are separated by an igneous sill. This assemblage zone is characterized by the first appearance of miospore species including *Verrucosisporites nitidus*, *Retispora macroreticulata*, *Verruciretusispora loboziakii*, *Raistrickia variabilis*, *Apiculiretusispora fructicosa*, and *Grandispora echinata*. Many of the miospore species in this assemblage have previously been recorded from the Late Devonian and Early Carboniferous strata of southern Ireland (Higgs, 1975; Keegan, 1977; Van Der Zwan and Van Veen, 1978; Van Veen, 1981; Higgs et al., 1988; Clayton et al., 1974), England (Dolby, 1970; Dolby and Neves, 1970; Clayton et al., 1978; Turner et al., 1989), Turkey (Higgs et al., 2002), Saudi Arabia (Clayton et al., 2000), Algeria, Libya and Saudi Arabia (Clayton et al., 2002), and Australia (Playford, 1976). The first appearance of *Verrucosisporites nitidus* together with the continued presence of *Retispora lepidophyta* in this interval of the Khoshyeilagh Formation indicates the *Retispora lepidophyt–Verrucosisporites nitidus* (LN) Subzone of Clayton et al. (1978) and Higgs et al. (1988) and implies a latest Famennian (Strunian) age for this part of the formation. Marine palynomorphs (scolecodont, indeterminate chitinozoan and acritarch taxa) and ancyrate forms of miospores are also present in this interval of Khoshyeilagh Formation.

4.8. Miospore assemblage zone VIII

This assemblage zone is developed in a 104 m thick sequence of sandstone, shales, and fossiliferous limestones that extends through the lowermost part of Mobarak Formation (Fig. 2). The palynologically productive samples in this part of Mobarak Formation are recovered from the dark gray shale horizons, the fossiliferous limestones were found to be unsuitable for palynological studies. The base of this assemblage zone is characterized by the complete disappearance of *Retispora lepidophyta*, distinctive large ancyrate forms (*Hystricosporites* sp., *Ancyrospora* sp.), and chitinozoan taxa. The miospore assemblages from this unit are characterized by the first appearance of *Vallatisporites verrucosus*, *Retusotriletes incohatus*, and *Dictyotriletes submarginatus*, which are associated with abundant acritarch species such as *Gorgonisphaeridium ohioensis*, *Gorgonisphaeridium abstrusum*, and *Maranhites perplexus*

Plate 4. **Fig. 1**. *Cymatiosphaera perimembrana* Staplin, 1961. Sample MG-812, Member b of Padeha Formation. **Figs. 2, 3**. *Dictyotidium litum* Colbath, 1990. Sample MG-830, Member d of Padeha Formation. **Fig. 4**. *Ammonidium loriferum* (Deunff) Lister, 1970. Sample MG-835, Member d of Padeha Formation. **Fig. 5**. *Gorgonisphaeridium ohioense* (Winslow) Wicander, 1974. Sample MG-850, Khoshyeilagh Formation. **Fig. 6**. *Striatostellula sparsa* Hashemi and Playford, 1998. Sample MG-835, Member d of Padeha Formation. **Fig. 7**. *Solisphaeridium spinoglobosum* (Staplin) Wicander, 1974. Sample MG-812, Member b of Padeha Formation. **Fig. 8**. *Retusotriletes rotundus* (Streel) Streel, 1967. Sample MG-812, Member b of Padeha Formation. **Fig. 9**. *Densosporites rotatus* Staplin, 1960. Sample MG-812, Member b of Padeha Formation. **Fig. 10**. *Chomotriletes vedugensis* Naumova, 1953. Sample MG-777, Member b of Padeha Formation. **Fig. 11**. *Polyedryxium pharaonis* (Deunff) Jardiné et al., 1972. Sample MG-850, Khoshyeilagh Formation. **Fig. 12**. *Verruciretusispora loboziakii* Higgs et al., 2002. Sample MG-864, Khoshyeilagh Formation.

Planche 4. Figs. 1–4, 6, 7 and 11 : acritarches des membres b (Fig. 1, 7) et d (Fig. 2–4, 6) de la Formation de Padeha et de la Formation de Khoshyeilagh (Fig. 5, 11) et miospores du Membre b de la Formation de Padeha (Fig. 8–10) et de la Formation de Khoshyeilagh (Fig. 12)

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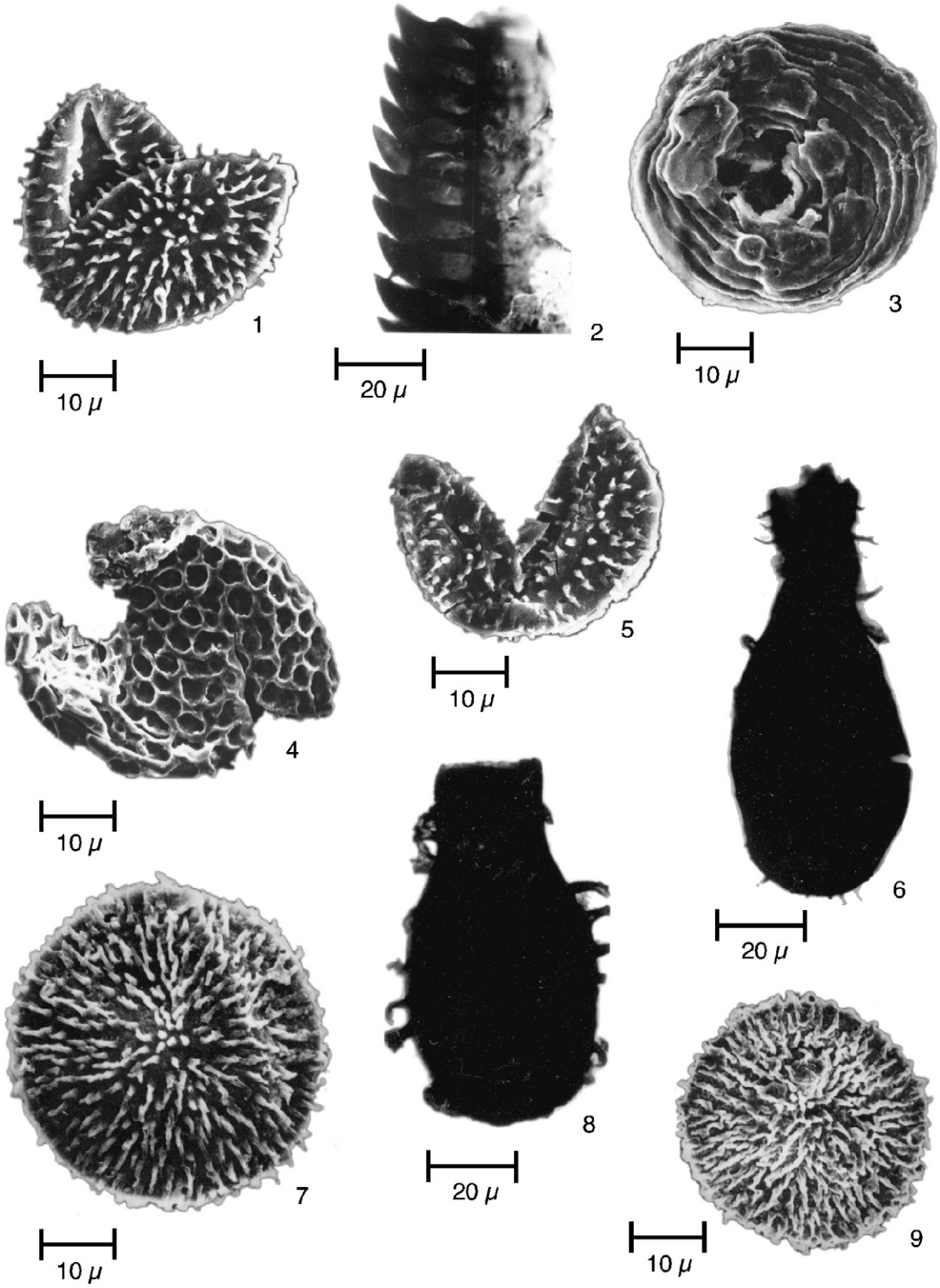

Plate 5. **Figs. 1, 7**. *Gorgonisphaeridium abstrusum* Playford in Playford and Dring, 1981. Sample MG-785, Member b of Padeha Formation. **Fig. 2**. Scolecodont. Sample MG-812, Member b of Padeha Formation. **Fig. 3**. *Chomotriletes vedugensis* Naumova, 1953. Sample MG-812, Member b of Padeha Formation. **Fig. 4**. *Dictyotidium torosum* Playford in Playford and Dring, 1981. Sample MG-812, Member b of Padeha Formation. **Fig. 5**. *Gorgonisphaeridium plerispinosum* Wicander, 1974. Sample MG-795, Member b of Padeha Formation. **Figs. 6, 8**. *Angochitina devonica* Eisenack, 1955. Sample MG-820, Member c of Padeha Formation. **Fig. 9**. *Helosphaeridium guttatum* Playford in Playford and Dring, 1981. Sample MG-790, Member b of Padeha Formation.
Planche 5. Acritarches (Fig. 1, 4–7, 9), scolécodonte (Fig. 2) et miospore (Fig. 3) du Membre b de la Formation de Padeha ; chitinozoaires (Fig. 6 et 8) du Membre c de la Formation de Padeha.

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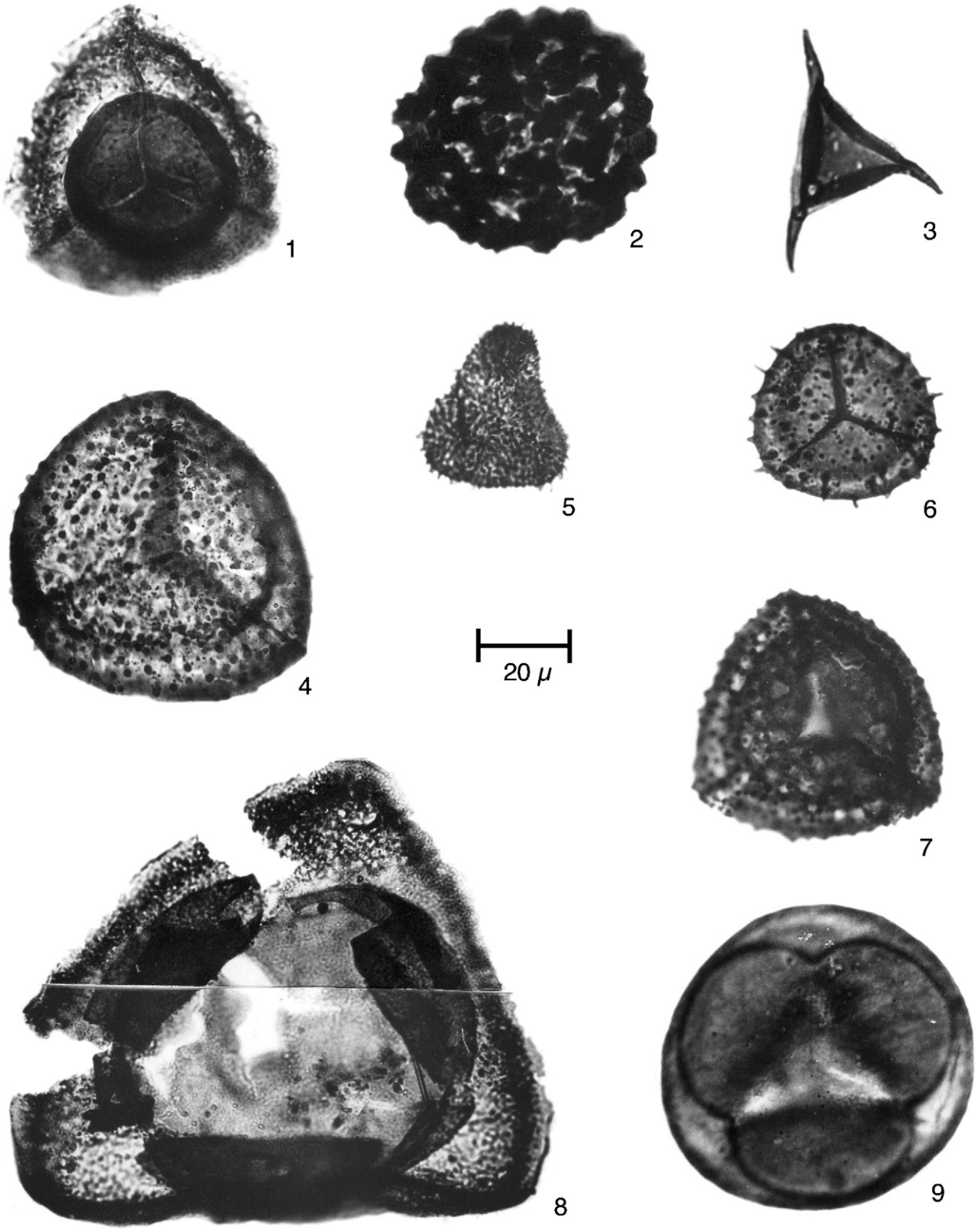

Plate 6. **Fig. 1**. *Densosporites rotatus* Staplin, 1960. Sample MG-830, Member d of Padeha Formation. **Fig. 2**. *Verrucosisporites nitidus* (Naumova) Playford, 1964. Sample MG-875, Khoshyeilagh Formation. **Fig. 3**. *Veryhachium pannuceum* Wicander and Loeblich, 1977. Sample MG-812, Member b of Padeha Formation. **Fig. 4**. *Grandispora gracilis* (Kedo) Streel, in Becker et al., 1974. Sample MG-830, Member d of Padeha Formation. **Fig. 5**. *Deltotosoma intonsum* Playford in Playford and Dring, 1981. Sample MG-850, Khoshyeilagh Formation. **Fig. 6**. *Grandispora cornuta* Higgs, 1975. Sample MG-850, Khoshyeilagh Formation. **Fig. 7**. *Grandispora echinata* Hacquebard, 1957. Sample MG-864, Khoshyeilagh Formation. **Fig. 8**. *Auroraspora torquata* Higgs, 1975. Sample MG-835, Member d of Padeha Formation. **Fig. 9**. *Retusotriletes distinctus* Richardson, 1965 (MG-812, Member b of Padeha Formation.
Planche 6. Fig. 1, 2, 4, 6–9 : Miospores de la Formation de Padeha (Membre d : Fig. 1, 4, 8 ; Membre b : Fig. 9) et de la Formation de Khoshyeilagh (Fig. 2, 6 et 7) ; acritarches de la Formation de Padeha, Membre b (Fig. 3) et de la Formation de Khoshyeilagh (Fig. 5).

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(Fig. 2). The miospore assemblages suggest the *Vallatisporites verrucosus–Retusotriletes incohatus* (VI) Subzone of Clayton et al. (1978) which was established in the Lower Mississippian (Tournaisian) sediments of England (Clayton et al., 1978) and southern Ireland (Keegan, 1977; Higgs et al., 1988). Based on the presence of characteristic miospores of the VI Subzone, a Lower Mississippian (Tournaisian) age is assigned to the basal part of Mobarak Formation. This is consistent with the foraminiferal age assignment of Bozorgnia (1973).

5. Conclusions

Fifty-three palynomorph taxa were identified from the Padeha, Khoshyeilagh, and Mobarak formations, and their distributions are plotted on Fig. 2. These species have been arranged into eight stratigraphic assemblage zones. The assemblage zones I–IV are developed in the Padeha Formation (Members of b, c, and d) and suggest a Late Devonian (Frasnian) age. The miospores identified in the lower part of the Padeha Formation (Member b) indicate that many are long-ranging species. However, this part of Member b also contains a number of microphytoplankton species including *Chomotriletes vedugensis*, *Papulogabata annulata*, *Lophosphaeridium segregum*, *Helosphaeridium guttatum*, *Gorgonisphaeridium plerispinosum*, *Gorgonisphaeridium discissum*, *Dictyotidium torosum*, *Cymatiosphaera perimembrana*, *Solisphaeridium inaffectum*, and *Solisphaeridium spinoglobosum* that clearly indicate an Early Late Devonian (Frasnian) age. The presence of the Frasnian acritarch species, *Chomotriletes vedugensis*, is particularly noteworthy. The assemblages zones V–VII occur in the Khoshyeilagh Formation and indicate a Late Devonian (Famennian) age. Assemblage zone VIII appears in the Mobarak Formation and represents the Lower Mississippian (Tournaisian). The miospores recovered from assemblage zones V–VIII are closely comparable to those recorded from biozones associated with Late Devonian–Early Carboniferous strata in England, Belgium, France, Germany, Canada, Western Australia, Libya, Saudi Arabia, Turkey, and Russia. This similarity suggests that the parent plants of these miospores were cosmopolitan and were able to survive under varied climatic conditions. The ancyrate miospore taxa (*Ancyrospora* and *Hystricosporites*) occur only in the Padeha and Khoshyeilagh formations. The presence of acritarch, scolecodont, and chitinozoan taxa within the Padeha, Khoshyeilagh, and Mobarak formations together with shelly macrofauna suggest a shallow marine environment for these formations.

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References

Afshar-harb, A., 1979. The stratigraphy, tectonic and petroleum geology of Kopet-Dagh region, northern Iran. Ph.D. thesis, Petroleum Geology Section, Royal School of Mines, Imperial College London (unpublished).

Ahmadzadeh-heravi, M., 1975. Stratigraphie und fauna im Devon des östlichen Elburz (Iran). Clausthaler Geologischen Abhandlungen 23, 1–114.

Alavi-naini, M., 1972. Étude géologique de la région de Djam. Geological Survey of Iran, Report no. 23 (unpublished).

Allen, K.C., 1965. Lower and Middle Devonian spores of north and Central Vestspitsbergen. Palaeontology 8, 687–748.

Assereto, R., Gaetani, M., 1964. Nuovi dati sul Devoniano della catena dell'Imam Zadéh Hashim (Elburz Central Iran). Rivista Italiana di Paleontologia e Stratigrafia 70, 631–636.

Avkhimovitch, V.I., Nekryata, N.S., Obuhovskaya, T.G., 1989. Devonian palynostratigraphy of the Pripyat Depression, Belorussia. In: McMillan, N.J., Embry, A.F., Glass, D.J. (Eds.), Devonian of the World, 3, Paleontology, Paleoecology, and Biostratigraphy. Canadian Society of Petroleum Geologists, Memoir 14, Calgary, pp. 559–566.

Balme, B.E., 1962. Upper Devonian (Frasnian) spores from the Carnarvon Basin Western Australia. Palaeobotanist 9, 1–10.

Balme, B.E., 1988. Miospores from Late Devonian (Early Frasnian) strata, Carnarvon Basin, Western Australia. Palaeontographica Abteilung B 209, 109–166.

Balme, B.E., Hassell, C.V., 1962. Upper Devonian spores from the Canning Basin Western Australia. Micropaleontology 8, 1–28.

Becker, G., Bless, M.J.M., Streel, M., Thorez, J., 1974. Palynology and ostracod distribution in the Upper Devonian and basal Dinantian of Belgium and their dependence on sedimentary facies. Mededelingen Rijks Geologische Dienst, N.S. 25, 9–99.

Brice, D., 1999. New data on systematics of some Famennian spiriferids brachiopods from Afghanistan and Iran. Senckenbergiana lethaea 79, 281–295.

Brice, D., Lafuste, J., de Lapparent, A.F., Pillet, J., Yassini, I., 1974. Étude de deux gisements (Silurien et Dévonien) de l'Elbourz oriental (Iran). Annales de la Société Géologique du Nord 93, 177–218.

Bozorgnia, F., 1973. Palaeozoic foraminifera biostratigraphy of Central and East-Alborz Mountains, Iran. National Iranian Oil Company, Geological Laboratories, Publication 4, 1–185.

Byvscheva, T.V., Higgs, K.T., Streel, M., 1984. Spore correlation between the Rhenish Slate Mountains and the Russian Platform near the Devonian–Carboniferous boundary. Courier Forschungsinstitut Senckenberg 67, 37–45.

Clayton, G., Coquel, R., Doubinger, J., Gueinn, K.J., Loboziak, S., Owens, B., Streel, M., 1977. Carboniferous miospores of Western Europe; Illustration and Zonation. Mededelingen Rijks Geologische Dienst, N.S. 29, 1–71.

Clayton, G., Higgs, K., Gueinn, K.J., Van Gelder, A., 1974. Palynological correlation in the Cork Beds (Upper Devonian-Lower Carboniferous) of southern Ireland. Proceedings Royal Irish Academy 746, 145–156.

Clayton, G., Higgs, K., Keegan, J.B., Sevastopulo, G.D., 1978. Correlation of the palynological zonation of the Dinantian of the British Isles. Palinologia 1, 137–147.

Clayton, G., Owens, B., Al-Hajri, S., Filatoff, J., 2000. Latest Devonian and Early Carboniferous miospore assemblages from Saudi Arabia. In: Al-Hajri, S., Owens, B. (Eds.), Stratigraphic palynology of the Palaeozoic of Saudi Arabia. GeoArabia, Special Publication 1, Bahrain, pp. 146–153.

Clayton, G., Wicander, R., Pereira, Z., 2002. Palynological evidence concerning the relative positions of northern Gondwana and southern Laurussia in latest Devonian and Mississippian times. Special Papers in Palaeontology 67, 45–56.

Clendening, J.A., Eames, L.E., Wood, G., 1980. *Retusotriletes phillipsii* n. sp., a potential Upper Devonian guide palynomorph. Palynology 4, 15–22.

Colbath, G.K., 1990. Devonian (Givetian-Frasnian) organic-walled phytoplankton from the limestone of Billy Hills reef complex, Canning Basin Western Australia. Palaeontographica Abteilung B 217, 87–145.

Coquel, R., Latreche, S., 1989. Étude palynologique de la Formation d'Illerène (Dévono-Carbonifère) du Bassin d'Illizi (Sahara Algérien Oriental). Palaeontographica Abteilung B 212, 47–70.

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Coquel, R., Loboziak, S., Stampfli, G., Stampfli-vuille, B., 1977. Palynologique du Dévonien supérieur et du Carbonifère inférieur dans l'Elburz oriental (Iran nord-est). Revue de micropaléontologie 20, 59–71.

Dolby, G., 1970. Spore assemblages from the Devonian-Carboniferous transition measures in south-west Britain and southern Eire. Colloque sur la Stratigraphie du Carbonifère, Congrès et Colloques. Université de Liége 55, 267–274.

Dolby, G., Neves, R., 1970. Palynological evidence concerning the Devonian-Carboniferous boundary in the Mendips, England. Compte Rendu du 6e Congrès International de Stratigraphie et Géologie du Carbonifère (Sheffield, 1967) 2, 631–646.

Ghavidel-syooki, M., 1988. Palynostratigraphy and Paleoecology of the Faraghan Formation of southeastern Iran. Ph.D. thesis, Michigan State University, East Lansing (unpublished).

Ghavidel-syooki, M., 1992. Palynostratigraphy and paleogeography of Padeha and Khoshyeilagh formations in Kuh-e-Ozum, at Kopet-Dagh region, northeastern Iran. National Iranian Oil Company, Paleontological Report No. 407 (unpublished).

Ghavidel-syooki, M., 1994. Biostratigraphy and paleo-biogeography of some Paleozoic rocks at Zagros and Alborz mountains. Geological Survey of Iran with cooperation of Deputy Ministry of Project and Planning 18, 1–168.

Ghavidel-syooki, M., 1995. Palynostratigraphy and palaeogeography of a Palaeozoic sequence in the Hassanakdar area, Central Alborz Range, northern Iran. Review of Palaeobotany and Palynology 86, 91–109.

Ghavidel-syooki, M., 1999. Investigation on the Upper Palaeozoic strata in Tange-Zakeen and introducing Zakeen Formation, Kuh-e-Faraghan Zagros Basin, Southern Iran. Geological Survey of Iran. Geosciences Scientific Quarterly Journal 29/30, 54–73.

Ghavidel-syooki, M., 2001. Palynostratigraphy and palaeogeography of the Late Devonian strata in northeastern Esfehan city, Central Iran. In: Goodman, D.K., Clarke, R.T. (Eds.), Proceedings of the IX International Palynological Congress 1996. Houston, Texas, USA, pp. 37–51.

Ghavidel-syooki, M., 2003. Palynostratigraphy of Devonian sediments in the Zagros Basin, southern Iran. Review of Palaeobotany and Palynology 127, 241–268.

Golshani, F., Janvier, Ph., Brice, D., Lapparent, A.F., 1973. Sur la paléogéographie et la paléobiologie du Dévonien dans la région de Kerman en Iran. Comptes Rendus de l'Académie des Sciences de Paris 276, 697–700.

Hashemi, H., Playford, G., 1998. Upper Devonian palynomorphs of Shishtu Formation, Central Iran Basin, east-central Iran. Palaeontographica Abteilung B 246, 115–212.

Hemer, D.O., Nygreen, P.W., 1967. Devonian palynology of Saudi Arabia. Review of Palaeobotany and Palynology 5, 51–61.

Higgs, K.T., 1975. Upper Devonian and Lower Carboniferous miospore assemblages from Hook Head, County Wexford, Ireland. Micropaleontology 21, 393–419.

Higgs, K.T., Clayton, G., Keegan, J.B., 1988. Stratigraphic and Systematic Palynology of the Tournaisian rocks of Ireland. Geological Survey of Ireland Special Paper 7, 5–93.

Higgs, K.T., Finucane, D., Tunbridge, I.P., 2002. Late Devonian and Early Carboniferous microflora from the Hakkari Province of southeastern Turkey. Review of Palaeobotany and Palynology 118, 141–151.

Jardiné, S., Combaz, A., Magloire, L., Peniguel, G., Vachey, G., 1972. Acritarches du Silurien terminal et du Dévonien du Sahara algérien. Compte Rendu du 6e Congrès International de Stratigraphie et Géologie du Carbonifère, Krefeld (1971) 1, 295–311.

Keegan, J.B., 1977. Late Devonian and Early Carboniferous miospores from the Galley Head-Leap Harbour region of southwest Ireland. Pollen et Spores 19, 545–573.

Kimpe, W.F.M., Bless, M.J.M., Bouckaert, J., Conil, R., Groessen, E., Meessen, J.P.M.T., Poty, E., Streel, M., Thorez, J., Vanguestaine, M., 1978. Paleozoic deposits east of the Brabant Massif in Belgium and the Netherlands. Mededelingen Rijks Geologische Dienst 30, 37–103.

Kimyai, A., 1972. Devonian plant microfossils from the Central Elburz, Iran. Pollen et Spores 14, 187–201.

Kimyai, A., 1979. Devonian spores from the Hassanakdar area, Iran. Pollen et Spores 21, 481–498.

Le Hérissé, A., Servais, T., Wicander, R., 2000. Devonian acritarchs and related forms. Courier Forschungsinstitut Senckenberg 220, 195–205.

Loboziak, S., Streel, M., 1981. Miospores in Middle-Upper Frasnian to Famennian sediments partly dated by conodonts (Boulonnais France). Review of Palaeobotany and Palynology 38, 49–66.

Maziane, N., Higgs, K.T., Streel, M., 2002. Biometry and paleoenvironment of *Retispora lepidophyta* (Kedo) Playford, 1976 and associated miospores in the latest Famennian nearshore marine facies, eastern Ardennes (Belgium). Review of Palaeobotany and Palynology 118, 211–222.

McGregor, D.C., Playford, G., 1992. Canadian and Australian Devonian spores, zonation and correlation. Geological Survey of Canada Bulletin 438, 1–125.

Naumova, N.S., 1953. Spore-pollen assemblages of the Upper Devonian of the Russian Platform and their stratigraphic significance. Transactions of Institute of Geological Sciences, Academy of Sciences, USSR 143, 1–204 (in Russian).

Ottone, E.G., 1996. Devonian palynomorphs from the Los Monos Formation, Tarija Basin Argentina. Palynology 20, 105–155.

Owens, B., 1971. Miospores from the Middle and Early Upper Devonian rocks of Western Queen Elizabeth Island, Arctic Archipelago. Geological Survey of Canada Paper 70, 1–157.

Owens, B., Streel, M., 1967. *Hymenozonotriletes lepidophytus* Kedo, its distribution and significance in relation to the Devonian-Carboniferous boundary. Review of Palaeobotany and Palynology 1 (1–4), 141–150.

Paris, F., Richardson, J.B., Riegel, W., Streel, M., Vanguestainé, M., 1985. Devonian (Emsian-Famennian) palynomorphs. Journal of micropalaeontology 4, 49–82.

Playford, G., 1976. Plant microfossils from the Upper Devonian and Lower Carboniferous of the Canning Basin Western Australia. Palaeontographica Abteilung B 158, 1–71.

Playford, G., 1981. Late Devonian acritarchs from the Gneudna Formation in Western Carnarvon Basin, Western Australia. Geobios 14, 145–171.

Playford, G., 1983. The Devonian miospore genus *Geminospora* Balme, 1962, a reappraised based upon topotypic *G. lemurata* (type species). Memoir of the Association of Australasian Paleontologists 1, 311–352.

Playford, G., 1991. Australian Lower Carboniferous miospores relevant to extra-Gondwana correlations: an evaluation. In: Brenckle, P.L., Manger, W.L. (Eds.), Intercontinental Division and Correlation of the Carboniferous System. Courier Forschungsinstitut Senckenberg 130, Stuttgart, pp. 85–125.

Playford, G., Dring, R.S., 1981. Late Devonian Acritarchs from Carnarvon Basin Western Australia. Special Papers in Palaeontology 27, 1–78.

Rafighei-oskuei, N., 1992. Palynostratigraphy and palaeobiogeography of Padeha Formation at its type locality in Ozbak-Kuh. M.Sc. thesis Shahid Beheshti University, Tehran (unpublished).

Richardson, J.B., 1965. Middle Old Red Sandstones spore assemblages from the Orcadian Basin, north-east Scotland. Palaeontology 7, 559–605.

Richardson, J.B., McGregor, D.C., 1986. Silurian and Devonian spore zones of the Old Red Sandstone continent and adjacent regions. Geological Survey of Canada Bulletin 364, 1–79.

Staplin, F.L., 1961. Reef controlled distribution of Devonian microplankton in Alberta. Palaeontology 4, 392–424.

Stepanov, D.L., 1971. Carboniferous stratigraphy of Iran, Compte Rendu du 6e Congrès International de Stratigraphie et Géologie du Carbonifère (Sheffield, 1967) 4, 505–1517.

Streel, M., Higgs, K., Loboziak, S., Riegel, W., Steemans, P., 1987. Spore stratigraphy and correlation with faunas and floras of the Ardenne-Rhenish regions. Review of Palaeobotany and Palynology 50, 211–229.

Streel, M., Loboziak, S., 1996. Paleozoic spore and pollen. Chapter 18B. Middle and Upper Devonian miospores. In: Jansonius, J., McGregor, D.C. (Eds.), Palynology, principles and applications. American Association of Stratigraphic Palynologists Foundation 2, Dallas, pp. 575–587.

Streel, M., Paris, F., Riegel, W., Vanguestaine, M., 1988. Acritarch, chitinozoan and spore stratigraphy from the Middle and Late Devonian of northeast Libya. In: El-Arnauti, A., Owens, B., Thusu, B. (Eds.), Subsurface Palynostratigraphy of Northeast Libya. University of Garyounis Publications, Benghazi, pp. 111–128.

Turner, N., Spinner, E., Soanes, C., 1989. Further studies on the palynology of the Upper Devonian and Lower Carboniferous transition strata at Burrington Combe, Somerset, England. Pollen et Spores 31, 289–315.

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Van Der Zwan, C.J., Van Veen, P.M., 1978. The Devonian-Carboniferous transition sequence in southern Ireland: Integration of palaeogeography and palynology. Palinologia 1, 469–479.

Van Veen, P.M., 1981. Aspects of Late Devonian and Early Carboniferous palynology of southern Ireland. V. The change in composition of palynological assemblages at the Devonian-Carboniferous boundary. Review of Palaeobotany and Palynology 34, 67–97.

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

Wicander, R., Playford, G., 1985. Acritarchs and spores from the Upper Devonian Lime Creek Formation Iowa U.S.A. Micropaleontology 13, 97–138.

Wicander, R., Wood, G.D., 1997. The use of microphytoplankton and chitinozoans for Interpreting transgressive / regressive cycles in the Rapid Member of the Cedar Valley Formation (Middle Devonian) Iowa. Review of Palaeobotany and Palynology 98, 125–152.

Zaman, Sh., 2001. Devonian Spiriferids and Rhynchonellids paleontology and their biostratigraphy in the basal part of Khoshyeilagh Formation at the type locality (Khoshyeilagh area). M.Sc. thesis, Shahid Beheshti University, Tehran (unpublished) (in Persian).

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