Geologic controls on element concentrations in the Upper Freeport coal bed

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Introduction

The primary objective of this investigation was to determine the geologic controls on variations of mineral matter in the Upper Freeport coal bed near Homer City, Pa. (fig. 1). Mineral matter consists of the inorganic constituents of coal, including mineral phases and elements other than organically bound hydrogen, oxygen, nitrogen, and sulfur [1]. By this definition, organic sulfur is not part of the mineral matter; however, variations of all sulfur forms including organic sulfur were considered in this study.

The concentrations of 70 elements were determined on 75 bench-channel and 21 complete bed-channel samples from two deep mines in the study area (fig. 2). Ultimate, proximate, sulfur forms, maceral, and pyrite morphological analyses were also conducted on these samples. Scanning electron microscope [2] and electron microprobe [3] analyses were conducted on selected channel and column samples to determine element-mineral and maceral associations.

Results

The Upper Freeport coal bed of the Homer City study area is divisible in the field into five zones (fig. 3). In the northern part of the area where all five zones are present, the coal bed averages 83 inches (211 cm) in thickness; in the southern part where only three zones are present, the coal bed averages 48 inches (122 cm) in thickness. Laboratory analyses show that each of the five zones consists of distinct mineral matter-maceral associations. Elements that tend to be concentrated in the upper and/or basal zones of the bed include As, Cd, Cl, Fe, Hg, Mn, Pb, Se, S, and Zn.

Linear regression analysis was used to determine relationships among elements, sulfur (total, pyritic, and organic), ash, and maceral concentrations on the 75 bench-channel samples. On the basis of this statistical analysis, element concentrations in the coal can be related to three variables: ash, pyritic sulfur, and calcium (reported as CaO). The elements (some of which are reported as oxides) that positively correlate with each of the three variables are shown in figure 4. Only manganese is positively correlated with all three variables. The fusinite-semifusinite maceral concentrations correlate with the ash content.

Discussion

The mineral-matter content of the Upper Freeport coal bed of the Homer City area was controlled by interrelated geologic, geochemical, and paleobotanical variables. The elements that positively correlate with the ash (fig. 4) probably accumulated contemporaneously with the peat. Possible sources include: 1) mineral matter incorporated by plants, or 2) detrital minerals and dissolved elements incorporated during the peat stage of coal formation. Element concentrations resulting from mixed sources such as deposition of detrital minerals, sorption of dissolved ionic species, and mineral matter of plant origin would not lead to a strongly interrelated assemblage. Fusinite and semifusinite are generally believed to be the coalified products of partially oxidized peat and plant material. Oxidation results in a loss of organic matter and a concentration of residual mineral matter;

therefore, as the fusinite-semifusinite content of the coal increases, the ash and statistically related element contents also increase. Plant inorganic matter must be the major source of the ash-related elements. This interpretation is consistent with 1) the moderate ash content (8-15%), 2) the positive correlation between ash and fusinite-semifusinite content, and 3) the element-ash correlations illustrated in figure 4.

The calcium in the coal bed is primarily in authigenic calcite. Fixation of the calcium in the peat by ion exchange and/or as calcium salts of humic acids with subsequent liberation of CO_2 and organically bound calcium during coalification may have resulted in the formation of calcite in macerals and cleats. The buffering effect of calcium carbonate species supplied to the ancestral peat partially controlled the pH. Sulfate-reducing bacterial activity is greatest at neutral pH and minimal or nonexistent at pH 4.0 or less [4]. Therefore, pH values near neutral favor 1) bacterial generation of sulfide species if sulfate ions are present, 2) bacterial degradation of peat that could result in the concentration of mineral matter, and 3) retention of mineral matter because of decreasing solubilities as pH increases.

Low pH (<4.0) would favor a low-ash (<8%), low-sulfur (<1%) coal. Partial neutralization of waters of the ancestral peat of the Upper Freeport coal is indirectly indicated by the presence of 1) calcite in coal macerals and cleats and 2) mixed carbonate and clastic sediments directly under the coal bed. The Upper Freeport coal studied is a medium ash (8-15%), medium sulfur (1-3%) coal that is consistent with partial neutralization of peat waters.

The pyrite in the Upper Freeport coal is usually concentrated in the upper and/or basal zones of the bed throughout the area. Genetically, pyrite and the associated trace elements As and Hg appear unrelated to the bulk of the coal ash. Although pH conditions were suitable for pyrite deposition, pyrite concentrations were controlled by the availability of ferrous iron and appropriate sulfur species.

Summary

The elements in the Upper Freeport coal bed of the area can be genetically related to three variables (i.e., ash content, pyritic sulfur content, and calcium content). The buffering effect of dissolved calcium carbonate species may have been sufficient to maintain a pH of 4 or greater. Under these pH conditions, sulfate-reducing bacteria generated sulfide species, which reacted to form minerals such as pyrite, sphalerite, chalcopyrite, and galena. During coalification, the calcium salts of humic acids decomposed to form calcite and carbon compounds that may account for the calcite in coal macerals and cleats. The pH conditions that existed during peat formation were conducive to the retention of mineral matter, the bulk of which was of plant origin.

References

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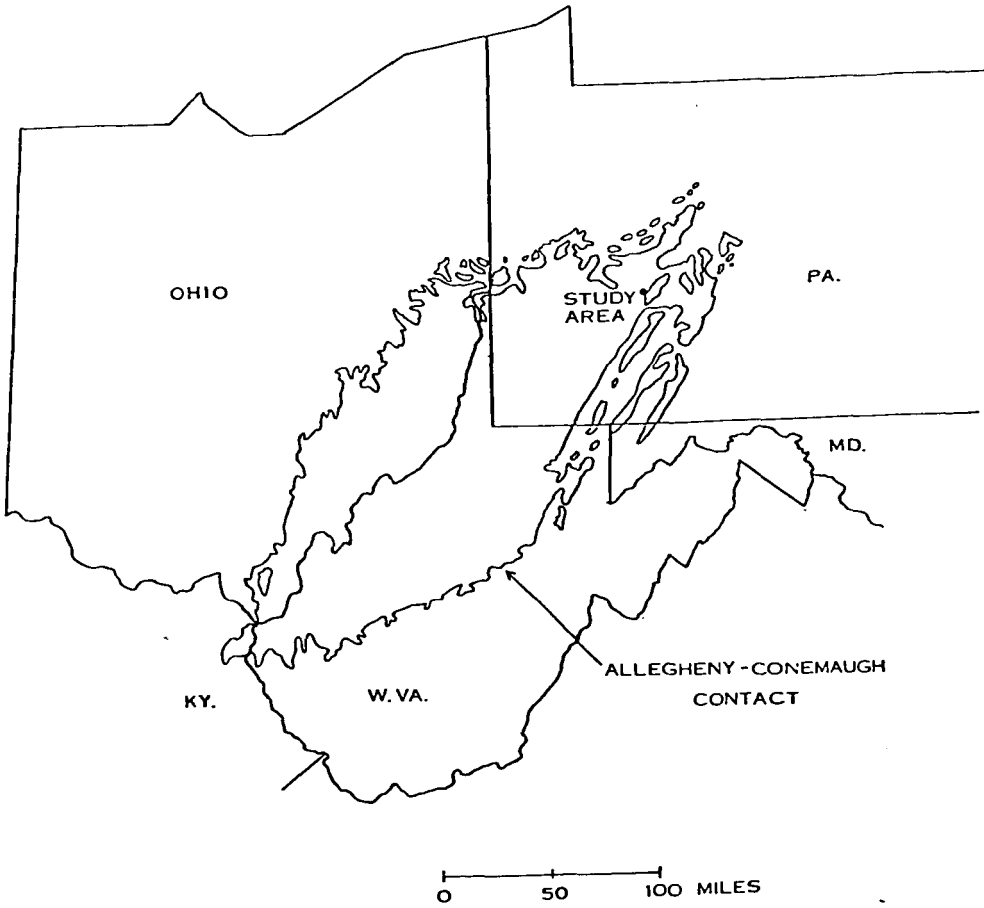

Figure 1. - Index map of Homer City, Pa., study area and Allegheny Group-Conemaugh Group contact.

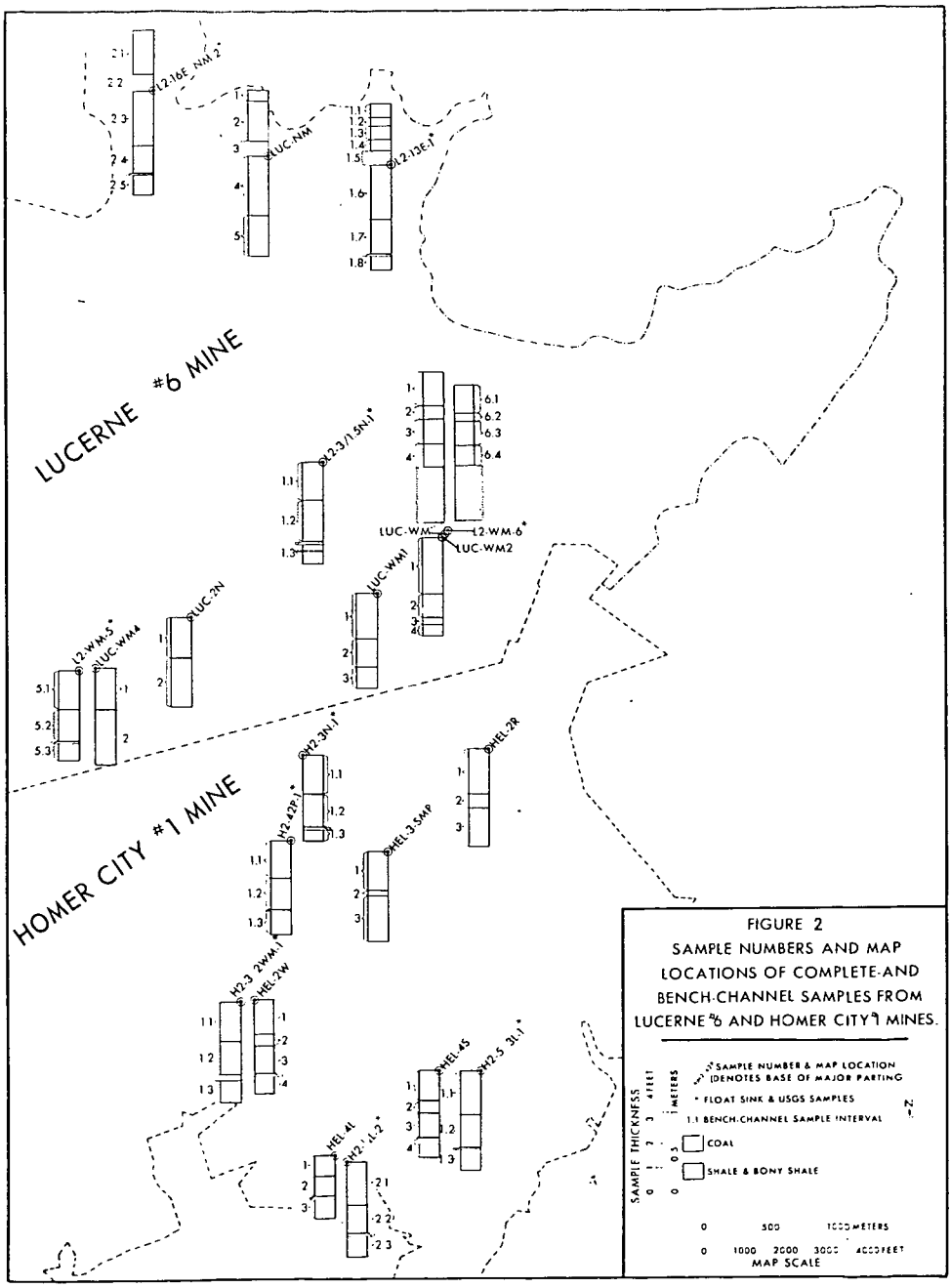

FIGURE 2
SAMPLE NUMBERS AND MAP LOCATIONS OF COMPLETE-AND BENCH-CHANNEL SAMPLES FROM LUCERNE #6 AND HOMER CITY #1 MINES.

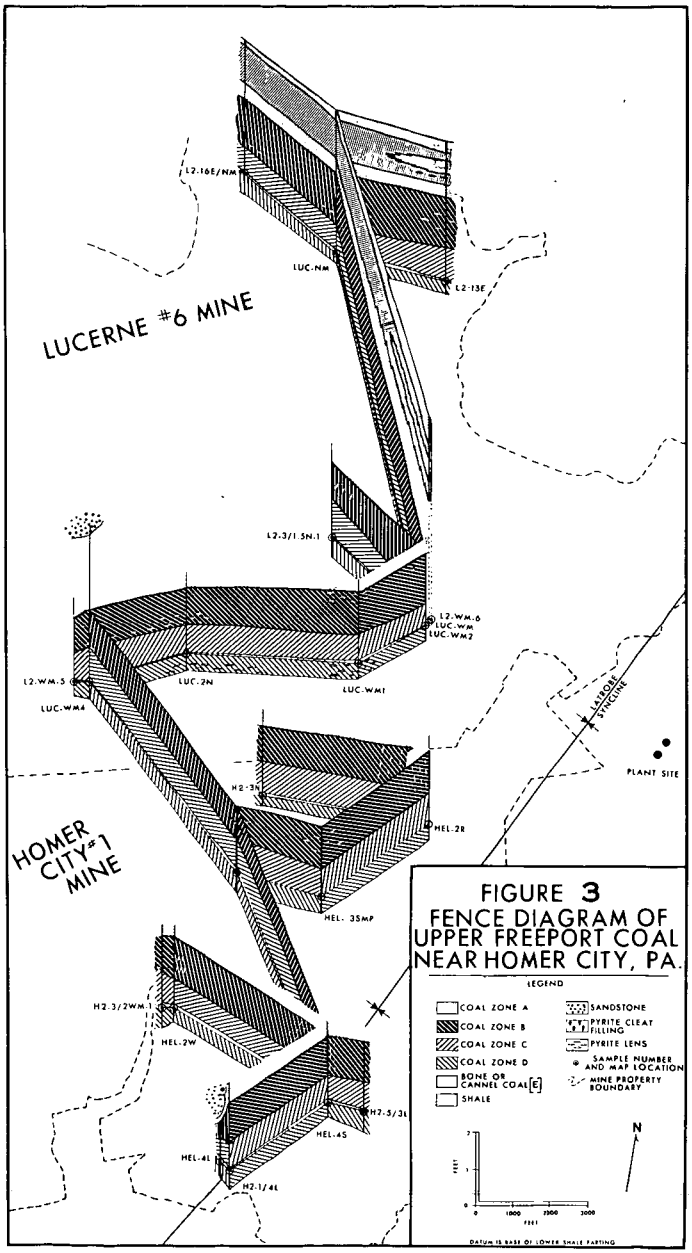

FIGURE 3
FENCE DIAGRAM OF UPPER FREEPORT COAL NEAR HOMER CITY, PA.

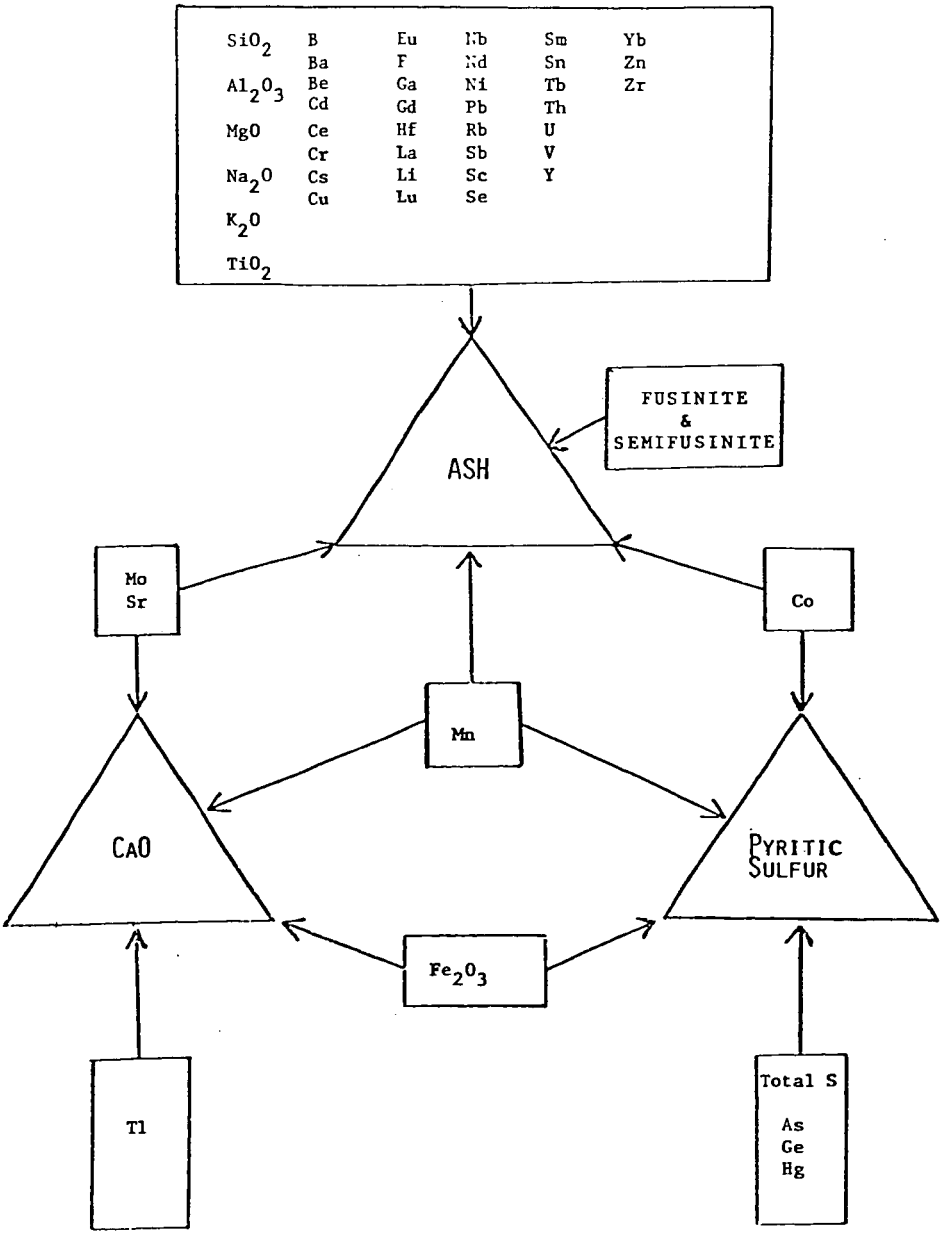

Figure 4. Mineral matter constituents and macerals of the Upper Freeport coal that statistically positively correlate with ash, pyritic sulfur, and calcium.