Chapter-1

INTRODUCTION

The sedimentary sequences preserve records of tectonic, climate and biological evolution of our planet. They are the most striking evidence of a wet and dynamic Earth. They are the products of surface processes and store valuable information on processes like weathering, transportation and diagenesis during the Earth's history. (Bio) chemical sediments, precipitated from seawater, preserve information on the chemical evolution of the sea with time and the evolution of life on the Earth. It is therefore, essential that we study and understand the formation of sediments and sedimentary rocks to unravel the mysteries of our planet.

Deciphering the provenance of sediments is one of the most important aspects of any study on sedimentary sequences. Provenance study deals with the history of the sedimentation from their sources, which is basically the reconstruction of the parent-rock compositions from which the assemblages of sediments have been derived and the study of climatic and physiographic conditions under which their formation had taken place. The inference of the sediment provenance from the final product i.e. the sedimentary rocks (sequences), is not straightforward because of the involvement of various agents in the pathways from the source to sink (basin). For a successful provenance analysis one has to understand in greater detail the nature and extent of compositional and textural modifications suffered by the sediments.

Study of sedimentary provenances started as early as in the 19th century with the microscopic investigation of accessory (heavy) minerals of modern sands. Earlier attempts were to trace accessory minerals of recent beach and river sands to their parent rocks (Weltje & Eynatten, 2004, and references therein). The provenance analyses of old sediments using accessory minerals were first attempted by Thürach

(1884). The usage of the petrographic analysis of major framework constituents for the provenance became possible after the invention of thin-section petrography by H.C. Sorby in 1880 and who carried out the first detailed study of various types of quartz. The influence of climate on the preservation of feldspars was recognized as early as 1886 by Judd. Later Mackie (1899a&b), developed criteria for the recognition of quartz grains derived from igneous and metamorphic rocks and tried to interpret feldspars as indicators of prevalent climatic conditions. The early part of 20th century saw the full development of the thin-section sandstone petrography and at the same time quantitative characterization of bulk sediment properties by chemical analysis became popular (see Weltje & Eynatten, 2004).

The first systematic quantitative investigations of sand bulk mineralogy started in the 1930s with modal composition, combining various methods of separation with mounting-and-counting techniques. Later Krumbein and Pettijohn (1938) presented the first comprehensive overview of quantitative methods in sedimentary petrography and in the 1940s, P.D. Krynine and F.J. Pettijohn proposed the first versions of the sandstone classification schemes that are still being used. The importance of tectonic control on the compositional and textural properties of sandstones had been advocated by Krynine. He was inspired by the ideas of his teacher M.S. Shvetsov, who realised already in the 1920s that sandstone mineralogy could be related to tectonic setting (Folk and Ferm, 1966). The invention of a practical point-counting device in 1949 opened the flood gate for the routine measurement of modal composition from thin sections in sandstones and received new impulses through the work of Dickinson (1970), who established clear cut operational definitions for grain types to improve the reproducibility of detrital modes.

The use of geochemistry for the provenance determination started as early as 1916 but its real impetus came in the later part of the 20th century when attempts were made to derive the composition of continental crust (Taylor and McLennan, 1985), and to understand tectonic settings and provenance (Bhatia 1983; Bhatia and Crook, 1986; Roser and Korsch, 1986). It has now been established that chemical composition of sediments (siliciclastic/chemical) can be used effectively to identify the sources of sediments, tectonic settings in the provenance and prevalent climatic conditions. For example, the Rare Earth Elements (REE), which behave as a chemically coherent group due to their similarities in ionic radii and non fractionating behaviour during weathering and diagenesis, are very useful in deriving information about the sources of sediments as well as climatic conditions that prevailed at the time of their deposition (Taylor and McLennan, 1985). Similarly, Nd isotopic ratio is a good indicator of sediment provenance, since Sm and Nd do not get fractionated during weathering/deposition/diagenetic processes (Miller and O'Nions, 1984; Nelson and DePaolo, 1988; Basu et al., 1990; Gleason et al., 1994). Geochronology of sedimentary sequences, in general, is difficult in the absence of dateable igneous material and lack of robust biostratigraphy. In such scenarios, detrital zircon geochronology has proven to be one of the most reliable tools for establishing relative chronology of various formations in a sequence. Detrital zircon geochronology can also reveal a lot about the source rocks, which in turn can be used to develop a depositional model for a sedimentary basin.

1.1 The Proterozoic time on the Earth

The period of Earth's history between 2.5 Ga and 543 Ma is known as the **Proterozoic Eon.** Covering about 43% of Earth's history, it records many of the most exciting geological events of our planet. During this Eon, continents formed over stable cratons and 'modern plate tectonics' began to take control over all geodynamic processes. This exciting period of the Earth has been divided into three subdivisions namely: Paleoproterozoic Era (2500-1600Ma); Mesoproterozoic Era (1600-1000Ma) and Neoproterozoic Era (1000-543Ma). The major events during Proterozoic that shaped our planet are listed in Table 1.1. The table also lists some of the major events of this period in Indian Geology. Some of the important events of the Proterozoic Eon that have caught our imagination are: the global glaciations and the rise of atmospheric oxygen in the Paleoproterozoic and Neoproterozoic (Hoffman et al., 1998; Catling and Claire, 2005; Kopp et al., 2005), the origin of eukaryotes in the Paleoproterozoic (Javaux et al., 2001), and evolution of animals in Neoproterozoic (Yin et al., 2007), and stabilization of the continents (Condie, 1982). The Proterozoic Eon began and ended with episodes of global glaciations (Hoffman et al., 1998; Hoffman and Schrag, 2002; Kopp et al., 2005). The net result of the Paleoproterozoic and Neoproterozoic glaciations was probably a dramatic increase in atmospheric O_2 concentration (Rye and Holland, 1998; Catling and Claire, 2005). Since aerobic respiration and synthesis of membrane lipids (sterols and unsaturated fatty acids) by eukaryotic organisms require certain levels of molecular oxygen, the link between the rise of atmospheric O_2 concentration in the Paleoproterozoic and the appearance of sophisticated morphologies of eukaryotes at ~1800 Ma is appealing. Similarly, multi-cellular life forms like *Ediacara,* resembling the modern day jelly-fish, may have become abundant after the Neoproterozoic glaciations.

In the Proterozoic Eon modern plate tectonics began to govern over other processes in shaping the form of the Earth's crust (Condie, 1982). The first definite proof of the formation of a supercontinent, between 1300-1000 Ma, named as "Rodinia" and its break-up at ~ 750Ma, and various mountain building activities such as Greenville Orogeny have also been reported from this Eon. In India, the evolution of the Aravalli-Delhi mountain belts and the Satpura mountain belt are considered to be of Mesoproterozoic age (see Ramakrishnan and Vaidyanadhan, 2008). It is quite possible that the mantle on which the continental lithospheres floated was hotter, less viscous, and could have been closer to the surface resulting in swift movements of continents. These small continents could have collided quite often and tended to fracture or suture with greater frequency.

Therefore, for understanding the evolution of the Earth, one has to understand the events of the Proterozoic Eon. The Proterozoic sedimentary basins are the best places where the records of these events have been faithfully recorded. The atmosphere, biosphere, hydrosphere, and lithosphere of the Earth affect each other and co-evolve over time, hence for understanding the evolution of the history of the Earth's various systems one needs to unravel the mysteries recorded in the sedimentary deposits.

Table 1.1: Major events of the world and India observed during the Proterozoic Eon*.

A) Paleoproterozoic Era (2500 to 1600 Ma)
• Stable continents first appeared. • First free oxygen is found in the oceans and atmosphere around 2500 Ma. • Great Oxidation Event also called the Oxygen Catastrophe: at 2400 Ma. Oxidation precipitates dissolved iron creating banded iron formations. Anaerobic organisms are poisoned by oxygen. • Start of Huronian ice age : 2400 Ma • Opening of the Aravalli basin : 2300Ma • Organisms with mitochondria capable of aerobic respiration appear: 2200 Ma • End of Huronian ice age : 2100 Ma • Intensive orogeny (mountain development) • Meteor impact, 300 km crater Vredefort, South Africa : 2023 Ma • Solar luminosity became 85% of the current level : 2000 Ma • Oxygen starts accumulating in the atmosphere • Major pulse of the Aravalli orogeny : 1900Ma • Meteor impact, 250 km crater Sudbury, Ontario, Canada: 1850 Ma • Complex single-celled life appeared with abundant bacteria • Initiation of sedimentation in the 'Purana Basin's : ~1700 Ma
B) **Mesoproterozoic Era** (1600 to 1000 Ma)
• Photosynthetic organisms proliferate. • Oxygen builds up in the atmosphere above 10%. • Formation of ozone layer starts blocking ultraviolet radiation from the sun. • Eukaryotic (nucleated) cells appear: 1500 Ma Green (Chlorobionta) and red (Rhodophyta) algae abound. • Delhi Orogeny : 1500 Ma • Spore/gamete formation indicates origin of sexual reproduction : 1200 Ma • Formation of the supercontinent ***Rodinia: 1100 Ma*** • Mountain building activity e.g. Greenville orogeny
C) **Neoproterozoic Era** (1000 to 542 Ma)
• Multicellular organisms appear : 1000 Ma • Start of Stuartian-Varangian ice age : 950 Ma • Massive granitization in the Aravalli-Delhi Orogen:1000Ma • **Cryogenian Period** (850 to 630 Ma) • Breakup of Rodinia and formation of the supercontinent ***Pannotia: 750 Ma*** • End of last magnetic reversal : 750 Ma • Mass extinction of 70% of dominant sea plants due to global glaciation *("Snowball Earth"* hypothesis) : 650 Ma • **Ediacaran (Vendian) Period** (630 to 542 Ma) • Soft-bodied organisms (Jellyfish, Tribrachidium, and Dickinsonia) appeared : 580 Ma • End of Stuartian-Varangian ice age : 570 Ma • Pannotia fragmented into Laurasia and Gondwana : 550 Ma

**(Schopf and Klein (1992) and other web resources)*

1.2 Proterozoic Basins of India

The sedimentary sequences started developing over the Indian Peninsula after its emergence as a large shield after accretion of smaller Archean cratons, around 2500Ma ago (Rogers, 1986). The old sedimentary sequences, at present exposed in structurally controlled manner and classified as 'Purana Basins' were formed after the Archean-Proterozoic transition (~2500Ma). These basins are named as the *Aravalli, Delhi, Vindhyan, Bhima, Kaladgi, Indrawati, Chhatisgarh-Raipur, Khariar, Cuddapah, Pranhita-Godavari,* etc. (Fig. 1.1). The Central Indian Tectonic zone (CITZ), which is of Mesoproterozoic age (Acharyya, 2003), divides these basins into northern and southern groups. Numerous basins in southern group are erosional with several major unconformities and were developed on the Dharwar, Baster and Singhbum cratons. In north the largest basin is known as the Vindhyan Basin, and the sedimentary sequences known as the Vindhyan Supergroup, developed on the Bundelkhand and Aravalli cratons.

One of the most intriguing aspects yet to be understood is the places of origin of the sediments for these massive and almost contemporaneous ocean basin deposits. Their coexistence is established by numerous geochronological studies (Rasmussen et al., 2002; Ray et al., 2002, 2003; Sarangi et al., 2004; Ray, 2006; Chakrabarti et al., 2007; Patranabis-Deb et al., 2007; Malone et al., 2008; Bengtson et al., 2009; Turner et al., 2010). Considering the thickness of the various Proterozoic basins, it is quite obvious that massive amounts of sediments poured into these basins and that enormous amount of weathering and erosion must have taken place in various orogens and cratons (e.g. Aravalli-Delhi, Satpuras, Bundelkhand, Dharwar, and Singhbum etc.). Since majority of these Proterozoic sequences are mostly undeformed and unmetamorphosed, they are believed to have preserved intact geological records of the Proterozoic India.

The Vindhyan Supergroup of rocks, deposited in the Vindhyan Basin, cover an aerial extent of ~ 178,000 km^2, spread from Sasaram (Bihar) along the Son river Valley in the east to Chittorgarh, Kota, Bundi, Sawai Madhopur districts of Rajasthan in the west (Fig. 1.1). The basin is bounded by the Aravalli-Delhi orogenic belt (2500-900 Ma) in the west, and by the Satpura orogenic belt (1600–850 Ma) in the south and south-east. Low-grade metamorphic rocks of the Mahakoshal (2400 Ma) and the Bijawar (2100 Ma) Supergroups border its eastern margin. The granite and gneisses of the Bundelkhand craton (3.3-2.5 Ga), which are acting as the basement ridges in the centre divide the basin into eastern (Son valley) and western (Rajasthan) sectors (Prasad and Rao, 2006). The ~4 km thick Vindhyan Supergroup comprises predominantly shallow marine deposits that are mildly deformed and mostly unmetamorphosed. The Supergroup has been divided into the Lower Vindhyans (Semri Group) and the Upper Vindhyans (Kaimur, Rewa and Bhander Groups). This has been done based on a major unconformity between the two divisions (Bhattacharyya, 1996).

The major lithologies of the supergroup are: sandstone, shales and limestones with minor volcaniclastics. The rocks from the eastern sector (i.e. Son Valley) have been subjected to more detailed investigation compared to those in the western sector in Rajasthan. Individual formations of the Vindhyans in the west have been stratigraphically correlated to those in the east based on lithostratigraphy (Prasad, 1984; Soni et al., 1987), the validity of which has been questioned by many workers (e.g. Ray et al., 2003, M. Sharma, personal communication).

The Vindhyan sequences are important because of their vastness in time and space, and as a result they are likely to contain important information on the evolution of the Earth's atmosphere, climate, sedimentary cover and life. Age estimates indicate that the initiation of sedimentation in this basin took place as early as 1721 Ma (Ray, 2006), while the youngest sediments extend up to the Precambrian–Cambrian boundary (Chakraborty, 2006). This duration of sedimentation is considered to be one of the longest amongst all the Proterozoic sequences of the world. These sedimentary sequences have been studied in greater detail for various fossils in form of stromatolites, trace fossils, algae and controversial small shelly fossils etc. (see Venkatchala et al., 1996; Azmi et al., 2006). Discoveries of controversial small shelly

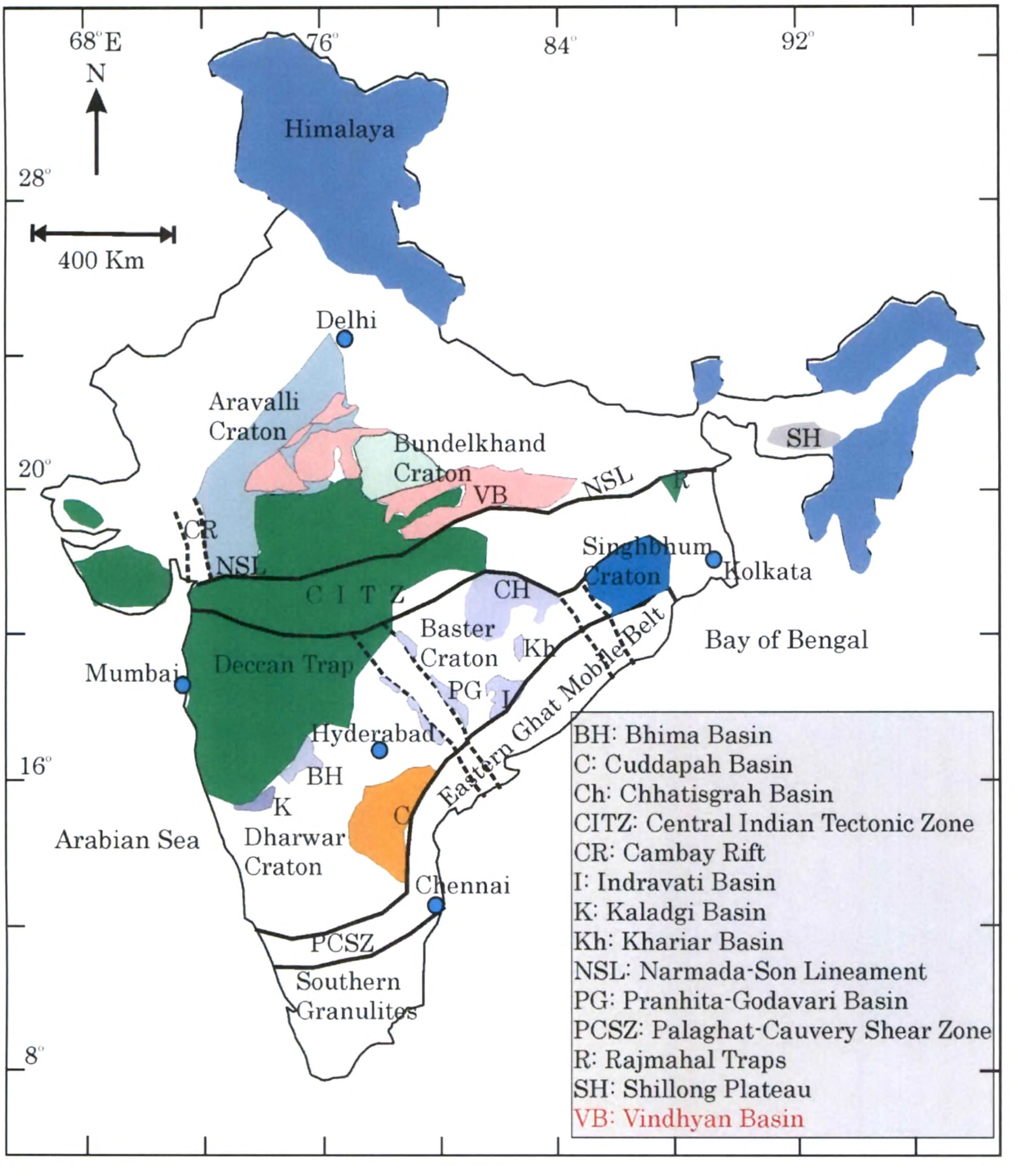

Fig. 1.1: The Proterozoic (Purana) Basins of Indian shield along with major tectonic and geological features (after Ramakrishnan and Vaidyanadhan, 2008).

fauna (Azmi, 1998), the triploblastic metazoan fauna (Seilacher et al., 1998) and numerous plant fossils, and the discovery of Edicara type fossil assemblages (De, 2003, 2006) suggest that the rocks of the Vindhyan Supergroup contain information about the evolution of advanced life on our planet (Bengtson et al., 2009).

The Vindhyan Supergroup in Rajasthan is believed to have been deposited as an infill of the failed rifts on the Aravalli craton (Mondal et al., 2002). In the eastern sector, rifting is along a series of east to west trending faults in a dextral trans-tensional setting in which the volcaniclastic units are obsereved. Chakrabarti et al., (2007) studied the Vindhyans in the Son valley and proposed a "foreland" type setting for the basin on the basis of geochemical signatures of the volcaniclsatic sediments (Porcellanite Formation). Recently Raza et al. (2009) worked on the geochemistry of the basal volcanic sequence (Khairmalia and Jungel) and attributed the formation of the Vindhyan Basin (at~1800 Ma) to a collisional event in the Aravalli-Delhi Fold belt.

Geochemical and isotopic investigations on Vindhyan rocks (Kumar et al., 2002; Ray et al., 2002; Ray et al., 2003; Kumar et al., 2005) have shown that there exists valuable information in these rocks on the Proterozoic environment of global significance. There have been reports of indirect evidences for Neoproterozoic glaciations in the form of negative $\delta^{13}C$ excursions in carbonate rocks of the Upper Vindhyan sequences that generated a lot of interest (Kumar et al., 2002; Ray et al., 2003). The identification of 'Blaini glaciation' event (Kaufman et al., 2007) confirms that Indian subcontinent was under glaciation during the Neoproterozoic, hence it is likely to expect that the Vindhyan Supergroup, which believed to extend well into Neoproterozoic, to contain similar evidences for one or more of these glaciations. Interestingly, in a recent study, Malone et al. (2008), based on detrital zircon geochronology in conjunction with the paleopole position argued that the Vindhyans are older than 1000 Ma and therefore, unlikely to contain any evidence for glaciation. The argument of older age than 1000 Ma for the upper age limit is based on the similarity of paleopole positions for the Rewa and Bhander group of rocks with that derived from the Majhgawan Kimberlite (~1073 Ma old) and not with that derived from the ~770 Ma old Malani Igneous Suite. However, in an earlier work Evans (2009) had observed that *"No field stability tests have been performed on either the Majhgawan kimberlite or the Rewa/Bhander units, so there remains the possibility that these poles represent a two-polarity magnetic print across north-central India" (page 386)*. Hence, the proposal for the above upper age limit of the Vindhyans, from statistically insignificant number of dates from detrital zircon and paleomagnetic pole data, remains doubtful and needs to be tested with new data. Gregory (2008) reconstructed the Apparent Polar Wandering Pole (APWP) for the Indian landmass based on the available age and paleolatitude data (Fig. 1.2). In view of the arguments given by Evans (2009), the reconstruction of Gregory (2008) also remains doubtful.

Geochemical and isotopic studies in the Vindhyan Supergroup are too few and mostly concentrated in the Son Valley sector (Paikaray et al., 2008; Chakrabarti et al., 2007; Mishra and Sen, 2010). The geochemical work of Paikaray et al. (2008) on the shale formations from all across the Vindhyan Supergroup in the Son Valley sector suggested that predominantly granitic sources were responsible for the sediments for the Lower Vindhyans, whereas partial contribution from basaltic sources was envisaged for the Upper Vindhyans. They also argued that the Archean-Paleoproterozoic rocks, exposed beyond the southern basin margin also contributed sediments for these shales. Mishra and Sen (2010) used various discrimination diagrams and elemental ratios for the Kaimur Group of rocks, which are quartz arenite, sublitharenite to litharenite and litharenite to shale, and came to a conclusion that all these rocks were derived from similar source rocks which had undergone severe chemical weathering, under a hot-humid climate in an acidic environment with higher p_{CO2} facilitating high sediment influx in the absence of land plants. The geochemical approach towards deciphering the provenance of the Bhander Sandstone in the Son Valley was attempted recently by Banerjee and Banerjee (2010). They suggested that these sandstones were derived in major part, from granitic sources from the continental interior.

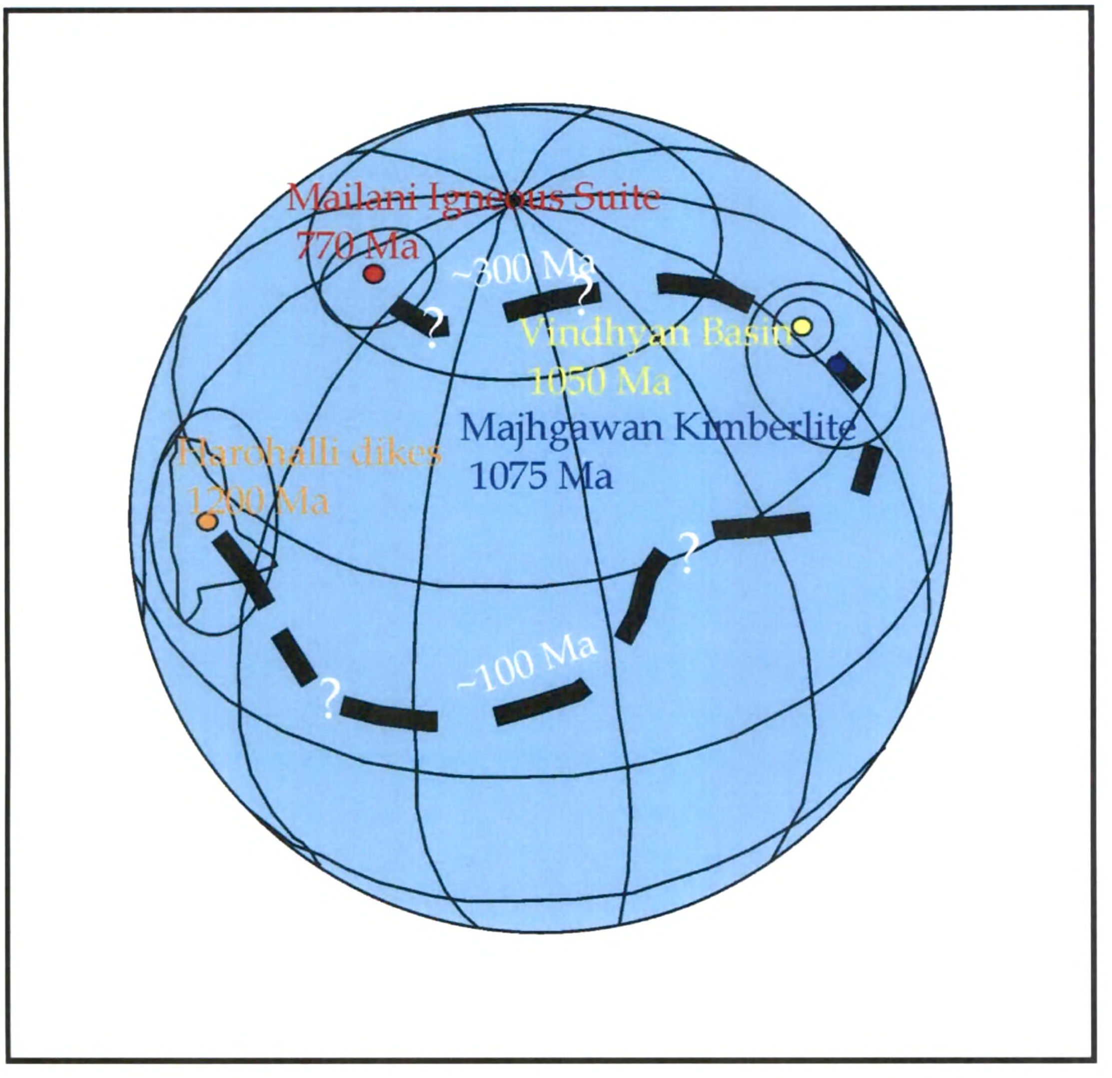

Fig. 1.2: Apparent Polar Wandering Pole (APWP) for India with reliable Proterozoic poles. Poles are from Harohalli Dikes, the Majhgawan Kimberlite, the Mailani Igneous Suite and the Vindhyan Basin (Adapted from Gregory, 2008).

The only Nd-isotopic studies carried out on the Vindhyans of the Son Valley, is by Chakrabarti et al. (2007). They used Nd-isotopic studies in conjunction with trace element geochemistry and inferred that majority of the sediments were derived from a now-extinct Andean-type arc in the south of the basin. This arc, according to them, came into existence as a result of a southerly dipping subduction prior to the collision of the Bhandara and Bundelkhand cratons and the Vindhyan Basin formed as a foreland Basin after the collision.

Unlike the radiogenic isotope studies, there are quite a few studies on C and O isotope systematics in carbonate formations in Vindhyan Supergroup (Kumar et al., 2002, Ray et al., 2003, and Kumar et al., 2005). In this context the studies by Ray et al. (2003) is quite significant and extensive, covering almost all the limestone formations from the western and eastern sectors. According to this work the secular patterns of carbon isotope trends do not support the earlier assumptions that the carbonate sequences at the southern margin correlate with those at the western or northern margins of the Vindhyan Basin. Kumar et al. (2002) believed that they had discovered evidences for one of the Neoproterozoic glaciations in the Lakheri Limestone in the Bundi area in Rajasthan from their observations of a negative excursion in $\delta^{13}C$ profile and presence of a misidentified tilloid unit at the base. Similarly, Kumar et al. (2005) suggested that the Lakheri Limestone of Rajasthan, considered correlatable to the Bhander Limestone of the eastern margin, is stratgraphically older and might have been deposited under the colder climatic conditions that prevailed during the Sturtian glaciations. They further argued that the sedimentation in the Vindhyan Basin ceased around 700 Ma ago and hence the Precambrian-Cambrian transition record is not recorded in them. In a recent work, Sarkar et al. (2009) using the sulphur isotope geochemistry of the various Proterozoic basins including the Vindhyans from the Son Valley argued for prevalence of extreme environmental conditions similar the hypothesized global Proterozoic sulphidic anoxic ocean in the Vindhyan Basin.

As of now, only a limited amount of geochemical work on the Vindhyans (only Semri Group) from the western margin (Rajasthan Vindhyans) is available (Raza et al., 2002, 2010) and results of these studies based on major and trace elements geochemistry suggest that the Banded Gneissic Complex (BGC) of Rajasthan is the major source of the Vindhyan sediments. It is to be noted that only a limited amount of C and O isotopic data (Kumar et al., 2002, Ray et al., 2003), are available for carbonate formations in the Vindhyans of Rajasthan. Worse is the scenario for geochronological information in this sector. Except for an indirect age information from Sr-isotope stratigraphy (Ray et al., 2003) and limited detrital zircon age data (Malone et al., 2008) mostly from the Upper Vindhyans, the ages of depositions of the Vindhyans of Rajasthan are still unknown. The importance of the Vindhyans of Rajasthan also lies in the possibility that these rocks can yield clues for evolution of multi-cellular life on our planet. In the context of Indian Geology, the Vindhyans of Rajasthan are very interesting since they got deposited during the time when the Delhi Basin was also getting filled, and remained largely undeformed and unmetamorphosed. Therefore, it is important to study the Vindhyan Supergroup in Rajasthan for developing a better understanding of the evolutionary history of the vast Vindhyan Basin. Apart from understanding the evolution and history of sedimentation of the Vindhyans, attempts are also necessary to understand the configuration of the Indian shield during the Proterozoic. The present work is an attempt in this direction to understand the above aspects of the Vindhyan Basin using geochemical and isotopic tools.

1.3 Aims of the present investigation:

The major objectives of this Ph. D. work were to:

1) delineate sources of sediments for various formations of the Vindhyan Supergroup using chemical and isotopic tracers,
2) correlate various formations of the western Vindhyans (Rajasthan) with those of the eastern Vindhyans (in Son Valley),

3) understand the causes of breaks in sedimentation within the Vindhyan Super group,
4) establish chronology of carbonate formations using Sr-isotope stratigraphy and that of some siliciclastic formations using detrital zircon dating,
5) understand the variations of $\delta^{13}C$ and $\delta^{18}O$ in carbonate formations in the supergroup and establish their local/global significance, and
6) propose a geodynamic model for the evolution of the Vindhyan Basin and the deposition of the Vindhyan Super group.

1.4 The Structure of the Thesis

To achieve the objectives of the present investigation samples from various formations of the Vindhyan Supergroup in Rajasthan were collected after extensive fieldwork based on available geological maps. Selected samples were subjected to various experimental studies using state of art instruments and results have been interpreted.

The present thesis is divided into four chapters. The **first chapter (Introduction)** introduces the scope of the work and its importance in the present understanding of the Vindhyan Geology. It also discusses the importance of various geochemical tools, such as major and trace element geochemistry, radiogenic isotope studies and stable C-O isotope that are used in this work to characterize the sources of the Vindhyan sediments and understand the evolution of the basin. The major objectives of this work are also outlined and discussed.

The **second chapter (Geological Framework and Analytical Methods)** deals with geology of the study areas (Chittorgarh and Bundi-Lakheri) and our field observations. Geological details of various formations of the Lower and the Upper Vindhyan sequences, exposed in the both the sectors are given. The sampling strategy followed and the details of samples collected during various field excursions are listed in this chapter. Extensive sampling was done in Chittorgarh and Bundi districts with an aim to study the intrabasinal correlations.

Sample preparation methods for various geochemical techniques are discussed in this chapter. X-ray Fluorescence Spectroscopy (XRF) method has been used for major element contents and Inductively Coupled Plasma Mass Spectrometry (ICPMS) for trace element contents. Thermal Ionization Mass Spectrometry (TIMS) for radiogenic isotopic ratios and Isotopic Ratio Mass Spectrometry (IRMS) for C and O isotopic ratios have been used. A detailed account of these techniques is given in this chapter. A brief description of the Sensitive High Resolution Ion Microprobe (SHRIMP) technique utilized (at GSC Canada) for U-Pb dating of detrital zircons, is also given.

The **third chapter** deals with "**Results and Discussion**" which contains all the details of the studies performed and possible inferences. All the results generated during this work which forms a large database of major and trace elements and isotopic ratios in Vindhyan formations have been given. A small but important dataset for U-Pb detrital zircon ages for a lower Vindhyan formation is also presented here. Results of stable C-O isotopic ratio variations in carbonate formations of the Upper Vindhyans are given and their implications are discussed. Our effort to date the topmost carbonate formation by Sr-isotope stratigraphy is also detailed in this chapter.

An attempt has also been made to correlate the sequences in the west with those in the east using geochemical/chronological parameters in terms of provenance sources of the sediments. At the end, the implications of the findings are discussed and a geotectonic model has been proposed for the origin and evolution of the Vindhyan Basin.

The summary of the work with future scope is presented in the **last (fourth) Chapter.**