2.1 Introduction

The area under investigation encompasses an important part of the Central Indian Tectonic Zone (CITZ) with its diverse lithotectonic units of Phanerozoic, Proterozoic, and Archaean age (Valdiya, 2010). The area consists of Purna graben, Mahakoshal belt including Son-Narmada-Tapti (SONATA) lineament, Satpura mobile belt, and Archaean cratons. Four major cratonic nuclei are the Bundelkhand, Bastar, Singhbhum and Dharwar located in the south, southeast, east and northern and western part of the study area. The less deformed intra-cratic Vindhyan, Chattisgarh and Bastar basins were formed during Paleoproterozoic-Mesoproterozoic period at the paleo-plate boundaries. The SONATA zone extends for a distance of 1600 km in the NE-SW direction, from the west coast to the northeastern margin of the Indian shield.

The CITZ, passing all along the SONATA, is characterized by a suture between the northern Bundelkhand craton and the southern Dharwar–Bhandara cratons (Radhakrishna and Naqvi, 1986; Tewari et al., 2001). This is regionally bounded by Narmada North Fault (NNF) and the Narmada South Fault (NSF) (Yedekar et al., 1990; Nair et al., 1995), forming about ~ 120-150 km wide distinct CITZ. West (1962) reported that the SONATA lineament is an ancient line of weakness, and the land to the north (e.g., Vindhyans) and south (e.g., Gondwanas) of the line undergone vertical movements during geological times. The Satpura hills are also considered as the uplifted shoulders of the Narmada rift valley (Shankar, 1988). The vertical block tectonics in Vindhyan province was accompanied by deposition of Precambrian sediments of ~ 5.5 km thickness during its downward movements (Kaila et al., 1989). Southern block, though evolved as an elevated land was devoid of sedimentations during its early period, received sediments during Gondwana period. Number of linear ‘rifts’ were also evolved in the Gondwana basins (Figure 2.1) during the late Paleozoic–Mesozoic break-up of the supercontinent Gondwanaland (Mahadevan, 1994).
Figure 2.1 Tectonic Map of the study area reconstructed by Generic Mapping Tools (GMT version 3.4.1; Wessel and Smith, 2002). Topography data including drainage patterns are after http://www.gina.alaska.edu. The faults, lineaments, plateau and type of formations are after the Atlas of Geological Survey of India (2000). Cratons and Fold belt details were taken from Sharma (2009) and Valdiya (2010).

Significant changes in the crustal character took place during the breakup of Gondwanaland and subsequent northward movement of the cratonic block over the Reunion hotspot plume-head resulting in a burst of volcanic activity ~ 65 my ago (Morgan, 1981; Dewey and Stephens, 1991; Mahoney et al., 2002). Deccan plateau was mostly blanketed by these basaltic lavas, and experienced vertical tectonics (Kailasam, 1979). The traps continue north of the Vindhyan range in the Malwa plateau region, and
the area comprising the Vindhyan and Satpura ranges with the intervening Narmada valley. The SONATA tectonic zone has played an important role in the formation of a series of folded structures in the Vindhyan formations to its north (Kaila et al., 1989). These areas are thermally anomalous with relatively high geothermal gradients and heat flow (Shankar, 1988). There is geological evidence that the NSF was again partially reactivated during Deccan volcanism in the area. Faulting activity was continued in post-trappean times offsetting the Quaternary sediment cover. One such example exhibited by block faulting is noticed to the southeast of Jabalpur area (Srivastava et al., 1999).

2.2 Archaean Cratons in Central India

Bundelkhand, Bastar, Singhbhum, and Dharwar cratons are separated from each other by Proterozoic mobile belts (Valdiya, 2010). They are bounded by shear and thrusts zones. These belts experienced episodic deformation, metamorphism and granite emplacement. Early crustal development in these cratonic provinces took place around the nuclei of Palaeo-Archaean rocks, and the process of cratonization or stabilization was completed by the end of the Neo-Archaean about 2600 - 2500 Ma ago (Valdiya, 2010). The evolution of the Archaean cratons entailed stretching and rifting of sialic crust. This was followed by basic volcanism and attendant intrusion of basic to ultrabasic plutons. Subsequently, sedimentation took place in tectonically evolved intra-cratic linear basins, and finally, granite emplacement occurred on extensive scales. The tectonic evolution of these four cratons is described below.

2.2.1 Bundelkhand Craton

Constituting the core of the north-western expanse of the Indian Shield, the Archaean Bundelkhand craton is also described as Aravalli or Rajasthan craton. It lies in the tight embrace of the early Proterozoic fold and fault belts of the NE-SW oriented Aravalli range and the ENE-WSW tending Satpura Range (Figure 2.1). It covers the eastern Rajasthan, south-western Uttar Pradesh, and north-western Madhya Pradesh. Later Proterozoic Vindhyan sedimentary succession marks a probable cover through the middle of the craton. The NE-SW tending Great Boundary Fault, which demarcates the
western limit of the Vindhyan domain, divides the craton into two blocks: Bundelkhand in the east and the Malwa in the west (Valdiya, 2010).

Evolved through episodic deformation, metamorphism and plutonic-volcanic activities during the Archaean and Proterozoic times, the Bundelkhand craton is constituted of a number of lithotectonic units or rock complexes that form the basement of the Proterozoic sedimentary successions of the larger Aravalli domain (Sharma and Upadhyay, 1975; Sharma, 1977; Naha and Mohanty, 1988). Multiple phases of the ductile deformation, attended granite magmatism and metamorphism have made the differentiation and delineation of various lithotectonic units. The Archaean complexes also occurred as isolated inliers within the surrounding fold and fault belts of Early Proterozoic rocks. There was thickening of the crust due to addition of or underplating of granitic magma (Sharma, 1998, 1995), or multiple thrusting and staking of slabs during the second phase of deformation (Sinha Roy et al., 1993). The crust was rifted apart again and greater Bundelkhand craton broke into eastern (Bundelkhand) and western (Mewar) blocks. The geodynamic evolution of the Bundelkhand craton was completed with emplacement of ~ 2550 Ma old granites in the Broach and Bundelkhand regions. Subsequent rifting in the early and late Proterozoic times developed basins for deposition of the Aravalli and Delhi successions. Each of them was involved in orogeny, known as the Aravalli and Delhi orogeny, respectively.

2.2.2 Bastar Craton

The Bastar craton is known as Bhandara craton covers southern Chattisgarh, northeastern Maharashtra, south-western Orissa and north-western Andhra Pradesh (Valdiya, 2010). The volcano-sedimentary supracrustals cover forms the linear belts and islands. Later involved in strong Proterozoic tectonism, both the basement gneisses and covering volcano-sedimentary rocks were highly deformed and metamorphosed to medium grade metamorphism, but reaching to granulite grade in the south-western part. The southwestern and northwestern boundaries of the Bastar craton are demarcated by the NW-SE oriented Gondwana grabens, occupied by the Godavari and Mahanadi rivers. The elongated linear basins became sites of protracted sedimentation towards the close of the Palaeozoic era. The faults responsible for the formation of rift basins represent ancient faults that were formed probably at the end of the Neo-Archaean time. North of
the craton a crustal-scale shear zone (i.e., Central Indian Shear zone) oriented broadly along ENE-WSW, extends for more than 500 km (Yedekar et al., 1990; Nayak, 1990; Jain et al., 1991; Bandyopadhyay et al., 1995) and also called the CITZ (Hanuma, 2003).

2.2.3 Singhbhum Craton

One of the most conspicuous features of the Singhbhum craton is the curvilinear shear zone that demarcates its northern boundary against the Chhotanagpur gneissic terrane. More than 500 km in length, the deep Singhbhum shear zone is represented by a ~ 1-5 km wide zone of fractures. Some of the fractures reach the mantle, providing pathways to outpouring lavas and ultrabasic plutons (Banerjee, 1962, 1969, 1977). It was originated as a normal fault along which the northern block gradually subsided, giving rise to what is known as the Singhbhum basin of Proterozoic antiquity. Subsequent reversal of the sense of movement made it a shear zone, and further, there was southwards thrusting of rocks onto the Archaean Singhbhum craton.

2.2.4 Dharwar Craton

A large part of the northeastern Dharwar craton is under the cover of Proterozoic sedimentary successions represented by Kaladgi, Bhima and Cuddapah supergroups. The western margin of the Dharwar craton is marked by more than 700 m high western Ghat escarpment (Valdiya, 2010). The southern margin of the Dharwar craton is marked by a system of shear zone extending east-west from coast to coast. This 60-80 km wide shear zone system defined in the north by the Moyar - Bhavani Shear zone, and in the south by the Palghat-Cauvery shear zone, the real boundary of the Dharwar craton. The transcurrent shear zone system contains a number of prominent massifs of rocks (Rajaram and Harikumar, 2002). Some workers believed that the Palghat - Cauvery shear zone represents a dextral shear system with oblique – slip that brought about horizontal displacement of the order of tens of kilometers (Drury et al., 1984; Ramakrishnan, 1990, 2003; Chetty, 1994, 1995).

2.3 Fold belts in Central India

The fold belts of the central India region, namely the Mahakoshal, Satpura, Sakoli and Dongargarh, are sandwiched between the Rajasthan-Bundelkhand craton in the
north and the Bastar craton in the south (Sharma, 2009). Of these, the Mahakoshal and Satpura belts are located in ENE-WSW trending CITZ. The CITZ is broad belt of unequal width. Its narrow northern belt is believed to represent the Palaeoproterozoic Mahakosal fold belt while the wider southern belt is represented by the Mesoproterozoic Satpura fold belt. The fold belts occupy the Proterozoic terranes of Madhya Pradesh, Maharashtra, and Uttar Pradesh. The fold belts of the central Indian region received early attention of the geological Survey of India (GSI) and Nair et al. (1995). The Geologist of GSI studied the meta-volcanic and meta-sedimentary rocks of upper Narmada-Son (SONA) valley and gave the name Mahakoshal group to the rocks earlier considered Bijawar series (Pascoe, 1964), in view of their differences in lithology, structures, tectonics and nature of intrusive. The belt south of Narmada-Son valley zone is Satpura fold belt, made up of Sausar group of rocks was mapped by GSI workers.

2.3.1 Mahakoshal Fold Belt

The evolution of the Mahakoshal fold belt (MFB) started with intra-cratonic rifting of the continental crust during Archaean period (Sharma, 2009). The intra-cratonic rift was obviously mantle-activated caused by upwarping of Moho between the faults (Shankar, 1991; Rao et al., 1990). Converging Bastar craton from south and Bundelkhand craton from north resulted N-S compression on this belt. The folding of the MFB in the north by converging plates of Bastar and Bundelkhand created extension in the south, and finally, developed the Satpura rift basin to the south of the SONA zone. The SONA zone controlled the orientation of the Satpura rift since its evolution. The SONA zone delineates the southern boundary of the Gondwana basin. The SONA zone in the north is bordered by Son-Narmada North Fault (SNNF) and in the south by the Son-Narmada South Fault (SNSF). The reactivation of Son-Narmada lineament during Satpura orogeny helped to retain the existing parallelism of Satpura fold belt with Mahakoshal fold belt. Roy et al. (2002) reported that the SNSF is the southern boundary of the MFB, which shows that the deformation associated with N-S compression was superposed by a strong sinisterly shearing movement that may have facilitated exhumation of lower crustal rocks south of the SNSF (Sharma, 2009).
2.3.2 Satpura Fold Belt

The Satpura belt is most likely to have formed in the Mesoproterozoic time, mostly between 1525 and 1600 Ma which is the age of the Semri series of the undeformed Vindhyan supergroup now delimited by Satpura belt (Valdiya, 2010). The N-S trending basement gneisses were rifted and the evolved intra-cratonic basin received the cratonic sediments. The basinal sediments were subsequently compressed in Satpura orogeny, documented by the presence of recumbent folds (over thrust) along the northern and southern margins of the belt. The orogenic trend and the overturning of the folds from both sides towards a crystalline core suggest that the stable crustal blocks to the north and south of the orogeny collided to evolve the Satpura fold belt.

2.3.3 Dongargarh Fold Belt

The evolution of the Dongargarh fold belt is typical of intra-continental rift (Sharma, 2009). Initially, rifting of the Amgaon gneissic basement started in an extensional regime with rift margins trending N-S, and later bimodal volcanic were emplaced in this rifted zone. Syntectonic partial melting of continental crust at depth took place in this area (Sensarma et al., 2004). They interpreted this by plume tectonics where the bimodal igneous province with equal volumes of coeval felsic and mafic volcanic rocks were documented in Dongargarh fold belt.

2.3.4 Sakoli Fold Belt

The evolution of the Shakoli fold belt (SKFB) is still not clear among the geoscientists. There is no systematic evolutionary model. The existence of Archaean gneissic rocks of Amgaon group all around the triangular shaped SKFB indicates that the supracrustal rocks had an ensialic rifting. The rifting was initiated by crustal extension and was subsequently filled with coarse clastics followed by basic volcanic. This is expressed in the gravity high all over the SKFB (Verma and Banerjee, 1992). These were overlain by thick pelites and bimodal volcanic that are indicative of deposition in a rapid subsiding trough that was forerunner of the Sakoli orogeny. The end of sedimentation is marked by deposition of thin clastics over the pelites, indicating shallow water sedimentation. Bandyopadhyay et al. (1995) reported that the Sakoli supracrustals have been deformed by four episodic folding.
Apart from the above discussed cratons and fold belts, several major drainage/river systems and associated basins passes all through the CITZ. These are, namely, the Chambal and Betwa Rivers flow northward and meet with Yamuna River. While the river Son falls directly into the Ganga River. Narmada, Tapti and Mahi Rivers flow westward and meet the Arabian Sea. Wainganga River meets the Godavari in the south (Figure 2.1). Within the course of the rivers the remnant sedimentary basins, sub basins and sub-sub-basins were formed over a longer span of time. These basins are the main water resources for irrigation and domestic water purposes for local peoples.