CHAPTER - I
INTRODUCTION

The Proterozoic Era of the earth history is considered to be a period of accelerated crustal growth (Taylor and McLennan, 1985) during which first stable craton developed (Windley, 1984). The availability of stable crust led to the formation of non-linear large sedimentary basins which accumulated huge amount of sedimentary fill. A large part of the peninsular Indian shield is occupied by Meso and Neo-Proterozoic platform covers which have been named as “Purana basins”. These are the (1) Vindhyan Basin (2) Cuddapah-Kurnool Basin (3) Bhima Basin (4) Kaladgi Basin (5) Pranbita-Godavari Valley Basin (6) Chhattisgarh Basin (7) Indravati Basin (8) Khariar Basin (9) Abujhmar Basin (10) Bijawar Basin (11) Gwalior Basin and (12) Sukma Basin or Sabari Basin (Figure 1).

Amongst these basins, the Vindhyan Basin of Central India is one of the largest and best preserved Proterozoic sedimentary basins throughout the world, covering a vast area of 1,78000Km² (Figure 2). The Vindhyan Supergroup preserves the thickest Precambrian sedimentary succession in India. The strata are exposed in three major sections: Son Valley, Bundelkhand and Rajasthan. Substantially thick Vindhyan rocks have also been recognized under the Gangetic alluvium. The duration of sedimentation, if continuous, is certainly among the longest in the world. The Vindhyan Basin parabolically enclosing the Archean domain of Bundelkhand massif and lies in front of Aravalli and Satpura orogenic belts. The margins of the basin are demarcated by an arcuate thrust belt comprising the Mesoproterozoic Aravalli-Delhi Fold Belt (ADFB) and the Satpura orogenic belts (SB) referred to as the Mid-Proterozoic mobile belt (MPMB) of Radhakrishna and Naqvi (1986). It is believed that the basin was formed as a consequence of the collision of the Bundelkhand Craton with the Deccan, Protocontinent in the south and Mewar Craton in the north during the early Mesoproterozoic period (Yadlekar et al, 1990; Raza et al; 1993, and Raza et al; 2009). The Proterozoic Vindhyan Supergroup of India has attracted the attention of geologists since 1856 owing to the presence of diverse rock types (Oldham, 1856). The thick (4000 m) and unmetamorphosed sediment are fill of this basin has been broadly divided into two lithostratigraphic units. The Lower Vindhyan
Figure 1. The Meso-Neoproterozoic Sedimentary Basins of Peninsular Indian Shield.
comprising Semri Group and the Upper Vindhyan comprising Kaimur, Rewa and Bhander groups each separated by conglomerate units (Auden, 1933). The Semri Group is folded (Chakraborty, 1996), whereas Upper Vindhyans are known to be structurally undisturbed.

Vindhyan Basin comprises of about 6000m of calcareous, argillaceous and arenaceous sediments deposited in shallow marine environment. Age estimates indicate that the initiation of sedimentation took place as early as 1721 Ma (Ray, 2006) while the youngest sediments extends upto the Precambrian Cambrian-Cambrian boundary (Chakraborty, 1990; Ray et al; 2002). Although occurrence of microfossils (acritarch) suggests the age range of Vindhyan Supergroup from 1500-550 Ma with presence of major unconformities between the various subgroups (Prasad et al; 2005). The radiometric dates suggest the initiation of Vindhyan Basin at about 1721+90 Ma (Sarangi et al; 2004) 1631 Ma (Ray et.al; 2002) and ~ 1628 Ma (Rasmussen et al; 2002). The Grypaenia bearing Rohtas Group in the upper part of Semri Group gives Pb-Pb isochrone age of 1550+40Ma (Sarangi et al; 2004) and Kaimur Group as 1140-900Ma (Vinogradov et al; 1964). It is obvious that the Semri sedimentation initiated sometimes in the temporal span from 1600 Ma to 1700 Ma (Valdiya, 1995). The entire basinal sequence of the basin belongs to two distinct depositional cycles. The first one dominantly calcareous and argillaceous and is characteristically developed in the lower part (Lower Vindhyan). The second arenaceous and argillaceous sequence developed in the Upper part (Upper Vindhyan). The occurrence of a regional unconformity between Lower and Upper Vindhyan (Jokham Ram, 1996) suggest a younger age for the Upper Vindhyan. The kimberlite pipes, which intrude the Semri and Kaimur groups have been dated as 1140+ 112 Ma (Paul et al; 1975). The paleomagnetic pole position and zircon geochronology of Upper Vindhyan suggests the age of Upper Vindhyan Group not less than ~ 1075 Ma. (Gregory et al; 2006, Malone et al; 2008). Based on available date the age range of Upper Vindhyan sedimentation is considered as ~ 1100-650 Ma (Ray, 2006) or 1100-1070 Ma (Malone et al; 2008).

of sedimentation each culminating in a tectono-magmatic activity, have been identified (Gupta et al.; 2003) in the Semri Group. Singh (1973) interpreted the depositional environment of the Vindhyan Basin to include high gradient environment. According to Chanda and Bhattacharya (1982), the Vindhyan Basin developed in an intracratonic embayment with conditions fluctuating from beach environment through tidal flat lagoon complex to tidal shelf along with barrier beach-dune complexes. Chakraborty (1996) suggests that the braid plain erg-transition appears to be a common phenomenon of the Proterozoic Era and its record should abound the terrestrial sandstones of that age. Vindhyan sediments are considered to have deposited in environments ranging from fluvial to deep marine (Bhattacharya and Morad, 1993; Bose and Chakraborty, 1994; Chakraborty, 1993; Chakraborty and Bhattacharya, 1996, Ahmad et al; 2012). Storm dominated sedimentation has been reported by Bose et al. (1988).

**GEOLOGICAL SETTING**

In the Son Valley section, the Vindhyan Supergroup unconformably overlies the metamorphites of ~ 2500 Ma old (Rb-Sr) Bijawar Group of rocks (Crawford and Compston, 1970). Along the southern edge of the Vindhyan Basin and along the eastern edge of the Bundelkhand granite-gneiss complex occurs a low grade metamorphic Group of Volcano-sedimentary rocks known as the Mahakoshal Group (2400Ma) and the Bijawar Group (2100Ma), respectively (Das et al; 1990; Roy and Bandyopadhyay, 1990). It is constituted of a thick pile of rocks occupying a large area extending from Sasaram (Bihar) in the east to Chittorgarh (Rajasthan) in the west and Dholpur (Rajasthan) in the north to Hoshanabad (Madhya Pradesh) in southwest comprising sandstones, shales and Limestone. The Vindhyan sedimentary rocks are marine, possibly deposited in an E-W elongated epeiric sea opening westward (Chanda and Bhattacharya, 1982; Bose et al; 2001). The lower Vindhyan is considered to have been developed in an intracratonic rift basin (Bose et al; 1997), on the other hand, the Upper Vindhyan formed in an intracratonic sag basin (Sarkar et al; 2002) with a compressional interlude in between. The Vindhyans are bordered by the Aravalli Delhi orogenic belt (2500-900Ma) (Roy, 1988) in the west and the Satpura orogenic belt (1600-850Ma) (Verma, 1991) to the south and east. The Bundelkhand massif (3.3-2.5Ga) (Crawford and Compston, 1970; Mondal et al., 2002) occurs at the
centre of the basin and divide it into two sub-basins- Son Valley in the east and Aravalli-Vindhyan in the west.

Much of the northern part of the Vindhyan Basin along with the Aravalli Delhi fold belt and the Bundelkhand granite-gneiss is overlain by recent alluvium of the Gangetic plain while the southern part of the basin is covered by Deccan trap Lava (Cretaceous to Oligocene) (Krishnan, 1968). The southern edge of the Vindhyan Basin is also marked by a major structural feature called the Narmada-Son lineament which is considered to have formed along Archean structural trends and remained active throughout the geologic history up to the present (Naqvi and Rodgers, 1987; Kaila et al; 1989). South of this lineaments, a southerly dipping reverse fault separates the Vindhyan Supergroup rocks from the Satpura belt in the Son Valley (Tewari, 1968). This faulting caused deformation of the Vindhyan sedimentary rocks exposed immediately to the north but can not be traced farther west, as it is possibly covered by the Great Boundary Fault, another major lineament characterized by westerly dipping faults, which separates the Vindhyan from the Aravalli- Delhi fold belt rocks. Major part of the basin consists of unmetamorphosed sediments providing suitable environments for the deposition of hydrocarbons.

LOCATION OF THE STUDY AREA

The Patherwa Formation, Semri Group, Vindhyan Supergroup (Auden, 1933) exposed as a linear belt along the Son river in parts of the Sonbhadra District Latitude (24° 20’ to 24° 35’) and Longitude (82° 06’ to 83° 24’). The area enjoys a typical tropical climate with distinct summer, rainy and winter seasons. The summers are hot and winters are cold with mean maximum and minimum temperatures of about 43°C and 11°C, respectively. The area is easily accessible by rail and by road from all the major cities of India. Both private and government transport is available for communication.

Some excellent exposures of Patherwa Formation can be found within a radius of about 40Km from the Chopan town, along the hills and as well as the banks of the Son River. Samples were collected from various locations and different horizons in and around the area (Figure 3).
Figure 3. Geological map of the study area.
PREVIOUS WORK

Williams was the first geologist who studied the Vindhyan rocks of “Keymore” range in the west of the Son River in the early part of 1848. Oldham (1856) studied Vindhyan rocks of Central India and proposed the name “Vindhyan” for all the formations seen in the scarps of Vindhyan range and classified them into three subgroups, “Kymore”, “Rewah” and “Bundar” in ascending order. Medlicott (1859) in his report on the Vindhyan rocks of Bundelkhand agreed with the classification given by Oldham. However, he observed a group of rocks comprising limestone, shale and sandstone between the Vindhyan rocks and the crystalline basement and termed it Semri Group.

Much of our knowledge of Vindhyan stratigraphy is based on the excellent early investigations of various parts of the Great Vindhyan Basin by the Geological Survey of India (Medlicott, 1859; Mallet, 1869; Oldham et al; 1901; Heron, 1922, 1936; Coulson, 1927 and Auden, 1933). Laterly, much valuable work has also been done by some universities of India, notably those of Lucknow, Calcutta and Aligarh. Excellent historical reviews of the Vindhyan literature have been presented by Ahmad (1962, 1971) and Misra (1969).

Mallet (1869), after a regional study of Vindhyan rocks in northwestern and central India finally correlated the “Semri Series” with “the Sub-Kymore Series” and included them in the Vindhyan System. He also introduced the term “Lower Vindhyan” for the “Semris” and “sub-kymores and grouped the other three sub units (“Kymores, Rewah, and Bundair”) into what he called the “Upper Vindhylans”. It is unfortunate that the “terms” “Upper” and “Lower” Vindhyan have persisted in literature despite the very valid objections raised by Auden (1933) and Ahmad (1971). Thus after the addition of a fourth sub-unit (semri) to its base Oldham’s original lithostratigraphic classification became well established in Vindhyan stratigraphy and continues to be in use till date.

Heron (1936) carried out detailed mapping of the entire region describing the stratigraphic sequence, lithology and structural feature of the Vindhyan rocks. Ahmad (1962) reconstructed the paleogeography of the Vindhyan Basin, after studying the geology of the Vindhyan system. He gave an idea that large part of the Vindhyan
Basin was connected with the main eastern basin. Large part of the Vindhyan Basin went to form a craton during Gondwana period and a great thickness of Bhandar and post-Bhandar beds have been removed. He concluded that post-Vindhyan but pre-Gondwana rocks were deposited in this area. Basumalick (1962) concluded that Bhandar Sandstone deposited under tidal flat environment. Jafar et al. (1966) on the basis of paleocurrent studies suggested that the Vindhyan sedimentation took place in two phases, i.e., in a restricted basin in Semri times and in extended basin across Aravalli craton.

During last five decades, a great deal of work has been carried out on various aspects of Vindhyan rocks such as stratigraphy and primary sedimentary structure (Mishra and Awasthi, 1962; Prasad, 1976, 1984; Banerjee and Sinha, 1981; Valdiya, 1982; Soni et al., 1987; Prasad and Verma, 1991), Paleogeography and sedimentation (Ahmad, 1962, 1981; Akhtar, 1976; Bhardwaj, 1977; Singh, 1980; Rao et al; 1981; Ghosh, 1981; Chanda and Bhattacharya, 1982; Srivastava et al; 1983; Bhardwaj and Mathur, 1989; Banerjee et al; 2006; Chakraborty, 2006).

A number of workers give the geotectonic aspects of the Vindhyan Basin e.g. Narain and Kaila (1982) worked on the seismic data analysis of the Vindhyan Basin along the Son Valley revealing several deep fractures within the crust underlying the Vindhyan and Mahakoshal belts of Son Valley as revealed by DSS profiling. Radhakrishna and Naqvi (1986) stated that the two episode of collision in the North Indian Shield corresponding to the paleoproterozoic/Aravalli-Sakoli orogeny and Mesoproterozoic/ Neoproterozoic Delhi-Saucer orogeny have been evolved probably as a curvilinear mobile belt (MPMB) following the boundary of Bundelkhand craton. Yadlekar et al, (1990) has identified the Narmada- Son lineament as the Central Indian Suture Zone (CISZ). Gravity and magnetic surveys in the Son Valley have revealed that the Mahakoshal are present under the Vindhyan occurring in successive narrow east-west trending zones (Das, 1988). Geophysical and deep drill- core studies have revealed the existence of the Vindhyan sediments under the Gangetic alluvium (Das, 1988; Kaila et al; 1989; Verma, 1991). Raza et al, 2009) stated that the Lower Vindhyan volcano sedimentary succession was deformed and exposed to erosion before deposition of the Upper Vindhyan rocks. The orogenic forces were active intermittently throughout the Vindhyan sedimentation. Chakraborty and Bhattacharya
(1996) delineated that the coarser siliciclastic facies of the Vindhyan Basin fluctuated among alluvial fan braid plain, fan delta, eolian, shallow marine and lacustrine environment. The carbonates are interpreted to represent deposition in different parts of ramp setting varying from intertidal to deep offshore (Banerjee, 1997). Since then number of workers have made significant contributions on sedimentation history, depositional environment and age correlation of Vindhyan Basin (Venkata Chala et al; 1996; Sarkar et al; 1998; Chakraborty et al; 1998; Bose et al; 1990, 2001; Gupta et al; 2003; Sarkar et al; 2004a; Sarangi et al; 2004; Banerjee and Kumar, 2007; Prasad, 2007; Sarkar et al; 2008; Ahmad and Majid, 2010; Ahmad et al; 2012) suggesting depositional environment ranging from fluvial-deltaic to shallow marine environment.

A few authors (Singh, 1973; Bose et al; 2001; Gupta et al; 2003; Banerjee et al; 2005; Ahmad et al; 2012) are confined to deciphering depositional environments of the Patherwa Formation (Semri Group) outcropped eastern part of the Uttar Pradesh. The eastern part of the basin to which the present study is virtually virgin for geological investigations in general and the sedimentological studies in particular. Therefore, there exists a gap in knowledge about the depositional environment, sediment dispersal and diagenetic aspects of the sedimentary succession in this part of the Vindhyan Basin. The present study is an attempt to fill up this knowledge gap by taking up a detailed facies analysis, sediment geochemistry, provenance and diagenetic history of the Patherwa Formation of the basin in order to reconstruct the depositional model for the chosen area.

**AIM AND SCOPE OF INVESTIGATION**

The present study mainly aims at reconstructing the sedimentation and history of the Patherwa Formation (Semri Group) in eastern Vindhyan Basin. For this purpose two field sessions were devoted during the month of February 2009 and October 2010 for detailed lithofacies studies, measurement of sections, collection of paleocurrent data and collection of samples for the follow up laboratory investigations. Four well exposed lithostratigraphic sections were measured from Markundi, Kewta, Obra and Hardi localities. Lithologs were prepared on the basis of field data and lithofacies were identified.
Thin section of sandstone samples were prepared and used for the petrographic study. The textural attributes of the sandstones, such as size, sorting, skewness, kurtosis, roundness and sphericity were studied with a view to interpreting the provenance and estimating the influence of texture on the detrital modes and petrofacies. Statistical parameters of grain size were computed according to the method of Folk (1980). Bivariant plots were plotted to find out interrelationship of various textural attributes.

Lithofacies analysis of the sandstones was carried out to interpret the depositional environment of the Patherwa Formation. The depositional environment is based on field data. Detrital mineralogy of the sandstones, including light and heavy minerals fractions, was studied for the purpose of description and petrographic classification of the studied sandstones and interpretation of their provenance. Classification scheme of Folk (1980), based on composition of common detrital framework constituents and Dickinson (1985), based on tectonic setting of provenance were employed in the present study.

Thirty one samples of sedimentary rocks were chosen for geochemical analysis: one sample of very coarse grained sandstone, seven samples of coarse grained sandstone, eleven samples of medium grained sandstone and twelve samples of fine grained sandstone of four sections of Patherwa Formation. The samples were analyzed for their major element by XRF at NIO, Goa using bead pellets and trace elements by ICP-MS at NGRI. First I chipped the sample and after that powdered the sample in pulverizer into 20 mesh size. Ultimately, the representative sample was taken after quartering and coning process. Pressed discs made from a 2:3 mixture of powdered sample and binder were analyzed by XRF. The REEs of selected samples were analyzed by ICP-MS. An attempt was made to study the diagenetic history of the sediments. Thin sections were analyzed to study the types of grain contacts, porosity reduction and cementation.

*Geochemical approaches are equally applicable to coarse and fine grained sedimentary rocks. These contrasts with petrographical approaches were provenance studies for the grained as well as very coarse grained sediments are difficult. An important caveat is that fine grained sediments typically represent more*
homogeneously mixed sources, but it is compositional variability that commonly leads to insights about provenance and attended sedimentary processes. There is growing evidence that even intimately associated sand and muds may be derived from quite different sources with different sedimentary histories and so both require evaluation (e.g., McLennan et al., 1990). The trace elements or isotope systems may be very sensitive in entifying minor components not readily recognized petrographically (e.g., Hiscott, 1984; Nelson and Depaolo, 1988). In some cases, recognizing even trivial amounts of certain exotic components, e.g., ophiolites, may be of considerable importance in understanding the tectonic history.

Vindhyan basin is placed in the category III of petroliferous basins of India by ONGC. On the basis of depositional and diagenetic interpretation, a comparison and correlation of Vindhyan Basin will help in evaluating its hydrocarbon potential. Furthermore petrography and geochemistry will help to elucidate the type and composition of source terrain. Despite the fact that sedimentary rocks are abundant in the area, geochemical studies of advance nature have not been attempted so far.