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Bacteria from the Archaean Banded Iron-Formation of Kudremukh region, Dharwar Craton, South India

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Scanning electron microscopic study of the Archaean (> 2.6 Ga old) banded iron-formation of the Bababudan Group, Dharwar Supergroup reveals the presence of coccoid and rod-shaped bacteria in syngenetic pyrite grains of the Kudremukh iron-formation. These resemble sulphur reducing bacteria.

Key-words—Bacteria, Banded Iron-Formation, Dharwar Craton, Archaean (India).

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साराँश

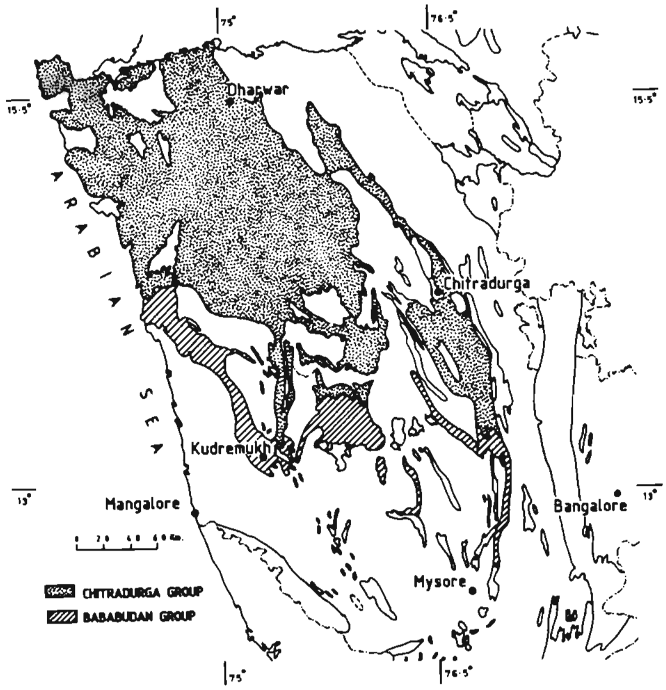
दक्षिण भारत में धारवाड़ क्रेटन के कुद्रेमुख क्षेत्र की आर्कियन युगीन पट्टित लौह शैलों से जीवाणु

बेंगलूर श्रीनिवासा वेंकटाचाला, मुकुन्द शर्मा, आर० श्रीनिवासन, मनोज शुक्ला एवं ऍस० ऍम० नक्वी

धारवाड़ महासमूह में बाबाबुदान समूह के आर्कियन (लगभग 2.6 जी.ए.) युगीन पट्टित शैलों के क्रमवीक्ष्ण सूक्ष्मदर्शीय अध्ययन से कुद्रेमुख लौह शैलों के सहजनित पाइराइट कणों में कोकॉयड एवं दंडाकार जीवाणु मिले हैं। ये जीवाणु गंधक अवकारक जीवाणुओं से सजातीयता व्यक्त करते हैं।

THERE has been intensive research in the area of Early Precambrian (Archaean) palaeobiology during the last two decades (see Schopf, 1975, 1983; Nagy *et al.*, 1983). These studies are oriented towards understanding of the antiquity of biological processes on the Earth and the influence they have had on the evolution of the unique atmospheric, hydrospheric and biospheric environment that characterises our planet. The iron-formations were dominantly deposited during the Precambrian. The magnitude on which they were deposited during the Precambrian has not repeated itself in the later part of Earth's history (James, 1983). The Precambrian iron-formations have been considered as large scale sinks for the oxygen evolved during the early part of the Earth's history (Cloud, 1973, 1976). Photosynthesis and photodissociation are considered to have contributed oxygen to the Earth's ecosystem. It has been known that some bacteria preferentially precipitate iron. In an effort to look for the influence of organic activity on the precipitation of iron, palaeobiologists have searched for organic signatures in the Precambrian banded iron formations (BIF) for over three decades which have yielded fruitful results (Tyler & Barghoorn, 1954; Schopf *et al.*, 1965; Walter & Hofmann, 1983).

Extensive deposition of iron took place during the Archaean in India (see James, 1983; Radhakrishna *et al.*, 1986). These rock formations are well-developed in the Archaean supracrustal belts of South India, where they are designated as Dharwar schist belts (Map 1). The Dharwar sequence has been classified by Swami Nath and Ramakrishnan (1981) into Lower Bababudan Group and Upper Chitradurga Group. Banded iron-formation occurs extensively at the top of the Bababudan Group. The iron-formation of the Bababudan Group is well developed in the Bababudan schist belt and in the Kudremukh-Kodachadri schist belt of the Western Ghat mountain ranges of South India. Deep drilling investigations have been carried out in the Kudremukh area in connection with prospecting for iron ore. Some of the drill cores from these bore-holes have not been affected by the post-Precambrian weathering processes. Examination of some of the unweathered cores have



Map 1—Showing the locality (After Swami Nath *et al*, 1981).

shown the presence of unoxidized pyrite grains within them. One such core from the bore-hole no. 6N/195 taken from a depth of about 63 m during the course of our investigations has disclosed the presence of coccoid and rod-shaped bacteria in pyrite grains.

The petrological work has been carried out by NGRI and the palaeobiological work by the Sahni Institute. Stubs containing the figured bacteria and hand specimens showing isoclinal fold are deposited in the Sahni Institute's repository.

GEOLOGICAL SETTING

The Kudremukh banded iron-formation belongs to the Bababudan Group of Dharwar Supergroup. Available geochronological data (Taylor *et al*, 1984) have substantiated that the Dharwar Supergroup is older than 2.6 Ga confirming their Archaean age. The Kudremukh iron-formation is intimately associated with metabasalts (amphibolites) whose age on the basis of Sm-Nd geochronology has been suggested to be 3.2 ± 0.23 Ga (Drury *et al*, 1983). The rock formations of the Dharwar craton have been metamorphosed under conditions varying from green schist to upper amphibolite facies. The last major episode of metamorphism which has affected the region is considered to be 2.6 Ga. In the Kudremukh region the grade of metamorphism falls in the almandine-amphibolite facies as indicated by the garnetiferous nature of the amphibolites, as well as, the development of cummingtonite, grunerite and magenesio-riebeckite in the iron-formation.

The Kudremukh iron-formation consists of magnetite, variety of iron silicates, iron carbonates and pyrite. The common occurrence of metamorphic silicate minerals in the Kudremukh banded iron-formation along with the presence of relict carbonate bands and pyrite rich layers indicates that the primary iron-formation of Kudremukh consisted of non-oxide type beds (Srinivasan, in preparation). The pyritic and carbonate layers are co-fold with the chert and iron rich layers indicating that they are syngenetic sedimentary bands (Pl. 1, fig. 1). The ore minerals, both the oxides as well as the sulphides, are euhedral and appear to have undergone metamorphic recrystallisation accompanying isoclinal folding in the area. Some of the pyrite grains are broken and sheared. Archaean iron-formations of Kudremukh have been subjected to enrichment of iron by post depositional weathering processes. It is believed by most workers that this enrichment is due to post-Cretaceous lateritic weathering.

TECHNIQUES OF STUDY

Scanning electron microscopy was carried out on pyrite using the following method: The bore-hole samples were washed with dilute hydrochloric acid for 30 seconds and then 2 mm cubes were cut from different portions of the core sample. They were repeatedly washed with reagent grade acetone. The washed pieces were transferred to small glass bottles which were also cleaned with acetone. The bottles containing the specimens were subjected to ultrasonic (Bransonic 221) treatment for six minutes. Then the specimens were repeatedly washed in acetone. After thorough drying they were mounted on the stubs. Gold-Palladium coating was given on a horizontal stage in vacuum evaporator for 165 seconds (on 1.4 KV and 15 MA) resulting into a coating thickness of 34650 Å. The material was then studied on PHILIPS 505 SEM. In all, nine stubs gave positive results. Six of them are preserved at the Birbal Sahni Institute of Palaeobotany, Lucknow.

DESCRIPTION OF BACTERIA

Biota that are included in this communication consist of bacteria embedded in pyrite grains. Bacteria that rest on pyrite as well as recrystallised chert laminae are also recorded. Bacteria found within pyrite are considered syngenetic with the host pyrite as they are seen ingrained in the mineral (Pl. 1, fig. 2). They have also left behind their impressions on the pyrite grains (Pl. 1, figs 3, 4). The bacteria resting on pyrite and chert which are not included in the mineral need further study to authenticate their syngenecity; therefore the latter are only illustrated here (Pl. 1, figs 5, 6) and are excluded from the main discussion of this paper.

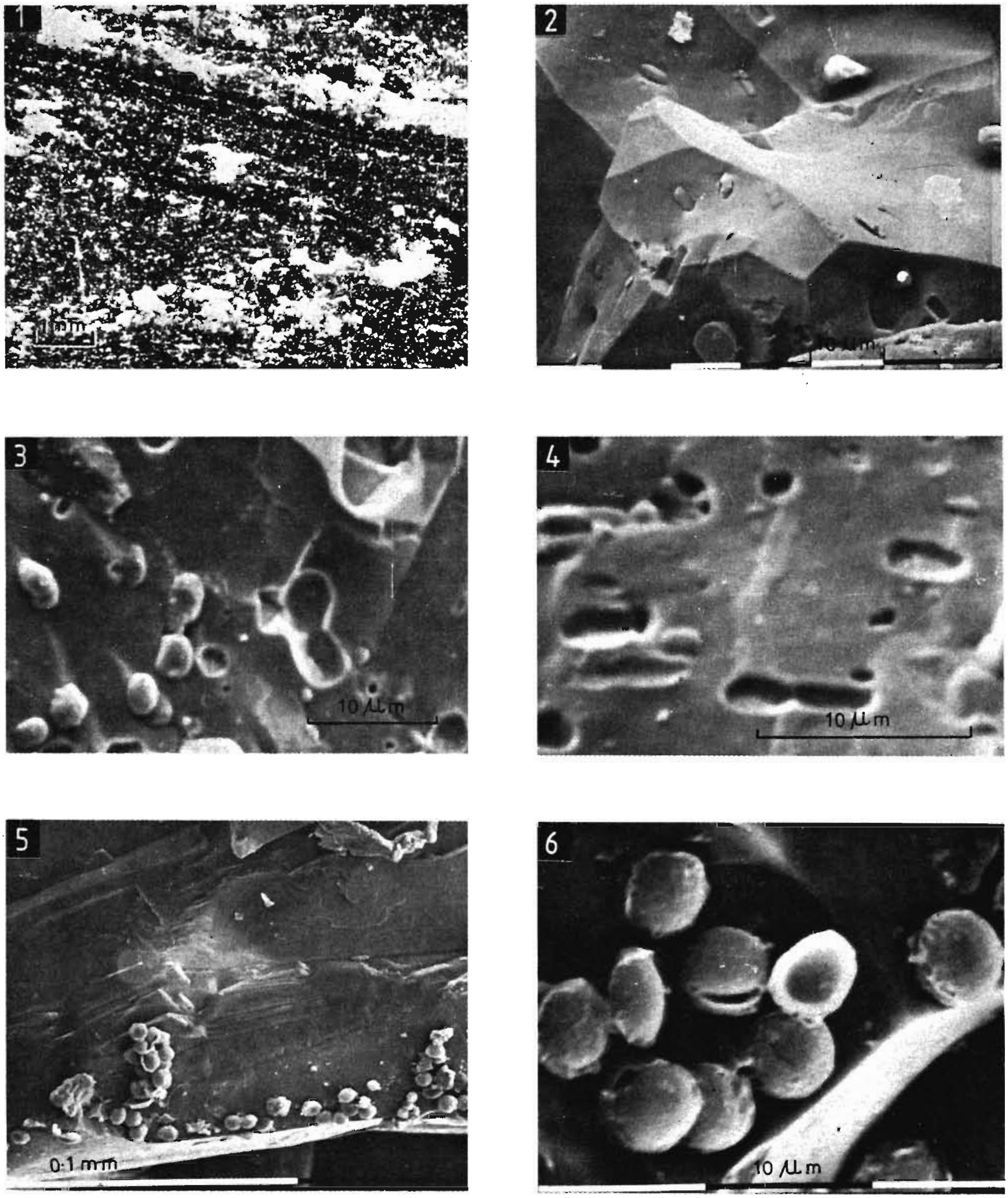


PLATE 1

1. Isoclinal fold in banded iron-formation showing pyrite layers (white) co-folded with iron rich (dark) and silica rich (grey) laminae. Note that some pyrite grains have developed euhedral outline due to metamorphic recrystallisation.
2. Subspherical to elliptical-shaped coccoid bacteria and rod-shaped bacteria embedded in pyrite grain.
3. Coccoid bacteria and their negative impression left on pyrite.
4. Negative impression of rod-shaped bacteria in pyrite. Note constriction in the middle indicating possible division of bacteria.
5. Coccoid bacteria resting on chert-layer.
6. Detail of saucer-shaped bacteria resting on chert. Note the horizontal division of cell and equatorial mucilaginous sheath. These resemble *Thiovulum*.

SYNGENETIC BACTERIA

The syngenetic bacteria are represented by two morphological types (i) coccoid and (ii) rod-shaped.

Coccoid bacteria—The coccoid bacteria are nearly spherical. Their diameter varies from 2-4 μm (Pl. 1, fig 3). They occur as individuals or in group of two or three surrounded by some sheath-like material which may be relicts of original mucilaginous matter (not illustrated here). These sheaths can be studied only under very high magnification. It is proposed to take up such studies later for a detailed account.

Rod-shaped bacteria—The rod-shaped bacteria embedded in pyrite are illustrated in Pl. 1, fig. 4. They are 1-2 μm long and 0.5 μm broad. Some of them show constriction in the middle which may be indicative of division of bacteria.

DISCUSSION AND CONCLUSION

The presence of syngenetic carbonate and pyrite layers in the Kudremukh iron-formation coupled with the ubiquitous development of metamorphic iron silicates suggests that the Kudremukh iron-formation is composed of beds which were deposited as nonoxide type iron-formation. The nature of the Kudremukh iron-formation or atleast some beds in them were therefore of the nature of mixed carbonate and sulphide types. Such iron-formations are known to have accumulated under reducing conditions (James, 1954; Klein, 1983).

The presence of pyrite in non-detrital sedimentary rocks is considered to be a consequence of interaction of microbiologically generated H_2S with iron compound leading to the formation of pyrite (Ehrich, 1981). It has been found that some bacteria, such as the members of the family Siderocapsaceae and *Thiobacillus* play an important role in metabolically concentrating iron compounds.

The morphology and size parameters of the coccoid and rod-shaped bacteria found in the Kudremukh iron-formation compare well with members of Siderocapsaceae and *Thiobacillus* respectively (Bergey's Mannual of Determinative Bacteriology, eds. Breed *et al.*, 1957, pp. 89-217). Some species of *Thiobacillus* are known to thrive and precipitate iron under reducing condition.

Schopf (1965) reported bacteria similar to the Siderocapsaceae from the 2.0 Ga old Gunflint cherts. Occurrence of similar bacteria in the iron-formation of Kudremukh indicates that such bacteria were also present as far back as the Archaean. Elemental analysis of this material is planned as further confirmatory studies.

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