Coal Studies

PHOSPHORUS IN BRITISH COLUMBIA COKING COALS

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INTRODUCTION

Phosphorus occurs in all coals to some extent because it is essential to plant life. Knowledge of the phosphorus content and its associations in coking coal is important from an economic point of view, as phosphorus in steel has a detrimental embrittling effect and its presence in coking coals is therefore limited to as little as 0.01 per cent.

For reference, phosphorus content of United States coals ranges from 0.0002 to 0.1430 per cent and averages 0.0185 per cent (Abernethey and Gibson, *in* Van der Flier, 1985). The world average is estimated at 0.05 per cent (Valcovic, 1983).

A study under the coal quality project was begun in 1989 to examine in detail the occurrence of phosphorus in British Columbia coking coals. The study area includes the East Kootenay coalfields and the Peace River coalfield, which together account for all of British Columbia's current coking coal and semi-coking coal production (Figure 4-1-1). The main objectives of the study are to: determine the phosphorus content of coals; determine the affinity of phosphorus in coal (organic versus inorganic); and identify phosphorus-bearing minerals in low-temperature ash. In addition, petrography, proximate analysis, sulphur and trace element contents will be determined. These data will be used to discern correlations, if any, between phosphorus content and other analytical parameters.

PREVIOUS WORK

The pioneer of trace element analysis of coal was Goldschmidt (1935). Since then a great deal of work has been done on the occurrence, distribution and associations of trace elements in coal; much of this relates to phosphorus. For examples and more detailed bibliographies refer to Gluskoter *et al.* (1977), Van der Flier (1985), Van der Flier-Keller and Fyfe (1987), and Goodarzi *et al.* (1987).

Phosphorus has been noted to have an affinity with organics (Rao *et al.*, 1951, Bogdanov, 1965, and Kuhn *et al.*, 1978, *in* Van der Flier, 1985), inorganics (Brown and Swaine, 1964, *in* Van der Flier, 1985) and a combination of the two (Francis, 1961, and Gluskoter, 1977, *in* Van der Flier, 1985).

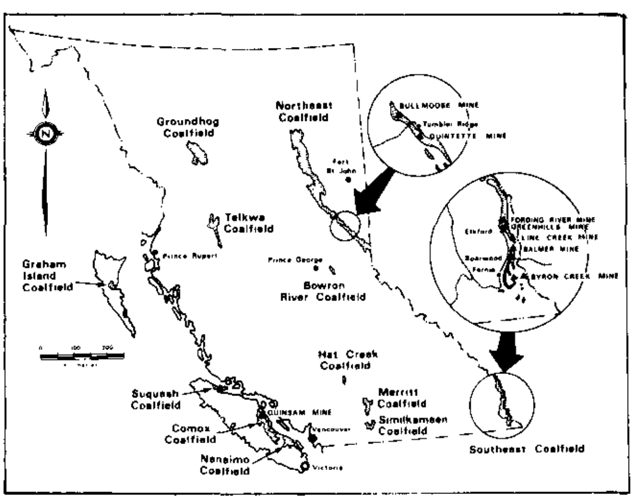

Figure 4-1-1. Sampling location map.

METHODS OF STUDY AND FIELDWORK

The project was approached in two steps. The first was the creation of a database of analyses of diamond-drill core the samples recorded in existing company assessment reports. All results included in this paper were generated by statistical analysis of these data. The second approach entailed the collection of fresh, unoxidized coal samples from each of the seven coking and semi-coking coal mines in British Columbia: Balmer, Greenhills, Fording, Line Creek and Byron Creek in the East Kootenay coalfields, and Bullmoose and Quintette in the Peace River coalfield (Figure 4-1-1).

DATABASE

Initially, a data search was performed, and a historic coal-quality database was set up using dBase III PLUS, a copyrighted database management software package. Using coal quality analysis data from British Columbia coal assessment reports, more than 1900 borehole sample records were entered into the database. The criterion for inclusion was the existance of phosphorus analyses, either in the form of P_2O_5 in coal or P_2O_5 in ash. (For this report, "P_2O_5" will refer to P_2O_5 in coal. The phosphorus contribution to the total weight of P_2O_5 is 43.64 per cent. Each record in the database contains three components: sample identification information, raw-coal data, and clean-coal data. The identification section contains location and sample-type information. The raw and clean-coal data contain the available proximate, sulphur, P_2O_5, mercury, chlorine and fluorine analyses. The clean-coal data were grouped by specific gravity fraction. To date, only raw-coal data has been studied, focusing on phosphorus versus ash relationships for coals from the Peace River and East Kootenay coalfields. Future work is planned to expand the quality program to include clean-coal data and a number of additional minor and trace elements.

Phosphorus and ash data were then grouped and copied to ASCII text files. These in turn were edited with the DOS editor, EDLIN, to the format required for GEO EAS (Geostatistical Environmental Assessment Software), a complimentary software package distributed by the United States Environmental Protection Agency. X-Y scatter plots of P_2O_5

in coal versus ash were then plotted (Figures 4-1-2 and 3; *see* Nicholls, 1968). Histograms were also constructed to help visualize the distribution of the data. Four histograms were compiled, one for each of P_2O_5 and ash for both the East Kootenay coalfields (Figures 4-1-4 and 5) and the Peace River coalfield (Figures 4-1-6 and 7). In all plots, only samples with 50 per cent or less ash were considered.

FIELDWORK

Channel samples were collected from each of the seven producing coking or semi-coking coal mines included in the study. An effort was made to obtain a sample from as many different seams as possible at each mine. In all, 68 samples were acquired. All samples from Balmer, Byron Creek, Fording, Greenhills, Quintette and Bullmoose were full-seam samples, while the samples from Line Creek were taken in 0.5-metre increments. Fording accounted for eight of the samples, representing seven seams; Byron Creek for three samples, all from the Mammoth seam; Greenhills, Balmer and Bullmoose for six samples each, from as many seams; and Quintette for two samples from two seams. Line Creek accounted for the remaining 33 samples, from four seams.

Sampling involved the removal of an approximately 8 by 8 centimetre channel of coal over the entire sample interval. This was accomplished by chipping with a geological hammer and collecting the material in a gold pan for the harder coals, and by utilizing a small scoop for the softer coals. Every attempt was made to take the samples perpendicular to bedding. The samples were then stored in labelled plastic bags for transport to the laboratory. Accurate thickness measurements were taken of all sample intervals.

Preparation and chemical analyses of the samples were done at Chemex Labs Ltd. in Vancouver, according to the flow chart in Figure 4-1-8. The raw sample was first dried and blended, then crushed to -5.3 millimetres. The material was split into three portions; one was crushed to -20 mesh, one crushed to -60 mesh, and the third set aside as reserve. A second split was taken from the material crushed to -60 mesh, with one half used at Chemex for analysis, and the other returned to the Geological Survey Branch. Some of the latter will be utilized for low-temperature plasma ashing and mineral determination by x-ray diffraction, and the remainder will be used for trace element determination by neutron activation analysis. The portion crushed to -20 mesh was returned for petrographic analysis. Chemex is responsible for proximate analysis, sulphur forms, P_2O_5 in coal, and chlorine, fluorine and mercury determinations. Results from all analyses will be reported in a later publication.

RESULTS

Data from the East Kootenay coalfield are represented by an X-Y plot of P_2O_5 in coal versus ash (Figure 4-1-2) and two histograms, one showing P_2O_5 distribution (Figure 4-1-4), and the other showing ash distribution (Figure 4-1-5). Together they represent a set of 601 data points, ranging from 0.010 to 0.240 per cent P_2O_5, and containing less then 50 per cent ash. From the plots we can see a concentration of points below 0.05 per cent P_2O_5 and between 10 and 32 per cent ash. The ash histogram shows a distribution close to normal with a mean of 24.54 and moderate positive skewness and positive kurtosis (peakedness). The P_2O_5 histogram shows a bimodal distribution. The first population is a symmetrical group of points with high kurtosis and containing less than 0.050 per cent P_2O_5, and the second is positively skewed and represents points beyond 0.050 per cent P_2O_5.

The Peace River coalfield data are also represented by similar plots and histograms (Figures 4-1-3, 6 and 7). A set of

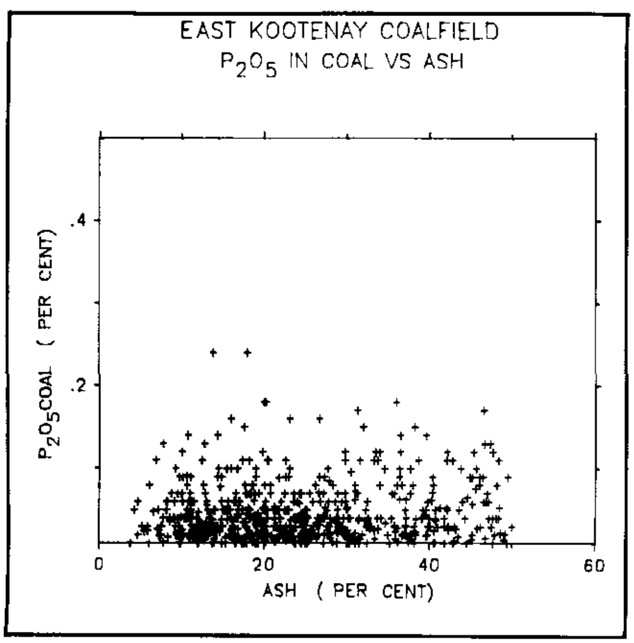

Figure 4-1-2. X-Y plot of P_2O_5 versus ash for the East Kootenay coalfield.

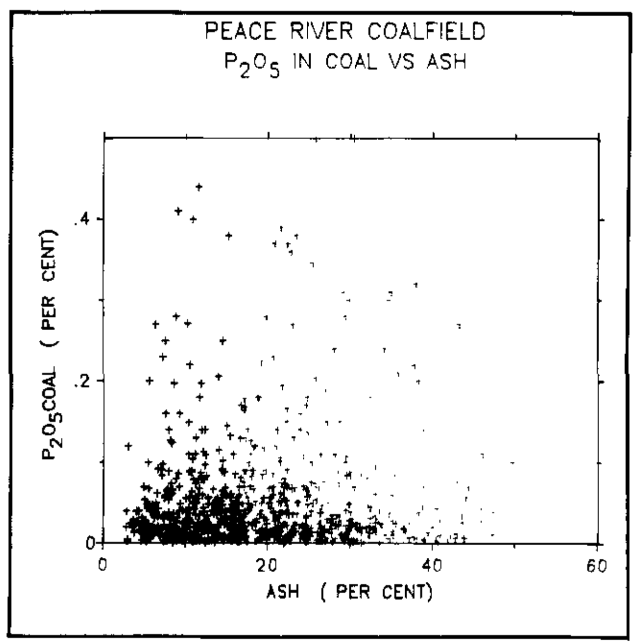

Figure 4-1-3. X-Y plot of P_2O_5 versus ash for the Peace River coalfield.

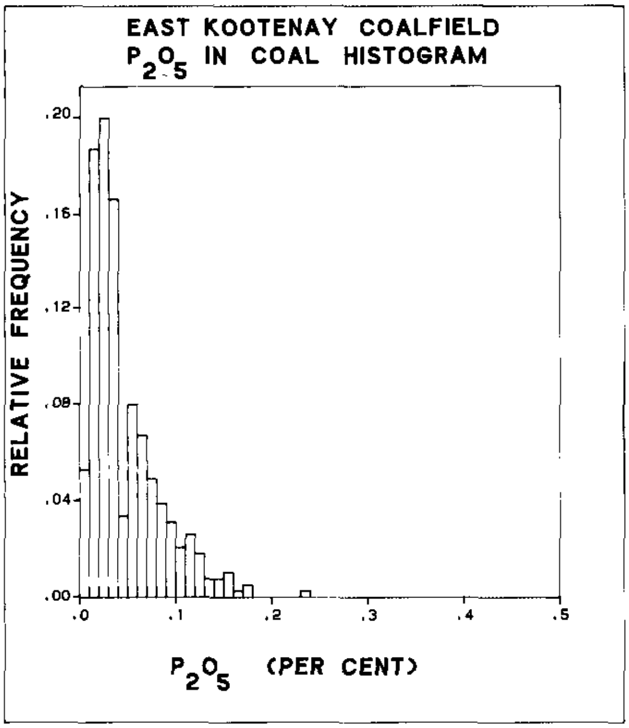

Figure 4-1-4. Histogram of P_2O_5 distribution for the East Kootenay coalfield.

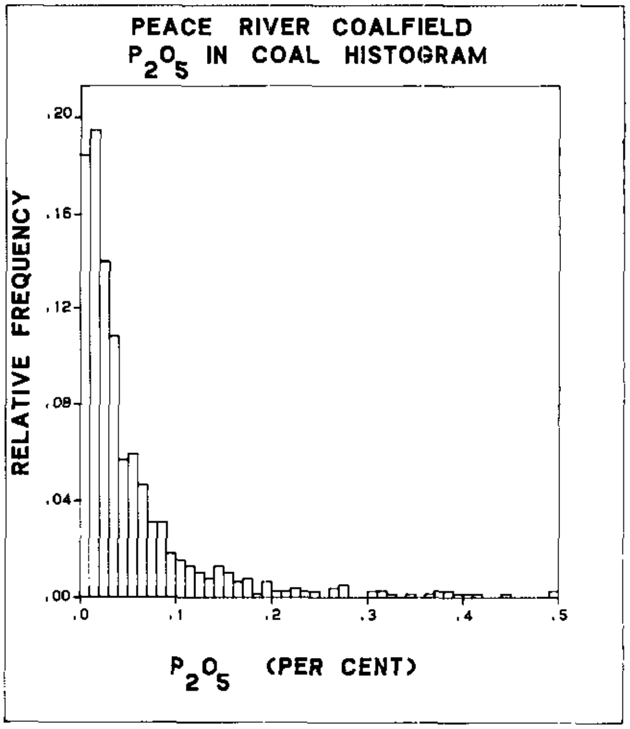

Figure 4-1-6. Histogram of P_2O_5 distribution for the Peace River coalfield.

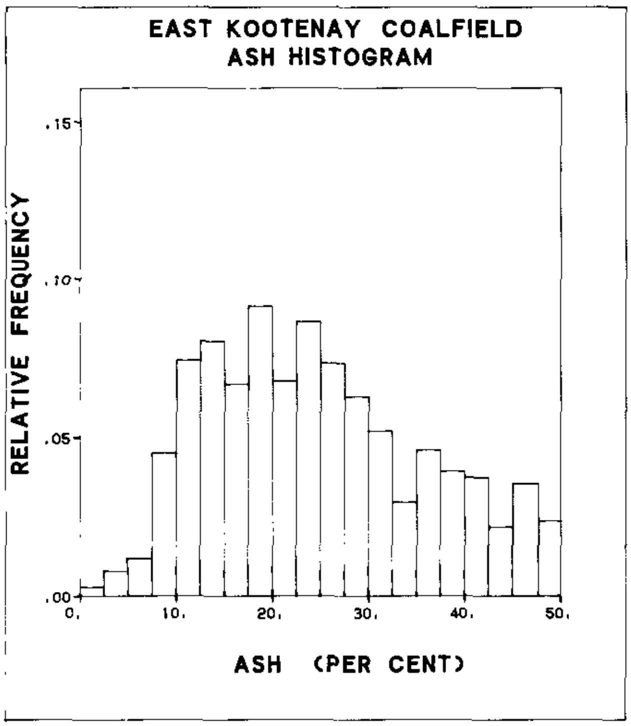

Figure 4-1-5. Histogram of ash distribution for the East Kootenay coalfield.

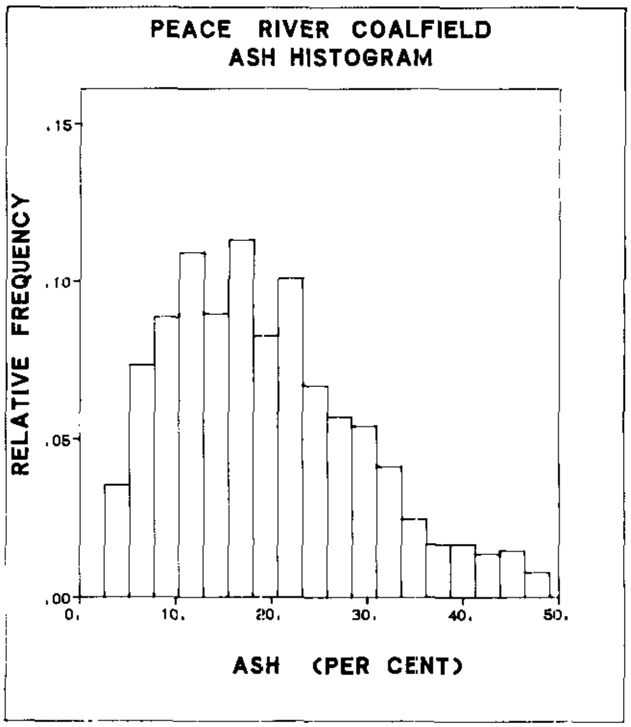

Figure 4-1-7. Histogram of ash distribution for the Peace River coalfield.

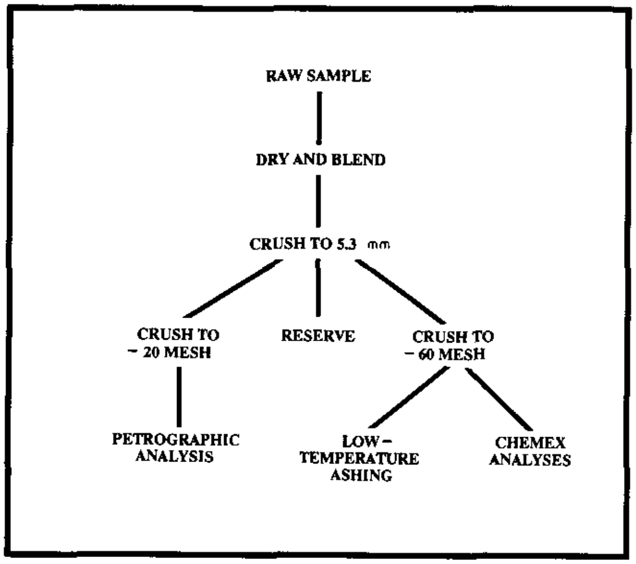

Figure 4-1-8. Simplified flowchart of sample analysis.

798 data points, ranging from 0.002 to 0.500 per cent P_2O_5 and containing less then 50 per cent ash are represented. There is a concentration of points between 5 and 30 per cent ash and below 0.050 per cent P_2O_5. The ash histogram shows a distribution similar to that for the East Kootenay coalfields, but with a higher positive skewness. The mean in this case is 18.92 per cent. Although not as apparent as in the East Kootenay coalfield, the P_2O_5 histogram for the Peace River Coalfield shows signs of a similar bimodal distribution.

DISCUSSION

The bimodal P_2O_5 distribution in both coalfields is thought to represent both organic and inorganic affinities of P_2O_5 in these coals. We can assume that all coals contain a certain amount of organic P_2O_5, since all plants need phosphorus to live. This organic phosphorus is thought to be represented by the population with less than 0.050 per cent P_2O_5. The skewed population with greater than 0.050 per cent P_2O_5 would then represent the organic phosphorus found in all coals, plus the inorganic phosphorus contributed by mineral matter. This interpretation is based on the similarity in distribution of the higher P_2O_5 population and the ash content, especially their positive skewness. The inorganic component of phosphorus is expected to vary with the amount of ash in the sample and/or the amount of P_2O_5 in the ash. Further work will be aimed at determining more precise associations and ultimately the controls on the distribution of phosphorus in coking coals of British Columbia.

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