NATURE AND ORIGIN OF MICRO-FRAGMENTAL AND MINERAL CONSTITUENTS OF THE BOKARO COALS*

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ABSTRACT—A detailed microscopic study of the durain of Bokaro coals has been undertaken. The Bokaro coals are banded in appearance and most of them are generally rich in vitrain, with durain exhibiting silky lustre. Exception to these are a few seams which are characterized by a hard and dull durain.

Microscopical examination, based on 300 thin and 25 polished sections, reveals three types of durain in these coals. In the fibrous durain shreds of vitrinite with bedded pattern are dominant. The durain produced as a result of degradation is made up of decomposed bits of vitrinite. This type of durain is more prevalent especially in the Kargali and Kuju coals. In the third type of durain the opaque attritus dominates. Fusinite forms an important constituent of durain and occurs in small fragments and lenticles.

Mineral matter is largely dispersed in durain and includes allogenic and authigenic varieties; epigenitic minerals are scarce.

It appears that the plant debris which formed coal was subjected to a widespread microbial activity during the early history of deposition.

INTRODUCTION

THE Bokaro coalfield is situated in the district of Hazaribagh, Bihar and extends between 23°45′ and 23°50′ N. Lat. and 85°30′ and 86°03′ E. Long. In the chain of Damodar Valley coalfields, this coalfield is the third from the east and is adjacent to Jharia. The Karanpura coalfield which lies towards its west is separated from it by a stretch of Archaeans about 2 miles wide.

Although this coalfield occupies an important position amongst the coalfields of the Damodar Valley and happens to be the most productive coalfield of Bihar, very little information is available regarding the nature of its coals, especially of their petrographic characters. Surange *et al.* (1953) who were probably the first to study the microstructure of Bokaro coals, examined the microfossils of some seams of the West Bokaro coalfield. In his memoir on the Petrology of Indian Coals, Dr. Ganju (1955) described the microstructure of some Kargali coals. Recently Casshyap (1963) has reported the occurrence of sclerotioids in some coals of the Kargali seam. It is thus clear that the earlier studies on these coals were of localized nature and did not cover much ground.

The present study seems to be the first elaborate attempt on the Bokaro coals in this direction and describes in detail the nature of durain prevalent in these coals. Mineral matter and fusinite which form essential components of durain have also been discussed. Microstructure of vitrinite are included in another paper,likely to be sent for publication shortly.

GEOLOGY OF THE AREA

The Bokaro coalfield forms a narrow enlongated trough of Lower Gondwanas

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extending 40 miles from east to west and about 4 to 10 miles from north to south. The stratigraphic sequence, as suggested by Hughes (1867, p. 1), is as follows.

Panchet Series	Upper Panchets Lower Panchets
Damuda Series	Raniganj Group Ironstone shale Group Barakar Group
Talchir Series	

The Gondwana rocks comprised of the Talchir, Damuda and Panchet series, rest on and are surrounded by the Archaeans. The Talchirs which underlie the Barakars are poorly developed and occur in thin and narrow outcrops near the eastern and western extremity. The Barakars cover the greatest part of the field and the younger group of rocks occur in narrow patches mostly around the Lugu hill. The southern boundary of the coalfield is faulted whereas the northern, eastern and western limits show mixed effects of denudation and faulting. Faults are of common occurrence with the result that the strata are much distrurbed and the stratigraphy is complex at various places.

The Barakars are the chief coal-bearing strata in the area and all the productive coal seams are confined to these rocks. Eight productive coal seams, five belonging to the East Bokaro coalfield and three to the West Bokaro coalfield are known to occur. The various coal seams in their downward succession, as also the number of samples collected from these are given below; the number of thin and polished section made are also recorded :

East Bokaro Coalfield		Thickness	No. of collected specimens	No. of thin sections prepared	No. of polished sections prepared
12-foot A	seam	12 ft.	9	9	—
Jarangdih	seam	20 ft.	12	11	—
Kargali	seam	41-100 ft.	194	188	13
Bermo	seam	36- 45 ft.	13	11	—
Karo	seam	50- 80 ft.	62	59	7
West Bokaro Coalfield					
Kuju	seam	40 ft.	15	13	5
No. XI	seam	30 ft.	5	5	—
No. X	seam	20 ft.	4	4	—

Explanation of Plate 1

(All figures are from thin sections)

1&2. Fibrous type of durain with abundant shreds and bits of vitrinite. Micrinite, microspores and finely granular mineral matter are the other constituents. A brown rounded resin in the central portion of Fig. 1 is fairly conspicuous. Kargali seam, Bokaro colliery, Quarry No. 7, Sample No. $KB_7/4$ and $KB_7/74$ respectively (X 70)

3. A similar type of durain as that in Fig. 1 and 2. Finely granular quartz is prominent. Kargali seam, Kargali colliery, Quarry No. 2, Sample No. $KK_2/5$.

4. Closely spaced long shreds of vitrinite. Grains of siderite as well as some small nodules are fairly prominent. Bermo seam,, DVC Quarry, Sample No. BQ/8. (X 70)

5. Durain showing three resin bodies. A twisted megaspore lies near the lower margin. Kargali seam, Bokaro colliery, Quarry No. 7, Sample No. $KB_7/103$, X125.

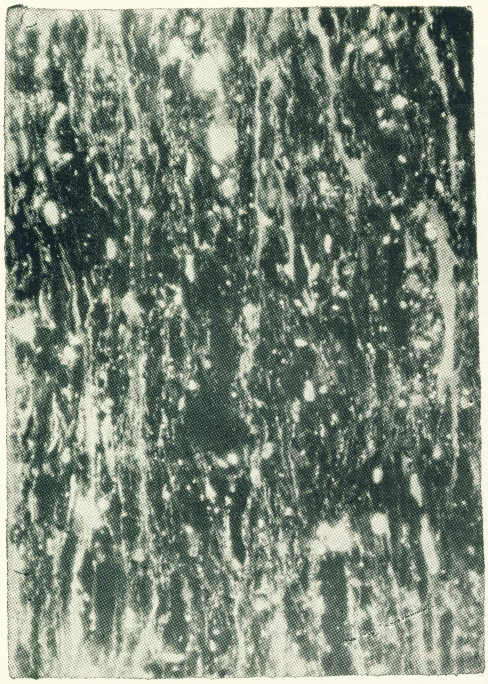

Fig 1 (X70)

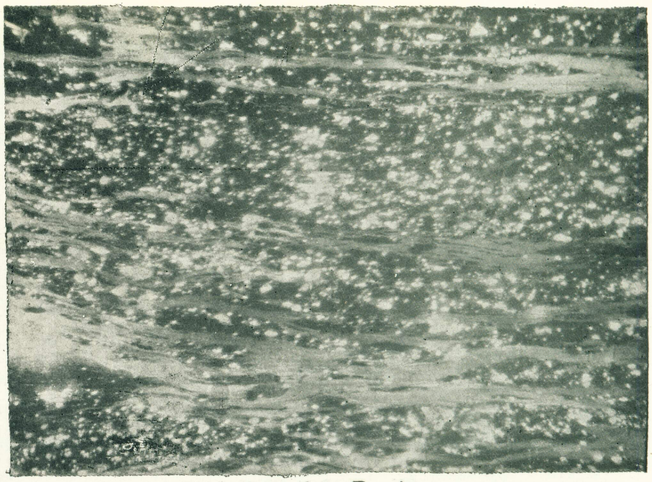

Fig. 3, (X7o).

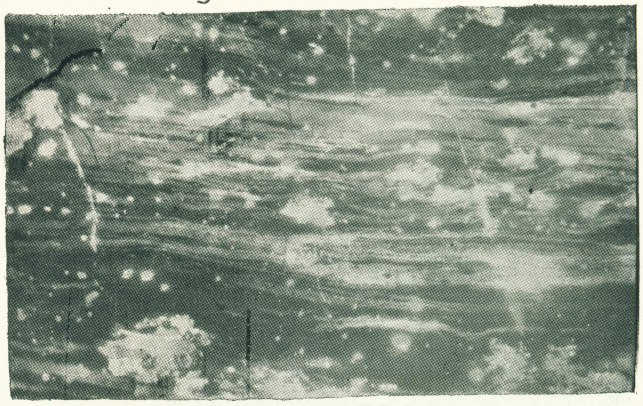

Fig.4 (X 70).

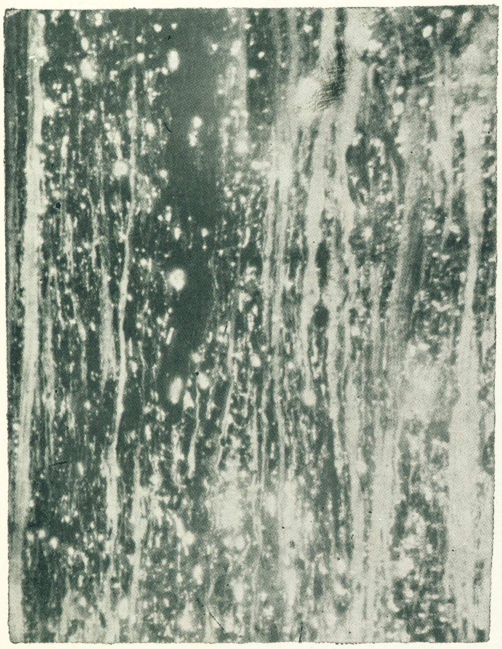

Fig 2 (X70).

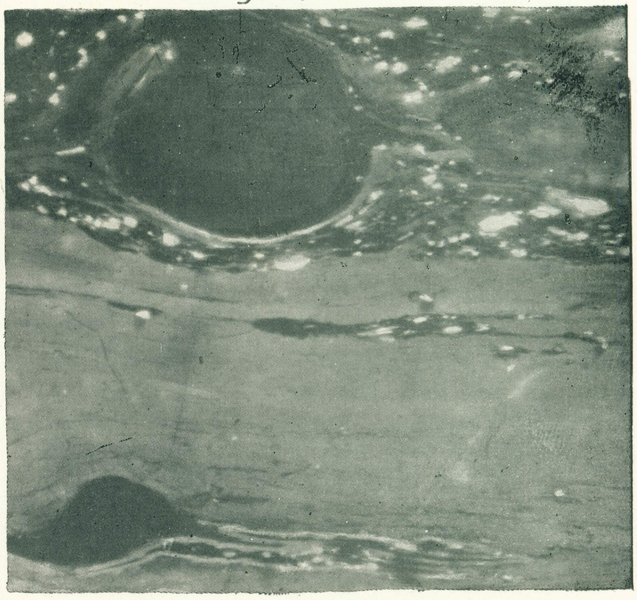

Fig. 5 (X125).

CASSHYAP: MICRO-FRAGMENTAL AND MINERAL CONSTITUENTS OF BOKARO COALS

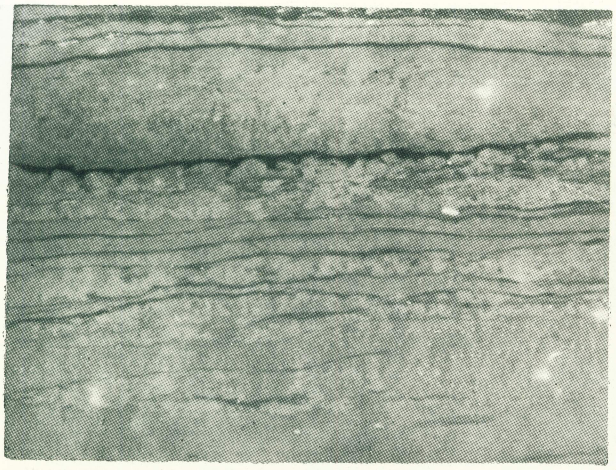

Fig.1. (X 125)

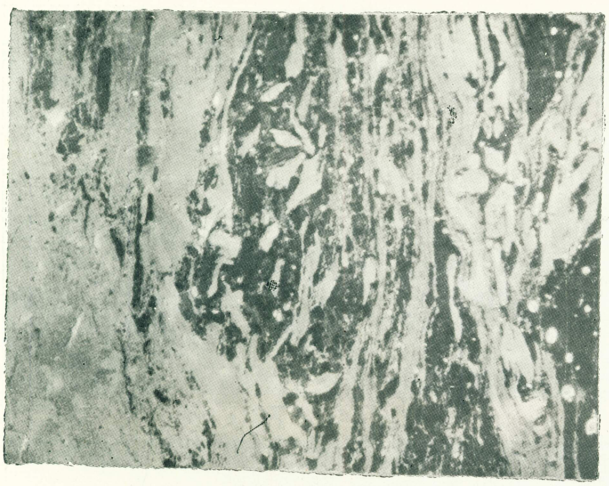

Fig.2. (X125).

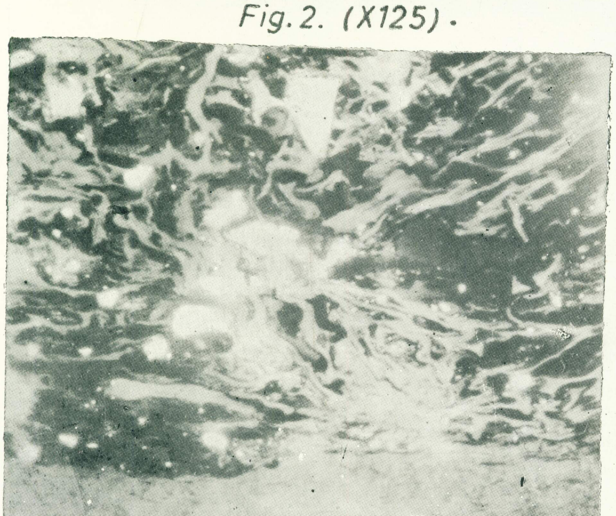

Fig.3. (X125).

Fig.4.(X125)

Fig.5 (X125)

ÇASSHYAP : MICRO-FRAGMENTAL AND MINERAL CONSTITUENTS OF BOKARO COALS

MICROSTRUCTURE

Although the Bokaro coals are distinctly banded in appearance, there is a wide variation in the proportion of various lithotypes. Coals of the Kargali, 12-foot, Jarangdih and Bermo seams are more or less alike in that they are rich in vitrain bands and often show a silky lustre. Durain is hard and shining and encloses shreds of vitrain. Fusain is less conspicuous and occurs in small irregular patches. Karo measure coals which are different from these are generally characterized by a hard granular durain while vitrain is present as a subordinate constituent. In the West Bokaro coalfield the Kuju coals are similar to those of the Kargali seams and often show a silky lustre. Coals of No. X and No. XI seams are generally dull in appearance.

Microscopical examination reveals that at least three classes of durain occur in these coals depending upon the type of micro-fragmental constituents that they contain. In the fibrous durain streaks of vitrinite are closely spaced and are dominant. The second type of durain is characterized by decomposed bits of vitrinite. In the third type opaque constituents are dominant. Fusinite and mineral matter are the other important constituents of these durains and have also been described.

A detailed description of durain types is as follows.

(a) *Fibrous Durain*

This type has been observed to occur abundantly in the Kargali, Kuju and Bermo seams. The presence of well bedded vitrinite strips is a characteristic feature of this type which is illustrated in Plate 1, fig. 1. Thin shreds of vitrinite form the dominant constituent and these are mixed up with micrinite, microspores and finely granular mineral matter composed of quartz, muscovite and kaolinite. An oval dark brown resin is conspicuous in the centre of the figure. A similar type of durain showing long fibres of vitrinite appears in Plate 1, Figs. 2 to 5. Finely granular mineral matter composed largely of quartz is fairly abundant in Figs. 2 and 3 whereas granules of siderite are common in Fig. 4. Dark brown resins are observed in Fig. 5 which also shows a folded exine near the lower edge. Some durains of Kargali and Kuju seams include cuticles showing toothed and corrugated outlines as shown in Plate 2, fiig. 1.

(b) *Durain produced as a Result of Degradation*

This type of durain is prominent in certain sections of the Kargali and Kuju seams. The chief constituent is the woody degradation matter which is comprised of pale yellow or dark brown and opaque parts of decomposed cell walls. These two forms of degraded

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Explanation of Plate 2

(All figures are from thin sections)

1. Durain showing rows of dark brown cuticles with toothed margins. Kargali seam, Kargali colliery, Quarry No. 2, Sample No. $KK_2/13$, X125.
2. Durain formed as a result of discomposition of cell walls. A thin band of vitrinite lies across the right-hand margin. Kargali seam, Bokaro colliery, Quarry No. 7, Sample No. $KB_7/87$, X125.
3. An earlier stage of decomposition to that shown in Fig. 2. Disintigrated shreds of vitrinite are coarse, lath-like and randomly twisted. A remnant of the original tissue lies along the lower margin. Kargli seam, Kargali colliery, Quarry, No., Sample No. $KK_2/2$, X125.
4. Durain showing decomposed bits of vitrinite as also an isolated tracheid which showing spiral thickenings is conspicuous across the middle. Kuju seam, Kuju colliery, Sample No. WB/K_3, X125.
5. A similar type of durain as in Figs. 2 and 4. Brown oval resins are quite common and often enclose gas bubbles and opaque granules. Kuju seam, Kuju colliery, Sample No. WB/K_5, X125.

matter were described by Thiessen and Sprunk (1935) as 'Translucent humic matter' and 'Brown matter' respectively. A typical example of this class of durain is illustrated in Plate 2, fig. 2. The original tissue present in the left-hand side of the figure shows signs of decomposition here and there. An earlier stage in the formation of this type of durain is shown in Plate 2, fig. 3, where the distintigrated fragments are in the form of twisted fibres, coarser in size. A remnant of the original tissue seen near the lower margin displays clear evidence of decomposition at various places.

The resins, and sometimes the tracheids also, form a part of the durain. Plate 2, fig. 4, illustrates in the middle an isolated tracheid mixed in a fragmentary mass of yellow and brown coloured bits. The tracheid shows a characteristic spiral thickenings. Fig. 5 shows oval and rounded resin bodies with a pale narrow outerborder and brownish central zone which encloses gas bubbles and a opaque granular substance. Microspores and grains of quartz are fairly conspicuous amongst the finer ingredients.

A significant feature of this durain is that its constituents are similar to the brown fragmental matter observed in the lumens of the cells of woody tissue constituting vitrinite bands.

Various workers have observed and discussed the nature and origin of this material (Hoffman and Stach, 1931; Hickling and Marshall, 1933; Thiessen and Sprunk 1935, 1936 and more recently Ganju, 1955). The generally accepted views regarding the origin of these constituents are those expressed by Thissen and Sprunk (*loc cit.*). These authors suggested that the biological decomposition of the primary walls and middle lamellae have yielded the coarse fragmentary mass of durain as well as of the cells of vitrinite tissue.

(c) *Durain with Opaque Attritus*

The third type of durain differs from the first two in that the opaque matter is its prominent component and vitrinite is scarce. These durains generally include a greater proportion of mineral matter. Plate 3, fig. 1 represents a typical example of this type of durain. The opaque matter is composed of micrinite, streaks of high rank vitrinite and fusinite and the mineral matter includes quartz and muscovite. An angular grain of quartz is observed in the lower right-hand corner, while a flake of muscovite showing well developed cleavage is conspicuous in the middle right-hand side of the figure.

FUSINITE

Fusinite constitutes a minor ingredient of these coals and occurs mixed in durain or in

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Explanation of Plate 3

(All figures are from thin sections)

1. An opaque attritus type of durain showing an abundance of fusinite granule and massive micrinite and mineral matter. Karo seam, Turio colliery, Quarry No. 2, Sample No. T/2.
2. Woody tissue preserved as fusinite showing serially arranged thick-walled rectangular cells. The cells often exhibit scalariform thickenings and the cavities are filled with a finely crystalline substance. Jarangdih seam, Jarangdih colliery, Sample No. JJ/3, X170.
3. Transverse section of a woody tissue preserved as fusinite exhibiting the same general characters as in Fig. 2. Kargali seam, Bokaro colliery, Quarry No. 7, Sample No. KB_7/78.
4. A fragment of siltstone embedded in durain. Quartz and lath-like kaolinite are the chief constituents with carbonaceous matter filling the interspaces. Kargali seam, Kargali colliery, Quarry No. 3, Sample No. $KK_3$9,/ X125.
5. Durain showing vermicular piece of kaolinite under crossed nicols. Two direetions of extinction are conspicuous. Kargali seam, Bokaro colliery, Quarry No. 2, Sample No. KB_2/12F. Crossed Nicol X170.

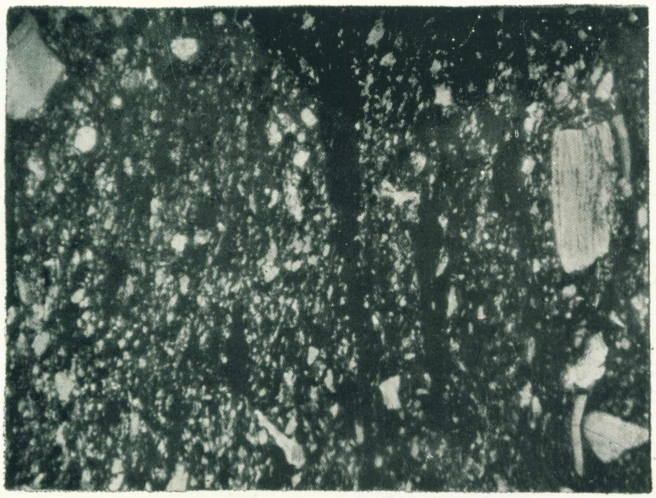

Fig. 1. (X 70).

Fig. 4. (X 125).

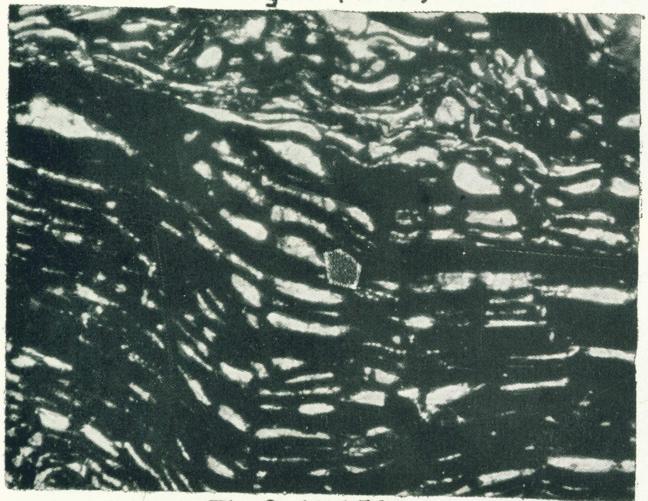

Fig. 2. (X 170)

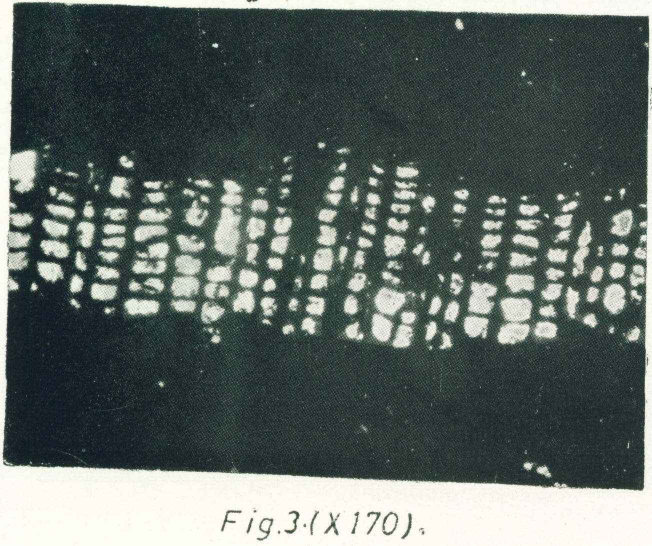

Fig. 3. (X 170).

Fig. 5. (X170).

CASSHYAP : MICRO-FRAGMENTAL AND MINERAL CONSTITUENTS OF BOKARO COALS

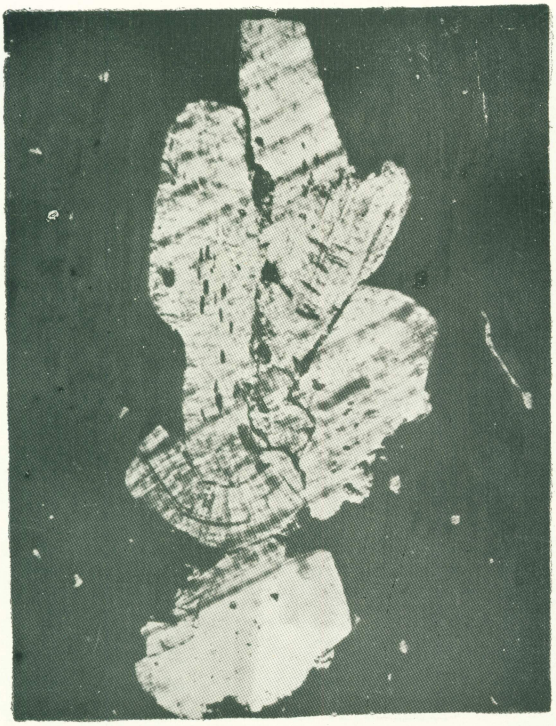

Fig. 1. (X170).

Fig. 2. (X125).

Fig. 3. (X 40)

Fig. 4 (X250)

CASSHYAP : MICRO-FRAGMENTAL AND MINERAL CONSTITUENTS OF BOKARO COALS seperate bands or lenticles. Typical examples of woody tissues preserved as fusinite are illustrated in Plate 3, Figs. 2 and 3. The tissues are cut transversely, with the thick walled rectangular cells showing a characteristic serial pattern. Near the upper right-hand corner and along the lower margin in Fig. 2 the cells exhibit signs of crushing. The lumens are filled with finely crystalline clay minerals which shows high birefringence. Both the tissues show characteristic scalariform thickenings.

MINERAL MATTER

The mineral matter forms an essential component of coal and occurs disseminated in varied proportion in the durain, fusinite and vitrinite. The mineral matter in coal may be inherant or extraneous. The inherent matter includes the inorganic constituents present in the coal forming plants and forms an insignificant amount of the ash. The main part of the ash is constituted of extraneous matter and it is important to study the nature and origin of these minerals.

Mackowski (see Francis, 1954, p. 488) has observed two types of inorganic mineral impurities in coal which may be introduced at different periods :

(1) Syngenitic mineral matter—This is introduced in the early stage of the formation of coal, that is during the biochemical change.

(2) Epigenitic mineral matter—This is incorporated during the maturing process after the completion of biochemical change.

The syngenitic group of minerals occur more frequently in coals and may include 'allogenic' and 'authigenic' types. The allogenic minerals are those which are derived from the pre-existing rocks and are transferred to the place of deposition. These include grains of quartz, mica, zircon etc. 'Authigenic' minerals on the other hand originate in the place of deposition and include kaolinite, siderite, calcite, pyrite, etc.

The epigenitic minerals are formed by solutions like iron sulphides or carbonates. Such minerals occur as components of fusinite or as films in shrinkage cracks or cleats.

Like most other Indian coals, the Bokaro coals also contain abundant mineral matter which usually occurs in a disseminated state in durain. The minerals are generally fine grained but coarse grained varieties are not altogether absent. Quartz is the most important syngenitic allogenic mineral and shows irregular outline; micas with lath-like form are less common. Kaolinite and siderite occurring in vermicular and nodular forms respectively are the only authigenic minerala present. Epigenitic minerals occur less frequently.

SYNGENITIC MINERALS

Allogenic

Quartz–It is the most abundant mineral component and usually occurs in fine grains in the durains as shown in Plate 1, Figs. 2 and 3 and Plate 3, Fig. 1. The grains are generally subangular to subrounded but angular

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EXPLANATION OF PLATE 4

(All figures are from thin sections)

1. A group of kaolinite crystals under crossed nicols. Fibrous structure of the mineral and dark rod-like inclusion are quite characteristic. Eastern Karo seam, Turio colliery, sample No. T/4. Crossed Nicols X170.
2. Durain showing abundance of siderite nodules. Bermo seam, Dhori colliery, Sample No. BQ /4. X125.
3. A large nodule of siderite exhibiting fibrous structure in the central portion. Kargali seam, Kargali colliery, Quarry No. 2, Sample No. KK_2/28. X40.
4. A sprial tracheid replaced by siderite. Jarangdih seam, Jarangdih colliery, Sample No. JJ/3. X250.

grains are also met with. This mineral often contains fine accicular inclusions and shows wavy extinction suggesting that it is mostly of metamorphic origin.

In addition to quartz there are some other allogenic components like micas, fragments of quartzite and siltstone which occur scarcely. Subangular quartzite fragments have been observed to occur in the Kargali and Karo seams. In a specimen from the Kargali seam (KK3/12) a large fragment of fine grained siltstone shown in Plate 3, Fig. 4 has been observed to occur in durain. It is comprised of quartz grains, vermicular kaolinite and carbonaceous matter which occupies the inter spaces of the framework.

Authigenic

Kaolinite–It is an important member of the authigenic group and is often a prominent constituent of durains of the Kargali and Karo seams. It occurs in fine and coarse grains, the latter being more conspicuous due to their typical vermicular and fibrous form.

Kaolinite is one of the most commonly occurring clay minerals. Montmorillonite and Illite (Hydro-mica) are the other important members of this group. Clay minerals are hydrous alluminium silicates formed through the action of continuous succession of processes ranging from hydro-thermal solutions to supergene percolating waters and weathering.

A characteristic feature of the clay minerals is their platy or flaky structure. Owing to their very fine size they are generally difficult to identify in thin sections. Special techniques like chemical, optical and X-ray studies have to be employed for a correct identification. But some compound crystals of Kaolinite and other clay minerals often encountered in sedimentary rocks including coal are large enough to be examined conveniently in thin sections. A compound crystal represents the authigenic variety and is formed as a result of integration after deposition (Williams *et al.*, 1955, p. 331). Such crystals gradually enlarge in size by this process and often acquire large vermicular form.

Sprunk and O'Donnell (1942) and Mackowski (*loc. cit.*) have observed worm-like crystals of kaolinite. A coiled grain of kaolinite is shown in Plate 3, Fig. 5. The entire grain appears to extinguish in two principal directions indicating a radial orientation of the flakes which comprise the grain. A group of kaolinite crystals under crossed nicols is shown in Plate 4, Fig. 1. Two crystals in the upper portion are seen to contain dark rod-like inclusions which may be particles of kaolinite coloured by organic pigment (Carozzi, 1960, p. 102).

Siderite–Siderite is the next important authigenic mineral and is particularly prominent in the Kargali and Bermo seams. Its grains occur scattered in durains and also in some vitrinites. This mineral is a carbonate of iron and is believed to have been formed under swamp and lagoon conditions from iron bearing solutions.

Siderite may occur in small granules or form large nodules. Fresh crystals are grey in colour, but often they take a brown stain of limonite on the surface or at the borders. The nodules vary considerably in size as shown in Plate 1, Fig. 4, and Plate 4, Figs. 2 to 4. Plate 4, Fig. 3 shows a large nodule exhibiting fibrous central core tinged brown. Sometimes siderite replaces woody tissue in coal as observed in Plate 4, Fig. 4 where a tracheid showing spiral thickenings is formed of siderite.

Epigenitic Minerals

The only epigenitic component found to occur in these coals is some kind of a clay mineral resembling kaolinite. It occurs in fine prismatic crystals in cracks and cleats and shows weak birefringence. The mineral was probably formed as a result of percolation of mineral solution and subsequent precipitation.

CONCLUSIONS

The three classes of durain, different as they are from each other, give ample testimoney to the fact that the coal forming plant debris was subjected to a large scale microbial activity during the early history of deposition. This activity of micro-organisms not only resulted in the disintigeration of tissue into coarser and finer bits but possibly also gave rise to some such constituents of opaque attritus as granular micrinite, massive micrinite and fusinite. There are however, some fusinite lenticles which remain unaffected by this activity and exhibit well preserved woody structure. That the debris containing plant fragments was transported prior to its deposition is proved by the disseminated nature of the mineral constituents and their dominantly detrital character.

ACKNOWLEDGEMENTS

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