A NEW LYCOPHYTE MIOSPORE SPECIES FROM THE MIDDLE JURASSIC OF IRAN

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ABSTRACT – A new, morphologically distinctive, lycophyte species from the Middle Jurassic (Bajocian-Callovian) Dalichai and Baghamshah formations of north and central Iran is introduced herein. It is typified by featuring distinct polygonal amb, well-defined margo, and prominent reticulate exine except for the proximal face. The new taxon occurs as minor constituent of diverse, well-preserved palynofloras comprising both marine and land-derived palynomorphs that collectively denote a Middle Jurassic (Bajocian-Bathonian-Callovian) age. The apparent short stratigraphic range and conspicuous morphological attributes of the new taxon likely nominate it as a potentially valuable biostratigraphic index for inter-basinal correlation of Middle Jurassic strata across north and central Iran.

Key words: miospores, *Retitriletes*, Middle Jurassic, Iran.

RESUMO – O presente estudo apresenta uma nova espécie de Lycophyta, morfologicamente distinta, do Jurássico Médio (Bajociano-Calloviano) das formações Dalichai e Baghamshah do Norte e Centro do Irã. Caracteriza-se por âmbito poligonal distinto, margo bem definido e exina reticulada proeminente, exceto para a face proximal. O novo táxon ocorre como constituinte menor de diversas palinofloras, bem preservados que compreendem palinórmfos tanto assembleias marinhas como continentais, que denotam em conjunto um Jurássico Médio (Bajociano-Batoniano-Calloviano). A curta distribuição estratigráfica e os conspícuos atributos morfológicos do novo táxon, permitem nomeá-lo como um índice bioestratigráfico, potencialmente valioso para a correlação de estratos entre bacias do Jurássico Médio em todo o norte e centro do país.

Palavras-chave: miósporos, *Retitriletes*, Jurássico Médio, Irã.

INTRODUCTION

Much potential exists for palynological studies of Mesozoic sequences in Iran, especially for the Triassic and Jurassic strata. Palynological investigations of Jurassic sediments have already been accomplished (e.g. Kimyai, 1968, 1974; Arjang, 1975; Achilles *et al.*, 1984; Bharadwaj & Kumar 1986, 1988; Sajjadi *et al.*, 2007; Dehbozorgi *et al.*, 2013) in various parts of the country. Jurassic palynomorphs, particularly miospores, from north and central Iran are comparatively better documented.

In east central Iran, investigations have focused exclusively on the coal-bearing Jurassic strata around Kerman. Palynological investigation in the Alborz Mountains in the northern part of the country has been conducted on near-coeval and mostly coal-bearing sediments similar to those in central Iran.

During routine palynological investigations of Middle Jurassic strata from several localities in north and central Iran, the authors encountered a morphologically distinctive,

previously unreported reticulate trilete spore species, which is detailed herein as *Retitriletes polygonatus* sp. nov.

During routine palynological investigations of Middle Jurassic strata from several localities in north and central Iran a morphologically distinctive, previously unmatched reticulate trilete spore species was encountered. It has been recorded from well-preserved miospore assemblages recovered from the intervals cropping out at four localities in the Alborz Mountains, northern Iran and one locality in central Iran (Figure 1). Because of its short stratigraphic range, the species can be regarded as a biostratigraphic index for the region. The main aim of the present contribution is, therefore, to describe the morphological features of this new taxon and compare it to closely related morphological entities previously known from elsewhere.

LOCATIONS AND GEOLOGICAL SETTING

Five sections were measured and sampled in detail at Central Alborz Mountains and central Iran (Figure 1). The

Figure 1. Location map of the studied sections.

Dalichai Formation is well exposed at four localities, the Balu section with a thickness of 594 m, is located in Payambaran area, north of Semnan, northern Iran ($35^{\circ}43'N$, $53^{\circ}26'E$). The other, Lavan section, which reaches 160 m is exposed at northeast of Damghan ($36^{\circ}22'N$, $54^{\circ}14'E$). Two other sections of Dalichai Formation, one at the Kanz section with a thickness of 292 m ($35^{\circ}48'N$, $53^{\circ}40'E$), and the other, Sharaf section with a thickness of 217 m ($35^{\circ}56'N$, $53^{\circ}47'E$), are widely distributed near the area of Jam, Central Alborz Ranges, northeastern Iran. The outcrop of the Baghamshah Formation, the Virab section, with a thickness of 279 m ($35^{\circ}48'N$, $53^{\circ}59'E$), is located in central Iran.

Iranian geology is classified into a number of diverse tectonostratigraphic units (Stöcklin, 1968). The Alborz Basin is located on the southern border of south Caspian Basin in northern Iran and the Central Iran Basin. The Alborz range has evolved from the Triassic to the present-day during the Cimmeride and Alpine Orogenies (Alavi, 1996) and is situated between the Caspian Sea to the north and the Iranian Plateau to the south (Stöcklin, 1974). The mountains consist of Late Precambrian basement with a Gondwanan affinity, similar to the Arabian-Nubian platform (Hassanzadeh *et al.*, 2002).

The Central Iran Basin is one of the most important and complicated structural zones in Iran and comprises a vast area of the Iranian Plateau. This area was a stable platform during Paleozoic times, but the late Triassic movements

caused the creation of horsts and grabens limited by faults and fold-and-thrust belts. According to Stöcklin (1968), central Iran is limited by the Alborz Mountains to the north, Lut Block to the east, and Sanandaj-Sirjan zone to the south-southwest. Central and north Iran (the Iran Plate) occupied a position at the southern margin of Eurasia in the Late Triassic (Seyed-Emami, 2003). Close lithologic and faunistic relationships between North and central Iran during deposition of the Shemshak Group (Late Triassic-Middle Jurassic) indicates that the two areas were palaeogeographically closely related, probably forming a kind of archipelago (Seyed-Emami *et al.*, 2008).

In the Late Bajocian, a widespread transgression caused a new and large sedimentary cycle. This event continued until the end of the Jurassic (Fürsich *et al.*, 2009). The Middle and Upper Jurassic sedimentary successions in north and central Iran comprise five formations including Dalichai, Lar (Alborz) and part of the Badamu Limestone, Hojedk and Baghamshah (central Iran).

The Dalichai Formation is represented by shales, calcareous shales, marls, and richly ammonitiferous limestones (Steiger, 1966), being widely distributed in north Iran. It disconformably overlies the dark, siliciclastic coal-bearing Shemshak Formation and underlies gradually the light cliff-forming carbonates of the Lar Formation. In addition to ammonites, a diverse fauna includes belemnites, pelecypods, brachiopods, echinids, sponges, bryozoans, and foraminifera, in the sediments related to this rock unit has been reported from different stratigraphic sections (Alavi-Naini, 1972; Sussli, 1976; Nabavi & Seyed-Emami, 1977). The ammonites of Dalichai Formation indicate Late Bajocian to Oxfordian age, but there is no place in which the formation includes this total range (Sussli, 1976; Nabavi & Seyed-Emami, 1977; Seyed-Emami *et al.*, 1985; Schairer *et al.*, 1991; Seyed-Emami *et al.*, 1995).

Three of the sections studied are located in the Jam region, eastern Semnan, and partly related to central Iran (Figure 1). One of the distinct structural units influencing the sedimentation pattern throughout the Jam area is the Attari fault which extends in a NE-SW direction. According to Alavi-Naini (1972) this fault had a significant role in Jam area and separated it into two different parts, Zone A and Zone B. Zone A is located in the northwestern of the Jam and is associated with Alborz Mountains. Zone B is related to Central Iran Mountains and constitutes most of the Jam in the southeastern part of it (Figure 2). In the Jam area (Zone B) the Parvadeh Formation is followed by the Baghamshah Formation in the Middle Jurassic (Dogger) while at the same time, Dalichai Formation has been deposited in the northwestern of this area (Zone A). In this study, two sections of the Dalichai Formation are located in Zone A and the only section of the Baghamshah Formation is located in Zone B.

Baghamshah Formation is characterized chiefly by alternating of uniform pale-green marly shale, silty to fine sandy, soft-weathering, with a few thin harder layers of sandstone, and minor salt and gypsum content in some horizons. It overlies with transitional contact the underlying

Figure 2. Attari fault location in two structural-sedimentary zones, Alborz and Central Iran in Jam area (modified from Alavi-Naini, 1972).

Parvadeh Limestone, and is topped with a disconformable contact, by the Parpa Limestone. Ammonites of this rock unit are representative of Upper Bathonian to Upper Callovian age (Seyed-Emami *et al.*, 1997, 1998).

MATERIAL AND METHODS

A total of 170 palynological samples were collected exclusively from five outcrops mentioned above (Figure 3). All samples were prepared following standard palynological processing procedures (*e.g.* Phipps & Playford, 1984; Traverse, 2007), including HCl (10-50%) and HF (40%) treatment for dissolution of carbonates and silicates, respectively. Then the residues were saturated with ZnCl₂ solution (specific gravity 1.9 g/ml) for density separation. All the residues were sieved with a 15 µm mesh sieve prior to making strew slides. Three slides for each preparation were examined by transmitted light microscope. All the strew slides prepared are stored in the collection of Faculty of Geology, Tehran University, Iran catalogued as 1-55 FH.DI; 1-32 Ka.DI; 1-26 Sh.DI; 1-29 La.DI and 1-28 Vi.B.

ASSOCIATED PALYNOFLORAS AND THEIR BIOSTRATIGRAPHIC SIGNIFICANCE

Diverse and well-preserved palynomorphs dominated by spores, pollen grains, dinoflagellate cysts, foraminiferal test linings, fungal spores and acritarchs (see Appendix 1 for the taxonomic list) occur in samples of the Dalichai and the Baghamshah formations. Occurrence of miospores species with known vertical ranges include *Klukisporites variegatus* Couper, 1958, *Converrucosporites pricei* McKellar, 1998,

Osmundacidites senectus Balme, 1963, *Sellaspora asperata* (Dettmann) emend. McKellar, 1998, *Concavissimisporites verrucosus* Delcourt & Sprumont emend. McKellar, 1998 and *Murospora florida* (Balme) Pocock, 1961 collectively indicate a Dogger age according to data offered by such authors as Balme (1964), Arjang (1975), Ashraf (1977), Bharadwaj & Kumar (1986), Filatoff & Price (1988), McKellar (1998), Sajjadi *et al.* (2007), Dehbozorgi *et al.* (2013). Furthermore, based on the existence of such distinct dinoflagellate cyst species as *Meiourogonyaulax valensii* (Riding & Thomas, 1992) base of the succession examined, herein, is considered to be no older than Bajocian. The Bathonian age is confirmed by the presence of *Adnatosphaeridium caulleryi* (Riding & Thomas, 1992; Ghasemi-Nejad *et al.*, 2012; Mafi *et al.*, 2013). The relatively low diversity of the contemporaneous dinoflagellate cysts assemblage in the upper part of the succession seems to be consistent with a Callovian age (Ghasemi-Nejad *et al.*, 2012; Mafi *et al.*, 2013).

SYSTEMATIC PALAEONTOLOGY

Anteturma PROXIMEGERMINANTES R. Potonié, 1970
Turma TRILETES Reinsch emend. Dettmann, 1963
Suprasubturma ACAVATITRILETES Dettmann, 1963
Subturma AZONOTRILETES Lubert emend. Dettmann, 1963
Infraturma MURORNATI Potonié & Kremp, 1954

Retitriletes van der Hammen ex Pierce emend.
Döring *et al.*, 1963

1956 *Retitriletes* van der Hammen, p. 76. (*nom. nud.*).
1961 *Retitriletes* van der Hammen ex Pierce, p. 21.

Figure 3. Litostratigraphic columns of the studied sections. **A**, Balu; **B**, Kanz; **C**, Sharaf; **D**, Lavan; **E**, Virab. **Symbol: ***, records of the new species.

1963 *Retitriteles* van der Hammen ex Pierce emend. Döring, Krutzsch, Mai & Schulz, in Krutzsch, p. 8.

Type species. *Retitriteles globosus* Pierce, 1961; by original designation.

Discussion. *Retitriteles* van der Hammen ex Pierce emend. Döring *et al.*, 1963 accommodates azonate, trilete miospores with a net like distal reticulum which may be extended proximo-equatorially or to the laesurae termini. The validity of *Lycopodiumsporites* Delcourt & Sprumont 1955 and its relationship with other genera have been discussed by Döring *et al.* in Krutzsch (1963, p. 8), Srivastava (1972, p. 29-30;

1975, p. 56-58) and McKellar (1974, p. 12-13; 1998, p. 99). Döring *et al.* (1963) considered *Lycopodiumsporites* to be invalid but Srivastava (1972) and McKellar (1974) accepted it as incorporating azonate, trilete miospores with distal foveo-reticulate sculpture.

Retitriteles polygonatus sp. nov.
(Figures 4A-L; 5A-L)

Holotype. slide FH3/2; Figure 5A-C.

Type locality. Iran, Semnan, Balu section, 20 m, sample 3.

Stratigraphy. Dalichai Formation.

Figure 4. A-L, *Retitriteles polygonatus* sp. nov. A, D, H, J, distal foci; C, E, F, proximal foci; B, G, I, K, L, median foci. Scale bars = 20 µm.

Figure 5. A-L, *Retitriteles polygonatus* sp. nov. A, D, F, H, J, distal foci; B, E, G, I, L, proximal foci; C, K, median foci. Scale bars = 20 μ m.

Etymology. Latin, Polygonal amb.

Diagnosis. Miospores radial, trilete. Amb pentagonal to hexagonal, sides straight to convex, apices rounded to weakly pointed. Laesurae distinct to moderately indistinct, straight to weakly sinuous, extending to, or nearly to equator, usually marked by a characteristic defined margo (lips 1-2.5 μ m wide individually) laevigate proximally, proximo-equatorial region occasionally bearing extension of distal sculpture, reticulate distally and equatorially with thick to narrow, concave - to straight - sided muri, ca. 3-5 μ m wide, 2-11 μ m high, and, polygonal to subpolygonal lumina ca. 5-13 μ m (rarely up to

15 μ m) in diameter; in some specimens muri are so thin and delicate that sometimes are folded at the margin (Figures 4A,5H).

Description. Amb pentagonal, 55 μ m in overall equatorial diameter; laesurae $\pm$ indistinct, weakly sinuous, extending to equator, margo (lips 2 μ m wide individually), sculptured distally with an irregular reticulum comprising anastomosing muri 2-11 μ m high, 3 μ m wide, with concave sides. Lumina polygonal to subpolygonal or irregularly elongate, 9-15 μ m in diameter. Proximal surface is laevigate, with an imperfect reticulum proximo-equatorially.

Dimensions. (16 specimens): Equatorial diameter 32 (55) 65 μm (including sculpture).

Comparison. *Retitriletes polygonatus* sp. nov. is distinguishable from other species of the genus by its pentagonal to hexagonal amb; wide and high muri; polygonal to subpolygonal or irregularly elongate lumina. This new species differentiated from *R. facetus* (Dettmann) Srivastava, 1975 (p. 58), from south-eastern Australia and *R. neofacetus* McKellar, 1998 (p. 111-112, pl. 15, figs. 9-14), from the Middle Jurassic of the Surat Basin, Queensland, in possessing a laevigate exoexine. *R. watherooensis* Backhouse, 1978 (p. 24-25, pl. 3, figs. 1-3), from the Late Jurassic-Early Cretaceous of the Perth Basin, Western Australia, is identifiable primarily by very small distal meshed reticulum.

The Surat Basin post-Jurassic species *Retitriletes siobhaniae* McKellar, 1998 (p. 107-108, pl. 14, figs. 1-9), and *R. circolumenus* (Cookson & Dettmann) Backhouse, 1978 (p. 22-23, pl. 2, figs. 7, 8), from the Late Jurassic-Early Cretaceous of the Perth Basin, Western Australia, show subcircular, subelliptical or irregularly elongate lumina and they are proximally laevigate except in contact areas. This new species of *Retitriletes* differs from *R. parvireticulatus* Backhouse, 1988 (p. 67-68, pl. 9, figs. 15, 16), from the Late Jurassic-Early Cretaceous of the Perth Basin, Western Australia, *R. huttonensis* McKellar, 1974 (p. 14-15, pl. 5, figs. 7-12), and *R. rosewoodensis* (de Jersey) McKellar, 1974 (p. 14, pl. 5, figs. 4, 5), from the Early-Middle Jurassic of the Surat Basin, by the possession of larger lumina bounded by wider and higher muri on the distal surface. *R. austroclavatidites* (Cookson) Döring, Krutzsch, Mai & Schulz, 1963 (p. 16), from the Middle-Late Jurassic of the Germany, can be distinguished by its subcircular to convexly subtriangular amb and possesses smaller lumina bounded by narrow and lower muri. *R. singhii* (Singh) Srivastava, 1972 (p. 32, pl. 27, fig. 10), from the Maestrichtian of Alberta, Canada, is distinguishable by proximal sculpture which is variably developed (irregularly rugulate). The Surat Basin Middle-Late Jurassic species *Retitriletes proxiradiatus* McKellar, 1998 (p. 102-103, pl. 13, figs. 6-12), is distinguishable by an imperfect, radially oriented proximal reticulum.

Natural botanical affinity. Lycophyte: Raine *et al.* (2011).

Stratigraphic range. Middle Jurassic (Bajocian-Bathonian-Callovian).

CONCLUSIONS

Diverse, well-preserved Middle Jurassic palynofloras retrieved from the Dalichai and Baghamshah formations of northern and central Iran comprise both marine and terrestrial palynomorphs. The latter include, *inter alia*, a new distinct reticulate, lycophyte spore species erected herein as *Retitriletes polygonatus* sp. nov. The possible restricted stratigraphic cooccurrence within the interval examined and distinct morphological features of the new taxon might indicate its utility in regional correlation of the Middle Jurassic strata across north and central Iran.

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Appendix 1. List of palynomorph taxa in alphabetic order.

MIOspores

- Aequitriradites norrisii* Backhouse, 1988
Alisporites grandis (Cookson) Dettmann, 1963
Alisporites lowoodensis de Jersey, 1963
Alisporites similis (Balme) Dettmann, 1963
Alisporites microsaccus (Couper) Muir, 1964
Anapiculatisporites dawsonensis Reiser & Williams, 1969
Anapiculatisporites sp. cf. *A. pristidentatus* Reiser & Williams, 1969
Annulispora densata de Jersey, 1959
Aratrisporites fischeri (Klaus) Playford & Dettmann, 1965
Araucariacites australis Cookson ex Couper, 1953.
Biretisporites sp.
Callialasporites dampieri (Balme) Sukh Dev, 1961.
Callialasporites minus (Tralau) Guy, 1971
Callialasporites trilobatus (Balme) Sukh Dev, 1961
Camarozonosporites ramosus (de Jersey) McKellar, 1974
Cerebropollenites macroverrucosus (Thiergart) Schulz, 1967
Chasmatosporites apertus (Rogalska) Nilsson, 1958
Chasmatosporites major Nilsson, 1958
Concavissimisporites punctatus (Delcourt & Sprumont) Brenner, 1963
Concavissimisporites verrucosus Delcourt & Sprumont emend. McKellar, 1998
Converrucosisporites parvumulus McKellar, 1998
Converrucosisporites pricei McKellar, 1998
Contignisporites burgeri Filatoff, McKellar & Price in Filatoff & Price, 1988
Classopollis simplex (Danzé-Corsin & Laveine) Cornet & Traverse, 1975
Classopollis sp.
Cyathidites australis Couper, 1953
Cyathidites minor Couper, 1953
Cycadopites crassimarginis (de Jersey) de Jersey, 1964
Cycadopites follicularis Wilson & Webster, 1946
Cycadopites sp. cf. *C. follicularis* Wilson & Webster, 1946
Cycadopites granulatus (de Jersey) de Jersey, 1964
Deltoidospora sp.
Densoisporites velatus Weyland & Krieger emend. Karsnova, 1961
Dictyophyllidites harrisii Couper, 1958
Dictyophyllidites mortonii (de Jersey) Playford & Dettmann, 1965
Dictyotosporites complex Cookson & Dettmann, 1958
Foveosporites pseudoalveolatus (Couper) McKellar, 1998
Gleicheniidites senonicus Ross emend. Skarby, 1964
Ischyosporites crateris Balme, 1957
Klukisporites variegatus Couper, 1958
Klukisporites lacunus Filatoff, 1975
Laevigatosporites ovatus Wilson & Webster, 1946
Limbosporites lundbladii Nilsson, 1958
Limbosporites antiquus (de Jersey) de Jersey & Raine, 1990
Limbosporites denmeadii (de Jersey) de Jersey & Raine, 1990
Limbosporites sp. A of McKellar, 1998
Matonisporites crassiangulatus (Balme) Dettmann, 1963
Murospora florida (Balme) Pocock, 1961
Neoraistrickia truncata (Cookson) Potonié, 1956
Neoraistrickia taylorii Playford & Dettmann, 1965
Neoraistrickia parvibacula McKellar, 1998
Osmundacidites senectus Balme, 1963
Osmundacidites wellmanii Couper, 1953
Perotrilites granulatus Couper emend. Evans, 1970
Phlebopterisporites equiexinus (Couper) Juhász, 1979
Platysaccus queenslandi de Jersey, 1962
Podocarpidites astrictus Haskell, 1968
Podocarpidites ellipticus Cookson, 1947
Polycingulatisporites crenulatus Playford & Dettmann emend. McKellar, 1974
Retitriletes austroclavatidites (Cookson) Döring, Krutzsch, Mai & Schulz, 1963
Retitriletes clavatoides (Couper) Döring, Krutzsch, Mai & Schulz, 1963
Ricciisporites tuberculatus Lundblad, 1954
Rugulatisporites neuquenensis Volkheimer, 1972
Sellaspora asperata (Dettmann) emend. McKellar, 1998
Sellaspora passa McKellar, 1998
Staplinisporites caminus (Balme) Pocock, 1962
Striatella seebergensis Mädler, 1964
Striatella balmei Filatoff & Price, 1988

Striatella sp. cf. *S. balmei* Filatoff & Price, 1988
Striatella scanica (Nilsson) Filatoff & Price, 1988
Striatella parva (Li & Shang) Filatoff & Price, 1988
Todisporites major Couper, 1958
Todisporites minor Couper, 1958
Toripustulatisporites kainophyticus Krutzsch, 1959
Trilites volkheimeri (Filatoff) Sajjadi & Playford, 2003
Trilobosporites antiquus Reiser & Williams, 1969
Verrucosisporites major (Couper) Burden & Hills, 1989
Verrucosisporites varians Volkheimer, 1972

DINOFLAGELLATE CYSTS

Adnatosphaeridium caulleryi (Deflandre) Williams & Downie, 1969
Carpathodinium predae (Beju) Drugg, 1978
Cleistosphaeridium sp.
Cometodinium jurassicum Poulsen, 1996
Ctenidodinium combazii Dupin, 1968
Ctenidodinium ornatum (Eisenack) Deflandre, 1938
Compositosphaeridium polonicum (Gorka) Erkmen & Sarjeant, 1980
Conosphaeridium striatoconum (Deflandre & Cookson) Cookson & Eisenack, 1969
Gonyaulacysta jurassica (Deflandre) Norris & Sarjeant, 1965
Meiourugonyaulax valensii Sarjeant, 1966
Mendicodinium groenlandicum (Pocock & Sarjeant) Davey, 1979
Nannoceratopsis sp.
Pareodinia ceratophora Deflandre, 1947
Valensiella ovulum (Deflandre) Eisenack, 1963

ACRITARCHA

Circulisorites parvus de Jersey emend. Norris, 1965
Micrhystridium spp.
Veryhachium sp.

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