ABSTRACT

The physical, chemical and microscopic changes brought about by the intrusion of a mica-peridotite dyke in the Dishergarh seam have been investigated.

The vitrain bands show distortion, folding and fading of lustre. Near the contact the coal is converted into 'jhâmâ' which shows columnar structure.

The chemical characteristics of the coal show more rapid changes on approaching the dyke. The coal has been affected up to a distance of 8 feet from the contact or slightly beyond, but is practically unaltered at a distance of 11 feet.

The microstructures of fusain have not been affected. Vacuoles and cracks appear in the vitrain bands which increase in number and size as the dyke is approached. These are now filled with secondary mineral matter.
Introduction

The Raniganj Coalfield, an important coalfield of the Damodar valley, is situated about 130 miles north-west of Calcutta within longitudes 87° 20' and 86° 36' and latitudes 23° 32' and 23° 51'. The junior author visited the area during the winter season of 1954–55 for field-work in connection with obtaining suitable material for petrological examination of these coals. Representative sets of samples from all the workable seams in the different collieries were collected. The petrological investigation has been nearly completed and the work is being submitted shortly in the form of a thesis for the Ph.D. degree. The entire work was carried under the guidance of Prof. P. N. Ganju, Head of the Geology Department, Aligarh Muslim University, and the present paper constitutes a part of the main investigation.

According to Gee (1932, p. 21), the succession in this coalfield is as follows:

- **Recent and Sub-Recent**: Alluvial and lateritic deposits.
- **Upper Gondwanas**: Supra-Panchets (of Panchet hill, etc.).
  - (?) Durgapur beds.
  - (?) Unconformity.
  - Panchet series.
- **Lower Gondwanas**: Damudas.
  - Talchir series.
  - (large unconformity).
  - (Archæans.)

The Barakar measures attain a total thickness of 2,100 ft. and include seven productive coal seams, while the Raniganj measures are 3,400 feet thick and contain ten productive coal seams. The two measures are separated by 1,200 feet thick Ironstone Shales. The Dishergarh seam is the fourth seam from bottom in the Raniganj measures.

The Raniganj measures of the Dishergarh-Asansol area have been divided by Gee (loc. cit., p. 200) into five stages as follows:

- (v) Bharat Chak-Kumarpur sandstones (300 to 350 feet).
- (iv) Chinakuri-Fatehpur-Bansarakdih coal measures (650 to 700 feet).
- (iii) Seetalpur-Aldihi-Manoharbahal coal measures (1,250 feet).
- (ii) Sitarampur coal measures (400 to 450 feet).
- (i) Ethora sandstones (650 to 700 feet).
The seam under discussion is contained in the Sitarampur coal measures of the Dishergarh-Sheetalpur area. The samples were collected at Pit Nos. 9 and 10 of the Sodepur colliery. The seam here is 17 feet thick and strikes N 71° 45' E with a gradient of 1 in 5.5 due S 18° 15' E. The mica-peridotite dyke, 12 feet wide, runs in a NNW-SSE direction and its contact with the coal seam is exposed in the underground working 500 feet east of the shaft level. Ten samples, including those of the dyke, were collected within a distance of 11 feet on the eastern side of the dyke. The location of the coal samples is given in the table below and a shaft section of Pit No. 11 in the Sodepur colliery is shown in Text-Fig. 1.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>1</th>
<th>2</th>
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<th>4</th>
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<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>Distance in feet</td>
<td>Dyke</td>
<td>Dyke</td>
<td>Jhama mixed</td>
<td>0'</td>
<td>0'</td>
<td>1'</td>
<td>2'</td>
<td>3'</td>
<td>4'</td>
<td>5'</td>
</tr>
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</table>

The Gondwana rocks of the Damodar valley coalfields are intruded by a number of basic and ultra-basic igneous intrusions which have affected the coal seams. During his survey of the Raniganj coalfield, Blanford (1861, pp. 141-49) observed the occurrence of igneous intrusions in the strata but did not differentiate these into mica-peridotites and dolerites. Hughes (1866) has differentiated the mica-peridotite and dolerite intrusions during his survey of the Jharia coalfield. Holland and Saise (1895, p. 132) have described the post-Damuda mica-peridotite and basaltic dykes of the Giridih coalfield and their effects on coal seams in the following words:

"Even the narrow dykes of peridotite, where they pass through the coal seams, are bordered with a zone of beautifully columnar coke two or three feet thick on either side of the dyke. The volatile bituminous matter having been driven off, the resulting contraction in the mass produced a columnar structure with injections of thin films of igneous rock along the cracks."

These authors also noticed an increase in the ash percentage of coal on approaching the dyke.

Heslop (1899-1900, p. 415) examined the effects of dolerite dykes on the coals of the Natal coalfield and concluded that no definite rule can be laid down to determine the distance along which the coal is affected but roughly speaking "the coal is found unaffected at a distance from the dyke,
equal to the thickness of the dyke”. Describing the effects of a 22 feet thick dyke on a Natal coal seam, Stanley (1908-09) observes that the coal has
Effects of a Mica-peridotite Dyke on the Dishergarh Seam

Evidently been infiltrated by mineral solutions and 18 feet away from the dyke the coal was practically unaltered.

Russell (1904–05, p. 241) examined the effect of dolerite dykes on the coals of the Cape Colony and observed that “the coal was affected on either side of a vertical dolerite intrusion and the following are some examples: A dyke, 5 feet thick, affected the coal on either side to a distance of 20 feet; 8 feet, 35 feet; 12 feet, 50 feet; 18 feet, 50 feet; 30 feet, 80 feet; and 30 feet, 200 feet.” He concluded that the area of coal affected was not proportional to the width of the dykes.

Whitehead (1904–05) observed the effects of whinstone and dolerite dykes on the Transvaal coals. The dykes are 1,000 to 1,500 feet thick and have changed the quality of coal within a certain radius according to the size of the dyke.

The burning of coal by dolerite dykes and sills in the Central Coalfield of Scotland has been reported by Hinxman et al. (1917) and Carruthers and Dinham (1920). Regarding the effects of the whinsill on these coals Clough et al. (1926, p. 58) state that “the coal is not only altered in character, but is also thinner generally.” Briggs (1934–35, p. 193) commenting on the temperature of the whin sills says that “it seems probable that the temperature would, as a rule, be under rather than over 1,000° C.”

Marshall (1936) examined the effects of the 17-foot Westerhope dyke on Brockwell Seam in the Northumberland Coalfield. He investigated the nature of the physical changes by studying polished blocks wherein he observed the distortion, folding and faulting of the horizontal laminae, complete destruction of structure, appearance of vesicles and cracks which increased in number and size as the dyke was approached. The structure of the fusinite, however, was not affected. The results of his chemical investigation revealed a most rapid change between 2 and 3 feet from the contact.

While describing the thermal metamorphism of coal seams Marshall (1952, p. 139) states: “The alternation produced is related to the temperature of intrusion and the amount of heat available,.........the width of the dyke or sill fissure, the period of operation, the character and particular circumstances of intrusion.”

The caking effect on Indian coals by igneous intrusions have been studied by determining the proximate analyses of coals taken at various distances from the dyke or sill by Hughes (1866), Bose (1888), Fermor (1927), Fox (1930) and Gee (1932). The burnt coal has been named ‘Jhāmā’ and regard-
ing the origin of this term Fox (1930, p. 130) observes: “So far as I can discover the term Jhāmā was first introduced into geological literature by Dr. Saise in 1894. It had evidently been applied to the naturally coked coal in the Giridih coalfield some time before.” The same author (1931, pp. 59–60) wrote subsequently: “It has been the practice for many years among mining engineers and others in India to speak of this natural coke as Jhāmā—a vernacular term, normally applied to overburned and fused bricks”.

Regarding the age of the Damodar valley dolerites, Fox (1930) is of the opinion that they may be probably equivalent to the Deccan traps—Middle Cretaceous age. Gee (1932) has shown that the dolerites of the Raniganj coalfield are younger than the mica-peridotites.

**Effects of the Dyke on the Dishergarh Seam**

*Physical changes.*—The dyke has produced 2½ to 3 feet of ‘ Jhāmā ’ on either side. The burnt coal (jhāmā) has lost its original banding and lustre and appears dull. The zone of ‘ jhāmā ’ is divided into a number of columns which are highly fractured and filled with mineral matter. This should be expected as a result of sudden heating of the coal by the igneous intrusion. This phenomena, seen in Sample No. 3, is illustrated in Plate XXXI, Fig. 1. The fractures appear white and the characteristic banding of the bituminous coal is not seen. At a distance of two feet from the contact, the coal shows traces of original banding as revealed in Plate XXXI, Fig. 2. The mineral filled fractures are here clearly demarcated.

Beyond the zone of ‘ jhāmā ’, the physical changes undergone by coal are distinctly exhibited within a distance of 3 to 6 feet. The vitrain bands, now more carbonized, show marked crumpling at a distance of 4 feet from the margin of the dyke as shown in Plate XXXI, Fig. 3. Further away, the crumpling becomes less marked until at a distance of 7½ feet, the coal appears normal. Plate XXXI, Figs. 4 to 6 show this effect clearly.

Apart from the crumpling of the bands, the appearance of coal has changed markedly. As already stated the burnt coal appears lustreless. The coal gradually regains its lustre. Sample Nos. 4 and 5 show dull lustre and further away the lustre is normal.

The crumpling of the bands indicates that the constituents of coal passed through a plastic state and the extreme folding denotes compressional pressure during the period of operation.
Chemical changes.—In order to ascertain the effect of the dyke on the chemical characters of coal, the proximate analyses, carbon dioxide, calorific value and specific gravity determinations were carried out. Results of the chemical investigations are shown in Table I and the variation of various contents is plotted in Text-Fig. 2.

**Text-Fig. 2.** Variation in moisture, ash, volatile matter and carbon dioxide percentages and calorific value (B. Th.U.) in Dishergarh Seam as a result of a mica-peridotite dyke intrusion.

The results show that the moisture, volatile contents and the calorific values decrease as the dyke is approached. On the other hand, the ash and CO$_2$ percentages and the specific gravity increase in this direction.

The fall in the moisture and volatile contents is clearly due to the effect of the heat of intrusion on coal. An increase in the ash percentage has resulted due to the infilling of secondary mineral matter in the cracks. This also explains why there is a higher CO$_2$ percentage in samples closer to the dyke. The fall in the calorific value (as determined) is obviously due to the high contamination of ash in the coal.
TABLE I

Results of the proximate analyses of coal of the Dishergarh Seam adjacent to the mica-peridotite dyke in the Sodepur colliery, Raniganj Coalfield

<table>
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<tr>
<td>10</td>
<td>11</td>
<td>2.83</td>
<td>32.70</td>
<td>13.98</td>
<td>50.49</td>
<td>39.31</td>
<td>60.69</td>
<td>0.008</td>
<td>12168</td>
<td>15829</td>
<td>1.43</td>
<td>Non-swollen, slightly porous, greyish-black hard, bright, shining, non-fissured</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>7½</td>
<td>2.66</td>
<td>31.66</td>
<td>11.72</td>
<td>53.26</td>
<td>56.97</td>
<td>63.03</td>
<td>0.094</td>
<td>12634</td>
<td>14756</td>
<td>1.38</td>
<td>Very poorly caking non-coherent, soft button</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>2.50</td>
<td>15.34</td>
<td>12.63</td>
<td>69.63</td>
<td>18.07</td>
<td>81.07</td>
<td>0.012</td>
<td>12722</td>
<td>14989</td>
<td>1.48</td>
<td>Non caking</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>5</td>
<td>2.52</td>
<td>8.92</td>
<td>14.32</td>
<td>74.24</td>
<td>10.72</td>
<td>89.28</td>
<td>0.100</td>
<td>12218</td>
<td>14633</td>
<td>1.50</td>
<td>do.</td>
<td>0</td>
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<td>6</td>
<td>4</td>
<td>2.31</td>
<td>7.50</td>
<td>16.22</td>
<td>73.87</td>
<td>9.34</td>
<td>90.66</td>
<td>0.184</td>
<td>12101</td>
<td>14872</td>
<td>1.55</td>
<td>do.</td>
<td>0</td>
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<tr>
<td>5</td>
<td>3</td>
<td>2.14</td>
<td>4.86</td>
<td>20.51</td>
<td>72.39</td>
<td>6.41</td>
<td>93.59</td>
<td>0.540</td>
<td>11063</td>
<td>14303</td>
<td>1.62</td>
<td>do.</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>1.62</td>
<td>4.32</td>
<td>28.24</td>
<td>65.82</td>
<td>0.15</td>
<td>93.85</td>
<td>1.248</td>
<td>10314</td>
<td>14705</td>
<td>1.73</td>
<td>do.</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0.74</td>
<td>4.87</td>
<td>37.98</td>
<td>66.41</td>
<td>7.94</td>
<td>92.06</td>
<td>3.464</td>
<td>7632</td>
<td>12454</td>
<td>2.19</td>
<td>do.</td>
<td>0</td>
</tr>
</tbody>
</table>
There is a sudden fall in the volatile contents from 31.66% to 15.34% in samples which are at a distance of 7½ feet and 6 feet respectively from the dyke, indicating a loss of 16.32% in a distance of 1½ feet. In the sample 5 feet away from the dyke the volatile matter has dropped to 8.92%. After this, the fall is more or less regular and in the sample two feet away from the contact it has dropped to 4.32% ($CO_2 = 1.248\%$) and increased to 4.87% in the sample one foot away from the contact. The slight increase is due to the higher percentage of $CO_2$ in this sample ($CO_2 = 3.464\%$).

The moisture content shows a gradual decrease from 2.83% to 2.14% with the decreasing distance from 11 to 3 feet. The sample 2 feet away from the contact shows a low moisture content of 1.62%. It has dropped to 0.74% in the sample one foot away from the contact.

The ash percentage gradually increases within 11 and 3 feet but in the close proximity of the dyke it increases rapidly.

The trend in the increase of specific gravity is a gradual one from 1.43 to 1.73, but it increases abruptly to 2.19 in the closest sample due to high ash percentage.

The caking tests have revealed that except sample No. 10, which shows B.S. Swelling No. 1, no other sample yields a cake. This is due to the loss of caking components on devolatilization.

*Effects on microstructure.*—In order to investigate the effects of the dyke on the microstructure, studies of the thin sections and polished blocks were made. Only sample Nos. 9 and 10, which are 7½ and 11 feet distant from the dyke respectively, could be thinned sufficiently to yield good sections. These samples did not reveal any distortion or obliteration of the microstructures.

Sample No. 8, which is 6 feet away from the contact, shows a drop in the volatile matter to 15.34% and thus being more carbonized could not be thinned sufficiently. The examination of polished surface revealed that the vitrain bands contain a number of small vacuoles due to sudden escape of the volatile contents. These vacuoles are filled with secondary mineral matter. The examination of other blocks closer to the dyke showed that the number and size of the vacuoles increased nearer the dyke. Plate XXXII, Fig. 1 illustrates a carbonized band of vitrain showing numerous vacuoles but no trace of cellular structure. Besides the vacuoles there are several cracks, now filled with mineral matter, which must have been formed due to shrinking of the vitrain band on cooling.
The number of vacuoles has increased to maximum in sample No. 3 which has been converted into 'jhāṃā'. Its high percentage of ash (37·98) is obviously due to the mineral matter filling the vacuoles as seen in Plate XXXII, Fig. 2.

The fusain tissues have been noticed to retain their cellular structure. The sample 5 feet away from the contact, shows cellular structure of fusain derived from wood as illustrated in Plate XXXII, Fig. 3. The cell-walls appear white and the cell cavities filled with mineral matter appear dark in the photograph. In this tissue the fusain has retained its structure due to the presence of mineral matter in the cell cavities. Secondly, being highly carbonized prior to the intrusion of the dyke, the heat of intrusion did not bring any drastic change in the tissue. Although the tissue shows 'bogenstruktur' at some places, especially in the upper left-hand side of the photograph, such type of structure is frequently seen in the fusain of normal coals.

Another well-preserved structure of wood in fusain showing clearly preserved scalariform thickenings is seen in Plate XXXII, Fig. 4. This microphotograph is taken from the sample 2 feet away from the contact. Traces of structures in fusain were also seen in sample No. 3, one foot away from the contact.

It is clear from the above examples that the fusain tissue has withstood more firmly the effects of heat as compared to the vitrain tissues.

**Temperature of the mica-peridotite intrusion.**—The temperature of mica-peridotite must have been high to keep it in a molten state. Describing the petrology of a number of natural cokes, Marshall (1945, p. 126) writes: "During the cindering or coking of coal by igneous intrusion into the seam or closely adjacent to the seam, relatively high temperatures were probably attained (up to 1,000 °C) under great pressure for relatively great intervals of time". Pascoe (1929, p. 137) observes that to make a coke of the composition of jhāṃā "requires a temperature of about 500 °C. It is to be concluded, therefore, that the dykes of mica-peridotite could not have been at a very much higher temperature than 500 °C. " Fox (1930, pp. 142-143) is of opinion that the fluid mica-peridotite "was probably at a lower temperature than 1,200 ° or even 1,000 °C. ” Clegg (1955, p. 14) examined the effects of a mica-peridotite dyke on the Hamburg (No. 5) coal, Williamson County, Illinois. He found by differential thermal analysis that "the maximum temperature at the coal-dyke contact was about 600 °C."

From the above it appears that the temperature of the mica-peridotite must be fairly high during the time of intrusion and this accounts for the
Effects of a Mica-peridotite Dyke on the Dishergarh Seam

Crumpling, fracturing and formation of natural coke in the immediate vicinity of the intrusion.

That rapid cooling of the margins of the dyke in contact with coal has taken place is apparent from the small grain size of mica-peridotite, as seen in Plate XXXII, Fig. 5. The normal grain size of the dyke sample from the central portion of the dyke is shown in Plate XXXII, Fig. 6.

SUMMARY AND CONCLUSIONS

A study of the Dishergarh seam in Sodepur colliery was made to investigate the physical, chemical and microscopic changes undergone by coal due to the intrusion of a mica-peridotite dyke.

Megascopic examination of the coal showed distortion, folding and fading of lustre of the vitrain bands on approaching the dyke. The coal near the contact has been converted into a zone of 'jhāmā' 2½ to 3 feet thick which appears columnar in structure.

Chemical investigation revealed the loss of moisture, volatile matter, calorific value and caking power and an increase in the ash and CO₂ percentages.

Fusain shows well-preserved cellular structures while the microstructures in vitrain have been obliterated. Vacuoles and cracks appear in the vitrain bands and these increase in number and size nearer the contact and are filled with secondary mineral matter.

In the light of these investigations it is concluded that:

(i) The dyke has affected the coal up to a distance of 8 feet or slightly beyond as the coal is practically unaltered at a distance of 11 feet.

(ii) The chemical characteristics of the coal have changed first abruptly and gradually away from the dyke.

(iii) Only fusain has retained its cellular structure even in the comparatively highly altered region. The structures of vitrain are obliterated indicating that it has passed through a plastic state.

REFERENCES


EXPLANATION OF PLATES

PLATE XXXI

(All photographs are from polished surfaces)

Fig. 1. A specimen of ‘jhāmā’ showing cracks filled with secondary mineral matter. The typical banding of a bituminous coal is absent. Sample No. 3, 1 foot from the contact, × (nat. size).
Fig. 1 (nat. size)

Fig. 2 (nat. size)

Fig. 3 (x3)

Fig. 4 (x3)

Fig. 5 (nat. size)

Fig. 6 (nat. size)

FIGS. 1–6
Effects of a Mica-peridotite Dyke on the Dishergarh Seam

Fig. 2. A specimen of 'jhāmā showing traces of original banding. Sample No. 4, 2 feet from the contact, × (nat. size).

Fig. 3. A specimen of coal showing intense crumpling and folding of the vitrain bands. Sample No. 6, 4 feet from the contact, × 3.

Fig. 4. A specimen of coal showing moderate crumpling of the vitrain bands. Sample No. 7, 5 feet from the contact, × 3.

Fig. 5. A specimen of coal showing a few folded bands of vitrain. Most of the bands do not show this effect. Sample No. 8, 6 feet from the contact, × (nat. size).

Fig. 6. A specimen of coal showing normal banding. Sample No. 9, 7½ feet from the contact, × (nat. size).

Plate XXXII

(Figs. 1 to 4 are from polished surfaces of coal in incident light; Figs. 5 and 6 are from thin sections of dyke in transmitted light)

Fig. 1. Carbonized vitrain band showing small vacuoles filled with secondary mineral matter. Sample No. 6, 4 feet from the contact, × 145.

Fig. 2. Same features as in Fig. 1. The vacuoles are larger in size. Sample No. 3, 1 foot from the contact, × 215.

Fig. 3. Fusain showing woody structure. Well-preserved ‘Bogenstruktur’ is seen in the top left-hand side. Sample No. 7, 5 feet from the contact, × 175.

Fig. 4. Fusain showing scalariform thickenings in a woody tissue. Sample No. 4, 2 feet from the contact, × 175.

Fig. 5. Mica-peridotite dyke showing small grain size of minerals due to the effect of chilling at the contact. Sample No. 2, mica-peridotite dyke, × 33.

Fig. 6. Mica-peridotite dyke showing normal grain size of minerals. Sample No. 1, mica-peridotite dyke, × 33.