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Palynoassemblage from intertrappean sediments of Satpura Group, Betul district, Madhya Pradesh: implications in understanding age and palaeoclimate

Hemant Sonkusare, Bandana Samant* & D. M. Mohabey

JPSI

Palynological study of eleven intertrappean beds at ten stratigraphic levels in Betul district, Madhya Pradesh provided new insight into biota, age and depositional environment of Satpura Group. Study indicates presence of monospecific assemblage of dinoflagellate cyst *Pierceites deccanensis* at Hiradehi intertrappean at lower stratigraphic level. Diverse palynoassemblage represented by 3 genera and 3 species of pteridophytes, one genus and one species of gymnosperms, 8 genera and 10 species of angiosperms and 12 genera and 12 species of fungal spores are recorded from Kanhobagholi intertrappean at higher stratigraphic level. Presence of age marker taxa such as *Azolla cretacea*, *Aquilapollenites bengalensis*, *Aquilapollenites intertrappeus*, *Echitricolpites* sp., *Farabeipollis minutes*, *Farabeipollis deccanensis* sp. nov., *Jiangsupollis major* suggest Late Cretaceous (Maastrichtian) age for this intertrappean. Microflora of intertrappean beds at lower stratigraphic levels (Hiradehi and Topidhana) show deposition in semiarid-arid climate and intertrappean beds at higher stratigraphic levels especially Kanhobagholi in warm humid climatic conditions and freshwater to estuarine depositional environment. Two intertrappean namely, Kanhobagholi, and Hatnajhiri from this part also yielded freshwater ostracodes.

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[1]*Postgraduate Department Of Geology, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur-440001, India.*
**Corresponding author's e-mail: bandanabhu@gmail.com*

INTRODUCTION

Deccan Volcanic Province (DVP) is one of the largest continental flood basalt provinces in the world, occupying an area of about 500,000 km^2 in peninsular India in the states of Maharashtra, Madhya Pradesh, Gujarat, Karnataka, Telangana, Andhra Pradesh, Uttar Pradesh and Rajasthan. Duration of Deccan volcanism is still debated to be long, i.e. for about 6-7 Ma (Sheth and Pande, 2014) to short of about 1 Ma (Courtillot *et al*., 1986, 2000). Chenet *et al*., (2007, 2008) proposed that volcanism occurred in three phases, earliest one in 67-68 Ma in Maastrichtian followed by main phase in Maastrichtian Chron 29 R and the last phase in Paleocene at the base of Chron 29 R and ending in Chron 29 N. Recently, Renne *et al*. (2015), Schoene *et al*. (2015) and Sprain *et al*. (2019) suggested that the major volcanic eruptions are post K-Pg boundary and of very short duration which along with Chicxulub impact (Alvarez *et al*., 1980) contributed to the Cretaceous-Paleogene ecosystem crises. The impact of voluminous lava flows, 1.3x10^6 Km^3 (Jay and Widdowson, 2008) on the Indian biota is expected to be more pronounced because of its close proximity to lava flows as volcanism not only changed the physical environment due to the release of large amount of climate modifying gases but also changed topography and soil type which ultimately affected the ecosystem.

The Deccan volcanic flows on the basis of petrography, geochemistry, magnetostratigraphy and Deccan basalt flow mapping are classified into four groups namely Sahyadri, Malwa, Amarkantak and Satpura Groups. The lava flows of the western India, including Kutch and Saurashtra, are still not formally classified (Deshmukh, 1984; Deshmukh *et al*., 1996; Cox and Hawkesworth, 1984; Nair *et al*., 1996, published geological maps and District Resource Maps of Geological Survey of India) (Fig.1). The intertrappean sediments between the flows are the windows which help in assessing biodiversity, palaeoclimate and depositional environment at the Deccan volcanic activity in different parts of DVP. As the Deccan volcanism was having different source, eruptive centers and timing of eruption (Hansen, 2005, Kale *et al*., 2020) therefore, understanding of flora in each sub province is important to have comprehensive picture of biodiversity in DVP.

A lot of floral and faunal data are available from the Sahyadri and Amarkantak groups of DVP (Summarized by Khosla and Verma 2015; Mohabey and Samant 2019; Kapgate, 2005; Bonde, 2008, Smith *et al*., 2015). Recently some fauna and flora was recorded from the Malwa Group in the north of Narmada river (Mohabey *et al*., 2018; Mohabey and Samant, 2013, 2019) but faunal or palynological data from the intertrappean sediment of Satpura Group, in the south of Narmada river are still not clear. This lack of knowledge has restricted our understanding of age, depositional environment

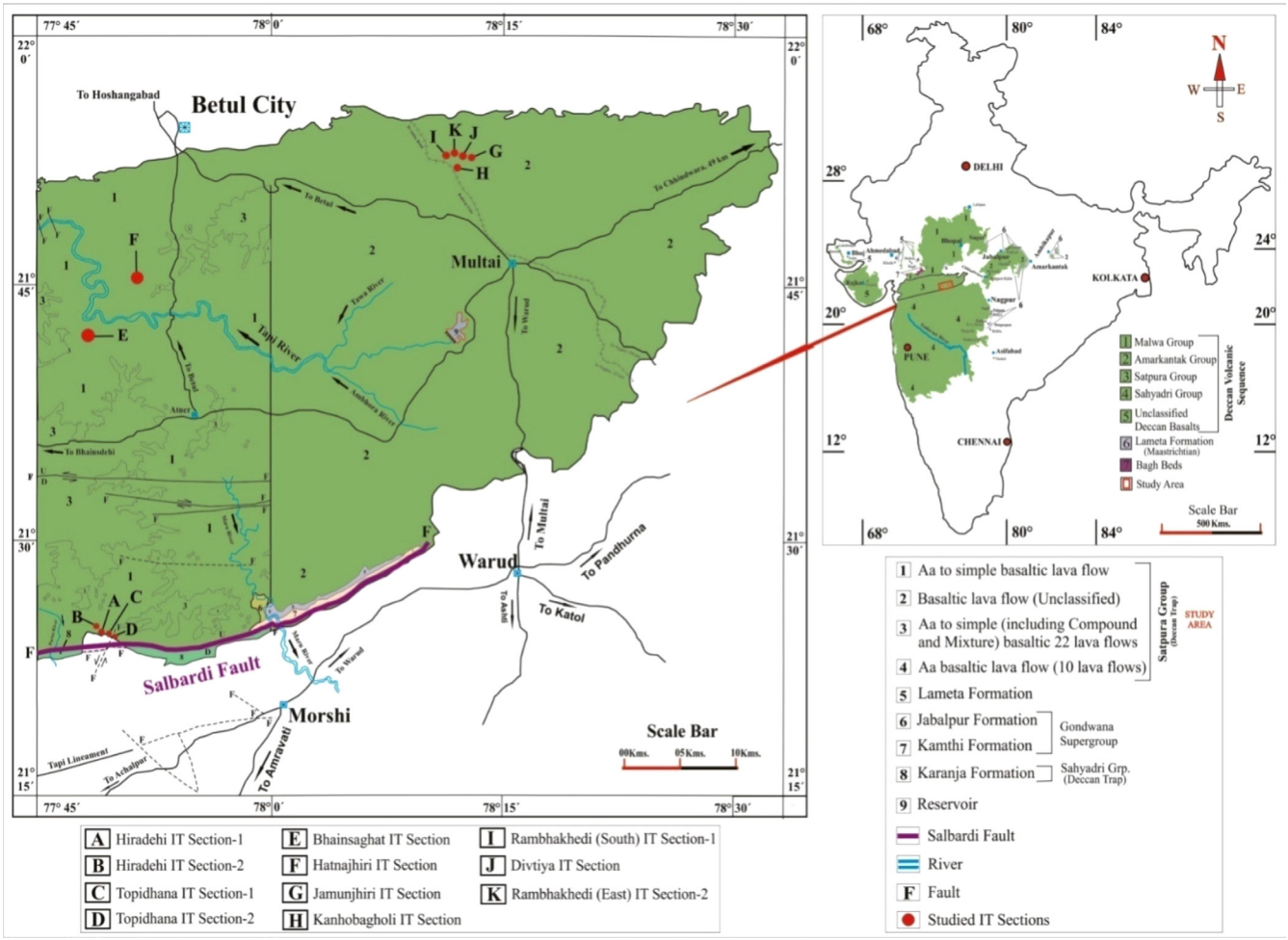


Fig. 1:- Map showing location of studied intertrappean sections (Map after District Resource Map (DRM), GSI, 2002).

and climate during the deposition of intertrappean sediments of this group. The present palynofloral record has helped in bridging this major lacuna in our knowledge.

GEOLOGY OF THE AREA

In the study area of Betul district, Archaean rocks are mostly exposed in northern part. These rocks are overlain by Jabalpur (Lower Cretaceous) and Kamthi Formations (Upper Permian to Lower Triassic) of Gondwana Supergroup. The Gondwana sediments are unconformably overlain by Late Cretaceous Lameta sediments. These 6-7 m thick Lameta sediments consist of nodular limestone, cherty limestone with intercalations of tuffaceous shales and clay. Tuffaceous shales are generally angular to sub-angular and partings of chert are present in sandy matrix and variegated white to brownish clay. They are generally northerly dipping and with very low dips of below 7°-8° (Geological Survey of India, 1998, Betul Quadrangle Geological Map (QGM), 55G; Tiwari and Bhattacharya, 1984, GSI unpublished report; Pant and Murty 2004).

In Salbardi area, the Lameta sediments are overlain by about 874 m thick lava flows. These flows are divided into two categories viz. (a) flows towards the northern part of Salbardi lineament and (b) flows towards the southern part of Salbardi lineament. The flows towards the north of Salbardi lineament are classified as Satpura Group and to the south as Sahyadri Group. The flows of Satpura Group are mostly composed of 'Pahoehoe' and 'Aa' type flows. The flows towards the north of Salbardi lineament are 'aa' to simple Pahoehoe type. The southern flows are exposed in the Purna and Tapi rivers and composed of about 15 flows assigned to be Sahyadri Group. Sahyadri Group are often 'aa' to simple, mixed and compound Pahoehoe type. Many volcanic features represented by pipe vesicles, ropy structures, pahoehoe toes and cooling joints are present in the volcanic flows. In the lower part of top flow pipe vesicles and amygdules are also present. Middle portion of flows are generally columnar and bottom flows are with vesicles and horizontal joints (Geological Survey of India, 1998, Betul Quadrangle Geological Map (QGM), 55G).

Intertrappean sediments of the study area are in the southeastern and southwestern parts of Betul district, Madhya Pradesh. As per District Resource Map (2002) and Quadrangle Geological Map (QGM, 1998) of the study area, the flows are placed in Satpura Group. All the studied intertrappean beds occur towards the north and west of Salbardi Fault (Fig. 1). Lithologically, intertrappean beds comprise chert, cherty limestone with nodular structure, clay,

Table-1: Co-ordinates and reduce level of studied intertrappean sections in Satpura Group:

Sr. No.	Locality	Intertra-ppean (IT)	Co-ordinates		RL (m)
			Latitude	Longitude	
1	Hiradehi-1	IT	21°24'09.8"N	77°48'53.2"E	469
2	Hiradehi-2	IT	21°24'42.2"N	77°48'52.6"E	486
3	Topidhana-1	IT	21°24'25.6"N	77°49'32.2"E	501
4	Topidhana-2	IT	21°24'20.9"N	77°49'43.3"E	509
5	Bhainsaghat	IT	21°42'05.2"N	77°48'07.6"E	575
6	Hatnajhiri	IT	21°46'01.4"N	77°50'59.2"E	665
7	Jamunjhiri	IT	21°52'38.3"N	78°13'00.8"E	750
8	Kanhobagholi	IT	21°51'55.2"N	78°12'12.6"E	759
9	Rambhakheri South	IT	21°52'40.5"N	78°11'07.4"E	779
10	Divtiya	IT	21°52'39.5"N	78°12'16.00"E	780
11	Rambhakheri East	IT	21°52'43.00"N	78°11'46.6"E	784

shale, sandy shales. Three intertrappean beds near villages Jamunjhiri, Kanhobagholi, Divtiya and two intertrappean beds near village Rambhakhedi are present in the northwest of Multai area of Betul district, Madhya Pradesh (Table-1). Lithologically, these intertrappean beds comprise cherts, cherty shales, tuffaceous shales and clay at some places (Figs. 2, 3). Thickness of these sediments varies from 0.7 m to 3.0 m and highest elevation in the area is about 784m. The most common rock types are black to greenish cherts, cherty limestone and shale at some places. Gastropods (*Physa, Lymnia,* and *Viviforms*) and ostracodes (Tiwari and Bhattacharyya, 1986, GSI unpublished report) are commonly recorded from these intertrappean. Fossil dicots and monocot plants and roots of monocots are also present in most of the intertrappean sediments. Towards the southwest of Betul city, intertrappean beds near Hatnajhiri and Bhainsaghat occurs at about 665 m elevation and towards the northwest of Salbardi fault two intertrappean beds near villages Hiradehi and Topidhana are present (Fig. 2). Bivalves were recorded from the fossiliferous micritic limestone of Topidhana intertrappean (Srivastava and Kandwal, 2013). Structurally, the study area is part of Tapti lineament and Satpura range (Geological Survey of India, 1998, Betul Quadrangle Geological Map (QGM), 55G). Out of the studied intertrappean beds, only Kanhobagholi and Hiradehi intertrappean beds have yielded palynomorphs. Detailed lithology and stratigraphic position of all the studied intertrappean beds are given in Figs. 2 and 3 and location of the studied intertrappean are given in Table 1.

MATERIALS AND METHODS

About 50 samples were collected from intertrappean in Satpura Group. In the laboratory, samples were washed with distilled water and crushed to fine powder. About 30-40 grams of each sample was taken for standard maceration. For removal of carbonates they were given 10% HCL treatment and for removal of silica, samples were treated with 40% Hydrofluoric Acid (HF). After that, the samples were treated with Nitric acid (HNO_3) for oxidation and with 5% Potassium Hydroxide (KOH) for removal of humic matter. Duration of

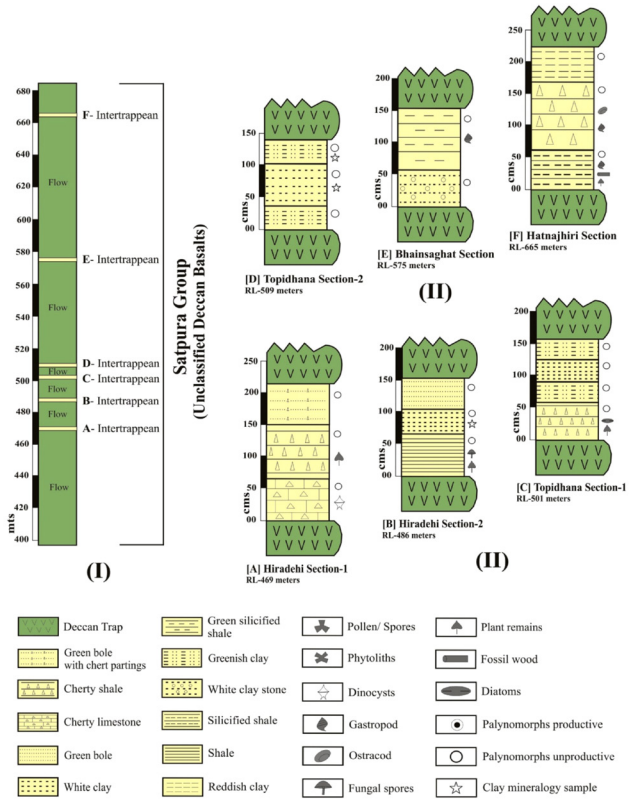


Fig. 2, I:- Stratigraphic position of studied intertrappean beds in the Deccan Volcanic Province (DVP). **II:-** (A, B, C, D, E, F): Lithosections of the studied intertrappean.

chemical treatment varies from sample to sample. Later on organic residue was sieved using 10-15 microns (µm) sieves.

After completion of maceration, the final residue was divided into two parts, one part was kept for future reference and another part was taken for slide preparation for optical and Scanning Electron Microscope (SEM) study. About 6-10 or more (wherever necessary) slides were prepared using standard mounting media *viz.*, Polyvinyl Alcohol (PVA) and Canada balsam. All the slides were scanned under 20X objectives using the Biological Olympus BX-51 microscope. Optical photographs were taken under 20X, 40X and 100X objectives. SEM study of the selected palynomorphs was carried out using single grain mounting of the desired grain on the SEM Stub. All the optical slides are stored in the Museum of Department of Geology, RTM Nagpur University, Nagpur (Maharashtra), India.

Clay mineral analysis of Hiradehi and Topidhana intertrappean was carried out for climate interpretation. For separation of total clay and fine clay standard "International Pipette Method" (Jackson, 1979) was used. The samples were analyzed with X- Ray Diffraction (XRD) at the National Bureau of Soil Survey and Land Use Planning (NBSS and LUP), Nagpur, Maharashtra.

Ostracodes from the samples of Kanhobagholi, and Hatnajhiri intertrappean sediments were separated by breaking the rock into small pieces. All the palynological, micropalaeontological and optical slides of the studied specimens are stored in the Museum of the Department of Geology, RTM Nagpur University, Nagpur.

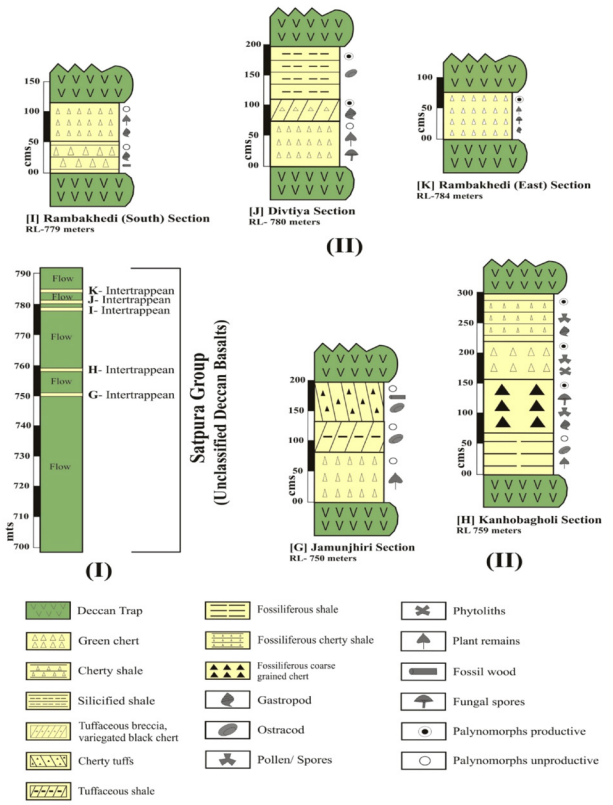


Fig. 3, I:- Stratigraphic position of studied intertrappean beds in the Deccan Volcanic Province (DVP). **II:-** (G, H, I, J, K): Lithosections of the studied intertrappean beds.

SYSTEMATICS

Eleven intertrappean sections were studied for palynofloral analysis from Satpura Group of Betul district. Of these, mainly Kanhobagholi intertrappean and Hiradehi intertrappean yielded palynomorphs. Recovered palynomorphs from these intertrappean sediments are described in four groups namely pteridophytes, gymnosperms, angiosperms and Non Pollen Palynomorphs (NPPs). Kanhobagholi intertrappean sediments yielded 3 genera and 3 species of pteridophytes, one genus and one species of gymnosperms, 8 genera and 10 species of angiosperms and 12 genera and 12 species of fungal spores, of these one species of angiosperm and one species of fungal spore are newly erected (Plate I-III). In addition to these, many other organic remains such as mycorrhizal fungi, phytoliths of Poaceae and other plant organic matter such as parts of tracheids, vessels and leaf cuticles were also recorded from this intertrappean. Very diverse and good concentration of microforaminiferal linings were also recovered from it (Plate-IV). Description of organic linings is based on the terminologies given by Stancliffe (1989). Hiradehi intertrappean yielded peridinoid dinoflagellate cysts (Plate-III, Figs. 22-24) and some fungal spores. In addition, two intertrappean namely, viz, Hatnajhiri and Bhainsaghat yielded freshwater ostracod assemblage (Plate-V).

Taxonomic description of palynomorphs and NPPs recorded from the intertrappean beds are given in alphabetical order and only new forms are described. Palynomorphs, NPPs and ostracodes recovered from the studied intertrappean sediments and their concentration are given in Table 2. Description of micofossils recorded from the intertrappean beds is given below.

I) Gymnosperm pollen

Genus: *Ephedripites* Bolchovitina ex Potonie emend. Krutzsch 1961

Type species: *Ephedripites mediolobatus* Bolchovitina ex Potonie 1958

Ephedripites sp.
(Pl.-I, Fig. 6; Pl. II, Fig. 15)

Description: Pollen grain oval in shape; isopolar, polyplicate, 12-14 ridges, ridges long, running parallel from pole to pole, about 2-3 µm thick, ridges smooth to slightly crenulated as observed in SEM; psilate.

Dimensions: 15-40 µm in size; grooves about 1 µm wide; exine 1-2 µm thick.

Remarks: In overall morphological characters, the recorded morphotype show similarity with that of *E. ovatus* Bolchovitina ex Potonie emend (Krutzsch, 1961) but former is distinctly longer than *E. ovatus* with slightly crenulated ridges. As only two forms are recorded therefore no new name has been assigned.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Ephedraceae.

Specimen studied: 02

II) Angiosperm pollen

*Genus: **Echitricolpites*** De Silva Pares Regali, Uesugi and Da Silva Santos 1974

Type species: ***Echitricolpites communis*** De Silva Pares Regali, Uesugi and Da Silva Santos 1974.

Echitricolpites sp.
(Pl. I, Figs. 13-14)

Description: Pollen grain triangular in shape; mesocolpial area straight to slightly curved; tricolpate; colpi tenuimarginate, colpal margins smooth; exine intectate, sexine and nexine not differentiable; spinulate, spines sparsely distributed, thin, pointed tips; end of the spines straight to curved, exine distinctly thick at the base of spines, interspinal area psilate to microreticulate.

Dimensions: 25-38 x 36-40 µm in size; colpi 4-6 µm in length; exine 1-2 µm thick; spines about 5-7 µm long and root of the spines wide (3-6 µm);

Remarks: The genus *Echitricolpites* De Silva Pares Regali, Uesugi and Da Silva Santos 1974 includes echinate, tricolpate pollen grains. In overall characters the recorded species show similarity with the genus. Due to poor preservation of the grains it cannot be assigned to any species. However, palynomorphs having similar morphology have been recorded from Maastrichtian intertrappean sediments.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 02.

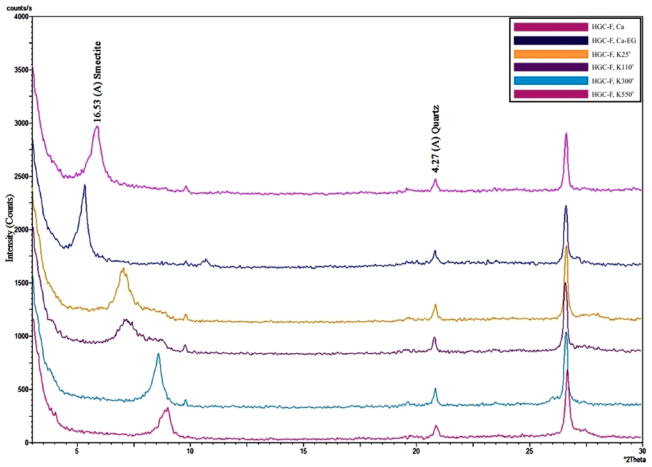


Fig. 4 (A): X-Ray Diffraction pattern of Fine clay (Green) in intertrappean sediments of Hiradehi section.

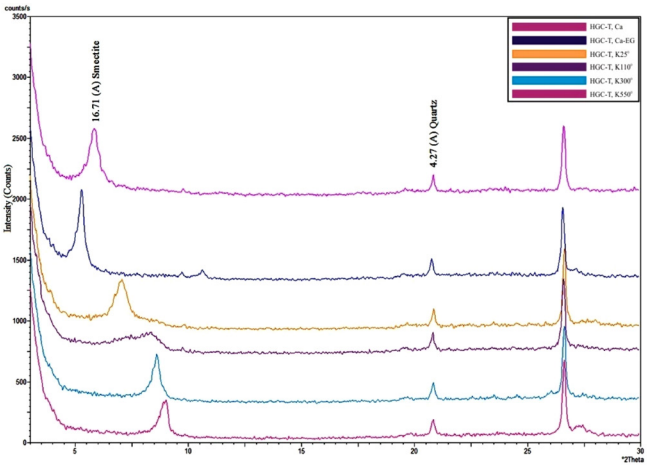


Fig. 4 (B): X-Ray Diffraction pattern of Total clay (Green) in intertrappean sediments of Hiradehi section.

Genus: ***Farabeipollis*** Nandi and Chattopadhyay 2002
Type species: ***Farabeipollis simplex*** Nandi and Chattopadhyay 2002

Farabeipollis deccanensis sp. nov.
(Pl. I, Figs. 23-28)

Derivation of name: After its record from Deccan intertrappean sediments

Holotype: Pl. 1, fig. 25; Paratype, Pl. 1, figs. 23, 26, 27

Diagnosis: Pollen grain oval in shape; heteropolar; colpi short and protrusion directed upward; exine thin at polar region and thicker at the base of equatorial protrusion; psilate.

Description: Pollen grain oval to barrel in shape; heteropolar; poles broadly rounded to acutely rounded, one pole distinctly short; equatorial projections curved upward, ends of the equatorial projections sometimes bifurcating; tricolpate; colpi present at the end of projection; exine thin in some specimens, nexine and sexine almost undifferentiable, in some specimens exine distinctly thicker (3 µm) at the base of equatorial projection and thinner at the polar region and apertural region; psilate sculpture.

Dimensions: 17-29 x 35-39 µm in size; projections 11-15 µm long, colpi 4-5 µm long; exine 1-2 µm thick, nexine 0.2 to 0.88 µm, sexine 0.2 µm to 0.93 µm

Remarks: Heteropolar poles, curved equatorial projection, thin exine at polar region and thicker at the base of equatorial protrusion are the diagnostic features of the newly erected species.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 20.

III) Non Pollen Palynomorphs (NPPs)

A) Fungal Spores

Genus: ***Dicellaesporites*** Elsik 1968
Type species : ***Dicellaesporites popovii*** Elsik 1968

Dicellaesporites intertrappea sp. nov.
(Pl. III, Fig. 1)

Derivation of name: After its record from intertrappean sediments

Holotype: Pl. III, fig. 1.

Diagnosis: Spores barrel shaped; septa thin; hyaline septal girdle about 2-3 µm wide, melanine and/ or dark brown to light yellow in colour; spore wall thin; psilate.

Description: Spores barrel shaped, ends flat to slightly curved; septa thick, hyaline, septal girdle generally broad throughout the width of the spore, sometimes narrow in the central part and wider towards the peripheral region, spore wall thin; psilate.

Dimensions: 15-36 µm in size; septal girdle about 2-3 µm wide

Remarks: Barrel shape and distinctly hyaline septal girdle are the diagnostic character of these fungal spores.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 05.

Dicellaesporites sp.
(Pl. III, Figs. 2-3)

Description: Spores oval in shape; ends broadly rounded; cells equal in size; septa thin; spore wall thin; psilate to spinulate sculpture.

Dimensions: 15-22 x 17-25 µm in size; septal girdle about 2-3 µm wide.

Remarks: Rounded ends and cells of equal size are the diagnostic characters of these fungal spores. Since only two forms are recorded therefore no new name has been proposed.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 02.

Genus: ***Involutisporonites*** Clarke 1965
Type species: ***Involutisporonites foraminus*** Clarke 1965

Involutisporonites sp.
Pl. III, Figs. 7-8

Description: Fungal spores coiled; transversely septate; multicellate; multiseptate; cells smaller in centre and bigger in outer region, individual cells circular to subcircular; spore

Table-2 (A, B): Biota and their concentration from intertrappean sediments of Satpura Group, Betul district, Madhya Pradesh. **(A):** Studied microflora and their concentration

Flora	Locality	Group	Fossil Taxa	Fossils count	References
Pollen/ Spores	Kanhobagholi	Pteridophytes	*Azolla cretacea*	02	**Present Study**
			Cyathidites australis	05	
			Gabonisporis vigourouxii	07	
	Kanhobagholi	Gymnosperms	*Ephedripites ovatus*	01	**Present Study**
			Ephedripites sp.	03	
	Kanhobagholi	Angiosperms	*Aquilapollenites bengalensis*	46	**Present Study**
			Aquilapollenites intertrappeus	02	
			Echitricolpites sp.	02	
			Farabeipollis minutus,	65	
			Farabeipollis deccanensis sp. nov.	22	
			Incrotonipollis neyvelii	02	
			Jiangsupollis major	02	
			Proxapertites operculatus	04	
			Striacolporites ovatus	02	
			Striacolporites sp.	01	
			Spinozonocolpites echinatus	03	
			*Spinizonocolpite*s sp. A	01	
			Dicellaesporites intertrappea sp. nov.	05	
			Dicellaesporites sp.	02	
			Diporicellaesporites fusiformis	01	
			Inapertisporites sp.	02	
Fungi	Kanhobagholi	Fungal Spores	*Involutisporonites* sp.	02	**Present Study**
			Papulosporonites multicellates	16	
			Papulosporonites siwalikus	05	
			Papulosporonites subcircularis	15	
			Phragmothyrites sp.	03	
	Jamunjhiri	Fungal Spores	*Monoporisporites* sp	01	
	Hatnajhiri, Kanhobagholi and Rambhakhedi	Chlamydospores of Mycorrhizal fungi	*Palaeomycites globatus*	> 20	**Present Study**
Plant tissues	Divtiya	Poaceae (Angiosperm)	Long silica cells	01	**Present Study**
			Burnt leaf cuticles	01	**Present Study**
Diatom	Topidhana	--	*Aulacoseira* sp.	> 100	**Present Study**
Dinoflagellate Cysts	Hiradehi	Peridiniaceae	*Pierceites deccanensis*	40	**Present Study**

wall thin; psilate.

Dimensions: 17-25x42-50 µm in size.

Remarks: Cells smaller in center and bigger in outer region are the diagnostic characters of these specimens.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 03.

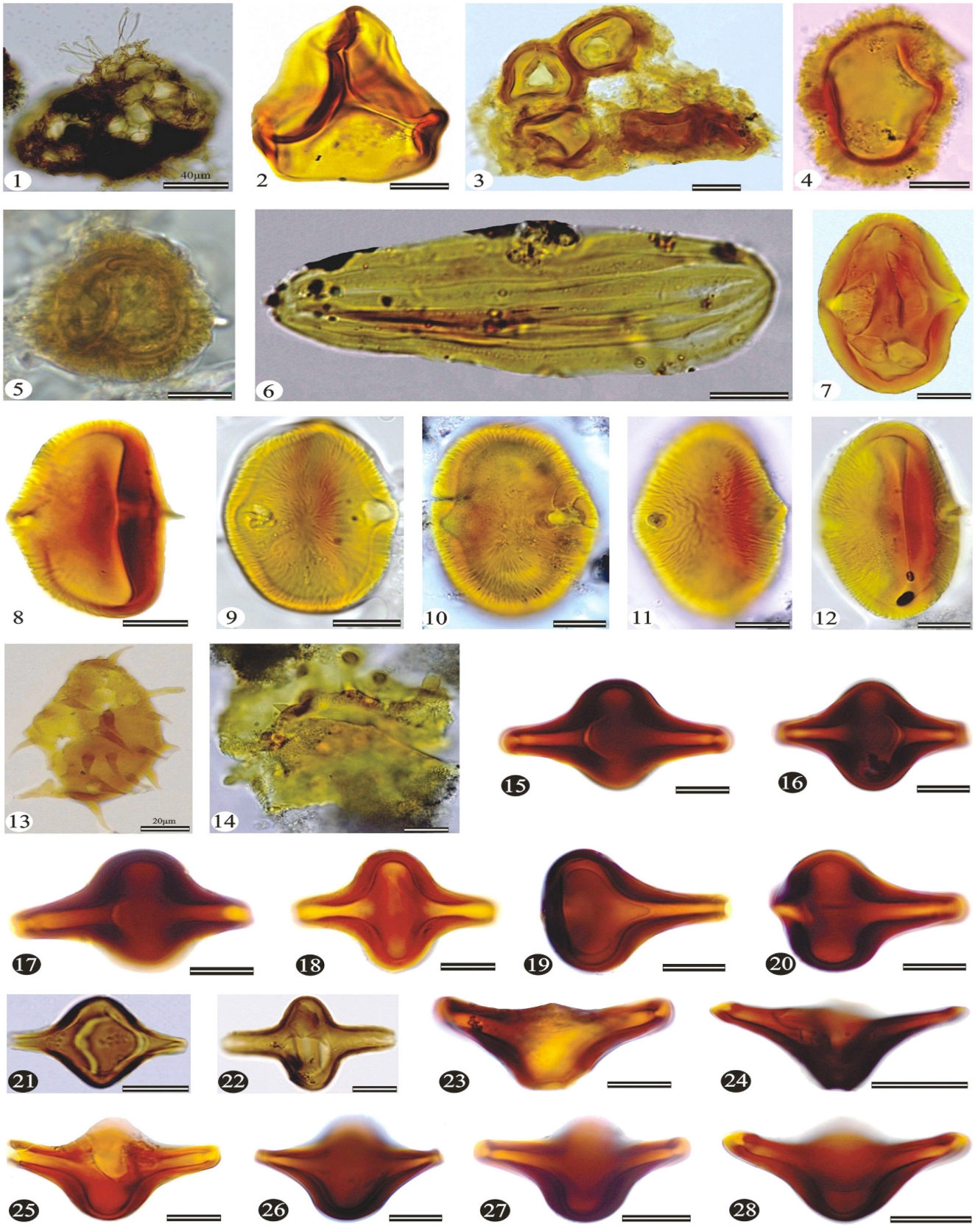
Genus: ***Monoporisporites*** Van der Hammen emend.

EXPLANATION OF PLATE-I

(Scale bar represents 10 µm or otherwise mentioned)

Fig.-1. ***Azolla cretacea*** Stanley 1965; Slide No.- PGNU/BG-C-16-5/It1; Fig.-2. ***Cyathidites australis*** Couper 1953; Slide No.- PGNU/PGNU/KN/IT/1; Fig.-3-5. ***Gabonisporis vigourouxii*** Boltenhagen 1967. Slide Nos.- (3) PGNU/KN/IT/2, EF- 59Q; (4) PGNU/KN/IT/3 and (5) PGNU/BT/IT/4; Fig.- 6. ***Ephedripites* sp.**; Slide No.- PGNU/AMB/It6; Figs.- 7-10. ***Aquilapollenites bengalensis*** Baksi and Deb extended Samant, Mohabey and Paudayal 2013 in equatorial view; Slide Nos.- (7) PGNU/KN/IT/5, (8) PGNU/KN/IT/2, (9) PGNU/BT/IT/6 and (10) PGNU/ BT/IT/7; Figs.- 11-12.***Aquilapollenites intertrappeus*** Samant *et al*., 2013 in equatorial view; Slide Nos.- (11, 12) PGNU/BT/IT/8; Figs.- 13-14. ***Echitricolpites* sp.**; Slide Nos.- (13) PGNU/KN/IT/9 and (14) PGNU/BT/IT/8; Figs.- 15-22 ***Farabeipollis minutus*** Samant *et al*., 2013 in equatorial view (showing variations in morphological characters) Slide Nos.- (15) PGNU/KN/IT/10, (16) PGNU/KN/IT/11, (17) PGNU/KN/IT/5, (18) PGNU/KN/IT/12, (19) PGNU/KN/IT/12, (20) PGNU/KN/IT/15, (21) PGNU/KN/IT/13, (22) PGNU/KN/IT/14; Figs.- 23-28 ***Farabeipollis deccanensis*** sp. nov. in equatorial view (showing morphological variations) Slide Nos.- (23) PGNU/KN/IT/16, (24) PGNU/KN/IT/10, (25) PGNU/KN/IT/12, (26) PGNU/KN/IT/17, (27) PGNU/KN/IT/11, (28) PGNU/KN/IT/11.

Plate I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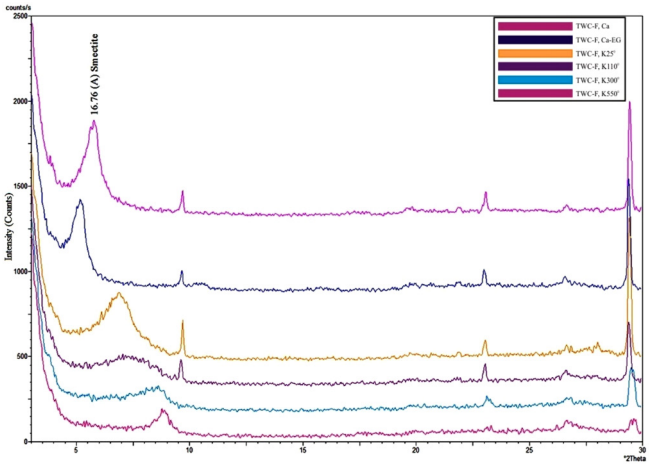

Fig. 5 (A): X-Ray Diffraction pattern of Fine clay (White) in intertrappean sediments of Topidhana section.

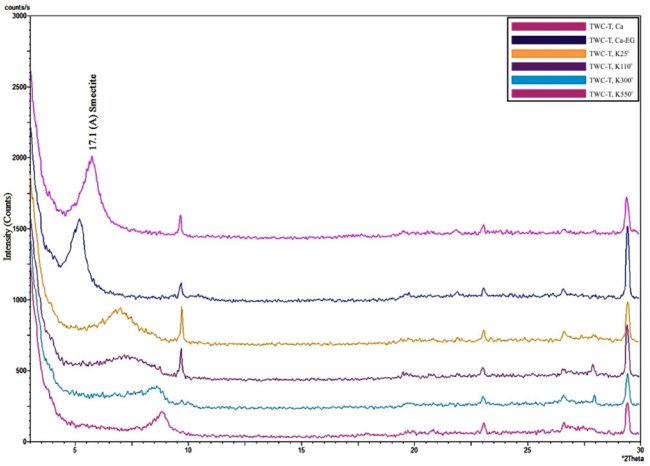

Fig. 5 (B): X-Ray Diffraction pattern of Total clay (White) in intertrappean sediments of Topidhana section.

Kalgutkar & Jansonius 2000
Type Species: ***Monoporisporites minutus*** Van der Hammen1954

Monoporisporites sp.
(Pl. III, Fig. 9)

Description: Fungal spore oval in shape; monoporate; nonseptate; unicellate; cell wall psilate to finely punctate.

Dimensions: 15-33 µm in size.

Remarks: Only one form is recoded.

Type Locality and Horizon: Jamunjhiri intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 01.

Genus: ***Phragmothyrites*** Edwards 1922 emend. Kalgutkar & Jansonius 2000
Type species: ***Phragmothyrites eocaenicus*** Edwards 1922. *Microthallites* Dilcher1965.

Phragmothyrites sp.
(Pl. III, Fig. 21)

Description: Stroma circular, discoidal; non-ostiolate; center of stroma consists of irregularly angled cells; central cells often much darker than the rest of the stroma, central cells are nonporate or ± rectangular and subrounded by radially elongated nonporate cells, rest of the cells non porate; peripheral outline slightly undulating, cells of outermost layer relatively hyaline free mycelium lacking.

Dimensions: 80-90 µm in diameter.

Remarks: Discoidal ascomata, non ostiolate, radially arranged hyphae are the diagnostic character of this genus. Only three form are recorded and due to poor preservation specific character are difficult to ascertain.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Microthyriaceae.

Specimen studied: 03.

B) Dinoflagellate cysts

Genus: ***Pierceites*** Habib and Drugg1987
Type species: ***Pierceites schizocystis*** Habib and Drugg1987

Pierceites deccanensis Prasad *et al*. 2018
(Pl. III, Figs. 22-24)

Description: Dinoflagellate cysts pentagonal-triangular in shape; wall about 0.5-1 µm thick; one apical horn and two equal entapical horn present, archeopyle is expressed by sutural lines of dehiscence, defining plate boundaries; cyst surface smooth.

Dimensions: 30-48 x 53-64 µm in size

Remarks: In overall appearance it shows similarity with *Pierceites deccanensis* described by Prasad *et al*. 2018. Due to poor preservation of the present form, most of the characteristics are not distinct.

Type Locality and Horizon: Hiradehi intertrappean (Cherty limestone), Betul District, Madhya Pradesh.

Affinity: Peridiniaceae.

Specimen studied: 40.

Indian fossil record: Infratrappean sediments of Ashtona, Yavatmal district, Maharashtra.

EXPLANATION OF PLATE-II

(Scale bar represents 10 µm or otherwise mentioned)

Figs.- 1-2 ***Incrotonipollis neyvelii*** (Baksi, Deb and Siddhanta) Jansonius and Hills 1981; Slide Nos.- (1, 2) PGNU/BT/IT/8; Figs.- 3-4. ***Jiangsupollis major*** Song 1980; Slide Nos.-(3) PGNU/KN/IT/18, (4) PGNU/BT/IT/8; Figs.- 5-6 ***Proxapertites operculatus*** Van der Hammen 1956; Slide Nos.- (5) PGNU/BT/IT/8 (6) PGNU/BT/IT/4; Fig.- 7. ***Striacolporites* sp.** in equatorial view; Slide No.- PGNU/BT/IT/4; Figs.- 8-9. ***Spinizonocolpites echinatus*** Muller 1968; Slide No.- (8) PGNU/KN/IT/19 and (9) PGNU/BT/IT/4; Fig.- 10. ***Spinizonocolpites* sp. A**; Slide No.- PGNU/BT/IT/8; Figs.- 11-12. ***Azolla cretacea*** Stanley 1965 (Fig. 2- Magnified view of Glochida); Fig.- 13. ***Gabonisporis vigourouxii*** Boltenhagen 1967; Fig.- 14. ***Ephedripites ovatus*** Pierce 1961; Fig.- 15. ***Ephedripites* sp.**; Figs.- 16-17. ***Aquilapollenites bengalensis*** Baksi and Deb extended Samant, Mohabey and Paudayal 2013; Fig.- 18. ***Proxapertites operculatus*** Van der Hammen 1956

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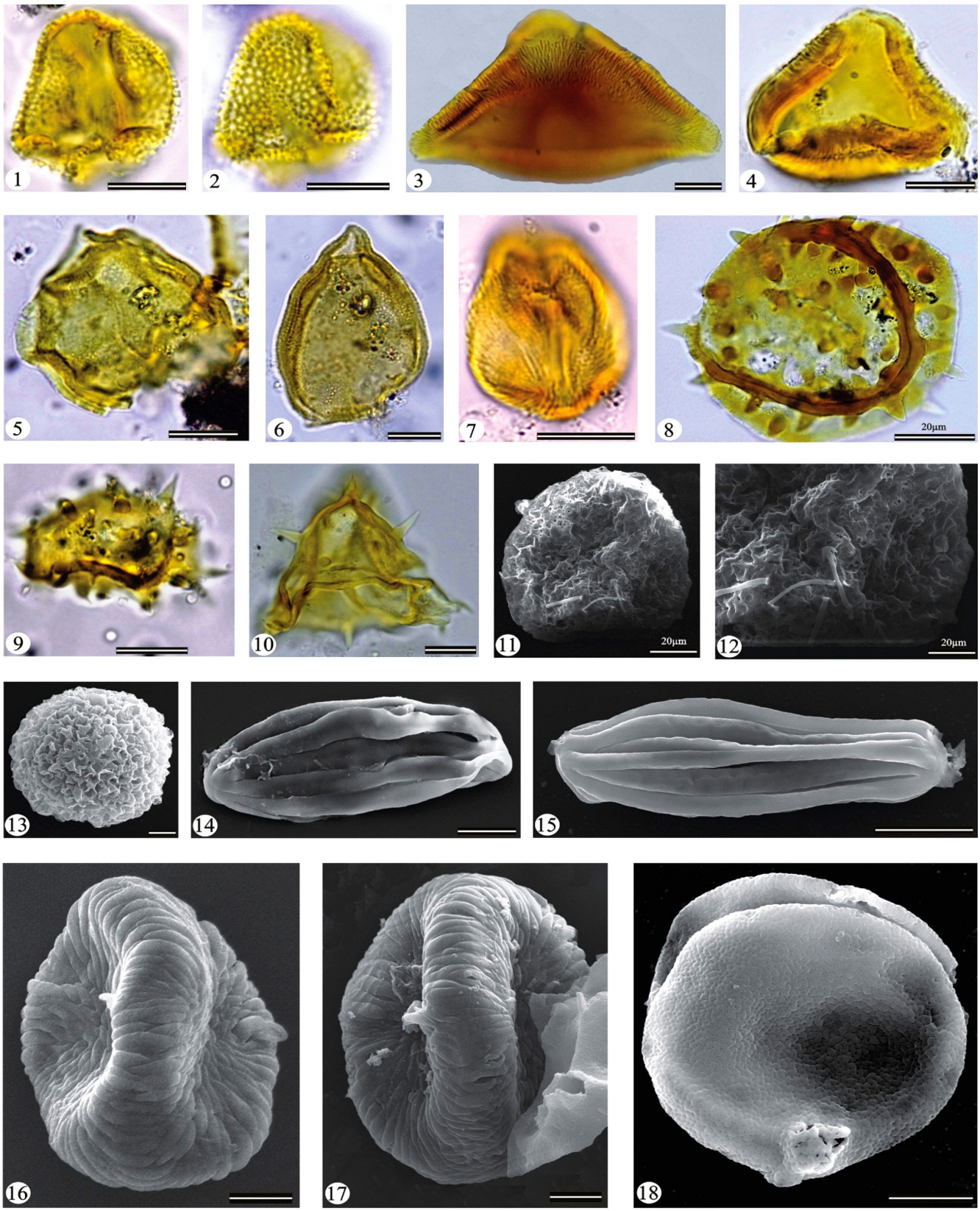
Plate II



(B): Studied microfauna and invertebrates and their concentration

Fauna	Locality	Group	Fossil Taxa	Fossils count	References
Micro foraminiferal Linings	Kanhobagholi	?Foraminifera	Trochospiral Type A	15	**Present Study**
			Trochospiral Type B	17	
			Trochospiral Type C	10	
			Trochospiral Type D	01	
Gastropods	Bhainsaghat	Mollusca	*Physa*, *Lymnia*, *Turitella*, *Viviforms* and *Paludina*	> 50	GSI unpublished reports: Tiwari and Bhattacharya (1986); Bhattacharya and Rao (1988) and **Present Study**
Freshwater (limnic) Ostracodes	Kanhobagholi	Arthropoda	*Candoniella* sp.	> 50	**Present Study**
			Cypridopsis sp.	> 50	
			Paracypretta sp.	> 10	
			Paracypretta jonesi	> 20	
	Hatnajhiri	Arthropoda	*Mongolianella* sp.	> 20	
Bivalves	Hiradehi	Mollusca	*Unio deccanensis*, (?) *Venericardia*sp.	-	Srivastava and Kandwal (2013)

C) Microforaminiferal Linings

a) Trochospiral Type A
(Pl. IV, Figs. 1-4)

Description: Form trochospiral; almost circular in shape; coiled; multicellular; multi chambered; proloculus rarely visible however when present very small in size and circuler in shape; cells are concentrically arranged, central/inner cells small in comparison to peripheral cells, cells pentagonal torectangular in shape, in some forms height of the cells is more than width, in some vice versa; septa thick; aperture rarely visible, when present about14-25 µm in size; wall thin (0.5-1 µm) sometimes thick (about 2 µm); wall smooth.

Dimensions: about 30-55 x 57-63 µm in size; septa 1.5-2 µm thick.

Remarks: Coiled, trochospiral forms are the diagnostic features of these specimens.The above described forms (Trochospiral Type A) are recorded only from Kanhobagholi intertrappean.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 15.

b) Trochospiral Type B
(Pl. IV, Figs. 5-9)

Description: Form trochospiral; sub-circular to oval in shape; multichambered; cells rectangular to slightly elliptical, sometimes pentagonal; inner cells small and pentagonal, outer cells rectangular, outer cells sometimes have more width than length; septa and wall of more or less equal thickness; wall thick to thin and smooth.

Dimensions: about 34-64 x 65-70 µm in size; wall about 1-2 µm thick.

Remarks: Sub-circular to oval shape, small size of the cells, outer cells wider thanlong are the diagnostic features of these specimens. Trochospiral A has less number of chambers and large size of chambers than that of Trochospiral B.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain.

Specimen studied: 17.

c) Trochospiral Type C
(Pl. IV, Fig. 10-11)

Description: Form trochospiral; circular to oval in shape; multichambered; cells rectangular to circular; test with processes, processes thin and broad, sometimes with many spines/ processes are present on individual cells; wall thick to thin, generally smooth.

Dimensions: about 53-58 x 63-68 µm in size; spines/ processes about 2-4 µm long; wall about 1-2 µm thick

Remarks: Rectangular to oval shape and presence of spines/processes on cells are the diagnostic features of these specimens.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

EXPLANATION OF PLATE-III
(Scale bar represents 10 µm or otherwise mentioned)

Fig.-1 ***Dicellaesporites intertrappea* sp. nov.**; Slide No.- PGNU/KN/IT/12; Figs.- 2-3 ***Dicellaesporites* sp.**; Slide Nos.- (2) PGNU/KN/IT/10 and (3) PGNU/KN/IT/12; Fig.- 4 ***Diporicellaesporites fusiformis*** Ramanujam and Srisailam 1980; Slide No.- PGNU/KN/IT/20; Fig.-5 ***Inapertisporites* sp. A**; Slide No.- PGNU/It40; Fig.- 6 ***Inapertisporites* sp. B**; Slide No.- PGNU/BT/IT/4; Figs.- 7-8. ***Involutisporonites* sp.**; Slide Nos.- (7) PGNU/KN/IT/20 and (8) PGNU/KN/IT/21; Fig.-9. ***Monoporisporites* sp.**; Slide No.- PGNU/JM/IT/22; Fig.- 10. ***Multicellites* sp.**; Slide No.-PGNU/KN/IT/23; Figs.- 11-14. ***Papulosporonites multicellatus*** (Saxena & Singh 1982a) Kalgutkar & Jansonius 2000; Slide Nos.- (11) PGNU/KN/IT/24, (12) PGNU/KN/IT/16; (13) PGNU/KN/IT/25 and (14) PGNU/KN/IT/23; Figs.- 15-16. ***Papulosporonites siwalikus*** (Saxena & Bhattacharyya 1987) Kalgutkar & Jansonius 2000; Slide Nos.- (15) PGNU/KN/IT/21 and (16) PGNU/KN/IT/5; Figs.- 17-20. ***Papulosporonites subcircularis*** (Chandra *et al*., 1984) Kalgutkar & Jansonius 2000; Slide Nos.- (17) PGNU/KN/IT/16, (18) PGNU/KN/IT/26, (19) PGNU/Knhbgl-2, R/It16 and (20) PGNU/ KN/IT/21; Fig.- 21. ***Phragmothyrites* sp.**; Slide No.- PGNU/KN/IT/27; Figs.- 22-24. ***Pierceites deccanensis*** Prasad *et al*. 2018; Slide Nos.- (22) PGNU/HRD/IT/28; (23) PGNU/HRD/IT/28 and (24) PGNU/HRD/IT/28.

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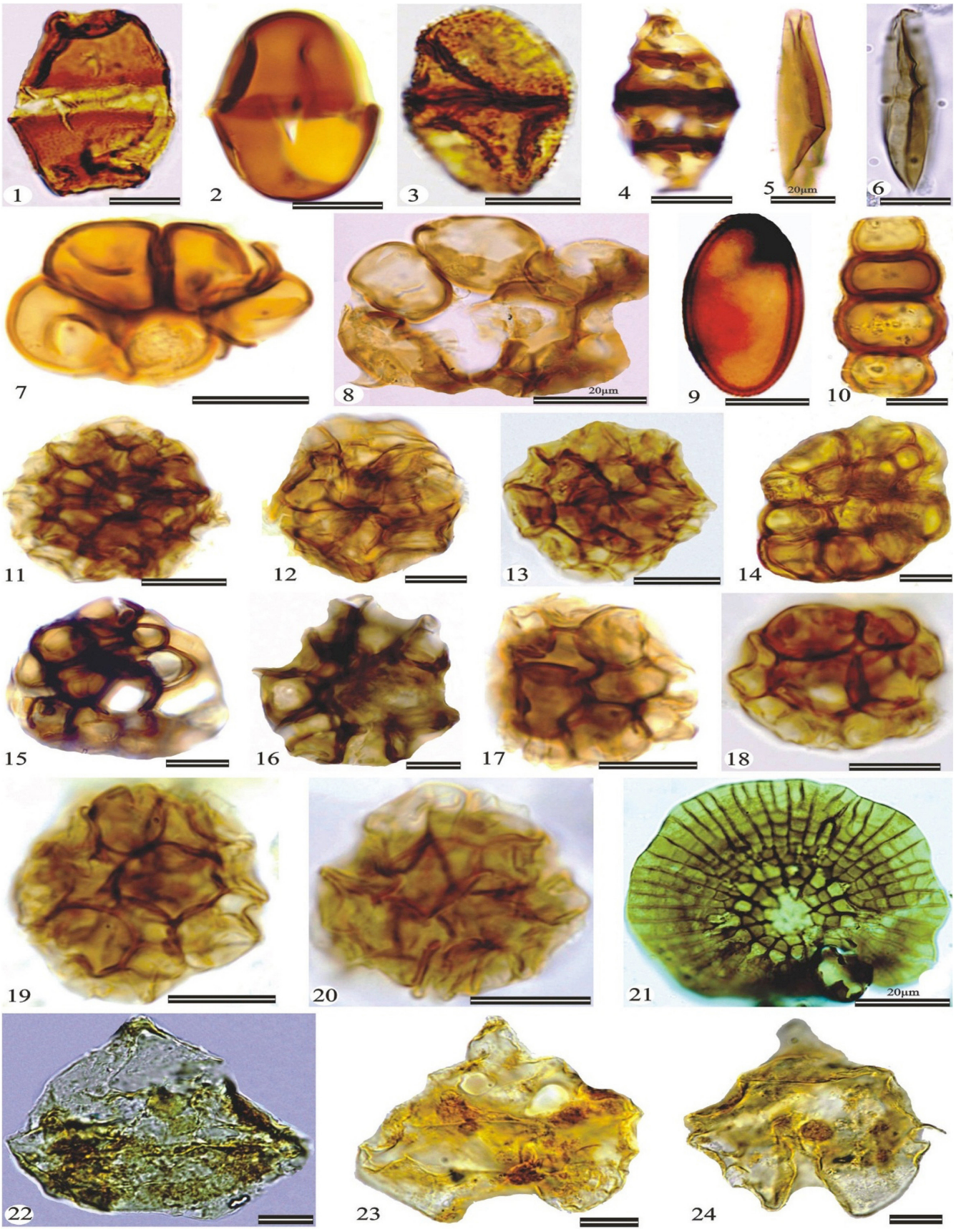
Plate III



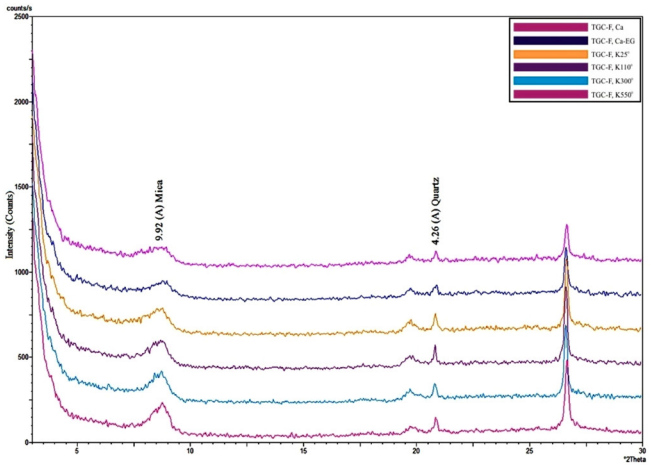


Fig. 6(A): X-Ray Diffraction pattern of Fine clay (Green) in intertrappean sediments of Topidhana section.

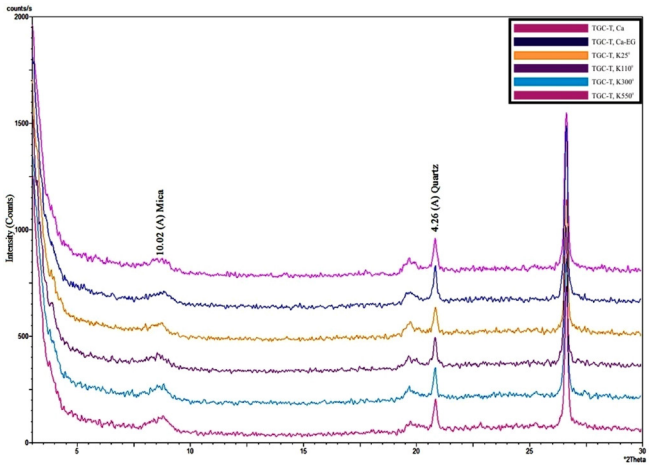


Fig. 6 (B): X-Ray Diffraction pattern of Total clay (Green) in intertrappean sediments of Topidhana section.

Affinity: Uncertain.
Specimen studied: 10.

d) Trochospiral Type D
(Pl. IV, Fig. 12)

Description: Form trochospiral; oval to subcircular in shape; multichambered; multicellate; cell wall thin, cells small and almost equal in size, polygonal, sometimes rectangular; wall thin and smooth.

Dimensions: about 60-69 μm in size; cell wall about 0.5-1 μm,

Remarks: Trochospiral forms, oval to subcircular shaped and large number of small cells of almost equal size are the diagnostic features of these specimens. It differs from type A, B in having large number of small chambers.

Type Locality and Horizon: Kanhobagholi intertrappean (chert), Betul District, Madhya Pradesh.

Affinity: Uncertain

Specimen studied: 01

IV) Freshwater (limnic) Ostracodes

Phylum: **Arthropoda** Von Siebold, 1848
Subphylum: **Crustacea** Pennant, 1777
Subclass: **Ostracoda** Latreille, 1806
Order: **Podocopina** Muller 1894
Suborder: **Cypridocopina** Jones, 1901
Superfamily: **Cypridoidea** Baird, 1845
Family: **Candonidae** Kaufmann, 1900
Genus: ***Candoniella*** Schneider, 1956
Type species: ***Candoniella suzini*** Schneider, 1956

Candoniella sp.

(Pl. V, Figs. 1-3, Photographs under light microscope).
(Pl. V, Figs. 16-19, Photographs under SEM).

Material: 25 carapaces.

Description: Carapace small and large, elongate in the lateral view, dorsal margin arched and slightly flat, closer view of dorsal margin showing nodes in SEM (Pl. V, fig.- 17), ventral margin almost straight or slightly convex, anterior and posterior sides rounded, left valve large (Pl. V, figs.- 1, 19), curvature is different at posterodorsal, dorsal and anterodorsal margins, surface of valve smooth.

Dimensions: Length- 2.1-1.3 mm, width- 0.7-0.5 mm.

Remarks: Carapaces large elongate, surface almost smooth and pointed endtowards anterior side are the characteristic features. At higher magnification, nodesare seen with smooth ornamentation on surface view.

Type Locality and Horizon: Kanhobagholi intertrappean (light brownish shale). Betul district, Madhya Pradesh.

Specimen studied: 10.

Genus: ***Cypridopsis*** Brady, 1868
Type species: ***Cypris vidua*** O. F. Müller, 1776

Cypridopsis sp.
(Pl. V, Figs.- 4-6, Photographs under light microscope).
(Pl. V, Figs.- 20-23, Photographs under scanning electron microscope, SEM).

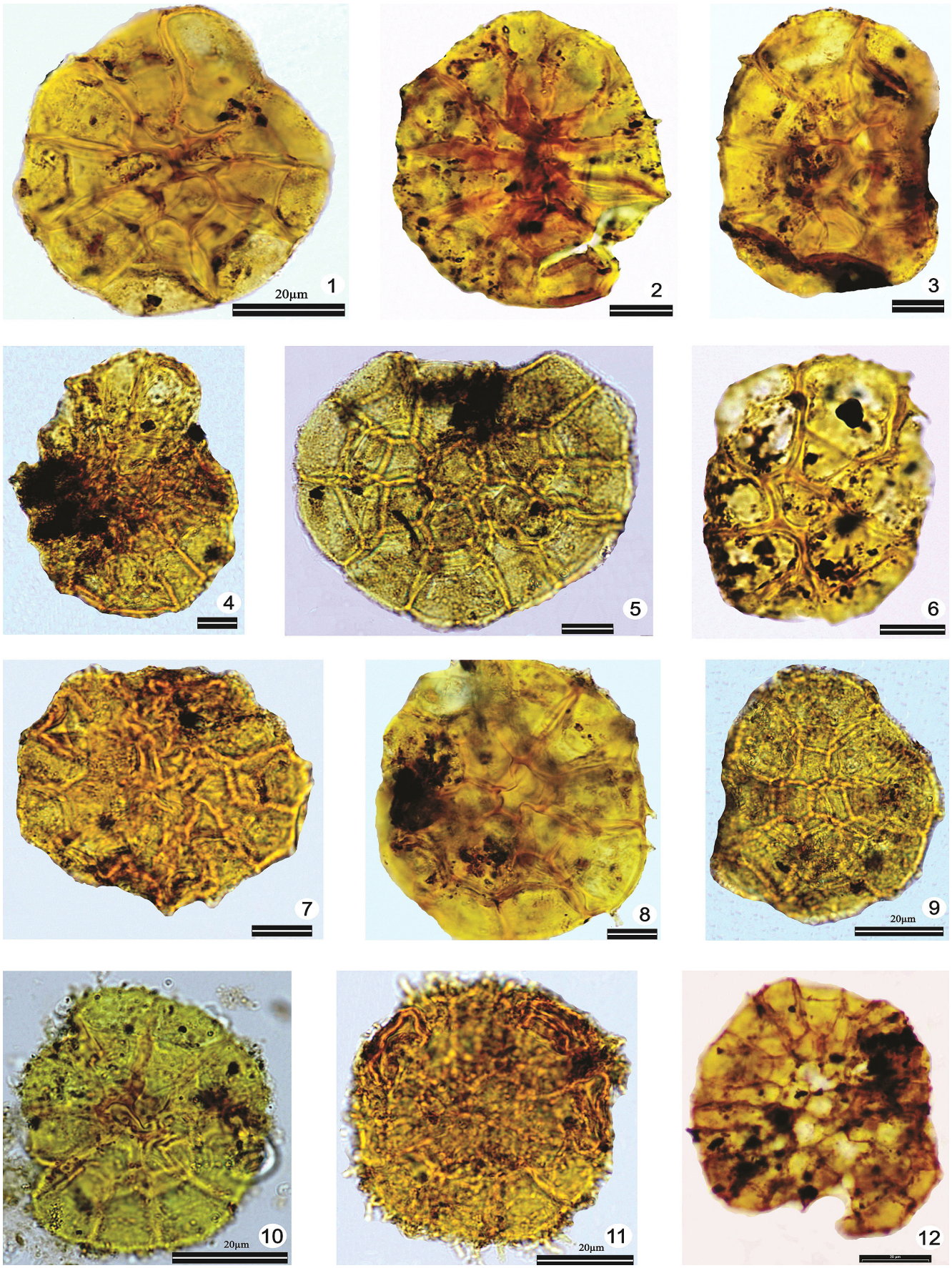
Material: 20 carapaces.

Description: Carapace subspherical, reniform, sub-ovate in lateral outline, subcircular, laterally inflated fragments, length equals to width; arched, sub-angulate and subcircular in dorsal outline, fusiform; dorsal margin strongly convex;

EXPLANATION OF PLATE-IV
(Scale bar represents 10 μm or otherwise mentioned)

Microforaminiferal linings: Figs.- 1-4. **Trochospiral Type A** Slide Nos.- (1) PGNU/KN/IT/29; EF-63V/3, (2) PGNU/KN/IT/30; EF-64H/1, (3) PGNU/Knhbgl-B1/It56; EF-63V/2, (4) PGNU/KN/IT/29; EF-59S/4. Figs.- 5-9. **Trochospiral Type B** Slide Nos.- (5) PGNU/KN/IT/29; EF-53W, (6) PGNU/KN/IT/29; EF-52D/1, (7) PGNU/KN/IT/29; EF-38U/2, (8) PGNU/KN/IT/29; EF-68M/1, (9) PGNU/KN/IT/29; EF-56O. Figs.- 10-11. **Trochospiral Type C** Slide Nos.- (10) PGNU/KN/IT/31; EF-65R/1, (11) PGNU/KN/IT/29; EF-40P/4. Fig.- 12. **Trochospiral Type D** Slide No.- PGNU/KN/IT/29; EF-67X/2.

Plate IV



ventral margin with slight concavity; left valve and right valve more or less equal; dorsal margin strongly arched, ventral margin meridionaly concave, apex at mid-height; posterior margin sloping in upper half and rounded in lower half, apex below mid-height. In dorsal view, carapace biconvex, with maximum width slightly posterior to middle, anterior end pointed and posterior end rounded, tumid appearance in dorsal view, and the obtusely angled dorsal margin differentiate this species from other species of *Cypridopsis.*

Dimensions: Length- 0.9-0.7 mm; width- 0.6-0.5 mm.

Type Locality and Horizon: Kanhobagholi intertrappean, (light brownish shale rock) and Hatnajhiri intertrappean, (greenish fossiliferous chert rock), Betul district, Madhya Pradesh.

Remarks: In SEM, pitted ornamentation are observed on the surface of entire valves.

Specimen studied: 10.

Genus: ***Paracypretta*** Sars, 1924

Paracypretta jonesi Bhatia and Rana, 1984
(Pl. V, Figs.- 7-9, Photographs under light microscope).

Material: 40 carapaces.

Description: Large carapaces; inflated, subtriangular in lateral view and very arcuate to subumbonate dorsally; dorsal margin symmetrically convex, subangulate in the middle; greatest height and width nearly equal and about 2/3 of length; left valve and right valve almost equal in size or left valve larger than right valve, overlapping all along margin; dorsal margin symmetrically convex, subangulate in the middle; ventral margin straight; posterior margin slightly compressed; anterior and posterior margins broadly rounded; surface of each valve ornamented with minute and very dense puncta.

Dimensions: Length- 1.4-1.2 mm; width- 1-0.8 mm.

Remarks: For the first time, Bhatia and Rana (1984) reported this species from the intertrappean beds of Gitti Khadan, Nagpur.

Type Locality and Horizon: Kanhobagholi intertrappean (light brownish shale), Betul district, Madhya Pradesh.

Specimen studied: 10.

Genus: ***Paracypretta*** Sars, 1924

Paracypretta sp.
(Pl. V, Figs- 10-12, Photographs under light microscope).

Material: 15 carapaces.

Description: Large carapaces, inflated, subtriangular laterally; subovate in lateral outline; compressed anteriorly, anterior margin broadly rounded and posterior margin narrowly rounded than the anterior; left valve slightly larger than right valve, dorsal margin gently arched to nearly straight; ventral margin with a slight anteroventral concavity; left valve overlaps right valve along dorsal and posterior margins.

Dimensions: Length- 1.2-1 mm; width- 0.9-0.7 mm.

Remarks: The important characters in these species are the presence of reticulate ornamentation. Surface ornamented has very minute pits in ventral half. Pits aredensely or sparsely spaced.

Type Locality and Horizon: Kanhobagholi intertrappean (light brownish shale), Betul district, Madhya Pradesh.

Specimen studied: 10.

Type species: ***Mongolianella palmosa*** Mandelstam, 1956

Mongolianella sp.
(Pl. V, Figs. 13-15, Photographs under light microscope).

Material: 20 carapaces.

Description: Carapace large; elongate (bean shaped), subrectangular to subcylindrical; dorsal margin in which the central part is straight and slightly convex upward; fusiform; ventral margin almost straight or slight concave in the middle of it; the left and large valve overlaps the right one around the anteriodorsal margin and the middle part of ventral margin; maximum height at the anterior part, anterior part broadly rounded, posterior end narrowly rounded; surface of valve smooth.

Dimensions: Length- 1.1-0.9 mm; width- 0.5-0.3 mm.

Remarks: The species is widely recorded from the intertrappean beds.

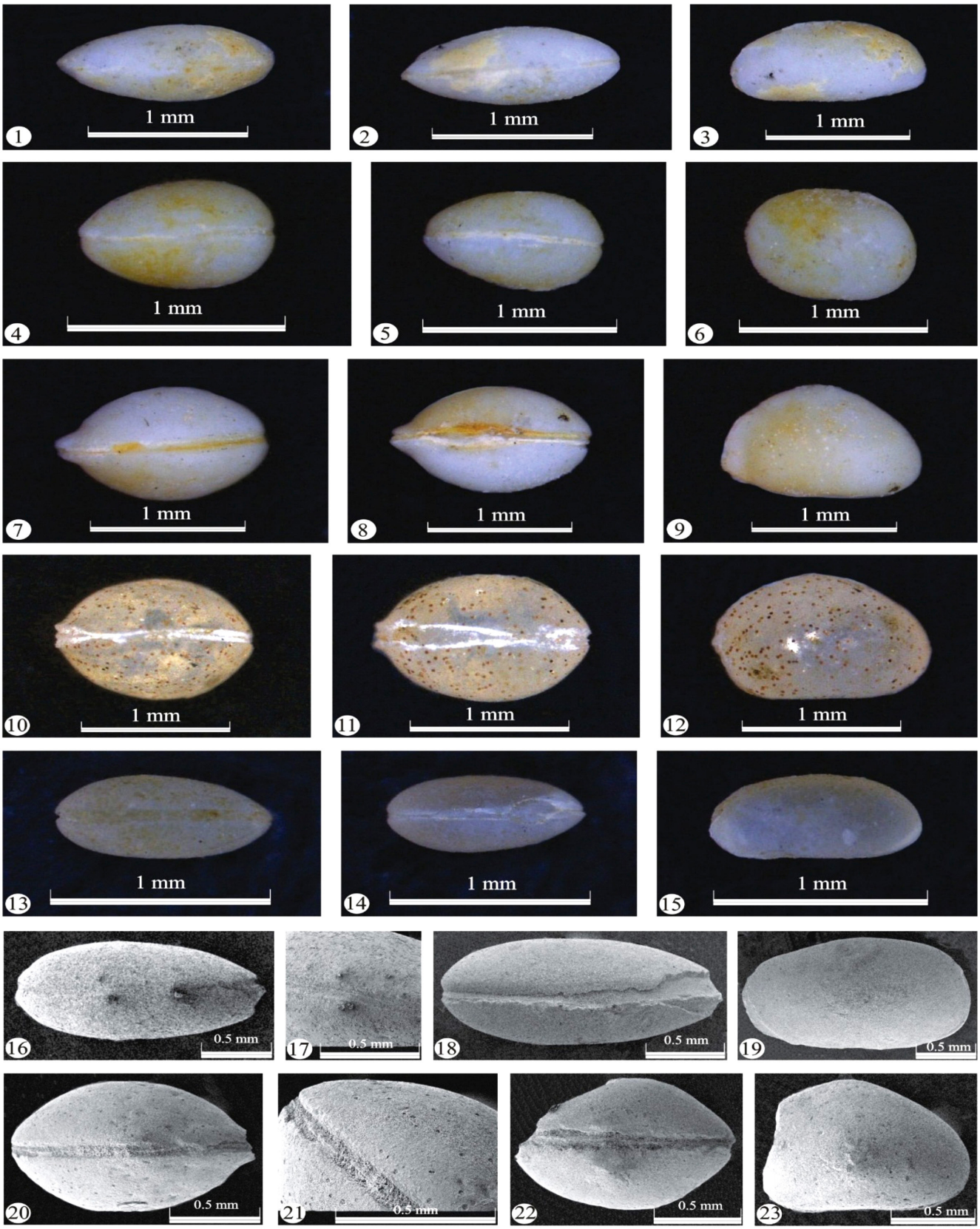
Type Locality and Horizon: Hatnajhiri intertrappean (greenish fossiliferous chert), Betul district, Madhya Pradesh.

Specimen studied: 10.

EXPLANATION OF PLATE-V
(Scale bar represents 1 mm)

(a) Freshwater Ostracodes from Kanhobagholi intertrappean: Fig.-1. ***Candoniella* sp.** (Dorsal view); Slide No.- PGNU/KN/IT/36; Fig.-2. ***Candoniella* sp.** (Ventral view); Slide No.- PGNU/KN/IT/36; Fig.-3. ***Candoniella* sp.** (Right carapace); Slide No.-PGNU/KN/IT/36; Fig.-4. ***Cypridopsis* sp.** (Dorsal view); Slide No.- PGNU/KN/IT/37; Fig.-5. ***Cypridopsis* sp.** (Ventral view); Slide No.- PGNU/KN/IT/37; Fig.-6. ***Cypridopsis* sp.** (Left carapace); Slide No.- PGNU/KN/IT/37; Fig.-7. ***Paracypretta jonesi*** (Dorsal view); Slide No.- PGNU/KN/IT/35; Fig.-8. ***Paracypretta jonesi*** (Ventral view); Slide No.- PGNU/KN/IT/35; Fig.-9. ***Paracypretta jonesi*** (Left carapace); Slide No.- PGNU/KN/IT/35; Fig.-10. ***Paracypretta* sp.** (Dorsal view); Slide No.- PGNU/KN/IT/33; Fig.-11. ***Paracypretta* sp.** (Ventral view); Slide No.- PGNU/KN/IT/33; Fig.-12. ***Paracypretta* sp.** (Left carapace); Slide No.- PGNU/KN/IT/33; **(b) Freshwater Ostracodes from Hatnajhiri intertrappean:** Fig.-13. ***Mongolianella* sp.** [Dorsal view (posterior to left)] Slide No.- PGNU/HRRS/IT/32; Fig.-14. ***Mongolianella* sp.** [Ventral view (posterior to left)] Slide No.- PGNU/HRRS/IT/32; Fig.-15. ***Mongolianella* sp.** (Left carapace) Slide No.- PGNU/HRRS/IT/32 **(c) SEM of Freshwater Ostracodes from Kanhobagholi intertrappean:** (Scale bar represents 0.5 mm) Fig.- 16. ***Candoniella* sp.** (Dorsal view); Slide No.- PGNU/KN/IT/34; Fig.-17. ***Candoniella* sp.** (Closer view showing nodes); Slide No.- PGNU/KN/IT/34; Fig.-18. ***Candoniella* sp.** (Ventral view); Slide No.- PGNU/KN/IT/34; Fig.-19. ***Candoniella* sp.** (Left carapace); Slide No.- PGNU/KN/IT/34; Fig.-20. ***Cypridopsis* sp.** (Dorsal view); Slide No.- PGNU/KN/IT/33; Fig.-21. ***Cypridopsis* sp.** (Closer view of the hinge); Slide No.- PGNU/KN/IT/33; Fig.-22. ***Cypridopsis* sp.** (Ventral view); Slide No.- PGNU/KN/IT/33; Fig.-23. ***Cypridopsis* sp.** (Right carapace); Slide No.- PGNU/KN/IT/33

Plate V



DISCUSSION

Palynological study of intertrappean beds namely (i) Hiradehi-1, (ii) Hiradehi-2, (iii) Topidhana-1, (iv) Topidhana-2, (v) Bhainsaghat, (vi) Hatnajhiri, (vii) Jamunjhiri, (viii) Kanhobagholi, (ix) Divtiya, (x) Rambhakheri south, and (xi) Rambhakheri east, at 10 stratigraphic levels in Satpura Group was carried out. Flows in this part are not classified into different formation (GSI, Quadrangle Geological Map (QGM) 1998) as has been carried in Sahyadri, Amarkantak and Malwa Group by Geological Survey of India hence, Reduced Level (RL) is taken as a stratigraphic level in the study area. Stratigraphically, Hiradehi intertrappean occurs at the lowest stratigraphic level (RL 469, Fig. 2 I) and Rambakhedi at the highest stratigraphic level (RL 784; Fig 3, I). All the studied intertrappean in this area are sandwiched in between over 300 m thick lava pile at different stratigraphic levels. It is observed that intertrappean sediments at the lower levels, i.e. Hiradehi and Topidhana have dominantly aquatic microfossil and are devoid of fossil woods. Hiradehi intertrappean yielded monospecific fresh water peridinoid dinoflagellate cyst *Pierceites deccanensis* (Pl. II, Fig. 22-24) and good number of fungal spores, a few chlamydospores of *Glomus* like mycorrhizal fungi and a lot of biodegraded plant remains. Topidhana intertrappean, which occurs at slightly higher stratigraphic level (RL 501, Fig 2, I, C) yielded mostly frustules of centric diatom *Aulacoseira.*

Peridinoid dinocysts *Pierceites deccanensis* Prasad *et al*. (2018) from Hiradehi intertrappean shows similarity with dinocysts recorded from infratrappean sediments of Ashtona, Yavatmal district, Maharashtra (Prasad *et al.,* 2018) and intertrappean beds of Kurli in Yavatmal district, Maharashtra which also occur at lower stratigraphic levels (Samant and Mohabey, 2016). Record of centric diatoms *Aulacoseira* is common in the Late Cretaceous (Maastrichtian) Deccan volcanic associated Lameta and intertrappean sediments. Importantly, oldest record of this freshwater diatom is from the Lameta sediments of Nand-Dongargaon Basin (Ambwani *et al*., 2003; Samant and Mohabey, 2014). These centric diatoms are ubiquitous and are known from the many intertrappean sediments in Chandrapur (Samant and Mohabey, 2014), Chhindwara district (Ambwani *et al.,* 2003; Thakre *et al*., 2017) and Naskal, in Telangana (Singh *et al*., 2007).

For palaeoclimatic interpretation clay minerals were also analyzed from Hiradehi and Topidhana intertrappean beds as these intertrappean beds have soft shales and clay (Figs. 2-3). In Hiradehi section, total clay fraction consists of dominantly Smectite (63.03%) and Quartz (36.96%) and fine clay fraction also has Smectite (58.99%) and Quartz (41.00%) (Table 3, Figs. 4 A, B). From the Topidhana section, two clay samples were analyzed. The lower white clay yielded only Smectite both in total clay and fine clay whereas upper green clays in total clay fraction yielded dominantly Quartz (63.15%) and Mica (36.84%). In fine clay fraction mica was dominant (68.87%) followed by Quartz (31.12%) (Table 3; Figs. 5 A, B and Figs. 6 A, B). Overall, Smectite dominant clays from Hiradehi and Topidhana sections indicate prevalence of arid to dry climatic conditions. Dominance of Quartz and mica in the upper part of the Topidhana intertrappean suggest detrital input into the lake, could be due to prevalence of aeolian conditions caused by arid climatic conditions.

At the higher stratigraphic level (RL 759 m, Fig. 3, I) in Kanhobagholi intertrappean, good concentration of spores and pollen grains of pteridophytes, gymnosperms, angiosperms and Non Pollen Palynomorphs (NPPs) are recorded. Pteridophytes are represented by *Azolla cretacea*, *Cyathidites* sp., *Gabonisporis vigourouxii*, gymnosperms by genus *Ephedripites*, and angiosperms by *Aquilapollenites bengalensis*, *Aquilapollenites intertrappeus*, *Echitricolpites* sp., *Farabeipollis minutus*, *Farabeipollis deccanensis* sp. nov, *Incrotonipollis neyvelii*, *Jiangsupollis major*, *Proxapertites operculatus*, *Striatricolporites* sp. and *Spinozonocolpites echinatus.* Non Pollen Palynomorphs (NPPs) are represented by fungal spores, epiphyllous fungi and microforaminiferal linings. Fungal spores of taxa *Dicellaesporites intertrappea* sp. nov., *Dicellaesporites* sp., *Diporicellaesporites fusiformis*, *Involutisporonites* sp., *Monoporisporites* sp., *Multicellites* sp., *Papulosporonites multicellatus, Papulosporonites siwalikus*, *Papulosporonites subcircularis*, and fungal fruit bodies of *Phragmothyrites* sp. are present in the assemblage.

Microforaminiferal linings recorded from the Kanhobagholi intertrappean sediments show close similarity with that of microforaminiferal linings recorded from Mohagaon Kalan intertrappean, Chhindwara district, Madhya Pradesh (Thakre *et al*., 2017). Importantly, these linings from the intertrappean sediments are distinctly different in morphology, especially in cell structure and coiling pattern from the microforaminiferal lining recorded from the marine to near marine sediments of Bengal basin (Phadtare and Thakur, 1992), Paleogene sediments of western India (Tabaei and Singh 2002; Monga *et al*., 2015), Assam (Kumar *et al*., 2001) and Imphal (Singh *et al*., 2013). Hence, it is probable that microforaminiferal linings from the intertrappean sediments belong be some extinct group.

In addition to microflora, this intertrappean also yielded well preserved megaflora, such as, fruit of *Indovitis* (Vitaceae; Manchester *et al.,* 2013), flowers of *Sahanipushpam* (?Araceae; locality spelled as Jaulkheda Kapgate *et al.*, 2011) and *Sahanianthus* (Dr. Dasharath Kapgate, personal communication) and many fossil woods and roots of dicot and monocot plants. Other nearby intertrappean localities in this area namely, Divtiya, Rambhakhedi and Jamunjhiri (Fig. 3) also have fossil woods of dicot and monocot plants but macerated samples only yielded phytoclasts of plants and mycorrhizal fungi. Overall, presence of good number of fossil woods in many intertrappean beds at higher stratigraphic level indicate good vegetation in this part of Satpura Group.

On the basis of palynoassemblage such as, *Azolla cretacea*, *Gabonisporis vigourouxii*, *Aquilapollenites bengalensis*, *Aquilapollenites intertrappeus*, *Echitricolpites* sp., *Farabeipollis minutes*, *Farabeipollis deccanensis* sp. nov., *Jiangsupollis major*, Late Cretaceous (Maastrichtian) age is assigned to this intertrappean. The recorded palynoassemblage show similarity with Maastrichtian palynoassemblage of Kurli, Daiwal, Khandala-Ashta, Anandvan, Surli and Sindhi of Nand-Dongargaon basin (Samant and Mohabey, 2009, 2014) and Singpur (Samant *et al*., 2008), Mohgaon Kalan (Kar and Srinivasan, 1998; Kumaran *et al*., 1997; Thakre *et al*., 2017), Ranipur (Mathur and Sharma, 1990) and Padwar intertrappean beds (Prakash *et al*., 1990, Kar *et al*., 1998; Kar and Singh, 2014) in Mandla-Jabalpur-Chhindwara area in Amarkantak Group. Palynoflora

Table-3: Clay minerals in intertrappean sediments of Satpura Group, Betul district, Madhya Pradesh.

Distribution of Clay Minerals							
FM	**Locality**	**Sample Nos.**	**Percentage of Minerals**				**Total %**
			Smectite	**Mica**	**Kaolinite**	**Quartz**	
IT	Hiradehi	HGC-FC	58.99	-	-	41.00	99.99
		HGC-TC	63.03	-	-	36.96	99.99
	Topidhana	TGC-FC	-	68.87	-	31.12	99.99
		TGC-TC	-	36.84	-	63.15	99.99
		TWC-FC	100.00	-	-	-	100.00
		TWC-TC	100.00	-	-	-	100.00

Abbreviations:

FM- Formation
IT- Intertrappean sediments
FC- Fine clay
TC- Total clay

HGC- Hiradehi Green clay
TGC- Topidhana Green clay
TWC- Topidhana White clay

also show some similarity with Naskal intertrappean in South eastern part of Sahyadri Group (Singh *et al.,* 2006).

The palynomorphs such as *Proxapertites operculatus* and *Spinizonocolpites echinatus* from the Kanhobagholi intertrappean are also good depositional environment indicators. Fossil pollen of *Proxapertites operculatus* is an extinct monocot herb that is commonly recorded from the coastal environment along the shores of river channels and lagoons (Zetter *et al*., 2001) and *Spinizonocolpites echinatus* is related to back mangrove rhizomatic palm *Nypa* which grows in brackish to estuarine conditions (Muller, 1979). Hence, presence of *Proxapertites operculatus* and *Spinizonocolpites echinatus* suggest estuarine depositional environment. Interestingly, in addition to estuarine depositional environment indicator palynomorphs, fresh water taxa such as *Azolla cretacea* (Salviniaceae) and *Gabonisporis* (Marsileaceae) have also been recorded from this intertrappean. This intertrappean has also yielded fresh water ostracodes such as *Candoniella* sp. *Cypridopsis* sp. *Paracypretta* sp. and *Paracypretta jonesi.* Hence, overall biota of this intertrappean suggests estuarine to fresh water depositional conditions at the time of deposition.

Some reproductive fruit bodies of epiphyllous fungi mainly of family microthyriaceae are also present in this intertrappean. These fungi are abundantly found in forest of tropical and subtropical climate and they require heavy rainfall rather than temperature for their growth. High precipitation and air humidity are crucial factors for their growth (Selkirk, 1975; Johnson and Sutton, 2000; Limaye *et al*., 2007) and they show highest abundance and taxonomic diversity in warm and humid subtropical to tropical regions (Reynolds and Gilbert, 2005; Thaung, 2006; Hofmann, 2010; Hosagoudar *et al*., 2011; Piepenbring *et al*., 2011; Dilcher, 1965; Selkirk, 1975; Lange, 1976; Elsik, 1978; Kalgutkar and Jansonius, 2000; Tripathi, 2009; Conran *et al*., 2016). Record of epiphyllous fungi and many fossil woods of dicot and monocot plants from the Kanhobagholi intertrappean sediments suggest good vegetation and prevalence of warm and probably humid climatic conditions at the time of deposition. Freshwater ostracodes from Kanhobagholi and Hatnajhiri intertrappeans of Satpura Group of Betul district, Madhya Pradesh are represented by four genera and one species namely *Candoniella* sp., *Cypridopsis* sp., *Mongolianella* sp. and *Paracypretta jonesi*. Recorded ostracodes show similarity with the freshwater ostracodes assemblage reported from other intertrappean beds (summarized in Khosla and Verma, 2015).

CONCLUSIONS

Palynological studies of 11 intertrappean beds namely Kanhobagholi, Rambhakhedi (two sections), Divtiya, Jamunjhiri, Hatnajhiri, Bhainsaghat, Hiradehi (two sections) and Topidhana (two sections) of Satpura Group, in Betul district have provided valuable insight into biota, age, depositional environment and climate of palaeontologically scarcely explored Satpura Group. Palynological data shows presence of aquatic flora dominating intertrappean beds at the lower stratigraphic levels and good terrestrial vegetation at the higher stratigraphic levels.

Hiradehi intertrappean yielded monospecific peridinoid dinoflagellate cysts *Pierceites deccanensis* and Topidhana intertrappean mostly centric diatom *Aulacoseira* which suggest that initially aquatic biota dominated the water bodies. Smactite dominated clays and chertified limestone in this area suggest prevalence of arid to semiarid climatic conditions at the time of deposition.

Kanhobagholi intertrappean at the higher stratigraphic levels yielded good number of well-preserved spores and pollen assemblage along with fungal spores and microforaminiferal linings. Palynoflora has pteridophytes-angiosperm dominated assemblage. Taxa such as, *Azolla cretacea*, *Gabonisporis vigourouxii*, *Aquilapollenites bengalensis*, *Aquilapollenites intertrappeus*, *Echitricolpites* sp., *Farabeipollis minutes*, *Farabeipollis deccanensis* sp. nov., *Jiangsupollis major*, suggest Late Cretaceous (Maastrichtian) age for this intertrappean. Presence of pollen grains of *Proxapertites operculatus, Spinizonocolpites, Azolla cretacea, Gabonisporis* and epiphyllous fungi of family Microthyriaceae and many dicot and monocot fossil woods in this intertrappean suggests deposition in warm, humid climatic conditions in freshwater to estuarine depositional environment.

Lithology, clay mineralogy, and microfossil assemblage from the intertrappean sediments of Satpura Group indicate change in climatic conditions from semiarid to arid in the lower stratigraphic level (Hiradehi, and Topidhana) to warm humid at the higher stratigraphic level (Kanhobagholi, Jamunjhiri, Divtiya and Rambhakheri).

Palynoassemblage of Kanhobagholi intertrappean shows close similarity with Maastrichtian palynoassemblage of Sahyadri Group (Daiwal, Anandvan, Khandala-Ashta, Kurli, Shimbala, Shankar Lodhi, Singpur) and Amarkantak Group (Mohgaon Kalan Fossil Forest, Ranipur and Padwar). Hiradehi intertrappean has dinoflagellate cysts *Pierceites deccanensis* which show similarity with dinocysts recorded from the Maastrichtian intertrappean sediments of central India. Topidhana intertrappean has ubiquitous centric diatom *Aulacoseira*.

Two intertrappean beds namely Kanhobagholi and Hatnajhiri intertrappeans yielded some well preserved fresh water ostracodes. The recovered forms show similarity with the freshwater limnic ostracodes assemblage reported from many intertrappean beds of Deccan volcanic province

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