

# Reappraisal of palaeofloristics of Himmatnagar Sandstone vis-à-vis palaeogeographic significance

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## ABSTRACT

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The state of Gujarat physiographically comprises three distinct zones—the Gujarat Mainland, the Saurashtra and the Kachchh. The sedimentary deposits of Himmatnagar Sandstone (23°36'00": 72°57'45") are mainly exposed in Gujarat Mainland. Palaeobotanical study reveals occurrence of plant fossils *Matonidium*, *Weichselia*, *Cladophlebis*, *Gleichenia*, *Sphenopteris*, *Dictyophyllum*, *Pachypteris*, *Pagiophyllum* and *Araucarites*. Bennettitales are absent. Numerically pteridophytes are represented by 61%, pteridosperms are represented by 7% and cycads are represented by 7% while conifers are represented by 24%.

The assemblage is compared and correlated with contemporaneous deposits in India and other Gondwanic continents and found that it is coeval to fossil floral assemblage of Dharangdhara Formation, (Saurashtra) and Bansa Formation of South Rewa (in central part of India) and Athgarh Formation on east-coast of India, in having common occurrence of Wealden frond *Weichselia* with dominance of pteridophytic fronds and conifers of family Araucariaceae. Due to common occurrence of pteridophytes and conifers (at generic level) the flora also resembles to Bluff flora of Alexander Island (Antarctica) and Barco flora of Baqueró Formation of Patagonia (South America) indicating that the dispersal of biota might have taken place through Kerguelen Plateau or Gunnars ridge via Antarctica.

**Key-words**—Himmatnagar, Palaeoflora, Palaeogeography, Early Cretaceous, India.

## हिम्मतनगर बलुआपत्थर के पादपअध्ययन के पुनर्मूल्यांकन की तुलना में पुराभौगोलिक महत्ता

नीरू प्रकाश, नीलम दास, निशीत वाई. भट्ट एवं पारस एम. सोलंकी

## सारांश

भू-आकृतिविज्ञान के रूप में गुजरात राज्य तीन पृथक अंचलों—गुजरात मुख्य भूमि, सौराष्ट्र एवं कच्छ में समाविष्ट है। हिम्मतनगर बलुआपत्थर (23° 36' 00" : 72° 57' 45") के अवसादी निक्षेप मुख्यतः गुजरात मुख्य भूमि में अनावरित हैं। पुरावानस्पतिक अध्ययन पादप जीवाश्मों *मेटोनीडियम*, *व्येकसीलिया*, *क्लेडोफ्लेबिस*, *ग्लीकिनिया*, *स्फीनोप्टेरिस*, *डिक्टोओफायल्लम*, *पेचीप्टेरिस*, *पेजियोफायल्लम* एवं *एरोकैराइटिस* की प्राप्ति व्यक्त करता है। बेनेटिटेलीय नदारद हैं। संख्या रूप में टेरीडोफाइट्स 61% से निरूपित हैं, टेरीडोस्पर्म 7% से निरूपित हैं तथा साइकैड 7% से रूपायित हैं जबकि शंकुवृक्ष 24% से निरूपित हैं।

समुच्चय भारत एवं अन्य गोंडवानी महाद्वीपों में समकालीन निक्षेपों के तुल्य एवं सहसंबंधित है तथा पाया कि टेरीडोफाइट पौधों व एरोकैरीएसी कुटुंब के शंकुवृक्षों की प्रधानता से विल्डेन पौधा *वीचसेलिया* की साधारण प्राप्ति में ध्रुवधारा शैलसमूह, (सौराष्ट्र) व दक्षिण रीवा (भारत के मध्य भाग) एवं भारत के पूर्वी-तट पर अथगढ़ शैलसमूह की जीवाश्म पुष्पी समुच्चय के समकालीन है। टेरीडोफाइटों व शंकुवृक्षों की साधारण प्राप्ति की वजह से वनस्पति—जात एलेक्सेंडर द्वीप (दक्षिण ध्रुव) की वनस्पति—जात तथा पटगोनिया (दक्षिण अमेरिका) में बेक्युरो शैलसमूह की बार्को वनस्पति—जात से भी मिलती—जुलती है द्योतित कर रही है कि जीवजात का विसर्जन दक्षिण—ध्रुव से होकर केरगूलेन पठार अथवा गनर्स पर्वत—श्रेणी के जरिए से हुआ होगा।

**सूचक शब्द**—हिम्मतनगर, पुरावनस्पति—जात, पुराभूगोल, प्रारंभिक चाकमय, भारत।

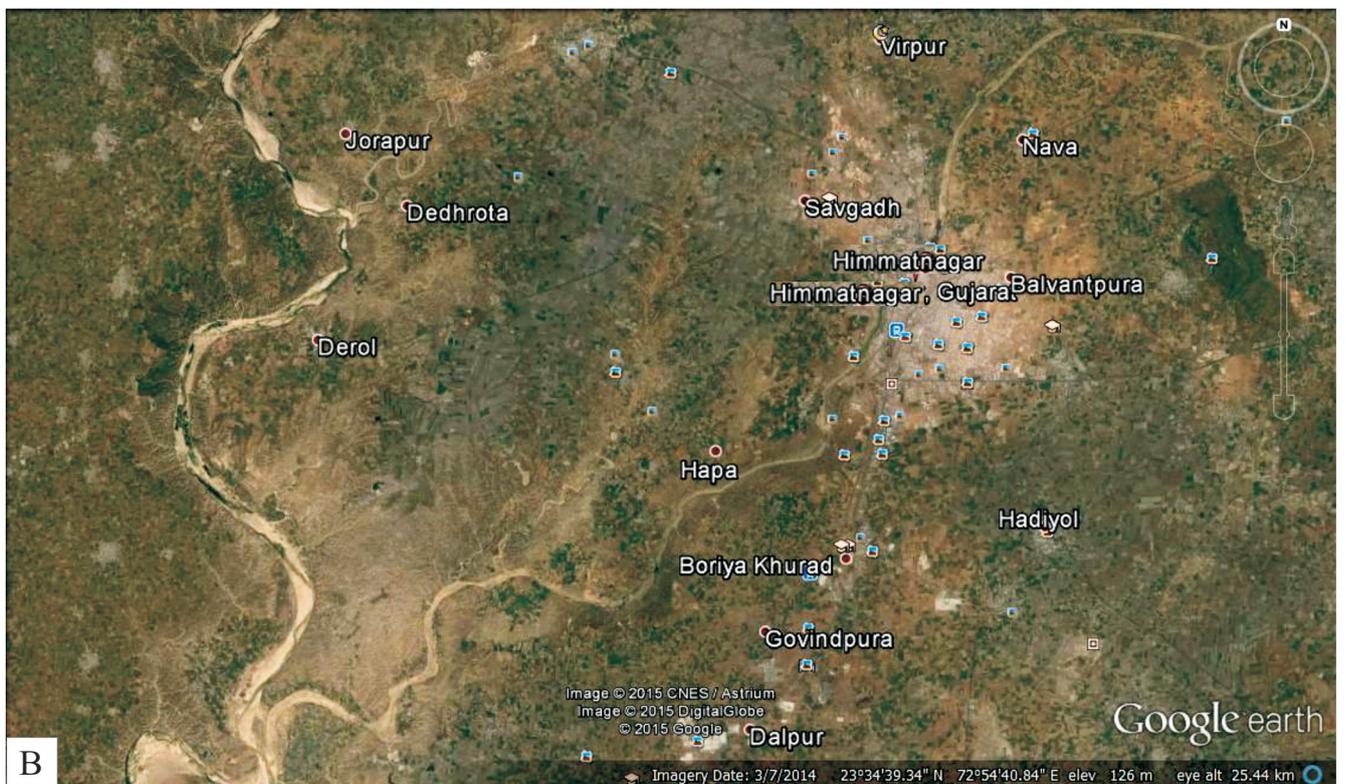
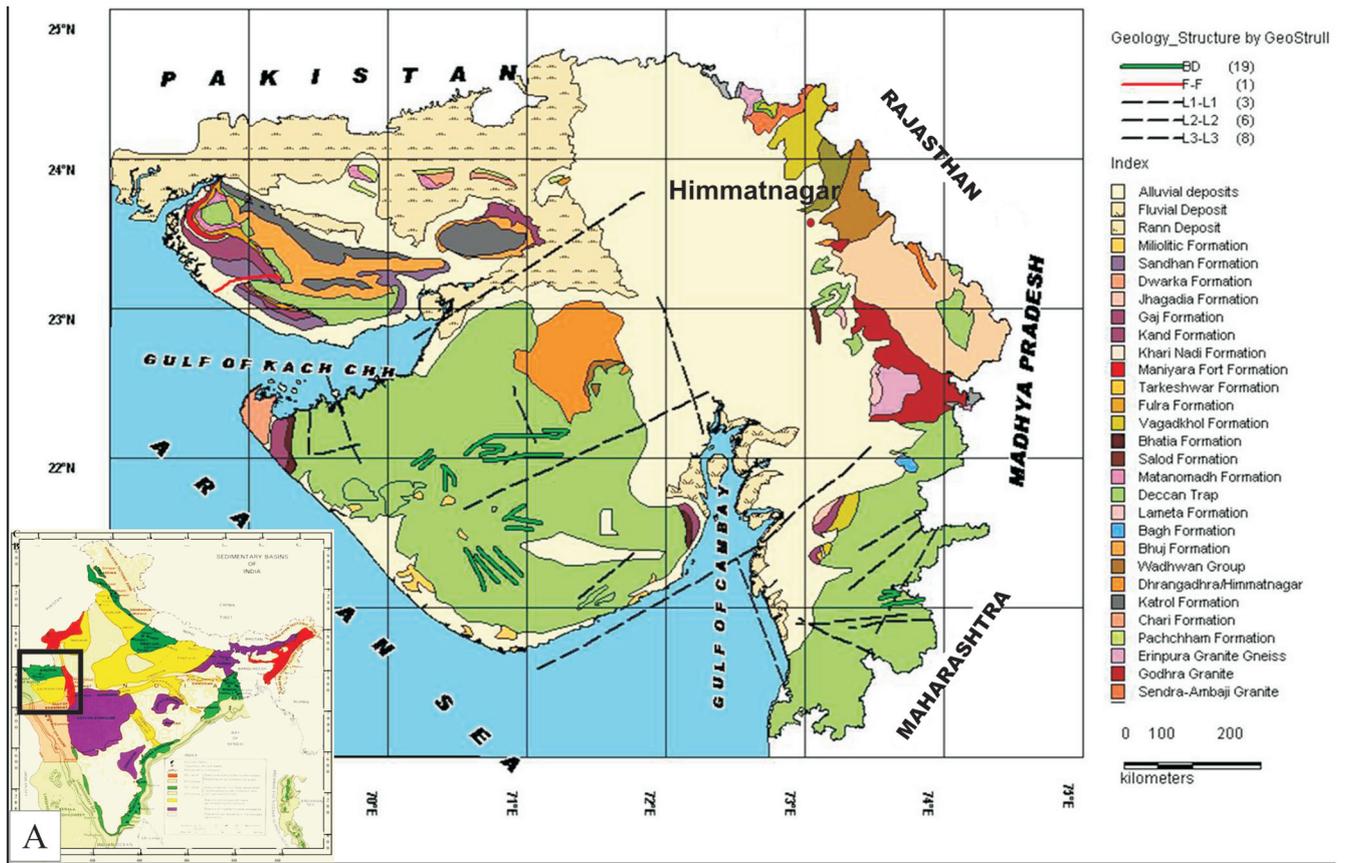


Fig. 1—A. Geological map of Gujarat. B. Satellite map showing location of study area.

**INTRODUCTION**

**P**HYSIOGRAPHICALLY, Gujarat comprises three distinct zones—the Gujarat Mainland, the Saurashtra and the Kachchh (Fig. 1). The sedimentary deposits of Himmatnagar Sandstone Formation was formally known as Ahmednagar (Middlemiss, 1921), is exposed around Himmatnagar Town, in Sabarkantha District of Gujarat Mainland. Alternate sequence of conglomerate sandstone and shales are found around the Himmatnagar Town. Sahni (1936) for the first time recorded genus *Matonidium* and *Weichselia* from Berna of Himmatnagar Town (collected and provided by Heron and Mukherjee of Geological Survey of India). *Cycadean* frond has been reported by Murty (1967). Banerji *et al.* (1983) reported few plant remains which were collected from 1 km NE of Himmatnagar Railway Station and was published in a proceeding after that no study has been made. The communicated paper recorded few pteridophytic fronds and is aimed to reassess its palaeofloristics, palaeoenvironment of deposition and geographic correlation with in India and other Gondwanic countries.

**GEOLOGICAL SETTING**

Himmatnagar sandstones are exposed in the northern Gujarat in a quadrangular outline from Valasana in NW to Aglod in SW on Sabarmati River section and from Vavdi in NE to Lalpur in SE direction, as undisturbed and almost horizontal, 30–60 m thick sequence of sandstone, shales and conglomerates. The sandstone predominates with silty shales at places and pockets of conglomerates at few places. The Cretaceous–Himmatnagar sandstones rest unconformably over the Precambrian Erinpura Granite (Fig. 2) and occurs in a series of low lying plateaus (Akhtar & Aquil, 1984). The plant fossils are preserved as impression on yellowish–brown ferruginous conglomeratic sandstone.

**MATERIAL AND METHOD**

Large numbers of plant fossils are found embedded in the yellowish–brown ferruginous sandstone of the northern side of Wantra Hill, purplish–pink shale, on the surface of the bedding plane of the Hathmati River section. The studied fossils were collected from rocky knoll near the railway station which were deposited in BSIP Museum and are studied in natural state under Olympus binocular microscope. Photographs are taken by using Nikon 15 D camera. Images are also acquired by using Cell–Sens standard 1.8 software.

**COMPOSITION OF FLORA**

Flora of Himmatnagar Sandstone is less diversified and relatively inadequately known. Numerically flora is dominated by pteridophytic frond *Matonidium indicum* and *Weichselia reticulate*, *Cladophlebis* and *Sphenopteris* (Pl. 1) along with the representation of 23% conifers and 8% each with pteridosperms and cycads. Bennettitales, pentoxylales and ginkgoales are lacking (Fig. 3).

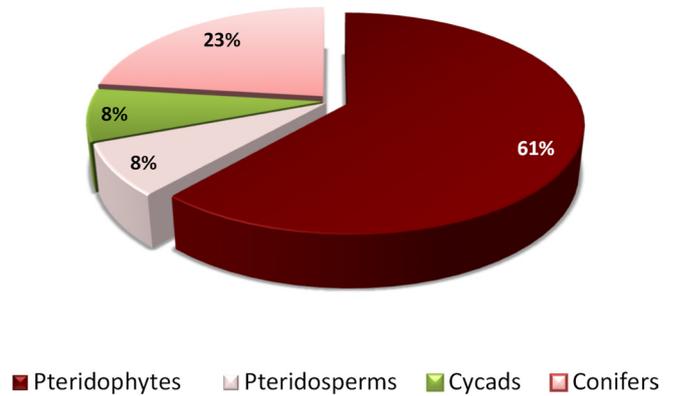


Fig. 3—Pie chart showing palaeofloral composition of Himmatnagar.

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

Fig. 2—Generalised surface stratigraphy of Himmatnagar Sandstone.

C R E T A C E O U S		KACHCHH MAINLAND BHUU FM (UMIA)	SAURASHTRA WADHWAN SST FM DHARANGDHARA FM	GUJARAT MAINLAND BAGH BEDS NIMAR SST HIMMATNAGAR SST	PRANHITA-GODAVARI CHIKIALA / GANGAPUR	SATPURA JABALPUR FM	SOUTH REWA BANSA	MAHANADI ATHGARH SRIPERMABUDUR GOLAPILLI, RAGHAVAPURAM, TIRUPATI BEDS	DAMODAR KOEL VALLEY	RAJMAHAL VOCANICS	KAMPTEE-WARDHA
M E S S O Z O I C	UPPER	JHURAN FM (KATROL)									
	MIDDLE	JUMARA FM (CHARI)			BAGRA FM						
	LOWER	JHURIO FM (PATCHAM)			KOTA FM		BANDHAVGARH FM				
T R I A S S I C	UPPER				DHARMARAM FM		PARSORA FM		SUPRA PANCHET FM	DUBRAIPUR FM	
	MIDDLE				MALERI FM BHIMARAM FM YERRAPALLI FM UPPER KAMTHI MB	DENWA FM					
	LOWER				MIDDLE KAMTHI MB LOWER KAMTHI MB	PANCHMARHI FM	PALI FM	UPPER KAMTHI MB	PANCHET	PANCHET FM	
P A L E O Z O I C	UPPER				BARREN MEASURES BARAKAR FM	BIJURI FM MOTURFM	RANIGANJ FM BARREN MEASURES	LOWER KAMTHI MB RANIGANJ FM	RANIGANJ FM		KAMTHI FM
	LOWER				TALCHIR FM	BARAKAR FM	BARAKAR FM KARHARBARI	BARREN MEASURES BARAKAR FM KARHARBARI FM	BARREN MEASURES BARAKAR FM KARHARBARI FM	BARAKAR FM	BARAKAR FM
	U.CARBONIFEROUS?					TALCHIR FM	TALCHIR FM	TALCHIR FM	TALCHIR FM	TALCHIR FM	TALCHIR FM
PROTEROZOIC AGE UNCERTAIN		BASEMENT	BASEMENT	BASEMENT							

Non-deposition / erosion



Table 1—Stratigraphic correlation of Gondwana sediments of India (modified after Dutta *et al.* 1983).

Floristic Zone	South Rewa	Satpura	Pranhita-Godavari	Cauveri	Mahanadi	East-Coast	Rajmahal	Rajasthan	Kachchh	Saurashtra	Gujarat Main land	Gardeshwar	Dondgargaon
<i>Azolla</i> Assm. Zone													Dondgargaon Formation
<i>Weichselia-Onychiopsis-Gleichenia</i> Assm. Zone	Bansa Floral Assm. E.Cretaceous (Aptian-Albian)	-	Gangapur Assm.-2 E.Cretaceous (Aptian-Albian)		Algarh Floral Assm. E.Cretaceous (Aptian-Albian)	Gollapalle, Raghavapuram, Budavada, Vemavaram, Sriperumbudur Floral Assm. E.Cretaceous (Neocomian)	Sonajuri Assm. Zone E.Cretaceous (Aptian-Albian)	Sarnu hill Floral Assm.	Bhuj Assm.-2 E.Cretaceous (Neocomian)	Dharmadhara Floral Assm. E.Cretaceous (Aptian-Albian)	Himmatnagar Floral Assm. E.Cretaceous (Aptian-Albian)	Gardeshwar Floral Assm. E.Cretaceous (Aptian-Albian)	
<i>Allocladus-Brachyphyllum-Pagiophyllum</i> Assm. Zone		Jabalpur Floral Assm. E.Cretaceous (Neocomian)	Gangapur Assm.-1				Rajmahal Assm.-2 (Nipania between lava flow 4-5) E.Cretaceous (Neocomian)						
<i>Dictyozamites-Pterophyllum-Anomozamites</i> Assm. Zone		Changan Floral Assm. E.Cretaceous (Barriassian)		Sivaganga Floral Assm. E.Cretaceous (Barriassian)			Dubrajpur Floral Assm. E.Cretaceous (Barriassian)	Parivar Floral Assm. E.Cretaceous (Barriassian)					
<i>Pachypteris-Cladophlebis darwensis</i> Assm. Zone									Jhuran Floral Assm. L. Jurassic (Titonian)				
<i>Hausmannia-Philophyllum-Araucarioxylon</i> Assm. Zone			Koia Floral Assm. M. Jurassic										
<i>Brachyphyllum-Pagiophyllum-Desmiophyllum</i> Assm. Zone	Hartala Floral Assm. E. Jurassic												
<i>Marattiopsis-Pterophyllum-Dicroidium</i> Assm. Zone	Parsora Floral Assm. L. Jurassic												
<i>Pagiophyllum-Elatocladus-Dicroidium</i> Assm. Zone	Tiki Floral Assm. L. Triassic												
<i>Gopadia-Glotolepis-Dicroidium</i> Assm. Zone	Panchet Floral Assm. M. Triassic												
<i>Lepidopteris-Dicroidium-Glossopteris</i> Assm. Zone	Panchet Floral Assm. E. Triassic												

Table 2—Comparative floristic zonations of Indian Gondwana basins (modified after Sukh-Dev, 1987).

## PALAEOFLOREAL CORRELATION WITH OTHER INDIAN GONDWANAN BASINS

Palaeofloristically the Himmatnagar flora shows dominance of mostly pteridophytes belonging to family Matoniaceae, Osmundaceae, Gleicheniaceae and conifers of family Araucariaceae. Elements of family Podocarpaceae are relatively less known. Pteridosperm is represented by only one genus *Cycadopteris*. The characteristic Himmatnagar flora shows resemblance with Bansa flora of South Rewa Basin, M.P. (Bose & Sukh-Dev, 1959, 1961, 1972) and Athgarh flora of Mahanadi Basin, Odisha (Prakash & Sukh-Dev, 1994; Table 2) in having common floral elements, e.g. *Gleichenia*, *Weichselia*, *Cladophlebis*, *Cycadopteris*, *Pagiophyllum*, *Brachyphyllum* and *Araucarites*. But Himmatnagar flora slightly differs in possessing *Matonidium* and *Dictyophyllum* fronds and absence of *Ptilophyllum* frond which are reported from both the floral assemblages. The fossil floral assemblage of Dharangdhara Formation, (Saurashtra Basin) is characterized by the dominance of pteridophytic fronds, like *Equisetum*, *Matonidium*, *Phlebopteris*, *Gleichenites*, *Cladophlebis*, *Sphenopteris* followed by co-occurrence of conifers, like *Allocladus*, *Brachyphyllum*, *Araucarites* and *Coniferocaulon* (Borkar & Chiplonkar, 1973). However, pteridosperm is represented only by *Cycadopteris*, henceforth, is akin to the flora of Himmatnagar Sandstone. Lithostratigraphically it is also equivalent to Dharangdhara, Bansa, Gangapur and Athgarh formations (Table 1).

## PALAEOFLOREAL CORRELATION WITH OTHER GONDWANAN CONTINENTS OF SOUTHERN HEMISPHERE

### Antarctica

Bluff flora of Alexander Island (Cantrill & Falcon-Long, 2001) is richest and well documented embodies number of plant fossils of various groups and families shows resemblance with flora of Himmatnagar Sandstone in having common representation of families, like Matoniaceae

*Matonia*, (*Matonidium*–Himmatnagar Sandstone Formation), Dicksoniaceae *Husmannia* (*Dictyophyllum* in Himmatnagar Sandstone Formation), Podocarpaceae and Araucariaceae. But presence of two species of *Ptilophyllum*, Pentoxylales and angiosperms differentiate it from the flora of Himmatnagar Sandstone.

### Australia

The Perth and Carnarvon basins of western Australia (McLoughlin & Pott, 2009) show floral affinity at generic level, like *Cladophlebis*, *Pagiophyllum* and *Matonidium* but can be easily differentiated in having number of species of *Ptilophyllum* and *Otozamites*.

### New Zealand

The Murihiku Forearc flora of New Zealand (Pole, 2009) shows dominance of conifers over other plant groups and share common elements, like *Cladophlebis*, *Dictyophyllum*, *Pagiophyllum*, *Brachyphyllum* and *Araucarites* but due to occurrence of *Lycopodites*, *Nilssonia*, *Ptilophyllum* and *Pterophyllum* the New Zealand flora can be differentiated from the flora of Himmatnagar Sandstone.

### South America

The youngest Barcó flora of Baqueró Formation (Archangelsky, 2001) is characterized by absence of bennettitales, ginkgoales and share common elements, like *Cladophlebis*, *Gleichenia*, *Hausmannia* (*Dictyophyllum* in flora of Himmatnagar Sandstone) along with the presence of *Pseudoctenis* in the Barcó flora of Baqueró Formation, South America which probably may be the local variations of the flora.

## ENVIRONMENT OF DEPOSITION

The rocks of Himmatnagar Sandstones Formation are mainly gritty conglomerates at base, followed by shales and

## PLATE 1



- |  |   |
|--|---|
| <p>1–7. <i>Matonidium indicum</i> Sahni, 1936.<br/>1 &amp; 7. Sterile frond with long, complete or incomplete pinnules showing venation; Specimen No. BSIP 40801, 40807.<br/>2. Fertile frond showing circular–elliptical sori present along both the side of midrib; Specimen No. BSIP 40803.<br/>3. Fertile frond with short pinnules showing faint circular–elliptical sori along both side of midrib; Specimen No. BSIP 40804.<br/>4–6. Stem of various thickness showing longitudinal ridges and furrows; Specimen No. BSIP 40805, 40807.<br/>8–10. <i>Weichselia reticulata</i> (Stokes et Webb, 1824) Fontaine in Ward, 1899.</p> | <p>8. Sterile frond showing pinnules with a deep median groove end short of the broadly rounded apex. Pinnules showing faint reticulate venation; Specimen No. BSIP 40808.<br/>9. Fertile frond showing pinnules with only two sori at the base of pinnule on either side of midrib; Specimen No. BSIP 40809.<br/>10. Fertile frond showing two basal pinnules with about eight sori present along both the side of midrib; Specimen No. BSIP 40810.<br/>11. <i>Sphenopteris</i> ?–Frond showing pinnules with lobed margin, visible median vein and faint secondary veins; Specimen No. BSIP 40811.<br/>12. <i>Cladophlebis indicus</i> (Oldham &amp; Morris) Sahni &amp; Rao–Portion of pinnae with pinnules showing venation; Specimen No. BSIP 40812.</p> |
|--|---|

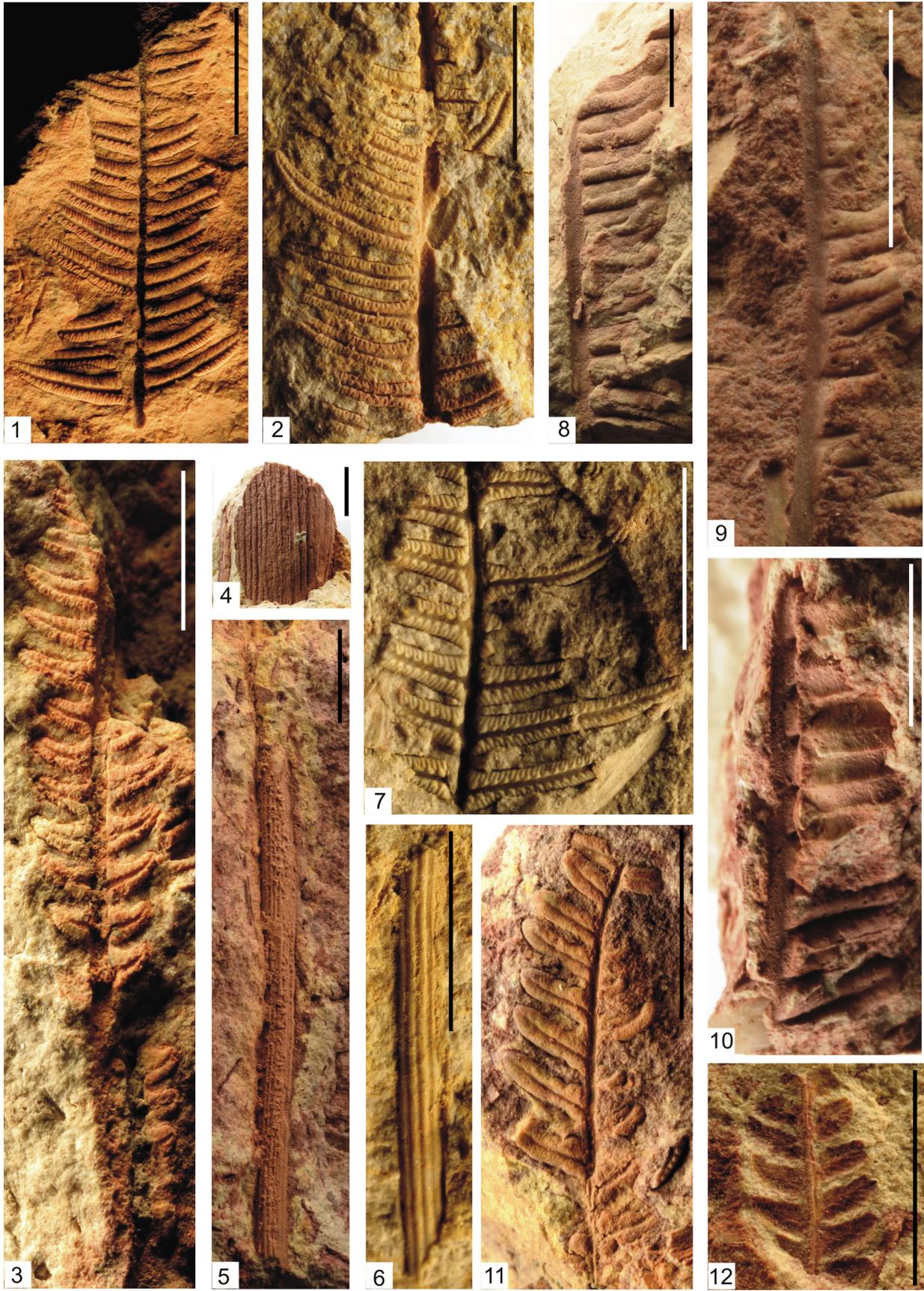


PLATE 1

sandstones. The sequence is divisible into lower and upper part. The lower part is mostly massive with poor to moderately preserved abundant plant fossils in both shales and sandstones and appears that they might have transported from short distance. The upper part is cross-stratified, medium to coarse grained, gritty to pebbly sandstone with lower erosional contact and channel structures at places. Scarce to common occurrence of trace fossils (*Skolithos*, *Monocraterion*, *Calycraterion*, etc.) indicate marginal marine to marine environment of deposition right from foreshore-tidal flat to upper shoreface and locally estuarine for lower part of the sequence. The upper part shows cross-stratified sandstone indicating its fluvial to marginal marine environment of deposition.

### CONCLUSION

The youngest floral assemblage of Indian Gondwana, i.e. Himmatnagar floral assemblage of western India is lithostratigraphically/palaeofloristically co-relatable with Dharangdhara (Saurashtra Basin), Bansa (South Rewa Basin) and Athgarh formations (Mahanadi Basin) and is assigned an early Cretaceous (Aptian-Albian) age. The palaeofloristics of Himmatnagar Sandstone Formation also shows resemblance with Barcó (youngest division of Baqueró Formation of Patagonia, Argentina) flora of South America. It is well-established that India was a part of Gondwana (Africa, Australia, Antarctica and South America) and located adjacent to Madagascar (Ali & Aitchison, 2008). The terrestrial connection between South America and Indo-Madagascar via Antarctica was probably through Kerguelen Plateau or Gunners ridge that existed until 88 Ma (Chatterjee & Scotese, 2010; Khosla & Verma, 2015). The dispersal of biota might have taken place through Kerguelen Plateau.

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