

Taxonomical identification of a new petrified multiseeded capsular fruit from the Deccan Intertrappean beds of Bhutera, India

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ABSTRACT

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The fossil flora of the Deccan Intertrappean beds of central India provides a unique opportunity for detailed investigation, taxonomic affinities and biogeographic relationships of plants during the late Cretaceous–early Palaeogene Period. The fossils found in cherts were deposited during quiescent intervals of lava flows.

The present paper deals with a fossil fruit collected from the Deccan Intertrappean beds of Bhutera (lat. 22°06.58' N, long. 79°08.42' E) of Chhindwara District, Madhya Pradesh, India. The fruit was exposed in transverse oblique plane. The serial peel sections were taken for detailed study. The present fruit is small, dicotyledonous, obovate, unilocular, multiseeded, dehiscent capsular fruit. On comparison with modern dicotyledonous families, the fruit shows a close resemblance with Portulacaceae.

Key-words—Capsular, Deccan Intertrappean, Dicotyledonous, Multiseeded, Portulacaceae.

भुटेरा, भारत की दक्कन अंतःट्रेपी संस्तरों से प्राप्त एक अभिन्न अशमीभूत बहुबीजीय संपुटी फल का आकारिकीय अभिनिर्धारण

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सारांश

मध्य भारत में दक्कन अंतःट्रेपी संस्तरों की जीवाश्म वनस्पतिजात विलंबित चाकमय–प्रारंभिक पैलियोजीन अवधि के दौरान पादपों के विस्तृत अन्वेषण, आकारी बंधुताओं एवं जैवभौगोलिक संबंधताओं हेतु अनूठा अवसर प्रदान करती है। चर्टों में मिले जीवाश्म लावास्तर शांत अंतरालों के दौरान निक्षेपित हो गए थे।

मौजूदा शोध-पत्र का सरोकार जिला छिंदवाड़ा, मध्य प्रदेश, भारत में भुटेरा (22°06.58' उत्तर अक्षांश, 79°08.42' पूर्व रेखांश) के दक्कन अंतःट्रेपी संस्तरों से संगृहीत जीवाश्म फल से है। फल अनुप्रस्थ तिर्यक समतल में अनावरित था। विस्तृत अध्ययन के लिए क्रमिक छिलका खंडों को प्रयुक्त किया गया। मौजूदा फल लघु, द्विबीजपत्री, प्रतिअंडाकार, एककोष्ठकी, बहुबीजीय, स्फुटनशील संपुटी फल है। आधुनिक द्विबीजपत्री कुटंबों से तुलना करने पर फल पोर्टुलेसी से निकट साम्य दर्शाता है।

सूचक शब्द—संपुटी, दक्कन अंतःट्रेपी, द्विबीजपत्री, बहुबीजीय, पोर्टुलेसी।

INTRODUCTION

THE fossil flora of the Deccan Intertrappean beds of central India provides a unique opportunity for detailed investigation of taxonomic affinities and biogeographic relationship of plants that populated the Indian subcontinent about 66 million years ago. The fossils are found in cherts that were deposited during quiescent intervals between the basaltic lava flows.

The Deccan Traps are one of the largest Continental Flood Basalt (CFB) provinces in the world, occupying an area of about 500,000 sq. km in peninsular India (Jay & Widdowson, 2008). The duration of activity of this Large Igneous Province (LIP) was debated for a long time. Recent studies based on $^{40}\text{Ar}/^{39}\text{Ar}$ dating indicate that the duration of the volcanism ranging from < 1 my (Hofmann *et al.*, 2000) to 7–8 my (Sheth *et al.*, 2001). The Deccan volcanism is of considerable interest to biologists as well as to geologists as it is considered to be one of the causes of mass extinction at the Cretaceous–Palaeogene Boundary (KPB) (Samant & Mohabey, 2009).

The fossil fruit was found exposed in oblique transverse plane and was collected from a new locality Bhutera (lat. $22^{\circ}06.58'$ N, long. $79^{\circ}08.42'$ E) of Chhindwara District, Madhya Pradesh (Fig. 1). It is 30 km from Chhindwara on Seoni road and 10 km from north of Jhilmily railway station. No fossil record is cited from this locality.

A number of dicotyledonous fruits were previously described from the Deccan Intertrappean beds of India. Among these the prominent ones known so far are—*Enigmocarpon parijai* (Sahni, 1943), *Indocarpa intertrappea* (Jain, 1964), *Harrisocarpon sahnii* (Chitale & Nambudiri, 1973), *Sahnioecarpon harrisii* (Chitale & Patil, 1973), *Daberocarpon gerhardii* (Chitale & Sheikh, 1973), *Deccanocarpon arnoldii*

(Paradkar, 1975), *Enigmocarpon sahnii* (Chitale & Kate, 1977), *Centrospermocarpon chitaleyi* (Sheikh & Khubalkar, 1979) *Euphorbiocarpon drypeteoides* (Mehrotra *et al.*, 1983), *Grewia mohgaonse* (Paradkar & Dixit, 1984), *Oleaceocarpon nagpurensis* (Sheikh *et al.*, 1986), *Duabangocarpon deccanii* (Kadoo & Kolhe, 2002), *Chitaleocarpon intertrappea* (Kapgate *et al.*, 2006) and *Spinocarpon mohgaonse* (Kapgate, 2013). A unilocular multiseeded dicot fruit is described from this locality for the first time.

MATERIAL AND METHODS

The fossiliferous cherts were collected from Bhutera of Chhindwara District, Madhya Pradesh, India. After breaking the chert the specimen was exposed in oblique transverse plane. After etching with hydrofluoric acid and washing with water, serial peel sections were taken by peel technique. The peels were mounted on DPX mountant. Thus the fruit revealed details of morphology and anatomy through examination of fractured surface, serial sectioning, and successive peels.

Description—The present fruit is unilocular, multiseeded, and dehiscent having free central placentation (Pl. 1.4, Fig. 2.2). The fruit measures 3×2.5 mm in oblique transverse section along with very short stalk. The fruit is differentiated into outer pericarp and inner pulp containing seeds and locule. The detailed description of each part is given below in the following sequence—fruit morphology, stalk, pericarp, inner pulp, locule, placenta, seed, seed coat and embryo.

Fruit morphology—The petrified, well preserved fruit is small, obovate in shape (Pl. 1.1). It is broad in the middle and narrower towards the base than the apex. The apex is marked by the presence of two small blunt projections called umbos (Pl. 1.1, Fig. 2.1), whereas the base is marked by small pointed end with an opening. The fruit stalk appears below the umbo.



Fig. 1— A. Satellite map of Bhutera Locality. B. Map showing Locality.

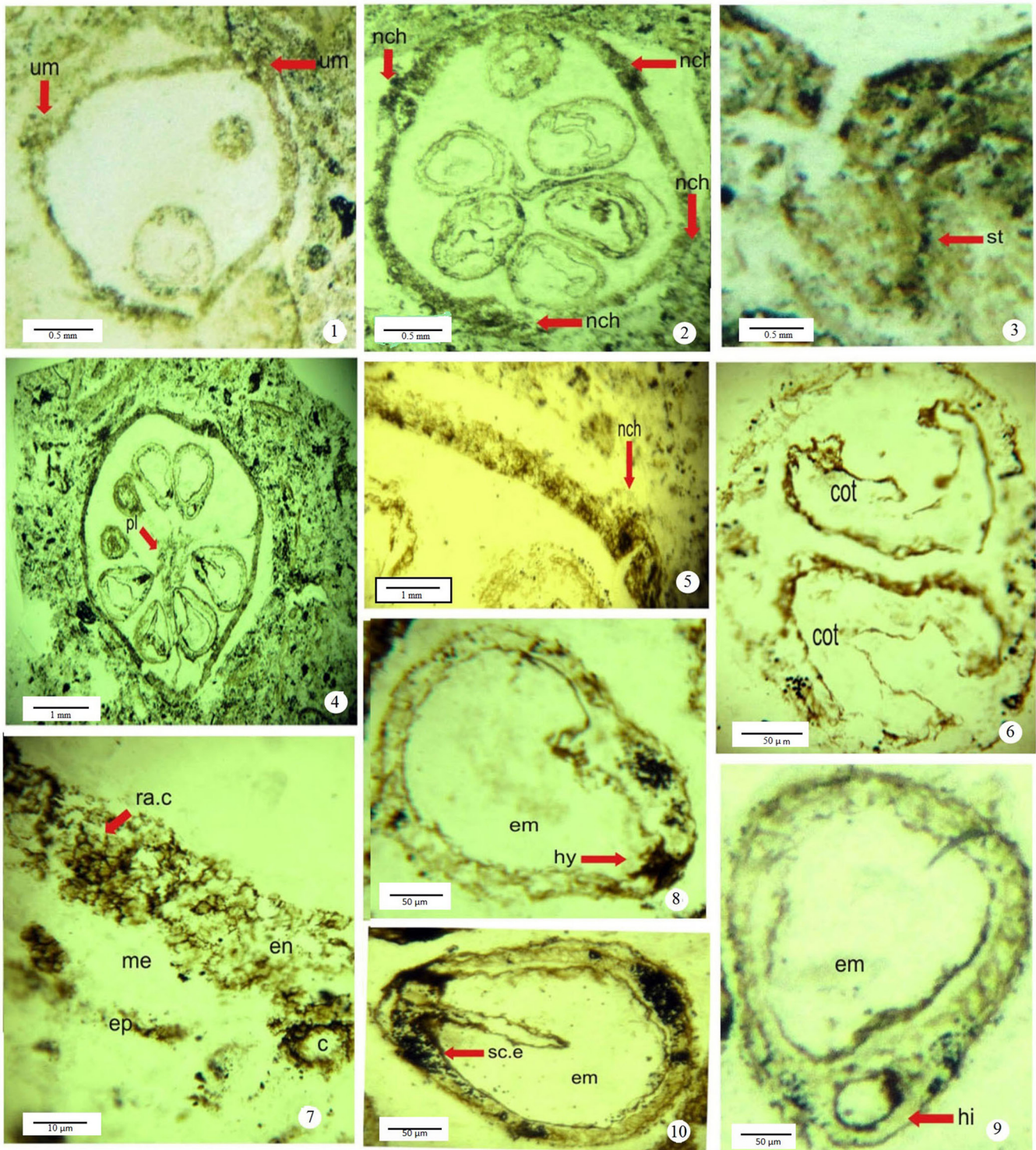


PLATE 1

1. T.S. of fruit showing two umbos (um).
2. T.S. of fruit showing four notches (nch).
3. Magnified view of stalk of the fruit (st).
4. T.S. of fruit showing free central placentation (pl).
5. Close view of notch (nch).
6. Magnified view of seed showing two cotyledons (cot).
7. Magnified view of pericarp showing outer epicarp (ep), middle mesocarp (me) and inner endocarp (en) with radially arranged cells (ra.c) and canal (c).
8. 9. 10. Single seed showing seed coat with dark secretory elements (sc.e), embryo (em), hilum (hi), hypostase (hy).

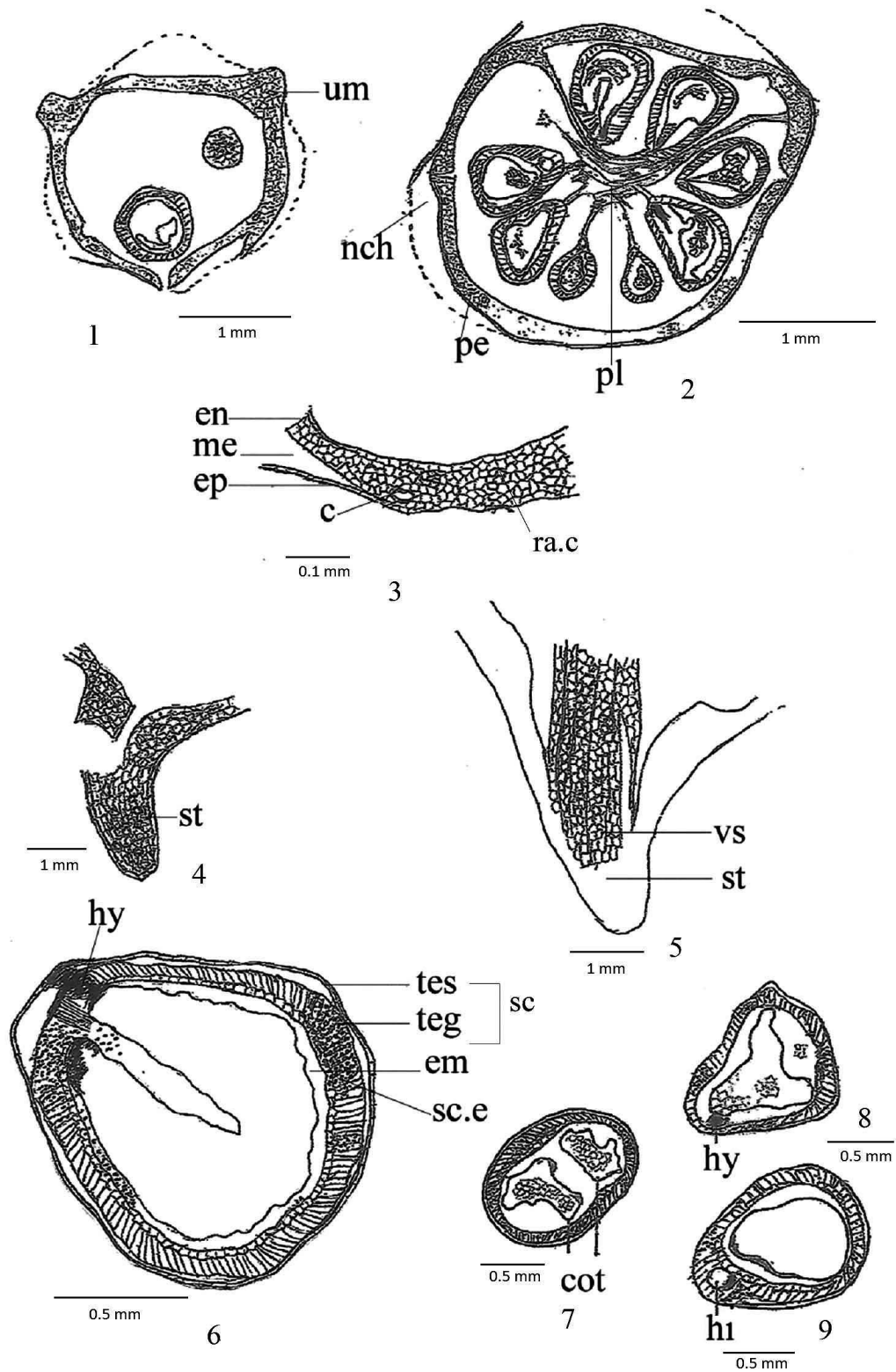
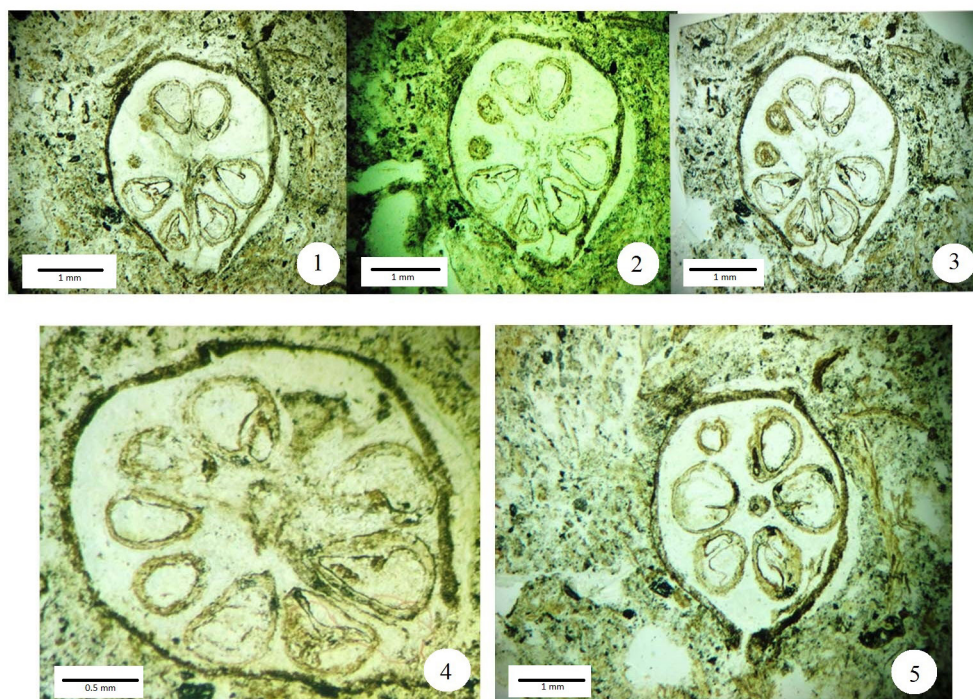


Fig. 1—1. T.S. of fruit showing two umbos (um), 2. T.S. of fruit showing eight seeds, free central placentation (pl) and notches (nch), 3. Magnified view of pericarp (pe) [epicarp (ep), mesocarp (me), endocarp (en)], canal (c) and few radiating group of cells (ra.c), 4. Magnified view of stalk (st), 5. Magnified view of stalk (st) with vascular supply (vs), 6. Magnified view of seed showing seed coat (sc)- testa (tes), tegmen (teg), embryo (em), hypostase (hy), secretory elements (sc.e), 7. Single seed with cotyledons (cot), 8. Single seed showing hypostase (hy), 9. Single seed with hilum (hi).



Extant member of Portulacaceae (*Portulaca oleracea*) showing dehiscence.



Successive stages of seeds of fossil fruit *Portulacaceocarpon bhuterensis*

PLATE 2

The fruit measures 3 mm in length and 2.5 mm across at the broadest middle part.

The umbo is bent and directed to two ends at apex. It measures about 75 μm in width and is elevated above the pericarp. To the inner side of the pericarp below the umbo there is distinct parenchymatous tissue which gives biconvex shape to the umbo (Sheikh & Khubalkar, 1979).

Stalk—It is short, 2.2 mm long and 1.2 mm broad, slightly curved near opening of the fruit. It is 10–12 cells in thickness. The stalk shows single layered epidermis, few celled cortex and central vascular strand (Pl. 1.3, Fig. 2.4).

Pericarp—The fruit wall or pericarp is well preserved and moderately thick, measures about 70–91 μm and is differentiated into outer epicarp, middle mesocarp, and inner endocarp (Pl. 1.7, Fig. 2.3). However only the endocarp is very well preserved and is seen enclosing the seeds.

Epicarp—It is the outermost layer of the fruit and is not continuous but irregular in appearance, measuring about 10 μm in thickness. It is separated during preservation and is seen lying some distance away from the endocarp. The separated epicarp is made up of one layer of thin walled, horizontally elongated parenchymatous cells and measures about $1 \times 3 \mu\text{m}$.

Mesocarp—The gap between endocarp and epicarp strongly suggests the presence of soft parenchymatous mesocarp which is not preserved. It appears to be 12–25 μm thick.

Endocarp—It is the innermost layer measuring 48–56 μm in thickness and consists of 3–7 layers of thick walled polygonal cell; some radiating groups of parenchymatous cells contain canal. The cells measure about 1–4 μm .

Four conspicuous notches of about 5 μm are seen distinctly on the inner side of the endocarp (Pl. 1.2). The wall is elevated on the outer side of the notch and forms a ridge; it is about 6 cells in thickness. Vascular bundle in the fruit wall observed as a black spot at some places.

Inner pulp—In between pericarp and seeds a few thin walled parenchymatous cells are preserved at places (Pl. 1.4); otherwise except for the seed and placenta no other tissue is preserved. These cells inside fruit measure about 3 \times 4 μm in size.

Locules—In oblique transverse section single locule is seen with well-preserved seeds (Pl. 1.1, 2, 4, Fig. 2.2). The diameter of locule is 2.2 \times 1.6 mm.

Placenta—The placentation is free central; the seeds are attached with their funicles. Vascular supply is seen in placenta as 5–8 dark thick walled cell patches.

Seed—seeds are arranged around the free-central placenta all along their length (Pl. 2.1, 2, 3, 4, 5). The average total number of seeds in the fruit calculated from the serial transverse sections is found to be 18. The seeds are aluminous and obovate, gradually become narrow towards the base (Pl. 1.8, 9, 10, Fig. 2.6) and measure 98 \times 76 μm .

Seed coat—The testa is made up of single layer of elongated cells measuring about 3 μm in thickness. However, at some places a distinct gap of about 4 μm thickness is seen below the testa. The tegmen is two cells in thickness measuring about 18 μm . The outer cells are large and elongated measuring 15 μm in thickness, while inner cells are small and squarish measuring 3 μm in thickness. The seed is bitegmic. A gap is observed between the tegmen and the embryo showing nuclear endosperm. The mark left on a seed coat is hilum. Squarish to hexagonal dark spots are seen in seed coat all along its development considering it as a secreting element.

Embryo—Embryo appears to be made up of thin walled cells with single layer epidermis. It is well preserved, relatively large and curved; embryo cut in different planes is seen inside the seeds (Pl. 1.8, 10, Fig. 2.6). Embryo measures about 75 \times 56 μm in size. The embryo is dicotyledonous having two cotyledons. At the chalazal end of the seed is seen a dark structure of hypostase. The undifferentiated cellular mass of thin walled parenchymatous cells is found.

DISCUSSION AND IDENTIFICATION

The above described specimen revealed following important details for its identification.

1. Fruit is unilocular, multiseeded, dehiscent and obovate.
2. Fruit wall is multilayered and fleshy with irregular vascular strands in the endocarp.
3. Presence of two umbos and four notches on fruit wall.
4. The fruit has a curved and short stalk.
5. Total number of seeds is 18.
6. Seed coat is thick and differentiated into testa and tegmen having secretary element and presence of hilum.
7. Embryo large, curved, hypocotylar and dicotyledonous.
8. Nuclear endosperm.

From these characters it is evident that the described fruit was formed from unicarpellary, syncarpous, superior ovary with central placentation, having many ovules in a locule. Nature of the fruit appears capsular due to fleshy pericarp and dehiscence.

COMPARISON WITH FOSSIL FRUITS

The previously described fossil fruits from the Deccan Intertrappean beds of India are different from the present fruit in a number of characters. *Enigmocarpon parijai* (Sahni, 1943) is 2.3 mm long and 1.5–2 mm broad and 6–12 locular with thick spongy wall. Each loculus contains the rows of seeds. *Endocarpa intertrappea* (Jain, 1964) is septifragal capsule with columella and a fleshy testa. It is 30.0 \times 2.3 cm in size and much larger than the present fossil. *Daberocarpon gerhardii* (Chitale & Sheikh, 1973) is ten locular fruit containing single seed in each locule. *Sahniocarpon harrisii* (Chitale & Patil, 1973) had pentalocular capsule, one seed in each locule with persistent calyx, while present fruit is unilocular capsule without persistent calyx. *Harrisocarpon sahnii* (Chitale & Nambudiri, 1973) is pentalocular capsule, two seeds in each locule with loculicidal dehiscence. *Deccanocarpon arnoldii* (Paradkar, 1975) is an eight locular capsule with one seed in each loculus. *Centrospermocarpon chitaleyii* (Sheikh & Khubalkar, 1979) differs in having one umbo, one notch, seeds arranged in two rings; seeds in peripheral rings are non-endospermic and in five tiers with spiny seed coat. *Euphorbiocarpon drypetecides* (Mehrotra *et al.*, 1983) trilocular, dicotyledonous drup with single seed in each locule. *Grewia mohgaonse* (Paradkar & Dixit, 1984) differs in having five lobed drupaceous fruit, two pyrened structure with one seed in each pyrene. *Wingospermocarpon mohgaonse* (Sheikh & Kapgate, 1984) is unilocular with seven winged seeds. *Orygiocarpon jhargadi* (Yawale & Channe, 1998) differs

in having pentalocular, many seeded, loculicidal capsule. *Duabangocarpon deccanii* (Kadoo & Kolhe, 2002) differs from the present fruit as it is multiseeded, multilocular capsular fruit with persistent calyx. *Chitaleocarpon intertrappea* (Kapgade *et al.*, 2006) differs from the present fossil as it is seven locular, seven ribbed capsular fruit with loculicidal dehiscence. *Zygophyllaceocarpon tetragonii* (Bobade & Kokate, 2013) differs in having septicial capsule having one to many seeds of oblong to linear shape in each locule. Thus, the present fossil fruit does not resemble any of the fossil capsular fruits described earlier.

COMPARISON WITH THE MODERN TAXA

The present fossil fruit was also compared with the modern dicotyledonous families like Aizoaceae, Balsaminaceae, Caryophyllaceae, Clusiaceae, Dilleniaceae, Flacourtiaceae, Geraniaceae, Malpighiaceae, Marcgraviaceae, Myrtaceae, Onagraceae, Passifloraceae, Portulacaceae, Sterculiaceae, Ternstroemiaceae, Zygophyllaceae, etc. which resembles in size and shape of the fruit, many seeds, type of embryo, presence of endosperm and capsular fruits.

Family Zygophyllaceae differs in having septicial nature of fruits with membranous testa, loculicidal dehiscence and axile placentation, while the present fruit has free central placentation. Family Dilleniaceae differs in having funicular aril and few or solitary seeds. Family Marcgraviaceae shows spherical capsule and numerous small seeds, while Clusiaceae differs in having septifragal opening. Family Ternstroemiaceae possesses 2 to 5 chambered capsular or baccate fruits and family Geraniaceae has only one seeded capsular fruits, whereas present fruit is many seeded. Family Balsaminaceae differs in loculicidal dehiscence with compressed seeds. Family Onagraceae differs in having central column bearing seeds with persistent calyx. Family Myrtaceae differs in having persistent calyx at the crown of the fruit, while in family Flacourtiaceae the fruit is 3–5 chambered. Family Malpighiaceae differs in having winged seeds. Family Passifloraceae differs in pulpy fruit, seeds having sac like aril, while family Sterculiaceae differs in having leafy cotyledons.

Families like Portulacaceae, Caryophyllaceae, Aizoaceae are very close to the present fruit in having unilocular fruits with valvular dehiscence, capsular fruits and rounded to spherical shape of seed, but only family Portulacaceae has free central placentation and multiseeded fruits like the present fossil fruit.

Finally summing up the comparison and discussion on the described fossil fruit it can be concluded that the present specimen under investigation resembles much to the fruits of family Portulacaceae. On comparing with the genus of the same family like *Claytonia virginica*, *Portulaca grandiflora*, *Portulaca oleracea*, *Talinum teretifolium*, the present fruit closely resembles with *Portulaca oleracea*. Hence, the present

fruit is named as *Portulacaceocarpon bhuterensis* gen. et sp. nov. The generic name is after the family and specific name is after the locality.

A recent molecular phylogenetic study showed that the family Portulacaceae is monophyletic with high support and is composed of two main clades (Ocampo & Columbus, 2012). One of them has opposite-leaved representatives restricted to the Old World (OL clade), the second main clade has species with alternate or subopposite leaf arrangement and are distributed around the world (AL clade). *Portulaca* L. is the only genus in the recently recircumscribed Portulacaceae (Nyffeler & Egli, 2010). The family has ca. 100 species that are distributed worldwide mainly in tropical and subtropical regions. Plants of this family are herbs, annuals or perennials.

Holotype—VDN/Ang. Fruit/Deposited in Botany Department, Institute of Science, Nagpur.

Horizon—Deccan Intertrappean beds.

Locality—Bhutura, Madhya Pradesh, India.

Age—Uppermost Cretaceous–Early Palaeogene.

Diagnosis

Portulacaceocarpon gen. nov.

Fruit is dicotyledonous, unilocular, dehiscent capsule with many seeds in a locule, free central placentation.

Portulacaceocarpon bhuterensis gen. et sp. nov.

Fruit is a unilocular capsule, obovate, measuring 2.5–3 mm in width. Fruit wall 70–81 μm thick, differentiated into epicarp, mesocarp and endocarp. Epicarp 10 μm thick, one layered of thin walled parenchymatous cells; mesocarp fleshy; endocarp 48–56 μm thick, 3–7 cells layered, polygonal, radially arranged thin walled cells. Free central placentation, seed attached with funicle, total 18 seeds, presence of hilum. Each seed wall measuring 21 μm in size. Seed coat differentiated into two layers, bitegmic. Endospermic nucleus, dicot embryo, hypostase at chalazal end.

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