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The Middle Jurassic (Bajocian–Bathonian) flora of the Tabas Block, central Iran

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Abstract

The present study discusses the outcome of palynlogical and palaeobotanocal investigations of Middle Jurassic strata of the Tabas Block. The most commonly identified spore type is a trilete spore, *Klukisporites*, which accounts for 30 per cent, and the genus *Ischyosporites* which makes up 12 per cent of the spore collection. Plant fossils recovered from the borehole studied are indicative of a varied assemblage, starting with a diverse range of ferns and followed by Cycadophytes, Ginkgophytes and Coniferophytes. The predominance of the Lowland group in the Tabas Block during the Bajocian–Bathonian, as indicated by the Sporomorph EcoGroup (SEG) and Plant EcoGroup (PEG) models, suggests that the strata studied were laid down mainly in a lowland environment. Dinoflagellate cysts were found in locations that correspond to river and coastal ecogroups, hinting at marine influence.

Keywords: Sporomorph EcoGroup, Plant EcoGroup, palynology, palaeobotany, Hojedk Formation

1. Introduction

During the Jurassic Period, several significant geological events occurred. These events included the fragmentation of the supercontinent Pangea, an increase in global temperatures due to the release of large amounts of the greenhouse gas CO_2, a rise in sea level and expansion of shallow continental seas (Ogg et al., 2016; Button et al., 2017; Vickers et al., 2022). Typically, this period is associated with a warm and humid climate, which is believed to have been caused by elevated atmospheric CO_2 levels (Hallam, 1985; Berner, 1994; Berner & Kothavala, 2001; Ghosh et al., 2001). Moreover, periods of climate deterioration, leading to possible glaciations in high latitudes, have been suggested for the Jurassic stages Pliensbachian, Bajocian to Bathonian, upper Callovian to lower Oxfordian and Tithonian (Price, 1999; Dromart et al., 2003).

Fossilised plants offer valuable insights into plant diversity as well as palaeoclimatic, palaeoenvironmental and palaeoecological conditions of the past (Creber & Chaloner, 1985; Feng et al., 2013, 2017, 2019). Palynomorphs are frequently used as proxies in palaeoclimate studies due to their abundance in sedimentary deposits and their close correlation with vegetation composition and climatic/environmental changes (Traverse, 2007).

Researchers have documented the palaeoclimatic record of the Middle Jurassic (Bajocian) relatively well through the use of marine carbonates and organic matter proxies (O'Dogherty et al., 2006; Dera et al., 2011; Korte et al., 2015). However, despite the increasing availability of isotopic composition data for fossil wood, coal and other terrestrial materials (e.g., Hesselbo et al., 2003), it remains crucial to expand investigations into terrestrial environments and climates. The primary aim of the present paper is to examine the palaeoflora found in Bajocian–Bathonian deposits within the northern Neo-Tethys Ocean. The current study focuses on the leaf flora and palynomorphs recorded from the Hojedk Formation situated in the Tabas Block.

2. Geological setting

The triangular outline of the Central Iran Basin is caused by its narrow extensions to the north-east and north-west and its central location in the country. It is bordered by Dasht-e-Lut on the east, the Sanandaj-Sirjan Metamorphic Belt in the south, south-west and west, and the Alborz Mountains in the north. The Tabas Block in the centre, the Yazd Block in the west and the Lut Block in the east comprise the three main parts of the Central-East Iranian Microcontinent (CEIM; Takin, 1972). The central structural component of the CEIM is the Tabas Block, which was part of the Cimmerian microplate assemblage along with the adjacent basement fault-bounded Lut and Yazd blocks (Stampfli & Borel, 2002). This microplate broke off from Gondwana during the Permian, drifted north as the oceanic crust of the Palaeotethys subducted north, and finally collided with the southern edge of Eurasia (the Turan Plate) during the early Late Triassic (Stocklin, 1974; Saidi et al., 1997; Stampfli & Borel, 2002; Wilmsen et al., 2009).

This collision closed the Palaeotethys and brought the Eo- and Main-Cimmerian orogenic events in northern and central Iran to an end (Wilmsen et al., 2009). These tectonic events affected the history of the Shemshak Group's Upper Triassic and Lower Jurassic, which included the uplift and deformation of the foreland framework in northern and central Iran (Fürsich et al., 2009; Wilmsen et al., 2009; Seyed-Emami et al., 2020).

The thick Upper Triassic–Jurassic succession in this region was divided into several formations (Stocklin & Nabavi, 1971), which were then combined into two lithostratigraphical groups: the Middle–Upper Jurassic Magu Group (northern Tabas Block) or Bidou Group (southern Tabas Block) and the Upper Triassic–lower Middle Jurassic Shemshak Group (Aghanabati, 1999).

The coal-bearing Shemshak Group (Fürsich et al., 2009), formerly the Shemshak Formation (Carnian–Bajocian), was deposited in the Alborz Mountains and central Iran in a foreland basin during the early to middle Cimmerian orogeny (Aganabati, 1999). The Alborz Mountains, Tabas and Kerman regions of east-central Iran contain a number of formations that make up the Shemshak Group (Aganabati, 1998, Fürsich et al., 2009).

The Hojedk Formation is a thick sequence of coal-bearing terrigenous sedimentary rocks that overlie the marine Badamu Formation (Seyed-Emami et al., 2004). The Stratigraphic Names Committee of Iran named the Hojedk Formation in 1964 (Stöcklin & Setudehnia, 1971). The fossiliferous coal horizons yield a well-preserved leaf flora. According to Lasemi & Kheradmand (1999), the strata of the Hojedk Formation were laid down in a river-dominated, fault-controlled delta and meandering river system. Therefore, this formation is comparable in time to the coal-bearing Dansirit Formation in the southern Alborz, which is also marginally marine and deltaic (Fürsich et al., 2009). Both formations indicate a distinct shallowing of the depositional environments in northern and eastern central Iran prior to the Mid-Cimmerian tectonic event (Fürsich et al., 2009). Based on ammonite records for both underlying and overlying units (Badamu & Parvadeh formations, respectively) (Seyed-Emami et al., 2020) and plant macrofossils (Badihagh et al., 2019), the Hojedk Formation is generally dated as late Bajocian to early Bathonian (Badihagh et al., 2019).

3. Previous studies

Various researchers have explored plant micro- (Kimiyai, 1968; Arjang, 1975; Ashraf, 1977; Achilles et al., 1984) and macrofossils (Schweitzer, 1978; Schweitzer et al., 1997) from the Middle Jurassic in Iran and Afghanistan. Several fossils of bryophytes, lycophytes, equisetales and ferns were reported by Schweitzer (1978) and Schweitzer et al. (1997). In addition to this material, plant remains assignable to Caytoniales, Cycadophytes, Bennettites, Ginkgophytes, Czekanowskiales and Coniferales have also been documented from Middle Jurassic deposits in Iran (Barnard & Miller, 1976; Schweitzer & Kirchner, 1995, 1996, 1998, 2003; Schweitzer et al., 2000). Compared to leaf floras, fossil woods are infrequently found. *Cupressinoxylon* (Seward, 1912) and *Mesembrioxylon* sp. (Sitholey, 1940; Jacob & Shukla, 1955) have been recorded from the Saighan Series of northern Afghanistan. Poole & Ataabadi (2005) documented the discovery of conifer woods from the Hojedk Formation in Iran.

Mesozoic deposits extending from central Iran northwards and eastwards into Afghanistan contain well-preserved floras. These Mesozoic plant-bearing deposits are crucial because they form a continuous series from the Norian to the Middle Jurassic (Schweitzer et al., 1997). The fossils originate from mining areas in northern and central Iran and north-east Afghanistan (Schweitzer et al., 2000).

A few studies explored the Middle Jurassic flora of Iran in the first half of the twentieth century (Tipper, 1921). However, the second half of that century played a crucial role in uncovering the history of micro- and macrofloral investigations in the Central Iran Basin (Huckriede et al., 1962; Assereto et al., 1968; Corsin & Stampfli, 1977; Fakhr, 1977). After Assereto (1966) had defined the Shemshak Formation, many authors studied this and recorded different species of *Neocalamites*.

Kilpper (1964) and Barnard (1965) reported sphenophytes from the Shemshak Formation of the Alborz Mountains in northern Iran. Schweitzer et al. (1997) revised the Jurassic flora of Iran in detail, accounting for all previously described species. The lower Mesozoic strata (Norian–Rhaetian) in Kerman in the Central Iran Basin have yielded remains of *Neocalamites* (Assereto et al., 1968; Corsin & Stampfli, 1977; Fakhr, 1977). However, most of the specimens examined were either too small or poorly preserved to be identified accurately (Schweitzer et al., 1997).

4. Material and methods

A borehole located in the Mazino Coal Mine (Fig. 1) on the Tabas Block was selected to investigate the palynology and palaeobotany of the Hojedk Formation. Previous studies have recorded that the formation was of Bathonian–Bajocian age, based on its stratigraphical characteristics and fossil content (Ameri et al., 2013; Ameri, 2018; Badihagh et al., 2019).

4.1. Microfossils

A palynological analysis was performed on 60 samples. Standard palynological processing techniques, which involve acid digestion (Traverse, 2007), were used to create the palynology slides. A Leitz Wetzlar microscope was used to examine the material, and photographs were captured using a Sony DSC-W530 digital camera. For each sample, the frequency of spores, pollen grains, dinoflagellate cysts and sedimentary organic matter were determined by counting. The SEG model (Abbink, 1998; Abbink et al., 2004) was employed to examine the palaeoclimate and palaeoenvironment of the Bajocian–Bathonian deposits in the intervals studied.

4.2. Macrofossils

Several specimens were collected from the Hojedk Formation on the Tabas Block. During the extraction of material, stratigraphical control was maintained at each sample site. The samples obtained for this research range in size from 100 to 500 mm in length and width. All plant identifications were made by direct observation using a dissecting microscope, with oblique lighting to emphasise details of the fossil leaves. Following cleansing, the specimens were photographed under a low-angle incidental light using an Olympus E-500 camera.

Various studies were consulted to identify the leaves, leaflets and reproductive organs of Bennettitales, Caytoniales, Coniferales and ferns (Harris, 1964; Watson & Sincok, 1992). The macrofossils were quantitatively analysed by counting each identifiable plant fragment on both sides of the rock slabs. These plant fossils were then associated with their respective presumed environments, known as PEG, by considering literature data and morphological characters. This approach allowed

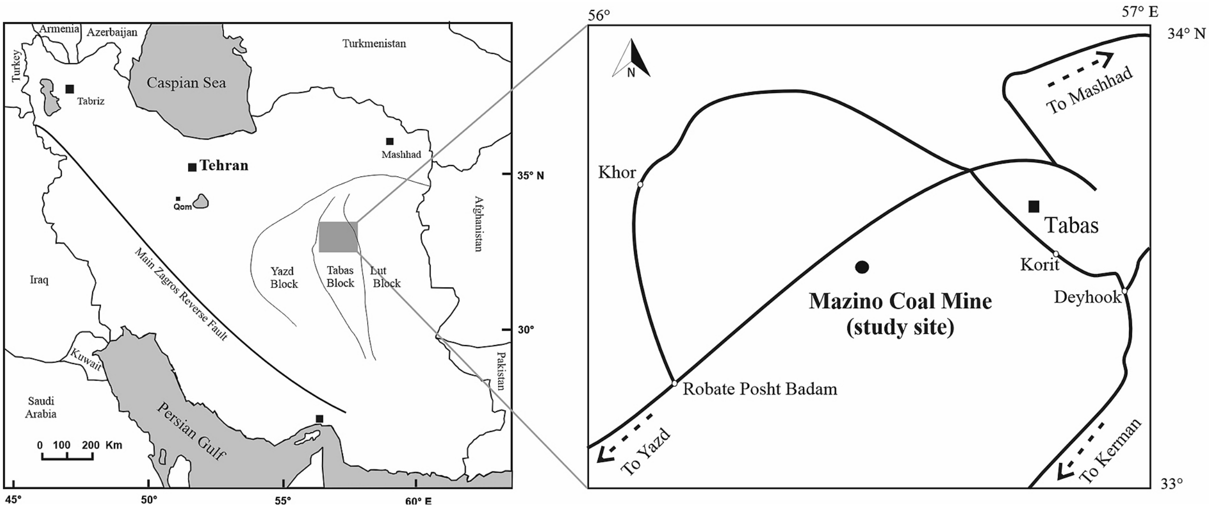

Fig. 1. Locality map showing the borehole studied within the Mazino Coal Mine.

for identifying variations in plant composition and distribution between different environments and provided valuable insights into the palaeoecology of the study area.

5. Results

5.1. Microfloral assemblage

The palynomorphs present in the interval studied on the Tabas Block exhibit poor preservation, and numerous specimens are too degraded to permit identification. The predominant identified type is trilete spores, with the genera *Klukisporites* comprising 30 per cent and *Ischyosporites* 12 per cent of the spore assemblage, respectively. The presence of dinoflagellate cysts in the Hojedk Formation indicates a brief period of marine influence during deposition. The genus *Cribroperidinium* was the most abundant of dinoflagellate cysts found in the borehole studied. *Alisporites*, *Araucariacites* and *Chasmatosporites* were the most often observed pollen genera in this borehole in the Mazino mining area (Fig. 2A). A selected number of recorded palynomorphs is shown in Figure 3.

5.1.1. Sporomorphs Ecogroup (SEG) model

The SEG model utilises palynology to reconstruct the palaeoclimate in shallow environments during the Late Jurassic period, as demonstrated in studies such as Abbink (1998) and Abbink et al. (2004). The spore and pollen grains present on the Tabas Block have been categorised into four SEGs. Table 1 and Figure 2B provide detailed data sets for the SEGs identified in the intervals studied. Table 1 also classifies all the identified spores and pollen grains based on their parent plant habitats. Ferns constitute the predominant genera identified in the borehole studied. Additionally, species belonging to Lycophyta, Bryophyta and Coniferophyta have been observed.

The SEG data obtained from the Tabas Block exhibit a significant increase in 'lowland' elements during the Bajocian–Bathonian. This EcoGroup is typically associated with lowland areas. The SEG data presented in Figure 2B and Table 1 indicate the influence of coastal, tidal and river vegetation on the prevalence of the dominant lowland group throughout the rock unit.

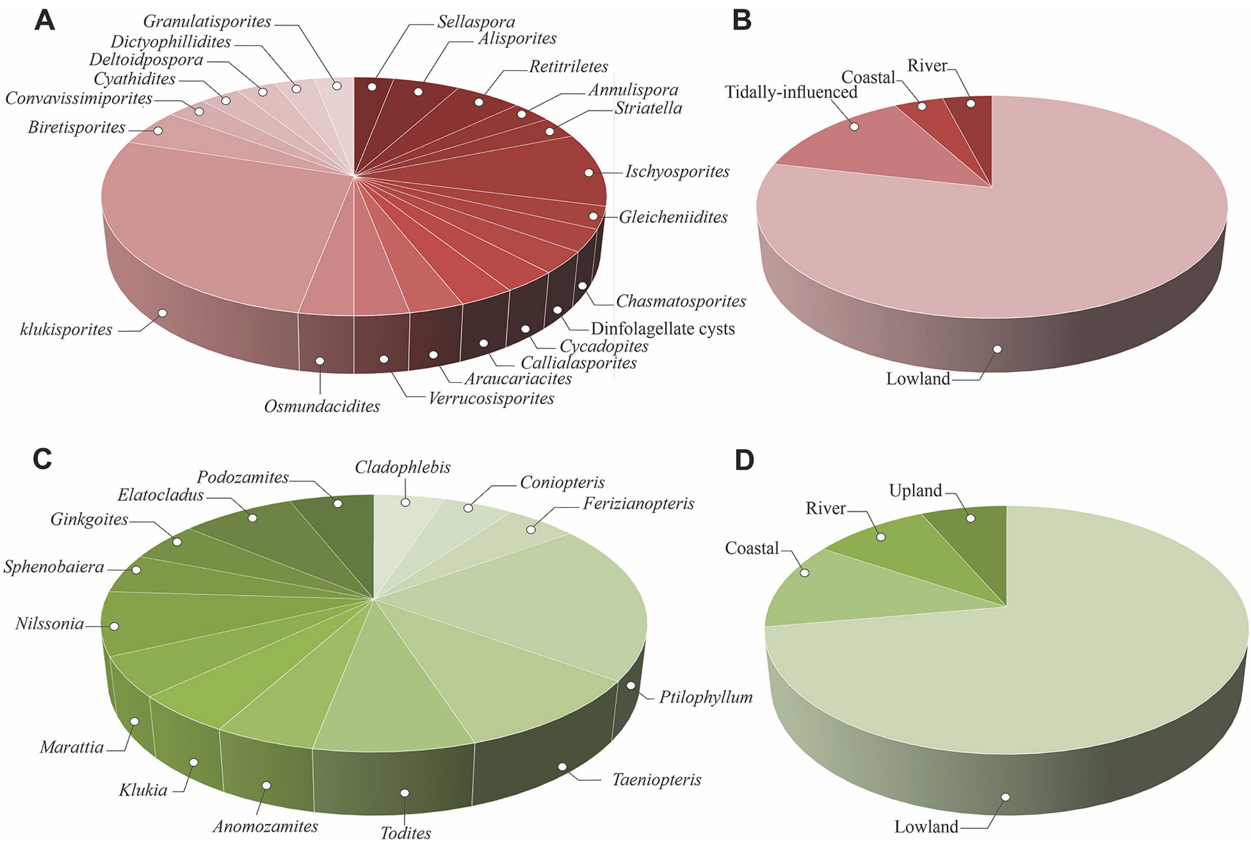

Fig. 2. Pie chart illustrating the frequency distribution of: **A –** Palynomorphs; **B –** SEG; **C –** Plant fossils; **D –** PEG recorded within the Hojedk Formation in the present study.

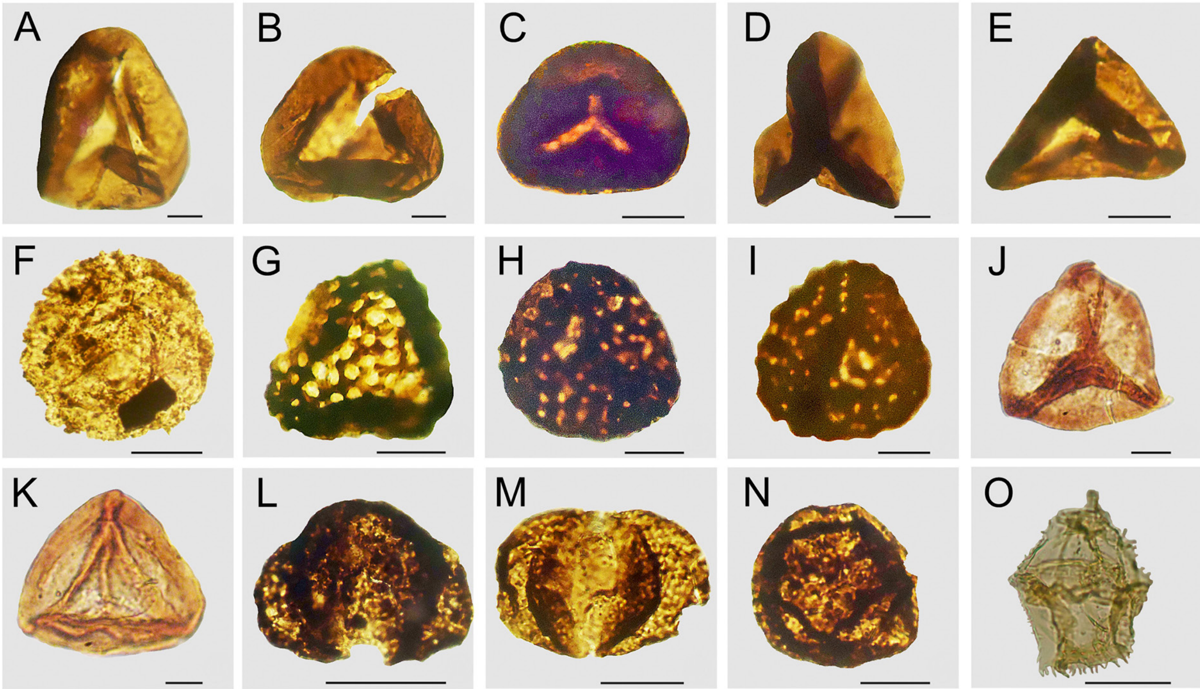

Fig. 3. Selected palynomorphs from the study interval on the Tabas Block (scale bar equals 20 μm). **A –** *Cyathidites australis* Couper, 1953; **B –** *Cyathidites minor* Couper, 1953; **C –** *Deltoidospora hallii* Miner, 1935; **D, E –** *Dictyophyllidites mortonii* (de Jersey) Playford & Dettmann, 1965; **F –** *Osmundacidites wellmanii* Couper, 1953; **G-I –** *Klukisporites variegatus* Couper, 1958; **J, K –** *Gleicheniidites senonicus* Ross emend. Skarby, 1964; **L –** *Alisporites australis* de Jersey, 1962; **M –** *Alisporites lowoodensis* de Jersey, 1963; **N –** *Araucariacites australis* Cookson ex Couper, 1953; **O –** *Gonyaulacysta jurassica* (Deflandre) Norris & Sarjeant, 1965.

Table 1. Attributions of the palynological assemblage to main plant groups and to sporomorph ecogroups.

SEG	Sporomorph genera	Known or probable parent plant affinity	Climatic indicator
Lowland	*Chasmatosporites*	Ginkgophyta/Cycadophyta	Drier, cooler
	Cyathidites	Pterophyta (Cyatheaceae, Dipteridaceae, Dicksoniaceae)	Warmer, wetter
	Deltoidospora	Pterophyta (Cyatheaceae, Dipteridaceae, Dicksoniaceae)	Drier, warmer
	Dictyophyllidites	Pterophyta (Dipteridaceae, Dicksoniaceae, Cyatheaceae, Matoniaceae)	Warmer, wetter
	Gleicheniidites	Pterophyta (Gleicheniaceae)	Warmer, wetter
	Ischyosporites	Pterophyta (Schizaeaceae)	Warmer, wetter
	Klukisporites	Pterophyta (Schizaeaceae)	Warmer, wetter
	Osmundacidites	Pterophyta (Osmundaceae, Marattiaceae)	Wetter
	Sellaspora	Pterophyta/Pteridophyta	Warmer, wetter
	Striatella	Pterophyta (Pteridaceae)	Warmer, wetter
Coastal	*Araucariacites*	Coniferophyta (Araucariaceae)	Drier, cooler
River	*Annulispora*	Bryophyta (Sphagnaceae)	Wetter
Tidally-influenced	*Alisporites*	Pteridospermophyta (Corystospermaceae)	Warmer, drier
	Retitriletes	Lycophyta (Lycopodium)	Warmer, wetter

5.2. Macrofloral assemblage

The borehole studied shows a diverse range of ferns, including *Cladophlebis*, *Coniopteris*, *Ferizianopteris*, *Todites*, *Klukia* and *Marattia*. Cycadophytes, such as *Ptilophyllum*, *Taeniopteris*, *Anomozamites* and *Nilssonia,* were also found, as well as only two types of Ginkgophytes, namely *Sphenobaiera* and *Ginkgoites*. Coniferophytes, such as *Elatocladus* and *Podozamites,* were also observed (Fig. 2C). A selected number of recorded plant fossils is presented in Figure 4.

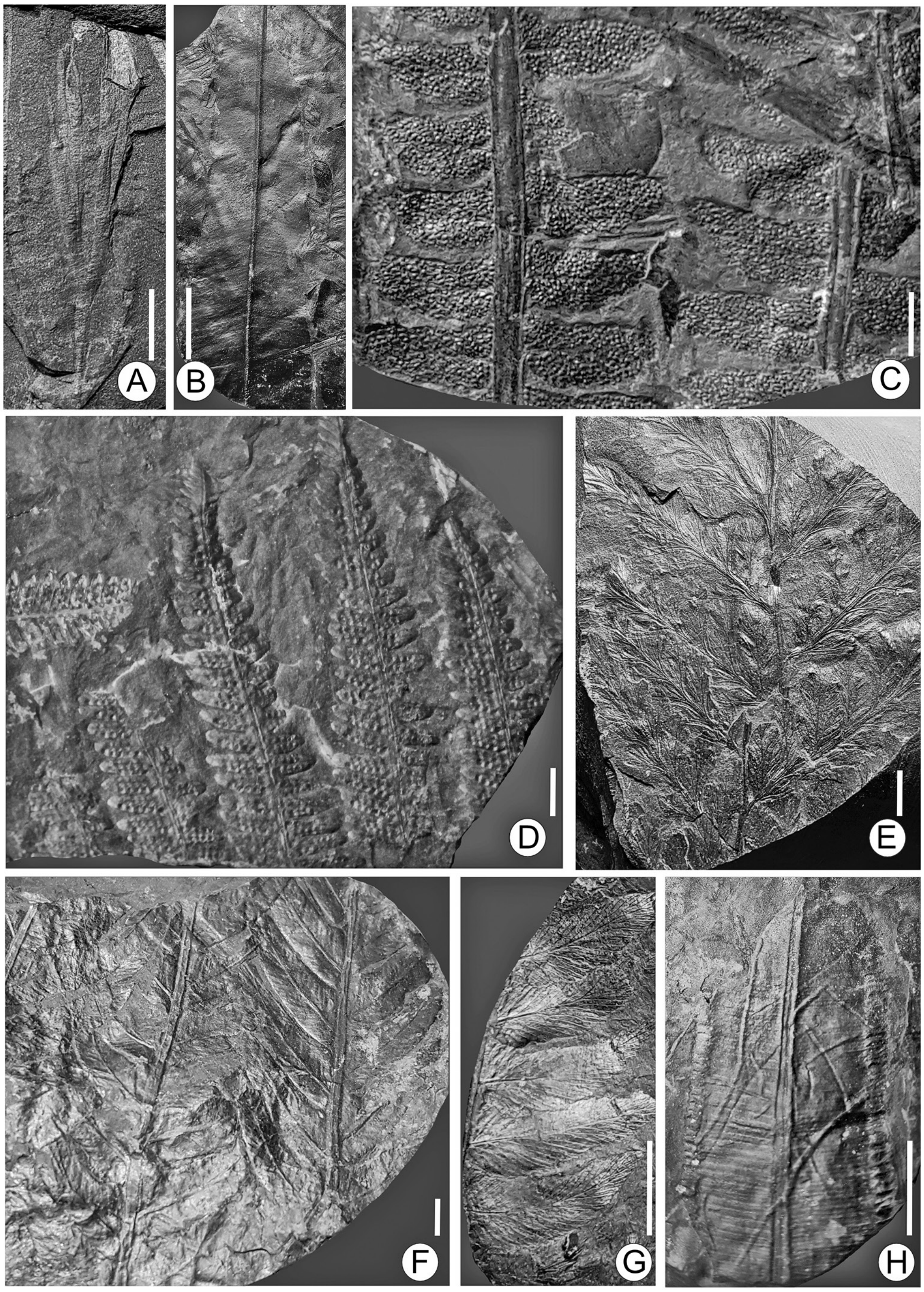

Fig. 4. Selected plant fossils from the study area (scale bar equals 10 mm). **A –** *Sphenobaiera longifolia* (Pomel) Florin, 1936; **B –** *Nilssonia sarakhs* Barnard & Miller, 1976; **C –** *Todites williamsoni* (Brongniart) Seward, 1900; **D –** *Klukia exilis* (Philips) Raciborski emend. Harris, 1961; **E –** *Coniopteris hymenophylloides* Seward, 1990; **F –** *Cladophlebis* sp; **G –** *Cladophlebis denticulata* (Brongniart) Fontaine, 1889; **H –** *Marattia intermedia* (Münsters) Kilpper, 1964.

5.2.1. PEG model

To gain insight into the palaeoecology of the study area, the macrofossils were categorised into different PEG based on their environmental requirements, following the approach proposed by Abbink (Abbink, 1998; Abbink et al., 2004) for sporomorphs. This classification system, as described by Costamagna et al. (2017), has helped group the macroplant fossils into distinct ecogroups based on their ecological needs. This approach offers a better understanding of the palaeoecology of the study area and the environmental factors that shaped the distribution of different plant species during the Middle Jurassic. The PEG model (Table 2; Fig.

Table 2. Attributions of plant fossils to main groups and to sporomorph ecogroups.

PEG	Genus	Plant Group	Climatic indicator
Lowland	*Cladophlebis*	Ferns	Wetter
	Coniopteris	Ferns	Wetter
	Ferizianopteris	Ferns	Wetter
	Ptilophyllum	Cycadophytes	Drier
	Taeniopteris	Cycadophytes	Drier
	Todites	Ferns	Wetter
	Anomozamites	Cycadophytes	Drier
	Klukia	Ferns	Warmer, wetter
	Marattia	Ferns	Warmer, wetter
	Nilssonia	Cycadophytes	Drier
Coastal	*Sphenobaiera*	Ginkgophytes	Warmer, wetter
	Ginkgoites	Ginkgophytes	Warmer, wetter
River	*Elatocladus*	Coniferophytes	Drier
Upland	*Podozamites*	Coniferophytes	Cooler

2D) helped differentiate the macroplant fossils into different ecogroups based on their respective ecological requirements. In the Middle Jurassic of the Tabas Block, four distinct plant ecogroups were identified: the River PEG, the humid Lowland PEG, the dry Lowland PEG and the Coastal/Tidally influenced PEG.

6. Discussion

During the Jurassic Period, conifers were the prevalent forest trees across the ancient world, and it was during this time that most modern conifer families originated and diversified (Miller, 1977, 1982; Stewart & Rothwell, 1993; Leslie et al., 2012). Despite their critical role in Jurassic environments, our current knowledge of the palaeobiology and palaeoecology of conifer species is limited, given the scarcity and incompleteness of the Jurassic record. Various studies, including those by Vakhrameev et al. (1970), Vakhrameev (1991), Wang et al. (2005) and Falcon-Lang et al. (2009), have suggested that during the Mesozoic era conifers typically thrived on slopes that were relatively dry and well drained in upland forests. Nonetheless, it is worth noting that not all conifer species were confined solely to these drier habitats.

In general, ferns thrive in environments that are shaded and humid and that have moderate to warm temperatures. However, not all fern species are limited to these specific conditions (Abbink et al., 2004; Van Konijnenburg-van Cittert, 2002). Most extant ferns tend to thrive in humid environments, whether in tropical or temperate regions – although, as mentioned before, they can also survive in drier habitats. Because ferns that live in warm and humid environments are more common, their spores are commonly used as indicators of humidity levels (Harris, 1961; Van Konijnenburg-van Cittert & van der Burgh, 1989).

Cycadophytes, encompassing Cycadales and Bennettitales, are gymnosperms of an ancient lineage dating back to the Palaeozoic era (Brenner et al., 2003; Condamine et al., 2015). Among macroremains available, the genera *Nilssonia*, *Anomozamites*, *Taeniopteris*, and *Ptilophyllum* are classified as members of this group. According to Abbink's research in 1998, Matoniaceae (*Deltoidospora*) tends to thrive under warm, dry conditions. Pollen of *Araucariacites* is associated with the family Araucariaceae (Tralau, 1967; Boulter & Windle, 1993). A significant presence of these pollen grains during the Jurassic Period is linked to warm climatic conditions, as Mohr (1989) indicated. *Alisporites* has been linked to the Corystospermales group because of the discovery of its pollen grains within *Pachypteris*-type plants. This association suggests that *Alisporites* existed in drier lowland environments, consistent with the known habitats of the Corystospermales.

6.1. Palaeoenvironment and palaeoclimate

The findings obtained from both the SEG and PEG models are consistent with each other, with the Lowland group being the dominant category in both models (Fig. 2). The river and coastal groups identified in both PEG and SEG analyses are located precisely where dinoflagellate cysts have been found. In other words, the sedimentary strata in the Tabas Block were predominantly deposited in a lowland environment with the presence of marine influences.

According to Schweitzer et al. (1997), during the Middle Jurassic period, the deposits in the western and northern regions of Alborz were exclusively terrestrial. However, in the central and eastern parts of Alborz, as well as in the Kerman Basin to the south, there were sporadic occurrences of marine intercalations within the deposits.

During the Middle Jurassic, Iran was situated within Vakhrameev's Euro-Sinian Region (Vaez-Javadi, 2018). This region was characterised by warm and humid climatic conditions from the Late Triassic to the Middle Jurassic (Vakhrameev, 1991). The palynological and palaeobotanical data obtained from the borehole studied also support the notion of a generally warm and humid climate during the Bathonian-Bajocian. Tables 1 and 2 show that most of the recorded species are indicative of a warmer and wetter climate. The results of the palaeoclimate analysis based on both palynology and palaeobotany are in agreement with each other.

6.2. Comparison and correlation

Ameri et al. (2013) identified gymnosperm and pteridophyte plant fossils from the Hojedk Formation in Kerman (Iran), suggesting that the deposition of the formation occurred under subtropical conditions. Ameri (2018) focused on plant fossils from the same formation but in a different location and identified 13 species, in seven genera, of macro plant fossils, including gymnosperm and pteridophyte groups, dating back to the Bajocian–Bathonian. These findings provided further insight into the flora of Iran during this Jurassic; however, the plant species documented in the current study exhibited a greater diversity in comparision to those previously reported by Ameri (2018).

In their study, Badihagh et al. (2019) examined the palynological and palaeobotanical aspects of the Hojedk Formation. The presence of minor marine palynomorphs, such as proximate dinoflagellate cysts, suggests a transgression in their studied interval. The palynological assemblages found in the Hojedk Formation indicated a diverse range of parent flora, with ferns, bryophytes and gymnosperms (including mainly conifers and ginkgophytes) being the most prevalent in descending quantitative order (Badihagh et al., 2019). By comparing these parent floras with modern plant ecology, those researchers concluded that these palynomorphs accumulated in a moist, warm climate during the Middle Jurassic. Additionally, a comparison of the parent plants with previous palaeofloristic studies revealed that the Tabas Block was located in the mid-Asian portion of the Indo-European floristic province of the Northern Hemisphere. In line with the research conducted by Badihagh et al. (2019), a minor (3 per cent) presence of dinoflagellate cysts in the Hojedk formation was identified in the current study. However, the diversity of spores and pollen grains was found to be greater in the present study.

Vaez-Javadi & Mirzaei-Ataabadi (2006) conducted a study on Jurassic plant macrofossils from the Hojedk Formation in east-central Iran, which suggested that the formation was of Bajocian–Bathonian age. Those researchers also found evidence of a uniform palaeoclimate and environment in Iran during this time, which is consistent with the findings of Vaez-Javadi's later studies on Middle Jurassic flora and palynology in Iran (Vaez-Javadi, 2018, 2019). In her 2018 study, Vaez-Javadi focused on the Hojedk Formation in south Kouchekali, the south-western area of Tabas City, and found that the relative abundance of certain plant groups suggested a humid subtropical climate for that locality. The findings also confirmed a uniform palaeoclimate and vegetation cover in Iran during the Middle Jurassic period. In 2019, Vaez-Javadi conducted a study on the Middle Jurassic palynology of the southwest Tabas Block in central-east Iran, which showed an abundance of ferns and cycadophytes as parent floras, indicating a moist, warm climate during the early Middle Jurassic. The findings also revealed that the region comprised several environments, including upland, warmer lowland, wetter lowland, rivers and a delta. Consistent with previous studies, the palaeovegetation observed in the present study suggests a subtropical climate. Similar to the research conducted by Vaez-Javadi (2019), ferns also contributed significantly to the palaeovegetation observed in the current study.

China has been the subject of several investigations that have focused on palaeovegetation of Middle Jurassic age. Palynomorphs present in the Tarim Basin located in north-west China were studied by Jiang et al. (2008), during which they detected specific miospores such as *Callialasporites dampieri*, *Cyathidites australis*, *Dictyophyllidites harrisii*, *Klukisporites variegatus* and *Osmundacidites wellmanii*. In the current study, *Klukisporites variegatus* was identified as the most abundant palynomorph, representing a significant proportion of miospores identified. Additionally, other miospores previously found in China were detected in the current study for the study area. Sun et al. (2010) conducted a study on the strata and floras of the Junggar Basin in Xinjiang, north-west China, of Late Triassic to Middle Jurassic age. The Late Triassic to early Middle Jurassic floras from the basin were found to consist of four floristic assemblages. The Neocalamites–Marattiopsis assemblage (Ass. III, Early Jurassic) and the Coniopteris–Raphaelia assemblage (Ass. IV, Middle Jurassic) are part of the early Middle Jurassic "Siberian flora" (continental floristic province). Certain species that were identified in Sun et al.'s (2010) study were also identified in the present study. In a study conducted by Zhang et al. (2021), the palynoflora and palaeoclimate of the late Early Jurassic in eastern Liaoning, China, were investigated. The palynoflora in the upper part of the Changliangzi Formation were found to be dominated by pteridophyte spores (64.01 per cent, on average) and gymnosperm pollen grains (34.99 per cent, on average), while bryophyte spores made up less than 1 per cent of the total palynoflora. The dominant component of this palynoflora alternates between pteridophyte spores and gymnosperm pollen, indicating a varied environment during the late Early Jurassic in eastern Liaoning, China. The present study conducted in Iran and that by Zhang et al. (2021) in eastern Liaoning, China, indicate a significant and similar dominance of pteridophyte spores. This suggests a parallel pattern of prevalence for this group in both regions.

The research conducted by Stukins et al. (2013) focused on the Middle Jurassic period (Lajas Formation) in the Neuquén Basin of Argentina. Based on the presence of commonly occurring taxa such as *Deltoidospora*, *Araucariacites australis* and *Callialasporites* spp., their study could only establish a partial correlation with the palynoflora of the Hojedk Formation. The palynoflora observed in the northern region of Argentina was the focus of research by Volkheimer et al. (2008). Their study identified the presence of certain miospores from the Triassic–Middle Jurassic, including *Araucariacites*, *Callialasporites* and *Dictyophyllidites*, which were also identified in the present study.

In an effort to reconstruct vegetation and evaluate potential dinosaur-plant interactions, Slater et al. (2018) carried out a study on spores and pollen from the Middle Jurassic Ravenscar Group in northern Yorkshire, England. In that study, several taxa in common were identified, including *Deltoidospora* spp., *Dictyophyllidites harrisii*, *Araucariacites australis*, *Cycadopites* spp. and *Callialasporites* spp. In the present study, the miospores identified in a study by Slater et al. (2018) were also found in the Hojedk Formation.

7. Conclusions

The present study discusses the results of a palynological and palaeobotanical analysis of Middle Jurassic strata present on the Tabas Block. Both SEG and PEG models suggest that the Lowland group was the dominant category during the Bajocian in the Tabas Basin. The river, coastal and upland groups identified in both models correspond to the locations where dinoflagellate cysts were found. This indicates that while marine influences were present during this time, the sedimentary strata were laid down mainly in a lowland environment.

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