

Tectonic Framework and Evolution of India*

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Abstract: The first ever Tectonic Map of India was published by the Geological Survey of India in 1963 and was presented before the 22nd International Geological Congress, 1964. This map was revised by the Survey in 1968 and the manuscript of the revision was presented before the 23rd International Geological Congress, 1968. In 1970, the Oil and Natural Gas Commission published another Tectonic Map of India and this contains some additional data on the sedimentary basins. The paper deals with the interpretations pertaining to tectonic framework and evolution of India, as presented in revised manuscript of Tectonic map, 1972. They can be summarised as follows:

1. In the Precambrian shield there are three distinct mega-cycles of volcanic-sedimentary metamorphic tectogenesis till about 1600 m.y.b.p. followed by three distinct mega-cycles of predominantly platform and aulacogen development interspersed by anorogenic plutonism and volcanism. The former straddled the Archaean-Middle Proterozoic period while the latter developments happened during the Riphean and Vendian.

2. The Precambrian shield has been considered to be continuing to the north as the basement of the Himalaya. Subsequent reactivation of the same during the Caledonian and Hercynian tectogenesis and Cenozoic orogenesis is indicated by field evidences. Cenozoic orogenesis/reactivation affected the younger Caledonian and Hercynian platforms too.

3. The Tertiary and Quaternary orogenesis of the Himalaya is considered to be due to the activities along three principal mega-lineament systems and the rudimentary Cretaceous-Eocene eugeosyncline of the 'Indus suture' seems to be controlled by Hercynian tectonic pattern and mega-lineaments.

4. Hercynian geosynclinal developments of the Karakorum-Himalaya and the Hindukush are areally related and follow an E-W arcuate trend (convex to the north) in the Karakorum Himalaya sector.

5. The so called 'eugeosynclines' of the 'Indus suture' are actually westward continuations of the Mesozoic geosynclines of southern Tibet.

6. Principal lineaments, as evident from geological, geophysical and geomorphic data have been shown to have played a significant role in sedimentation, metamorphism and deformation, magmatism and tectogenesis-orogenesis.

INTRODUCTION

The first ever Tectonic Map of India was published in 1963 (GSI, 1963), which, in conformity with the international practice, adopted age of folding as the principal criterion. The junior author was assigned the task of compiling this map by the Geological Survey of India, and the work was carried out under the supervision of the then Director General, Geological Survey of India. This map succeeded in identifying areas of Archaean, Proterozoic, Vindhyan and Himalayan-Naga-Lushai folding and various platform areas with cores of different ages of consolidation. Identification of units of smaller order within the principal units varied both in principle and approach, and was done only in respect of younger members. The precision and palaeogeographic validity of these aspects of the map naturally were not its strong points, and there was a subjective approach. The principal objective of the compilation was to demonstrate the applicability of the modern principles of regional tectonic analysis in outlining of the principal units, though delimitation of the areas of Proterozoic, Vindhyan and younger folding and the platform areas of different categories is in need of modification in view of what has become known in the succeeding years. Moreover, the Sindhu-Ganga-

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Brahmaputra valleys, as depicted on this map, were generalised. Though the complex nature of this valley comprising both platform edges and numerous marginal basins was strongly suspected, subjective outlining of the same would have made the map rather speculative.

REVISED TECTONIC MAP OF 1968

With the passage of time the shortcomings of this Tectonic Map were becoming apparent to the compiler, and a determined effort was made by the Geological Survey of India in 1968 to elaborate and review the interpretations, particularly in respect of the Pre-Cambrian Shield. This map was not printed, but a report (GSI, 1968) on the same was published by the Sub-Commission for the Tectonic Map of the World, Commission for the Geological Map of the World, in its Bulletin No. 8 of 1968, immediately after the 23rd Session of the International Geological Congress, Prague 1968.

In this map, within the Pre-Cambrian Shield of India, were identified the following areas of folding/consolidation, each of which perhaps comprises several sub-cycles/phases:

1. Oldest Gneisses and Schists (older than 3000 m.y.)
2. Dharwar and older cycles (ending ca. 2600 m.y.)
3. Eastern Ghats Cycle (ending ca. 2200 m.y.)
4. Iron ore-Bhilwara Cycles (ending ca. 2000 m.y.)
5. Sakoli, Amgaon and Aravalli Cycles (ending ca. 1300 m.y.)
6. Singhbhum and Erinpura Cycles (ending ca. 850 m.y.)

This map further suggested that the Dharwar and older cycles could be correlated with the Bielomorides; the Eastern Ghats and the Iron-Ore cycles with the Sveco-Fennian and Ante-Sveco-Fennian and Sakoli-Amgaon-Aravalli cycles to the Gothides and Mayumbian. The Singhbhum and Erinpura cycles were contended to include several Pre-Baikalian cycles, and represent the equivalents of Riphean, Dalslandian, Kibara-Urundi, Katanga and Grenville cycles.

This map also depicted the Karakorum sector, to the north of the Himalaya, as a Hercynian fold belt with reactivated basements of Riphean consolidation. It was further contended that the Cretaceous-Palaeogene geosynclinal development in the Himalaya proper was of rudimentary nature and occurred along the "Sindhu (Indus) suture", the corresponding Naga-Lushai geosyncline in the continuation of the Arakan-Yoma being wider and more complete in development. In both the belts miogeosynclinal developments were not well revealed. In the case of the latter, the molasse zone is often obliterated beneath the thrust sheets. This map did not depict the structural-stages, especially to do away with subjective aspects.

The platform cover on this map was subdivided into two groups viz., the Riphean and the younger Vindhyan, both resting on older basement. The Vindhyan platform cover was suggested to be continuous northward under the Ganga valley. The Riphean and Vindhyan platform developments were separated in space by the reactivated welt of the Satpura.

The other important tectonic unit on which this map presents a radically different view is the Himalaya. The Himalaya has been considered essentially to be a reactivated

platform with a rudimentary Cretaceous-Eocene geosyncline along the "Sindhu suture" and corresponding orogenic depressions along the margin further south. Within this belt, reactivated regions of Riphean folding and succeeding platform covers were delineated.

TECTONIC MAP OF INDIA (1968), COMPILED BY THE OIL AND NATURAL GAS COMMISSION, INDIA

The Oil and Natural Gas Commission, India, published a Tectonic Map of the country on the same scale as the above. The map is dated 1968, but was put in circulation only towards the end of 1970. Five Soviet Petroleum specialists had been associated with this work, and the details are predominantly of petroleum bias, and pertain more to the basins of oil and gas prospects. Other principal tectonic units, namely the Pre-Cambrian shield and the Himalaya, have been treated in a generalised manner.

This map divides the Indian Pre-Cambrian shield into areas of Dharwar, Aravalli, Eastern Ghat, Satpura and Delhi folding (in that order in time), most of which are shown to be separated by deep-seated faults. The Himalaya and the Arakan-Yoma (in place of "Naga-Lushai") fold belts/tectonic zones have been classified under areas of Cenozoic tectogenesis. Sub-division of these areas into units of lesser order has not been attempted at all. The remainder of the country has been classified under sediment covered Indian platform. This cover has been further sub-divided into structural units of several orders (like synclises and depressions of Proterozoic development). Three principal grabens have been shown to be traversing the platform and merge into marginal shelves and similar basins. The northern, north-eastern and western margins of the Platform have been subdivided into several shelves, namely (from west to east) the Saurashtra-Kutch Shelf, Rajasthan Shelf, Punjab Shelf, West Uttar Pradesh Shelf, Eastern Uttar Pradesh Shelf, West Bengal Shelf, Northern Shillong Shelf and Upper Assam Shelf, separated by the Cambay-Graben and Lahore-Delhi, Faizabad and Monghyr-Saharsa Ridges.

Other features of significance include the deep-seated faults (some of which are also shown on the Geological Survey's compilation of 1968). Quite a few of these faults have been shown to extend into the offshore areas.

The interpretations on the platform and marginal shelves, as depicted on the map, are improvements upon the previous efforts. Those for the Himalaya and Naga-Lushai belts are retrograde steps. In so far as the Pre-Cambrian Shield is concerned, some discussion is warranted.

The sequence of tectonic developments as envisaged by the O.N.G.C. compilers neither satisfies the stratigraphic relations nor the recent isotopic age data. In fact the ages of folding identified by them seem to be based on very old dates from lead-helium and potassium-argon methods, both of which are seriously inadequate in the context of unfolding of the history of tectonic evolution. There is no reason to conclude that the "Eastern Ghats" cycles are much younger than the "Dharwar", particularly as the "Eastern Ghats" Group of Kerala and Tamil Nadu, comprising the granulites, are not only stratigraphically older than the Dharwar to the north and northwest but also yield dates of metamorphism much older than the dates of crystallisation recorded for the Dharwar volcanics and Pre-Dharwar basement gneisses (Crawford, 1968). Moreover, the Aravallis and the Dharwar-Eastern Ghats are areally separate, and their relative positions are stratigraphically indeterminate. Some guidance is provided by isotopic age data, and dates yielded by components of basal conglomerates and syn-

tectonic and late-tectonic gneisses/granites of the Aravallis (Crawford, *op. cit.*) clearly demonstrate that the deposition of the Aravallis must have begun much later than that of the Eastern Ghats and most of the Dharwar Sub-divisions. The "Satpura" cycle or group, as depicted on the map, includes several areally separate stratigraphic groups of contrasted facies, metamorphism and structural developments. The envisaged "Satpura" cycle, perhaps indicates a phase of deformation/uplift affecting the entire region, though the individual stratigraphic components of different areas might have had different histories of development prior to the "Satpura" event. The identification of Satpura folding as such should not be construed to have any stratigraphic-tectonic connotation. It only represents the youngest deformation/uplift event. The same is partially true about "Delhi folding". The identification of "Delhi folding" was initially based on dating of pegmatite minerals which is of little tectonic significance. Recent isotopic age data on granites and gneisses indicate that the tectonic evolution of the Delhi Group of metamorphites and associated granites and gneisses is chronologically close but younger than that of the Aravallis.

It is thus evident that the Pre-Cambrian folding events and their order as identified by the O.N.G.C. compilers are confusing and erroneous.

RECENT WORK ON REGIONAL TECTONIC ANALYSIS

As a part of the International Upper Mantle Project and, thereafter, the International Geodynamics Project, the Geological Survey has been reviewing the earlier compilations of the Tectonic Map under a programme of the Geological Survey of India. This project is under the supervision of senior author, the other author continues to be associated with the programme for the revision of the Tectonic Map. (Fig. 1). The data furnished by the O.N.G.C. compilers in regard to the shelf areas bordering the platform have been taken into consideration.

In the course of the above work, the Tectonic Map of India, both the 1st edition and the revision of 1968, are both undergoing radical revision. The fundamental criteria for tectonic interpretations, i.e. age of folding and age of folding of basement (in case of platforms) have been broadly retained. In the case of the Pre-Cambrian shield, the exposed or revealed stratigraphic relations and/or isotopic age data on the oldest metamorphism and crystallization have been utilised as the principal criteria, besides utilising isotopic age data on basal conglomerate components and post tectonic-granitoids and other plutons in defining the time limits of the evolution of a particular stratigraphic-tectonic group.

In defining the limits of broad tectonic units, palaeogeographic evidences, wherever available, have been utilised. But in the Ancient Platform such a technique is not applicable. As such, the erosional outlines of the units have to be retained. However, a detailed geomorphic interpretation of the important lineaments have been found to be immensely rewarding in delineating older tectonic units and their limits, particularly in the Himalayas and the shelf areas. In course of the studies it was evident that the lineaments constitute a pattern, and either reflect the boundaries of tectonic units or provide indications for the same.

However, the current revision of the regional tectonic interpretations has led to a more comprehensive understanding of the tectonic framework and evolution as briefly outlined in the following text.

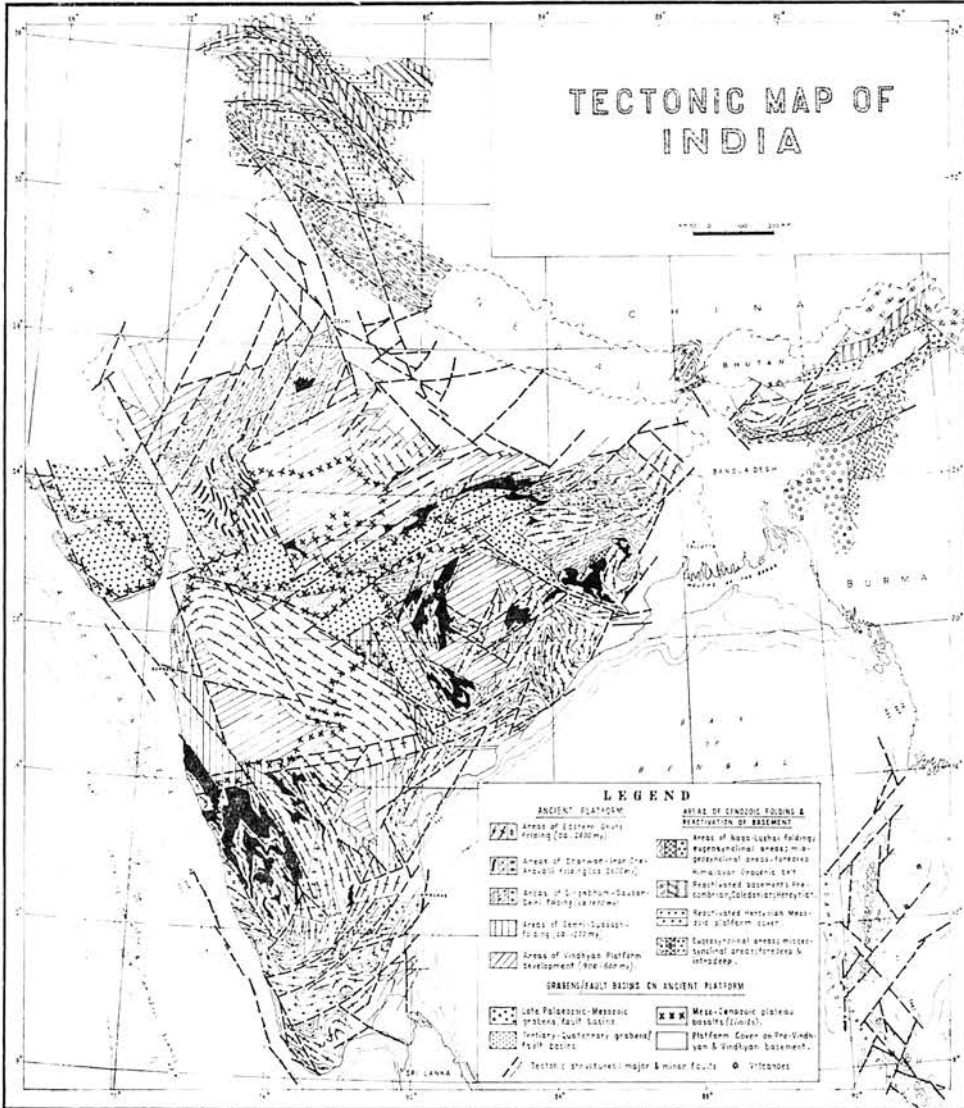


Fig. 1. Tectonic Map of India, 1972.

Pre-Cambrian Shield/Ancient Platform

The oldest sector is identified as the 'Area of Eastern Ghats (or preferably Kerala-Dravida-Kalinga) folding' —in which the oldest recorded date of metamorphism/deformation is around 2600 m.y. for the granulites. These belts (both in southern and north-western parts of the shield) contain even older relicts (sometimes reactivated) like those of Kamakshipalayam, Chengalur (south India) and Udaipur (western India). Syn- and post tectonic gneisses and granitoids comprise complex bodies (parts of which

might have been reactivated/remobilised later) and include the Peninsular Gneissic Complex, Bellary Gneiss, the Carnatic Gneiss, Kanara Gneiss, Gneisses of Hyderabad and Karimnagar, Singhbhum Gneissic Complex, Bundelkhand Gneissic Complex, Berach Granite and Banded Gneissic Complex and Gneisses of Shillong Plateau.

These folding/metamorphic complex of events are broadly correlatable to those of Bielomorian and Zagoride cycles.

The next sedimentary-metamorphic-granitisation event complex culminated around 2000 m.y. and is identified as the Dharwar-Iron ore Aravalli-folding, chronologically equivalent to the Karelian (early) and Post-Birimian events. The belt affected by such folding (both in south, east and western parts of the Shield) include older sectors like those at Ayoor and Kolar Gneisses, Bangalore Gneiss and Bezwada Gneiss. The widespread belts of metamorphosed sedimentary and volcanic rocks (comprising the Dharwar, Bijawar, Agori, Bengpal, Bailadila, Iron-ore and Aravalli Groups) are associated with syn- and late tectonic gneisses and granitoids including Bengpal Gneiss, parts of Singhbhum Granite and Gavalia and adjacent Gneisses and the Closepet, Molakalmur, Dudhi, Dadikar and Ahar Granites.

Stratigraphically overlying the above and having a later deformation/metamorphic history are the sequences of Singhbhum, Chhotanagpur-Gangpur-Dongargarh-Sausar and Delhi with associated syn- and late-tectonic gneisses (namely Gneisses of Chhotanagpur, Udaipur and adjacent areas and Amgaon and Granites of Bairat, Dongargarh and Singhbhum). These events of metamorphism and granitisation happened between 2000 and 1600 m.y. and correspond to parts of the Karelian and Mayumbian cycle of events.

At this stage of Pre-Cambrian tectonic evolution there appears to have been a change of regimen, broadly corresponding to the beginning of Riphean platform development. Several anorogenic intrusives of intermediate to basic nature preceded the period of platform development. These include the intrusives of Kishengarh (syenites), Simplipal (Gabbro), Punalur (Pyroxenite), Cuddapah dykes (Dolerites), Singhbhum dykes (Dolerites) and perhaps dykes of Bundelkhand (Doleritic).

Subsequent tectonic evolution of the Pre-Cambrian shield was marked by wide areas of sedimentation and some volcanism but near-absence of granitisation/metamorphism and related phenomena following deformation which also varied widely. Folding was acute at places particularly towards end of the first cycle which has been tentatively identified as the "Semri-Cuddapah folding" affecting sequences in the Cuddapah, Vindhyan, Kaladgi, Pakhal and Kolhan basins. Anorogenic plutons post-dating the event include Chelima Kimberlite dykes, Majhgawan Kimberlite, Pegmatites of Chhotanagpur plateau and volcanic activity on the earlier consolidated land areas to the western and southern fringe of the Vindhyan basin. This phase of evolution closed around 1200 m.y. from now, to be followed by a period of quiet platform sedimentation in the northern part of the Peninsular shield and uplift and anorogenic plutonism further south, west and east. Anorogenic intrusives include those of Ajmer Granite, Untala Granite, Chhapoli Granite, Erinpura Granite (?), Bengal Gneiss, Dubrajpur Granite, Sivamalai Syenite and Pegmatites of Rajasthan, Gaya and Hazaribagh, Seringapatam Porphyry and Venkatapuram Dolerites (?). These events ended before 850 m.y. and roughly correspond to part of the events of Gothian, Kibara and Irumides cycles.

Overlapping some of the events enumerated above and following the Semri-Cuddapah folding, there ensued a period of platform sedimentation leading to the formation of Kaimur, Rewa, Bhandar, Kurnool, Palnad, Bhima and Sullavai Groups. Some of these, as well as forerunning sequences like those of the Pakhals followed by the Sullavai perhaps generated in aulacogens of protracted history. In the northwestern and central parts of the shield, the uplift of these sequences were followed by volcanism leading to the Malani and Barmer Rhyolites and the lavas of Khairagarh, and this volcanic activity was also associated with plutonism in the consolidated sectors reflected in the Chhotanagpur Pegmatites, Myllem Granite (in the eastern part of the shield); Jalor, Siwana and Jasai Granites and Pegmatites of Rajasthan (in west); and Dongargarh Granite, Ramnad Granite, Kanyakumari and Madurai Granites, Salem pyroxenites and Chamundi Hill and associated Granitoids (in the south). These events concluded before 650 m.y., whereafter, preceding the Cambrian there was a period of further deposition of platform cover represented by the sequences of Chattisgarh-Bastar and Jodhpur-Nagaur Basins. Granites and pegmatitic intrusions (like those of Jalor, Barmer, Shillong and Sular) which presumably succeeded the above events heralded the period of upheaval and tension of the remainder of the shield.

These Vindhyan and subsequent uplifts correspond broadly to the Baikalian, Riphean and Vendian tectonic developments.

The Peninsular Shield remained a land mass of comparatively little activity during the Caledonian cycle, excepting that the Vindhyan platform cover extending northwards beneath the present day Sindhu-Ganga valley, had not perhaps fully emerged at the beginning of Cambrian.

The Himalaya, Sindhu-Ganga-Brahmaputra Valley and Naga-Lushai fold belt

Caledonian geosynclines of restricted extension had developed to the north of the Kashmir valley and in parts of Zaskar range; and corresponding platform developments occurred in the northern parts of Kumaon and Nepal (the areas now lying to the north of the Great Himalayas). An extension of this platform development continued westwards into Rupshu and the Spiti Basins where platform deposition continued through time.

A widespread hiatus is believed to have preceded the development of the Hercynian geosynclines and platforms. It is quite likely that parts of the Rupshu limb of the Caledonian platform cover continues to the Caledonian geosynclinal developments further north, mostly reactivated and granitised, in parts of Ladakh Granite Gneiss and the complexes around and perhaps to the north of Pangong-tso.

Hercynian geosynclinal development was widespread in Kashmir valley and the Karakorum, and in an arcuate disposition continued to the Hindukush as well as to the north of Garbyang in the east (Kumaon Himalaya, north of the Great Himalaya). Platform developments continued in Spiti basin. The Indian Shield suffered rifting and faulting and continental late Palaeozoic coal bearing formations accumulated in the faulted basins within the Indian Shield.

The Hercynian geosynclines of the Karakorum and the Himalaya maintained a roughly E-W arcuate (convex to north) disposition. The close of Hercynian Cycle is not marked in sedimentation. Marine platform deposition continued in Spiti and Kashmir basins as well as to the east in Southern Tibet, as the Karakorum emerged

with reactivated and remobilised pre-Hercynian and pre-Caledonian basement. The E-W arched fabric was retained even as far south as the Spiti basin, which fitted well to the Riphean-Vindhyan-Caledonian folded sequences (i.e. including the Jutogh, Chail, Shalkhala, Simla-Dogra, Jaunsar, Shali-Deoban, Tejam-Pithoragarh, and Krol-Tal Groups) that had already consolidated but suffered reactivation. The Hercynian geosynclines perhaps continued to the east in Tibet, now beneath the Mesozoic platform cover, to link up with the Mesozoic geosynclinal developments of southeastern China and Burma with a significant southeastward sweep.

Post Jurassic upheaval of the ancient platform and epi-Hercynian platforms of the Himalaya followed the Hercynian framework as well as the ESE-WNW and N-S megalineament fabric. Narrow faulted basins developed between the Spiti-Rupshu and the Ladakh Range as well as between the Kailas and Kiogar regions of Tibetan zones (the latter perhaps being unrelated to the rudimentary flyschoid Cretaceous-Eocene sequences of Spiti. The above fault basins ("Indus-suture" of Gansser, 1964) berthed eugeosynclinal domains where Cretaceous-Eocene flysch and ophiolite developed. These are the only sites of Tertiary geosynclines of Himalayas. These "eugeosynclines" in "Suture zones" or "aulacogens" merge eastwards with the Mesozoic geosynclines of southern Tibet; and westwards flank the Nanga Parbat massif along N-S deep dislocations. Finally they are again entrapped in the E-W arcs of Karakorum Hercynian chains, and small basins of Cretaceous-Eocene ophiolites-flysch associations occur along the Hercynian trends, as those of Yasmin and Chitral.

Post-orogenic marginal depressions of molasse are rare near the "suture" zone. However, as the Himalaya-Karakorum-Hindukush complex, comprising consolidated Hercynian, Caledonian and Pre-Caledonian fold belts and Palaeozoic-Mesozoic platforms, as a whole, was reactivated during the Tertiary, molasse foredeeps and intra-deeps formed. Orogenesis along three principal sets of deep dislocations and the resultant positive geomorphic prominences were followed to the south by annular basins resting partly on Eocene-Miocene shelf sequences (on the mountain flank) and Cambrian-Pre-Cambrian basement to the south. From Pliocene onwards these narrow basins (Siwalik) became the recipient of the molasse, which suffered upheavals only from Pleistocene onwards.

The continental Hercynian grabens or fault basins of the Peninsular shield merged in the west with the Jurassic and younger marine platform sequences of Saurashtra, Kutch and Rajasthan, while the eastern margin of the Indian shield from the south to the northeastern end also received Cretaceous marine incursions. This was followed both to the east and west by rifting and development of grabens preceded by wide-spread volcanism in the Deccan.

To the east of the eastern edge of the shield, the shelf zone is followed further east by the Naga-Lushai-Arakan Yoma eugeosynclinal-miogeosynclinal and foredeep complex (Tertiary-Quaternary) terminating against the Mogok-Stone tract and Shan Plateau crystallines, the latter continuing northwards into the Mishmi Hills complex against, which the NEFA Himalaya (a complex of Riphean-Hercynian generation) and the flanking narrow molasse basin terminate.

The above ensemble of the tectonic framework and evolution of India is significantly different from the previous ones in the following respects:-

1. It identifies within the Pre-Cambrian shield three distinct megacycles of volcanic-sedimentary-metamorphic tectogenesis till about 1600 m.y. followed

by three distinct megacycles of predominantly platform and aulacogen development interspersed by anorogenic plutonism. The former straddles the Archaean-Middle Proterozoic period while the latter happened mostly during the Riphean and younger periods before the Cambrian.

2. The Pre-cambrian shield is envisaged to continue into the Himalaya and has been reactivated during Caledonian-Hercynian tectogenesis and Tertiary orogenesis.
3. The Himalayan uplift during the Tertiary and Quaternary is controlled by three principal sets of megalineaments, and the configuration of the rudimentary Creta-Eocene eugeosynclines was controlled by the Hercynian tectonic pattern and megalineaments.
4. The Hercynian geosynclinal development of the Karakorum-Himalaya and the Hindukush are areally related and generally follow an E-W arcuate trend (convex to the north) in the Karakorum-Himalaya Sector.
5. The Creta-Eocene "eugeosynclines" of the "Sindhu suture" are actually westward continuations of the Mesozoic geosynclines of southern Tibet.

A discussion of the roles of the megalineaments in the tectonic evolution of both the shield and the Himalaya-Karakorum-Naga-Lushai belt and Sindhu-Ganga-Brahmaputra valley sectors is relevant in this context. However, a separate study is under progress on this subject and will be reported later.

The revised Tectonic Map of India (on a scale of 1:2,000,000) emerging from the above analysis is expected to be presented before the SEAFE Regional Group on Tectonic Map in March, 1972. The illustration accompanying this paper is a generalised reduction of the revised Tectonic Map of India (1:2,000,000, 1971), prepared by the authors.

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