ESTABLISHMENT OF FACIES VARIATION IN KAIMUR GROUP OF ROCKS AND THEIR ASSOCIATION WITH URANIUM MINERALIZATION IN DHOHA -DURSENDI AREA, GWALIOR DISTRICT, M.P.

by

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DECLARATION

I, hereby declare that the investigation presented in the thesis has been carried out by me. The work is original and has not been submitted earlier as a whole or in part for a degree / diploma at this or any other Institution / University.

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DEDICATIONS

Dedicated to my family

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SYNOPSIS

The Vindhyan Basin is one of the largest intracratonic sedimentary basins of the world. The Vindhyan basin exposed around Gwalior is situated on northwestern fringe of Bundelkhand massif and unconformably overlies the Bundelkhand granite. In the study area, the Vindhyan Super Group of rocks (Kaimur Group) comprising sandstones with intercalation of shale-sandstones, shales with breccia conglomerate and gritty sansdstone at the base are exposed. Thoughout the world, Lower to Middle Proterozoic basins have been targeted as thrust areas for uranium investigations due to their high potentiality for uranium deposits. The work done in the study area is establishing the facies association of the Kaimur group of rocks overlying Bundelkhand Granite massif from surface exposures and sub-surface core samples from characteristics of different lithology and structures of rocks and carrying out radioelemental distribution study to understand the relationship of any possible uranium mineralization with any particular facies association, which can help in understanding the distribution of uranium throughout the basin.

Facies association of Kaimur Group of rocks in study area was established here with necessary provenance study and an idea of palaeoenvironmental depositional setting was reflected. A dominantly marginal marine setting for most of the lithofacies was interpreted with a transgressive and regressive event one after another. The marine environment of deposition for shale and shale-sandstone units of Kaimur Group of rocks was supported by presence of glauconites from petrographical studies of rock samples. Geochemical studies of samples also depicted a Passive Margin tectonic setting of deposition. Provenance study was carried out both via petrographical and geochemical studies and a continental block province of felsic igneous rocks is interpreted as provenance of these sediments. Radiomental studies was carried out of each lithofacies of Kaimur Group of rocks but no facies showed any promising values of uranium to be interpreted as uranium mineralisation controlled by any facies. . For future exploration aspects more studies will be necessary if there is other type of mineralization with some other controlling factors.

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1 Establishment of facies variation in Kaimur Group of rocks and their potentiality of uranium mineralization in Dhoha-Dursendi area, Gwalior District., M.P.

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CHAPTER 1

INTRODUCTION

1.1 Introduction:

The Vindhyan Basin is one of the largest intracratonic sedimentary basins of the world. The basin has been studied for more than a century since the time of Oldham (1856) and Mallet (1869). Auden (1933) provided the basic data for all the subsequent studies on the Vindhyan Basin (Ahmad 1958; Banerjee 1964, 1974; Singh 1973, 1980, 1985; Chanda and Bhattacharyya 1982; Soni et al. 1987; Chakraborty and Bose 1990, 1992; Prasad and Verma 1991; Bhattacharyya and Morad 1993; Akhtar 1996; Bhattacharyya 1996; Sarkar et al. 1996, 1998, 2002a, b, 2005, 2006; Ram et al. 1996; Bose et al. 2001, 2015; Banerjee and Jeevankumar 2003, 2005; Banerjee et al. 2006a, b, c, 2010; Paikaray et al. 2008).

The Vindhyan Basin is the largest epicontinental Proterozoic basin in India. Geographically, Vindhyans are located between 21◦N and 28◦N latitudes, and about 75◦E and 84◦E longitudes. Archean Bundelkhand Granite Complex and the Cretaceous Deccan Traps divide Vindhyan outcrops into two broad areas, viz. the Son Valley covering Bihar, Jharkhand, Uttar Pradesh, and Madhya Pradesh in central India, and the Chambal Valley covering Rajasthan and western Madhya Pradesh in Western India. Large part of the basin is covered by Deccan Traps in the southern-central part and approximately about 10,000 sq. km. is recognized hidden under the Gangetic alluvium (Mathur, 1965; Venkatachala et al., 1996). The sedimentary pile is up to 4500 m thick (Ahmad 1971). The stratigraphic units comprising the Vindhyan Supergroup are traceable laterally within an individual sector, but they vary in sedimentological attributes from one sector to that of the other.

According to Mazumdar et al. (2000), the basin lies between the gneiss and granite of the Archaean (>2.5 Ga) Aravalli– Bundelkhand province to the north and east. Lower

Vindhyans rest unconformably on the basement granite and palaeoproterozoic Gwalior/ Bijawar Group of rocks. Despite having the similar time of deposition these two palaeoproterozoic basins have different sedimentation pattern. Gwalior basin records sedimentation of BIF whereas in similar time period Bijawar basin records phosphorite deposits (Chakraborty et al., 2015).

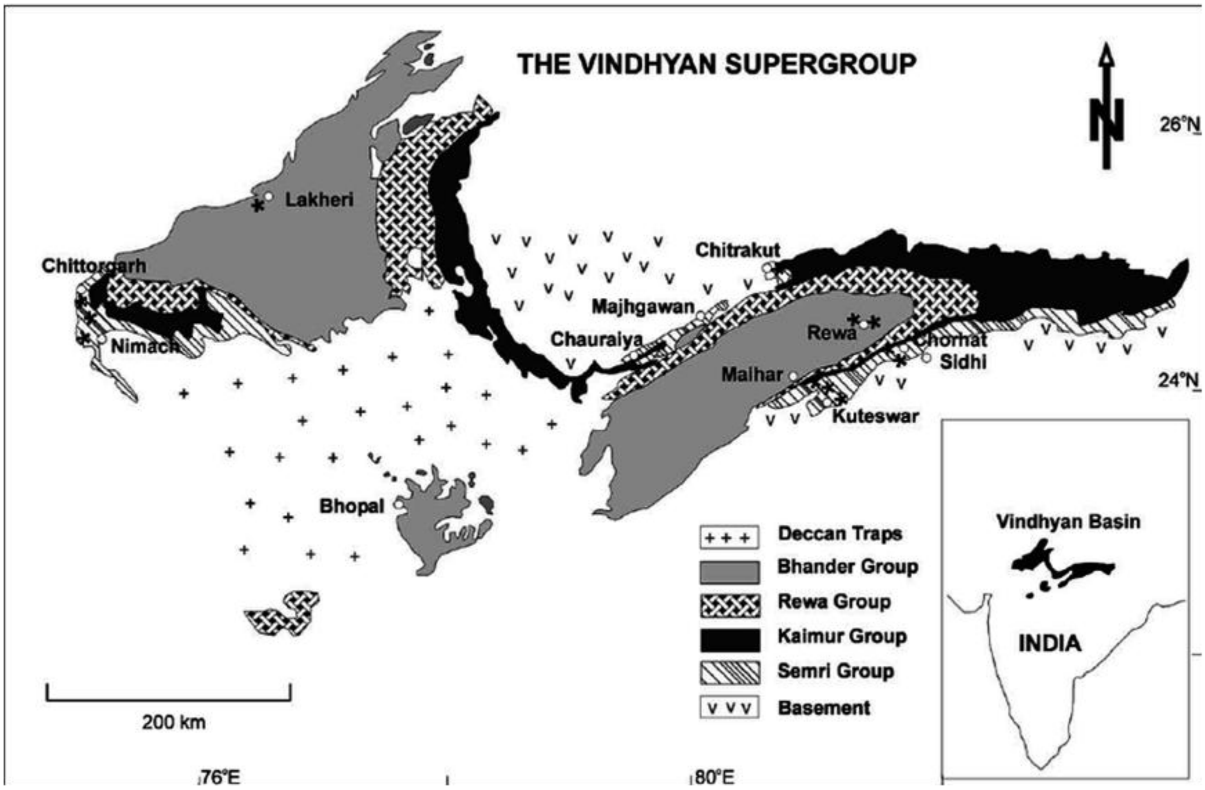


Figure 1.1 Distribution of outcrops of Vindhyan Supergroup, after Ray et al.,2003

Both Bijawar and Gwalior Group are present between the Bundelkhand gneisses and Vindhyans but they are widely separated geographically. Gneissic rocks occupy the largest tract beneath Vindhyans especially in the areas of Bundelkhand, Allahabad, Gwalior and Son Valley under the Kaimur scarps.

The Vindhyan outcrop belt forms a syncline in the Son Valley area with E–W elongation and closure in the east. The dips of the beds on two flanks converge towards the axis of the syncline. The younger rocks occur near the core of the syncline, whereas the older formations occur near the flanks of the syncline. Exposures of the Semri Group are conspicuously asymmetrical on both sides of the E–W oriented synclinal axis. The Semri exposures are discontinuous and occur as small patches to the north. The Upper Vindhyan, however, is uniformly distributed on both sides of the synclinal axis. The eastward closure of the outcrop indicates the westward plunging nature of the syncline.

1.1.1 Age of Vindhyan

The age of the Vindhyan Supergroup remains controversial because of apparent conflicting reports of radiometric dates and putative trace fossils (Venkatachala et al. 1996). The available age information till the last century brackets the age of the Vindhyan from 1200 to 550 Ma. The report of triploblastic metazoans by Seilacher et al. (1998) from the Lower Vindhyan Semri Group has created tremendous interests in Vindhyan geology, particularly on chronostratigraphy and bio-sedimentology.

The age of the Lower Vindhyan is firmly established based on SHRIMP U–Pb ages of magmatic zircons within the volcaniclastic units comprising the Porcellanite Formation of the Lower Vindhyan. Back-to-back publications of two broadly similar ages of 1628 ± 8 Ma (Rasmussen et al. 2002) and 1630.7 ± 0.8 Ma (Ray et al. 2002) redefine the age of the Porcellanite Formation as well as the Semri Group. Kajrahat Limestone samples, about 150 m above the basement, has yielded a Pb–Pb isochron age of 1729±110Ma (Sarangi et al. 2004). These radiometric dates indicate the Vindhyan basin possibly opened at ca. 1800Ma (Basu and Bickford 2015). An ash bed in the Rampur Shale of the Rohtas Formation yielded a U–Pb zircon age of 1599 ± 8 Ma (Rasmussen et al. 2002). Another set of Pb–Pb isochron age for the Rohtas Limestone has produced 1514±120 Ma (Chakrabarti et al. 2007. The Semri Group, therefore, brackets an age range between ~1800 and ~1500 Ma.

The age of the Upper Vindhyan is far more controversial, although much progress has been made in recent years towards resolving this issue. The kimberlite pipes within Majhgawan and Hinota produced ages of 974 Ma to 1067 ± 31 Ma and 1170 ± 46 Ma by various techniques (Chalapathi Rao 2006), indicating a Mesoproterozoic age for the oldest sediments of the Upper Vindhyan sequence. Indirect evidence has supported a general view that the Rewa and Bhander groups belong to mid Neoproterozoic in age. Bhander Group carbonate Sr isotope ratios show the age of Bhander limestone ~1.0 Ga (Gopalan et al. 2013). Turner et al. (2014) also found that the Upper Bhander Sandstone contained no detrital zircons younger than ~1020Ma. Based on these lines of evidence, they considered the closure of the Vindhyan sedimentation by ~1000 Ma. Subsequently, Gopalan et al. (2013) reported Pb–Pb ages of 908 ± 72 Ma and 1073 ± 210 Ma for the Bhander and Lakheri limestones, respectively. Further, Tripathy and Singh (2015) reported a Re–Os age of 1210 ± 52 Ma for the Bijaigarh Shale in the Kaimur Group. The recent paleomagnetic and detrital zircon data, therefore, indicate that the Vindhyan Basin was closed around 900–1000 Ma (Malone et al. 2008; Gopalan et al. 2013; Basu and Bickford 2015). Therefore, on the basis of varied kinds of evidence, the most acceptable age of the Vindhyan Supergroup starts from ~1800 Ma to ~1000–900 Ma (Rasmussen et al. 2002; Ray et al. 2002, 2003; Ray 2006; Gopalan et al. 2013; Basu and Bickford 2015; Gilleaudeau et al. 2018).

1.1.2 Geological setup of Vindhyan Basin:

Vindhyan Basin formed on the Aravalli craton, which stabilized by 2.5 Ga (Mondal et al., 2002). The western, southern and eastern margins of the Vindhyan basin are demarcated by an arcuate thrust belt comprising of the Aravalli-Delhi and Satpura orogenic belts. Bundelkhand massifs occur in the central part of the basin as an isolated block. In the western sector, the Vindhyan basin is thought to have been deposited as an infill of the failed rifts of the Aravalli craton (Mondal et al., 2002). Rifting thinned part of the crust along a series of east to west trending faults in a dextral transtensional setting (Bose et al., 2001). Vindhyan sediments are undeformed to slightly deformed. Confirmation of tectonic changes in the fault block underlying Vindhyan basin are pointed out by basin wide unconformities, sedimentation disturbances, and changes in palaeoslope level (Prasad and Rao, 2006; Chaudhuri et al., 2002; Bhattacharya, 1996 and references there in).

1.1.3 Structural Architecture

Vindhyan basin is bounded by number of major faults. North-western and south-eastern boundaries are represented by NE-SW trending Great Boundary Fault (GBF) and ENE-WSW trending Narmada-Son lineament respectively. Great Boundary Fault is separating the Aravalli–Delhi orogen from the Vindhyan, also marks the western margin of the Vindhyan basin. The Son–Narmada lineament in the southern margin, which constitutes a series of southerly dipping reverse faults (Kaila et al. 1985), is a prominent linear feature in the Indian subcontinent with a total strike length of 1200 km and marks the boundary between the Aravalli–Bundelkhand Province and the Dharwar Province (Mazumder et al. 2000; Acharyya 2003). The Great Boundary Fault (GBF; Tewari 1968; Naqvi and Rogers 1987; Narain 1987; Verma 1991; Srivastava and Sahay 2003) consisting of a series of northeast–southwest trending, northwesterly dipping faults, runs for about 500 km .Other important intrabasinal faults are Kota-Dholpur, Ratlam-Shivpuri, Basoda-Barsingarh, Kannod-Damoh and Bansipur-Rewa (Ram et al., 1996).

The Vindhyan succession is by and large a horizontal to subhorizontal-lying pile of sedimentary rocks. However, along the southern and western margins against the Satpura–Aravali Mobile Belt, the rocks are folded and faulted, and characterized by strong shearing and attendant brecciation. In the Narmada Lineament zone, strong deformation gave rise to overfolds and isoclinal folds with nearly vertical beds (Choubey 1971a). In the Chittaurgarh–Jhalrapatan belt in southwestern Rajasthan—where the tectonic boundary swerves from NW–SE to NE–SW—the axes of tight folds dip steeply (50°–70°) westwards (Krishnan and

Swaminath 1959). The deformation of the marginal Vindhyan is related to the transpressional Great Boundary Fault, traceable from Mewar to Fatepur Sikri near Agra.

The Vindhyan Basin is segmented into smaller elongate subbasins by multiplicity of faults, some of which are wrench faults (Ram et al. 1996; Das et al. 1990). The subbasins are of the nature of half-graben tilting northwards. The structural architecture of the domain is attributed to combined influence of rifting and dextral shearing (Bose et al. 2001).

The existence of the basin-wide unconformity separating the Semri Group of the Lower Vindhyan (Mesoproterozoic) from the Kaimur–Rewa–Bhander successions of the Upper Vindhyan carries an implication that the Vindhyan domain was affected by a tectonic upheaval before commencement of Neoproterozoic sedimentation. While the Semri sediments in the northern margin of the Vindhyan Basin are confined to their present limit, the Upper Vindhyan extends far northwards into the Indo-Gangetic domain. Thus, much larger area came under the sway of the Vindhyan sea during the Neoproterozoic time. This fact is further borne out by development of many Neoproterozoic basins in the Peninsular India to the south.

1.1.4 Igneous Intrusives

The Vindhyan succession is intruded by a few mafic and felsic intrusive bodies. A large number dolerite dikes and sills occur within the Semri Group (Auden 1933; Ahmad 1971; Srivastava and Iqbaluddin 1981), the Rewa Formation (Soni et al. 1987 and references therein) and the Bhander Formation (Soni et al. 1987). Several diamondiferous ultramafic pipes intrude the Kaimur Formation in Majhgawan and Hinota in the Panna area (Mathur and Singh 1971; Kailasam 1979; Chalapathi Rao 2005, 2006). The Majhgawan pipe occurs on the western limit of the Panna diamond belt (80 × 50 km) and is localized in a NE–SW to ENE–WSW trending crestal zone of the upwarped eastern margin of the Bundelkhand craton (Halder and Ghosh 1978). The Hinota pipe is a circular intrusion with a shallow crater of up to 80 m (Chalapathi Rao 2006). The Mesoproterozoic diamondiferous ultramafic pipes at Majhgawan and Hinota, which intrude the Kaimur Group of Vindhyan rocks, combine the petrological, geochemical and isotope characteristics of kimberlite, orangeite (Group II kimberlite) and lamproite, and hence are characterized as belonging to transitional kimberlite orangeite–lamproite rock type. While the Hinota pipe produced 1170 ± 46 Ma age by K/Ar technique (Paul et al. 1975), the Majhgawan kimberlite yielded 974 Ma to 1067 ± 31 Ma by various techniques (Chalapathi Rao 2006).

1.1.5 Volcanism

In Rajasthan area, Semri sedimentation commenced with contemporaneous volcanic activity as indicated by andesitic tuff, pyroclastics and breccias, formally known as Khairmalia Pyroclastics (1250 Ma;Crawford and Compston 1970; Prasad andVerma 1991; Raza et al. 2001). TheKhairmalia volcanics has no equivalent in the SonValley (Prasad 1984). The Semri Group in the Son Valley is distinctive from Upper Vindhyans by having huge piles of volcanic materials (mainly Porcellanite Formation). Porcellanite Formation is mostly pyroclastic in nature (Auden 1933; Ghosh 1971; Chakraborty et al. 1996; Rasmussen et al. 2002). Volcaniclastics of the Porcellanite Formation occur in the form of surges, tuffs and epiclastics. Mishra et al. (2018) considered Plinian-type eruptions from isolated events along a 300-km crustal fracture in the Son Valley region. Regarding the depositional setting of the Porcellanite Formation, Srivastava (1977) recognized subaerial deposition. Felsic volcanic materials occur at specific levels within Kaimur and Rewa Formations (Chakraborty et al. 1996).

1.1.6 Uranium Mineralization

Lower to Middle Proterozoic basins have been targeted as thrust areas for uranium investigations due to their high potentiality for unconformity related uranium deposits. The area along the northern margin of Bundelkhand granite represent geological set up with

Lower Proterozoic Gwalior Group unconformably overlain by the Middle Proterozoic Vindhyan Super Group of rocks. The study area lies in the western margin of Bundelkhand massif, where Vindhyan Super Group of rocks unconformably overlies the basement Bundelkhand granite. The sedimentary sequences have been subjected to faulting and developed fractures and faults. The Bundelkhand granite which forms provenance for Vindhyan Super Group contains appreciable content of uranium (13-32 ppm). In view of these facts the proposed area provides ideal setting for hosting unconformity related uranium mineralisation.

Satellite imagery of the proposed area also indicates presence of ENE-WSW trending major lineament, besides other set of lineaments trending NW-SE to NNW-SSE. Preponderance of such lineaments and their intersections is additional feature of the proposed area. The main objective of the work in proposed area would be to establish the facies association of the overlying Kaimur group of rocks from surface exposures and sub-surface core samples and gamma ray log data which can give characteristics of different lithology; and to understand the relationship of uranium mineralization with any particular facies association, which can help in understanding the distribution of uranium throughout the basin.

1.2 Principal Objectives

1. To establish the facies variation of different rocks of Kaimur Group exposed in the proposed area from surface and sub-surface samples.
2. Facies-wise petro-mineralogical, geochemical and radio-elemental variation studies of different lithounits and host-rock characterization.

3. To understand Facies variation and their control of uranium mineralization (if any) that may lead to suggest the exploration methodology for further Uranium exploration.

1.3 Methodology

1. Literature review has been done to understand the regional geology of the area and to understand facies related studies from previous works.
2. Traverses were taken in study area and all the lithounits were properly studied and available lithological, structural and radioelemental data were collected.
3. Detailed geological Mapping and sampling was carried out in the Dhoha-Dursendi area of Gwalior district on 1:5000 scale over an area of 5 sq km, covering basement Bundelkhand granites to overlying Vindhyan sediments, nature of their contact and its bearing on uranium mineralization.
4. Facies association has been established for all the rock formations from their lithology and texture, body geometry on surface outcrops and primary structures available.
5. Geochemical, radio-elemental as well as petro-mineralogical studies of selected samples was carried out to characterize the rocks, understand the distribution and geochemical behaviour of uranium and alteration patterns.

CHAPTER 2

REGIONAL GEOLOGY

2.1 Introduction

Traditionally, the Vindhyans are divided into two- Lower Vindhyans and Upper Vindhyans (Auden, 1933; Shastry and Moitra, 1984). Lower Vindhyans are popularly called as the Semri Group. And the Upper Vindhyans include Kaimur, Rewa and Bhander Group of rocks in the stratigraphic order. Semri Group has also been referred as Semri Series by Auden (1933). It is made up of carbonate rocks, tuffs and acid volcanic. Sandstone occurs as minor component. Semri Group is made up of 4 stages or formations- Basal, Porcellanite, Kheinjua

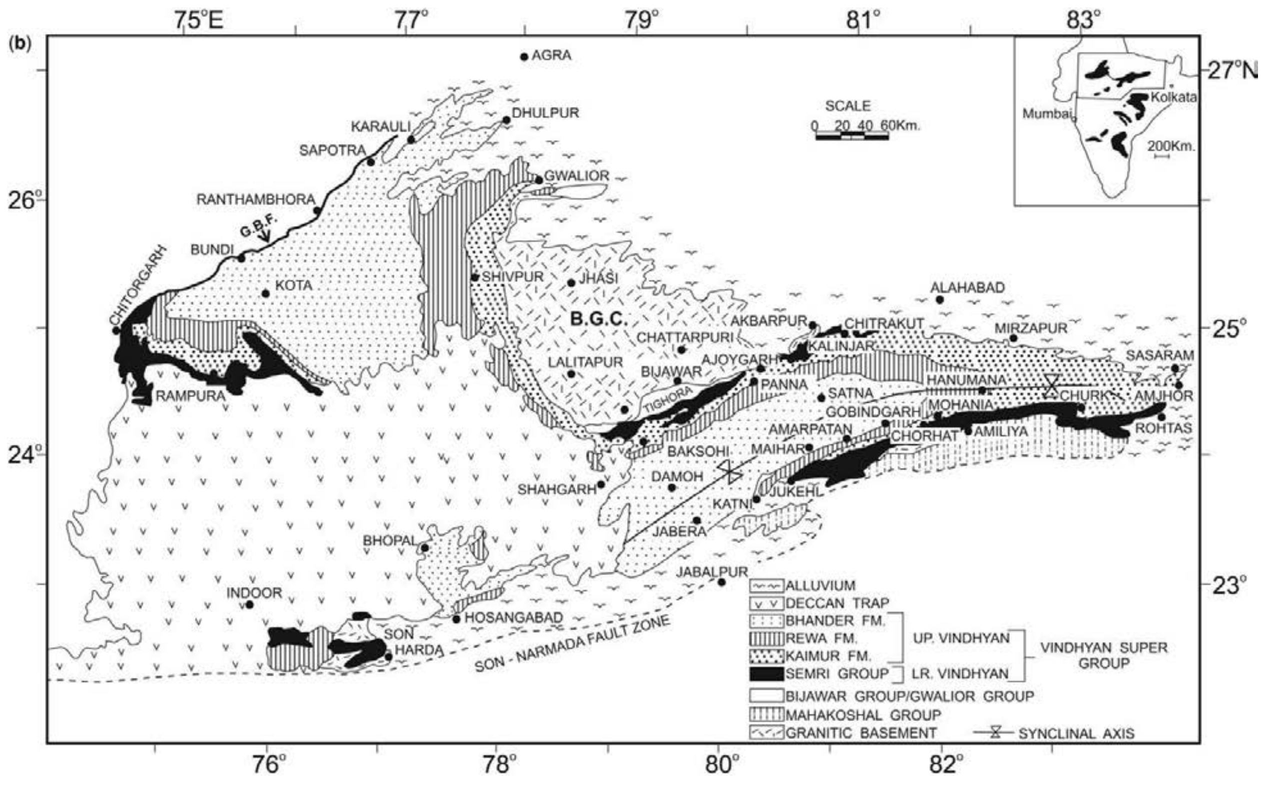


Figure 2.1: Geological map of Vindhyan Basin consisting all rock groups (after Bose et al 2001)

and Rohtas (Shastry and Moitra, 1984 and Bhattacharya, 1996). Semri Group rests unconformably over pre-Vindhyan sediments such as granites, metamorphics and metasedimentary rocks of Bundelkhand massifs, Bijawars or Mahakoshals. The Rohtas Formation of Semri Group is unconformably followed by Kaimur Group of Upper Vindhyans.

The Mesoproterozoic sedimentary rocks in the Vindhyan Basin (Misra 1969) are represented by the Semri Group. The earliest formation is a basal conglomerate unit known as the Deoland Formation (Chakraborty and Bhattacharyya 1996). Next is a diamictite unit known as Arangi Shales with an assemblage of flysch rocks comprising shales with coaly matter, and muddy, wacke sandstones. In the Son Valley, the Arangi succession is made up of vertically stacked facies of upward-fining fan-delta sediments and of turbidites, characterized by graded bedding, flute marks, sole marks, and ripple laminations formed under deep water slope-to-basin environment (Chakraborty and Bhattacharyya 1996). In the Chitrakoot area in south-central Uttar Pradesh, the Bundelkhand gneisses are overlain directly by shallow-water, intertidal to peritidal sediments. The succession consists of pelletal limestones and sandstones, characterized by abundant glauconite and stromatolitic siliceous dolomite as seen in the Lodhwara, Kamtanath, Sangrampur and Muradnagar hillocks (Anbarasu 2001). Elsewhere in the Son Valley, the Patherwa–Arangi succession is followed upwards by platform deposits, comprising dominant carbonates with shales (Kajrahat Limestone). After an interregnum due to acid volcanism, shales and limestones– dolomites were deposited for a long period. The olive-coloured Koldaha Shale records synsedimentary deformation, discernible in the belt between Chorhat and Shikarganj. Towards the later part of the Semri time, there was extensive formation of dolomitic bioherms (Salkhan Limestone, Rohtas Limestone). These are characterized by stromatolites, microbial laminites and thrombolites, formed in the shallow shelf. Significantly, the dominating carbonate formations also contain lenticular deposits of debris flows below the base of storm waves represented by intraformational carbonate breccia. This assemblage (Bhagwar) is associated with sediments characterized by ripple-cross-laminations, climbing ripples and Bouma sequence of turbidites (Chakraborty and Bhattacharya 1996). The Kajrahat Limestone in the Son Valley and the

Bhagwanpura Limestone in Rajasthan exhibit development of stromatolites of the types Kussiella together with domal and laminated forms (Valdiya 1969). In the Chorhat area, this horizon is characterized by burrows formed by triploblastic animals, identified as worm-like metazoan (Seilacher et al. 1998). It seems that towards the close of the Semri time, the Vindhyan Basin in the Son Valley was overtaken by tectonic instability. This situation heralded the onset of a regional tectonic upheaval, putting to end the Mesoproterozoic sedimentation in the entire Peninsular India.

Table 2.1 Lithostratigraphy of the Lower Vindhyan Semri Group in Son valley and Rajasthan (After Bhattacharya, A.K., 1996) :

Kaimur Group

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~Unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Bhagwar Shale

Rohtas Limestone

Rampur Formation

Salkhan Limestone

Koldaha Shale

Deonar Formation

Kajrahat limestone

Arangi Formation

Deoland formation

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~Unconformity~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~

Bijawar/Bundelkhand granite/Prearavalli

Kaimur Group is represented in the Son Valley by two bands of gritty and conglomeratic quartzite in the lower division. The lower quartzite grades upward into flagstones and shales representing ripple-marks and mud- cracks which further grade into thin bedded, micaceous and carbonaceous shales. Above it lays the Susnai Breccia which consists of angular, banded fragments. The Susnai Breccia is overlain by the upper silicified quartzite with marked cross bedding and ripple marks, which forms a prominent scarp in the Son valley. This passes upwards into the Bijaigarh shales which are carbonaceous, pyritiferous and micaceous and generally yellow in color. The Upper Kaimurs which overlie the Bijaigarh Shales, consist of greenish flagstones and sandy siltstones which crop out along the Kaimur Scarp and are revealed in the Mangesar hill. Above these are the Dhandraul Quartzites which are white to light pinkish in color.

Table 2.2 Stratigraphic succession of upper vindhyan is given below (Son valley, after Bhattacharya 1996):

Bhander Group	Shikaoda Sandstone (Upper Bhander Sandstone)
	Sirbu Shale
	Bundi Hill Sandstone (Lower Bhander Sandstone)
	Lakheri Limestone (Bhander Limestone)
	Ganurgarh Shale
~~?~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
Rewa Group	Govindgarh Sandstone (Upper Rewa Sandstone)
	Drammondganj Sandsone
	Jhiri Shale
	Asan Sandstone (Lower Rewa Sandstone)
	Panna Shale
~~?~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	
Kaimur Group	Dhandraul Sandstone
	Mangesar Formation (Scarp Sandstone)
	Bijaigarh Shale
	Ghaghar Sandstone
	Susnai Breccia/ Guruma Shale
	Sasaram Sandstone
~~Unconformity~~~~~~	
	Semri Group

The Kaimurs are succeeded by the Rewa Group composed of somewhat coarser sandstones than those of the Kaimurs, and cross-bedded flagstones. The two Groups are separated by a zone of diamond bearing conglomerate.

The Bhander Group is the uppermost unit of the Vindhyans which is separated from the Rewa Group by a horizon of diamond-bearing conglomerate. The Bhander sandstones are fine grained and soft, usually of a red color. They are fairly thick bedded. The upper Bhander frequently show ripple marks. The Bhander Limestone is of variable thickness and quality, passing from a good limestone to calcareous shale .The Bhander contains veins and beds of gypsum. Sirbu shales of this group resemble to the salt pseudomorph shale of the Salt Range and contain salt pseudomorphs at certain places.

Geology of the area:

The Proterozoic Vindhyan-Gwalior basin exposed around Gwalior is situated on northwestern fringe of Bundelkhand massif and unconformably overlies the Bundelkhand granite. In the study area, the Vindhyan Super Group of rocks (Kaimur Group) comprising sandstones with intercalationof shales with breccia conglomerate and ferrugenous shale at the base are exposed.

The brief stratigraphy of the study area is given below:

Stratigraphic succession in the western part of Gwalior Basin, Gwalior district, M.P.

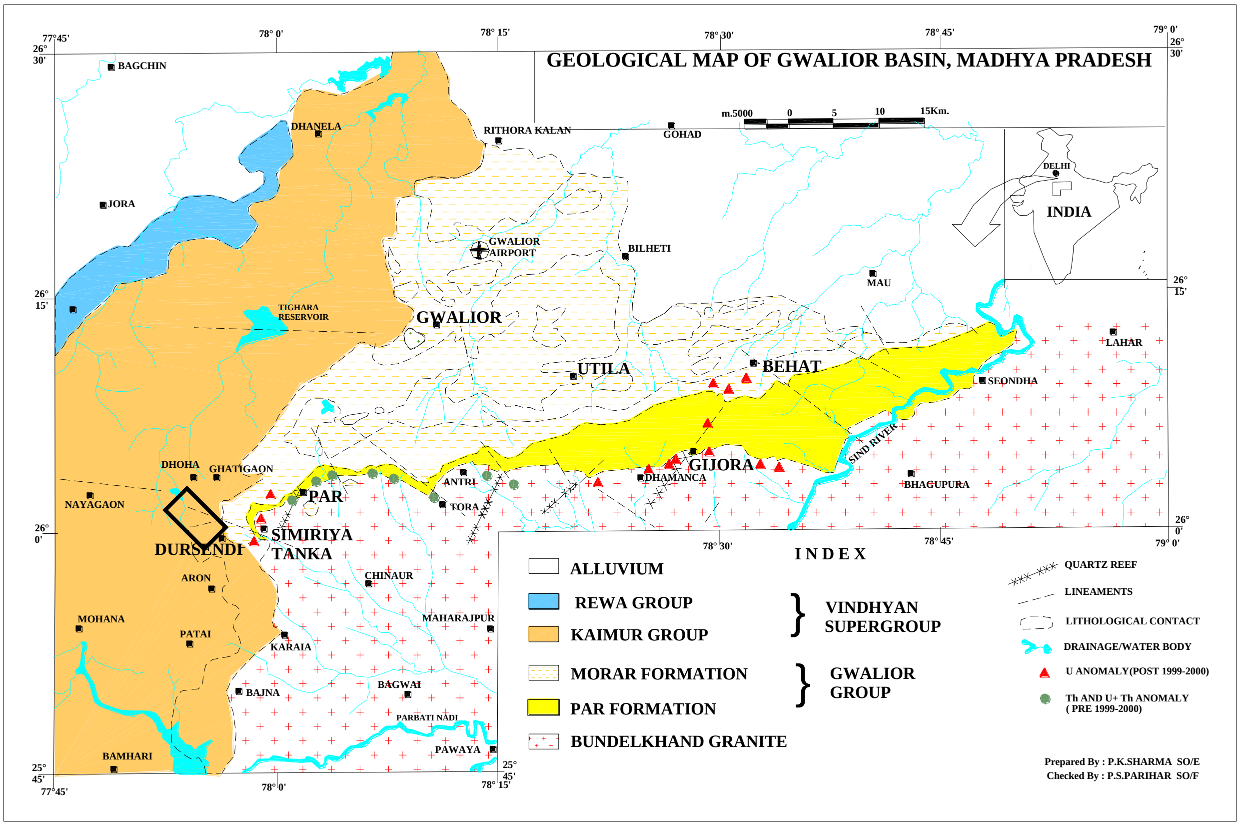


Figure 2.2: Regional Geology of Study area, consisting Gwalior and Vindhyan Basin and basement Bundelkhand granite(prepared by P.K. Sharma, SO-H) Study area has been marked.

Kaimur Group	Fine grained white/pinkish sandstone
	Thin intercalation of shale-sandstone, Breccia conglomerate with ferruginous sandstone and gritty sandstone

~~~~~~~~~~~~~~~~~~~~~~~~~~~~Unconformity~~~~~~~~~~~~~~~~~~~~~~~~~

Bundelkhand Granitoid Complex	Medium to coarse grained / porphyritic granite / gneiss with quartz reefs and basic dykes

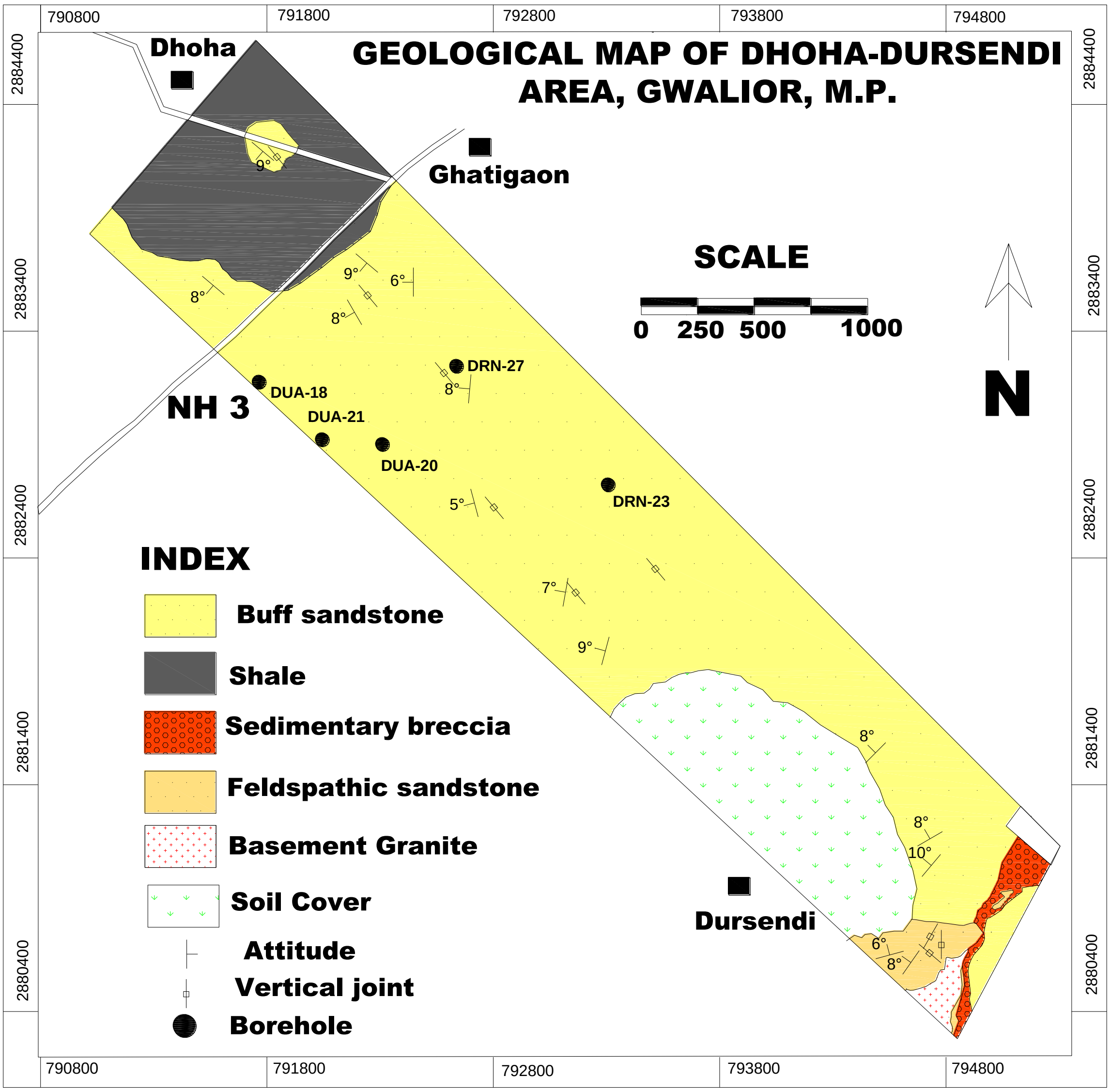


Figure 2.3: Geological map of the study area i.e. Dhoha-Dursendi area, Gwalior District, M.P.

Bundelkhand Granitoid Complex:

The vast Bundelkhand granitic province has a regional slope towards northeast and borders Kaimur which ranges to the west. Generally, it is considered as a monotonous
~~~~~~~~~~~~~~~~~~~~~~~~~~~~

granitic complex, however, a minimum of five phases of granitic activity has been reported elsewhere from this complex. This includes a large scale K – rich granite magmatism followed by late stage hydrothermal phases in the form of profuse intrusion of giant quartz reefs (Rahman, A. and Zainuddin, S.M., 1993). It is medium to coarse-grained even porphyritic biotite granite of grey and pink colour, which appears to be hydrothermally altered especially near its unconformable contact with overlying Gwalior Group of rocks. In contrast, by and large, relatively fresh (less altered) mesocratic granite is exposed below the Vindhyan cover. Nonetheless, there are exceptions e.g. the granitic pluton due west of Simiriya Tanka is leucocratic, relatively fresh, although it forms the basement for Gwalior Group. Similarly, in Ranighati area, the granitic basement near its contact with Vindhyan is highly altered. In addition, quartz reefs trending E-W and NE-SW form important physiographic feature within this granitoid complex. A number of basic dykes also traverse the basement.

Vindhyan Super Group (Kaimur Group):

In this area, Kaimur Group is represented by breccia conglomerate and gritty sandstone (basal unit) overlain by shale-sandstone. These sediments rest directly over basement and commonly form flat-topped plateau. In general, conglomerate is laterally impersistent and at many places, sandstone rests directly over Bundelkhand granite. It is also exposed in Ranighati ghat section and fine sandstone rests over granite. The conglomerate is polymictic, having clasts of variable sizes, more commonly dominated by Banded Haematite Jasper fragments set in a ferruginous matrix. Kaimur sandstone is fine grained, white to pinkish colour, occasionally having thin intercalations of clay and shale.

In Dhoha-Dursendi area, 5 major lithounits have been encountered. In southern side of the study area, due to low elevation basement Bundelkhand granite is exposed. Gritty feldspathic sandstone and/or sedimentary breccia made of clasts of Gwalior Group of rocks overlie the basement granite. Lateral facies change has also been observed between these two sedimentary units. Gritty feldspathic sandstone occur as bedded deposit, dip of bed is very low, varies between 5-10◦ dipping mostly towards north-west. Three sets of joints have been observed: 1) NW-SE, 2) NE-SW and 3) N-S. Asymmetric ripple marks have been observed in some places although it is not common probably due to coarse grain size of the unit. Palaeocurrent direction varies from 60-80◦. Sedimentary breccia is mostly clast supported often intercalated with ferruginous sandstone.

Buff coloured sandstone is exposed in most of the part of study area. Proper outcrops are very limited due to dense vegetation. The sandstone beds dip mostly northwest to southwesternly with dip amount of 7-9◦. One set of joint is observed throughout this sandstone i.e. NW-SE. In northwestern part of study area, ferruginous brown shale outcrop is exposed. The shale beds are almost subhorizontal and occur as thin planar laminations.

Due to scarcity of outcrops in study area most of the lithological data are collected from boreholes and they have studied thoroughly for facies study.

CHAPTER 3

FACIES STUDY

3.1 Introduction

The term “facies” was introduced into geology by Nicholaus Steno (1669). It meant the entire aspect of a part of the earth’s surface during a certain interval of geologic time (Teichert, 1958). The word itself is derived from the latin facia or facies, implying the external appearance, or look of something. The meaning of the word facies has been much debatable in geology (Moore 1949, Teichert, 1958). It is widely used in sedimentary geology but also has a somewhat different meaning in the area of metamorphic petrology.

The word facies now is used in both a descriptive and an interpretive sense, and the word itself may have either a singlular or plural meaning. Descriptive facies include lithofacies and biofacies, both of which are terms used to refer to certain observable attributes of sedimentary rock bodies that can be interpreted in terms of depositional or biological processes. An individual litho facies is a rock unit defined on the basis of its distinctive lithologic features, including composition, grain size, bedding characteristics and sedimentary structures. Each lithofacies represents an individual depositional event. Lithofacies may be grouped into lithofacies associations, which are characteristic of particular depositional environments. These assemblages form the basis for defining lithofacies models. A biofacies is defined on the basis of fossil components, including either body fossils or trace fossils. For the purpose of sedimentological study, a deposit may be divided into a series of facies units, each of which displays a distinctive assemblage of lithologic or biologic features. These units may be single beds a few millimetres thick or a succession of beds tens to hundreds of meters thick. J.L.Wilson (1975) recommended the use of microfacies in studying thin sections of carbonate rocks.

The scale of an individual lithofacies or biofacies unit depends on the level of detail incorporated in its definition. It is determined by the variability of the succession, the nature of the research undertaken or the availability of rock material for examination. Facies units defined on the basis of outcrop, core, well-cutting or geophysical criteria tend to refer to quite different scales and levels of detail.

The term facies can also be used in an interpretive sense for group of rocks that are thought to have been formed under similar conditions. This usage may emphasize specific depositional processes. Alternatively, it may refer to a particular depositional environment, such as shelf carbonate facies or fluvial facies, encompassing a wide range of depositional processes.

Facies modelers have yet to categorize all sediment types in every variety of depositional environment; for example no one has yet attempted to erect a universal lithofacies scheme for clastic rocks comparable to the scheme of J.L.Wilson (1975) for carbonates.

Facies analysis of stratigraphic unit deals with the three dimensional behaviour of that unit within the surrounding units and is used for reconstruction of palaeoenvironment, palaeotectonics and palaeogeography. A sedimentary facies comprises one or more 'lithofacies' and any facies differs from other adjacent to it in having one or more lithofacies constituents which are absent in others (Moore, 1949). Thus term lithofacies denotes the sum total of lithological characteristics of sedimentary rock. A facies model could be defined as a general summary of a specific sedimentary environment, written in terms that make the summary useable in at least four different ways (Walker, 1984). Four important functions that a facies model must fulfil are - a norm, for purposes of comparison; framework and guide for future observations; predictor in new geological situations; and integrated basis for interpretation of the environment or system that it represents. However, the term facies is widely used with different connotations viz. in environmental sense, e.g. shallow marine facies; in the observational sense, e.g. cross bedded sandstone facies; and so on. A facies itself can be subdivided into sub-facies or grouped into facies associations or assemblages (Reading, 1978).

In the present study area, as outcrops are rare and most of the lithofacies studies were done from core rock samples collected from boreholes. For this reason the observation became limited as some of the important features like sedimentary structures can not be properly studied or interpreted from borehole samples. Still facies study has been done using the limited data observed from those samples and some rock units exposed in the surface outcrops.

3.2 Facies

The successions are entirely siliciclastic. It begins with conglomerate with angular clasts i.e. breccia or very coarse grained to pebbly arkosic sandstone over unconformity with Bundelkhand granite.

3.2.1 Facies A: Clast supported, crudely bedded gravel (Gh), Based on Fluvial classification after Miall, 1996:

This facies is characterized by clast-supported breccia conglomerate beds with bed parallel clast orientation of highly angular BHJ, jasper clasts.

These beds are tabular, sometimes intercalated by fine ferruginous sand which is thought to be product of suspension fall out. These conglomerates are oligomictic, made up of clasts of BHJ, jasper and rock fragments. Some of the clasts are even fractured. Clast size vary widely, varies from 2-12 cm. The little amount of matrix present between the clasts is ferruginous fine sand to silty, granular and poorly sorted, texturally immature. This facies occurs more frequently towards the basal part of the studies sections and mostly lies on top of Bundelkhand Granitic basement rocks.

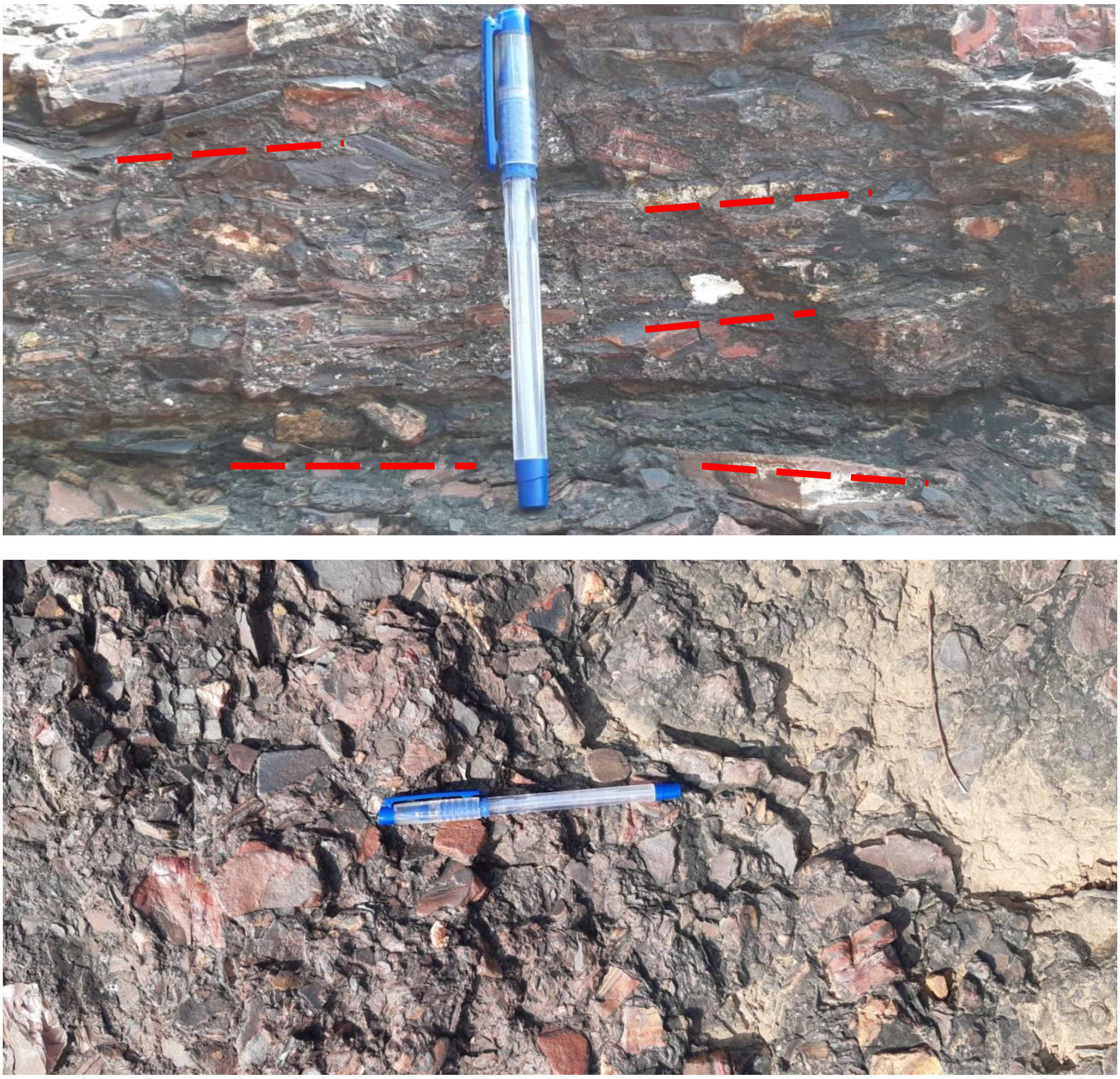


Figure 3.1: (a) Bed parallel orientation of clasts in breccia conglomerate lithofacies of Dursendi area, (b) Clast supported breccia conglomerate with BHJ and jasper clasts mainly, low matrix content

3.2.2 Facies B: Very coarse sub-feldspathic sandstone, gritty (Sh), Based on Fluvial classification after Miall, 1996:

This facies is characterized by gritty sandstone bodies, with planar bedded geometry, in some surfaces crudely developed ripple marks present. Overall planar bedded geometry is observed in outcrops with sharp contact with basement Bundelkhand Granite below. Poor sorting with few mm to 1 cm size grain size mostly, most of the grains are quartz and some feldspar grains are observed, so mineralogically mature but texturally immature.

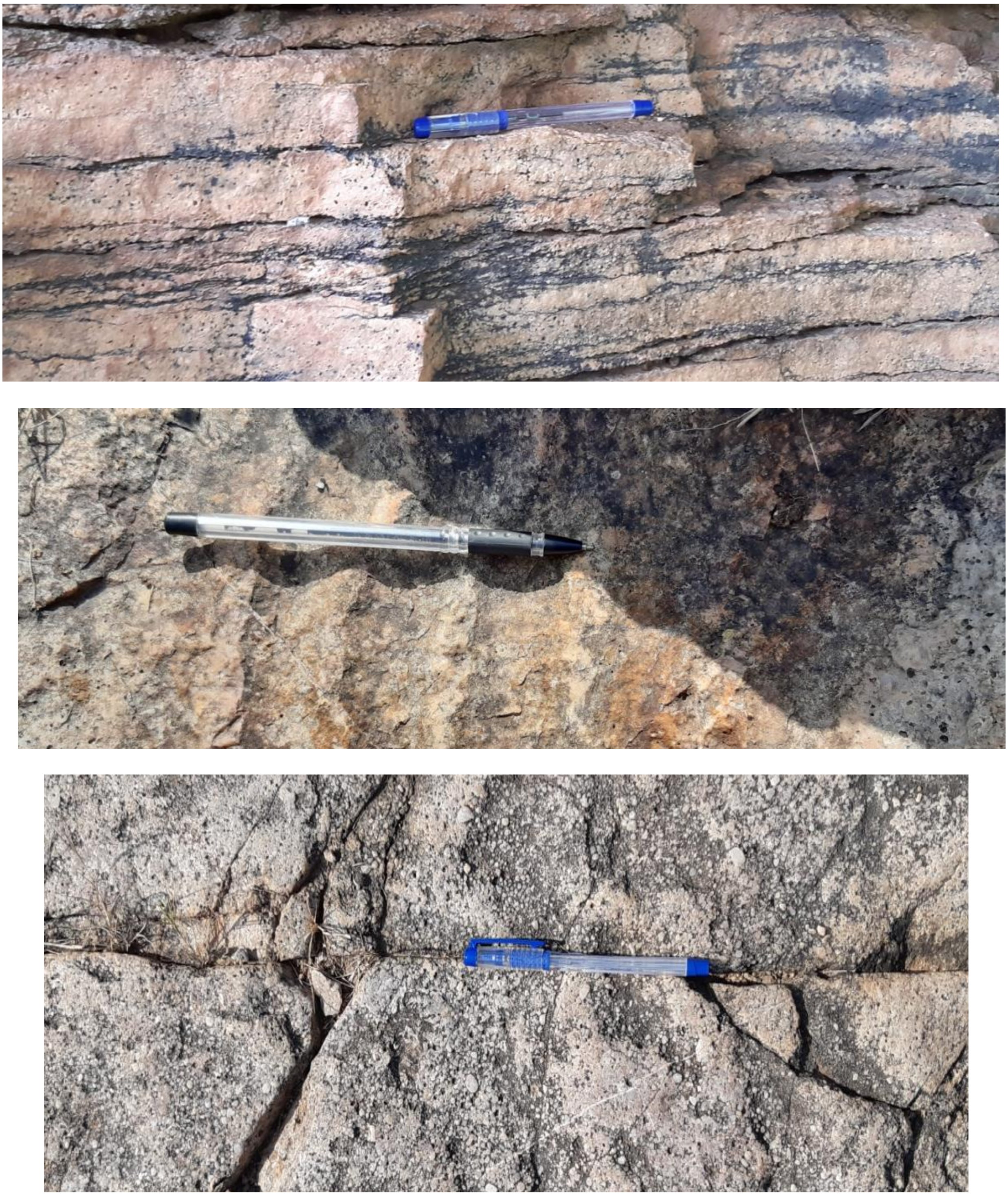


Figure 3.2: (a) Planar bedded geometry of gritty sandstone in Dursendi area outcrop, (b) Asymmetric ripple marks on bedding surface of gritty sandstone, (c) 2 sets of joints exposed in gritty sandstone in Dursendi area

Asymmetric ripple marks (Fig 3.2b) were observed on some surfaces and palaeocurrent direction derived from this ranges from 60-90◦ i.e. NE-E. Three sets of joints were also observed in this facies: NW-SE, NE-SW and N-S trending joints.

3.2.3 Facies C: Shale-sandstone intercalation:

This facies is not exposed in study area, stratigraphically it lies above gritty sandstone facies and properties of this facies i.e. lithology, texture, grain size were observed from borehole core samples only, so for this reason observable data is limited. This column of sediments forms huge thickness in study areas ranging from 5 to 20 m of thickness, the facies is

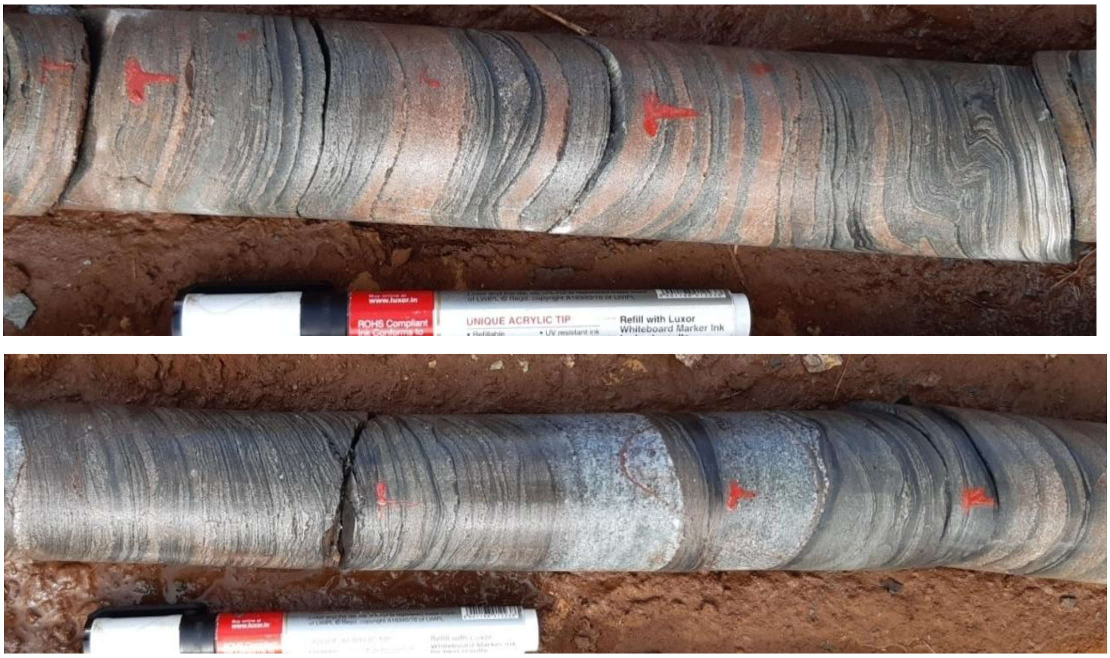


Figure 3.3: Shale-sandstone intercalation unit with soft sedimentary deformation structures observed in boreholes of Dhoha-Dursendi area

characterized by alternating thin layers of fine grained sandstone and shale, each laminae varies from 2 mm to several cm. Sandstone is very fine grained, planar and wavy laminations were observed. There are two types of shale present dominantly ferruginous brown shale and green shale indicating rhythmic changes in depositional environment. Shale unit is very rich in soft-sedimentary deformation structures.

3.2.4 Facies D: Shale:

The overlying facies unit of shale-sandstone facies is shale. Different types of shale are observed over shale-sandstone unit in different sections, most common is alternating ferruginous brown-green shale unit. Thickness of this unit varies mostly from 5-15 m and very rich in soft-sedimentary deformation structures, water escape structures etc.

Grey shale is also common in several sections, in some sections very thick unit of black shale is observed, ranging from 10-20m in thickness. Grey shale-brown-green shale are mostly planar and wavy laminated whereas black shale is massive, and often pyritiferous.

Shale unit is mostly studied from borehole samples and at the furthermost NW-W part of study area laminated brown shale outcrop is exposed and that has been observed and studied thoroughly.

Figure 3.4: (a) ferruginous brown and green shale intercalation unit from boreholes of Dhoha area, (b) massive black shale with little pyrite on broken surface

Figure 3.5: ferruginous brown shale outcrop in Dhoha area

3.2.5 Facies E: Ferruginous sandstone:

This facies is characterized by fine to very fine grained sandstone unit with ferruginous matrix. Grain size is very fine, well sorted, mostly quartz grains, so mineralogically and texturally mature. Primary sedimentary structures like planar stratification, cross stratification observed in this facies but as these are studied from core samples their orientations and palaeocurrent direction could not be measured.

Figure 3.6: Fine ferruginous sandstone unit with planar and cross lamination observed in boreholes of Dursendi area

3.2.6 Facies F: Buff coloured sandstone:

This facies is characterized by medium to coarse grained buff to white coloured sandstone unit. Grain size is medium to coarse, low angularity, medium to well sorted, mostly quartz grains, in places feldspar can be observed but less, so mineralogically and texturally mature. In places grain size increases upwards becoming more coarse. No primary sedimentary structure observed in core samples. This is the topmost unit of the study area and has an average thickness of 12-15 m. Very compact units, in places it gives quartzite like appearance.

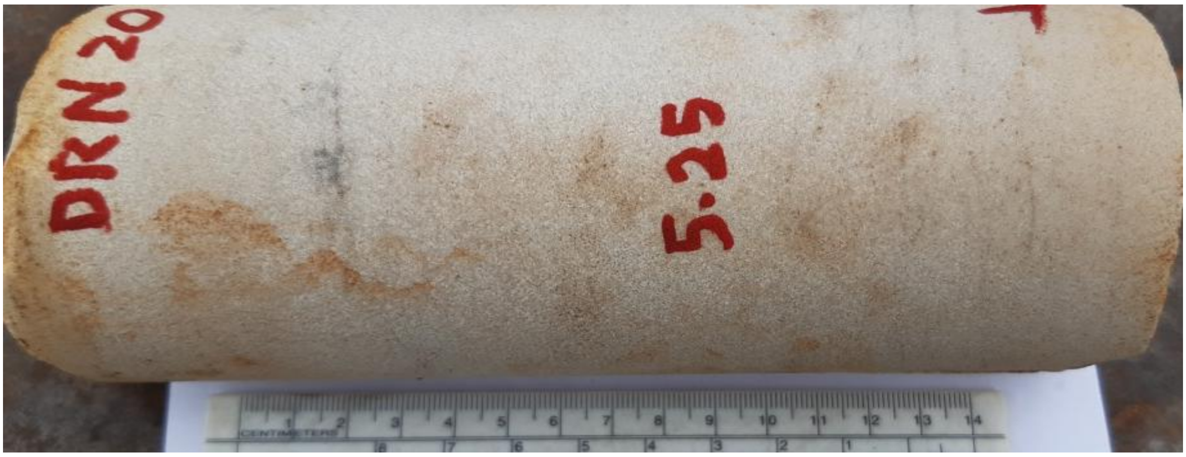


Figure 3.7: Medium to coarse grained buff coloured sandstone observed in boreholes of Dursendi area

CHAPTER 4

FACIES ASSOCIATION AND SEQUENCE ARCHITECHTURE

4.1 Introduction

Vertical association of lithofacies represents the order of occurrence of various major lithofacies in the outcrop from bottom to top. For interpretation of particular sedimentary environments from these major lithofacies, it is necessary to combine closely related facies into facies associations or 'group of facies genetically related to one another and which have some environmental significance' (Collinson, 1969). The association represents the amalgamation of depositional mechanisms with varying energy condition associated with a particular depositional system, as one entity. Sequence architecture, on the other hand, gives an account of the lateral as well as temporal changes in disposition of different facies and their association. Understanding the sequence architectural pattern in the framework of depositional mechanism is indispensable to gather any kind of knowledge regarding the depositional environment of those facies.

Facies are ultimately interpreted in environmental and paleogeographic terms, though not always indicate environment directly. For any meaningful assertion of facies paleogeography, the most important criteria is its association (Miall, 1980; Hallam, 1981; Walker, 1984; Reading, 1986); as facies study may incorporate body geometry, lithology and primary structures, its position with respect to erosional surfaces, grain size etc which depicts their depositional condition, but they don't exactly decipher any specific sedimentary environment. Associations differ from each other in the total combination of facies within them, their mutual proportions, and internal organization.

With the help of facies association in study area i.e., lower part of Kaimur Group of rocks is subdivided into several associations in this chapter. The problem is most of the lithofacies don't have surface outcrop; they were identified from subsurface borehole core data. For this reason there are certain limitations in inferring the facies associations, field relation or contact surface between individual facies is not well established due to these limitations. So only similar lithologies or similar depositional conditions are taken in consideration in clubbing some lithofacies together to form one facies association. This study area has been subdivided into 3 following facies associations.

4.2 Facies Associations

4.2.1 Facies association A: Basal Fluvial facies association

The lower Kaimur succession in this area is entirely siliciclastic. It begins with an unconformity related breccia conglomerate or pebbly sandstone that is overall fining upward. Facies association A comprises of two lithofacies- (a) clast supported breccia conglomerate and (b) gritty sandstone. Outcrops of both lithologies are found to be lying above Bundelkhand granite with unconformable contact and both facies show lateral transition with each other.

The basal conglomerates are polymictic, bed parallel clast orientation is observed with tabular body geometry. Sandstones are texturally immature, gritty with bedded body geometry and asymmetric ripple marks on bedding surface with is very irregular.

Interpretation: These poorly sorted coarse grained sediments arranged in fining upward nature and bearing unimodal palaeocurrent attributes could indicate them as fluvial channel deposits. Due to lack of outcrop data, most interpretations are mostly indicative.

4.2.2 Facies association B: Middle marine offshore facies association

The second association comprises grey-red-green shale-sandstone interbedded facies grading upward to red-green and massive black shale. Its basal surface is sharp, interbedded sandstone in the lower facies is sheet like. Internally it contains massive division followed by planar and wavy laminae.

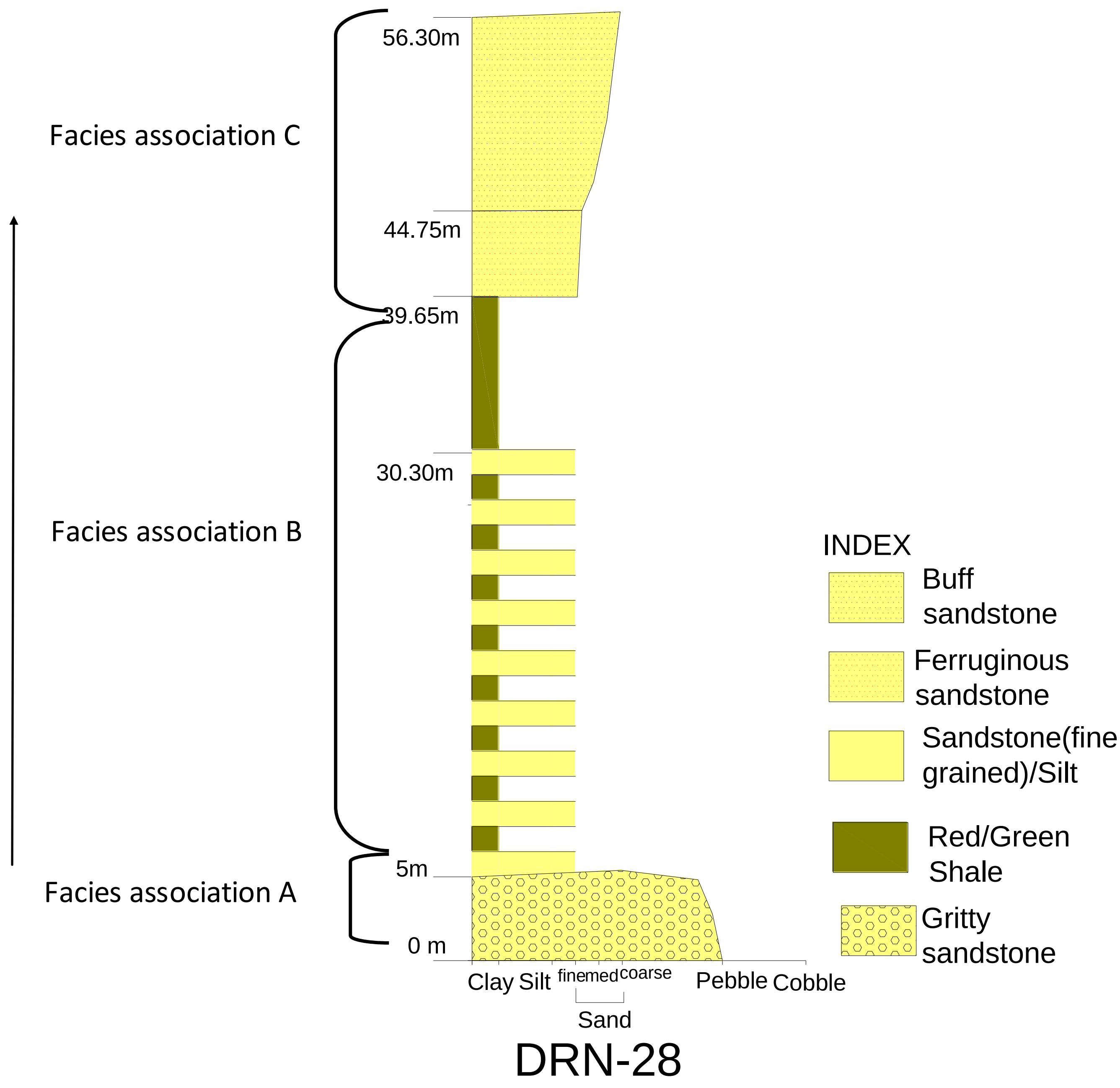


Figure 4.1: High resolution litholog depicting succession of lower Kaimur strata from borehole of dursendi area, 3 facies associations are marked here

Interpretation: This facies association is inferred as a deposit of marine offshore condition deepening progressively. A shale facies over shale-sandstone and shale-sandstone over coarse grained fluvial channel deposits indicates progressive deepening of the basin or a rise in relative sea-level. As most of the observations are made from borehole core samples, the interpretation is an indicative one.

4.2.3 Faccies association C: Upper marine shallow shelf facies association

The uppermost facies association comprises a transition from shale-sandstone to fine grained ferruginous sandstone facies grading upward to coarse grained buff to white coloured sandstone facies.

Interpretation: These sandstones are well sorted, both mineralogically and texturally very matured. The association is interpreted to be of possible marine shallow self and coastal dune environment. Here also, observations are made mostly from sub-surface samples leading to limitation of data for perfect interpretation.

4.3 Sequence architecture:

Sequence stratigraphy developed initially as a tool for stratigraphic correlation (Sloss et al. 1949). It is suggested that the driving force which generates sequences and their bounding unconformities, be it eustatic sea-level change, tectonic movements or some other process, also generates predictable three dimensional stratigraphic architechture. In this study area, as outcrops are limited, to study and establish sequence architecture is very limited but from facies associations and facies study some insightful information came through from which a history of sedimentation through time can be enlighted.

From a fining upward basal conglomerate/gritty sandstone facies transitioning to a shale-sandstone interbedded facies which grades upward to red-green shale and massive black shale, therefore possibly a transgressive phase can be present here; where a marine offshore facies overlies a fluvial facies association due to probable rise in eustatic sea level or basin subsidence. Afterwards, fine grained well sorted mature sandstone lithofacies overlies the shale facies, the sandstone facies association shows coarsening upward trend which can indicate a regressive phase. So a transgressive and a regressive phase are in play here in lower Kaimur group of rocks.

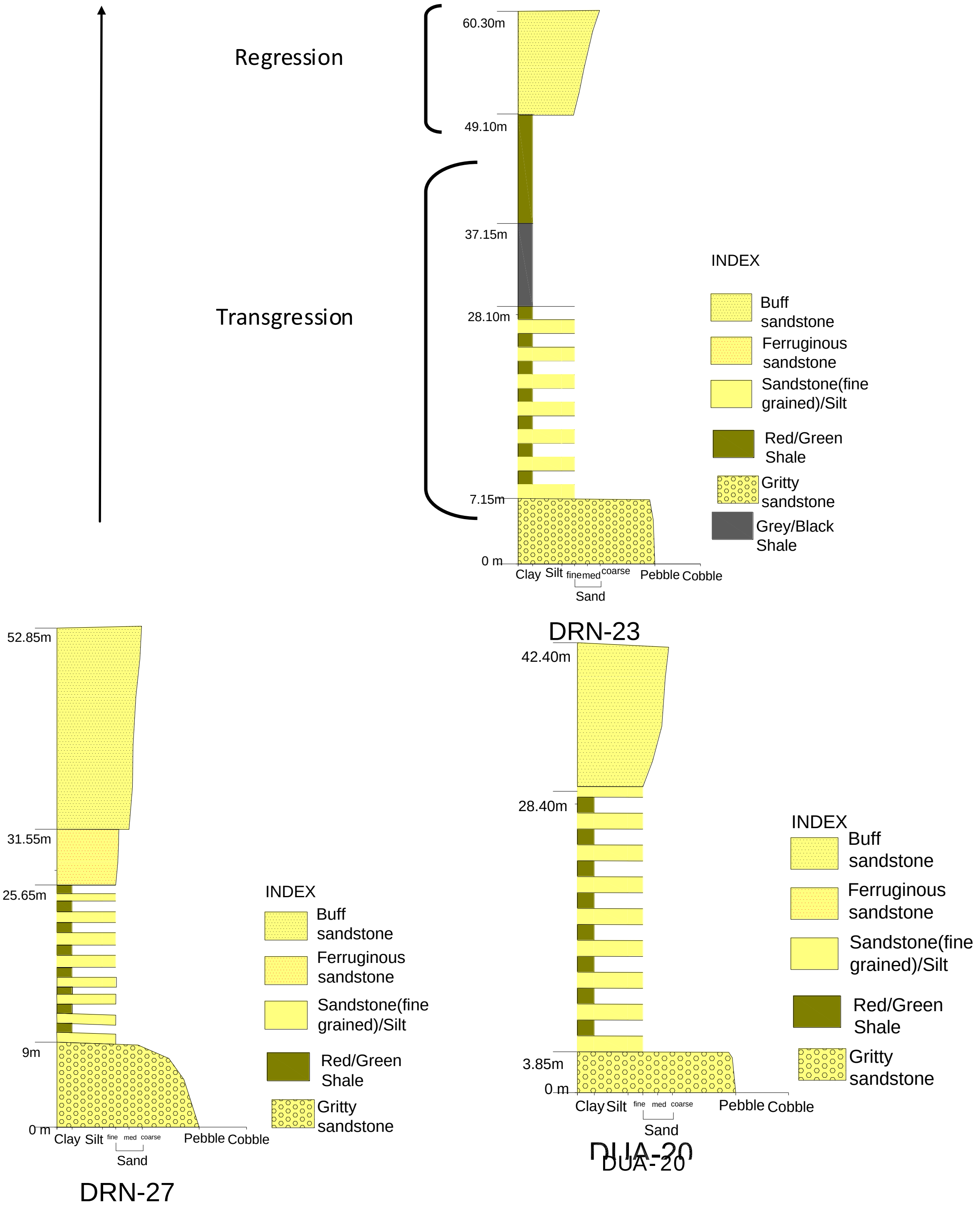


Figure 4.2: Trangressive and regressive phase shown in high resolution lithologs of successions from boreholes of Dhoha-Dursendi area

CHAPTER 5

PETROGRAPHY

5.1 Introduction

Petrography of sedimentary rocks, hydrodynamically controlled and diagenetically influenced sediment composition associated with sediment transport and deposition, play a pivotal role to comprehend and interpret provenance, tectonic setting, weathering intensity and stratigraphic correlations in clastic sediments (Dickinson & Suczek, 1979; Dickinson, 1985; Valloni, 1985; Zuffa, 1985, 1987, 1991; Pettijohn et al., 1987). Petrographic details of the facies instill confidence in the interpretation.

Sedimentary Petrography deals with the mineral composition, their characteristics, textural relationships within the rock with the help of petrographic microscope. Petrography refers to the study of thin section of rock under petrological microscope. In the present study also petrographic study has been conducted on the basis of the examination of rocks using thin sections. With the help of petrography we can tell the provenance, energy conditions and diagenetic history of the rock. It is also a very useful tool in the study of sedimentary rocks for the interpretation of the nature of the climate and relief of the source area to constitute important evidence to conclusion about the tectonic framework. Therefore, petrographic microscopy has remained for many years the primary tool for studying the composition of sandstones.

Petrography is also an efficient tool to understand the weathering and alteration pattern for sedimentary rocks. Formation of specific diagenetic gives an indication towards the grade of diagenesis. It also indicated towards the any exchange of ions that has taken place during the process of diagenesis. Typical diagenetic or alteration textures can be identified under the microscope.

There are certain types of sedimentary rocks like mudstone, shale for which only petrographic study can not that much of help but certain textures of grain alteration which can't be visible in hand specimen can be observed under microscope which will help us to correlate these things with geochemistry and give us a complete view of their genesis and depositional environment.

Therefore in this study petrographic study has been carried out for all lithofacies that have been identified and interpreted accordingly.

5.2 Rock types identified under microscope

Four distinct rock types can be identified under the microscope according to the Pettijohn's classification.

- Quartz arenite
- Sub-feldspathis arenite
- Mudstone
- Sandy mudstone

Quartz arenite:

The rock is medium grained, compact, yellowish grey coloured.

Microscopically, the rock is composed mainly of quartz (>90%)as major component, with sporadic clasts of feldspar, rock fragments and other detrital grains which is mostly mica. Monocrystalline quartz (mainly unstrained) is predominant with occasional clasts of polycrystalline quartz and microcrystalline quartz (chert).

Clay and fine siliciclastic material (2-3 modal percentage) are present as matrix along intergranular space. It contains fine silt sized quartz, clay diagenetically altered to chlorite and other micas. Globular glauconites are observed in some sections.

Size of clasts varies from 45microns to 90 microns. Clasts are rounded and well sorted. Authigenic silica cementation present as quartz overgrowth. As a result of compaction, the grain boundaries attained triple point junction. The composition of framework clasts reflects igneous provenance. The rock is matured texturally as well as mineralogically, indicating stable tectonic conditions.

Sub-feldspathic arenite:

The rock is medium to coarse grained, compact and grey in colour.

Microscopically, the rock is composed mainly of quartz with subordinate amount of feldspar and rock fragments. Zoned zircon is noted as accessory. Rock fragments comprises perthite, granite and polycrystalline quartz. Feldspar clasts include K-feldspar and plagioclase. Some of these are fractuted and kaolinised. Feldspar content is about 5-6% in the rock.

Mostly clay and sericitic material (3-4% modal percentage) are present as matrix along intergranular space, although fine siliciclastic material also present as matrix in some sections. Siliciclastic material contains fine silt sized quartz, and in places clay diagenetically altered to other micas.

Clasts are subrounded to subangular. Grain to grain contact is straight, concavoconvex and sutured at places. Most of the places it has attained triple point junction. The rock is moderately sorted and show moderate textual maturity. Monocrystalline quartz, perthite and zoned zircon indicate plutonic igneous provenance.

In some sections there are bimodal grain size distribution where larger clasts are more rounded than the smaller ones. This could be due to the mixing of source during deposition or sieving effect of smaller grains after deposition of larger clasts. This portion is correlated with gritty sub-feldspathic sandstone lithofacies. And in many portions feldspar content in very low with large rounded clasts of monocrystalline and polycrystalline quartz with subangular small quartz clasts between with silica cement between them and very little matrix. This portion is mineralogically very mature.

Mudstone

The rock is fine grained and friable, reddish brown in colour.

Microscopically, the rock is composed of clay and silt. The clay comprises chlorite and sericite. Silt sized clasts quartz, feldspar, glauconite and opaques. Clasts are angular to subrounded. Opaques are fine sized pyrite, which are partially oxidised to limonite. Limonitised pyrite specks are present throughout the section. Sample is composed of clay, silt sized quartz, feldspar, mica and glauconite. Sand sized glauconite and feldspar are present. There is abundance of silt sized limonitised clasts. Clasts are angular.

Sandy mudstone

The rock is fine grained, compact and dark grey coloured. This section is correlated with lithofacies shale-sandstone intercalation.

Under the microscope, the rock is composed of quartz, feldspar and mica of varying size from silt to sand. Clasts are angular and ill sorted. Globular glauconite is observed. Feldspar clasts are sericitised at places. However, fresh microcline clasts are also present. Sericite and chlorite matrix, which form 2-3modal volume percentage are present in intergranular spaces. Biotite and muscovite flakes are aligned in a particular direction. Grain boundaries are concavo-convex and straight indicating good compaction. The rock is mineralogically and texturally immature.

Intertonguing of clay bands are observed composed of chlorite, sericite, clay, fine silt of quartz, feldspar, glauconite, limonite and fine flakes of mica. Specks of pyrite and chalcopyrite are noted. Globular glauconite are formed as a result of diagenetic alteration. At places, on and along the grain boundaries of glauconite, mica and chlorite iron oxides are observed as a result of alteration. Presence of glauconite indicates shallow marine condition.

No radioactive mineral phases observed in any of these sections.

5.3 Provenance study:

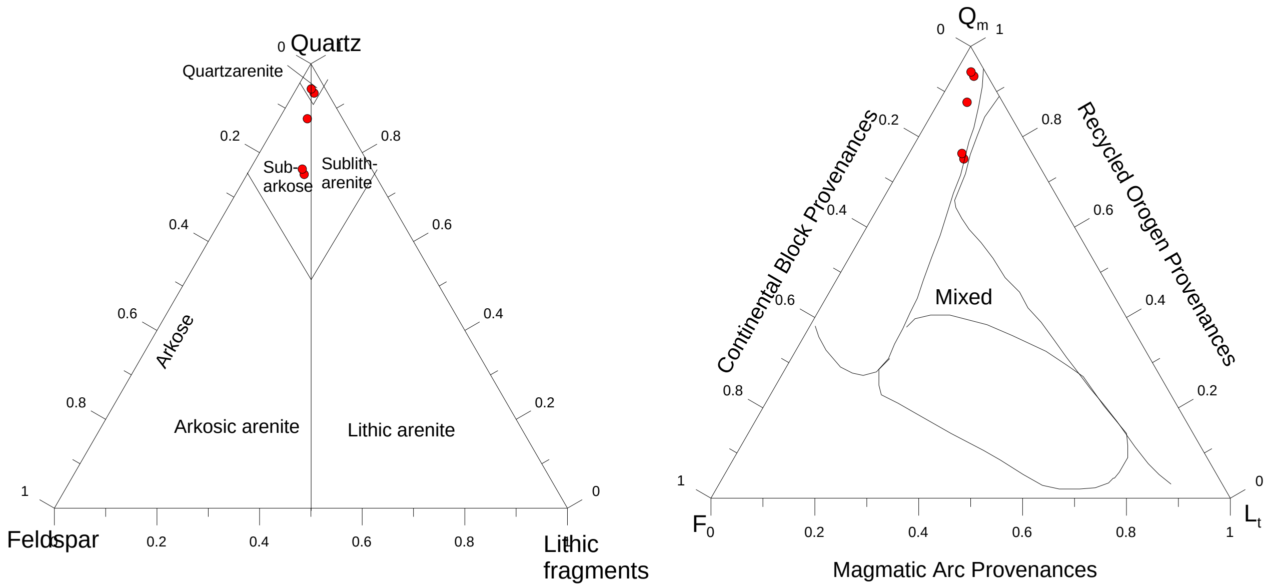


Figure 5.1: (a) QFL – triangular plot for classification of different sandstone samples; (b) QmFLt triangular plot, after Dickinson and Suczek (1979) of the same set of sandstone samples

5 sandstone samples were observed under microscope and grain counting was done manually on a volumetric basis, later different plots were attempted using the Quartz, Feldspar and Lithic fragments quantity data. In the QFL plot in Fig 5.1(a) it shows that 2 samples fall under quartz arenite field and other three fall under subarkose field very close to sublitharenite field.

In second plot, monocrystalline quartz quantity data was considered and the QmFLt plot was done after Dickinson and Suczek, 1979. The plot shows that the provenance of these sandstones are continental block provinces. From zircon inclusion found in petrographic study it supports this provenance of sandstones.

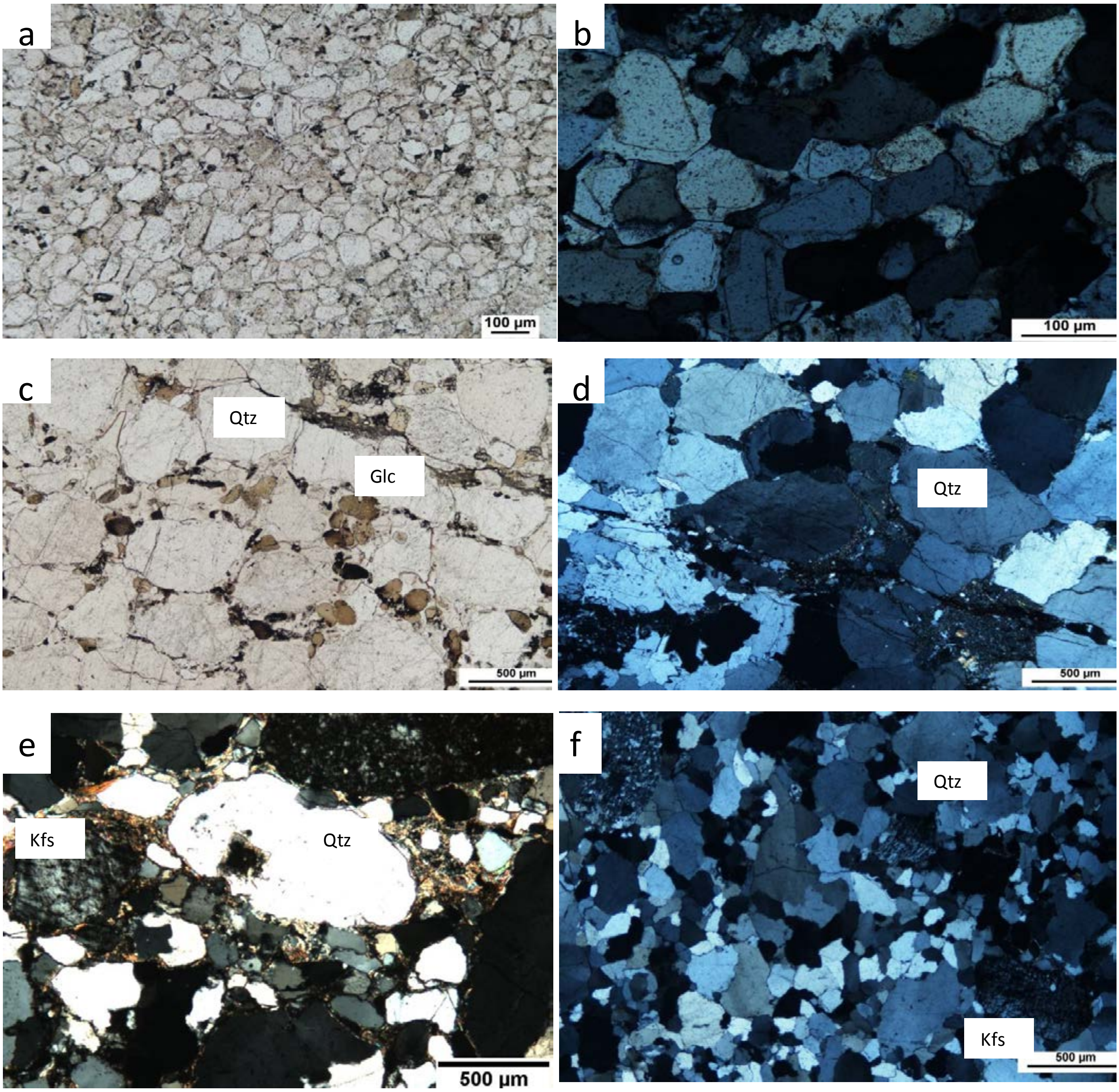


Figure 5.2 (a) Quartz arenite sample under plane polarized light, (b) quartz grains showing syntaxial overgrowth of silica cement in quartz arenite, (c) globular glauconite grains observed in some quartz arenite samples, (d) silica vein cutting across grains along fracture in quartz arenite, (e) bimodal size distribution of grains with large K-feldspar and polycrystalline quartz in sub-feldspathic arenite, (f) sapmle of sub-feldspathic sandstone with large rock fragment and K-feldspar

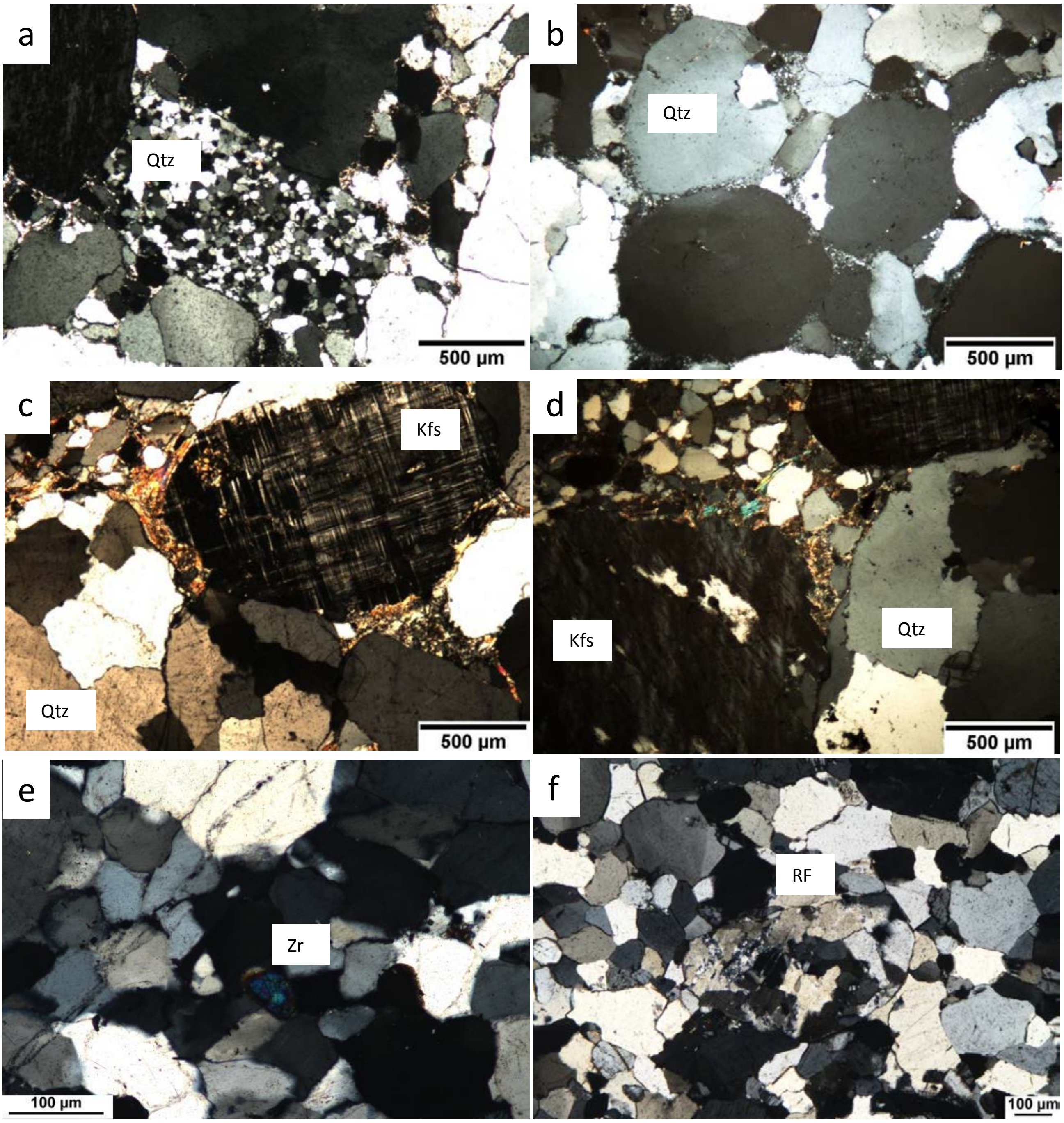


Figure 5.3: (a) large polycrystalline quartz grain in sub-feldspathic arenite, (b) rounded larger grains with smaller grains between them indicating bimodal grain distribution and textural inversion in sub-feldspathic arenite, (c) large K-feldspar grain with clayey matrix in subfeldspathic arenite, (d) large rock fragment and K-feldspar grain, (e) zoned zircon grain in subfeldspathic arenite, (f) granitic rock fragment observed in subfeldspathic arenite

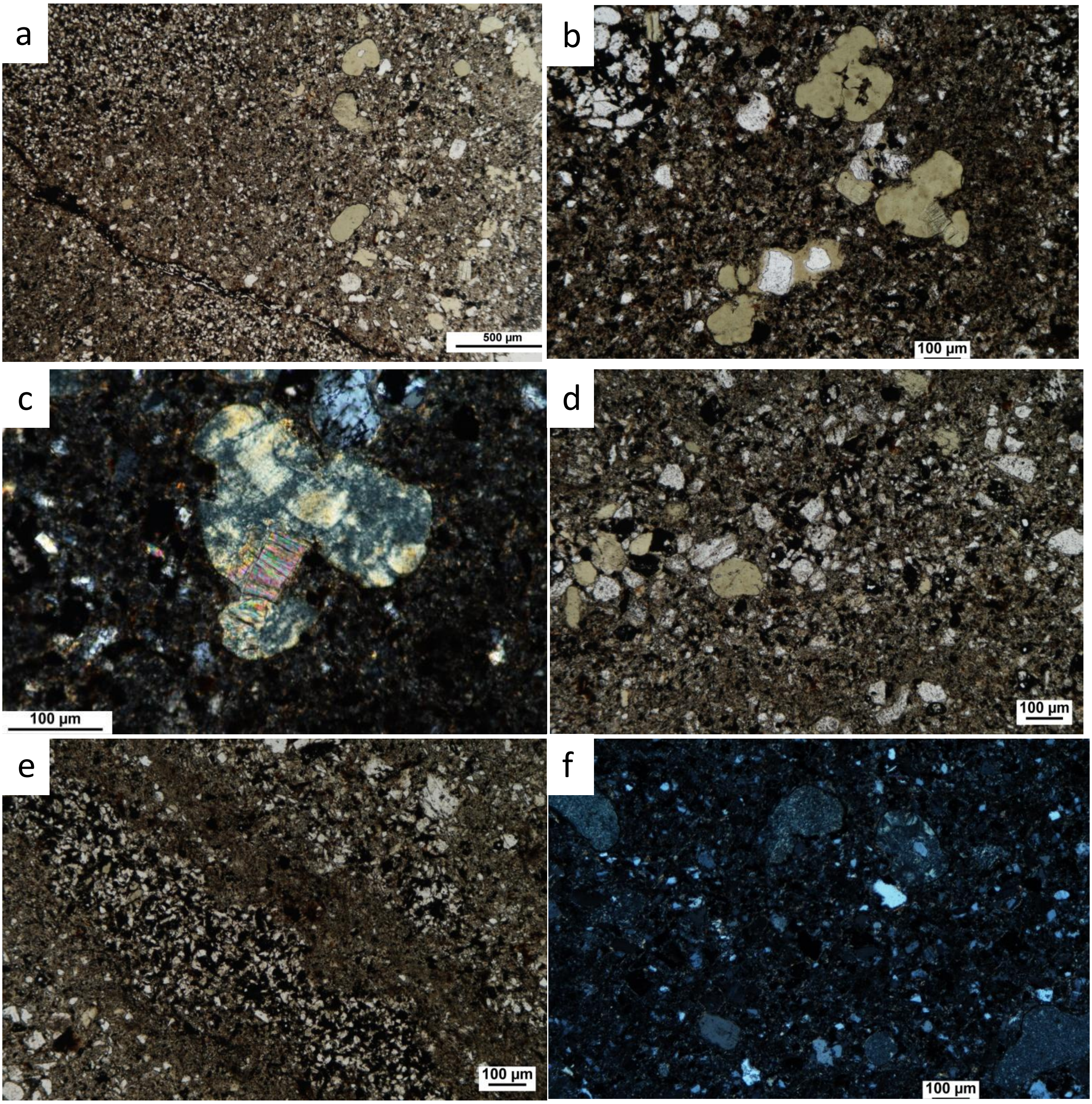


Figure 5.4: (a) mudstone section under Plane polarized light with glauconite grains, (b) glauconite grains developing nucleating over quartz grain, (c) alteration of muscovite to glauconite, (d) glauconite grains with lots of opaques(pyrite and carboniferous matter) in black shale, (e) silt and clay rich band in shale, (f) glauconite grains under XPL

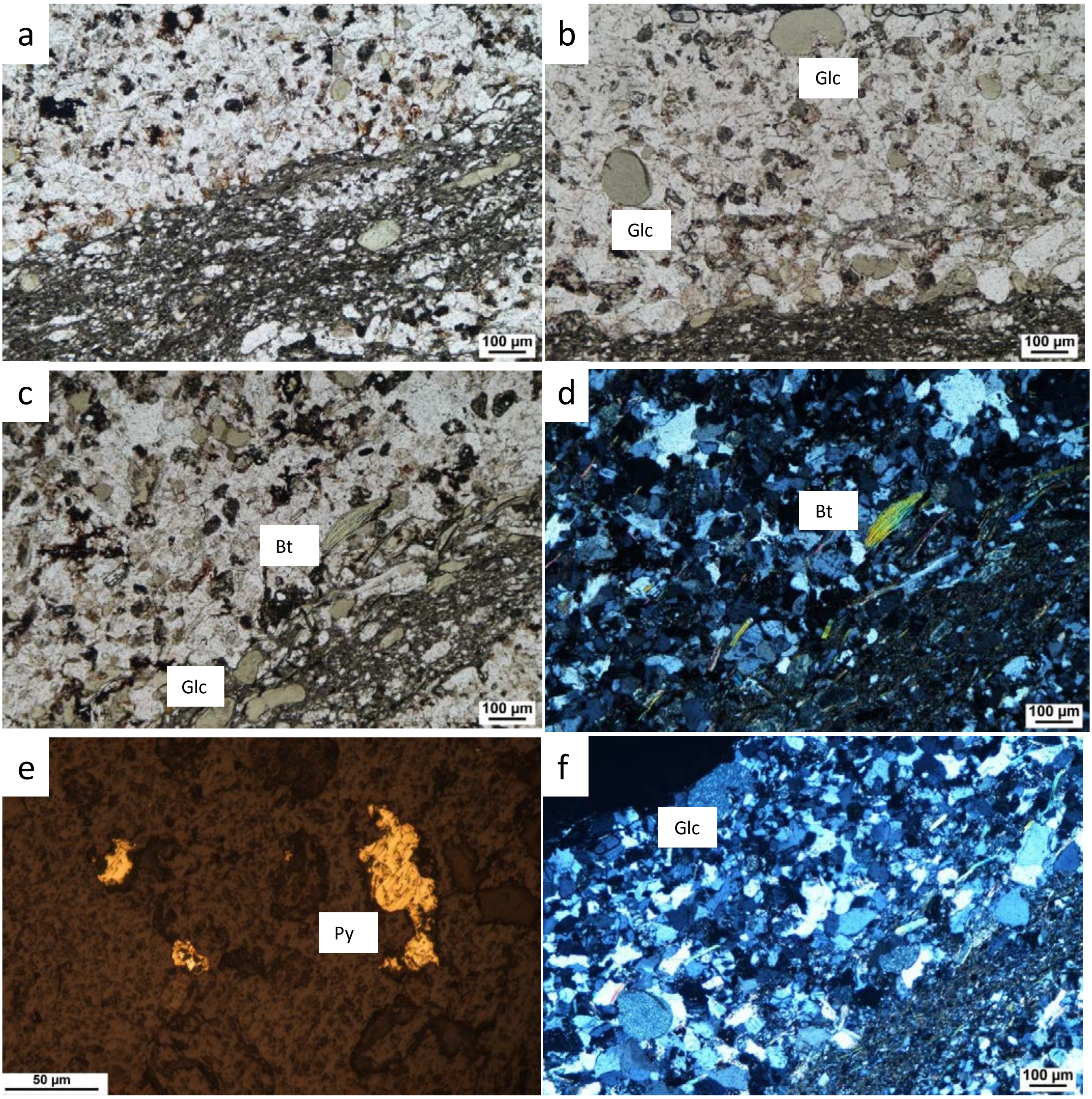


Figure 5.5: (a) clay band within fine sandstone under PPL, (b) large globular glauconites in sandy mudstone, (c) greenish biotite observed in sandy mudstone, (d) greenish biotite under XPL, (e) pyrite flakes in clay rich part of sandy mudstone, (f) sandy mudstone under XPL with glauconites

CHAPTER 6

GEOCHEMISTRY OF SEDIMENTS

6.1 Introduction:

The chemical and mineral composition of clastic sedimentary rocks controlled by the composition of their source rocks, intensity of the weathering of source rock, transportation distance, environment sedimentation and depositional diagenetic reaction. The geochemistry of sedimentary rocks therefore reflects a combination of provenance, chemical weathering and tectonic evaluation (Taylor and McLennan, 1985; McLennan et al., 1993; Nesbitt et al., 1997, Yan et al., 2007).

A number of authors have suggested that chemical composition of sediments varies with grain size of mineral constituents, chemical and mechanical weathering of labile grains and source rock lithology (Boggs, 1968; Bhatia, 1983; Bhatia and Crook, 1986; Whitmore et al., 2004). The key factor in the geochemistry of siliciclastic rock is the chemical behavior of detrital mineral phase and formation of new mineral phase during erosion, transportation and deposition. The chemical characteristics of siliciclastic sedimentary rock can be evaluated from the bulk chemical composition.

The ratio of the most immobile elements (SiO_2 and TiO_2) to the most mobile (CaO and Na_2O) one increases from oceanic island arc (OIA) through continental island arc (CIA) and active continental margin (ACM) to the passive margin (PM) tectonic setting due to relative chemical stability (Bhatia, 1983; Roser and Korsch, 1988). Bhatia (1983), used geochemical parameters such as Fe_2O_3 + MgO, TiO_2, Al2O_3/SiO_2, K_2O/Na_2O and Al_2O_3/(CaO + Na_2O) to discriminate the plate tectonic settings of sedimentary basin. The geochemical concept behind these plots is general decrease in Fe_2O_3+MgO, TiO_2 and Al_2O_3/SiO_2 and increase in K_2O/Na_2O and Al_2O3/CaO+Na_2O as the tectonic setting changes in the sequence OIA-CIA-ACM-PM. Oceanic island arc (OIA): high abundance of Fe_2O_3+MgO (8-14%) and TiO_2 (0.8-1.4%) and high Al_2O_3/SiO_2 (0.24-0.33) and lower K_2O/Na_2O (0.2-0.4) ratios. Continental island arc (CIA): lower Fe_2O_3+MgO (5-8%), TiO_2 (0.5-0.75) and Al_2O_3/SiO_2 (0.15-0.22), and high K_2O/Na_2O (0.4-0.8) ratios. Active continental margin (ACM): very low Fe_2O_3+MgO (2-5%) and TiO_2 (0.25-0.45%), and K_2O/Na_2O ratio of approximately 1 and Passive margin (PM): enriched in SiO_2 and low in Al_2O_3, Na_2O and CaO, and K_2O/ Na_2O ratio is more than 1. Roser and Korsch (1986) established three tectonic settings in his K_2O/Na_2O vs. SiO_2 discrimination plot: oceanic island arc, active continental margin (including continental margin arcs) and passive margins. For provenance study two Discrimination function diagram proposed by Roser and Korsch,(1988) are used. Amajor (1987) used TiO_2 vs. Al_2O_3 plot help to understand the provenance of sediments has also been used in the present study.

6.2 Sampling and Analytical Procedures:

22 samples have been collected for geochemical study, most of them are collected from boreholes but some are collected from outcrop also. Those samples are analysed for major, minor and trace elements studies using XRF method. Out of 22 samples 13 samples (BO-275 to BO-292) have been analysed in XRF Lab., Central Region, Nagpur with a detection limit of 5 ppm and 9 samples (XA-5198 to XA-5208) have been analysed in XRF Lab., Western Region, Jaipur with a detection limit of 10 ppm.

6.3 Major and trace element concentration:

The results show that in sandstones (n=17) SiO_2 concentration varies from 70.17-93.65% which is also taken as common factor for correlation with other oxide elements, followed by Al_2O_3 (3.53-13.75%), TiO_2 (0.06-0.56%), Fe_2O_3 (t) (0.15-8.92%), MgO (0.01-0.9%), MnO (<0.01-0.02%), CaO (<0.01-0.47%), Na_2O (0.2-2.09%), K_2O (0.01-4.26%) and P_2O_5 (<0.01-0.07%). The high Fe_2O_3 content in some samples corresponds to the ferruginous sandstone rock samples. Overall, MgO and CaO is low throughout all samples in contrast to Fe_2O_3.

In shale (n=5) samples, SiO_2 concentration varies from 60.16-62.63%, followed by Al_2O_3 (15.8-18.54%), TiO_2 (0.54-0.83%), Fe_2O_3 (t) (4.45-14.34%), MgO (0.84-1.93%), MnO (<0.01-0.02%), CaO (0.27-2.14%), Na_2O (0.36-1.58%), K_2O (3.09-7.88%) and P_2O_5 (0.06-0.09%). Samples bearing high Fe_2O_3 values are of ferruginous red shale. High concentration of silica in these shales may indicate its maturity.

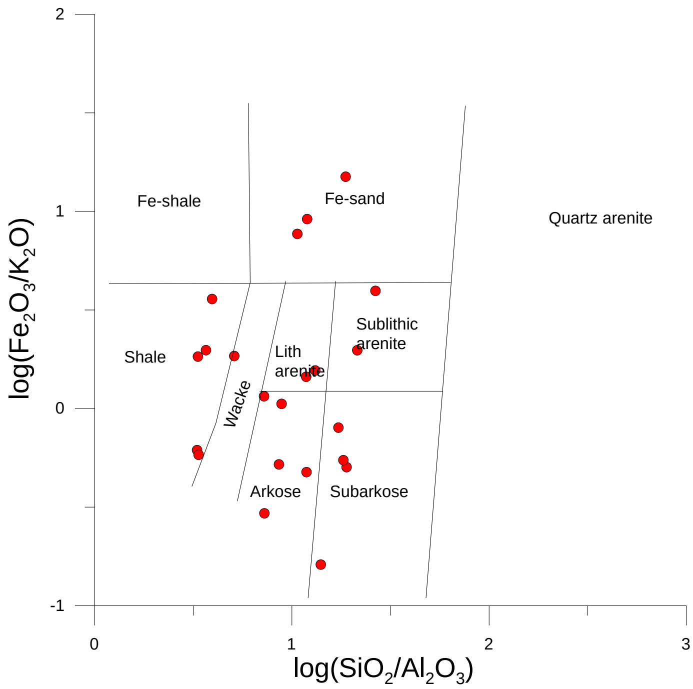
6.4 Interpretation of geochemical data:

In shale samples, the high K_2O values over Na_2O support the petrographic observation of enrichment of minerals like sericite, K-feldspar and glauconite. High Al_2O_3 content suggests presence of clay minerals and micas whereas low TiO_2 content indicates rarity of Ti-bearing minerals such as ilmenite which is common in sandstone samples also.

The logarithmic graph of SiO_2/Al_2O_3 vs. Na_2O/K_2O plot after Pettijohn et al., 1987 (Fig.6.1) of only sandstone samples shows that most of the sandstones fall on the arkose-subarkose-litharenite boundary field which is not co relatable with petrography as in petrography along with sub-feldspathic arenite quartz arenite is also observed.

The logarithmic graph of Fe_2O_3/K_2O vs. SiO_2/Al_2O_3 plot after Heron., 1988 (Fig.6.1) shows plotting of all samples including sandstone and shales; all 5 shale samples fall on shale field, whereas sandstone samples mostly fall on arkose-subarkose field with the exception of ferruginous sandstone samples. So the wide variation of samples in this diagram is for two reasons: 1) here all samples are plotted including shale whereas in Pettijohn's diagram only sandstones are plotted, 2) as these sediments are from wide range of sources.

These classifications of sedimentary rocks using geochemistry are indicative or corroborative mostly as only through geochemistry classification can't be conclusive.



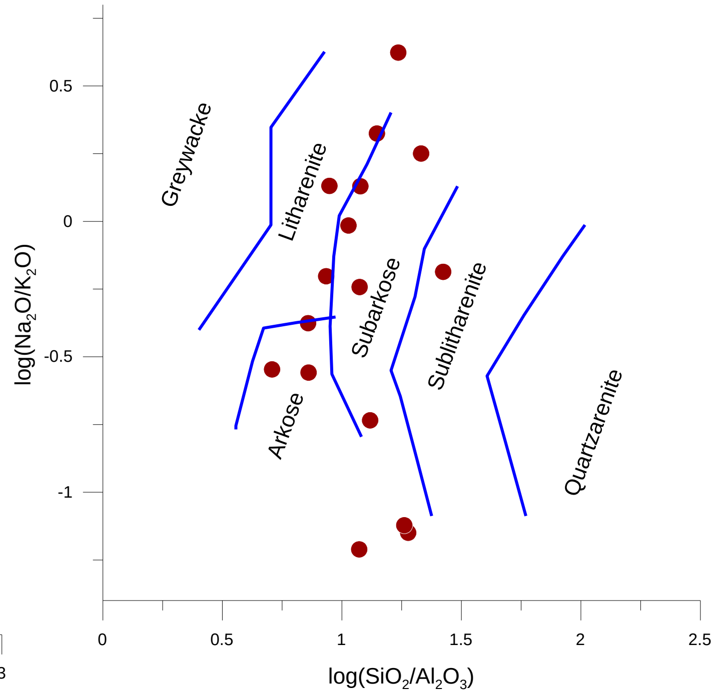


Figure 6.1 (a) Chemical classification of lower Kaimur group of rocks in log(Fe2O3/K2O) vs log(SiO2/Al2O3) diagram after Heron, 1988., all 5 shale samples fall in shale field whereas most of the sandstones fall in arkose-subarkose field;
(b) Chemical classification of sandstone samples in log(Na2O/K2O) vs log(siO2/Al2O3) diagram after Pettijohn et al. 1987., most of the samples fall in arkose-subarkose-litharenite boundary.

6.4.1 Study of provenance:

The TiO2 vs Al2O3 plot after Amajor, 1987 show that the analysed samples fall in the granite-granite-basalt fields. Most of them fall below granite field due to their very high Al2O3 and very low TiO2 content, this infers their provenance is Ti- depleted more felsic igneous rocks.

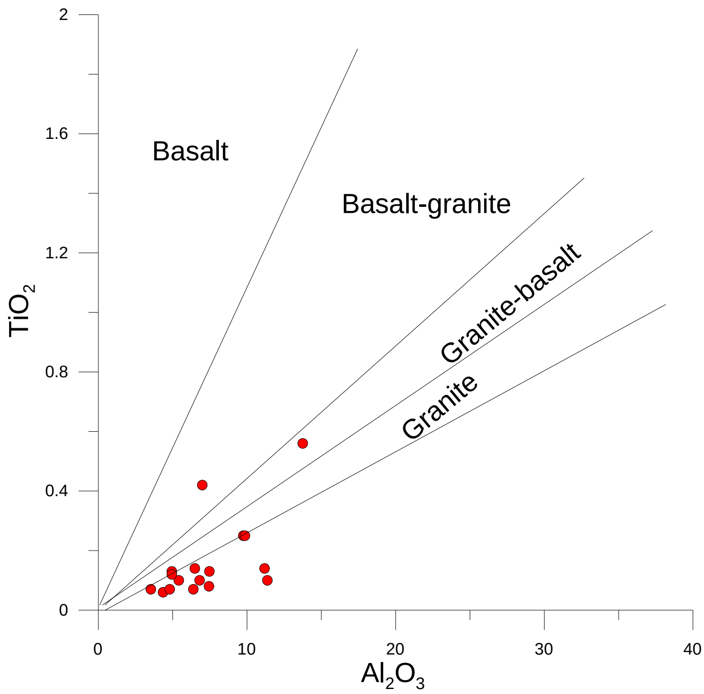


Figure 6.2 TiO2 vs Al2O3 plot to decipher provenance lithology after Amajor 1987.

Na, K, Ca and Mg concentrations are

enriched/depleted by these pro cesses, whereas Ti, Al,Zr remain unaffected because of low

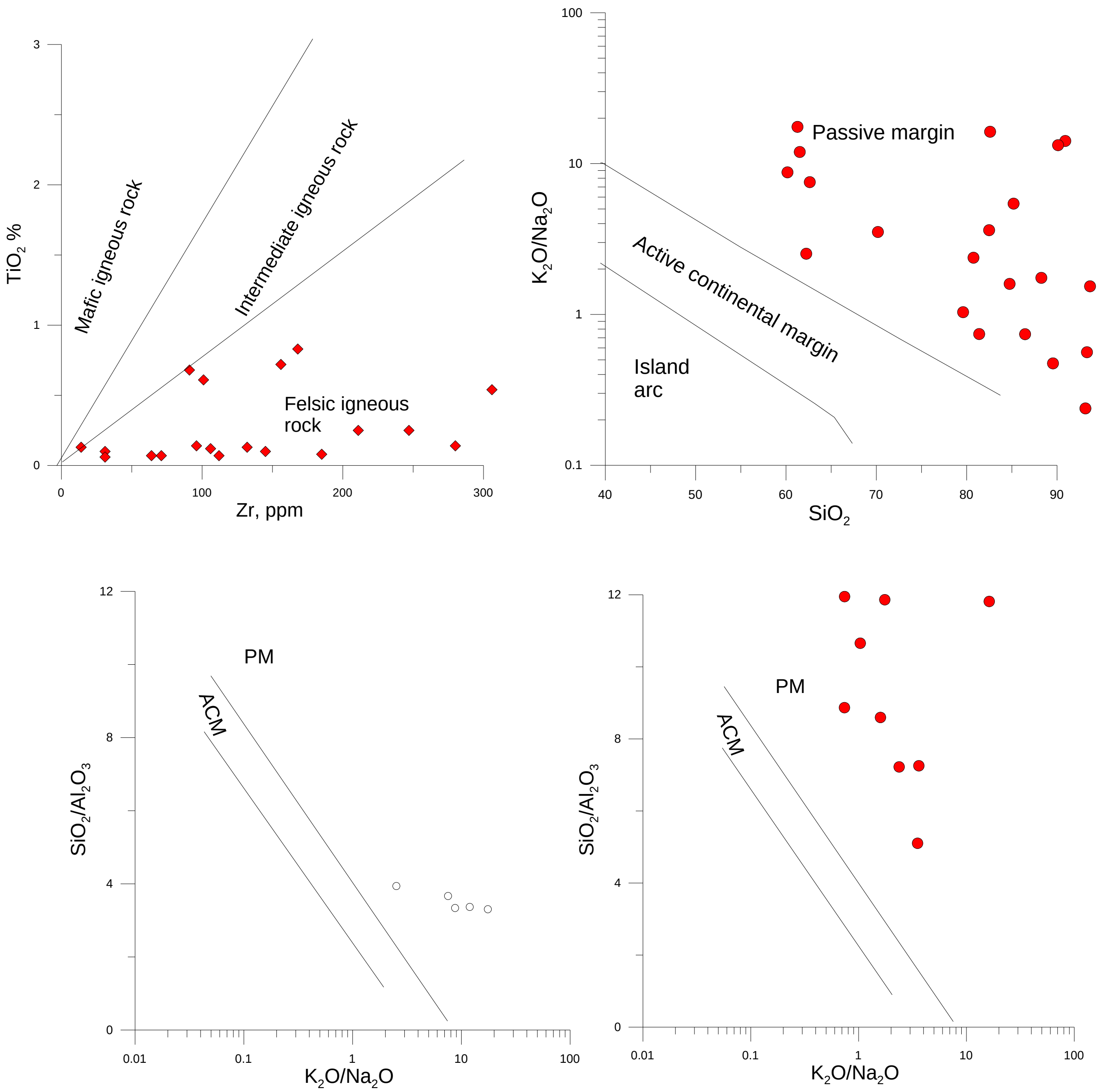


Figure 6.3 (a) TiO2% vs Zr(ppm) plot for provenance study (b) Diagram after Roser and Korsch 1986 for differentiation of plate tectonic settings. The Kaimur group of rocks of present area fall on passive margin field; (c) Discriminant diagram after Maynard et al. 1982 for differentiation of plate tectonic settings, The sandstone of this area falls on passive margin field, PM passive margin, ACM active continental margin, (d) Discriminant diagram after Maynard et al. 1982 for differentiation of plate tectonic settings, the shales of this area also fall on this passive margin field.

solubility of their oxides and hydroxides in low temperature aqueous solutions (Stumm and Morgan, 1981). For this reason TiO2% vs Zr(ppm) plot shows us the provenance of sedimentary rocks, in this area it can be seen that all samples fall on the felsic igneous rock field.

6.4.2 Study of tectonic and depositional setting:

The plots of major oxide ratios like SiO2, Al2O3, K2O, Na2O can be used to discriminate three major tectonic provinces of deposition namely Passive Margin, Active continental Margin and Island arc setting. The logarithmic plot between the ratios SiO_2 vs K_2O/Na_2O after Roser and Korsch, 1986 gives idea about the tectonic condition of deposition for the sedimentary rocks in particular tectonic environment. According to the figure all the data falls under Passive Margin field. The plot of SiO_2/Al2O3 vs K_2O/Na_2O after Maynard et al. 1982 also shows that both the sandstones and shales deposited in passive margin settings.

6.5 Facies wise radioelemental distribution:

Facies wise radioelemental distribution is a key part of this project. In buff sandstone lithofacies U value varies from 21-106 ppm, but in some samples <5 ppm value is also recorded; in subfeldspathic gritty sandstone U value reaches up to 59 ppm in one sample but it is mostly <5 ppm in other samples; in ferruginous sandstone lithofacies all samples show <10 ppm U value, only one showing 21 ppm; in shale-sandstone and other shale samples U values are mostly <5 ppm.

Table 6.5 Facies wise radio-elemental distribution:

Lithofacies	U (ppm)	Th (ppm)
White to buff sandstone	<5 to 106	<5 to 70
Ferruginous sandstone	<5 to 21	15 to 46
Shale	<10	13 to 32

Shale-sandstone	<10	<10 to 28
Gritty sandstone	<5 to 59	<5 to 50

All these values are obtained from whole rock analysis of different lithounits fround in bore holes done by XRF method. It is clear in whole rock analysis, no lithofacies carry significant amount of uranium; therefore indicating absence of facies controlled uranium mineralization.

CHAPTER 7

DISCUSSION

7.1 Facies study and sequence architechture

In this study, six lithofacies have been identified and characterized from both surface outcrops and sub-surface borehole data of Dhoha-dursendi area. The basal breccia conglomerate and sub-feldspathic gritty sandstone lithofacies form facies association A which lies just above Bundelkhand granite stratigraphically in this sector. By studying the structure, lithology, body geometry this association is interpreted to be of fluvial channel deposits. After some period, there is a relative rise in sea level probably due to basin subsidence and a nearly marine offshore environment was prevailed at that time when the facies association B (shale-sandstone bodies) was deposited which graded up to black shale stratigraphically. This can be corroborated with a rapid marine transgression period with progressive deepening of the basin. Later a marine regression period came followed by a coarsening upward sequence of fine ferruginous sandstone grading upward to coarse grained mature quartz arenites (facies association C) over shale-sandstone rocks reflecting a shallow marine shelf environment. This study can be correlated with lower Kaimur Group of rocks in other parts of Vindhyan basin (Bose et al. 2001, Bose et al. 2015). As most of the observations are made from sub-surface core samples, the interpretations are mostly indicative.

7.2 Petrographic studies:

Petrographic studies were carried out for each individual lithofacies samples and four type of rock nomenclature were given. Petrographic studies are helpful not only in identifying a rock type but also to interpret its provenance and probable condition of deposition. Provenance studies were carried out for some sandstone samples and it was inferred that the sediments came from continental block provenance probably from granitic source as evidenced from presence of zircon accessory mineral and granitic rock fragments. The presence of glauconites in shale-sandstone and shale samples indicates their marine condition of deposition which supports the facies association study.

7.3 Geochemistry of sediments:

Major oxide and trace element data were used in interpretation of geochemical datas of sedimentary rocks of study area. The logarithmic graph of SiO_2/Al_2O_3 vs. Na_2O/K_2O and Fe_2O_3/K_2O vs. SiO_2/Al_2O_3 plot of sandstone samples shows that most of the sandstones fall on the arkose-subarkose-litharenite boundary field which is not correlatable with petrography as in petrography along with sub-feldspathic arenite quartz arenite is also observed. Although classification of sedimentary rocks using geochemistry is mostly indicative. Provenance study has also been carried out using durable element and oxide data like of Ti and Zr. TiO_2 vs Al_2O_3 plot and TiO_2% vs Zr(ppm) plot indicate the source of these samples to be of felsic igneous rock origin mostly granitic. Discrimination diagram was made using plot of SiO_2/Al_2O_3 vs K_2O/Na_2O to interpret the tectonics of deposition which is to be Passive Margin setting.

7.4 Uranium mineralization and control of facies:

Radiometric survey was carried out over 5 sq km of study area but no significant anomaly was encountered. Along with it samples were analysed of each lithofacies both from borehole cores and surface outcrops, but no significant U value in any of those facies was found. In buff sandstone lithofacies U value varies from 21-106 ppm, but in some samples <5 ppm value is also recorded. No signficant radioactive phase was observed during petrographic study of these sandstones. In shale samples, U values are mostly below 5 ppm which is mostly insignificant. Therefore it can be inferred that there is no facies controlled U mineralization in lower Kaimur Group of rocks of this study area.

CHAPTER 8

CONCLUSION

The siliciclastic rock units of the lower part of the Kaimur Group from Dhoha-Dursendi area, NW part of Vindhyan basin has been studied in detailed to characterise their depositional conditions and palaeoenvironment. The state-of art facies analysis has been done identifying six genetic facies, not all of them can be observed in outcrops but stratigraphy can be established using subsurface data along with outcrop data. Within the ambit of sequence stratigraphic framework the facies architechture show a transgressive trend and then a regressive trend. At lower part there is basal breccia conglomerate/gritty sandstone unit, succeeding this unit there occurs a thick unit of sheeted sandsone-shale interbedded rock unit grading upward to thick shale unit. This constitutes the Transgressive System Tract (TST) of the succession. Following this, there overlies the fine grained sandstone facies gradually coarsening upward. Initiation of regression started after deposition of shales as it gradually changed to a fine grained arenaceous unit. This constitutes the HST of the succession.

The geochemical analysis has also been done to understand the provenance, depositional and tectonic setting. The graphs have been plotted with the geochemical proxies to determine the provenance which indicate that the source rock is felsic igneous rock in composition. The proxies of tectonic and depositional model indicate that the sediments have been deposited in a passive margin setting. From petrographic studies marine environment of deposition is interpreted due to the presence of glauconites in sandstone and shale samples. Therefore both from petrographic and geochemical data a marginal marine setting of sedimentation is indicated. Although study of XRD technique will support the presence of glauconites more accurately; so it can be a nice scope for future studies related to this study area.

From the radio-elemental distribution of all lithofacies study, it is concluded that content of uranium is highly variable within each lithofacies and in most of the samples it is below 10 ppm; therefore it can be concluded there is no uranium mineralization in the study area controlled by any certain facies. Therefore the important interpretation of this study is the absence of uranium mineralization with sedimentation revealing absence of any facies controlled mineralization. For future exploration aspects more studies will be necessary if there is any other type of mineralization with some other controlling factors.

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