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A conifer Pagiophyllum yafraiensis sp. nov. from the Jurassic Khashm az Zarzur Formation, Yafran, Jebel Nefusa – Libya.

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Highlights

- ***Pagiophyllum yafraiensis* sp. nov. from the Jurassic Khashm az Zarzur Formation was introduced.**
- **The age of Khashm az Zarzur Formation was assigned to (Callovian-Oxfordian) in age**
- **A warm humid environment was interpreted due to the presence of *Pagiophyllum* and *Brachyphyllum* conifers flora, this is also supported sedimentologically.**

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ABSTRACT

The Jurassic flora from the Khashm az Zarzur Formation in the vicinity of Yafran village in Jebel Nefusa, northwestern Libya was studied. Among which a new species of fossil conifer, *Pagiophyllum yafraiensis* sp. nov. was described and illustrated.
This new species occurred in association with *Piazopteris branerii, Brachyphyllum* sp., *Hirmerella* sp., *Otozamites* sp., and *Samaropsis* sp. According to the stratigraphic position of the Khashm az Zarzur Formation dated as (Callovian-Oxfordian), however, a Late Jurassic (Bathonian-Tithonian) age has been assigned palynologically.
The global paleogeographical distribution of the genus *Pagiophyllum* is also illustrated herein.

1. Introduction

Jebel Nefusa is one of the major geological features in northwestern Libya. It is a prominent escarpment rising sharply from a flat plain (the Jefarah) about 75 km, south of Tripoli, as an east-west ridge separating the Ghadames Basin from the Jifarah Basin (El Zooki, 1980a) (Fig. 1). This uplift extends for 400 km from Misratah to the Tunisian border and continues in Tunisia (Hallett, 2002). Fieldwork has been undertaken during the year 1974. Plant fossils were collected from the upper part of Kashm az Zarzur Formation "which was named Chameau Mort Formation" in two sections, the first section (S10) just below Eghaish village and the other section in a sand quarry (S11) just below Yafran town in Al Jebel Nefusa, Northwestern Libya (Fig. 1). These two sections provide the basis upon which the collected fossil plant of this formation has been studied. Rare studies are published in the fossil plants of the Libyan Jurassic-Cretaceous world.

Photographs and latex replicas were prepared in the British Museum. The illustrated specimens including the *Pagiophyllum yafraiensis* sp. nov. are deposited at the paleontology cabinet of the Geological Museum of the Earth Sciences Department, University of Benghazi, Benghazi- Libya.

2. General Stratigraphy

The Mesozoic rocks exposed in the Jebel Nefusa range in age from Late Triassic to Late Cretaceous (Figs. 2, 3). The stratigraphy of the area is complicated as different nomenclatures are applied by different authors as in Fig. 3, this problem needs more stratigraphical investigations to unify the rock names of the exposed rock units in the region. The Jurassic rocks exposed in the area are arranged into two groups according to El Zouki (1980a), which are from bottom to top (Fig. 2):

a) Bir el Ghenem Group (Lower to Middle Jurassic), comprising the Bu Gheilan Limestone - Bir el Ghenem gypsum Formation; Bu en Niran Formation; and Abreghe Formation.
b) Tigi Group (Middle to Upper Jurassic), comprising of the Tacbal Limestone and Khashm az Zarzur Formation of El Hinnawy and Cheshitev (1975) "previously Giosc Shale and Chameau Mort Sandstone" and Shakshuk Formation. On the other hand, the Lower Cretaceous is represented by the Cabao (Kabaw) Formation of the Weldean age and the Albian Chicla (Kiklah) Formation.

The Upper Cretaceous is represented by:

i) Nefusa Group (Cenomanian), comprising the Ain Tobi Formation, Jefern Marl Formation, and Garian Formation. These three formations of this group are Cenomanian in age.
ii) Tigrinna Formation (Cenomanian–Turonian) is the youngest Formation in the area.

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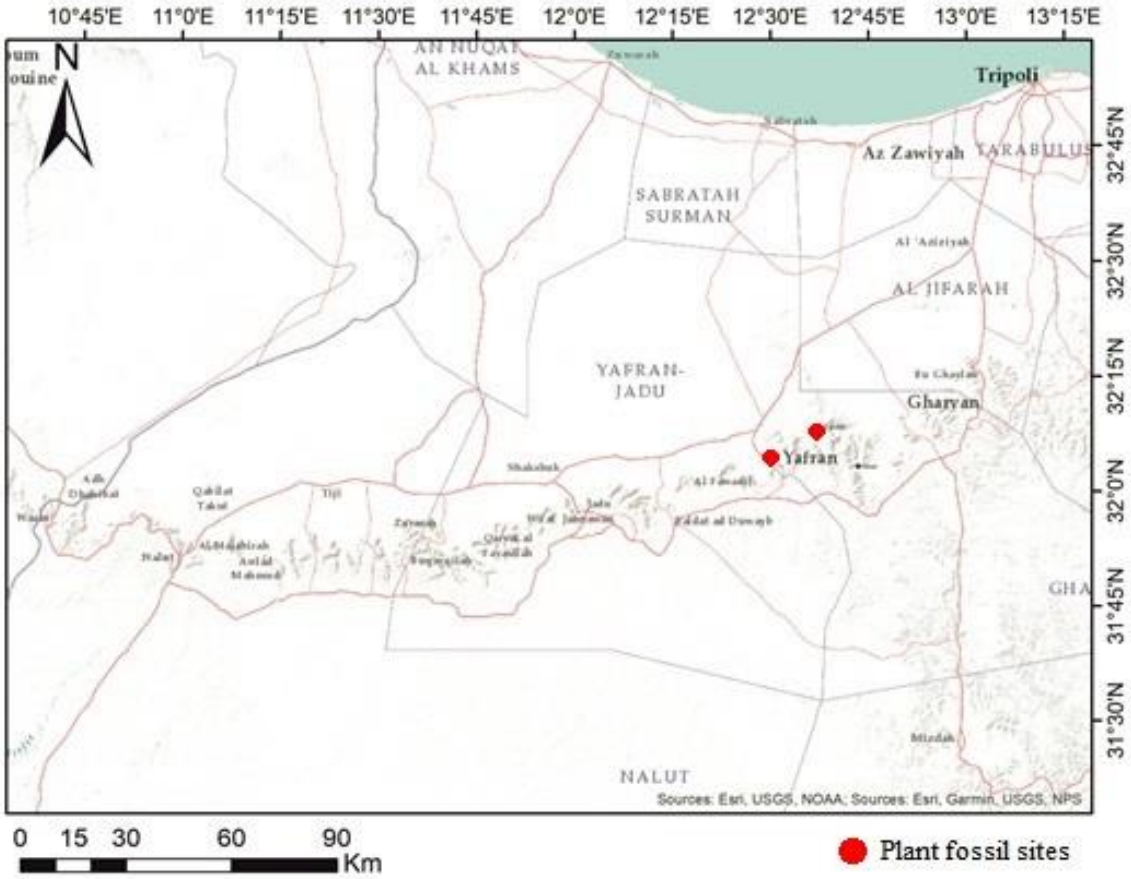

Fig. 1. Location map of the Jebel Nefusa area, northwestern Libya, the two plant fossil collection sites are indicated by Red dots (modified after El Zouki, 1980a).

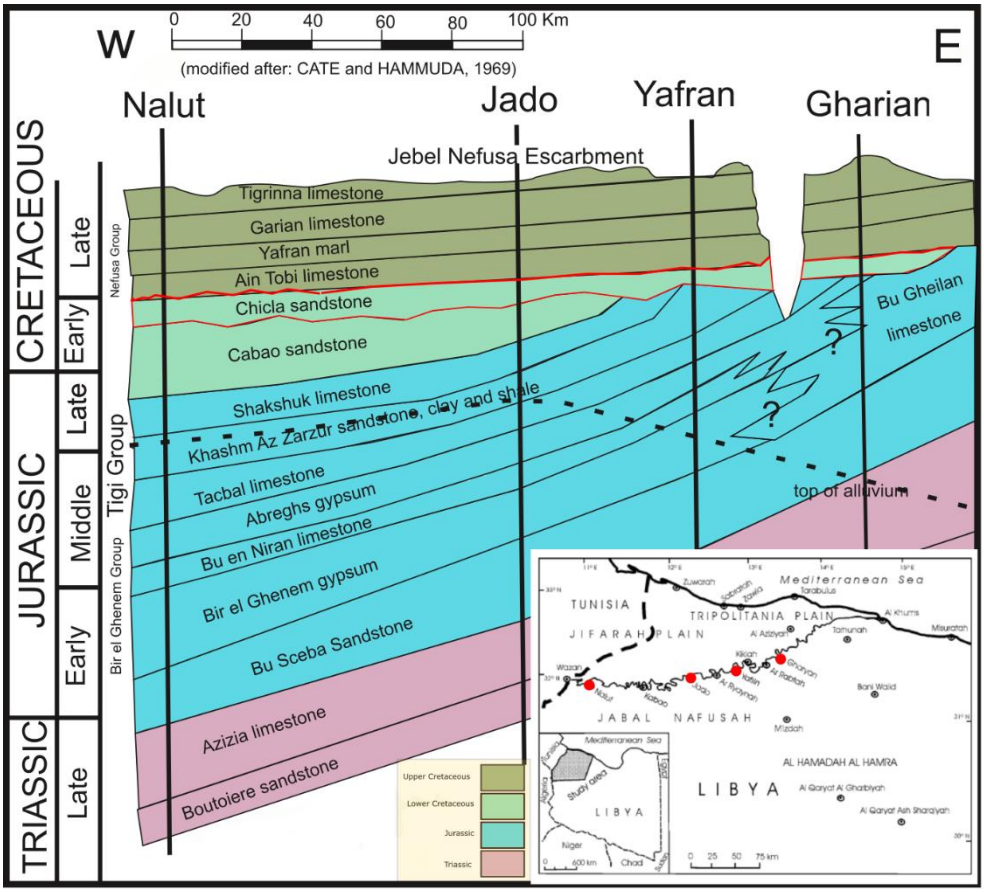

Fig. 2. A stratigraphic relationships of the Mesozoic rocks, Jebel Nefusa area (Modified after Cate and Hammuda, 1969; El Zouki, 1976, 1980a; Hallett 2002). The index map after Shiref and Salaj (2007)

2.1 Stratigraphy of the Upper Jurassic and Lower Cretaceous

The upper Jurassic in the area is represented by the Khashm az Zarzur Formation and the Shakshuk Formation (Figs. 2, 3). The Khashm az Zarzur Formation "formerly Chameau Mort Formation of Burollet (1963)" was named by El Hinnawy and Cheshitev for the two rock units overlying the Tekbal Formation which were formerly known as the Giosc Shale and the Chameau Mort Sandstone (Banerjee, 1980). The Khashm az Zarzur Formation is exposed in the scarp of the Jabal Nafusah from the vicinity of Kiklah village in the east to Wazin village in the West at the Tunisian border. The lower unit is lacustrine claystone with traces of salt and gypsum, with freshwater pelecypods, plant remains, and fossil wood. The upper unit, however, is a continental sandstone as evidenced by SEM analysis of the sand grains with marked cross beddings and occasional claystone bands that deposited close to the shoreline containing plants fossils (El Zouki, 1980b; Hallett, 2002), it comprises multicolored and gypsiferous shale and mudstone with ferrugineous organic-rich laminae, thin beds of marl and containing abundant plant fossils. In Yafran and Kiklah areas the Khasm az Zarzur Formation is overlain by the Kiklah Formation and underlain by the Tacbal Formation. In Jado area, the base of the Khasm az Zarzur Formation is unexposed but attains thickness over 30m and it is overlain by the Shakshuk Formation.

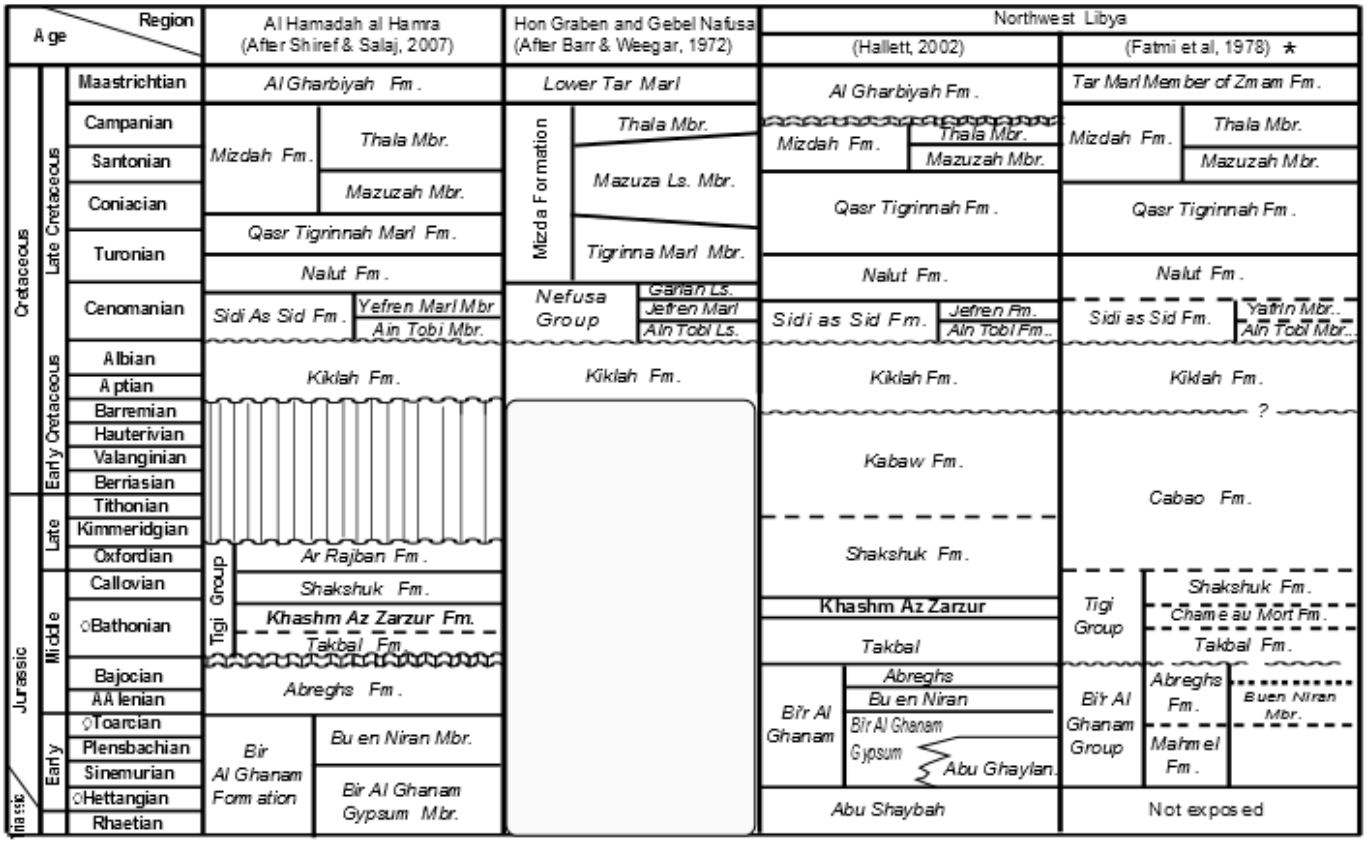

Fig. 3. Different Nomenclatures used by different authors for the Jurassic- Cretaceous deposits in the NW region of Libya (* IRC = Mann 1975; Smetana 1975; El-Hinnawy and Cheshitev 1975; Antonovic 1977; Novović 1977); Burollet 1977; Fatmi 1977; El Zouki 1976; Hammuda 1969; Desio et al 1963; Fatmi et al., 1980; and Christe 1955).

3. Systematic Paleontology

Kingdom: Plantae Haeckel, 1866
Phylum: Pinophyta Reveal, 1996
Class: Pinopsida Burnett, 1833
Order: Pinales Dumortier, 1829
Family: Araucariaceae Henckel and Hochstetter, 1865
Genus: *Pagiophyllum* Heer, 1881

Pachyphyllum (Pomel) Saporta, 1873

Definition: This fossil conifer foliage has been variously assigned to several different conifer groups including Araucariaceae and Cheirolepidiaceae Taylor *et al.* (2009). Most *Pagiophyllum* species have affinities with other conifers such as the Cheirolepidiaceae and Taxodiaceae (Harris, 1979). *Pagiophyllum* leaves are helically arranged with length exceeds width (Stockey, 1982). They were found around the globe during the Permian to the Cretaceous period https://en.wikipedia.org/wiki/Pagiophyllum. The geographical distribution of the genus during the Jurassic world is shown in Fig. 6 (e.g. South Mexico, Cuba, Brazil, Columbia, North Yorkshire of England, North America, and Australia).

Pagiophyllum yafraiensis sp. nov.
(Figs. 4, 5 a-c)

Diagnostic features of the species: It is diagnosis by having papillae on the ordinary epidermal cells of the leaf, quite unlike the other known species.

Etymology of the genus: After Yafran city, where the specimens are found at the Jebel Nefusa escarpment northwest of Libya,
Description: *Pagiophyllum yafraiensis* sp. nov. is a well-preserved conifer shoot of about 2 cm long. The leaves are spirally arranged and variable in shape but they are always more than twice as long as broad (Fig. 5a-c). The scanning electron microscope has shown that the surface of the leaf is covered with tiny papillae and well-defined rows of stomata. The stomata of this new species surrounded by papillose subsidiary cells are very similar to those of the *Pagiophyllum kurrii* Schimper and *P. connivens* Kandall. In general, the dense covering of papillae often indicates that the plant grew in a dry habitat.

Fig. 4. *Pagiophyllum* ***yafraiensis*** sp. nov. from Khashm az Zarzur Formation, Jebel Nefusa, Yafran in Libya.

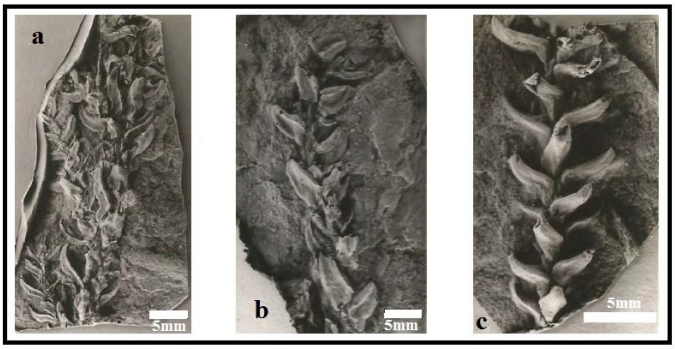

Fig. 5. SEM photos of *Pagiophyllum* ***yafraiensis*** sp. nov. from Khashm az Zarzur Formation, Jebel Nefusa, Libya.

Occurrence: The conifer *Pagiophyllum* is recorded from all the continents of the old Jurassic land (Pangea) in the forms of *P. burmense, P. marwarensis, P. peregrinum, P. rewaensis, P. maculosum, P. connivens, P. compactum*, and *P. spinosum* (Fig. 6), However. In this study, the newly introduced species *Pagiophyllum yafraiensis* sp. nov. reported from Jurassic age in the Khashm az Zarzur Formation in the vicinity of Yafran city, Jebel Nefusa the northwestern region of Libya.

Associated assemblage: The *Brachyphyllum* sp. (Figs. 7a, b) A conifer leafy twig of about 1cm long. The spirally arranged leaves here are about twice as long as broad, shorter than in *Pagiophyllum*. The leaves of this species are also densely covered by well-defined rows of stomata (Fig. 7b). The stratigraphical range is long and it extends throughout the Mesozoic. *Brachyphyllum* in certain species may overlap the generic morphological features of *Pagiophyllum* (Harris, 1979).

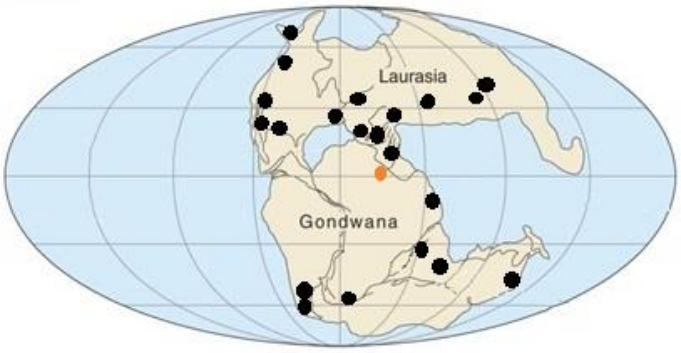

Fig. 6. *Pagiophyllum* sites related to a reconstruction of Jurassic Pangea from literature (black dots) and Libyan site in (red dot) (Global Plate Tectonics, 2001).

Piazopteris branerii (White) Lorch, (Figs 7 c, d) Many fertile with very few fertile pinnae, age early Jurassic to Cretaceous, some of this Matoniacea pinnulea probably belong to the *Weichaelia reticulata* (Stokes and Webb) Fontain which range in age from Middle Jurassic to Cenomanian, and it is commonly regarded as having been a plant of dry or salty habitats. This species is reported by Ash (1972) from the Lower Jurassic rocks, which was formerly thought to be of Triassic age near Ain Sukhana in the Gulf of Suez area of Egypt.

Hirmerella sp. (?) (Cone): There are several poorly preserved cones occurring in close association with the *Brachyphyllum* leafy shoots, and it is quite possible that some of them may belong to the *Hirmerella*, which is believed to be a member of the conifers that produced the peculiar pollen grains "*Classopollis*-type" in the Mesozoic time as suggested by Krassilov (1982). However, to make certain more materials need to be examined. If this proves to be true, then these are the first *Hirmerella* recorded from the African continent (C. Hill, personnel communication), thus they are of considerable interest. The *Hirmerella* group ranges in age from late Triassic "Rhaetian" to Early Cretaceous.

Otozamites sp. (leaf): This species occurs as small poorly preserved leaves. It ranges in age from Triassic to Early Cretaceous.

Samaropsis sp. (seed): They occur as seeds of uncertain classification, however, this species is known from Paleozoic, Mesozoic, and Cenozoic.

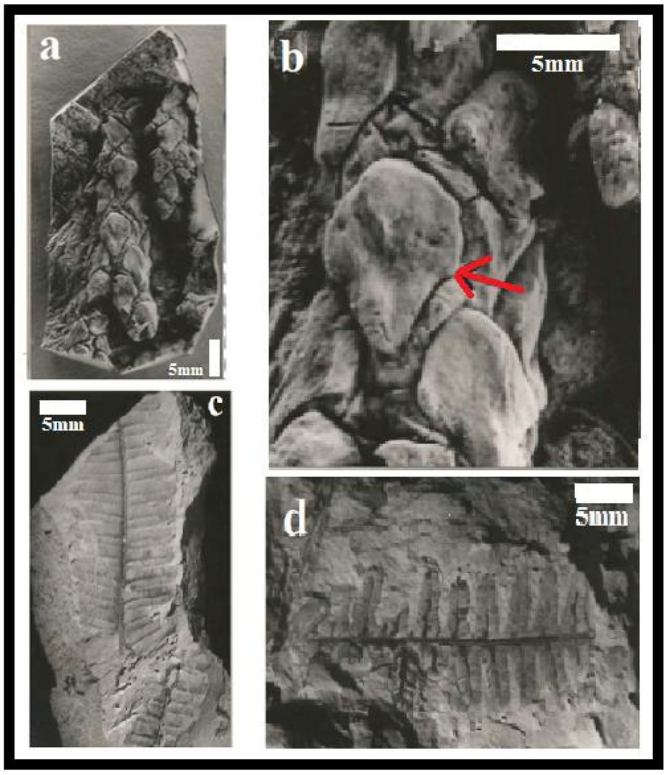

Fig. 7. SEM Latex replicas photos of *a, b) Brachyphyllum* sp. (stomata on the leaves arrowed; c, d) *Piazopteris branerii*.

4. Discussions

The *Pagiophyllum yafraiensis* sp. nov. is described and illustrated from the Khashm az Zarzur Formation for the first time. The described species is well preserved in a ferruginous clay of yellowish-brown color, soft, non-calcareous, non-swelling, with very rare quartz silt, few organic matters, and plant remains. The assigned age range of the reported associated plant assemblage from the previously published works is ranged from Jurassic to Early Cretaceous. However, none of the reported taxa (*Brachyphyllum* sp. *Piazopteris branerii*, *Hirmerella* sp., *Otozamites* sp., and *Samaropsis* sp.) are diagnostic of a specific age. The previous workers wrongly

determined some of these species and used them as strong stratigraphic markers, for example, *Piazopteris branerii* was incorrectly referred to as *Pecopteris* by Hammuda (1969, plate 2, figs. 13-15, p.69) (C. Hill personal communication).

The data on the flora in particular the co-occurrence of both *Pagiophyllum* and *Brachyphyllum* conifers as well as the sedimentological evidence suggest that warm and humid environments prevailed (El Zouki, 1980a). Furthermore, the abundance of conifers, particularly Podocarpacea (Chinnapa and Rajanikanth, 2017) with the taphocoenosis of the flora comprises local to regional elements derived from the riverbank, floodplain, back swamp, and valley settings (Fig. 8).

Burollet (1963) assigned the Khashm az Zarzur to Late Jurassic (Callovian- Oxfordian) age based on the plant *Laccopterix saighanensis*. Hammuda (1969) reported from this rock unit *Pecopteris phillipsii*, *Neuropteris* sp., and *Zamites* sp. which point to the Jurassic age. In the Gulf of Suez area of Egypt Ash (1972) assigned the Early Jurassic age to rocks near Ain Sukhana due to the presence of *Piazopteris branneri*. A palynological investigation of a sample from a surface exposure in the vicinity of Yafran assigned the concerned Khashm az Zarzur Formation to Bathonian – Tithonian age (Hallett, 2002).

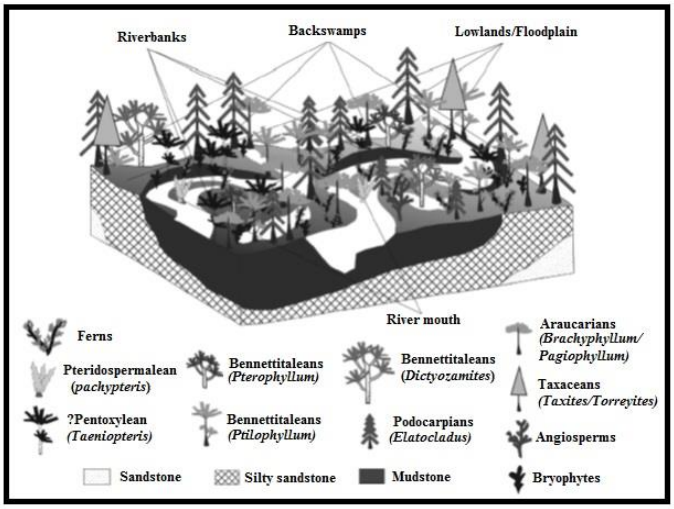

Fig. 8. Paleoecological reconstruction of Early Cretaceous flora from Pranhita-Godavari Basin (after Chinnapa and Rajanikanth, 2017).

5. Conclusions

- Six plant fossils taxa are reported from the Khashm az Zarzur Formation in the vicinity of Yafran, among which *Pagiophyllum yafraiensis* sp. nov. is described and illustrated herein.
- According to the sedimentological evidence and the associated floral assemblage, a warm with humid climate has been suggested.
- The collected fossil plants generally suggest a Jurassic to Lower Cretaceous age, but none of these species is diagnostic of a specific age. However, according to Burollet (1963) and Hammuda (1969), the stratigraphic position of the exposed Kashm az Zarzur Formation "formerly known as Giosc Shale and Chameau Mort sandstone" which containing the *Pagiophyllum yafraiensis* sp. nov. is upper middle to lower early jurassic (Callovian-Oxfordian) in age. However, based on palynological evidence the age was assigned to Bathonian-Tithonian (Hallett, 2002).

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