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# Stromatolites of the Kaladgi Basin, Karnataka, India: Systematics, biostratigraphy and age implications

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## ABSTRACT

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Systematics of the stromatolites of the Proterozoic Kaladgi Basin is attempted. The main purpose is to document the diversity and distribution of the various stromatolite forms occurring in the Bagalkot Group of the Kaladgi Supergroup. An assemblage of six taxa is recognized from the Bagalkot Group. The forms *Asperia digitata (=Yelma digitata)*, *Ephyaltes edingunnensis, Eucapsiphora leakensis, Kussoidella karalundiensis*, *Pilbaria deverella* and *Yandilla meekatharrensis* are described. These forms are not recorded from any other Proterozoic Sequence of India of the Palaeoproterozoic age. Similar forms are recorded from Africa, Australia, Canada and China. *Asperia digitata*, a digitate stromatolite, is known from the Proterozoic Sequence of the Palaeoproterozoic age in other parts of the world. Poorly constrained age of the Bagalkot Group of the Kaladgi Supergroup can be ascertained on the basis of the reported assemblage as Late Palaeoproterozoic to Early Mesoproterozoic (Orosirian-Statherian to Calymmian Period).

**Key-words**—Stromatolites, Systematics, Kaladgi Supergroup, Palaeoproterozoic, Karnataka, India.

## कलाड्गी द्रोणी, कर्नाटक, भारत के स्ट्रोमैटोलाइट्सः वर्गिकी, जैवस्तरिकी एवं आयु निहितार्थ

मुकुंद शर्मा एवं एस.के. पांडे

## सारांश

प्राग्जीव कलाड्गी द्रोणी में स्ट्रोमैटोलाइट्स की वर्गिकी का प्रयास किया गया है। कलाड्गी उच्चसमूह के बागलकोट समूह में प्राप्त हो रहे विविध स्ट्रोमैटोलाइट् रुपों की विविधता व वितरण का प्रलेख करना मुख्य उद्देश्य है। बागलकोट समूह से छः टैक्सा की एक समुच्चय अभिनिर्धारित की गई है। इन रुपोंः *एस्पेरिया डिजीटाटा (=येल्मा डिजिटाटा), एफीयलेटीज एडिंगनेन्सिस, इयुकैप्सीफोरा लीकेन्सिस, कुसेडेल्ला कर्लुडेन्सिस, पिल्बेरिया डेवरेल्ला* एवं *यंडिला मीकेथरेन्सिस* के वर्णन दिए गए हैं। पुराप्राग्जीव काल में भारत के किसी अन्य प्राग्जीव अनुक्रम से ये रुप अभिलिखित नहीं किए गए हैं।अफ्रीका, आस्ट्रेलिया, कनाडा एवं चीन से इसके सदृश रुप अभिलिखित किए गए हैं। दुनिया के अन्य भागों में पुराप्राग्जीव काल के प्राग्जीव अनुक्रम से अंगुष्ठाकार स्ट्रोमैटोलाइट् *एस्पेरिया डिजिटाटा* ज्ञात है। वर्णित समुच्चय के आधार पर कलाड्गी उच्चसमूह में बागलकोट समूह की आयु अंतिम पुराप्राग्जीव से प्रारंभिक मध्य प्राग्जीव (ओरोसिरियन-स्टेथेरियन से कैलीम्मियन अवधि) जो पहले नियत नहीं थी निर्धारित की जा रही है।

**संकेत-शब्द**—स्ट्रोमैटोलाइट्, वर्गिकी, कलाड्गी उच्चसमूह, पुराप्राग्जीव, कर्नाटक, भारत।

## Stromatólitos da Bacia Kaladgi, Karnataka, India: Implicações sistemáticas, bioestratigráficas e de idade

## RESUMO

A sistemática dos estromatólitos da bacia proterozóica Kaladgi é preliminarmente estabelecida. O principal objetivo é documentar a diversidade e a distribuição das formas de vários estromatólitos ocorrentes no Grupo Bagalkot do Supergrupo Kaladgi. Uma assembléia de seis táxons é reconhecida como sendo do grupo Bagalkot. As descrições são feitas para estas

formas: *Asperia digitata (=Yelma digitata), Ephyaltes edingunnensis, Eucapsiphora leakensis, Kussoidella karalundiensis*, *Pilbaria deverella* e *Yandilla meekatharensis* que não são registradas em nenhuma outra sequência paleoproterozóica da Índia. Formas similares são registradas na África, Austrália, Canadá e China. *Asperia digitata*, um estromatólito digitado é conhecido a partir da sequência paleoproterozóica de outras partes do mundo. Idade precariamente estabelecida do Grupo Bagalkot do Supergrupo Kaladgi pode ser determinada com base na assembléia registrada como neo-paleoproterozóica a eo-mesoproterozóica (Períodos Orosiriano-Stateriano a Calimiano).

**Palavras-chave**—Estromatólitos, Sistemáticas, Supergrupo Kaladgi, Palaeoproterózoico, Karnataka, India.

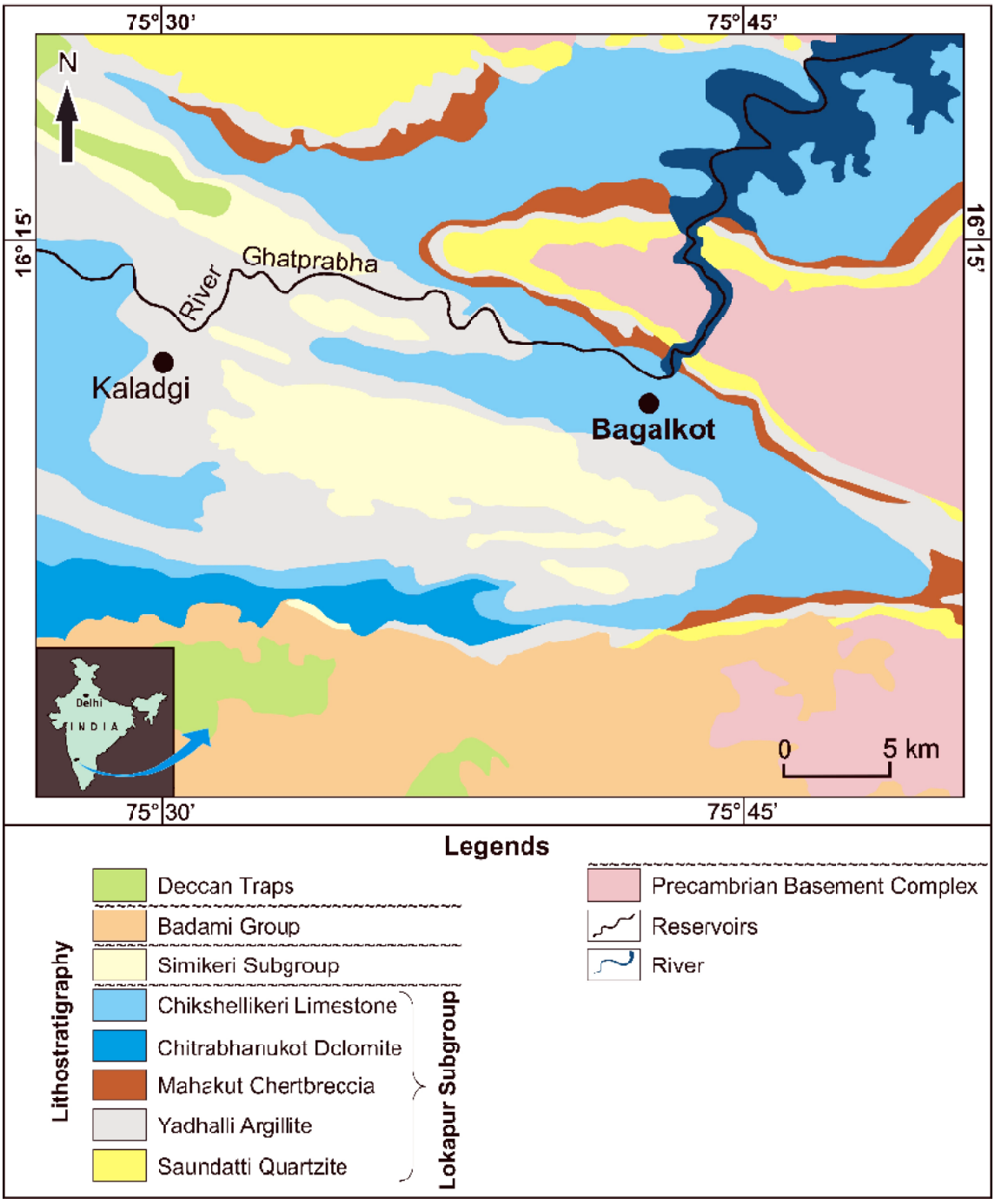


Fig. 1—Part of the geological map of the Kaladgi Supergroup exposed around Bagalkot (after GSI, 1981; Kale *et al.*, 1999). Inset shows the distribution of Proterozoic basins in south India.

## INTRODUCTION

Stromatolites are an important component of the Precambrian biosphere. Systematics of the stromatolites has helped in ascertaining the age of vast sequences of the Proterozoic Eon (2500-542 Ma). In absence of the availability of the precise radiometric age of different strata of any Proterozoic succession, these are still used to determine the age of encompassing sequences. In India, stromatolites are known from the Proterozoic Cuddapah, Vindhyan, Chhattisgarh, Indravati basins in peninsular India and Pithoragarh, Deoban, Jammu and Arunachal areas of Extra-peninsular India. Diverse assemblages occur in various carbonate units of the Palaeo-Mesoproterozoic successions. Various columnar and branching groups and forms of the stromatolites are useful local biostratigraphic markers in characterizing each formation. Comprehensive studies have demonstrated their usefulness in biostratigraphy of vast basins like the Vindhyan and the Cuddapah Supergroups of the peninsular India (Sharma, 1996, Sharma *et al.,* 1998; Misra, 2004; Sharma & Shukla, 2004; Misra & Kumar, 2005; Pandey, 2011). Although the Kaladgi Supergroup is amongst the smallest of the Purana basin of Peninsular India yet it has attracted least attention for the palaeobiological studies. Earlier, the Kaladgi Basin was considered a Neoproterozoic succession (Chandrasekhar Gowda and Govindarajulu, 1980). Geochronological data on the age of its different formations are still lacking. Widespread development of stromatolites is, therefore, important in ascertaining the age of the Chitrabhanukot Dolomite Member of the carbonate unit of the Bagalkot Group of the Kaladgi Basin. In the present paper, the stromatolites recorded from the Bagalkot Group are systematically described; and their age implications and biostratigraphic potential are discussed.

## GENERAL GEOLOGY AND AGE

The Kaladgi Basin is considered as a supracrustal basin in the peninsular India that evolved under extensional regime (Kale & Phansalker, 1991). The sediments of the Kaladgi Supergroup were deposited on the northern fringes of the Dharwar Craton marked by the Eparchaean unconformity and are exposed on the southern fringes of the Deccan Trap Province (Fig. 1). Shallow marine sediments comprising orthoquartzites (quartz-rich sandstones), argillites (mudstones and shales) and carbonates (limestones and dolomites) are the principal constituents of the Kaladgi Supergroup. This sequence is practically unmetamorphosed but extensively deformed resulting into identifiable two main types of tectonic deformation, viz. inherited and superimposed (Patil-Pillai & Kale, 2011).

The original classification scheme by Foote (1876) has undergone several modifications. Jayaprakash *et al.* (1987) accorded the status of the Supergroup to this sequence and divided it into the lower Bagalkot and upper Badami Groups. The former was divided into the Lokapur and the Simikeri Subgroups on the basis of succession of strata and an intervening disconformity between them. The lithological

| Group | Sub group | Formation | Member |
|---|---|---|---|
| | | **Deccan Trap** | |
| | | ~~~~~~Angular and Erosional unconformity~~~~~~ | |
| KALADGI SUPERGROUP | BADAMI (NEOPROTEROZOIC) | Konkankoppa Limestone | |
| | | Halkurki Shale | |
| | | | Gokak Sandstone |
| | | | Kendur Sandstone |
| | | Cave Temple Arenite | Torgal Conglomerate |
| | | ~~~~~~Angular and Erosional unconformity~~~~~~ | |
| | SIMIKERI | Lakshanhatti Dolomite | |
| | | Niralkeri Chert-breccia | |
| | | Arlikatti Argillite | |
| | | | Tulasigeri Quartzite |
| | | Muchkundi Quartzite | Bevinmatti Conglomerate |
| | | ~~~~~~~~~~Disconformity~~~~~~~~~~ | |
| | BAGAL KOT (PALAEO - MESO PROTEROZOIC) | | Chikshellikeri Limestone |
| | | Petlur Carbonate | Chitrabhanukot Dolomite |
| | | Mahakut Chert-Breccia | |
| | LOKAPUR | | Yargatti calc. Shale |
| | | Yargatti Argillite | Jalikatti Phyllite |
| | | | Manoli Ferrug. Shale |
| | | | Timmapur Quartzite |
| | | Saundatti Quartzite | Almatti Quartzite |
| | | | Salgundi Conglomerate |
| | | ~~~~~~Angular and Erosional unconformity~~~~~~ | |
| | | **Precambrian Basement Complex (PBC) Granitoids, Gneisses & Metasediments** | |

Fig. 2—Lithostratigraphic succession of the Kaladgi Basin (modified after Jayaprakash *et al*., 1987; Kale *et al*.; 1999; Jayaprakash, 2007).

contents of both these subgroups are identical, although the latter is restricted to narrow basinal structures, while the Lokapur Subgroup is exposed throughout the Kaladgi Basin. Some doubts have been expressed whether the two subgroups represent two separate cycles of transgressive sedimentation or not (Kale & Phansalkar, 1991; Kale *et al.,* 1999). The revised lithostratigraphy of the Kaladgi Basin is given in Fig. 2.

The oldest sequence of the basin, the Bagalkot Group, represents a transgressive suit of the shoreline siliciclastics which grades laterally and vertically into tidal-flat carbonates (Petlur Carbonate) interbedded with washed, silicified products of syn-sedimenatry deformation structures (Mahakut Chert-Breccia) (Sharma *et al.,* 1998; Patil-Pillai & Kale, 2011). The carbonate sequence occurs as thinly bedded, flaggy and wave and tidally influenced mud and carbonate flats and as reefs (Jayaprakash *et al.,* 1987; Jayaprakash, 2007; Kale *et al.,* 1999; Patil-Pillai & Kale, 2011). The distinctive organosedimentary structures (stromatolites) from the carbonates in the Bagalkot Group are the only reliable and definite evidence of the biogenic activity, and tool for estimating the age and biostratigraphy of this sequence. The previous records of microbial remains obtained from macerations were not reproducible in subsequent studies, rendering them rather unreliable for biostratigraphic evaluations.

The isotopic studies of the carbonate formations of the Kaladgi Supergroup are commonly interpreted them as members of a genetically related (Sathyanarayan *et al.,* 1987). Variously named Ghatprabha and Vidyanagar Dolomite contain algal mats which are indicative of intertidal to subtidal facies. Collectively, the Kaladgi Basin carbonates were considered to have deposited between 2.0 to 1.0 Ga periods. A significant trend has been noted in the concentration of Sr values in the Gaddankeri Limestone which scatter between 200 and 300 ppm whereas they decrease to 50 ppm in dolomitic lithologies in response to progressive dolomitization (Sathyanarayan *et al.,* 1987).

## PREVIOUS PALAEOBIOLOGICAL STUDIES

Records of stromatolites are quite old from the Kaladgi Basin. These were documented around Lokapur, in southwestern part of the Kaladgi Basin and around Chitrabhanukot (Viswanathiah *et al.,* 1964; Govinda Rajulu & Chandrasekhara Gowda, 1966, 1968, 1975). Large sized stromatolites are known from the variegated limestones along the northern bank of the Ghatprabha River from the rocks of the uppermost division of the Lower Kaladgi near Alagundi (Viswanathiah & Chandrasekhara Gowda, 1970); reported forms include *Collenia compacta, Collenia columnaris, Cryptozoon proliferum* and *Cryptozoon*. Viswanathiah and Sreedhara Murthy (1972) recorded stromatolites from Lower Kaladgi around the village Devalapur about 24 km northwest of Nidgundi (N-16°22' E-75°44') comprising *Cryptozoon proliferum* and *Collenia* and small size colonies near Kuligod (Viswanathiah & Chandrasekhara Gowda, 1975); the other reported forms include *Collenia compacta* and *Collenia symmetrica*. In an elaborated synthesis of the data on the Kaladgi Basin, Jayaprakash *et al.* (1987) have mentioned the occurrences of stromatolites in the Dolomitic beds of the Lokapur Subgroup. Sharma *et al.* (1998) have reported the occurrence of small digitate stromatolites from the Yargatti Formation; they described the 11 cycles of a typical microstromatolitic form, *Yelma digitata* Grey 1984 from the Chitrabhanukot Dolomite and suggested that it indicates a Palaeoproterozoic age for the host sediments. On the contrary, Chandrasekhara Gowda and Govinda Rajulu (1980) considered, on the basis of stromatolites occurrences, the age of the Kaladgi Basin to be Late Precambrian.

Microbial remains reported from the Kaladgi Basin are meagre. Venkatachala and Rawat (1973) identified algal microfossils, acritarch and cellular tissue with amorphous organic debris in the rocks of the Lokapur Subgroup. Viswanathiah *et al.* (1976) recorded acritarchs belonging to the genera *Ressochitina, Cyathochitina, Conochitina* and *Acanthichitina* from the Badami Group of rocks.

It is significant that true stromatolites are encountered only in the dolomitic horizons of the carbonate sediments in the Bagalkot Group, while the limestone horizons are devoid of any organosedimentary structures. The reasons for this selective development may be environmental, but cannot be ascertained at this stage. The distribution of the stromatolites in various localities of the Bagalkot Group is discussed. Our studies have revealed the presence of *Ephyaltes edingunnensis, Eucapsiphora leakensis, Kussoidella karalundienis*, *Pilbaria deverella* and *Yandilla meekatharrensis* in the Chitrabhanukot Dolomite and Lakshanhatti Dolomite. It is concluded that the stromatolites do not indicate a major temporal difference in the age of the Lokapur and the Simikeri Subgroups. This assemblage is indicative of a Late Palaeoproterozoic to Early Mesoproterozoic age for the carbonates (particularly the dolomitic horizons) from the Bagalkot Group. The geochronological dates of the argillites from the Bagalkot Group (Padmakumari *et al.,* 1998) appear to bear out with this inference.

## PLATE 1

*Asperia digitata* (Grey, 1984 comb. nov., Grey, 1994a) polished slabs showing columns of microstromatolites. →

1. *Asperia digitata* polished slab showing algal laminites in the lower part, followed by small columns in the upper part, Specimen No. BSIP - 39961.
2. Portion marked by a box is enlarged in Fig. 2.
3. Polished slab of *Asperia digitata* showing algal laminites, columns and their branching pattern, Specimen No. BSIP - 39962.

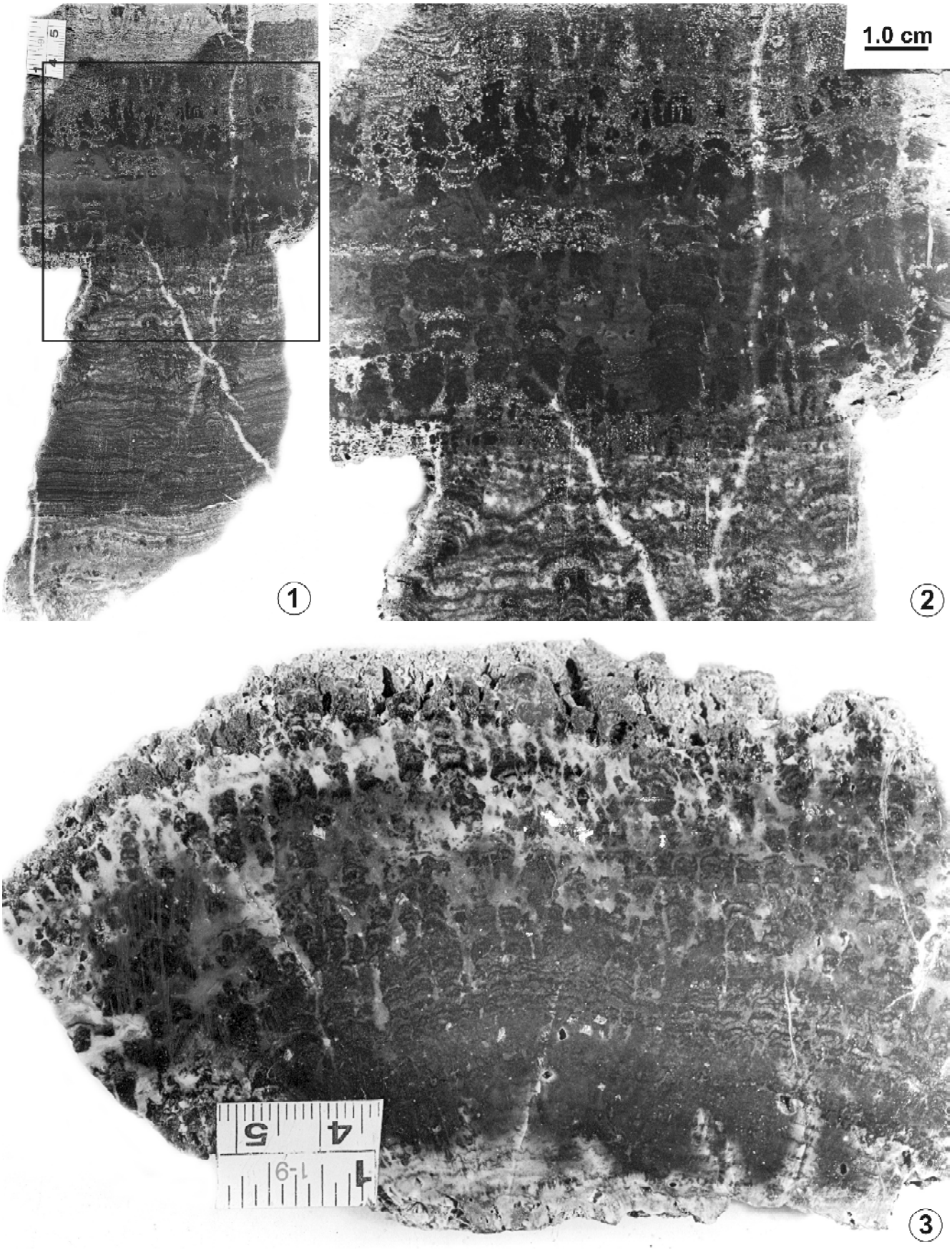


**PLATE 1**

## METHODS AND REPOSITORY

The stromatolites described in this paper were collected by the author (MS) in association with Vivek Kale and Late Manoj Shukla in 1988, 1993 and 1999 from seven localities (Chikanmurmatti, Bagalkot, Manapur, Lokapur, Askarkop, Shahpur and Yargatti all in the Karnataka State). Samples were collected from seven stromatolite bearing localities. In morphological description, we have followed terminology proposed by Hofmann (1969), Walter (1972) and Preiss (1976) which is broadly consistent with the terminology used by Russian workers. Further, we have followed the binomial nomenclature for description of stromatolites as proposed by Raaben *et al.* (2001). All the hand specimens and petrographic thin sections are deposited in the repository of the Museum of the Birbal Sahni Institute of Palaeobotany (polished Specimen Nos. 39961-39978 and Slides No. 14507-14525). These can be retrieved by the statement no. 1306.

## SYSTEMATICS

### Group *Asperia* Semikhatov 1978

1978 *Asperia* Semikhatov, p. 120
1984 *Yelma* Grey, p. 45

*Type form—Asperia aspera Semikhatov,* 1978, p. 121, Rocknest Formation (unit 8), Canada, Palaeoproterozoic, about 1.9 Ga.

*Diagnosis*—Small digitate cylindrical to sub-cylindrical columns, frequently branching, column margins wrinkled with cornices. For further details see Semikhatov, 1978, p. 120 (translation in Grey, 1985, p. 99).

*Remarks*—Biogenecity of the *Asperia* and synonymous forms are critically debated. Hofmann and Jackson (1987) considered these forms as abiogenic whereas Grey, (1984) held these structures as biogenic with substantiating evidences. Sharma and Shukla (1998), Sharma *et al.* (1998), Riding and Sharma (1998) while discussing the origin of microstromatolites considered these as biogenic structure. *Asperia digitata* occurs profusely in the Chitrabhanukot Dolomite Member of the Yargatti Formation in the Kaladgi Basin.

*Distribution and age*—Australia: Duck Creek Dolomite, Wyloo Group, western Pilbara, Western Australia; Canada: Rocknest Formation; India: Chitrabhanukot Dolomite Member, Yargatti Formation, Bagalkot Group, Kaladgi Basin, probably Palaeoproterozoic-precise age uncertain.

### *Asperia digitata* Grey 1994a

(Pl. 1.1-3; Pl. 2.1-3; Pl. 3.1-3; Pl. 4.1, 3)

1978 *Asperia aspera* Semikhatov, p. 120
1984 *Yelma digitata* Grey 1984, p. 50-52
1985 *Asperia ashburtonia* Grey, p. 101-102
1994a *Asperia digitata* Grey, p. 196, comb. nov.

*Material*—Specimen Nos. BSIP-39961, 39962, 39963, Slide Nos. BSIP-14507, 14508, 14509, 14511, 14513; additional Specimen No. 39964, Slide Nos. 14510, 14514, 14525.

*Diagnosis*—Small digitate columnar form, closely crowded parallel to sub parallel columns, some show terete shape, cross section circular to oblong 3-5 mm, height of the column varies between 2-5 cm, branching pattern bifurcate to multi-furcate. Lamina profile range from flat to gently convex, some of the over arching laminae form wall structure in the columns; microstructure is banded type and constituted of light and dark laminae. Light laminae are thicker than dark laminae. The light laminae are 50 to 200 μm and dark laminae are 20-80 μm. Many specimens are altered and silicified.

*Remarks*—In all the known occurrences this stromatolite occurs in a cyclic pattern; Grey 1984 described *Yelma digitata* from Earaheedy Group and reported three cycles; Sharma *et al.* (1998) reported eleven cycles of the *Yelma digitata* from north of Yargatti in Karnataka. *Yelma* was subsequently merged with *Asperia* as *A. digitata* comb. nov. (Grey, 1994a). Since then the description by the Sharma *et al.* (1998) has also been assessed and we are inclined to merge it within the *Asperia digitata*.

*Distribution and age*—Australia: Yelma Formation, Earaheedy Group, Western Australia; India: Chitrabhanukot Dolomite Member, Bagalkot Group, Karnataka. Probably Palaeoproterozoic-precise age uncertain.

### Group—*Ephyaltes* Vlasov 1977

1977 *Ephyaltes* Vlasov, p. 114-115.
1984 *Ephyaltes* Vlasov, 1977; Grey, p. 23-24.
1994a *Ephyaltes* Vlasov, 1977; Grey, p. 196-204.

*Type form—Ephyaltes myriocranus* Vlasov 1977, from the Satka Formation, southern Urals.

*Diagnosis*—See Vlasov (1977, p. 114). For the diagnosis and comments on the taxonomic group see a translation by Grey, 1984, p. 23.

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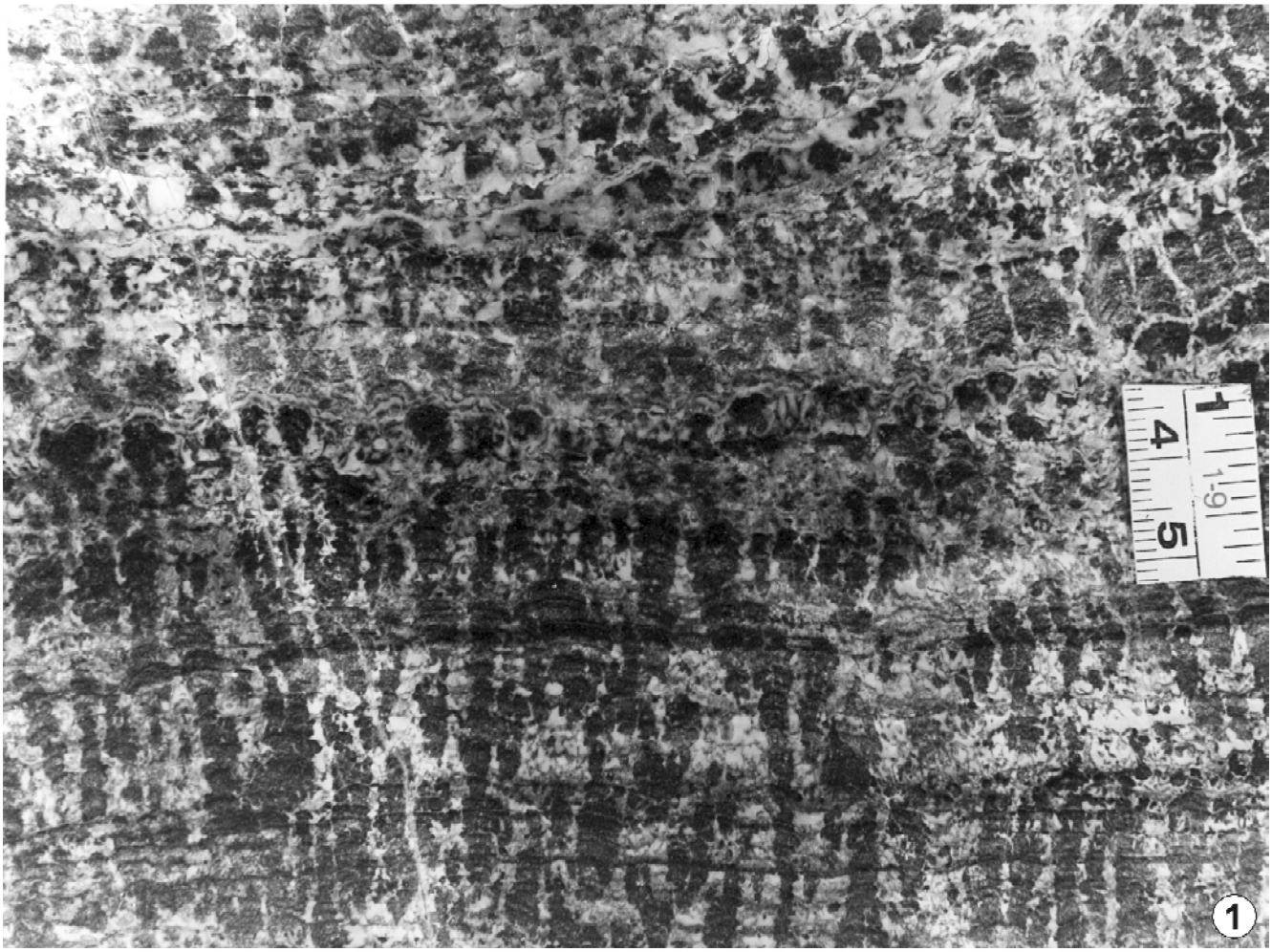
**PLATE 2** →

*Asperia digitata* (Grey 1984 - comb. nov. Grey, 1994a). Polished block of a hand specimen showing *Asperia digitata* showing well developed columns and branching pattern.

1. Polished slab showing well developed columns, branching pattern in the lower part of the specimen and poorly developed and diagenetically altered, distorted columns in the upper part, Specimen No. BSIP - 39963.
2. Polished plan view in petrographic thin section showing circular outlines of the columns of *Asperia digitata,* Slide No. BSIP - 14507.
3. Polished longitudinal view in petrographic thin section showing naked column margins of *Asperia digitata*, Slide No. BSIP - 14508.



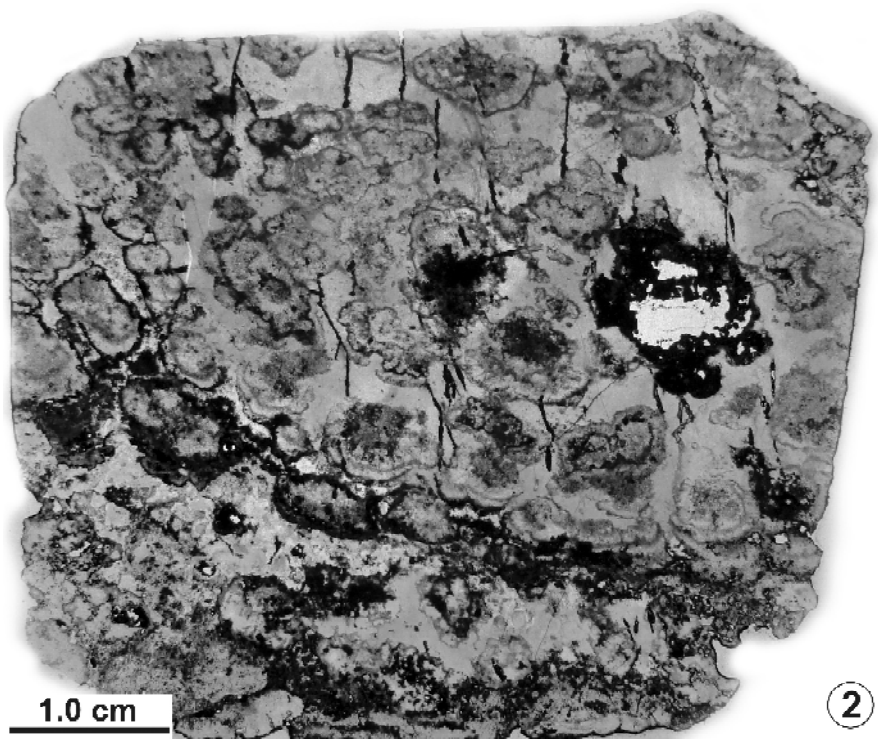





**PLATE 2**

*Content—Ephyaltes myriocranus* Vlasov 1977, *Ephyaltes gorgonotus* Vlasov 1977, *Ephyaltes edingunnensis* Grey 1994a.

*Distribution and age*—Australia: *Ephyaltes edingunnensis* occur in the Yelma Formation, Earaheedy Group (1.69 Ga), Earaheedy Basin; Russia: *Ephyaltes myriocranus* and *Ephyaltes gorgonotus* are found in the Satka Formation of the southern Urals in the type section of the Lower Riphean (1.65 to 1.35 Ga). Probably Palaeoproterozoic-precise age uncertain.

***Ephyaltes edingunnensis*** Grey 1994

(Pl. 6.1, 2)

1994a *Ephyaltes* Vlasov, Grey, p. 196-204, figs 6-11.

*Material*—Numerous specimens from two localities, Specimen No. BSIP-39975; Slide No. 14523; additional Slides Nos. BSIP-14519, 14520, 14521, 14522.

*Diagnosis*—Laterally linked conical stromatolites with distinct axial zone and banded microstructures. For further details see Grey, 1994a, p. 198.

*Remarks*—Columns of *Ephyaltes edingunnensis* are conical, axial zone angle is between 10°-25°, columns closely spaced, collectively forming dome-shaped structures, column height varies up to 20-25 cm. Columns are affected by secondary alteration mostly dolomitized or silicified. Bioherms diameter ranges between about 70-80 cm, in plan view cross section bioherms are rounded and clustered. Branching not observed. Laminae are conical and on the sides they continue to next column. Microstructure is finely banded comprising of alternation of dark and light laminae. There is a large range of variation in the thickness of dark and light laminae that vary between 10-60 μm. Laminae thickness are uniform throughout the cones. Grey (1994a) discussed the formation of the rampart surrounding *Ephyaltes edingunnensis* which have protected the cones from the current and decrease in turbulence around the centre of the bioherm allowing the development of cones. Donaldson (1976) suggested that such cones grew in submerged, quite water conditions.

*Distribution and age*—India: Chitrabhanukot Dolomite Member of Yargatti Formation, Lokapur Subgroup, Kaladgi Basin, probably Palaeoproterozoic-precise age uncertain.

**Group—*Eucapsiphora*** Cloud & Semikhatov 1969

1969 *Eucapsiphora paradisa* Cloud & Semikhatov, p. 1039.
1994a *Eucapsiphora leakensis* Grey, p. 205-211.

*Type form*—*Eucapsiphora* Cloud and Semikhatov 1969, from the Esperanza Formation McNamara Group, Mount Isa inlier.

*Diagnosis*—Cloud and Semikhatov (1969) provided only a description of the stromatolites, not a diagnosis considering the limitation of not observing the original specimen Grey (1994a) attempted the synopsis of the salient features of the group based on Cloud and Semikhatov's description. As per the synopsis provided by Grey (1994a) "the *Eucapsiphora leakensis* is a columnar stromatolite with narrow straight or curved columns that pinch and swell, and thicken conspicuously before branching into two or three subparallel to somewhat divergent daughter columns. Columns are often connected at bases or by bridging. Laminae are weakly convex to nearly flat. Marginal zone generally smooth, but with local over hangs and discontinuous walls".

*Content—Eucapsiphora paradisa* Cloud & Semikhatov 1969, *Eucapsiphora* cf. *paradisa* Cloud & Semikhatov 1969 in Cao & Zhao 1977, *Eucapsiphora comata* Zhu *et al.* 1987, *Eucapsiphora huaiyinensis* Zhu *et al.* 1987, *Eucapsiphora longotenuia* Cao & Zhao 1981, *Eucapsiphora stenoclada* Zhu *et al.* 1987, *Eucapsiphora leakensis* Grey 1994a.

*Distribution and age—Eucapsiphora paradisa* has been reported from the Esperanza Formation, McNamara Group of the Mount Isa Inlier (Cloud & Semikhatov 1969). This formation is correlated with the part of Urquhart Shale with U-Pb date of 1670 ±17 Ma (Page, 1981). For laterally equivalent Mount Isa Group sediments a date of 1650 Ma were obtained (Page unpublished data, in Blake & Stewart, 1992). Most of the Chinese Forms have been reported from Hutuo Group and have an age of between 2.5 Ga and 1.85 Ga. *Eucapsiphora leakensis* has been reported from Mount Leake Sandstone, Earaheedy Group, Earaheedy Basin which is probably of the Palaeoproterozoic age (Grey, 1994a). In the Kaladgi Basin, this stromatolite occurs in the Chitrabhanukot Dolomite Member of the Lokapur Subgroup.

***Eucapsiphora leakensis*** Grey 1994a

(Pl. 5.1-4)

1994a *Eucapsiphora leakensis* Grey, p. 205-211, figs 12A-D, 13A-E, 14A-G, 15

*Material*—Specimen Nos. BSIP-39965, 39966, 39967 from single locality.

**PLATE 3** →

*Asperia digitata* (Grey, 1984, comb. nov., Grey, 1994a); Polished petrographic thin section of *Asperia digitata* showing microstructure and texture.

1. Banded microstructure and texture in *Asperia digitata*.
2, 3. Gradual enlargement of the marked areas; petrographic thin section no. BSIP-14509.

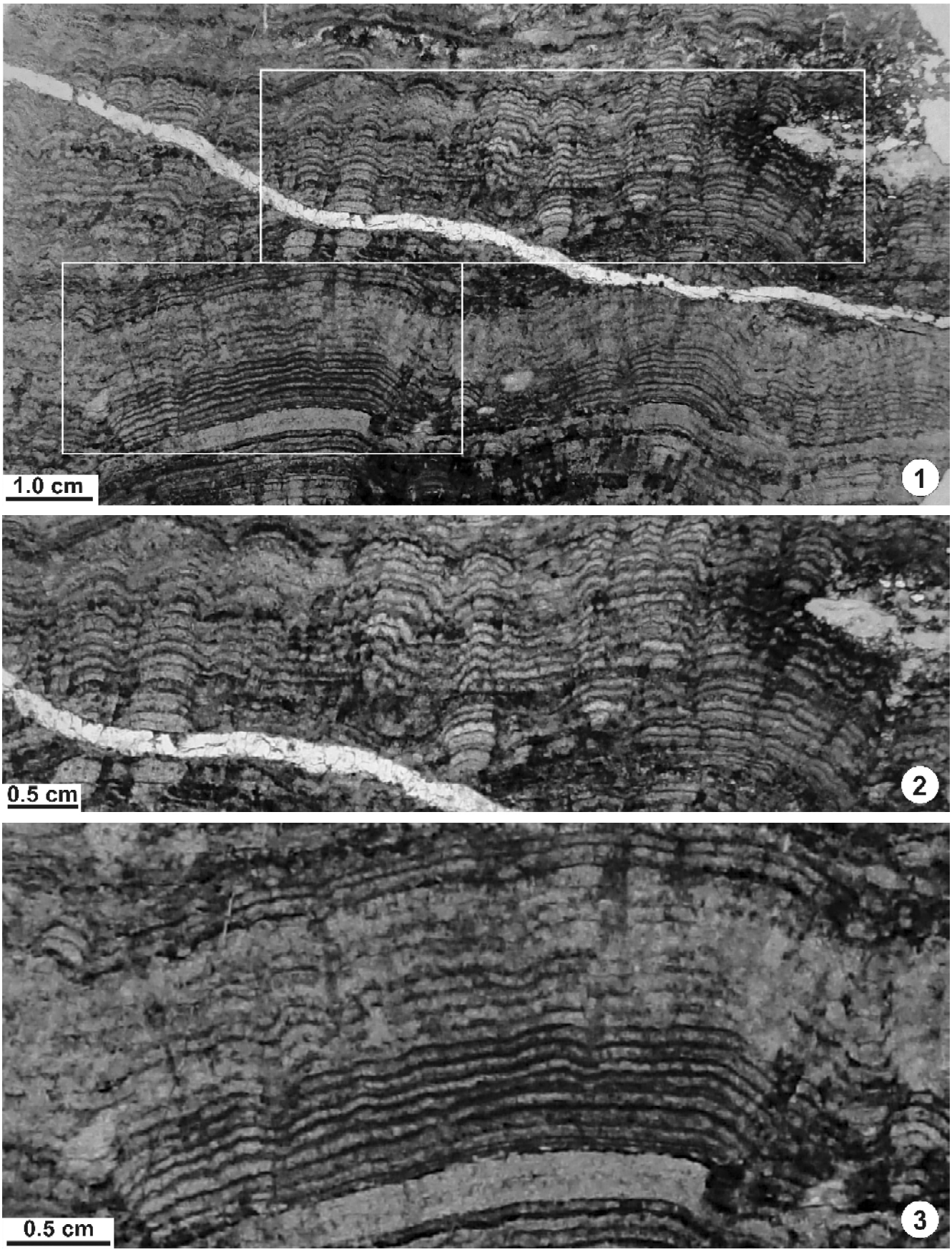



**PLATE 3**

*Diagnosis*—Columnar branching stromatolites with bifurcate to trifurcate branching, alpha style, columns margins are irregular. The base of the stromatolites are stratiform. For further details see Grey, 1994a, p. 205-206.

*Remarks*—Grey (1994a) compared various morphoforms of group *Eucapsiphora*. The columns of this group show the distinctive pinching and swelling resulting into constricted appearance. The laminae are steeply inclined. Chinese forms show more abundant bridging and lack of steeply inclined laminae. Forms recorded from the Kaladgi Basin have inclined laminae and have smoother column margins which show some similarity with *Segosia* Butin, 1966. Exceptional elongation of columns suggests the relatively high energy environment. The presence of micro unconformities and wedging laminae suggest their development in relatively high energy environment.

*Distribution and age—Eucapsiphora paradisa* occurs in Esperanza Formation of McNamara Group, with an age of about 1.67 Ga (Page, 1981; Blake & Stewart, 1992). *Eucapsiphora leakensis* has been recorded from Earaheedy Basin, probably Palaeoproterozoic. In Kaladgi Basin, *Eucapsiphora leakensis* occurs in the Chitrabhanukot Dolomite Member of the Lokapur Subgroup exposed in Muddapur area. Jayaprakash (2007) has placed this unit into a separate Formation and Member designated as Bamanbundi Dolomite Member of the Muddapur Formation, probably Palaeoproterozoic, precise age uncertain.

**Group—*Kussoidella*** Semikhatov 1978

*Type form—Kussoidella limata* Semikhatov 1978, Taltheilei Formation, Great Salve Supergroup, Great Salve Lake, Canada, Aphebian.

*Diagnosis*—(As given by Grey 1994b, p. 282 based on translation of Semikhatov, 1978, p. 138-9) "straight or weakly bent, sub-cylindrical columns with gentle pinching and swelling. There is no enveloping wall. Branching infrequent occurs by way of simple disintegration of parent column into two, rarely into three daughter columns of lesser diameter, usually parallel or almost parallel to the parent (passive branching). Often the daughter columns rapidly terminate their growth with the formation of short digitate shoots. Lateral margins of the columns uneven, with short fragile projections, separate peaks and connecting bridges, sometimes of considerable thickness. Some columns may coalesce. Laminations variable throughout the form from flattened to strongly convex; inheritance of the laminations average".

*Contents—Kussoidella limata* Semikhatov 1978, *Kussoidella* f. *indet.* Semikhatov 1978, *Kussoidella karalundienis* Grey 1994b.

*Remarks*—Semikhatov (1978, p. 138) mentioned that walls were absent in the specimens observed by him. However, Grey (1994b) after re-examining the type material expressed the opinion that there was wall *senu* Walter (1972, p. 14) although not extensively developed. In the Australian specimens, Grey (1994b) noted patchy walls. In Kaladgi specimens, walls are noted in the zones which are less altered by dolomitization. Generally, the laminae are oblong to convex, in some cases steeply convex, smooth to wavy.

*Comparison—Hutuoella* Zhu 1982 which is a parallel branching stromatolite with bumps and bridges appears to be a synonymous form.

*Distribution and age*—Australia: Elgee Siltstone, Kimberley Group Margaret River, Kimberley Craton; Canada: Taltheilei Formation Great Slave Supergroup and Rocknest Formation, Epworth Group, Great Salve Lake area, Canada. India: Bamanbundi Dolomite Member, Lokapur Subgroup, Palaeoproterozoic (Aphebian).

***Kussoidella karalundienis*** Grey 1994b

(Pl. 4.2; Pl. 7.1)

1994b *Kussoidella karalundienis* Grey p. 282-287, figs 5-8.

*Material*—Specimen No. BSIP-39968, Slide No. BSIP-14512; additional Specimen Nos. 39969 & 39970.

*Diagnosis*—Closely spaced, long cylindrical, erect, straight columns with 1-2 cm diameter and about 10 cm in length, branching infrequent at irregular intervals. Wall structure is patchy; laminae are smooth, gently to steeply convex. Laminae are continuous across the column. Some specimens are completely altered and preserved as dolomitized specimens. For further details see Grey, 1994b, p. 282-287.

*Remarks*—Grey (1994b) discussed the preservational aspects of the *Kussoidella* Semikhatov 1978. In Glengarry Formation although the specimens are poorly preserved they have a more extensive development of patchy wall. In the Bamanbundi Dolomite, stromatolites have more steeply convex laminae, less frequent bridging, closer spacing of the columns and more distinctly defined laminae. Microstructure of the

**PLATE 4** →

*Asperia digitata* (Grey 1984, comb. nov. Grey, 1994a); and *Kussoidella karalundienis* (Grey, 1994b), polished petrographic thin sections showing microstructure and textures.

1. Banded microstructure as seen in silicified zones of *Asperia digitata,* petrographic thin section no. BSIP-14511.
2. Polished petrographic thin section showing microstructure and column margins of *Kussoidella karalundienis,* petrographic thin section no. BSIP-14512.
3. Polished petrographic thin section showing poorly preserved column margins of *Asperia digitata,* petrographic thin section no. BSIP-14513.

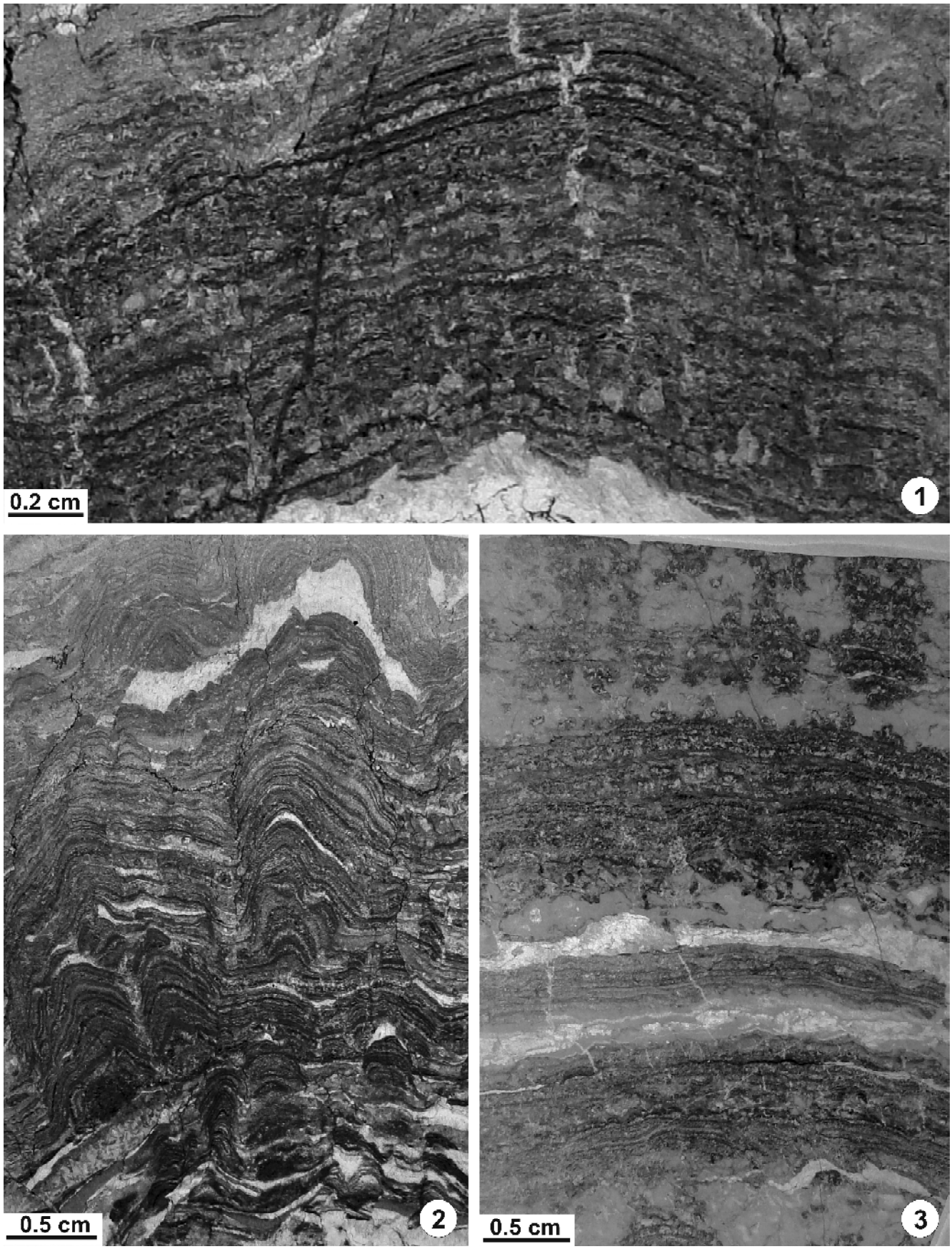



**PLATE 4**

stromatolite is represented by the couplets of light and dark laminae; light laminae are thicker than dark laminae. Light laminae are lensoid in nature.

*Distribution and age*—India: Bamanbundi Dolomite Member, Muddapur Formation, Bagalkot Group, Kaladgi Basin, Karnataka, India, approximately Palaeoproterozoic-precise age uncertain.

**Group—*Pilbaria*** Walter 1972

1972 *Pilbaria* Walter, p. 167.

*Type form—Pilbaria perplexa* Walter 1972, Duck Creek Dolomite, Wyloo Group, Western Pilbara, Western Australia.

*Diagnosis*—See Walter, 1972, p. 167.

*Content—Pilbaria perplexa* Walter 1972, *Pilbaria boetsapia* Bertrand-Sarfati & Eriksson 1977; *Pilbaria beidaxingensis* Cao & Zhao 1981; *Pilbaria deverella* Grey, 1984; *Pilbaria inzeriaformis* Bertrand-Sarfati & Eriksson 1977; *Pilbaria miniscula* Zhu *et al.* 1987.

*Distribution and age*—Australia: Duck Creek Dolomite, Wyloo Group, Western Australia (Walter, 1972; Grey, 1985, ~1.84 Ga, Pidgeon & Horowitz, 1991), Koolpin Formation, Pine Creek Geosyncline, Central Australia, (Crick *et al.,* 1980, ~1.9 Ga, Needham *et al.,* 1988), Yelma Formation, Earaheedy Group, Earaheedy Basin, probably Palaeoproterozoic, precise age uncertain; Canada: Rocknest Formation, Epworth Group, Great Slave Lake area, northern Canada, (Semikhatov, 1978, ~1.9 Ga); China: Assemblage 2, Hutuo Group, China, (Zhu *et al.,* 1987, p. 27, age between 2.5 and 1.8 Ga); India: Chitrabhanukot Dolomite Member, Yargatti Formation, Lokapur Subgroup, Kaladgi Basin, South Africa: Schmidtsdrift Formation, Transvaal Group, South Africa, (Jahn *et al.,* 1990, ~2.5 Ga or older); probably Palaeoproterozoic, precise age uncertain.

***Pilbaria deverella*** Grey 1984

(Pl.7.2-6)

1984 *Pilbaria deverella* Grey, p. 38-39, p. 21-23. Text-figs 22-34.

*Type specimen*—Holotype F 12374 from 3.5 km southeast of sweetwaters well, near Lake Nabberu, NBR 001, 25°36'31" 5, 120°23'58"E.

*Material*—Specimen Nos. BSIP-39971, 39972, 39973, 39974.

*Diagnosis*—Large cylindrical columnar stromatolites with smooth column margins, outlines, branching infrequent to absent, lamina are steeply convex. For further details see Grey, 1984, p. 38.

*Remarks*—Columns are cylindrical usually erect, up to 5-12 cm in diameter, height varies from 20 to 30 cm. On the margins, laminae overlap each other downwards making distinct wall structures. Inter-columnar spaces are pronounced and distinct separating the columns. Lamina shapes are steeply convex to parabolic, in certain specimens even conical. Couplets of dark and light laminae are pronounced showing streaky to lensoid microstructures. Dark laminae are 50-300 μm in thickness where as light laminae are 80- 500 μm. In Indian specimens we have not noted any radial fan fabric which was noted in Australian specimens. Indian specimens are well preserved and most of the diagnostic features of *Pilbaria deverella* as previously described by Grey (1984) are noted.

*Distribution and age*—Australia: Yelma and Frere Formation, Earaheedy Group, Earaheedy Basin; probably Palaeoproterozoic precise age uncertain. India: Chitrabhanukot Dolomite Member, Kaladgi Basin, probably Palaeoproterozoic-precise age uncertain.

**Group—*Yandilla*** Grey 1984

1984 *Yandilla* Grey, p. 44.

*Type form—Yandilla meekatharrensis* Grey 1984, p. 44-45, Yelma Formation, Earaheedy Group, Earaheedy Basin, probably Palaeoproterozoic precise age uncertain.

*Diagnosis*—Broad fan shaped irregular columnar structures with patchy walls, branching infrequent. Vermiform microstructure is characteristic of this form.

*Content—Yandilla meekatharrensis* only.

*Distribution and age*—Australia: Yelma Formation, Earaheedy Group, Earaheedy Basin, Palaeoproterozoic precise age uncertain.

***Yandilla meekatharrensis*** Grey 1984

(Pl. 6.3-5; Pl. 8.1, 2)

1984 *Yandilla meekatharrensis* Grey, p.44-45. Pl.26-27; text figs 26-29.

1994a *Yandilla meekatharrensis* Grey, p. 213-215, fig. 18.

*Material*—Specimen Nos. BSIP-39976, 39977, 39978; additional Slides BSIP-14515, 14516, 14517, 14518, 14524. Many specimens have been collected from Bamanbundi and Lakshanhatti Dolomite of Kaladgi Basin.

**PLATE 5** →

*Eucapsiphora leakensis* (Grey, 1994a); polished slabs showing lamination pattern and column developments.

1. Banded laminae of stromatolite, Specimen No. BSIP-39967.
2. Showing base of the stromatolite formed by a stratiform layers and gradual development of gamma type column, Specimen No. BSIP-39965.
3, 4. Polished slab of *Eucapsiphora leakensis* showing lamination pattern and column style, gradual enlargement of the area marked in 3, Specimen No. BSIP-39966.

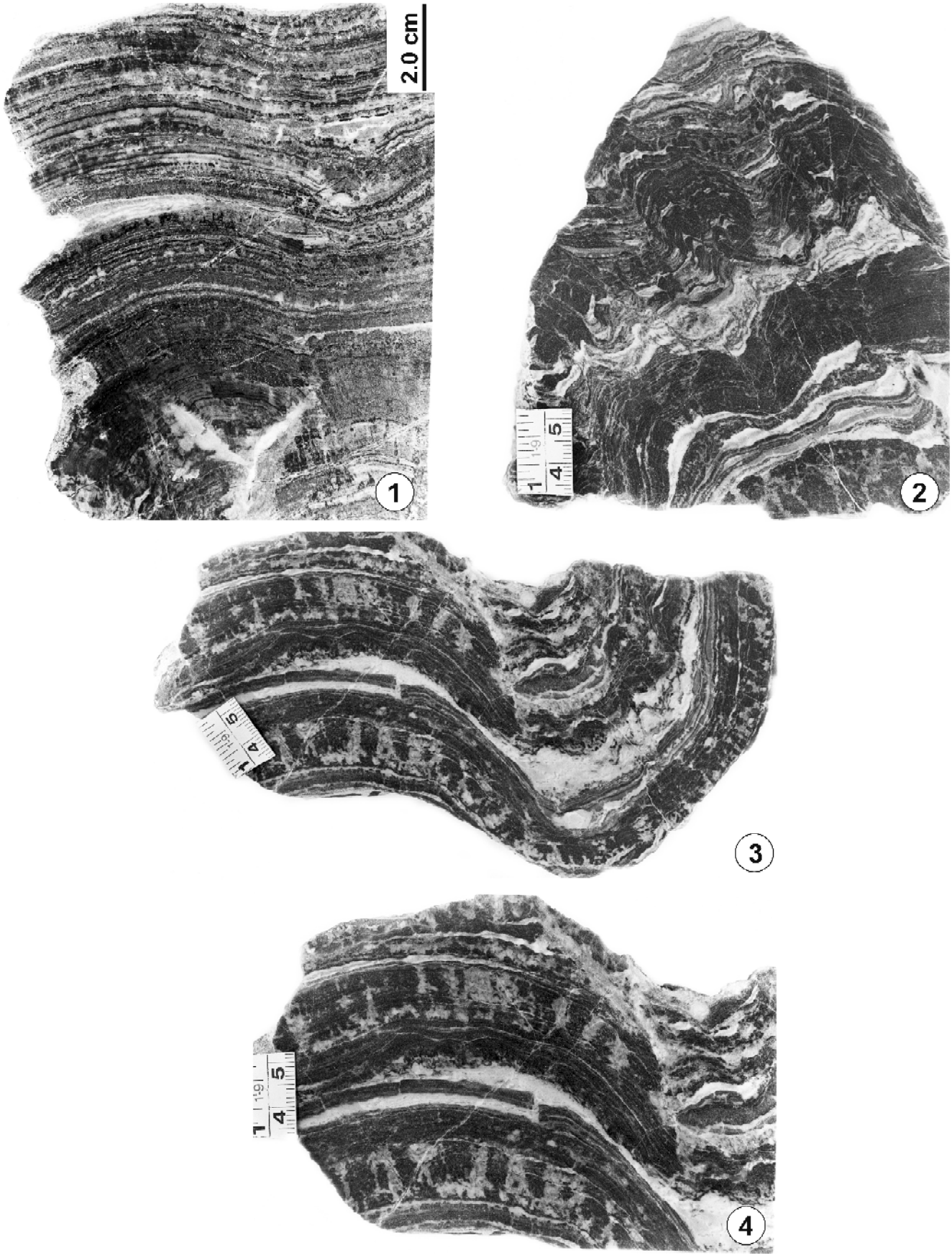



**PLATE 5**

*Diagnosis*—Fan-shaped stromatolite fascicle, bifurcate branching noted, with patch walls, column margins are ragged and uneven, some columns show small bumps and peaks. Laminae show flat to gently convex nature. For further details see Grey 1984, p. 44-45.

*Remarks*—Specimens from Kaladgi Basin conform to the diagnosis for *Yandilla meekatharrensiss* Grey 1984. In field they are well preserved. Stromatolites occur in domical bioherms about 5 m in diameter and about 2 m high. The stromatolites are characterized by turbinate columns with irregular margins with peaks, bumps and bridges. The vertical section of the stromatolite is fan-shaped with a broad top to the column. The microstructure is vermiform.

*Distribution and age*—India: Bamanbundi and Lakshanhatti Dolomite of Kaladgi Basin, Palaeoproterozoic precise age uncertain.

## DISCUSSION

### Biostratigraphical and palaeoecological significance

The Late Palaeoproterozoic to early Mesoproterozoic stromatolites diversity is not well recorded from the India. However, the stromatolites diversity is well documented in the younger basins, viz. the Vindhyans (Kumar & Misra, 2007; Misra & Kumar, 2005; Sharma, 1996; Sharma & Shukla, 2004; Moitra, 1999) and biostratigraphic usefulness of these assemblages are well demonstrated (Misra, 2004; Misra & Kumar, 2005; Pandey, 2011). The main significance of the stromatolites recorded in the paper lies in demarcating the outcrops of the Chitrabhanukot Dolomite Member and Chikshellikeri Limestone Member of the Bagalkot Group. These stromatolites are comparable at group-level with taxa occurring in the Earaheedy Group and Glengarry Group, Western Australia.

The groups *Yelma, Pilbaria* and *Ephyaltes* have widespread distribution in the Palaeo-Mesoproterozoic successions. Grey (1994a) proposed a com. nov. *Asperia digitata* (=*Yelma digitata*) and concluded that both *Pilbaria* and *Asperia* are globally distributed and commonly found in the same formation. *Pilbaria perplexa* and *Asperia ashburtonia* are found in Duck Creek Dolomite (2.0 Ga) in the Wyloo Group of Western Australia (Walter, 1972; Grey & Thorne, 1985; Grey, 1985). *Pilbaria perplexa* and *Asperia aspera* occur in the Rocknest Formation (1.89 Ga) of the Epworth Group in the Wopmay Oregen of northern Canada (Semikhatov, 1978). *Pilbaria perplexa* has also been recorded from the Hutuo Group (2.5-1.8 Ga), China (Zhu *et al.,* 1987). The Group *Pilbaria* with other forms have been recorded from Schmidtsdrift Formation in the Transvaal Group (2.5 Ga), South Africa (Bertrand-Sarfati & Eriksson, 1977). Incidentally, both *Pilbaria* and *Asperia* (=*Yelma*) occur in the Chitrabhanukot Dolomite Member of the Bagalkot Group. The occurrence of these two forms at the global level is suggestive of Palaeoproterozoic age (Orosirian to Statherian) with the exception of South African occurrence.

In Australia, *Asperia* (=*Yelma*) and *Pilbaria* occur in interbedded successions comparable to upward shallowing cycles; Pilbariform stromatolites occur in a lagoonal phase whereas Asperiform stromatolites occur in an emergent condition (Grey, 1994a). In Yargatti area, 11 cycles of *Asperia digitata* (=*Yelma digitata*) are reported in the Chitrabhanukot Dolomite Member (Sharma *et al.,* 1998) typically the stromatolites in every cycle show emergent conditions as reflected by the presence of vugs in the microstructure studies of the stromatolites. Similar upward-shallowing cycles have been reported in the Rocknest Formation (Hoffman, 1975; Grotzinger, 1986), later studies reported the occurrence of these two forms of stromatolites but their relationship was not established. In the Earaheedy Basin, bioherms of *Ephyaltes edingunnensis* are closely associated with *Pilbaria-Asperia*

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**PLATE 6** →

*Ephyaltes edingunnensis* (Grey, 1994a).

1. Polished slab of *Ephyaltes edingunnensis* showing a column of laterally linked conical stromatolite, Specimen No. BSIP-39975.
2. Polished petrographic thin section showing microstructure of the stromatolite column, thin section no. BSIP-14523.

3, 4, 5. Polished slabs of *Yandilla meekatharrensis* (Grey, 1984)

3. A polished slab showing a part of column and irregular margins, Specimen No. BSIP-39976.
4, 5. Polished slab showing stratiform lamination pattern in the upper part of the column, Specimen No. BSIP-39977.

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**PLATE 7** →

*Kussoidella karalundienis* (Grey, 1994b) and *Pilbaria deverella* (Grey, 1984).

1. Polished slab of *Kussoidella karalundienis* showing cylindrical, erect columns with pointed ends and gentle swelling, Specimen No. BSIP-39968.

2-6. Polished slabs of *Pilbaria deverella* showing column shapes in vertical and transverse plan views.

2. Showing smooth columns in vertical plan view, Specimen No. BSIP-39971.
3. Cylindrical shapes of the column in longitudinal section, Specimen No. BSIP-39974.
4, 5. Concave to parabolic laminae pattern in the column, showing wispy microstructure, Specimen No. BSIP-39972.
6. Plan outline of the columns as oblong to circular, Specimen No. BSIP-39973.

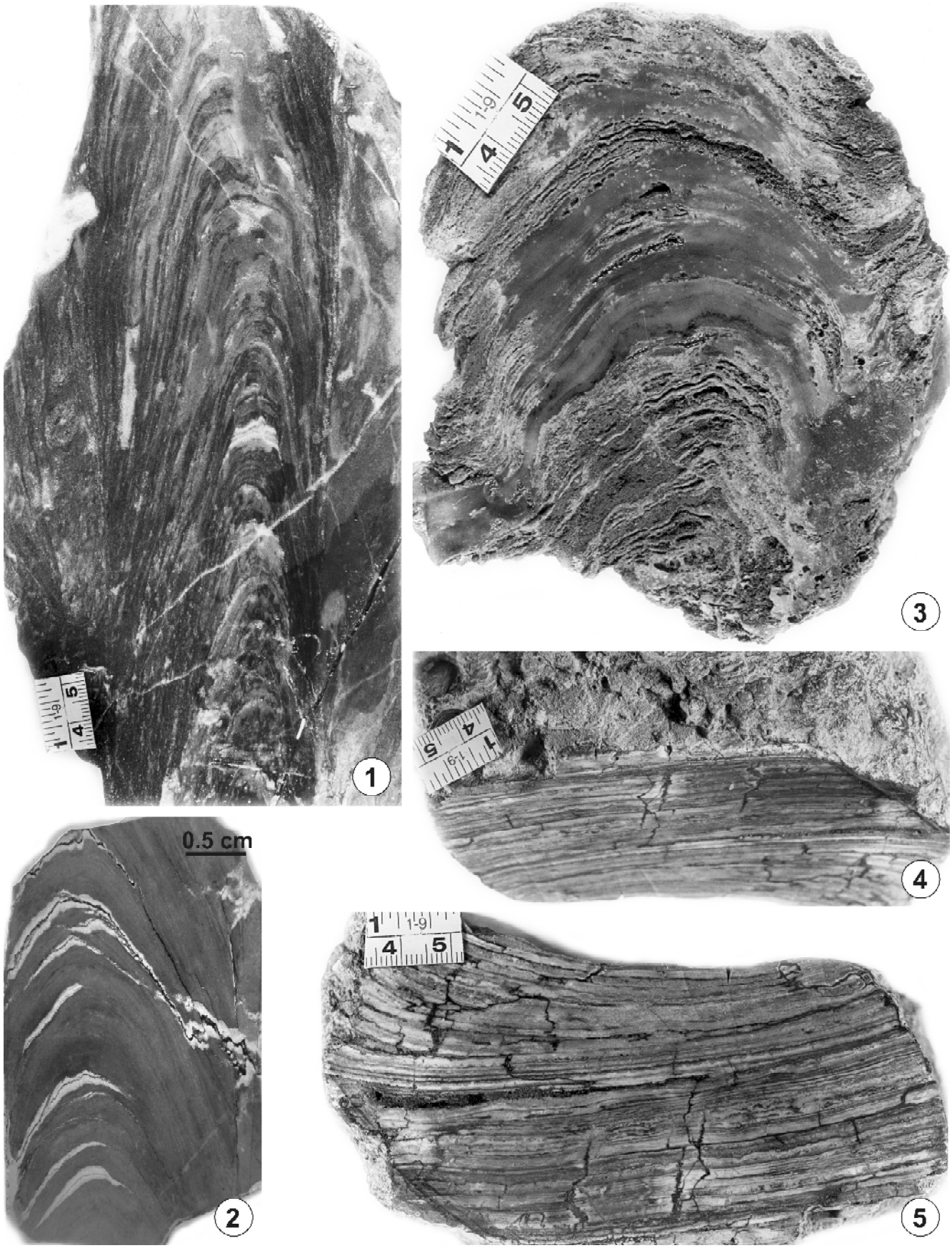


**PLATE 6**

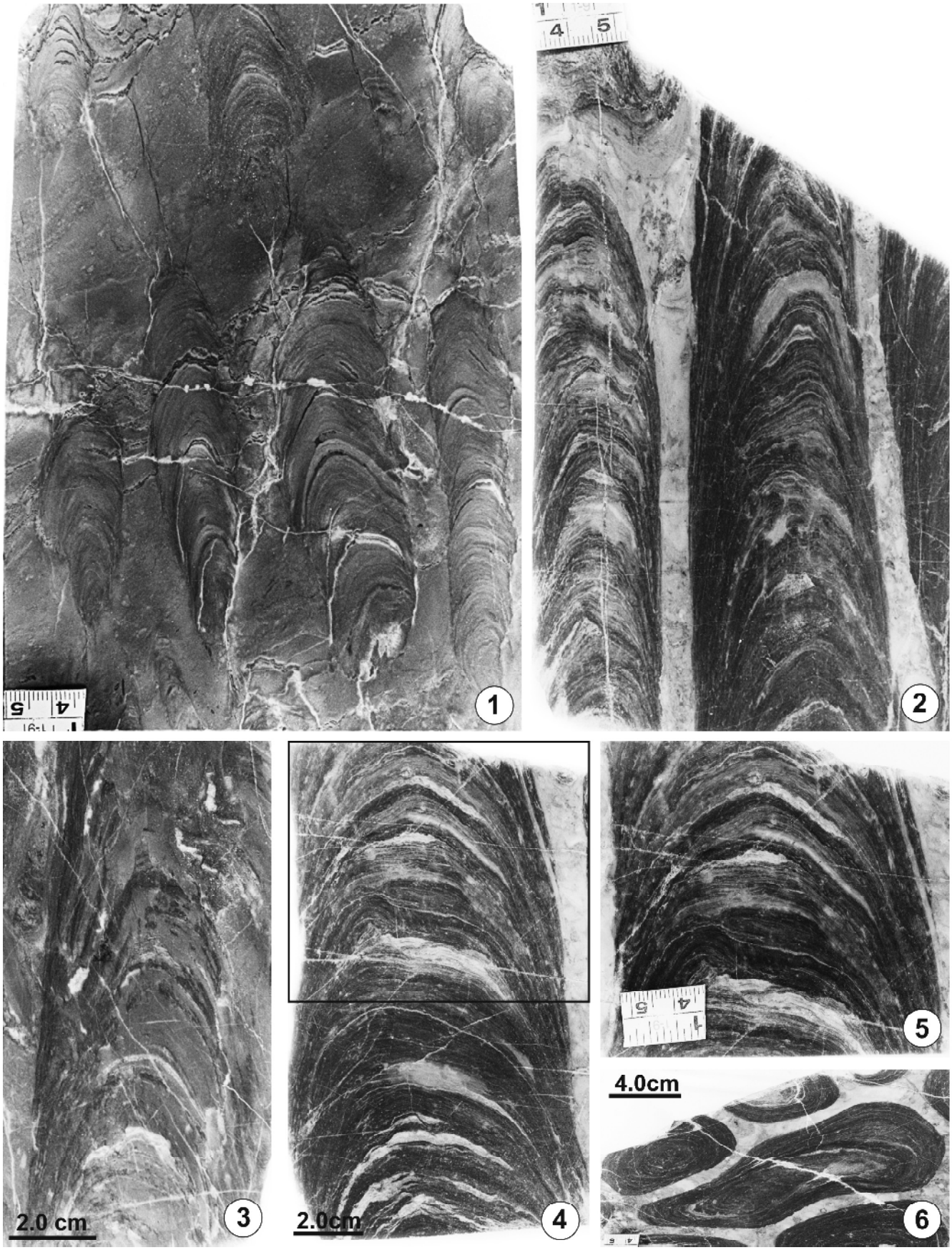


**PLATE 7**

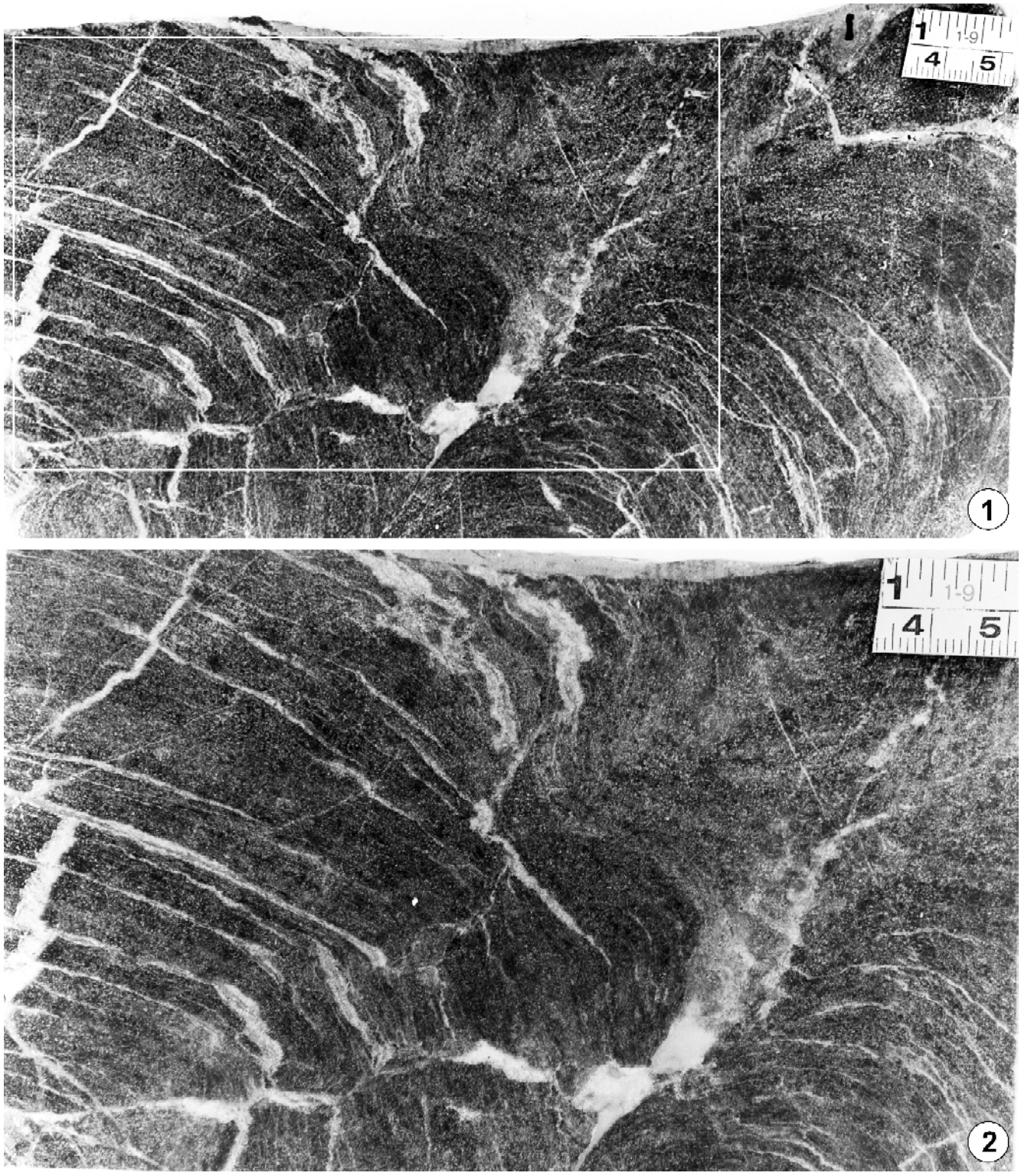

**PLATE 8**

*Yandilla meekatharrensis* (Grey, 1984).

1, 2. Polished slabs of the stromatolite columns showing progressively expanding upward column, gradual enlarged view shown in figure 2, Specimen No. BSIP-39978.

Complex in the upward-shallowing cycles with periodic localized subsidence (Grey, 1994a). Similar association has been noted in the Bagalkot Group where *Ephyaltes edingunnensis* has been recorded in the same succession where *Pilbaria* and *Asperia* are found. Such occurrence of coniform columnar stromatolite in the Bagalkot Group can also be interpreted in terms of localized subsidence.

## CONCLUSIONS

The present study demonstrates that stromatolite's diversity is restricted to a few taxa and confined to the Chitrabhanukot Dolomite Member of the Bagalkot Group of the Kaladgi Supergroup. The relationship between stromatolite taxa and depositional environment can be established in the well exposed sections. In the absence of any definitive geochronological data, stromatolitic assemblage of the carbonate horizons of the Chitrabhanukot Dolomite and their correlation with other global occurrences has been used to establish the biostratigraphic correlation. Occurrence of *Asperia digitata* (=*Yelma digitata*), a typical Orosirian (Late Palaeoproterozoic) stromatolite, north of Yargatti region in Belgaum District of Karnataka helps constrain the age of Bagalkot Group. On this basis, Sharma *et al.* (1998) have indicated that the sedimentation started in the Bagalkot Group around 1800 Ma. Independent geochemical studies based on carbon and strontium isotopic compositions of carbonates and shales support Late Palaeoproterozoic to the Early Mesoproterozoic age for the deposition of the Bagalkot Group of the Kaladgi Basin (Padmakumari *et al.,* 1998; Sambasiva Rao *et al.,* 1999).

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## REFERENCES

Bertrand-Sarfati J & Eriksson KA 1977. Columnar stromatolites from the Early Proterozoic Schmidtsdrift Formation, Northern Cape Province South Africa-Part 1, Systematic and diagnostic features. Palaeontologia Africana 20: 1-26.

Blake PH & Stewart AJ 1992. Stratigraphic and tectonic framework, Mount Isa Inlier. *In*: Stewart AJ & Blake OH (Editors)—Australian Geological Survey Organization Bulletin 243: 1-11.

Butin RV 1966. Fossil algae from the Proterozoic of Karelia. Karel'skoy kninzhnoy Izdatel'stvo, Petrozavodsky 34-63 (in Russian).

Cao R & Zhao W 1977. Stromatolites from the Sinian Suberathem in China in East Liaoning and their stratigraphic significance. In: Selected works for a scientific symposium on Iron Geology of China, sponsored by Academia Sinica, 1977, Stratigraphy and Palaeontology: 61-86 (in Chinese).

Cao R & Zhao W 1981. Sequence of Precambrian stromatolite assemblages in North China. Acta Palaeontologica Sinica 20: 508-517.

Chandrasekhara Gowda MJ & Govinda Rajulu BV 1980. Stromatolites of the Kaladgi Basin and their significance in Palaeoenvironmental studies. Geological Survey of India Miscellaneous Publication 44: 220-239.

Cloud PE & Semikhatov MA 1969. Proterozoic stromatolite zonation. American Journal of Science 267: 1017-1061.

Crick IH, Muir MD, Needham RS & Roarty MJ 1980. The Geology and Mineralization of the south Alligator Valley Uranium Field. Proceedings of International Uranium Symposium on the Pine Creek Geosyncline, International Atomic Energy Agency Vienna 273-285.

Donaldson JA 1976. Aphebian stromatolites in Canada: implication for stromatolite zonation. *In*: Walter MR (Editor)—Stromatolites, Development in Sedimentology 20, Elsevier, Amsterdam: 371-580.

Foote RB 1876. Geological features of the South Mahratta Country and adjacent district. Memoirs of the Geological Survey of India 12: 70-138.

Govinda Rajulu BV & Chandrasekhara Gowda MJ 1966. Stromatolites limestones from the Kaladgi Formation around Lokapur, Bijapur District, Mysore State. Journal of Mysore University, Section B 20: 7-16.

Govinda Rajulu BV & Chandrasekhara Gowda MJ 1968. Algal stromatolitic from the southwestern part of Kaladgi Basin, Lokapur, Mysore State, India. Journal of Sedimentary Petrology 38: 1059-1064.

Govinda Rajulu BV & Chandrasekhara Gowda MJ 1975. Stromatolitic from the Kaladgi (Precambrian) Formation, Chitrabhanukot, Bijapur District, Karnataka State, India. *In*: Naganna C (Editor)—Studies in Precambrians, Prof C Pichamuthu Commemorative Volume, Bangalore University, Bangalore: 263-282.

Grey K 1984. Biostratigraphic studies of stromatolites from the Proterozoic Earaheedy Group, Nabberu Basin, Western Australia. Geological Survey of Western Australia Bulletin 130: 1-123.

Grey K 1985. Stromatolites in the Proterozoic Duck Creek Dolomite, Western Australia. Geological Survey of Western Australia, Professional Paper for 1983: 94-103.

Grey K 1994a. Stromatolites from the Palaeoproterozoic Earaheedy Group, Earaheedy Basin, Western Australia. Alcheringa 18: 187-218.

Grey K 1994b. Stromatolites from the Palaeoproterozoic (Orosirian) Glengarry Group, Glengarry Basin, Western Australia. Alcheringa 18: 275-300.

Grey K & Thorne AM 1985. Biostratigraphic significance of stromatolites in upward shallowing sequences of the early Proterozoic Duck Creek Dolomite, Western Australia. Precambrian Research 29: 183-206.

Grotzinger JP 1986. Cyclicity and Paleoenvironmental dynamics, Rocknest platform, northwest Canada. Geological Society of America Bulletin 97: 1208-1231.

Hoffman PF 1975. Shoaling - upward shale-to-Dolomite cycles in the Rocknest Formation, Northwest Territories, *In:* Ginsburg RH & de Klein GV (Editors)—Springer-Verlag, New York: 257-265.

Hofmann HJ 1969. Attributes of stromatolites: Geological Survey of Canada paper 69-39, 77p

Hofmann HJ & Jackson JD 1987. Proterozoic ministromatolites with radial fibrous fabric. Sedimentology 34: 963-971.

Jahn BM, Bertrand-Sarfati J, Morin N & Mace J 1990. Direct dating of stromatolitic carbonates from the Schmidtsdrif Formation (Transvaal Dolomite), South Africa, with implications on the age of the Ventersdorp Supergroup. Geology 18: 1211-1214.

Jayaprakash AV 2007. Purana Basins of Karnataka. Memoirs of the Geological Survey of India 129: 1-135.

Jayaprakash AV, Sundaram V, Hans SK & Mishra RN 1987. Geology of the Kaladgi-Badami Basin, Karnataka. Memoirs Geological Survey of India 6: 201-226.

Kale VS, Patil-Pillai S, Nair-Pillai S, Phansalkar VG & Peshwa VV 1999. A process responsive lithostratigraphic classification of the Kaladgi Basin, Karnataka. *In*: Field workshop on Integrated Evaluation of the Kaladgi and Bhima basins. Geological Society of India: 4-7 (Abstract).

Kale VS & Phansalkar VG 1991. Purana Basins of Peninsular India: a review. Basin Research 3: 1-36.

Kumar S & Misra Y 2007. The Palaeoproterozoic stromatolite Group *Mistassinia* from the Kheinjua Formation, Semri Group, Chopan area, Sonbhadra District, Uttar Pradesh. Journal of the Palaeontological Society of India 52: 97-102.

Misra Y 2004. Stromatolite biostratigraphy of Vindhyan Basin. Ph.D. thesis, University of Lucknow, 149p (Unpublished).

Misra Y & Kumar S 2005. Coniform stromatolites and the Vindhyan Supergroup, central India: implication for basinal correlation and age. Journal of the Palaeontological Society of India 50: 153-167.

Moitra AK 1999. Biostratigraphic study of stromatolites and microbiota of the Chhattisgarh Basin, MP, India. Palaeontologia Indica New Series 51: 1-95.

Needham RS, Stuart-Smith PG & Page RW 1988. Tectonic evolution of the Pine Creek Inlier, Northern Territory. Precambrian Research 40/41: 543-564.

Padmakumari VM, Sambasiva Rao VV & Srinivasan R 1998. Model Nd and Rb-Sr Ages of the shales of the Bagalkot Group, Kaladgi Supergroup, Karnataka. National Symposium on Late Quaternary Geology and sea level changes. Cochin University, Kochi p.70.

Page RW 1981. Depositional ages of the stratiform base metal deposits at Mount Isa and McArthur Rivers, Australia, based on U-Pb zircon dating of concordant tuff horizons. Economic Geology 76: 648-658.

Pandey SK 2011. Biozonation and correlation of Neoproterozoic Bhander Group, central India. Ph.D. thesis, University of Lucknow, 131p. (Unpublished).

Patil-Pillai S & Kale VS 2011. Seismites in the Lokapur Subgroup of the Proterozoic Kaladgi Basin, south India: A testimony to syn-sedimentary tectonism. Sedimentary Geology 240: 1-13.

Pidgeon RT & Horowite RC 1991. The origin of olistoliths in Proterozoic rocks of the Ashburton Trough, Western Australia, using zircon U-Pb isotopic characteristics. Australian Journal of Earth Sciences 38: 55-63.

Preiss WV 1976. Basic field and laboratory methods for the study of stromatolites. *In*: Walter MR (Editor)—Stromatolites, Development in Sedimentology 20, Elsevier Amsterdam: 5-13.

Raaben ME, Sinha AK & Sharma M 2001. Precambrian stromatolites of India and Russia. BSIP Monograph - 3, Birbal Sahni Institute of Palaeobotany, Lucknow 125 pp.

Riding R & Sharma M 1998. Late Palaeoproterozoic (~ 1800-1600 Ma) stromatolites, Cuddapah Basin, southern India: cyanobacterial or other bacterial microfabrics? Precambrian Research 92: 21-35.

Sambasiva Rao VV, Parthasarthy G, Padmakumari VM & Srinivasan R 1999. Shales of the Proterozoic Bagalkot and Bhima groups, southern India - A mineralogical and chemical appraisal. *In:* Field workshop on Integrated Evaluation of the Kaladgi and Bhima basins. Geological Society of India: 33-35 (Abstract).

Sathyanarayan S, Arneth JD & Schidlowski M 1987. Stable isotope geochemistry of sedimentary carbonates from the Proterozoic Kaladgi, Badami and Bhima groups, Karnataka, India. Precambrian Research 37: 247-256.

Semikhatov MA 1978. Some Aphebian carbonate stromatolites of the Canadian Shield. *In*: Raaben ME (Editor)—Lower boundary of the Riphean and stromatolites of the Aphebian. Trudy Geologisckeskogo Instituta, Akademiya Nauk SSSR, 312: 111-147 (In Russian).

Sharma M 1996. Microbialites (Stromatolites) from the Mesoproterozoic Salkhan Limestone, Semri Group, Rohtas, Bihar: Their systematics and significance. Memoir Geological Society of India 36: 167-196.

Sharma M & Shukla M 1998. Microstructure and microfabric studies of Palaeoproterozoic small digitate stromatolites (Ministromatolites) from the Vempalle Formation, Cuddapah Supergroup, India. Journal of the Palaeontological Society of India 43: 89-100.

Sharma M & Shukla M 2004. Studies in Palaeo-Mesoproterozoic stromatolites from the Vempalle and Tadpatri formations of Cuddapah Supergroup, India. *In*: Srivastava PC (Editor)—Vistas in Palaeobotany and plant morphology: Evolutionary and environment perspectives. UP offset, Lucknow, India: 1-25.

Sharma M, Nair S, Patil S, Shukla M & Kale VS 1998. Occurrence of tiny digitate stromatolite (*Yelma digitata* Grey, 1984), Yargatti Formation, Bagalkot Group, Kaladgi Basin, Karnataka, India. Current Science 75: 360-365.

Venkatachala BS & Rawat MS 1973. Organic remains from the Bhima Basin and remarks on the age of Vindhyans and subsurface sediments in the Ganga Valley. Geophytology 2: 107-117.

Viswanathiah MN & Chandrasekhara Gowda MJ 1970. Algal stromatolites from the Kaladgi (Precambrian) formations near Alagundi, Bijapur District, Mysore State. Journal of the Geological Society of India 11: 378-385.

Viswanathiah MN & Chandrasekhara Gowda MJ 1975. Algal stromotlies in high calcium limestone from Kaladgi Group (Precambrian) near Kuligod, Belgaum District, Karnataka. Proceedings of the 4th Colloquium of Indian Micropalaeontology and Stratigraphy, ONGC, Dehradun: 201-206.

Viswanathiah MN, Govinda RBV & Sathyanarayan S 1964. Stromatolitic limestones in the Lower Kaladgis (Precambrian), Mysore State. Bulletin of the Geological Society of India 1: 25-27.

Viswanathiah MN & Sreedhara MTR 1972. Occurrence of algal stromatolites from Lower Kaladgi Limestones (Precambrian) near Nidgundi, Bijapur District, Mysore State. Current Science 41: 171-172.

Viswanathiah MN, Venkatachalapathy V & Khadeer A 1976. Microfossils from the Badami Group, Karnataka, south India. Journal of the Geological Society of India 17: 340-343.

Vlasov FY 1977. Precambrian stromatolites from the Satka Formation in the Southern Urals. Trudy Institut Geologii i Geokhimikha, Sverdlovsk Ural'skii Nauchnii Tsentr, Academiya Nauk SSR 126: 101-128.

Walter MR 1972. Stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian: Special Papers in Palaeontology no.11.

Zhu S 1982. An outline of studies on the Precambrian stromatolites of China. Precambrian Research 18: 367-396.

Zhu S, Xu C & Gao J 1987. Early Proterozoic stromatolites from Wutai Mountain and its adjacent regions. Bulletin of the Tianjin Institute of Geology and Mineral Resources 17, Chinese Academy of Geological Sciences, Beijing: 1-221 (in Chinese).