SOME PHYSICAL CONDITIONS WHICH AFFECT SPONTANEOUS HEATING IN COAL MINES.

By W. Kirby, *B.Sc., M.I.Min.E., Chief Inspector of Mines in India.*

Spontaneous heating in coal mines is of great importance on account of the considerable losses of coal involved in the resulting fires and the dangers incurred in dealing with these fires.

The causes of spontaneous heating may be considered under two headings:—(*a*) Physical, and (*b*) Chemical. With the limited space at my disposal I propose to discuss the most important physical conditions in mines which are conducive to initiating spontaneous heating and which will be of more interest to the mining engineer than the chemical aspect of the subject.

The physical conditions which influence spontaneous heating in coal seams might be classified as follows:—

(1) The thickness of the coal seams.
(2) Nature of the coals, geological conditions and the crushing of pillars.
(3) The nature of adjoining strata.
(4) Depth of the coal seams.

1. *The thickness of the coal seams.*

The thicker the seams the more difficult it becomes to extract all the coal, and some small coal is generally lost in the goaves, due to 'weight' coming on the small pillars or 'stooks', necessitating the leaving of coal in the goaves. This coal becomes crushed and is one of the primary causes of the spontaneous heating. Again, the cleavage planes in thick seams are usually very pronounced and may lead to deterioration of the pillars in the 'first working' particularly where the galleries have been driven to the full height in thick seams. There are sometimes soft bands in coal seams, *e.g.*, No. 15 seam in the Jharia coalfield, which deteriorate and are likely to create conditions conducive to spontaneous heating, because of the gradual weakening of the pillars which may result in collapses and the production of small coal and other conditions likely to promote heating.

2. *Nature of the coals, geological conditions and the crushing of pillars.*

The nature of the coals and the geological conditions play an important part in the stability of pillars.

The friability of coals varies considerably throughout the Jharia coalfield. In the eastern portion of the field there is a soft band, 2′–4′ thick, in the middle of 15 seam, which crumbles up in the hand, and the cleavage of the coal is also very pronounced. These conditions encourage deterioration of pillars. In the south-east part of the Jharia coalfield there is a 4′-5′ section of very

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friable coal, about 12 feet from the roof and in addition the seam is traversed with slickensides, and these factors have an important bearing on the liability of the coal to crush and form small coal. In the year 1932, I read a paper before the National Association of Colliery Managers (Indian Branch) entitled 'The Causes of Spontaneous Combustion underground in mines in the Jharia Coalfield together with a consideration of some preventive measures', in which I referred to an explanatory note on a geological section and the geological conditions in this part of the coalfield by Dr. Fox, and I cannot do better than quote this note in full and give the section (Figure 1).

Dr. Fox states:—

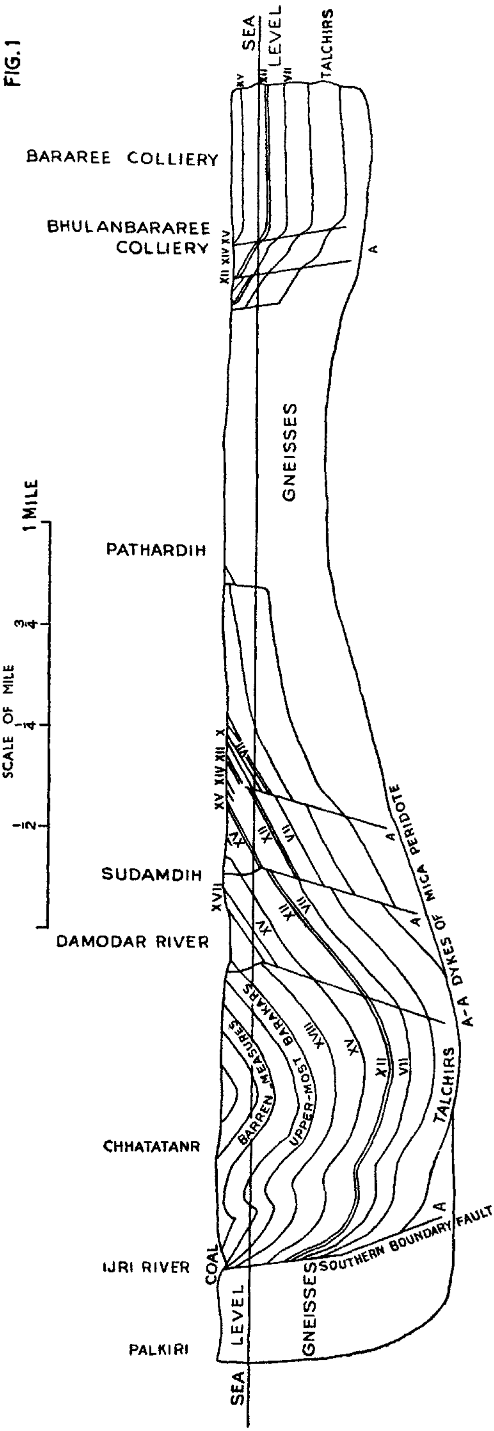
'The section is drawn to the scale of 4 inches to one mile, both vertically and horizontally, on the line, roughly of longitude 86° 26′; across sheet No. 8 of the Geological Map of the Jharia Coalfield. The northern part of this section was dealt with in a special excursion of the Mining and Geological Institute of India on the 10th February, 1930. The intention of that excursion was to show that the gneisses of Pathardih were not the relics of an ancient ridge on which the Coal Measure sediments were laid down. And it was proved on the ground that the coal-bearing strata on each side of this Pathardih horst had not been let down by simple faulting. The evidence was clear that shearing had occurred along the line of the gneiss-coal measure boundary, as though the gneisses had been driven westwards into the sedimentary rocks, or that the coal-bearing strata had been thrust against the gneisses from the west. (See *Transactions, Mining and Geological Institute*—Volume XXV, pages 176–179, 1931, and the Map of the Bhulanbarari area given with it.)

'With regard to the area south of the Pathardih horst the outcrops of the seams do not show the same spectacular sweep as they approach the gneisses. In fact, at first sight there is apparently strict parallelism between the outcrops and the boundary, such as would be expected with beds gently dipping away from the rocks on which they rest undisturbed. The first irregularity, however, becomes evident in tracing the outcrops of No. X and No. XI/XII seams from west of Sawardih to Chasnala. They converge eastward, and so does the outcrop of No. XIV seam with respect to that of No. X seam. There is little evidence of faulting between. Examined closely it is found that faults must exist between each of the seams named—between X and XI-XII near Chasnala, and between XIV and XI/XII south of Sawardih. When the thickness of the beds and the dips of the strata are carefully drawn in section it is discovered that there are irregularities between XV seam and XVIII seam in the Sudamdih tract. And the mapping has shown unusual seams and beds above XVIII seam in the area south-east of Sitanala.

'The explanation of these features is difficult but the clues are to be seen in the banks of the Damodar river south of Tasra (23° 38′; 86° 28′) and also north-east of Bhojudih railway station. In each case the strata are found striking almost at right angles to the direction of their outcrops at Sudamdih and Chasnala. The dips increase steadily from Pathardih to the south bank of the Damodar by the railway bridge, but at no place are the dips as steep as those seen south of Tasra. And just east of Bhojudih the dips are not only up to 80°, but the strike has swung round so as to give definition to a deep trough to the west under Bhojudih and onward. Crushed coal in a seam on the banks of the Ijri further confirms the synclinal structure west of Bhojudih. All these evidences are depicted in Sheet No. 8 of the Geological Map of the Jharia Coalfield. And there can be no question that the evidence as a whole confirms a westward forcing in of the gneisses or an eastward thrust of the Gondwana strata.

'On pages 87-88 and 151-152 of the memoir on the geology of the Jharia coalfield (*Memoir, Geological Survey, India,* LVI, 1930), questions of shearing along the bedding

FIG. 1



SECTION PALKIRI AND SUDAMDIH TO BHULANBARAREE of the strata are considered. The question to be decided is along which of the beds—sandstones, shales or coal seams—is sliding likely to occur. The general opinion from experience is that the plane between a thick sandstone and a bed of shale is most likely to function as a gliding or shear zone. In this case the strata themselves will not be greatly affected if the folding or sliding is not excessive. On the other hand there is little doubt that if a coal seam becomes involved in a shear zone the coal will be seriously affected by almost the smallest movements. The result will be that any cohesion or strength of the coal will be greatly reduced and it is doubtful if any reliability can be placed on such material to withstand roof weight. Of actual data in this connection we have evidence of two kinds—one in the curious failures of coal pillars in *certain* seams in *certain* areas, and the other in the liability of the same seams to ignition by spontaneous combustion.

'In the last paragraph emphasis is intended on the word certain. It is well known that the coal in the various seams in the Barakar series in the Jharia coalfield is not the same. In some it is dull and hard and strong; in others it is bright and brittle and friable. Taking these extremes as types of two seams it is evident that under stresses inducing a strain along the bedding of the seams the bright coal will shear rather readily. It is nearly always the better quality coal. Consequently, when such a seam is opened for working, the pillars will be subject to spalling; collapses are likely to occur in an inexplicable way to those who do not appreciate the loss of cohesion that has occurred in the geological past; and, lastly, such coals will readily oxidise and heat up and ultimately ignite with access of air. It is true that nearly all bright coals with a volatile percentage over 25 are liable to spontaneous combustion, under suitable conditions, even when in undisturbed seams. But when shearing, especially relatively slight shearing (enough to impair the strength of the coal), has taken place these seams are much more liable to fire when worked by the pillar and stall methods now in vogue in the Damodar valley coalfields.

'The section which accompanies this note is to indicate the geological structure along one line from the southern boundary fault near Bhojudih northwards through Sudamdih and through the gneissic horst of Pathardih to the coal measures about Bhulanbarari. It is by no means certain that over-riding is absent in the Barren Measure sandstone about Chhatatanr, and the considerable thickness of strata which has been designated Upper most Barakars may also be due to a duplication of the measures as the result of over-riding (as explained on page 88 of the Jharia memoir already referred to). With regard to the fault immediately north of Sudamdih there seems little doubt that over-riding has occurred and that this is not a normal but an overthrust fault. It must, however, be kept in mind that the direction of shearing (over-riding or overthrusting) is not merely up and down along the fault plane, but that the greatest movement appears to have been along a horizontal direction in the shear or fault plane. This is very hard to detect in the field unless the face of the fault is seen, but the mapping of the surrounding areas leaves no room for doubt. It is to be noted that the intrusions of peridotite have occurred after the strata were disturbed and dislocated by tectonic movements—probably while the Barakar coal seams were still overlaid by 10,000 feet or so of younger strata.

'With regard to the whole question of structure of the Jharia coalfield there is abundant evidence of shearing in several places, both in the south and east as well as to the west of the field. At the point of the Pathardih horst in the Bhaura (Bhowra) area the gneisses appear to have ploughed under the coal measures. And in each case which has been scrutinised the evidence points to a general compressive effect along an east-west direction, *i.e.*, roughly parallel to the main line of faulting. It seems that the great boundary fault is the chief tectonic feature, and that along this line the strata on the down-throw side has not been let down equally all along. In consequence of this there are deep sags—now the coalfields of Raniganj, Jharia, Bokaro and Karanpura—and in these sags over-riding has followed the bending of the strata—the successive (or certain) beds slipping (or shearing) over the next below—as already referred to on page 88 of the Jharia memoir.

All these subsidiary movements combined are not easy to unravel, but the sum effect has been communicated to certain coal seams in certain areas, and those coal seams in those areas are both liable to spontaneous combustion and to collapse to a greater degree than should normally be expected.'

Shale and sandstone bands in seams are likely to affect the liability of a seam to heat spontaneously, as when coal is crushed and heat generated, the shale bands, which are poor conductors of heat, are likely to retain the heat and assist spontaneous combustion. In the Jharia coalfield fourteen fires have occurred after premature collapses of pillars have taken place and there is no doubt that the friability of the coal and the geological disturbances were important contributory factors.

Dr. Penman, in Table II of his paper * 'The Crushing Strength of Coal Pillars', gave the approximate average crushing strength of pillars in lbs. per square inch for Nos. 15, 14 and 13 seams in the Jharia coalfield, as 1,000, 1,100 and 1,050. It is significant that these three seams which are the most liable to spontaneous combustion have the lowest crushing strengths of the coals given in the table.

The crushing of pillars may be directly responsible for fires. I know of one case in the Jharia coalfield where a pillar in 15 seam adjoining a depillaring area at a depth of 550 feet was badly crushed and eventually the pillar went on fire spontaneously. The effect of crushing is to produce small coal and also to generate heat due to the grinding action produced.

In Volume LXIV (1922-1923), *Transactions of the Institute of Mining Engineers*, Prof. Briggs gives the results of experiments carried out on the heat generated by the crushing of coal, and he states, 'A fragment of average Bituminous coal 1/300th inch in diameter, if suddenly produced by crushing, will, in the midst of similarly conditioned particles, obtain a temperature rise of 52°F. If the waste in which the crush takes place has a temperature of 75°F., this particle will thus be raised, practically instantaneously, to a temperature of 127°F. Under the same conditions a fragment 1/100th inch across will attain a temperature of about 92°F.'

The heat generated accumulates in the small coal produced and as the temperature increases the affinity for oxygen increases, until the temperature of ignition is reached. The most important factor in the crushing of pillars is the small coal produced which is so much more susceptible to oxidation than coarse coal.

3. *The nature of adjoining strata.*

Spontaneous combustion is greatly influenced by the capacities of various strata for conducting heat. Ordinary shale, still air and coal are bad conductors of heat, while sandstone is a good conductor. Herschel and Lebour (*Transactions of the Institute of Mining Engineers*, Volume LXIV, 1922-1923, Briggs, Spontaneous Combustion, initiated by crushing) show that ordinary

* *Transactions of the Mining and Geological Institute of India*, Volume XXV.

coal measure shale is not such a good conductor of heat as coal (unspecified) and that soft sandstone is twice and hard sandstone three times as good a conductor as coal.

These differing conductivities have an important influence on spontaneous heating. Take for example the 3-ft. shale roof, which is of a carbonaceous nature, above No. 15 seam in the Bararee-Bhulanbarari area. It is very probable that this shale has contributed greatly to the initiation of spontaneous heating in some instances. There is also the 7-ft. 'parting' between Nos. 15 and 14-A. seams. Then there are the shales, chiefly of a carbonaceous nature, between Nos. 14 and 13 seams. At Gopalichuck this 'parting' varies from 3′–14′. At Ekra it thins out to about 6′, combined with a 2-ft. sandstone band. At Mudidih it thickens up to 14 feet.

I quote these examples to indicate that seams with adjoining beds of shale should be treated with suspicion. For instance, if No. 15 seam is being depillared and as much coal as possible has been extracted, there is the 3-ft. shale roof which is always a potential danger. Accumulated masses of fallen shale roof may lie in the goaves for months, covering small coal, which readily oxidises. The shale being a poor conductor of heat will not allow the heat produced by the oxidation to be dissipated, as it is generated, which results in the shale and coal reaching the temperature of ignition. Analogous conditions exist where there are contiguous seams with 'partings', consisting chiefly of shales. On the other hand if the adjoining strata are sandstones, there is not the same tendency for the heat to be retained, as the sandstones are comparatively good conductors of heat.

At two mines where fires have occurred in the goaves of No. 14 seam, the shales between Nos. 14 and 13 seams have fired on the surface when thrown on the 'spoil heap', indicating that they are liable to self-heating due to their carbonaceous nature. I am of the opinion, therefore, that many of the shales in the Jharia coalfield have played a considerable part in the development of spontaneous heating due to their insulating properties and their composition.

4. *Depth of the coal seams.*

The greater the depth of the coal seams the greater is the liability to crush and form small coal due to the pressure of the superincumbent strata. Even where pillars of adequate size are left for the particular depth worked the coal may be of a friable nature and 'shedding' may take place, resulting in the gradual deterioration of the pillars. At great depths where there are extensive workings there may be difficulty in adequately ventilating the workings so that heat created by crushing or goafing operations may not be readily dissipated.

A detailed study of the physical conditions prevailing in coal seams is essential when considering the causes of spontaneous combustion underground, and the means to be adopted to prevent these spontaneous heatings.