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FOSSIL SEEDS FROM THE LAMETA FORMATION (LATE CRETACEOUS), JABALPUR, INDIA

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ABSTRACT

Fossil seeds are reported here from the classic Bara Simla Hill section of the Lameta Formation at Jabalpur. They are associated with a freshwater ostracod, charophyte and dinosaur assemblage that suggests a Maastrichtian age. The Lameta beds locally underlying the Deccan basalts have been shown to be pedogenically modified alluvial plain deposits containing one of the most extensive dinosaur nesting sites in the world. The Lameta seeds are preserved as three dimensional carbonate casts and are distinguishable into three distinct morphotypes.

Key words: Lameta Formation, Maastrichtian, Seeds, Jabalpur, Madhya Pradesh.

INTRODUCTION

During the last two decades, our understanding of the Deccan traps and the sedimentary beds associated with this activity has been greatly enhanced (Courtillot *et al*., 1986; Sahni *et al*., 1994). It has been established that the Deccan volcanic activity straddled the Cretaceous-Tertiary Boundary (Duncan and Pyle, 1988) and documents the latest stratigraphic record of dinosaurs (Sahni *et al*., 1996), and that the biotas associated with the Deccan volcano-sedimentary sequences show a surprising lack of endemism in the context of geodynamic drifting models for the Indian Plate during the latest Cretaceous (Sahni, 1984; Krause *et al*., 1997). Further support for this latter hypothesis comes from the presence of the seed casts, probably representing seed cuticular structures comparable to *Costatheca* and *Spermatites* which are reported here for the first time from the Lameta Formation (Maastrichtian) exposed at the classic Bara Simla Hill locality, Jabalpur Cantonment. It was from this locality that the first report of dinosaurs was made by a Captain Sleeman in 1828 (in Matley, 1921).

So far there is a single report of an angiospermic seed belonging to the Family Boraginaceae from the Lameta Formation of the Balasinor area, Gujarat (Mathur and Mathur, 1985). During screening and washing from 1982 onwards about 2 tons of the green marl and variegated shale bands that are exposed at Bara Simla Hill, Jabalpur, several unidentified seed specimens were collected in association with charophytes, ostracods, molluscs and microvertebrates (Tripathi, 1986; Sahni and Tripathi, 1990; Khosla, 1996). However, in the initial stages they were neglected because their taxonomic assignment was uncertain, with opinion being divided as to whether they were arenaceous foraminifera (Kumar and Tandon, 1977) or seeds (S.B. Bhatia, personal communication). The true identity of these specimens could not be established until after the publication of the papers by Batten and Zavattieri (1995, 1996). In fact, unlike the previously reported occurrences listed by Batten and Zavattieri (1995), the Indian specimens are in fact preserved as carbonate casts in three dimensions, instead of being made up of cuticular sporopollenin. In most of the seed specimens of Type-I a, b, the fine external ornamentation and cell structure has been lost. However, the ribs or costae are well preserved. Fine structure ornamentation is present in some of the better preserved specimens of Type-II where cell structure can also be made out.

The present study relates to a collection of seeds (over 100 specimens) recovered from Bara Simla Hill section (fig. 1). All were obtained by screen washing of two productive horizons: the Green Marl and the Variegated Red Shale which lie within the Lower Limestone Bed (Tripathi, 1986; Sahni and Tripathi, 1990).

During the last decade, considerable progress has been made in understanding the biotas and stratigraphy and sedimentology of the Bara Simla

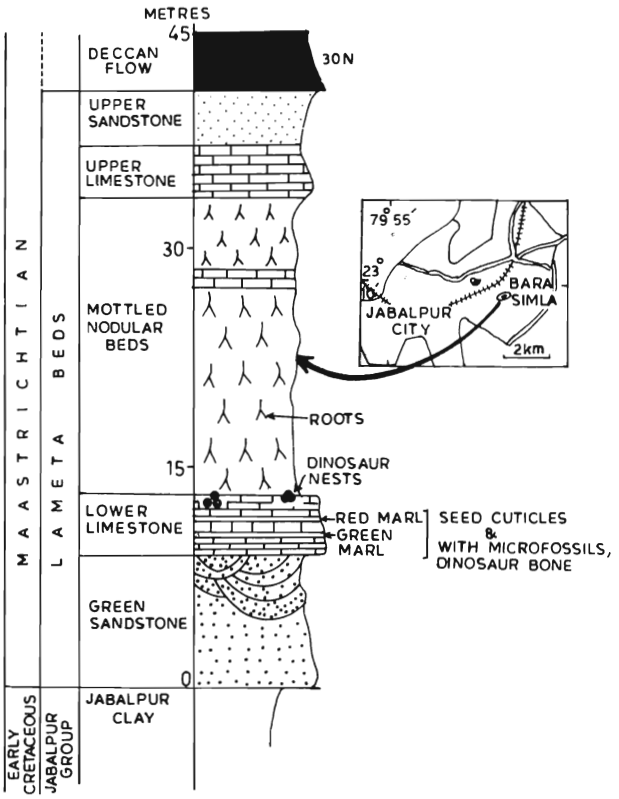

Fig. 1. Stratigraphic succession of the Lameta Formation at Bara Simla Hill, Jabalpur (Madhya Pradesh) showing the seed-bearing horizon and the associated biotas (section modified after Tandon *et al.*, 1995).

Hill Section. Brookfield and Sahni (1987) suggested that the Lameta beds exposed at Bara Simla Hill were essentially pedogenically modified, alluvial plain sediments laid down in semi-arid climate. This view generated some controversy as it ran counter to the then generally held view that the Lameta Beds were shallow intertidal marine deposits (Singh, 1981). The specimens now ascribed to the seeds were considered to be species of the arenacous foraminifera, *Jaculella*, *Saccammina* and *Psammophaera* (Kumar and Tandon, 1977). It has since been conclusively established in a series of papers based on the nature of biotas and the presence of dinosaur nests within the Lower Limestone (Sahni *et al.*, 1994), sedimentological considerations (Tandon *et al.*, 1995, 1998) and regional field geology (Mohabey, 1996) that in fact the thin sedimentary horizons associated with the basal basaltic flows of the Deccan volcanics are mainly fluvio-lacustrine deposits. The Lower Limestone in the Bara Simla Hill locality consists of a nodular, brecciated and massive calcrete within which is an irregularly developed green marl band which has yielded the skeletal remains of dinosaurs (Huene and Matley, 1933; Chatterjee and Rudra, 1996), charophytes, ostracods, and molluscs (Sahni and Tripathi, 1990; Sahni and Khosla, 1994a) as well as microvertebrates and now casts of seeds.

Associated with the seeds are the remains of rhizoconcretionary structures and rare petrified stem fragments (Tandon *et al.*, 1995, 1998). The megafaunal component comprises a variety of saurischian dinosaurs (*Titanosaurus indicus*, *T. blanfordi*, *T. colberti* and *Jainosaurus septentrionalis*; Hunt *et al.*, 1994; Jain and Bandopadhyay, 1997) and the abelisaurids *Indosaurus* and *Indosuchus* (Chatterjee and Rudra, 1996). Dinosaur eggshells comprise three parataxa: *Megaloolithus baghensis*, *M. cylindricus*, and *M. jabalpurensis* (Khosla and Sahni, 1995). The fishes are represented by four species, i.e. *Apateodus striatus*, *Phareodus* sp., *Pycnodus* sp. and *Stephanodus* sp. The ostracods studied in detail by Sahni and Khosla (1994a) comprise several taxa known mainly from the Mongolian and Chinese localities; of special interest is a gigantic species of *Mongolocypris* (over 4 mm in length). The gastropods are represented by three species, namely *Lymnaea subulata*, *Paludina normalis* and *Physa prinsepi*. The charophytes are represented by two species, namely *Microchara sausari* and *Platychara* cf. *P. sahnii* (Sahni and Khosla, 1994a; Khosla, 1996). These have a distinct affinity to freshwater ostracod and charophyte assemblages reported from central and East Asia (Sahni and Khosla, 1994a,b; Bhatia *et al.*, 1996; Khosla, 1996). Dicot and palm leaves have been reported from the Lameta Formation at Polgaon (Maharashtra; Mohabey, 1996).

The seed casts range from 0.73 mm to 1.93 mm in length and are usually poorly preserved. Along with other calcareous fossils, the best preserved specimens were recovered from the nodular and brecciated calcrete (= Lower Limestone). The Indian specimens are calcified casts and have been taxonomically differentiated mainly on the following basis: shape, size, L/W ratio, both coarse and fine wall structure and the nature of the

apical (stalk) and basal (chalazal areas). The seeds do not contain any traces of an organic wall (sporopollenin) or carbonized film. The original material has generally been replaced by fine calcite. They are preserved in highly oxidized sediments and give a good idea of them in three dimensional appearance. The specimens attributed to seed cast Type-I a, b show an interesting variation in the coarseness of the calcite crystals occurring on the costae and in the intercostate areas. In all the studied specimens, the costae bear larger well-developed crystals while the intercostate areas have fine, porous calcite. Based on length/width ratios, specimens assigned here to seed cast Morphotypes Type I a, b and II.

REPOSITORY OF SPECIMENS AND ABBREVIATIONS

The specimens described in this paper are stored in the Vertebrate Palaeontology Laboratory of Centre of Advanced Study in Geology, Panjab University, Chandigarh and labelled VPL/AS/BSH (Vertebrate Palaeontology Laboratory, Ashok Sahni, Bara Simla Hill); mm: millimeters.

SYSTEMATIC PALAEONTOLOGY

Seed Type-I a
(Pl.I, figs. a-f)

Material: 4 seeds and few other uncatalogued specimens.

Holotype: VPL/AS/BSH/100.

Description: In the holotype specimen and other specimens, the L/W ratio ranges from 1.52 to 1.93. Maximum width is at centre; base more or less rounded. This type is characterized by its very prominent stalk whose diameter is about one-quarter the width of the seed and of varying length depending on the state of preservation of specimens. There are 9 to 10 costae which appear to radiate from the apex. They are very prominent giving a deeply furrowed appearance to the surface (Pl. I, figs. a-f). The costae are on an average 50-100 mm wide and separated by intercostate areas 40-50 mm wide. The coarse calcitic crytals mentioned earlier protrude from the ridges, giving the surface an irregular, dentate appearance (Pl. I, figs. a, c, d-f) . In all the specimens of this type cellular structure could not be observed mainly because of the oxidized nature of the specimens and the presence of replacive calcite. This is fairly a homogenous group characterized by a robust stalk, inflated testa and robust ridges. The external surface is ornamented with ridges which appear to be radiating from the stalk and arranged in rows. The ridges are most prominent near the stalk region.

Dimensions (mm):

	Length	Width	L/W Ratio
(VPL/AS/ BSH/100)	0.73	0.48	1.52
(VPL/AS/ BSH/101)	1.42	0.82	1.73
(VPL/AS/ BSH/102)	1.2	0.62	1.93
(VPL/AS/ BSH/103)	1.15	0.68	1.69

Horizon and Locality : Variegated red shale and green marl horizon within the Lower Limestone horizon of the Lameta Formation at Bara Simla Hill, Jabalpur, Madhya Pradesh.

Seed Type-I b
(Pl. I, figs. g-h)

Material: 4 seeds and few other uncatalogued specimens.

Description: The seeds are elongated, moderately and equally inflated; L/W ratio 2.36; length usually more than twice as compared to width; maximum width is at centre. Both ends are rounded. The external surface is ornamented with fine ridges and striations. The morphology of the Indian specimens particularly (Pl. I, fig. g) shows the presence of 6 to 7 costae which extend from the apical to the chalazal end. Costae are mostly 60-80 mm wide whereas width of intercostate areas ranges between 40 and 60 mm. One of the specimen (Pl. I, fig. h) shows bent costae but this is considered to be a post-mortem feature either caused by desiccation of the seed prior to burial or as a result of calcite replacement. Several broken and uncatalogued specimens in the collection are referable to this type.

Dimensions (mm):

	Length	Width	L/W Ratio
(VPL/AS/ BSH/104)	1.04	0.44	2.36
(VPL/AS/ BSH/105)	1.37	0.7	1.95

Horizon and Locality: Variegated red shale band

and green marl within the Lower Limestone horizon of the Lameta Formation at Bara Simla Hill, Jabalpur, Madhya Pradesh.

Seed Type-II
(Pl. II, figs. a-i)

Material: 8 seeds and several other uncatalogued specimens.

Description: Seeds are elongate-elliptical in shape; straight to slightly convex on one side but rather more convex on the other; base more or less broadly rounded; stalks of varying dimensions (broad in figs. Pl. II, a, b, d, e and narrow in Pl. II, figs. f-i). External surface is generally smooth but faintly developed ridges are seen in two specimens (Pl. II, figs. b- d). Cell sizes can be made out in a few specimens (Pl. II, figs. b, c); their width and length varies from 18-27 x 44-72 mm.

Dimensions (mm):

	Length	Width	L/W Ratio
(VPL/AS/ BSH/ 106)	1.47	0.57	2.57
(VPL/AS/ BSH/107)	1.93	0.73	2.64
(VPL/AS/ BSH/ 108)	1.52	0.5	3.04
(VPL/AS/ BSH/109)	1.57	0.52	3.01
(VPL/AS/ BSH/110)	1.62	0.57	2.84
(VPL/AS/ BSH/ 111)	1.5	0.47	3.19
(VPL/AS/ BSH/ 112)	1.45	0.52	2.78
(VPL/AS/ BSH/113)	1.55	0.6	2.58

Horizon and Locality : Variegated red shale and green marl within the Lower Limestone horizon of the Lameta Formation at Bara Simla Hill, Jabalpur, Madhya Pradesh.

DISCUSSION

Age

The Lameta Formation is a sequence of mainly alluvial, pedogenically modified, calcic arenaceous rocks which are patchily distributed over an area exceeding 10,000 sq. km, locally underlying the oldest Deccan basalt lava flow in the region. During the last 20, years considerable attention both at national and international level has been focussed on these rather thin (usually less than 40 m) beds in connection with three IGCP projects (216, 245 and 350). The following general conclusions have been drawn from these studies:

The Lameta Formation is a succession of freshwater alluvial plain deposits of Maastrichtian age that contain the last stratigraphic record of dinosaurs in the form of skeletal elements and nests (Sahni *et al.*, 1994). The age of the Lameta Formation has been established on both palaeontological and stratigraphic grounds (Sahni and Bajpai, 1988; Tandon *et al.*, 1995, 1998). The supporting evidence for a Maastrichtian age comes from ostracod and charophyte assemblages (Bhatia *et al.*, 1990 a, b, 1996; Sahni and Khosla, 1994 a, b; Srinivasan *et al.*, 1992); the presence of a unique ray, *Igdabatis*, found in the Maastrichtian of India, Niger (Courtillot *et al.*, 1986) and Spain (Soler-Gijon and Martinez, 1998); and an *Aquilapollenites* palynological assemblage (Dogra *et al.*, 1994; Sahni *et al.*, 1996). The associated dinosaur assemblage (Buffetaut, 1987) believed earlier to be Turonian is now considered to be much younger. The Lameta sequence falls within the 30 N Chron and contains clay minerals derived from a Deccan volcanic source (Salil and Shrivastava, 1996; Salil *et al.*, 1994, 1996). The volcanic activity itself has been dated as close to the boundary between the Cretaceous and Tertiary (Courtillot *et al.*, 1986).

The main Lameta facies are represented by coarse-grained, current-bedded sandstones, sandy carbonates, palustrine flats and alluvial fan deposits (Brookfield and Sahni, 1987; Tandon *et al.*, 1990). The controversy regarding the marine or freshwater nature of deposits has been largely laid to rest on the basis of the biota recovered (Sahni *et al.*, 1994), isotopic signature (Sarkar *et al.*, 1991; Ghosh *et al.*, 1995) and detailed sedimentological studies (Brookfield and Sahni, 1987; Tandon *et al.*, 1990, 1995, 1998).

Affinities

Seed cast Type-I a and b seems to be most similar in lateral outline and size to *Costatheca diskoensis* described by Hall (1967) from the Cretaceous of Disko Island (West Greenland) and recently redescribed by Batten and Zavattieri (1996). The specimens of Type-II are also similar in shape, size and length/width ratio and all other features to *Spermatites elongatus* reported from the Cretaceous

deposits of West Greenland (Disko Island, Batten and Zavattieri, 1996). However, as both *Costatheca* and *Spermatites* have been described as seed cuticles (with sporopollenin) and the Lameta seeds are three dimensional (sediment-filled) casts, a definite relationship to the previously described taxa must await further data from macerated material. The former report of angiospermic seeds in the Lameta Formation strengthens the idea of the Jabalpur specimens also belonging to this category.

The presence of seeds probably related to the seed cuticle taxa *Costatheca* and *Spermatites* raises interesting questions regarding dispersal. The lack of endemism in Indian Late Cretaceous continental biotas has been stressed repeatedly (e.g. Sahni, 1984; Sahni and Bajpai, 1988), including recently by the common occurrence in Argentina, Madagascar and India of a Late Cretaceous gondwanathere mammal (Krause *et al.*, 1997). Affinities with Laurasia were noted by Sahni *et al.* (1982) on the basis of microvertebrates. In fact, the microfossil component of the biota has been shown to have mainly Laurasian affinities (e.g., ostracods (Sahni and Khosla, 1994a; Bhatia *et al.*, 1996 and charophytes, Srinivasan *et al.*, 1992, 1994). The presence of *Aquilapollenites* is also rather surprising in Indian Late Cretaceous biotas (Sahni, 1990; Sahni *et al.*, 1996) as it was formerly believed that India was not in the *Aquilapollenites* phytogeographic province in the Cretaceous (Srivastava, 1978). Kar (BSIP, personal communication) has recovered two species of *Aquilapollenites* described previously by Baksi and Deb (1981) from the Bengal basin.

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EXPLANATION OF PLATES

Plate I

Scanning electron micrographs. a-f. Seed Type-I a

a, Type-I a (VPL/AS/BSH/100) bar length = 100 μm; b, Type-I a (VPL/AS/BSH/101) bar length = 100 μm; c, Type-I a (VPL/AS/BSH/102) bar length = 100 μm; d, Type-I a (VPL/AS/BSH/103) bar length = 100 μm; e, Type-I a (VPL/AS/BSH/103) close-up of proximal cap of specimen depicted in figure d (bar length = 10 μm); f, Type-I a (VPL/AS/BSH/103) enlarged part of figure d showing costae and intercostate areas (bar length = 10 μm).

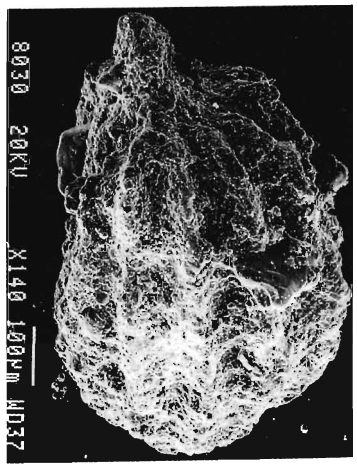
g-h. Type-I b.

cg, Type-I b (VPL/AS/BSH/104) bar length = 100 μm; h, Type I b (VPL/AS/BSH/105) bar length = 100 μm.

Plate II

Scanning electron micrographs. a-i. Type-II **(Bar length in specimens a, c-i =100 μm; b= 1 mm)**

a, Type-II (VPL/AS/BSH/106); b, Type-II (VPL/AS/BSH/107); c, Type-II (VPL/AS/BSH/107) enlarged part of figure b showing arrangement of cells; d, Type-II (VPL/AS/BSH/108);e, Type-II (VPL/AS/BSH/109); f, Type-II (VPL/AS/BSH/110); g, Type-II (VPL/AS/BSH/111); h, Type-II (VPL/AS/BSH/112); i, Type-II (VPL/AS/BSH/113).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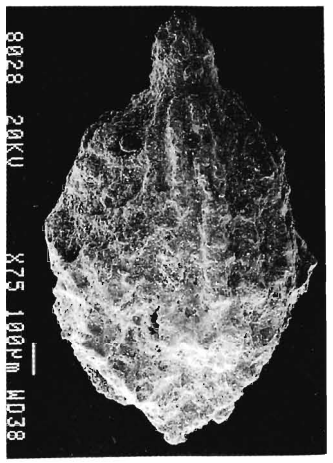
a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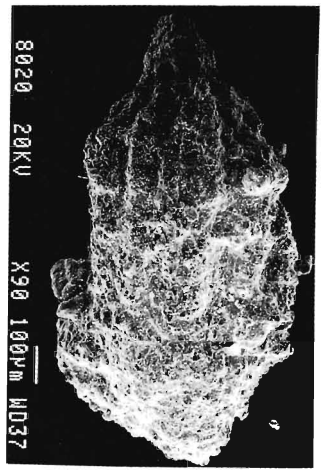
b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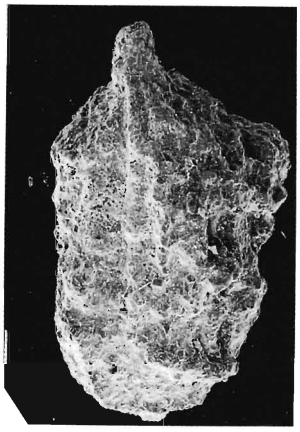
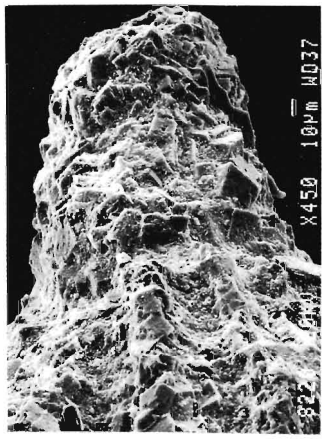
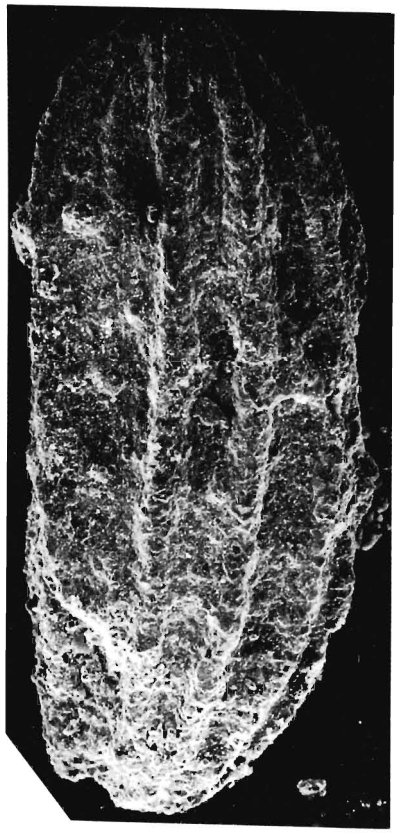
c



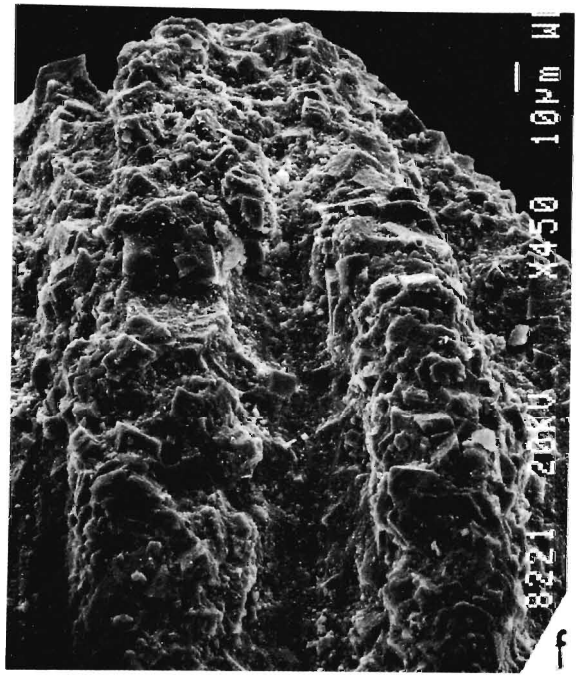
d


X450 10µm WD37

e



g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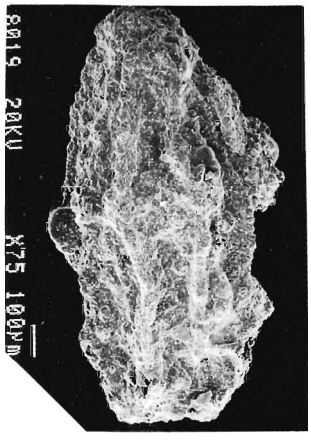
f


8016 20KV X75 100µm

h


a
b
c
d
e
f
g
h
i