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Stromatolites studies in India: An overview

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ABSTRACT

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Indian subcontinent with extensive Archaean and Proterozoic sedimentary successions has number of stromatolites occurrences which offers avenues of stromatolites studies. The present paper traces the efforts, strengths and gaps in stromatolites studies in India and summarizes significant Indian contributions made in the past in the country and briefly mentions the global advancements made in this field. The overview covers the period of active research from 1908-2005.

Key-words—Stromatolites, Precambrian, India.

भारत में स्ट्रोमेटोलाइट का अध्ययन : एक सर्वेक्षण

मुकुंद शर्मा

सारांश

भारतीय उपमहाद्वीप में विस्तृत आर्कियन एवं प्रोटीरोजोइक अवसादी शैल अनुक्रमों में अनेक स्ट्रोमेटोलॉइटी संरचनाए पाई जाती हैं जो कि उनके अध्ययन के अवसर प्रदान करती हैं। वर्तमान शोध पत्र भारत में स्ट्रोमेटोलॉइट अध्ययन के प्रयासों, उनके ठोस योगदान एवं खामियों का पता लगाने का प्रयास करता है तथा विगत वर्षों में इस क्षेत्र में वैश्विक अग्रगामी सुधारों की चर्चा करता है। इस सर्वेक्षण में 1908-2005 के मध्य किए गए शोध सम्मिलित हैं।

संकेत-शब्द—स्ट्रोमेटोलॉइट, पूर्वकैम्ब्रियन, भारत।

INTRODUCTION

STROMATOLITES commonly found in carbonate sequences of Precambrian are one of the evidences of Precambrian life. They are varied, found in abundance and occasionally associated cherts with them yield microscopic fossils. These microfossils are a great source of our knowledge of early life. Stromatolites have also been used in biostratigraphy. In India, structures similar to presently considered stromatolites were noted by McClelland in early ninetieth century (1834, recorded as ring-like features). Subsequently, King (1872, p. 189) reported them as peculiar laminated and segregated limestone (Fig. 1a) where as Auden (1933, pl. 1, Fig. 2) photo-documented and recorded such structures in Vindhyan Basin only as spheroidal bodies (Fig. 1b). No systematic studies were undertaken until sixties of the last century. Investigations of the late sixties revealed the records of extensive stromatolites occurrences in the Precambrian rocks of India. Continued search led to discoveries of stromatolites even in younger Gondwana sediments of the marginal marine Talchir Formation (Pandya, 1987), later inferred to be of fresh water origin (Ghosh *et al.*, 2001). In spite of the extensive occurrences of stromatolitic structures in India and also in other parts of the world, no efforts were made to study them systematically in the first half of the twentieth century. The purpose of the present paper is to trace the stromatolites' studies in India and how Indian workers responded to the developments taking place in the field of stromatolites studies in other parts of the world. It also summarizes the Indian contributions in this field of study.

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STROMATOLITES' STUDIES

The study of laminated spheroidal and columnar structures *sensu* stromatolites is almost a century old. Ernst Kalkowsky (1908) coined the two-terms "stromatoid" and "stromatolith" (words originated from Greek *stromat* means to spread out, Latin *stroma* means bed covering and Greek *lithos* means stone) along with ooid and oolith but without comprehensive definition of stromatolites. Since 1908, stromatolites have been recorded in almost every Precambrian sedimentary terrain on all the continents except the Antarctica. Besides Precambrian (Archaean and Proterozoic), these structures are also reported from a few Phanerozoic sedimentary deposits. At present, the Shark Bay and the Hamelin pool in Australia, Yellowstone National Park, Salt Lake City in Western United States, Baja California in North America, Solar Lake and Ras Muhammed Pool in Sinai desert, Dead Sea and Lake Hoare in Antarctica (Parker & Simmons, 1981) are such spots where stromatolites very similar to the ancient ones grow even today. Demonstrably we can divide the entire span of stromatolites' studies in the last century in three distinct periods: firstly, the investigative phase of studies 1900-1950 AD, secondly stabilizing phase 1951-1975 AD and lastly swinging phase of disinterest/interest in the 1976-2000 AD. Last five years (2000-2005) have once again seen resurgence of interest in the stromatolites' studies.

INDIAN SCENARIO

In India, the early reports of stromatolites were mainly those which described them from the Cuddapah and Kaladgi supergroups as 'algal' limestone (Srinivasa Rao, 1943, 1944, 1949; Vaidyanadhan, 1961; Viswanathiah & Govindarajulu, 1963; Viswanathiah &Aswathanarayana Rao, 1967). The first report describing *sensu stricto* stromatolite was from the Marwar Supergroup (Khilnani, 1964), subsequently, a few concerted attempts of taxonomical descriptions were made by Valdiya (1969, 1989), Kumar (1976), Chandrasekhar Gowda and Govind Rajalu (1980), Tiwari, (1989), Sharma (1996) and Moitra (1999). The other frontiers of investigation, viz. definition, classification, geochemistry and isotopic studies, as attempted in different parts of the world, were not addressed with same vigour in India.

Issues and opportunities

In spite of the multifaceted aspects of studies in the past, stromatolites, even at present, are as much enigmatic as they were in the early part of the last century. Walter (1976, p. 1) in his book '*stromatolites*' commented that Kalkowasky *'coined and defined the word stromatolith, yet there is increasing controversy and confusion as to its use'*. On the global scale, the debate concerning their definition (microbial and laminated/genetic/descriptive), nature (biogenic/abiogenic), formation (accretion/precipitation), causative organisms (bacteria/cyanobacteria; prokaryotes/eukaryotes), status (index-fossil/general-fossil), biostratigraphic potential (mileposts), classification (binomial Linnaean system/sedimentary structures/geometric nomenclature) and economic importance (primary/secondary enrichment), depositional environment indicator (dipsticks/real/proxy) etc., are far from resolved. Even the understandings about the ascent and decline (rise and fall) of stromatolites in the earth history are shrouded in the hypotheses, assumptions and premises. A few attempts have demonstrated the usage of modern stromatolites in understanding the Sun-Earth-Moon dynamics including measurement of the Earth's rotation (Awramik & Vanyo, 1986; Sheldon, 1989). Similar attempts can be made on stromatolites of different geological ages. These studies are possible only

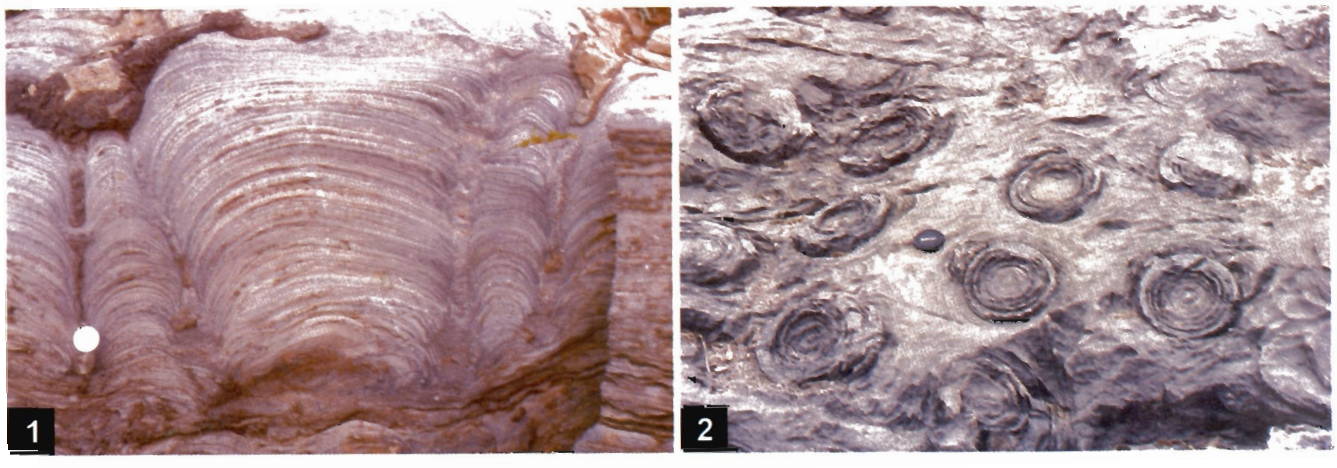

Fig. 1—1 Stromatolite from the Vempalle Formation, Cuddapah Supergroup, earlier described by King (1872) as peculiar laminated and segregated limestone; 2. Stromatolite from the Fawn Limestone Formation, Vindhyan Supergroup, earlier described by Auden (1933) as spheroidal limestone.

on undisturbed and extensive exposures. Incidentally such exposures are easily accessible in different parts of India, where these relationships and other hypothesis can be tested (Sharma, 2003). In recent years, few researchers have recorded secular and temporal variations in the stable isotopic composition of the stromatolite bearing carbonate rocks while others have attempted to estimate the age of the stromatolites by dating the host carbonates with the help of lead isotopes. Reports of structures similar to the algal laminites on the surface of the Mars has provoked researchers related to life on that planet.

Indian status—Observations made by the geologists in the nineteenth century records peculiar structures in the carbonate rocks. These descriptions at best are considered passing references to *sensu-stricto* stromatolites. Since, the involved scientific issues are wide and open, opportunity for detailed studies are also large. In Indian scenario, stromatolites are mainly described under short reports and only rarely these are subjected to description with taxonomic details. Many seminal papers on the definition of the stromatolites testify that the cloud of uncertainty surrounds its nomenclature (Kalkowsky, 1908; Awramik & Margulis, 1974; Krumbein, 1983; Burne & Moore, 1987; Riding, 1999). Indian workers, on this issue, unfortunately, have made no contribution. The genesis of stromatolites has also been debated at several levels and most of the stromatolite researchers agree with Hoffman (1973) that "something that haunts geologists working on ancient stromatolites is the thought that they might not be biogenic at all." In many cases, biogenic origin has been established (Grey, 1984; Sharma & Shukla, 1998; Riding & Sharma, 1998; Batchelor *et al.*, 2004, 2005), while, in some other cases no proof could be found (Hofmann & Jackson, 1987; Grotzinger & Rothman, 1996; Sharma & Sergeev, 2004). In order to classify stromatolitic structures, researchers have proposed a number of schemes. Two of them proposed by the Indian researchers (Bhattacharya, 1980; Raaben & Sinha, 1989) are worth mentioning because of their novel approach. Classification scheme of Raaben and Sinha (1989) has been further refined by Semikhatov and Raaben (2000) and that is presently *in vogue*. Hofmann (1976) and Zhang and Hofmann (1982) had applied statistics and computer programs for morphometric analysis of stromatolites. This technique has been found useful in stromatolite biostratigraphy. Banerjee and Chopra (1986) have successfully used this technique in India.

Direct dating of stromatolitic carbonates is a good geochronological tool (Moorbath *et al.*, 1987; Jahn & Cuvellier, 1994). Banerjee and Russell (1993) presented Pb/Pb dating of Proterozoic rocks of India at the Vindhyan Seminar held at Jadavpur University. Results were unfortunately never published (Banerjee pers. comm. to Sharma), however, the unpublished work is available for consultation (Russell, 1995). There is only one stance in our country where this new technique has been attempted (Zachariah *et al.*, 1999, on Cuddapah stromatolites). Geochemical analysis of stromatolites for understanding the marine chemistry and the environment is being extensively used. Such analyses were initiated in late seventies (Schidlowski *et al.*, 1975, 1976). In this regard, a few attempts were made in India as well (Banerjee, 1971; Sathyanarayan *et al.*, 1987; Kumar, 1988; Kumar & Tewari, 1995; Kumar *et al.*, 2002).

Geomicrobiology has opened a new vista in deciphering the role of microbes in enrichment of minerals in the earth's history. A lot of efforts have been made towards the understanding the role of microbes in enrichment of phosphorites, magnesite and uranium. These economic minerals are found in abundance in association of stromatolites in Indian Precambrian sequences. Even in some cases, the enrichment of base-metal deposits have also been attributed to the stromatolites (Verma, 1980). The Indian researchers have made significant contributions in understanding the phosphorite genesis and role of microbes. The phosphorite occurrence in association with stromatolites is comprehensively studied in the Aravalli rocks of Rajasthan (Banerjee, 1971; Chauhan, 1973); Bijawars Group in central India (Banerjee, 1982); Tal Group in Garhwal Himalaya (Patwardhan & Ahluwalia, 1973; Patwardhan, 1980; Banerjee *et al.*, 1986), Gangolihat Dolomite, in Uttaranchal (Patwardhan, 1973). The magnesite deposits associated with stromatolites are recorded in the Jammu Limestone (Raha, 1975) and in the Gangolihat Dolomites (Valdiya, 1968). Strata-bound uranium mineralization in the stromatolite bearing Vempalle Formation of the Cuddapah Supergroup was reported and also its genesis discussed (Vasudev Rao *et al.*, 1989). Although stromatolites are good indicator of depositional environment yet very few serious efforts have been made in using the stromatolites in basinal analyses in India (Chandrasekhara Gowda & Govinda Rajalu, 1980; Banerjee, 1980; Banerjee & Basu, 1980; Raha, 1980; Sarkar & Bose, 1992). If recent publications on stromatolites are any indicator then it is clear that researchers are interested in understanding the marine chemistry, depositionals environment and evolution of atmosphere using isotopic signals in the carbonates hosting the stromatolites (Melezhik & Predovsky, 1989; Melezhik *et al.*, 1997a, b, 1999).

FUTURE RESEARCH DIRECTION

Poor radiometric age constraints of the Precambrian basins of India and extensive exposures of stromatolites in these terrains offer opportunities to conduct varied studies particularly related to the biostratigraphy and geochronology. Sudden glaciations in the earth history and change in atmospheric conditions are recorded in carbonate deposits that are deciphered by various isotopic patterns. Studies of the palaeoclimatic fluctuations on the earth in the past are very much required. Rise and fall of stromatolites are also seen in terms of related mass extinction and advent of new

groups of plants and animals. Breakup of Rodinia and floating Indian mass experienced drastic changes that can be studied by the patterns recoded in extensive carbonates deposited in the Precambrian. Undisturbed exposures available in India can be a target of Sun-Earth-Moon system studies. Global interest in Search for Extraterrestrial Life (SETL) has opened a new vista for stromatolites studies. On earth, stromatolites are repository of primitive benthic microbial remains. In depth knowledge about stromatolites will be useful in Indian endeavours of Search for Extra Terrestrial Intelligence (SETI) and the global mission on Mars as any primitive life forms on other planets is presumed to be similar to early life on the earth. The scopes of studies are in plenty and universities and institutions together can play an important role in initiating these studies.

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