



OCCURRENCE OF *BRACHYPHYLLUM REGULARIS* BORKAR *ET* CHIPLONKAR FROM HIMMATNAGAR SANDSTONE AND ITS GEOGRAPHIC DISTRIBUTION IN INDIAN GONDWANA BASINS

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ABSTRACT

Conifer morphogenus *Brachyphyllum* (Brongniart) Harris, 1979 and its species *Brachyphyllum regularis* Borkar *et* Chiplonkar (1973) is reported for the first time from Hathmati River section of Himmatnagar Sandstone Formation of Gujarat. Closely adpressed short thick leathery leaves are adapted to a long period of drought and xeric conditions. These xeromorphic features indicate that araucarian trees often grew in the forest which is not far from the coastal area in tropical to subtropical climatic conditions. Its occurrence in Himmatnagar Sandstone is significant as it extends its geographic distribution from Songad, Saurashtra to Himmatnagar and East-Coast area (Athgarh and Gollapalle) during Early–Middle Cretaceous age.

Keywords: *Brachyphyllum regularis*, Hathmati River section, Early Cretaceous, Himmatnagar Sandstone.

INTRODUCTION

Himmatnagar (23° 36' 00" N; 72° 57' 45" E) is situated in Sabarkantha district of Gujarat and was earlier named as Ahmadnagar Sandstone by Middlemiss (1921) and renamed as Himmatnagar Sandstone by Gupta and Mukherjee (1938). Gujarat is physiographically comprises of three distinct zones – the Gujarat Mainland, the Saurashtra, and the Kachchh Mainland. The sedimentary deposits of Himmatnagar Sandstone are exposed in Gujarat Mainland (Fig. 1). Geology of the state was mainly dealt by Middlemiss (1921) and Akhtar and Aquil (1984). Sahni (1936) for the first time recorded genus *Matonidium* and *Weichselia* from Berna while few plant fossils were also recorded by Banerji *et al.* (1983) from a hillock near the railway station of Himmatnagar. The authors are reporting *Brachyphyllum regularis* for the first time from newly discovered Hathmati River section of Himmatnagar Sandstone.

GEOLOGICAL SETTING

The Himmatnagar town (23°36'16" N and 72°57'39" E) is a part of Himmatnagar Tehsil of Sabarkantha District in north Gujarat is situated at about 80 km NNE of Ahmadabad. Here sandstones predominate as main rock type and are mainly horizontal to sub–horizontal and exposed in the form of flat-topped hillocks on the east of Himmatnagar and the stream and river sections on the west of Himmatnagar Town below thin alluvium cover. Himmatnagar Sandstone Formation rests unconformably over Archeozoic Erinpura granite and is overlain by Deccan Traps of Cretaceous – Tertiary age and soil of alluvium of mainly Holocene age. It comprises an alternate sequence of shales, sandstones and conglomerates, ranges in age from Neocomian to Albian, i.e., Early to Middle Cretaceous (Fig. 2). Fromfield observations, Bhatt *et al.* (2016) subdivided Himmatnagar Sandstone Formation into lower and upper members. Plant fossils and trace fossils are well preserved in silty shale and grey-wacks of its lower member (Fig. 3).

At Hathmati River (23° 36' 31" N; 72° 51' 42" E), about 18 – 20 m thick section is exposed (Fig. 3). The base of the

section could not be seen as it is submerged in water. The lower part of the section consists mainly of massive to horizontally stratified sandstone. The basal sandstone is overlain by 2 m thick ferruginous fine silty shale, which contains plant fossils. This horizontal plant bearing bed of purplish-pink coloured silty shale is followed upward by 3 m fine grained sandstone with contorted bedding. This sandstone bed is overlain by multi layers of ~3 – 3.5 m thick shale. It is again followed by ~3 m thick horizontally stratified sandstone. This entire sequence is overlain by channelized gritty to cobbly trough cross-stratified graded sandstone.

MATERIAL AND METHODS

Four well-preserved specimens of *Brachyphyllum* were collected from the 18-20 m thick Hathmati River section of Himmatnagar Sandstone Formation. The plant fossils were first examined in the natural state under a stereo binocular microscope (Olympus SZH) and photographed by using a Nikon 15 D camera with Cell-Sens standard 1.8 image analysis software. All specimens are deposited in Birbal Sahni Institute of Palaeosciences Museum, Lucknow, India.

SYSTEMATIC PALAEOBOTANY

Class **Pinophyta** Cronquist *et al.*, 1966

Order **Pinales** Dumortier, 1829

Genus ***Brachyphyllum*** (Brongniart)
Harris, 1979

Brachyphyllum regularis Borkar *et* Chiplonkar, 1973
(Pl. I, figs. 1-6)

Description: Conifer twig broad, straight, sometimes irregularly branched, branches up to 9 cm long and 7-15 mm wide, branching at an angle of 25°–40°. Scale leaves sub-hexagonal apparently looking circular in shape, 7 mm in length and 5 mm in width, spirally disposed, arranged in such a manner that amongst every four adjacent leaves a squarish inter-space

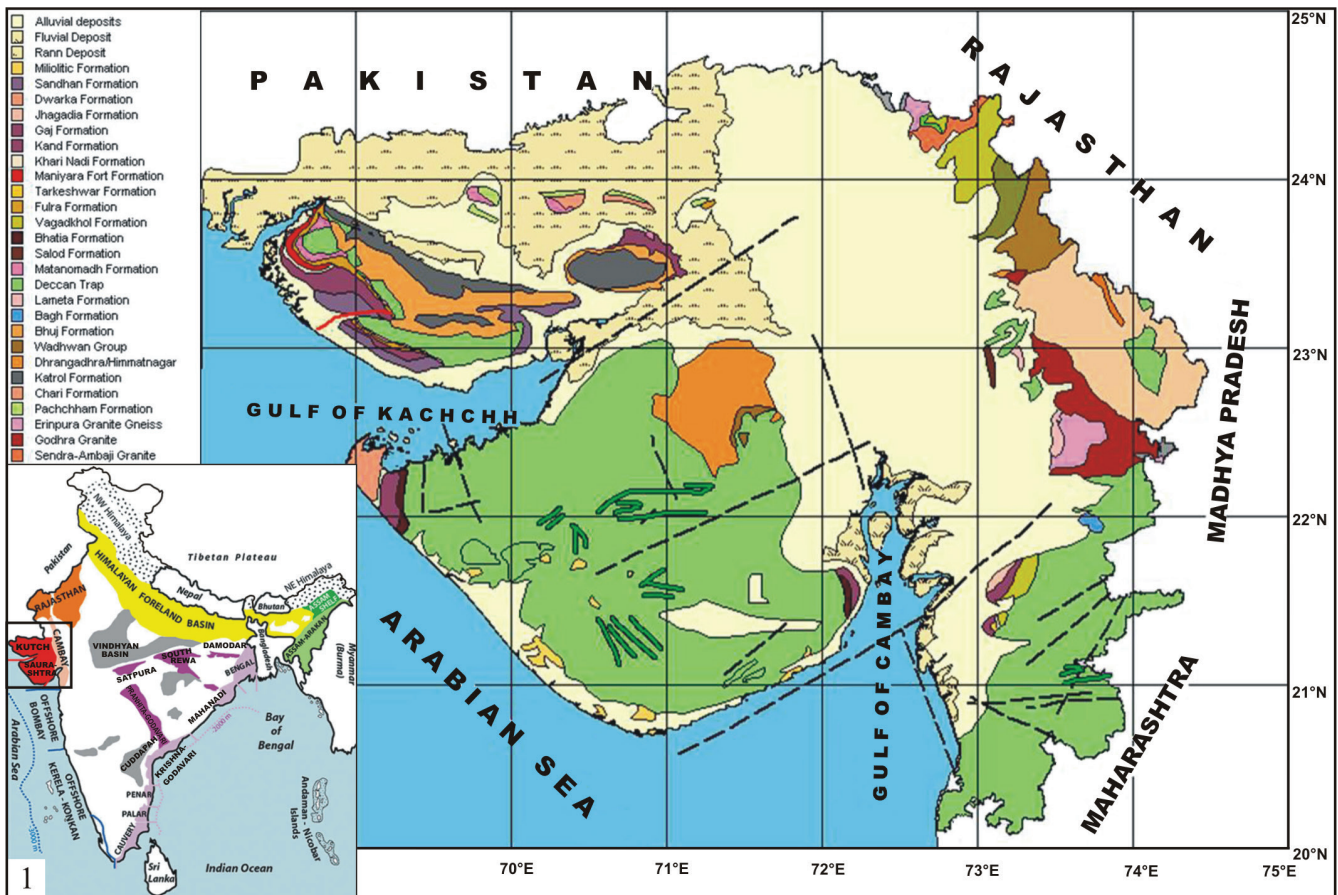


Fig. 1. Geological map of Gujarat.



Fig. 2. Google Satellite Map showing location of study area.

is left. Margin entire. Apex acute. Exactly in the center of each leaf, a circular to sub-circular pit or tubercle is present.

Specimen: BSIP Museum No. 41174, 41175, 41176, 41177.

Locality: Hathmati River Section, Himmatnagar.

Horizon and age: Himmatnagar Sandstone Formation, Early Cretaceous.

EXPLANATION OF PLATE I

Brachyphyllum regularis Borkar et Chiplonkar: Figs. 1, 2. Leafy conifer twig showing spirally arranged rhomboidal to sub-hexagonal leaves with protuberance in the center. Specimen Nos. 41174 (Holotype) and 41175. Fig. 3. Small fragmentary leafy shoots showing spirally arranged leaves. Specimen No. 41175. Figs. 4, 5, 6. Branched conifer twig showing faint impressions of leaves. Specimen nos. 41174, 41176 and 41177 (Scale Bar = 1 cm).



Age	Formation	Lithology
Recent	Alluvium	Alluvium
..... Unconformity		
Upper Cretaceous- Tertiary (Palaeocene)	Deccan Trap	Basalt
..... Unconformity		
Early – Middle Cretaceous	Himmatnagar Sandstone	Silty-greywacke, varied coloured stratified shale, sandstone, yellowish brown conglomerates
..... Unconformity		
.....Precambrian Basement Rocks.....		

Fig. 2. Generalized Surface Stratigraphy of Himmatnagar Sandstone.

Remarks: The morphogenus *Brachyphyllum* (Brongniart) Harris, 1979 is reported for the first time from the Early Cretaceous beds of Himmatnagar Sandstone Formation.

Comparison: The present specimen closely agree with the gross features of *Brachyphyllum regularis* Borkar *et* Chiplonkar (1973) reported from Early Cretaceous beds of Songad, Kathiawar, Saurashtra Basin; Gollapalle Formation, Krishna-Godavari Basin (Pandya and Sukh-Dev, 1990) and Athgarh Formation, Mahanadi Basin (Prakash and Sukh-Dev, 1995), but shows comparatively less demarcating inter-space at the center of the pattern of arrangement of leaves. Rhomboidal leaves are also reported in *B. rhombicum* (Feistmantal) Sahni (1928), *B. bravifolia* and *B. rhomboidalis* Srivastava *et al.* (1985), but their leaves are comparatively much smaller and showing cuticular features. *Brachyphyllum regularis* also resembles with twigs of *B. nepos* and *B. gracile* reported from Jurassic of France by Saporta (1884) and *B. obesum* from Lower Cretaceous of Crato Formation, Brazil (Kunzmann *et al.*, 2004) in having knob-like projections over similar type of leaves but this is not a regular feature in the French and Brazilian specimens. In general, shape and size of leaves, the species also resemble with *B. obtusum* and *B. ningshiaense* Du *et al.* (2013), but they differ in not possessing knob like projections as well as in the arrangement of leaves.

REMARKS ON PALAEOENVIRONMENTAL IMPLICATIONS

Genus *Brachyphyllum* is established for sterile leafy branches

with spirally arranged imbricate and scale-like leaves in which the length of the free part or total height of the leaf and cushion is as long as or less than the width of the leaf cushion (Harris, 1979; Ohana and Kimura, 1993; Du *et al.*, 2013). The conifer genus is most commonly found in Jurassic – Early Cretaceous palaeofloral assemblage of India and abroad (Sukh-Dev, 1987) it may be due to its wide environmental tolerance (Vakhrameev, 1970, 1991; Alvin, 1982; Hesselbo *et al.*, 2003; Greb *et al.*, 2006; Wang *et al.*, 2005; Popa and Van Konijnenburg-van Cittert, 2006; Barbacka, 2011).

Although genus *Brachyphyllum* is worldwide in distribution from Late Triassic to Late Cretaceous (Alvin, 1982; Kunzmann *et al.*, 2006) still its affinity is controversial, may be allied to Podocarpaceae, Araucariaceae, Cheirolepidaceae or Taxodiaceae (Alvin, 1982; Stockey, 1982, 1994; Bose and Banerji, 1984; van der Ham *et al.*, 2003; Passalia, 2009). They are most commonly referred to family Araucariaceae in Indian records as leafy twigs of *Brachyphyllum* are frequently found in

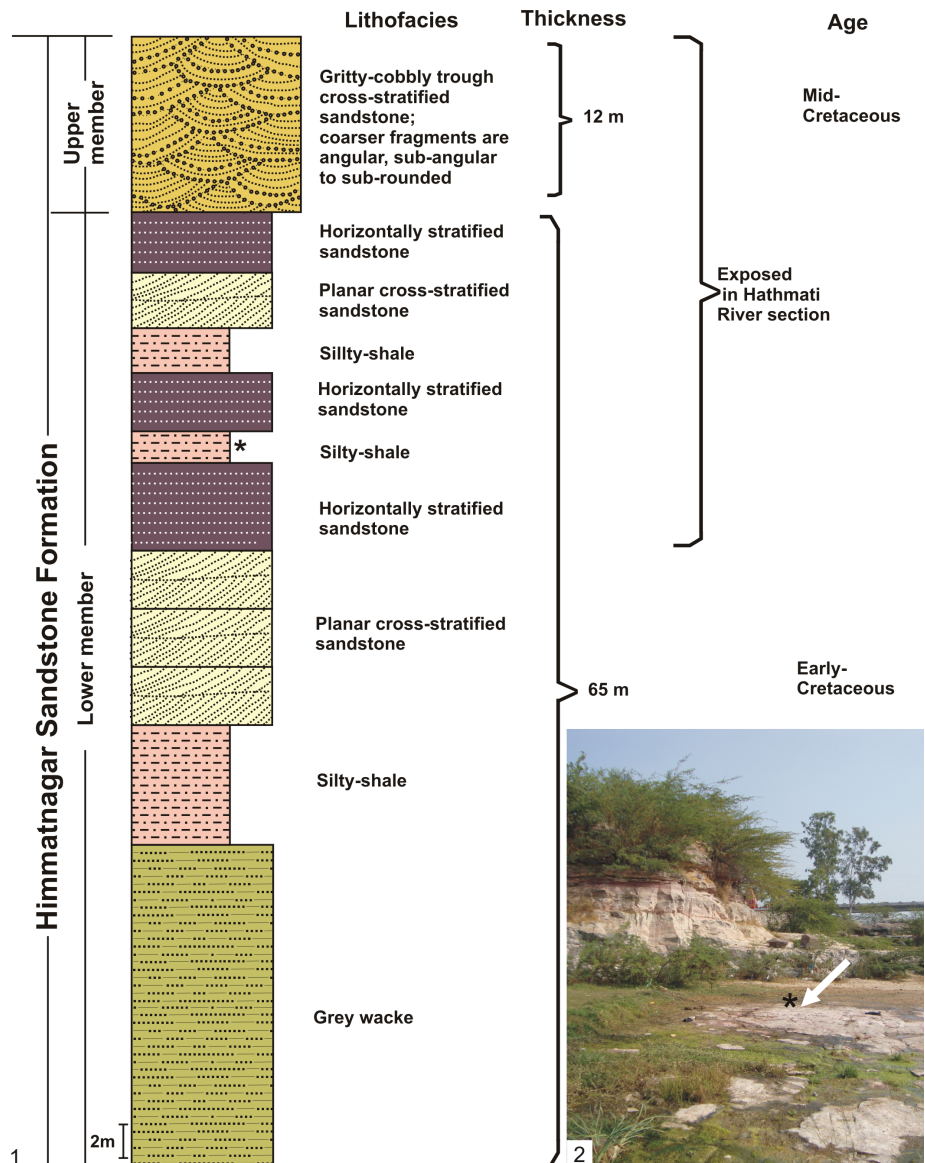


Fig. 3. (1) Composite litholog showing stratigraphic division and lithofacies distribution (modified after Bhatt *et al.*, 2016). (2) Localities map from where plant fossils are collected. (* showing plant fossil horizon).

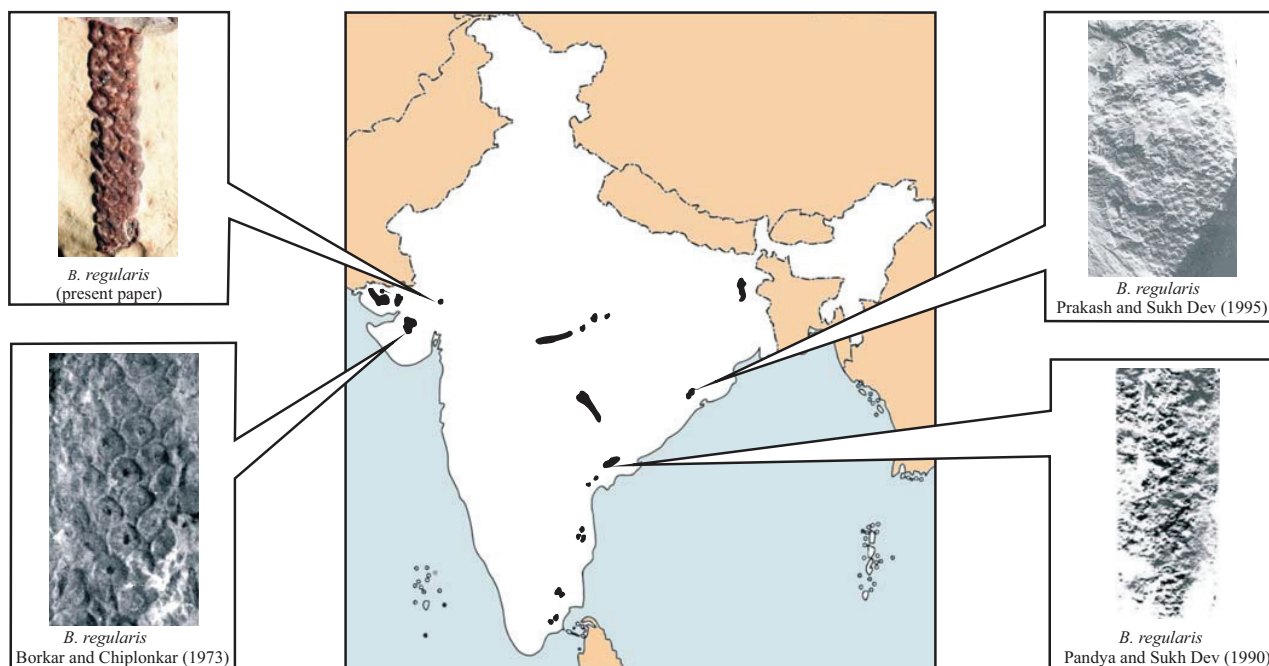


Fig. 4. Geographical distribution of *Brachyphyllum regularis* Borkar et Chiplonkar in Indian Gondwana.

association with cone scales (*Araucarites*) of Araucariceae. But presently due to lack of other allied evidences (e.g., cuticle and pollen), it is preferred here to put in *incertae sedis*. Probably the conifer trees belonging to genus *Brachyphyllum* might have evolved in response to ameliorating climatic conditions after Permian-Triassic extinction (Kershaw and Wagstaff, 2001) and has been recorded in both the hemisphere (Stockey, 1990) but had maintained its dominance in the vegetation of Southern hemisphere (Florin, 1963; Kershaw and Wagstaff, 2001). It was likely due to the rising sea levels through the Jurassic resulted in both precipitation and temperature that facilitated the development of forest vegetation (Kershaw and Wagstaff, 2001). The coniferous canopy was almost certainly evergreen as indicated by leaf physiognomy and its comparison with modern podocarps and araucarians (Falcon-Lang and Cantrill, 2001). They show major adaptability in light of competition with angiosperm and extant genera of Mesozoic vegetation. Its thick leathery leaves and succulent shoots are adapted to a long period of drought and xeric conditions which is also evidenced by the presence of cuticular characters e.g., thick cuticle with sunken stomata, circularly arranged subsidiary cells with thick walled epidermal cells and presence of stomatal hairs (in other Indian species of *Brachyphyllum*). These xeromorphic evidences indicate that these conifer trees might have grown in the forest not far from the coastal area (Harris, 1979; Vakhrameev, 1991) and might be of coastal halophyte types that grows in sub-saline environment (Jung, 1974). This view gets support by European floral statistical analyses done by Barbacka *et al.* (2014) where *Brachyphyllum* fossils fall in a group typical of lagoonal coastal vegetation that thrived under tropical to subtropical climatic conditions (Karakitsios *et al.*, 2015; Vakhrameev, 1975 and Vakhrameev *et al.*, 1978).

PALAEOGEOGRAPHIC OCCURRENCE

Brachyphyllum regularis is very characteristic species

which was earlier only recorded from Early Cretaceous beds of Songad, Saurashtra Basin by Borkar and Chiplonkar (1973). Later Pandya and Sukh-Dev (1990) and Prakash and Sukh-Dev (1995) reported this species from Athgarh Formation of Mahanadi Basin as well as from Gollapalle Formation of Krishna-Godavari Basin of East-Coast (Fig. 4). Its occurrence in Himmatnagar Sandstones is very significant as it extends its geographic distribution from Songad, Saurashtra to Himmatnagar and to East-Coast area (Athgarh and Gollapalle) during Early – Middle Cretaceous (Aptian–Albian) age.

CONCLUSION

Brachyphyllum regularis has been recorded for the first time from Hathmati River section of Himmatnagar Sandstone Formation belonging Early-Middle Cretaceous age.

Conifer genus *Brachyphyllum regularis* is widespread in both the hemispheres but is dominant in the southern hemisphere.

The conifer trees might be of halophyte type that grows near the coastal areas that thrived under tropical-subtropical climatic conditions.

Other records are from Early Cretaceous sedimentary deposits of East-Coast area indicating its geographic occurrence from east to west.

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