

## Four New Equisetites Species (Sphenophyta) from the Hojedk Formation, Middle Jurassic (Bajocian-Bathonian), the North of Kerman, Iran

H. Ameri<sup>1\*</sup>, H. Khalilizade<sup>2</sup> and F. Zamani<sup>3</sup>

<sup>1</sup>Department of Ecology, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Islamic Republic of Iran

<sup>2</sup>Department of Geology, Payame Noor University, Shiraz, Islamic Republic of Iran

<sup>3</sup>Department of Geology, Faculty of Sciences, Isfahan University, Isfahan, Islamic Republic of Iran

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### Abstract

Middle Jurassic (Bajocian-Bathonian) Sphenophyta fossils of the silicified level peats of the Pabdana Coal Mine (Kerman) recovered. Four new species of Sphenophyta described for the first time. They include *Equisetites pabdanaei* sp. nov., *Equisetites sparseii* sp. nov., *Equisetites hojedkii* sp. nov. and *Equisetites irregularii* sp. nov.,. Descriptions of the above mentioned new species has been done based on their exclusive length of internodes, rib shapes, grooves, jointed stems, ribs density, number of grooves and form of nodes location. Recovered specimens include huge stems, which their length and width ranges are 260-310mm and 140-150mm respectively. Recognized species are associated with some Bajocian –Bathonian genera including: *Nilssonia*, *Podozamites* and *Phlebopteris*. Comparison of the recognized species with equisetums to some parts of Gondwana indicated that the Kermanian equisetums are similar to those of Australia, China, Afghanistan, central and south of Europe. Therefore, the Kerman Basin was a part of Gondwana during the Bajocian – Bathonian time interval.

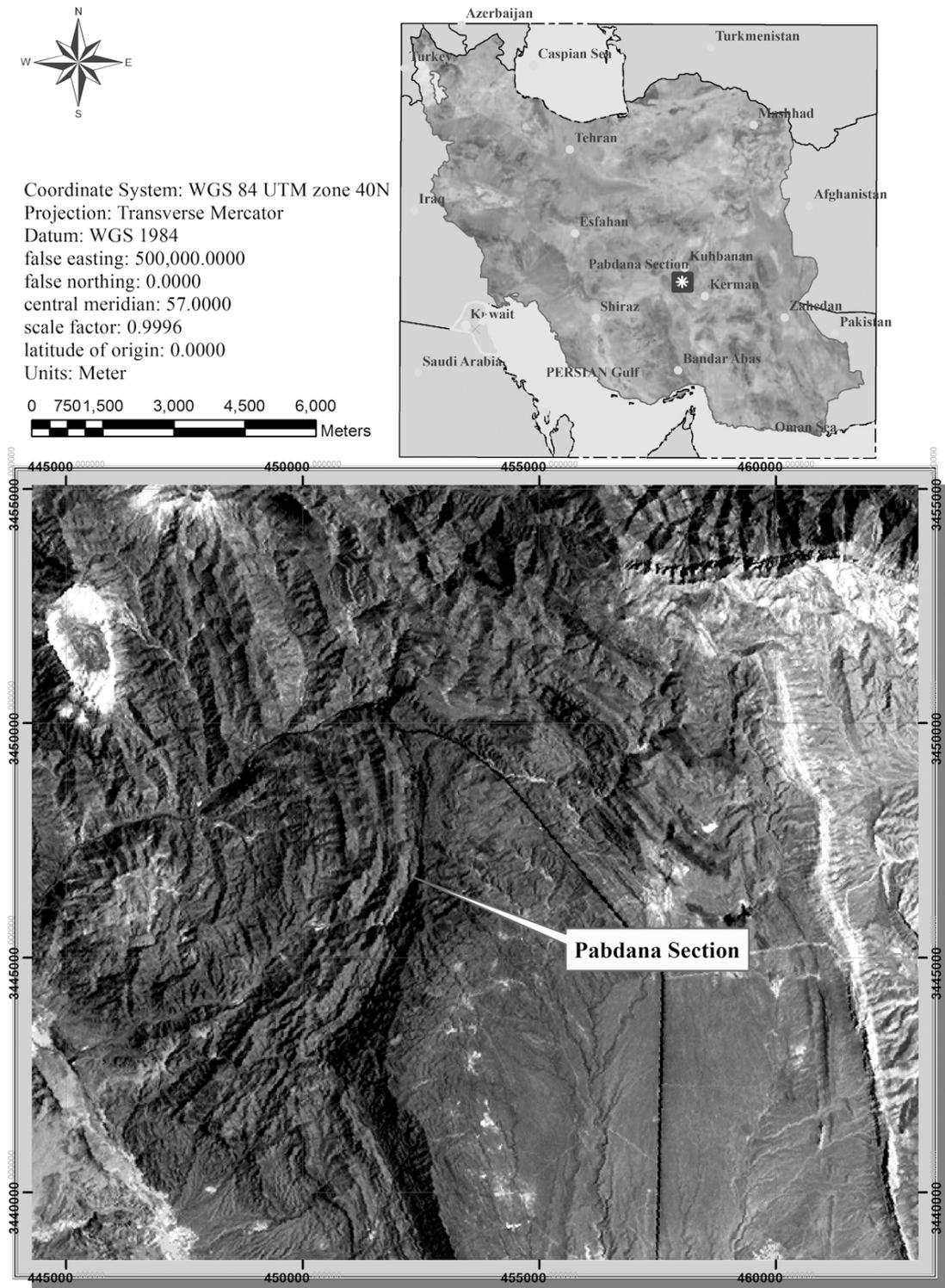
**Key words:** *Equisetites*, plant fossils, Middle Jurassic, Iran.

### Introduction

Sphenophyta taxa are very important in Upper Triassic-lower Jurassic of central and south of Europe and China [1, 2]. The Shemshak Group, consists of a series of marine and non-marine units in the age of Upper Triassic to Middle Jurassic and distributed over the Central Iran (Fig. 1). This group subdivided to four formations which are dated roughly as follow: the Nayband Formation belongs to Carnian to Rhaetian;

The Abe-Haji Formation related to Hettangian to Toarcian, the Badamu Formation refers to Aalenian and Hojedk Formation belongs to Bajocian to Bathonian. [3]. The Hojedk Formation (Bajocian – Bathonian) flora in Pabdana section is one of the most diverse and paleobotanically significant flora from Iran and includes: Filicales, Cycadales, Equisetales, Bennettiales, Coniferales and Corystospermales (Fig. 8). This flora mostly consists of compressed fossils; however impressions and pith casts may also occur.

\* Corresponding author: Tel: +983436226611; Fax: +983436226617; Email: ameri.hamed@gmail.com



**Figure 1.** Location of Pabdana section on Satellite image at the north Kerman, Central Iran. (Satellite Image , Landsat 7, p160 r39)

Equisetales are the most dominant plant fossils in studied strata. Although Jurassic flora of Kerman region

have been known more than 130 years, but there are no reports of the giant Equisetales stems and cones. The

first report from the coal horizons of Kerman area published by foreign researchers [4], but since that time, several literatures by domestic and foreign researchers with different approaches published on Jurassic

deposits of Central Iran [5,6] and more recent studies have been conducted by authors [7].

The Pabdana Section located at 7-10 kilometers south of Pabdana Coal Mine and 150km north of

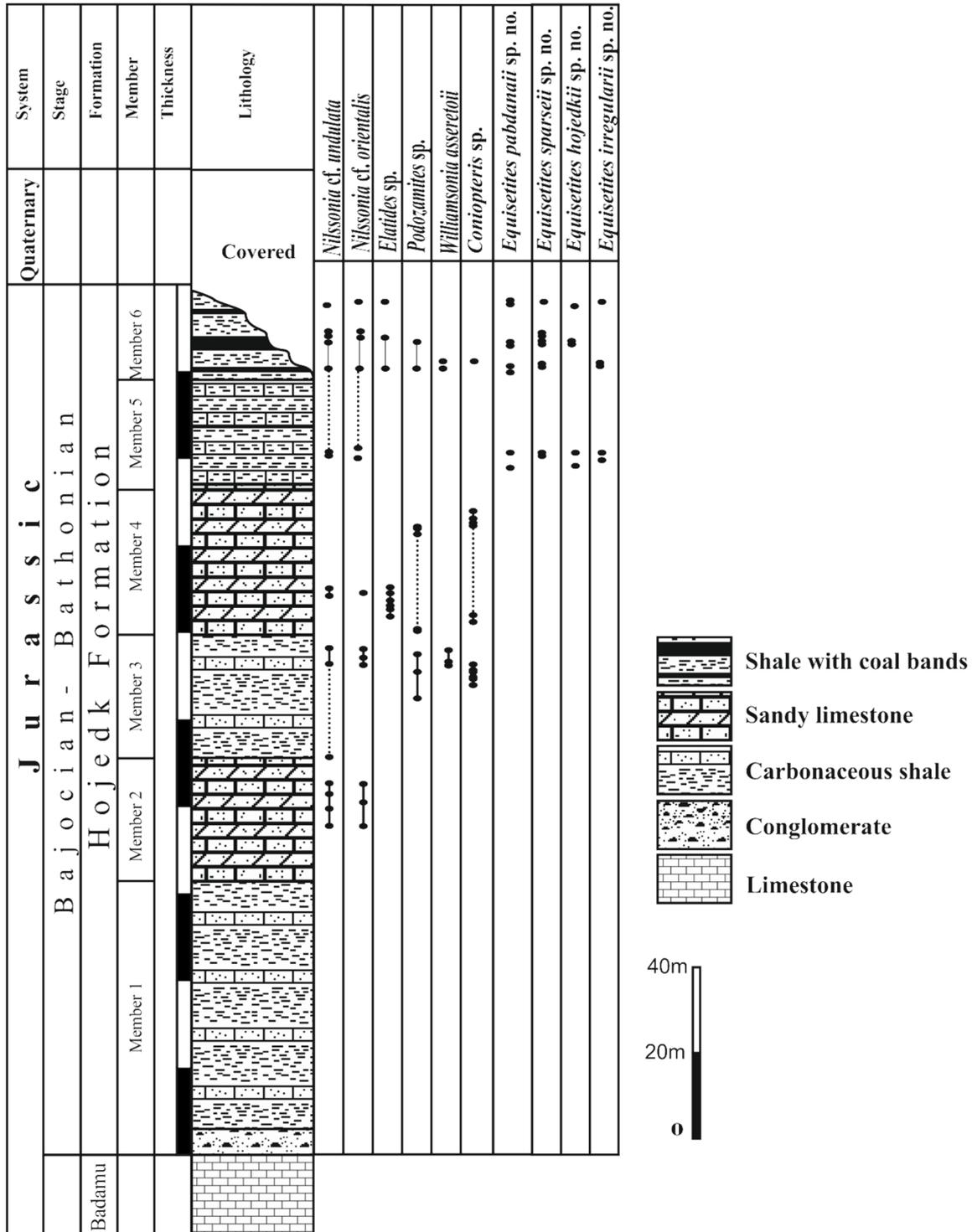


Figure 2. Vertical distribution of plant fossils from the Hojedk Formation in Pabdana section.

Kerman (with 31° 09'12" N, 56°29'59" E coordinates) (Fig.1).

In this paper, authors tried to describe four new species of Equisetales related to the terrestrial plant fossils of the Hojedk Formation (Bajocian – Bathonian) cropped out at Pabdana section.

### Geological setting

Jurassic deposits, the most abundant deposits in north of Kerman, involve Abhaji, Badamu and Hojedk formations (Shemshak group). Abhaji and Hojedk Formations are mainly composed of sandstone and sandy to argillaceous shale alternations with light green- grey to brown- green aspect; Intercalations of coal and carbonaceous shale occur in these Formations too. Badamu Formation, mainly consists of fossiliferous Early Jurassic (Bathonian) marine beds is an index key facies between Abhaji and Hojedk formations. Badamu formation include limestone strata which contain ammonite and belemnite fossils. In the studied area, Hojedk Formation is well exposed next to Pabdana coal mine and consist of sandstone, sandy limestone, and shale with several coal horizons. Plant fossils materials studied herein found in the sandstone and sandy limestone beds. The lower boundary of the succession dominantly covered by quaternary alluvial fans. The underlying marine Badamu Formation dated as Toarsian- Lower Bajocian (based on ammonite fauna) [6, 8], Hence the Hojedk Formation must be deposited during the Middle Bajocian-Lower Bathonian time interval. Therefore content plant fossils of the Hojedk Formation probably belong to Late Bajocian [7]. The thickness of Hojedk Formation in studied area is 205 m.

The lithological nature of the Hojedk Formation is very variable in different areas; based on this variability this formation could be roughly divided into six Members in the studied area;

Member 1: consists of more than 62 m fossil less yellow to grey calcareous shale, olivaceous to dark shale with intercalations of sandstone.

Member 2: involves 35 m grey limestone, containing *Nilssonia* remains.

Member 3: consists of 30 m sandy limestone with broken pieces of wood, leaf and cone.

Member 4: composed of 37 m calcareous shale, with intercalations of sandstone, calcareous shale beds are fossiliferous and contain *Phlebopteris*, *Coniopteris*, *Elatides*, *Podozamites*, *Klukia*, *Equisetites*, and *Cladophlebis* species.

Member 5: involves 27 m of limestone, shale limestone, with giant *Equisetites* stems.

Member 6: includes 21 m of coal, carbonaceous shale, and olivaceous shale with stem fragments,

*Equisetites*, *Podozamites* and *Phlebopteris* species.

### Materials and Methods

Fossils described in this paper were collected from a new fossil locality, a sedimentary sequence occurring next to a coal mine at about 1 km north of Pabdana coal mine (Fig. 1), 49 km north of Zarand, the Hojedk Formation in the studied area 200 m thickness and starts with dark grey sandstones sandy limestone and shales, coals and black shales (Fig. 2). All studied specimens were stored in the Laboratory of Palaeontology, Bio-palaeontology Department of Graduate University of Advanced Technology, Kerman, Iran. These repositories are abbreviated as BDG. The deposited material belongs to 50 specimens collected in Pabdana coal mine and labelled as: BDG1-BDG53. Samples were taken from the rock layers, dense grey fine-grained sandstone, and coal layers of Hojedk Formation. The flora from this locality described for the first time in this study. The specimens photographed by a Nikon D 90 digital camera with a Nikon 105mm Macro lens. Polarized light sources and a corresponding analysing filter used in order to enhance contrast. Digital images were processed using standard graphics software (Adobe Photoshop CS5).

### Results

#### Systematic Palaeontology

Division: Pteridophyta

Phylum: (Equisetophyta Sinnott, 1930) Sphenophyta

Class: Equisetopsida C. Agard

Order: Equisetales Domertie

Family: Equisetaceae Richard ex Michaux, 1803

Genus: *Equisetites* Linne, 1753

*Equisetites pabdanae* nov.sp.

(Fig.3, Fig. 7-a.)

Holotype: Specimen *E. pabdanae* is designated as the Holotype (Fig. 3, Fig. 7-a)

Repository: Bio-palaeontology Department of Graduate University of Advanced Technology (BDG), Kerman, Iran. BDG 3-5

Horizon: Hojedk Formation, Bajocian-Bathonian (middle Jurassic)

Etymology: the specific epithet *pabdanae* refers to the sample location which is Pabdana Coal Mine.

Diagnosis: Aerial stems tall, unbranched except for rare convexity at the internodes, stem surfaces covered with projecting sharp and thick grooves. Stem width is 250 mm however, it may reach to 260 mm in the nodes outstanding. The internode length is 310 mm with rib and without branches. Numbers of internodes reliefs

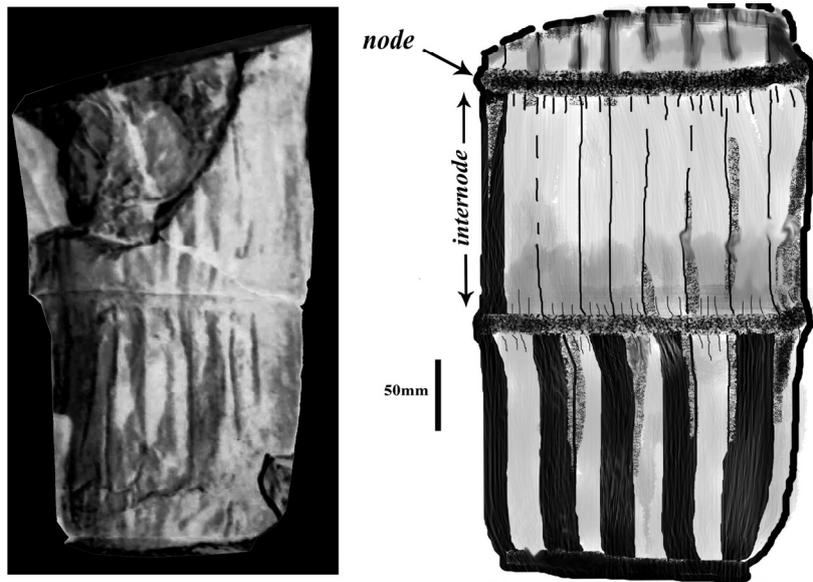


Figure 3. Drawing of *Equisetites pabdanaii* nov. sp. Scale bar represent 5 cm

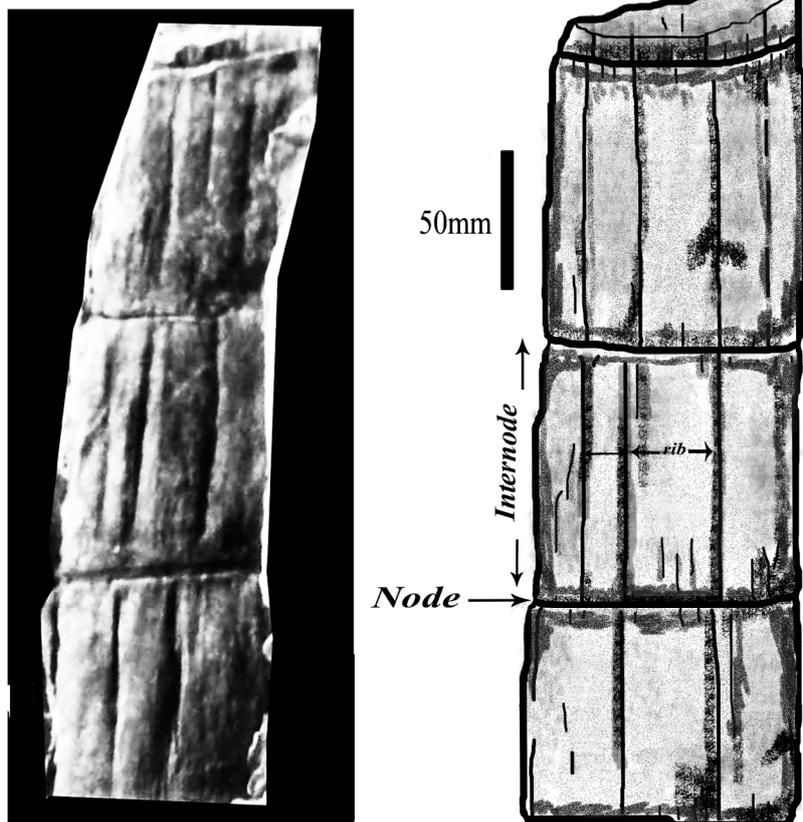


Figure 4. Drawing of *Equisetites sparseii* nov. sp. Scale bar represent 5 cm

are eleven to twelve. Grooves depth is about 2mm and relatively to each other, the rib thickness vary frequently, more and less.

Description: *E. pabdanaii* is represented by many large fossils of aerial stems (Fig. 3). Largest stems were at least 650mm tall based on field observations, and

260mm width at the base. This sample has primary shoots with 3 nodes and 2 internodes. *E. pabdanaii* is a unique sample, maintenance is good, grooves and nodes on the stem can be seen clearly. Thickening and relief

can be seen in the nodes sites. Belt-like reliefs created on the local nodes with 20mm diameters, without leaves trace and leaf sheaths (Fig. 3).

Comparison: these samples can be compared with

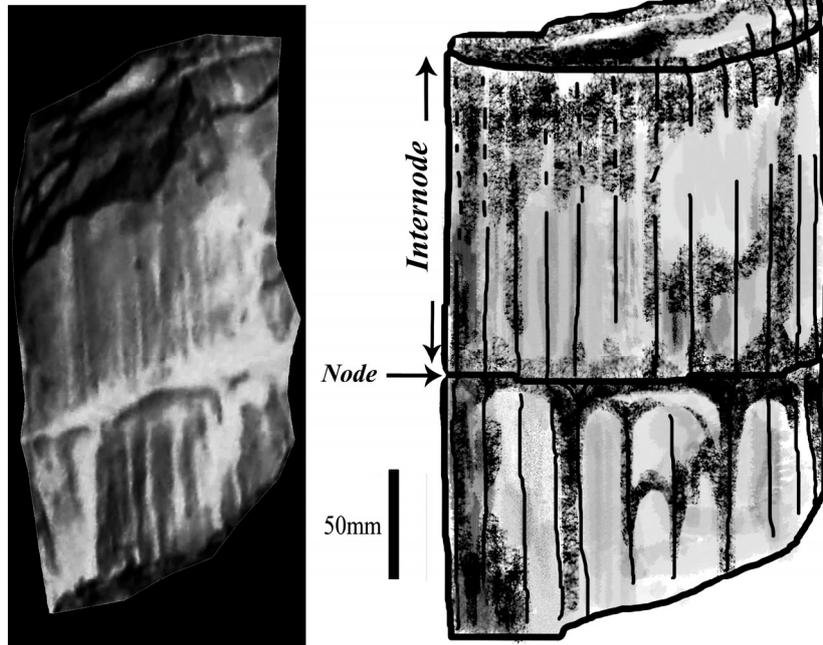


Figure 5. Drawing of *Equisetites hojedkii* nov. sp. Scale bar represent 5 cm

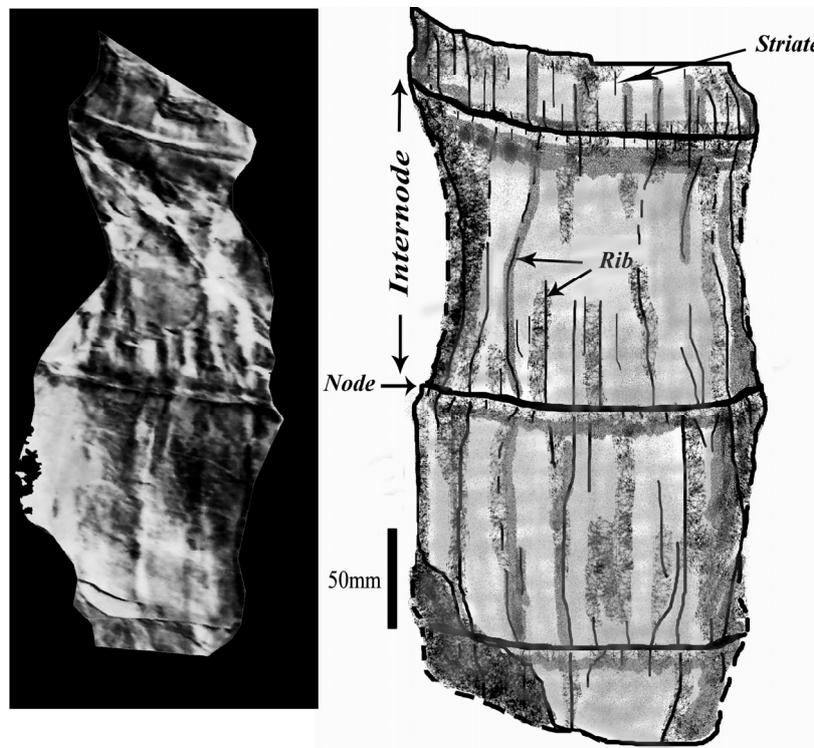
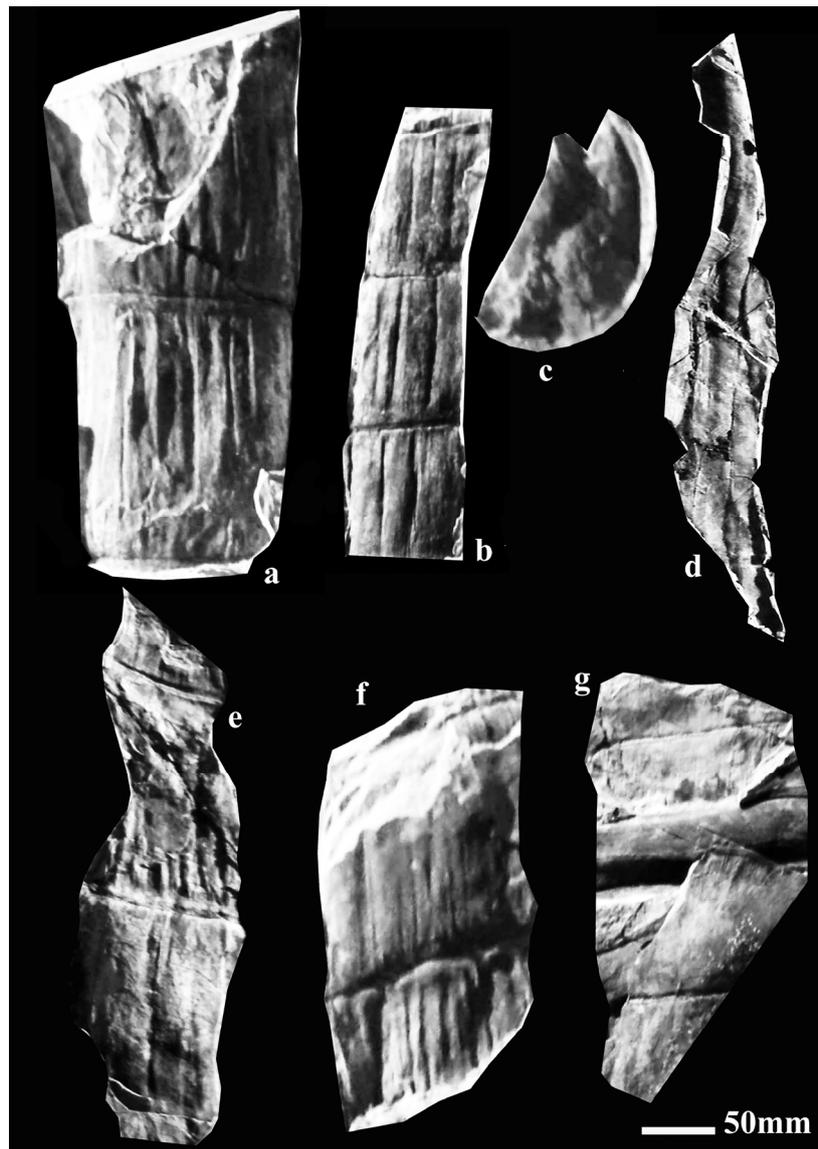


Figure 6. Drawing of *Equisetites irregularii* nov. sp. Scale bar represent 5 cm



**Figure 7a.** *Equisetites pabdanaii* nov. sp. Portion of a large primary Shoot fragment with 3 nodes and long internodes. Specimen BDG. 77. **b,** *Equisetites sparseii* nov. sp. Primary shoot with 3 nodes and internodes. Specimen BDG. 78. **c,** *Equisetites hojedkii* nov. sp. Part of diaphragm probably from sample BDG. 79. **d,** *Equisetites irregularii* nov. sp. Portion of a long primary Shoot fragment with 5 nodes and internodes. Probably belong to BDG. 79. Specimen BDG. 81. **e,** *Equisetites irregularii* nov. sp. Large decayed primary shoot with 3 nodes and internodes. Specimen BDG. 80. **f,** *Equisetites hojedkii* nov. sp. Portion of a large primary Shoot fragment. Specimen BDG. 79. **g,** *Equisetites irregularii* nov. sp. Part of decayed primary shoot with very thin ribs. Specimen BDG. 81

*Equisetites arenaceus*. That is one of the largest known *Equisetites* species with more than 250mm diameter [9]. But the different morphological characteristics are stem shape and the size of ribs. Stem shape in the *Equisetites arenaceus* is the telescoping form. Internodes is less long (60-20mm and in some specimens, it maybe reach to 140mm). The stems surfaces smooth, without grooves [1]. Whereas, the *E. Pabdanaii* have 11-12 ribs with relatively deep grooves (above 2mm depth). The

most important distinction is high length of the internodes (about of 310mm). *Equisetites arenaceus* is covered by leaf sheaths at the nodes [1]. Whereas, the *E. Pabdanaii* have not leaf sheaths and leaf trace.

Discussion: the taxonomy of fossils Sphenophyta is complex. Usually important factors in taxonomic descriptions are the numbers of leafs, sheaths nature, and stems morphology and characteristics of stem [10]. According to the described sample, the affinity to

*Equisetites* genus is obvious, because *Exquisite* has main characteristics of nodes shape and internodes, but *E. pabdanaii* has very different in the length of internodes, ribs shape, grooves and location of nodes. This species is accompanied with *Nilssonia*,

*Podozamites* and *Phlebopteris* species and could be related to Bajocian- Bathonian time interval.

Family: Equisetaceae Richard ex Michaux, 1803

Genus: *Equisetites* Linne, 1753

*Equisetites sparseii* nov. sp.



**Figure 8a.** *Nilssonia feriziensis* Fakhr, 1977. Showing main rachis and Part of leaf. **b.** *Nilssonia* cf. *tenuicaulis* (Phillips, 1829) Fox – Strang ways, 1892. Part of leaf with pinnae and showing venation. **c.** *Elatides thomassi* Harris, 1979. Some part of shoots and showing 2 twigs in distal in proximal of frond. **d.** *Cladophlebis* sp. Nathorst, 1913. Part of penna with pinnules. **e.** *Todites princeps* (Presl in Sternberg, 1838) Gothan, 1914. Part of frond with pinnules. **f.** *Phlebopteris* sp. cf. *polypodioides* (Givulescu et Popa) Schweitzer et al., 1998. **g.** *Coniopteris* cf. *hymenophylloides* (Brongniar) Seward, emend. Harris, 1961. Part of sterile (left) and fertile (right) frond and showing position and pinnae shape. **h.** *Eboracia lobifolia* (Phillips) Thomas, 1911. Part of frond and showing venation. **k.** *Podozamites distans* (Presl, 1838) Braun, 1843. Distal part of frond and showing main rachis and folioles.

(Fig.4, Fig. 7-b)

Holotype: Specimen *E. sparseii* is designated as the Holotype (Fig. 4, Fig. 7.)

Repository: Bio-palaeontology Department of Graduate University of Advanced Technology (BDG), Kerman, Iran. BDG 6-10 Horizon: Hojedk Formation, Bajocian-Bathonian time interval (Middle Jurassic)

Etymology: the specific epithet *sparseii* refers to arrangement of ribs which have small sporadic and indented ribs at the surface of stem.

Diagnosis: stems tall, unbranched, stem surfaces covered by projecting grooves, this species has low number of ribs (4 or 5). Ribs thickness is variable. The average width of the ribs is 40mm however they are between 30 to 50mm. Node location is concave with approximately 10mm wide and 5mm deep. Stem width is 140mm but in node location is outstanding to 150mm, internode length is 190mm with sparse ribs and without branches. The number of internodes and nodes is 3.

Description: *Equisetites sparseii* represented by several well preserved large parts of stem (Fig. 4). The largest stems have at least 660mm long base on field observations, and 150mm width at the base. These

samples have primary shoots with 3 nodes and 3 internodes, groove directions between adjacent nodes are continuous or none continuous. *E. sparseii* and *E. Pabdanaii* discovered from single layer. Stem width and length are smaller than *E. pabdanaii*. Stem is without leaves traced and leaf sheaths.

Comparison: *Equisetites sparseii* has internode length as 190mm to 140mm. stem width is less than *E. Pabdanaii* (310mm length and 260mm width). Whereas the *E. beanie* stem has 90mm width, with two nodes and internodes (with 70mm length). Besides, stem surface covered by high density of narrow ribs, 112 ribs in stem width, 8 ribs per 10mm, rib width 1mm. While the *E. sparseii* internodes length is 140mm, with 5-4 ribs in stem width. The average width of ribs is 30mm; while in *E. munsteri* the average width of ribs is 10mm and there are 72 ribs in width of stem [10]. The *E. sparseii* internodes length are greater than those of *E. munsteri*. Densities of ribs in *E. munsteri* are denser than *E. sparseii*. *E. sparseii* in comparison with *E. arenaceus* is longer and smoother. *E. arenaceus* have smooth stem surface, without grooves, but *E. sparseii* have sharpen grooves with thickened grooves on the



Figure 9. Sandstone layer containing: *Equisetites pabdanaii*, *E. sparseii*, *E. hojedkii* and *E. irregularii*. Six shoots can be seen.

stem surface.

*E. lateral*, *E. leaves*, *E. column*, *E. woodsii*, *E. bryanii* and *E. nicoli* aren't comparable with *E. sparseii* because they have very narrow stems (about 25mm-30mm), and are compared with each other by diaphragm diameter and strobili [11].

Discussion: According to the described sample, there is obvious affinity to *Equisetites* genus. One of the main characteristics of Equisetales is sharp nodes and internodes, but *E. sparseii* is very differences in the length of internodes, ribs shape, ribs density, number of grooves and form of nodes location. Therefore we are referred a new species based on special features.

Family: Equisetaceae Richard ex Michaux, 1803

Genus: *Equisetites* Linne, 1753

*Equisetites hojedkii* nov. sp.

(Fig. 5, Fig. 7-c& f)

Holotype: Specimen *E. hojedkii* is designated as the Holotype (Fig. 5, Fig. 7-c& f)

Repository: Bio-palaeontology Department of Graduate University of Advanced Technology (BDG), Kerman, Iran. BDG11-13

Horizon: Hojedk Formation, Bajocian-Bathonian (Middle Jurassic)

Etymology: the specific epithet *hojedkii* refers to the Hojedk Formation; because the samples are collected from this formation. Diagnosis: stems tall, unbranched, stem width 150-140mm, stem surface covered by projected sharp grooves in stem width. Internode length is 160mm. Width of ribs are 10-15mm with low depth (0.5mm). Node location has a concavity which has around 8mm width and 7mm depth.

Description: *E. hojedkii* is alongside with *E. sparseii* and well preserved in the single sandy limestone layer. The largest stem length is 300mm, and width is 140mm at the middle stem. *E. hojedkii* has primary shoots with 2 nodes and 3 internodes. Always grooves directions between two nodes are continuous. Grooves density is one per 10mm and stem is direct. Diaphragm section has 140mm width and find alongside with stems [fig. 5].

Comparison: *E. hojedkii* has 210mm stem width. This species is smaller than *E. Pabdanaii*. But *E. hojedkii* is longer than *E. sparseii*, internodes length is 200mm that smaller than those of *E. Pabdanaii* and longer than another Equisetal species. Number of ribs in the *E. hojedkii* is rather similar to *E. pabdanaii* (12-11 ribs) but their arrangement in the later is irregular. The ribs on the one side of the node are narrow but on the other side are thick.

Discussion: According to the sample described, there are obvious affinity to *Equisetites* genus, because Equisetal have sharp nodes and internodes, but *E. hojedkii* is distinguishable by the length of internodes,

ribs shape, grooves pattern, location of nodes and nodes characteristics. This species strongly differ with another Equisetal species. Therefore we are referred a new species based on its special features.

Family: Equisetaceae Richard ex Michaux, 1803

Genus: *Equisetites* Linne, 1753

*Equisetites irregularii* nov. sp.

(Fig. 6, Fig. 7-d, e & g.)

Holotype: Specimen *E. irregularii* is designated as the Holotype (Fig. 6, Fig. 7-d, e & g)

Repository: the Bio-palaeontology Department of Graduate University of Advanced Technology (BDG), Kerman, Iran. BDG 16-19

Horizon: Hojedk Formation, Bajocian-Bathonian (Middle Jurassic)

Etymology: the specific epithet *irregularii* refers to irregular arrangement of ribs on the surface of stem.

Diagnosis: width of stem is 210mm, which is where the nodes outstanding to 230mm, with grooves, 11-10 grooves in the stem width. Internodes length is 200mm, width of ribs are variable (10-30mm) and irregular. There is a convexity in nodes location with 10mm width.

Comparison: *E. irregularii* is alongside with *E. sparseii* and *Equisetites pabdanaii* and well preserved in the limestone layer. Stems is tall, unbranched, width of stem is 200mm to 210mm, stem surface covered by sharp projection. In width of stem there are 11-10 grooves. Internode length is 200mm. The width of ribs is irregular and variable (10-30mm). There is a convexity in nodes location with 10mm width. The largest stem length is 520mm and 210mm width at the middle of stem. This taxon has primary shoots with 3 nodes and 4 internodes. The groove directions between two nodes are always discontinuous. Stem is directed. Grooves have a low density (one groove in 20mm).

Comparison: *E. irregularii* has stem width 210mm. This species is wider and longer than the *E. sparseii* and *E. hojedkii* but narrower and smaller than *Equisetites pabdanaii*. *E. irregularii* is similar to *E. hojedkii* in number of ribs, but ribs pattern of *E. irregularii* is irregular and different. Ribs around of nodes location are different with those of *E. hojedkii*. The ribs on the one side of the node are narrow but on the other side are thick.

Discussion: According to the described taxon, there are obvious affinity to *Equisetites* genus, because Equisetal have sharp nodes and internodes but *E. Irregularii* is distinguishable by the length of internodes, ribs shape, grooves pattern, location of nodes and ribs characteristics. This species is strongly differing with another Equisetal species. Therefore we are referred a new species based on its special features.

## Discussion

Large Sphenophyta are assigned the Equisetites, these flora are present from Upper Permian through recent, but particularly common in Triassic or younger rocks units in many parts of the world, including : Europe[9,12,13], North America[14], Antarctic[11,], China[15], and New Zealand[16].

Sphenophyta taxa are very important in Upper Triassic-lower Jurassic of central and south of Europe. The *E. arenaceus* and *N. merianii* are most common in the studied area. They are abundant in some layers. Paleogeography and paleoecology of the Sphenophyta reconstructed based on recognized Equisetites genera and species [1]. Unfortunately lacking of studies on diversity and dispersion on plant fossils of Iran caused to low published literatures on Middle Jurassic (Bajocian - Bathonian). Introduced taxa in this study, produce complete information about assemblage of Jurassic Equisetal from Iran. Authors are able to introduce new species of Sphenophyta based on presence of abundant ribs on the stem surfaces, node forms, width of stem and length of internodes.. There are most remarkable features in introduced taxa in relation to other Sphenophyta fossils. *Equisetites sparseii* has 190mm internodes length and 140mm stem width. *Equisetites sparseii* is smaller than *E. Pabdanaii* (310mm length and 260mm width). While the *E. beanie* has 90mm stem width with only two nodes and internode (with 70mm length). Stem surface covered by high density of narrow ribs, 112 ribs in stem width, 8 ribs per 10mm, rib width 1mm. While the *E. sparseii* internodes length is 140mm, with 5-4 ribs in stem width. The average of the ribs width is 30mm While, those of *E. munsteri* is the 10mm width. *E. munsteri* has 72 ribs in the width of stem[10]. While the *E. sparseii* internodes length greater than *E. munsteri*. Densities of ribs in *E. munsteri* are more than *E. sparseii*. *E. arenaceus* in comparison to *E. sparseii* is taller and smoother. *E. arenaceus* have smooth stem surface, without grooves, but *E. sparseii* have sharpen grooves with thick grooves on the stem surface. *E. lateral*, *E. leaves*, *E. column*, *E. woodsii*, *E. bryanii* and *E. nicoli* aren't comparable to *E. sparseii* because they have very narrow stems (about 25mm-30mm), and are compared with each other by diaphragm diameter and strobili [11]. *E. hojedkii* has 210mm stem width. *E. hojedkii* in comparison to *E. Pabdanaii* is smaller. But it is longer than *E. sparseii*. *E. hojedkii* internodes length is 200mm that smaller than those of *E. Pabdanaii* and longer than those of another Equisetal species. Number of ribs in the *E. hojedkii* is similar to those of *E. pabdanaii* (12-11 ribs) but variable and irregular. The ribs on the one side

of the node are narrow but on the other side are thick. *E. pabdanaii* is comparable to *Equisetites arenaceus*. That is one of the largest known *Equisetites* species with more than 250mm diameter [9]. But they are different in stem shape and size of ribs. Stem shape in the *Equisetites arenaceus* have the telescoping forms. Internodes is short (60-20mm and in some specimens, it maybe to 140mm). The stem surfaces are smooth, with no grooves [1]. Whereas, the *E. pabdanaii* have 11-12 ribs with relatively deep grooves (above 2mm depth). The most important character is high length of the internodes (about of 310mm). *Equisetites arenaceus* are covered by leaf sheaths at the nodes. Whereas, the *E. Pabdanaii* have not leaf sheaths and leaf trace. *E. irregularii* has 210mm stem width, wider and longer than the *E. sparseii* and *E. hojedkii* but narrow and smaller than the *Equisetites pabdanaii*. This taxon similar to *E. hojedkii* in number of ribs but *E. irregularii* has irregular and different ribs pattern in relation to *E. hojedkii*. The ribs around of nodes location are different. The ribs on the one side of the node are narrow but on the other side are thick.

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