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Palynostratigraphy of the Middle Jurassic sediments in Hojedk Formation, Tabas Block, East–Central Iran

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ABSTRACT

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Diverse and moderately preserved palynofloras occur in the Middle Jurassic sediments of the Hojedk Formation in the South Kouchekali, southwestern of Tabas, east central Iran. The palynofloras comprise thirty–nine species including spores (fourteen species allocated to nine genera) and various types of pollen (twenty–five species designated to thirteen genera). Vertical distribution of miospores allows erection within the Hojedk Formation of one biozone–*Klukisporites variegatus* Assemblage zone–and two distinctive stratigraphically successive biozones, viz. *Callialasporites trilobatus–Parcisporites cacheutensis* Assemblage zone, and *Contignisporites problematicus* Taxon range zone based on the first observed occurrence (FOO) and the last observed occurrence (LOO) of selected taxa. These biozones are compared with palynozones from ±coeval strata in Iran and elsewhere. Based on the association of key miospore species such as *Klukisporites variegatus*, and *Callialasporites dampieri* within the Hojedk palynofloras, the host strata are assigned to the Middle Jurassic. Abundance of ferns and cycadophytes in parent floras implies that the host strata accumulated under a moist warm climate during the Middle Jurassic in this locality.

Key–words—Middle Jurassic, Miospores, Palynostratigraphy, Palaeoclimate, Tabas Block, Iran.

पूर्व–मध्य ईरान के तबस खंड के होजेक शैलसमूह में मध्य जुरासिक अवसादों की परागाणुस्तरिकी

फातेमह वेज़ जवादी

सारांश

पूर्व–मध्य ईरान के दक्षिण–पश्चिम तबस की दक्षिण कौचेकली में होजेक शैलसमूह के मध्य जुरैसिक अवसादों में पृथक एवं मध्यम परिरक्षित परागाणु वनस्पति–जात प्राप्त होती है। परागाणु वनस्पति–जात बीजाणुओं (नौ वंश को नियत चौदह जाति) सहित उन्तालीस जाति और विभिन्न प्रकार के पराग (तेरह वंश को पच्चीस जाति अभिहित) सन्निहित हैं। सूक्ष्मजीवाणुओं के ऊर्ध्वाधर वितरण एक जैव मंडल *क्लुकोस्पोराइटिस वेरीएगेटस* समुच्चय मंडल के होजेक शैलसमूह की परिधि में तथा दो विशिष्ट स्तरिकरूप से उत्तरोत्तर जैवमंडल अर्थात *कैल्लीएलास्पोराइटिस ट्रिलोबेटस–पार्सीस्पोराइटिस केचुटेन्सिस* समुच्चय मंडल और प्रथम प्रेक्षित घटना (एफ ओ ओ) व चयनित टैक्सा की अंतिम प्रेक्षित घटना (एल ओ ओ) पर आधारित *कंटीनीस्पोराइटिस प्रॉब्लमेटीकस* वर्गक परिसर मंडल उद्धर्षण प्रदान करते हैं। इन जैवमंडलों की ईरान और अन्यत्र में ±समकालीन स्तरी तल से प्राप्त परागाणुमंडलों से की जाती है। होजेक परागाणुवनस्पति–जात परिधि में मुख्य सूक्ष्म जीवाणु जाति जैसे कि *क्लुकीस्पोराइटिस वेरीएगेटस* और *कैल्लीएलोस्पोराइटिस डैम्पीएरी* के साहचर्य पर आधारित मेजबान स्तरी तल मध्य जुरैसिक को नियत हैं। मूल वनस्पति–जात में पर्णांग एवं साइकैडोफाइट की प्रचुरता द्योतित करती है कि इस इलाके में मध्य जुरैसिक के दरम्यान आर्द्र और कोष्ण जलवायु के अधीन मेजबान स्तरी संचित हो गई थी।

सूचक शब्द– मध्य जुरैसिक, सूक्ष्मजीवाणु, परागाणुस्तरिकी, पुराजलवायु, तबस खंड, ईरान।

INTRODUCTION

IRANIAN Jurassic palynological assemblages have been investigated by Arjang (1975), Kimyai (1968, 1974, 1977), Achilles *et al.* (1984), Bharadwaj and Kumar (1986), Wheeler and Sarjeant (1990), Vaez–Javadi and Ghavidel–Syooki (2005), Sajjadi *et al.* (2010), Dehbozorgi *et al.* (2013), Navidi–Izad *et al.* (2015) and Hashemi–Yazdi *et al.* (2014). Despite these studies, palynological contents of the Jurassic deposits, however, remain unexplored, especially in east–central of Iran. Palynological analysis of the Hojedk Formation, South Kouchekali, southwestern Tabas, therefore, is undertaken to document and to appraise the stratigraphic significance of miospores. The locality of coal deposits has been known for a long time for its deposits of coal. The coals consist of clay resources with a rich macroflora (Vaez–Javadi, 2014, 2015) and the geology in general have been subject to scientific studies for these years.

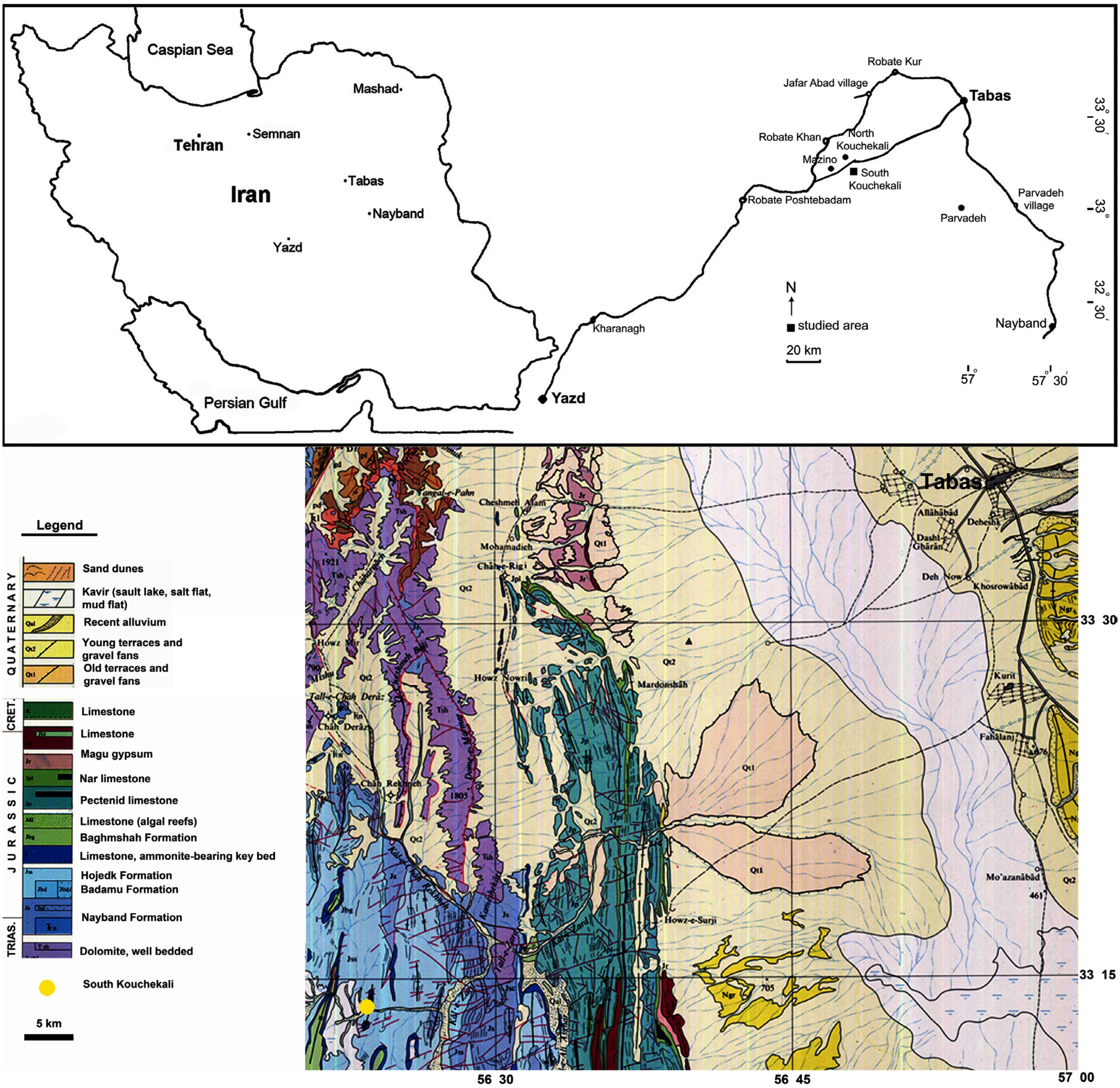

Fig. 1—Sketch map of Iran and location of the stratigraphic core–column of South Kouchekali and geological map of Tabas Block (After Aghanabati & Haghipour, 1978).

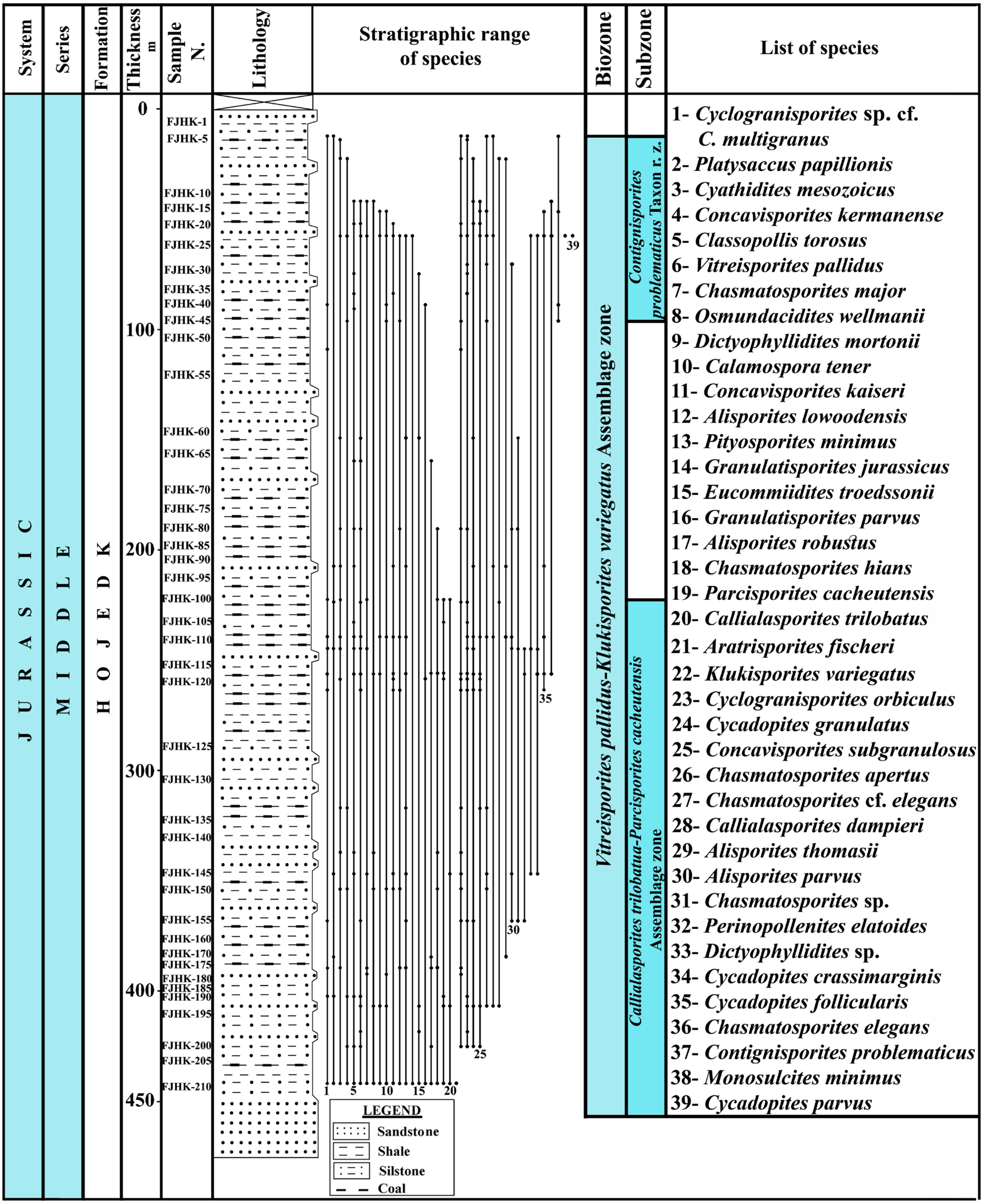

Fig. 2—Distribution of miospore species through the succession sampled and proposed palynostratigraphic units of the Hojedk Formation at the South Kouchekali, Tabas, east–central Iran.

GEOLOGICAL AND GEOGRAPHICAL SETTING

Of several fault–bounded blocks identified within the central Iran Basin, the north–south trending Tabas Block is demarcated by the Naybandan and Kalmard faults to the east and west, respectively (Aghanabati, 1977). The Tabas Block contains exceptionally thick and well–exposed Upper Triassic–Jurassic successions. In east central Iran, the Middle Jurassic Hojedk Formation with significant geographic distribution (Tipper 1921, Seyed–Emami 2004a, b, Aghanabati 1998) encompasses predominantly marginal marine facies at the base of the Shemshak Group. The geological setting with special emphasis on the coal seams was first described in 1997 by National Exploration Coal Mine Company. The fossils reported in this paper were collected from core number 210 at the South Kouchekali about 62 km southwestern of the Tabas city (Fig. 1). Here, the Hojedk Formation measured about 462 m thick and consists of dark grey siltstones, sandstones, shales and several coal seams (Fig. 2).

East–central Iran, originally a microcontinental that collided as part of the Cimmerian continent collage (Şengör, 1990) with Eurasia in the Late Triassic, contains a thick and well exposed Jurassic sedimentary rocks. Most of the Jurassic rocks are found on the Tabas Block, the middle one of three blocks that constitutes the so–called Central–East Iranian Microcontinent (CEIM; Takin, 1972). The other two blocks are the Yazd Block in the west and the Lut Block in the East. After the Cimmerian orogeny activities, faulting to the central Iran created a new basin between the faults. The high amount of subsidence associated with these events caused the deposition of a thick sequence of terrigenous sediments that lasted until the Middle Cimmerian (Bajocian–Bathonian) (Berberian & King, 1981). Tipper (1921) called the sandstone–shale deposits with coal seams in the Kerman Basin 'Jurassic Plant bearing Series'. Beckett (1956) named these deposits 'Coal bearing Series'. The National Stratigraphic Committee of Iran (Aghanabati, 1998 in National Stratigraphic Committee of Iran, 1994) coined the name 'Hojedk Formation' for this rock unit. The Hojedk Formation is comparable to member D of Assereto's (1966) subdivisions of the Shemshak Formation in the Alborz Mountains, the Dansirit Series of Alborz, Northern Iran (Schweitzer & Kirchner, 2003) and Dansirit Formation of the Shemshak Group in North Iran (Fürsich *et al.*, 2009). Hojedk Formation in this area consists of siltstone, shale with several coal horizons and sandstone. The fossils introduced in this paper were collected from a measured stratigraphic core–section, number 210 in the South Kouchekali, about 67 km southwestern of the Tabas city: 33º13'22" North latitude and 56º23'6" East longitude (Pl. 1). Here, the Hojedk Formation measured about 462 m thick and consists of dark grey siltstones, sandstones and shales, coal seams and black shales. The lower portion of the succession is dominated by sandstones (Fig. 2).

MATERIAL AND METHODS

Forty palynologically promising samples selected out of 210 collected from the core number 210, South Kouchekali, southwestern Tabas (Fig. 2) constitute the basis of this investigation. Standard palynological procedures (*e.g.*, Phipps & Playford, 1984) utilized for retrieval and concentration of the palynomorphs. After a mild surface washing the samples were crushed and ca. 50g were weighed out. This fraction of the material was chemically treated as follows: ca. 20 h. of cold 10% HC1, 30 h. 40% HF and 20 min. of 90°C 10% HC1. The samples were then washed in water and sieved on a 20 µm filter. The organic residues were evaluated, attention being focused on the palynomorph content, as the purpose was exclusively biostratigraphy/systematics. In this context the optimal conditions for microscopical observations are clean preparations with transparent light brown palynomorphs. The palynomorphs, if too dark, were bleached with 5% KOH. All the slides have been microscopically scanned and 28 of the richest and most diverse from different levels through out the section were counted to differentiate marine and terrestrial palynomorph components. These slides were abbreviated FJHK (acronym Fatemeh, Javadi, Hojedk Formation, and Kouchekali). Afterwards, distribution of miospore species was studied and biozonation was recognized. All rock samples, residues, and strew slides used herein are permanently housed in the Palynology Collection at the School of Geology, College of Science, University of Tehran, Tehran, Iran.

PLATE 1 ⟶

1. *Cyathidites mesozoicus* (Thiergart 1949) Potonié 1955, FJHK–22.
2, 6, 16. *Klukisporites variegatus* Couper 1958, FJHK–7, FJHK–117, FJHK–174.
3, 12, 13. *Concavisporites kermanense* Arjang 1975, FJHK–7.
4, 5. *Concavisporites subgranulosus* Couper 1958, FJHK–22.
7. *Dictyophyllidites* sp., FJHK–22.
8. *Granulatisporites jurassicus* Pocock 1970, FJHK–22.
9. *Concavisporites kaiseri* Arjang 1975, FJHK–109.
10. *Osmundacidites wellmanii* Couper 1953, FJHK–117.
11, 17. *Granulatisporites parvus* Potonié & Kremp 1955, FJHK–117, FJHK–174.
14, 15. *Cyclogranisporites* sp. cf. *C. multigranus* Smith & Butterworth 1967, FJHK–174, FJHK–112.
18, 19. *Dictyophyllidites mortonii* (de Jersey 1959) Playford & Dettmann 1965, FJHK–22.
20. *Calamospora tener* (Leschik 1955) de Jersey 1962, FJHK–5.
21. *Callialasporites dampieri*, FJHK–193.
22, 23. *Chasmatosporites apertus* (Rogalska 1954) Nilsson 1958, FJHK–109, FJHK–4.
24. *Cyclogranisporites orbiculus* Potonié & Kremp 1955, FJHK–197.
25. *Vitreisporites pallidus* (Reissinger 1950) Nilsson 1958. Scale bars= 20 µ.

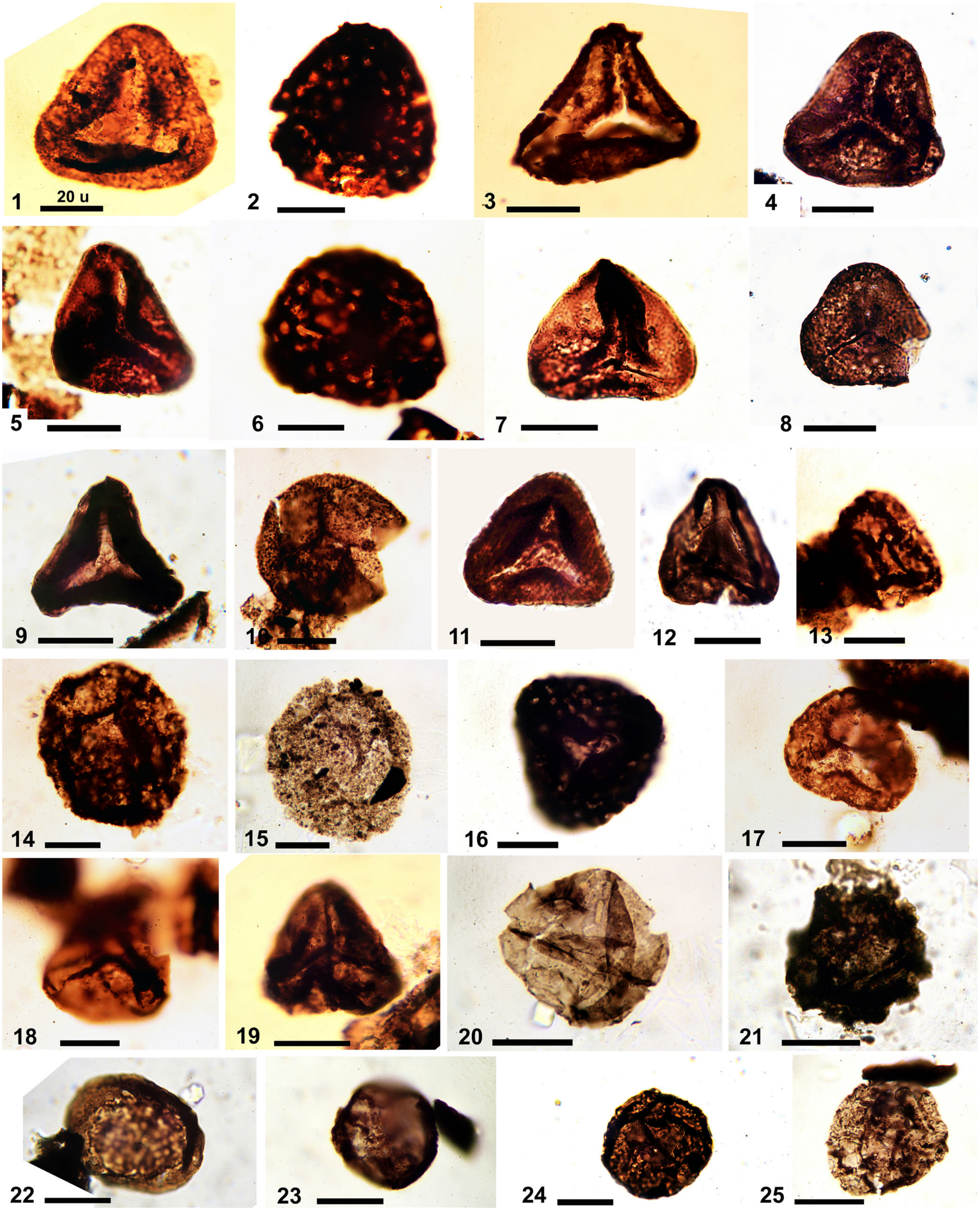

PLATE 1

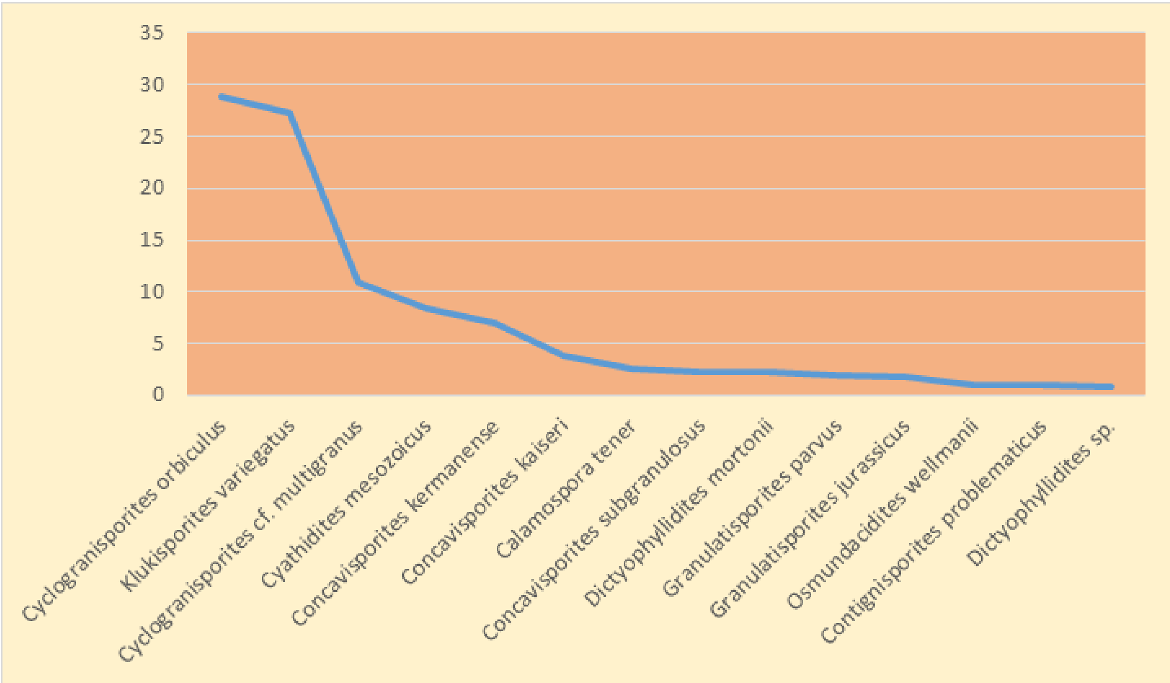

Fig. 3—A comparable chart of relative abundance of various spore taxa during the Middle Jurassic in the South Kouchekali, Tabas.

RESULTS

The Hojedk Formation samples contain fourteen species of spores (nine genera) and twenty–five species of pollen (thirteen genera). Four of the most common and often quantitatively abundant species, in descending order, are *Cyclogranisporites orbiculus* (Marattiales), *Klukisporites variegatus* (Schizaeaceae), *Cyclogranisporites* sp. cf. *C. multigranus*, and *Cyathidites mesozoicus* (with diverse fern affinities) with 28.84%, 27.27%, 10.94%, and 8.38% respectively (Fig. 3). Relative abundance of the gymnosperms, *Chasmatosporites apertus, Chasmatosporites elegans, Classopollis torosus, Chasmatosporites hians, Cycadopites crassimarginis* (monosulcate pollen), and *Alisporites thomasii, Vitreisporites pallidus* (bissacate pollen) with 17.76%, 16.45%, 11.40%, 5.70%, 5.70%, and 5.04% respectively dominate the assemblage (Fig. 4).

Figure 2 shows the stratigraphic distribution of certain miospore species of known stratigraphic value and/or persistence throughout the studied section. The vertical ranges of certain miospore species with known stratigraphic significance and/or persistence throughout the section investigated authorize introduction of one biozone. It is an assemblage biozone with its lower and upper boundaries identified by the first observed occurrence (FOO) and the last observed occurrence (LOO) of *Klukisporites variegatus* and *Vitreisporites pallidus* (Fig. 2). This biozone contains following miospores: *Cyathidites mesozoicus* (Thiergart, 1949) Potonié 1955, *Calamospora tener* (Leschik, 1955) de Jersey 1962, *Dictyophyllidites mortonii* (de Jersey, 1959) Playford & Dettmann 1965, *Dictyophyllidites* sp., *Granulatisporites jurassicus* Pocock 1970, *Granulatisporites parvus* Potonié & Kremp 1955, *Cyclogranisporites* sp. cf. *C. multigranus* Smith & Butterworth 1967, *Cyclogranisporites orbiculus*

PLATE 2 →

1. Tracheid tissue.
2. *Cycadopites crassimarginis* (de Jersey 1959) de Jersey 1964.
3. 4. *Chasmatosporites elegans* Nilsson 1958, FJHK–22.
5. *Eucommiidites troedssonii* (Erdtman 1948) Hughes 1961.
6. *Cycadopites follicularis* Wilson & Webster 1946, FJHK–22.
7. *Classopollis torosus* (Reissinger 1950) Couper 1958.
8. *Chasmatosporites hians* Nilsson 1958, FJHK–100.
9. *Cycadopites granulatus* (de Jersey 1962) de Jersey 1964, FJHK–7.
10. *Chasmatosporites major* Nilsson 1958, FJHK–174.
11. *Contignisporites problematicus* Döring 1965, FJHK–4.
12. *Chasmatosporites* sp., FJHK–112.
13. *Chasmatosporites* sp. cf. *elegans* Nilsson 1958, FJHK–22.
14. *Cycadopites parvus* (Bolkhovitina 1953) Pocock 1970, FJHK–22.
15. *Alisporites lowoodensis* de Jersey 1963, FJHK–109.
16. *Alisporites parvus* de Jersey 1962, FJHK–109.
17. *Perinopollenites elatoides* Couper 1958, FJHK–112.
18. *Parcisporites cacheutensis* Jain 1968.
19. *Alisporites thomasii* (Couper) Nilsson, FJHK–109.
20. *Alisporites robustus* Nilsson 1958, FJHK–174.
21. *Callialasporites dampieri* (Balme 1957) Sukh Dev 1961, FJHK–7.
22. *Callaiasporites trilobatus* (Balme 1957) Sukh Dev 1961, FJHK–178.

Scale bars= 20 µm.

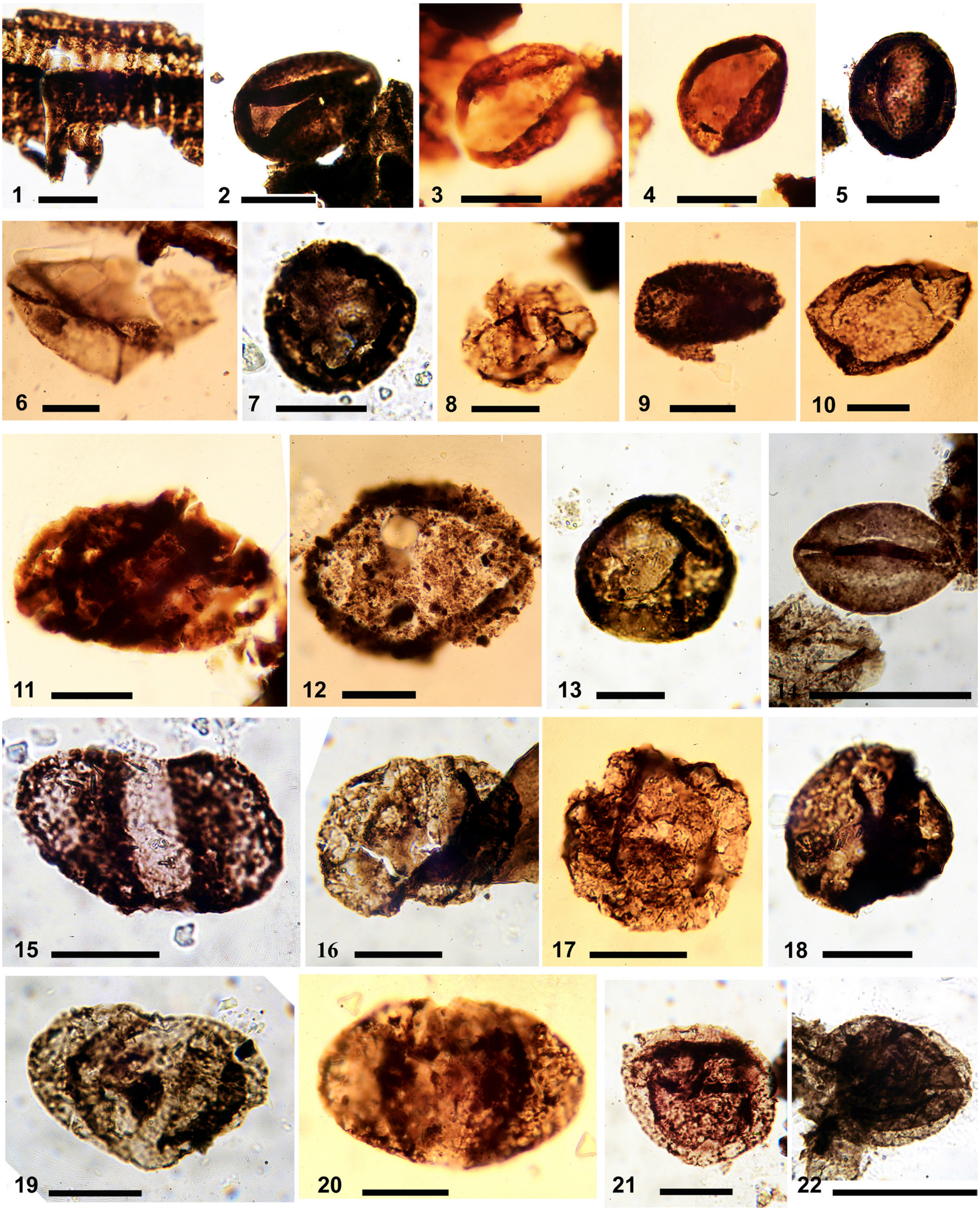

PLATE 2

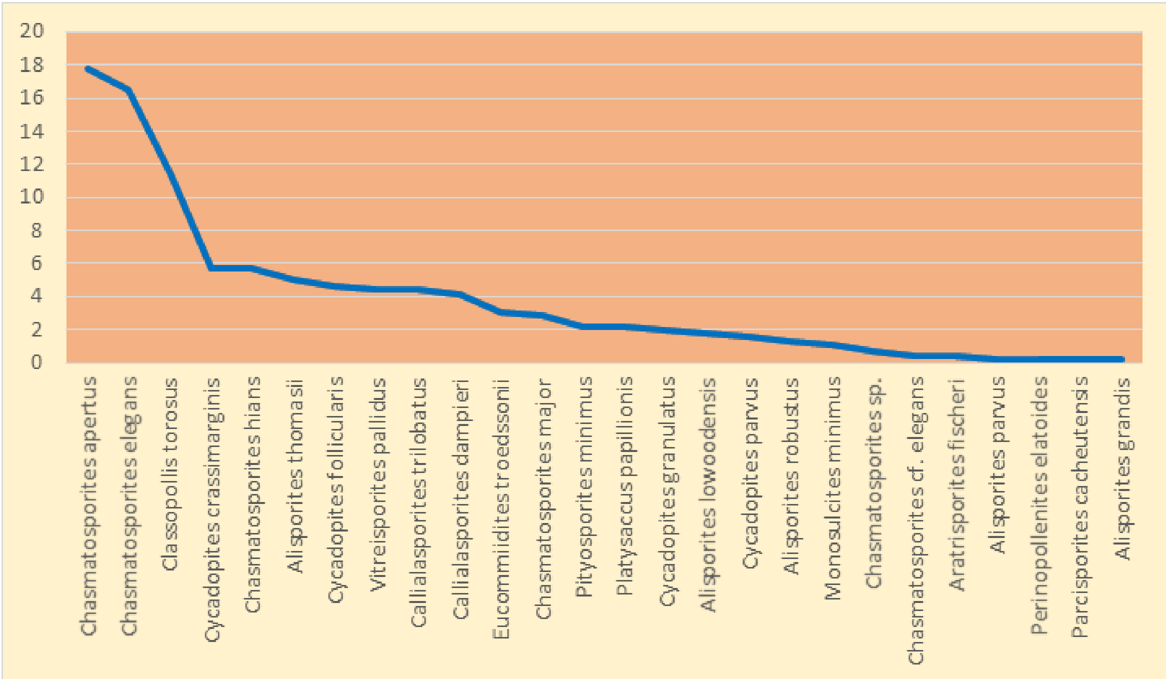

Fig. 4—A comparable chart of relative abundance of various pollen taxa during the Middle Jurassic in the South Kouchekali, Tabas.

Potonié & Kremp 1955, *Osmundacidites wellmanii* Couper 1953, *Concavisporites kaiseri* Arjang 1975, *Concavisporites kermanense* Arjang 1975, *Concavisporites subgranulosus* Couper 1958, *Klukisporites variegatus* Couper 1958, *Contignisporites problematicus* (Couper, 1958) Döring 1965, *Cycadopites crassimarginis* (de Jersey, 1959) de Jersey 1964, *Cycadopites follicularis* Wilson & Webster 1946, *Cycadopites granulatus* (de Jersey, 1962) de Jersey 1964, *Cycadopites parvus* (Bolkhovitina, 1953) Pocock 1970, *Monosulcites minimus* Cookson 1947, *Aratrisporites fischeri* (Klaus, 1960) Playford & Dettmann 1965, *Perinopollenites elatoides* Couper 1958, *Callialasporites dampieri* (Balme, 1957) Dev 1961, *Callaiasporites trilobatus* (Balme, 1957) Dev 1961, *Eucommiidites troedssonii* Erdtman 1948, *Chasmatosporites apertus* (Rogalska, 1954) Nilsson 1958, *Chasmatosporites elegans* Nilsson 1958, *Chasmatosporites* sp. cf. *C. elegans* Nilsson 1958, *Chasmatosporites hians* Nilsson 1958, *Chasmatosporites major* (Nilsson, 1958) Pocock & Jansonius 1969, *Chasmatosporites* sp., *Classopollis torosus* (Reissinger, 1950) Couper 1958, *Alisporites lowoodensis* de Jersey 1963, *Alisporites parvus* de Jersey 1962, *Alisporites thomasii* (Couper, 1958) Nilsson 1958, *Alisporites robustus* Nilsson 1958, *Pityosporites minimus* (Couper, 1958) Ziaja 2006, *Parcisporites cacheutensis* Jain 1968, *Platysaccus papillionis* Potonie & Klaus 1954, *Vitreisporites pallidus* (Reissinger, 1950) Nilsson 1958.

Moreover, two informal consecutive miospore–based biozones were idenitified. These biozones are upward: *Callialasporites trilobatus–Parcisporites cacheutensis* Assemblage Zone which is established based on the interval between the LADs of *Callialasporites trilobatus* and *Aratrisporites fischeri*, and *Contignisporites problematicus* Taxon Range Zone which is established basing on the LOO and FOO of this species. Primarily based on the FOO and LOO criteria of stratigraphically significant species, these are compared with those introduced in almost coeval strata from both Iran and elsewhere. The taxa with known stratigraphic import and/or persistence are illustrated in Plates 1–3.

DISCUSSION

Here, the erected biozone–*Klukisporites variegatus* Assemblage zone–in the Middle Jurassic deposits of Tabas Block, central–east Iran is compared to Iran and elsewhere biozonation (Table 1) *e.g.* it compares to the *Klukisporites variegatus–Concavisporites subgranulosus* Zone in The Yorkshire, England (de Jersey, 1970), *Ischyosporites variegatus–Duplexisporites problematicus–Tsugapollenites dampieri* Zone in the southwest of Germany (Weiss, 1989), *Callialasporites–Perinopollenites* Zone in the Bornholm, Denmark (Koppelhus & Nielsen, 1994), *Tugapollenites* (*Callialasporites*) *segmentus–Callialasporites dampieri* Assemblage zone in the Eastern Queensland, Australia (Reiser & Williams, 1969), *Contignisporites cooksoniae* Assemblage Zone in the West Bengal, India (Vijaya & Sen, 2005), and *Ischyosporites variegatus–Duplexisporites problematicus* Zone in the Karkar and Dahana–i–Tor, Afghanistan (Ashraf, 1977).

Palaeoenvironmental elucidation of the Middle Jurassic is based upon the palaeoecological and phytogeographic significance of the palynofloras identified and on the associated floral evidences. However, some doubts regarding botanical affinity of dispersed miospores inhibit precise syntheses. The natural alliances of the dispersed miospores are inferred on the basis of morphological similarities with those of extant plants and/or the known contents of fossil fructifications of established natural affinities. Botanical affinities of some taxa have been assigned with varying degrees of confidence, some to more than one major natural group and others more doubtfully assigned. Inferred natural botanical affinities of spores and pollen grains identified in this study are cited in Table 2.

Affinity and ecological preferences of parent plants together with their related miospore genera present in the Hojedk palynofloras are as follows: Pteridophyta are among the most abundant lineage of vascular plants in lowland floral communities that appear in the Devonian with several thousand extant species today. These have extensive fossil records during most of the Mesozoic and almost all are isosporous (DiMichele & Phillips, 2002). The predominant pterophytes are represented by such families as Schizaeaceae, Osmundaceae, Dipteridaceae, Dicksoniaceae, Cyatheceae,

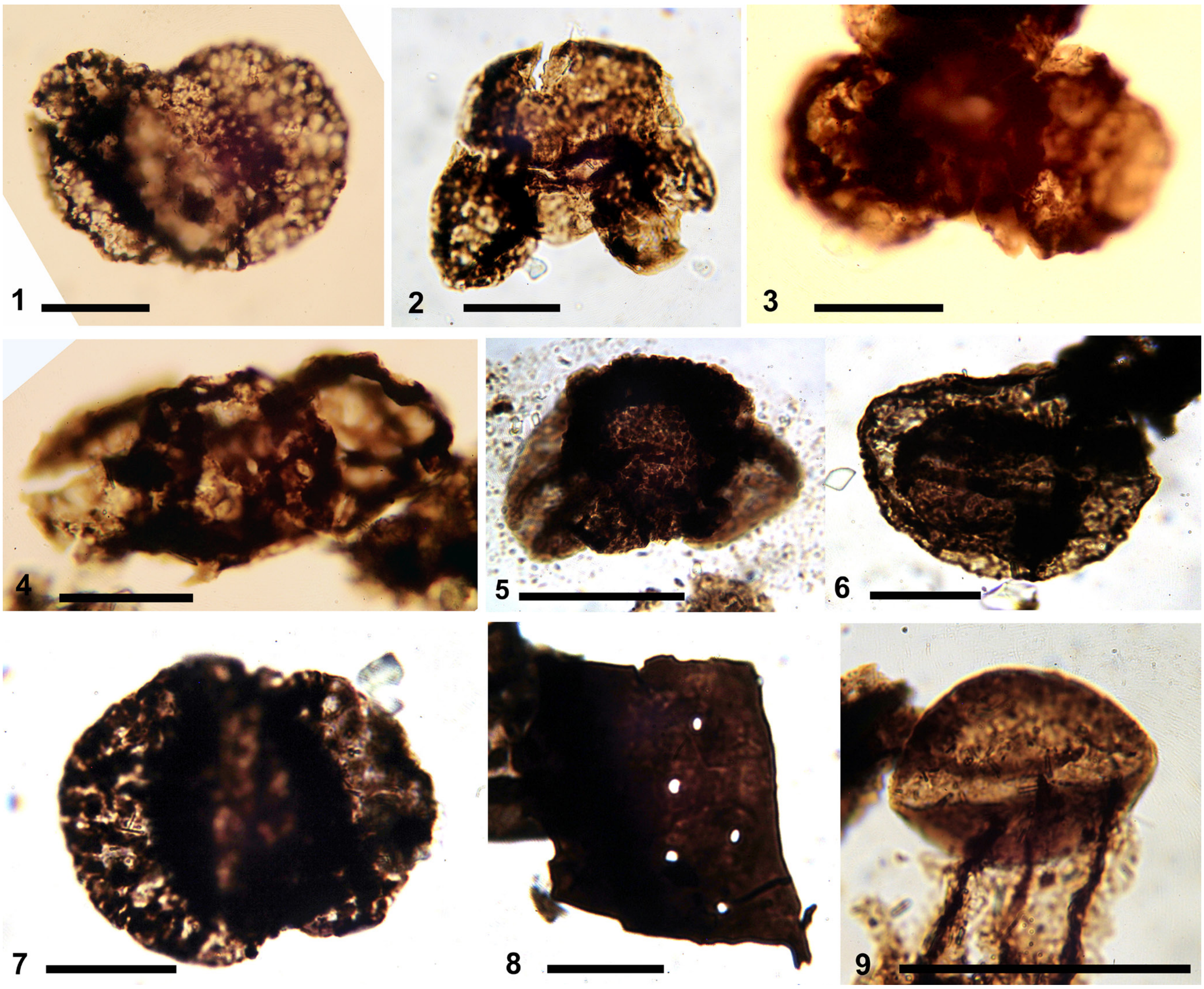

PLATE 3

1. *Alisporites thomasii* (Couper 1958) Pocock 1962, FJHK–7.
2, 5. *Pityosporites minimus* (Couper 1958) Ziaja 2006, FJHK–109, FJHK–22.
3, 4. *Platysaccus papillionis* Potonie & Klaus 1954, FJHK–209.
6. *Aratrisporites fischeri* (Klaus 1960) Playford & Dettmann 1965, FJHK–209.
7. *Alisporites grandis* (Cookson 1953) Dettmann 1963, FJHK–209.
8. A tracheid, FJHK–209a.
9. *Monosulcites minimus* Cookson 1947, FJHK–22c.

Scale bars= 20µm.

PERIOD		JURASSIC			
EPOCH		MIDDLE			
AGE		AALENIAN	BAJOCIAN	BATONIAN	CALOVIAN
IRAN	E ALBORZ Jajarm[1]	*Vitreisporites pallidus-Cycadopites follicularis* Assemblage zone			
IRAN	SEMNAN Dictash[2]		*Contignisporites-Striatella* Assemblage zone	*Classopolis* Oppel zone	
IRAN	KERMAN Eshkelli Pabdana... [3, 4]		*Klukisporites* zone; *Klukisporites variegatus* subzone		
IRAN	KERMAN Hojedk[5]	*Klukisporites variegatus-Monosulcites minimus* Assemblage zone			
IRAN	TABAS S Kouchekali	*Vitreisporites pallidus-Klukisporites variegatus* Assemblage zone: *Calialasporites trilobatus-Parcisporites cacheutensis* Assemblage subzone; *Contignisporites problematicus* Taxon Range zone			
AFGHANISTAN	Karkar & Dahana-i-Tor[6]	*Ischyosporites variegatus-Duplexisporites problematicus* zone			
AUSTRALIA	WESTERN Perth Basin[7]	*Exesipollenites tumulus* Assemblage zone; *Dictyophyllidites harrisi* Assemblage subzone		*Callialasporites dampieri* Assemblage zone; *Dictyotosporites complex* Oppel zone	*Klukisporites scaberis* Oppel zone
AUSTRALIA	EASTERN Queensland Surat Basin[8]	*Tsugapollenites* (*Callialasporites*) *segmentus-Callialasporites dampieri* Assemblage zone			
ENGLAND	Yorkshire Deltaic series[9]	*Klukisporites variegatus-Concavisporites subgranulosus* zone			
DENMARK	Bornholm Baga Fm.[10]	*Callialasporites-Perinopollenites* zone			
GERMANY	Swabian Alb[11] SW Germany	*Ischyosporites variegatus-Duplexisporites problematicus-Tsugapollenites dampieri* zone			
CANADA	Western Canada[12]	*Alisporites thomasii-Vitreisporites pallidus-Pflugipollenites* (*Callialasporites*) *dampieri* zone			
EGYPT	Eastern Desert[13]	*Classopollis/ Circulina-Deltidospora* spp. Assemblage zone	*Verrocosisporites* spp.-*Converrocosisporites* spp. *Trilobosporites* spp. Assemblage zone		
INDIA	West Bengal[14]		*Contignisporites cooksoniae* Assemblage zone		

Table 1—Correlation chart of the South Kouchekali Jurassic palynological zones with those from other areas in Iran and elsewhere ([1]Vaez–Javadi & Ghavidel–Syooki 2005, [2]Navidi–Izad *et al.* 2015, [3]Arjang 1975, [4]Hashemi–Yazdi *et al.* 2014, [5]Kimyai 1968, [6]Ashraf 1977, [7]Filatoff 1975, [8]Reiser & Williams 1969, [9]de Jersey 1970, [10]Koppelhus and Nielsen 1994, [11]Weiss 1989, [12]Pocock 1962, [13]Ibrahim *et al.* 2001, [14]Vijaya and Sen 2005).

Spores*	**Botanical affinity**
Calamospora tener (Leschik 1955) Mädler 1964	Sphenophyta, Equisetales
Cyathidites Couper 1953	Filicopsida (Cyatheaceae, Dipteridaceae, Dicksoniaceae)
Cyclogranisporites orbiculus Potonié & Kremp 1955	Filicopsida (Marattiales)
Dictyophyllidites Couper emend. Dettmann 1963	Filicopsida (Dipteridaceae, Matoniaceae)
Coniopteris hymenophylloides (Brongniart) Seward 1900	Filicopsida (Matoniaceae, Dicksoniaceae)
Klukisporites Couper 1958	Filicopsida (Schizaeaceae)
Osmundacidites wellmanii Couper 1953	Filicopsida (Osmundaceae)
Granulatisporites (Ibrahim 1933) Schop, Wilson Bentall 1944	Lycopsida, Equisetopsida, Filicopsida, Cycadopsida
Aratrisporites	Lycopsida (Pleuromeiaceae: *Annalepis*)
Pollen grains Botanical affinity*	Botanical affinity
Alisporites Daugherty 1941	Pteridospermophyta (Lyginopteridales, Corystospermaceae)
Cycadopites Wodehouse ex Wilson & Webster 1946	Pteridospermophyta (Peltaspermaceae, Ginkgopsida, Cycadopsida)
Platysaccus Naumova ex Potonié & Klaus 1954	Pteridospermophyta (Corystospermaceae)
Vitreisporites pallidus (Reissinger 1950) Nilsson 1958	Pteridospermophyta (Caytoniales)
Callialasporites Sukh Dev 1961	Coniferopsida (Araucariaceae)
Classopollis Maljavkina emend. Cornet & Traverse 1975	Coniferopsida (Cheirolepidiaceae)
Pityosporites (Couper 1958)	?Coniferales
Chasmatosporites Nilsson 1958	Ginkgopsida, Cycadopsida
Monosulcites minimus Cookson 1947	Cycadales, Ginkgoales (*Ginkgo huttoni*)
Perinopollenites elatoides Couper 1958	Coniferopsida (Taxodiaceae)
Eucommiidites troedssonii (Erdtman) Potonié 1958	Cycadopsida (Cycadales)

Table 2—Inferred botanical affinities of miospores discussed herein.

* Based on data provided by Couper 1958, 1960; Mädler 1964; Pocock 1970; van Konijnenburg–van Cittert 2007, 1971; Filatoff 1975; Filatoff & Price 1988; Vakhrameev 1991; Dettmann & Clifford 1992; Balme 1995; Abbink,1998; Ziaja 2006.

Matoniaceae and Marattiaceae. Abundance of *Klukisporites variegatus* (belongs to Filicophyta) in the Hojedk Formation reflects plenty of its parent plant, *Klukia exilis* Raciborski 1890 which had a wide geographic distribution in various regions, from the northern, central and eastern Iran during the Middle Jurassic (Fakhr, 1977; Vaez–Javadi & Mirzaei–Ataabadi, 2006; Vaez–Javadi, 2014, 2015). The moisture–dependant Filicophyta indicates a warm and humid, tropical to subtropical climate (Vakhrameev, 1991; Jansson *et al.*, 2008). In the Middle Jurassic deposits of Hojedk Formation, Filicophyta exhibits remarkable percentages including families mentioned above. Pteridospermophyta is represented palynologically by two families comprising Peltaspermaceae and Corystospermaceae. Monosulcate pollen *Cycadopites* has been assigned not only to Pteridospermophyta but also to the Ginkgophyta and Cycadophyta (Balme, 1995). This pollen grain is attributed to Cycadophyta or Ginkgophyta in Hojedk palynofloras. In the sediments from Hojedk Formation also occur pollen grains of seed ferns, small in size pollen of *Vitreisporites pallidus*, produced by the Caytoniales (Ziaja, 2006). Corystospermaceae contributes a bisaccate dispersed pollen comprising *Alisporites* to the Hojedk palynofloras. Of gymnosperms, Coniferophyta and Ginkgophyta are represented in the Hojedk Formation's palynofloras. Affinity of the dispersed conifer pollen grains appear to be with Araucariaceae, Podocarpaceae, and Cheirolepidiaceae. Araucariaceae is well represented in terms of diversity and distribution in the Northern Hemisphere during the Jurassic. Podocarpacean pollen indicates a warm climate with no seasonal amplitudes indicative of coastal environments (Abbink, 1998). *Classopollis*, ranging from the Upper Triassic to Upper Cretaceous (Pflug, 1953; Van der Ham *et al.*, 2003), is one of the well–known and distinctive pollen grains of extinct Cheirolepidiaceae family extracted from cheirolepidiaceous cones, *Classostrobus* (Alvin, 1982; Alvin *et al.*, 1978). Given the distribution of *Classopollis*, Cheirolepidiaceae is indicative of warm habitats at low palaeoaltitudes during the Mesozoic especially Cretaceous

(Backhouse, 1988; Taylor *et al.*, 2009; Diéguez *et al.*, 2010). The oldest evidence of the Ginkgophyta is considered to be from the Permian (Taylor *et al.*, 2009). Today, Ginkgophyta has only one living species, *Ginkgo biloba* Linnaeus (van Konijnenburg–van Cittert, 2008; Taylor *et al.*, 2009) which can tolerate a wide range of climatic conditions from Mediterranean to cold temperate (Diéguez *et al.*, 2010). Totally, ginkgoaleans were adapted to the warm temperate or subtropical climate like their living beautiful representative *Ginkgo biloba* (Wu *et al.*, 2006; Van Konijnenburg–Van Cittert, 2008). *Chasmatosporites* is assigned to Ginkgophyta in the Hojedk Formation's palynofloras.

Consequently, with respect to the wide geographical distribution of the Hojedk Formation throughout the Tabas Block as well as index terrestrial microflora therein and the inferred climatic preferences of its parent plants, it can be concluded that the Hojedk Formation was deposited in a lowland to coastal environment with a warm to semi–warm humid climates. Besides, the plant megafossils that belong to Filicophyta, Cycadophyta, Pteridospermophyta, Coniferophyta, and Ginkgophyta recorded from the Jurassic strata of northern Iran (Schweitzer & Kirchner, 1995, 1996, 1998, 2003; Schweitzer *et al*., 1997; Vaez–Javadi & Allameh, 2015) verify the generalization presented herein. Therefore, it can be concluded that there was almost uniform vegetation through Iranian Plate during the Middle Jurassic.

CONCLUSIONS

The present investigation of the Hojedk Formation in the South Kouchekali, southwestern of Tabas, east–central Iran has revealed a diverse assemblage of nearly well preserved spores and pollen. The palynofloras comprise thirty–nine species including spores (fourteen species allocated to nine genera) and various types of pollen (twenty–five species designated to thirteen genera). Distribution of these miospores permitting the establishment of one biozone–between two species: *Klukisporites variegatus–Vitreisporites pallidus* and two informal biozones. They are upward: *Callialasporites trilobatus–Parcisporites cacheutensis* Assemblage zone and *Contignisporites problematicus* Taxon range zone. Four of the most common and often quantitatively abundant species, in descending order, are *Cyclogranisporites orbiculus*, *Klukisporites variegatus*, *Cyclogranisporites* sp. cf. *C. multigranus*, and *Cyathidites mesozoicus* with 28.84%, 27.27%, 10.94%, and 8.38% respectively. In monosulcate taxa of the gymnosperms such as *Chasmatosporites apertus, Chasmatosporites elegans, Classopollis torosus, Chasmatosporites hians, Cycadopites crassimarginus*, and bisaccate pollen such as *Alisporites thomasii, Vitreisporites pallidus* with 17.76%, 16.45%, 11.40%, 5.70%, 5.70%, and 5.04% respectively dominate the assemblage. In addition, relative abundance of spore and pollen are 60.69% and 39.31% respectively in this core–section. Moreover, *Klukisporites* (*Ischyosporites*) *variegatus, Callialasporites* (*Tsugapollenites*) *dampieri, Vitreisporites pallidus* Assemblage zone is the most spread biozone through the early Middle Jurassic of the Iran. Inferred natural relationships of the Hojedk sporae dispersae imply derivation from such diverse parental flora as Sphenophyta, Filicophyta, Coniferophyta, Ginkgophyta, Pteridospermophyta, and Cycadophyta. With respect to the wide distribution of the microfloras assigned to the mentioned taxa as index terrestrial microflora and the inferred climatic preferences of its parent plants, it can be concluded that the Hojedk Formation was deposited in a lowland to coastal environment with a warm to semi–warm humid climates.

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