CHAPTER 6
APPLICATION OF GEOPHYSICAL LOGS ON CBM & GEOLOGICAL STUDY OF AREA OF INTEREST(AOI)

Geophysical logs provide rapid measurements that can be used in well-site decision-making. Well logs are important information source for CBM prospect evaluation. It defines coal layers without any ambiguity and offers a permanent record which facilitates spatial correlation. Geophysical Well log characteristics of Coal bed bears a strong semblance to coal ranking, recognizes cleat potential & fracture zones and provides inferences on Thermal history that are vital for prospect evaluation. Well logs are one of the most important reliable data source in various map preparation needed for reservoir estimation , forecast production potential, and plan for optimal recovery of methane gas. In the present chapter , we discuss the basic principles of the many logging tools, which should be more helpful for CBM exploitation.

In this chapter, also Geological analysis of Jharia coalfield is completed. Our Area of Interest(AOI)is a part of Jharia coalfield only . The Stratigraphy of the area has been delineated. It is helpful to work out the geological history of the area.

6.1 INTRODUCTION

Valuable geological information can be obtained by utilizing geophysical logging carried out through wire-line. It often refers to a measurement of one or more physical parameters of rock as a function of well depth. From this physical parameters the rock property are inferred. But this results are not limited to rock property measurement only. Other types of properties measured through these logs are mainly fluid flow, cement quality, casing concern etc.

6.2 INFORMATION AVAILABLE FROM LOGS

Depending on the well operator's objectives, a wide variety of information may be of value. The following list contains coal characteristics that may be addressed with logs and other sources. This list is generally in the order of increasing complexity.

- Depth of the coal
- Thickness of the coal
- Proximate analysis
  - Volatiles
  - Moisture
  - Ash
  - Fixed carbon
- Sorption isotherm
- Gas storage
- Cleating (fracturing)

Any particular logging program may consist of a few or many instrument (tools) depending upon the amount of rock (coal) in formation is desired. Though the following list of logs contain most of the tool types common to the oil field and applicable to coalbed methane project it is not represent to the all tools available; Specially, it does not include speciality tools particularly those not yet applied to coal evaluation.

A list of logging categories follows:

Resistivity Logging

Gamma ray Logging

Acoustic(sonic) Logging

Density Logging

Natural gamma ray spectrometry logging

Induced gamma ray spectrometry logging

6.3 RESISTIVITY LOGGING

The primary uses of resistivity logging are formation correlation from well to well and the distinction of hydrocarbons from water in the formation. Formation resistivity is a property of the rock that indicates how resistive the rock appears to the flow of electrical current.

There are two basic forms of resistivity logging. The first is "electrical" logging. The second is "induction" logging. Electrical logging (the very first form of logging that was initially developed to map subsurface ore deposits) is a technique of measuring formation resistivity from a series of electrodes. Formation resistivity can vary as a function of depth into the rock because of the invasion of drilling fluid (mud filtrate) into porous / permeable rock during the drilling process. It happens when the mud hydrostatic pressure exceeds the formation pressure. The "resistivity profile", which is the resistivity variation into the rock from the borehole, is a function of mud filtrate salinity and the salinity of the fluid being moved during invasion (salt water, fresh water, oil, gas).

Electrical resistivity measurements are made from carefully spaced borehole (and surface) electrodes which, depending on spacings, give a log of resistivity values as a function of depth and distance into the rock from the borehole. As a rule, the depth of investigation of an electrical resistivity device varies from a few inches to a few feet. (A micro-resistivity device has a depth of investigation of a few inches. The deep laterolog may be on the order of several feet.)

Induction resistivity is obtained quite differently from electrical resistivity. As one might infer, the resistivity measurement is obtained by inducing currents into the formation. This is done by using a series of specially placed coils in the tool. The presence of a magnetic field (resulting from currents flowing in the tool coils) causes current to flow in the formation around the borehole. The formation current path is something like a donut around the borehole. The formation currents, in turn, create a magnetic field that causes currents to flow in other (measurement) coils in the tool. The voltage on the measurement coils is a function of the formation currents, which is an inverse function of formation resistivity. Therefore, the voltage from the measurement coil, with appropriate conversions and calibrations, can be displayed as formation resistivity. As a general rule, most induction tools have a depth of investigation of a few to several feet. Vertical resolution is also a few to several feet.

Typically, various combinations of electrical and induction logs are combined in a logging program to obtain needed measurements depending on borehole diameter, mud salinity, anticipated formation resistivity range, and desired depths of investigation.

Frequently associated with resistivity logging (but technically not a resistivity measurement) is the spontaneous potential (SP) log / curve. This potential (voltage) is measured with a very simple electrode configuration. The voltage normally results from the electrochemical reaction that occurs when fluid of one salinity (such as mud filtrate) encounters fluid of another salinity (such as formation water) in porous / permeable media (such as reservoir rock). The primary uses of the SP are an indicator of permeable rock (reservoirs) and as a source for calculating formation water salinity (resistivity) when other factors are known (such as mud filtrate resistivity, formation temperature, etc.). The SP, however, can be fraught with problems. For example, it may read too low in reservoir rocks containing clays. It may read too high in reservoir rocks that have "taken" large quantities of mud in a relatively short period of time. Under the right conditions, though, the SP can be of great value as a source for the value of formation water resistivity, R_w.(R_w must be known in traditional oilfield calculations for identifying the presence or absence of hydrocarbons.)

6.3.1 TOOL RESPONSES IN COAL

In coal deep-reading resistivity logs read high (low conductivity) (Johnston, 1990). Shallow-reading resistivity logs read high - but will vary as a function of the mud (or mud filtrate) that invades into the cleat (fracture) system (Johnston and Scholes, 1991). If the cleats are narrow enough, only the mud filtrate will invade the cleat system. This leaves behind a mud cake buildup on the borehole wall. Under the right conditions, the mud cake can be detected by a special response on certain micro resistivity devices (Mullen, 1988). In this case, the shallower of the shallow-reading curves will read a lower value than the deeper of the shallow-reading curves. This is because the mud cake has a lower resistivity than the coal - so, any error to the reading is in the direction of too low. Because a given thickness of mud cake (usually 1/3 to 1/2in.) is a larger percentage of the shallower reading curve's domain than of the deeper reading curve's domain, the shallow curve resistivity measurement will be lower than that of the deeper curve. Wider cleats allow the entire mud system (rather than only mud filtrate) to invade; and a mud cake is not developed. Therefore, no "mud-cake" response is observed on the micro-resistivity log. Because cleats are the primary permeability system in a coal, relying solely on the micro-resistivity device can cause the most permeable (wider) cleats to be missed.

Clays (components of ash) will generally cause the resistivity logs to read low (Johnston, 1990). This is because of the presence of bound, conductive water usually associated with clay.

The traditional uses of resistivity logs are correlation of formations in one well to the same formations in another well and identification of coal/non coal bearing formations by combining resistivity measurements with knowledge of porosity (from porosity logs), knowledge and certain formation modeling relationships.

6.4 GAMMA RAY LOG

Gamma ray logging is the measurement of the natural gamma radiation emitted by rock formations. The primary use of gamma ray logging is to distinguish reservoir rocks from shale.

This radiation has been, and will continue to be, given off by subsurface strata. Generally, the higher the radiation, the less likely that the rock is a potential reservoir rock. Shale, which typically have little (or no) permeability and cannot produce the fluids they contain, will have higher radiation than rocks that may develop effective pore space. This is because the clay minerals that are a large portion of shale composition contain naturally radioactive elements such as potassium and thorium. Non-shale that can, but do not necessarily, contain pore space are rocks such as sandstone and carbonates. It is possible for these rocks to have no pore space (zero porosity). But, unlike shale, it is also possible for them to have significant pore (void) space for containing and producing fluids. In the oil field application, the identification of non-shale (low gamma ray counts) is one step. Another step is to determine from porosity logs if the rock has pore space (porosity) available for containing fluids. Then, of course, it must be determined whether the pore space contains water or hydrocarbons. This determination is made with the resistivity logs. The determination can be made because the water is normally conductive, and the hydrocarbons are not. As a side comment, the distinction between fresh (non saline) water and hydrocarbons becomes very difficult with traditional logs because both types of fluid are nonconductive. ("Dielectric" types of logs can be very helpful under these conditions.)

It should be added that, unlike traditional hydrocarbon reservoirs, coals rarely contain pore space. The gas exists in micro-pores in the coal matrix. It also exists in cleats (fractures) in the coal matrix after de-watering the coal. It migrates out of the coal matrix and travels along the cleat system to the borehole for production to the surface.

Referring back to the gamma ray log, it usually reads low (count rate) in pure coals. If certain impurities such as clay minerals are inter-bedded with the coal, the gamma ray log will likely identify this.

6.4.1 TOOL RESPONSES IN COAL

Gamma ray tools will usually read very low counts per second (low API Units) because of the lack of naturally radioactive elements in pure coals (Johnston, 1990). Clay minerals contain naturally radioactive elements. Therefore, the presence of clays will cause higher readings in coals (Johnston, 1990). Other ash components, such as fine-grained sand, will generally have no effect on the gamma ray readings in coals.

6.5 SONIC LOGGING

The primary use of some logging is the traditional measurement of formation porosity.

There are many types of sonic devices. In addition to their use for formation evaluation, they are the basis for the measurement of cement quality around casing. One example of this is the Cement Bond Log (CBL).

As applied to formation evaluation, sonic devices measure certain characteristics of a sound wave emitted from a transmitter in the tool. The wave arrives at one, or more, receiver(s). The sound wave properties to be measured are usually the travel time and / or the amplitude of the sound wave. (Velocity, which is a common measurement, is the inverse of travel time.). There are also several applications for the measurements (fracture identification, etc.). However, the most common use is the calculation of porosity from travel time. There is (in most cases) a linear relationship between effective (non-fracture) porosity and travel time in clean (clay-free) reservoir rock. For our purposes here, though, the sonic log has less value than in its oil field application. The gas is stored in micro-pores in the coal matrix. The sonic log does not "see" these micro-pores as porosity in the traditional sense. However, the sonic tool is mentioned here because it can help in the identification of coal seams. (It reads high apparent porosity.) The units of sonic compressional wave slowness measurement are microseconds (of sound wave travel) per foot.

6.5.1 TOOL RESPONSES IN COAL

These generally read high porosity (high travel time) in coals (Johnston, 1990). Clays generally don't have a large effect on these logs in coal seams. This is because the apparent porosity of pure clay is in the same range as the apparent porosity of coals.

Other ash components, such as fine-grained quartz may reduce the apparent sonic log porosity (Ellis et al., 1988).

6.6 NEUTRON LOGGING

The primary purpose of neutron logging is the measurement of traditional formation porosity. As with sonic tools, there are many types of neutron tools. A popular type is the "compensated" style, which uses a neutron source and multiple (2) neutron detectors. The neutron source emits neutrons into the formation. The neutron count rate in the detectors is generally an inverse function of porosity. It is also affected by the borehole conditions. If the ratio of the two detector count rates is taken, it is much less affected by the borehole conditions (mud weight, mud salinity, etc.). Therefore, the porosity value calculated from the detector count rate ratio is much less affected by borehole conditions than single detector neutron porosity logs. The neutron log is not directly applicable as a porosity log in coals. Again, this is because the gas occurs in micro-pores. It is of great value, though, in identifying coals. It reads very high apparent porosity in coal because of the particular makeup of the coal. (The hydrogen in the coal is interpreted as high porosity by the system.). The units of neutron log measurement are usually directly in apparent neutron percent porosity or in standard neutron API Units.

Neutron logs usually read high apparent porosity in coals (Johnston, 1990). This is because they generally regard hydrogen as an indication of porosity. Coal, of course, is high in hydrogen content.

Clays generally don't have a large effect on the apparent porosity of the coal. Similar to sonic logs, the apparent porosity of the clay is in the same range as the apparent porosity of coals. Other ash components, such as fine-grained quartz, may reduce the apparent neutron coal porosity (Johnston, 1990).

6.7 DENSITY LOGGING

Two primary use of density logging is the measurement of traditional formation porosity. In coal evaluation, it is very useful for calculating coal properties such as proximate analysis (fixed carbon, moisture, Volatiles and ash).

Density tools (also called gamma- gamma density tools) utilize a gamma ray source placed a distance (in the range of 1 ft) from a gamma ray detector. The gamma ray count rate in the detector is an inverse function of rock density. If the matrix density is constant, rock density is an inverse function of porosity. Therefore, count rate is a direct function of porosity (i.e., as porosity increases, the gamma ray count rate increases). This is simply because it is easier for gamma rays to find their way from the source through the rock to the detector when porosity is high. An improvement to density logging is the addition of a short spaced gamma ray detector to be used in the compensation of the bulk density reading for mud cake and slight borehole irregularities. It is useful in s4nPly identifying coals. It reads very high apparent porosity in coal seams. .

On very modem density logs, an additional curve is presented called photoelectric effect (Pe). This curve can be quite useful for rock type identification; but it is not used directly in coal evaluation.

6.7.1 TOOL RESPONSES IN COAL

Because of the low matrix density of coals, density logs will read low density (high apparent porosity).

Ash components, such as fine-grained quartz, can have dramatic effects on the density log. These cause the density to go up substantially. This causes the apparent porosity of the coal to be reduced (higher density, lower apparent porosity).

The photoelectric effect (pe) curve associated with the density log (on certain tools) reads in the range of 0.17 to 0.20 in pure coals. It will move from this value in response to ash depending on the elemental makeup of the ash. Generally, the Pe of ash minerals is at least ten times the Pe of coal.

6.8 NATURAL GAMMA RAY SPECTROMETRY LOGGING

The primary use of natural gamma ray spectrometry logging is to measure the naturally radioactive source elements of potassium, uranium, and thorium. This allows conclusions to be drawn regarding clay type and, in some cases, occurrence of fractures.

When a naturally occurring gamma ray impinges upon the gamma ray detector from the formation, it will strike the detector with a certain energy level (measured in KEV or MEV). Using a mathematical model, the energy level of the gamma ray can be used to determine the source element (potassium, thorium, uranium). In pure coals, the occurrence of natural gamma radiation (thus potassium, thorium, uranium) is later low. In fact, if it is a coal and the natural spectral gamma ray readings are higher than pure coal - then naturally radioactive impurities are usually present in the coal. One of these relates back to the high radiation of shale on the regular gamma ray tool. The clay portion of the shale causes a high natural gamma ray count rate. It is often clay in the coal that causes a higher than normal natural gamma ray count rate. Clay is often a significant portion of the ash in the coal. Thus, the natural spectral gamma ray can help confirm the ash content from the density log calculations.

Finally, the natural gamma ray log can help categorize the types of shale adjacent to the coal. This knowledge may help describe the depositional environment of the coal, thus, possibly, the coal quality.

6.8.1 TOOL RESPONSES IN COAL

These logs convert the naturally occurring gamma radiation into the most likely elemental composition that emits the gamma rays. The elemental model is based on potassium, uranium and thorium. Because pure coal is very unlikely to contain sizable quantities of these elements, they all read low. (The regular gamma ray tool is actually a device that responds to all of these elements in total. So, if the total radiation is low, as mentioned in the gamma ray comments, the elemental components would also be low.) Clays increase these readings according to the contribution of potassium, uranium and thorium in the clay.

Other ash components, such as fine-grained sand, will respond as low count rates. (Unless, of course, these ash components have radioactive potassium, uranium or thorium associated with them.)

6.9 INDUCED GAMMA RAY SPECTROMETRY LOGGING

The purpose of the induced gamma ray spectrometry log is to identify the elemental makeup of the rock. Readings from the tool allow a description of the rock formation in terms of selected elemental abundances. Probably one of the most complex tools in the logging industry, the induced gamma ray spectrometry tool utilizes a pulsed neutron source. As the name implies, the source can be turned on, bombarding the formation with neutrons, then turned off. The off portion of the cycle allows time for measurement of gamma ray spectral information (gamma ray energy level) contained in gamma radiation resulting from neutrons captured by the elements in the rock. The gamma ray spectral (energy level) data, in conjunction with a mathematical model, allows conclusions to be drawn regarding the elements making up the rock that was bombarded by neutrons and emitted the gamma rays.

The induced gamma ray spectrometry log (or the full geochemical version) is not directly used for coal identification and fundamental analysis.

6.9.1 TOOL RESPONSES IN COAL

These tools (particularly the expanded, geochemical systems) will generally respond with good accuracy to the elemental makeup of the coal. The total range of the elemental investigation of these devices is generally sufficient to identify key coal elements (carbon, hydrogen, etc.).

Ash components (including clay minerals) have the effect of indicating more elements (or higher percentages of existing elements) on the induced gamma ray spectrometry log. Typical additional elements are silicon, calcium, iron, aluminum, and potassium.

6.10 AREAL EXTENT OF AREA OF INTEREST(AOI)

The Jharia Coalfield is situated about 260km northwest of Kolkata in the heart of the Damodar Valley, mainly along the north of the river. The coalfield lies within the district of Dhanbad, and the town of Dhanbad is in the north-eastern margin.

The coalfield is named after the chief mining centre Jharia which is situated in the eastern part of the field. The field is roughly sickle shaped, its longer axis running northwest-southeast. The coal basin extends for about 38km in an east-west direction and a maximum of 18km in north-south direction and covers an area of about 456 sq km.

6.11 STRATIGRAPHY OF JHARIA COALFIELD

The general Stratigraphic succession is given in Table 6.1. The basement metamorphic rock are overlain by the Talchir Formation followed by the Barakar Formation, which is major coal bearing horizon. Above it comes the barren Measures followed by the Raniganj formation which is also coal bearing.

Table 6.1: STRATIGRAPHIC SUCCESSION OF THE JHARIA COALFIELD

Age	Formation	Lithotype	Max.Thickness
Jurassic or Tertiary Lower Jurassic		Dolerite Dykes Mica lamprophyred dykes &sills	
Upper Permian	Raniganj	Fine grained Feldspathic Sandstone, Shale with Coal seams	800m
Middle Permian	Barren Measures	Buff coloured Sandstone,Shale and Carbonaceous Shale	730m
Lower Permian	Barakar	Buff coloured coarse and medium grained feldspathic sandstone, grits, Shale, Carbonaceous-shale and Coal Seams.	1250m
Upper Carboniferous	Talchir	Greenish Shale and fine – grained Sandstone.	245m
	Unconformity		
Archaean		Metamorphics	

6.12 METAMORPHIC ROCKS

The coalfield is surrounded by metamorphic rocks made up of Granites,Granite-gneisses, Quartzites, Mica-schists and Amphibolites. Gneisses are the dominant rock types. In the North-West part of the coalfield, at Dumra an outlier of metamorphic rocks is exposed. Otherwise, within the basin metamorphic rocks occur only at different depths.

6.13 TALCHIR FORMATION

Rocks of the Talchir Formation are of Fluvio-glacial origin marked by a basal boulder bed resting on the Pre-Cambrian basement. The type rocks of the formation are basal boulder beds, tillite, sandstone, Conglomerate, laminated fine-grained sandstone and greenish needle shales. The prevailing colour of the Talchir sediments is greenish buff.

The formation is exposed kin an almost continuous stretch around the northern crescent shaped periphery and also at depth, the formation gradually thins out. This type section is exposed along Jamunia nala where the full sedimentary sequence of 180m in two cycles can be seen.

6.14 BARAKAR FORMATION

This Formation consisting of fluviatile deposits is the lowermost member in the Jharia coalfield. This is the most important Formation containing coal seams and covers an area of 210 sq km. The sediments of this Formation maintain an erosional contact with the underlying Talchir rocks near the basin periphery and towards depth the contact appears normal.(sengupta,1980). At increasing depth, the Talchir sediments get thinner and ultimately die out making the Barakar sediments lie directly over the metamorphic. The Barakar Formation consists of coarse –grained sandstones, conglomerates, shale, carbonaceous shale, silt-stones, fireclays and coal seams.

The Barakar sandstones show un-decomposed feldspars suggestive of unstable source rock area and rapidly subsiding conditions. The coal seams are generally thick and suggest a slowly sinking basin. The total thickness varies from 800-1250 metres .

6.15 COAL SEAMS

Originally T.H. Ward(Fox 1930) identified 18 seams in the Jharia coalfield and number them I to VIII. Fox(1930) who revised the geology retained the same nomenclature. Sengupta(1980) has recognized 49 seams in the Jharia coalfield of which 26 seams are impersistent and only locally are mineable.. The rest 23 seams are regional in distribution and being mined. Sengupta(1980) has kept the original nomenclature in numbering seams I to XVIII, for other seams he suffixed alphabet to the number underlying more prominent seams which is shown by Table 6.2.

Table 6.2: MAJOR COAL SEAM GROUPS DEVELOP IN BARAKAR FORMATION

SL. NO	SEAM GROUP	MEMBERS
1	XVIII	XVIIIG,XVIIIF,XVIIIE,XVIIID,XVIIIC,XVIIIB,XVIIIA XVIIITOP, XVIIIBOTTOM/COMBINED
2	XVII	XVIIA,XVIITOP,XVIIBOTTOM/COMBINED
3	XVI	XVIE,XVID,XVIC,XVIB,XVIA,XVITOP, XVIBOTTOM/COMBINED
4	XV	XVB,XVA,XVTOP,XVBOTTOM/COMBINED
5	XI,XII,XIII ,XIV	XIVA,XIV,XIVA/XIVCOMBINED,XIIIB,XIIIA,XIII,XIIA, XII, XI, XI/XIICOMBINED, XI/XII/XIIICOMBINED, XI/XII/XIII/XIVCOMBINED
6	IX,X	XB,XA,X,IX,IX/XCOMBINED
7	VIII	VIIIF,VIIIE,VIIID,VIIIC,VIIIB,VIIIA,VIII
8	V,VI,VII	VII,VI,V,V/VI/VIICOMBINED
9	I,II,III,IV	IV,III,II,IV/III/IICOMBINED, I,II/ICOMBINED

As shown in the Table 6.2,seam no I in the Golakdih area located in the eastern part of the coalfield has been referred to as the zeroth seam in the mining industry. But according to Sengupta(1980) since this was only a split section of seam I, no separate identity has been given to it.

From detailed study of the coal seam pattern developed within the Barakar Formation with respect to : 1) Its splitting and coalescing tendencies and 2) Nature and variation in the development pattern of the interseam sediments. Sengupta(1980) regrouped the coal seam of the Barakar Formation in nine(9) groups as already shown in Table 6.2. The coal seams are exposed in the form of a sickle trending west to east-north-northwest to south-southeast, except in the vicinity of the faults the dip is generally low, between

6-10 degrees. The dip direction of the undisturbed coal seams is towards the interior of the basin.

6.16 BARREN MEASURE FORMATION

This Formation is called Barren Measures because except for a few thin lenses of coal it is completely devoid of coal seams. The constituent rock types are coarse to pebbly sandstone, sandy shale, carbonaceous shale and sideritic bands. The lithologic unit of this formation is shown in Table 6.3.

TABLE 6.3: LITHOLOGIC UNITS OF BARREN MEASURES FORMATIONS

FORMATION	MEMBER	UNIT (Thickness in m)	LITHOLOGY
	Upper Member	Mohuda Sandstone (198m)	Massive sandstones with shaly Sandstone, Carbonaceous shale and pebbly sandstone beds at top.
Barren Measures		Harishapur shale(40m)	Black shale and carbonaceous shale
	Lower Member	Petia sandstone(183m)	Pebbly sandstone with carbonaceous shale bands
	Lower Member	Shibabudih shale(180m)	Grey shale, Carbonaceous shales, with inter-bedded pebbly sandstones and sideritic bands

This formation is widely exposed covering a total thickness ranges from 600 to730m.

6.17 RANIGANJ FORMATION

Overlying the Barren Measures the Raniganj Formation occupies an oval basin covering an area of 58sq.km at the south-western part of the basin. This is the uppermost coal-bearing sequence of the Jharia basin. The rock types includes coarse to fine grained sandstone, shale, carbonaceous shales and coal seams. This Formation has maximum thickness of 800m.

On the basis of available surface and sub-surface data, Raniganj Formation has been broadly subdivided into two members viz Upper and Lower by Sengupta(1980).The lithological units of the Formation is shown by Table 6.4 below.

TABLE 6.4:LITHOLOGIC UNITS OF THE RANIGANJ FORMATION

MEMBER	LITHOLOGY	THICKNESS
Upper Member	• Very coarse to medium grained sandstones with occasional shale bands • Medium grained sandstone with coal seams	80m 15-30m
	• Pale greenish to white, massive, • coarse to medium grained, cross banded sandstones-shale	120-140m·
Lower Member	• Medium to fine grained feldspathic sandstone with calcareous concretion, • shaly sandstones, siltstones	300-550m

6.18 FAULTS OF JHARIA BASIN

The Gondwana sediments of the Jharia basin are disturbed by a large number of various types of fault system. The major fault systems are:

Southern boundary fault: In the entire southern part, this is the most prominent fault. The trend of the fault is WNW-ESE and it is not a single line but a zone of parallel fractures.

The southern boundary fault has a stratigraphic throw of about 1800 m towards north. The fault plane dips 53-60 degrees from the horizontal. Due to the faulting the coal seams escaped erosion and are preserved.

Besides the southern boundary fault to the south, number of interbasinal faults have been identified.The fault angles varies from 45-65 degree with the horizontal.(Sengupta,1980).

The important among these are:

1) E-W trending fault system

2) NW-SE and NNW-SSE trending faults.

3) NE-SW fault systems

4) Low angle faults.

The low angle normal faults have been encountered in Sudamdih mine. The faults have varying throw ranging from a few centimetres to more than 50 metres. The fault in Sudamdih area have created problems in mining.

6.19 TECTONIC HISTORY OF JHARIA BASIN

During the Talchir time, the major part of the Jharia coalfield was a positive area and only the northern and north-western fringes subsided. During the early Barakar time, the entire Jharia basin subsided. In the initial stage, subsidence took place by a general down warping of the basinal floor. From the middle Barakar onwards, the pattern of subsidence began to be increasingly modified. By contemporaneous faulting.

According to Mukhopadhyay (1985), during the Upper Barakar time, southern boundary fault was initiated along a small segment of jharia basin and extended with the deposition of Barren Measures.

The pattern of subsidence in the Jharia basin underwent a sharp change during Barren Measures. One E-W trending elongate sub-basin developed stretching from Dugda in the west to Jamadoba in the east. The centre of maximum subsidence was around Mahuda. The south-eastern edge of the basin was marked by the appearance of an elongate ridge on the basement floor. This is the Parbatpur-Pathardih ridge separating the Bhojudih sub-basin situated in the south-eastern end of the coalfield. At the end of the Barren Measures around Mohuda an elliptical basin formed. This resulted due to subsidence of Barren Measures as well as faulting. The boundary of Barren Measures and Raniganj Formation is demarcated by the Bamangora Fault.

6.20 SEDIMENTATION HISTORY OF JHARIA BASIN

The Talchir Formation is exposed all along the northern boundary of the basin. But maximum extent of Talchir Formation has been recorded around Kapuria.In the deeper parts of the basin,sediments of the Talchir Formation are absent and the Barakar Formation directly overlie the metamorphics.

During the post Talchir period, basin deformation took place by a network of faults within the basin. Deposits of the Barakar Formation are characterized by repetitive fining upward cycles. Each sequence commonly starts with sandstone overlain by shaly sandstone, shale, shale-sandstone intercalations, sandy shale, siltstone, carbonaceous shale and ends in coal. However, each individual cycle may not comprise of all the lithic units due to variations in the depositional environment.