Chapter – V

Summary and Conclusions

In this work, I have made an attempt to improve our understanding of the global events and evolutionary processes that shaped the earth during the Proterozoic Eon, from the perspective of the Indian geology. For this purpose, I have studied the sedimentary records of two of the largest Proterozoic sedimentary successions of India – the Neoproterozoic-early Cambrian Marwar Supergroup and the Mesoproterozoic Chhattisgarh Supergroup, using various geochemical tracers such as trace element concentrations, stable and radiogenic isotopes. The major findings from each basin are provided in the concluding sections of the chapters 3 & 4. The aim of this chapter is to summarize the major results in a regional and global context and to discuss the directions that can be taken in the future studies.

5.1 General conclusions

5.1.1 Chemical evidence for the Neoproterozoic glaciations

Using Sr isotope stratigraphy, I have determined an approximate age of 570 Ma for the Gotan Formation of the Bilara Group in the middle part of the Marwar Supergroup. The age of the formation and the magnitude of $\delta^{13}C$ negative excursion hint at preservation of the Ediacaran Negative excursion – 2 (EN2) in the Marwar basin and which can be considered as an evidence for the ~580 Ma Gaskiers glaciation. The importance of this discovery lies in the fact that, even though the Gotan Limestone lacked any physical signatures of a glaciation such as dropstones or diamictites, it still preserved the chemical signal in the form of $\delta^{13}C$ negative excursion. Also, there were doubts raised about the global nature of the Gaskiers glaciation, with some suggesting it could be regional like the Phanerozoic glaciations, in the light of new geochronological constraints which suggested a shorter duration (<0.34 Ma) for the event (Pu et al., 2016). However, taking into account that the Indian shield was at the equator during Gaskiers glaciation (Davis et al., 2014), this result confirms that the signal of glaciation was preserved even at the equatorial landmasses and suggests that the $\delta^{13}C$ excursion associated with the Gaskiers glaciation is globally correlatable. Additionally, this study also reveals that the long depositional hiatus (~100 Ma) between the Jodhpur (~700 Ma) and Bilara (~570 Ma) groups could be the reason for the absence of any evidence for the Marinoan glaciation in the Marwar Basin.

5.1.2 Global tectonics and the evolution of the Marwar Basin

Based on my study, I propose a 3-stage evolutionary model for the Marwar Basin. The basin opened up and the initiation of sedimentation took place subsequent to the disbanding of the Supercontinent Rodinia in the Cryogenian. The Jodhpur Group was deposited during this period. This was followed by a period of non-deposition for almost 100 million years. The subsequent deepening of the basin and the deposition of middle carbonate sequences of Marwars occurred during the initiation of amalgamation of the Gondwanaland in the Ediacaran. The end phase of the basin evolution saw the large scale deposition of sandstones, as a result of the erosion following the collisional assembly of Gondwanaland, which is correlated globally (Ashwal et al., 2013). Thus, the contemporary tectonics by and large controlled the evolution of the Marwar basin.

5.1.3 The Mesoproterozoic Ocean

The sustained enriched $\delta^{13}C$ (2.6 – 3.6‰) shown by the Raipur Group carbonates is a result of the increased organic carbon burial flux during the late Mesoproterozoic. This change in the dynamics of the carbon cycle is recorded globally (Bartley and Kah, 2004). The data from the present study along with the existing information support our current understanding of the Mesoproterozoic Ocean. During this time period the deep oceans had remained largely anoxic while pockets of euxinia existed at the cratonic basin margins, where surface waters supported high biological productivity (Lyons et al., 2014).

5.1.4 Timing of amalgamation of the Indian cratons/blocks

The South Indian Block (SIB), consisting of the Dharwar and Bastar cratons was amalgamated with the North Indian Block (NIB) consisting of the Bundelkhand Craton, forming the unified Indian landmass sometime during the late Paleoproterozoic to early Neoproterozoic. The timing of this suture, however, remained equivocal with arguments supporting either ~1.6

Ga or ~1.1 Ga as the probable time of amalgamation and the rocks of the CITZ were believed to have recorded the history of this event. From the quantitative provenance analysis of the Chhattisgarh siliciclastics, it became quite evident that a significant portion of the sediments, mainly of the Raipur and Kharsiya Groups, is derived from the northward located CITZ. Taking into account of the fact that these groups were deposited between 1.3 Ga and 1.0 Ga, based on the $\delta^{13}C$ stratigraphy and the age of Sukhda Tuff, the timing of the amalgamation of NIB and SIB can be fixed at ~1.6 Ga, which was much before the initiation of sedimentation in the Chhattisgarh basin at ~1.45 Ga (Das et al., 2011). This discovery suggests that the peninsular India had almost attained its present day configuration by the time of maximum packing of the Columbia Supercontinent at ~1.45 Ga (Meert and Santosh, 2017) and can therefore be considered as a single landmass for the continental reconstructions beyond the Rodinia.

5.2 Basin specific conclusions

5.2.1 Provenance of sediments in the Marwar Basin

The quantitative provenance analysis of the siliciclastics of the Marwar Basin has revealed that the rocks of the Delhi Supergroup had remained as a constant source of sediments throughout its depositional history by contributing more than 30% of the total sediment budget of the basin. Contributions from the Erinpura Granites were probably limited to the Jodhpur Group; however, it is difficult to rule out a complete absence of sediments derived from these in the younger groups. The BGC-2 was the dominant source in the initial phase of evolution of the basin with a sediment supply >70% to the Jodhpur Group. However, its contribution to the basin appears to have ceased subsequent to the deposition of the Girbhakar Formation.

While the fluvial activity was virtually non-existent during the deposition of carbonates of the Bilara Group, some amount of siliciclastics did make it into the basin. The composition of these sediments suggests that these were rich in heavy minerals (e.g., garnet) and were primarily derived from the Delhi Supergroup. When the clastic sedimentation resumed with the deposition of the Nagaur Group, the provenance continued to be dominated by the Delhi’s and Erinpura Granites. Interestingly, the MIS, despite its close proximity had very limited contribution to the sediment budget of the entire Marwars; except for at the depositional sites very near to the contact of the topmost MIS and bottommost Marwars.

5.2.2 Provenance of sediments in the Chhattisgarh Basin

The geochemical quantitative provenance analysis of the siliciclastics of the Chhattisgarh Supergroup had shown that the provenance had changed significantly during the evolution of the basin. The basin opened up at the eastern margin of the Sonakhan Greenstone Belt (SGB) where the deposition of the Singhora Group took place. The SGB and the basement Bastar granitoids sourced more than 60% of the total sedimentary budget of the Singhora, and a large part of the Chandarpur Group. The later stage of the Chandarpur sedimentation saw the provenance becoming more dominated by the Mahakoshal rocks (> 50%) and the mafic granulite belts, RKG and BBG, of the CITZ. As the basin evolved with the basement granites largely covered up and the Sonakhan highlands eroded, the provenance shifted from the southern part of the basin towards the north of the basin. Overall, the sediment sources of the Chandarpur Group were diverse with the basement Baster Granitoids and Mahakoshal Group rocks contributing equally along with the SGB, with minor contributions from the mafic granulite belts. By the time of deposition of the Raipur and Kharsiya Groups, the SGB and the basement Bastar granitoids were largely cut-off as source regions. More than 90% of the sediments were sourced from the northerly located mafic granulite belts and the Mahakoshal Group rocks with only minor inputs from the SGB.

5.3 Looking to the future

The Purana basins have always intrigued the geoscience community of India; however, until late, most of the attempts were limited to bio- and litho-stratigraphic aspects. Integrated geochemical and geochronological efforts were sporadic. There are a couple of projects which I would like to take up in the future,

1. Establish a complete geochemical record of the Proterozoic Eon from an Indian subcontinent perspective. This would involve study of the Paleoproterozoic Purana basins, some of the early Paleoproterozoic metasedimentary sequences and bridging the gap in the sedimentary records by intrabasinal correlations.
2. Absence of high quality geochronologic data still remain as an Achilles heel in constraining the ages of various Proterozoic successions in India. The timings of opening and closure of most of the Purana basins remain unknown. Dating the limestone

sequences and some of the volcaniclastics could partly resolve the issues. A comprehensive detrital zircon geochronology would go a long way in providing chronological constrains.