Precambrian Banded Iron Formations of India

Proceedings of the Group Discussion held at Dharwad,
May 20-22nd, 1985

The Annual General Meeting of the Geological Society of India, this year, was held at Dharwad, the seat of the Karnataka University. Synchronizing with this occasion, the Department of Geology, Karnataka University, Dharwad, with the assistance of the University Grants Commission and the Department of Science and Technology, organised a Group Discussion on the Precambrian Banded Iron Formations of India.

The primary object of holding this discussion was to take stock of the present state of knowledge about this unique formation, identify gaps in our knowledge and draw up a future course of action.

INAUGURATION

The Group Discussion was inaugurated by Dr. S. V. P. Iyengar, former Deputy Director General, Geological Survey of India.

In the unavoidable absence of Prof. C. S. Pichamuthu, President of the Geological Society of India, Dr. Kurien Jacob, Vice President of the Society, presided over the function and after a few preliminary remarks about the role played by the Geological Society in promoting Earth Science studies in the country, read extracts from the prepared Presidential Address of Dr. C. S. Pichamuthu. Important points made out in the address were:

Sources of Iron and Silica

A controlling factor involved in the deposition of major iron formations was the composition of ocean waters during the Archaean and early Proterozoic time which differed significantly from that of later eras in pH and oxidation potential. The early oceans were major reservoirs for dissolved iron and silica, the ultimate source of which was volcanic, terrestrial, and even cosmic. Opinions are divided on the question of the mechanisms by which iron and silica were withdrawn from such a reservoir to form BIF.

Either surface weathering or volcanism appeared to be quantitatively inadequate as sources for the major Proterozoic BIFs, though they are probably the ultimate sources for the iron. The low alumina content as opposed to the high iron in BIF is difficult to explain if both are considered as being derived by the weathering of igneous rocks. Alumina must, therefore, be removed or iron added during the conversion of the parent material to iron formation. The problem of alumina disposal is a real one. There being no known silica-secreting procaryotes, and no probable eucaryotes older than about 2000 m.y., it is improbable that there was a biological source for silica in the BIF. A physico-chemical source for the silica from combination of weathering and volcanism is much more likely. The abundance of soda amphiboles in some localities implies probably saline marine waters'.
Deposition of Iron in Depositional Basins

'The immediate causes of precipitation in the basin are not clear. According to Trendall, precipitation was caused by the oxidation of the ferrous iron in the basin water by oxygen evolved during photosynthesis by algae. There is not, however, much evidence in its favour. Ewers and Morris (1981) consider the BIF as chemical sediments which accumulated under very stable conditions without contemporaneous disturbances, and that the chemical composition of the primary precipitate was close to that of the present BIF. Macrobands of shale mark volcanic episodes. There are annual layers composed of small-scale regular lamination within many chert bands defined by some iron-bearing mineral within a fine mosaic of quartz'.

He felt that any model seeking to explain BIF must account for the following: (1) the rhythmic banding of the BIF which involves the problem of how the iron was transported in a soluble state to the sites of deposition and to precipitate it as thin iron-rich bands in areas extending over hundreds of kilometres; (2) the sources and storage sites of iron and silica; (3) the essential limitation of BIF to rocks older than 2000 m.y.; (4) variations in facies of the BIF between Archaean and Proterozoic deposits; (5) anomalous occurrence of deposits younger than 2000 m.y.

On the Precambrian atmosphere itself he said: 'There is considerable difference of opinion regarding the composition of the Precambrian atmosphere. The Precambrian is only a convenient term to comprise a vast assortment of rocks which are all older than the Cambrian and covering an age span of about 3000 m.y. There cannot, therefore, be a Precambrian atmosphere, or special Precambrian environment of sedimentation, or anything typical or characteristic of the whole course of Precambrian time. This implies that no one iron-formation, however carefully studied, can be used to make generalisations regarding the origin of these rocks. The iron of BIF is not a direct biological precipitate, but a chemical by-product of the presence of the photosynthetic oxygen in the surrounding water column. The transition from an anaerobic to an aerobic state of hydrosphere and atmosphere was not abrupt, but occurred over a range of perhaps 300 m.y. (2300 to 2000 m.y. ago). For all that, 2000 m.y. ago still seems to be a reasonable round number to apply to the beginning of a persistent generally oxidised atmosphere'.

On the vexed question of the age of iron formations he had this to say: 'Despite the uncertainties in the basic data, it is seen that most of the world's iron-formations fall within four general age-groupings: middle Archaean (3500-3000 m.y.), late Archaean (2900-2600 m.y.), early Proterozoic (2500-1900 m.y.), and late Proterozoic-early Phanerozoic (750-450 m.y.).'

After a vote of thanks given by T. C. Devaraju convenor, the inaugural session came to an end.

TECHNICAL SESSION

Iron Formations of Greenstone Belts

Dr. S. V. P. Iyengar conducted the proceedings of this session. In his keynote address, he reviewed the distribution of Precambrian banded iron formations in space and time in India. Three regions namely, Karnataka, Bihar and Orissa, and
Madhya Pradesh, were identified as the major iron ore provinces of India. Strong lithological similarities in the three major iron ore provinces were emphasized. Three major cycles were identified in their formation. The earliest cycle was represented by Banded Magnetite Quartzites (BMQ) associated with mafic and ultramafic rocks, clastic sediments being rare. In the second cycle, basic volcanic flows and basic tuffaceous sediments were less conspicuous and clastic sediments dominated. Banded iron cherts were more common. A third cycle was marked by association with dolomite, limestone and manganiferous sediments. He pointed out that the Indian iron formations were formed in a conspicuously shaly environment with enriched ores tending to be aluminous.

S. Warren Carey from Tasmania, Australia, a Foundation Fellow of the Society, came out with a new theory regarding the origin of BIFs. He discounted the aqueous origin for the thinly bedded iron formations and felt they showed characteristics of aeolian deposits. According to him they originated as a result of often repeated global dust storms equivalent to the present day dust storms on Mars. He explained that in a drying basin, storms would blow many times around the Earth and sediments would record the hierarchy of major bands, mesobands, macrobands which would be panglobal, and not restricted to local phenomena.

R. N. Mishra of the Geological Survey of India, reviewed the banded iron formations of Karnataka. He pointed out that they principally occur in three major associations namely, (a) in granulite-gneiss region (b) in older greenstone and (c) in younger Dharwar Supergroup. In terms of major element chemistry the three had some broad resemblance to the Lake Superior-Algoma-Ukraine-Hamersley kinds, but differed from them in terms of trace element chemistry. The Banded Iron Formations of Karnataka had higher proportions of mafic trace elements which indicate volcanic proximity. The restricted time period of Banded Iron Formations and abundance in the Archaean of Karnataka, were linked with a thinner crust, greater geothermal gradients and oxygen deficient atmosphere.

R. L. N. Dikshit made the point that sulphide facies iron formations should be investigated thoroughly for base metals as well as gold, silver, tungsten, arsenic and sulphur.

T. C. Devaraju, K. S. Anantamurthy and S. D. Khandali describing the Banded Iron Formations of Chikkanayakanahalli schist belt considered them as having been formed by inorganic chemical deposition in a generally quiet miogeosynclinal shelf environment of a restricted sedimentary basin, as terminal phases of carbonate deposition.

A comparative study of the Banded Iron Formations of Sandur schist belt in Karnataka with that of the Gurumahisani-Badampahar-Tomka-Daiteri belt of Orissa was presented by K. L. Chakraborty and P. S. N. Murthy. Absence of carbonate, silicate and sulphide facies, low $\text{Al}_2\text{O}_3$, CaO and MgO were characteristic of the Indian BIF's. Trace element abundances were very low pointing to low temperature sedimentary origin. The source of iron was thought to be the result of weathering of mafic rocks.

B. Krishna Rao and others described association of manganese-rich bands with the lower sequences of Banded Iron Formations of Shimoga and North Kanara districts of Karnataka. Alteration of these manganiferous Banded Iron Formations
had resulted in the development of supergene manganese deposits through a long process of laterite weathering.

D. B. Nadagouda, R. S. Hanagodimath and T. C. Devaraju, describing the iron Formations of Huliyar and Kudurekanve areas of Karnataka, pointed to their low trace element content. Based on field and geochemical characteristics they considered the iron formations of this region to represent chemical sediments deposited in shelf region of miogeosynclinal environment under near neutral and predominantly CO$_2$ enriched conditions.

**SPECIAL EVENING LECTURE**

A special evening lecture on 'Expanding Earth' was delivered by Professor Warren Carey. The main burden of his thesis was that the Proterozoic Earth was only half the size of the present day Earth and that the Earth was gradually expanding. While he gave qualified acceptance to the plate tectonic theory, especially that part which accounted for spreading of continents, he came down heavily on subduction. He swore that this concept was absurd. He ascribed a more important role to vertical tectonics.

**CULTURAL PROGRAMME**

The participants were entertained at a cultural programme on the night of 20th consisting of recitation of poems of famous poets of Karnataka, singing of Yellamma songs, followed by an exquisite dance programme and yakshagana from a troupe from Honnavar. The programme provided excellent fare and was greatly appreciated by all the delegates.

**VISIT TO THE KALI HYDROELECTRIC PROJECT**

The second day of the Group Discussion was wholly devoted to a visit to the famous Kalinadi Hydroelectric Project and to the examination of the extensive graywacke formation of Supa-Dandeli area.

The party consisting of 65 participants left by a special bus for Dandeli. The chief geologist of the Karnataka Power Corporation, Sri. V. S. Upadhyaya took charge of the party on arrival at Dandeli and explained the salient features of the giant project, one of the most prestigious power projects of Karnataka aimed at providing 910,000 Kilowatts of power at an expenditure of Rs. 270 crores. The all-concrete dam, 101 m high is almost nearing completion and the visitors were able to see the ropeway, the batching plant and 20 tonne cable way placing concrete and raising the dam to the required height. Incidentally, the Supa dam is the highest concrete dam built in Karnataka so far and had encountered innumerable foundation problems which had been successfully overcome. The visitors were told that it was one of the most intensively investigated dam sites in the country. After a sumptuous lunch, the party drove to the Bommanhalli pick-up and saw a magnificent exposure of graywackes on the bed of the Kali river. A visit to Sykes Point overlooking the Nagjhari valley and watching the sun-set from this vantage point marked the end to a memorable visit to a part of Karnataka where nature's bounty is being harnessed by the ingenuity of man to usher in a new era of work, wealth and prosperity to the rest of the State. The delegates appreciated the excellent arrangements made by the Power Corporation for their visit and thanked the authorities sincerely before taking leave of them.
IRON FORMATIONS OF HIGH-GRADÉ REGIONS

The third day's proceedings started with a discussion on the iron formations of high-grade terrains. The session was presided over by Prof. K. Laajoki, University of Oulu, Finland. He opened the discussion with a paper of his own on the Banded Iron Formations of Finland. The following categories of iron formations were documented:

Archaean

1. BIFs associated with the c. 2800 Ma greenstones and schists of eastern Finland.
   a. Metalava hosted (Algoma-type): Kuhmo,
   b. Metasediment hosted: Ukkolanvaara, Huhus

Late-Archaean – Early Proterozoic

2. Algoma-type BIFs of the Lapponia: Kittila

Early Proterozoic

4. Algoma-type BIFs of south and central Finland (Svecofennian): Jussario, Nyhamn. (Eugeoclinal).

Two papers were presented in this session dealing with mineral chemistry of Banded Iron Formations of high-grade region and P-T conditions of metamorphism. T. C. Devaraju, K. Laajoki and M. Basavanna described the mineralogy of the iron formations of granulite terrain of Karnataka. Mineral chemistry of BIFs indicated the presence of a variety of iron-rich silicate mineral phases, which were Mn-rich and Mn-poor. This enabled the division of BIFs of high-grade region into two groups namely, Mn-poor BIFs and Mn-rich BIFs. The silicate mineral phases recognised were: quartz, garnet, opx, cpx, olivine, pyroxenoid, amphibole, plagioclase, apatite and zircon. The occurrence of K-feldspar as a major mineral phase, occurrence of olivine as a minor phase and common occurrence of accessory apatite and zircon were reported. Opaque mineral phases were represented by magnetite and hercynite. The mineral paragenesis suggested that these were evolved under granulite facies conditions and were later retrograded to amphibolite facies.

The silicate mineral phases of the BIFs of high-grade region were described by B. Mahabaleswar. These phases were represented by quartz, hypersthene, ferrohypersthene, lamellar pyroxenes, almandine, pyroxferroite, ferro and ferroan pargasite. Except pyroxferroite, all the other minerals were Mn-rich and for this reason he found it difficult to separate the BIFs of high-grade terrains into Mn-rich and Mn-poor bands. The chemical composition of the minerals was dependent upon host rock composition, oxygen fugacity and P-T conditions of metamorphism. Though applicability of various geothermometric and barometric methods was rather poor
for these rocks which are Mn-rich, a temperature and pressure estimate of 600-650°C and 6 to 8 Kbars was indicated.

**SPECIAL LECTURE**

This session was followed by a special lecture by Prof. J. Lintz, Jr. USA, on ‘Biosphere and the Banded Iron Formation’. It was a general lecture aimed at explaining the role played by primitive organisms in the precipitation of iron and silica.

**GEOCHEMISTRY AND PALAEOBIOLOGY**

Prof. Joseph Lintz Jr. of U.S.A. chaired this session. There were six papers. The study of geochemical aspects of BIF continues to be a neglected field as reflected by the limited number of papers presented at the session.

S. K. Behera gave an account of the Banded Iron Formations which occur along the western margin of the Kolar schist belt, and pointed to a genetic link with gold mineralisation, although the geological and geochemical reasons were by no means clear. The variations in major and trace element abundances were pointed to indicate a change in environmental conditions of deposition.

Tapan Majumder elaborating on his thesis that magnetite was the precursor mineral in the Precambrian BIFs of eastern India, stated that magnetite was crystalline at the time of formation. The trace element data of magnetite indicated a sedimentary origin. The presence of magnetite in these rocks which are older than 3.3 Ga (Sm-Nd model age) was in accordance with an oxygen deficient atmosphere during that time.

Avinash Nautiyal from Lucknow came out with a long list of biological remains, mostly Acritarcha, Cyanophycean algal remains in the iron formations of Kiriburu and Meghataburu. The occurrence of these microfossils, according to him, indicated that BIFs of the above mentioned regions were deposited in marine, nearshore, lagoonal, warm and highly oxidizing environment during the Middle Algonkian.

P. S. N. Murthy reported certain microfossils of disc, filament and plate types from the BIFs of Donimalai, Sandur schist belt, Karnataka. He pointed out that these micro-organisms had a major role to play in the precipitation of iron.

**STRUCTURE AND SEDIMENTOLOGY**

This session was conducted by Prof. D. Mukhopadhyay, Indian School of Mines, Dhanbad. He started the session with a masterly presentation of his own on the structure of the BIFs of Bababudan area of Karnataka. According to him, the Banded Iron Formations in the SE Bababudan hills, Karnataka, display a macroscopic synformal bend gently plunging WNW. This forms the SE corner of a horse-shoe shaped regional synclinal fold closure which encompassed the entire Bababudan ranges. These iron formations contain minor folds, the geometry of which indicates that they are buckle folds modified to varying extent by flattening. These minor folds are frequently non-cylindrical and the fold axes show curvature, branching and en echelon patterns. Such patterns are due to the interference of progressively growing
neighbouring folds whose initiation is controlled by the presence of initial perturbation in the layers. Development of folds at different stages of progressive deformation had given rise to nonparallelism of fold axes and axial planes. He felt that the earlier folds were preserved in a less disturbed orientation in the Bababudan belt.

Structural study of the iron formations of eastern India was presented by Prof. S. Acharya. He pictured three phases of folding with an early east-west, a NNE-SSW and a later east-west, folding movements in that order, of which the middle one was most intense. Later folding had been responsible in cross-folding the main folds and folding of the fold axis.

P. S. N. Murthy and K. Kameswara Rao, described certain sedimentary structures in the BIFs of Donimalai area of Sandur. Primary structures noticed were classified into non-deformational sedimentary structures, penecontemporaneous deformation structures and post-deformational structures. These structures, according to them, indicated an environment where some parts had high energy depositional features while others showed more typical low energy micro-banded features common in Algoma-type.

Other speakers included R. P. Mohenty and H. Sahoo from Orissa and V. C. Chavadi from Dharwar who dealt with environmental aspects of iron ore deposition. The absence of clastic textures and organic remains indicates that these were inorganic chemical precipitates formed in continental shelves.

CONCLUDING SESSION

Dr. B. P. Radhakrishna who chaired the concluding session expressed his sense of appreciation at the way the seminar was conducted and the valuable contributions made by different authors representing different organizations drawn from all over the country. He said most of the iron formations of the world fell within the following geological age groups.

- Mid Archaean (3500 – 3000 m.y.)
- Late Archaean (2900 – 2500 m.y.)
- Early Proterozoic (2500 – 1900 m.y.)
- Late Proterozoic to Early Palaeozoic (750 – 450 m.y.)

The oldest iron formations so far recognised were that of Issua, Greenland, formed around 3750 m.y. ago. The youngest was the one described by O’Rourke from Nepal. The largest development of iron formations in India appears to be confined to Late Archaean (2900 – 2500 m.y.). Proterozoic which was a major epoch in iron sedimentation in the rest of the world was not represented in India. He summarised the information on the distribution of iron formation of India in space and time in the form of a Table (see next page).

In conclusion, he expressed his desire of bringing out an informative volume on the Banded Iron Formations of India and gave briefly the plan he proposed to adopt in gathering information for the volume.

On behalf of the Geological Society he thanked the Vice-Chancellor Karnataka University for the gracious invitation extended to the Society for holding its scientific session at Dharwad, Prof. T. C. Devaraju and his colleagues in the geological department, Karnataka University for the extraordinary pains taken in organizing
the seminar so successfully. M. S. Rahman, Department of Mines and Geology and V. S. Upadhyaya of Karnataka Power Corporation for the clock-like precision with which the tours to Kalinadi were conducted. With a vote of thanks preferred by Prof. T. C. Devaraju, convenor, the Seminar came to an end on the evening of the 22nd May 1985.

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Prof. D. Mukhopadhyay from ISM, Dhanbad, and Prof. Acharya from Orissa thanked the organizers for the excellent arrangements made for their stay and for the efficient manner in which the seminar was conducted.

 Bangalore University
 Bangalore

B. MAHABALESWAR