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ARUMBERIA AND ASSOCIATED FOSSILS FROM THE NEOPROTEROZOIC MAIHAR SANDSTONE, VINDHYAN SUPERGROUP, CENTRAL INDIA

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ABSTRACT

Three types of microbial mats, one body fossil and one unnamed form are reported from the Maihar Sandstone, the youngest lithostratigraphic unit of the Bhander Group (Upper Vindhyans). These are *Arumberia banksi* Glaessner and Walter, *Arumberia vindhyanensis* n. form, *Rameshia rampurensis* n. group and n. form, *Beltanelliformis minuta* McIlroy, Crimes & Pauley and Form A. *Arumberia* and *Rameshia* are considered as organosedimentary structures formed by the interaction of microbial community with the siliciclastic sediments. They flourished in shallow marine tidal setting. On the basis of the presence of *Arumberia,* an Ediacaran age is suggested for the Maihar Sandstone.

Keywords: *Arumberia,* Microbial mats, Ediacaran, Maihar Sandstone, Vindhyan Supergroup, Central India

INTRODUCTION

The Precambrian calcareous rocks are well known for the preservation of microbial mats as stromatolites, but their presence in the siliciclastic rocks has gained attention only after their discovery in the modern siliciclastic sediments (Davis, 1968; Bauld *et al.*, 1992; Noffke *et al.*, 1997; Schieber *et al.*, 2007; Gerdes, 2007). Identification of microbial mats in the siliciclastic rocks is difficult in absence of definite clues for their morphological manifestations though attempts have been made to identify surface features in modern sediments which owe their presence to microbial activity. Schieber *et al.* (2007) have summarised the available information about interaction of microbial mats with siliciclastic sediments both from the modern environmental settings as well as from the ancient rocks. Eriksson *et al.* (2007) have considered microbial mats as sedimentary structures albeit of a complex organo-physico-chemical origin. In the present paper the microbial mats are considered trace fossils which are produced by interaction of microbial community and environment of deposition. In the Precambrian which represents about 80% of the time span of earth, the microbial community evolved with time since Archaean. This evolution in Precambrian is well manifested in producing varied morphologies in carbonate sequences in the form of stromatolites; many of which are time controlled. Similarly the microbial community must have also produced mat structures in the siliciclastic sediments some of which might have been time controlled. However, not much information is presently available on these structures. One such organo-sedimentary structure is *Arumberia* Glaessner and Walter reported from the siliciclastic sediments and considered to have been formed by the interaction of sediments with microbial mats. It has a restricted distribution in the late Neoproterozoic (Bland, 1984; McIlroy and Walter, 1997). The paper describes *Arumberia* and associated fossils from the Late Neoproterozoic Maihar Sandstone, the youngest lithostratigraphic horizon of the Vindhyan Supergroup, Maihar area, district Satna, Madhya Pradesh (M.P.) and discusses its significance in biostratigraphic correlation and in suggesting age.

GEOLOGICAL SETTING

The Vindhyan Supergroup occupies 1,66,400 sq km in Central India constituting the largest Proterozoic basin in India (Fig. 1). In addition about 40,000 sq. km is concealed under the Gangetic alluvium in the north (Srivastava *et al.*, 1983). It extends from Deri-on-Son, Bihar in the east to Hoshangabad (M.P.) and Chittorgarh, (Rajasthan) in the west. In the southern and southwestern parts, it is covered by the Deccan Traps. Representing deposits of an intracratonic basin, the Vindhyan Supergroup attains a huge thickness of more than 4 km. The rocks are represented by sandstones, shales, limestones, dolostones, conglomerates and porcellanites. The rocks are unmetamorphosed and least disturbed. The rocks, in general show excellent preservation of sedimentary structures, stromatolites, carbonaceous mega fossils and microfossils (Auden, 1933; Valdiya, 1969; Singh, 1976; McMenamin *et al.*, 1983; Prasad, B., 1984; Kumar, 1980, 2001; Venketachala *et al.*, 1996; Kumar and Srivastava, 1997, 2003; Prasad, 2007, Prasad *et al.*, 2007; Misra and Kumar, 2005; Sharma, 2006).

The Vindhyan Supergroup has been subdivided into four groups; in stratigraphic order these are the Semri Group, the Kaimur Group, the Rewa Group and the Bhander Group. Each group is further subdivided into different formations (Table 1). The Semri Group is generally referred to as the Lower Vindhyan and the Kaimur, Rewa and Bhander Groups have been clubbed as the Upper Vindhyan. The Bhander Group is the youngest group of the Vindhyan Supergroup and has been subdivided into four formations in the Maihar area, Satna district, M.P. In stratigraphic order these are the Ganurgarh Shale, the Bhander Limestone, the Sirbu Shale and the Maihar Sandstone (Table 1). The Maihar Sandstone is the youngest stratigraphic horizon of the Bhander Group, which shows gradational contact with the underlying Sirbu Shale (Fig. 2, 3). It has also been referred to as the Upper Bhander Sandstone (Bhattacharyya, 1993). The Maihar Sandstone forms well developed scarps in the southwestern, eastern and northern sides of Maihar township and always forms a cap rock (Plate I-a). The Maihar Sandstone

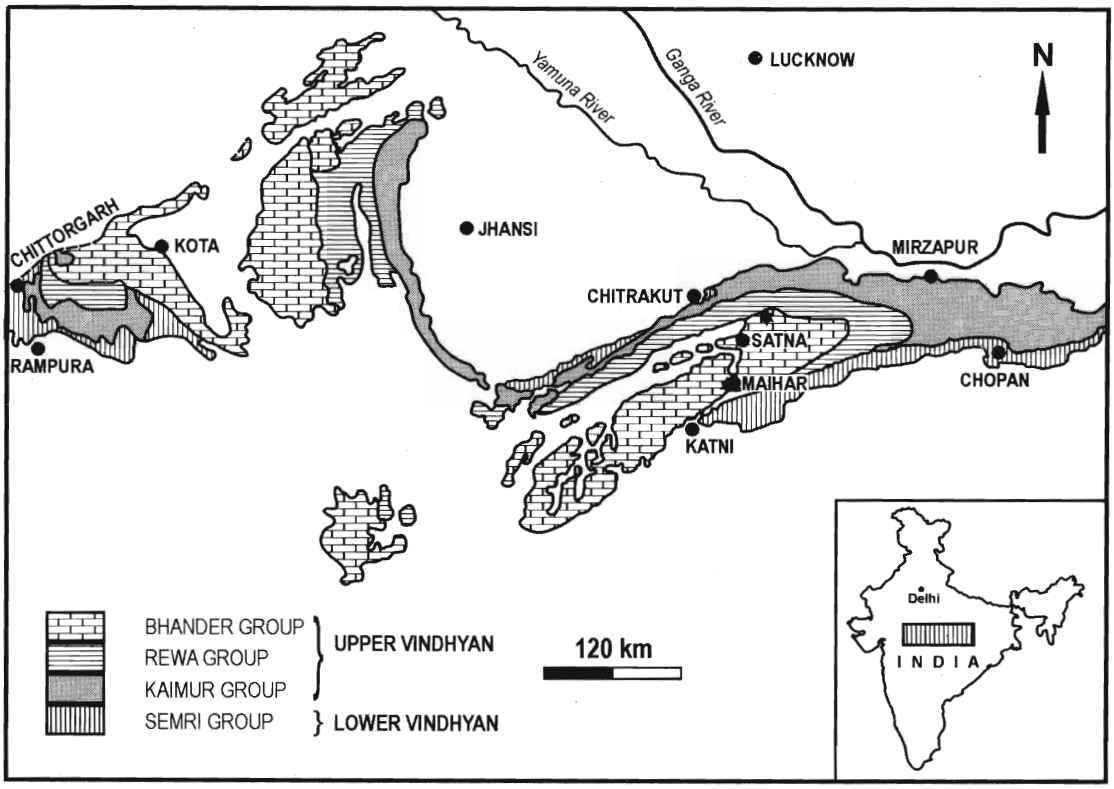


Fig. 1. Location and geological map of the Vindhyan Basin (after Krishnan and Swaminath, 1959).

Table 1: Lithostratigraphy of the Son Valley Section, Uttar Pradesh and Madhya Pradesh (modified after Auden, 1933; Bhattacharyya, 1993).

Supergroup	Group	Formation	Important fossils	Reference
Vindhyan Supergroup		Maihar Sandstone	*Arumberia, Beltanelliformis*	(Present work)
		Sirbu Shale	*Chuaria–Tawuia* assemblage	Kumar and Srivastava (2003)
	Bhander Group	Bhander Limestone	*Chuaria–Tawuia* assemblage, *Baicalia baicalica, Tungussia* and sponge spicule (?)	Kumar and Srivastava (2003), Kumar (1976,1999)
		Ganurgarh Shale	–	
	Rewa Group	Sandstone and shale	*Chuaria–Tawuia* assemblage	Rai *et al.* (1997)
	Kaimur Group	Sandstone and shale	–	
		UNCONFORMITY		
	Semri Group	Rohtas Formation	*Grypania–Chuaria* assemblage	Kumar (1995)
		Kheinjua Formation	Coniform stromatolites	Misra and Kumar (2005)
		Porcellanite Formation	–	
		Basal Formation	Coniform stromatolites	Misra and Kumar (2005)
		UNCONFORMITY		
		Bundelkhand Granites/Bijawar phyllites		

is about 50 to 60 m thick and is represented by sandstone, siltstone and subordinate shale. It shows excellent preservation of sedimentary structures including mud and dessication cracks, large and small scale cross bedding (Pl. I, fig. b), flaser and lenticular bedding, parallel bedding, wave and current ripples, interference ripples, primary lineation, flute cast, current

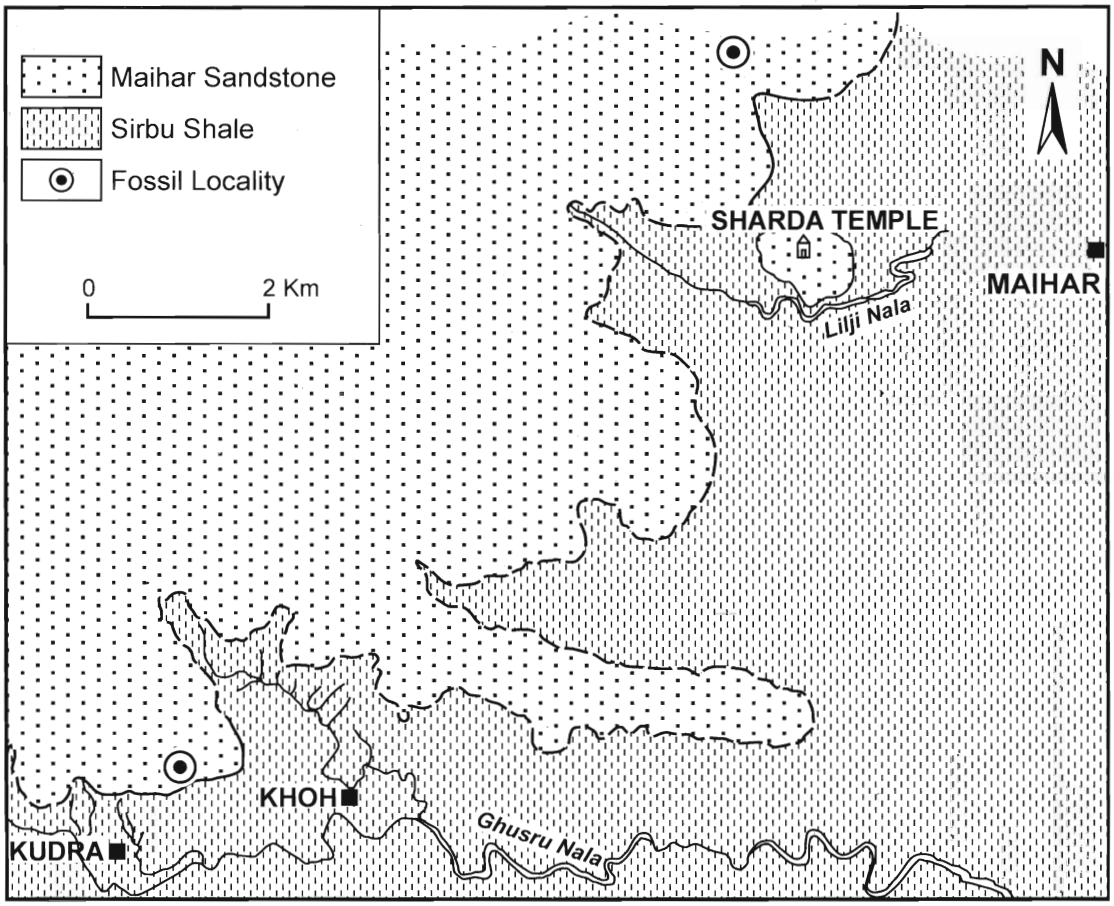


Fig. 2. Geological map of the *Arumberia*-bearing localities, Maihar area, Satna district, M.P.

crescent mark, penecontemporaneous deformational structures, intraformational conglomerates (Plate I-c) and breccia. Singh (1976) has suggested that the Maihar Sandstone is a deposit of tidal flat – shoal complex where lower part represents sandy and muddy tidal flats and the upper part represents shoal sand bar complex with prominent wave and strong tidal currents. According to Basumallick (1962) the Maihar sandstone is moderate to poorly sorted subgraywacke. He has assigned tidal flat environment of deposition to the whole succession of the Maihar Sandstone.

AGE OF THE MAIHAR SANDSTONE (BHANDER GROUP)

In recent years, a number of papers have been published on radiometric dates which modified the concept of the beginning of the sedimentation in the Vindhyan Basin from 1400 Ma to ca. 1800 Ma (see Misra and Kumar, 2005 and references there in). Recently, Ray (2006) has reviewed the age of the Vindhyan Supergroup and opined that the age of the Lower Vindhyans in the Son Valley is now resolved, where as the problems with the age of the Upper Vindhyans and their correlation remain to be answered. Though no radiometric dates are available for the Bhander Group, but $^{87}Sr/^{86}Sr$ data for the Bhander Group (Ray *et al.*, 2003) points to a Neoproterozoic age. In absence of the radiometric dates, the age of the Bhander Group in general and age of the Maihar Sandstone in particular have to be based on the available palaeontological record and lithostratigraphic correlation. The stromatolites are abundantly recorded from the Bhander Group and on this basis age has been suggested. The Bhander Group is characterized by the presence of *Baicalia, Tungussia* and *Patomia* and complete absence of coniform stromatolites (Kumar, 1982; Misra and Kumar, 2005). On the basis of stromatolites, Kumar (1982) has suggested upper Riphean age for the Bhander Limestone. In the Maihar area, the Maihar Sandstone is underlain by the Sirbu Shale, from which Kumar and Srivastava (2003) have reported *Chuaria-Tawuia* association along with other carbonaceous megafossils including *Phascolites* and they have suggested that the age of the Bhander Group is somewhere between upper Riphean and Vendian. Rai (1999) for the first time reported the occurrence of microbial mat textures from the Maihar Sandstone and suggested Vendian age.

No Cambrian fossil has so far been discovered from the Bhander Group. The Ediacaran fossils reported by De (2003, 2006) are not convincingly biogenic and hence ignored. Recently Prasad (2007) has studied the microfossils recovered from the Bhander Group by maceration technique and on this basis has suggested latest Cryogenian to late Vendian age (ca. 650–544 Ma). Thus, the present available data supports a late Neoproterozoic age for the Maihar Sandstone.

ARUMBERIA GLAESSNER AND WALTER, 1975

Glaessner and Walter (1975) erected a new genus *Arumberia* to describe long, narrow, subparallel, straight to gently curved grooves seen on the lower surfaces of Arumbera Sandstone, Northern Territory, Australia. They interpreted these

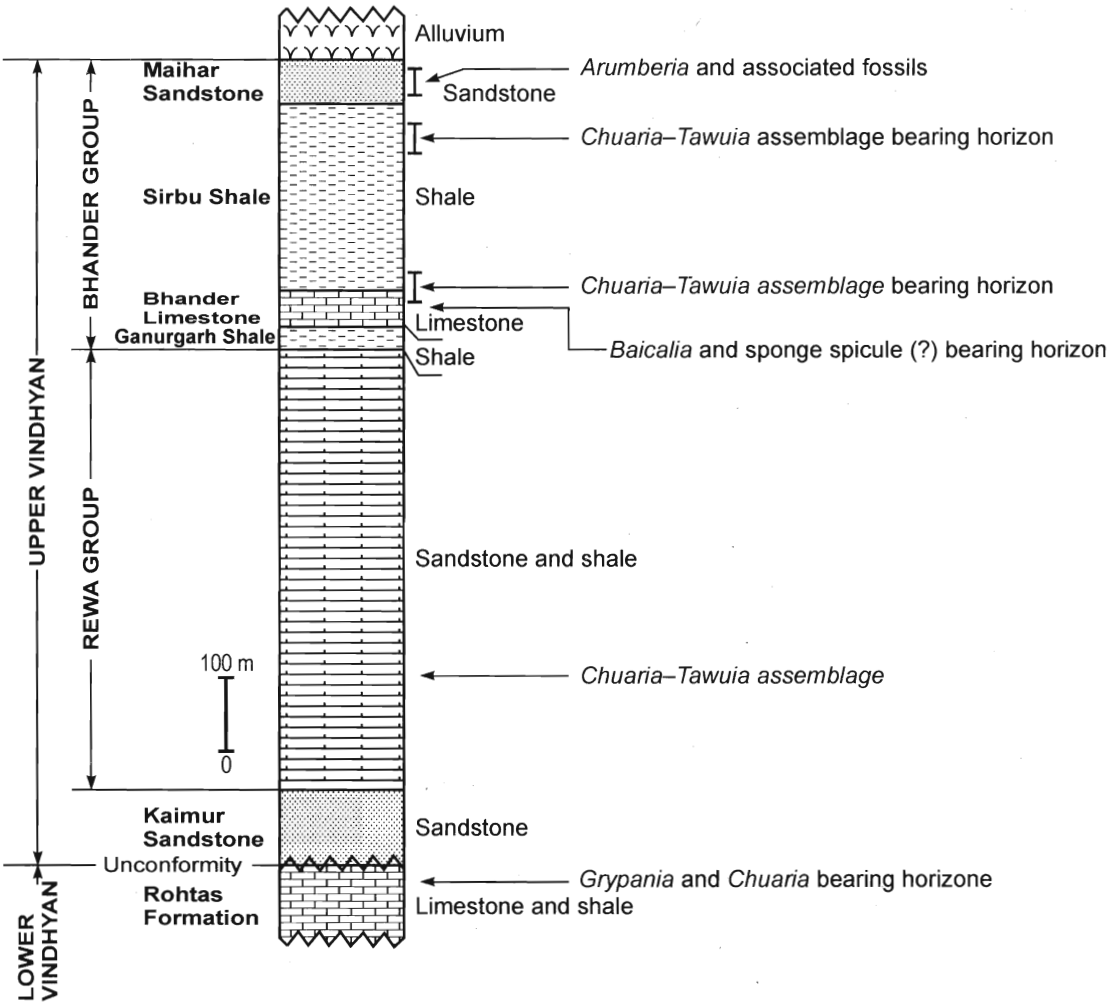


Fig. 3. Stratigraphic section of the Bhander Group showing position of the fossiliferous horizons.

structures as the remains of a cup shaped animal probably a Coelenterate grade. Brasier (1979), however, suggested an inorganic origin to these markings. He compared these markings with the structures produced by paired vertices in the flume experiments of Dzulynski and Walton (1965). They argued that the nature of both short lived and long lived vertices were responsible for the formation of fine grooves including lateral extent of the radial grooves and double ridges. Bland (1984) emphasized that *Arumberia* is restricted to latest Precambrian and lower Cambrian. On this basis he supported an organic origin. McIlroy and Walter (1997) interpreted *Arumberia* as formed by the action of currents on cohesive muddy surface, which may have been microbially bound. It is true that there are many morphologies produced in the flume experiments of Dzulynski and Walton (1965) as well as those produced in the experiments of Allen (1982) which compare well with the ridges and grooves seen in the *Arumberia* morphology, but the most important point is the preservation of such structures in the sandy, non-cohesive material. If such structures are preserved in sandy material then some process must have been involved in making the sand cohesive and most logical is the role of microbial mats, which flourished at the time of sedimentation. *Arumberia,* in the present work is considered as an organosedimentary structure produced by the interaction of microbial mats, prevailing hydrodynamic conditions and the type of sediments.

Use of binomial nomenclature for describing *Arumberia* is retained for the ease of communication and convenience. This use can be compared with the similar practice for describing stromatolites, an organosedimentary structure well pre-

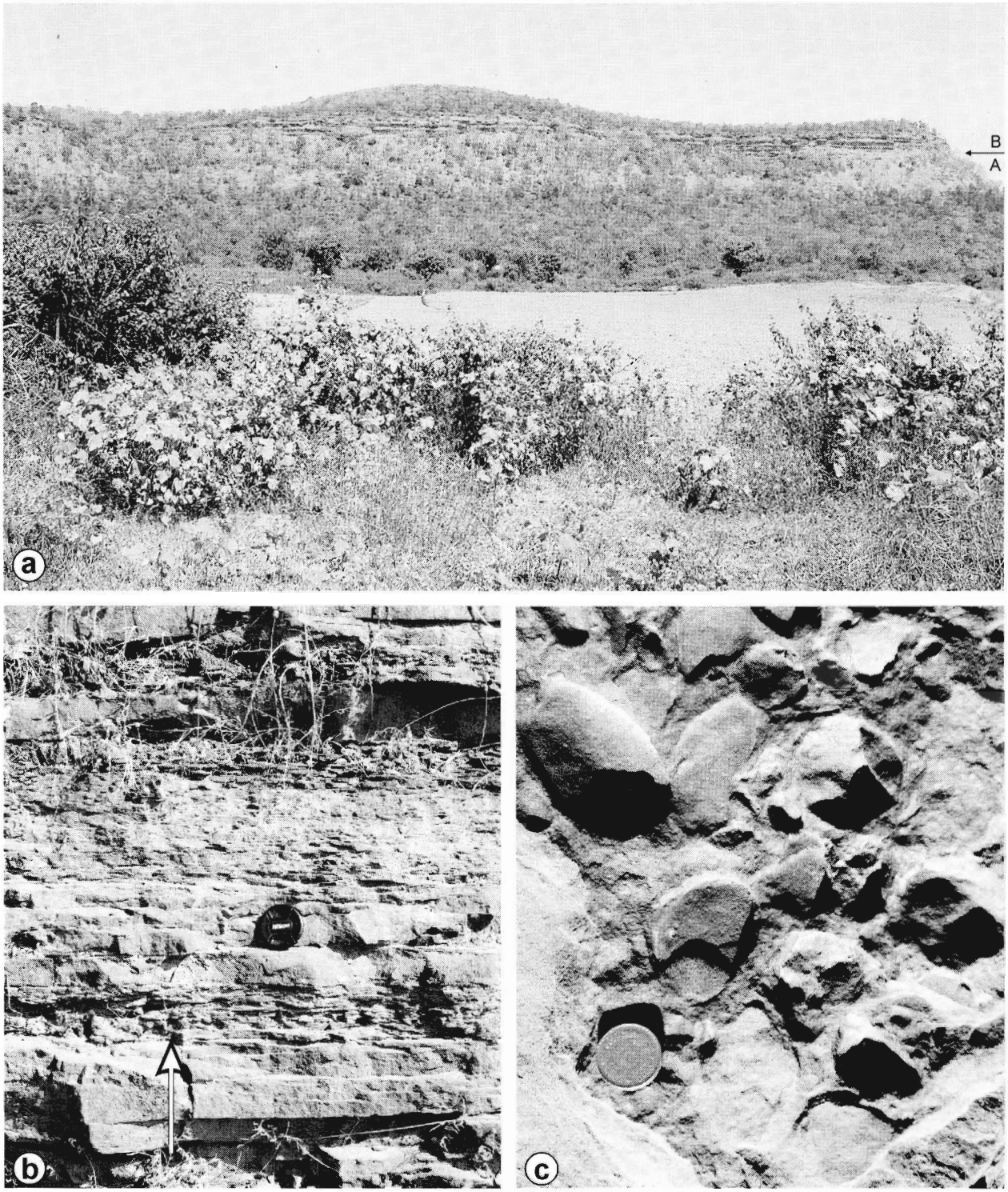
EXPLANATION OF PLATE I

a. View of the scarp showing Maihar Sandstone as cap rock overlying the Sirbu Shale. View towards the north from Kudra village. (A= Sirbu Shale, B= Maihar Sandstone)

b. Large scale cross bedding and ripple bedding in Maihar Sandstone, Rampur hillock, Maihar area, M. P. The arrow marks the development of ***Arumberia*** on the bedding surface. Diameter of lens cover = 5.5 cm.

c. Sandstone clasts seen in intraformational conglomerate, Maihar Sandstone, Rampur hillock, Maihar area, M. P. Diameter of coin = 2.3 cm.

Plate I



served in carbonate rocks. It is further emphasized here that *Arumberia* is not a genus in the traditional sense, but a morphogroup and its species are considered as a morphoforms.

Arumberia recorded in the Maihar Sandstone is generally in fine grained sandstone. Unless the fine sand is made cohesive by some process delicate morphology of *Arumberia* is impossible to preserve. There are also some places when the entire surface is covered with scaly structures, whose morphology can not be explained by invoking inorganic processes (Pl. II, figs. c, d). Thus, the delicate morphologies of *Arumberia* in fine sand favour a biogenic origin. Microbial community which produced *Arumberia* is not preserved, as is the case with most of the stromatolites. The Maihar Sandstone is about 50–60 m thick and shows abundant presence of *Arumberia* in the middle to upper part (Fig. 3). The top 5-6 m which shows large scale cross bedding and forms the cap rock is devoid of *Arumberia*.

Salient features of *Arumberia* in the Maihar Sandstone are summarized below:

1. The morphology of *Arumberia* is characterized by the presence of thin ridges and grooves seen on both top and sole of the bed and extends from several mm to tens of cm in length. The ridges show height up to 1 mm and are upto 5 mm apart. The ridges and grooves are parallel to subparallel and show branching. They also merge with each other and are also curved. At places, the grooves are criss crossed forming different shapes like oblate, elliptical, lobate, cuspate, lenceolate etc. Long blade like form with a marked groove in the middle is also seen. The different types of morphologies associated with *Arumberia* are shown by the line diagrams in Fig. 4 a,b,c, d & f and Pls. II, III, IV and V.
2. In most cases the orientation of the grooves and ridges follows the dominant palaeocurrent direction (Pl. II, fig. a).
3. The ridges and grooves are seen on plane bedding surface, superimposed on rippled surface, washed ripple surface and also on the flute casts (Pl. II, figs. a,c; Pl. III, fig. b; Pl. V, fig. b).
4. When *Arumberia* is developed on the rippled surface, it shows variation with respect to crest and trough of the ripple (Pl. II, fig. a). At places, it is restricted on the crest and stoss side. It is also seen within the trough. Entire rippled surfaces are also covered by ridges and grooves.
5. When *Arumberia* is developed on the flute cast, the ridges and grooves radiate from an apex point or a linear zone, which may not be the highest portion of the flute cast (Pl. III, figs. b, c and d).
6. In one instance, the grooves and ridges are radiating in all the directions on a flute-like structure.
7. Sandstone clasts are also associated with *Arumberia* (Pl. V, fig. a).
8. Rounded to elliptical mounds of 1- 4 mm in diameter seen on the bedding surface and considered as microbial mat but are not included in *Arumberia* and given a different name *Rameshia* (n. gr.) because of the absence of grooves and ridges (Pl. IV, figs. a, b).

TAXONOMY

Five forms have been described, out of which two belong to *Arumberia*, one to a new mat form *Rameshia* group nov. and other two are *Beltanelliformis minuta* and Form A. All the samples are deposited in the Museum of the Centre of Advanced Study in Geology, University of Lucknow, Lucknow, U.P.

Group ***Arumberia*** Glaessner & Walter, 1975

Type Form: *Arumberia banksi* Glaessner & Walter, 1975

Arumberia banksi Glaessner & Walter, 1975

(Pl. II, figs. 4 a, b, c, d; Pl. III, figs. a, b, c, d; figs. a, b, c, d).

Sample No: R106, R1306, K106 and K706

Locality: Rampur Hillock and Kudra village, Maihar, Satna district, M.P

Stratigraphic Horizon: Maihar Sandstone, Bhander Group.

Lithology : Brown coloured fine-grained sandstone.

Description : It consists of array of straight to gently curved parallel to subparallel ridges about 1 mm wide and separated by flat to gently concave furrows of 1-3 mm in width. Relief from ridge top to furrow bottom is less than 1mm. Ridge ranges in length from 1.5 cm to 14.0 cm. Generally the ridges are parallel, but they also bifurcate and rarely trifurcate. The ridges are parallel to current direction or more or less right angle to the crest of the ripple, but exceptions are also noted. Ridges are developed on plane surface as well as on the stoss side of the ripple. In some specimens bedding surface is almost flat and the ridges form a carpet. At places the grooves are criss crossed and anastomosing or scaly. They are also curved, subparallel and radiate from a pointed and twisted nose.

Remarks: The present form shows smaller length of ridges compared to *Arumberia banksi,* described from the Arumbera Sandstone southwest of Alice Springs by Glaessner and Walter (1975). Originally *Arumberia banksi* was considered a cup shaped animal (Glaessner and Walter, 1975), but now it is considered a microbially bound sedimentary structure (McIlroy and Walter, 1997).

Group ***Arumberia*** Glaessner & Walter, 1975

Type Form: *Arumberia banksi* Glaessner & Walter, 1975

Arumberia vindhyanensis n. form

(Pl. IV, fig. d; Pl. V, figs. a, b) Fig. 4 f;

Holotype: Sample no: K206.

Paratype: Sample no: K406, K506, K606.

Locality: Kudra village, Maihar, Satna district, M.P.

GPS value: N 24° 12.35′; E 80° 38.24′

Stratigraphic Horizon: Maihar Sandstone, Bhander Group.

EXPLANATION OF PLATE II

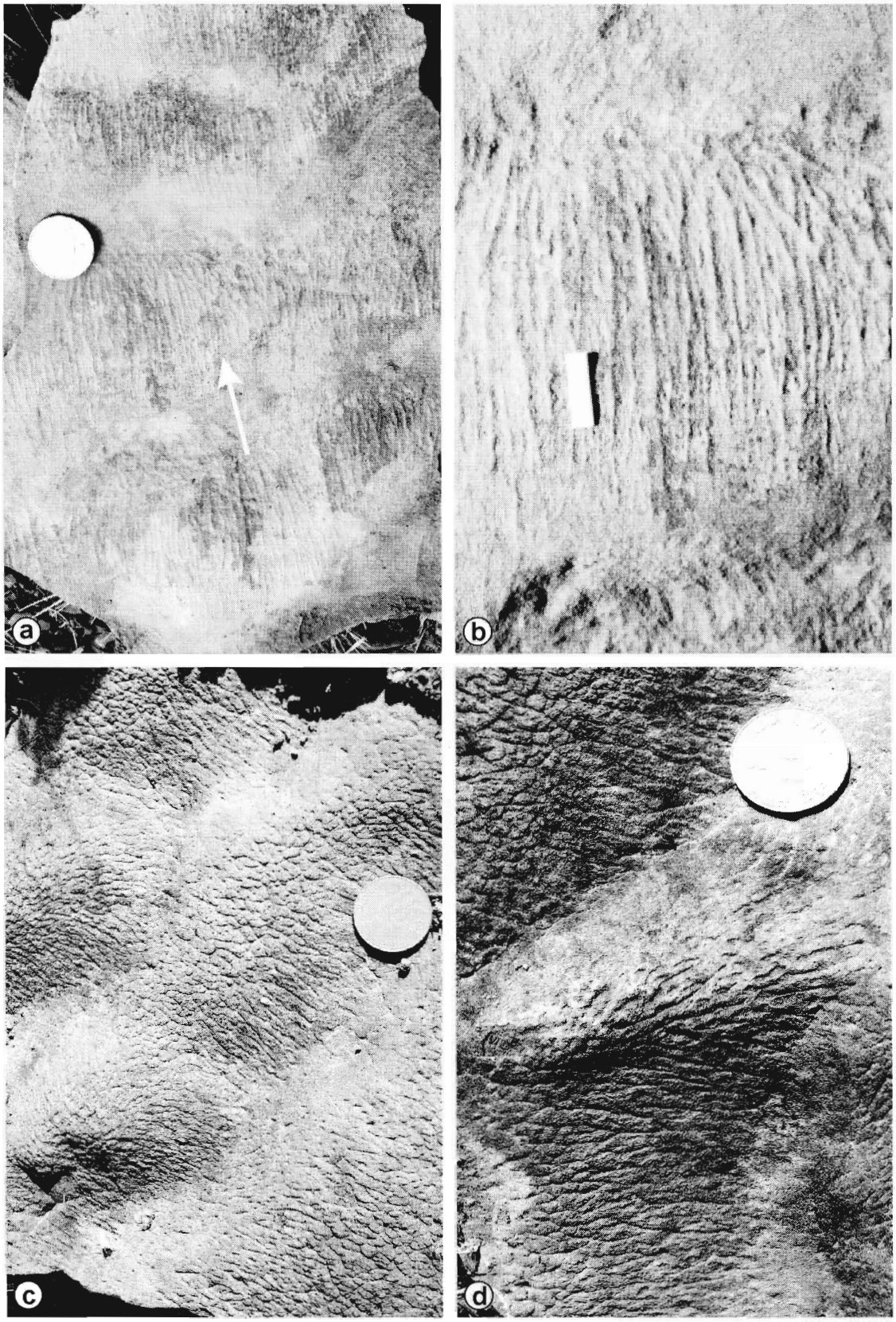
a. ***Arumberia banksi*** on rippled surface of the Maihar Sandstone, Rampur hillock, Maihar area. The arrow shows the palaeocurrent direction. Diameter of coin = 2.2 cm.

b. Close up view of ***Arumberia banksi,*** Rampur hillock, Maihar area. Scale length = 1.0 cm.

c. ***Arumberia banksi*** on rippled surface, Kudra village, Maihar area. Sample number K106. Diameter of coin = 2.2 cm.

d. Close up view of ***Arumberia banksi*** showing criss-crossed nature of grooves, Kudra village, Maihar area. Diameter of coin = 2.2 cm.

Plate II



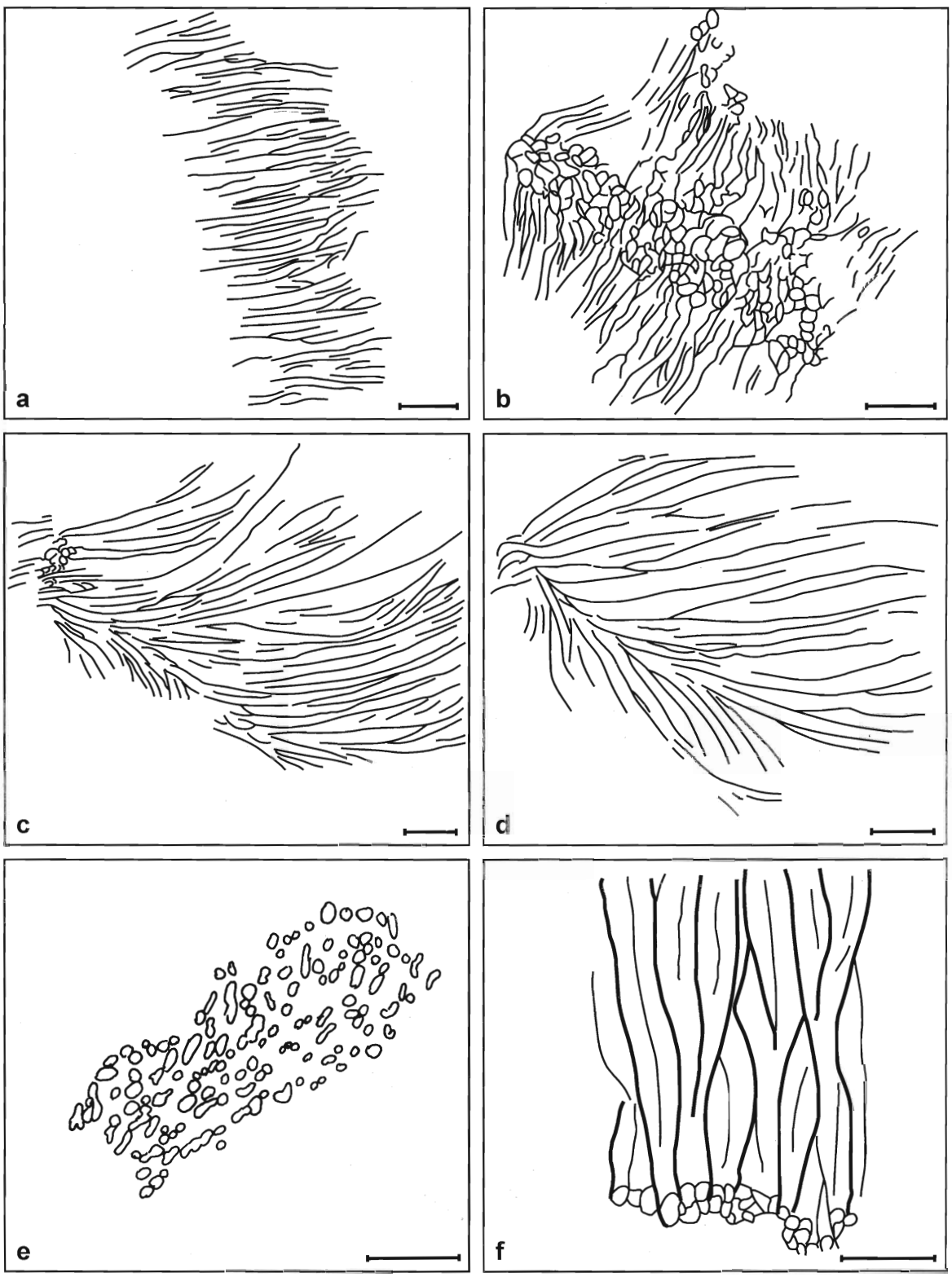


Fig. 4. Synoptic line diagram showing morphological features of the different morphoforms:
a. ***Arumberia banksi*** Glaessner & Walter, 1975. (Scale bar = 2.0 cm)
b. ***Arumberia banksi*** Glaessner & Walter, 1975. (Scale bar = 2.0 cm)
c. ***Arumberia banksi*** Glaessner & Walter, 1975. (Scale bar = 2.0 cm)
d. ***Arumberia banksi*** Glaessner & Walter, 1975. (Scale bar = 2.0 cm)
e. ***Rameshia rampurensis*** n. gr. and n. form (Scale bar = 2.0 cm)
f. ***Arumberia vindhyanensis*** n. form (Scale bar = 3.0 cm)

Lithology: Dark brown coloured fine-grained sandstone.

Derivation of name: The form is named after the Vindhyan Range.

Diagnosis: Long slender leaf-like morphology formed by the grooves. Slightly tapering at the base, where it is rounded. Distal end is spatulate or blunt at the tip. In many cases, mid grooves divide the structure into more or less equal parts. Leaf-like morphology is oriented broadly in palaeocurrent direction. Sometimes they overlap with one another. With the increase in length, their relief tends to decrease. Grooves about 1 mm wide and range in length from 1-13 cm with mean value as 3 cm. Width between two grooves varies from 2- 9 mm. Relief from ridge top to furrow bottom is less than 1 mm.

Remarks: It differs from *A. banksi* in having a leaf like morphology in which a groove divides the leaf like structure in equal parts. The form is densely populated and attached only with the crest of ripple or mounds of irregular surface. Possibly a specific community of algae was responsible for the formation of this form.

Group ***Rameshia*** n. gr.

(Figs. 4 e; Pl. IV, figs. a, b)

Type Form: *Rameshia rampurensis* n. form

Holotype: Sample no. R206

Locality : Rampur Hillock, Maihar, Satna district, M.P.

GPS value: N 24° 16.51′; E 80° 42.55′

Stratigraphic Horizon: Maihar Sandstone, Bhander Group.

Lithology: Dark brown coloured fine grained sandstone.

Derivation of name: The group is named in honour of the late Dr. Ramesh Chandra Misra who has made significant contributions in the study of the Vindhyan Basin.

Diagnosis: Rounded or elliptical mounds with granular surface about 1- 4 mm in diameter arranged haphazardly on a trough of rippled surface. Crests of the ripples are generally devoid of these mounds. Sometime mounds coalesce to form small ridge like morphology.

Remarks: The present group differs from *Arumberia* in not showing ridges and grooves, which are its diagnostic characters. In *Arumberia banksi* the mounds are also reported with grooves and ridges (see Glaessner and Walter, 1975) but they show a definite pattern whereas in the present form the mounds are haphazardly arranged and they also coalesce with out the presence of ridges and grooves. It has some similarity with *Beltanelliformis minuta* (original species *B. minutae* has been modified as *B. minuta* because *Beltanelliformis* appears to be feminine and as per the codes of nomenclature the species should be *minuta* and not *minutae* as described by McIlroy *et al.* 2005 from the Synalds Formation, Shropshire, England) which has been considered a body fossil where as *Rameshia* is considered an organosedimentary structure produced by the interaction of microbial mats with the sediments. It is identified on the basis of small mounds covering large surface of the sandstone bed.

Rameshia rampurensis n. form

(Figs. 4 e; Pl. IV, figs. a, b)

Derivation of name: Form is named after Rampur village as it is best exposed on Maihar–Rampur Road.

Diagnosis: As for group.

Remarks: As for form.

Group ***Beltanelliformis*** Menner, in Keller *et al.*, 1974

Type Form: *Beltanelliformis brunsae* Menner, in Keller *et al*, 1974.

Beltanelliformis minuta McIlroy, Crimes & Pauley, 2005

(Pl. V, figs.c, d)

Sample No: BM106

Locality: Rampur Hillock, Maihar, Satna district, M.P.

GPS value: N 24° 16.51′; E 80° 42.41′

Stratigraphic Horizon: Maihar Sandstone, Bhander Group.

Lithology: Red coloured fine grained sandstone.

Description: Small circular to elliptical impression without concentric or radial markings. Diameter of individual specimens ranges from 1.25 mm to 2.94 mm, with mean as 2.24 mm (N = 40). Hyporelief is usually less than 1 mm in depth.

Remarks: Specimens are preserved in positive hyporelief and compare well with *B. minuta* described from the Synalds Formation (Longmyndian Supergroup, Shropshire, U.K. Wade (1969, pl. 69, fig. 7) records 'minute fossils' preserved in positive hyporelief on the slab of sandstone from the Neoproterozoic of the Central Mount Stuart Beds, central Australia. Examples described as 'Dubiofossil C' and suggested to be possible small *Beltanelliformis*, were recorded from late Neoproterozoic strata of the Warnecke Mountains, Yukon, Canada by Narbonne & Hofmann (1987, text fig. 10 i). Bland (1984) has also illustrated spheroid impressions, which appear to be examples of *Beltanelliformis minuta* from Lightspout Group of Longmyndian Supergroup at the Longmynd.

Form - A

(Pl. IV, fig. c)

Sample no: RC106

Locality: Rampur Hillock, Maihar, Satna district, M.P.

GPS value: N 24° 16.59′; E 80° 42.51′.

Stratigraphic Horizon: Maihar Sandstone, Bhander Group.

Lithology: Red-coloured, fine-grained sandstone.

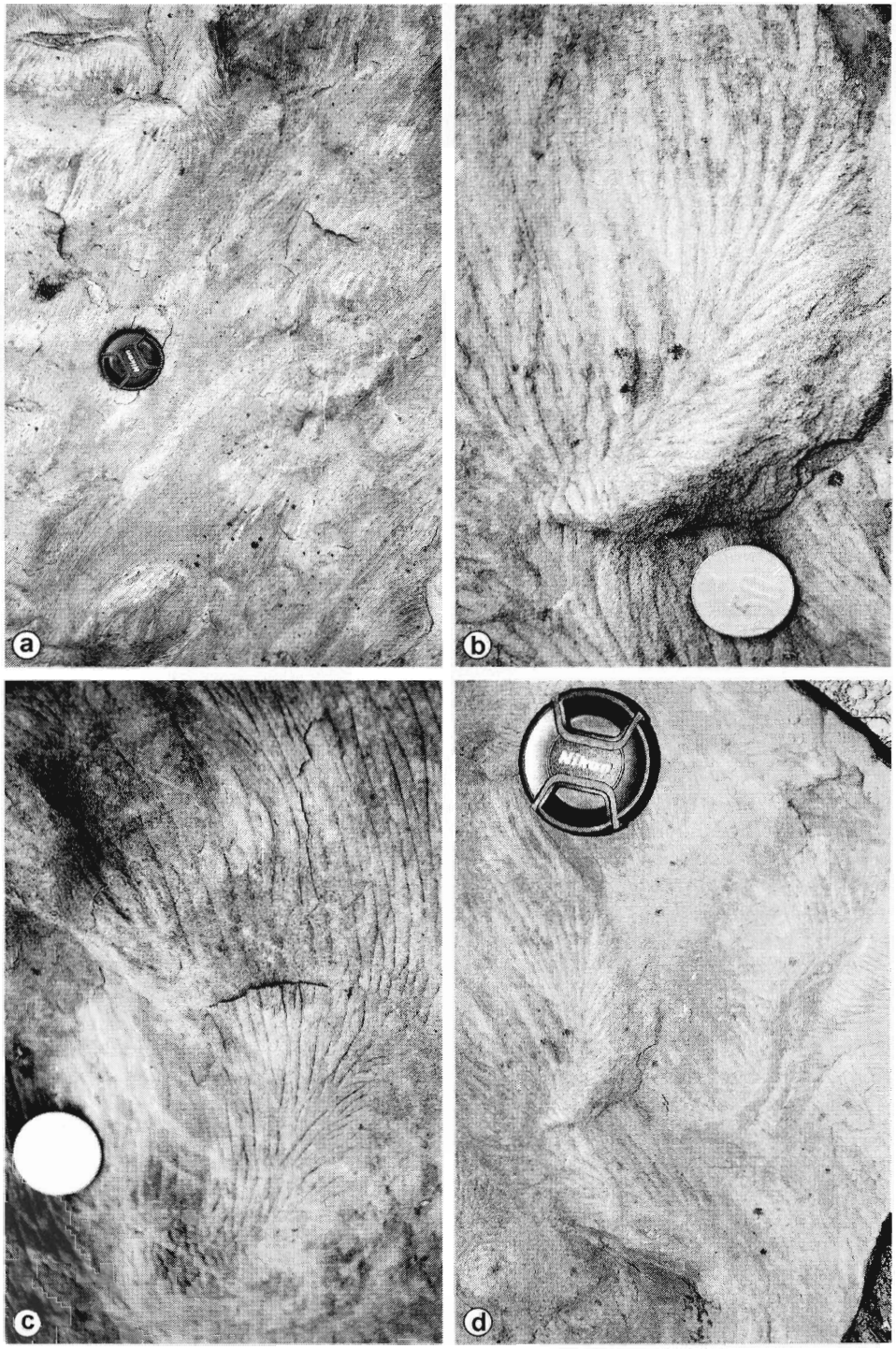
Description: Semicircular morphology containing at least seven visible circular rings seen on a surface showing presence of *Arumberia banksi*. It is partially preserved and the original structure must have been circular or subcircular in outline. The form shows sutured and serrated margins. The diameter of the semicircular morphology is about 2.5 cm. The height of the individual ring is less than 0.5 mm. Width of the rings is about 1 mm. Only two partially preserved specimens have been recorded.

Remarks: Originally, it must have been a discoidal form. Since it is incomplete form, no final interpretation can be attempted. However, it may represent a microbial mat structure.

DISCUSSION AND CONCLUSIONS

1. The paper describes five forms from the Neoproterozoic Maihar Sandstone, out of which two belong to *Arumberia* Glaessner and Walter, one to a new group and form *Rameshia rampurensis* and other two are *Beltanelliformis minuta* D. McIlroy, T.P. Crimes & G.C. Pauley and an informal form referred to as Form A from the eastern part of the Vindhyan Basin (Son valley Section) from the Maihar area, district Satna, Madhya Pradesh. The *Arumberia* forms are *Arumberia banksi* Glaessner & Walter, 1975 and *Arumberia vindhyanensis* n. form. The morphological differences between different morphoform are shown in Fig. 4.

Plate III



EXPLANATION OF PLATE III

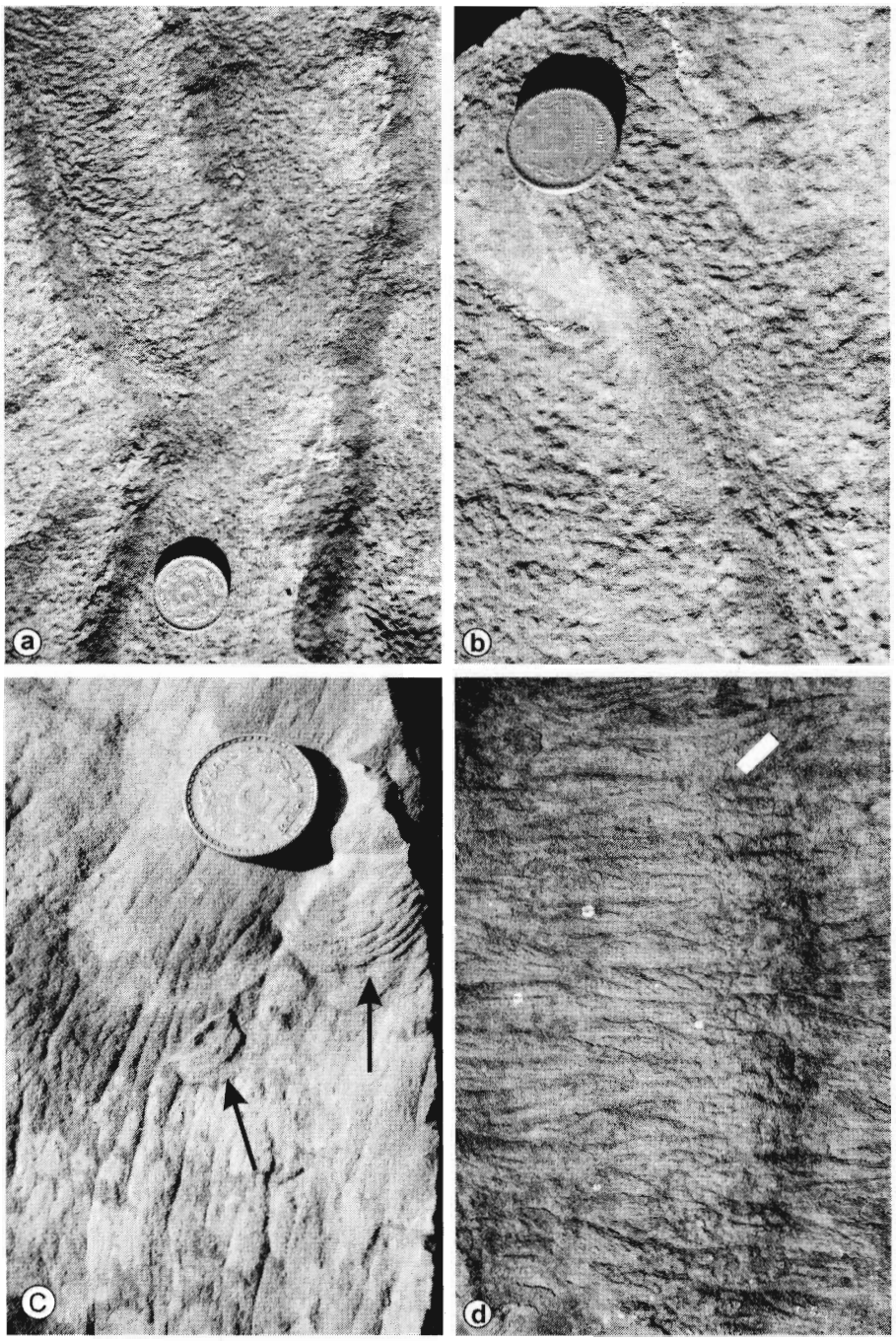
a. View of the flute casted surface of sandstone showing development of ***Arumberia banksi***, Kudra village, Maihar area. Diameter of lens cover = 5.5 cm.

b. Close up view of ***Arumberia banksi*** in which the grooves are developed from the twisted nose of a flute caste, Kudra village, Maihar area. Sample number K706. Diameter of coin = 2.2 cm.

c. Close up view of ***Arumberia banksi*** showing curved grooves, Kudra village, Maihar area. Diameter of coin = 2.2 cm.

d. ***Arumberia banksi*** showing multidirectional grooves, Kudra village, Maihar area. Diameter of lens cover = 5.5 cm.

Plate IV



KUMAR AND PANDEY

EXPLANATION OF PLATE IV

a. ***Rameshia rampurensis*** n. gr. and form on rippled surface of the Maihar Sandstone, Rampur hillock, Maihar area. Sample number R206. Diameter of coin = 2.3 cm.

b. Close up view of ***Rameshia rampurensis*** n. gr. and form showing small rounded to elliptical mounds, Rampur hillock, Maihar area. Diameter of coin = 2.3 cm.

c. Form A: semicircular morphology (marked by arrows) seen in association with ***Arumberia banksi*** developed on the upper right hand margin, Rampur hillock, Maihar area. Diameter of coin = 2.3 cm

d. ***Arumberia vindhyanensis*** n. form on the rippled surface, Kudra village, Maihar area. Long slender leaf-like morphology is developed on the stoss side of a ripple. At the crest it is rounded. Mid grooves divide the leaf-like structure. Sample number K206. Scale length = 1.0 cm.

2. *Arumberia* and *Rameshia* are considered as organo-sedimentary structures produced by the interaction of microbial community, which flourished over the noncohesive siliciclastic surface.
3. The *Arumberia*-bearing Maihar Sandstone represents deposit of a tidal flat–shoal complex. Thus, the *Arumberia* flourished in a typical shallow water marine setting with moderate energy level.
4. The *Arumberia*-bearing Maihar Sandstone can be suggested an Ediacaran age on the basis of world wide occurrence of *Arumberia* near transition zone between latest Neoproterozoic and Cambrian. This suggestion gets support from the fact that as no typical Cambrian fossil has so far been reported from the Vindhyan rocks. The reported small shelly fauna and brachiopod by Azmi (1998) and *Spriggina* by Kathal *et al.* (2000) from the Rohtas Formation are untenable (see Kumar, 2001). The association of *Beltanelliformis* with *Arumberia* considered as a typical Ediacaran form gives additional support for the Ediacaran age to the Maihar Sandstone. There are 13 reported occurrences of *Arumberia* from all over the world including the present one (Table 2). Three reports are from the Late Precambrian to Lower Cambrian (Walter, 1980; Kirschvink, 1978; Bland, 1984) and rests are

Table 2: Occurrences of *Arumberia* from the different stratigraphic horizons.

Sl. No.	Occurrences	Stratigraphic Horizon	Age	Country	Reference
1.	*Arumberia*	Bonney Sandstone (Lowest member of Pound Subgroup) in Flinders Ranges, South Australia.	Latest Precambrian	South Australia	Bland, 1984.
2.	*Arumberia*	Erudina Siltstone Member of the Billy Creek Formation.	Lower Cambrian	South Australia	Bland, 1984.
3.	*Arumberia banksi*	Arumbera Sandstone in Amadeus Basin, central Australia.	Latest Precambrian (?)	central Australia	Discovered by Banks in 1966 and described, named and illustrated by Glaessner & Walter, 1975.
4.	*Arumberia*	The Central Mount Stuart Formation, Georgina Basin, central Australia.	Sub-Cambrian to early Cambrian.	central Australia	Noted by Kirschvink, 1978 & Walter, 1980.
5.	*Arumberia*	The Longmyndian of England & Wales	Latest Precambrian (?)	England & Wales	Salter (1856 a, b, 1857), in Bland, 1984.
6.	*Arumberia*	The Sylvitsa Series, Urals, U.S.S.R.	Late Precambrian (?)	U.S.S.R.	Bekker, 1980 in Bland, 1984.
7.	*Arumberia*	The Séries Rouges du golfe normanno-breton in Northern France & Channel Islands.	Low lower Cambrian (Slightly younger or older ages possible)	France & Channel Islands	In Bland, 1984.
8.	*Arumberia*	Erquy and Bréhec Seqences.	Late Precambrian	France	Bland, 1984.
9.	*Arumberia*	The Signal Hill & Musgravetown groups, Avelon Peninsula, Newfoundland.	Latest Precambrian	Canada	In Bland, 1984.
10.	*cf. Arumberia*	Auborus Formation, Nama System, South-West Africa.	Late Precambrian	South-West Africa	Miller, 1975, in Bland, 1984.
11.	*cf. Arumberia*	Visigsö Formation	Late Precambrian	Southern Sweden	Kaudern, 1932 in Bland, 1984.
12.	*Arumberia*	Mashan Group, Heilongjiang, North China.	Ediacaran affinity	Northern China	Liu Xiaoliang, 1981
13.	*Arumberia*	Maihar Sandstone, Bhander Group	Ediacaran	Central India	Present Study

EXPLANATION OF PLATE V

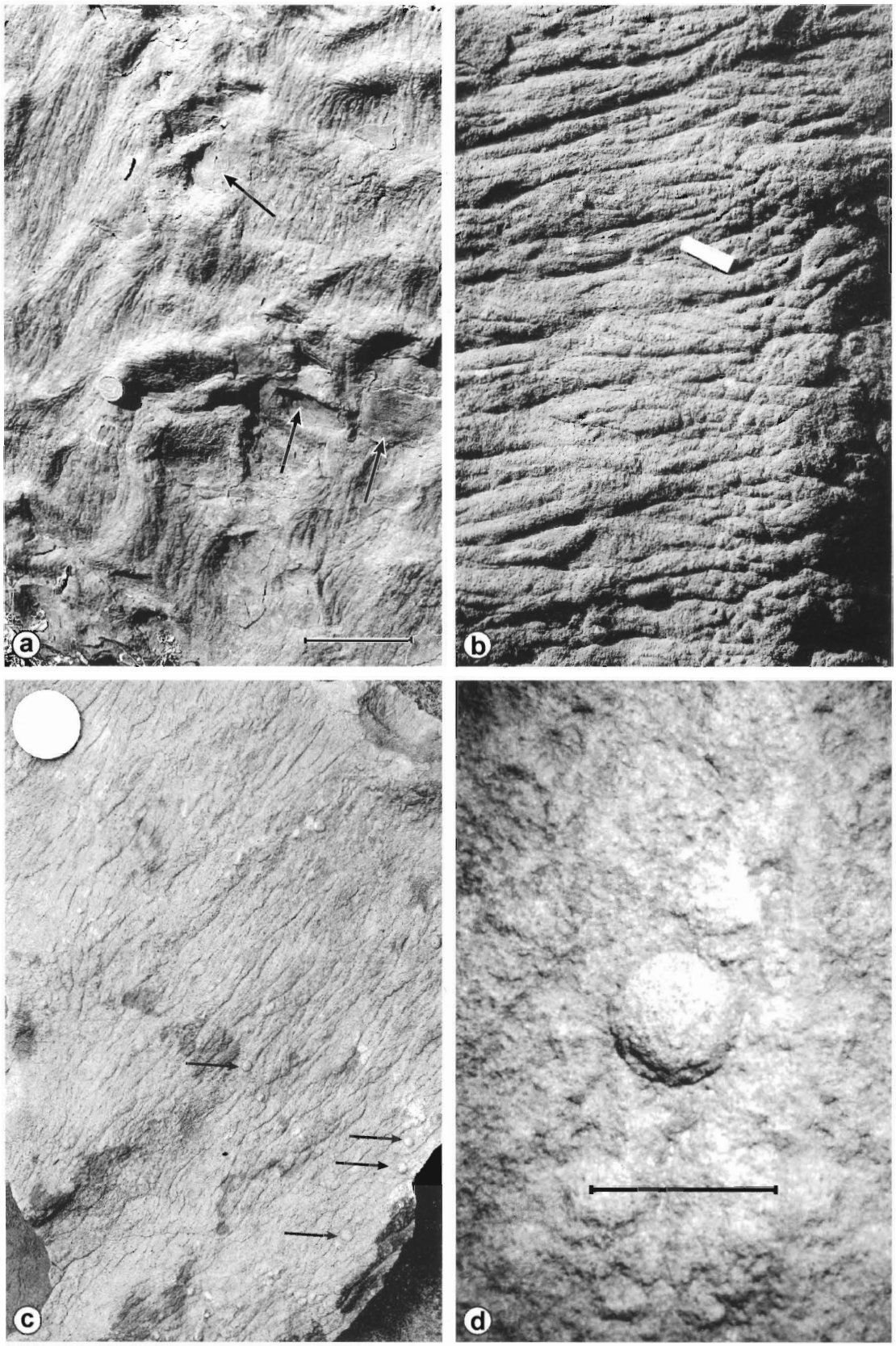
a. View of ***Arumberia vindhyanensis*** n. form on irregular surface of the Maihar Sandstone, Kudra village, Maihar area. The presence of angular clasts are marked by arrows. Scale length = 2.3 cm.

b. Close up view of ***Arumberia vindhyanensis*** n. form, Kudra village, Maihar area. Midgroove devides the leaf-like form into two equal parts. Scale length = 1.0 cm.

c. ***Beltanelliformis minuta*** associated with microbial mats on the bedding surface of the Maihar Sandstone, Rampur hillock, Maihar area. Diameter of coin = 2.2 cm.

d. Close up view of ***Beltanelliformis minuta***, Rampur hillock, Maihar area. Scale length = 3.0 mm.

Plate V



from the Late Precambrian (Bland, 1984; Glaessner and Walter, 1975; Liu Xiaoliang, 1981). Bland (1984) opined that all the sequences in which *Arumberia* has been found, appear to be latest Precambrian to Lower Cambrian while McIlroy and Walter (1997) have said that it is present in the latest Neoproterozoic and has not been recorded from the pre-Ediacaran Proterozoic rocks. It appears that *Arumberia* flourished near Cambrian–Precambrian boundary.

5. In the light of the suggested Ediacaran age to the Maihar Sandstone, it is necessary to review the record of Ediacaran forms by De (2003, 2006) from the Bhander Group of the Maihar area, M.P. In 2003, he has described two medusoid genera resembling *Ediacaria* (Sprigg 1947) and *Hiemalora* (Fedonkin, 1982) from a shale horizon occurring at the base of the Bhander Group (Ganurgarh Shale), Maihar area, M.P. However, nothing can be made out from the photographs concerning the morphology of the said forms. Much of the inferences are drawn on the basis of reconstruction. In our opinion they do not look biogenic and hence the identification is unacceptable. In 2006, he again described 9 coelenterate genera, one arthropod genus and a few unnamed possible new forms belonging to sponge and coelenterate from the two horizons belonging to Bhander Limestone and the Sirbu Shale respectively. None of the forms look convincingly biogenic. Again much of the inferences concerning the morphology of the forms are based on the reconstructions. With very poor quality material it is difficult to make important and significant conclusions and as such the discovery is ignored. In the Ganurgarh Shale at the base of the Bhander Limestone and in the overlying Sirbu Shale horizon *Arumberia* has not been recorded. Only in the Maihar Sandstone, the youngest horizon of the Bhander Group, *Arumberia* is abundantly seen. In the light of the above facts the chances of the discovery of Ediacaran assemblage is possible only in the Maihar Sandstone horizon and any Ediacaran fossil reported underlying this horizon needs a thorough scrutiny.
6. Form A represents a circular body with concentric rings. Only two poorly preserved forms have been recorded and it is not possible to reconstruct the actual body of the fossil. There is a possibility that it represents a microbial mat structure.

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