

SULPHUR IN COAL.

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The presence of sulphur in the Tertiary coals of India attracted the notice of early workers¹ and in the analytical results published only total sulphur was recorded. Moreover as granules and lumps of pyrite were easily detected in the hand specimens the sulphur content of the coal was attributed chiefly to pyrite by almost all the workers in India. It has long been known that the high grade coals of Upper Assam on account of large sulphur content could not be efficiently utilised for many important uses. Richard Smith,² however, in discussing the analytical results of Makum coals suggested that sulphur might be present in the coal partly in organic constituents and partly as iron pyrite and probably as sulphates. But in the analyses published he recorded the amounts of total sulphur only.

Though the presence of sulphur was noted by early workers and the railway authorities in Assam the knowledge regarding the sulphur compounds in the Tertiary coals of India was very meagre and no detailed work in this line was published. It will be pointed out in a succeeding chapter that the total sulphur is not the only factor to be considered, but the amounts of different sulphur forms should be determined before any coal is recommended for particular use.

It may be mentioned in this connection that on account of the researches of Powell and Parr³ our knowledge regarding sulphur in coal has recently been greatly widened. As a result of investigations it has been found that sulphur in coal generally occurs in four different forms, namely: (i) Pyritic sulphur; (ii) Sulphate sulphur; (iii) Organic sulphur; and (iv) Free sulphur.

The present author had an opportunity of studying a number of high sulphur Tertiary coals of India and he is highly indebted to Dr. Fox for extending facilities for this work and also for his valuable suggestions.

It will not be out of place here to mention something regarding the source and origin of sulphur compounds in coal. It may be pointed out that the coals formed under fresh water conditions have always a very low total sulphur content, whereas the coals formed under marine and brackish water or estuarine conditions have always a very high percentage of sulphur. This question has been discussed by several earlier workers who think that both pyrites and organic sulphur compounds are better developed under estuarine and marine water by biochemical processes helped by sulphur secreting bacteria (see Clarke—Data of Geo-chemistry, pp. 150, 518). A certain amount of sulphate and pyrites is also formed by pure chemical processes.

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The sulphur compounds in coal might have been derived from various sources and in different ways as summarised below :—

- (i) Organic sulphur compounds originally present in the plants that are ultimately converted into coal. Small amounts of organic sulphur compounds (proteins, etc.) from vegetable debris are gradually concentrated in the final coal substance, as we know that about 10 ft. of plant debris get compacted and reduced to make only one foot of coal seam.
- (ii) The soil on which the plants grew might have been rich in sulphur salts and sulphur secreting bacteria and the plants might have thus obtained a sufficient supply of sulphur compounds and, after assimilation, these salts were probably retained as various organic sulphur compounds, besides some inorganic sulphur salts. Such plants might have better contributed to the sulphur content of some high sulphur coals. The remains of sulphur bacteria might have given rise to sulphates in the soil to be ultimately used as plant food.
- (iii) After deposition in the marine and estuarine waters the vegetable debris were subjected to complicated process of putrefaction and coalification when complex chemical and biochemical changes started, together with the activity of micro-organisms under favourable conditions, as a result of which various sulphur compounds have possibly been formed and retained by the coals as their constituents. In this way pyrites as well as many organic sulphur compounds have been formed by bacterial activity. Some pyrites and sulphates might have also been formed by purely inorganic processes.

Only unaltered and fresh specimens and those clean pieces having no pyrite patches were subjected to laboratory investigations. During analytical work the methods adopted by Powell and Parr were generally followed. In the fresh and unaltered specimens of Tertiary coals of India the author had been able to detect all the forms of sulphur except the free sulphur. While visiting some coalfields in the Khasi Hills (Assam) and Bokaro coalfield (Hazaribagh) the writer could however find in the weathered coal faces traces of free sulphur. But this appears to have been formed by secondary changes during the process of weathering. Such altered and weathered specimens were not used for the quantitative determination of various sulphur forms.

For pyritic sulphur determination 1 gm. of coal (100 mesh) is digested with 80 c.c. dilute nitric acid (1 : 3) and the solution allowed to stand at room temperature for about 4 days during which time all the pyrite will be completely oxidised and dissolved. Any sulphate if present will also go into solution. The solution is then filtered, the nitric acid driven off by evaporation and the residue taken up in some water and hydrochloric acid. The sulphur is then

precipitated as BaSO_4 by barium chloride solution and the amount of sulphur in coal is obtained by calculation. The value for pyritic sulphur is then obtained by subtracting the amount of sulphate sulphur determined separately.

The sulphate sulphur is determined by extraction of coal with dilute hydrochloric acid. 5 gm. of coal (100 mesh) is digested with 300 c.c. of 3% hydrochloric acid for 40 hours at about 60°C . A higher temperature would cause the sulphur to escape as sulphuretted hydrogen gas. The solution is then filtered and the sulphur precipitated by the barium chloride method.

A certain amount of organic sulphur could be leached by phenol and pyridine treatment but complete removal of organic sulphur was not effected by such organic solvents. The amount of organic sulphur was therefore obtained by difference.

The total sulphur in coal was determined by following the usual Eschka method.

In the hand specimens of many of the Tertiary coals of India patches, granules and lumps of pyrite are often easily detected. When occurring as fine disseminations in coal it may escape detection by the naked eye but when such coal is exposed to moist air for some time the pyrite gets decomposed and altered to ferrous sulphate. During this process increase in volume takes place and the coal usually is fissured and reduced to powder. Such a change is often observed in museum specimens exposed to humid climate.

In the Gondwana coals of India pyrite and marcasite are found to occur in very small patches and the sulphur content is usually very low as compared to that of the Tertiary coals of India.

In the case of pyrite occurring in big lumps and granules, conditions may sometimes be favourable for their removal by mechanical washing arrangements but this process would not be successful when there is very fine disseminations of pyrite.

When coal is burnt, *i.e.* during the process of combustion, pyrite is decomposed and sulphur is oxidised to SO_2 and subsequently to SO_3 and finally to sulphuric acid. This is why the sulphur bearing coals when burnt on the grates give off sulphurous smoke and the metallic parts of the boiler get easily corroded and damaged. When coal seams containing pyrite are exposed to humid atmosphere in mines pyrite is gradually oxidised and converted to ferrous sulphate with the formation of some amount of sulphuric acid. This is why the percolating water accumulating in the sump is generally acidic and the pumping machinery including the pipes get corroded and damaged.

High volatile pyritous coals when subjected to process of high temperature carbonisation give off sufficient sulphurous smoke and the gas that is obtained has always to undergo purification process if it is to be used for town lighting and other domestic purposes. If such coal happens to be of good quality caking type the coke obtained by high temperature carbonisation

usually retains a certain amount of sulphur and the coke is thus rendered unsuitable for being used in the smelting operations. It has been found that pyrite in the coal on combustion is completely decomposed and the sulphur is eliminated as SO_2 to be finally oxidised to sulphurous and sulphuric acids, iron being converted to oxide or silicate as the conditions prevail.

Sulphur in the shape of sulphate of iron, calcium, aluminium, etc., sometimes occurs in coal specimens and usually remains in the ash after complete combustion and may thus be regarded as an inert form of sulphate sulphur. The only deteriorating effect of this form of sulphur is that it will absorb some amount of heat during combustion. This sulphate sulphur is generally found to occupy the joints and cleats and the planes of laminations showing that this might be due to process of secondary infiltration. It may however form a part of the original inorganic matter which on combustion gives rise to inherent ash. It has been found that during combustion the sulphate sulphur suffers very little change and usually remains as an inert sulphate in the ash.

While dealing with Tertiary coals of N.W. India and Assam it was found that the amounts of total sulphur in many of them were much higher than the ash contents as shown in Table I. This feature attracted the notice of the present author who advanced a suitable explanation in a previous publication.⁴

TABLE I.

	Mach.	Watch- ing.	Borjan.	Tipong- Pani.	Nam- dang.	Cherra- punji.	Lait- ringow.	Than- ginat.
Ash % ..	2.32	0.42	3.03	3.92	0.69	2.76	3.65	2.43
Total sul- phur %	3.95	5.10	3.75	5.11	3.01	3.18	3.78	3.91

On laboratory investigation of clean and fresh specimens (see Table IV) it was found that the pyritic sulphur content in the coals was very small compared to the total sulphur content. The coals, however, possessed a very low amount of ash. The major portion of the sulphur was found to be in an organic state of combination. This interesting feature can be explained by the assumption that the original vegetable mother substance was of great purity in the first place and during the time of deposition it was not mixed up or contaminated with large amounts of dirt or impurities, nor were the coal seams, after they had been deposited, traversed by percolating water charged with iron or other salts. The sulphur deposited in the coal seam was in various organic compounds which on burning leaves no ash. This accounts for the low ash and high sulphur content of these coals. This organic form of sulphur was apparently formed and deposited in the coal during the process of coalification including biochemical changes and bacterial activity and the source would be in the original mother substance together with the remains of sulphur secreting organisms. It

was pointed out by Anderson Roberts⁵ that the presence of sulphur in the coal acid was a definite proof of the existence of organic sulphur in the coal. In support of the suggestion now made by the present writer some evidence in the shape of laboratory investigations may be cited. Clean, fresh and unaltered pieces of Watching and Namdang coal of Upper Assam were carefully selected and particular attention was given to remove any trace of visible pyrite granules or patches. These specimens on analysis were found to contain very small amounts of pyritic and sulphate sulphur whereas organic sulphur was present in sufficient amount. The ash content in either case was well below 1% whereas the total sulphur was 5% and 3% respectively for Watching and Namdang coals. The specimens of these coals were allowed to remain in the museum under humid Calcutta climate for a number of years and after careful re-examination the coal fragments appear to have remained very fresh and have retained the same lustre as before. No pyrite patches were visible nor could any amount of sulphate be detected on close examination. The coal pieces have thus suffered no crumbling due to decomposition and oxidation of pyrite. The coal has in other words withstood the weathering remarkably well. A reference to analytical Table IV will show that these two specimens under examination contain small amounts of pyritic and sulphate sulphur. On being exposed to humid conditions for a long time all the pyritic sulphur should have been completely converted to sulphate and as a result of this alteration the value of sulphate would have been much greater in the weathered specimens. On re-examination a slight increase in sulphate has been noticed but complete oxidation and alteration of pyrite has not resulted. It may be said by way of explanation that as the coal is compact and as the pyrite occurs in very small granules and is interspersed in the coal substance it had escaped weathering. Only those few granules that came in contact with the atmosphere were oxidised to sulphate. On the other hand, other pyritous coal specimens on being subjected to similar weathering process have been completely reduced to powder with the formation of sulphate efflorescence products. The specimens on careful analysis appear to have retained the same amount of total sulphur. This shows conclusively that the major portion of sulphur is in an organic state of combination and is hence not affected by weathering. The organic sulphur compounds on combustion get completely decomposed and leave behind no ash. This may be considered to be the satisfactory explanation why we find in these coals a high percentage of sulphur irrespective or independent of low ash content. This would indicate that by any mechanical means of washing the organic sulphur cannot be removed and as there is a sufficient amount of organic sulphur in many of the Tertiary coals of India installation of washing plants will not prove very successful in eliminating all the sulphur content from the coals. Only the big lumps and granules of pyrite might be removed by such a process of washing or under more favourable conditions by hand-picking. During the process of coal combustion the organic sulphur is

completely decomposed and is given out as SO_2 in the product of combustion and will thus produce a corrosive effect on the metallic parts of boilers and other steam-raising plants.

The forms in which sulphur generally exists in coal are therefore: (i) pyritic, (ii) sulphate, (iii) organic, and (iv) free. When coal is carbonised or burnt these different forms of sulphur behave differently and are split up into forms which we record as (i) fixed sulphur, (ii) volatile sulphur, (iii) combustible sulphur, and (iv) non-combustible sulphur. It may be mentioned that the mere knowledge of the presence of organic, pyritic and sulphate sulphur in coal does not help the coal consumer to the fullest extent and his decision regarding proper selection of coal will not be satisfactory unless the amounts of fixed sulphur, volatile sulphur, combustible sulphur, and non-combustible sulphur are taken into proper consideration. In the following lines an explanation of these sulphur forms and their scope and bearing on industries is given.

(i) *Fixed sulphur*: It is the amount of sulphur retained by the coke when the coal is carbonised. This is a very important factor to the metallurgists and iron smelters. A metallurgical coke containing a high percentage of sulphur is not considered to be suitable for iron blast furnaces and other high class smelting operations. Some of the high grade caking coals of Upper Assam with the least possible ash and high volatile matter are excluded from high class metallurgical work on account of their high fixed sulphur content.

(ii) *Volatile sulphur*: It is the portion of sulphur which volatilises when the coal is carbonised at 950°C . for the determination of volatile matter. It will consequently vary with the variation of temperature of carbonisation. The volatile sulphur is a guide to the sulphur content of the gaseous and liquid products obtained from the coal. When this sulphur content is high the gaseous and liquid products will have to be further purified to get rid of the sulphur that is in excess of specified limit and this will naturally involve extra cost. It may be mentioned here that a certain amount of volatile sulphur may thus be recovered in the gas and other industries and may be subsequently utilised for the manufacture of sulphuric acid.

(iii) *Combustible sulphur*: This is the sulphur that is expelled during the complete combustion of coal. The combustible sulphur, however, includes the total amount of volatile sulphur. When present in appreciable amount in coal, this combustible sulphur corrodes the metallic structures of boilers. This item concerns the fuel engineers using coals for their different types of boilers and other steam-raising plants. Attempts should, however, be made to recover the combustible sulphur from the products of combustion in various factories and power-generating stations and may thus be utilised for our use.

(iv) *Non-combustible sulphur*: This is the sulphur left in the ash after the coal is completely burnt. This sulphur is considered to be inert in its activities.

The present writer made a quantitative determination of the various sulphur forms occurring in several specimens of Tertiary coals of India and Burma⁶ and some of the results are shown in Table IV. The author has also discussed the question of proper utilisation of these coals in the light of sulphur contents.

Some of the Upper Assam coals having a high percentage of fixed sulphur were carbonised at high temperature (950°C.) and an attempt was made to find out how the forms of sulphur were redistributed in the resulting coke.

Regarding the estimation of the different forms of sulphur in coke the usual methods mentioned by the author have been adopted and the results are already published.⁷ For the determination of sulphide sulphur a method similar to that used by Bradbury⁸ and described by Parr⁹ has been followed and the nature of the sulphur forms studied. About 2 grams of powdered coke are placed in a flask and about 150 c.c. HCl (1 : 1) poured into it and a stream of hydrogen gas is allowed to bubble through the liquid. The gas evolved is allowed to pass through a flask containing a saturated solution of sodium peroxide which will absorb any sulphuretted hydrogen that evolves from the coke. The content of the flask is next brought to boiling for half an hour and after these reactions are over the contents of sodium peroxide solution are tested for the presence of sulphide sulphur by the barium chloride method. The substance remaining in the flask containing coke and hydrochloric acid solution is next filtered and washed and the solution tested for the presence of sulphate sulphur in coke by the barium chloride method. The residue of this extraction is then treated with conc. nitric acid for two hours or more in order to extract any pyrite which might remain and it has been found in all cases that no trace of pyrite could be detected.

The finely powdered coke, which is boiled with dilute HCl to release the sulphide sulphur as H_2S , is further subjected to the action of nascent hydrogen in presence of dilute HCl at some elevated temperature. Under these conditions some amount of H_2S is removed and the action of nascent hydrogen on the coke indicates the organic nature of the coke sulphur. The organic form of resinic sulphur is not found to be present in the coke as no sulphur could be extracted from coke by means of pyridine.

From a careful study of the laboratory investigations as given in Table II it is believed that the major portion of coke sulphur is present in some unknown form. Formerly it was difficult to conceive any organic sulphur compound withstanding the high temperature of caking process and the development of a more stable inorganic form during the process was considered a more probable explanation. The treatment of the coke residue with HCl and HNO_3 in various ways has however failed to extract all of these sulphur contents. It is suggested that during the caking process secondary reactions taking place between the complex coal constituents and the decomposed sulphur compounds may be responsible to some extent for the quantity of sulphur in stable form which is retained by coke.

TABLE II.

%	Coal.	Coke.	Coke from coal washed with HCl.	Coke acted on by hydrogen.	Coke acted on by nascent hydrogen.
NAMDANG:					
Total sulphur ..	3.01	2.56	....	....	....
Volatile ,, ..	1.58	....	....	....	....
Fixed ,, ..	1.43	....	....	....	....
(Sulphur in coke) ..	....	2.56	2.48	2.56	2.56
Sulphide sulphur ..	0.00	0.03	0.03	0.06	0.10
Pyritic ,, ..	0.03	0.00	0.00	0.00	0.00
Sulphate ,, ..	0.02	0.016	0.00	0.016	0.016
Organic ,, ..	2.66	0.00	0.00	0.00	0.00
Unknown ,, ..	0.00	2.51	2.45	2.48	2.44
WATCHING:					
Total sulphur ..	5.10	4.11	....	....	....
Volatile ,, ..	2.82	....	....	....	....
Fixed ,, ..	2.28	....	....	....	....
(Sulphur in coke) ..	....	4.11	3.60	4.11	4.11
Sulphide sulphur ..	0.00	0.08	0.08	0.12	0.25
Pyritic ,, ..	0.43	0.00	0.00	0.00	0.00
Sulphate ,, ..	0.04	0.03	0.00	0.03	0.03
Organic ,, ..	4.54	0.00	0.00	0.00	0.00
Unknown ,, ..	....	4.00	3.52	3.96	3.83
TIPONG PANI:					
Total sulphur ..	5.11	3.72	....	....	....
Volatile ,, ..	3.00	....	....	....	....
Fixed ,, ..	2.11	....	....	....	....
(Sulphur in Coke) ..	....	3.72	3.45	3.72	3.72
Sulphide sulphur ..	0.00	0.10	0.10	0.11	0.24
Pyritic ,, ..	0.13	0.00	0.00	0.00	0.00
Sulphate ,, ..	0.05	0.02	0.00	0.02	0.02
Organic ,, ..	4.40	0.00	0.00	0.00	0.00
Unknown ,, ..	....	3.60	3.35	3.59	3.46

Regarding the occurrence of this stable form of sulphur in coke the various possibilities were discussed by Parr. It may be mentioned that in the case of the specimens under investigation nitric acid could scarcely extract any sulphur from coke showing that all the pyritic sulphur had completely decomposed. Treatment with different reagents including HF did not however release any H₂S. These considerations together with the results of nascent hydrogen treatment suggest the probability of some form of organic sulphur compound the definite nature of which has yet to be understood. It is however a well-known fact that nitrogen, sulphur and hydrogen may remain in organic combination at very high temperature (1000°C.) as shown by liberation of NH₃ and H₂S by treating red-hot coke with water vapour.

Laboratory investigations show that during the process of caking, pyritic sulphur gets completely decomposed as no trace of it is detected in the coke. The sulphate sulphur remains more or less unchanged and is retained by the

coke. A slight decrease of sulphate sulphur is perhaps due to the partial reducing action of red-hot carbon on the sulphate. The analytical results also show that by digesting the coal with HCl the sulphate sulphur is completely removed and that the coke obtained from this washed coal does not contain any sulphate sulphur. Regarding the sulphide sulphur form it may be said that during caking this form of sulphur gets slightly developed. Some experiments were carried out by the author to find out the possible nature and source of this sulphide sulphur. A portion of the coal was digested and washed with HCl to get rid of any sulphate sulphur and the washed coal was subjected to high temperature carbonisation and the resultant coke was analysed and the results given in Table II show that the coke from washed coal contains some amount of sulphide sulphur. Another portion of the coal that was washed with dil. HCl was further treated with an organic solvent like pyridine to get rid of organic resinic sulphur and subsequently subjected to caking process. The coke thus obtained was subjected to chemical treatment and was found to release a small amount of sulphide sulphur. These results indicate that the sulphide sulphur does not originate from sulphate or resinic organic sulphur but possibly from some other stable form of sulphur during the process of caking, the organic nature of which has yet to be properly understood.

Regarding the proper utilisation of the different coal samples, attention should always be given to the amount of the different sulphur forms in them. It is a well-known fact that a large amount of combustible sulphur in coal will have a corrosive action on the metallic structures of boilers and steam raising plants and that coal having a high percentage of fixed sulphur (1.5% or more) cannot be recommended for the manufacture of metallurgical coke suitable for blast furnaces and other high class smelting operations. It may however be noted that the above-mentioned high volatile coals of Upper Assam with low ash percentage may be tried as pulverised fuel or may be used for the manufacture of gaseous fuel. In the latter case the sulphur may be recovered from the gas during the purification process and utilised for the manufacture of sulphuric acid. As there is an appreciable amount of organic sulphur it will not be possible to get rid of all the sulphur by any mechanical process of washing. In support of this an experiment was carried out on a small laboratory scale when the clean and unaltered Namdang coal after washing was found to retain almost the whole amount of sulphur which was afterwards found to be mostly in an organic state of combination. The author however suggests that the sulphur content in the high grade coals may be reduced to some extent by mixing or blending with other varieties of coal or coke dust with lower sulphur content so that the blended coal may be a slightly better fuel. The ratio of such blends has to be determined by trials. The attention of the colliery proprietors and mining engineers is drawn to this suggestion for further investigation. The high sulphur coals may better be utilised in the ovens and kilns where the flame does not come in direct contact with

any metallic structures. In coals having low ash and low pyritic sulphur there will be little chance for the formation of fusible silicates or clinkers in the ash. In the case of some Upper Assam coals with a high amount of volatile matter and very low ash content the writer suggests that the different coal samples may be utilised as colloidal fuel (petroleum being easily available in the locality) so that a certain amount of petroleum might be reserved and coal might in turn be better utilised.

Formerly the high percentage of sulphur in the Tertiary coals of India was thought to be chiefly due to the presence in them of iron pyrite and the total sulphur alone used to be determined. It has now been found from the investigations of the present author that a coal with high total sulphur may have only a very small amount of pyrite in it and this high sulphur content may be due chiefly to the organic form.

In conclusion the author desires to draw the attention of the coal producers and coal consumers to the fact that the total sulphur is not the only criterion which should form the basis of selection of coal but that the different forms of sulphur in coal should be determined before a particular high sulphur coal is recommended.

In Table III the results of proximate analyses of some of the Tertiary coals of India are given and Table IV shows the amounts of different sulphur forms in them. The method of proximate analysis adopted in the laboratory has already been discussed in a previous communication.¹⁰

Explanation of Table IV.

The values of different sulphur forms are given in percentages of coal. Total sulphur is determined separately. Fixed sulphur is the amount of sulphur in coke calculated in terms of coal. This fixed sulphur together with volatile sulphur forms the total sulphur. Non-combustible sulphur is the amount of sulphur in ash calculated in relation to coal. The non-combustible sulphur and the combustible sulphur together form the total sulphur. Pyritic, sulphate and the organic sulphur determined separately all go to make up the total sulphur.

TABLE III. (*Proximate Analyses*).

%	Watching.	Borjan.	Tipong-Pani.	Nam-dang	Cherra-punji.	Laitrin-gow.	Thangi-nat.	Mach.	Maker-wal.	Dandot.	Jammu.
Moisture	6.31	4.60	2.45	2.05	1.96	1.75	1.44	10.83	3.78	5.09	0.83
Volatile Matter	39.16	48.91	41.52	41.95	43.70	42.00	36.64	40.57	49.79	43.41	14.40
Ash	0.42	3.03	3.92	0.69	2.76	3.65	2.43	2.32	10.00	12.10	12.11
Fixed carbon	54.11	43.46	52.11	55.31	51.58	52.60	59.49	46.23	36.43	39.40	72.66
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Colour of ash.	Light Pink.	Deep Pink.	Pink.	Faint Pink.	Pink.	Buff.	Brick Red.	Light Red.	Light Pink.	Brick Red.	Cream.
Nature of residue.	Slightly Caking.	Caking.	Strongly caking.	Very strongly caking.	Strongly caking.	Strongly caking.	Strongly caking.	Caking.	Caking.	Caking.	Strongly caking.

TABLE IV. (*Sulphur Content*).

%	Watching.	Borjan.	Tipong-Pani.	Nam-dang.	Cherra-punji.	Laitrin-gow.	Thangi-nat.	Mach.	Maker-wal.	Dandot.	Jammu.
Total sulphur	5.10	3.75	5.11	3.01	3.18	3.78	3.91	3.95	4.61	9.08	1.94
Fixed	2.28	1.66	2.11	1.43	1.66	1.48	2.02	1.74	1.55	4.77	1.08
Volatile	2.82	2.09	3.00	1.58	1.58	2.30	1.89	2.21	3.06	4.31	0.86
Pyritic	0.43	0.90	0.13	0.03	0.20	0.14	0.295	0.42	1.15	5.46	1.02
Sulphate	0.04	0.12	0.05	0.02	0.015	0.06	0.08	0.36	0.03	1.60	0.11
Combustible sulphur	5.05	3.39	5.05	2.96	3.02	3.74	3.86	3.77	4.53	8.91	1.91
Non-combustible	0.05	0.36	0.06	0.05	0.157	0.037	0.05	0.18	0.08	0.17	0.03
Organic sulphur	4.54	2.60	4.40	2.66	2.96	3.57	3.53	3.15	3.41	1.98	0.81

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