K. Naha

1932 – 1995
Preface

This special issue on the Precambrian is at once a tribute to and an acknowledgement of the enduring contributions made by Professor K Naha to structural geology in general and to the Precambrians of India in particular. These ancient terranes that cover over 80% of the Indian subcontinent have been multiply imprinted by tectonic and metamorphic events of various epochs resulting in highly tangled relationships of rock suites and complex deformation histories. In turn, they have encouraged a vexing suite of speculative models for their evolution. Naha's seminal contributions lie in developing the analytical frameworks for the resolution of interfering structural fabrics in such terranes in a coherent space-time relationship, using structural data on all scales - from map scale folds to hand specimens to metamorphic textures preserved in microscopic domains. These incisive approaches to field geology, with imaginative anticipations and uncompromising search for details and coherence, Naha pursued with the eye of a gifted microscopic petrographer, treating each mapping campaign as an end in itself. The structural maps and data presented by him thus constitute enduring contributions to the Precambrian geology of India even as they instruct and inspire keen geologists in the unrelenting quest for hard scientific evidence.

Kshitindramohan, son of Jitendramohan and Renuka Naha, was born in 1932 in Coomilla, presently in Bangladesh. After the partition of India, the Naha family migrated to Calcutta where Kshitin, as he was fondly called by his friends, graduated from school to college earning hononrs and medals all the way, despite the family's rather constrained circumstances, even lacking for books which he more than made up for by becoming an early addict to the library.

However, Naha turned away from the soft rewards of his academic distinctions including a lucrative position offered by an oil company. True to his nature, he preferred an ill paid research position at the Presidency College under his legendary teacher, Prof. S Ray, from which he was to launch a lifelong passion for resolving the problems of Precambrian geology through focussed studies on metamorphism in relation to structure and stratigraphy. Several other notable contributions followed: kinematic significance of deformation lamellae in quartz; geometry of reclined folds; large scale architecture of migmatites; revision of stratigraphy and structure in the early Precambrian terranes of central Rajasthan and southern India; methods of recognizing angular unconformity in metamorphic terranes, with rocks involved in superposed folding.

His observations on the kinematic significance of deformation lamellae in quartz was subsequently confirmed by the experimental studies of Griggs and his associates at the University of California, Berkeley. He was the first to characterize the geometry of reclined folds in the Singhbhum fold belt of eastern India, which are now known to be of common occurrence in many orogenic belts. Naha was also one of the pioneers in the analyses of fold-interference patterns. His studies served to demonstrate certain basic features in polyphase deformed terranes. Establishment of structural history in multiply folded sequences is not an easy task. It requires a great deal of caution to distinguish folds of different generations, as these, even of the same generation may have different styles. The orientation of a set of megascopic folds may be different in different parts of a later larger fold, whilst that of a set of folds superposed on a large scale fold may also be quite different in different parts of the early fold. Despite such limitations, careful analysis of fold styles and of their orientations, often enable one to distinguish folds of different generations. Prof. Naha mastered this art to such a perfection that his works, along with those of some other celebrated structural geologists, validated the basic observations on the time sequence of style and orientation of folds in polyphase deformed sequences.

Older and younger tectonic events can be distinguished by angular unconformity. Establishing angular unconformity in terranes where the sequences on either side of the unconformity are involved in multiple episodes of folding requires meticulous structural analysis. In the Aravalli mountain belt, the Precambrian Aravalli Supergroup and Delhi Supergroup are both involved in multiple folding events. Adducing evidence for an additional episode of deformation in the Aravalli sequence, not found in the Delhi rocks, Naha demonstrated the existence of an angular unconformity between the two sequences, an excellent example of an angular unconformity

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between polyphase folded sequences. On the other hand, he drew attention to features that argue against the existence of an angular unconformity between the Sargur and the Dharwar sequences of the South Indian craton as believed by some.

Naha also made an enduring contribution to elucidating the basement-cover relationship, important for the stratigraphy, structural geology and an overall understanding of the Precambrian crustal evolution, which he applied to the study of the Rajasthan and Dharwar cratons. Thus he demonstrated that the Precambrian gneissic basement did not develop in a single event, but evolved through different phases of rejuvenation. He was able to distinguish gneisses and migmatites developed syntectonically with the deformation of cover rocks from the relicts of the earlier basement, both in the Banded Gneissic Complex of Rajasthan, and the Peninsular Gneissic Complex of the Dharwar craton. Discovery of basement relicts, usually as small enclaves with a distinctive preexistent structural and metamorphic mineral fabric in synmigmatitic host gneisses has verily been regarded as an important discovery of the last decade in the study of Precambrian gneissic complexes of India. He proved the existence of a mantled gneiss dome in an Archaean Dharwar supracrustal belt, which points to strong basement reactivation and palingenesis during the deformation of cover rocks, and brought to light the similarity of structural geometry between rocks of low and high metamorphic grades in the Banded Gneissic Complex of Rajasthan and gneiss-granulite terrane of the Dharwar craton, which have far reaching implications for our understanding of the styles of deformation in the middle and lower crust. The structural patterns of closed outcrops related to shear dominance and sheath folding in the middle and lower crust as observed in the North Atlantic and the Limpopo provinces may not be valid everywhere, for coaxial refolding seems to be quite common at these depths as observed in parts of the southern Indian granulite terranes.

Professor Naha received a number of well earned awards in recognition of his wide ranging contributions: S L Biswas Medal of the Asiatic Society in 1958; National Mineral Award (1970); Shanti Swarup Bhatnagar Prize (1972); National Lectureship (1978–79); Jawaharlal Nehru Fellowship (1986-87) to name a few. He was elected to the Fellowship of the Indian National Science Academy in 1977 and of the Indian Academy of Sciences in 1983 as well as of several other Academies and institutions.

This issue on the ‘Recent Researches on the Precambrian’ has been especially designed to rhyme with the spirit of Professor Naha’s scientific approaches and contributions. It consists of sixteen papers presenting new significant results; the first eight present the theoretical perspective for the study of Precambrian Geology, generally and in particular the structural aspects in important Precambrian terranes of India. The last eight papers present the petrological and geochemical perspectives of some of these as well as of other comparable terranes highlighting their significance in geodynamic interpretation. The first paper by S Sengupta and S K Ghosh deals with the kinematics of the Singhbhum Shear Zone. They describe the sequence of development of numerous mesoscopic shear zones and the geometry of structures successively produced during progressive deformation. D K Mukhopadhyay and others describe the deformation events in the Chur Klippe in the Himachal Himalayas and infer the presence of several stacked thin thrust sheets in the klippe. The ductile shearing, large scale folding and thrusting are related to the development of the Main Central Thrust Zone in the Himalayas. The main metamorphism is shown to be pre-kinematic with reference to the development of the Main Central Thrust Zone. R O Grelling describes the geometry of thrust sheets in a Proterozoic accretionary orogen in the Arabian-Nubian Shield. The gneiss dome surrounded by low grade sequences is interpreted as an antiformal stack with the highest thrust sheet being the oldest and the lowest one the youngest. A balanced, retrodeformable section is constructed. D Saha presents a theoretical approach for deriving a flow law in polyphase aggregates. The constituent phases in the aggregates are assumed to be strained through the simultaneous operation of diffusive mass transfer and dislocation creep. N Mandal and others describe the deformation microstructures in quartz and feldspar in high grade metamorphic rocks on the basis of optical and TEM studies. They show that feldspar is deformed mostly by recrystallization accommodated dislocation creep while quartz is deformed by dislocation climb dominated dislocation creep and also by diffusion controlled mechanisms. Dhruba Mukhopadhyay and others discuss the complexities of fold geometry in the banded iron formation from the southeastern part of the Bababudan Schist Belt. The variability of the geometry of structures on all scales is ascribed to development of folds at different stages of a progressive deformation episode, the structures formed at earlier stages having been modified by those formed subsequently.

The paper by B Chadwick and others presents a synoptic view of the stratigraphy, structure, basin development and geochronology of the Dharwar craton. Highlighting the difference between the eastern and western Dharwar cratons they propose a plate tectonic model for the evolution of the craton. Naha and his co-workers (incidentally this is the last paper authored by Naha) analyze the structural geometry of the calc gneisses in an area within the southern granulite belt and address the question of the relationship between the structures in the Dharwar craton and those in the granulite terrain.
S K Sen and S Bhattacharya present chemical data in support of their hypothesis that the leptynites in the Eastern Ghats granulite belt are derived by partial melting of khondalites. They invoke the process of dehydration melting of micas in pelites and psammites and have set up mass balance equations. In two companion papers, M Raith and others and A Maji and others discuss the petrogenesis of anorthosites and ferrodiorites from two localities in the Eastern Ghats granulite belt. M Raith and others describe the geochemistry of ferrodiorite suite from the Bolangir Anorthosite Complex and present a model of the evolution of the ferrodiorite melt through polybaric fractional crystallization of a mantle derived melt and its subsequent crustal contamination. For the Turkel Anorthosite Complex A K Maji and others suggest that the anorthosite and leuconorite were derived by polybaric fractionation of mantle derived melts. The associated ferrodiorites represent anorthosite residual melts. The bordering granites and granodiorites were originated by incongruent melting of crustal rocks. S Sengupta and others give a comprehensive account of the geochemistry of the mafic rocks from the Iron Ore Group of Singhbhum, Orissa and show that three distinct geochemical types are present. On the basis of major, trace and rare earth elements geochemistry they hypothesize that the tholeiitic melt was generated from a LREE enriched source. M Deb and U Sehgal discuss geothermobarometry and fluid fugacities in the Rampura-Agucha sulphide deposits in Rajasthan. P K Banerjee presents a model of emplacement of ultramafic bodies in southern Orissa involving collision of two terranes. J K Zachariah and others discuss how Sm-Nd isotopic data help in constraining petrogenetic models and illustrate this with an example from the eastern Dharwar craton of south India. R Srinivasan and others describe the geochemical characteristics of the stromatolitic cherts from the Dharwar Supergroup. On the basis of Rb-Sr isotopic data they assign a date of ca. 2.5 Ga to these rocks; this is close to the age of regional metamorphism of the Dharwars.

In putting this volume together to commemorate Professor Naha's scientific life, we have been acutely aware of the exacting standards he set for his own endeavours, and of his commitment to order the evolutionary history of the Precambrians of India. The set of papers that it contains, including his last, would, we hope, in some measure impart the enduring quality of his own works. We are extremely grateful to all the contributors who responded most spontaneously and to the Academy staff for their painstaking work in bringing out this publication. A special word of gratitude is due to Prof. Supriya Sengupta, Professor Naha's long time friend and colleague for providing some details about his personal life.