Origin of thick coal seam in the Gondwana sequence of Jamalgonj basin, Bangladesh

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ABSTRACT

The Jamalgonj basin is an E-W elongated graben/half-graben type intracratonic basin in the Stable Shelf/Bogra Slope of the Platform area of Bangladesh. The present basin area is more sagged and deepest part of the Permian basin and is thought to be the easternmost continuation of Gondwana basins in India. The basin contains Gondwana sequence (>555 m) with more than seven coal seams of variable thickness.

The coals are high volatile bituminous type and contain high ash, low sulphur, moderate to high vitrinite, moderate inertinite, low exinite and high mineral matter. Lower seams are high in vitrinite than those of the upper. The coal seams contain several intraseam partings of shaley coal, coaly shale and carbonaceous shale/mudstone.

The thick coal seams were deposited in moderately to poorly drained, densely vegetated and comparatively long persistent backswamps adjacent to the channel-floodplain environments of fluvial regime. This type of thick seams are thought to be formed due to the combined interaction of several factors such as, localised aggradation of fluvial channel, abandonment of part of the channel area, slow and steady subsidence, long and protected time of peat accumulation, favourable palaeoclimate, palaeoflora, etc. with variable magnitude.

INTRODUCTION

In the Jamalgonj basin, a subcrop of the Permian Gondwana sequence with several thick coal seams has been discovered in 1962 by UN-Pakistan, Mineral Survey Project. Since its discovery, several feasibility studies have been carried out (FKR, 1966; RRI, 1976). Ten boreholes have been drilled in this basin during 1962-1964 and seven coal seams have been found within a depth ranging from 640 m to 1158 m amsl. The coal field occupies about 40 km^2 area of the Joypurhat, Bogra and Naogoan districts of the northwestern Bangladesh (Fig. 1). Very few studies have so far been carried out regarding the origin of the thick Gondwana coal seams of Bangladesh (Islam, 1993; Uddin and Islam, 1992). Hence, an attempt has been made to interpret the available data to provide an idea about the origin of the thick coal seams in this basin.

GEOLOGY OF THE BASIN

The Gondwana basin of the Jamalgonj area lies in the Stable Shelf/Bogra Slope of the Platform area (Fig. 1). It occupies an E-W elongated oval-shaped gravity low area with minimum Bouger anomaly value- 40 mgal at its centre. This intracratonic basin is an E-W elongated asymmetric graben/half-graben with an E-W trending northern boundary fault (Buzrak-Durgadaha Fault). The fault is a composite type normal step fault (Fig. 2) having about 357 m down throw towards south (Kappelmayer, 1965; Ahmed and Zaher, 1965). Although it formed earlier but was active during early and middle Tertiary. Gravity data and sedimentary filling materials indicates another fault in the south-southeastern boundary of the basin. The contour on top of the Gondwana sequence and especially on top of the thick seam III indicates a synclinal fold of the sequence.

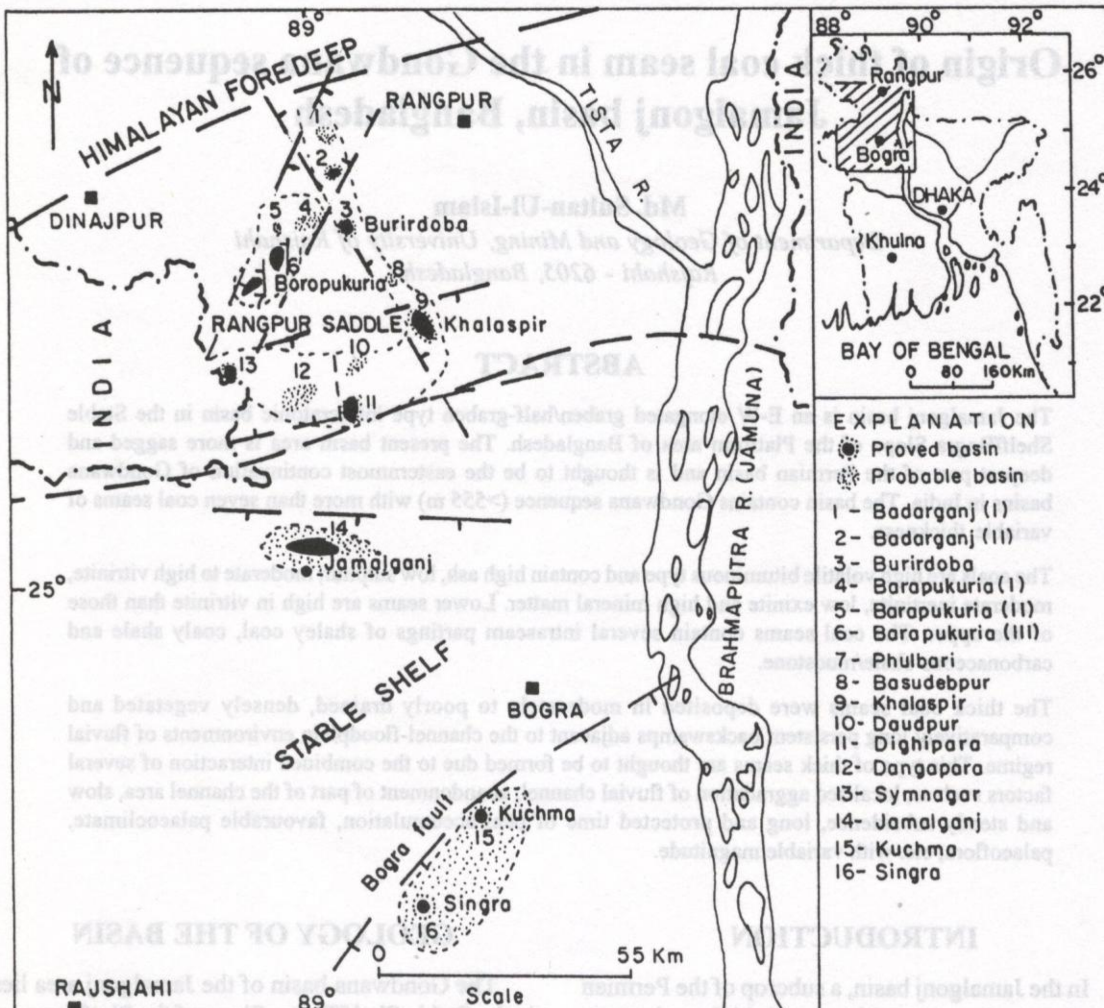

Fig. 1: Location map of the Jamalgonj basin, Bangladesh (modified after Uddin and Islam, 1992).

Geophysical and borehole based stratigraphy indicates that the Gondwana sequence of Permian to Lower Triassic (?) age is overlain by Cherra, Sylhet Limestone, Kopili, Jamalgonj, Dupi Tila and Alluvium formations of Paleocene to Recent age. Although a maximum stratigraphic thickness of about 527 m of the Gondwana sequence are penetrated a thickness of about 1200 m of that are assumed to be present in this basin (FKR, 1969). The base of the Gondwana sequence is not reached but a basal part with the Talchir Boulder Bed is expected to lie on the Archean Basement Complex as it is found in other Gondwana basins of this region.

Lithology of the Gondwana Group varies remarkably. It is divided into two parts (Rahman and Zaher, 1980). The upper part with maximum thickness of 250 m consists of medium to very coarse grained even gritty and conglomeratic arkosic sandstone frequently alternated with microbreccia, conglomerate and occasional thin bands of mudstone and dark siltsone layers. Cross beddings are abundant in the sandstones. A Lower Triassic age is informally asigned to this part of the sequence (Rahman and

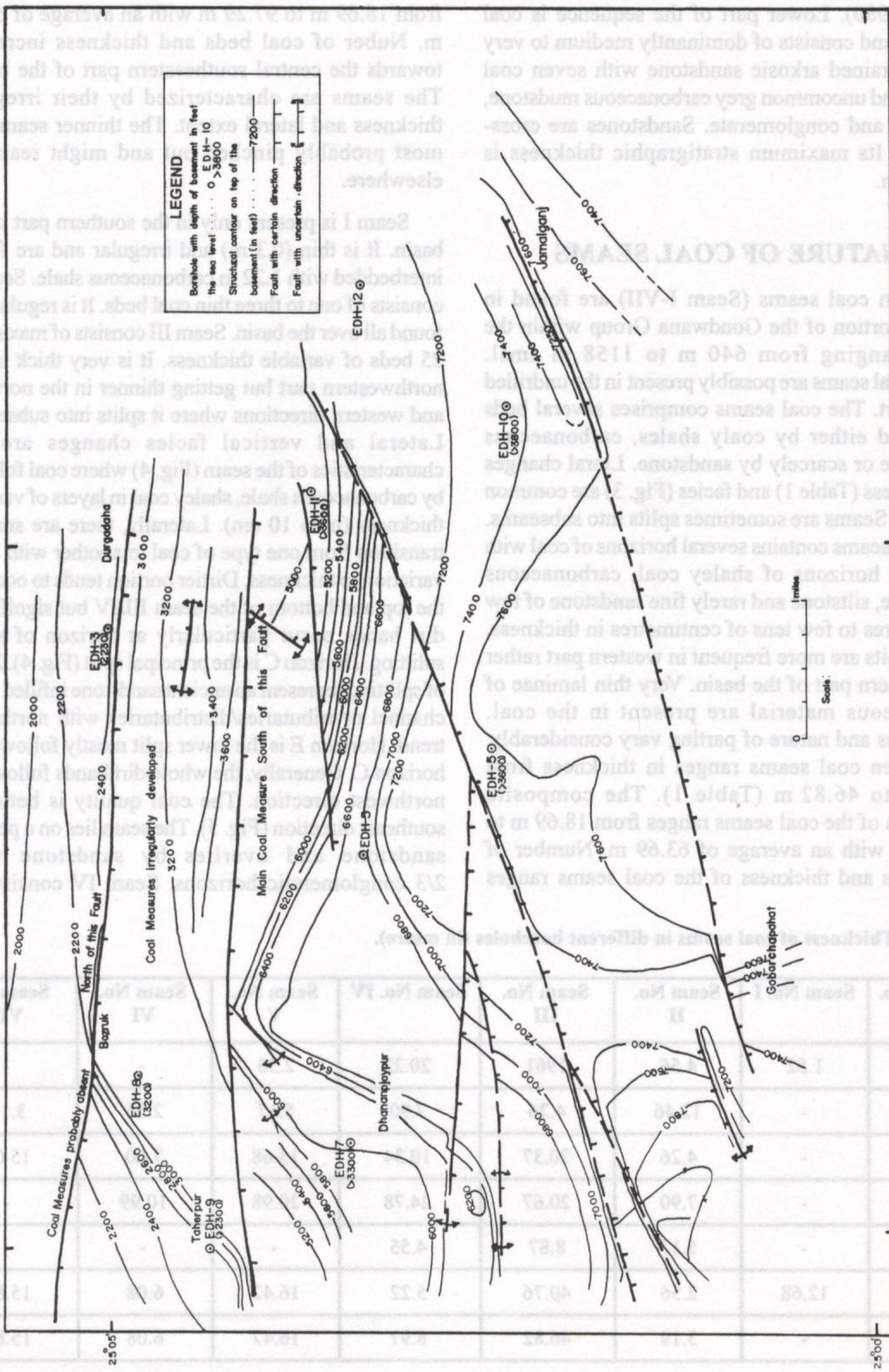

Fig. 2: Basement structure in the Jamalgonj basin, Bangladesh (modified after Kappelmeyer, 1965).

Zaher, 1980). Lower part of the sequence is coal bearing and consists of dominantly medium to very coarse grained arkosic sandstone with seven coal seams, and uncommon grey carbonaceous mudstone, siltstone and conglomerate. Sandstones are cross-bedded. Its maximum stratigraphic thickness is 304.88 m.

NATURE OF COAL SEAMS

Seven coal seams (Seam I-VII) are found in drilled portion of the Gondwana Group within the depth ranging from 640 m to 1158 m amsl. Additional seams are possibly present in the undrilled basal part. The coal seams comprises several beds separated either by coaly shales, carbonaecous mudstone or scarcely by sandstone. Lteral changes in thickness (Table 1) and facies (Fig. 3) are common features. Seams are sometimes splits into subseams. The coal seams contains several horizons of coal with frequent horizons of shaley coal, carbonaceous mudstone, siltstone and rarely fine sandstone of few centimetres to few tens of centimetres in thickness. These units are more frequent in western part rather than eastern part of the basin. Very thin laminae of argillaceous material are present in the coal. Thickness and nature of parting vary considerably. The seven coal seams ranges in thickness from 1.52 m to 46.82 m (Table 1). The composite thickness of the coal seams ranges from 18.69 m to 97.29 m with an average of 63.69 m. Number of coal beds and thickness of the coal seams ranges from 18.69 m to 97.29 m with an average of 63.69 m. Nuber of coal beds and thickness increases towards the central southeastern part of the basin. The seams are characterized by their irregular thickness and lateral extent. The thinner seams are most probably pinched out and might reappear elsewhere.

Seam I is present only in the southern part of the basin. It is thin (0.3 m) and irregular and are found interbedded with 1.22 m carbonaceous shale. Seam II consists of one to three thin coal beds. It is regular and found all over the basin. Seam III consists of maximum 25 beds of variable thickness. It is very thick in the northwestern part but getting thinner in the northern and western directions where it splits into subseams. Lateral and vertical facies changes are the characteristics of the seam (Fig. 4) where coal follows by carbonaceous shale, shaley coal in layers of varying thickness (upto 10 cm). Laterally, there are smooth transition from one type of coal to another with large variation in thickness. Dirtier portion tends to occur at the top and bottom of the seam III/IV but significant dirt bands occur particularly at horizon of seam splitting. Horizon C is the principal split (Fig. 4). Zone of splitting represent an ancient sandstone infilled river channel or tributaries/distributaries with northwest trend. Horizon E is the lower split mostly follows the horizon C. Generally, the whole dirt bands follow the northwest direction. The coal quality is better in southeast direction (Fig. 5). The seam lies on a pebbly sandstone and overlies by sandstone with 2/3 conglomeratic horizons. Seam IV consists of

Table 1: Thickness of coal seams in different boreholes (in metre).

Hole No.	Seam No. I	Seam No. II	Seam No. III	Seam No. IV	Seam No. V	Seam No. VI	Seam No. VII
5	1.52	4.56	1961	20.22	2.36	-	-
6	-	12.46	4.26	7.90	5.17	2.56	3.19
7	-	4.26	20.37	10.34	13.68	7.60	15.05
8	-	7.90	20.67	24.78	20.98	10.99	-
9	-	5.17	8.87	4.55	-	-	-
10	12.68	2.56	40.76	5.22	16.42	6.08	15.81
11	-	3.19	46.82	8.97	16.42	6.08	15.81

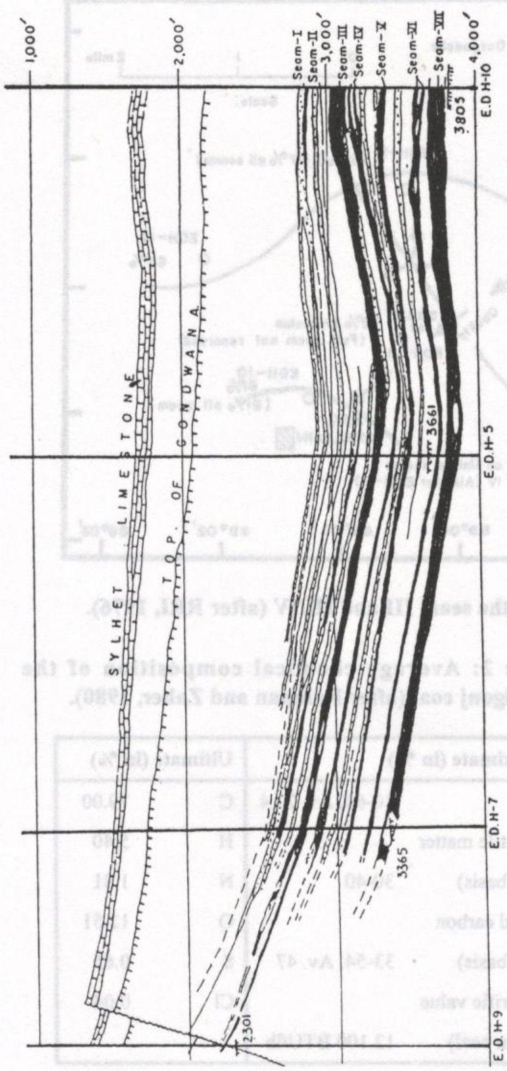

Fig. 3: Geological cross-section of the Jamalgonj coal field, Bangladesh (after savornin, 1964).

several beds (3-19) of variable thickness separated by coaly shales. In the northwestern part the seam IV and III are separated by conglomeratic episodes. Seam V is rather thin and irregular and becomes thin from south towards north and northwestern parts. Seam VI consists of one to seven beds. Its thickness increases towards the central-southern part of the basin. In northern part the coal grades into mostly shale and shaley coal. The interseam between VI and V is sandstone with conglomerate. It is missing in the central-northern part most probably due to facies changes or erosion. Seam VII consists of large number of cleanest coal beds separated by carbonaceous shale. Its thickness is variable.

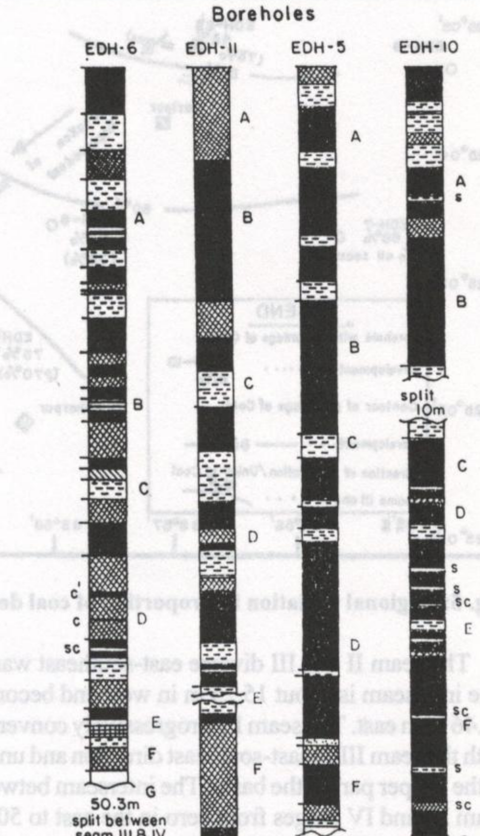

Fig. 4: Vertical section of the coal seam III and IV.

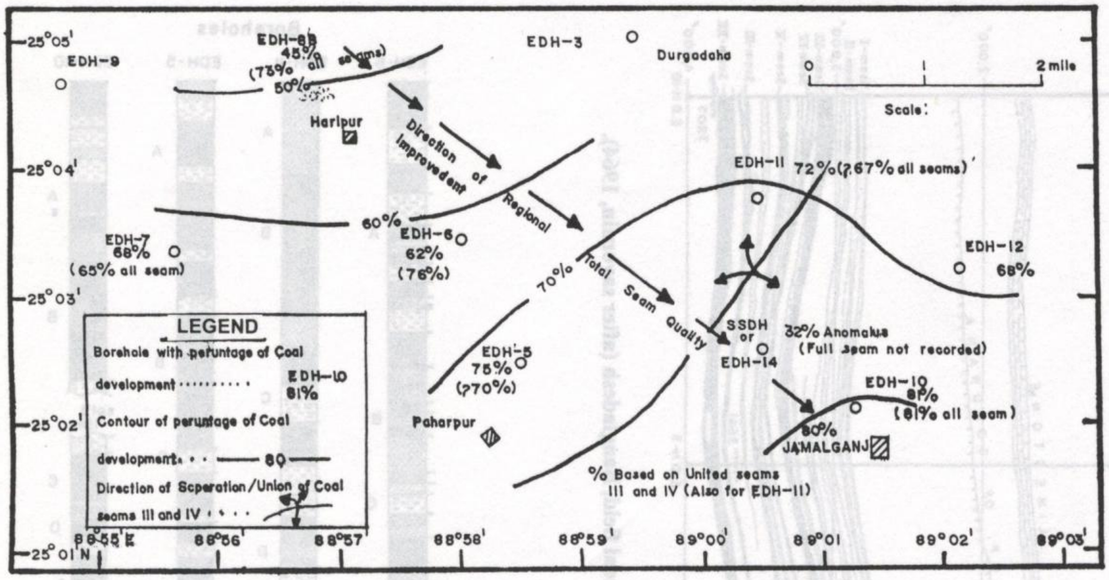

Fig. 5: Regional variation in proportion of coal development in the seam III and III/IV (after RRI, 1976).

The seam II and III diverse east-southeast wards. The interseam is about 15.25 m in west and becomes 91.46 m in east. The seam IV progressively converges with the seam III in east-southeast direction and unites in the deeper part of the basin. The interseam between seam III and IV ranges from zero in the east to 50.30 m in the west. Upper contact of the coal seams in most cases are sharp. In few cases, it is gradational. The roof rocks are medium to very coarse grained feldspathic sandstone, conglomeratic, sandstone or gritstone. These sandstones especially in the southern and south eastern part contain several conglomeratic horizons. This indicates a rejuvenated tectonic impulse and channel sedimentation. Lower contact of these coal seams are in most cases gradational. The bottom rocks grade from gritstone to feldspathic sandstone, carbonaceous sandstone, carbonaceous shale, mudstone and coal. Carbonaceous shale/mudstone below coal beds ranges from 0.3 m to about 2.9 m in thickness.

CHARACTERISTICS OF COAL

Generally the coals are bright with alternate bands of bright and dull coals. Chemically, these are typical Gondwana coal (Table 2). Ash content is higher in the upper seams. Fixed carbon and calorific values slightly increase with increasing depth. The coal is high volatile bituminous coal (RRI, 1976). The rank increases towards the east and southern part of the basin.

Table 2: Average chemical composition of the Jamalgonj coal (after Rahman and Zaher, 1980).

Proximate (in %)		Ultimate (in %)	
Ash	10-60, Av. 22.4	C	79.00
Volatile matter		H	5.40
(dry basis)	30-40	N	1.81
Fixed carbon		O	12.51
(dry basis)	33-54, Av. 47	S	0.65
Calorific value		Cl	0.04
(clean coal)	12.100 BTU/lb		

The coal of the upper seams contains comparatively higher inertinite, moderate exinite and lower vitrinite than those of the lower seams (Table 3). Dispersed mineral matter content is high (1.7-18.5%) with most of these contain less than 10%.

ORIGIN OF THICK COAL SEAMS

Thin and moderately thick coal seams are more abundant and are associated with fining upward sandstone sequence. Their thickness and

Table 3: Average petrographic composition of the Jamalgonj coal (after Rahman and Zaher, 1980).

Seam	Vitrinite %	Exinite %	Intertinite %	Mineral Matter %
Upper	19.5 - 44.2	3.6 - 22	27.6 - 41.7	4.7
Lower	46.7 - 61.4	5 - 10	21.8 - 22.5	8.8

composition varies irregularly. These are splitted and in many cases, grades laterally into shaley coal, coaly shale, carbonaceous shale, etc. All these indicating a short to moderately peristent and comparatively less restricted backswamp condition. These swamps lie adjacent to the floodplain and were frequently invaded by flood water and repeatedly encroached by crevasse channels (Fig. 6). Very thick seams are abundant in the basin which extended throughout the present basin area with gradual changes in thickness. Several thin partings of generally mudstone present throughout the basin. In many places, the coal grades vertically and laterally into shaley coal, coaly shale or carbonaceous mudstone. These indicates a long persistant, moderately restricted, densely vegetated backswamps adjacent to floodplain and channel (Fig. 6). These basins accompanied by slow but gradual subsidence as it is found in cratonic basins.

Both the symmetrical and asymmetrical cycles of sedimentation are present in these sequence. Asymmetric cycles are generally developed in sequence rich in sandstone, which is typically seen in this basin. Direct emergence of coarse clastics on coal seams indicate a tectonic impulse and recurrence of channel environment. The symmetrical cycles indicate a gradual change of environment of deposition. The thick cross-bedded sandstone at the base of these seams were deposited in channel but

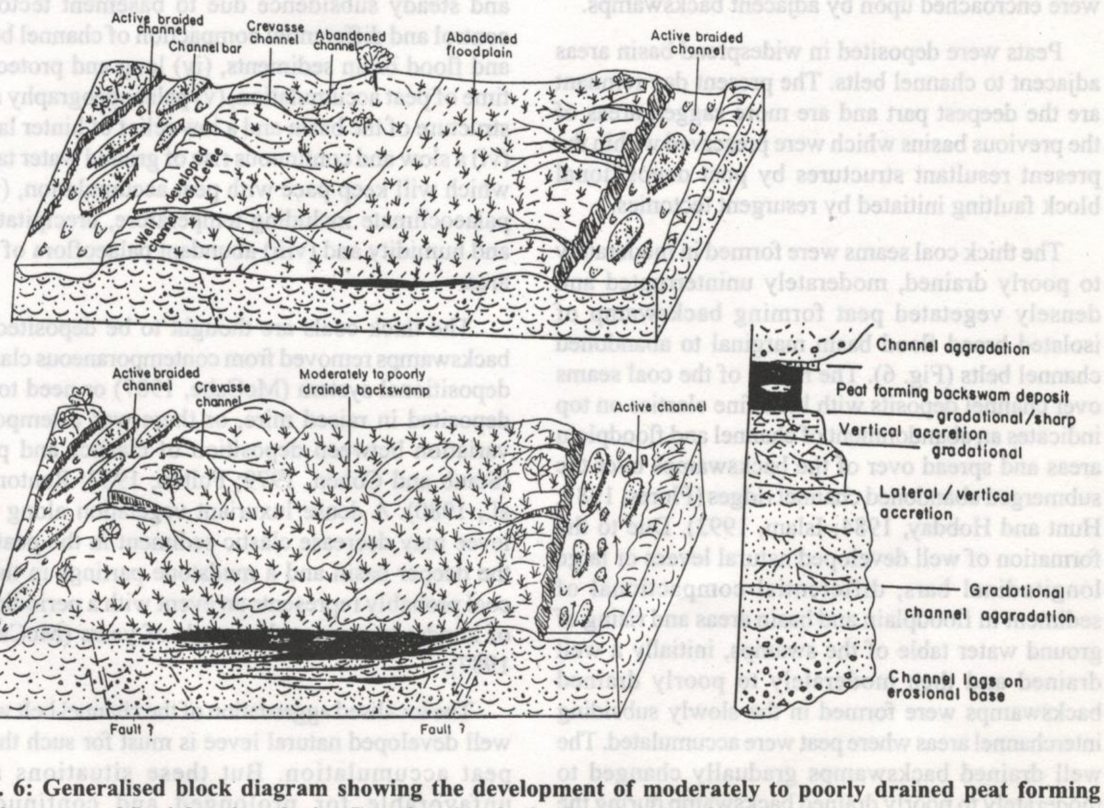

Fig. 6: Generalised block diagram showing the development of moderately to poorly drained peat forming backswamps of fluvial regime during Permian time in the Jamalgonj and adjoining area.

fine sandstone, siltstone, interlaminated mudstone-siltstone and mudstone might have been deposited at natural levee, crevasse channel and splay in the floodplain. These sequence with abundant organic materials indicate a flood basin or backswamp with sparse vegetation. The seams which are associated with only arenaceons rocks indicate and abandoned channel condition. Cyclic and repeated sequences of sandstone, siltstone, mudstone and coal indicate a repeated recurrence of channel, floodplain and flood basin environments and spasmodic tectonic activity along the basin margins or fault zone areas. Microbreecia and conglomerate episodes in different horizons of the sequence supports this view. Like a typical backswamp facies, the coal facies consists of coal and carbonaceous mudstone where the coal beds are underlain, overlain and grade laterally into and interbedded with the carbonaceous mudstone. In some cases, thick coal beds are just above channel-overbank deposits suggesting an abandonment of channel-overbank deposits which served as topographically high alluvial ridges that frequntly were encroached upon by adjacent backswamps.

Peats were deposited in widespread basin areas adjacent to channel belts. The present day remnant are the deepest part and are more sagged areas of the previous basins which were preserved within the present resultant structures by post depositional block faulting initiated by resurgent tectonics.

The thick coal seams were formed in moderately to poorly drained, moderately uninterrupted and densely vegetated peat forming backswamp of isolated broad flood basin marginal to abandoned channel belts (Fig. 6). The riding of the coal seams over channel deposits with little fine clastics on top indicates an abandonment of channel and floodplain areas and spread over of the backswamps over the submerged abandoned channel ridges (Flores, 1981; Hunt and Hobday, 1984; Islam, 1993). Due to the formation of well developed natural levees or large longitudinal bars, differential compactional of sediment in floodplain and basin areas and rising of ground water table of the swamps, initially a well drained and then moderately to poorly drained backswamps were formed in the slowly subsiding interchannel areas where peat were accumulated. The well drained backswamps gradually changed to moderately to poorly drained backswamp during the deposition of thick coal seam which is indicated by the presence of channel sandstone at the base and frequent presence of carbonaceous shale/mudstone, shaley coal and high ash coals in these coal seams. The partings of fine clastic and shaley coal were formed during moderate to widespread incursion of flood water into the backswamps.

The thick coal seam of the basin is associated with abandoned channel deposits are found in sandy braided river (Hazzeldine and Anderton, 1980) and alluvial fan (McKenzie and Britten, 1969) environments. But the thick coal with remarkable percentage of fine clastic deposits are generally associated with channel-flood basin deposits of meander belt or channel-lake deposit (Flores, 1983; Coleman, 1966).

Hence, these thick coal seams of the Jamalganj basin is thought to be the result of combined interaction of varying magnitudes of the followings: (i) localised aggradation of fluvial channel, (ii) abandonment of part of the channel area, (iii) slow and steady subsidence due to basement tectonic control and differential compaction of channel belts and flood basin sediments, (iv) long and protected time of peat accumulation, (v) palaeogeography and structure of the basin and a low relief of hinter land, (vi) a slow and continuous rise of ground water table which will keep pace with peat accumulation, (vii) palaeoclimate including temperature, precipitation and humidity and (viii) abundant palaeoflora of the area.

The thick coals are thought to be deposited in backswamps removed from contemporaneous clastic depositional system (McCabe, 1987) or need to be deposited in raised mire, or there was a temporal variation between deposition of clastics and peat (Staub and Cohen, 1979; Fulton, 1987; Renton et al., 1980). A dense luxuriant vegetation along the levee may decrease clastic sediment in the peat of the deeper basin and a mudstone partings in these coal probably represents an event with a periodicity of hundreds or even thousands of years (McCabe, 1987).

The localised aggredation of the channel belt with well developed natural levee is must for such thick peat accumulation. But these situations are unfavorable for prolonged and continuous accumulation of thick peat (McCabe, 1984; Flores, 1981, 1983). It is believed that the same situation was prevailed in the study area but clustering of channel belt deposits which is coeval to thick coal seam deposition, if present, was most probably outside of the present basin area. Palaeogeography and structure of the basin with low relief of the hinter land most probably play an important role in the deposition of thick coal seam and preventations of coarse clastic incursion in the backswamps. During deposition of the coal seam, the palaeogeography of the area was most probably in peneplain stage with a few irregularity at bottom sediment surface. It is indicated by the thickness of the seam. But the greater subsidence had been occurred along the central and east-southeastern parts of the basin and the thickness of the coal seam is higher in that areas.

The Gondwana vegetation was dominated by swamp-dwelling Gymnosperm with subsequent Glossopterids deciduous plants which grew in humid temperate climate (Hobday, 1987). The Jamalgonj coal does not contain broad bands of bright coal and are alternated with bright and dull coals. These are thought to be the product of temperate or cool climate and a relatiely stunted flora (Chandra and Taylor, 1982). The coal contains moderate inertinite, moderately abundant vitrinite and low exinite. It also contains abundant mineral matter. Fusain present as discrete layers and lenses. The dull and bright coals are present in repeated fashion. These indicate periodic dry events or exposure of peat swamps to dryness (Scott and Collinson, 1978; Teichmüller, 1982; McCabe, 1984; Chandra and Taylor, 1982). The inertinite rich coals also indicate a lower rate of subsidence of the basin area which is supported by the cratonic position of the Jamalgonj basin. The repeated sequence of vitrinite and inertinite coal with an upward increase of inertinite indicate an increasing desiccation of the swamps or a relatively stable basement. Again thick peat can be developed where accumulation of peat debris exceeds it degradation.

Accumulation of thick peat needs a long and protected period of time (McCabe, 1984, 1987; Collinson and Scott, 1987). It is very difficult to provide an idea about the time span required for the deposition of these thick coal seams. Based on a peat accumulation rate of 1.72 m/1000 years for 26 modern swamps and compaction ratio of 6:1 for peat to bituminus coal (Murchison, 1982), the Jamalgonj backswamps for the deposition of the sem III may have persisted for as long as 1,64,000 years. A further exploration around the basin and in most part of the Platform area may provide a comparatively better scenario of depositional history of thick coal seams.

CONCLUSIONS

The Gondwana sequence of the Jamalgonj basin contains several horizons of thick coal seam. These coals are high volatile bituminous type with high ash and low sulphur. Lower seams are high in vitrinite, moderate in inertinite and low in exinite than those of the upper seams.

These thick coal seams were deposited in moderately to poorly drained, densely vegetated and comparatively long persistent backswamps adjacent to channel-floodplain fluvial regime. Both the allochthonous and autochthonus type of peat deposition might have been occurred in this area. These thick coal seams are the results of combined interaction of several factors. The present basin area is thought to be more sagged and deepest parts of the previous basin now preserved within crystalline basement by post depositional block faulting and resurgent tectonics.

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