PETROGRAPHIC AND CHEMICAL INVESTIGATION OF SOME ETHIOPIAN COALS

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ABSTRACT

The petrographic and chemical investigations and possible industrial potential of two coal occurrences from Mush and Kindo Valleys in Ethiopia have been discussed. The bulk of the coals from Mush Valley have a high ash content and moisture and belongs to high volatile-type with a calorific value of 4600 B. T. U. It falls under the category of carbargillite and carbonaceous shales, characterized by vitrinoids (V_4 and V_5) andxylinoids (below 0.31 reflectance). The coals from Kindo Valley, characterized by high ash content, low sulphur and high moisture, and falling in between high to medium volatile coals, with a calorific value ranging between 3400-6300 D.T.U., fall between bituminous and sub-bituminous rank characterized by vitrinoids (V_1—V_{26}). Based on the present study, it is suggested that the Mush Valley coals should be gasified at the spot and used, while that from Kindo Valley should be assesed for the quality and survey must be extended by putting drill holes in the area.

INTRODUCTION

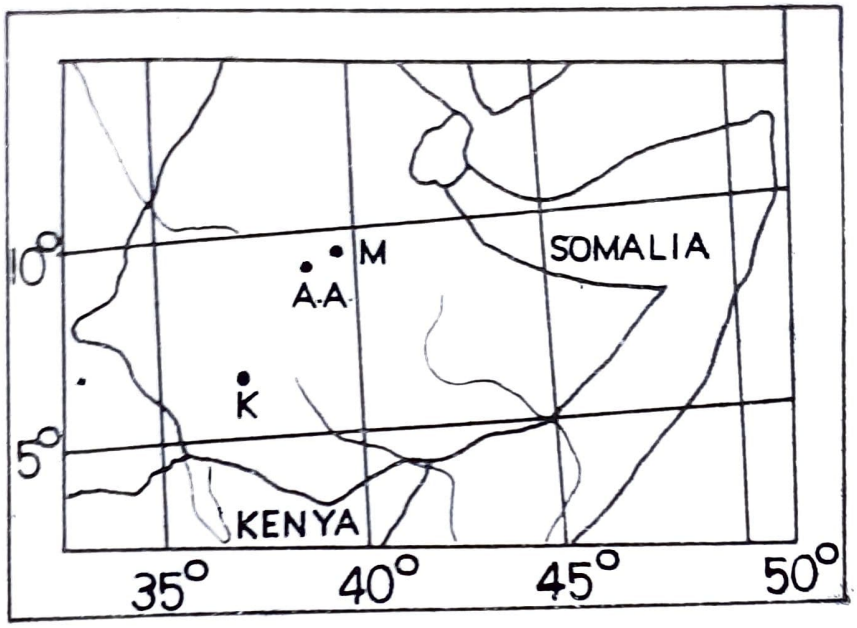
According to JELENC (1966), the coals occurring in Ethiopia may be divided mainly into two groups: 1. Coals in the lacustral sediments of the Trap Series, 2. Coal in the basal sediments deposited on the Pre-Cambrian schists. The two occurrences of coal studied belong to the group-1 (Intervolcanic) from Mush Valley and Kindo Valley in Shoa and Sydamo provinces respectively. The coals from Mush Valley was taken up for study, owing to proximity of the deposit to Addis Ababa, while the coals of Kindo Valley studies carried out pertains to proximate analysis, mega- and micro-petrography, reflectance study and calorific value. In the context of the world's energy crisis, an attempt has been made to assess the industrial potential of these coals for a meaningful commercial exploitation from the above studies.

GEOLOGICAL SETTING

The coal bearing sedimentary succession of rocks are exposed at the Mush Valley, situated 40 km from Debri Berhan in the direction of Desse at the co-ordinates 9°45′49″ N and 35°40′7″ E ; the locality of coals from Kindo Valley is situated 93 km south-west of Wollomo Sodo at 6°30′10″ N and 37°15′10″ E, shown on map 1.

The coal bearing sedimentary succession of Mush Valley lies upon the Mio-Pliocene volcanic rocks of rhyolite composition (JUSTIN VISENTINE, 1974). The succession is undisturbed, comprising sandstones, siltstones, shales, and carbonaceous shales ; the entire thickness measures to 384 meter which is overlain by tuffs interbedded with basalts.

The coal-bearing sediments around Kindo Valley is distinctly Intervolcanic and possibly of Mio-Pliocene age (?). The coals are underlaid by highly weathered basalt (altering to haematitic ochre). Overlying the coal is a highly weathered, lateritised volcanic rock, sometimes resembling a brown tuffaceous sandstone. Kindo Valley is



MAP I: LOCATION MAP

an open, narrow syncline, whose west limb dips about 40° and whose east limb rises about 28° (JELENC, 1966). The area is structurally folded.

ORIGIN OF COAL

The petrographic nature and the mode of occurrence of the coal-bearing succession of Mush Valley suggest a fluviatile origin to these sediments deposited on basalt substratum. The fine-grained predominant dark colour, presence of woody lignite beds containing petrified stumps in growth position—all attests to the above conclusion. As these coal-bearing sediments rest on a basaltic substratum, it may be inferred that the former are younger than the latter ; this fact also explains to the low degree of carbonization and low calorific values.

The coal-bearing sediments of the Kindo Valley, in general, points to a shallow basin deposition of continental type (JELENC, 1966). Probably the area was a gradually subsiding shallow lake-basin bordered by swamps. Vegetation was not luxuriant as gleaned by the total absence of exinoids and impoverishment of inertinoids. The coal-bearing sediments here also rest on basalt substratum, and the high rank exhibited in these coals may be attributed to metamorphism by volcanic extrusions rather than to superincumbent pressure of the overlying rocks of folding.

SAMPLING

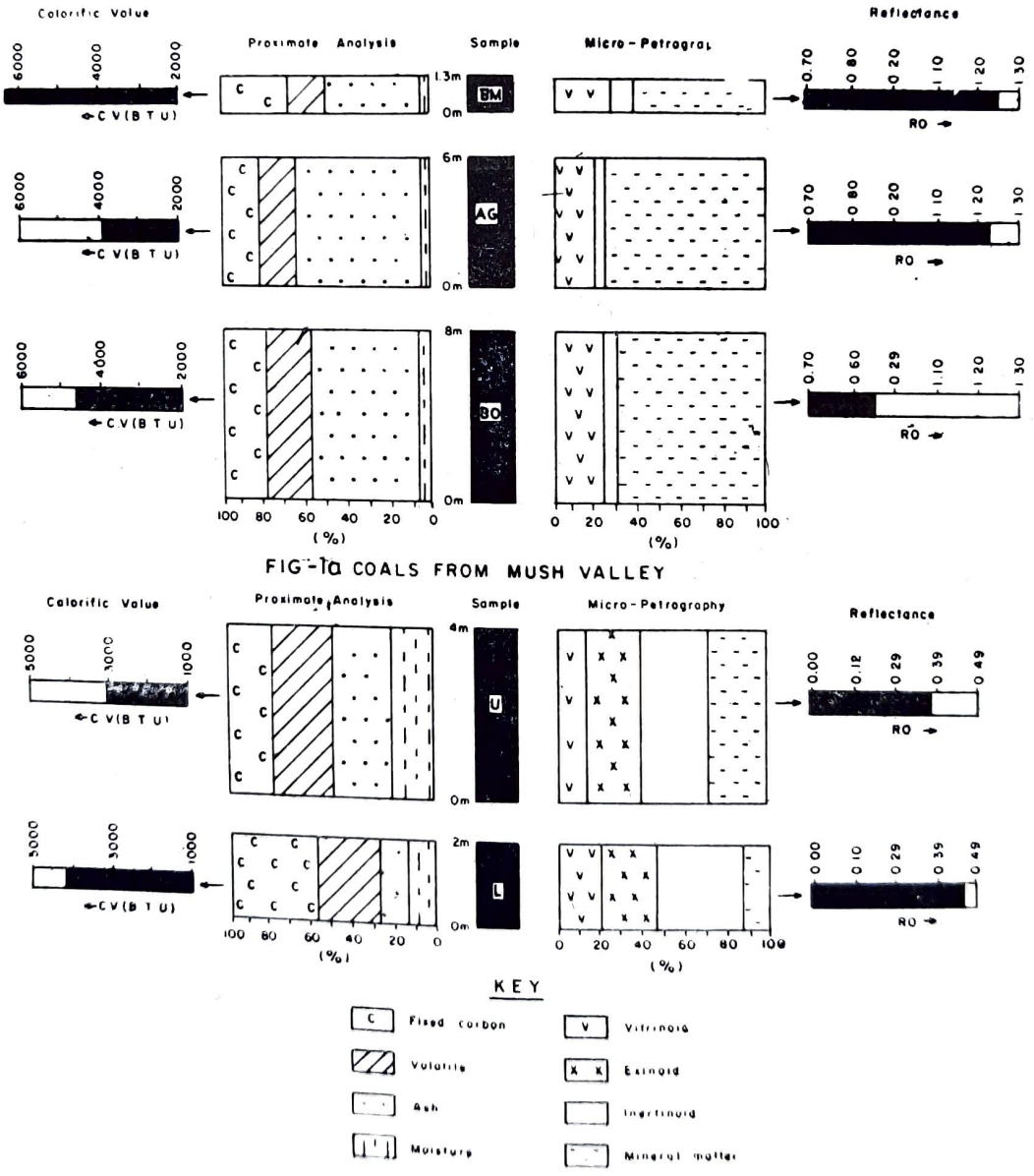
The samples collected are of the nature of bulk composite channels. In the case of Mush Valley, the coals as well as the coal bearing sediments are horizontal, hence the samples were collected at regular stratigraphic intervals. In the case of Kindo Valley, owing to moderate to high dips, channels were taken along the dip direction. In all, 15 sub-channels in the case of Mush Valley and 21 sub-channels in the case of Kindo Valley have been taken, which were regrouped into two bulk composite-samples in the case of Mush Valley and three bulk composite-samples in the case of Kindo Valley, respectively.

OBSERVATION

Mega- and Micro-petrography

Mega-petrography pertains to "Litho-types" in terms of vitrain, durain and fusain, brightness of coal and banding. The coals from Mush Valley are all characterized predominantly by durain and carbargillite with scanty vitrain. The proportion of litho-types assigns the coals to the category of dull to semi-dull type. Banding is not well displayed, but, nevertheless, microbanding can be seen with the help of a hand lense. Two types of fractures are distinctly seen making the coals highly fragile. The coals from Kindo Valley are characterized by fair amount of vitrain, subordinate durain and sporadic fusain (Fig. 1). The proportion of vitrain and durain is almost equal; but occasionally durain predominates over vitrain. The nature and amount of litho-types render the coal to fall between bright to semi-dull category. Banding is mostly in the form of laminations, and most of the vitrain exhibits a hackly fracture, and well-developed cleat is seen in these coals.

FIG-1 COALS OF KINDO VALLEY



Text-fig. 1

The micro-petrography of the coals from Mush Valley shows a distinct difference between the coals of the lower part and upper part; coals from lower part are rich in vitrinoids in comparison to the coals from the upper part, and less in mineral matter (Fig.

1a). Fusinoids and micrinoids are also more in the lower part than the upper part. The vitrinoids observed are mostly with structure (telenoid), frequently filled in by granular mineral matter, possibly clay minerals (?). Frequently fine-grained micrinoid is found associated in the cell cavities of the vitrinoids. Exinoids are more abundant than vitrinoids comprising sporinoids, resinoids. Resinoids are globular and occasionally occur as rodlets. The inertinoids are represented by fusinoids, semi-fusinoids, micrinoids and very rarely by sclerotinoids. Fusinoids occur both with large cells and small cells. Micrinoid is predominantly granular and fine-grained. The mineral matter in the coals of the upper part comprise chiefly clay minerals, sulphur minerals and silica minerals relegating the coals to carbagrillite and carbonaceous shales.

The micro-petrography of the coals of Kindo Valley displays the most striking feature, which characterizes these coals—namely, the depletion of exinoids, impoverishment of inertinoids, and predominance of vitrinoids and mineral matter. In general, the mineral matter is high (62.7-76.1). The vitrinoids are mostly of collinoid type (vitrinoid without structure). The inertinoids are mostly represented by semi-fusinoids, and by scanty sclerotinoid and fusinoid. Fusinoids are mostly characterized by small cells. Exinoids represented from traces to 0.4 per cent comprise mostly resinoids and cutinoids. Sporinoids are typically absent. The mineral matter consists of clay minerals, secondary silica minerals and ferruginous minerals(?).

Reflectance Study

Reflectance measurements were made on scratch-free vitrinoids from the polished pellets used to determine the micro-petrography, with the help of Leitz Photovolt Multiplier, using glass standards.

The reflectance determined from Mush Valley coals ranged from 0.20-0.40—that is, characterized by xylinoids (reflectance < 0.31). The coals from the lower part are characterized by vitrinods (reflectance > 0.31). The vitrinoid found in the lower part is of the type V_4, which assigns the coals to high volatile type. The coals from the upper part, characterized by the presence of xylinoids, are assigned to lignite category (SPACKMAN, 1963).

The reflectance study carried out and the average reflectance calculated on the coals of Kindo Valley, ranged from 0.85-1.25, thereby assigning the coals to fall between high volatile and medium volatile coals respectively. According to SPACKMAN (1963) high volatile coals are characterized by the vitrinoid types (V_4 to V_9), respectively.

CALORIFIC VALUE STUDY

The calorific values were determined on the two bulk composite samples of the Mush Valley (the coals from the lower part and the coals from the upper part respectively) ; and on three bulk composite samples from Kindo Valley, using a Baum-calorimeter. The coals from the lower parts of the Mush Valley gave a calorific value of 4100 B.T.U., and that from the upper part gave a value of 3000 B.T.U. These calorific values assigns the ranks to the coals to range from sub-bituminous to lignites, respectively.

The calorific values determined for the coals of Kindo Valley ranged between 3400 B.T.U. and 6300 B.T.U. These values attest the rank ranging between sub-bituminous and bituminous. Of the three bulk composite samples studied from Kindo Valley, only one sample (Badalameta) belongs to the bituminous rank, while the majority of the coals belong to sub-bituminous rank.

Proximate Analysis

The proximate analysis pertains to the moisture, ash, volatile, and fixed carbon. Sulphur determinations were also carried out on these sample. Duplicate analysis was carried out for each chemical parameter to check the precision.

The proximate analysis of the coals from Mush Valley suggests that the coals from the lower part has a better grade in comparison to the upper part. The coals from the lower part are high in the fixed carbon, volatile and low in ash and moisture. The coals from Mush Valley, in general, are high in sulphate—sulphur and pyritic sulphur.

The coals from Kindo Valley are characterized by a high ash content (45.3-62.2%). Moisture is also high (2.7-4.5%). The volatiles calculated on D.A.F. basis assigns the coals to a high volatile to medium volatile category (volatile on D.A.F. basis—27.6 to 42.6%). Fixed-carbon varies from 19.4-33.6 per cent. Sulphur in these coals is low (0.21-0.28%) which is far below the critical limit assigned for industrial use.

Table 1

	PROXIMATE ANALYSIS					MICRO-PRTROGRAPHY				
Sample	Moisture %	Ash %	Volatile %	Fixed Carbon	Calorific Value B.T.U.	Vitrinoid %	Exinoid %	Inerti-noid %	Mineral Matter %	Reflect-ance in Oil
U	21.3	29.0	29.2	20.5	3,000	13.4	26.4	31.9	28.3	0.29
L	14.6	13.4	31.0	41.0	4,100	20.6	27.5	39.6	12.3	0.45
BO	4.5	55.4	20.3 (42.6)	19.8	4,590	21.5	0.2	3.7	74.6	0.85
AG	2.8	62.2	15.6 (32.5)	19.4	3,950	19.7	0.0	4.2	76.1	1.25
BM	3.8	45.3	17.3 (27.6)	33.6	6,300	26.4	0.0	10.9	62.7	1.25

U— Upper part of coals
L— Lower part of coals
BO— Bohudemba
AG— Agale
BM—Badalmeta (42.6, 32.5, 27.6)—Volatiles calculated on D. A. F. basis

As the low-rank coals (lignites and sub-bituminous) are potential source of germanium, the coals from the Mush Valley as well as from Kindo Valley were subjected to low temperature carbonization, and the ash obtained subjected to germanium determination. The determinations did not give encouraging results. Probably this may be due to bulking up of the samples, as it is well known that germanium is confined to either to the top or bottom six inches of the low rank coals. The germanium determinations carried out on the bulk composite samples gave values ranging from (50-150 ppm), while 500 ppm and above is considered economically feasible. Hence, it is suggested that a careful and systematic sampling of the top as well as bottom six inches of the above coals may give fruitful results.

Industrial Potential

Owing to the high ash content, low carbon content as well as calorific value, and the inaccessibility of the area, it is not economical to mine the coals from Mush Valley on a large scale. Mining can be undertaken for limited use after beneficiation

and washing. Owing to the low carbon content of the coals, it is suggested that they may be gasified at the spot and used.

In comparison to the coal occurrences reported from various parts of Ethiopia (JELENC, 1966) the coals of the Kindo Valley seems to be of the highest rank falling between sub-bituminous to bituminous border. Though the coals occur as discontinuous outcrops on the surface, possibly they may be continuous at depth. No doubt, these coals are high in ash but if the ash contains 5 per cent, CaO and MgO and possess pozzolonic property, it can be added in the cement plant as a substitute for gypsum. As the deposits are found scattered at different places, it is suggested to put 4-6 bore holes up to 100 feet to assess the quality of the coals on fresh core samples, to know the continuity of the coals at depth, and to explore the possibility of the existence of new seams at depth.

CONCLUSIONS

From the foregoing account, the following conclusions have been drawn :

(1) The coals from Mush Valley are principally lignites and carbargillites characterized by durain, lack of banding, and dull in nature while those of Kindo Valley are essentially sub-bituminous falling on the borderline of bituminous, characterized by vitrain and durain in almost equal amounts, showing laminations and banded nature, exhibiting bright to semi-dull nature.

(2) The micro-petrography shows difference between the bottom and top parts of the coals from Mush Valley with respect to vitrinoids and mineral matter, which are antipathetic with respect to one another (increase of mineral matter and decrease of vitrinoids from bottom to top). Vitrinoid is essentially of telinoid type and micrinoid is fine-grained and granular in nature. The mirco-petrography of the coals from Kindo Valley are characterized by the absence of exinoids, impoverishment in inertinoids. The vitrinoids are mostly of collinoid type and mineral matter predominate the coal.

(3) The reflectance study indicates that the coals from Mush Valley is characterized by vitrinoid type (V_4) and xylinoids (Reflectance <0.31) attesting to the high volatile and lignitic nature of the coals. The coals from the lower part of Mush Valley fall under high volatile sub-bituminous (presence of vitrinoids) and the upper part coals belong to lignites (presence of xylinoids). The coals from Kindo Valley are characterized by vitrinoids ranging in reflectance from 0.85-1.25, pointing to the types of vitrinoids from V_8 to V_{12}. These types of vitrinoids point to the high and medium volatile nature of the coals.

(4) The calorific values determined on the coals of Mush Valley range between 3000 to 4100 B.T.U.; coals from the Kindo Valley range between 3480 to 6300 B.T.U. The coals from Mush Valley, on the basis of the calorific value, range from lignite to sub-bituminous rank, while the coals from Kindo Valley falls between sub-bituminous to bituminous rank. Majority of the coals from Kindo Valley (except one occurrence—Badalmeta) conforms to sub-bituminous rank.

(5) The proximate analysis of the coals from Mush Valley points to low carbon content, high ash and moisture. The sulphate-sulphur as well as pyritic sulphur is also high. The coals from Kindo Valley is remarkably high in ash. The volatiles calculated on D.A.F. basis assign the coals to range from high volatile to medium volatile category.

(6) The mode of occurrence, geological setting, mega- and micro-petrography points to fluviatile and lacustrine origin to both the coals. In the case of Kindo Valley coals, there seems to be a paucity in the luxuriant vegetation as indicated by the absence of exinoids and impoverishment in inertinoids.

(7) Owing to the high ash-content, low carbon-content and calorific value, the coals of the Mush Valley can be mined on a small scale for limited use ; it is suggested that the coals may be gasified at the spot and used. The coals from Kindo Valley, as they point to the highest rank in comparison to other coals reported from Ethiopia, must be investigated by sub-surface survey (drilling). Much of the ash content of these coals can be reduced by washing and beneficiation. The reserves of coal at Kindo Valley seems to be promising for further investigations and also for industrial use.

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