CHAPTER -1

Introduction
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Formation, metamorphism and reworking of the crust and the accretion of several crustal fragments have all started as early as Archean, in a manner somewhat analogous to the processes active today (Dewey and Windley, 1981; de Wit, 1998). The Archean terranes are generally made up of vast expanses of granitoid gneisses and other intrusives interspersed with linear belts of supracrustal rocks which are referred to as greenstone belts. Therefore, these are also referred to as greenstone-granite terranes that form the nucleus of continental crust in southern Africa, Canada, Greenland, Baltic Shield, northeast Brazil, India and western Australia (Condie, 1981, 1994; Kröner, 1985; Radhakrishna, 1990; de Wit and Ashwal, 1997; de Wit, 1998; Kusky and Polat, 1999; Kerrich and Polat, 2006).

The ubiquity of greenstone-granitoid terranes in Archean cratons around the world is so striking that their association needs to be studied to understand the evolution of such terranes. Another unique feature of the greenstone-granite terranes is the occurrence of gold in hydrothermal quartz-carbonate veins (Mueller et al., 1988; Kerrich and Feng, 1992). These gold bearing quartz-carbonate vein systems could have been formed by pressure solution and subsequently advected along the greenstone-granite terrane boundaries by lateral secretion or other exhalative processes (Fyfe, 1978; Fyfe and Kerrich, 1985).

The greenstone belt rocks are metamorphosed to different degrees ranging from lower greenschist facies to upper amphibolite facies in Archean cratons. The relation between the time of formation of the rocks of the greenstone belts and the surrounding granitoids, and also the time of metamorphism are of particular interest to understand the crustal evolution during the Archean.

The Archean greenstone belts consist of komatiites, tholeiites, felsic volcanic rocks and sediments. Komatiites are unique as they represent ultramafic magmas that formed almost entirely during Archean (Nesbitt et al., 1982; Campbell et al., 1989; Grove and Parman, 2004). Several models have been proposed for the growth of the Earth's crust on the basis of studies carried out in the Archean greenstone-granitoid terranes. Adiabatic upwelling of plumes that originated from lower mantle has been suggested as a mechanism that generated komatiite magmas by low extent partial melting in some greenstone belts (Rajamani et al., 1985; Rajamani et al., 1993). The
generation and emplacement of Archean komatiites has also been attributed to several other geodynamic settings (Kusky and Polat, 1999) including mid-ocean ridges (de Ronde and de Wit, 1994), intra-oceanic plume setting (Jochum et al., 1991; Xie et al., 1993; Arndt et al., 1997; Condie, 2003), subduction zones (Parman et al., 1997), and continental rifts (Nisbet et al., 1993). Puchtel et al., (1998) found the trace element composition of Kostomuksha greenstone belt in Baltic Shield to have signatures similar to that of recent ocean plateaux. They therefore related the tectonic setting for that greenstone belt with an ocean plateau model which could have had a mantle plume origin and associated underplating.

Subduction related magmatism in an island-arc setting, much similar to the Phanerozoic examples, but with smaller plates, were suggested as the major crustal growth process active during Archean for some of the greenstone belts (Polat et al., 1999; Smithies et al., 2003). Condie (2005) suggested some of the non-arc-type greenstone belts could have been produced at ocean ridge sites. Even a plume-arc interaction has been proposed by some workers (Abbott, 1996; Hollings and Wyman, 1999). However, in a recent review on Archean geodynamics, Condie and Benn (2006) have kept the question open about the crust forming processes during Archean, emphasizing the need for more precise information.

Understanding petrogenesis and tectonic setting of formation of granitoids is much more challenging. The granitoid magmas could have been derived by partial melting of a variety of sources, including mantle, oceanic crust, and pre-existing continental crustal rocks (Hanson, 1978). Addition of juvenile granitoid magmas must have contributed significantly to crustal growth during Archean (Kusky, 1993, 1998; Abbott et al., 1997). The Early Archean was predominated by the tonalite-trondhjemite-granodiorite (TTG) suite of rocks which were products of partial melting of subducting oceanic plates at shallow depths, due to very low angle of subduction and higher heat production (Martin et al., 2005).

In contrast, the Late Archean is characterized by low heat production, thinner oceanic plates and steeper angles of subduction. This could have led to a decline in the slab melting and consuming of some slab-melts by the mantle peridotite (Rapp et al., 1999). Consequently, the partial melting of mantle peridotite, metasomatised and enriched by the slab-melts, could have given rise to sanukitoids and quartz-monzodiorite magmas. Differentiation of these magmas or partial melting of rocks
represented by these magmas might have yielded granodiorites and granites (Shirey and Hanson, 1984, 1986; Smithies, 2000; Moyen et al., 2003; Martin et al., 2005). Thus the Late Archean granitoid terranes are characterized by quartz-monzodiorite - granodiorite - granite (QMG) suite of rocks.

The Indian Precambrian shield can be considered to have been made up of four major cratons that had evolved about individual Archean nuclei (Naqvi et al., 1974 and Naqvi and Rogers, 1987). They are the Dharwar, Singhbum, Bastar and Aravalli cratons. The Dharwar Craton occurs in the southern peninsula of the Indian shield and is surrounded by the Deccan basalts to the north, Arabian Sea to the west, Southern Granulite Terrain to the south and Eastern Ghats Granulite Terrain to the east. The Dharwar Craton can be divided into a western Dharwar craton and an eastern Dharwar craton based on the distinctness in the composition and disposition, including areal extents of the schist belts in either side, as well as, the age relationship between the schist belts and the surrounding granitoids. Earlier, a linear belt of granitoid intrusives, known as the Closepet batholith, that occurs to east of the Chitradurga Schist Belt was considered as the boundary between these two cratons (Viswanatha and Ramakrishnan, 1981; Allen et al., 1986; Radhakrishna and Vaidyanathan, 1994). Later, the division has been demarcated by an approximately N-S trending sinistral shear zone that forms the eastern boundary of the Chitradurga Schist Belt of the western Dharwar craton (Chadwick et al., 1992; Chadwick et al., 2000).

The western Dharwar craton is characterized by the presence of volcanoclastic and chemical sediments with the sedimentary component dominating over the volcanics. Chitradurga, Bababudan and Shimoga schist belts form part of the western Dharwar craton. The schist belts of the eastern Dharwar craton are made up of a thick pile of basaltic rocks subordinated with chemical sediments and negligible quantity of clastic sediments such as greywacke, unlike their western counterparts. A clear indication of a gneissic basement as reported for the supracrustals of the western Dharwar craton (Chadwick et al. 1981a & b, 1985 a & b) is not deciphered in the eastern Dharwar craton. Tonalite-trondhjemite-granodiorite (TTG) suites of rocks make up the granitoids of the western Dharwar craton while quartz-monzodiorites, granodiorites and granites (QMG) predominate the eastern Dharwar craton.
The eastern Dharwar craton in southern India is an Archean shield area that consists of linear supracrustal belts, also referred to as greenstone belts or schist belts, surrounded by granitoid rocks. These supracrustal belts are considered as suture zones along which different plates of varied composition were welded together by tectonic events. Based on geochemical and isotope studies of the Kolar and Ramagiri schist belts and the granitoids surrounding the belts, an accretionary origin has been proposed for the eastern Dharwar craton (Krogstad et al., 1989; Zachariah et al., 1996; Balakrishnan et al., 1999). These authors considered the schist belts as suture zones, emplaced in subduction-related settings, which were juxtaposed with the granitoids by tectonic forces.

On the other hand, the Closepet batholith in the eastern Dharwar craton has been inferred to have been related to a major thermal and accretionary event resulting from mantle plume activity that was prevalent during Late Archean (Jayananda et al., 1995). The terminology ‘Closepet batholith’ was however questioned by Chadwick et al. (1996) and Chadwick et al. (1997), calling it a misnomer, as they contain both anatetic and juvenile components and are not appreciably distinct from the rest of the granitoids. Alternatively, these authors described the Late Archean plutonic rocks of the eastern Dharwar craton as the Dharwar batholith based on their scale, distribution and composition (Chadwick et al., 1996). They also suggested that the accretion of the batholith took place as a series of anatetic and juvenile additions in the form of steep wedges and sheets (Chadwick et al., 1997).

The Hutti Schist Belt and the surrounding granitoids, however, have not been studied in such detail to understand the petrogenesis and the Archean tectonics that essentially sculptured the eastern Dharwar craton. The Kolar and Ramagiri schist belts are well known for gold mineralization and presently the Hutti Schist Belt is the major producer of gold in India.

Petrographic and geochemical studies have been carried out on the rocks of the Hutti Schist Belt, as well as, the surrounding granitoids (Giritharan and Rajamani, 1998; Basir, 2000). While detailed geochronological data on the Kolar and Ramagiri schist belts and the surrounding granitoids of the eastern Dharwar craton are available (Krogstad et al., 1989; Krogstad et al., 1991 & 1995; Zachariah et al., 1995; Balakrishnan et al., 1999), geochronolgical data on the rocks of the Hutti area are lacking except for a SHRIMP Pb-Pb age for a granodiorite clast from Palkanmardi.
polymictic conglomerate occurring NE of the Hutti Schist Belt (Vasudev et al., 2000). Hence, there is need to place constraints on the time of emplacement of the metavolcanics of the Hutti Schist Belt, the time of intrusion of the granitoids around the Hutti Schist Belt, and models on crustal evolution in the Hutti area. This will enable us to understand the overall evolution of the eastern Dharwar craton.

Titanite is a widespread accessory mineral found in igneous and metamorphic rocks. It generally has a high U/Pb ratio and is increasingly used as a geochronometer (Tilton and Grünlenfelder, 1968; Tucker et al., 1987; Heaman and Parrish, 1991; Mezger et al., 1991; Frost et al. 2000). Titanite is a repository of rare earth elements (REE) and hence controls the REE fractionation in rocks, if present in considerable abundance. Hence, a detailed trace element of titanites from the granitoids would be useful in understanding their petrogenesis.

In this thesis work, an attempt has been made to determine the ages of the schist belt rocks and granitoids occurring in Hutti area using radiogenic isotope techniques (U-Pb, Sm-Nd and Rb-Sr). A geochemical study on titanites occurring in the granitoids of the eastern Dharwar craton has been taken up to understand the significance of titanite in the petrogenesis of granitoids. The feasibility of employing Sm-Nd mineral isochron technique for dating Archean granitoids has also been explored.