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Late Triassic and Middle Jurassic Floral Changes in Central and Central-East Iran

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Abstract
Upper Triassic and Middle Jurassic deposits in the central and central east of Iran contain diverse and well-preserved plant macrofossils. The data were collected from 23 localities; four investigated in the present study, 19 in other localities in the Tabas Block, five in the Kerman Basin, and one in Shahreza. Analysis of the composition of plant communities in the Ghadir Member of the Nayband Formation (Upper Triassic) and the Hojedk Formation (Middle Jurassic) indicates significant changes in their floral composition. Based on fossil evidence and statistical analyses, it is evident that genera *Clathropteris* Brongniart and *Thaumatopteris* Goeppert (Family Dipteridaceae of Filicales) disappeared in the Middle Jurassic deposits, while *Klukia* Raciborski and *Coniopteris* Brongniart of families Schizaeaceae and Dicksoniaceae appeared and became widespread. In addition, the diversity and abundance of the representatives of the Order Bennettitales decreased significantly, such that *Zamites* Brongniart and *Nilssoniopteris* Nathorst were absent by the end of the Middle Jurassic. The Cycadales flourished by genus *Nilssonia* Brongniart and expanded with numerous species in these areas. Among the seed ferns, the Peltaspermales with the genus *Scytophyllum* Bornemann disappeared in the Middle Jurassic, and instead, the Caytoniales and Corystospermales with the genera of *Sagenopteris* Presl and *Pachypteris* appeared. Moreover, in the Middle Jurassic, small-leaved conifers such as *Elatides* Heer emend. Harris and *Cyparissidium* Heer became abundant and spread in the central and central eastern Iran.

Keywords: Late Triassic; Middle Jurassic; Fossil Floral Changes; Central-Central East Iran.

Introduction

This research compiled the available data on plant macrofossils as well as recently collected samples from different localities spanning the Late Triassic to Middle Jurassic interval. All plant-bearing deposits throughout central and central-east Iran occur in the upper part of Howze-e-Khan Member of the Nayband Formation (Rhaetian) and the Hojedk Formation (Aalenian-early Bathonian). These plant macrofossil assemblages have been studied by several authors (e.g. Jalalifard, 2011; Vaez-Javadi, 2014, 2015, 2018, 2025; Vaez-Javadi & Namjoo, 2016; Mehdizadeh et al., 2018, 2020; Badihagh et al., 2019; Vaez-Javadi & Abbaszadeh, 2022). The present study aims to use floristic data to evaluate the extent of changes in plant macrofossil assemblages from the Late Triassic to the Middle Jurassic throughout central and central-east Iran.

The Iranian microplate was a continental block that collided with Eurasia during the Late Triassic (Alavi et al., 1997; Zanchi et al., 2009a, 2009b, 2015; Zanchetta et al., 2013; Berra et al., 2017) as a part of the Cimmerian continental collage (Sengör, 1979, 1990). Takin (1972) referred to this microplate as the Central East Iranian Microcontinent (CEIM), which consists of three blocks: Yazd (western), Tabas (central), and Lut (eastern) blocks. Following the Cimmerian orogenic events, faulting to the north and south of this area created a new basin between the faults

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(Shahabpour, 1998; Berberian & King, 1981) in which thick Jurassic successions were deposited. These units are well exposed particularly within the Tabas Block (Vaez-Javadi, 2020).

The Nayband Formation is the oldest stratigraphic unit of the Shemshak Group in Central Iran. Ghavidel-Syooki et al. (2014) summarized the literature concerning this formation as follows. The Nayband Formation was introduced by Douglas (1929) in Nayband area and divided into three series, Houz-e-Sheikh (lower), Nayband (middle) and Howz-e-Khan (upper). Later, Stöcklin (1961) revised these series and demonstrated that Howz-e-Sheikh succession is younger than Nayband. The Type section of the Nayband Formation was introduced by Brönnimann et al. (1971) and approved by National Iranian Stratigraphic Committee (NIRSC) in 1976 (Nabavi, 1977). The type section of Nayband Formation consists of four members, arranged in ascending stratigraphic order: a) Gelkan Member (late Carnian-early Norian), b) Bidestan Member (middle Norian), c) Howz-e-Sheikh Member (late Norian), and d) Howz-e-Khan Member (late Norian-early Rhaetian). These four members of the Nayband Formation do not exhibit uniform lithology or thickness and their characteristics change from one locality to another. Consequently, Kluyver et al. (1983) added three new informal members to the formation. However, geologists of the Steel National Company (SNC) combined these three informal members into the Ghadir Member. Therefore, the Nayband Formation consists of five members (Gelkan, Bidestan, Howz-e-Sheikh, Howz-e-Khan and Ghadir) ranging in age from the middle-late Rhaetian (Aghanabati, 2009).

Aghanabati (1975) assigned all sandstone and shale deposits occurring between the Nayband Formation (Upper Triassic) and the oolitic limestone of the Badamu Formation (Toarcian–Bajocian) to the Ab-e-Haji Formation, which represents the second formation of the Shemshak Group in Central Iran. The Ab-e-Haji Formation was informally divided into two members: the Basal Quartzitic Sandstone Member, characterized by thin-bedded conglomerates in its lower part, and the Upper Shale Member, which contains irregular lenses of bauxite and iron pyrite. Because well-preserved fossil evidence is lacking, the age of the formation has been determined mainly based on its stratigraphic position. Accordingly, the Ab-e-Haji Formation has been assigned to the Early Jurassic (Liassic). Its type section is located southwest of Tabas City at 56°05′ E longitude and 33°19′ N latitude.

Deposition of a thick sequence of terrigenous sediments continued until the Bajocian-Bathonian interval (Berberian & King 1981) during the Middle Cimmerian event. Tipper (1921) referred this succession as the “Jurassic Plant-Bearing Series” in the Kerman Basin, which consists of sandstone and shale deposits containing coal seams. Beckett (1956) later named these deposits the “Coal-Bearing Series”. However, Middle Jurassic plant bearing succession in the central Iran subsequently named the Hojedk Formation by the National Stratigraphic Committee of Iran (1964 in Aghanabati, 1998). This formation consists mainly of siltstone, shale with several coal horizons, and sandstone.

Geological setting and locations

The plant macrofossil sites sampled and studied in the present research include two localities in the Parvadeh coal mine area (Upper Triassic) and two localities in the Chahrekhneh and Cani Carbon coalmine areas (Middle Jurassic) (Fig. 1). The geographic locations of studied localities are as follows:

Parvadeh mine area (Nayband Formation), southwest Tabas: two localities at 33° 2′ N latitude and 56° 55′- 56° 58′ E longitude.

Chahrekhneh area (Hojedk Formation), southwest of Tabas: 33° 17′ 56″ N latitude and 56° 24′ 56″ E longitude.

Cani Carbon open-pit mine (Hojedk Formation), southwest of Tabas: 33° 22′ 30″ N latitude and 56° 10′ 30″ E longitude.

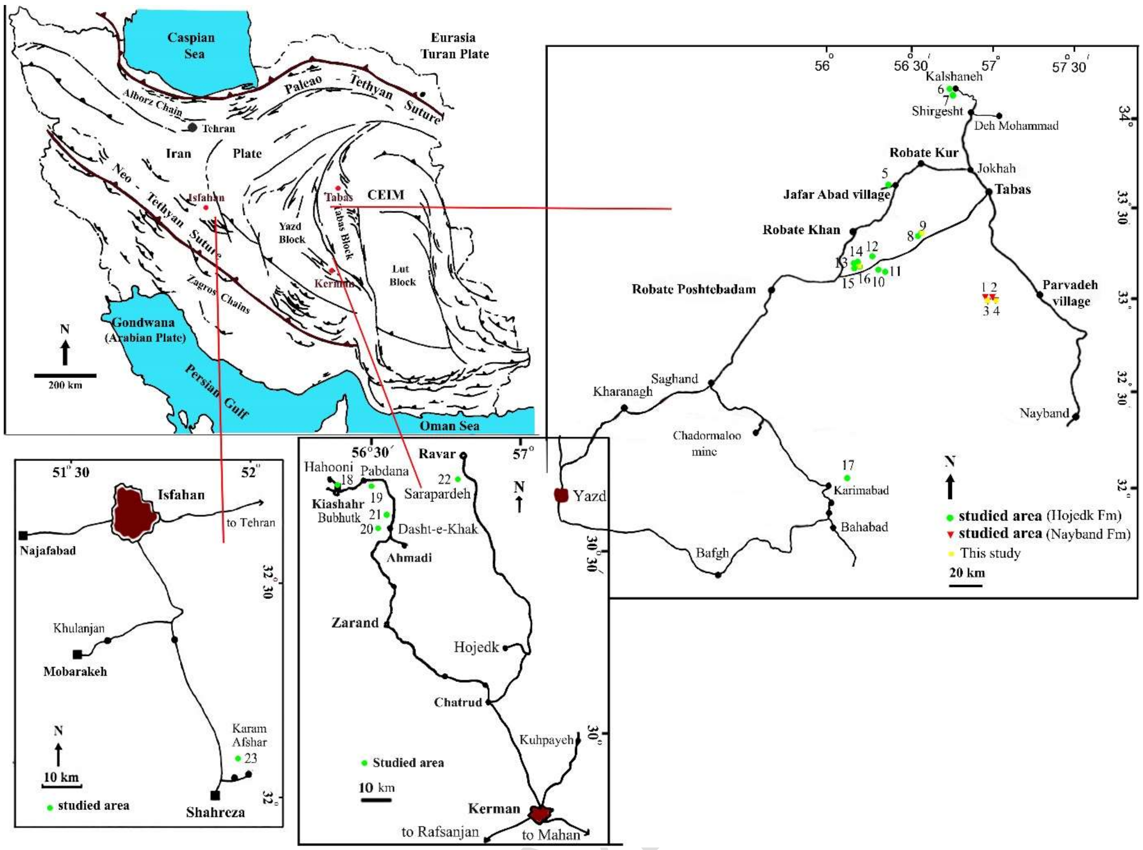

Figure 1. Sketch map of Iran showing the locations of the studied boreholes and outcrops mentioned in this paper (simplified tectonic map of Iran showing the main structures; CEIM= Central East Iranian Microcontinent; modified from Alavi et al., 1997; Vaez-Javadi & Mirzaie-Ataabadi, 2006, 2019; (1-4) Parvadeh mine areas, Upper Triassic Nayband Formation (Jalalifard, 2011; Vaez-Javadi, 2014; Ghavidel-Syooki et al., 2014, and this study); Middle Jurassic Hojedk Formation: (5) Jafar Abad (Vaez-Javadi, 2014); (6, 7) Kalshaneh (Vaez-Javadi, 2015; Mehdizadeh, 2019); (8, 9) Chahrekhneh (Mehdizadeh et al., 2020, and this study); (10, 11) South Kouchekali (Badihagh et al., 2019; Vaez-Javadi, 2018); (12) North Kouchekali (Vaez-Javadi & Namjoo, 2016); (13-16) Mazino, Takht-e-Saffar, and Cani Carbon coal mines (Vaez-Javadi, 2014; Vaez-Javadi & Abbaszadeh, 2022; Vaez-Javadi, 2025, and this study); (17) North Bahabad (Mehdizadeh, 2019); (18) Hashooni coal mine (Vaez-Javadi & Mirzaie-Ataabadi, 2006); (19) Pabdana (Vaez-Javadi & Mirzaie-Ataabadi, 2006); (20) Dasht-e-Khak (Vaez-Javadi & Mirzaie-Ataabadi, 2006); (21) Babhutk (Ameri et al., 2014); (22) Sarapardeh (Khalilizadeh et al., 2020), and (23) Karam Afshar section, northeast Shahreza (Vaez-Javadi & Mirzaie-Ataabadi, 2019)

Material and methods

In this study, 125 samples were collected from the Parvadeh coal mine area, and 316 samples from Cani Carbon and Chahrekhneh open-pit coal mines. These samples exhibit wide variation in both preservation quality and state of fossilization. The specimens were prefixed as FJHCc for the Middle Jurassic samples and FJPGh for the Late Triassic samples. The studied material is housed in the school of Geology, Faculty of Science, University of Tehran. The specimens were photographed using a Cannon camera, and the images were enhanced with Photoshop CC 2014. All species were counted and statistical charts were prepared. In addition, data from previous studies were incorporated to provide a more comprehensive understanding of the vegetation during these time intervals. Moreover, 'Floral gradient' average score and Sørensen (1957) similarity quotient were used to improve the accuracy of interpretations regarding vegetation changes.

Ziegler et al. (1996) and Rees et al. (2000) produced two-dimensional plots of localities and taxa, illustrating variance within the datasets along two principal axes. The locality plots indicated that Axis 1 was generally correlated with paleolatitude, whereas the taxa plots showed that Axis 2 was associated with a distinct transformation in foliar physiognomy, ranging from coniferophytes and cycadophytes with small leaves and thick cuticles at lower latitudes to broad-leaved deciduous ginkgophytes at higher latitudes. Collectively, these patterns were interpreted to reflect warm and dry climatic conditions centered around 35° N latitude, whereas cool temperate conditions extended to approximately 80° N latitude, with the highest floral diversity occurring within the warm temperate zone.

The score assigned to each taxon represented its "centroid" within the Eurasian latitudinal spectrum, ranging from approximately 30° N to 80° N. Thus, *Zamites* was associated with localities assigned to the dry subtropical biome, whereas *Raphelia* was characteristic of cool temperate conditions. These studies established a "floral spectrum through time" for the Mesozoic.

To obtain a more accurate comparison, Sørensen's similarity index was used to evaluate the similarity between plant macrofossil assemblages. Using the formula $Qs = 2C / (A + B)$, the similarity index (SI) was calculated for Late Triassic plant macrofossil assemblages (A) and Middle Jurassic plant macrofossil assemblages (B). In this equation, C represents the number of taxa (species or genera) common to both assemblages.

Results

The studied areas in the Tabas Block contain various species of plant macrofossils attributable to the Late Rhaetian and the Middle Jurassic. For the purpose of comparing floral assemblages, the plant macrofossils were classified into two major categories: (1) Late Triassic and (2) Middle Jurassic (Tab. 1). In total, 21 species belonging to 14 genera were identified and photographed from two tunnels in the Parvadeh coal mine area (Figs. 2–6). In addition, 19 species belonging to 13 genera were identified and photographed from the Middle Jurassic floral assemblages of the Cani Carbon and Chahrekhneh open-pit coal mines (Figs. 7–10).

Table 1. Late Triassic and Middle Jurassic plant macrofossil assemblages from the Tabas Block, central-east Iran

Assemblage 1- Late Triassic Flora
Equisetites arenaceus (Jaeger 1827) Schenk 1864, *E. muensteri* Sternberg 1833, *Neocalamites* sp., *Clathropteris* sp., *Todites crenatum* Barnard 1965, *Thaumatopteris* sp., *Phlebopteris muensteri* (Schenk 1867) Hirmer & Hoerhammer 1936, *Lobifolia rotundifolia* Corsin & Stampfli 1977, *Scytophyllum persicum* (Schenk 1887) Kilpper 1975, *Nilssoniopteris schenkiana* Barnard 1965, *Pterophyllum aequale* (Brongniart 1824) Nathorst 1878, *P. bavieri* Zeiller 1903, *P. contiguum* Schenk 1883, *P. schenki* (Zeiller 1886) Zeiller 1903, *P. tietzei* Schenk 1887, *Nilssonia brevis* Brongniart 1825, *Nilssonia* sp. cf. *N. orientalis* Heer 1878, *N. pseudobrevis* (Barnard 1967) Corsin & Stampfli 1977, *Androstrobus* sp., *Sphenobaiera* sp. cf. *S. grandis* Kilpper 1971, and *Carpolithes* sp.
Assemblage 2- Middle Jurassic Flora
Equisetites beanii (Bunbury 1851) Seward 1833, *Equisetites* sp. cf. *E. columnaris* (Brongniart 1828) Phillips 1875, *Coniopteris hymenophylloides* (Brongniart 1828) Seward 1900 emend. Harris 1961, *Dictyophyllum nilssonii* (Brongniart 1836) Goeppert 1846, *Ferizianopteris undulata* Fakhr 1977, *Klukia crenata* Vaez-Javadi 2006, *Klukia exilis* (Phillips 1829) Raciborski 1890, *Lobifolia rotundifolia* Corsin & Stampfli 1977, *Todites crenatum* Barnard 1965, *Sagenopteris nilssoniana* (Brongniart 1824) Ward 1900, *Otozamites graphicus* (Leckenby 1864) Phillips 1875, *Ptilophyllum harrisianum* Kilpper 1968, *Nilssonia ingens* Schweitzer et al. 2000, *N. macrophylla* Jacob & Shukla 1955, *N. orientalis* Heer 1878, *Nilssonia* sp. cf. *N. tazarensis* (Sadovnikov 1991) Schweitzer et al. 2000, *Nilssonia* sp. cf. *N. undulata* Harris 1932, *Elatides thomasii* Harris 1979, and *Podozamites distans* (Presl 1838) Braun 1843.

Figure 2. Representatives of Late Triassic taxa from the Ghadir Member. (1) *Phlebopteris muensteri* (Schenk) Hirmer & Hoerhammer, FJPGh-5; (2) *Equisetites muensteri* Sternberg, FJPGh-1; (3) *Lobifolia rotundifolia* Corsin & Stampfli, FJPGh-4; (4) Diaphragm of an *Equisetites* sp., FJPGh-2. Scale bars = 1cm

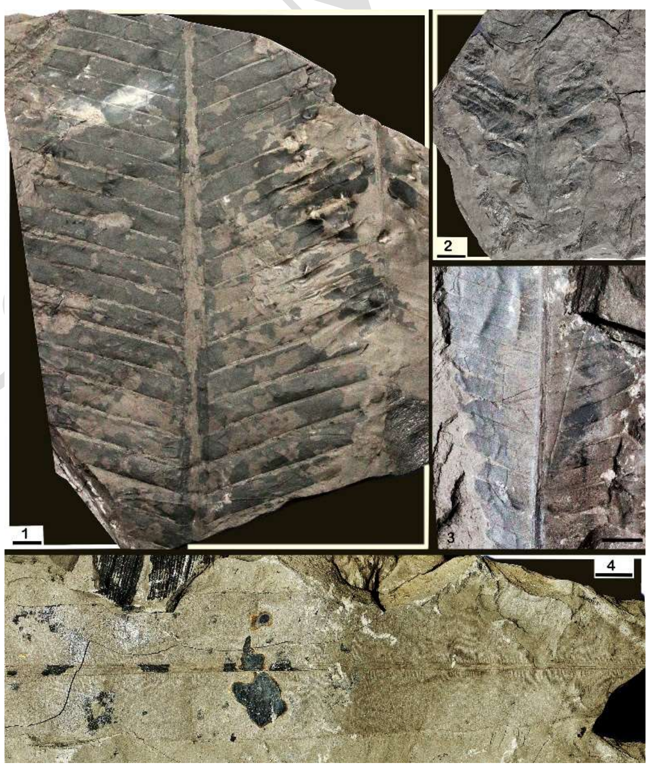

Figure 3. Representatives of Late Triassic taxa from the Ghadir Member. (1) *Pterophyllum aequale* (Brongniart) Nathorst, FJPGh-10; (2) *Scytophyllum persicum* (Schenk) Kilpper, FJPGh-6; (3) *Pterophyllum contiguum* Schenk, FJPGh-11; (4) *Nilssoniopteris schenkiana* Barnard, FJPGh-7. Scale bars = 1cm.

Figure 4. Representatives of Late Triassic taxa from the Ghadir Member. (1) *Nilssoniopteris schenkiana* Barnard, FJPGh-8; (2) *Pterophyllum schenki* (Zeiller) Zeiller, FJPGh-12; (3) cf. *Androstrobus* sp., FJPGh-13; (4) *Nilssonia* sp. cf. *N. orientalis* Heer, FJPGh-14. Scale bars = 1cm

Figure 5. Representatives of Late Triassic taxa from the Ghadir Member. (1, 2) *Nilssonia pseudobrevis* (Barnard) Corsin & Stampfli, FJPGh-18; (3) *Nilssoniopteris schenkiana* Barnard, FJPGh-9; (4) *Carpolithes* sp., FJPGh-15; Scale bars = 1cm

Figure 6. Representatives of Late Triassic taxa from the Ghadir Member. (1, 3) *Pterophyllum tietzei* Schenk, FJPGh-16; (2) *Nilssonia brevis* Brongniart, FJPGh-17; (4) cf. *Thaumatopteris* sp., FJPGh-3. Scale bars = 1cm

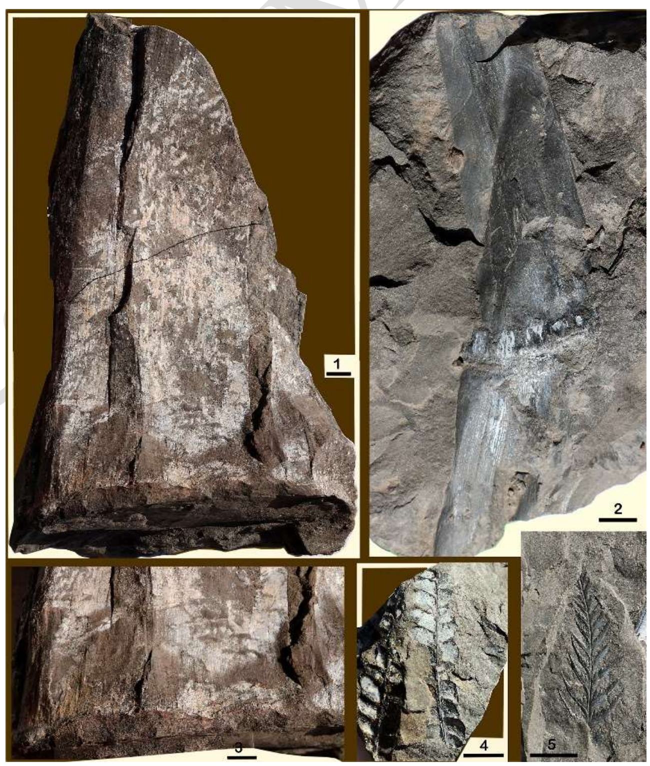

Figure 7. Representatives of Middle Jurassic taxa from the Hojedk Formation. (1, 3) *Equisetites beanii*, FJHCc-1; (2) *Equisetites* sp., FJHCc-2; (4) *Coniopteris hymenophylloides* (Brongniart) Seward emend. Harris, FJHCc-7; (5) *Klukia crenata* Vaez-Javadi, FJHCc-10. Scale bars = 1 cm

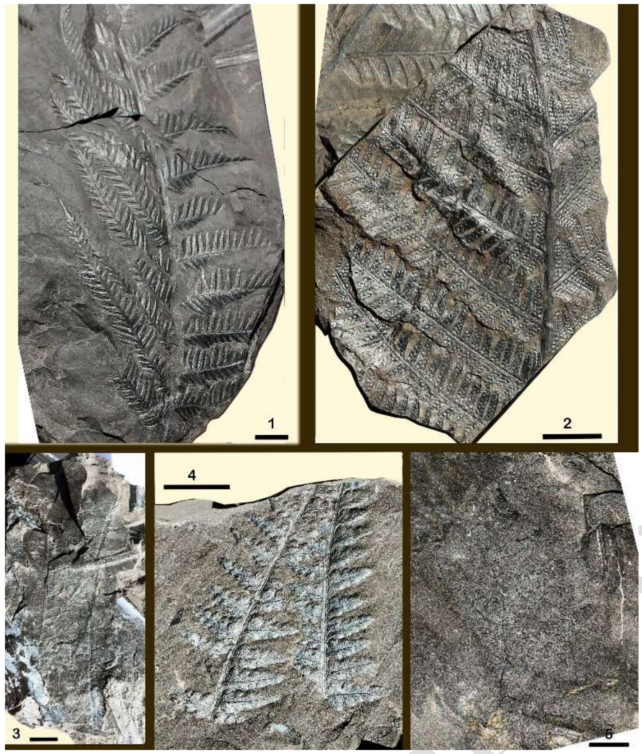

Figure 8. Representatives of Middle Jurassic taxa from the Hojedk Formation. (1) *Klukia crenata* Vaez-Javadi, FJHCc-11; (2) *Klukia exilis* (Phillips) Raciborski, FJHCc-12; (3) *Dictyophyllum* sp., FJHCc-9; (4) *Todites crenatum* Barnard, FJHCc-21; (5) *Dictyophyllum nilssonii* (Brongniart) Goeppert, FJHCc-8. Scale bars = 1 cm

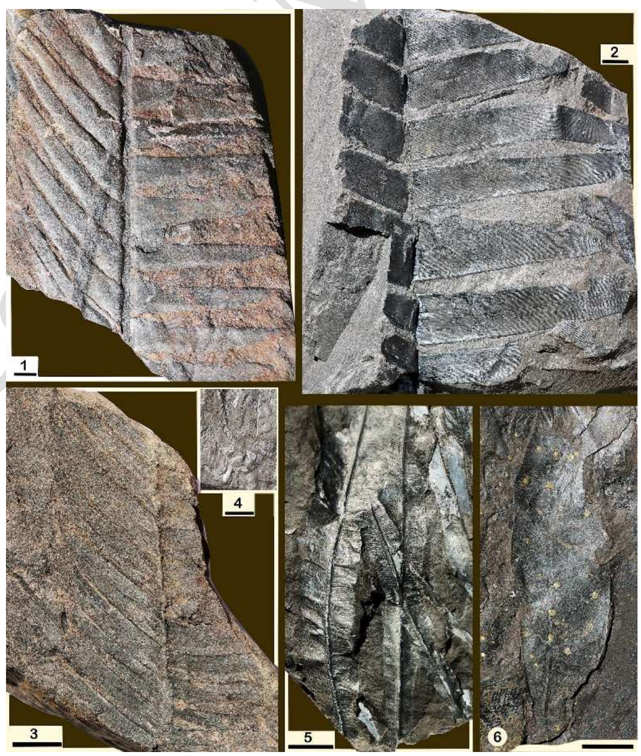

Figure 9. Representatives of Middle Jurassic taxa from the Hojedk Formation. (1) *Ptilophyllum harrisianum* Kilpper, FJHCc-42; (2) *Nilssonia macrophylla* Jacob & Shukla, FJHCc-34; (3) *Nilssonia* sp. cf. *N. tazarensis* FJHCc-35; (4) *Ferizianopteris undulata* Fakhr, FJHCc-16; (5) *Nilssonia* sp. cf. *N. undulata* Harris, FJHCc-40; (6) *Sagenopteris nilssoniana* (Brongniart) Ward, FJHCc-24. Scale bars = 1cm

Figure 10. Representatives of Middle Jurassic taxa from the Hojedk Formation. (1) *Nilssonia orientalis* Heer, FJHCc-38; (2) *Otozamites graphicus* (Leckenby) Phillips, FJHCc-28; (3) *Podozamites distans* (Presl) Braun, FJHCc-48; (4) *Nilssonia ingens* Schweitzer et al., FJHCc-31. Scale bars = 1cm.

Based on these data, representatives of *Clathropteris* Brongniart and *Thaumatopteris* Goeppert (fern Family Dipteridaceae), *Scytophyllum* Bornemann (seed ferns, Order Peltaspermales), *Nilssoniopteris* Nathorst, and *Zamites* Brongniart (Order Bennettitales, cycadophytes) are absent from the Middle Jurassic floral assemblages of the Tabas Block. Following the disappearance of these taxa, *Coniopteris* Brongniart (Family Dicksoniaceae), *Klukia* Raciborski (Family Schizaeaceae, Order Filicales), *Sagenopteris* Presl (seed ferns, Order Caytoniales), and *Elatides* Heer emend. Harris (conifers, Order Cupressales) appeared and became widely distributed throughout the Tabas Block.

Relative abundance of Macrofossil taxa

Evaluation of statistical data on the presence and actual counts of different plant taxa allows an overview of changes in vegetation composition across one or more regions. Despite the limited statistical data available for Late Triassic plant macrofossils in central and eastern Iran, some data exist from the Parvadeh mine area (Tab. 2; Fig. 11). In contrast, the statistical data for Middle Jurassic plant macrofossils from the Hojedk Formation are considerably more extensive, allowing a more reliable evaluation and comparison of floral composition (Tab. 3; Fig. 12). Comparison of these datasets indicates that representatives of Cycadales and Coniferales increased in abundance, whereas representatives of Bennettitales declined or disappeared during this time interval.

Discussion

Comparison with other regions

Several authors have studied late Triassic plant macrofossil remains from central and central-east Iran. Vassiliev (1984) reported and illustrated 31 species belonging to 17 genera from the Parvadeh area, southwest of Tabas. Jalalifard (2011) reported and described 25 species belonging to 12 genera from the Parvadeh mine area, located between 32° 50′–33° 05′ N latitude and 56° 45′–57° 15′ E longitude. Ghavidel-Syooki et al. (2014) reported 12 species belonging to eight genera from the Parvadeh area.

Table 2. Relative abundance of Late Triassic plant macrofossil orders in the Parvadeh mine areas

	Order	R. A.%	Localities	Author (s)
Late Triassic	Bennettitales	28.7	Parvadeh mines area	Vaez-Javadi (2014)
	Cycadales	14.85		
	Coniferales	1.98		
	Bennettitales	32.8		This study
	Cycadales	19.2		
	Coniferales	2.4		

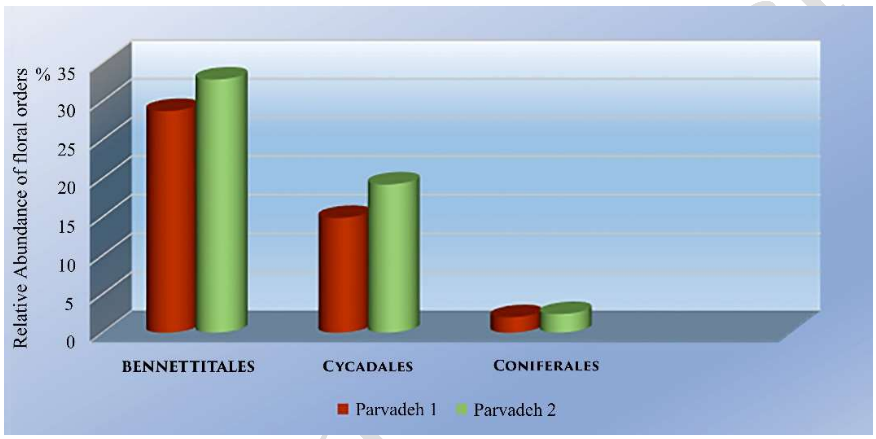

Figure 11. Relative abundance of different plant orders in the Late Triassic macrofossil assemblages from the Parvadeh area, southwest of Tabas. Parvadeh 1 (Vaez-Javadi, 2014); Parvadeh 2 (this study)

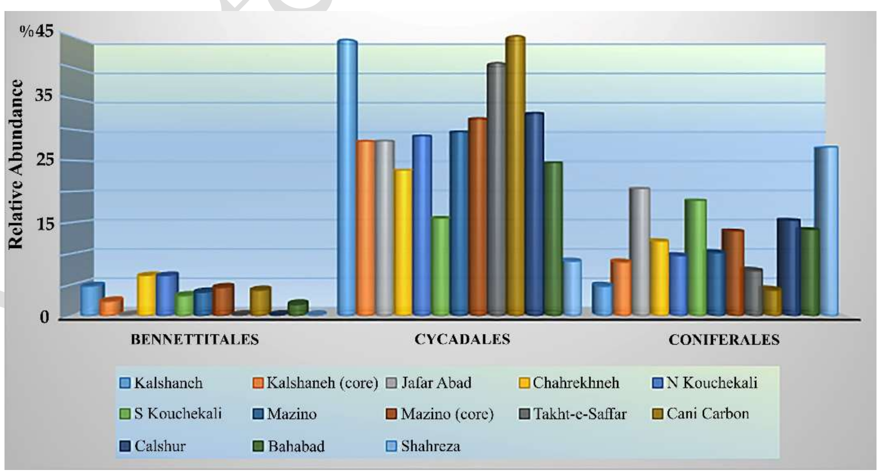

Figure 12. Relative abundance of three plant orders—Bennettitales, Cycadales, and Coniferales—across central and east-central Iran during the Middle Jurassic. Data is based on: Kalshaneh outcrop (Vaez-Javadi, 2015); Kalshaneh and Bahabad cores (Mehdizadeh, 2019); Jafar Abad and Mazino open-pit coal mine (Vaez-Javadi, 2014); North Kouchekali and South Kouchekali (Vaez-Javadi & Namjoo, 2016; Vaez-Javadi, 2018); Mazino core (Vaez-Javadi & Abbaszadeh, 2022); Takht-e-Saffar open-pit coal mine (Vaez-Javadi, 2025); Cani Carbon open-pit coal mine (this study); Calshour (Mehdizadeh et al., 2018); Shahreza (Vaez-Javadi & Mirzaie-Ataabadi, 2019)

Table 3. Relative abundance of Middle Jurassic plant macrofossil orders in various localities of central and central-east Iran

	Order	**R. A. %**	**Localities**	**Author (s)**
Middle Jurassic	Bennettitales	3.80	Mazino open mine	Vaez-Javadi (2014)
	Cycadales	5.30	Kouchekali	
	Coniferales	0	Jafar Abad	
	Bennettitales	29.69	Mazino open mine	
	Cycadales	23.18	Kouchekali	
	Coniferales	28.20	Jafar Abad	
	Bennettitales	10.16	Mazino open mine	
	Cycadales	9.27	Kouchekali	
	Coniferales	20.51	Jafar Abad	
	Bennettitales	0	Calshur	Mehdizadeh et al. (2019)
	Cycadales	32.69	Calshur	
	Coniferales	15.38	Calshur	
	Bennettitales	2.23	Chahrekhneh	Mehdizadeh et al. (2020)
	Cycadales	23.50	Chahrekhneh	
	Coniferales	12	Chahrekhneh	
	Bennettitales	6.45	North Kouchekali	Vaez-Javadi & Namjoo (2015)
	Cycadales	29.03	North Kouchekali	
	Coniferales	9.67	North Kouchekali	
	Bennettitales	3.2	South Kouchekali	Vaez-Javadi (2018)
	Cycadales	15.7	South Kouchekali	
	Coniferales	18.59	South Kouchekali	
	Bennettitales	1.81	Bahabad	Mehidizadeh (2019)
	Cycadales	24.7	Bahabad	
	Coniferales	13.86	Bahabad	
	Bennettitales	2.30	Kalshaneh (core)	Medizadeh (2019)
	Cycadales	28.16	Kalshaneh (core)	
	Coniferales	8.62	Kalshaneh (core)	
	Bennettitales	4.76	Kalshaneh (outcrop)	Vaez-Javadi (2015)
	Cycadales	44.44	Kalshaneh (outcrop)	
	Coniferales	4.76	Kalshaneh (outcrop)	
	Bennettitales	4.54	Mazino (core)	Vaez-Javadi & Abbaszadeh (2022)
	Cycadales	31.82	Mazino (core)	
	Coniferales	13.63	Mazino (core)	
	Bennettitales	0	Takht-e-Saffar	Vaez-Javadi (2025)
	Cycadales	40.68	Takht-e-Saffar	
	Coniferales	7.25	Takht-e-Saffar	
	Bennettitales	0	Shahreza	Vaez-Javadi & Mirzaie-Ataabadi (2019)
	Cycadales	8.77	Shahreza	
	Coniferales	27.19	Shahreza	
	Bennettitales	4.11	Cani Carbon	This study
	Cycadales	45	Cani Carbon	
	Coniferales	4.11	Cani Carbon	

Vaez-Javadi (2014) described and illustrated 31 species belonging to 19 genera from the Parvadeh coal mine, located at 33° N latitude and 56° 58′ E longitude. Schweitzer & Kirchner (1996, 1998, 2003), together with Schweitzer et al. (1997, 2000, 2009), described and illustrated 19 species belonging to 13 genera from the Darbidkhun area of the Kerman Basin. Mannani et al. (2021) reported only three species— *Clathropteris meniscoides* (Brongniart) Brongniart, *Clathropteris obovata* Ôishi, *Nilssonia pseudobrevis* (Barnard) Corsin & Stampfli— from an area northeast of Isfahan, located at 34° 04′ 10″ N latitude and 52° 01′ 40″ E longitude. Therefore, the Late Triassic plant macrofossil assemblages of east-central Iran comprise 70 species assigned to 37 genera (Tab. 4).

Table 4. Complete plant macrofossil assemblages of the Late Triassic and Middle Jurassic in central and central-east Iran.

Assemblage 1- Late Triassic Flora
Equisetites arenaceus (Jaeger 1827) Schenk 1864, *Equisetites* sp. cf. *E. columnaris* (Brongniart 1828) Phillips 1875, *Equisetites* sp. cf. *E. conicus* Sternberg 1833, *E. muensteri* Sternberg 1833, *Equisetites* sp. cf. *E. laevis* Halle 1098, *Neocalamites* sp. cf. *N. hoerensis* (Schimper 1869) Halle 1908, *Neocalamites* sp. cf. *N. lehmannianus* (Goeppert 1846) Weber 1968, *Neocalamites* sp. cf. *N. meriani* (Brongniart 1828) Halle 1908 (Sphenophyta), *Marattia intermedia* (Muenster 1836) Kilpper 1964, *Phlebopteris affinis* (Schenk) Seward 1900, *P. polypodioides* Brongniart 1828, *P. muensteri* (Schenk 1867) Hirmer & Hoerhammer 1936, *Taeniopteris tenuinesrvis* Brauns 1862, *T. reversa* Prynada 1934, *Macrotaeniopteris virgulata* Schimper 1869, *M. lata* Morris & Oldham 1878, *Clathropteris meniscoides* (Brongniart 1825) Brongniart 1828, *Dictyophyllum exile* (Brauns 1862) Nathorst 1878, *Gleichenites aphlebioides* Schweitzer et al. 2009, *Thaumatopteris fuchsia* Ôishi 1936, *Todites crenatum* Barnard 1965, *T. princeps* (Presl 1838) Gothan 1914, *Lobifolia* sp. cf. *L. iranica* Fakhr 1977, *L. rotundifolia* Corsin & Stampfli 1977, *Cladophlebis nebbensis* (Brongniart 1828) Nathorst 1876, *C. sahabii* Fakhr 1977, *Thainguyenopteris parvipinnulata* Srebrodol'Sakaya 1969 emend. Sadovnikov 1987 (Filicophyta), *Scytophyllum persicum*, *Scoresbya dentata* Harris 1932, *Anthrophyopsis crassinervis* Nathorst 1878 (Pteridospermophyta), *Angiopteridium auriculatum* Fontaine 1889, *Ptilozamites nilssonii* Nathorst 1878, *Nilssoniopteris musafolia* Barnard 1965, *N. schenkiana* Barnard 1965, *Pterophyllum aequale* (Brongniart 1824) Nathorst 1878, *P. angustilobum* Prynada 1934, *P. bavieri* Zeiller 1903, *P. contiguum* Schenk 1883, *P. nathorsti* Schenk 1883 emend. Barnard 1967, *P. propinquum* Goeppert emend. Antevs 1919, *P. schenki* (Zeiller 1886) Zeiller 1903, *P. tabassicum* Vassiliev 1984, *P. tietzei* Schenk 1887, *Pterotaenium fazlii* Vassiliev 1984, *Dictyozamites asseretoi* Barnard 1965, *Otozamites ashtarensis* Barnard 1967, *O. imparipinnatus* Vassiliev 1984, *Cycadolepis harrisii* Vassiliev 1984, *Nilssonia acuminata* (Presl 1838) Goeppert 1844, *N. brevis* Brongniart 1825, *Nilssonia* sp. cf. *polymorpha* Schenk 1867, *N. orientalis* Heer 1878, *N. pseudobrevis* (Barnard 1967) Corsin & Stampfli 1977, *N. undulata* Harris 1932, *Androstrobus* sp., cf. *Weltrichia primaeva* Schweitzer & Kirchner 2003, *Williamsonia iranica* Vaez-Javadi 2014 (Cycadophyta), *Baiera muensteriana* (Presl 1833) Heer 1876, *Ginkgoites persica* Vaez-Javadi 2014, *Sphenobaiera* sp. cf. *S. grandis* Kilpper 1971, *S. longifolia* (Pomel 1849) Florin 1936, *Carpolithes cinctus* Nathorst 1878 (Ginkgophyta), *Brachyphyllum* sp., *Schizolepis* sp. cf. *S. follinii* Nathorst 1876, *Pagiophyllum peregrium* (Lindley & Hutton 1833) Zittel 1890, *Podozamites angustifolius* (Eichwald 1865) Schimper 1870, *P. lanceolatus* (Lindley & Hutton 1836) Braun 1843, *P. distans* (Presl 1838) Braun 1843, *P. latissimus* Stanislavski 1971, *P. schenki* Heer 1876 and *Sciadisca parvasensis* Vassiliev 1984 (Coniferophyta).
Assemblage 2- Middle Jurassic Flora
Ricciopsis scania Lundblad 1954 (Bryophyta); *Selaginellites falcatus* (Lindley & Hutton 1836) Schweitzer, van Konijnenburg-van Cittert & van der Burg 1997 (Lycophyta); *Annulariopsis simpsonii* (Phillips 1875) Harris 1947, *Equisetites beanii* (Bunbury 1851) Seward 1833, *E. columnaris* (Brongniart 1828) Phillips 1875, *E. lateralis* (Phillips 1829) Phillips 1875, *Neocalamites* sp. cf. *N. ishpushtensis* Jacob & Shukla 1955, *Phyllotheca equisetitoides* Schmalhausen 1828 (Sphenophyta); *Marattiopsis intermedia* (Muenster 1836) Kilpper 1964, *M. muensteri* (Goeppert 1842) Schimper 1874, *Todites crenatum* Barnard 1965, *T. princeps* (Presl 1838) Gothan 1914, *T. fakhri* Vaez-Javadi 2014, *T. williamsonii* (Brongniart 1828) Seward 1900, *Coniopteris concinna* (Heer 1876) Chen et al. 1990, *C. hymenophylloides*, *C. nerifolia* Genkina 1963, *Dicksonia mariopteris* Wilson & Yates 1953, *Ferzianopteris undulata* Fakhr 1977, *Eboracia lobifolia* (Phillips 1829) Thomas 1911, *Lobifolia iranica* Fakhr 1977, *L. rotundifolia* Corsin & Stampfli 1977, *Dictyophyllum nervulosum* (Sternberg 1825) Kilpper 1964 , *D. nilssonii*, *Dictyophyllum* sp. cf. *D. rugosum* Lindley & Hutton 1834, *Phlebopteris angustiloba* (Presl 1838) Hirmer & Horhammer 1936, *Phlebopteris* sp. cf. *P. formosa* (Givulescu & Popa 1998) Schweitzer et al., 2009, *P. muensteri* (Schenk 1867) Hirmer & Hoerhammer 1936, *Klukia exilis* (Phillips 1829) Raciborski 1890, *K. crenata* Vaez-Javadi 2014, *K. westii* Jacob & Shukla 1955, *Rhizomopteris rezaii* Vaez-Javadi 2014, *Cladophlebis aktashensis* Turutanova–Ketova 1930, *C. australis* (Morris 1845) Seward 1904, *C. denticulata*

(Brongniart 1828) Nathorst 1876, *C. feriziensis* Fakhr 1975, *C. whitbyensis* (Brongniart 1828) Brongniart 1849, *Taeniopteris intermedia* Muenster 1836, *Spiropteris* sp. (Filicophyta); *Pachypteris lanceolatus* Brongniart 1828, *Sagenopteris colpodes* Harris 1940, *S. nilssoniana* (Brongniart 1824) Ward 1900, *S. phillipsii* (Brongniart 1824) Presl 1838, *Anomozamites lindleyanus* Schimper 1871, *Otozamites graphicus* (Leckenby 1864) Phillips 1875, *O. harrisianus* (Kilpper 1971) Schweitzer & Kirchner 2000, *Pterophyllum feriziense* Fakhr 1977, *Ptilophyllum harrisianum* Kilpper 1968, *P. pectinoides* Sternberg, 1823, *Ctenis* sp. cf. *C. kaneharai* Yokoyama 1906, *C. sulcicaulis* (Phillips 1829) Ward 1905, *Nilssonia bargi-bidi* Barnard & Miller 1976, *N. bozorga* Barnard & Miller 1976, *N. feriziensis* Fakhr 1977, *N. herriesi* (Harris 1946) Schweitzer et al. 2000, *N. ingens* Schweitzer et al. 2000, *N. kaiseri* Schweitzer et al. 2000, *N. macrophylla* Jacob & Shukla 1955, *N. orientalis* Heer 1878, *N. pterophylloides* Nathorst 1879, *N. sarakhs* Barnard & Miller 1976, *N. schaumburgensis* (Dunker) Nathorst 1880, *N. tazarensis* (Sadovnikov 1991) Schweitzer et al. 2000, *N. tenuicaulis* (Phillips 1829) Fox–Strangways 1829 , *N. tenuinesrvis* Nathorst 1880, *N. undulata* Harris 1932, *Beania mamayi* Thomas & Harris 1960, *Pseudoctenis lanei* Thomas 1913, *P. webwri* (Seward 1907) Prynada in Delle, 1967, *Weltrichia* sp., *Williamsonia asseretoi* Barnard 1965 (Cycadophyta); *Baiera* (*Ginkgoites*) *baieraeformis* (Kilpper 1971) Schweitzer & Kirchner 1995, *B. concinna* (Heer 1876) Kawasaki 1925, *Ginkgo cordilobata* Schweitzer & Kirchner 1995, *Ginkgoites khorassanicus* Fakhr 1977, *G. huttonii* (Sternberg 1833) Heer 1876, *G. parasingularis* Kilpper 1971, *G. lepida* Heer 1876, *G. sibirica* (Heer 1876) Walkom 1924, *G. taeniata* (Braun) Harris, *Sphenobaiera* sp. cf. *S. grandis* Kilpper 1971, *S. longifolia* (Pomel 1849) Florin 1936, *Carpolithes semicostatus* Vassiliev 1984 (Ginkgophyta); *Czekanowskia* sp. cf. *C. rigida* Heer 1876, *Cupressinocladus pseudoexpansum* Barnard & Miller 1976, *Cyparissidium rudlandicum* Harris 1979, *Elatocladus zamioides* (Leckenby 1864) Seward 1919, *Elatocladus* sp. cf. *E. ramosus* (Florin 1958) Harris 1979, *Elatides thomasii* Harris 1979, *Pagiophyllum curvifolium* (Dunker), *P. insigne* Kendall 1948, and *Podozamites distans* (Presl 1838) Braun 1843 (Coniferophyta).

Middle Jurassic deposits throughout central Iran (Shahreza and Isfahan) and east-central Iran (Tabas and Kerman), assigned to the Hojedk Formation, contain well-preserved floras. Several authors have studied these macrofossil assemblages. Vassiliev (1984) reported and illustrated 13 species belonging to 11 genera from Babnizu in the Kerman Basin and Mazino, southwest of Tabas. Vaez-Javadi & Mirzaie-Ataabadi (2006) described and illustrated 36 species belonging to 20 genera from three localities in the Kerman Basin, located between 31° 15′–31° 31′ N latitude and 56° 40′–57° E longitude. Schweitzer & Kirchner (1996, 1998, 2003), together with Schweitzer et al. (1997, 2000, 2009), described and illustrated 28 species belonging to 16 genera from the Hojedk and Eshkeli areas of the Kerman Basin. Vaez-Javadi (2014) described and illustrated 26 species belonging to 18 genera from the Mazino open-pit coal mine, southwest of Tabas, located at 33° 21′ N latitude and 56° 09′ E longitude. Ameri et al. (2014) described and illustrated eight species belonging to seven genera from Babhutk, 120 km north of Kerman, located at 31° 21′ 56″ N latitude and 56° 30′ 41″ E longitude. Vaez-Javadi & Namjoo (2016) reported and illustrated 29 species belonging to 19 genera from North Kouchekali, southwest of Tabas, located at 33° 17′ N latitude and 56°18′ E longitude. Vaez-Javadi (2015) reported and illustrated 16 species belonging to 11 genera from the Kalshaneh section, northwest of Tabas, located at 34° 07′ N latitude and 56°40′ E longitude. Vaez-Javadi (2018) reported and illustrated 29 species belonging to 18 genera from South Kouchekali, Well No. 210, southwest of Tabas, located at 33° 13′ 22″ N latitude and 56°23′06″ E longitude. Mehdizadeh (2019) described and illustrated 16 species belonging to 12 genera from an exploration coal core in northeastern Bahabad, located at 32° 06′ 39″ N latitude and 56° 10′ 41″ E longitude. Mehdizadeh et al. (2018) described and illustrated 15 species belonging to nine genera from the Calshour area, southwest of Tabas, located at 33° 05′ 30″ N latitude and 56° 04′ 15″ E longitude. Badihagh et al. (2019) reported and illustrated 21 species belonging to 17 genera from Exploration Well No. 233 in South Kouchekali, located at 33°15′ 39″ N latitude and 56°22′44″ E longitude. Vaez-Javadi and Mirzaie-Ataabadi (2019) reported and illustrated 21 species belonging to 15 genera from the Karam Afshar section in northeastern Shahreza, southeast of Isfahan City, located at 32°04′50″ N latitude and 51° 58′ 14″ E longitude. Mehdizadeh et al. (2020) described and illustrated 33 species belonging to 21 genera from an exploration well in the Chahrekhneh area, southwest of Tabas, located at 33° 17′ 56″ N latitude and 56° 24′ 56″ E longitude. Khalilizadeh et al. (2020) introduced and illustrated 18 species belonging to 13 genera from the Sarapardeh section, northern Kerman, located at 30° 56′ 48″ N latitude and 56° 42′ 24″ E longitude. Vaez-Javadi and Abbaszadeh (2022) reported and illustrated 25 species belonging to 17 genera from Mazino Well No. 1, southwest of Tabas, located at 33° 17′ 56″ N latitude and 56° 24′ 01″ E longitude. Vaez-Javadi (2025) described and illustrated 29 species belonging to 17 genera from the Takht-e-Saffar open-pit coal mine, southwest of Tabas, located at 33° 22′ N latitude and 56°11′ E longitude. Overall, the Middle Jurassic plant macrofossil assemblages of central and east-central Iran are extremely diverse and comprise 92 species assigned to 44 genera, as summarized in Table 4.

Floral gradient

To compare the two major floral assemblages of the Late Triassic and Middle Jurassic, the “Floral gradient” method of Rees et al. (2000) and the Sørensen similarity index (Sørensen, 1957) were applied.

The average ‘Floral gradient’ scores of the Late Triassic plant macrofossil assemblages in this study and from the other lovalities in the Parvadeh area are 55.2, and 49.7, respectively (Fig. 13). The average ‘Floral gradient’ scores of the Middle Jurassic plant macrofossil assemblages from Takht-e-Saffar, Bahabad, Kalshaneh borehole, Kalshaneh outcrop, Calshour, Chahrekhneh, Jafar Abad, Cani Carbon, Mazino borehole, Mazino open-pit coal mine, South Kouchekali, and North Kouchekali are 57.7, 54.2, 57.7, 58.5, 69, 56.3, 56.7, 54.89, 53.5, 55.5, and 56.2, respectively (Fig. 14). In addition, the average ‘Floral gradient’ score of the Middle Jurassic plant macrofossil assemblages in Sarapardeh, Hashooni coal mine, Dasht-e-e-Khak, Pabdana, Babhutk coal mine, and Shahreza section are 59, 60.25, 62.62, 69.16, 66.4, and 66.3, respectively (Fig. 15). The Kerman Basin shows relatively higher ‘Floral gradient scores’, indicating that the plant macrofossil assemblages correspond to a relatively temperate palaeoenvironment.

The ‘Floral gradient’ value for the entire floral assemblage of Yorkshire (England) is 53.8, which is comparable to the average score of the Tabas area in east-central Iran (Tab. 5).

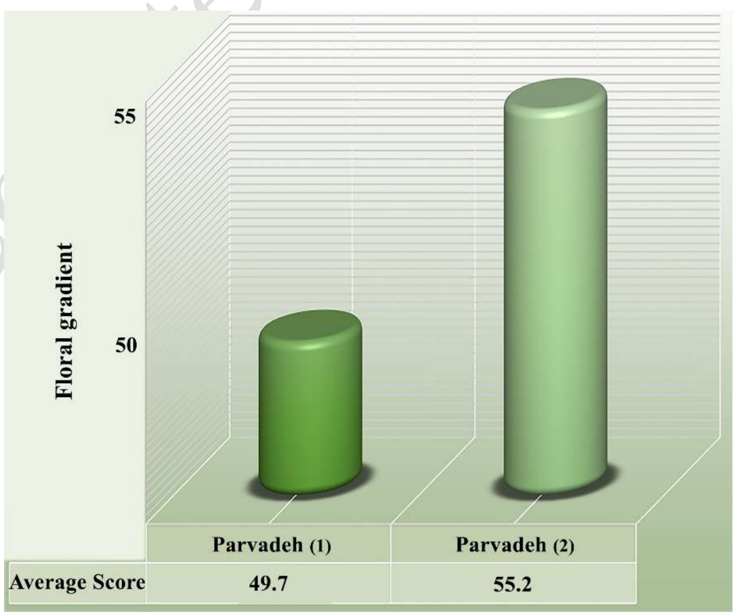

Figure 13. ‘Floral gradient’ values of the Late Triassic plant macrofossils reported in the Parvadeh coal mine areas by (1) Vaez-Javadi (2014), and (2) this study

Table 5. Floral Gradient scores for the studied areas in east-central Iran (data modified after Rees et al., 2000). References are: Parvadeh mine areas, Upper Triassic Nayband Formation (1) Vaez-Javadi, 2014), and this study; Middle Jurassic Hojedk Formation: (2) North Kouchekali (Vaez-Javadi & Namjoo, 2016); (3) South Kouchekali (Badihagh et al., 2019; Vaez-Javadi, 2018); (4) Mazino open pit mine (Vaez-Javadi, 2014); (5) Mazino core (Vaez-Javadi & Abbaszadeh, 2022); (6) Jafar Abad (Vaez-Javadi, 2014); (7) Calshur (Mehdizadeh et al., 2018); (8) Kalshaneh outcrop (Vaez-Javadi, 2015) (9) Kalshaneh core (Mehdizadeh, 2019); (10) Bahabad (Mehdizadeh, 2019); (11) Takht-e-Saffar open pit coal mine (Vaez-Javadi, 2025); (12) Kerman Basin (Hashooni and Pabdana coal mine, and Dasht-e-Khak) (Vaez-Javadi & Mirzaie-Ataabadi, 2006); (13) Kerman Basin (Babhutk) (Ameri et al., 2014); (14) Shahreza (Vaez-Javadi & Mirzaie-Ataabadi, 2019), and (15) Yorkshire, England (Harris, 1961, 1964, 1969, 1974, 1979)

Stratigraphical range		Late Triassic		Middle Jurassic															
Genus	**Score**	**Parvadeh mines [1]**	**Parvadeh mines (this study)**	**North Kouchekali [2]**	**South Kouchekali [3]**	**Mazino (open mine) [4]**	**Mazino (core) [5]**	**Cani Carbon (this study)**	**Jafar Abad [6]**	**Chahrekhneh (this study)**	**Calshur [7]**	**Kalshaneh (outcrop) [8]**	**Kalshaneh (core) [9]**	**Bahabad [10]**	**Takht-e-Saffar [11]**	**Kerman Basin [12]**	**Kerman, Babhutk [13]**	**Shahreza [14]**	**Yorkshire [15]**
Raphelia	100																		
Lycopodites	91																		*
Phoenicopsis	89																		
Czekanowskia	87															*			*
Desmiophyllum	85																		*
Pityophyllum	84																		
Sphenobaiera	81					*						*	*		*	*		*	*
Ginkgo	78	*	*	*	*		*			*		*				*		*	*
Taxocladus	78																		
Baiera	78																		*
Haumsania	77																		*
Pseudotorellia	76																		
Equisetites	76	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Podozamites	72		*	*	*	*		*		*	*	*	*	*	*	*	*	*	*
Coniopteris	72			*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Cladophlebis	70	*		*	*	*	*	*	*	*	*		*	*	*	*		*	*
Anomozamites	64			*	*														*
Ctenis	60			*					*	*		*	*						*
Elatides	57			*	*	*	*	*	*	*		*	*	*		*	*	*	*
Nilssonia	55	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Elatocladus	52	*		*	*													*	*
Todites	52	*	*	*	*	*		*	*	*				*	*	*			*
Sphenopteris	51																		
Taeniopteris	50				*		*		*	*					*			*	
Pterophyllum	45	*	*	*	*	*		*											*
Pagiophyllum	28					*									*				*
Sagenopteris	21			*	*	*	*	*	*	*		*	*	*	*	*			*
Pachypteris	13								*										*
Ptilophyllum	13			*	*	*	*	*		*		*	*	*					*
Brachyphyllum	9																		*
Otozamites	9		*													*			*
Zamites	0																		*
Average score		**49.7**	**55.2**	**56.2**	**55.5**	**53.5**	**54.89**	**53.3**	**56.7**	**56.3**	**69**	**58.5**	**57.7**	**54.2**	**57.7**	**60.83**	**66.4**	**66.3**	**53.8**

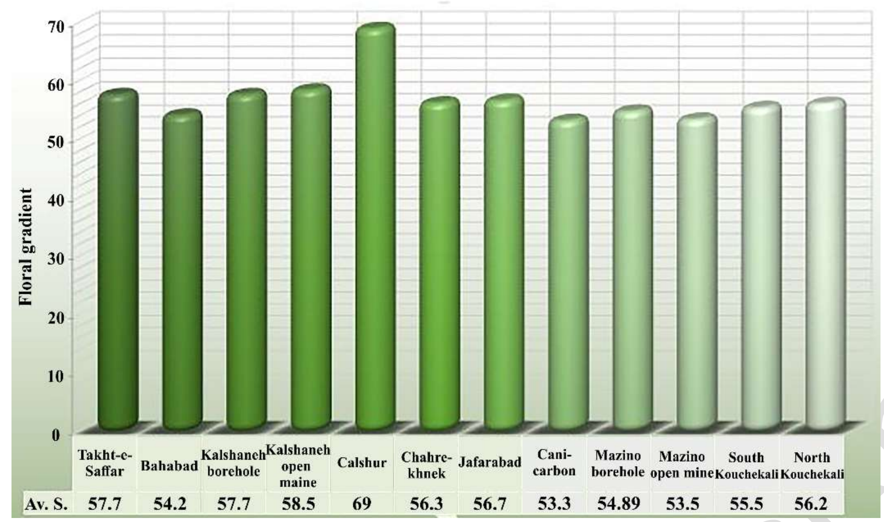

Figure 14. 'Floral gradient' values of the Middle Jurassic plant macrofossil assemblages reported from various localities in the Tabas area (Vaez-Javadi, 2014, 2015, 2018, 2025; Vaez-Javadi & Abbaszadeh, 2019; Mehdizadeh et al., 2018, 2020; Vaez-Javadi & Namjoo, 2016, and this study: Cani Carbon and Chahrekhneh)

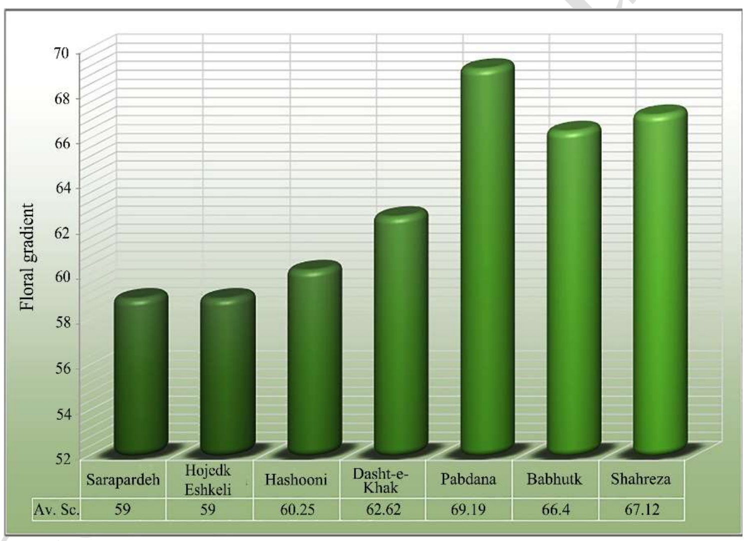

Figure 15. 'Floral gradient' values of the Middle Jurassic plant macrofossil assemblages reported from various localities in the Kerman Basin and Shahreza (Khalilizadeh et al., 2020; Schweitzer & Kirchner, 1996, 2003; Schweitzer et al., 2000; Vaez-Javadi & Mirzaie-Ataabadi, 2006; Ameri et al., 2014; Vaez-Javadi & Mirzaie-Ataabadi, 2019)

Comparison of the Late Triassic and Middle Jurassic Floral Gradient charts indicates that the overall macrofossil assemblage changed only moderately. Although representatives of the Bennettitales declined or disappeared, other cycadophyte taxa appeared and became more prominent. However, some limitations exist when applying the Floral Gradient method because of the restricted number of genera included in the analysis. Ziegler et al. (1993, 1996) considered 34 genera, whereas Rees et al. (2000) reduced this number to 32 genera. In addition, possible taphonomic and sampling biases should also be taken into account.

Sørensen's similarity index

Considering the entire Late Triassic and Middle Jurassic plant assemblages and applying the

Sørensen similarity quotient, similarity indices of 0.09 at the species level and 0.35 at the genus level were obtained. These results indicate low similarity at the species level and moderate similarity at the genus level between the two assemblages. This pattern suggests that many species and genera were either endemic or became extinct during this time interval.

Furthermore, palynological data reported by Vaez-Javadi (2018, 2020) and Vaez-Javadi & Ghanbarian (2021) indicate that sea level rose toward onshore areas during this period, resulting in extensive terrestrial environments being affected by marine influence. In addition, the similarity index between the Tabas flora and the Yorkshire flora is 0.59 at the genus level, indicating a relatively high similarity between these two plant macrofossil assemblages.

Conclusions

The present study of Late Triassic–Middle Jurassic plant macrofossil assemblages from the Tabas Block in east-central Iran confirms significant floral changes during this interval. In general, the following conclusions can be drawn:

The fern genera *Clathropteris* Brongniart and *Thaumatopteris* Goeppert completely disappeared by the Middle Jurassic whereas the genera *Klukia* Raciborski and *Coniopteris* Brongniart appeared and became widespread.

The Order Peltaspermales (Pteridopspermophyta), represented by a single genus and species (*Scytophyllum persicum*), completely disappeared from the vegetation of Iran at the end of Triassic. In contrast, the genera *Sagenopteris* Presl and *Pachypteris* Brongniart, belonging to the orders Caytoniales and Corystospermales, respectively, appeared and expanded during the Middle Jurassic.

The order Bennettitales (Cycadophyta) experienced a pronounced decline in diversity and abundance from the Late Triassic to the Middle Jurassic. The genera *Nilssoniopteris* Nathorst and *Dictyozamites* Oldham disappeared completely in the Middle Jurassic, while the genera *Pterophyllum* Brongniart emend. Harris with ten species, *Anomozamites* Schimper emend. Harris with three species, and *Otozamites* Braun with three species were well represented in the Late Triassic, only a single representative of each genus occurs in the Middle Jurassic. In addition, the genus *Zamites* Brongniart has not been reported from the Tabas Basin in either Triassic or Jurassic deposits. Conversely, the genus Ptilophyllum, which is absent from Triassic deposits, appears in sediments of the late Middle Jurassic.

Within the division Ginkgophyta, the genera *Baiera* Braun and *Sphenobaiera* Florin are represented by only one species in the Late Triassic. (Presl) Heer disappeared by the Middle Jurassic, whereas *Ginkgoites* Seward and *Sphenobaiera* Florin persisted into the Middle Jurassic, although with low diversity and abundance.

Among the conifers, the genera *Elatides* Heer emend. Harris, *Cyparissidium* Heer, and *Cupressinocladus* Seward appeared and expanded in the Middle Jurassic floral assemblages.

Statistical analysis indicates that the relative abundance of Bennettitales in the Late Triassic flora of the Parvadeh mines area is 28.7%, whereas this order constitutes only approximately 2.8% of the plant macrofossil assemblage in the Middle Jurassic.

The relative abundance of Cycadales is 19.2% in the Late Triassic flora of the Parvadeh mines area, but increases to approximately 45% in the Middle Jurassic flora of the Cani Carbon area. In addition, Coniferales, with a relative abundance of about 2% in the Late Triassic, increase to 12.75% in the Middle Jurassic plant communities of central and east-central Iran. The small-leaved conifer *Elatides* Heer emend. Harris, characterized by high ecological resilience, became one of the dominant elements of Middle Jurassic vegetation.

Floral gradient' values from the Late Triassic plant macrofossil assemblages are 49.7 and 55.2 in this study and in previous studies, respectively.

Floral gradient' values from the Middle Jurassic plant macrofossil assemblages are 57.7, 54.2, 57.7, 58.5, 69, 56.3, 56.7, 54.89, 53.5, 55.5 and 56.2 in the Takht-e-Saffar, Bahabad, Kalshaneh borehole, Kalshaneh open-pit coal mine, Calshour, Chahrekhneh, Jafarabad, Cani Carbon, Mazino borehole, Mazino open coal mine, South Kouchekali, and North Kouchekali localities, respectively.

Floral gradient' values from the Middle Jurassic plant macrofossil assemblages in Sarapardeh, Hashooni coal mine, Dasht-e-Khak, Pabdana, Babhutk coal mine, and Shahreza section are 59, 60.25, 62.62, 69.16, 66.4, and 66.3, respectively.

Sørensen similarity indices calculated for the entire Late Triassic and Middle Jurassic plant macrofossil assemblages are 0.09 at the species level and 0.35 at the genus level.

Comparison of 'Floral gradient' values from these 23 localities indicates that the composition of plant macrofossil assemblages changed gradually from the Late Triassic to the Middle Jurassic, showing a general trend toward more temperate floral elements.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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