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ORIGINAL PAPER

The Rhaetian ferns and seed ferns from the Shemshak Group, Ghoznavi area, N.E Alborz Mountain, Iran

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Abstract
A complete profile was measured and sampled in the study area to determine the age of the Shemshak Group. A total of 159 samples were collected from plant-fossiliferous horizons and subsequently investigated in the Geosciences Faculty of Shahid Beheshti University Laboratory. Fifteen identified plant macrofossil species (ten genera) were categorized into Osmundales, Dipteridales, Marattiales, and Peltaspermales. The species encountered are *Korallipteris yipinglangensis*, *Cladophlebis nebbensis*, *Cladophlebis haiburnensis*, *Cladophlebis denticulata*, *Clathropteris meniscioides*, *Dictyophyllum exile*, *Thainguyenopteris parvipinnulata*, *Osmundopsis sturii*, cf. *Marattiopsis intermedia*, *Scytophyllum waehneri*, and *Peltaspermum decipiense.* In this study, 5 ferns and seed ferns species are reported for the first time in the northeastern Alborz Mountain. A Late Triassic (Rhaetian) age is assigned to the Shemshak Group based on ferns and seed ferns chronostratigraphy. Also, a lowland deltaic environment, including wet and drier conditions, is suggested by ferns and seed ferns revealed in the studied area.

Keywords Late Triassic · Plant macrofossil · Pteridophyta · Pteridospermophyta · Alborz Mountains

Introduction

The Shemshak Group contains abundant plant macrofossils that have been investigated by previous researchers in different localities of the northeastern of Alborz Mountain: 12 fern species were described from the Shemshak Group in eastern Alborz (Ghoznavi, Azadshahr, Farsian, and Nodeh localities) by Corsin and Stampfli (1977). Likewise, 4 fern and one seed fern species were reported by Vaez-Javadi (2006) (Narges-Chal area). Also, 3 ferns species were described from Ghoznavi-Farsian area by Najafi in 2009. Moreover, 5 additional species of fern, seed fern, and their reproductive organs are reported in this paper.

The current study is based on a continuous and complete profile of the Shemshak Group, which is measured and sampled for the first time in the northeastern Alborz. In this study, we focus on describing ferns and seed ferns of Ghoznavi area in order to improve the understanding of the Rhaetian palaeoenvironments, the corresponding habitats, and subenvironments in the northeastern Alborz. (Figs. 1 and 2).

Geological setting

The Shemshak Group is well-developed at the Farsian area, north of Shahrud City, in the northeastern Alborz Mountain (geographical coordination: 360 26′N latitude and 550 28′E longitude). This group has 1200 m thickness in its type locality (Aghanabati 2004), but this thickness varies from one place to another throughout the Alborz chain (e.g., 2662 m in the Ghoznavi village). The Shemshak Group consists of a gray to black shale succession, siltstone, and sandstone, intercalated with coal seams. The Shahrud-Azadshahr paved road is the main road to access the studied area: Ghoznavi village is

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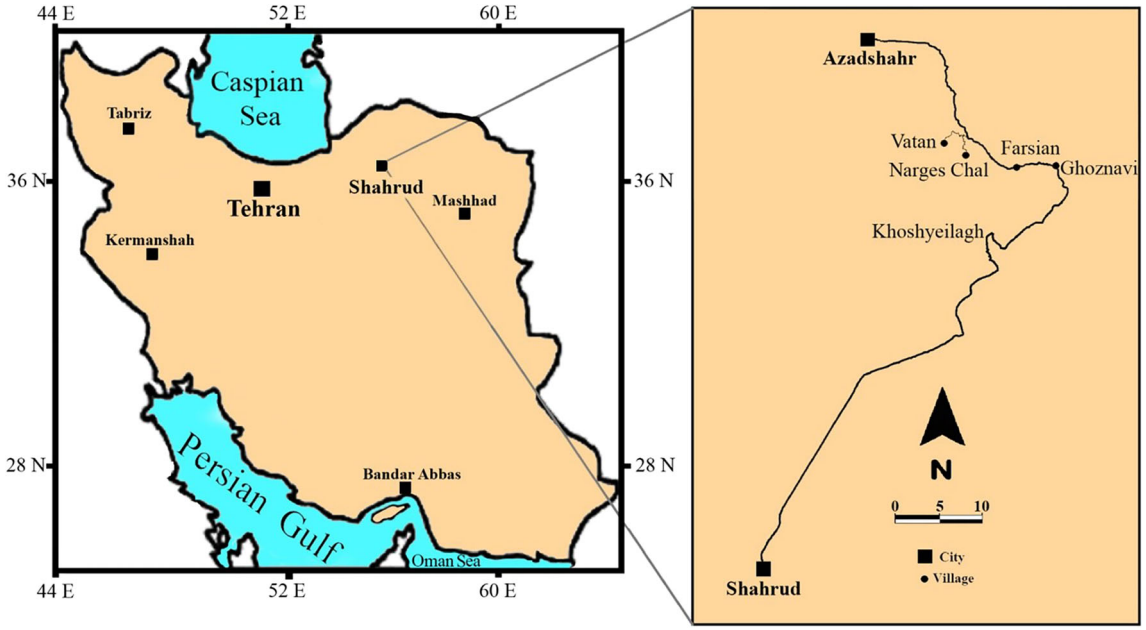


Fig. 1 Location map showing the studied area and other previously studied sites in the northeastern Alborz

located in 105 km north of Shahrud and 20 km south of Azad Shahr. The Shemshak Group rests on the Elika Formation (Lower Triassic) in this area. The lower contact of this group is characterized by a bauxite conglomerate, which is disconformable with the underlying limestones of the Elika Formation; the upper contact is transitional with the overlying argillaceous limestones of the Dalichai Formation (Middle Jurassic).

Materials and methods

Based on available data, no continuous and complete profile has been previously prepared from the Shemshak Group because of the hard mountainous conditions of this part of the Alborz Mountains. In this study, a measured and sampled complete profile has been presented from the Shemshak Group during several field trips in the Ghoznavi-Farsian areas in 2015–2018. A few meters of the profile, in the basal part, were measured in the Ghoznavi area; the rest were measured from the Narges-Chal village to Shahrud-Azadshahr road and up to the Farsian coal mine. In the studied area, the true thickness of the Shemshak Group is 2662 m, including several plant macrofossil-bearing horizons, which have not been considered previously. Among the encountered plant macrofossil horizons, the upper horizon was considered for the current investigation, which is characterized by abundant and well-preserved plant macrofossils (such as leaves, stems, cone, and reproductive organs). The samples are stored in the Geosciences Faculty of Shahid Beheshti University proceeded by the MG-MF prefixes under (1–359) accession numbers. The samples were identified by using a binocular microscope and photographed using a Panasonic FZ200 Digital Camera. The oblique light was used to enhance the contrast and reveal fine details of venation and leaf morphology.

Systematic palaeontology

Division Pteridophyta

Incertae sedis

Genus *Korallipteris* Vera and Passalia, 2012

Type species: *Gleichenia argentinica* (Berry) Herbst, 1962.

Korallipteris yipinglangensis (Li and Cao, 1976) Vera and Passalia, 2012

Fig. 3a–c

Selected synonyms:

1976 *Gleichenites yipinglangensis* Li and Cao (name only).

2009 *Gleichenites yipinglangensis* Wang, p.154, pl. 8, figs. 1-6.

Material: MG-MF 25, 39, 40 and 41 (four specimens).

Description. The collected specimens are sterile frond fragments with 1mm wide grooved rachis. The frond fragments are up to 40mm long. Pinnules are small (2–2.5 mm wide and 3–4 mm long), separated, typically alternative to sub-opposite, arising from rachis at 70–90^0. Pinnules have rounded apex and slightly contracted base. The pinnule margins are undulate to lobate. The venation pattern is anadromous and sphenopteroid, consisting of a midvein, which extends to two-third of the pinnule length, and twice forked lateral veins.

Remarks. The undulate pinnule margin of this species resembles the *Todites princeps* (Corsin and Stampfli 1977), but our species has thinner rachis and denser veins. *Korallipteris yipinglangensis* is somewhat similar to *Ferizianopteris*

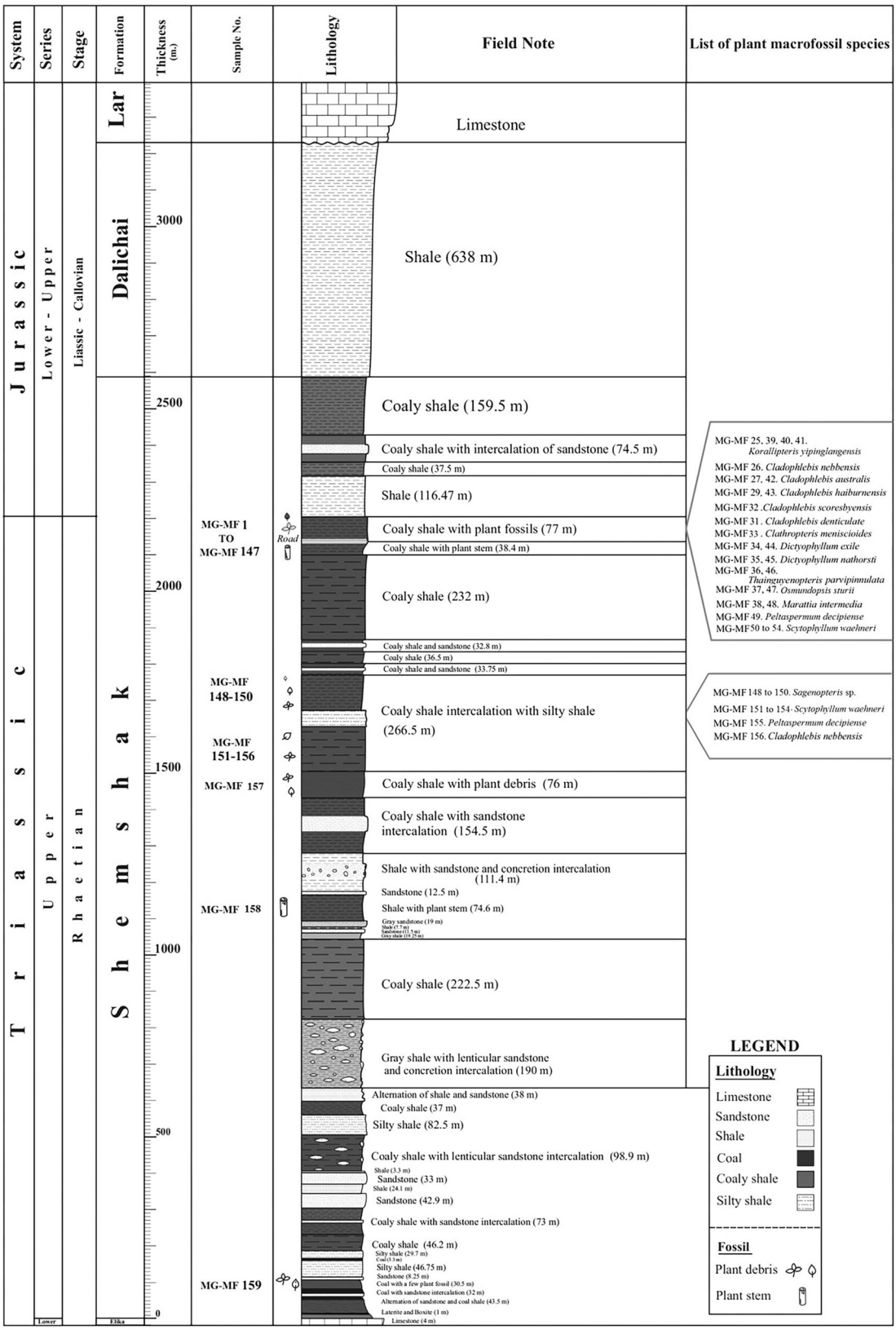


Fig. 2 Stratigraphic column of Shemshak Group in the Ghoznavi area, N.E of Alborz

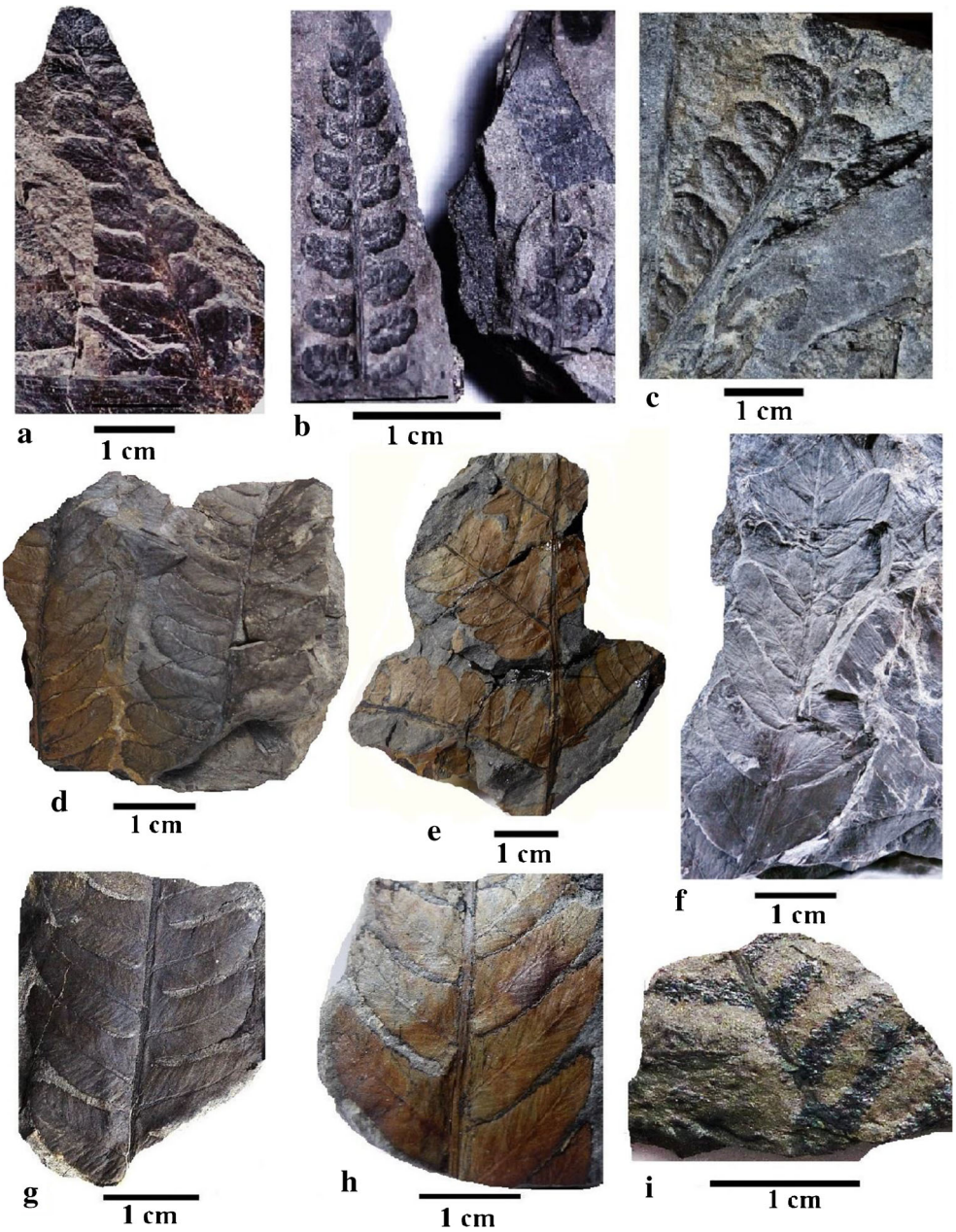


Fig. 3 **a–c** *Korallipteris yipinglangensis*; **d, e** *Cladophlebis nebbensis*; **f** *Cladophlebis haiburnensis*; **g, h** *Cladophlebis denticulata*; **i** *Osmundopsis sturii*

undulata (Fakhr 1977), but our species has less prominent catadromic pinnules and different venation pattern with a distinct midvein. The collected specimens are similar to *Gleichenites yipinglangensis* from the Upper Triassic of Yunnan in China in terms of pinnules shape and outline. It should be mentioned that the names of *Gleichnites* and *Microphyllopteris* genera and their related species are invalid because of nomenclature problems according to Cantrill (1998), Nagalingum and Cantrill (2006), and Vera and Passalia (2012). Therefore, they have to be assigned to the *Korallipteris* genus and its related species.

Occurrence. Hitherto, this species has been known only from the Late Triassic of China (Li et al. 1976; Li and Wu 1982; Wu 1982).

Phylum Pteridophyta

Order Osmundales

Family Osmundaceae

Genus *Cladophlebis* Brongniart, 1849

Type species. *Cladophlebis haiburnensis* (Lindley and Hutton, 1836) Brongniart, 1849

Cladophlebis nebbensis (Brongniart, 1828) Nathorst, 1878

Fig. 3d, e

Selected synonyms:

1977 *Cladophlebis nebbensis* Corsin and Stampfli; p. 521, pl. 4, figs. 3-5.

2006 *Cladophlebis nebbensis* Vaez- Javadi; p. 399, pl.1, fig.4; fig.5G.

Material. MG-MF 26, 15, 620 (3 specimens).

Description: The specimens of this species are sterile frond fragments. The most complete frond fragment (Fig. 3e) is a 60mm long bipinnate frond, bearing 6 branches. The main rachis is up to 1mm wide. The pinna rachis is up to 0.5mm wide, arising at 50^0. Pinnules are inserted subopositely at 80^0 on the main rachis, separated by less than 0.5mm wide gaps. Pinnules are 10mm long and 5mm wide and slightly contracted at the base. One-third of the upper part of the margin is serrate. The pinnule margins are parallel along the three-fourth of their length, ending in rounded apex. The veins are distinct. The midvein reaches the pinnule apex. Secondary veins arise at 45° and fork once. The number of veins at the margin of pinnule are 14–16.

Remarks. *Cladophlebis nebbensis* resembles *C. ichunensis*, *C. rosserti*, and *C. haiburnensis*. In *C. ichunensis*, the first lateral vein, in the basiscopic side of the pinnules, arises from the rachis instead of the midvein as in *C. nebbensis*. The pinnule apex is acute in *C. rosserti*, while that of *C. nebbensis* is rounded. *C. haiburnensis* pinnules differ in having acroscopically expanded margins, lanceolate to falcate outline, and subacute apices, while *C. nebbensis* pinnules have contracted bases; oblong outline; parallel margins, serrate in the upper third of the pinnule; and rounded apices.

Occurrence. This species has a wide stratigraphic range, from the Late Triassic (Carnian) to the Middle Jurassic (Bajocian). Hitherto, it has been recorded from the Middle-Late Triassic of Argentina (Frenguelli 1947); Late Triassic (Carnian) of Japan (Yokoyama 1905) and Russia (Volynets and Shorokhova 2007); Late Triassic (Rhaetian) of Vietnam (Zeiller 1903) and China (Deng et al. 2017); Triassic-Jurassic of Greenland (Harris 1946) and Poland (Barbacka et al. 2014); Early Jurassic of Japan (Ôishi 1940); Jurassic of Denmark (Mehlqvist et al. 2009); and Kamenka in Russia (Thomas 1911). So far in Iran, it has been illustrated in Late Triassic (Rhaetian)-Early Jurassic (Liassic) of the Shemshak Formation in Zirab, Central Alborz (Fakhr 1977) and the Jurassic of Kerman (Vaez-Javadi 2006).

Cladophlebis haiburnensis (Lindley and Hutton, 1836) Brongniart, 1849

Fig. 3f

Selected synonyms:

1977 *Cladophlebis haiburnensis* (Lindley and Hutton) Brongniart-Fakhr; p. 101, pl.5, figs. 4-6, text-fig. 3A, .

2019 *Cladophlebis haiburnensis* (Lindley and Hutton) Brongniart-Barbacka et al., p. 160, fig. 4.

Material. MG-MF 29 and 43 (two specimens).

Description. This species is observed in the MG-MF 29 and MG-MF 43 samples of the studied area. The specimens of this species are two frond fragments with 1mm wide grooved rachis. The frond fragments are maximum 60mm long and 30mm wide. Pinnules are curved, overlapped, and inserted oppositely subopposite at $40–55^0$. Pinnules are 16mm long and 6mm wide with basiscopically contracted and slightly acroscopically expanded base, entire margin, and subacute-obtuse apex. Secondary veins fork once near the midvein. The vein concentration near the margin is 20.

Remarks. *Cladophlebis haiburnensis* differs from other encountered species of the genus by its narrower rachis, the entire margin of the pinnule, and the pinnule subacute apex.

Occurrence. Until now, in Iran, this species has been recorded from the Late Triassic (Rhaetian)-Early Jurassic (Liassic) of Zirab (Kilpper 1964; Fakhr 1977); Karmozd and Tazareh (Sadovnikov 1976); and Middle Jurassic (Aalenian-Bajocian) of Central Alborz (Vassiliev 1984). Likewise, this species has been recorded from the Permian-Triassic of Siberia (Sadovnikov 2015); Early Middle Triassic of Argentina (Frenguelli 1947); Early Jurassic of Japan (Ôishi 1940), Poland (Barbacka and Bodor 2008; Barbacka et al. 2014; Barbacka et al. 2019), and Romania (Popa 1997); Middle Jurassic of China (Yabe 1922); Jurassic of Russia (Thomas 1911) and Yorkshire (Harris 1961); and Early Cretaceous of India (Goswami et al. 2010).

Cladophlebis denticulata (Brongniart, 1828) Fontaine, 1889

Fig. 3g, h

Selected synonyms:

1997 *Cladophlebis denticulata* Fontain Schweitzer; p. 179, pl.22, fig. 1-4.

2004 *Cladophlebis denticulata* Rees and Cleal; p. 26, pl. 6, fig. 4, pl. 7, figs. 1, 2, text-fig. 3D.

Material. MG-MF31, MG-MF 249 to 293 (45 specimens).

Description. This species is presented in the MG-MF31sample of Shemshak Group in the studied area. The collected specimens of this species are frond fragments with more than 30mm long and 30mm wide. Pinnules are commonly alternative, separated from each other, and attached to the rachis with the whole base. Pinnules are falcate, acute to obtuse in apex, 15mm long, and 8mm wide. Pinnule margins are dentate; the basiscopic margin is convex; and the acroscopic one is decurrent. Midvein is straight and distinct, and secondary veins fork once.

Remarks. *Cladophlebis denticulata* resembles *Cladophlebis aktashensis*, but it differs from the latter in having shorter pinnules with acute apex, rigid rachis, and the pattern of its venation; moreover, in this species, midvein is straight and the secondary veins fork once, while in *Cladophlebis aktashensis* lateral veins fork twice.

Occurrence. *Cladophlebis denticulata* has been recorded from the Late Triassic of Afghanistan (Jacob et al. 1955), Japan (Ôishi and Takahashi 1936), and Vietnam (Akagi 1954); Early Jurassic of Hungary (Barbacka and Bodor 2008; Barbacka et al. 2019); Jurassic of Yorkshire (Harris 1961), Kamenka in Russia (Thomas 1911), Poland (Raciborski 1894), Nürenberg (Gothan 1914), New Zealand (Arber 1917), Korea (Kawasaki 1925), Hupeh in China (Sze 1949), and Antarctica (Rees and Cleal 2004). Likewise, in Iran, this species has been recorded from the Late Triassic (Rhaetian)-Early Jurassic (Liassic) of Karmozd, Tazareh, Zirab, and Ghoznavi, Alborz Mountains (Sadovnikov 1976; Schweitzer et al. 1997; Kilpper 1964; Corsin and Stampfli 1977); Tabas, Central Iran (Vassiliev 1984); and Kerman, Central Iran basin (Schweitzer et al. 1997).

Genus *Osmundopsis sturii* (Raciborski) Harris, 1931

Type species. *Osmundopsis sturii* Raciborski, 1894

Osmundopsis sturii (Raciborski, 1894) Harris, 1931

Fig. 3i; Fig. 4a

Selected synonyms:

1970 *Osmundopsis* sp. Alavi and Barale, p.244, pl.3, fig. 1.

1997 *Osmundopsis sturii* (Raciborski) Schweitzer et al., p.169, pl. 18, fig. 1-8, text-fig. 28 D.

Material: MG-MF 37 and 47 (two specimens).

Description. The samples are once pinnate fronds that preserve up to 20 mm of fertile pinnae length. The rachis is 1mm wide, longitudinally striated, and bears sub-opposite branches (pinnules). The branches are up to 10mm long and 10mm wide, arising from the rachis at 3 mm distance and at an angle of 45–50^0. Also, the branches are densely covered with sporangial clusters. The sporangial cluster comprises numerous sporangia. The sporangia are 0.6 mm long and 0.4 mm wide.

Remarks. *Osmundopsis sturii* is distinguished from *O. plectrophora* due to its shorter pinnules and less distance

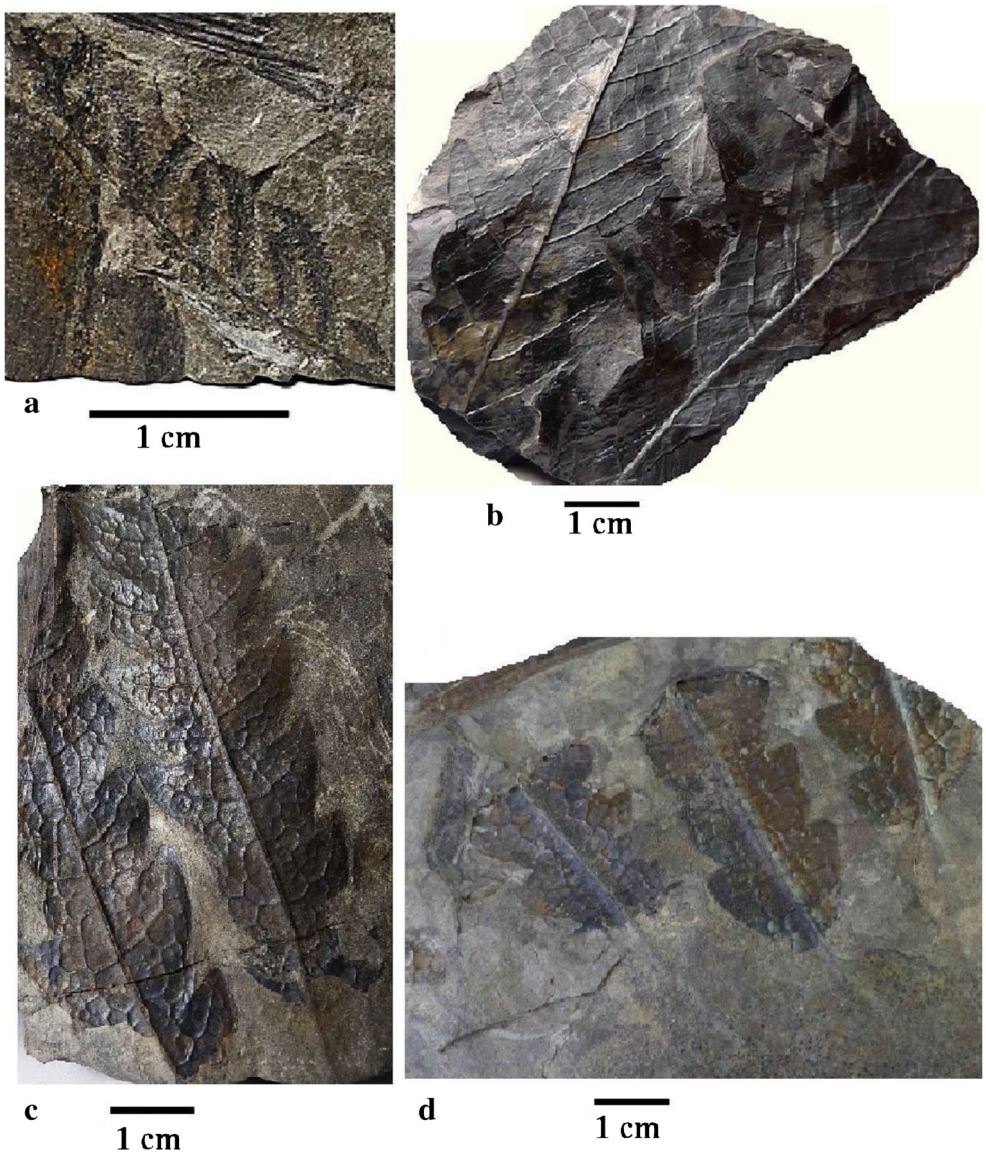


Fig. 4 **a** *Osmundopsis sturii*; **b** *Clathropteris meniscioides*; **c, d** *Dictyophyllum exile*

between the sporangial groups. Also, *Osmundopsis sturii* is comparable to *Osmundopsis hillii*; however, in *O. hillii*, the distance between the sporangial groups is larger, and the length of clusters is longer.

Occurrence: Up to now, this species has been recorded from the Early Jurassic of England (Harris 1961) and Argentina (Escapa and Cúneo 2012); Middle Jurassic of China (Xiang-wu 1991); and Early Middle Jurassic of Yorkshire (Schweitzer et al. 1997). Likewise, it has been recorded from the Late Triassic-Early Jurassic of Djam area, near Damghan city (Alavi and Barale 1970), and Late Triassic-Early Jurassic of Alborz, Iran (Kilpper 1964).

Phylum Pteridophyta

Order Filicales

Family Dipteridaceae

Genus *Clathropteris* Brongniart, 1828

Type species. *Clathropteris meniscioides* Brongniart, 1828

Clathropteris meniscioides Brongniart, 1828

Fig. 4b

Selected synonyms:

1977 *Clathropteris meniscioides* Fakhr; p.173, pl. 22, fig. 1-3, text-fig. 8G.

1977 *Clathropteris meniscioides* Corsin and Stampfli; p. 523, pl.1, figs 3-9.

2011 *Clathropteris meniscioides* Kustatscher and Van Konijnenburg-van Cittert; p.226, pl.6, figs A and B.

Material: MG-MF33 (one specimen).

Description. The frond fragments are linear, 52mm long, and 25mm wide. The lamina margin is serrate, incised to 6mm depth, giving rise to the lamina lobes. The acroscopic margin of the lobe is concave, and the basiscopic margin is convex. The rachis is 0.5mm wide. The secondary veins are simple, arising from the rachis at 45–50^0, and reaching to the margin. Tertiary veins depart at an angle of 90^0 to form fine reticulate meshes of 6 × 3 mm with reticulate venation inside.

Remarks. This specimen is attributed to *Clathropteris meniscioides* because of its typical venation pattern, the depth of pinnae incisions, and falcate lobes.

Occurrence. Up to now, this species has been recorded from the Late Triassic of South China (Lee 1964), Germany (Brauns 1862; Frentzen 1922; Weber 1968; Barth et al. 2014); Late Triassic (Rhaetian) of Japan (Ôishi 1938); Late Triassic-Early Jurassic of Massachusetts in North America (Cornet and Traverse 1975), and Hungary (Götz et al. 2011); Early Jurassic of Denmark (Moller 1902), Argentine (Choo et al. 2016), Sweden (Brongniart 1828), Antarctica (Bomfleur and Kerp 2010), and Hungary (Barbacka et al. 2019). Likewise, in Iran this species has been recorded from the Late Triassic of Tazareh (Sadovnikov 1976), Late Triassic-Early Jurassic of Shahrud (Corsin and Stampfli 1977), Tabas (Vassiliev 1984) and Shemshak (Fakhr 1977), and the Early Jurassic of Zirab (Kilpper 1964).

Genus *Dictyophyllum* Lindley and Hutton, 1834

Type species. *Dictyophyllum rugosum* Lindley and Hutton, 1834

Dictyophyllum exile (Brauns, 1862) Nathorst, 1878

Fig. 4c, d

Selected synonyms:

1977 *Dictyophyllum exile* Fakhr; p.72, pl. 20, figs. 2-5.

2011 *Dictyophyllum exile* Pott and McLoughlin; p. 1031, pl. 5, text-fig. A-D.

2012 *Dictyophyllum exile* Pott; p. 718, fig.4A.

Material: MG-MF 34, 44, 35, 45 (four specimens).

Description. This species is represented by linear-lanceolate sterile pinnae fragments, reaching up to 110mm long and 35mm wide. The pinnae midrib is 1mm wide. The pinnae margin is incised in lobes (5 to 15 mm). Lobes are falcate-triangular, 15 to 30mm long, 10mm wide, and attached to the midrib with the entire base; their apices are acute to subacute. The lobe midvein is distinct, arising from the midrib at 50–60^0, and curving slightly toward the apex. Secondary veins form polygonal to reticulated meshes.

Remarks. The pinnae of this species differ from those of *Dictyophyllum nathorsti* in having shorter and more crowded pinnules.

Occurrence. So far, this species has been recorded from the Carnian of Svalbard, Sweden (Pott 2012), Rhaetian of Daedong flora, South Korea (Kimura and Kim 1988), Greenland (Harris 1931), Sweden (Nathorst 1878; Pott and Mcloughlin 2011), and Abyek, Central Alborz Mountain (Fakhr 1977).

Phylum Pteridophyta

Incertae sedis

Genus *Thainguyenopteris* (Srebrodol'skaya, 1969) Sadovnikov, 1987.

Type species. *Thainguyenopteris parvipinnulata* Srebrodol' skaya, 1969.

Thainguyenopteris parvipinnulata (Srebrodol'skaya, 1969) Sadovnikov, 1987

Fig. 5a

Selected synonyms:

1969 *Thainguyenopteris parvipinnulata* Srebrodol'skaya; pl. 1, fig. 1-6, pl. 2, fig. 1.

1987 *Thainguyenopteris parvipinnulata* Sadovnikov; p. 89, pl. 9, fig. 1-3.

Material: MG-MF 36, 46 (two specimens).

Description. This species is represented by part of a frond fragment. The largest preserved frond fragment is 40mm long. The rachis is 1mm wide. Pinnules are attached to the rachis by their entire base or are slightly contracted at the base, arising at 60–90^0. Pinnules are about 6mm long and 4mm wide. Pinnule margins are slightly lobed, nearly parallel-sided for most of their length, and taper gradually to rounded apex. Several veins enter the base of pinnules, giving off lateral veins that immediately fork; subsequently, the anadromous vein forks for the second time. The vein concentration is 16 per centimeter.

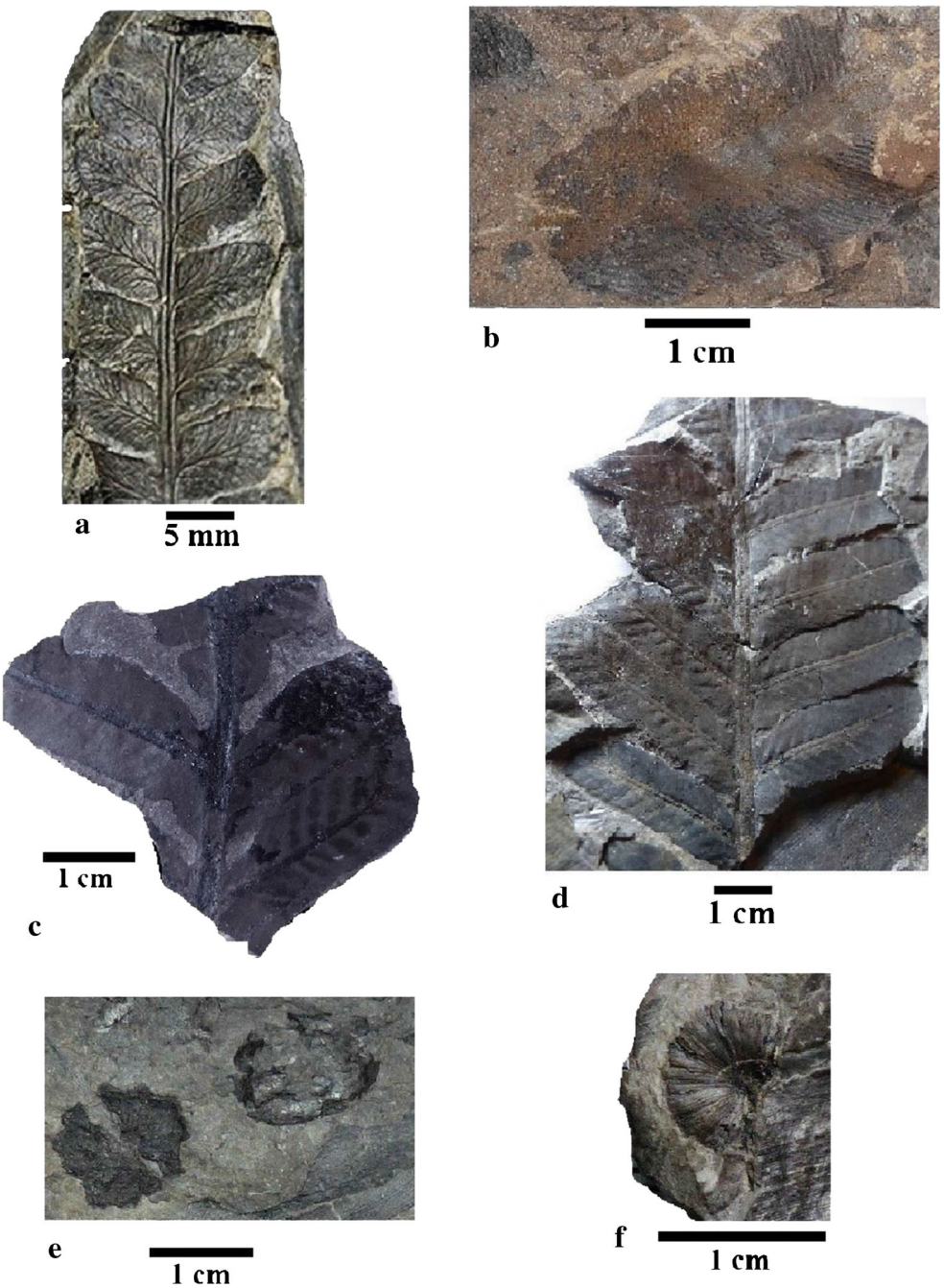


Fig. 5 **a** *Thainguyenopteris parvipinnulata*; **b** cf. *Marattiopsis intermedia*; **c, d** *Scytophyllum waehneri*; **e, f** *Peltaspermum decipiens*

Remarks. *Thainguyenopteris parvipinnulata* is characterized by its typical venation and the lobate margin of pinnules.

Occurrence: Based on the literature review, the age of the *Thainguyenopteris parvipinnulata* species is restricted to the Late Triassic (Norian-Rhaetian). So far, this species has been recorded from the Late Triassic (Norian) of Northern Vietnam (Srebrodol'skaya 1969) and the Late Triassic of China (Li et al. 1976). Also, this species has been recorded from the Late Triassic (Norian- Rhaetian) of Baladeh, Tazareh, and Shemshak in Central Alborz, Iran (Sadovnikov 1987).

Order Marattiales

Family Marattiaceae

Type species. *Marattiopsis dentata* (Starnberg) Schimper, 1869

cf. *Marattiopsis intermedia* (Muenster, 1836) Kilpper, 1964.

Fig. 5b

Selected synonyms:

1997 *Marattia intermedia* (Muenster) Schweitzer et al.; pp.153–155, pl.11, figs. 1-4; pl.12, figs. 1-9; text-fig.21.

2006 *Marattiopsis intermedia* Vaez-Javadi; p. 398, pl. 5, fig. 1; text-fig. 3B.

Material: MG-MF 38, 48 (two specimens).

Description. The species is represented by isolated, oblong pinnae. The largest preserved pinna fragment is 40mm long and 20–30 mm wide. The rachis is thick, striated, and 1–5 mm wide. The pinna commonly has lateral veins, which arise from the midrib at an angle of 45^0 and immediately fork near the midrib.

Remarks. It should be mentioned that determining the affinity of taeniopterids to gymnosperm or marattialean ferns is hard in the absence of sporangia on marattialean foliage. Some paleobotanists have recently stated that certain suspicious plant fossils can be differentiated from each other by using the divergence angle of vein from the rachis. Namely, if the veins arise from the rachis under a narrow-angle (e.g., less than 90^0), the specimen likely belongs to the marattialean ferns, and if the veins directly arise perpendicularly from the rachis, it could be assigned to gymnosperm taeniopterids (Van Konijnenburg-van Cittert et al. 2017).The species *Marattiopsis intermedia* is separated from other species of this genus mainly by its strong midrib (5 mm), the angle between the midrib and secondary veins, and the high concentration of the secondary veins (27/cm).

Occurrence: Up to now, this species has been recorded from the Middle Triassic of Italy (Scanu et al. 2016) and Late Triassic (Rhaetian)-Early Jurassic (Liassic) of Germany (Weber 1968). In Iran, this species has been recorded from the Late Triassic (Rhaetian)-Early Jurassic of eastern Alborz (Corsin and Stampfli 1977), western Alborz (Kilpper 1964), and Kerman (Schweitzer et al. 1997).

Phylum: Pteridospermophytes

Order Peltaspermales

Genus *Scytophyllum* Bornemann, 1856

Type species. *Scytophyllum bergeri* Bornemann, 1856

Scytophyllum waehneri (Stur 1886) Kustatscher, Pott and Van Konijnenburg, 2011

Fig. 5c, d

Selected synonyms:

1998 *Scytophyllum persicum* Schweitzer and Kirchner; pp. 20–22, pl. 2, figs. 1–2, pl. 3, figs 1-11, text-figs. 2, 3.

2006 *Scytophyllum persicum* Vaez-Javadi; p. 402, pl. 1, fig. 1, text-fig. 4A.

Material: MG-MF 50, 54, 151, 152, 153, 154, 155, 160 to 248 (96 specimens).

Description. The encountered specimens are abundant in the studied area, preserved as leave fragments. The size of leaves is unknown. The fragments are up to 170mm long and 70mm wide. The rachis is 1–4 mm wide, sculptured with zigzag lines. The pinnules are 12–40 mm long, 5mm wide, and oppositely inserted at an angle of $40–90^0$; they are coriaceous, attached in the apical part, but separated in the rest of frond. Pinnules are basiscopically decurrent and have undulate margins, ending in acute to obtuse apex. Midvein is clear, and lateral veins arise at 50^0, curving subsequently.

Remarks. The pinnae of *Scytophyllum waehneri* resemble those of *Scytophyllum bergeri*, but it differs in having smaller pinnules.

Occurrence. *Scytophyllum waehneri* (= *Scytophyllum persicum*) is an index species of the Late Triassic (Rhaetian). It is also a common species in the Northern hemisphere (Retallack 1995). Up to now, this species has been recorded from the Late Triassic (Rhaetian) of Russia (Dobruskina 1982) and Tajikistan (Dobruskina 1994). In Iran, this species has been recorded from the Late Triassic (Rhaetian) of Central Alborz (Schenk 1887; Krasser 1891; Zeiller 1905; Boureau et al. 1950; Lorenz 1964; Barnard 1965; Kilpper 1975; Sadovnikov 1978; Vassiliev 1984; Schweitzer and Kirchner 1998; Vaez-Javadi 2006).

Genus *Peltaspermum* Harris, 1937

Type species *Peltaspermum rotula*, Harris, 1937

Peltaspermum decipiens, Schweitzer and Kirchner, 1998

Fig. 5e, f

Synonym:

1998 *Peltaspermum decipiens* Schweitzer and Kirchner; p. 23, pl.4, figs. 1-7, text-fig. 4.

Material: MG-MF 49, 156 (two specimens).

Description. The collected specimens of this species are three isolated and flattened umbrella-like or disc-shaped cupule; one of them is attached to the axis. This species is an ovuliferous organ with 10 mm diameter and 17 marginal lobes (peltate discs). These lobes probably correspond to the number of produced seeds.

Remarks: It should be mentioned that there is no natural connection between the cupules and leaves, but according to Kustatscher and Van Konijnenburg-van Cittert (2010), it is probably related to the genus *Scytophyllum*.

Occurrence. Up to now, in Iran, this species has been recorded from the Upper Triassic of Zirab in Central Alborz (Schweitzer and Kirchner 1998).

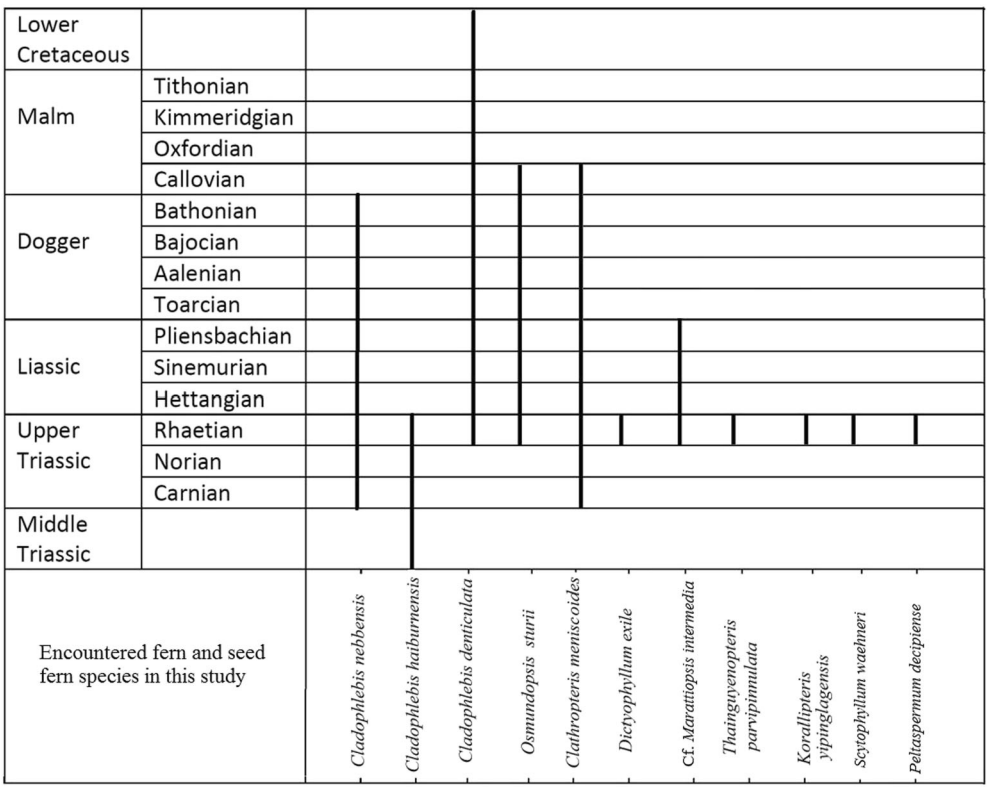
Discussion and conclusion

In the investigated area, the Shemshak Group contains abundant plant macrofossils such as Sphenophyta, Pteridophyta, Pteridospermophyta, Cycadophyta (Cycadales and Bennettitales), and Coniferophyta. In this paper, two phyla, Pteridophyta and Pteridospermophyta, are discussed: Pteridophyta is represented by nine species belonging to seven genera; the identified Pteridospermophyta (Peltaspermales) includes two species belonging to two genera. The palaeobiodiversity known from the Shemshak Group has been expanded in this study; 5 species out of 11 identified species, including *Korallipteris yipinglangensis*, *Cladophlebis haiburnensis*, *Thainguyenopteris parvipinnulata*, *Osmundopsis sturii*, and *Peltaspermum decipiens*, have been recorded for the

Table 1 Comparison of the Shemshak Group ferns and seed ferns as listed by Corsin and Stampfli (1977), Vaez-Javadi (2006), Najafi-Hajipour (2009), Vaez-Javadi (2016), and this study

List of macrofossil taxa in N. E Alborz Mountain	Corsin and Stampfli, 1977	Vaez-Javadi, 2006	Najafi, 2009	Vaez-Javadi, 2016	This work
Cladophlebis denticulata	×		×	×	×
Cladophlebis nebbensis	×	×			×
Cladophlebis whitbyensis	×				
Cladophlebis haiburnensis					×
Osmundopsis sturii					×
Phlebopteris polypodioides	×	×			
Dictyophyllum nathorsti	×	×	×	×	
Dictyophyllum exile			×	×	×
Dictyophyllum falcatum	×				
Clathropteris meniscioides	×			×	×
Korallipteris yipinglangensis					×
Todites princeps	×				
Marattiopsis intermedia		×			×
Lobifolia rotundifolia	×				
Marattiopsis muensteri	×				
Thainguyenopteris parvipinnulata					×
Scytophyllum waehneri		×			×
Anthrophyopsis sp.				×	
Peltaspermum decipiense					×

Table 2 Stratigraphic ranges of the encountered fern and seed fern species



first time from the eastern Alborz Mountain. Likewise, *Korallipteris yipinglangensis* is reported for the first time in Iran.

Moreover, a Rhaetian age has been suggested for the studied horizon by the occurrence of typical Rhaetic species (i.e., *Dictyophyllum exile*, *Scytophyllum waehneri*, *Peltaspermum decipiens*, and *Thainguyenopteris parvipinnulata*). (Tables 1 and 2).

The encountered ferns and seed ferns species are mostly cosmopolitan. Specifically, *Cladophlebis denticulata*, *Cladophlebis nebbensis*, *Cladophlebis haiburnensis*, and *Clathropteris meniscioides* have been recorded in both Southern hemisphere and Northern hemisphere indicating the cosmopolitan nature of these taxa. However, certain species are restricted to the Northern hemisphere (i.e., *Scytophyllum waehneri*, *Dictyophyllum exile*, cf. *Marattiopsis intermedia*, and *Thainguyenopteris parvipinnulata*). Therefore, currently, the Iranian plant macrofossils cannot be assigned to one of these two hemispheres.

The lowland deltaic environment (e.g., swamps, marshes, levees, flood plains) is indicated by the presence of well-preserved, large, and mature frond fragments of Pteridophyta and Pteridospermophyta in siliciclastic layers of the Shemshak Group (e.g., shale and sandstone).

A drier and more stressed sub-environment in delta lowland (i.e., levees) has been suggested by the presence of *Scytophyllum waehneri* seed fern, which is the most common species (with 96 specimens), along with *Peltaspermum decipiense*—probable female reproductive organ (Kustatscher et al. 2007). Likewise, *Cladophlebis denticulata* is the second common species (with 45 specimens), which has been considered as a typical species of drier conditions in drier delta lowland (i.e., delta levees and flood plains), considering its narrow pinnules and denticulate margin (Barbacka 2011). Similarly, *Korallipteris yipinglangensis* also indicates drier conditions.

On the other hand, all other encountered species indicate wetter sub-environments and corresponding habitats:

A humid climate in lowland delta plain (i.e., marshes and river banks) has been suggested by the Dipteridaceae large fronds (i.e., *Dictyophyllum* and *Clathropteris*) (Van konijnenburg-van Cittert 2002; Abbink et al. 2004; Cantrill 1995). Also, a warm and moist environment in delta lowland (Webb 200) has been suggested by the presence of Marattialean species (i.e., *Marattia intermedia*). Finally, the fragments of Osmundaceae ferns except *Cladophlebis denticulata* (i.e., *Cladophlebis nebbensis* and *C. haiburnensis*) also indicate wetter lowland sub-environment and warm conditions (Barbacka 2011).

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