MICRO-STRUCTURE OF COALS FROM THE HUTAR COALFIELD

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CONTENTS

INTRODUCTION

The study of coal petrology is proving of considerable interest and importance in recent years but our knowledge of the microscopic constitution of Indian coals (Banerjee, 1932; Ganju, 1954) is yet not comprehensive. It is important that a systematic petrological examination of all the productive coal seams in the Indian coalfields is made with a view to ascertain the composition of these coals and also to know what effect the microscopic constituents may have produced on the chemical properties of these coals. At the same time it would be possible to elucidate the anatomy of plants which have largely contributed in the formation of these coals. The microscopic examination should also be of considerable help in studying the regional variation in the rank of coal as well as in the variation of rank with depth.

A beginning in the study of micro-fossil contents in the Indian coals with a view to ascertain their possible use in the correlation of coal seams has been made by Ghosh and Sen (1948, 1953); but extensive researches in this line have to be carried out before it is possible to estimate the importance of using microspores by themselves in the methods of correlation of Indian coals. The nature and distribution of megaspores in a coal seam may, however, prove of greater interest in the problem of correlation of coal seams.

The material which forms the subject of this paper was collected from the Hutar colliery during a visit to the Hutar and Daltonganj coalfields in December, 1952, by the author who was directing the field work of post-graduate students in that area at that time.

The Sone Valley Hutar colliery is situated in the Hutar coalfield in the Palamau district of Bihar at a distance of about two miles from the Barwadih station on the Dehri-on-Sone Gomoh line of the Eastern Railway.

Geology of the Area

The Hutar coalfield is one of the three coalfields in the Palamau district, the other two being the coalfields of Aurunga and Daltonganj. This coalfield lies in the Valley of the Koel River and its eastern boundary is at a distance of about 12 miles to the west of the western limits of the Aurunga coalfield.

In all these coalfields coal is known to occur in the Damuda series. In the Hutar and Daltonganj coalfields the Barakar series is the coal-bearing formation and the Raniganj series is absent. In the Aurunga coalfield the deposits of the Raniganj series are also known to occur and these include a few minor coal seams. The workable coal seams in the Barakar series of the Aurunga field are known to be of a poor quality.

Fox (1934, p. 32) is of opinion that these coalfields are 'remnants of a much larger spread of Gondwana strata, and indeed were probably the westward extension of the Gondwanas of the Damodar Valley'.

A detailed account of the geology of this area is given by Ball (1878), who mapped the coalfield in the season 1877-1878. The coalfield was named as it is by him (*loc. cit.*, p. 4) after the village of Hutar. According to this author (*loc. cit.*, p. 91), the area of this coalfield is 78·6 square miles and the extent of different formations is as follows:—

Mahadeva series	..	14·1 sq. miles
Barakar group	..	57·0 ,,
Talchir ,,	..	7·5 ,,

The Barakars overlap the Talchirs. The Mahadeva series is largely developed west of the Koel river and is not known to occur in the areas east of that river. Ball (1878, 1881) gives the thickness of Gondwana formations as follows:—

Mahadeva series	..	1,000 feet
Barakar ,,	..	2,750 ,,
Talchir ,,	..	300 ,,

Dunn (see Fox, 1934, p. 154) has estimated that the Mahadevas and Barakars are much smaller in thicknesses than given by Ball.

The Raniganj and Panchet series are known to occur in the eastern parts of the Aurunga field. The Raniganj series is underlain by the Barakars and the Panchet series is overlain by the Mahadevas. The Raniganj and Panchet series are absent in the Hutar field and the Mahadevas which are recognized in the western parts of this field rest directly and perhaps unconformably on the Barakars. In this connection Ball (1878, p. 48) observes: 'It may be that the absence of the normal sequence of beds between the Barakars and Mahadevas in the west may really be due to denudation'.

Ball (*loc. cit.*, p. 45) is of the opinion that the Mahadeva series in the coalfields of Karanpura to Tatapani which lie on the same line of strike have identical lithological characters and 'that these now detached areas are the remnant of a once continuous deposit'. But these deposits differ in their lithological characters from those in the more eastern fields of Bokaro and Raniganj. This author goes on to say: 'On the other hand, there is a very considerable resemblance between these rocks both structurally and lithologically, and those of the Hingir field, whose fossil contents have determined their age as belonging to the Kamthi-Raniganj groups'.

Faulting is not very extensive in this area and the rock formations have low angles of dip. There is a main fault running in an east to west direction and there are also smaller faults along the north-western and western ends of the field. Ball (*loc. cit.*, p. 52) has classified the faults in the Aurunga and Hutar fields into three groups of (1) east to west faults, (2) north of east to south of west faults, and (3) north of west to south of east faults. Two east and west faults of the first group, one fault of the second group forming the north-west boundary and a fault of the

third group forming the 'terminal western boundary' are recognized in the Hutar coalfield by this author.

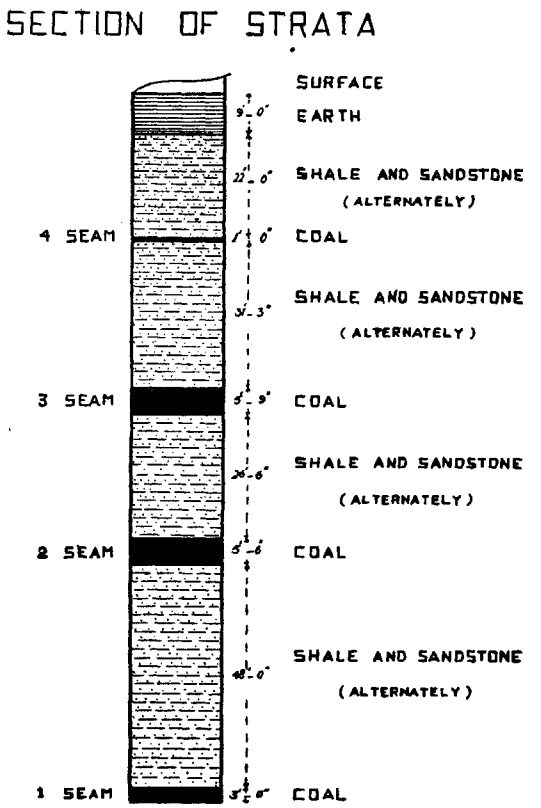
Intrusion of dolerite has taken place in the Talchir formations.

Coal seams

Dunn (see Fox, 1934, p. 155) has recognized five seams of coal and shaly coal along the Deori nala. Two seams, No. 2 and No. 3 from bottom, are being worked in the Hutar colliery. Messrs. Martin & Burn, Ltd., own this colliery and the note which follows is kindly supplied by the Manager of the colliery:—

'Two seams Nos. 2 and 3 are being worked in this colliery. Both the seams are outcropping on the south of the Deori River at the middle of the colliery lease hold. On the west the seams are traced up to the Koel River about three miles away from the colliery. On the east and south the exact extent is difficult to describe, because no exploration has been made to our knowledge. The mine is worked by means of inclines. Full dip S10°E at the 10 approximate. Output in 1953: 70,000 tons approximate.'

A section of the strata at the 23rd level of No. 3 seam as kindly supplied by the Manager of the colliery is shown in the figure below.



The samples of coal described in this paper were collected from seams Nos. 2 and 3.

The results of the proximate analyses of a few typical samples of the two seams, kindly determined by Mr. H. S. Pareek, are given in the table on next page

Results of the proximate analyses of Hutar coals

S. No.	Seam	Proximate Analysis (per cent)				Calculated on dry ashless basis		Calorific Value B.Th.U.		Volatile Coke Button	Colour of Ash	Colliery
		Moisture	Volatile Matter (less Moisture)	Ash	Fixed Carbon (by difference)	Volatile Matter	Fixed Carbon	As determined	On dry ashless basis			
1	No. 2 (Sample 1)	6·88	38·44	4·81	49·87	43·53	56·47			Non-caking	Light buff	Sone Valley Hutar
2	No. 2 (Sample 2)	7·94	38·78	4·55	48·73	44·31	55·69	11,736	13,411	,,	,,	,,
3	No. 3 (Sample 1)	6·37	50·26	8·11	35·26	58·77	41·23			,,	,,	,,
4	No. 3 (Sample 2)	7·64	42·12	4·41	45·83	47·89	52·11			,,	,,	,,

In hand specimen the Hutar coals are dull in appearance. The coal is composed largerly of dull bands of durain including numerous narrow strips of vitrain which are up to 2 or 3 mm. in thickness; many of these, however, are less than 2 mm. thick. These vitrain strips do not follow a persistent course but are present only in short narrow bands thinning out at the ends and merging in the general mass of durain. Their presence in this manner gives a streaky appearance to durain. The occurrence of vitrain in thick persistent bands is a very uncommon feature in these coals. Fusain is found in great abundance and a block of coal may easily split along fusain layers and the surfaces thus exposed are seen to consist almost wholly of charred strips of fusinized wood which can easily soil the hand. On account of these facts the Hutar coals are dull in appearance and lack the characteristic banding into bright and dull layers so conspicuously exhibited by the coals of the nearby Damodar Valley coalfields. In this respect as also in the nature of their microscopic constituents described below, the Hutar coals seem to resemble more closely the coals of the far away Talcher and Pench Valley fields.

Microscopical Examination

Microscopic study was made by an examination of thin sections in transmitted light and polished blocks in reflected light under oil immersion. Owing to the presence of a large proportion of high rank tissue like fusain and dark fungal bodies in these coals, their thin sections cannot be obtained easily and in the last stages of grinding most of this material is removed from the section. These constituents, however, reveal their structures in a clear manner on polished surfaces of coal. Low rank tissues like vitrain and many components of durain including spore material, resins and mineral matter can be examined in detail in thin sections.

A detailed examination of these coals has revealed the presence of well preserved and interesting structures in the different coal components. A major part of these coals is formed of micro-fragmental materials. Among the macro-fragmental components fusain and vitro-fusain are present in greater preponderance as compared to vitrain.

(*a*) Macro-fragmental coal

(1) *Fusain and Vitro-fusain*

Fusain is widely distributed in these coals and is easily distinguished in polished surfaces by its high reflectance showing it as the brightest component of coal. No attempt has been made to distinguish the various metamorphic stages of transformation from vitrain to fusain recognized by Seyler (1941, 1948), by measuring the reflectance of each step of transformation. The term vitro-fusain is used here in a wider sense including all the intermediates which may be present in these coals.

The structures in fusain and vitro-fusain tissues are shown in Plate XI, Figs. 1–6 and Plate XII, Figs. 1, 3 and 5. Plate XI, Figs. 1 and 2 show a transverse section of a woody tissue as seen in a polished surface. The pattern of cell walls appears white; the cell cavities are empty and appear dark. In Fig. 1, the cell walls are thin and show pits preserved in a clear manner. This fact leaves no doubt that we are dealing here with a woody tissue. The effect of pressure is apparent where the cell walls have undergone a slight folding. Fig. 2 shows more or less rectangular cells of a secondary woody tissue arranged serially and having comparatively thicker walls. Towards the left-hand side this structure passes into a band of thin-walled tissue similar to that in Fig. 1. This band, however, shows some broken cells as a result of pressure during coal formation; the band of secondary woody tissue having thicker walls has resisted this pressure. The cell cavities in both the bands are empty.

Plate XI, Figs. 3 and 5 show thick-walled woody tissues in fusain with empty cell cavities. On account of the fact that the tissues have yielded to pressure in different ways, the structures seen in the two figures appear somewhat different from each other.

In Fig. 5 there are blocks of thick-walled rectangular or rounded cells surrounded by broken and crushed mass of a similar kind of tissue. Fig. 3 shows a similar kind of picture with the difference that the cell walls in this tissue are comparatively thinner. In Fig. 3, the crushing of the cell walls in the central part has proceeded a step further and the broken and crushed mass is arranged in more or less a regular fashion. In this part the bogen structure which is characteristic in vitro-fusain is clearly seen. A similar structure is seen in Fig. 5 near the lower edge at the right-hand side.

Plate XI, Fig. 4 shows longitudinal section of a woody tissue revealing very well preserved bordered pits. The thick-walled wood fibres are folded and crushed at places and their cavities are empty. The walls of the fibres are seen to exhibit rows of bordered pits which have produced a chain-like structure. Plate XI, Fig. 6 shows the same kind of structure preserved in a clearer manner. This tissue, however, does not show any visible signs of crushing and the pits have produced a X-shaped chain in some fibres seen clearly in the central part.

A contact zone between two bands of a woody tissue in vitro-fusain appears in Plate XII, Fig. 1. On the left-hand side the section has cut the tissue longitudinally and the long thick-walled fibres of wood show bordered pits very clearly preserved; on the right-hand side the tissue is cut transversely and shows a mass of broken and crushed cells which have produced the characteristic bogen structure. The line of contact appears a rather sharp one.

A cellular tissue exhibiting some interesting features is shown in Plate XII, Fig. 5. There is a band of thin-walled tissue which is slightly compressed and as a result some cells are broken. A few cells have empty cavities. The cells generally show some opaque or semi-opaque material in their cavities. The cell contents have lower reflectivity as compared to the cell walls with the result that they do not appear equally bright. It is clear that these contents do not fill the cavities completely, but leave a narrow empty space which appears dark along their margins near the cell walls. In their outline they roughly resemble the general shape of the cell walls. The presence of these features makes it rather difficult to explain their origin. In all probability they represent some kind of a coal substance which was filling the lumen of the cells and has partly dried up in the process of coalification. These contents probably do not represent remains of plant fragments in the cell cavities. The presence of fragments of broken cell walls and of fine opaque and translucent granular matter in the lumen of cells was noticed in some Raniganj coals (Ganju, 1954). A characteristic feature of the fragmentary material is angular shape of its constituents, in contrast to rounded outline shown by the contents of the cells under discussion here. It is probable that the material was filling the cell cavity to its capacity in the initial stage and that it has gradually shrunk in the process of coal formation.

If the process of disintegration of the cell walls was complete in this tissue, the material forming the cell contents would be jumbled together and its identification would be a matter of doubt. It is possible, therefore, that the massive type of micrinite which forms an important constituent of durain in these coals has in part at least originated in this way from a similar kind of tissue.

Surrounding this tissue there are narrow bands of vitrain which appear less bright as compared to fusain and vitro-fusain materials and include round resin bodies. A well-preserved resin showing innumerable minute air bubbles appears near the edge in the upper left-hand side of this figure.

A thin section of fusain tissue in transmitted light is shown in Plate XII, Fig. 3. The cell cavities of a thick-walled woody tissue are seen here as rectangular white

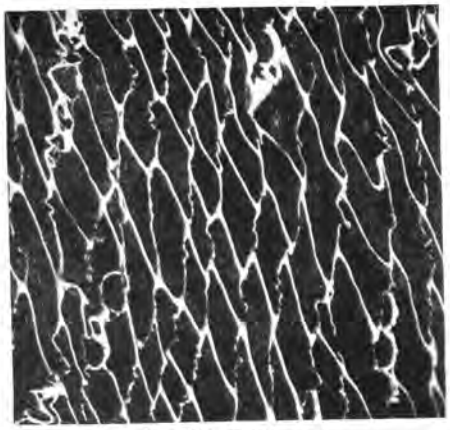


FIG. 1. (X 200).

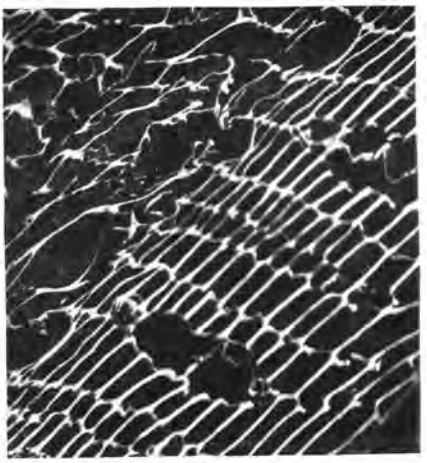


FIG. 2. (X 200).

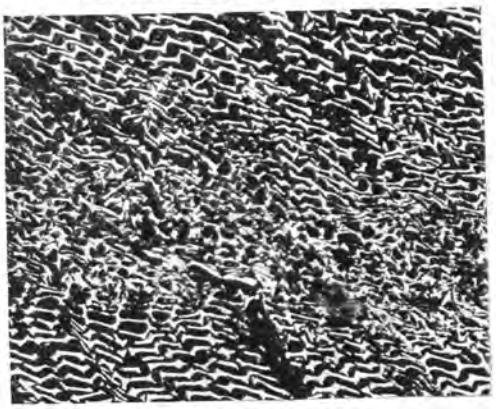


FIG. 3. (X 200).

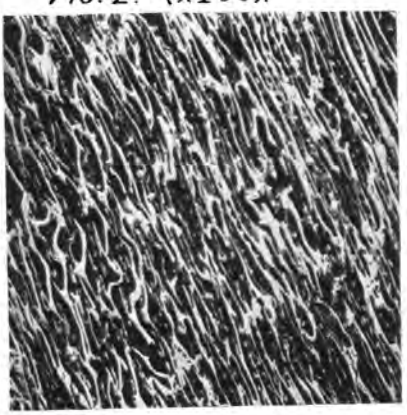


FIG. 4. (X200).

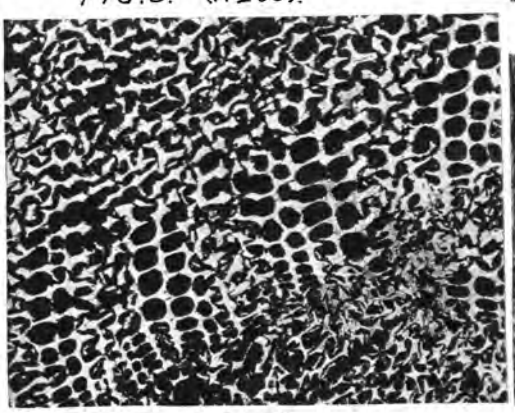


FIG. 5. (X200).

FIG. 6. (X200).

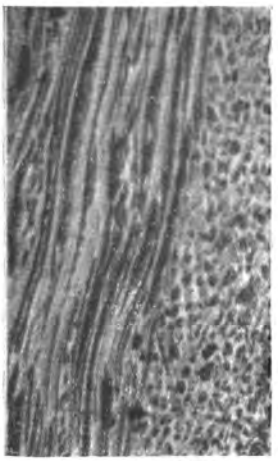


FIG. 1. (X200).

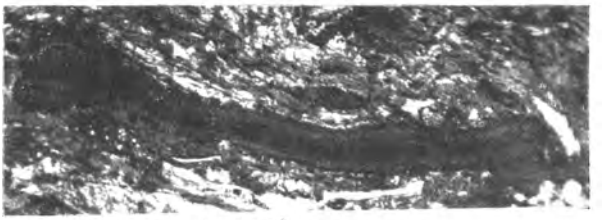


FIG. 2. (X200).

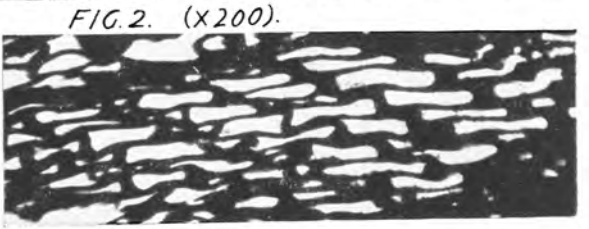


FIG. 3. (X400).

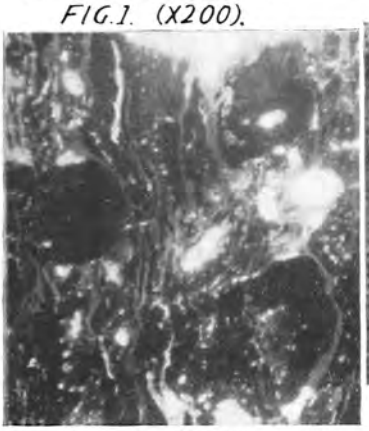


FIG. 4. (X100).

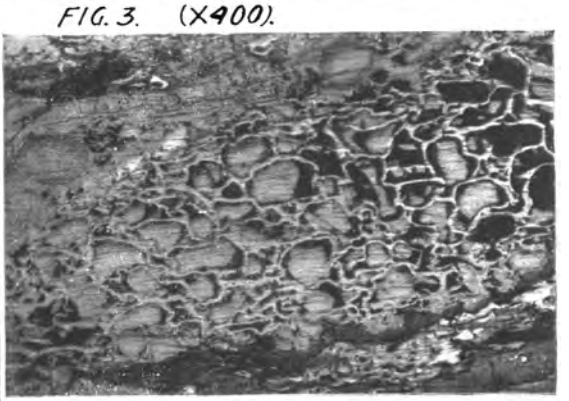


FIG. 5. (X200).

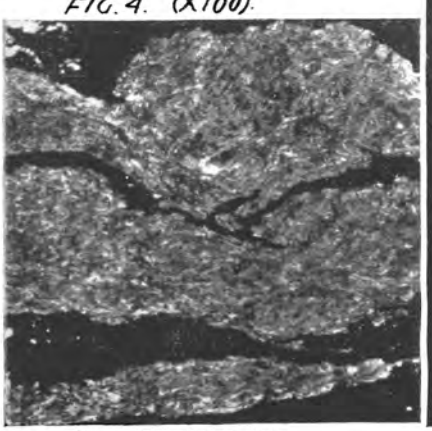


FIG. 6. (X100).

FIG. 7. (X400).

spaces. These are, however, not empty but filled with a mineral substance which is probably kaolinite. The cell walls do not transmit any light and are opaque. It is clear that this tissue does not show any visible signs of crushing on account of the fact that the cells are thick-walled and their cavities are filled with a mineral substance.

(2) *Vitrain*

It has been already indicated that the Hutar coals include only a few narrow irregular bands of vitrain which do not reveal any well-preserved structures, except some round or oval resin bodies. In reflected light vitrain tissue appears less bright as compared to fusain and vitro-fusain on account of its low reflectivity. This is clearly seen in Plate XII, Fig. 5 which shows a band of vitrain tissue in the upper left-hand side and a small portion of another band in the lower right-hand corner.

(*b*) Micro-fragmental coal

Durain

The durain in these coals shows a very variable composition. Its constituents observed in polished surfaces appear in Plate XII, Fig. 2 and Plate XIII, Figs. 2, 3 and 5–7, and those seen in thin sections are exhibited in Plate XII, Figs. 4, 6 and 7 and Plate XIII, Figs. 1 and 4.

A distinguishing feature of durain in these coals is the abundance of fungal bodies in different shape and forms and also of megaspores and microspores. The fungal bodies have caused a widespread decay of plant tissues. In addition to these dominant constituents, patches or rounded bodies of fusain, long narrow strips of vitrain which do not reveal any structure, fragments of wood fibres, micrinite, oval resins and mineral matter are abundant in durain. A detailed description of these constituents follows.

Spore exines

A detailed study of microspores in thin sections of coal is not possible on account of their very small size. They appear pale yellow or amber coloured, flatly compressed, short needle-like bodies scattered in the general mass of durain. Some durains may show microsporangia including closely packed microspores in large numbers. The microspores are probably studied in a better way by macerating the coal with Schultze solution. In this way the spores can be separated from the matrix and their surface features observed in minute detail.

Both seams No. 2 and 3 in the Hutar colliery show megaspore exines in large numbers. Plate XII, Fig. 7 and Plate XIII, Figs. 1 and 4 show some of these exines as seen in thin sections. Plate XII, Fig. 7 shows a peculiarly folded exine with its outer surface covered with a hair-like growth and having a small neck-like outgrowth at one end. Plate XIII, Fig. 4 shows two megaspore exines lying side by side embedded in an opaque material in a band of durain. Both these exines bear tuberculate outgrowths. The bigger spore on the lower left-hand side shows a wing-like appendage at one end. Plate XIII, Fig. 1 shows two megaspore exines, one in the centre near the upper edge and another near the lower edge in the right-hand side.

Plate XII, Fig. 2 and Plate XIII, Fig. 6 show two megaspore exines in durain as seen on polished blocks of coal. Both these exines bear tubercles on their outer surface and the exine in Plate XII, Fig. 2 shows also a neck-like attachment at the right-hand side. It is clear in Plate XIII, Fig. 6 that while nearly all the constituents of durain are prominently seen, the spore exine appears in the upper right-hand corner as a dark object not revealing any of its finer details.

The microspores in thin sections are seen in Plate XII, Figs. 4 and 6 and Plate XIII, Fig. 1 as short flatly compressed pale yellow bodies often with a crooked or an irregular crescent shape, scattered in the general mass of durain. In Plate XIII, Fig. 1 they appear as bright objects against the dark background of a highly carbonized ground mass in durain. A microsporangium-like body is seen in Plate XII, Fig. 6. Here a large number of small golden yellow bodies occur very closely packed together in durain. This object may be a torn portion of a compressed microsporangium. The sporangium was probably buried before it was ripe to burst and shed the spores. Similar objects are known to occur in the durains of Talcher coals.

Fungal bodies

A characteristic feature of these coals is presence of fungal bodies in large proportion. This fungal material usually appears dark in a thin section of coal, in the same way as do high rank tissues like fusain and vitro-fusain, and it is not easy to make the section any thinner for their examination in transmitted light. On the other hand, the fungal bodies show their features clearly in polished blocks. Their reflectivity approaches very near that of a high rank tissue in vitro-fusain.

Fungal remains and fungal spores have been described to occur in large numbers in the Tertiary coals of Assam and also in the Lower Gondwana coals of the Talcher coalfield (Ganju, 1954).

The main constituents of these fungal remains are sclerotia. They are hard and compact rounded bodies formed of a dense aggregate of interwoven hyphae and covered with a thick-walled outer coat of brown or blackish cells. They vary much in size and contain a good supply of reserve material. After remaining dormant for a considerable time they produce sporophores or conidiophores. The durain material round these hard ball shaped sclerotia is compressed very closely. It is generally noticed that these fungal bodies have destroyed the cellular structure of wood in coal in their vicinity.

Hacquebard (1952) has suggested that sclerotia which show no clear structure of the fungal hyphae may be termed 'sclerotioids' and when their structure is observed clearly the term sclerotium may be used.

The various types of fungal bodies in the Hutar coals are shown in Plate XII, Fig. 4 and Plate XIII, Figs. 2, 3, 5 and 6.

Plate XIII, Fig. 2 shows a fungal body resembling sclerotia. It is more or less oval in shape and has a mass of cellular structure surrounded by a hard solid ring. Another type of what is probably a fungal body showing a carved outline and some peculiar curved or straight markings on the surface is observed in Plate XIII, Fig. 5. These markings appear black and probably represent cracks caused by pressure on the outer hard shell of the body during the process of coal formation. In thin sections these cracks appear as white lines in the dark fungal body. This is observed in a fungal body in the upper right-hand side in Plate XII, Fig. 4. Similar objects have been described by Hacquebard (1950, 1952) under the term 'sclerotioids'. Plate XIII, Fig. 3 shows a rounded body probably of fungal origin. The material of durain surrounding these bodies has been closely compressed.

A small fungal body resembling sclerotia is seen embedded in the general mass of durain in Plate XIII, Fig. 6 at the upper left-hand side near the edge.

The fungal bodies in thin sections are shown in Plate XII, Fig. 4 which shows three dark bodies round or oval in shape, forming a major constituent of durain. On observing carefully it will be seen that the one near the upper margin shows a number of short straight or curved faint white lines which most probably represent empty cracks produced by pressure. These cracks have been referred to earlier in Plate XIII, Fig. 5. The fungal bodies are surrounded by thin and decomposed strips of woody vitrain. In all probability these strips are the decomposed products of a woody tissue which was destroyed by the agency of fungal organisms.

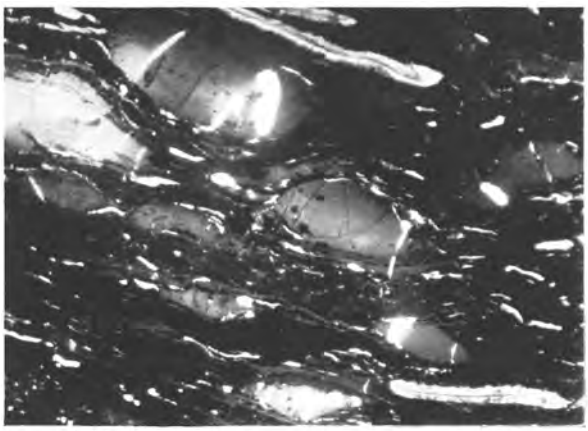


FIG 1. (X100)

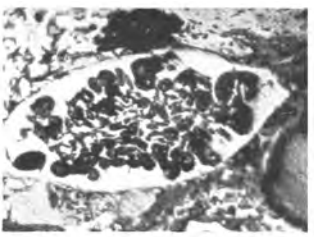


FIG.2. (X200).

FIG 3. (X200)

FIG.4. (X90).

FIG.5. (X200).

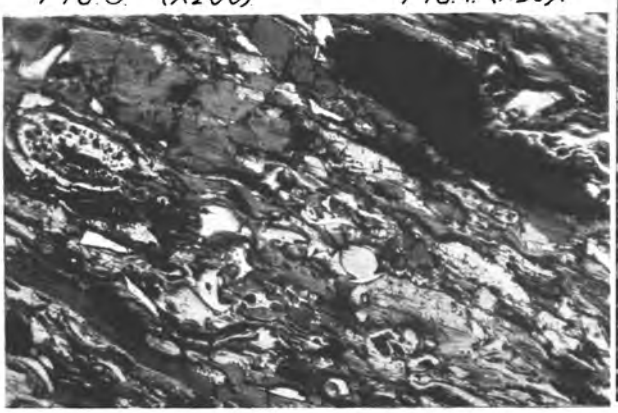


FIG. 6. (X200).

FIG.7. (X200).

In addition to these fungal bodies and spore exines the durain contains a large quantity of vitrain material occurring in small bits or in thin elongated strips which do not reveal any structure. Fusain occurs in small rounded balls or may be dispersed in a broken state in the general mass of durain. Narrow bands of vitro-fusain tissues are also prominent in some durains. These features are clear in Plate XIII, Figs. 6 and 7. Small grains of quartz and kaolinite constitute mainly the mineral matter present in these durains. Resinous bodies are found to occur in an appreciable amount. In thin sections they appear rounded or oval and brownish red in colour resembling closely vitrain in its colour and transparency. Their form, however, readily distinguishes these bodies from vitrain components. The resinous material may be homogeneous or finely granular often showing air bubbles in large numbers. Plate XIII, Fig. 1 shows a number of oval resins filled with a more or less homogeneous material and showing some dark granular bodies in small numbers. These resins show a few cracks which are most probably formed during the process of section making. An oval resin showing innumerable minute air bubbles as seen on a polished surface appears in Plate XII, Fig. 5 near the edge in the upper left-hand side.

Micrinite

The finely divided granular and coarse material which remains opaque in transmitted light and shows no traces of structure is included in micrinite. Finely granular micrinite has been described to occur in certain Indian coals (Ganju, 1954). While this variety is not observed in the Hutar coals, the massive type of micrinite, some of which is probably formed of bits of much decomposed and carbonized walls of wood fibres, is present in a fair amount in the durains of these coals.

Summary and Conclusions

A study of representative specimens of coal from seams No. 2 and No. 3 in the Sone Valley Hutar colliery was made with a view to ascertain the nature of microscopic constituents of these coals.

Examination in hand specimen reveals that these coals are composed largely of dull bands of durain including numerous narrow strips of vitrain which have produced a streaky appearance in the durain bands. Fusain is found in great abundance and a block of coal splits easily along the fusain layers revealing charred strips of fusinized wood on the surfaces thus exposed. Thick persistent bands of vitrain occur scarcely in the coals examined.

The results of proximate analyses of a few representative samples from the two coal seams show these coals to be generally lower in rank, as compared to coals of the Damodar Valley coalfields.

Microscopic study was made by an examination of thin sections in transmitted light and of polished surfaces in reflected light under oil immersion.

An examination of microscopic constituents has revealed that these coals are largely composed of woody tissues preserved as fusain and vitro-fusain which often show very well preserved cellular structures in reflected light. The cell walls are thick and the cell cavities usually empty. The effect of pressure is often evident where the cell walls are broken and crushed producing the bogen structure characteristic of vitro-fusain. Longitudinal sections of woody tissue have revealed bordered pits which have produced X-shaped chains in the walls of wood fibres. In certain woody tissues the cell cavities are partly filled with some opaque or semi-opaque material which has probably shrunk in the process of coal formation. In thin sections of some fusain bands the cell cavities appear filled with a mineral material resembling kaolinite.

Vitrain tissues occur scarcely and when present do not reveal any structure.

The durain shows a variable composition and its two distinguishing features lie in the abundance of fungal bodies and megaspore exines. The fungal objects, some of which resemble sclerotia, have caused a widespread decay in the woody tissues. Fusain occurs in a finely dispersed state or in small rounded balls. Long narrow strips of vitrain are abundant. Microspores are very abundant. The durain also includes bits of broken cell walls of wood fibres, angular fragments of micrinite, oval resins, and grains of quartz and kaolinite.

In the nature and distribution of their microscopical constituents the Hutar coals resemble more closely the coals of Talcher coalfield than they do to those of the Damodar Valley coalfields. This fact may suggest that similar conditions of deposition were prevailing in the Hutar and Talchir basins.

Abstract

The results of microscopical examination of coals from seams No. 2 and 3 in the Sone Valley Hutar colliery are described in this paper.

In hand specimen these coals do not exhibit a well developed banding into bright and dull layers but are largely composed of dull bands of durain including numerous streaks of vitrain. Charred strips of fusain are exposed in abundance on surfaces parallel to bedding planes.

Examination of microscopic constituents in thin sections and on polished surfaces shows that these coals are largely composed of woody tissues preserved as fusain and vitro-fusain which reveal well preserved plant structures. Vitrain tissues occur scarcely and do not exhibit any cellular structure. The durain shows fungal bodies and megaspore exines in great abundance. Its fusain constituents occur in a finely dispersed state or in rounded balls. Fragments of cell walls of fusinized woody tissue, narrow strips of vitrain, angular pieces of micrinite, oval resins, flatly compressed microspores, and grains of quartz and kaolinite are other recognizable constituents in durain.

In their appearance in hand specimens and in the nature of their microscopic constituents these coals are more or less similar to the Talcher coals but are markedly different from coals of the Damodar Valley coalfields.

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Description of Plates

Plate XI

(All figures are from polished surfaces in reflected light under oil immersion.)

Fig. 1. Transverse section of a woody tissue preserved as fusain. The cell walls showing pits are thin and appear white in outline; the cell cavities are empty and appear dark. Some cell walls are slightly folded as a result of compression. No. 2 seam. (×200).

FIG. 2. Rectangular cells of a secondary woody tissue in fusain arranged serially appear in the right-hand side. In the left-hand side this structure passes into a band of tissue similar to that in Fig. 1, but showing many broken cells. No. 2 seam. (×200).

,, 3. Thick-walled woody tissue in fusain showing effects of compression. The cell walls are broken and in the central part they are crushed producing the characteristic bogen structure. No. 2 seam. (×200).

,, 4. Longitudinal section of a woody tissue showing well preserved bordered pits, which have produced a chain-like structure in the walls of wood fibres. The fibres are broken at some places. No. 2 seam. (×200).

,, 5. Transverse section of woody tissue in fusain showing blocks of thick-walled cells surrounded by a broken and crushed mass of cell walls which have produced bogen structure at some places. No. 3 seam. (×200).

,, 6. Longitudinal section of a woody tissue similar to that in Fig. 4. The bordered pits have produced a X-shaped chain in some fibres. No. 2 seam. (×200).

PLATE XII

(Figs. 1, 2 and 5 are from polished surfaces in reflected light under oil immersion; Figs. 3, 4, 6 and 7 are from thin sections.)

FIG. 1. A contact zone between two bands of a woody tissue in vitro-fusain. On the left-hand side thick-walled wood fibres showing bordered pits are shown in longitudinal section; on the right-hand side a mass of broken cells which have produced bogen structure at some places are seen in transverse section. No. 2 seam. (×200).

,, 2. A megaspore exine showing a tuberculate outgrowth on the outer margin and a narrow neck-like attachment at the right-hand side. No. 3 seam. (×200).

,, 3. Transverse section of woody tissue in fusain as seen in a thin section. The cell cavities which appear white are filled with a mineral substance probably kaolinite. No. 2 seam. (×400).

,, 4. General view of durain showing three dark rounded or oval fungal bodies. The one near the upper margin shows a number of short straight or curved faint white lines which are probably cracks produced by pressure. The fungal bodies are surrounded by thin strips of vitrain. No. 3 seam. (×100).

,, 5. Transverse section of a band of thin-walled cells which are slightly compressed. Generally the cells include some material filling partly their cavities. The cell contents are probably formed of an opaque or a semi-opaque coal substance which was initially filling the lumens completely but has partly dried in the process of coal formation. The cell contents have lower reflectivity as compared to the cell walls. An oval resin including minute air bubbles is seen near the edge in the upper left-hand side. No. 2 seam. (×200).

,, 6. Part of a microsporangium-like body including a large clustre of microspores closely packed in durain. No. 2 seam. (×100).

,, 7. A folded megaspore exine. The outer surface appears to be covered with a hair-like growth and at one end in the upper part there is a small neck-like outgrowth. No. 3 seam. (×400).

PLATE XIII

(Figs. 1 and 4 are from thin sections; Figs. 2, 3, 5, 6 and 7 are from polished surfaces in reflected light under oil immersion.)

FIG. 1. Durain showing a number of oval resin bodies filled with a more or less homogeneous material and showing dark granular bodies in small numbers. Two megaspore exines stand prominently in durain which also includes microspores in large numbers. The microspores appear as pale yellow, flatly compressed, short needle-like objects often with a crooked shape. No. 3 seam. (×100).

,, 2. An oval fungal body resembling sclerotia. It shows a mass of cellular tissue surrounded by a solid ring. No. 2 seam. (×200).

,, 3. A rounded body of a probable fungal origin. The surrounding material of durain is closely compressed. No. 2 seam. (×200).

,, 4. Two megaspore exines showing tuberculate outgrowth are lying side by side in fusinized material in durain. The bigger exine at the left-hand side shows a wing-like appendage at one end. No. 2 seam. (×90).

,, 5. An oval body probably fungal in origin, showing a carved outline and peculiar curved or straight markings on the surface. These markings may be due to cracks caused by pressure during coal formation. In thin sections these cracks appear as faint white lines as shown in Plate II, Fig. 4. No. 2 seam. (×200).

FIG. 6. Durain showing its constituents clearly preserved. A small oval fungal body resembling sclerotia is seen in the upper left-hand side. A megaspore exine is preserved in the upper right-hand corner. Short narrow bands of vitrain and vitro-fusain tissues, finely divided and rounded fusain material, micrinite and grains of quartz and kaolinite are other characteristic constituents of this durain. No. 2 seam. (×200).

„ 7. General view of constituents of durain showing thin elongated strips of vitrain and vitro-fusain tissues, broken walls of wood fibres, some massive type of micrinite and spore exines. No. 3 seam. (×200).

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