CHAPTER-IX

SEDIMENTATION MODEL

9.1 Introduction

The complex interrelation of tectonism and sedimentation may be explained by the composition of sedimentary rocks as mineralogical as well as geochemical composition of terrigenous sedimentary rocks is controlled by provenance, weathering, transportation and diagenesis. The relationships between plate-tectonic settings and development of basins, nature of provenance, relief, transportation, diagenesis, climate, etc., have critically been studied by Dickinson et al., (1983) Dorsey (1988), Ingersoll & Suczek (1979), Bhatia (1983), Pettijhon (1984), and Suttner & Dutta (1986) and some others.

The composition of sedimentary rocks makes an important contribution in interpreting the plate-tectonic settings because the diversified nature of source rocks in provenance areas is the result of complex plate interaction that under varied physico-chemical and climatic control later dispersed and deposited in resultant basins of related types. Hence, the sedimentary composition is a powerful tool for understanding the ancient tectonic setting and its control on the development of sedimentary basins. Moreover, the consideration of texture, facies types and thickness of sedimentary strata depends largely on tectonic factors that can easily be understood in plate tectonic context. In interpreting the tectonic setting of basins, major elemental
geochemistry of sandstones been found more fruitful than the framework grain composition because the latter is relatively more susceptible to burial processes and metamorphism but the major geochemical oxides has been found to reflect the tectonic setting of the basin (Bhatia, 1983). Although diagenesis processes control the bulk composition of sandstones, the nature of diagenesis is itself dependant on the tectonic setting of the basin (Siever, 1979).

A sedimentary depositional environment is made up of a combination of physical, chemical and biological processes associated with the deposition of a particular type of sediment and, therefore, the rock types that will be formed after lithification, if the sediment is preserved in the rock record. The different depositional environments can be divided into the following categories:

A. **Continental**

This consists of a) alluvial, b) aeolian, c) fluvial, and, d) lacustrine environments of deposition.

B. **Transitional**

This consists of a) deltaic, b) tidal flat, c) lagoonal, and, d) beach environments of deposition.

C. **Marine**

This consists of a) shallow water marine, b) deep water marine, and, c) reef environments of deposition.
D. Other depositional environments

Some of the other important depositional environments are: a) volcanic, b) glacial, and, c) evaporite.

Each of these environments could be further subdivided into sub-environments. In the present area of study, however, the Barail sediments are observed to have been deposited in a deltaic environment. Deltas fall in the transitional environment category. They are of different types as follows:

Wave-dominated deltas

Wave-dominated deltas are continuously subjected wave erosion. Most of the sediments brought down by the rivers are deposited along the coast line. The Sunderban Delta formed by the Ganges and Brahmaputra rivers in India and Bangladesh is the largest delta in the world.

Tide-dominated deltas

In this type of delta erosion is also an important control. Erosion may be mainly sub-marine resulting in the formation of prominent bars and ridges. Tide-dominated deltas have few main distributaries. When a distributary channel silts up, it is abandoned, resulting in the formation of a new channel elsewhere.
Gilbert deltas

A Gilbert delta (named after Grove Karl Gilbert) is a specific type of delta formed from coarse sediments, as opposed to gently-sloping muddy deltas. Generally, a mountain river which deposits sediments into a freshwater lake tends to form a Gilbert delta.

River dominated Deltas

A river delta forms at the mouth of a river, where the river flows into an ocean, sea, estuary, lake, reservoir, another river that cannot remove the sediment supply quickly enough to delta formation, and sometimes inland regions where water spreads out and deposits sediments. In the formation of a river-dominated delta the tidal currents are not strong enough. The river carries and deposits sufficient sediments as the velocity decreases rapidly resulting in the deposition of most of the sediment load without being washed out. In the present study the Barail sediments are found to have been deposited in a river-dominated deltaic system. The basin of deposition appears to occur mainly towards the southeast of the area.

Deposition of the Barail Group commenced with thick beds of light grey sands which alternate with thinner beds of argillaceous / shaly sediments in a somewhat fluctuating high energy and low energy environment. This resulted in the development of thicker beds of sandstone and thinner interbeds of shale in Facies BF-1.

This was followed by a shift in depositional conditions in Facies BF-2. It is observed that sedimentation took place in a more stable, but high energy environment.
Thick beds of sand were deposited in a deltaic setting with occasional relatively thinner beds of shaly sediments. This resulted in the development of thick sandstone beds with thinner beds of shale. The upper part of this facies consists of prolific hydrocarbon-bearing reservoirs.

The uppermost facies of the Barail Group is Facies BF-3. In this facies a drastic change in sedimentation is observed from mainly high energy to mainly low energy. Facies BF-3 developed in vast stretches of brackish water swampland and floodplains which were occasionally observed to have been incised by meandering channels. The channels left behind deposits of sands which developed into sandstone beds, most of which contain hydrocarbons. The floodplains resulted in thick deposits of argillaceous sediments resulting in the development of thick mudstone beds. Gradual deposition of argillaceous sediments in swamps under reducing conditions resulted in the formation of thick beds of rich carbonaceous shales which contain abundant frambooids and crystals of pyrite. Moreover, thick coal seams developed due to transportation and deposition of huge amounts of plant material at certain horizons.

9.2 Results of the Study

Based on the different studies the depositional setting of the area under study can be inferred as follows:

9.2.1 The bivariate plot of Standard Deviation (SD) vs Mean Size (Mz) (Friedman, 1967) suggest the source of the sediment to be mainly river and beach sands, while the bivariate plot of Mean Size (Mz) vs Standard Deviation (SD) (after
Glister & Nelson, 1974) suggests a deltaic environment of deposition for the sediments. Thus, the depositional environment of the Barail Group of rocks is fluvio-deltaic in nature.

9.2.2 The mineralogical maturity index \((\text{MI})[\text{Quartz}/(\text{quartz}+\text{feldspar}+\text{lithic fragments}]]\) (after Bhatia and Crook, 1986), from modal analysis of the samples shows a higher degree of maturity in the subsurface while the same in outcrop samples shows relatively lower degree of maturity. The grains are mostly sub-spherical and dominantly sub-angular to sub-rounded. Presence of well-rounded grains in the subsurface samples indicates recycled sediments.

9.2.3 Different types of quartz grains in the ‘diamond diagram’ (after Basu et al., 1975), indicate middle-upper rank metamorphic rocks as the dominant sources for the sediments.

9.2.4 The triangular plot (Dickinson et al., 1983) of quartz, feldspar and lithic fragments (QFL), it is observed that all the sediments of the present study area are the products of recycled orogenic sources, while from the \(Q_mFL_t\) plot (Dickinson and Suczek, 1979; Dickinson, 1985) of quartz, feldspar and lithic fragments it is observed that all the subsurface sediments of the study area are the products of craton interior and quartzose recycled sediments. The samples from the outcrops are products of quartzose recycled and transitional recycled sediments.

9.2.5 The heavy mineral study was carried out mainly to decipher the provenance of the sediments through assemblage. The characteristic heavy mineral
association of the Barail Group is zircon-tourmaline-rutile-garnet-chloritoid-hornblende. Cratonic sources of igneous and metamorphic rocks may be considered as primary sources of the present sediments. The higher proportion of opaque minerals suggests igneous sources.

9.2.6 The Ternary plot of Na$_2$O-K$_2$O-Fe$_2$O$_3$+MgO (after Schwab, 1975, & Blatt et al., 1980) shows that the sandstones are largely restricted to ferromagnesian-potassic sandstone field. The bivariate plot of SiO$_2$ against total Al$_2$O$_3$+K$_2$O+Na$_2$O, after Shuttner & Dutta (1986); and the Provenance Discriminate Function Plot of $F_1$ vs $F_2$ (after Roser and Korsch, 1988) indicate the sediments to be dominantly of felsic igneous (P1) and intermediate igneous (P2) origin and also carry affinity to granites & gneisses (P4) for the Barail sediments. The bivariate plots of SiO$_2$ with those TiO$_2$, MgO, Fe$_2$O$_3$ and of TiO$_2$ with those of MgO, Fe$_2$O$_3$ favour a dominant acidic igneous source. The Ternary diagram of Fe$_2$O$_3$-MgO-TiO$_2$ (after Condie, 1967) shows that the sample points are scattered near the granite and quartz-monzonite field.

9.2.7 The reservoir rock quality of the Barail Group exhibits spatial variations within the study area but deteriorates towards the deeper parts of the basin. The reservoir rocks in the north-eastern part of the area of study are characterized by moderately tight packing density. Detrital clay pore fills and authigenic kaolinite are found to be the main cementing material along with minor proportions of siderite. Kaolinite and filamentous illite are observed to have occluded intergranular porosity.
9.2.8 Based on the overall understanding of the study the depositional environment of the Barail sediments is found to be a river dominated delta (fluvio-deltaic). Different types of log motifs associated with different types of sedimentary sequences observed in the area of study are given in Figure-9.1.

![Fig. 9.1: Log Motif and Typical Sedimentary Sequences](image)

Detailed analysis of the log data and other information gathered from different analysis are combined to arrive at the understanding of the depositional setting of the area of study for conceptualisation of the sedimentation model. The correlation with typical river dominated delta sequence with that of the log motif of one of the wells is shown in Fig.9.2. Thus, the conceptual depositional model which has been developed assumes a river dominated deltaic pattern. The conceptual model evolved out of the understanding of the study is presented in Fig.9.3.
Fig. 9.2: Vertical sequential evolution in a river dominated delta (after Walker, 1979)
Fig. 9.3: Conceptual Sedimentation model of Barail Group