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Facies Analysis and Depositional Model of Late Permian Raniganj Formation: Study from Raniganj Coal Bed Methane Block

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Abstract: The Raniganj Formation (late Permian) forms the uppermost economic coal-bearing unit of the Gondwana succession. The dominant facies interpreted from analysis of cores from the Raniganj formation are classified as Sandstone dominated facies, Sandstone - shale heterolith facies, Shale facies and Coal facies. The natural Gamma response of Raniganj Formation shows predominance of repetitive fining upwards cycles. Integration of core analysis and geophysical log data of the Raniganj formation indicates meandering fluvial environment. The lower part of Raniganj Formation is channel dominated which corresponds to thick amalgamated sand bodies while the upper part represent overbank shows predominance of channel avulsion indicating a gradual change in accommodation space. Five major fining upward depositional sequences, bounded by sub-aerial unconformities (sequence boundaries) have been dentified in Raniganj formation, based on changes in depositional style that are correlated regionally. Each sequence comprises of Low accommodation system tract (LAST) at base and high accommodation system tract (HAST) at top. LAST is characterized by vertically stacked, multistory amalgamated channel sandstone dominated facies, while floodplain dominated facies characterize HAST. The coal seams deposited in LAST are thicker and relatively more continuous than the frequent thin seams of HAST. Such facies distribution study would be helpful for the development strategy for CBM blocks based on production priority.

Keywords: Depositional model, Facies analysis, Coal bed methane (CBM), Raniganj coal field, West Bengal.

INTRODUCTION

Facies modeling is a way for the understanding of sedimentary environments and the origin of ancient sedimentary rocks. In the eastern part of Raniganj coal field, due to paucity of field exposures of Raniganj Formation, such study is dependent on the sub-surface data from drilled bore holes. Probabilistic models of geologic phenomena based on such point data have often been criticized because many different models can be constructed to explain a given set of data. Representation of a depositional facies sequence using detailed description of core sediments, therefore, allows quantitative integration of descriptive geology with electro-facies data of the drilled wells. Such integration can be used to construct more realistic geologic models.

The late Permian coal bearing Raniganj Formation of Indian Gondwana basin has not been extensively studied yet in the study area (Figure 1). The major litho-types of Raniganj Formation are very coarse to fine grained sandstone, siltstone, shale, coal and carbonaceous shale. Generally fining-upward sedimentary sequences are found which usually end in coal and sometimes shale (Sen and Banerjee, 2015). The main objective of this study is to integrate core description, drill cutting description and geophysical logs to analysis the facies assemblage and infer the depositional model of Raniganj Formation in Raniganj Coal bed methane (CBM) block of Essar Oil Limited, India.

GEOLOGY OF THE AREA

The Raniganj basin has a semi-elliptical shape and covers ~3000 sq. km between the Damodar and Ajoy rivers. The Raniganj CBM block of Essar Oil Limited lies in the easternmost part of the Raniganj coal field, West Bengal, India (Fig.1). The study area lies between 23°40' N to 23°40' N and 87°18' E to 87°28' E. The block is mostly covered by soil and alluvium with laterite capping at places. Below laterite or alluvium, in the northern part of the block, the Raniganj Formation is underlain by the Iron Stone Shale

Formation. Towards east and south, the surface cover progressively overlies younger rocks viz Panchet Formation and Tertiary sediments. In the eastern part of the block, the Rajmahal volcanics (Trap rocks) are overlain by the Tertiary sediments, obscuring the eastern limit of the coalfield (Sen and Banerjee, 2015). The regional stratigraphic sequence is presented in Table 1.

Table 1. Regional stratigraphic sequence in Raniganj Basin (after Sen and Banerjee, 2015)

Geological Age		Formation		Maximum Thickness (m)
Tertiary		Bengal basin clay, sand and limestone		300+
Unconformity				
Jurassic-Cretaceous		Rajmahal traps-intertrappeans trappeans		85+
Unconformity				
Triassic	Late	Supra-Panchet		200-300
Angular Unconformity				
	Early	Panchet		~600
Mostly gradational contact, Unconformity (local)/overlap at places				
Permian	Late	Raniganj	Damuda Group	1000
		Ironstone Shale		900
	Middle	Barakar		600
	Early	Talchir		300
Unconformity (erosional)				
Precambrian		Metamorphic rocks/Granite gneiss, schist with pegmatite and intrusives of metadolerite, dolerite and lamprophyre		

METHODS

Fifteen cores have been studied in detail to investigate the sedimentary structures and infer the possible depositional processes. The facies assemblages, inferred from the core analysis, had been correlated to the geophysical logs of more than hundred drilled wells (both vertical and directional). The integration of the two, therefore, was used to identify the sedimentary architectural elements both laterally and vertically as well as depositional model. Modern sedimentary depositional systems were used as analogues to support the interpretation of depositional model of Raniganj Formation, as developed from core analysis and well logs.

SEDIMENTARY FACIES ANALYSIS

Observations from Cores

From the detailed core studies the major lithologies observed are sandstone, shale, silt, shale-sandstone heterolith and coal. The primary structures observed are the major guide in building depositional architecture, are described as follows.

Sandstone Dominated Facies

Medium- to coarse-grained, planar and trough cross-stratified sandstone

This is one of the most common features, identified in the core samples. The base of medium- to coarse-grained sandstone is sharp, erosional, scoured (Figs. 2A, B) with prod marks (Fig.2C) and bounce marks. Usually the underlying facies is shale or sandstone or siltstone– shale heterolith. Sedimentary structures include planar and trough cross-bedding with reactivation surfaces. Current ripples and climbing ripples are also identified. Fore-sets of trough cross beds are defined majorly by ferruginous (Fig.2D) and rarely by thin carbonaceous material. The planar cross-bedded cosets are less common and these are underlain by trough cross beds. The trough cross beds show gradual decrease in size vertically.

Interpretation: As evidenced by profusion of current ripples and climbing ripples in sandstone, deposition was broadly under the influence of unidirectional current. Frequent presence of sharp, scoured base of these sandstone units indicate channels. Planar and trough cross stratification record the migration of channel bed forms. The occurrence of planar cross beds above the troughs indicates aggradation of the channel floor (Cant and Walker, 1976). The gradual decrease in the thickness of fore-sets / size of troughs within each coset in vertical order suggests decline in the height of bed due to fall in current competency and shallowing of channel (Walker and Cant, 1984).

Low angle, stratified, fine-grained sandstone

Fine grained sandstones with sharp bases are common which are occasionally inter-bedded with siltstones (Figs. 3A & B). These are generally observed as thin bands in between the trough cross stratified sandstone and heterolith. No distinct grain size variation is evident within these sandstones. Flat lamination and current ripple laminations are the major sedimentary structures present.

Interpretation: The presence of fine grained sandstone as thin bands within cross stratified sandstone and heterolith represents deposition mainly under low energy condition with occasional fluctuation in energy level. Current ripple

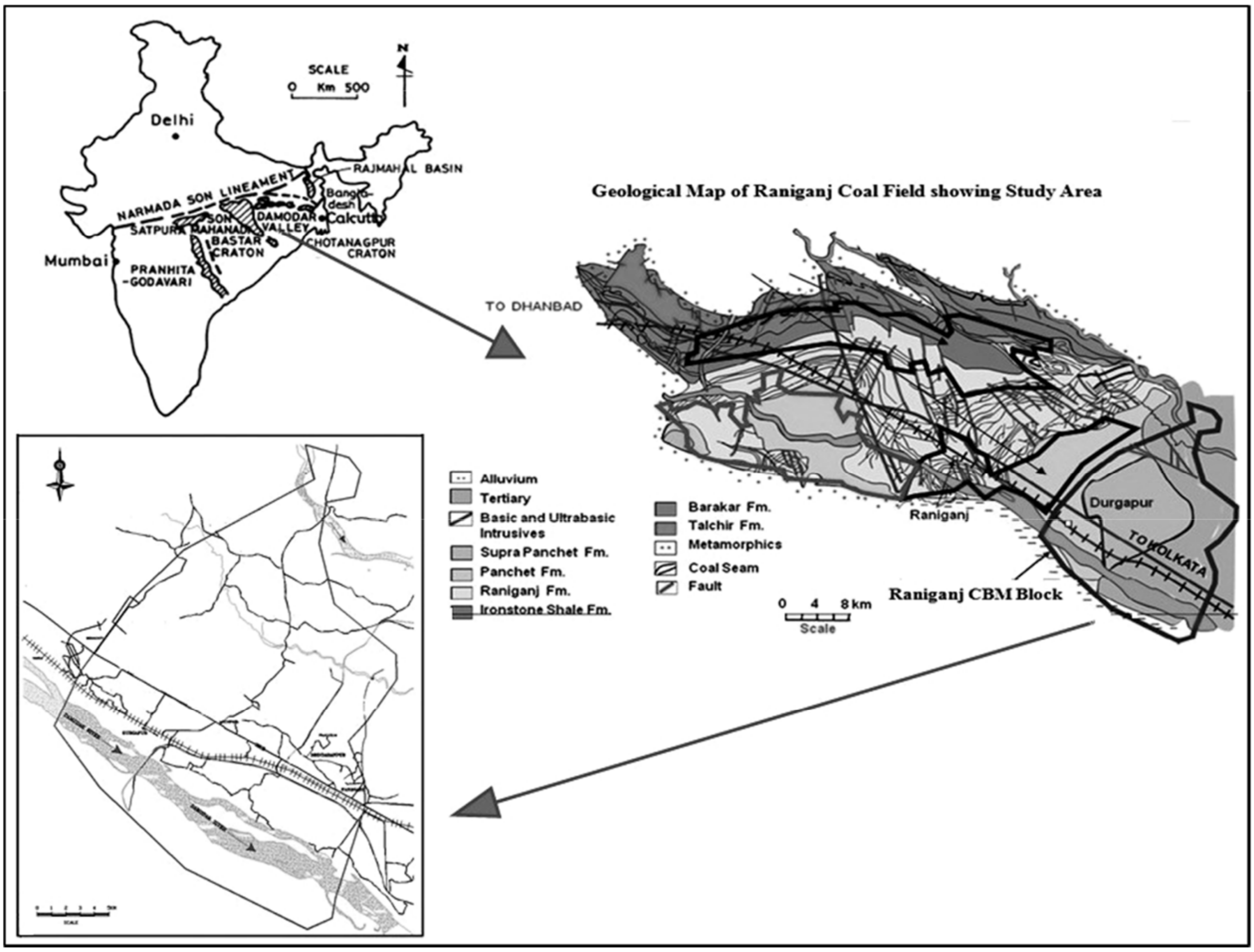

Fig.1. Raniganj coal field and CBM Block – study area (source: Essar Oil Limited)

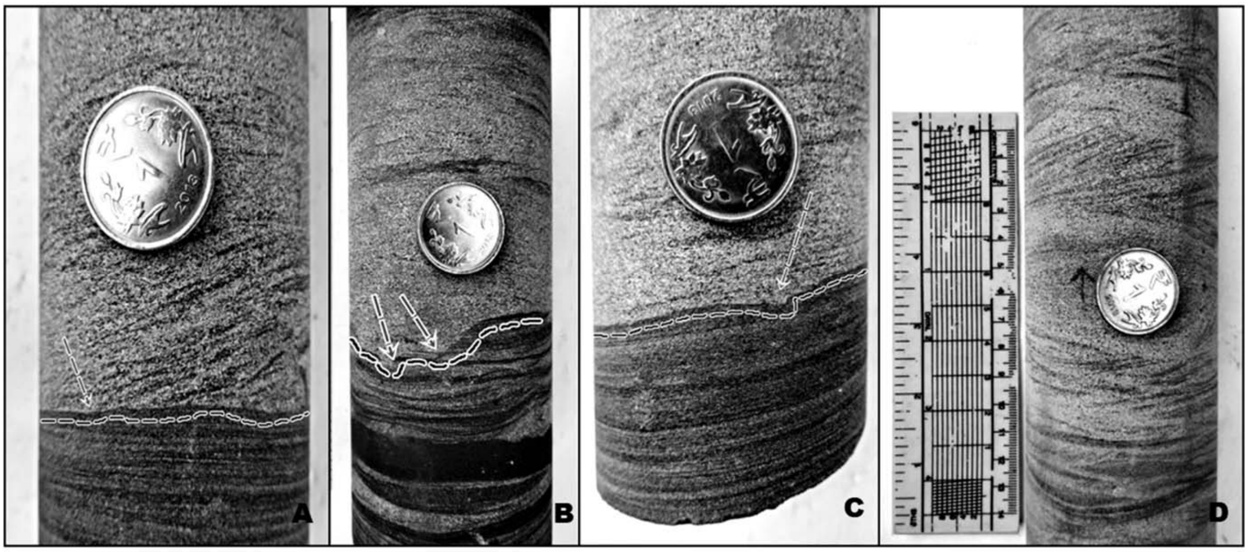

Fig.2. A. Sharp contact between cross stratified sandstone and shale; **B.** Scoured, erosional base of sandstone; **C.** Prod mark at sandstone base; **D.** Cross stratified sandstone with foresets defined by ferruginous material

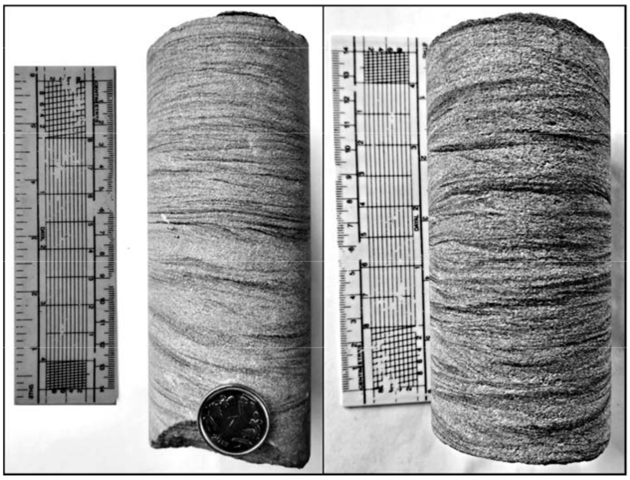

Fig.3. A & B. Low angle, stratified, sandstone, with foresets defined by ferruginous and carbonaceous material

lamination, flat lamination and silt inter-beds are also indicative of changes in velocity and sediment load within the channel (Opluštilet al., 2005).

Massive Sandstone

Medium- to coarse-grained massive sandstones, devoid of any primary sedimentary structure, have been observed. Occasionally these sandstones show a fining upward trend. These have erosive sharp scoured base with feldspathic basal lags (Fig.4A). Rip up clasts of the underlying beds, commonly shale, coal etc (Figures 4B, 4C) are also commonly present. Rip up clasts are of different size and shape. A maximum diameter of 6 cm of the clasts has been observed.

Interpretation: This litho-facies suggests planar sheet transport in upper flow regime (Rust, 1972). It represents a channel. The pebbly layers in basal parts of sandstone bodies are suggestive of channel lag deposits (Allen, 1970). Pebbly lag preserved on the base of the sandstone suggests the cessation of a rolling bed load, which could mean a fall in the initial energy of the depositional current.

Sandstone – Shale Heterolith Facies

This facies has inter-laminations of shale and fine to medium grained sandstone or siltstone overlying the channel sandstones. The sandstones commonly show well developed ripple cross laminations in close inter-bedding with shale (Fig.5). The ripple cross laminations are well marked by ferruginous matter, as also occasionally by carbonaceous material.

Interpretation: The geometry, internal structures and associations of this litho-facies indicate its deposition as vertical accretion in the overbank (levee) areas of fluvial system (Allen, 1970; Casshyap & Tewari, 1984).

Laminated sandstone–shale intercalations are often observed overlying erosional surfaces or medium- to coarse grained sandstones. Sedimentary structures at the upper

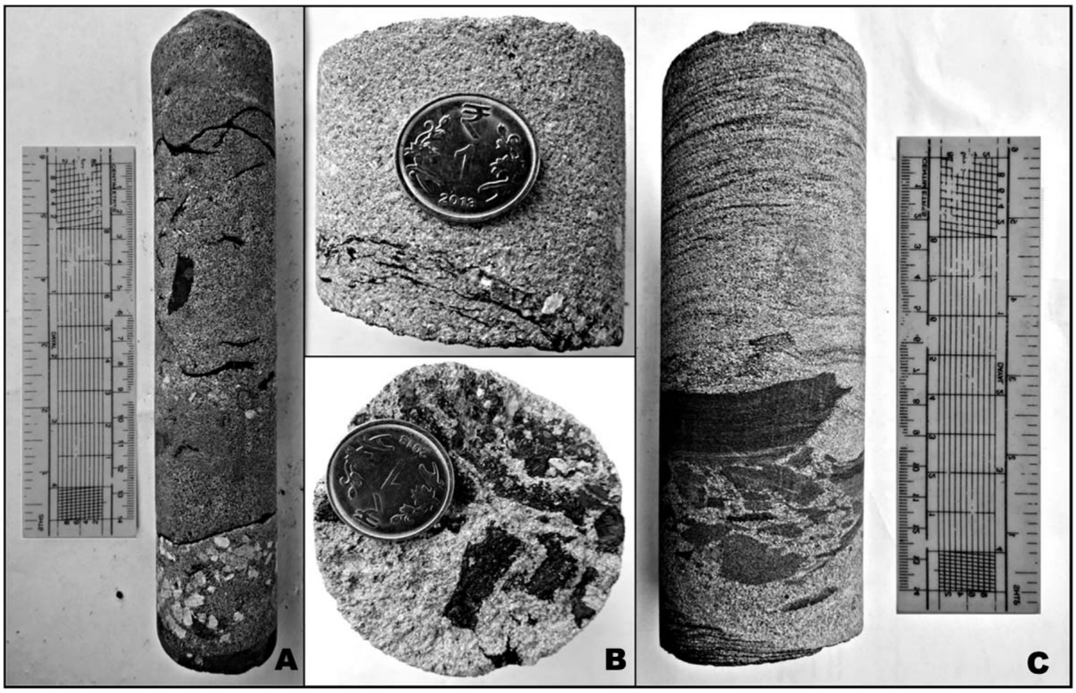

Fig.4. A. Massive sandstone with feldspathic basal lags; **B.** Coarse grained sandstone with coal as basal rip-ups; **C.** Medium grained sandstone with shale clasts as basal rip-ups.

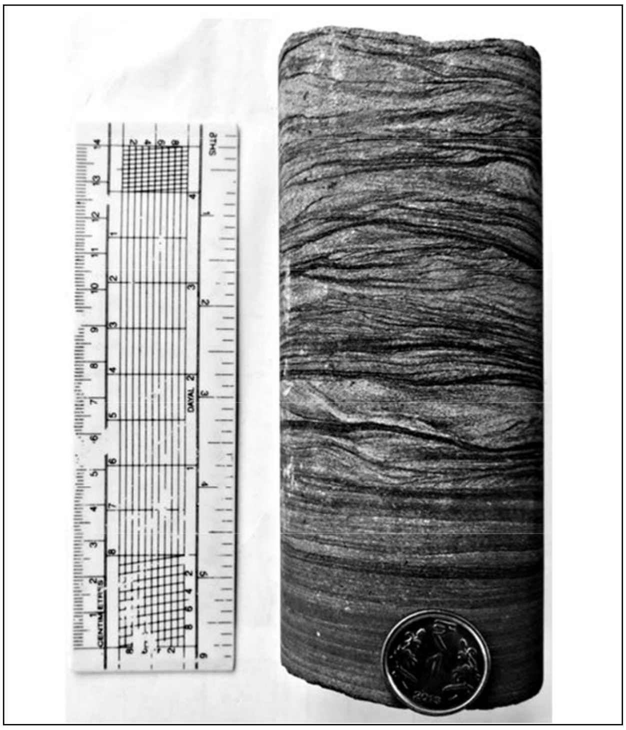

Fig.5. Sandstone – shale heterolith facies – Levee

part of heterolith have been locally destroyed by soft sediment deformation giving rise to different soft sediment deformation structure (SSDS) like convolute lamination, water escape structures etc (Figs. 6A, B and C).

Interpretation: Deposition of laminated sandstone-shale heterolith occurred mostly from suspension, but also by low velocity unidirectional currents. They most probably indicate an abandoned channel fill, as indicated by erosional base or by the presence of medium- to coarse-grained sandstone (Opluštil et al., 2005). Soft sediment deformations indicate overbank instability.

Shale Facies

Laminated shales (Fig. 7) form an important part of the whole sequence. This litho-facies lies in between the successive channel sandstones in multistory sequence and marks the top of each fining upward cycle. Parallel laminations are well marked by ferruginous or carbonaceous material. Shales are micaceous at places and usually fossiliferous. Common fossils are – *Glossopteris*, *Gangamopteris*, *and Vertebreria*. Burrows are usually observed in the upper part of the shale. Burrows identified

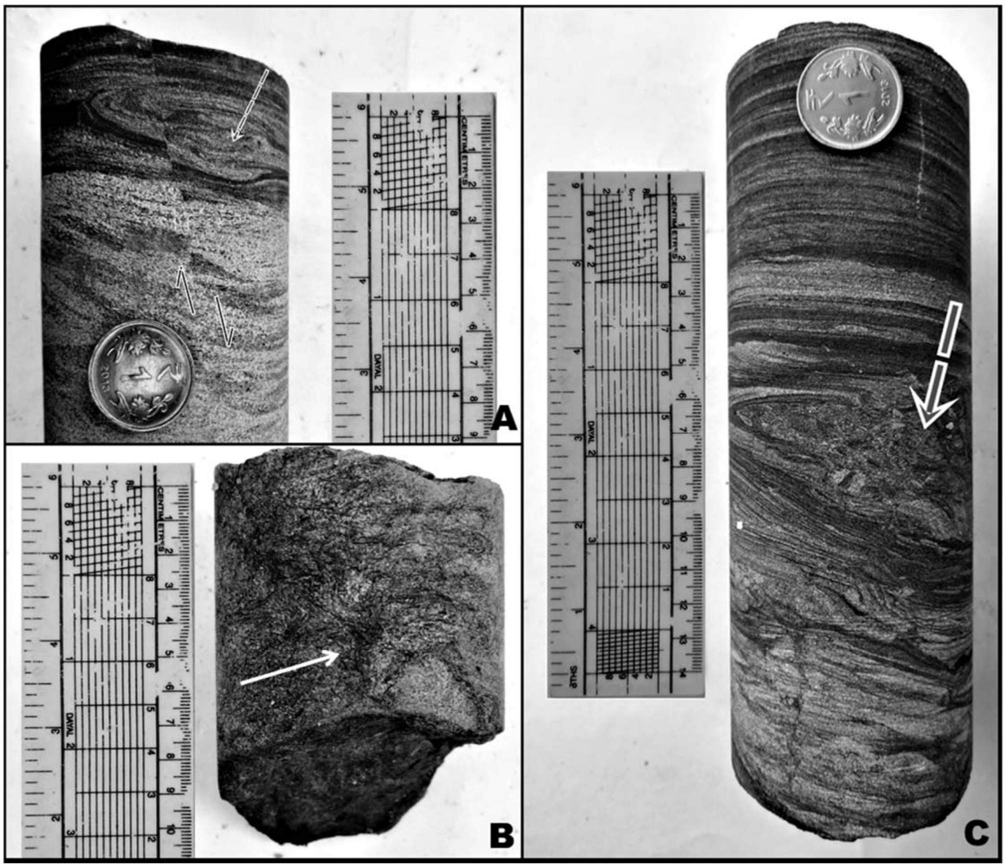

Fig.6. Different Soft sediment Deformation structures (SSDS) – A. Faulted convolute, B. Water escape structure, C. Sediment liquefaction induced deformation

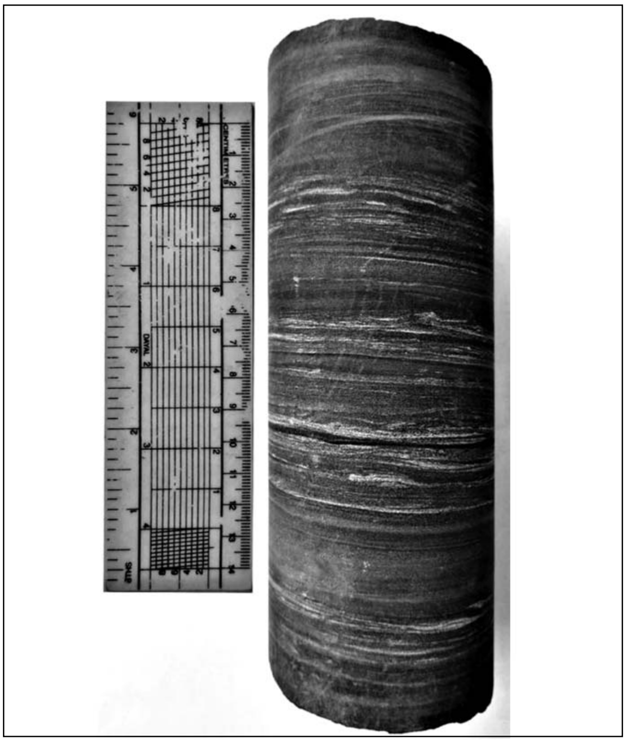

Fig.7. Laminated shale with minor silty intercalation– Floodplain deposit.

from the shale tops of the fining upward sequences, indicate a hiatus.

Interpretation: The laminated shale litho-facies indicates vertical accretion through suspension. In fluvial setting, this corresponds to deposition in flood plain area (Casshyap & Tewari, 1984). Thin lenticular shale beds, sandwiched between two channel sandstones imply deposition from suspension on channel bars during low stage (Rust, 1972).

Coal Facies

Six major groups of coal seams are identified in Raniganj basin. Coals are well cleated. Roof and floors are commonly shale. Coarse grained sandstones with basal coal/ carbonaceous lags act as roofs for some of the coal seams. Coal seams are characterized by high vitrinite with moderate to low inertinite and ash content. Secondary mineralization of pyrite and calcite are common in cleats (Figs.8A and B). Shaley coal and carbonaceous shale are often found.

Interpretation: Coal deposition occurred in the floodplain swamp having high groundwater level that maintained the reducing environment in the peatland. Gelification indices indicate the absence of severe oxidation and dehydration during peat accumulation (Suwarna and Hermanto, 2007). High vitrinite content in all the seams clearly indicates that in the swamp predominantly there were humic plant materials, primarily cellulose and lignin. Organic facies was interpreted from the maceral analysis and it indicates the depositional environment of the Raniganj coals ranged possibly from wet limnic-telmatic zone with limited clastic influx and little microbial attack activity, to telmatic wet forest swamp under rapid burial condition (Sen and Banerjee, 2015).

Analysis of Geophysical Logs

In the following section an interpretation of the lithology as encountered in the well logs is given. Gamma ray motifs along with density and resistivity log responses of the wells are correlated to know the spatial and temporal extents of different facies. The shapes of well-log curves have long been interpreted in terms of depositional facies because of their resemblance to grain size successions (e.g., Selley, 1978). We present one cross-section (Fig. 9) in which nine wells named as Well A, Well B, Well C, Well D, Well E, Well F, Well G, Well H and Well I have been correlated. For the detailed correlation purpose packet to packet

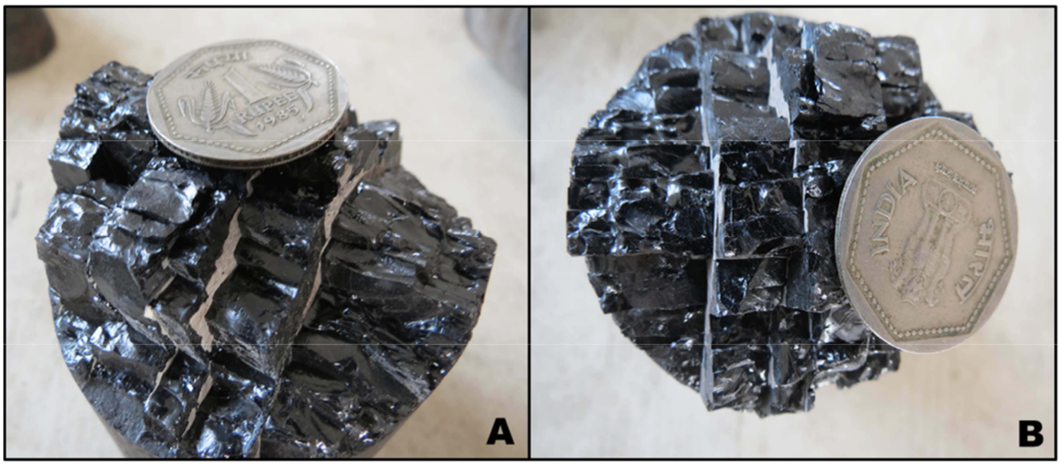

Fig.8. A. Coal cleats with Calcite mineralization, B. Two sets of mutually perpendicular cleats

approach has been used. Coal seams have been correlated as part of packet based on the characteristics of roof and floor lithology. The correlation of both the sandstone and coal has been given equal importance to understand the lateral continuity. The thick, persistent nature of the coals in the area makes them fairly reliable marker beds within the Raniganj Formation. As a result, correlation and mapping of the coal is of less challenge when compared to sandstone and shale. To overcome any further confusion in demarcation the lithology density and resistivity logs have been used with the Gamma log. Gamma ray has been used as main lithological distinguisher as well as its trend of variation is taken as representative of change in grain size. Together these two provides the basis of facies analysis. The understanding based on the core study is further supported by the correlation of the logs.

Sandstone Bodies

Major geometry

In the lower part of Raniganj the most common feature that is observed is bell shaped pattern at the top followed by one or more cycles of thick cylindrical low gamma ray responses. In the upper part the cylindrical patterns become thinner noticeably while bell-shaped patterns gradually become more dominant. Though fining upward trends within sandstones is mostly consistent, sandstone bodies that do not show change in grain size vertically and a few sequences that coarsen upward are observed. These sand bodies are of different thickness. These variations in pattern, their sequence of presence and relative thickness have been used as the major tool to identify different sedimentary architecture.

Architecture

Channel: Multistory sand bodies formed due to amalgamation of multiple channel deposits within the avulsion belt. In logs it is represented by multiple cycles of thick cylindrical low gamma ray responses. The cycles either ending shale by an interval of constant high gamma ray values (>150 GAPI) or in coal of low gamma ray and low density (<60 GAPI & <1.8 g/cc respectively). A change from channel sand-rich environments to a more overbank dominated environments is indicated by the gradual increase of the gamma ray towards the top of the formation (Tye, 1991, Bridge and Tye, 2000).

Channel-bar: A consistent fining upward trend within sandstones is indicative of channel-bar deposits. The bar thickness may change over a lateral distance. Then the fining upward sequences may change into those with little vertical variation in grain size over a large distance (Bridge, 1993; Lunt et al., 2004).

Crevasse: Thickness becomes the major criteria to differentiate crevasse deposit from channel deposit. In well logs it can be recognized by the relatively thin sandstone bodies with a thickness of 2 - 5 m. In some cases the crevasse deposits can be correlated to a channel belt but due to restricted width, often these thin sandstone bodies cannot be correlated in all wells.

Fine-grained Deposits and Coals

Fine sand shale and silt shale intercalation is represented by the serrated gamma response (gamma log value above 120 API) with multiple very fine scale fining upward (majorly) and coarsening upward (occasional) sequences. The lateral continuity of mudstone, shale is indicative of overbank deposit. The presence of sandstone bodies within the serrated sections are interpreted as crevasse splays/ levees. These are common features within the floodplain sequences between channel belt deposits. According to Bridge (1984), such floodplain sequences may be related to avulsion of main channels.

A number of coal seams are identified in the log. Majority of them are continuous and thick in the lower part of the Raniganj. In majority of the wells the coal seams are sandwiched between shale (even if the shale is as thin as a meter or less), this is indicative of low energy over bank deposit. In the middle part of the Raniganj packet the number of thin and discontinuous coal seams increase. Sometimes the coal seams are overlain immediately by sand. Some of these coals are laterally continuous, but others are truncated by channel-belt deposits. Therefore, the sudden absence of a coal seam in wells can be explained by erosion or non-deposition. Coal seams in Raniganj have often been subjected to splitting-merging. In major cases these splits are intervened by channel sand, which gradually gives up to thin shale band before merging with multi-chronus coal seam. This again indicates the lateral distribution from channel to inactive flood plain through active flood plain.

In Fig.9, a well correlation section to show basinal cross section from deeper to shallower area has been presented, which is left to right in the figure. Figure 9A shows locations of the correlated wells in map. This section indicates the continuity of the channel sand, overbank fines and coal seams. The major observations from this section are:

Coal seam: Splitting merging of coal seam is very common and in most of the cases the split sections of the coal is filled by channel sand (1100-1110m in Well A). This indicates the merged part deposited on the overbank

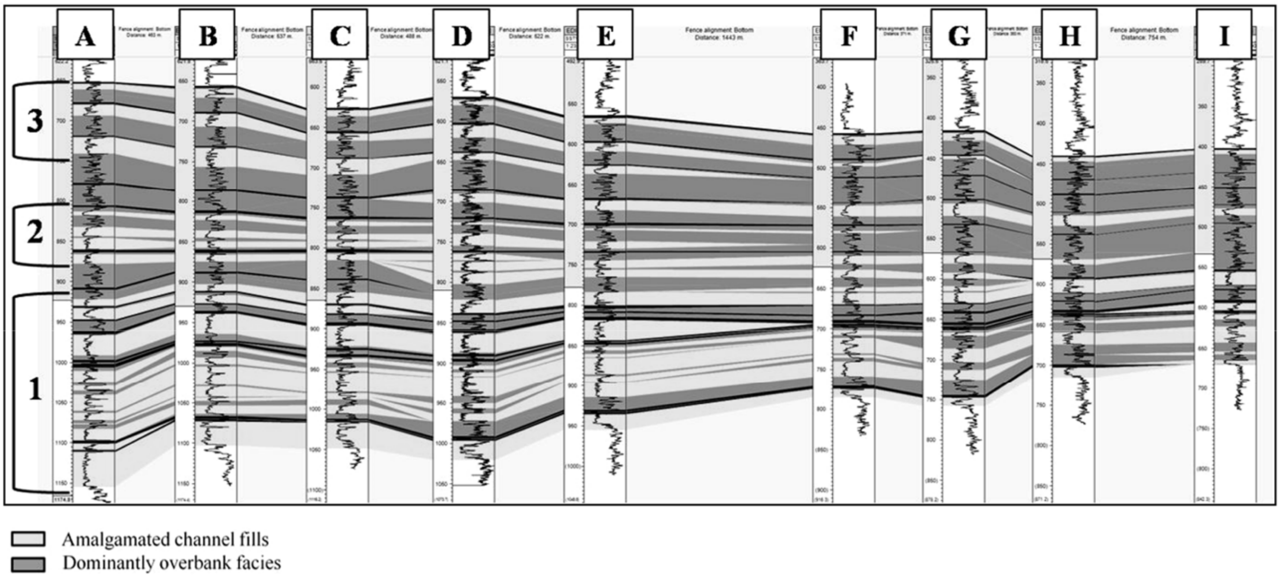

Fig.9. Correlated well section showing lateral and vertical disposition of channel, floodplain and coal facies, Raniganj formation and demarcation of three segments (as 1, 2 and 3) in the studied Well A, B, C, D, E, F, G, H and I.

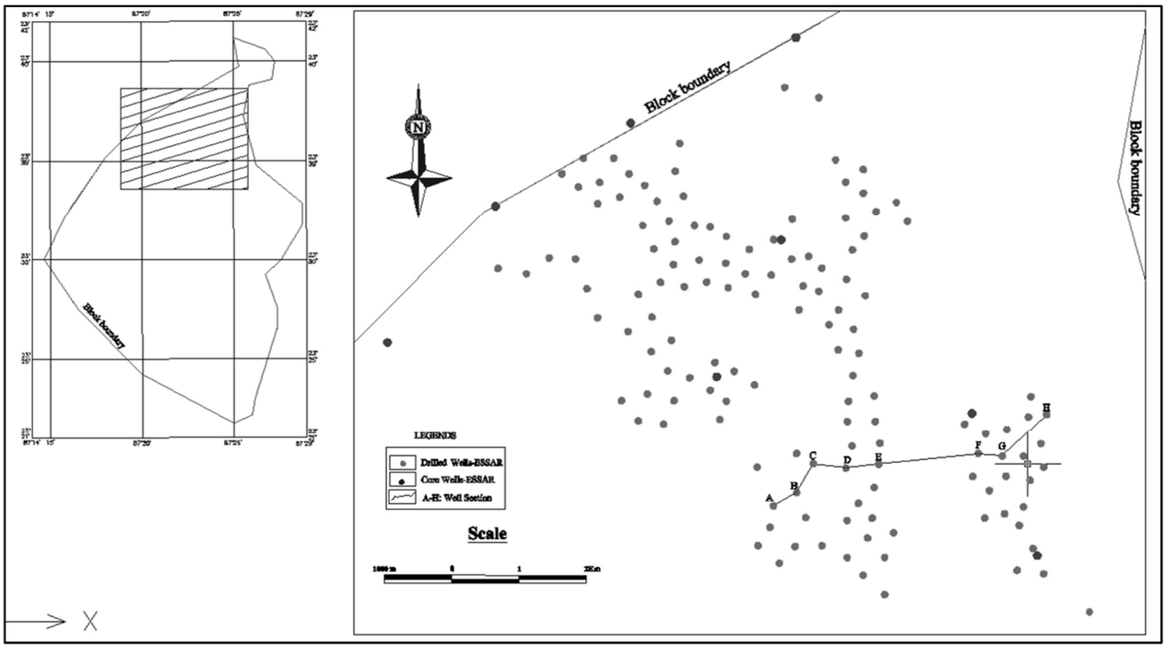

Fig.9A. Location of the studied Wells A, B, C, D, E, F, G, H and I in the map of study area.

section and merging of multichronus organic deposit. Continuous coal seams are also exhibiting lateral thickness variation. Local seams are generally thin and found to be laterally discontinuous (Coal seam lying between 905m to 910m in Well A). Channel wash outs are also contributing to the lateral discontinuity of coal seams (as exemplified in the WELL-I bottom).

Over bank Deposits: The clastic deposits in overbank are dominated by shale. In parts, sand and siltstone, representative of crevasse and splay deposit (majorly identified by thin low gamma sections within high gamma deposits, e.g.- ~ 3m thick sand body in Well D between 975-980m) are present. Coal seams are often found to be laterally degraded in nature within overbank to end up as shaley coal to carbonaceous shale. Correlation of the wells reveals existence of inter-fluve section in wells F (670m to 702m), G (630m to 670m), H (612m to 645m).

Sand Deposits: Sand deposits found is generally recognized as channel sand. Presence of point bar is also very evident. Thin sand bodies within over bank deposits are representative of crevasse and splay. The lateral continuity and variable thickness of sand is very evident. Channel sands are commonly found to pinch out into overbank deposits. Splays are seldom found to be connected to the channel. Amalgamated channel sands are very frequent in the bottom part of the Raniganj Formation (1000-1050m in Well B) but progressively it gives way to channel avulsion.

Based on the above observations three major segments have been demarcated, marked as 1, 2 and 3 along the vertical scale of well correlation section (Fig.9). The bottom most part (Segment-1) is channel dominated and represented by multistory sand bodies. The other two are mainly overbank facies dominated deposits while the top one (Segment-3) shows predominance of channel avulsion while the middle section (Segment-2) represents more of a transitional phase. This indicates a gradual change in accommodation space.

SEDIMENTARY ARCHITECTURAL ELEMENTS AND DEPOSITIONAL MODEL

Vertical relationships of various lithofacies constituting Raniganj Formation has been analyzed in core sections and geophysical well logs. The whole Raniganj Formation represents repetitive fining upward cyclic successions of variable scale, comprising very coarse- to fine-grained sandstone, siltstone, shale, coal and carbonaceous shale.

Coarse- to medium-grained cross stratified sandstones with sharp erosional base and pebbly lags, at the base of each fining upward cycle represent channel- to sheet-like and multistory amalgamated channel bodies. These resemble with laterally accreting / migrating channel bar deposits of fluvial system (Allen, 1970; Jackson, 1978). Cosets of trough cross-stratifications indicate unidirectional migration of dunes in shallow turbulent water (Collinson, 1978; Reading, 1986).

The inter-bedded sandstone-shale heterolith facies indicates deposition by relative weaker currents outside the main fluvial channel body – in the overbank (levee) area. The overlying laminated shale facies corresponds to vertical accretion through suspension in the protected areas away from the active clastic influx (channels) – distal floodplain area in fluvial setting (Casshyap and Tewari, 1984). The floodplain, interfluves were the areas, with limited/minor clastic influx and reducing condition, which promoted extensive coal deposition, though crevasse splays deposited clastic materials in floodplain, resulting fine- to medium-grained sandstones/siltstones within shale dominated successions. This finding is also supported by the observation made by Sen and Banerjee (2015) from the study of coal macerals of Raniganj coal seams.

These various lithofacies, occurring in fining upward successions should have been deposited laterally in similar fashion following Walther's Law. The whole assemblage, thus, can be attributed essentially to a meandering fluvial depositional system (Fig10).

Cyclic successions are almost every where in fluvial deposits and occur over a wide range of time scales. It indicates that the fluvial environment is characterized by processes that tend to reproduce the same depositional results repeatedly (Catuneanu et al., 2011). These are characterized by an initial phase of high fluvial transport energy, which may be recorded as an erosion surface,

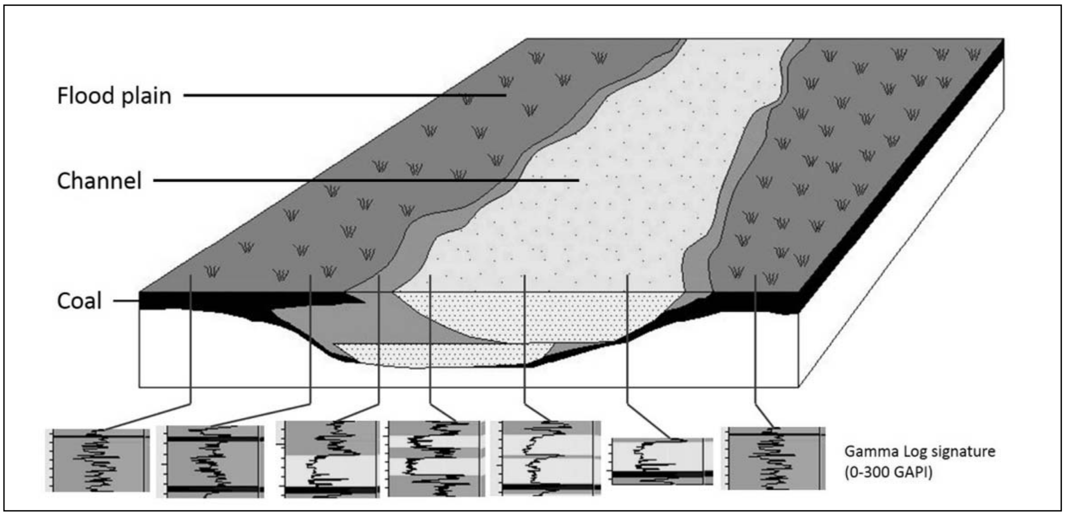

Fig.10. Schematic diagram representing the depositional environment of the Raniganj formation in study area, along with the Gamma ray log signatures (in 0-300 GAPI scale) of different sedimentary architectural elements constituting the fluvial model.

followed by deposition of increasingly fine-grained sediment, with associated sedimentary structures that decrease in scale.

SEQUENCE STRATIGRAPHIC APPROACH

A depositional sequence forms during a full cycle of accommodation change, involving both an increase (positive) and decrease (negative) in the space available for sediments to fill. The depositional sequence boundaries are formed during the periods of negative accommodation, though it may not be strictly required always (i.e., parasequences, genetic stratigraphic sequences, T-R sequences of Johnson and Murphy (1984), and systems tracts that form during positive accommodation). A genetic stratigraphic sequence is formed during a full cycle of change in accommodation space, but it may also form during the periods of positive accommodation in response to fluctuations in accommodation and/or sediment supply (Catuneanu et al., 2011). Therefore, a genetic stratigraphic sequence may or may not include an internal sub-aerial unconformity, depending on whether or not the corresponding cycle includes a stage of negative accommodation.

Systems tracts are interpreted on the basis of stratal stacking patterns, position within the sequence, and types of bounding surface (Van Wagoner et al. 1987, 1988, 1990; Posamentier et al. 1988; Van Wagoner 1995; Posamentier and Allen 1999). Systems tracts may be either shoreline-related, where their origin can be linked to particular type of shoreline trajectory, or shoreline-independent, where a genetic link to coeval shorelines cannot be determined. Shoreline-independent systems tracts are stratigraphic units that form the sub-divisions of sequences in areas where sedimentation processes are unrelated to shoreline shifts. These systems tracts are defined by specific stratal stacking patterns that can be recognized and correlated regionally, without reference to shoreline trajectories.

In upstream-controlled fluvial settings, fluvial accommodation may change independently of changes in accommodation at the nearest shoreline and create sequences comprising of low- and high-accommodation systems tracts (e.g., Shanley and McCabe 1994; Boyd et al. 2000). The timing of shoreline-independent sequences and systems tracts is commonly offset relative to that of shoreline-controlled sequence stratigraphic units and bounding surfaces (e. g., Blum and Tornqvist 2000). In fluvial depositional set up, the depositional styles may be defined by the degree of amalgamation of channel deposits, which may reflect syn-depositional conditions of available fluvial accommodation (i. e., low- versus high-accommodation settings; e. g., Shanley and McCabe 1994; Boyd et al. 2000). The fluvial succession consists of depositional sequences bounded by sub-aerial unconformities, which may be sub-divided into low- and high-accommodation systems tracts based on changes in depositional style that can be correlated regionally. Low accommodation system tract (LAST) is defined by channel dominated succession and high accommodation system tract (HAST) is represented by overbank dominated succession.

Study identifies five major fining upward depositional sequences in Raniganj Formation, named S1, S2, S3, S4 and S5. Each depositional sequence consists of LAST and HAST, bounded by sub-aerial unconformities (Fig.11). LAST is characterized by erosional based, vertically stacked, amalgamated multistory channel sandstone dominated facies and scarce preservation of floodplain facies. HAST is characterized by overbank dominated facies with lesser abundance of restricted thin sandstone facies. Vertical and

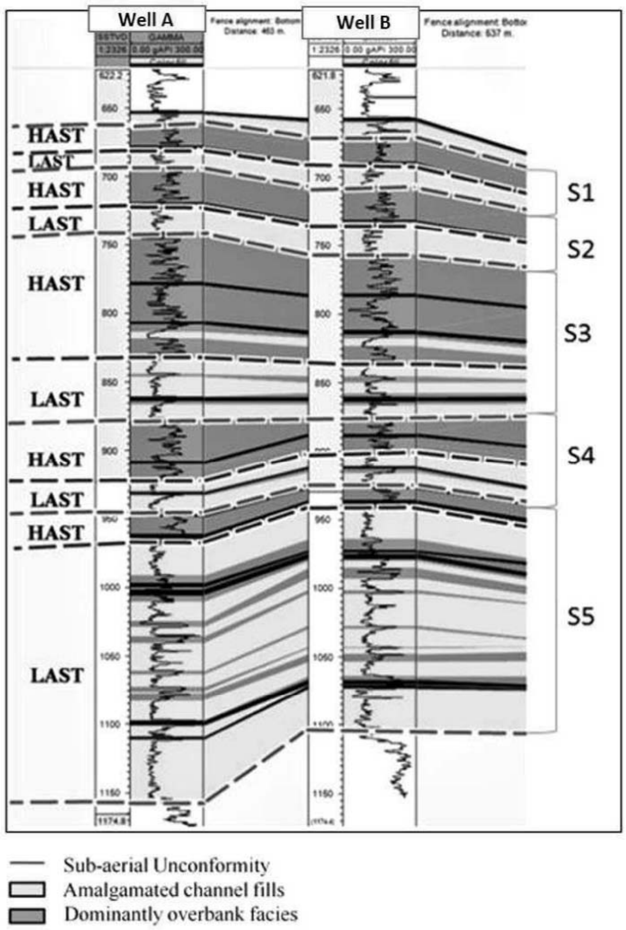

Fig.11. Stratal stacking patterns of fluvial succession and demarcation of LAST & HAST of Raniganj formation, Raniganj Coal bed methane block, Essar Oil Limited

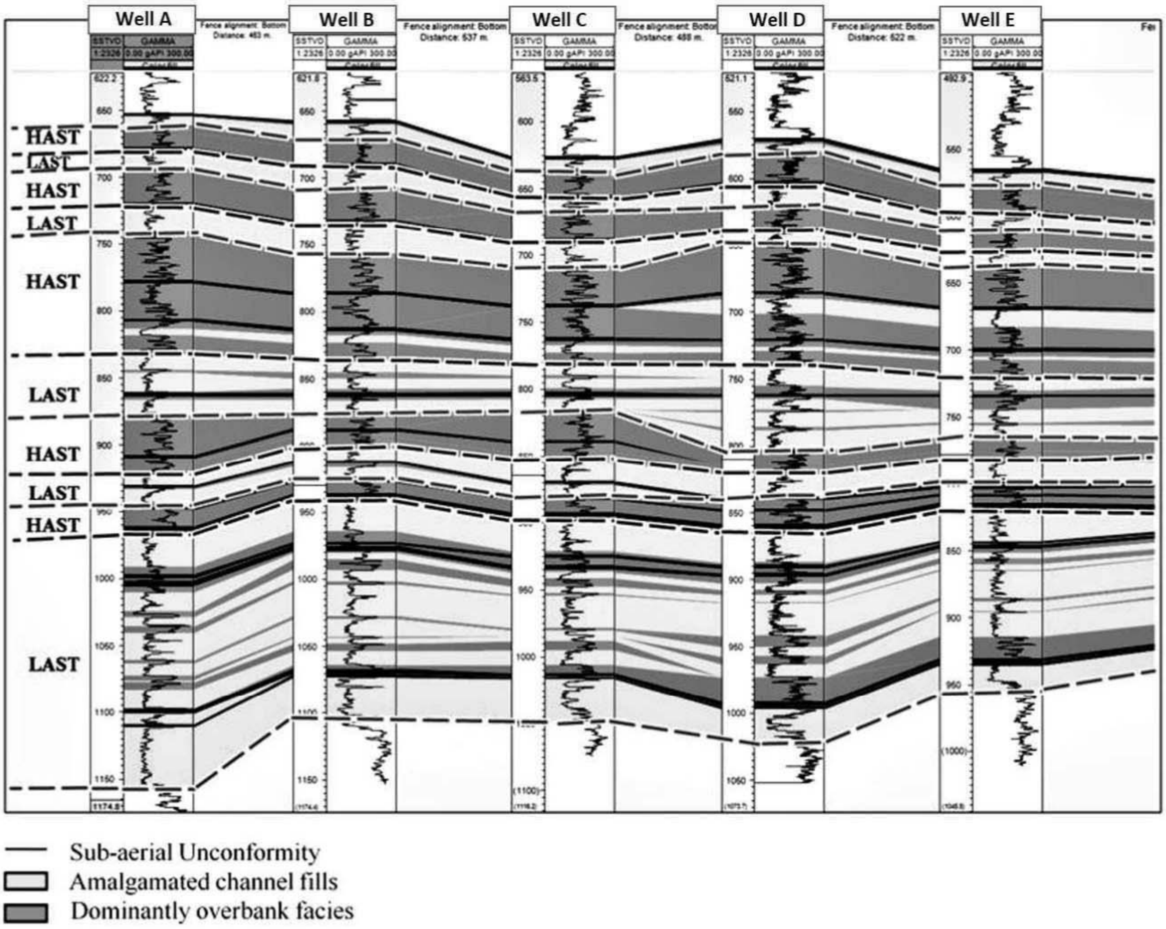

Fig.12. Vertical and lateral distribution of facies assemblages and system tracts, Raniganj Formation, Raniganj coal bed methane block, Essar Oil Limited

lateral distribution of these system tracts have been studied throughout the study area (Fig.12). Figures 13 and 14 represent the variation of sandstone thickness and coal seam frequency & thickness in HAST and LAST, demarcated in Raniganj Formation respectively. Less the accommodation, more is the sandstone thickness, i.e. more is the degree of amalgamation. Coming to the frequency and thickness of coal seams, study reveals lesser number but thick coals are deposited within low accommodation system tracts, while in high accommodation system tracts number of seams increases along with the decrease of seam thickness.

CONCLUSIONS

Analyses of sedimentary facies and architectural elements, as inferred from integration of core data and geophysical well logs, suggests a meandering stream depositional facies model for the Raniganj Formation in the coal bed methane block of Essar Oil Limited, eastern India, characterized by fining upward sequences from channel belt sandstones to levee – over bank deposits to back swamp floodplain deposits. Identified sedimentary architectural elements are – fluvial channels, back swamp - flood plain, levee and crevasse splays. Coals, having great CBM potential were deposited in the floodplain – a wet forest swamp. The channel sinuosity and frequency of lateral channel migration/avulsion results in lateral facies heterogeneity and coal splitting. Overall Raniganj Formation can be divided in five depositional sequences, each comprising of two general depositional facies assemblages: channel dominated facies and floodplain dominated facies, which are interpreted as low- and high-accommodation system tracts respectively. Keeping in mind that thicker seams are available in LAST parts and thin frequently splitted coal seams are available in HAST parts, completion strategies can be designed by adding gas content and saturation dataset along with this observation and interpretation. Thicker seams in LAST, if contains good gas, can be prioritized for completion and brought to production at first.

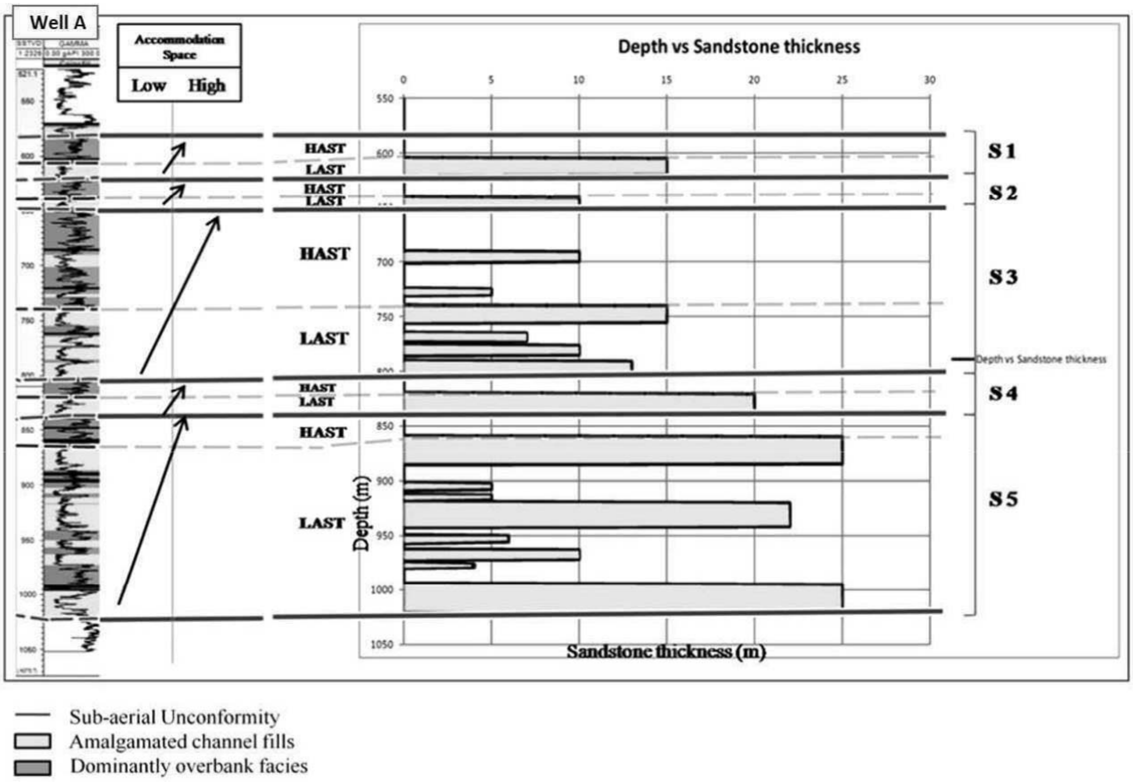

Fig.13. Control of Accommodation on thickness of sandstones, deposited in high and low accommodation system tracts, Raniganj Formation

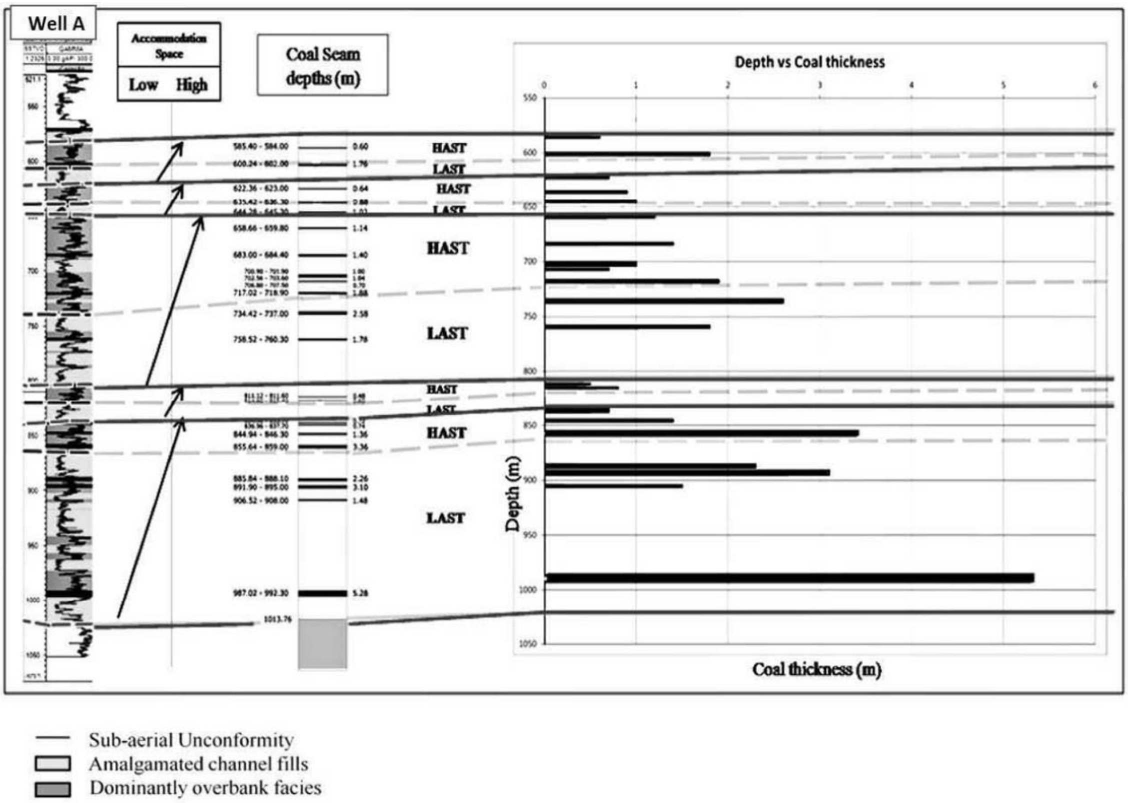

Fig.14. Control of Accommodation on frequency and thickness of the coal seams within HAST and LAST, Raniganj Formation

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