



Studies on the Correlation of the Mineralogy of Jharia Coal Field (Dhanbad) (Lodna and Bhowrah Coal) with their Geological Formation

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ABSTRACT

Experimental results of the study of the correlation of mineralogy with their geological formation are reported. These results suggest that high proportions of ash as up to 45% present in Gondwana coals of Jharia are confirmed by x-ray diffraction analysis and I.R. spectroscopy. The high mineral matter of such coals was in all probability incorporated during the transportation or "drifting" of the vegetable matter. These coals are also typified by the simultaneous presence of very low percentage of vitreous layers. These results suggest that the mineralogy of the coals of Jharia can be satisfactorily accounted for in terms of the drift origin of the Gondwana formation.

Key words: Correlation of mineralogy, Coal and geological formation.

INTRODUCTION

The changing patterns of energy used in recent years have focused attention of the scientists, technologists and energy planners to the significance of the world coal deposits, which are the mainstay of our fossil fuel supplies. It is now well realized that till the commercially exploitable alternative sources of energy are abundantly available, coal will continue to dominate the world's energy scenario. This is particularly true for India, since it is endowed with huge reserves of this fossil fuel, sufficient to last for 200 years or so. The deposits of coal, ranging from lignite through sub-

bituminous and bituminous to anthracite, belonging to different geological periods, are scattered over different geographical locations in the country. The presence of mineral matter and also several toxic and trace elements present in coal¹⁻⁴ are responsible for causing environmental pollution and as such are highly undesirable. Thermal Power generation is prone to pose alarming threats to our environment by way of causing environmental pollution which arises primarily due to the mineral matter (ash forming components) and other inorganic impurities present in our coals, which are essentially of 'drift' origin.

Eastern part of the country (Jharia) constitute the major percentage of the total reserves of coal and since the power generation in these States is dependent on the combustion of such inferior grade high ash content coals and since large number of coal-based industries are coming up in this region, it is rather imperative to have a comprehensive knowledge of their detailed analysis and complete mineralogical characteristics to realize the full utilization potential of these coals in a fuel efficient manner.

Reported in this paper are the results of Investigations on the correlation of mineralogy of Jharia coals (Lodna and Bhowrah) with their geological formation.

MATERIAL AND METHODS

Selection of Coals

The coal samples were collected from different sampling points of the coal mines These comprised the following :

- i) Lodna coal (Lodna colliery, Jharia Coalfield)
Dali Mine(Kalakot Coalfield)
- ii) Bhowrah Coal (Bhowrah Colliery, East Jharia Coalfield) Metka Mine (Metka Coalfield)

Preparation of Laboratory Coal Samples

The samples collected were treated for making them free from the dirt. For this, the samples were crushed to 12-0 mm size and the volume was reduced following the procedure of I.S.I. by coning and quartering. This was then further crushed to 3 – 0 mm size and about 1.5 kg. of the sample was taken by reducing its quantity following the same method. The sample were subsequently deshaled to remove the extraneous dirt by washing them following the method based on densitometric principle (float and sink method.) In case of Indian coals having ash content around 30-35% a gravity cut at a specific gravity of 1.80 was reported by Whitaker to be safety employed for removal of extraneous dirt only, without affecting their mineral matter content. As such the medium of 1.80 sp. Gravity was prepared with Bromoform and carbon tetrachloride. The float of the samples thus deshaled was air dried and finally crushed to 211 micron sieve (72 mesh B.S.) and used for all the subsequent mineralogical characterization.

Method of Analysis of Coals

Each of the above mentioned samples of Lodna and Bhowrah coal prepared above was subjected to proximate and ultimate analysis following the prescribed I.S.I. procedures⁵⁻¹⁰. The detailed proximate and ultimate analysis including the calorific value of these coals are included in Table 1.

Method for the preparation of Low Temperature Ash (L.T. A.) of the Lodna and Bhowrah Coals

The air dried and crushed samples of the coals were taken separately for preparing the L.T.A. For this each individual samples was placed in a standard silica dish in thin layers and the carbonaceous matter was destroyed by oxidation in a well ventilated low temperature muffle furnace at a temperature at $370 \pm 10^\circ\text{C}$ following the procedure of Hick's and Nagelschmidt¹¹. The process of oxidation was continued till constant weight was obtained and the final residue was the low temperature ash, which was eventually used for the analysis of minerals. Complete analysis of this low temperature ash was also made, whereby silica, alumina titanium, calcium and magnesium were determined following the prescribed I.S.I. procedure¹².

Experimental Procedures for the Instrumental Techniques used for the Identification and Characterization of Different Minerals

Several Complimentary instrumental techniques, like X-ray diffraction, Infrared Spectroscopy, were employed for a detailed mineralogical characterization of the minerals in raw sample and their low temperature ash. Details of the experimental procedures followed for each of these techniques and individually described in the following paragraphs.

X-ray Diffractometry

In general, the coal mineralogy was studied by X-ray diffractometric analysis method, following the experimental procedure described elaborately by Brown-esp. for identifying and studying the crystal structure of clay minerals. The powder X-ray diffraction method was used for the characterization of various mineral phases in the coals for which a Rich Seifert diffractometer (German make, model Ms III) was employed. This X-ray diffractometer was

equipped with a scintillation counter detector and pulse height discriminator. The radiation used for the analysis and Ni filtered Cu-K radiation operated at 40 K. B. and 30 n. a. The samples were continuously scanned at a speed of 0-30 (2 θ)/min. and the diffraction pattern was recorded on a strip chart, the paper speed being 6 mm/minute. In this manner X-ray diffractograms of all the individual coals and also of their corresponding L.T. Ashes were recorded. From the intensity and 2 θ values of the diffractograms, the various mineral phase were identified.

Infrared Spectroscopic Analysis

The mineralogical characterization of the low temperature ashes of all the above mentioned coals were also made by infrared spectroscopy technique, employing a Perkin Elmer 598 spectrometer. The KBr. Pellet method was used for this analysis. KBr pellet of the individual low temperature ashes of coals and lignite were prepared by firstly grinding separately the representative ash sample and A.R. grade KBr to a very fine powder (200 mesh) and then thoroughly mixing the weighed amount of both in a mortar and pestle, keeping the percentage of the ash in the mixture to about 0.5% weight of the total quantity. This mixture was eventually used for making the pellets with the help of hydraulic press at a pressure of 10 Ton. The grating of the spectrometer was fixed at 4000, 2000, 600 and 200 cm^{-1} and the spectra were recorded at a scanning time of 12 minutes. All the measurements were made at room temperature i.e. at 25°C.

RESULT AND DISCUSSION

Result and Discussion of X-ray defraction Analysis

A careful examination of X-ray diffraction result gives rise to the following observations.

1. The X-ray diffraction patterns of all the coals *vis-à-vis* their respective low temperature ashes are essentially similar in nature. However, in case of low temperature ashes, some additional minerals are seen to be present = albeit in minor phases, have escaped detection in original coals because of their being amorphose
2. α -quartz is predominantly present as major

phase in all the coals, as α -quartz, characterized by the highest peaks in the diffractograms. However, in Bhowrah coal, apart from quartz, Kaolinite too is in major phase, the peak of which is slightly less in intensity as compared to other coals.

3. The minerals present in minor phases in both type of coals are seen to be varying, differing from coal to coal. In general, the most common occurrence of the minor phases in the coals is that of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, pyrite, illite, gypsum, mica, and anatase, characterized by prominent peaks of lesser heights in the diffractograms.
4. The occurrence of minerals in traces or minor phases include those of anhydride, ferrosite, and $\text{FeSO}_4 \cdot \text{H}_2\text{O}$, anatase, which are represented by smaller yet conspicuous peaks in the diffractograms.

In this way the different minerals present as major and minor phases in the coals could be distinctly characterized by X-ray diffractometry (Table 2 & 3).

Result and Discussion of Infra-red (I.,R.) Spectroscopy

The IR spectroscopy Technique has found its application in coal research as a complimentary technique to X-ray diffraction and other instrumental methods. Although this technique is used primarily for the identification and quantification of various functional groups (e.g. OH, CH_2 , CH_3 , COOH), structural parameters ($\text{H}_{\text{ar}}/\text{H}$, $\text{H}_{\text{ar}}/\text{H}$, $\text{C}_{\text{ar}}/\text{C}$) of coal, it is also used to deduce information about the different mineral species present in coal. It may be mentioned here that since the broad band of the organic phases masked the bands from the constituent minerals, the mineral characterization used to be severely handicapped earlier. However, with the finer development in the methodology of low temperature ashing, the efficient and near quantitative elimination of the organic fraction of coal became possible, paving way for the clear mineralogical identification by Infra-red spectroscopy. Thus, Karr *et al.*,¹³ and Estop *et al.*,¹⁴ successfully demonstrated that a number of minerals occurring in coal could be accurately identified.

The I.R. spectra of low temperature ashes of the Lodna, Bhowrah (Jharia coalfield) and

the corresponding consolidated I.R. data namely absorption bands and the intensity of the peaks together with mineral species identified are summarized in Table 4.

The observations made out from these results are mentioned below.

1. Infrared spectroscopy is a good investigative tool to complement and supplement the X-ray diffraction analysis for the characterization of different mineral species found in admixtures in the coal. Some of the minerals that escape detection by X-ray diffraction have been identified by infra-red spectroscopy.
2. In almost all the studied coals of Jharia kaolinite and Quartz are seen to appear as major phases. The presence of quartz and Kaolinite together is indicated by the presence of bands in the region $680-800\text{ cm}^{-1}$ and between $1200-800\text{ cm}^{-1}$, characterized typically by overlapping and broadening of peaks. The ubiquitous presence of montmorillonite as a commonly occurring mineral in all the coals together with these major phases is also noticed.
3. The other minor phases present in these coals, which escaped detection by X-ray diffraction, are illite and persulphate.

Table 1: Proximate and Ultimate Analysis of Lodna and Bhowrah Coals used in the present work

S. No.	Coal (Colliery)	Proximate analysis (air dried basis)				Cal. Value	Ultimate analysis on dmmf basis (dmmf basis)				
		Moist %	Ash %	V.M. %	F.C. %		K. cal / Kg.	C %	H %	N %	S%
1.	Lodna (Jharia)	1.20	16.00	24.20	59.60	8700	90.0	4.7	1.9	0.7	2.7
2.	Bhowrah (East Jharia)	1.0	21.9	24.9	52.3	8720	80/8	5.0	2.0	0.6	2.6

Table 2: identification of minerals present in coals of jharia by X-ray diffraction

S. No.	Coal Sample from	Minerals Identified	
		Major Phase	Minor Phase
1.	Lodna Coal(Jharia Coalfields)	Quartz, Kaolinite	FeSO ₄ .7H ₂ O, Calcite anhydride, pyrite and very minute quantity of FeSO ₄ H ₂ O, mica, gypsum.
2.	Bhowrah Coal (Jharia Coalfields)	Quartz	FeSO ₄ , 7H ₂ O, Anhydride, pyrite and traces of calcite and gypsum

Table 3: Minerals present in Low temperature Ashses of Jharia Coals by X-ray Diffraction

S. No.	From	Major phases	Miner phases
1	Lodna	Quartz	Kaolinite, Illite, Anatase
2	Bhowrah	Quartz, Kaolinite and Gypsum	Calcite, Illite, Anatase

Thus, the infra-red spectroscopy technique has provided additional supplementary informations for the identification of several other mineral species present in the coals which could not be detected by X-ray diffraction.

Result and Discussion of Correlation of the Mineralogy of Jharia Coals with their Geological Formation

The coals of Jharia coalfields, like other Indian Coals found in restricted tracts over the peninsular shield belong to the geological age of Gondwana formation, are the area extension of main Gondwana formation. The Gondwana system of coal seam formation is believed to have initiated from deposition of vegetal matter via *allochthonous* mode or, more commonly, drift mode. The high mineral matter of such coals was in all probability incorporated during the transportation or "drifting" of the vegetable matter. In conformity with other coals of Gondwana formations distributed in different parts, the Jharia coals too contain high ash (mineral matter). being as high as upto 45 per cent. Furthermore, these coals are also typified by the simultaneous presence of very low percentage of vitreous layers containing *adventitious* minerals and thicker durations and shaly coal layers, which are invariably associated with high mineral matter contents. *Allochthonous* deposits are now firmly believed to differ from their *autochthonous* counterparts not only in the nature of organic components but also in the nature and proportions of the inorganic components present. Also, invariably finely divided portions of organic matter and large proportions of drift materials are intimately associated with fine clay or silt. during the course of sedimentation. This drift material formed bands of pockets of high ash materials in coal deposits that have different chemical compositions and hence chemically different properties from that of the associated minerals, the latter have been distributed unevenly during the process of drifting.

The Indian Coals of Gondwana formations belong to Permian age and are broadly put in the category of Permo-carboniferous group, which is characterized by the occurrence of thick and extensive deposits of coals. During the process of coalification, the inorganic constituents (mineral matter) got associated in two ways; firstly, by the

association of inorganic constituents present in the coal forming plants and secondly, by the association of inorganic constituents externally added to the coal forming deposits, the former being referred to as 'inherent' and the latter, "adventitious" mineral matter respectively. Yet another school of thought advocates that in the inherent mineral matter are included both the inorganic constituents of the parent plants and any inorganic constituent added to the deposits after the death of the plants that became chemically or colloiddally combined with the coal. Nevertheless, the differentiation between the inorganic constituents present in the plants, which comprise the true inherent inorganic matter, from that added afterwards but which existing in a state of chemical combinations with one or other of the organic constituents of coal (which is the fixed adventitious inorganic matter) and that added afterwards but which exists in a free or uncombined states. is very useful in the first two types of inorganic matter, which profoundly modify the chemical characteristics of the coal substance, whereas the last type generally functions as a diluent. Therefore, for the purpose of obtaining clean coal from these high ash content Gondwana coals, of which Jharia coals constitute an extended part, fine grinding of the coal, followed by gravity separation or by some other suitable physical method of separation, would be rewarding.

The high percentage of silica in Gondwana coals could presumably be ascribed to the incorporation of silica from the lining or membrane of the plants cells which became colloiddally complexed with the coaly matter. It is also possible that some of the plants, especially the great family of grasses that preferentially absorb silica, which got deposited in the coal walls, were carried away along with the marine water during the process of drifting. Likewise, the Lycopods probably absorbed alumina preferentially, which also eventually got incorporated in the coal mass during the process of drifting and subsequent coalification. Thus, the considerably high proportions of silica in the Gondwana coals in general and coals Jharia in particular are reasonably well explicable in the light of what has been mentioned above and is unequivocally confirmed by X-ray diffraction analysis and I.R. spectroscopy of the coals of Jharia coals.

The nitrogen and sulphur compounds of plants during decay in the course of coal formation also played their role to incorporate nitrogen and sulphur compounds in the coal. Nitrogen and sulphur are the known constituents of certain plant proteins that are rapidly hydrolysed by microbial agencies during wet decay. The primary products of hydrolysis of these proteins are complex amino acids, some of which might have combined with the degraded products of the compound celluloses to form humic acids, whereas others might have decomposed still further into the simple products like ammonia, hydrogen sulphide, carbon dioxide and water. Since the final behaviour of these nitrogen and sulphur compounds depends primarily upon the immediate environmental condition of the deposits, it is quite plausible that ammonia might have combined with any acids in the system, including humic acids, thus eventually appearing as part of either the organic or inorganic constituents of the coal. Similarly, the hydrogen sulphide might have also reacted with suitable metallic salts

according to the chemical conditions prevalent. In substantially neutral conditions it may well have reacted with iron salts, precipitating iron sulphide. Due to the decay of leaves rich in iron contents, there would be sufficient iron present in the system and the pH of the deposits being usually of the right order, it was quite probable for most of the plant sulphur to have released hydrogen sulphide and, after reacting with iron, to have precipitated as ferric sulphide in the upper layers of deposits, or as ferrous sulphate in the lower layer. During the process of coalification, these precipitates might have become converted into nodules of lenses or veins of iron pyrites or marcasites, while inherent iron sulphide might have remained amorphous or in colloidal form, intimately associated with the coal mass.

In this way, the mineralogy of the coals of Jharia coals (Lodna and Bhowrah) can be satisfactorily accounted for in terms of the drift origin of the Gondwana formation to which the studied coals belong

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