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A Middle Oxfordian (Jurassic) flora from the Kachchh Basin, western India, with the earliest record of bennettitaleans from the subcontinent

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ABSTRACT

We document two new forms of the bennetitalean genus *Williamsonia*, *Williamsonia* sp. A and *Williamsonia* sp. B, along with other fossil flora, such as horsetails and conifers, wood logs, flowers, and seeds (*Carpolithes* sp.) from the Middle Oxfordian Kanthkot Ammonite Beds (KAB), Washtawa Formation, exposed in the Wagad region of the Kachchh Basin, western India. This is the oldest and the only record of the genus *Williamsonia* from the marine Upper Jurassic rocks of India, as most of the records of this genus are from the early Cretaceous of India. The stuided horizon with plant fossils is rich in datable Middle Oxfordian ammonites and calcareous nannofossils.

Key-words: Horsetails, *Williamsonia*, Conifers, Middle Oxfordian, Washtawa Formation, Kachchh Basin

INTRODUCTION

Bennettitales is an extinct group of Mesozoic seed bearing plants characterized by pinnately compound leaves and bore complex reproductive structures. They were herbaceous mid storey plants and constitute a major portion of the Mesozoic vegetation in all the Gondwana (Eastern-Western) continents and has long geological history.

Traditionally, two families are recognized i.e., Cycadeoidaceae (Bennettitaceae) and Williamsoniaceae (Alvin et al. 1967, Taylor & Taylor 1993, Stewart & Ruthwell 1993). These families are distinguished by their growth habit and structure of reproductive organs. Cycadeoidaceae (Bennettitaceae) have short, herbaceous/ stocky trunk whereas Williamsoniaceae is characterized by the slender profusely branched stems.

The plant fossils are commonly found in the form of fronds, stems, flowers (male and female or bisexual) and bract scales. The reproductive structures are complex and may occur as male flower (*Weltrichia*), female (*Williamsonia*) and bisexual flower (*Amarjolia*). In the present communication we are documenting earliest record of two new forms of *Williamsonia* flowers along with seed *Carpolithes* sp. from the Wagad area, Kachchh District, Gujarat.

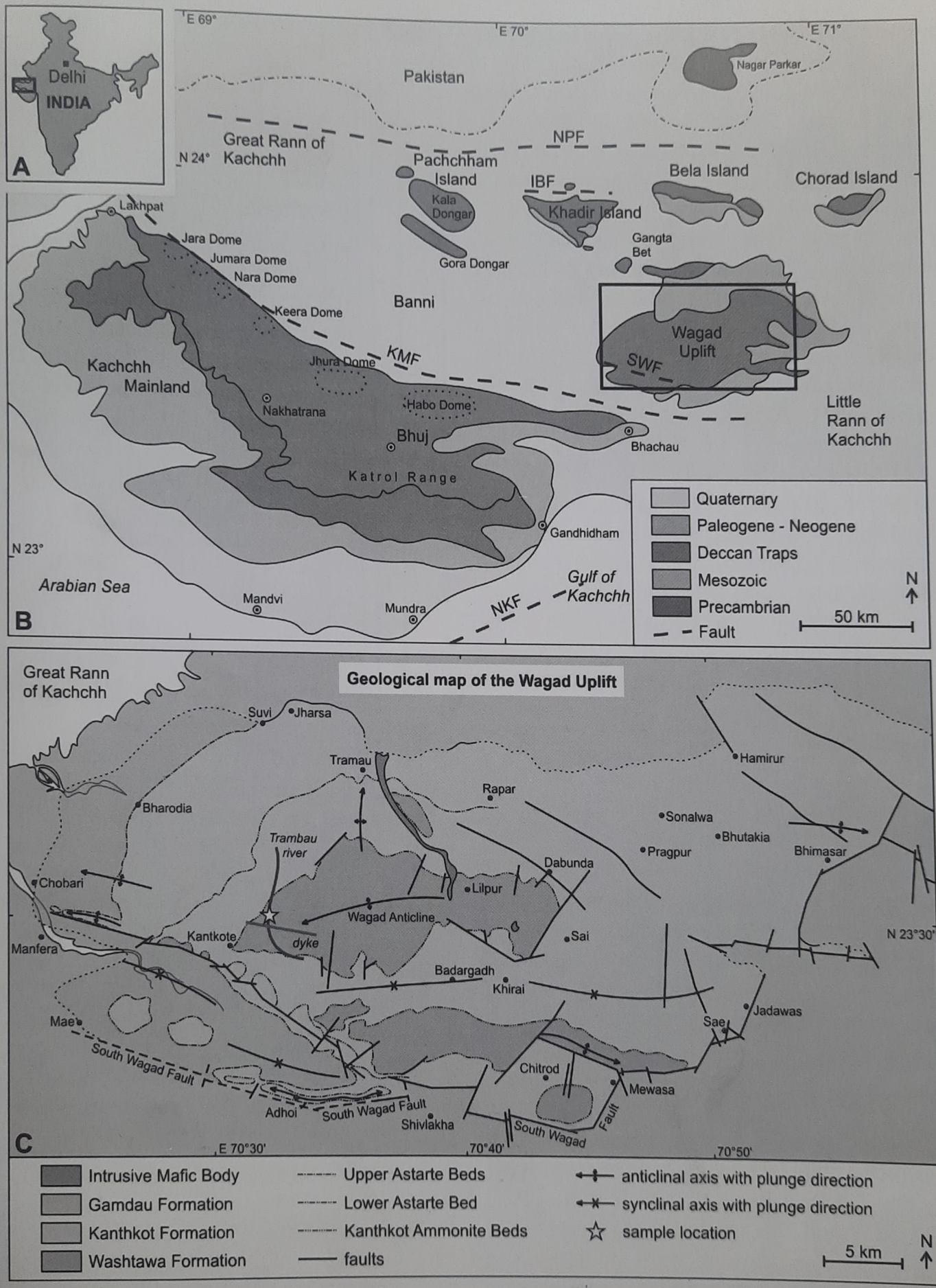
Plant fossils [pteridophytes (*Equisetites* sp.), and conifers (*Podozamites* sp., *Araucarites cutchensis*, Araucarian cone, *Brachyphyllum* sp.)] are also reported for the first time from the upper part of Nara Shale Member of Washtawa Formation, which were collected from a brick-red to yellowish, iron-rich calcareous sandstone succession and is exposed along the Trambau river between the villages of Kantkote and Jharsa in the Wagad uplift of the Kachchh Basin, western India. This sandstone succession called Kanthkot Ammonite Beds (KAB) has been dated as Middle Oxfordian (Pandey et al. 2012) and represents the uppermost part of the Washtawa Formation. The bedding planes of one horizon exposed at the dry river bed for more than thousand square meters is studded with a variety of ammonites, Equisetales, large conifers, and bennettitalean wood logs and pieces with attached fructifications and seeds. The ammonite assemblage contains *Perisphinctes* (*Liosphinctes*) *plicatilis* (Sowerby) and *Perisphinctes* (*Arisphinctes*) cf. *cotovuiformis* Enay and has been dated as Middle Oxfordian, more precisely as belonging to the Plicatilis/ Transversarium zones (Krishna et al. 1994, 1995, Pandey et al. 2012). Associated with the ammonites in shale partings, moderately diverse datable nannofossil flora has also been recorded. Based on the nannofossil assemblages in the under- and overlying horizons the best age suggested for the KAB is Middle Oxfordian (Rai et al. 2015). Other fossils include numerous belemnites, while remains of benthic organisms are surprisingly rare and almost restricted to gastropods of the genus *Eucyclus* (Alberti et al. 2013) and some oysters.

GEOLOGICAL SETTING

Kachchh, a pericratonic rift basin in Gujarat is situated on the western margin of the Indian subcontinent. The structural setup of the Kachchh Basin is governed by block faulting (Biswas 1987, 2005). The major uplifts are bounded by five parallel E-W trending faults which from north to south are: (1) Nagar Parkar Fault (NPF), (2) Island Belt Fault (IBF), (3) South Wagad Fault (SWF), (4) Kachchh Mainland Fault (KMF), and (5) North Kathiawar Fault (NKF). There are six major uplifts which were created due to the movement along these principle faults within the Kachchh Basin, viz., Pachchham, Khadir, Bela and Chorar hill (Island Belt), Wagad uplift and Mainland of Kachchh (Text figures 1A-C). The earlier work on the geology of Kachchh Basin is dealt by Wynne (1872), Waagen (1873-75), Poddar (1959, 1964), Pascoe (1959) and Biswas (1977, 1982, 1987, 1993, 2005).

The Jurassic rocks in the area are exposed in the Kachchh Mainland and on the so-called Island Belt (Text figures 1A-C). It is one of the most notable Mesozoic localities in the Indo-East African marine faunal province and is globally famous for its rich fauna of ammonites, other macro-invertebrates, foraminifers, ostracods, dinocysts and calcareous nannofossils, spanning the Pliensbachian to Albian time interval (for a review see Fürsich et al. 2013, Rai & Jain 2013). Stage and sub-stage boundaries have been precisely demarcated and correlated with European stages based on ammonites. However, little data so far has been published on Jurassic plant macrofossils of the basin, as most earlier published Jurassic records turned out to be Early Cretaceous in age (Sharma 1968, Pandya & Sukh-Dev 1990, Banerji 1992). The Mesozoic rocks deposited in the Kachchh Mainland are Patcham, Chari, Katrol and Umia formations of Waagen (1873-75). The upper part of Chari Formation of Oxfordian-Kimmeridgian age represented by Dhosa oolite is in condensed form in Mainland whereas in Wagad uplift they exhibit expanded succession. Biswas (1977) distinguished broadly three sub-basins within the Kachchh Basin and proposed an alternative litho-stratigraphic scheme of more regional applicability represented by Jhurio, Jumara, Jhuran and Bhuj formations in ascending order. The Jurassic succession dominantly comprises of sandstones, shales, marls, and limestones.

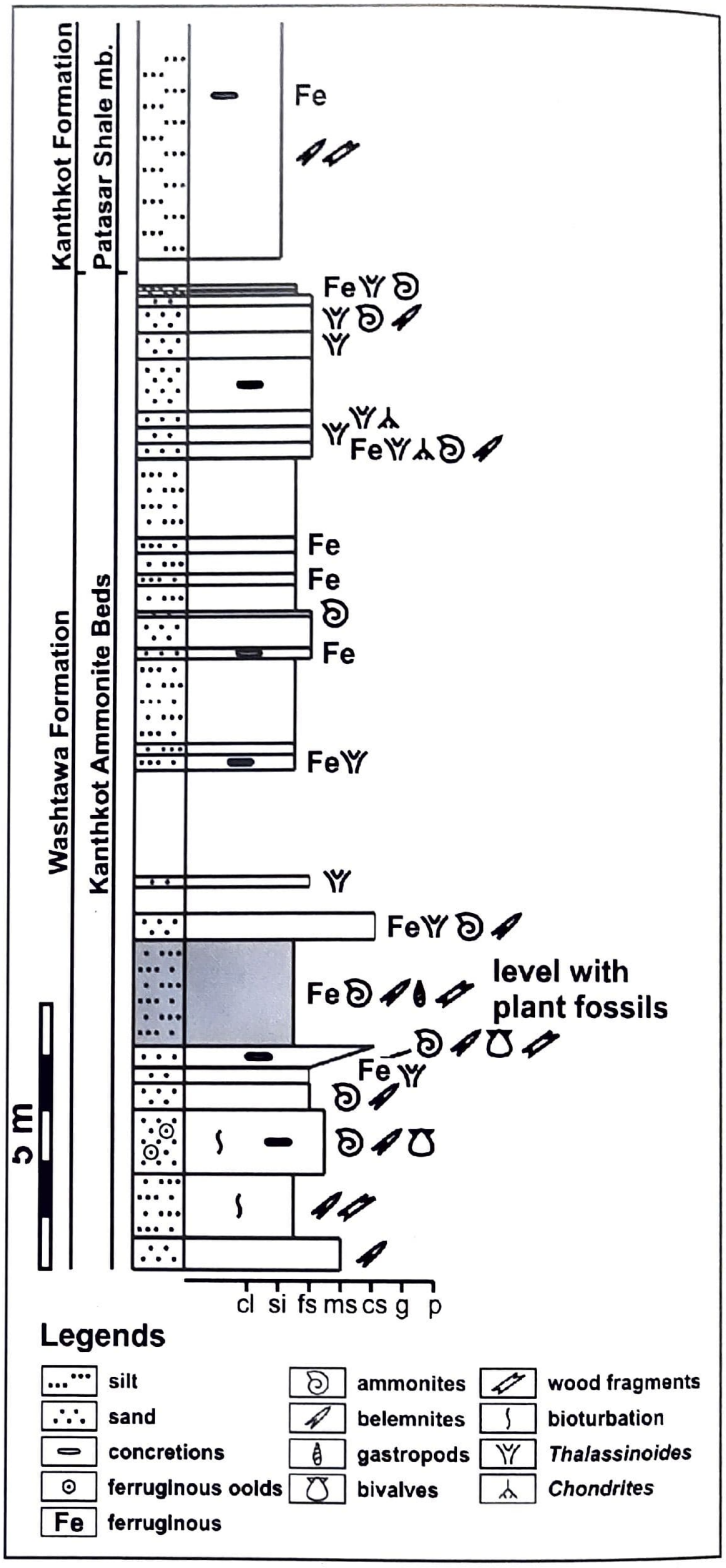
The Wagad uplift is situated between Mainland and the Island Belt towards northeastern side of Kachchh Mainland. It is the largest of the six major uplifts of the Kachchh Basin, bounded in the South by the high angle east-west striking Wagad fault. It constitutes a major geological province of the Kachchh basin and occurs as an isolated group of outcrops. The stratigraphy of Wagad has been worked out by Biswas (1977) and



Text Figure 1. Locality map, **A.** Inset map of India, **B.** Geological map of the Kachchh Basin demarcating the eastern part of the Wagad region, **C.** Geological map of the eastern part of the Wagad region, Kachchh Basin (modified after Deshpande & Merh 1980 and Fürsich et al. 2013).

Deshpande and Merh (1980). The whole sedimentary succession (ca. 600m thick) of Wagad area range in age from Callovian to Late Kimmeridgian (Text Figure 1C) and has been divided into three formations viz. Washtawa, Kanthkot and Gamdau in ascending order (Text-figure 2) encircled by a thin, narrow fringe of Tertiary sediments surrounded by alluvial and Rann areas. Sporadic work has been carried out on sedimentology, ichnofossil and sequence stratigraphy of Wagad area to decipher the environment of deposition (Deshpande 1972, Desai et al. 1975, Desai 1978, Deshpande & Merh 1980, Biswas 1980, Mishra 2009, Mishra & Biswas 2009, Pandey et al. 2012). Ammonites of Oxfordian to Late Kimmeridgian age were studied in some detail from this area by Krishna et al. (1998), Pandey et al. (2012), Roy et al. (2012), Pandey et al. (2013a, b) and Patel and Joseph (2012). Rai and Jain (2013) studied Bajocian-Kimmeridgian age calcareous nannofossils from Kachchh Mainland, Pachchham Island and Wagad area and recorded reworked calcareous nannofossils of Pliensbachian-Toarcian age in the basin. Rai et al. (2015) provided integrated nannofossil, dinocyst and ammonoid biostratigraphy for Washtawa and Kantkot formations of Wagad area.

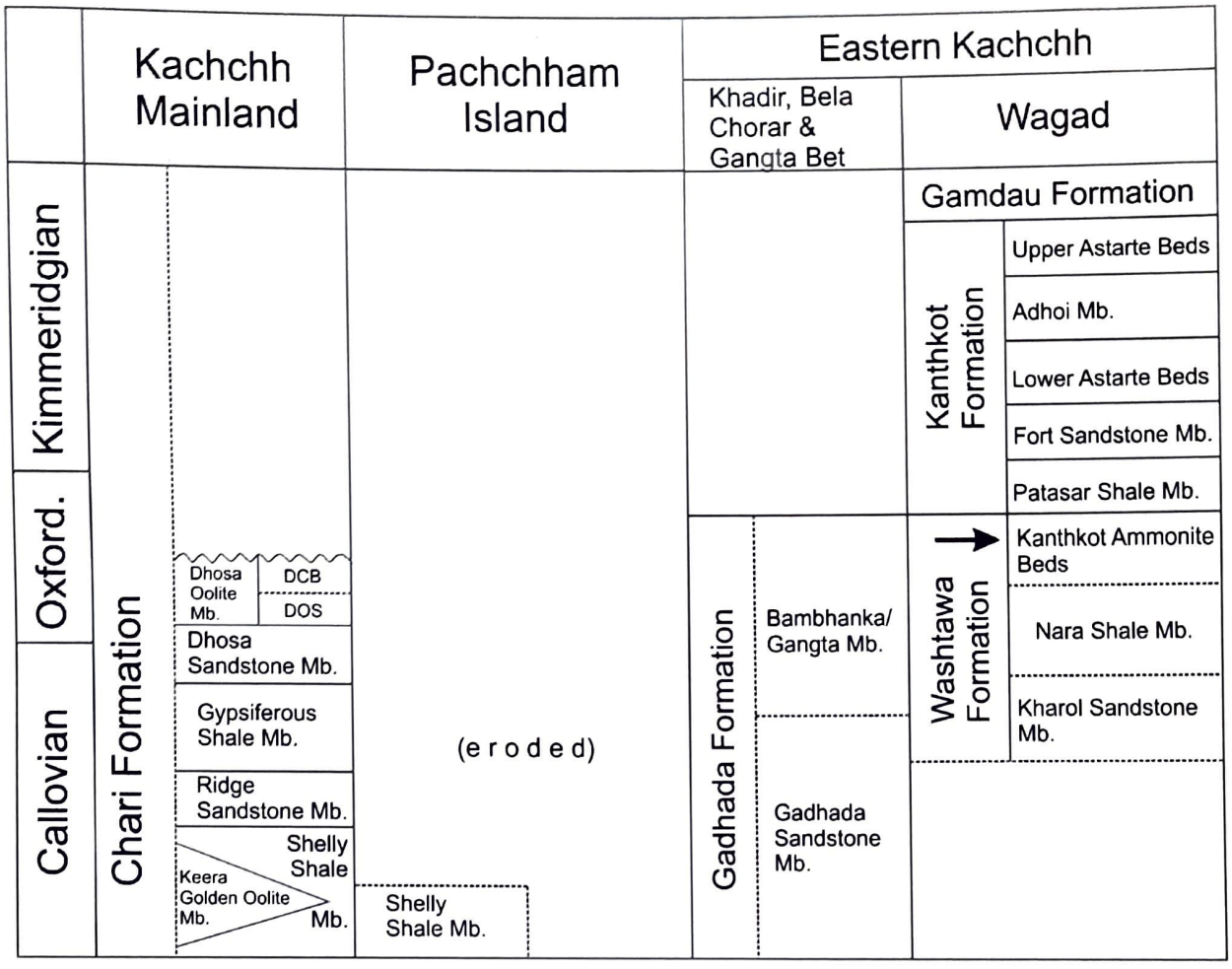
The marker KAB forms the upper part of the Washtawa Formation (Text Figure 2). Fossils of pteridophytes, bennettitalean fossil flowers, conifers, and stem logs along with ammonites and belemnites were observed and collected from these beds (Text Figure 3). This paper documents the composition of the plant assemblage, including the earliest record of bennettitalean fossil flowers in India along with their palaeogeographic distribution and palaeoecological significance.



Text Figure 2. Litholog of the KAB of the Washtawa Formation and the Patasar Shale Member of the Kanthkot Formation exposed along the Trambau river section (modified after Fürsich et al. 2013). The bed containing the flower *Williamsonia* and other plant fossils including wood logs (the Wood Log Bed of Fürsich et al. 2013) is marked.

MATERIAL AND METHODS

Two specimens of *Williamsonia* and ten seeds were collected from outcrop sections representing KAB along dry Trambau River (23°29'.32.9"N; 70°25' 42.2"E) in Wagad. The specimens are preserved as cast. The collected flowers were studied under Olympus stereomicroscope and images were taken by using Nikon camera D-5100. Thin-sections of *Bucklandia* (the stem) were prepared. The casts exhibit the fine structure of the wood, but as they consist of poorly indurated fine-grained argillaceous sediments, no anatomical features could be seen. The plant fossils



JCL: Jumara Coral Limestone Mb.; GYF: Goradongar Yellow Flagstone Mb.; JGO: Jhura Golden Oolite Mb.; CL/BLGO: Canyon Limestone/Badi Lower Golden Oolite; LPR: Leptosphinctes Pebbly Rudstone; DCB: Dhosa Conglomerate Bed; DOS: Dhosa Oolite Sandstone.

Text Figure 3. Lithostratigraphic framework of the Callovian to Kimmeridgian rocks exposed in the three sub-basins recognized by Biswas (1980) within the Kachchh Basin. Note the stratigraphic position of the KAB yielding plant fossils (arrow).

have been deposited in the museum of the Birbal Sahni Institute of Palaeosciences (BSIP), Lucknow with the locality number 7694 (Specimens no. BSIP 39992, 40142, 39993 A-J). In addition several plant fossils, such as those of equisetales and conifers were observed and photographed in the field.

AGE OF THE FOSSIL BEARING LEVEL

The topmost part of the Nara Shale Member of Washtawa Formation is represented by a highly ferruginous, sandy unit, referred as the KAB are rich in wood fragments and plant fructifications, ammonites, belemnites and rare gastropods (Text-figure 3). These beds are well exposed as escarpment section along the Trambau River (Plate 1, figures 1-2). Waagen (1873–1875) was the first to document ammonites from the Wagad Uplift in the Kachchh Basin followed by Spath (1927–1933). Later, Krishna et al. (1995, 1998, 2009a-c) and Pandey et al. (2012, 2013a, b) improved the ammonite- based biostratigraphic framework. The shales of the Washtawa Formation (Nara Shale Member, including the KAB) and the Kanthkot Formation (Patasar Shale Member) range from the Middle to Upper Oxfordian (Lower Plicatilis Zone to Bifurcatus Zone). The KAB were assigned Middle to Upper Oxfordian (Lower Plicatilis to Lower Bifurcatus zones) on ammonites (Pandey et al. 2012, Alberti et al. 2013). The lower part of the KAB was assigned to the Lower Plicatilis Subzone of the Plicatilis Zone (lower Middle Oxfordian) by Pandey et al. (2012). The central

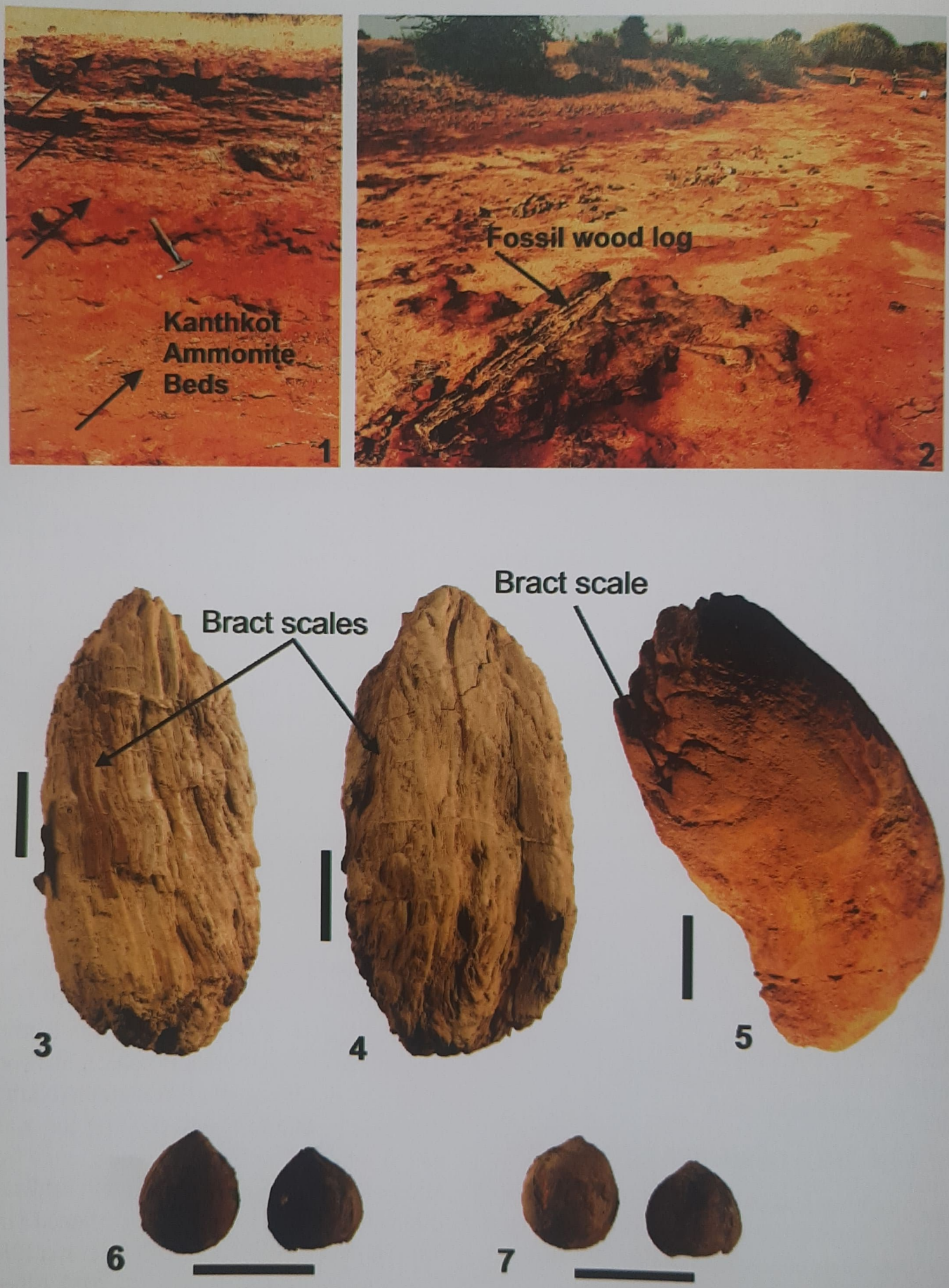


Plate 1

1. Field photograph showing the levels of KAB, which has yielded Middle Oxfordian ammonites (Pandey et al. 2012) and the plant fossils, **2.** One of the bedding planes with plant fossils exposed in the dry bed of the Trambau river (refigured from Fürsich et al. 2013), Coordinates: N23°29'36.0", E70°29'42.8", **3-4.** *Williamsonia* sp. A (BSIP 39992), note the bract scale, **5.** *Williamsonia* sp. B (BSIP 40142), Scale bar: 2 cm. **6-7.** Unfertilized/ fertilized ovuliferous seeds (*Carpolithes* sp.) (BSIP 39993 A-J).

part of the KAB is the richest ammonite bearing unit yielded ten taxa of the genus *Perisphinctes* enabling Pandey et al. (2012) to assign these to the Plicatilis–Parandieri subzones of the Plicatilis–Transversarium zones (Middle Oxfordian). The top part of the KAB yielded several perisphinctid taxa allowing the assignment of these levels to the Stenocycloides Subzone of the Bifurcatus Zone (lower Upper Oxfordian, Pandey et al. 2012). Four beds within the KAB at the Trambau River section have yielded a moderately diverse, slightly overgrown but datable nannofossil assemblage. The assemblage contains *Biscutum dubium*, *B. novum*, *Cretarhabdus* sp., *Cyclagelosphaera margerelii* (FAD *fide* Roth et al. 1983 marks Early Oxfordian), *Diazomatolithus lehmanii*, *Discorhabdus criotus*, *Ethmorhabdus gallicus*, *Hexapodorhabdus cuvillieri*, *Lotharingius hauffii*, *L. sigillatus* (LAD *fide* Casellato 2010 marks Middle Oxfordian), *Perissocyclus plethotretus*, *Polypodorhabdus escaigii* (FAD *fide* Thierstein 1976 marks Early Oxfordian), *Stephanolithion bigotii bigotii*, *Triscutum sullivanii*, *Watznaueria britannica*, *W. contracta*, *W. manivitiae* and *Zeugrhabdotus erectus*. Based on the nannofossil assemblages in the under- and overlying horizons, a Middle Oxfordian age has been deduced for these shale beds (Rai et al. 2015). *Cyclagelosphaera margerelii* (FAD; early Oxfordian) and *Polypodorhabdus escaigii* (FAD; early Oxfordian) continue upwards from underlying part of the Nara Shale Member recorded from the Nara and Washtawa domes of Wagad (Rai et al. 2015). Patasar Shale Member overlying the KAB exposed along the Trambau River section yielded nannofossils of Middle Oxfordian age (Rai et al. 2015). Therefore, the uppermost part of the section along Trambau River is not very thick and represents a condensed sedimentary sequence and has most probably provided the oldest occurrence of bennettitalean fossil flowers in India.

TAXONOMY

Division: Cycadophyta Bessey 1907

Class: Cycadopsida Foster and Gifford 1974

Order: Bennettitales Engler 1892

Family: Williamsoniaceae Carruther 1870

Genus: *Williamsonia* Carruther 1870

***Williamsonia* sp. A**

Plate 1, figures 3-4

Description: Closed flower, broadly lanceolate to ovate, 12 cm in length and 5.5 cm in width. Bracts narrow to linear, laterally fused, 24 in number, compact, arranged spirally, forming perianth of more than one whorl, slightly curved and tapering towards apex. Bracts are 2-3 mm wide, showing longitudinal striations. Apex is sub-acute to obtuse. Seminiferous and inter-seminiferous scales seem to be inconspicuous in the present specimen.

Comparison and remarks: The receptacle is not preserved in the present specimen. The specimen closely resembles *Williamsonia gigas* Feistmantel (1877) in form and size, described from the Lower Cretaceous of the Golapalli Formation (Godavari Basin) of the eastern part of India but *W. gigas* differs in being onion-shaped with a swollen lower middle region. The present specimen can be compared with *W. kakadbhitensis* described by Bose and Banerji (1984, p. 82) from the Lower Cretaceous Bhuj member of the Umia Formation of Kachchh which has smaller, hairy and less numerous bracts. In the present specimen, however, bracts are narrow to linear and not hairy. Some of the specimens of *W. blandfordi* (Feistmantel 1876) of Bose and Banerji (1984, p. 80, Text Figures D, K), resemble in shape and size of the present specimen, however, in *W. blandfordi* a dome-shaped receptacle is preserved in contrast to our specimen where a receptacle is lacking. *W. guptae* was reported from Jurassic rocks of the Rajmahal Hills by Sharma (1968, p. 375), but, later on was assigned a Cretaceous age (McDougall & McElhinny 1970). *W. guptae* differs from the present specimens in having more number of bracts (24 bracts). *W. carruthersii* (Seward) of Watson and Sincock (1992) from the Wealden of England shows some similarity in having an immature ovoid flower and narrow parallel bracts, but differs at the mature stage by opening like a flower and also by having cuticular features. All known comparable species of *Williamsonia* from India are shown in Table 1.

Table 1. Record of reproductive structures of bennettitales from India.

Sr. No.	Species	Area/Horizon	Age given/Actual age	Reference
1.	*Williamsonia kakadbhitensis*	Kachchh Basin (Kurbi, Kakadbhit & Walka Mota) Godavari Basin	Middle to Upper Jurassic/ Early Cretaceous	Bose & Banerji 1984
2.	*Williamsonia trambauensis*	Kachchh Basin (Trambau)	Middle to Upper Jurassic/ Oxfordian	Bose & Banerji 1984
3.	*Williamsonia sukhpurensis*	Kachchh Basin (Sukhpur)	Middle to Upper Jurassic/ Early Cretaceous	Bose & Banerji 1984
4.	*Weltrichia harrisiana*	Kachchh Basin (Kurbi & Kakadbhit) & Rajmahal Hills	Middle to Upper Jurassic/ Early Cretaceous	Bose & Banerji 1984
5.	*Williamsonia blanfordi*	Kachchh Basin (Kukurbit) & Godavari Basin	Not mentioned	Seward & Sahni 1920
6.	*Williamsonia indica*	Godavari Basin (Golapili) & Rajmahal Hills (Bindrabun)	Jurassic Series	Seward 1917
7.	*Weltrichia maldaensis*	Malda Basin, West Bengal	Upper Jurassic	Pal & Ghosh 1985
8.	*Weltrichia polyandra*	Rajmahal Hills	Jurassic-Cretaceous	(Ganju) Sitholey & Bose 1971
9.	*Weltrichia singhii*	Rajmahal Hills (Sakrigalighat)	Not mentioned	Bose 1967
10.	*Weltrichia santalensis*	Rajmahal Hills (Sakarigalighat, Dhokuti)	Not mentioned	Sharma 1969a
11.	*Williamsonia sahnii*	Rajmahal Hills (Khairbani village)	Not mentioned	Gupta 1943
12.	*Williamsonia microps*	Rajmahal Hills (Busko Ghat)	Jurassic Series	Feistmantel 1877
13.	*Williamsonia guptae*	Rajmahal Hills (Amarjola)	Middle Jurassic	Sharma 1968
14.	*Williamsonia amarjolense*	Rajmahal Hills (Amarjola)	Middle Jurassic	Sharma 1968
15.	*Williamsonia* cf. *W. scotica*	Rajmahal Hills (Amarjola)	Not mentioned	Sharma 1970a
16.	*Williamsonia sewardiana*	Rajmahal Hills (Amrapara)	Not mentioned	Sahni 1932
17.	*Amarjolia dactylota*	Rajmahal Hills (Amarjola)	Rajmahal Formation, Upper Jurassic	Bose et al. 1984
18.	*Williamsonia gigas*	Rajmahal Series	Jurassic Series	Seward 1917
19.	*Williamsonia seniana*	Satpura Basin (Sehora village)	Not mentioned	Bose & Kasat 1969

Specimen: B.S.I.P. Museum No. 39992

Locality: Trambau River (23°30'060"N: 70°29'635"E), Wagad region, Kachchh, Gujarat.

Horizon and age: Kanthkot Ammonite Bed, top of Washtawa Formation (Middle Oxfordian), Jurassic.

***Williamsonia* sp. B**

Plate 1, figure 5

Description: Flower bud is sub-sessile, covered up to three-fourth of its size by lozenge-shaped or thin, linear straight bracts. One-fourth of the bud open, companulate or semi-bulbous in shape, measuring 3-4 cm x 5 cm in size. Bracts incurved, acute at the apex, closely set, arranged in three whorls, and totalling 27 in number; sides parallel, showing incomplete faint linear longitudinal striations on surface. The point of detachment is not very clear.

Comparison and remarks: The present fructification of *Williamsonia* sp. B is a sub-sessile, hidden, half open bud of a *Williamsonia* flower, so far not reported from Kachchh. However, Sharma (1968) reported a similar type of closed hidden fossil flower named *W. amarjolense* from Early Cretaceous beds of Amarjola, Rajmahal Hills, Jharkhand (Table 1). *W. amarjolense* is almost similar in size and its bracts are incurved but are fewer in number. *W. sewardiana* Sahni

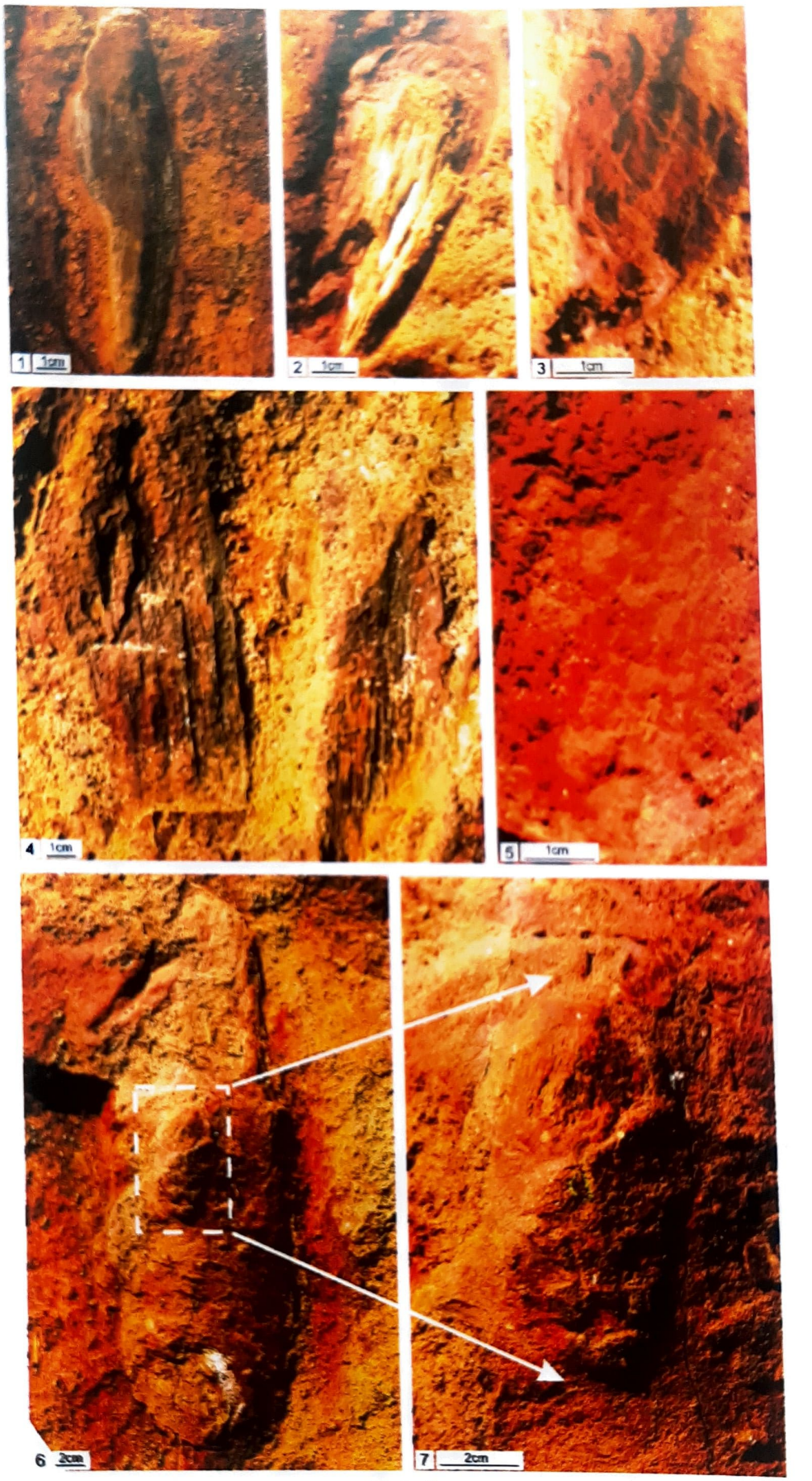


Plate 2

Field photographs of plant fossils, **1.** Lanceolate-shaped leaf of *Podozamites* (refigured from Fürsich et al. 2013, Fig. 133G), **2.** *Araucarites cutchensis* Feistmantel showing *Araucarites* cone scale, **3.** compressed Araucarian cone, **4.** *Equisetites* showing nodes, internodes, ridges and grooves, **5.** *Brachyphyllum* showing closely adpressed hexagonal leaves, **6-7.** Sessile *Williamsonia* flower laterally attached to a *Bucklandia* stem.

from the Rajmahal Hills (Sahni 1932) is a hidden flower which is also surrounded by bracts of stem. The bracts of both *W. sewardiana* and *Williamsonia* sp. B are linear and curved, but in *Williamsonia* sp. B bracts are not covered by dense hairs. Specimens of *W. carruthersii* Seward described by Watson and Sincock (1992) from the Wealden of England are similar in their mature stage as they open like a flower and have narrow parallel bracts but they differ in cuticular features.

Specimen: B.S.I.P. Museum No. 40142

Locality: Trambau river (23°29'36.0"N: 70°29'42.8"E), Wagad region, Kachchh, Gujarat.

Horizon and age: Kanthkot Ammonite Beds, Nara Shale member, top of the Washtawa Formation (Middle Oxfordian), Jurassic.

Genus*: *Carpolithes (Linnaeus ex Sternberg 1823) Brongniart 1822

***Carpolithes* sp.**

Plate 1, figures 6-7

Description: Small ovules, 15-25 mm long and 15-18 mm wide at the broadest point, preserved as casts or moulds. From the broadest point they gradually taper into a narrow blunt or acute apex.

Remarks: Numerous isolated ovules occur scattered on the bedding plane from which *Williamsonia* sp. A has been described. The ovules are assigned to *Carpolithes* sp. The specimens are preserved as casts and moulds and no anatomical details are preserved. The specimens are not attached to other identifiable plant remains and their affinity remains unknown. In gross morphology (such as size, obovate-shape, acute apex, flattened base, and smooth external surface) they are similar to *Carpolithes* sp. A described by Bose and Banerji (1984: p 120) from the Early Cretaceous sediments of the Kakadbhit area of Kachchh Mainland, western India, which contains a thick seed coat, which is not seen in our specimens. The present specimens resemble in gross features to *Carpolithes diospyriformis* Sternberg (1823) and to *Carpolithes* sp. described by Cleal and Rees (2003: 790) from the Middle Jurassic of Stonefield, Oxfordshire (United Kingdom), but they differ in size.

Specimen: B.S.I.P. Museum No. 39993 A-J

Locality: Trambau River (23°29'36.0"N: 70°29'42.8"E), Wagad region, Kachchh, Gujarat.

Horizon and age: Kanthkot Ammonite Bed, Nara Shale member, top of Washtawa Formation, (Middle Oxfordian), Jurassic.

OTHER PLANT FOSSIL RECORDS FROM KAB IN THE FIELD

***Equisetites* sp.:** The genus *Equisetites* is commonly known from Jurassic-Cretaceous sedimentary deposits of India. Field photographs show a resemblance to *E. rajmahalensis* Oldham & Morris, described by Bose and Banerji (1984) from Kachchh. Columnar stem incomplete, measuring 9 cm in length and 4-5.5 cm in width showing nodes and internodes. Internodes are marked with ridges and grooves. Nodes are slightly swollen with faint scale leaves, adhered on the nodes. Leaf segments linear, gradually tapering towards tips, about 4 mm long (Plate 2, figure 4).

***Williamsonia* sp.:** A sessile female flower of *Williamsonia* was also found attached laterally with a *Bucklandia* stem measuring 7 cm in length and about 4 cm in width. Stem measures 34.8 cm in length and 12.8 cm in width, shows very faint eye-shaped lenses of bracts at a few places, three-fourth of the sessile flower is covered with eye-shaped lenses of leaf bracts. Only one-fourth of the flower is open showing small, linear, lanceolate bract scales arranged in whorls, although, bract scales very faint and not clearly discernable (Plate 2, figures 6-7).

Podozamites (Brongniart) Braun 1843: Incomplete *Podozamites* leaf measuring 11.5 cm in length and 3.5 cm in width, linear, lanceolate, margin entire, apex obtuse and base truncate, faint longitudinal striations visible (Plate 2, figure 1).

Araucarites cutchensis Feistmantel 1876: *Araucarites cutchensis* is the type species of the genus *Araucarites*. The specimen found is a cone scale that is more or less wedge-shaped, measuring 7.8 cm in length and 3.5 cm in width at its broadest point. Distal margin curved or sloping. Base of scale narrow, truncate, tip short, broken, bluntly pointed, measuring 3 mm in length and 2 mm in width at broadest point. Dorsal side shows fine longitudinal striations. Obovate

seed embedded, measuring 2.2 cm in length and 1.8 cm width at broadest point, showing longitudinal striations. It is commonly known from the Jurassic-Cretaceous deposits of India (Plate 2, figure 2).

Araucarian cone: This is the first record of an Araucarian cone from the Wagad region. It is compressed, broken and moderately well preserved. It was found on the Trambau River bed associated with other floral elements (e.g., *Araucarites* stem). Although, Araucarian cone scales are commonly recorded in the Jurassic-Cretaceous deposits, a complete cone is rarely found. It resembles in shape with the Araucarian cone recorded by Taylor et al. (2009; p. 849). Cone is globose and obovoid in shape, measuring 2.2 cm x 1.6 cm in size with attached short stalk (11 mm in length, 8 mm in diameter), covered with remnants of broken scale leaves. Wedge-shaped cone scales, measuring 1-2 mm in length and 2-6 mm in width, densely arranged (Plate 2, figure 3).

***Brachyphyllum* sp.:** Conifer twig is fragmentary, measuring 5 cm in length and 1.5-2.0 cm in width. Leaves are thick, rhomboidal in shape, spirally arranged, closely adpressed on stem, margin entire, apex acute. Leaf base cushion is rhomboidal in shape, free part of the leaf mostly directed upward and not spreading out. *Brachyphyllum* is commonly known from the Jurassic-Cretaceous deposits of India (Plate 2, figure 5).

DISCUSSION AND CONCLUSION

In the Mesozoic, Bennettitales were one of the dominant plant groups growing in dry open land along with pteridophytes and conifers. They formed minor constituents of a mixed subtropical forest apparently existing in the hinterland of the Wagad area during Oxfordian times. Bennettitales proliferated during late Jurassic–early Cretaceous times and disappeared in the middle to late Cretaceous period at the advent of angiosperms. Rapid radiation of angiosperms was the probable cause of their sudden disappearance.

The stems of *Williamsonia* indicate presence of armour of leaf bases, which provided strength and acted as protective covering to withstand unfavourable conditions. The anatomy of the *Williamsonia* leaf shows sheathed vascular bundles, a thick cuticle and sunken stomata. A sclerenchymatous hypodermis acted as supporting tissue and provided rigidity from wilting in stressful conditions during dry periods. The mechanism of abscission in flowers and leaves provided protection against desiccation by lowering the transpiration rate during adverse conditions.

Globally, bennettitales were at their zenith during the Jurassic Period. McLoughlin and Pott (2009) described this period as the 'Age of Bennettitales' instead of age of Cycads. The bennettitales are represented by stem (*Bucklandia*), foliage (*Ptilophyllum*), and reproductive structures (male flower: *Weltrichia* Braun, female flower: *Williamsonia* Carruther and bisexual flower: *Amarjolia*). Bennettitales have been recorded from both the hemispheres (Barboni and Dutra 2013), but records from the northern hemisphere are more common (Popa 2014). Their records in South America are represented by leaf remains, scale leaves, and seed cones. Recently, McLoughlin et al. (2011) also recorded them in the early Oligocene.

Records from Australia and New Zealand are rare and include leaf foliage (Cantrill & Hunter 2005). Diverse fragmentary leaf foliage and other doubtful forms of *Williamsonia* have been reported from Antarctica (Cantrill & Hunter 2005). From India there are numerous records of leaves from several sedimentary basins but records of *Weltrichia*, *Williamsonia*, and *Amarjolia* are rare. In addition to leaves, stems and flowers have also been recorded from different sedimentary basins, e.g. the Rajmahal Basin of Jharkhand (Sitholey & Bose 1971, Banerji 1992, Sharma 1992), Golapalli area of Krishna Godavari Basin along the east Coast (Pandya & Sukh-Dev 1990), and the Kachchh Basin, western India (Bose & Banerji 1984) (Table 1).

Williamsonia flowers have been categorized into two types, based on the mode of attachment to the stem, viz. 'exposed type' (e.g., *W. guptai, W. amarjolense*) and 'partially embedded type' (e.g., *W. sewardiana*) (Sahni 1932, Gupta 1958, Sharma 1971). Both types of flowers have been recorded from

Amarjola area (the type locality) in the Rajmahal Hills, Jharkhand. The exposed type of flowers is borne either terminally or laterally on the stem with definite point of detachment and has a single type of bracts. The partially embedded type of flowers is surrounded by the bracts of the stem having no definite point of detachment (Sharma 1971). These flowers possess two types of bracts; one produced from the base of the receptacle and the other borne on the peduncle.

These fructifications occur on the two types of *Bucklandia* stems so far recorded from the Rajmahal Hills (Sharma 1971). Stems possessing spirally arranged rhomboidal marks of fallen leaf traces left by exposed type of fructification and stems which possess markings of narrow lozenge-shaped bases of bracts or thin linear straight bracts covering the partially embedded fructification (Sharma 1971), which probably on maturation became exposed and subsequently detached from the parent plant. Sharma (1974) suggested that the hidden type of flower is more advanced than the open type. This may be due to sterlization and reduction of the bracts, a view shared by the authors.

The present study indicates that *Williamsonia* sp. A and *Williamsonia* sp. B from the KAB at the top of the Nara Shale member of the Washtawa Formation of the Wagad region, Kachchh is the earliest record of this bennettitalean genus from India. Other records of *Williamsonia* are from the early Cretaceous of India. Also, the associated rich ammonite fauna allows pinpointing the age of the *Williamsonia*-bearing KAB to the Middle Oxfordian *Plicatilis* and *Transversarium* zones. Additionally, calcareous nannofossils from associated sediments support this age assignment. The abundant wood logs occurring scattered on the dry bed of Trambau River suggests that during Oxfordian times a conifer community with associated bennettitaleans existed on the coastal plains situated in the east of the Gulf of Kachchh. During extreme floods, the uprooted trees were carried within rivers to the coastal areas where they got accumulated together with a fully marine fauna of invertebrates such as ammonites and belemnites.

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