The Hettangian-Bajocian flora of the Shemshak Group, Kerman, Iran

La flora Hettangiano-Bajociano del Grupo Shemshak, Kerman, Iran

Hamed **Ameri** [1,*], Parisa **Shaghayeghi** [2]

[1] Department of Ecology, Institute of Science, High Technology and Environmental Science, Graduate University of Advanced Technology, Kerman, Islamic Republic of Iran.

[2] Department of Geology, Kerman Institute of Higher Education, Kerman, Islamic Republic of Iran.

* Corresponding author: (H. Ameri)
ameri.paleo@yahoo.com

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ABSTRACT

Numerous examples of macro plant fossils can be found in the Kerman region's Early and Middle Jurassic successions. The Ab-e-Haji, Badamu, and Hojedk formations were among these patterns. One of the suitable regions for paleobotanical study is the Chatroud section. In this region, the Lower-Middle Jurassic is approximately 210 meters thick. 18 species of macro plant fossils from 14 genera, including *Nilssonia polymorpha*, *Pterophyllum nathorsti*, *Podozamites distans*, *Elatocladus zamioides*, *Elatides thomasii*, *Nilssonia feriziensis*, *Nilssonia herriesi*, and *Beania* sp., which are identified and described in this study, along with *Pterophyllum schenki*, *Anomozamites marginatus*, and *Klukia exilis*. In this region, there are two plant assemblage zones known as *Anomozamites marginatus-Pterophyllum schenki* Zone and *Klukia exilis* Zone. The Hettangian-Bajocian age is preserved at the Chatroud section.

Keywords: Jurassic, Hettangian-Bajocian, plants, Biozone, Kerman, Iran.

RESUMEN

Numerosos ejemplos de macro plantas fósiles pueden ser encontrados en las sucesiones del Jurásico Temprano y Medio de la región de Kerman. Las formaciones Ab-e-Haji, Badamu, y Hojedk se encuentran entre estos patrones. Una de las regiones adecuadas para estudios paleobotánicos es el sección Chatroud. En esta región, el Jurásico Inferior-Medio tine aproximadamente 210 metros de espesor. 18 especies de macrofósiles de plantas de 14 géneros, incluyen Nilssonia polymorpha, Pterophyllum nathorsti, Podozamites distans, Elatocladus zamioides, Elatides thomasii, Nilssonia feriziensis, Nilssonia herriesi y Beania sp., los cuales son identificados y descritos en este estudio, además de Pterophyllum schenki, Anomozamites marginatus y Klukia exilis. En esta región existen dos zonas de asociación de plantas, conocidas como: Zona Anomozamites marginatus-Pterophyllum schenki y Zona Klukia exilis. La edad Hettangian-Bajocian está preservada en la sección Chatroud.

Palabras clave: Jurásico, Hettangiano-Bajociano, plantas, Biozona, Kerman, Irán.

1. Introduction

Iran was created up of several microcontinents and part of the Cimmerian plate located between the Laurasia margin and the Tethys Ocean during the Late Triassic to Middle Jurassic. Iranian Microplate was under the impression of Cimmerian orogeny which caused the closure of the Paleo-Tethys Ocean and opening of the Neo-Tethys Ocean. Shemshak Group is the term given to all terrigenous and carbonates successions that formed in Iran between the Early and Middle Cimmerian orogeny. The formations in this group are the Nayband Formation (Carnian-Rhaetian, carbonate), Ab-e-Haji Formation (Hettangian-Pliensbachian, shale and sandstone), Badamu Formation (Toarcian- Aalenian, sandstone and limestone) Hojedk Formation (Bajocian- Bathonian, shale and sandstone).

The Jurassic deposits in Iran can be divided into two sub-basins based on coal facies: Kerman and Tabas coal sub-basin (Central Iran with Bajocian-Bathonian age) and Alborz coal sub-basin (northern Iran with Aalenian-Bajocian age) (Ameri, 2018). In the Center Iran, there is a widespread distribution of the Ab-e-Haji and Hojedk formations. There are several coal horizons in these shale and sandstone layers. The Jurassic Cimmerian plate's most diverse and important paleobotanical vegetation was found in the northern Kerman region.

The Jurassic succession and plant fossils described in this paper are situated about 2 km east of the Hossein Abad village and 49 km north of Kerman city (Figures 1, 2).

Compression fossils make up the majority of the vegetation, however trace and pith casts can also be found, including: *Nilssonia, Pterophyllum, Podozamites, Elatocladus, Elatides, Cladophlebis, Klukia, Anomozamites, Ptilophyllum, Beania, Neocalamites, Geinitzia, Pagiophyllum, Ginkgoites.*

The oldest known report of the Kerman coal beds was done by Houtum-Schindler (1881) which studied several coal horizons in the Triassic and Jurassic of the Kerman area. Several studies have been done on the biostratigraphy of Jurassic in Central Iran (Poole, 2005; Schweitzer, 1995, 1998, 2003, 2000, 1996). Huckride (1962) listed flora of the Jurassic sediments in this area. Seyed Emami (1971) subdivided the Jurassic succession based on ammonites' remains. More recent studies by Ameri (2018) and Ameri *et al*. (2014a) indicated that the Kerman area is also rich in plant fossils. Ameri *et al*. (2014b) identified some new species of the Equisetales in the Kerman area.

In order to provide information on systematics and biostratigraphy, this study aims to describe 14 genera and 18 species of plant fossils from the Hettangian-Bajocian flora in the Chatroud region.

2. Geological Background

In southern of Hossein Abad gorge, between the villages of Hossein Abad and Deh Sib, 15 km northeast of the Chatroud town, and 49 km of the Kerman city, at geographic coordinates 56°58' E and 30°38' N, uplift in the southern flank of the Hossein Abad syncline exposes the thickest and complete succession of the Jurassic. This section is mapped in the Zarand geology Map of 1/100.000 (Vahdati Daneshmand, 1995). These highlands are limited by the Chatroud fault at the West and Dehu fault at the East. In Hossein Abad syncline is exposed the Upper Triassic to Lower Cretaceous sediments. The oldest rock unit exposed in Chatroud section is black and green shale and sandstones of Shemshak Group (Lower to Middle Jurassic. Numerous faults have interrupted the geological sequences in this region's southeast, causing Jurassic sediments to be found next to Paleozoic deposits (Figure 1).

More than 770 meters of Jurassic sediments are exposed in this area, which contained Ab-e-Haji, Hojedk and Bidu formations (Lower-Upper Jurassic). The Badamu Formation are not exposed in this section, accordingly the Ab-e-Haji and Hojedk formations with similar lithology cannot separable. The Ab-e-Haji and Hojedk formations are composed of layers of gray quartzite with several coal horizons that alternate with sandstone and sandy to argillaceous shale with dark green-gray to brown-green colors. This succession has a 210 m thickness. The Ab-e-Haji and Hojedk formations lithological makeup differs greatly between regions.

The Ab-e-Haji and Hojedk formations in the studied area can be divided into six members, including:

- Member 1: which is composed of more than 60 meters of yellow to grey calcareous shale, olivaceous to black shale deposits with interca-

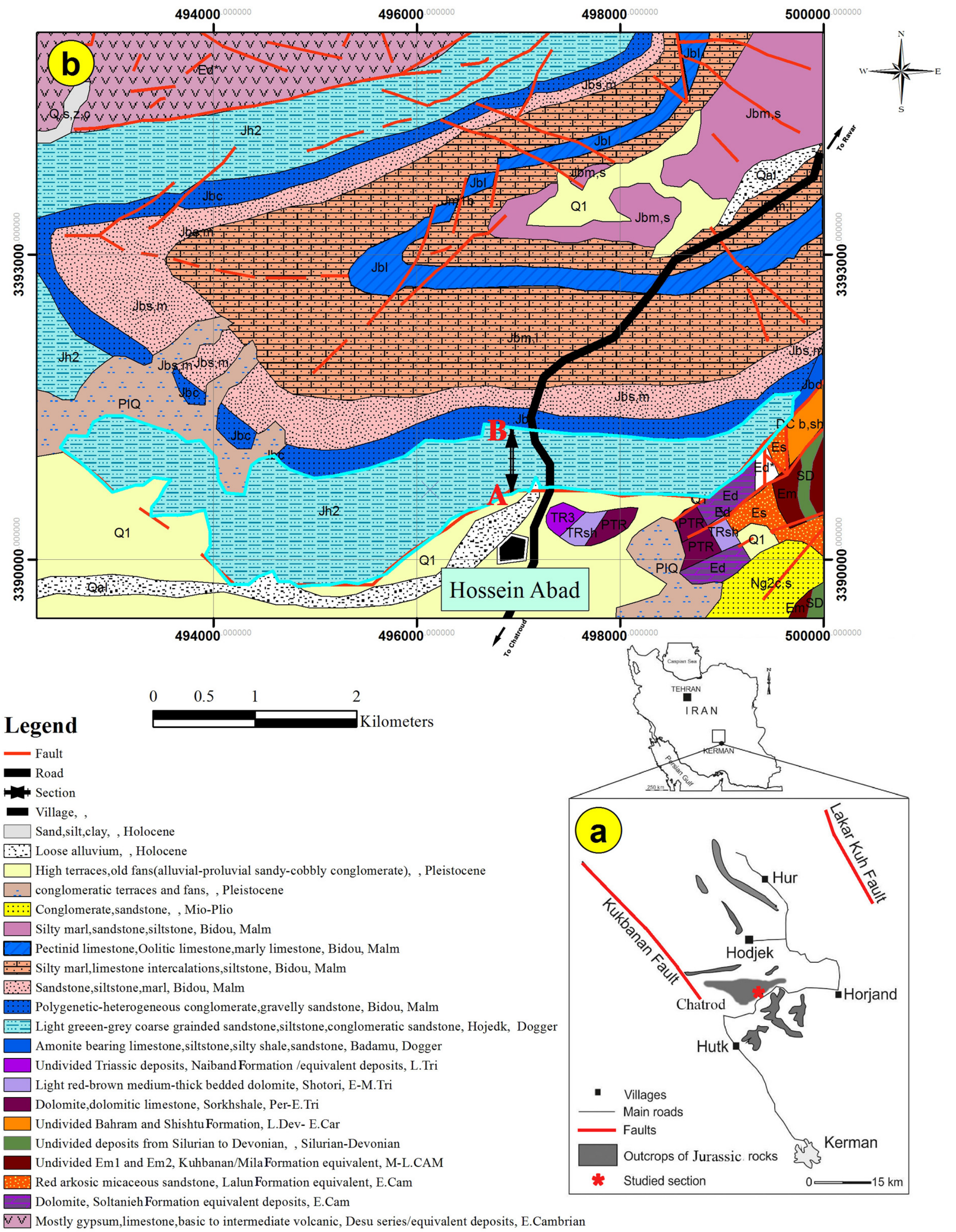

Figure 1 Shows the location of the studied section on a geological and road map of the Chatroud region.

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lations of cross-bedded sandstone, containing *Anomozamites marginatus, Nilssonia polymorpha and Elatocladus zamioides.*

- Membre 2: involves 35 m gray siltstone, shaly sandstone, coal horizons and sandstone, containing *Nilssonia polymorpha*, *Elatocladus zamioides* and *Pterophyllum schenki* remains.
- Member 3: consists of 30 m calcareous shale, sandy limestone, without fossils.
- Member 4: composed of 37 m calcareous

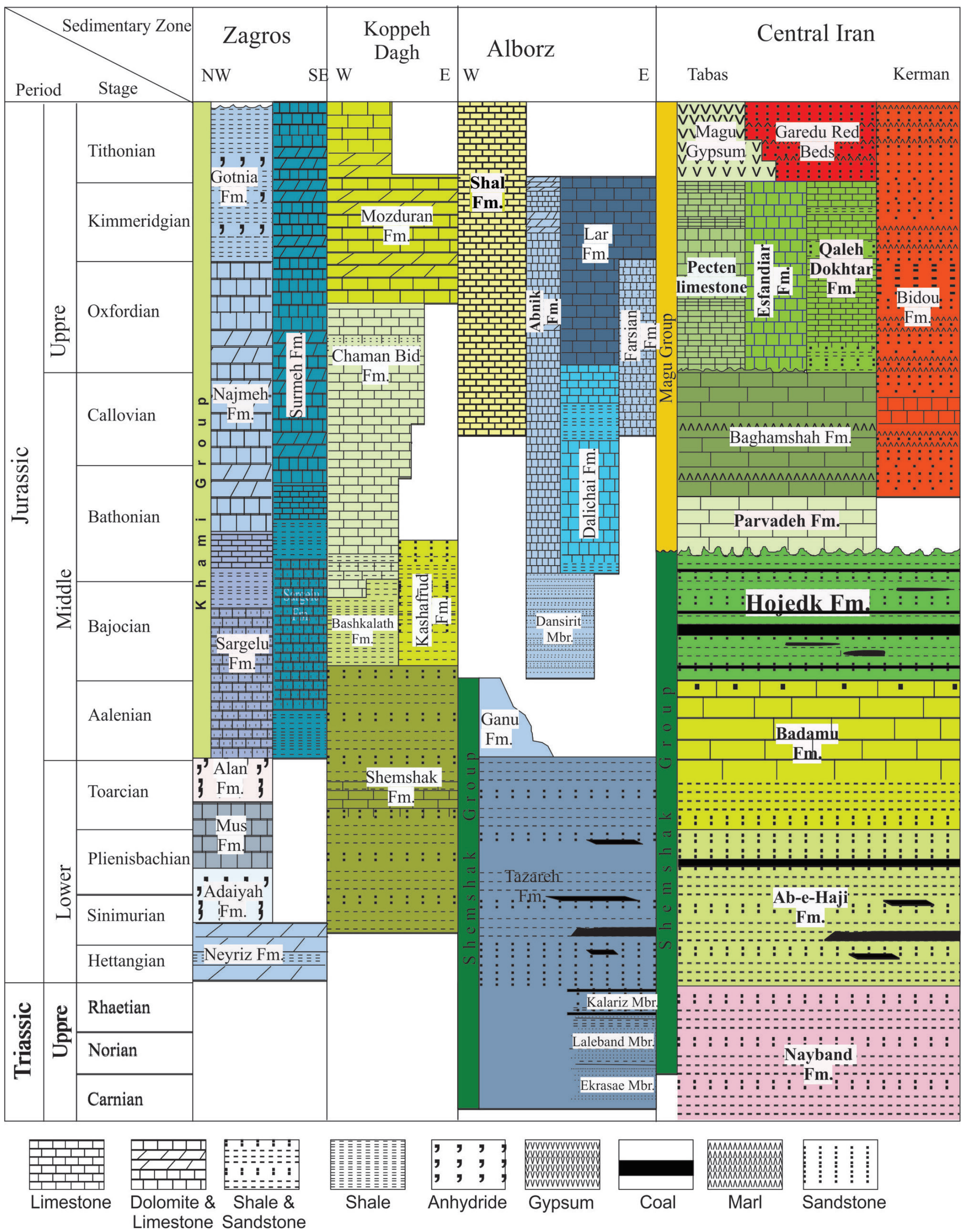

Figure 2 Stratigraphic correlation chart of Iran's Jurassic rock units, adapted slightly from Aghanabati (1998).

shale, with intercalations of sandstone, calcareous shale beds and contain *Klukia exilis, Cladophlebis denticulate*, *Nilssonia feriziensis, Nilssonia herriesi* and *Beania* sp.

- Member 5: involves 27 m of calcareous shale, shale limestone, with Equisetites stems.
- Member 6: includes 21 m of coal, carbonaceous shale, and olivaceous shale with stem fragments and contain *Klukia exilis, Cladophlebis denticulate*, *Nilssonia feriziensis, Nilssonia herriesi,* and *Beania* sp. remains.

This succession is disconformably overlies by the Bidu Formation. The Bidu Formation consists of 560 m heterogeneous succession of conglomerate, red to green sandstone and marl, limestone, marly limestone, red marl and sandstone. (Figure 3).

3. Materials and Methods

The Ab-e-Haji and Hojedk formations of Iran's Kerman Province provided the resources for the

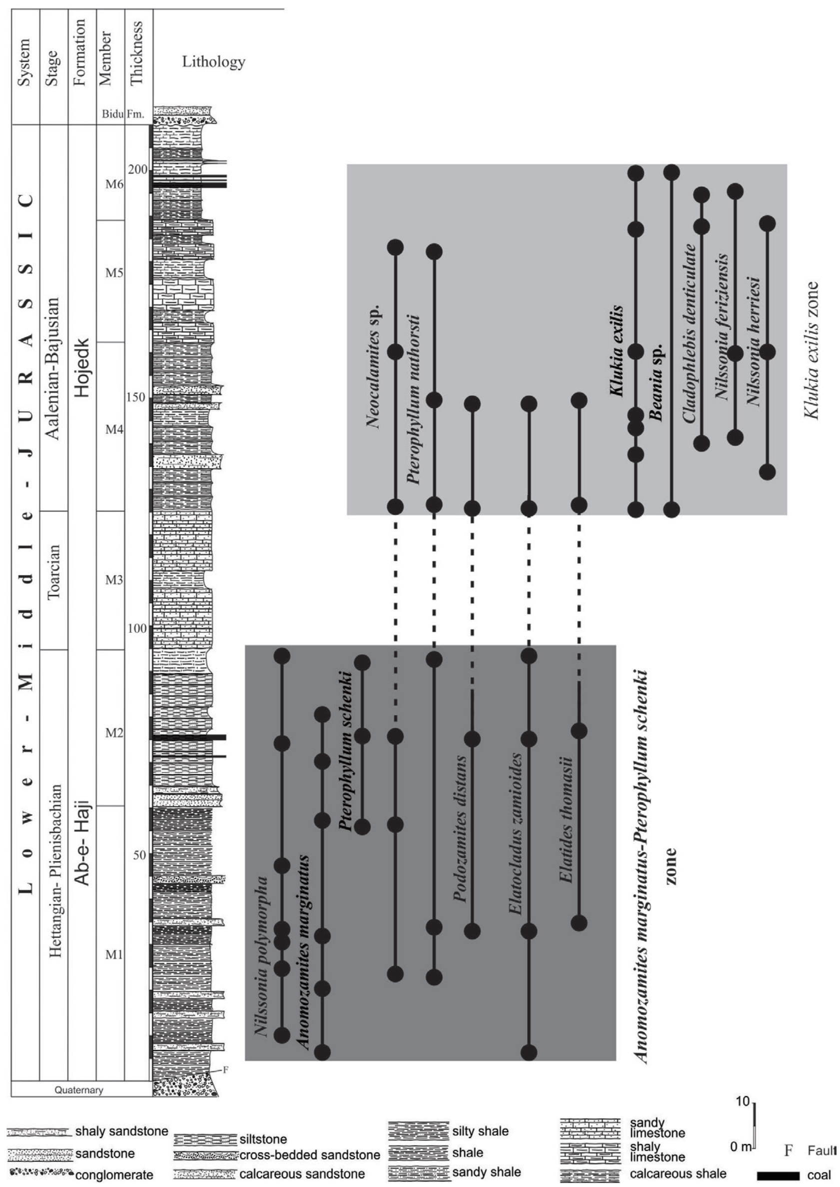

Figure 3 Biostratigraphic and Lithostratigraphic details of the Ab-e-Haji and Hojedk formations in the Chatroud section.

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current paper's research. There are several plant fossils in the coal-bearing. Based on the plant fossil, the Lower to Middle Jurassic is where it belongs (Ameri *et al.,* 2014a).

All investigated specimens have been stored in the Graduate University of Advanced Technology's Ecology Laboratory in Kerman, Iran. The abbreviation EDG stand for these deposited specimens. The material that was deposited contains 120 specimens with the labels EDG1100-EDG1220 which were collected in the Chatroud section. In the Ab-e-Haji and Hojedk formations, samples were taken from the coal layers, dense gray fine-grained sandstone layers, and rock layers. In this study, the flora from this location is described for the first time. The samples were captured using a Nikon D90 with a Nikon 105 mm macro lens. To improve the contrast, polarized light sources and a corresponding analyzing filter were employed. With the help of common graphics software (Adobe Photoshop CC), digital photographs were edited.

4. Systematic Palaeobotany

Class Coniferopsida
Order Coniferales
Family Podozamitaceae
Genus *Podozamites* (Braun, 1843)
Podozamites distans (Braun, 1843)
Figure 7h

1838 *Zamites distans* Presl in Sternberg; p. 196, plate 4, figure 1.
1967 *Podozamites distans*: Barnard; pp. 572–573, text–figure 5A.
1977 *Podozamites distans*: Fakhr; p. 141, plate XLVIII, figures 1–2.
2018 *Podozamites distans*: Vaez–Javadi and Mirzaie–Ataabadi; plate 4, figure 3a.

Material: Three specimens of frond fragments.
Description: Leaves inserted helically on a slim axis but arranged distichously in one plane due to twisting of the leaf bases. Leaves are ovate-lanceolate in shape. 36-up to 44 mm long (maximum length unavailable), 5.6-10 mm wide at their maximum wide, which is in the proximal third of the base. Base contracted, apex obtusely pointed. Veins are delicate, simple, or forking once near the leaf base but not elsewhere, running parallel through the middle part of the lamina, converging towards the apex. There are 14–18 veins per leaf width (22–28 veins per cm).
Remarks: *Podozamites distans* is very similar to *P. lanceolatus*, so their diagnosis is much confusing. *P. distans* leaves are wider than of *P. lanceolatus*. *P. distans* leaves are rather wider in proportion to their length than those of *P. lanceolatus*. Apex in *P. distans* less than pointed rather *P. lanceolatus*. In addition, the *P. distans* is a Rhaetian index and extensively extends in the Rhaetian to early Jurassic (eventually to middle Jurassic) whereas the *P. lanceolatus* is developed from the Middle Jurassic to the Early Cretaceous.

Podozamites schenki from the Rhaetian of Sweden, Persia and Siberia, are similar to *P. distans*, but has smaller stems and the more acuminate pinnules that differ with the *P. distans*.

Class Coniferopsida
Order Coniferales
Family Taxodiaceae
Genus *Geinitzia* (Endlicher, 1847)
Geinitzia sp.
Figure 7g

1851 *Criptomerites divaricatus* - Bunbury, p. 190, plate 13, figure 4.
1911 *Cheirolepis setosus* (Phillips) Seward - Krasser, p. 18.
2012? Geinitzia sp. - Scanu *et al.*, p. 82, plate 3, figure 4.
2016 *Geinitzia divaricata* (Bunbury) Harris – Giovanni *et al.*, figure 3a.

Material: A single moderately preserved branched leafy axis.
Description: Present specimen is fragment of sterile twig with helically arranged leaves. This

is 68 mm long the leaves are needle shape, with 3.5-4.5 mm long and 0.2 mm wide. Branches arise at up to 45°. The leaves are relatively uniform throughout their length, the base of leaves is slightly decurrent and the apex of leaves is acute.

Remarks: The described specimens belong to the genus *Geinitzia* on account of their quadrangular subdecurrent leaves. Among the species of this genus they are most similar to *G. reichenbachii* in form and size of the leaves. Those of *G. formosa* are smaller than in the studied material. *Geinitzia*- like shoots is the genus of the *Araucarites* in the Permian and those of genus of *Voltzia* at the Triassic. They differ from *Araucarites* in that the apprised needles are more scale like and smaller, and differ from the modern Araucariaceae in missing flat bases to the needles, although the fossils simulate the modern species *Araucaria heterophylla* (Burger and Ward, 2016). However, deficiency of cuticular characters and remarkable stratigraphic distance between the analyses specimen (Bajocian to Bathonian) and the type level of *Araucarites* (Permian) demonstrate that our identification should be treated with some precaution.

Class Coniferopsida
Order Coniferales
Family Araucariaceae
Genus *Pagiophyllum* (Heer, 1881)
Pagiophyllum sp.
Figure 7 b-d

Material: Three branched and unbranched shoot fragments.

Description: Branched and unbranched leafy twigs 27 to 58 mm long and 1–1.5 mm wide (ex-

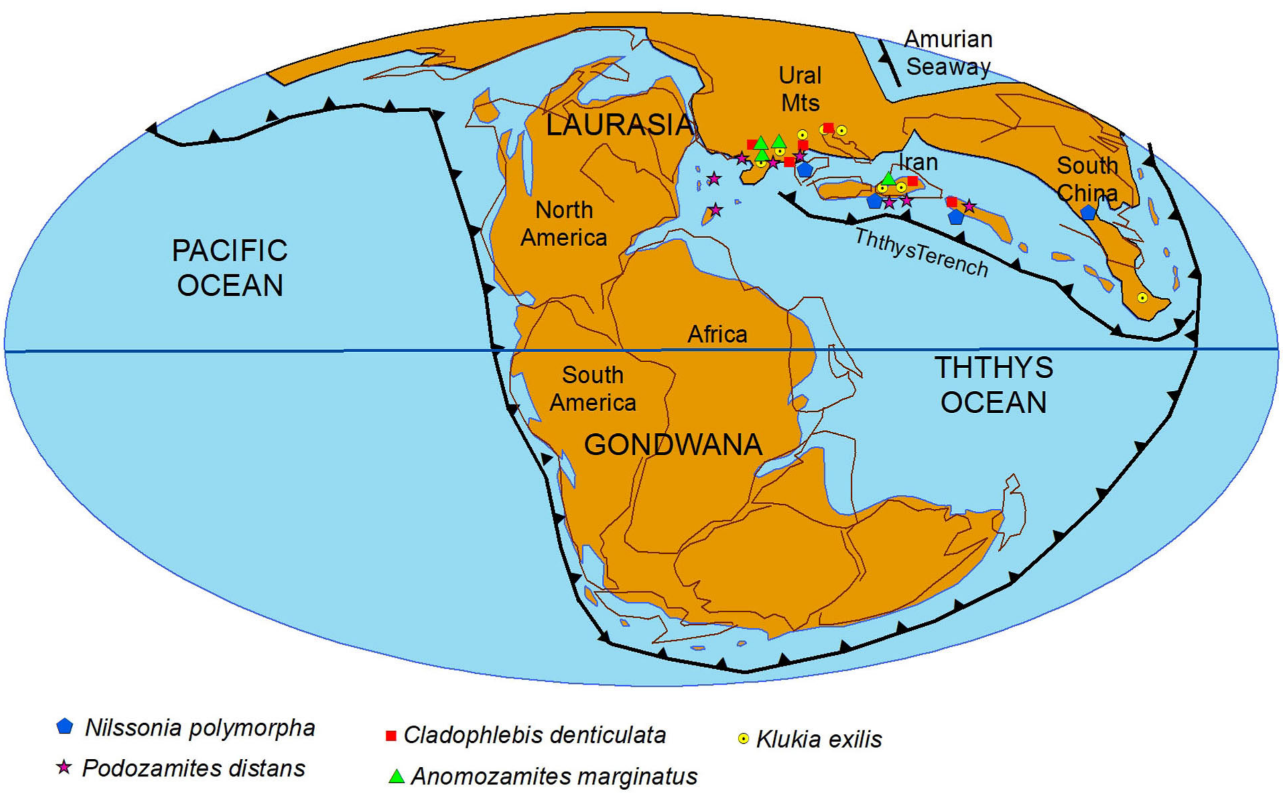

Figure 4 Paleogeographical reconstructions for the early Jurassic show the geographical distribution of plant fossils. The position of major continents is mainly after (Scotese, 2011).

cluding divergent leaves) Leaves are spirally arranged with 40 to 50 angles, 2–5.3 mm long and about 1 mm wide. In shape leaves are arising from rhomboidal leaf base cushion, decurrent, apex pointed or acute and entire margins. This leave is commonly found on isolated shoots.

Remarks: *Pagiophyllum* sp. from Kerman differs from the known taxa of *Pagiophyllum* in having fine twigs with narrow rhomboidal - shaped leaves. In generic shape of the leaves it is closely comparable with specimens of *P. mamillare* Brongniart illustrated by Sahni (1928), although the leaves in *P. mamillare* are broader and do not spread outwards from the shoot. In leaf shape *Pagiophyllum* sp. also resembles some of the leaves of *Allocladus bansaensis* (Sukh-Dev and Zeba-Bano, 1979), although these have much wider leaves. The leaves of the *Pagiophyllum* sp. are resembles with the leaves of *Sphenolopidium? argonense* Fontaine illustrated by Halle (1913), but the specimens from Kerman are different by being narrower and longer.

Class Cycadopsida
Order Bennettitales
Family Williamsoniaceae
Pterophyllum (Brongniart, 1825)
Pterophyllum schenki (Zeiller, 1886, 1903)
Figure 6 c

1984 *Pterophyllum schenki*: Sadovnikov; plate 30, figure 8.
2003 *Pterophyllum schenki*: Schweitzer and Kirchner; pp. 71-74, plate 15, figures 1-3; text-figure 25 a-c.

Material: One fragment of incomplete monopinnate leaf, base and apex are absent.

Description: Incomplete leaves fragment; frond is pinnate, leaf 36 mm length and 11 mm width. The rachis is 1.2 mm width, secondary leaf let (pinnules) are alternate arrangement and arise from the rachis at about angles 90°. The pinnae are rectangular-oblong in shape, truncate apex, and without expanding at base. The adjacent pinnae are close together. Venation system not good preserved 6-8 veins in each pinna, or 33-44 per cm, pinnae length *ca*. 5 mm and 1.8 mm width.

Remarks: These leaves may be compared with *Pterophyllum kalawchiensis* (Barnard, 1967), which are the species which they most closely resemble *P. kalawchiensis* is distinguished leaves up to 10 cm wide adaxial attached pinnae on a smooth rachis. In *P. schenki* the leaves are narrow up to only 5 cm wide with pinnae attached laterally to the rachis which shown well developed transverse wrinkles.

Pterophyllum nathorsti (Schenk, 1883; Barnard, 1967)
Figure 6 e

1967 *Pterophyllum nathorsti* Schenk emend Barnard; pp. 561-563, plate 48, figure 5; text-figure 3F.
2003 *Pterophyllum nathorsti*: Schweitzer & Kirchner; pp.68-70, plate 14, figures 2-7; text-figures 23a, b, 24.

Material: Two fragments of monopinnate leaves.

Description: Leaf once pinnate, linear. Entire leaf length unknown, preserved fragment 128 mm long and 32 mm wide. Its longitudinally striated rachis is 2.4 mm wide. Pinnae set closely. The pinnae are oppositely inserted at an angle of 65°-75° with the whole base, rounded apices, 14-16 mm long and 3.2-4.4 mm wide. The venation is poorly preserved, just in two pinnules available which are parallel, simple or forking once near the pinnae base, 5-7 per pinnae.

Remarks: *Pterophyllum contiguum* (Schenk, 1883) resemble *P. nathorsti* (Schenk, 1883) but it differs in having fine and dichotomous veins (Vaez javadi, 2006).

Genus *Pterophyllum* (Brongniar, 1828)
Pterophyllum sp.
Figure 6d

Material: several fragment of incomplete monopinnate leaf.

Description: Incomplete leaves fragment, frond is pinnate. The leaf base and apex are absent, length estimated at 106 mm and up to 31.6 mm widths. Petiole is present, 11.5 mm length and 1.5 mm width. The rachis is 1.4 mm width with longitudinally delicate ribs. Pinnae attached to the

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Figure 5 a-d) *Cladophlebis denticulata* (Brongniart, 1828; Fontaine, 1889) a, b) Fragments of sterile fronds c) Fragment of pinnae showing details of the margin (teeth indicated by arrows). d) Details of pinnule venation e) *Klukia exilis* (Philips, 1829; Raciborski, 1890; Harris, 1961). Fragment of sterile frond (Scale bars represent 1 cm in all figures).

rachis with whole of base width laterally, at angles 45°, semi-opposite. The adjacent pinnae are close together. Pinnae margin are straight and parallel. Pinnae are oblong in shape, maximum length 26.6 mm and 2.5 mm width which pinnae length reduced in near the petiole (8.3 mm) and usually rectangular in shape, acute apex, Venation system is delicate and simple, 8-10 vein in each pinna.

Remarks: These leaves may be most closely resembled with *Pterophyllum aequale* (Brongniart, 1825; Nathorst, 1878) but in *Pterophyllum* sp. the pinnae are narrower than pinnae in *Pterophyllum aequale*.

Class Cycadopsida
Order Bennettitales
Family Williamsoniaceae
Genus *Ptilophyllum* (Morris, 1840)
Ptilophyllum sp.
Figure 7a

Material: Partly preserved of monopinnate leaf.

Description: Leaf pinnate (base and apex are not preserved), 48 mm long and 32 mm width. The rachis is 1.2 mm width, connected by pinnae base. Pinnae attached whole of base width at upper surface of rachis emerge at an angle of 45° and alternative arrangement on both sides of the riches. Pinnae liner-lanceolate in outline, 21 mm length and 2.7 mm wide at the base of pinnae, pinnae base in acroscopic margin slightly rounded or straight but in basiscopic margin are markedly decurrent, entire margin, almost parallel. The basiscopic margin slightly curved upwards in at the one-third of end the pinnae length. the margins converged upwards apex, apex sub-acute, venation system not well preserved ,8-10 veins per each pinna, veins without margin cut and parallel, continue until the near apex, only mid veins continue to apex and the edge veins cut the margin.

Class Ginkgoopsida
Order Ginkgoales
Family Ginkgoaceae
Genus *Ginkgoites* (Seward, 1911)
Ginkgoites sp.
Figure 5f

Material: A single specimen of a fan-shaped leaf.

Description: Leaf fan shaped, 46 mm length and 43.6 mm width, with a long and slender petiole, that up to 20 mm length and 1.8 mm width the basal angle of leaf 75°, lamina at the base divided to two branches, left branch is not subdivide, and truncate apex, however right branch subdivided to two lobes, lobes oblong in shape, with 38-46 mm length and 7.2 –8.1 mm width, another lobe is shallowly notched apex. Veins are indistinct.

Class Cycadopsida (Barnard and Long, 1975)
Order Cycadales (Engler, 1829)
Family Nilssoniaceae
Genus *Nilssonia* (Brongniart, 1825)
Nilssonia polymorpha (Schenk, 1867)
Figure 8 c

1867 *Nilssonia polymorpha* Schenk; p. 127, plate 29, figs 1-9; P1. 30, figure I.

2000 *Nilssonia* cf. *polymorpha* Schweitzer *et al.*; p. 20, plate 3, figs 3-5.

2001 *Nilssonia polymorpha* Barbacka; p.526, plate 1, figure 1; plate 2, figs 4-6; plate 3, figures 1, 2.

Material: Several poorly preserved specimens of various part of lamina. One species is more distinct than the other.

Description: Several incomplete leaves fragment of *N. polymorpha* occurring Chatroud section. The leaves in this species have 111 mm length and 41.6 mm width, the leaf basal and apex not preserved. The rachis is 2 mm width and very slightly sunken. The margin is entire, but sometimes slightly incised or deeply torn. Veins are parallel and arise from the rachis at angles of 80º. The vein concentration is 22-24 per cm. veins were parallel and simple slightly curved towards to apex, and outage the margin.

Remarks: The name of *N. polymorpha* shows a wide variability in leaf morphology. This species was first described by Schenk (1867). Other authors (Nathorst, 1878, 1886, 1909; Harris, 1926,

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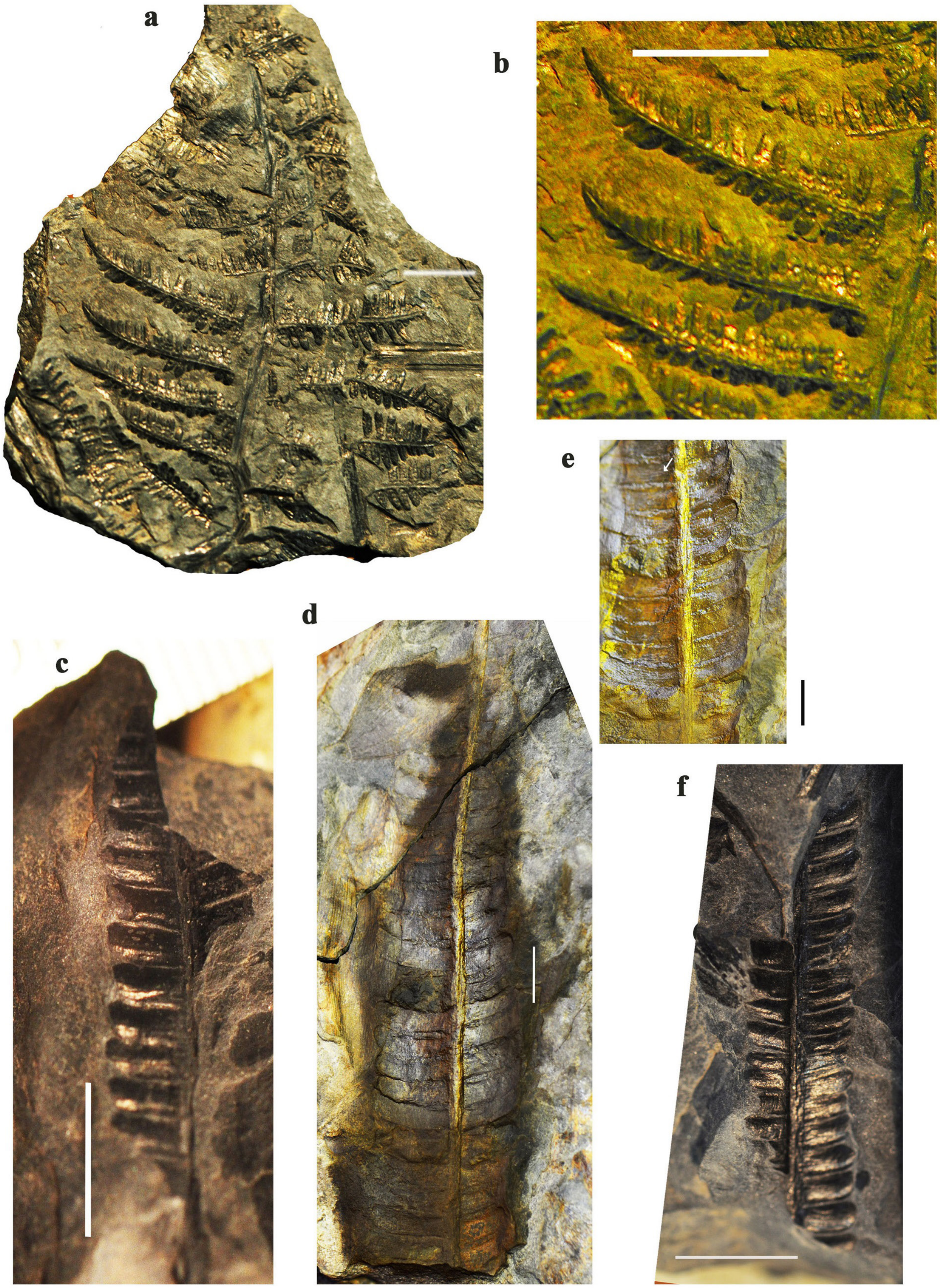

Figure 6 a, b) *Klukia exilis* (Philips, 1829; Raciborski, 1890; emend Harris, 1961) a) Fragment of fertile frond b) Distribution of sporangia c) *Pterophyllum schenki* (Zeiller, 1886, 1903), Part of the leaf fragment. d) *Pterophyllum* sp. Leaf fragment. e) *Pterophyllum nathorsti* (Schenk, 1883; emend Barnard, 1967) showing bifurcated vein (indicated by arrow). f) *Anomozamites marginatus* (Unger, 1850; Nathorst, 1878) leaf fragment. (Scale bars represent 1 cm in all figures).

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1932) have also mentioned different lamina shapes in this specimen. Harris (1932) gave the list of a number of revised specimens published by different authors under the name *N. polymorpha,* but in his opinion they were hardly determinate and probably belonging to different species. *N. polymorpha* is somewhat similar to *N. schaumbergensis* (Dunker) (Nathorst, 1880), *N. sarakhs* (Barnard and Miller, 1976) and *N. serratus* (Prynada) (Schweitzer *et al.,* 2000) but the *N. schaumbergensis* with narrower frond (less than 10 mm width) and dancer veins (30 per cm) is differ to *N. polymorpha. N. polymorpha* is more vein concentrations (24 per cm) but *N. sarakhs* has 18 veins per cm. *N. serratus* is differ to *N. polymorpha* by its more triangular- falcate shape of the pinnae and more veins each pinna.

Nilssonia feriziensis (Fakhr, 1975)
Figure 8 a, b

1975 *Nilssonia feriziensis* Fakhr, p. 219, plate 28, figures 3-5.
2000 *Nilssonia feriziensis*; Schweitzer *et al*., p. 35, plate 9, figure 3; plate 10, figure 1; text-figure 10 (fold-out 3).
Material: Two fragments of monopinnate leaves.
Description: Incomplete leaf fragments, 60-110 mm long and 50-55.2 mm wide. The leaf base and apex not preserved. The rachises are 2.1-2.8 mm width with longitudinally striated and sunken on the upper surface of leaf as a 1.2 mm deep furrow. Pinnae are weakly falcate in shape, arise from the rachis at angles of 55°-86°. The pinnae are 33.6-60 mm leaf arrangement is more or less alternate (whole length unknown) and 4-8 mm wide. The pinnae base is slightly curved, and narrow towards to apex pinnae apex were not clear (maybe acute). Veins are clear, parallel and slowly convergent towards to apex. 7-18 veins in each pinna.
Remarks: The *Nilssonia feriziensis* is very similar to *Nilssonia pterophylloides* but the main difference is that the pinnae bases are expanded in *N. pterophylloides* the pseudovenation is present in this specimen and a greater number of veins in *N. pterophylloides* comparison whit the *N. feriziensis*. *N. feriziensis* is quite similar to *N. riegeri* (Stur ex Krasser, 1909) from the upper Triassic of Lunz (lower Austria) (Pott *et al.,* 2007), but pinnae basally slightly expanded, and apex rounded in *N. riegeri.*

Nilssonia herriesi (Harris, 1946; Schweitzer *et al.*, 2000)
Figure 8 d

1911 *Nilssonia mediana* (Leck. ex Bean MS)-Seward; p. 29; plate 3, figures 45, 45a
1980 *Nilssonia mediana* (Leck. ex Bean) – Sadovnikov; p.86
2000 *Nilssonia herriesi* Schweitzer *et al*., p. 46, plate17, figure18; plate14, figures 1,2; text-figures 20a, b (fold-out 7).
Material: A single badly preserved of monopinnate leaf.
Description: Incomplete leaves fragment; 43.3 mm length and 36.5 mm widen (semi right of leaf and only semi parts of basal of pinnae in the left side preserved). Rachis not preserved. It can be seen that left and right pinnae meet in the middle of rachis. Pinnae arranged alternative- opposite up on the rachis. Pinnae arise from the rachis at angle of 90°; equal extend in the basiscopic and acroscopic pinnae. Straight margin slightly curved towards apex, rounded apex. Pinnae narrowed gradually towards apex and mostly band shaped. Pinnae have 36 mm length and 5-7 mm wide. Venation system is not clear. Similar veins, narrow, often parallel along the pinnae and converged towards the apex, 12-16 veins in each pinna.
Remarks: *N. herriesi* is similar to the *N. yabei* (Tateiwa, 1929), but its pinnae taper less quickly causing a more or less band shape. *N. macrophylla* (Jacob and Shukla, 1955) agrees in this larger leaf form. The pinnae base in the latter species is, however, not expanded.

Nilssonia sp. A
Figure 9b

Material: A single fragment of leaf, base and apex not preserved.
Description: One incomplete leaf fragment of *Nilssonia* sp. an occurring Chatroud section. Therefore, we cannot completely measure of character-

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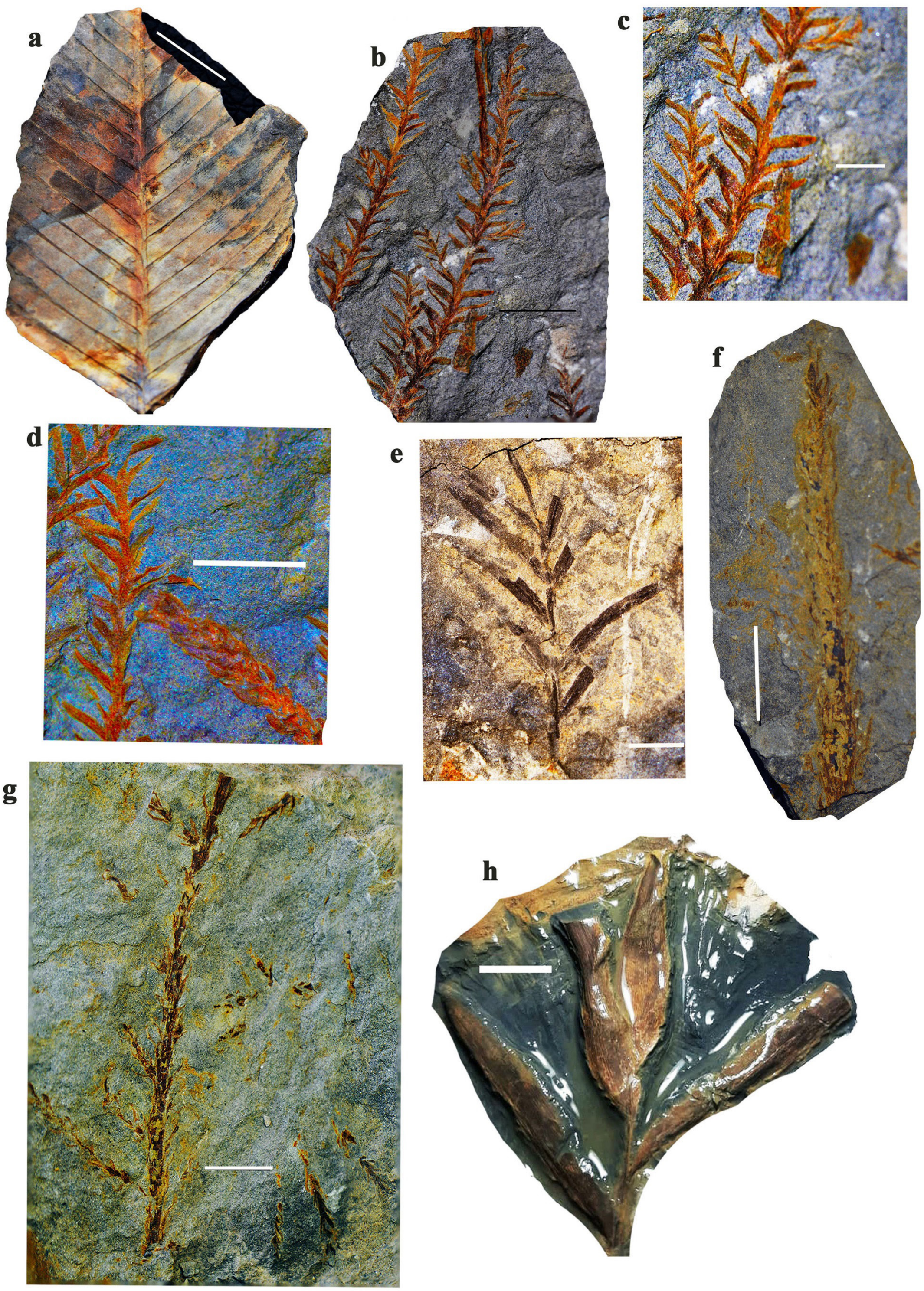

Figure 7 a) *Ptilophyllum* sp. Part of leaf showing rachis with pinnae. b-d) *Pagiophyllum* sp. leafy twigs. e) *Elatocladus zamioides* (Leckenby, 1864; Seward, 1919) leafy shoot with terminal leaflet. f) Elatides thomasii (Harris, 1979), fragment of foliated twig. g) *Geinitzia* sp. brunched foliated twig. h) *Podozamites distans* (Presl, 1838; Braun, 1843) leafy axis. (Scale bars represent 1 cm in all figures).

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istic of this sample. The lamina in this species has 55.5 mm length and 61 mm width, the leaf basal and apex not preserved. The rachis is 2 mm width the rachis surface is weakly longitudinally striated. The alternate or sub opposite pinnae arise from the rachis at angles of 60º-85. Pinnae are 23-33.3 mm length and 6.1-11.3 mm width. The pinnae baes are expanded at their basiscopic margin (lower margin), neighboring pinnae are separated by a sinus- shaped curve. The distance of between the pinnae is about 1.7 mm the more or less straight pinnae margin is almost parallel in the acroscopic margin. The venation system has weak preserved, parallel. The vein concentrations are 30/cm. the lateral veins cut the pinnae margin so that probably the mid veins continue to apex.

Nilssonia sp. B
Figure 9a

Material: One fragment of once pinnate leaf.
Description: Incomplete leaves fragment, 84 mm length and 43.3 mm width. The leaf base and apex not preserved. This species is characterized by pinnae with different width, that with a random process, the narrow pinnae are located between the width pinnae. The width of the pinnae at the base variable, 2.9 mm to 9 mm. the arrangement of the connection of the pinnae to rachis is form alternating to opposite due to the difference in width of pinnae. The shape of the pinnae is narrow isosceles triangle. The acroscopic and basiscopic margins are more or less symmetrically. Pinnae base without expended or very slightly pinnae apex is acute. Veins are arising from the middle of the rachis at angle 50º and immediately curve outwards. The veins almost parallel and converge near the apex.
Remarks: *Nilssonia* sp. B is comparable in shape with *N. ingens* (Schweitzer *et al.*, 2000) but differ in its narrower pinnae with their not (or nearly not) expanded bases. Macroscopically our leaves are most close to those of *N. macrophylla* (Jacob and Shukla, 1955) but differ in size of pinnae are 200 mm length and 9-28 mm in *N. macrophylla*, whereas, in the *N.* sp. B very smaller (21 mm length and 2.9-9 mm width).

Nilssonia sp. C
Figure 8e

Material: One specimen preserved, base and apex are absent.
Description: Incomplete leaves fragment, 91 mm length and 60 mm width. The leaf base and apex not preserved. Rachis is 2.5 mm width and delicate longitudinal ribs. Pinnae arrangement are alternative to semi opposite and arise from the rachis at angles 85º-90º, adjacent pinnae are close together, triangular shape. The basiscopic and acroscopic margins are almost straight the most of preserved pinnae length is 32.5 mm. Apex is not clear, pinnae width variable between 6.7-11.2 mm at the base. Not expanded the basiscopic and acroscopic margins. Venation system rear preserved veins parallel and delicate. There are 18-36 thin veins depending on the pinnae width, concentrations 34 veins/cm in the middle of the pinnae, it seems, the veins converge near apex.

Nilssonia sp. D
Figure 8 f

Material: A single leaf fragments, entire leaf length unknown.
Description: In this specimen the base and apex are absent. Length estimated at 106 mm, width *ca.*23.2 mm. The rachis is longitudinally striated, in proximal part 2.1 mm thick and in distal part narrowing to 1.4 mm. Pinnae with variable width and therefore partly alternately, partly oppositely attached; arising at an angle between 65°-75°. The pinnae lengths are equal about 11.5 mm and variable width between 2.8-5.3 mm the pinnae shape is triangular-falcate, some of them are rhomboidal. The pinnae margins are more or less entirely. Acroscopic margins are straight to weakly concave, basiscopic margins are strongly convex. The pinnae apex is usually rounded, rarely acute. Neighboring pinnae are separated up to the ra-

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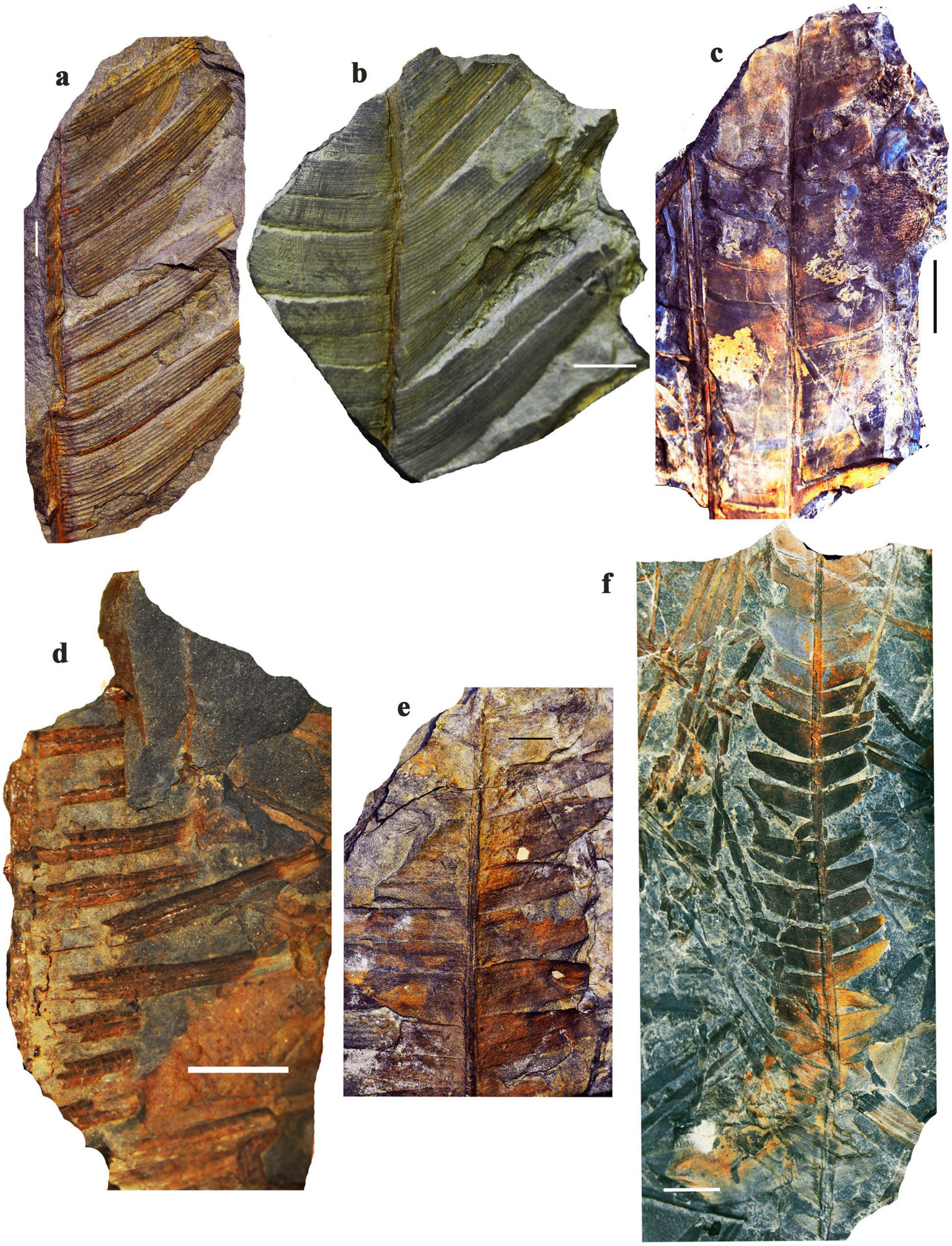

Figure 8 a, b) *Nilssonia feriziensis* (Fakhr, 1975) leaf fragments. c) *Nilssonia polymorpha* (Schenk, 1867) leaf fragment. d) *Nilssonia herriesi* (Harris, 1946; Schweitzer *et al.*, 2000) fragment of leaf, broken on the left side. e) *Nilssonia* sp. C part of leaf. f) *Nilssonia* sp. D linear leaf fragment. (Scale bars represent 1 cm in all figures).

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chis by a taper sinus-shaped curve. The venation system is, simple and almost parallel; basiscopic veins are more curved than acroscopic veins and they converge slightly towards the apex. There are ca.12-30 veins in each pinna.

Order Incertae sedis
Family Incertae sedis
Morphogenus *Spiropteris* (Schimper, 1869)

Type species *Spiropteris miltonii* (Brongniart) (Schimper, 1869)

Spiropteris sp.
Figure 9 d

Material: Imprint of a single coiled young fern.
Description: One incomplete fragment of *Spinopteris* sp. is occurring Chatroud section. Therefore, we cannot completely measure of characteristic of this sample. This species has up to 2.6 mm length and 3.2 mm width, smooth, without foliar appendage. Axis is involute.

Beania sp.
Figure 9 c

Material: One specimen preserved which showing the female cones of the Nilssoniaceae.
Description: A small fragment is preserved, longitudinally striated axis, 20.3 mm length and 2.1 mm width, 9 Sporangiophores which they are connected to the axis, with spiral form, and an angle of 90º-110º. The stalk is 1.7-3.5 mm length, 1.2 mm width and expanded in the basal part. Each stalk has one or two ovules (or seeds) in the end of stalk with ellipsoidal or rhomboidal in shapes, 2.1-5 mm 2.1-3.5 mm. Ovules are distinguished striped.

Neocalamites sp.
Figure 9 e

Material: A single specimen of a stem fragment. Only two nodes are visible which are separated by a 7.8 mm long internode.

Description: Incomplete secondary shoot fragment was, up to 60 mm length with node and internode, 6.4 mm width in the internode. Shoot have eminences in the node. The outer surface of the internode is characterized by broad longitudinal striae. In the top of each nodes have microphylls which curved towards up. The arrangement of the connection of the microphylls to shoot is whorled form. Maximum length of microphylls is 15 mm and between 0.7-1 mm widths. Microphylls were entirely free from base to up and vascularized by a single bundle.

Class Filicopsida
Order: Filicales
Family Schizaeaceae
Genus: *Klukia* (Raciborski, 1890) emend (Harris, 1961)
Klukia exilis (Philips, 1829) (Raciborski, 1890) emend (Harris, 1961)
Figure 6 a, b

1975 *Klukia exilis* Fakhr, p. 54, plate 9, figures 1-3;
2009 *Klukia exilis* H.-J. Schweitzer *et al.*, p. 27-31, Text-figure 2, plate 1, figures 1, 2, plate 2, figures 1-3, plate 3, figures 1-5.
2010 *Klukia exilis* Saadat-Nejad, *et al.*, p. 181-182, plate 1, figures 5-7.
Material: Two specimens of sterile and fertile bipinnate frond fragments.
Description: Incomplete leaf fragments, 53.6-75 mm long and, 41.8-67.6 mm width. The primary rachises are straight and the outer surface characterized by longitudinal grooves which is 53.6-73.5 mm long and 0.9-2 mm wide. The secondary rachises are straight and channeled along adaxial surface, with 22.7-25.8 mm long. The arrangement of the connection of the secondary rachis to primary rachis is suboppositely form an angle of 45º-50º. The pinnae are 22.7-40 mm long and 6.8-8 mm wide at the base, strongly elongated in outline. Pinnules are elongated, 2.5-6.3 mm long and 1.8-2.2 mm wide, with a decurrent base (although the fertile pinnules are narrower than sterile pinnules), entire margin and rounded apex the first pinnules in the acroscopic part longer than another pinnules in same pinna

and parallel with the primary rachis. Frond is katadromic. In the basiscopic margin the first pinnules is connected to secondary rachis with an angle 45º and compared to the other pinnules is shorter. The arrangement of the connection of the pinnules to rachis is form imparipinnate (odd pinnate) so in each pinna there is a terminal leaflet. Venation system is not good preserved, with a midrib which continued to top of pinnules. Lateral veins placed in both side of mid rib with angle 45º. In fertile pinnules are 4-6 ellipsoidal impressions distributed symmetrically along each side of midrib with 0.3-0.7 mm diameter.

Class Cycadopsida
Order: Bennettitales (Engler, 1892)
Family Unknown
Genus: *Anomozamites* (Schimper, 1870)
Anomozamites marginatus (Unger, 1850; Nathorst, 1878)
Figure 6 f

1850 *Pterophyllum marginatum*, Unger, p. 289
1991 *Anomozamites minor* (Brongniart) Nathorst; Barbacka, p. 18, plate 1 figs 6–7; plate 2 figs 1–3, Text figure 5.
2000 *Anomozamites marginatus* Barbacka; plate 1 figure 3, plate 2 figs 5-6, plate 3 figs 1-2, Figure 2.

Material: One fragment of monopinnate leaf with poorly preserved venation.

Description: Incomplete leave fragment, frond is pinnate, 35.5 mm length and 10 mm width. Frond is variable in shape. Pinnae attached to the rachis with whole of base width and laterally rachis with 0.6 mm width and wrinkled. Pinnae are 4-5 mm length and 2-3 mm width. Venation system weak preserved and only show on some pinnae, with simple and parallel veins trace that continue towards apex, rounded apex and sometimes truncate.

Order Filicales
Family Osmundaceae?
Genus *Cladophlebis* (Brongniart, 1849)
Cladophlebis denticulata (Brongniart, 1828; Fontaine, 1889)
Figures 5 a-d

2004 *Cladophlebis denticulata* (Brongniart) Harris: Rees and Cleal, pp. 26–28, text-figure 3D, plate 6, figure 4, plate 7, figs 1, 2.
2004 *Cladophlebis antarctica* Halle: Rees and Cleal, p. 25, text-figure 3C, plate 25, figure 2, plate7, figure 3.
2008 *Cladophlebis denticulata* (Brongniart) Harris: Ociepa in Birkenmajer and Ociepa, p. 34, figs 15A, 17F–G.
2008 *Cladophlebis antarctica* Halle: Ociepa in Birkenmajer and Ociepa, p. 32, figs 15B, 16, 17B.
2008 *Cladophlebis denticulata* (Brongniart) Fontaine: Barbacka and Bodor, pp. 135–138, plate 2, figure 5–9.

Material: The material consists of 7 sterile frond fragments were preserved mainly in sandstone and carbonaceous shale. Four of them are bipinnate fragments, not larger than 68.5 mm. The remaining specimens are fragments of separated pinnae reaching about 37 mm.

Description: Sterile fronds, bipinnate, Fragments 25-68.5 mm long and 22-62.8 mm wide. Rachis usually slightly ribbed 2.2-2.5 mm width. Pinnae fragment 21-37 mm length and 10.5-14 mm width and alternative arrangement. Pinnae axes attached to rachis with angle 45º-70º. Pinnae are oblong, entire margin, sometimes dentate in the end of pinnae. Pinnules have 5-7 mm length and 2-3.5 mm width, length to width ratio 1.4-2.5. Pinnae are sub-oppositely and oppositely emerge at angle about 45º, straight base, sometimes, acroscopic margin extended. Acute or sub-acute apex, midrib reaches pinnules apex, secondary veins dichotomies once, usually near midrib the lateral veins separated from midrib at angle 30º-45º the veins concentration is 6-12/0.5 cm in the near the margin of pinnae.

Order Coniferopsida
Class Coniferales
Family Podocarpaceae
Genus *Elatocladus* (Halle, 1913)
Elatocladus zamioides (Leckenby, 1864)
Figure 7 e

Material: Single leafy axis.

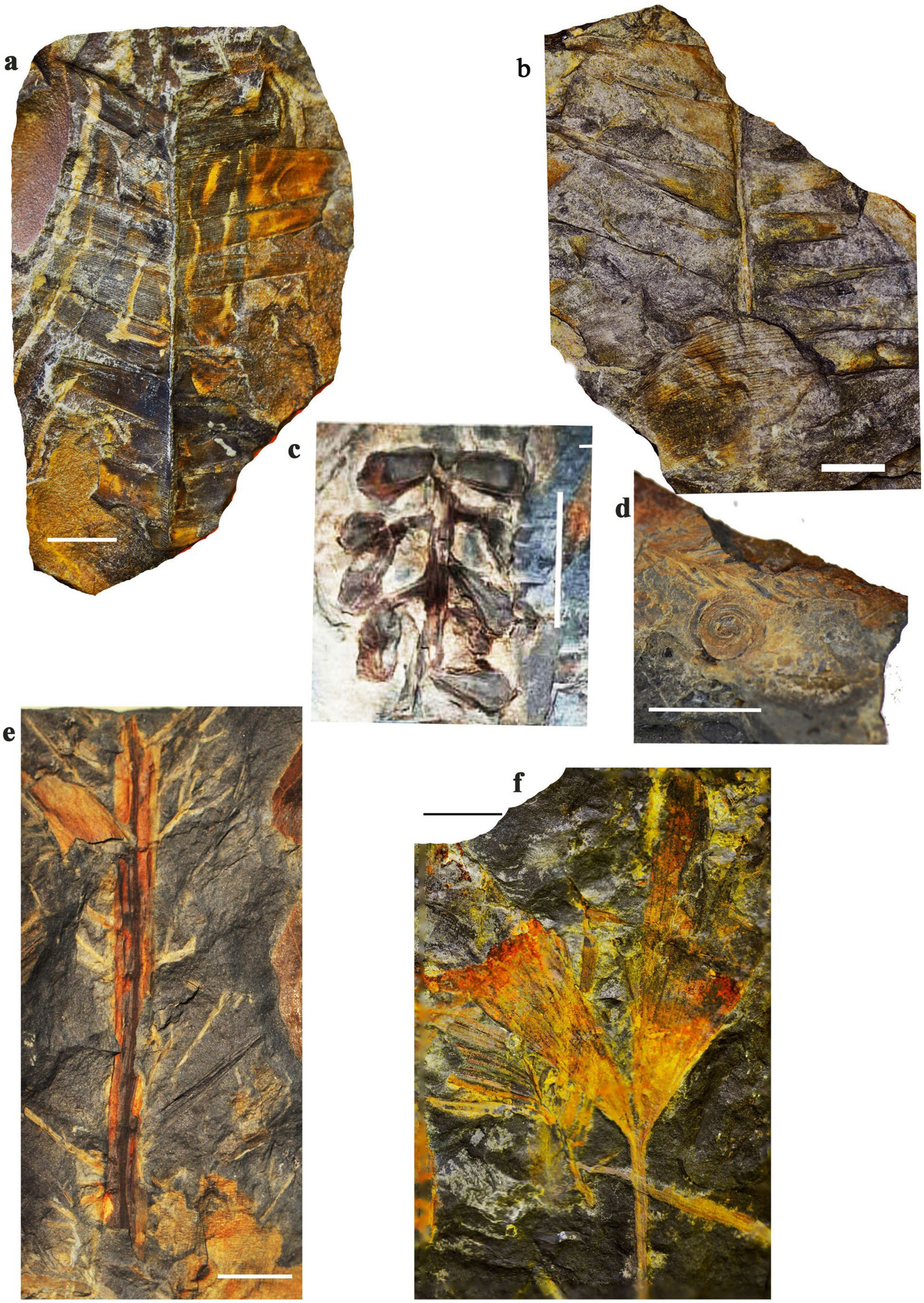

Figure 9 a) *Nilssonia* sp. B, leaf fragment without base and apex. b) *Nilssonia* sp. a fragment of leaf. c) *Beania* sp. axis with Sporangiophores. d) *Spiropteris* sp. coiled young fern. e) *Neocalamites* sp. stem fragment. f) *Ginkgoites* sp. fan-shaped leaf. (Scale bars represent 1 cm in all figures).

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Description: Shoot without branched, shoot base unknown but axillary buds present, shoot up to 34.3 mm length, shoot is narrow with 0.6 mm width. Leaves arrangement in a spirally on shoot, attached whole base, emerging at an angle 30º-50º, leaves linear-lanceolate in shape, 9.3-15 mm length and 0.9-1.8 mm width, entire margin, subacute apex, midrib prominent, running from base to apex. Folioles are without a petiole, base oblique, and decurrent.

Remarks: *Elatocladus zamioides* (Leckenby, 1864) from the middle Jurassic of Yorkshire was described as *Cycadites zamioides* and subsequently transferred to taxa its *E. zamioides* is very similar to some specimens from Jurassic beds as *Compsostrobus brevirostratus, E. confertus* (Morris, 1863), *E. plana* (Seward, 1911) and *E. persica. E. confertus* differs from *E. zamioides* in the shorter, a relatively broader leaves with an obtuse apex, with petiole and, elliptical in shape. The Indian species *E. plana* agrees closely with *E. zamioides* but differs in acuminate apex; lamina is slightly contracted at the base and longer leaves. *E. zamioides* differs from *E. persica* in the shorter and wider leaves and without petiole. The *E. zamioides* is very similar to *Compsostrobus brevirostratus* but *C. brevirostratus* differs from *E. zamioides* in the longer and narrower leaf, acuminate apex and acute base.

Class Coniferopsida
Order Coniferales
Family Cupressaceae *sensu lato*
Genus *Elatides* (Heer, 1876)
Elatides thomasii (Harris, 1979)
Figure 7 f

1979 *Elatides thomasii* Harris; pp. 74–77, plate 2, figures 8–13; text, figures 33E, J, 35 K, L.
1996 *Elatides thomasii*: Schweitzer and Kirchner.; pp. 103–113, plate 5, figures 1–5; plate 6, figures 1–8; plate 7, figures 1–10; plate 8, figures 1–7; text–figures 11, 12a, b, 13– 17, 18a–b, 19a–c, 20.

Material: One fragment of foliated twig preserved.

Description: Fragmentary twig with helically arranged leaves, leaves are narrow and falcate in shape, 3-6 mm long and ca.1mm wide basally, margins entire and tapering to acute apices, the free part of leaf forming half to one third of the whole length of the leaf.

5. Geographic and Stratigraphic Distribution of Taxa

Floristic association described here is widespread in Iran (Central Iran (Kerman, Tabas)) Alborz Basin) in the Lower–Middle Jurassic. Similar plant fossils assemblages have been distributed from the Asia at, Afghanistan (Schweitzer and Kirchner, 1996; Schweitzer *et al.*, 2000; Seward, 1911; Benda, 1964), Japan (Kawasaki, 1925; Endo, 1952; Oishi, 1938), Korea (Tatsuaki-Kimura and Bong-Kyun Kim, 1982), Russia (Thomas, 1911; Stanislavski, 1957; Vakhrameev, 1980), China (Yang, *et al.*, 2010; Zhou, 1995; Deng and Shang, 2000) and Transcaucasia (Prynada, 1933; Farinacci, 1967). From the Europe at Hungary (Barbacka, 2011; Barbacka and Bodor, 2008; Vozenin-Serra and Franceschi, 2000; Barbacka, 2000), Germany (Van Konijnenburg *et al.*, 2021; Barbacka *et al.*, 2015; Berger, 1812; Braun, 1843), Sardinia (Fontaine, 1889; Krasser, 1912, 1913, 1920), Yorkshire (Brongniart, 1828; van Konijnenburg-van Cittert, 2008), Poland (Raciborski, 1890, 1894), Greenland (Harris, 1926, 1932; Oishi, 1938), Romania (Czier, 2016), Sweden (Nathorst, 1886, 1878; Antevs, 1919), and New South Wales (White, 1981) (Table 1 and Figure 4).

Two plants fossil Biozones can be identified from the Ab-e-Haji and Hojedk formations in Chatrod section.

Anomozamites marginatus-Pterophyllum schenki zone and *Anomozamites marginatus* zone are found 7 meters from the base of the section, marking the lower boundary of this range. The first occurrence of *Anomozamites marginatus* is at the base of the Liassic *Thaumatopteris* zone (Harris, 1932; Barbacka, 2000). The last time *Pterophyllum schenki* was present can be used to determine the upper limit. The last occurrence of *Pterophyllum schenki* is within the upper part of the Liassic (Schweitzer and Kirchner,

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Table 1. The worldwide distribution of Lower to Middle Jurassic plant fossils.

Location	Asia														Europe								
	Iran								Transcaucasia	Afghanistan	Japan	Korea	Russia	China									
	Central Iran					Alborz																	
	Kerman				Tabas																		
	Pabdana	Babnizou	Hojedk	Lenjan		Karmozd	Tazareh	Alansar							Hungary	Germany	Sardinia	Yorkshire	Poland	Greenland	Romania	Sweden	New South Wales
Species / Authors	1, 2, 20	3, 4, 18	16	41-42	5, 20	6 - 8, 15, 19	4, 7-12 18, 21	13	41-42	43-46, 4, 3	34-36, 47	62	37-39, 53	65 66	22, 51, 54, 64	23, 49, 55-57	25, 24	26-33	40	48, 52	50, 63	58-60	61
Nilssonia polymorpha		*								*				*	*								
Pterophyllum nathorsti	*				*		*					*									*		
Podozamites distans	*	*	*		*		*			*					*	*		*				*	*
Elatides thomasii		*			*					*													
Cladophlebis denticulata		*					*			*			*		*		*			*			
Nilssonia feriziensis	*	*	*		*																		
Nilssonia herriesi		*					*			*													
Anomozamites marginatus				*											*	*				*			
Pterophyllum schenki	*				*	*					*									*			
Klukia exilis	*	*		*	*	*	*	*	*		*		*	*			*	*	*				

Note: *1*- (Schweitzer and Kirchner, 1995), *2*- (Ameri ***et al.***, 2014b), *3*- (Schweitzer and Kirchner, 1996), *4*- (Schweitzer ***et al.***, 2000), *5*- (Vaez Javadi, 2014), *6*- (Kipper, 1964), *7*- (Sadovnikov, 1976), *8*- (Schweitzer ***et al.***, 2009), *9*- (Kipper, 1971), *10*- (Sadovnikov, 1984), *11*- (Sadovnikov, 1991), *12*- (Schweitzer and Kirchner, 1998), *13*- (Popa ***et al.***, 2012), *14*- (Barnard and Miller, 1976), *15*- (Corsin ***et al.***, 1977), *16*- (Ameri ***et al.***, 2014a), *17*- (Ameri, 2018), *18*- (Schweitzer ***et al.***, 1997), *19*- (Fakhr, 1975), *20*- (Schweitzer ***et al.***, 2003), *21*- (Vaez Javadi, 2006), *22*- (Barbacka, 2011), *23*- (Van Konijnenburg ***et al.***, 2021), *24*- (Fontaine, 1889), *25*- (Krasser, 1912, 1913, 1920), *26*- (Brongniart, 1982), *27*- (Bunbury, 1851), *28*-(Zigno, 1856), *29*- (Phillips, 1829), *30*- (Seward, 1898, 1900), *31*- (Thomas, 1911), *32*- (Harris, 1946, 1961, 1964, 1969, 1979), *33*- (van Konijnenburg-van Cittert, 2008), *34*- (Kawasaki, 1925), *35*- (Oishi, 1940), *36*- (Endo, 1952), *37*- (Thomas, 1911), *38*- (Prynada, 1938), *39*- (Stanislavski, 1957), *40*- (Raciborski, 1890, 1894) *41*- (Prynada, 1933), *42*- (Farinacci, 1967), *43*- (Seward, 1911), *44*- (Sitholey, 1940), *45*- (Jacob and Shukla, 1955), *46*- (Benda, 1964), *47*- (Oishi, 1938), *48*- (Harris, 1926, 1932), *49*- (Barbacka ***et al.***, 2015), *50*- (Czier, 2016), *51*- (Barbacka and Bodor, 2008), *52*- (Oishi, 1938), *53*- (Vakhrameev, 1980), *54*- (Vozenin-Serra and Franceschi, 2000), *55*- (Berger, 1812), *56*- (Presl, 1838), *57*- (Braun, 1843), *58*- (Nathorst, 1886, 1878), *59*- (Halle, 1908), *60*- (Antevs, 1919), *61*- (White, 1981), *62*- (Tatsuaki Kimura and Bong-Kyun Kim, 1982), *63*- (Popa ***et al.***, (2012), *64*- (Barbacka, 2001), *65*- (Yang, ***et al.***, 2010), *66*- (Zhou, 1995; Deng and Shang, 2000).

2003; Vaez-Javadi, 2006). Other associated species are *Nilssonia polymorpha, N.* sp., *Pterophyllum nathorsti*, *Podozamites distans*, *Elatocladus zamioides*, and *Elatides thomasii.*

Klukia exilis zone: The first and last appearances of *Klukia exilis*, which are between 125 and 200 meters from the section's base, define the boundaries of this interstitial zone. There have been reports of and descriptions of *Klukia exilis* from all over the world, and its stratigraphic range is significant for the Middle Jurassic period. But according to Schweitzer *et al.* (2009), this species is regarded as a typical, marker taxon for the lower Middle Jurassic (Aalenian-Bajocian) in Iran and Afghanistan. *Nilssonia* sp., *Pterophyllum nathorsti, Podozamites distans, Elatocladus zamioides, Elatides thomasii, Cladophlebis denticulate, Nilssonia feriziensis, Nilssonia herriesi,* and *Beania* sp. are some of the other species that are associated.

6. Conclusion

In particular, the Ab-e-Haji and Hojedk formations succession of the Shemshak Group are widely cropped out in the Kerman basin. There are numerous, well-preserved fossilized plant remains from 18 species spread throughout 14 genera, in the Ab-e-Haji and Hojedk formations of the Chatroud region. *Nilssonia Pterophyllum, Podozamites, Elatocladus, Elatides, Cladophlebis, Klukia, Anomozamites, Ptilophyllum, Beania, Neocalamites, Geinitzia, Pagiophyllum,* and *Ginkgoites,* which is described for the first time in this study. Two plant assemblages' zones are identified in this area; *Anomozamites marginatus-Pterophyllum schenki* zone, that characteristic by the first appearance of *Anomozamites marginatus* and in upper limited by the last presence of *Pterophyllum schenki*. The Liassic is thought to include this time period. *Klukia exilis* zone this interval zone limited by the first and last appearance of *Klukia exilis*. In Iran and Afghanistan, this species is regarded as a representative, marker taxon for the lower Middle Jurassic (Aalenian-Bajocian). A humid-warm temperate climate can be deduced for the Lower-Middle Jurassic in the Kerman region based on the presence of Taxodiaceae family Taxodiaceae (Geinitzia), Equisetacea family (Neocalamites), Araucariaceae family (Pagiophyllum), and Williamsoniaceae family (Pterophyllum).

Author Contributions

Study concept and design: Ameri H., and Shaghayeghi P.; analysis and interpretation of data: Ameri H., and Shaghayeghi P., fieldwork: Ameri H., and Shaghayeghi P., drafting of the manuscript: Ameri H.; critical revision of the manuscript for important intellectual content: Ameri H.; statistical analysis: Ameri H., financing: Institute of Science, and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran.

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Conflicts of interest

No potential conflict of interest was reported by the authors.

References

Aghanabati, A., 1998, Jurassic stratigraphy of Iran: Tehran, Iran, Geological Survey of Iran, 356 p.

Ameri, H., 2018,The Bajocian–Bathonian plant fossil from the Hojedk Formation, Lenjan section, Kerman, Iran: Arabian Journal of Geosciences, 11(3), 66. https://doi.org/10.1007/s12517-017-3339-8

Ameri, H., Dastanpour, M., Khalilizade, H., Zamani, F., 2014a, Plant fossil remains from the Bajocian–Bathonian of Hojedk Formation, Babhutk area, Kerman, Iran: Arabian Journal of Geosciences, 7, 2293–2302.https://doi.org/10.1007/s12517-013-0878-5

Ameri, H., Khalilizade, H., Zamani, F., 2014b, Four New Equisetites Species (Sphenophyta) from the Hojedk Formation, Middle Jurassic (Bajocian-Bathonian), the North of Kerman, Iran: Journal of Sciences, Islamic Republic of Iran, 25(3), 253-264.

Antevs, E., 1919, Die liassische flora des Hörsandsteins: Geologiska Föreningen i Stockholm Förhandlingar, 41 (6), 524-527.

Barbacka, M., 2000, Bennettitales from the Mecsek Mountains Liassic, Hungary: Acta Palaeobotani, 40(2),111-127.

Barbacka, M., Bodor, E., 2008, Systematic and palaeoenvironmental investigations of fossil ferns Cladophlebis and Todites from the Liassic of Hungary: Acta Palaeobotanica, 48(2),133-149.

Barbacka, M., 2011, Biodiversity and the reconstruction of Early Jurassic flora from the Mecsek Mountains (southern Hungary): Acta Palaeobotanica, 51(2), 127-179.

Barbacka, M., Püspöki, Z., Bodor, E., Forgács, Z., Hámor-Vidó, M., Pacyna, G., McIntosh, R.W., 2015, Palaeotopography related plant succession stages in a coal forming deltaic succession in early Jurassic in Hungary: Palaeogeography, Palaeoclimatology, Palaeoecology, 440, 579-593. https://doi.org/10.1016/j.palaeo.2015.09.027

Barnard, P., 1967, Flora of the Shemshak formation. Part 2. Liassic plants from Shemshak and Ashtar: Rivista Italiana di Plaleontologia e Stratigrafia, 73,539-589.

Barnard, P. D., Miller, J.C., 1976, Flora of the Shemshak Formation (Elburz, Iran), Part 3: Middle Jurassic (Dogger) plants from Katumbargah, Vasek Gah and Imam Manak: Palaeontographica Abteilung B, 31-117.

Berger, F., 1812, Dissertation sur l'ophthalmie (Cand. Franc. Berger.): Doctoral dissertation.

Bonamo, P. M., 1975, The Progymnospermopsida: building a concept: Taxon, 24(5-6), 569-579.

Braun, K. F.W., 1843, Beiträge zur Urgeschichte der Pflanzen: Gedruckt bei FC Birner, Vol. 1.

Brongnian, A., 1825, Observations sur vegetaux fossiles renformes dans les Gres de Hoer en Scanie: Annales des Sciences Naturelles, Paris, I (4), 200- 219.

Brongniart, A., 1825, Essai d'une classification naturelle des champignons, ou Tableau méthodique des genres rapportés jusqu'à preśent à cette famille: Paris, FG Levrault, 107p.

Brongniart, A., 1828, Prodrome d'une histoire des végétaux fossils: Paris, FG Levrault, 232p.

Brongniart, A., 1849, Tableau des genres de végétaux fossils: Dictionnaire universel d'Histoire Naturelle, vol. 13, Martinet, Paris, 140p.

Burger, B. J, Ward, C. J., 2016, On the occurrence of fossil conifers with affinities to Geinitzia in the late Cretaceous (Campanian) Mesaverde Group, Williams Fork Formation of northeastern Utah, USA: PeerJ Preprints, 4, e1862v1861. https://doi.org/10.7287/peerj.preprints.1862v1

Costamagna, L.G., Kustatscher, E., Scanu, G.G., Del, Rio, M., Pittau, P., van Konijnenburg-van, Cittert, J.H., 2018, A palaeoenvironmental reconstruction of the Middle Jurassic of Sardinia (Italy) based on integrated palaeobotanical, palynological and lithofacies data assessment: Palaeobiodiversity and Palaeoenvironments, 98(1), 111-138. https://doi.org/10.1007/s12549-017-0306-z

Czier, Z., 2016, European Paleofloristic Affinities of the Romanian Jurassic Macroflora: Folia naturae Bihariae Oradea, 13, 66.

De Franceschi, D., Vozenin-Serra, C., 2000, Origin of Ginkgo biloba L. Phylogenetic approach: Comptes Rendus de L'academie des sciences. Serie III, Sciences de la vie, 323(6), 583-592.https://doi.org/10.1016/s0764-4469(00)00178-5

Deng, S., Wang, S., 2000, Klukiopsis jurassica—a new Jurassic schizaeaceous fern from China: Science in China Series D: Earth Sciences, 43, 356-363. https://doi.org/10.1007/BF02959446

De Zigno, A., 1856, Sulla flora fossile dell'oolite: Venecia, Presso la Segreteria dell'IR istituto, 15p.

Endlicher, S., 1847, Conspectus coniferrarum fossilium, in Endlicher S. (ed.), Synopsis coniferarum: Sangalli, Scheitlin & Zollikofer, 267–368.

Endo, R., 1952, Stratigraphical and paleontological studies of the later Palaeozoic calcareous algae in Japan II. Several previously described species from the Sakamotozawa section, Hikoroichi-mura, Kesen-gun, in the Kitakami Mountainous Land: Transactions and Proceedings of the Paleontological Society of Japan, 5, 139-144.

Engler, A., 1892, Syllabus der Vorlesungen über specielle und medicinisch-pharmaceutische Botanik: Eine Uebersicht über das ganze Pflanzensystem mit Berücksichtigung der Medicinal- und Nutzpflanzen: Berlin, Grosse Ausg, 186p. https://doi.org/10.5962/bhl.title.69853

Fakhr, M.S., 1975, Contribution a letude de la flora rheto-liassique de la Formation Shemshake de L Elbours (Iran): These, University Pierre et Marie Curie Paris VI: Publication du laboratoire de Paleobotanique de 1' University Paris, 2, 421.

Farinacci, A., 1967, La serie giurassico-neocomiana di Monte Lacerone (Sabina). Nuove vedute sull'interpretazione paleogeografica delle aree di facies umbro-marchigiana: Geologica Romana, 6, 421-480.

Fontaine, W. M., 1889, The Potomac or younger Mesozoic flora: US Government Printing Office, Vol. 15, 750p. https://doi.org/10.3133/m15

Halle, T. G., 1913, The mesozoic flora of Graham Land: Stockholm, Lithographisches Institut des Generalstabs, 123p.

Harris, T.M., 1926, Note on a new method for the investigation of fossil plants: New Phytologist, 25(1), 58-60.

Harris, T. M., 1932, The fossil flora of Scoresby Sound, East Greenland: 2. Meddel, om Grønland 85 (3): 1–112, pls.

Harris, T.M., 1937, The fossil flora of Scoresby Sound East Greenland, part 5: Stratigraphic relations of the plant beds. Medd. Grønland, 112(2), 1–114.

Harris, T.M., 1946, I.—Notes on the Jurassic flora of Yorkshire: Journal of Natural History, 13(97), 1-24.

Harris, T.M., 1953, Conifers of the Taxodiaceae from the wealden formation of Belgium: Mém. Inst. Royal Science. Natural Belgique, 126, 1–43.

Harris, T.M., 1961, The Yorkshire Jurassic Flora. Part 1: Thallophyta and Pteridophyta. London: British Museum (Natural History).

Harris, T. M., 1964, The Yorkshire Jurassic Flora. II. Caytoniales, Cycadales, Pteridosperms: London, British Museum (Natural History), 214p.

Harris, T. M., 1969. The Yorkshire Jurassic Flora. III. Bennettitales: London, British Museum (Natural History), 186p.

Harris, T.M., 1979, Notes on two of Raciborski's ferns: Acta Palaeobotanica, 18, 3-12.

Heer, O., 1876, Beiträge zur fossilen Flora Spitzbergens: gegründet auf die Sammlungen der schwedischen Expedition vom Jahre 1872 auf 1873 (Vol. 4). Norstedt, 176p.

Heer, O., 1881, Contributions à la flore fossile du Portugal: l'Académie Royale des Sciences, 78p.

Houtum-Schindler, A., 1881, Art. XX.—Notes on Marco Polo's Itinerary in Southern Persia (Chapters XVI. to XXI., Col. Yule's Translation): Journal of the Royal Asiatic Society of Great Britain and Ireland (New Series), 13(04), 490-497.

Huckriede, R., 1962, Zur geologie des gebietes zwischen Kerman und Sagand (Iran): Beihefte zum Geologischen Jahrbuch, (51),1-197.

Leckenby, J., 1864, On the sandstones and shales of the oolites of Scarborough, with descriptions of some new species of fossil plants: Quarterly Journal of the Geological Society, 20(1-2), 74-82.

Jacob, K., Shukla, B. N., West, W. D., 1955, Jurassic Plants from the Saighan Series of Northern

Afghanistan and Their Paleo-climatological and Paleo-geographical Significance.

Kawasaki, S., 1925, Bulletin Geology Survey Chosen (Korea), 4(1), 1-71.

Kimura, T., Kim, B.K., 1982, Coreanophyllum variisegmentum gen. et sp. nov. from the Daedong Supergroup, Korea: Proceedings of the Japan Academy, Series B, 58(6), 152-155.

Krasser, F., 1912, Williamsonia in Sardinien: Buchhändler, Sitzungsberichte Akademie der Wissenschaften in Wien, 121, 943-973.

Krasser, F., 1913, Die fossile Flora der Williamsonien bergenden Juraschichten von Sardinien: Anzeig. Akad. Wissensch, 4, 31-36.

Krasser, F., 1920, Doggerflora von Sardinien: Sitzungsberichte, Akademie der Wissenschaften in Wien, Mathematisch-naturwissenschaftliche Klasse, 129, 3-26.

Nathorst, A.G., 1878, Beiträge zur fossilen Flora Schwedens: uber einige rhätische Pflanzen von Pålsjö in Schonen: Schweizerbart.

Nathorst, A.G., 1880, Några anmärkningar Om Williamsonia Carruthers: Öfversikt af Kongliga Vetenskaps-Akademiens Förhandlingar, 9, 33-52.

Nathorst, A.G., 1886, Om floran i Skanes kolforande Bildingar. I. Floran vid Bjuf: Sveriges Geologiska Undersokning Serie C, 85, 83-116.

Nathorst, A.G., 1878-1886, Om floran i Skånes kolförande bildningar: Andra häftet. Sveriges Geologiska Undersökning, Serie C, 27, 33, 85, 1-126.

Nathorst, A.G., 1909, Paläobotanische Mitteilungen, 8. Über Williamsonia, Weilandia, Cycadocephalus und Weltrichia: Kungliga Svenska Vetenskapsakademiens Handlinga, 45, 1-37.

Nathorst, A.G., 1911, Paläobotanische Mitteilungen 9. Neue Beiträge zur Kenntnis der Williamsonia-Blüten: Kungliga, 46, 1-33.

Ôishi, S., 1938, On the Cuticles of Tertiary Ginkgoites Leaves from Kuzi, Iwate Prefecture: Journal of the Faculty of Science, Hokkaido Imperial University. Ser. 4, Geology and mineralogy, 4(1-2), 103-106.

Phillips, J., 1829, Illustrations of the Geology of Yorkshire. Part 1: The Yorkshire Coast: Printed for the author by T., Wilson, York, 1e192.

Poole, I., Ataabadi M. M., 2005, Conifer woods of the Middle Jurassic Hojedk Formation (Kerman Basin), Central Iran: Iawa Journal. 26(4),489. https://doi.org/10.1163/22941932-90000130

Popa, M. E, Javidan, M., Falahatgar, M., 2012, Klukia exilis (Philips 1829) Raciborski 1890 emend. Harris 1961 from Ahan Sar, Shemshak group, Iran: Acta Palaeontologica Romaniae. 8(1-2), 33-41 https://doi.org/10.1007/s12549-018-0361-0

Pott, C., Kerp, H., Krings, M., 2007, Pseudoctenis cornelii nov. spec.(cycadalean foliage) from the Carnian (Upper Triassic) of Lunz, Lower Austria. Annalen des Naturhistorischen Museums in Wien Serie A für Mineralogie und Petrographie: Geologie und Paläontologie, Anthropologie und Prähistorie, 1-17.

Prynada, B., 1933, Jurassic plants from the Tkvarcheli carboniferous Basin in Transcaucasia: Transactions of the United Geological and Prospecting Service USSR, 261, 1-40.

Raciborski, M., 1890, Flora retycka w Tatrach: Kraków, Nakł. Akademii Umiejętności, 243-260.

Raciborski, M., 1894, Flora kopalna ogniotrwalych glinek Krakowskich: Kraków, Nakł. Akademii Umiejętności, 101p.

Sadovnikov, G., 2019, Plant Communities and Ecostratigraphy of the Lower and Middle Jurassic of Northern Iran: Stratigraphy and Geological Correlation, 27(7),783-803. https://doi.org/10.1134/S0869593819070037

Sahni, B., 1928, Revisions of Indian fossil plants: Part 1: Coniferales (a. Impressions and Incrustations). Vol. 11. Alexander Doweld.

Schenk, A., 1867, Die fossile Flora der Grenzschichten des Keupers und Lias in Franken: Wiesbaden, C.W. Kreidel's Verlag, 232p.

Schimper, W. P., 1869, Traité de paléontologie végétale: ou, La flore du monde primitif dans ses rapports avec les formations géologiques et la flore du monde actuel(Vol. 1): JB Baillière et fils.

Schimper, W. P., 1870, Trait6 de Pal6ontologie V6g6tale ou la Flore du Monde Primitil 2: Paris, J.B. Baillidre et fils, 522p.

Schweitzer, H-J., 1978, Die räto-jurassischen Floren des Iran und Afghanistans. 5. Todites princeps, Thaumatopteris brauniana und Phlebopteris polypodioides: Palaeontographica Abteilung B, 168(1-3),17-60.

Schweitzer H-J., Kirchner, M., 1995, Die Rhäto-Jurassischen Floren des Iran und Afghanistans: 8. Ginkgophyta: Palaeontographica Abteilung B, 237(1-3),1-58.

Schweitzer, H-J., Kirchner, M., 1998, Die rhäto-jurassischen Floren des Iran und Afghanistans. 11. Pteridospermophyta und Cycadophyta I Cycadales: Palaeontographica Abteilung B, 248(1-3),1-85. https://doi.org/10.1127/palb/248/1998/1

Schweitzer, H-J., Kirchner, M., van Konijnenburg-van Cittert JH., 2000, The Rhaeto-Jurassic flora of Iran and Afghanistan. 12. Cyadophyta II. Nilssoniales: Palaeontographica Abteilung B: 254(1-3),1-63. https://doi.org/10.1127/palb/254/2000/1

Schweitzer, H-J., van Konijnenburg-van, Cittert, JH., van der Burgh, J., 1997, The Rhaeto-Jurassic flora of Iran and Afghanistan. 10. Bryophyta, Lycophyta, Sphenophyta, Pterophyta-Eusporangiatae and-Protoleptosporangiatae: Palaeontographica Abteilung B, 243(4-6),103-192.

Schweitzer, H-J., 1978, The derivation of the hermaphroditic flower of the angiosperms by consideration of new fossils from the Raetic of Iran: Courier Forschungsinst: Senckenberg, 30,16-26.

Schweitzer, H-J., 1977, Die rato-jurassischen Floren des Iran und Afghanistans. 4. Die ratische Zwitterblute Irania hermaphroditica nov. spec. und ihre Bedeutung fur die Phylogenie der Angiospermen: Palaeontographica, B. 161, 98-145.

Schweitzer, H-J., Kirchner, M., 1996, Die rhäto-jurassischen Floren des Iran und Afghanistans: 9. Coniferophyta: Palaeontographica Abteilung B, 238(4-6), 77-139.

Schweitzer H-J., Kirchner, M., 2003, Die Rhäto-jurassischen Floren des Iran und Afghanistans. 13. Cycydophyta III. Bennettitales: Palaeontographica Abteilung B, 264(1-6),1-166. https://doi.org/10.1127/palb/264/2003/1

Schwitzer H-J., Schweitzer, U., Kirchner, M., van Konijnenburg-van, Cittert, JH., van der Burgh, J., Ashraf, R.A., 2009, The Rhaeto-Jurassic flora of Iran and Afghanistan. 14. Pterophyta--Leptosporangiatae. (With 50 plates, 43 text figures and 3 tables in the text and on one fold-out): Palaeontographica Abteilung B. 279(1),1-108. https://doi.org/10.1127/palb/279/2009/1

Scotese, C.R., 2011, Paleogeographic and paleoclimatic atlas: AAPG Search and Discovery Article, 30192. https://doi.org/10.13140/2.1.5102.1440

Seward, A.C., 1898, Fossil plants: 1 reprint 1963, London, Hafner publishing, 414p.

Seward, A.C., 1900, Catalogue of the Mesozoic Plants in the Department of Geology: British Museum (Natural History), Part III-IV, The Jurassic Flora (Vol. 1), 385p.

Seward, A.C., 1911, The Jurassic flora of Sutherland: Transactions of the Royal Society of Edinburgh, 4'l (4), 648-709.

Seyed-Emami, K., 1971, The Jurassic Badamu Formation in the Kerman region, with some remarks on the Jurassic stratigraphy of Iran: Geological Survey of Iran, Report. 19(1-80),1-264.

Stanislavski, F.A., 1957, Jurassic Flora of the Don Basin and Dnieper-Donetz region: The

Academy of Sciences, 128p.

Sukh D, Dev S, Bano, Z., 1979, Occurrence of the genus Ctenozamites in the Jabalpur Formation.

Tateiwa, I., 1929, Geological atlas of Chosen (Korea), no. 10, Keishu-Eisen-Taikyu and Wakwan Sheets, 1/50000: Geology Survy Chosen (Korea), 168p.

Thomas, H.H., 1911, The Jurassic flora of Kamenka: in the Distrcit of Isium: Mém. Com. Géol. St.-Pétersb. n.s., v. 71, p. 1-95.

Unger, F., 1850, Genera et species plantarum fossilium: Braumüller, 627p. https://doi.org/10.5962/bhl.title.26645

Vaez-Javadi, F., 2011, Middle Jurassic flora from the Dansirit Formation of the Shemshak Group, Alborz, north Iran: Alcheringa, 35(1), 77-102. https://doi.org/10.1080/03115518.2010.489424

Vaez-Javadi, F., 2018, Middle Jurassic Flora from the Hojedk Formation of Tabas, Central East Iran: Biostratigraphy and Palaeoclimate implications: Rivista Italiana di Paleontologia e Stratigrafia,124(2), 299-316. https://doi.org/10.13130/2039-4942/10083

Vaez-Javadi, F, Mirzaei-Ataabadi, M., 2006, Jurassic plant macrofossils from the Hojedk Formation, Kerman area, east-central Iran: Alcheringa, 30(1), 63-96. https://doi.org/10.1080/03115510608619345

Vahdati-Daneshmand, F., Mosavvary, F., Mahmudy, Ghareei, M., Ghasemi,A., 1995, Geological Map of Zarand, 1: 100,000 Series, Sheet 7358: Geology Survey of Iran.

Vakhrameev, V.A., 1980, Classopollis pollen as an indicator of Jurassic and Cretaceous climates: Sovetskaya Geologiya, 8, 48-56.

van Konijnenburg-van Cittert, J.H., 2008, The Jurassic fossil plant record of the UK area: Proceedings of the Geologists' Association, 119(1), 59-72. https://doi.org/10.1016/S0016-7878(08)80258-1

van Konijnenburg-van Cittert, J.H., Pott, C., Schmeißner, S., Dütsch, G., Kustatscher, E., 2021, The Rhaetian flora of Wüstenwelsberg, Bavaria, Germany: Description of selected gymnosperms (Ginkgoales, Cycadales, Coniferales) together with an ecological assessment of the locally prevailing vegetation: Review of Palaeobotany and Palynology, 288, p.104398. https://doi.org/10.1016/j.revpalbo.2021.104398

White, M., 1981, Cylomeia undulata (burges) gen. et comp. nov., a lycopod of the early Triassic strata of New South Wales: Records of the Australian Museum, 33(16), 723-734. https://doi.org/10.3853/j.0067-1975.33.1981.270

Yang, X., Zhang, W., Zheng, S., 2010, An osmundaceous rhizome with sterile and fertile fronds and in situ spores from the Jurassic of western Liaoning: Chinese Science Bulletin, 55, 3864-3867. https://doi.org/10.1007/s11434-010-4191-3

Zeiller, M. D., 1886, Observations ur les genres Ulodendron et Bothrodendron. C. r. somrn. Sianc: Soc. Geological 3, 14, 1886-1888.

Zeiller, M. D., 1903, Vegetaux fossiles du terrain carbonifere du Donetz, 1 Lycopodiales: Trudy geological Kom. N.s. 13, 126p.

Zhou, Z., 1995, On some Cretaceous pseudofrenelopsids with a brief review of cheirolepidiaceous conifers in China: Review of Palaeobotany and Palynology, 84(3-4), 419-438. https://doi.org/10.1016/0034-6667(94)00078-X