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BOOK REVIEW

Tectonics of the Indian subcontinent

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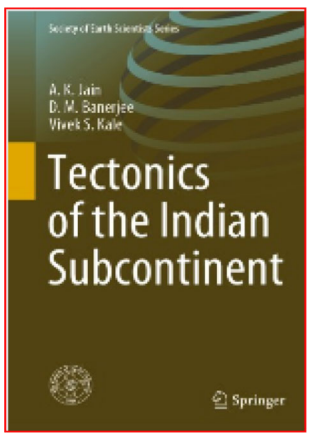

The book is published on the occasion of 36th International Geological Congress 2020 to be held in India. It covers a variety of data on geology, structures, geochronology, geophysics of the different terranes of India and neighbouring countries of Pakistan, Nepal, Bhutan, Bangladesh, Sri Lanka and Myanmar, ignoring political boundaries for Earth Sciences. The book is divided into ten chapters, each having a large number of figures, both colour and black-and-white, and a good number of tables and photomicrographs.

Chapter 1 is an introduction to the Tectonics of the Indian subcontinent under its three conventional divisions – Peninsular India, Himalayan Ranges (familiarly known as Extrapeninsular India) and the Indus–Ganga–Brahmputra plain known as Indo-Gangetic Plain in earlier text books and publications. Here, a brief account is given for five cratons of Peninsular India, namely Aravalli, Bundelkhand, Meghalaya, Singhbhum, Bastar and Dharwar and seven Proterozoic mobile belts in which the Chhotangapur Granite Gneiss Complex (CGGC), recognized as cratons in some books, is assumed here as a mobile belt and the Southern Granulite Terrain, a part of the Dharwar craton, is classed here as Pandyan Mobile Belt, without giving any convincing arguments. This chapter also gives a brief account of the Proterozoic sedimentary basins, popularly known as Purana basins, including those of the Himalayan orogenic belt. Chapter 1 closes with a brief account of Andman Arc. The starting paragraph of this chapter has a wrong statement saying that India and Australia have been separate plates for 3 million years and likely longer as given in Google and Wikipedia, but recent publication in Earth and Planetary Science Letters (EPSL), vol. 133, showed that the India–Australia plate started breaking about 8 million years ago.

Chapter 2 describes geological characteristics and geochronology of six Indian cratons of which Aravalli and Bundelkhand are located to the north of nearly E–W trending Central Indian Tectonic Zone (CITZ) and Dharwar, Bastar, Singhbhum and Meghalaya are towards the south of the zone. The Aravalli craton with 3.3 Ga old basement of the Banded Gneissic Complex (BGC) is divided into BGC-I and BGC-II to the north and south of

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Udaipur–Nathdwara in central Rajasthan. Many dislocation or shear zones shown in the map are not recorded in the seismic studies. Once joined to the Aravalli craton, the Bundelkhand craton is dominantly made of 2.5 Ga old granitoids in which inclusions of 3.5–3.3 Ga TTG gneisses represent the relics of basement, which is equivalent to the BGC of Rajasthan. The account of Dhala crater (wrongly printed crator in figure 2.7) appears to be out of place, but is interesting for a geologist to know. Meghalaya craton finds sufficiently a detailed description along with its carbonatite complexes. Amongst the southerly located cratons to the CITZ, the Bastar craton has very old rock (Sukma gneiss) of 3.56 Ga age, similar to the gneisses of Dharwar craton. These two cratons were separated by Prahnita–Godavari rift (Proterozoic), whose both arms have granulites. The Dharwar craton has a long crustal record from 3.6 to 2.5 Ga and is an illustrative example of granite–greenstone belt whose granitoid gneisses are often dome shaped. The description is fairly satisfactory. Here, the Eastern Dharwar Craton (EDC) is also considered different from the Western Dharwar Craton (WDC) as the former is stated to be invaded by granitic batholiths. The statement on p. 71 that 'greenstone and intervening gneisses and granitoids are called as the Dharwar batholiths' is incorrect and also confusing. The fundamental problem of E–W subduction and the relationship of the E–W running isograds with the N–S trending regional fabric are not discussed. The Singhbhum craton has a large coverage. The report of detrital zircon of 4.02 Ga from Champua is interesting as it suggests existence of Eoarchean crust in the Singhbhum region.

Chapter 3, tectonics of Sri Lanka, an Island nation in the Indian Ocean, is described for its three distinct topographic belts with N–S trends, all formed during Pan-African (600–550 Ma) event. In the central belt of Highland complex, the record of 3.5–3.0 Ga old gneisses is interesting, although it is correlated with Trivandrum block (Pandyan mobile belt of some authors).

Chapter 4 provides geological and tectonic evolution of the Proterozoic mobile belts, namely Aravalli–Delhi, Singhbhum, Eastern Ghats. Here the Prahnita–Godavari belt and Southern Granulite Belt or Pandyan Mobile Belt (of Ramakrishna and Vaidynadhan 2008) have been discussed in somewhat detail. Nearly all the fold belts border one or more cratonic blocks, but a clear tectonic setting in respect of colliding blocks or plates for the evolution of the fold belts is missing. It remains unclear as to how the Aravalli fold belt was formed in the plate tectonic setting and in the cratonic division into BGC-I and BGC-II. The authors visualize a hypothetical Marwar craton in the west to collide perhaps with the entire BGC block in the east. Such a physical entity cannot be hypothesized in real geology, particularly when the assumed Marwar craton is not recorded in the seismic profiles. It is here that Ensialic orogenesis model is applicable. The book mentions ensialic rifting instead of ensialic orogenesis. The Central Indian Tectonic Zone (CITZ) is discussed at an appreciable length in the book. It is a combination of three fold belts of varying metamorphic grade and age, namely the Betul supracrustal low-grade belt (1.5 Ga); the Sausar belt of polymetamorphic granulite belt (950 ± 50 Ma) and the NE-trending Mahakoshal belt within Narmada rift valley bordered by linear faults on both sides. It is held in this book as in many others, that the CITZ sutures the N and S cratonic blocks of India during Rodinia. Figure 4.18 of the book shows an unusual feature of Satpura fold belt colliding with Bastar craton. The CGGC (Chhotanagpur Granite Gneiss Complex) in the book is combined with the Singhbhum fold belt, but the authors fail to identify the crustal block in the north that collided with the Singhbhum craton located in south, evolving these two contiguous belts of high-grade CGGC and medium grade Proterozoic Singhbhum fold belt. The Eastern Ghats Mobile Belt bordering three cratons – Dharwar, Bastar and Singhbhum – on their eastern side is described in detail. It is largely a granulite belt and is considered vital in the Rodinia reconstruction of India and Antarctica. But the restoration depicted in figure 4.25 shows the Proterozoic fold belt in Antarctica located behind the Napier Complex comes in direct contact with the Dharwar craton. The Pandyan mobile belt here is described in brief for its geology. This mobile belt of deep crust (Granulite) is in continuation with the granulites of Dharwar craton and its evolution as mobile belt is left to speculation. All the shear zones in this terrain are described in a similar way as in the main Dharwar craton.

Chapter 5 provides description of Proterozoic Purana Basins, linked to the cratons and mobile belts. Here, several intracratonic undeformed basins, namely Marwar, Bayana, Vindhyan, Gwalior, Bijawar are in the northern peninsular India, whereas Chhatisgarh, Indravati, Sukma and other smaller basins occur in central India. In the

southern central India, the basins of Kaladagi, Bhima and the Prahnita–Godavari and Cuddapah basin with its sub-basins are described. Amongst these basins, the Marwar basin appears to be the youngest (∼750 Ma). In the simplified geological map (figure 5.2) of the Marwar basin, the sequence of Marwar Supergroup is shown in the reverse order in the Index, although correctly shown in the stratigraphic column drawn along side of the map. Bayana basin is at the east end of the Delhi–Aravalli fold belt. Its thickness and age are uncertain, and the reason why it is there where it is now, far off from the craton and the Proterozoic folds of Rajasthan, is left to the reader. The large Vindhyan basin in two regions, namely the Son Valley (Uttar Pradesh) and Rajasthan gets a more detailed geological tectonic description. Lithostratigraphy, age data and depositional environment are very well described along with basin tectonics. But recognition of south plunging syncline in Son Valley and adjacent anticline, so clearly observable in map, is missing in the tectonics of the Vindhyans. The Cuddapah basin and its sub-basins are well discussed with composite log and depositional environment as well as interpretation of sea level changes.

Chapter 6 gives a very detailed and lucid account of geology and tectonics of the Himalayan orogen, supplemented by geochronological and geophysical data. It begins with the thrust bound tectono-stratigraphic divisions of Himalyan orogen from south to north. The Indus–Ganga–Brahmputra plain abuts against the Sub-Himalaya along the Himalayan Frontal Thrust (HFT). To north of HFT is the Sub-Himalayan belt of Siwalik Ranges which abut against the Lesser Himalaya and its Proterozoic sediments with the Main Boundary Thrust (MBT). Further north, the Lesser Himalaya has the Main Central Thrust (MCT) at its contact with the Higher (Great) Himalayan Crystallines which again contacts with the Tethys Himalaya along a normal fault called South Tibet Detachment Fault (STDS). Beyond it in the north is the Indus Tectonic Shear Zone (ITSZ) which marks the northern limit of the Indian plate. The evolution of Himalaya starts with the subduction (Early Cretaceous) of oceanic plate of the Indian lithosphere along Shyok–Suture Zone (SSZ), formation of volcanic arc (Shyoke–Dras Volcanic Arc). The subduction appears to have shifted ESE along Indian–Tsangpo Suture Zone (ITSZ) giving rise to calc-alkaline granitoid (Trans-Himalayan Batholith) with the closure of Neo-Tethys. The sediments deposited on the north-moving Indian plate and those deposited from erosion of the volcanic Arc were involved in the collision zone and were subjected to heat from below, forming the metasediments of the Higher Himalayan crystalline (HHC). All along the ITSZ, the ophiolites (harzburgite + gabbro + basalt all mixed with marine sediments in the accretion zone) and their emplacement on the Indian continent and also on the Asian plate are clearly presented. Tethyan sediments comprising of sandstone, shale and limestones from Cambrian to Eocene, which were deposited on the Indian cratonic shelf in the Tethys Sea finds a clear description. This sedimentary zone lying within the southern Tibet is called Tibetan Himalaya. After describing how the different belts of the Himalaya were formed, the book contains a critical discussion on the thrust systems of MCT, Munsiary Thrust (MT) Vaikrita Thrust (VT), and STDS to avoid the prevailing confusion between Munsiary Thrust and the MCT and Vaikrita Thrust. Also Himalyan magmatism is discussed in greater detail using isotopic data, including fission track. Interesting is the attempt to constrain the different supercontinents from Columbia, Rodinia to Pangaea and Gondwanaland. Finally, a section on geologic evolution of the Himalaya is added which to this reviewer appears a repetition. A small repetition is also found on Tso-Morari crystallines which have ultra-high pressure assemblages in the eclogite lense occurring within Puga gneiss in contact with low grade rocks of Taglang La Formation. Status of this formation is not clear in this description. Lastly, the chapter gives an exhaustive account of Tethyan Himalayan sequence from Cambrian to Paleogene, using ages of detrital zircons. In the end of the chapter 6, a useful discussion is presented on the timing of India–Asia collision. The Karakoram sedimentary sequence is stated to have formed on the southern margin of the E–W trending Shyoke–Dras Volcanic arc, but did not state about the north-side sediments and their distinction from the Tethys sedimentary zone. In figure 6.26, Bhaironghati granite containing inclusions of Gangotri granite should have been shown younger in the Index. Furthermore, MCT in this figure should be labeled MT.

Chapter 7 is titled Trans-Himalayan and Karakoram Ranges. It provides the geology and tectonics of these two tectonic domains. This region covers the Himalaya in Pakistan and Tibet. Between the Shyok–Dras volcanic Arc and the

Asian plate is the Karakoram sedimentary sequence which was deposited on the southern margin of the Asian plate bordering Tethys Sea. The sea was closed first along the Shyok Suture Zone (SSZ) and thereafter along the ITSZ in the south. Both these suture zones are shown to bind the Trans-Himalayan Ladakh batholith and the Karakoram batholith further north. All along the ITSZ is the ophiolite complex which represents a good example of rising oceanic lithosphere and its decompression melting, giving rise to an association of harzburgite/blueschist, gabbro and basalt, often with pillowed structure. This rock association is mixed with marine sediments of accretionary wedge or prism as reported in ophiolites of Nidar, Zildat and at other places. Their discussion is followed by the description of Ladakh batholith. Here again the timing of India–Asia collision is given. Curiosity is left for the reader as to why the SSZ bounds the Karakoram batholith (Magmatic arc) on the north of the Arc whereas the ITSZ borders the Ladakh batholiths (also a Magmatic arc) on the southern margin.

Chapter 8 enumerates Deccan Volcanic Province (DVO) linking the eruption to the Kerguelen hotspot whose impact is recorded in the 130–115 Ma old Rajmahal–Sylhet traps. After separation from Madagascar between 88 and 83 Ma, India moved over the Reunion hotspot in the Indian Ocean and the Deccan basalt eruption occurred between 65 and 64 Ma time. Since DVO spreads over half-a-million square km area between latitude 16° and 24°N, the rate of movement of Indian plate appears very fast, about 80 cm per year. Another interesting, rather intriguing feature is that Infra-trappean sediments that were capped by basaltic lava flows escaped baking effect; a curiosity remains to be explained.

Chapter 9 gives an overview of the tectonics of western margin of India, especially the N–S trending Sahyadri Ranges which run parallel to the western coastline of peninsular India. The steeply west facing escarpment of Sahyadris are familiarly known as Western Ghats. The emergence of the Sahyadri is associated with the Cenozoic evolution of the western margin of the Indian subcontinent. The chapter also covers the continental shelf as well as marine basins, ridges and fractures of the Indian Ocean.

The last chapter, i.e., chapter 10 is on Geology and Tectonics of Bangladesh which is confined within Great Bengal Delta plain. The reason to include this chapter on Bangladesh geology is due to the fact that the configuration of this great basin and its fluvio-deltaic sedimentary fill is intimately linked to the world's largest orogenic system of the Himalaya. The authors include a table giving stratigraphy of the Bangladesh Bengal Basin as also the cross-section from the Indian craton to Ganga–Brahmputra and Indo-Myanmar Arc up to Sunda plate for understanding the geotectonics of the region.

The reviewer is definitely impressed by the massive task undertaken by the authors for incorporating 47 colour figures, besides many black and white sketches, 18 tables and many photomicrographs in this book and for their efforts making it up-to-date for geological data. In this day of internet and digital books, physical books still have a charm although many text books are available online and can be downloaded instantly. The purpose of writing a book is to communicate scientific information clearly and concisely. This aspect is only partially achieved, especially in respect of the evolution of Proterozoic fold belts. Evolution of the Himalaya is vividly stated in terms of plate tectonics, but the origin of Proterozoic fold belts of peninsular India are only vaguely presented. In plate tectonics, a fold belt or mobile belt forms only on one side – the site of colliding plates or crustal blocks. In Rajasthan, the Paleoproterozoic Aravalli fold belt not only occurs on both sides of the BGC craton, it also has a contact to its west with the Meso-Proterozoic Delhi fold belt. It failed to explain plate tectonics origin of these and other fold belts of the Indian cratons, although the book has covered various tectonic aspects of the Indian subcontinent. Even Ensialic orogenesis model was not applied for these fold belts, although described in the published literature. I am also surprised how a well-known publisher like Springer could publish this book, meant for graduate students, researchers and even for Earth-Science knowledge seekers, without Subject Index. In summary, I appreciate the book and find it useful for various aspects of geology and geophysics of the Indian subcontinent for its updated geochronological data and an exhaustive work on the Himalayan Mountain range. The book is highly priced at more than 12,000 Indian Rupees.

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