SEDIMENTOLOGICAL STUDIES IN PARTS OF JHARIA AND EAST BOKARO COALFIELDS *

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ABSTRACT

The brief investigations so far carried out on aspects of sedimentology in parts of Jharia and East Bokaro Coalfields have rendered it possible to classify the Gondwana rocks of these coalfields more or less according to facies and to establish tentatively the petrographic, sorting and heavy mineral characteristics of the individual facies on a fairly regional basis.

The heavy mineral assemblage of the Talchir stage is characterized by the predominance of garnet and a more or less complete absence of tourmaline. The Barakar assemblage is characterized by the predominance of tourmaline, fairly high proportion of zircon and complete scarcity of garnet. On the basis of heavy mineral assemblage a transition stage at the base of the Barakar is recognized which contains both garnet and tourmaline. But the garnets here are strongly etched, a characteristic feature which is not observed in the garnets of the Talchir stage. The Barren Measure and the Raniganj stages, though they contain a larger proportion of tourmaline, also display a fairly high count of garnet.

The shale-siliceous limestone facies of the Barakars, the entire Barren Measures and almost two-thirds of the Raniganj stage appear to be derived sediments from the same provenance.

Stratigraphic breaks almost on a regional scale which have ushered in a change in facies, occur between the lower and the middle Barakar groups and almost along the top of the Barakar horizon. Breaks of lesser significance occur in the Barren Measures and the Raniganj stage.

On the basis of increasing coarseness of sediments and an increased incidence of conglomerate occurrence, it is suggested that when the first Barakar sediments were deposited the direction of transportation was from west to east both in the Bokaro and the Jharia coalfields. We shall be in a position to obtain a more complete picture of aspects of sedimentation in the Gondwana basins of the Damodar Valley as our studies progress and detailed work is extended to the other basins of the valley as well.

INTRODUCTION AND SCOPE OF WORK

A detailed and comparative inquiry into the problem of Gondwana sedimentation in the coalfields of the Damodar Valley was initiated during the last field season (1956-57). The purpose of the investigation has already been stated in fair detail by K. Jacob (*in Press*). All aspects suggested therein could not be tackled during the limited period available for field and laboratory work, but in order to obtain a preliminary idea the following aspects of study received special attention and in this brief introductory account the results of our investigations on the lines suggested are incorporated, as they are considered of significance:

(1) Accurate measurement of type nala sections with a view to compiling stratigraphical successions in the different parts of the two coalfields;

(2) Classification of the sediments in the field into easily recognizable facies, and preparation of a lithofacies map;

(3) Collection of samples, from the different lithologic units and the careful petrological examination and analyses of selected samples of sandstones, in the first instance, to establish the petrographic, sorting and heavy mineral characteristics of the individual facies;

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(4) Based on these data, to correlate as far as possible, the sediments and coal seams of the two adjoining coalfields of the Damodar Valley, namely the Jharia and the East Bokaro basins.

It should be possible, after further work, to ascertain more adequately the influence of the environmental and tectonic factors on the formation of coal and how far these factors, either singly or collectively, acted as a control on the quality of coal.

Location of Lines of Traverses

In the Jharia coalfield, sections exposed in the Jamunia (86° 10′ 30″), Kudia (86° 14′ to 86° 17′) and another branch of the Kudia lying between the latter and Katrasgarh (all the nalas situated in sheets 73 I/I and 5) have been carefully measured. Based on comparison of the lithologic successions compiled from these traverses, a plan and vertical longitudinal sections have been prepared showing the distribution and tentative correlation of the lithologic units (Text-figs. 5 and 6).

The Jamunia nala exposes a complete succession of the Talchir, Barakar, Barren Measure and Raniganj stages. The Kudia and its tributary, where the Talchir succession is to a great extent curtailed, however give a better picture of the Barakar rocks on account of the gentle dips and simple structure.

In the Bokaro field the two nalas in the vicinity of Phusro station (along longitude 86° 01′ and 86° 03′) and the section exposed in the Damodar river have been measured in detail. Therefore, so far as the distribution of facies and their general properties are concerned, the present survey gives a comparative and regional picture of the Talchir and Barakar rocks in the eastern portion of Bokaro and western Jharia. Regarding sediment properties and facies distribution in the Barren Measures and Raniganj stages, sections along alternative traverses are not yet studied to permit the drawing of a comparative picture.

Classification of Gondwana Sediments

An attempt is made in the following pages to classify the Gondwana sediments on the basis of gross composition and the characteristics of sandstones of each group are detailed.

(*1*) *Talchir Stage*

The following is the generalized gross lithological composition of the Talchir stage and is representative of both the Jharia and Bokaro fields (Text-figs. 5 and 6).

Medium grained sandstone	20 per cent.
Fine grained greenish sandstone, laminated shale and clay ..	80 per cent.

The basal boulder bed, which is of restricted distribution, attains a maximum thickness of about 8 feet.

The thickness of individual beds varies from a fraction of an inch, in the case of shales and clays, to 2 feet in the case of sandstones. Totally lacking in scalar properties, these rocks however maintain a rough gradation. Individual units measuring on an average 6 feet thick are found composed of a greenish fine grained sandstone at the base which gradually grades into finely laminated shale and finally clay. Alternations of such units constitute the bulk of the Talchir stage. The shales and clays together form a higher proportion of the bulk than the sandstones.

Among the Talchir sandstones the predominant type is fine grained and greenish. This rock resembles a typical graywacke. More than 60 per cent of the rock constitutes the matrix which is composed essentially of a chloritic paste. Set in this matrix are highly angular grains of quartz and felspar. The felspars are very fresh

and their proportion is generally about half that of quartz. The medium grained buff sandstone occurs as thin bands, and judging from its lower proportion in the matrix, better rounding of grains and lower coefficient of sorting, it perhaps represents washed or reworked graywacke (*see* Table I).

The *sorting* displayed by the Talchir rocks as a group is extremely poor. The washed graywacke or the medium grained sandstones however are better sorted. The sorting values calculated for this rock indicate that it is a well sorted sediment with a uniform range of distribution and a high value of kurtosis for the median (Text-figs. 1 and 2; Table II).

The *heavy mineral* assemblage of the Talchir rocks is characterized by the predominance of garnet, either total absence of, or even if present, insignificant quantity of tourmaline and presence of monazite and epidote (Table II).

The nearby granite-gneiss appears to have contributed most of the mineral constituents to the Talchir rocks. Basic igneous rocks and quartzites have contributed the matrix and rock fragments respectively.

(2) *Barakar Stage*

Sediments of the Barakar stage comprise three lithofacies whose gross composition displays remarkable individuality. The type rocks whose relative proportion has been employed as the basis for this classification are the coarse grained sandstone and grit, flaggy sandstone and sandy shale, and calcareous sediments. In the case of the last mentioned, the first appearance of the rock is of greater significance than the actual proportion. The following is the gross composition of the three units, and the scalar and the vector properties of each group shall be discussed separately (Text-fig. 6).

	Lower	Middle	Upper
Calcareous sediments	–	–	1–7%
Sandy shale	–	51–67	46–68
Grit and coarse sandstone	62–73	4–11	0–7

Barakar Lower Group:

The sandstones comprising this group are white to pale buff in colour, coarse, friable and their total thickness varies from 300 to 380 feet. The thickness of the individual bed varies from 4 to 12 feet. The massive nature of these sandstones prevents cross bedding forming a characteristic feature. The average thickness of the cross bedded units is roughly 1 to 1½ feet. But the trend of the current bedding is rather confused and an accurate measurement of the attitudes is not possible.

The sandstones are essentially composed of quartz (46 to 71 per cent), set in a matrix of sericite and clay probably of a detrital nature (25 to 42 per cent) with a small proportion of rock fragments which, nevertheless, exceeds that of felspars. The basal grit of this unit which overlie the Talchir stage resembles the latter in the chloritic nature of the matrix and the presence of an occasional grain of clouded felspar (Table I).

The grains of quartz are angular to subangular in the basal grits and subrounded in the sandstones along the top of the horizon.

The sandstones and grits on the basis of their mineral constituents, nature and proportion of matrix and shape of the grains have been classified as 'Protoquartzites'. They represent a stage where the rock is mature enough to be totally rid of felspar content, but retains the detrital matrix and the rock fragments thus occupying a position between arkose and orthoquartzite.

The sorting of the sandstones is fair but that of grits tends to be poor and the distribution in the case of the latter is typically bimodal. The frequency curves drawn for samples from the Kudia and Mahtadih nalas, when compared to those

from the Jamunia, is negatively skewed. The median values are generally higher which indicates a tendency to coarseness towards east (Text-figs. 1 and 2; Table II).

The basal grit of the Barakar stage continues to retain Talchir characters with a fair proportion of garnet (nearly 40 per cent), the grains of which are strongly etched, a feature which makes it easily distinguishable from the garnets of Talchir assemblage. But the typical *heavy mineral* assemblage of the lower Barakar group is characterized by either a total absence or insignificant garnet content, predominance to tourmaline, an increase in the zircon ratio and the appearance of rutile in appreciable quantities (Table II).

Barakar Middle Group:

Separated from the lower group by a well developed grit zone the middle Barakar group is composed predominantly of sandy shale. Interbedded with sandy shales are thin bands of flaggy sandstone.

The total thickness of this group varies from 490 to 680 feet. The thickness of the individual bed of shale varies from half an inch to a maximum of four inches and that of sandstone from 3 to 12 inches. The latter displays well developed current bedding, and the thickness of the individual current bed varies from a fraction of an inch to a maximum of 3 inches.

The flaggy sandstones are essentially composed of quartz (60 to 75 per cent) and a small proportion of rock fragments (3 to 5 per cent) set in a matrix of clay, sericite and ferruginous material. The grains are subrounded. Petrographically these rocks are similar to those of sandstones and grits of the lower group except that the former contain less of detrital matrix and rock fragments and the grains show better rounding. These sandstones have reached a stage of greater maturity than the rocks of the lower group (Table I).

The flaggy sandstones as a whole are definitely better sorted than the sandstones of the lower group. They are also finer in average grain size with a low median value. The dispersion (of sorting values) is very small among the different samples, thus indicating the homogeneous nature of the whole group (Text-figs. 1 and 3; Table II). The frequency curve is skewed slightly and the skewness is generally positive which indicates that a larger proportion of the grains are finer than the median.

The heavy mineral assemblage of this stage is characterized by almost total absence of garnet, an increase in the zircon content which exceeds that of tourmaline and a high proportion of opaque ores.

Barakar Upper Group:

The total thickness of this stage varies from 520 to 820 feet. The marker horizon employed to demarcate this group is the calcareous sandstones. But for this rock type there is no marked change in the gross composition between the upper and the middle subdivisions.

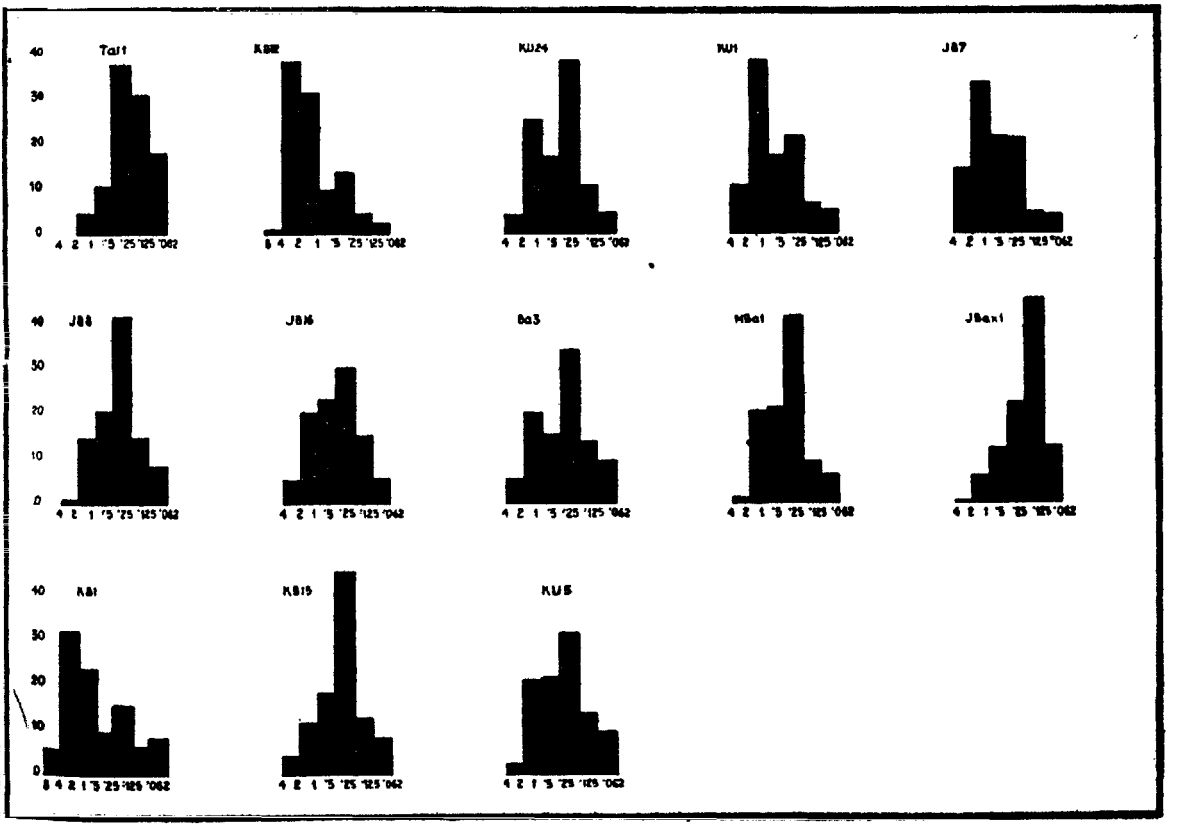
The calcareous sandstone is a thin bedded grey to brown, dense, massive rock varying in thickness from 8 inches to a maximum of 1½ feet. The outcrops are generally characterized by gaping solution cracks and the rock breaks with a conchoidal fracture. It generally occurs as thin bands interbedded with sandy shales; and individual units, composed of flaggy sandstone, sandy shale, calcareous sandstone and carbonaceous shale or coal, repeat themselves in almost a cyclic order.

The calcareous sandstone is essentially composed of angular grains of quartz (20 to 35 per cent), rock fragments (1 to 4 per cent) and felspar (1 to 3 per cent), set in a dense brown carbonate matrix (57 to 77 per cent). In view of the high specific gravity of this rock the matrix is probably sideritic. This rock to a great extent resembles what in modern American terminology has been described as calcarenite and calcilutite (Table I).

The fine grained sandstone which forms a subordinate quantity has the same mineral composition as the calcareous sandstone but in this case the matrix does not exceed 35 per cent and is composed of sericite and clay.

The *sorting* of these sandstones is fair but not so good as that of the middle group. The median, skewness, and kurtosis factors are low, but the value of sorting coefficient is rather high (Text-figs. 1 and 3; Table II).

Heavy mineral assemblage of this group of rocks is characterized by the predominance of tourmaline, a fair frequency of zircon with a definite increase in the rutile content and continued scarcity of garnet (Table II).



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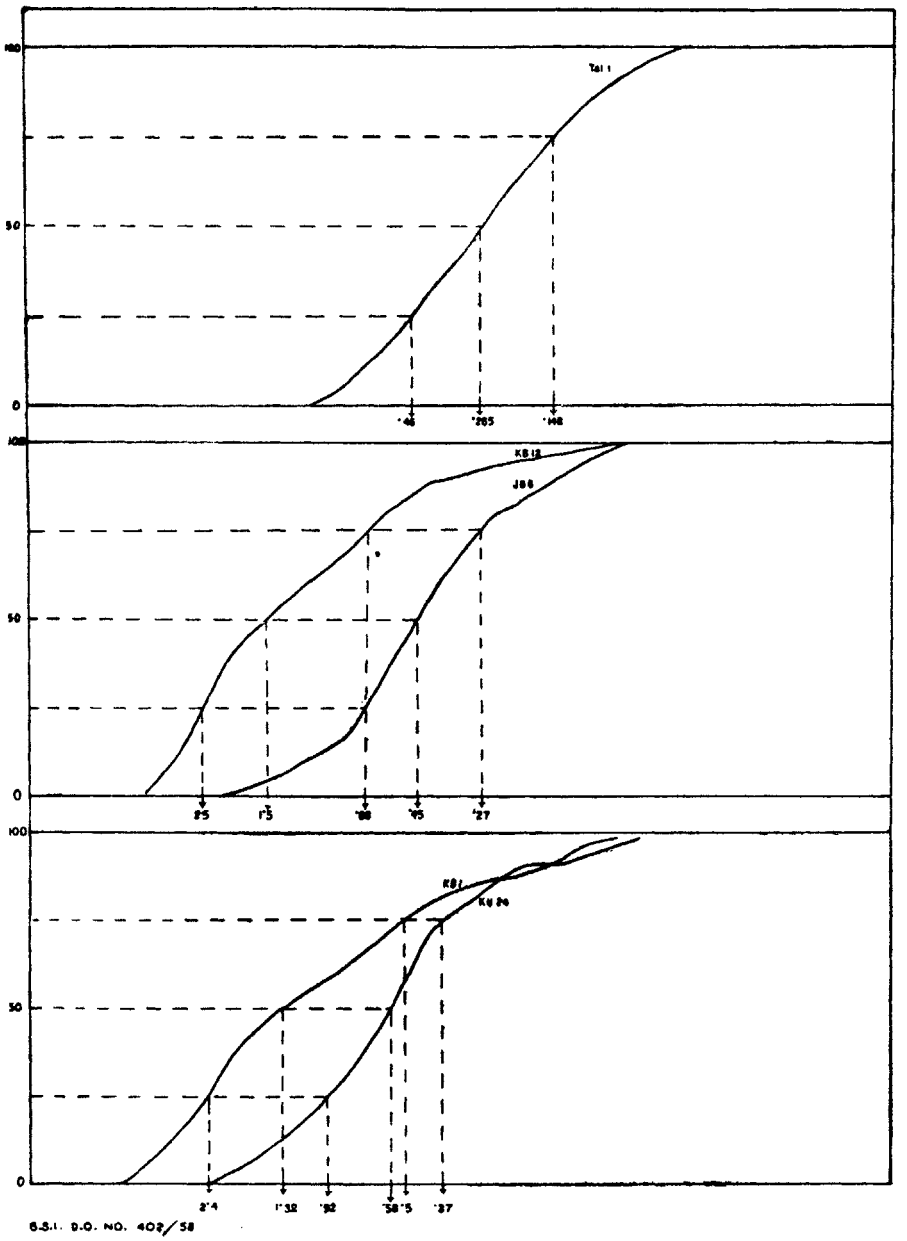
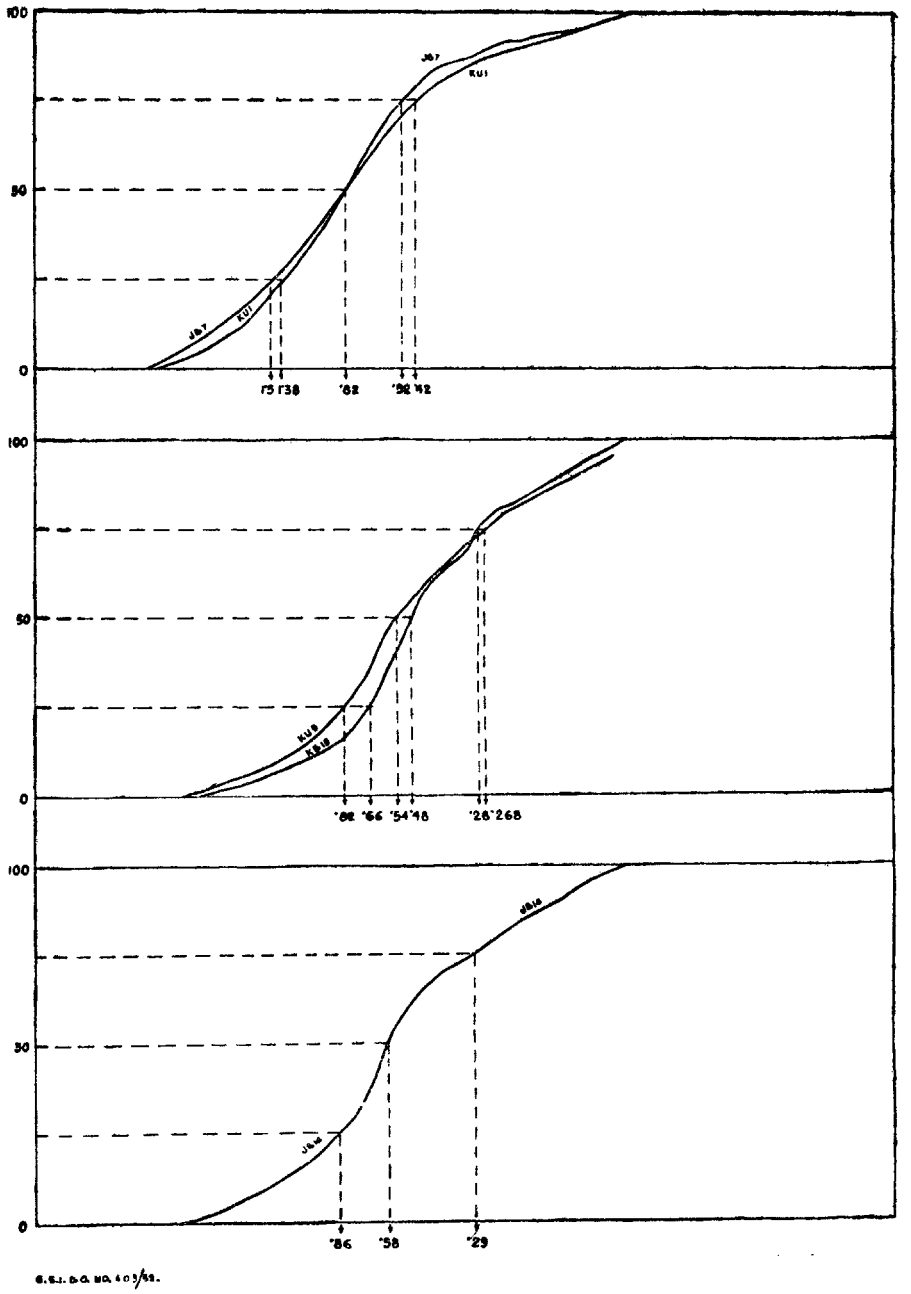
TEXT-FIG. 1. Mechanical analyses of Gondwana sandstones.

Tal1: Talchirs, Khudia nala. *KB12:* Lower Barakar, Matadih nala. *KU24:* Lower Barakar, Khudia nala. *KU1:* Middle Barakar, Khudia nala. *JB7:* Lower Barakar, Jamunia nala. *JB8:* Middle Barakar, Jamunia nala. *JB16:* Upper Barakar, Jamunia nala. *Ba3:* Barren Measures, Khudia nala. *MBa1:* Lower Barren Measures, Mahuda nala. *JBax1:* Lower Barren Measures, Jamunia nala. *KB1:* Lower Barakar, Matadih nala. *KB15:* Middle Barakar, Matadih nala. *KU5:* Middle Barakar, Khudia nala.



TEXT-FIG. 2. Mechanical analyses of Gondwana sandstones.

Tal1: Talchirs, Khudia nala. *KB12:* Lower Barakar, Matadih nala. *JB8:* Middle Barakar, Jamunia nala. *KB1:* Lower Barakar, Matadih nala. *KU24:* Lower Barakar, Khudia nala.



TEXT-FIG. 3. Mechanical analyses of Gondwana sandstones.

JB7: Lower Barakar, Jamunia nala. *KU1:* Middle Barakar, Khudia nala. *KU5:* Middle Barakar, Khudia nala. *KB15:* Middle Barakar, Matadih nala. *JB16:* Upper Barakar, Jamunia nala.

Source Material of Barakar Rocks

The three broad, but distinct, lithofacies into which the Barakar sediments fall, indicates at least one significant change in the provenance also.

The conglomerate horizon, which occurs at the base of the Barakar in the western extremity of the Jharia field, contains pebbles of quartzite nearly 50 per cent of which is the banded cherty type. The rest of the quartzite pebbles are the grey and white, medium grained type whose source is indeed very wide open to choose. But when compared to the quartzite pebbles found in the Talchir rocks, it is clear that the source of the banded quartzite is definitely different from the former.

The provenance for lower and middle groups of Barakar rocks appears to be the same. The mineral constituents are derived from granitic rocks and the sericite found in the matrix and the rock fragments have been contributed by low grade metamorphic rocks. The difference in the lithofacies between the lower and middle groups of Barakar is probably due to better sorting and deposition under quieter conditions rather than a difference in the provenance. Pebbles which are found frequently in the Barakar rocks are mostly of vein quartz.

The group of rocks found along the top of the Barakar stage however poses a different problem. The repeated occurrence of thin bands of calcareous sandstone and the presence of fresh felspar indicates a source which is evidently different from that of the lower stages. Another interesting feature is the fanglomerate containing boulders of quartzite and pebbles of granite gneiss, epidiorite, chlorite and biotite schist. This again seems to indicate a source which was different from that of the earlier sediments.

Barakar Rocks in the Bokaro Coalfield

The following is the gross composition of Barakar rocks in this field which attain a total thickness of not less than 800 feet (Text-fig. 7):

Sandstone	26 to 34 per cent.
Grit and conglomerate ..	24 to 33 per cent.

The petrography, texture and heavy mineral assemblage of these rocks reveal a striking resemblance to the coarse grit and sandstone comprising the lower group of the Barakar rocks of the Jharia coalfield. They probably represent a coarser variation of the Jharia rocks. There is also a closer parallelism with the Barakars found in the western extremity of the Jharia field (Table III).

The baffling rock type of this field is the group of greenish fine grained sandstone, nearly 300 feet thick, containing thin bands of carbonaceous shale, found south of the Govindpur-Pichri fault. These sandstones are best exposed in the Damodar river. These rocks fall into the group of sub-graywacke (angular grains of quartz and felspar, set in a fairly prominent chloritic matrix) and do not have anything in common with the type of Barakar rocks of this field with which they are in faulted contact.

(*3*) *Barren Measure Stage*

Rocks of this stage exposed in the Jamunia (western parts of the Jharia coalfield) fall into the following broad groups:

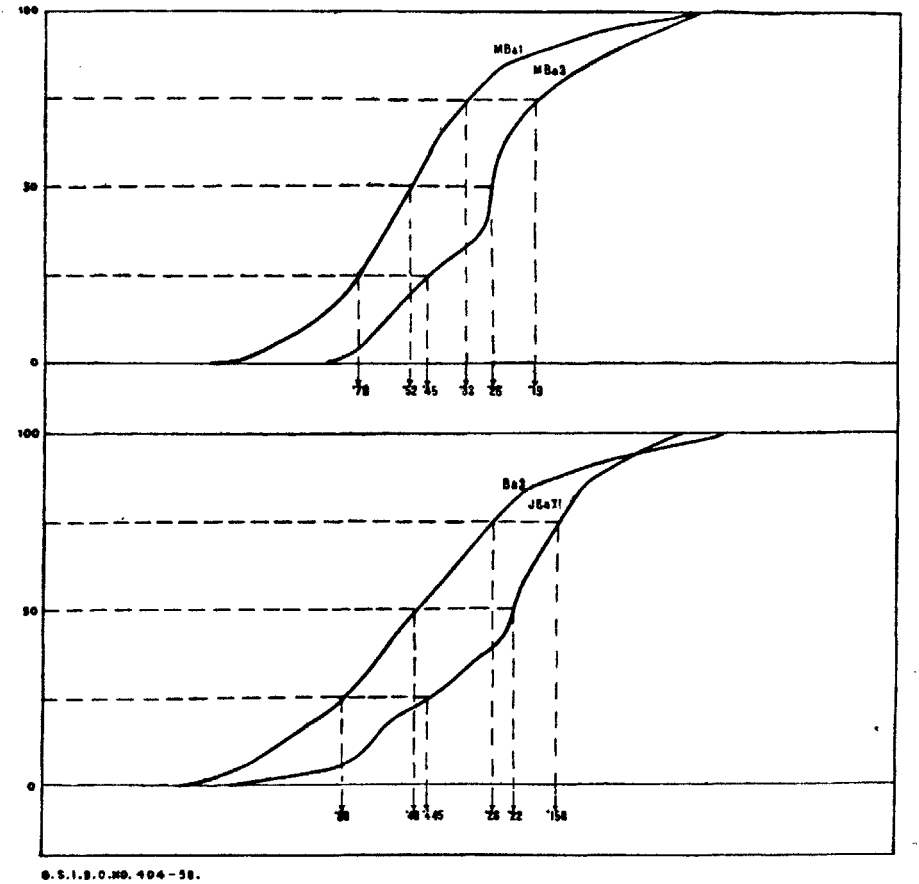
Finely laminated, micaceous, slightly ferruginous shale with interbedded flaggy sandstone	200′
Flaggy sandstone with intercalations of sandy shale	200′
Predominantly shaly horizon with thin bands of ferruginous and carbonaceous shale	200′
Medium grained sandstone with intercalations of sandy shale ..	600′

Bands of calcareous sandstone are intercalated with shales throughout this stage. The most striking rock type of the Barren Measure stage is the finely laminated micaceous sandy shale wherein the individual lamina has the thickness of a few inches and displays a remarkably fine current bedding which has a thickness even much less than what is stated above.

The Barren Measure sandstones belong to two different types. The scalar properties displayed by the two types are similar—the thickness of the individual beds vary from a few inches to a maximum of one foot. The sandstones generally display well developed current bedding.

The sandstone from the base of the stage is essentially composed of quartz (50 per cent), felspar (25 to 30 per cent) and rock fragments (10 to 15 per cent) set in a scanty matrix of sericite and ferruginous matter. The grains are mostly angular. The rock is a typical arkose (Table I).

The sandstone from the upper horizon of the Barren Measure stage differs with that from the base in its higher quartz content (65 to 70 per cent), reduced proportion of felspar, rock fragments and matrix. The grains are better rounded



TEXT-FIG. 4. Mechanical analyses of Gondwana sandstones.

MBa1: Lower Barren Measures, Mahuda nala. *MBa3:* Upper Barren Measures, Mahuda nala. *Ba3:* Barren Measures, Khudia nala. *JBaX1:* Lower Barren Measures, Jamunia nala.

and vary from subangular to subrounded. This sandstone can therefore be classified as subarkose.

The sorting of the sandstones of Barren Measures is fair. The arkosic type with a higher median value and low kurtosis is coarser than the subarkose and the distribution tends to be bimodal (Table II).

Heavy mineral assemblage of the Barren Measures is characterized by the reappearance of garnets. The tourmaline count though reduced still dominates. Proportion of zircon is much reduced, but rutile count increases and the presence of hornblende in appreciable quantity is noticed for the first time (Table II).

(4) *Raniganj Stage*

Rocks of this stage exposed in the Jamunia can be classified into the following groups:

Greenish, micaceous, felspathic, friable sandstone	500′
Coarse, felspathic, friable sandstone	100′
Sandy shale with alternating thin bands of calcareous sandstone—finely banded and ribbed	800′
Flaggy fine grained sandstone with alternating bands of sandy shale with a well developed calcareous sandstone at base	300′

The total thickness of this group is nearly 1,800 feet and there is a definite change in the facies towards the top of the stage. An interesting feature is the development of nearly 25 feet thick calcareous grits at the base of the Raniganj stage. Both the lower and the middle groups are characterized by the presence of a large number of thin bands of siliceous limestone. The total thickness of the calcareous bands is nearly 100 feet and when compared to the Barakar and Barren Measure this can easily be classed as predominantly calcareous. But separated by a thin pebble bed from the middle group is the type of sandstone which resembles a graywacke and distinctly different from the lower group.

The flaggy sandstone of the lower two groups displays excellent current bedding 80 per cent dipping towards S. 60° W. The thickness of the individual current beds on an average is less than half an inch. It is interesting to note that the associated siliceous limestones are devoid of this feature (Table I).

Coarse current bedding is observed in the greenish sandstones, but though the main trend is towards west, diagonally opposite trends are quite common indicating the turbulent conditions of deposition.

The heavy mineral assemblage of the lower group of Raniganj rocks is practically the same as that of the Barren Measure stage with the exception of garnets, which show an increase in proportion (Table II).

Probable Trend of Sedimentation in the East Bokaro and Western Jharia Coalfields

On account of the limited area covered during the present survey, the relevant data, which may have a bearing on the trend of sedimentation in these two coalfields during the lower Gondwana period, are briefly mentioned here. It would be premature to offer any definite conclusions at this stage, but a few probabilities are considered.

The Talchir stage in the western extremity of the Jharia field and the eastern part of East Bokaro coalfield has a well developed basal boulder bed. Judging from the complete lack of sorting and scalar properties, this bed probably represents a true tillite. Proceeding towards the top of the Talchir stage, one comes across a fair degree of sorting of sandstones and gradation from coarse to fine sediments displayed by alternating thin units. These features suggest that a major part of the Talchir rocks has been transported and deposited through the agency of water.

In eastern Bokaro, Chandrapura and the western extremity of the Jharia field, the basal bed of the Barakar stage is a well developed conglomerate which at places attains a maximum thickness of 50 feet. The conglomerate horizon persists for some distance towards the east from Jamunia; but approaching the centre of the basin it passes into a pebbly grit. In addition to this, the basal grit of the Barakar has undoubted Talchir features both in the composition of the rock and the heavy mineral assemblage which suggests a reworking of the Talchir rocks and hence an unconformity between the Talchir and the Barakar stages.

The Barakar stage itself is marked by many breaks in sedimentation of which one at least appears to be of major stratigraphic significance. The horizon of compact coarse sandstone and grit overlying the VII seam and which continues up to the IX seam appears to have been deposited by the reworking of the older sandstones. The better sorting of the constituents, the nature of the cement and characteristic overgrowth of quartz and the greater maturity these rocks have attained all point towards this possibility.

The other break which has a regional distribution is the one marked by the pebbly horizon occurring on the top of XII seam. This break however does not mark any significant change in facies.

The 'boulder conglomerate' about a foot thick which occurs practically all along the top of the Barakar stage is of a highly contrasting type with the other pebbly horizons, not only in the size of the boulders but also in the motley nature of the pebbles. This horizon marks, if not a major break in sedimentation, at least a change in provenance.

The change from the Barakar to the Barren Measure is gradual and in fact there is some similarity both in the composition and sorting characters of these two stages. There is however a significant change within the Barren Measures between the lower group of arkose and shale and the upper group of subarkose and finely laminated shales. The two horizons are separated by a pebble bed.

In the Raniganj stage again two-thirds of the group is different from the top 500 feet thick of sediments which have the appearance of graywacke.

The above-mentioned characteristics of the Gondwana sediments have been observed on a regional scale and are probably a consequence of changes both in the environment and the provenance of the source of sediments.

Concerning the direction in which the sediments have been transported, the only criterion that can be employed is the direction in which there is an increase or otherwise of the degree of coarseness of facies. Current bedding which has been observed quite often is much too erratic particularly in the Barakar rocks to render any accurate measurement of the attitudes possible. Therefore employing the conglomerate grit proportion as an indicator, at least in the basal Barakars, it is evident that the sediments have been transported from west to east both in the Bokaro and the Jharia coalfields. The position however changes when we come to top of the lower Barakars and upwards. There is a marked increase in the grit proportion as we proceed towards west which is in marked contrast to what is observed in the basal parts of the Barakars.

The few current bedding directions and alignment of pebbles in the basal Barakars indicates current movement either towards S. 15° E. or S. 15° W. Evidently this reflects fluctuations on a local scale and may not have a regional significance. But in the Barren Measure and the Raniganj stages there is definite evidence to show that the current movement was principally from east to west.

Summary and Conclusions

1. Even the limited field of Gondwana rocks that have been studied in detail has rendered it possible to classify them more or less according to facies and to

establish tentatively the petrographic and heavy mineral characteristics of the individual facies on a fairly regional basis.

2. The Talchir stage consists of basal tillite capped by a suite of graywacke and subgraywacke containing thin bands of lithic arenites which are a consequence of the reworking of former rocks.

3. The Barakar stage consists of three distinct lithofacies—the lower composed primarily of coarse protoquartzites, the middle predominantly a shaly horizon and an upper shaly horizon containing thin intercalations of siliceous limestone.

4. The Barren Measure stage is composed of arkose and subarkose with considerable thickness of finely laminated shales.

5. The major portion of the Raniganj stage comprises flaggy arkosic sandstones and a large number of thin bands of siliceous limestone. However there is a marked change in the facies towards the top where a subgraywacke suite of rocks is the predominant type.

6. The heavy mineral assemblage of the Talchir stage is characterized by the predominance of garnet and a more or less complete absence of tourmaline. The Barakar assemblage is characterized by the predominance of tourmaline, fairly high proportion of zircon and complete scarcity of garnet. On the basis of heavy mineral assemblage a transition stage at the base of the Barakar is recognized which contains both garnet and tourmaline. But the garnets here are strongly etched, a characteristic feature which is not observed in the garnets of the Talchir stage. The Barren Measure and the Raniganj stages, though they contain a larger proportion of tourmaline, also display a fairly high count of garnet.

7. There is a striking resemblance between the Talchir and the Barakar rocks of the eastern Bokaro and western Jharia. But in the case of Barakar rocks the facies represented in the Bokaro can only be compared with the lower stage of coarse protoquartzites of the Barakars of Jharia. There is complete parallelism in the trend of sedimentation and the sediment properties between these two groups of rocks.

8. The source material for the Talchir and the lower two groups of the Barakar stage, the lion's share of which was probably contributed by granitic rocks, was somewhat similar. The Talchir rocks are however distinguished by a matrix formed probably by the breaking down of basic igneous rocks and predominance of garnet. The basal Barakar conglomerate contains a wide assortment of banded and cherty quartzites which distinguishes it from the Talchir horizon. The shale-siliceous limestone facies of the Barakars, the entire Barren Measures and almost two-thirds of the Raniganj stage appear to be derived sediments from the same provenance.

9. Stratigraphic breaks almost on a regional scale, which have ushered in a change in facies, occur between the lower and the middle Barakar groups and almost along the top of the Barakar horizon. Breaks of lesser significance occur in the Barren Measures and the Raniganj stage.

10. On the basis of increasing coarseness of sediments and an increased incidence of conglomerate occurrence, it is suggested that when the first Barakar sediments were deposited the direction of transportation was from west to east both in the Bokaro and the Jharia coalfields. We shall be in a position to obtain a more complete picture of aspects of sedimentation in the Gondwana basins of the Damodar Valley as our studies progress and detailed work is extended to the other basins of the valley as well.

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TABLE 1

Petrography of Sandstones from Lower Gondwana of Western Jharia Coalfield

Horizon		Sp.G.	Description	Modal Analysis				Nature of matrix
				Quartz	Felspar	Rocks fragment	Matrix	
Raniganj		2·63 to 2·80	Medium to fine grained rock, composed essentially of subangular to rounded grains of quartz and felspars, set in a carbonate matrix. The latter corrodes and replaces both quartz and felspars.	Per cent 20 to 28	Per cent 10 to 13	Per cent 3 to 4	Per cent 57 to 65	Dense brown carbonate with few scattered crystals of calcite.
Barren Measure		2·35 to 2·5	Medium to fine grained rock, composed essentially of subangular to subrounded grains of quartz and felspar, set in a matrix of cherty, micaceous, and ferruginous matter.	50 65 to 70	25 to 30 10 to 15	10 to 15 5 to 10	5 to 15 10	Sericitic and ferruginous.
Barakar	Upper	2·74 to 2·88	Medium to fine grained rock, composed of angular to subangular grains of quartz and felspar, set in a matrix of micaceous and calcareous matter.	20 to 35	1 to 3	1 to 4	57 to 77	Essentially carbonate, non-carbonate rocks contain sericite matrix.
	Middle	2·40 to 2·58	Coarse to medium grained rock, composed of subangular to subrounded grains of quartz, set in a clayey, micaceous and ferruginous matrix.	60 to 70	——	3 to 8	20 to 30	Mostly sericitic, slightly ferruginous.
	Lower		Coarse grained grit, composed chiefly of quartz, set in a sericitic matrix, characterized by authigenic growth of quartz.	66 to 71	——	1 to 3	25 to 30	Composed of almost equal proportion of detrital quartz and ferruginous cement.
			Coarse grained inequigranular sandstone consisting of angular to subangular grains of quartz, set in a sericitic and slightly chloritic matrix.	46 to 55	——	6 to 12	36 to 42	Essentially sericitic and slightly chloritic binding detrital quartz.
Talchir		2·45 to 2·6	Medium to fine grained, compact clayey sandstone, composed essentially of quartz and felspar—angular to subangular, set in a chloritic paste.	20 to 25 40 to 50	6 to 10 25 to 30	8 to 10 3 to 5	50 to 55 15 to 37	Essentially chloritic and sericite paste.

TABLE II

Texture of Sandstones from Western Jharia — *Heavy Mineral Assemblage from Western Jharia*

Horizon		Median	So	Sk	Kurtosis	Remarks	Garnet	Tourmaline	Zircon	Epidote	Monazite	Rutile	Opaque Min.	Miscellaneous
Raniganj							Per cent 10 to 12	Per cent 7 to 9	Per cent Below 1	Per cent —	Per cent —	Per cent Below 1	Per cent 78 to 80	Per cent Kyanite Below 1
Barren Measure		0·22 to 0·52	1·54 to 1·84	0·95 to 1·45	0·199 to 0·227		18	30	4	—	—	14	30	Hornblende 4
Barakar	Upper	0·58	1·72	0·74	0·21		Below 1	48	10	Below 1	Below 1	12	29	Apatite Below 1
	Middle	0·45 to 0·54	1·57 to 1·59	0·77 to 0·91	0·198 to 0·214		0 to 2	8 to 19	16 to 28	Below 1	—	0 to 4	37 to 44	
	Lower	0·56 to 1·5	1·58 to 2·19	0·69 to 1·16	0·21 to 0·28		1 to 4	55 to 64	6 to 8	—	0 to 2	3 to 6	18 to 23	Apatite 0 to 6
Talchir		0·265	1·76	1·01	0·25		86 to 89	Up to 1	1 to 5	0 to 5	0 to 1	0·5 to 2	3 to 7	

TABLE III

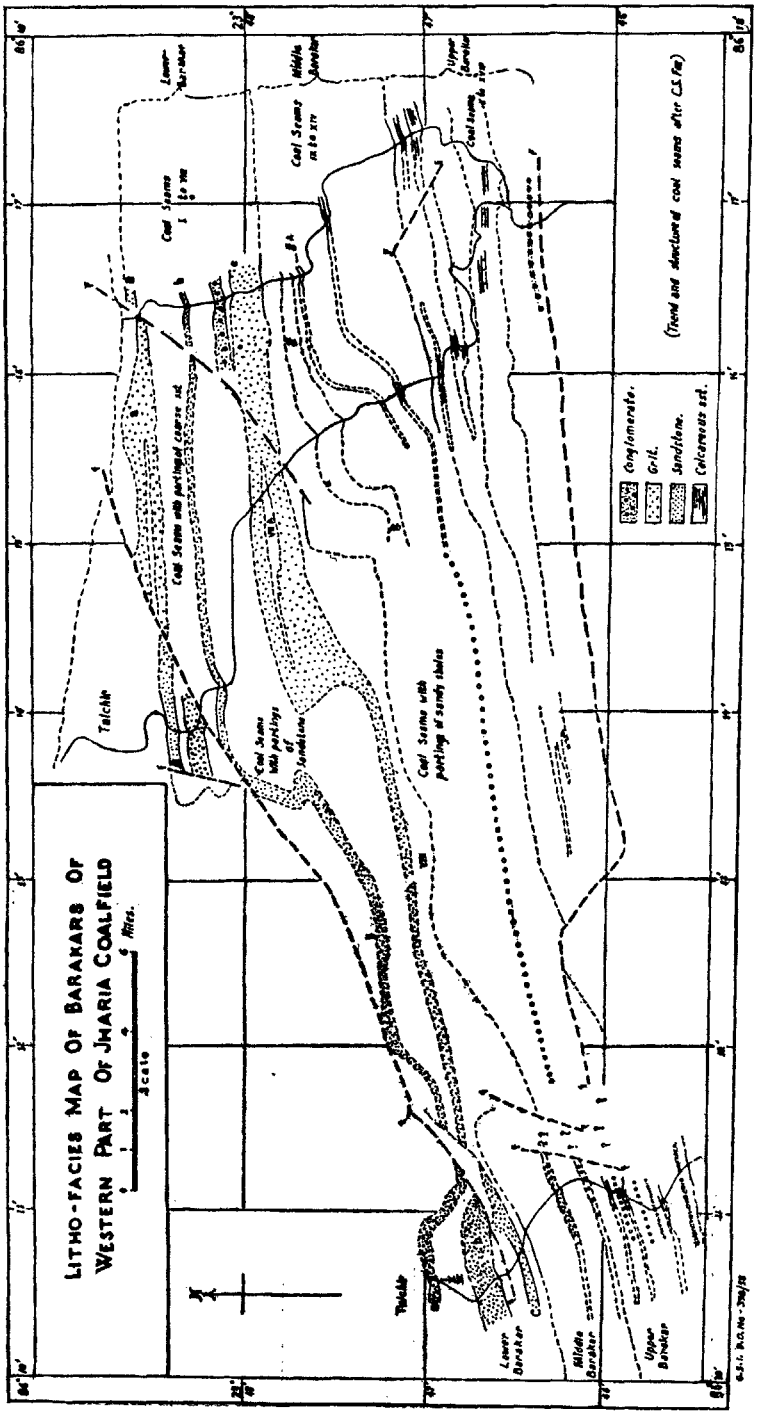
Petrography, Modal, and Heavy Mineral Assemblage of Lower Gondwana Rocks of Eastern Bokaro Coalfield

Horizon	Description	Modal composition				Nature of matrix	Heavy minerals				
		Quartz	Felspar	Rock fragment	Matrix		Garnet	Tourmaline	Zircon	Rutile	Opaque Min.
		Per cent	Per cent	Per cent	Per cent		Per cent	Per cent	Per cent	Per cent	Per cent
Barakar	Coarse to medium grained sandstones, composed chiefly of subangular to subrounded grains of quartz and small amount of rock fragments, set in a sericitic and ferruginous matrix.	50 to 60	Below 1	0 to 4	30 to 40	Mostly sericitic and ferruginous.	1 to 2	60 to 70	10 to 12	3 to 6	20 to 23
	Coarse grained, angular to subangular grains of quartz, set in a cement of sericitic and ferruginous matter.	45 to 55	—	10 to 15	25 to 35	Sericitic and ferruginous.	0 to 1	50 to 60	1 to 2	2 to 4	40 to 45
Talchir	Medium to fine grained, composed essentially of angular grains of quartz, felspar and rock fragments, set in a clayey, sericitic and chloritic paste.	40 to 45	6 to 10	5 to 6	40 to 50	Chloritic and sericitic paste.	75 to 80	<2	Up to 1	—	1 to 15

TABLE IV

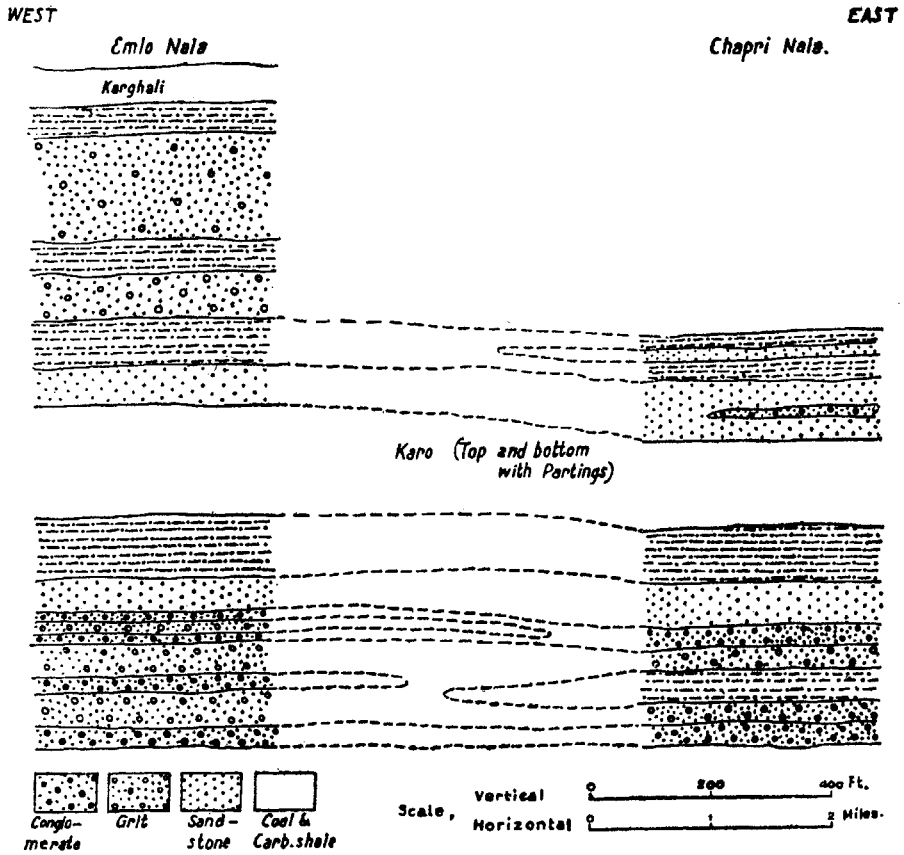
Geological Horizon and Location of Samples in the Western Parts of the Jharia Coalfield indicated in Graphs (Text-figs. 1–4)

Ba3	..	Barren Measures, Khudia nala
JB7	..	Lower Barakar, Jamunia nala
JB8	..	Middle Barakar, Jamunia nala
JB16	..	Upper Barakar, Jamunia nala
JBax1	..	Lower Barren Measures, Jamunia nala
KB1	..	Lower Barakar, Matadih nala
KB12	..	Lower Barakar, Matadih nala
KB15	..	Middle Barakar, Matadih nala
KU1	..	Middle Barakar, Khudia nala
KU5	..	Middle Barakar, Khudia nala
KU24	..	Lower Barakar, Khudia nala
MBa1	..	Lower Barren Measures, Mahuda nala
MBa3	..	Upper Barren Measures, Mahuda nala
Tal1	..	Talchirs, Khudia nala


LITHO-FACIES MAP OF BARAKARS OF WESTERN PART OF JHARIA COALFIELD
Scale
Miles
Conglomerate.
Grit.
Sandstone.
Calcareous sst.
(Trend and structural coal seams after C.S.Pal)
Talchir
Lower Barakar
Middle Barakar
Upper Barakar
Coal Seams with partings of sandy shales
Coal Seams with partings of sandstone

TEXT-FIG. 5.

VERTICAL AND LONGITUDINAL SECTION OF BARAKARS OF PART OF EAST BOKARO COALFIELD



	Emlo Nala				Chapri Nala			
Horizon	Conglom-erate	Grit	Sandstone	Coal and Carb shale	Conglom-erate.	Grit	Sand stone	Coal and Carb. Shale
Barakar	11%	22%	26%	41%	6%	8%	34%	42%

Total thickness with average dip = 1100 ft.

Total thickness with average dip = 844 ft. (Formations North of Gobindpur-Pichri fault)

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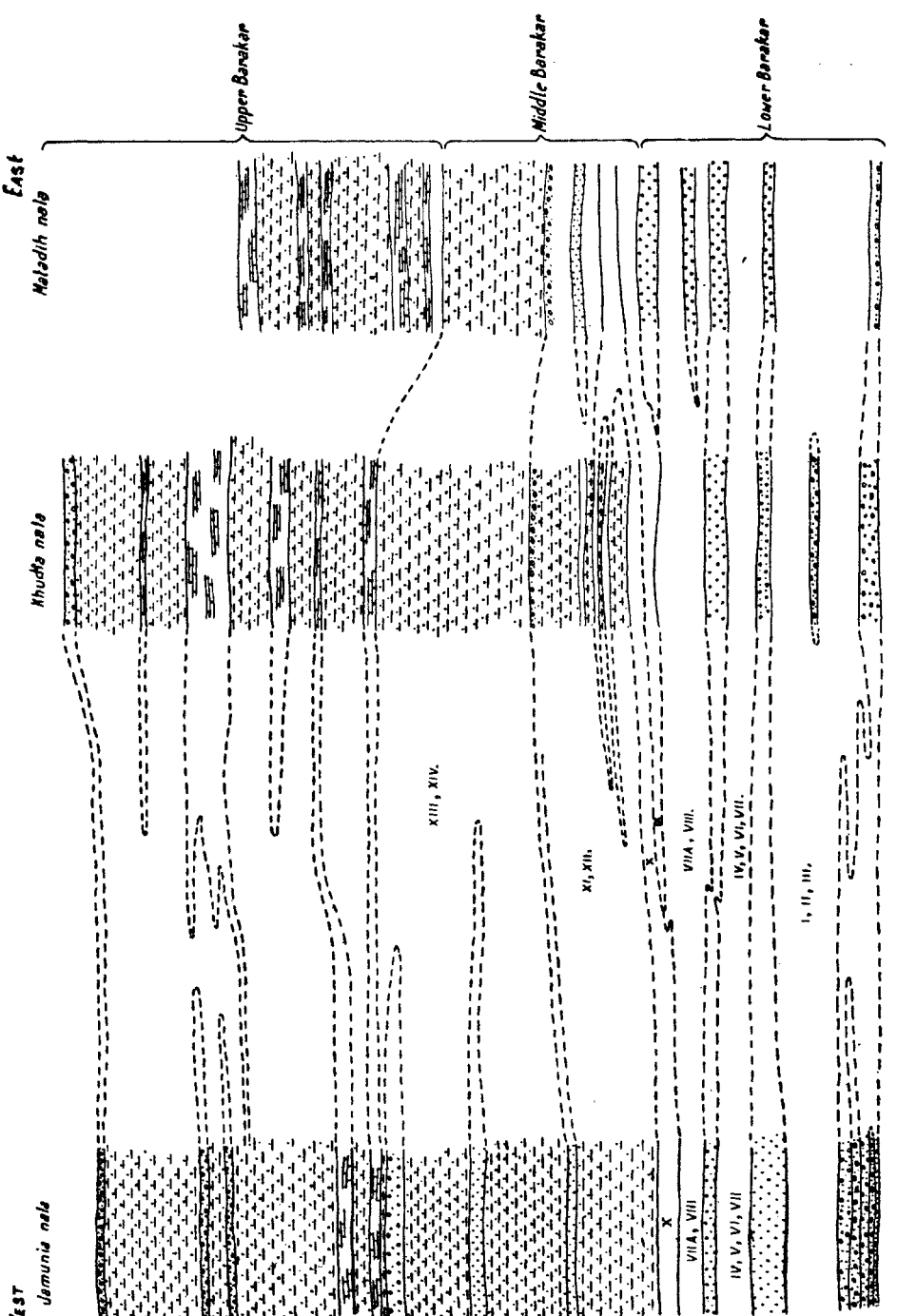
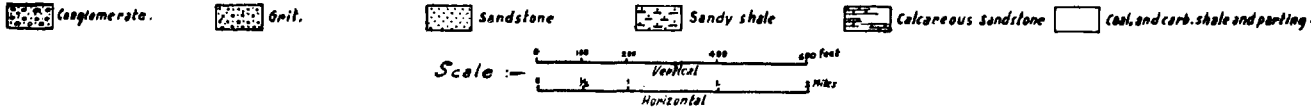
TEXT-FIG. 6.


VERTICAL AND LONGITUDINAL SECTION OF BARAKARS OF WESTERN PARTS OF JHARIA COAL FIELD
West
Jamunia nala
Khudia nala
Maladih nala
East
Upper Barakar
Middle Barakar
Lower Barakar
XIII, XIV.
XI, XII.
X
VIIA, VIII
IV, V, VI, VII
I, II, III.



		Jamunia nala							Khudia nala							Matadih nala						
		Conglomerate	Grit	Coarse and medium Sandstone	Sandy Shale	Coal and Carb. Shale	Calcareous Sandstone	Thickness	Conglomerate	Grit	Coarse and medium Sandstone	Sandy Shale	Coal and Carb. Shale	Calcareous sandstone	Thickness	Conglomerate	Grit	Coarse and medium sandstone	Sandy Shale	Coal and Carb. Shale	Calcareous sandstone	Thickness
Barakar	Upper	–	1%	5%	68%	25%	1·5%	685ft.	–	<1%	6%	57%	31%	6%	812 ft.	–	–	–	46%	47%	7%	520ft.
	Middle	–	1%	10%	61%	27%	–	680ft.	–	<1%	3%	67%	30%	–	608 ft.	–	1%	6%	51%	41%	–	491ft.
	Lower	10%	13%	49%	–	25%	–	470ft.	–	12%	61%	–	26%	–	510ft.	–	11%	53%	–	36%	–	535ft.

Total thickness of Barakar, calculated with average dip - 1835 ft. Total thickness of Barakar, calculated with average dip - 1930 ft. Total thickness of Barakar, calculated with average dip - 1546 ft.

Total thickness calculated for Barakars in Khudia nala, with maximum dip – 2260 ft.
" " " Matadih " " dip - about 1700 ft.

G.S.I.D.O. No. 399/58.

TEXT-FIG. 7.