

THE DISTRIBUTION OF TEN TRACE ELEMENTS AND MINERALS IN THREE LIGNITE SEAMS FROM THE MAE MOH MINE, THAILAND

Hart, Brian, Powell M.P., Fyfe, W.S. Department of Earth Sciences University of Western Ontario, London, Canada; Ratanasthien, B. Department of Geology, University of Chiang Mai, Chiang Mai, Thailand.

Keywords: Lignite, mineralogy, trace elements.

Introduction

Understanding the association of major, minor and trace elements in lignites and their accompanying strata is important from a number of perspectives (1) which include: potential health problems from environmental pollutants, rehabilitation after mining, combustion for power etc. The material which follows represents some preliminary observations on the mineralogy and distribution of 10 trace elements in lignites and accompanying sediments from the Mae Moh mine, Thailand.

Samples collected from freshly exposed mine faces were air dried and analyzed for moisture and ash. Trace element concentrations were determined on "whole" coals and sediments by NAA and XRF. All chemical analyses are expressed as a fraction of the total dry sediment. Mineralogy of both LTA and sediments was determined by XRD. The chemistry and morphology of individual particles were examined by the Electron microprobe. The analyses are used to make some conclusions about the spatial occurrence of these elements within the seam and their partitioning between organic and inorganic phases.

Mineralogy: XRD Analysis

In samples with >50% ash the mineralogy was determined on untreated material. In samples with <50% ash the mineralogy was determined on oxygen plasma low temperature ash. The minerals identified by XRD analysis include quartz, kaolinite, pyrite/marcasite, calcite, gypsum, illite, smectite (mixed-layer clay), jarosite, bassanite, spinel, anhydrite and ferroxahydrate.

Mineralogy Discussion

For the most part, the greater than 50% ash samples represent the mineralogy of the sediments (overburden, underclays and interseam partings) associated with the coals. In both the Q and K seams as well as the lower portion of J seam calcite dominates the mineralogy. In a previous study (2) a similar distribution for calcite was identified where it was suggested that the calcite might be both biogenic and derived from weathered limestone bedrock. Both origins are possible as the underlying Triassic sequence is marine and fresh water gastropods have been identified in many interseam sediments (3). Pyrite was identified in all but 4 sediment samples. While preliminary SEM work has indicated that much of the pyrite within the sediment and coal samples is framboidal, it also occurs as nodules and fracture fillings. The occurrences suggest both a syngenetic and epigenetic formation for the sulphide. Based on SEM analysis the quartz identified in all but 2 samples appears to be mostly detrital. Siliceous zones in which some of the quartz is extremely fine grained, may be due in part to an authigenic or biogenic origin. Preliminary SEM work has shown the clay minerals to be very fine grained. Detailed clay mineralogy on selected samples indicates that the proportion of kaolinite is slightly higher than illite and the occurrence of expandable clays increases down the section. The illite is likely detrital, and the poor crystallinity of the kaolinite suggests a similar origin.

Within samples of LTA calcite, as in the sediments, appears to be more common in the Q and K seams while quartz is identified throughout the section. Pyrite is present, mostly a major constituent, in all but the upper 2 LTA samples from J seam. As in the sediments, the proportion of kaolinite is greater than illite in the LTA samples. Minerals not identified in the sediments; bassanite (except in 2 samples), anhydrite and ferroxahydrite, are artifacts created during the ashing procedure. Anhydrite and bassanite are both dehydration products from gypsum. Bassanite can also form by the combination of organically associated Ca and sulphur released during the ashing procedure. Ferroxahydrite forms from similar mobile components in the coal as they are released during the ashing (4).

Vertical element variations

The NAA and XRF analysis for 10 elements in samples collected from the three seams is given in table 1.

J seam. For the elements reported, except U, the concentration decreases from the top to the bottom of the seam (Fig 1a;Cr as an example). The consistently high concentration of ash in samples from the upper portion of the seam is coupled with higher concentrations of trace elements. The elements Mo and Sb (Fig 1a;Sb) also showed increased concentrations in samples from the lower portion of the seam, while the concentration of U (Fig 1b;U) is variable.

K seam. The elements As, Co, Cr, Mo and U show higher concentrations in the samples closer to the seam margins (Fig 1b;U). Antimony, and to some degree Pb, are concentrated in the upper portion of the seam only (Fig1b:Pb). The distribution of Se down the seam is variable. The lowest concentration of all elements is found in the mid portion of the seam where the ash content of the samples is also low.

Q seam. Within the Q seam all elements except As and Se show a marked overall concentration increase from top to the bottom of the seam (Fig 1c;Co). Selenium is concentrated in the middle of the seam (Fig 1c;Se) while As is enriched in the upper 2 samples as well as the lower portion of the seam (Fig 1c;As).

Interpretation of element distribution

The relationship between ash content and element concentration in a coal can be used as a guide to determine whether an element is preferentially associated with the organic or inorganic fraction of the coal (5). Pearson correlation coefficients were calculated for 10 elements versus ash in each of the 3 seams. Based on these correlations only 2 types of element associations were recognized; those elements which are inorganically associated and those elements which show a mixed inorganic-organic association.

Correlation coefficients in the J seam reveal that only Pb and Th are inorganically associated. The remainder of the elements had correlation coefficients indicative of mixed organic-inorganic associations. In a more restricted group of samples, representing only mine designated lignite seams, an inorganic affinity was indicated for all elements except Mo, Sb and U. Correlation coefficients for the latter 3 elements indicates a mixed organic-inorganic association. Correlation coefficients for elements in K seam indicate that Mo, Ni, Pb, Sb, and U are most likely to be inorganically associated, whereas As, Co, Cr, Se, and Th show a mixed organic-inorganic

association. In the Q seam Cr, Mo, Pb, Th and U show a strong inorganic affinity while a mixed association is indicated for As, Co, Ni, Sb and Se.

Except for those elements which are consistently inorganically associated, for example Pb, there appears to be no reasonable agreement between correlation coefficients of elements with ash and their vertical distribution. The concentration for most elements in this study group, expressed as a fraction of the total dry sediment, appears to be linked to the inorganic content of the lignite seam. For example the upper samples in J seam are both high in ash and high in trace elements. Furthermore the samples from K seam which are low in ash are consistently low in trace elements. These observations are not necessarily indicated by the correlation coefficients.

Inconsistencies in correlation coefficients exhibited by many of the trace elements can be related to their wide range in concentration. A single sample can easily skew the distribution thereby changing the elements apparent association from one group to another. A good example of this is Co in Q seam where, apart from one, sample Q4A (Fig1c), the concentration clearly parallels the ash content.

The interpretation therefore is that most of the elements are associated with inorganic grains and occur either bound within minerals, as oxide films surrounding mineral particles or as ions adsorbed onto the surface of a mineral such as kaolinite. This interpretation works well for those elements which show distinct enrichment in sediment samples; for example, Q seam where Cr and Th are concentrated in both the mid-seam parting and the underclay.

Since the ash content of lignites reflects both the actual mineral particles and exchangeable ions held in the organic material, the possibility exists that a number of trace elements could be held in organic combination. Fractionation experiments (6) have shown that Cr, V and Ni were at least partially, or in the case of Cu and Zn wholly, complexed with the organic matter. Although no fractionation studies were performed on these coals an organic association is indicated for at least some of the Se, particularly in samples where high concentrations are not coupled with high ash content. The element As shows a similar relationship to ash in some samples and may also be partially organically complexed. However isomorphic substitution of As for Fe in pyrite may give rise to high As concentrations even in those low ash lignite samples which contain pyrite.

References

1. Swaine, D.J. "Trace Elements in Coal"; Butterworths and Co.: London, 1990; p.278
2. Ward, C.R., *International Journal of Coal Geology*, 1991, 17, 96-93.
3. Watanasak, M. "Proc. Int. Symp. on Intermontane Basins: Geology and Resources" T.Thanasuthipitak and P. Ounchanum, Eds. ; Chaing Mai University 1989, 327-335.
4. Morgan, M., E.; Jenkins, R.G.; Walker, P. L. *Fuel* 1981, 60, 189-193.
5. Karner, F.R.; Benson, S.A.; Schobert, H.H.; Roaldson, R.G. "The Chemistry of Low Rank Coals", H.H. Schobert Eds.; Amer. Chem. Symp. Series 264; Amer. Chem. Soc. Washington, DC, 1984, 175-193.
6. Miller, R.N.; Given, P. H. *Geochem. Cosmochem. Acta*, 51, 1311-1322.

TABLE 1 TRACE ELEMENT CONCENTRATION FOR 10 ELEMENTS IN 3 SEAMS FROM THE MAE MOH MINE

SAMPLE #	% Ash	As	Co	Cr	Mo	Ni	Pb	Sb	Se	Th	U
J1-1,2	91.82	28.80	6.95	122.95	6.63	57.97	30.67	3.28	0.88	25.12	2.31
J1-3	78.07	71.11	13.19	127.88	5.35	60.19	21.35	2.09	2.07	17.03	1.83
J1-4	85.65	269.43	37.38	114.91	28.60	249.86	18.84	9.58	1.18	16.33	4.74
J1-5	48.31	180.29	16.23	60.52	16.30	32.53	10.58	11.22	1.48	6.62	4.45
J2	54.40	65.94	10.33	58.94	8.88	30.56	14.35	5.80	1.60	9.16	2.88
J3A/J2	93.27	350.74	11.16	97.11	4.80	46.17	17.07	4.05	1.09	21.82	1.98
J3A	71.00	93.91	21.81	85.75	9.74	57.31	9.57	6.60	1.12	12.94	4.80
J3A/J3B1	92.75	15.92	11.20	96.70	1.94	39.51	23.68	0.78		19.03	0.22
J3B1	29.78	26.88	8.16	14.27	5.62		5.7	1.49	0.38	1.87	
J3/J4	90.59	71.32	7.04	32.54	6.74		7.07	3.01		5.58	2.01
J4U	31.48	117.35	16.96	28.88	12.02	44.42	4.62	8.21	1.19	2.54	3.28
J4U/J4L	62.41	68.58	9.46	69.88	2.82	21.91	15.65	2.69		14.88	1.48
J4L	32.42	79.18	14.47	14.82	4.01	22.52	4.72	1.92	1.28	2.16	0.44
J4/J5	98.07	41.52	6.76	25.39	8.07	18.82	7.13	3.60		4.96	4.01
J5A	22.63	95.11	3.96	29.31	5.14	22.09	4.81	2.28	0.79	0.85	2.10
J5A/J5B	85.68	66.14	7.90	28.73	2.82		10.05	2.63		4.95	1.70
J5B U	28.38	37.85	7.86	15.78	3.34	23.72	4.04	0.59	0.84	1.71	0.37
J5B U/J5BL	89.48	23.69	3.08	8.64		8.39		0.83	0.42	2.01	0.45
J5BL	24.21	54.62	5.78	7.38	2.40	7.82	3.8	1.23	0.49	0.92	0.55
J5B/J5C	67.00	109.47	8.40	29.17	8.50		9.8	3.43	0.89	8.69	1.80
J5C	34.07	105.04	7.57	12.78	24.38	13.89	8.83	9.54		9.78	5.83
J5/J8	94.41	3.07	8.23	32.30	3.89	22.84	8.93	0.48	0.62	7.22	2.33
J8A	13.40	61.41	1.85	7.15	4.55	0.00	4.73	1.56	0.48	0.15	0.31
J8A/J8B	85.20	8.49	5.73	19.13	1.78	12.61	7.38	0.68	0.62	4.81	0.58
J8B	7.07	35.10	2.03	3.80	13.08		3.48	11.08	0.39	0.71	7.70
J8B-1	88.74	85.30	2.93	5.47	4.15	10.09		2.47	0.50	1.08	0.60

Sample #	% Ash	As	Co	Cr	Mo	Ni	Pb	Sb	Se	Th	U
K1-1	89.32	31.57	8.59	25.46	8.17		12.43	6.38	0.42	4.96	3.18
K1-2	24.34	40.65	3.38	14.56	3.31		7.34	1.15	0.38	3.07	1.00
K1-3	64.35	ND	8.96	32.44	ND	27.87	13.85	ND	0.80	8.85	ND
K1/K2	91.06	38.94	0.39	4.18	3.71			2.12		0.15	1.33
K2-1	41.96	21.79	8.76	29.11	5.31	14.67	12.28	2.90	0.82	8.26	2.02
K2-2	35.61	11.68	3.46	11.48			8.32	1.65		2.80	0.68
K2-3	15.42	13.08	2.05	7.58	1.77	13.35	8.48	1.28	0.69	2.00	0.64
K3-1	9.13	9.41	1.83	3.78	1.68	10.95	5.27	1.05	0.23	0.59	0.34
K3-2	38.78	58.28	9.86	18.32	3.55	19.17	9.69	2.00	1.08	3.11	0.73
K3/K4	89.70	26.02	7.88	15.04	8.83		8.68	2.50	0.38	2.68	2.50
K4	47.45	75.02	14.58	26.64	4.98	19.75	7.55	1.98	1.43	4.60	1.48

Sample #	% Ash	As	Co	Cr	Mo	Ni	Pb	Sb	Se	Th	U
Q1-1	15.38	40.17	1.76	2.66			4.32	0.21	0.34	0.21	
Q1-2	22.50	32.16	3.57	2.21	1.48	10.61	3.12	0.36	0.57	0.23	0.22
Q1-3	38.30	8.72	2.00	2.50			4.7	0.48	0.18	0.27	
Q1-4	11.33	6.84	1.39	2.98		5.44	4.22	0.33	0.22	0.28	
Q1/Q2	27.90	10.39	1.50	1.77			5.97	0.38	0.39	0.23	
Q2-1	18.55	31.42	3.08	9.58	2.97			0.95	1.20	2.06	0.58
Q2-2	87.68	4.58	10.82	35.31		28.78	11.88	0.40	1.35	8.70	
Q2-3	17.62	18.61	3.55	12.50	3.46	15.97	4.4	1.08	0.77	2.80	0.58
Q2/Q3	27.50	21.24	3.98	8.22	3.00	11.94	4	0.74	0.21	1.02	
Q3-1	17.44	27.05	6.73	17.75	6.60	24.07	9.13	1.64		4.33	1.85
Q3-2	32.87	21.24	6.73	23.68	3.46	22.85	11.17	0.72	0.63	5.98	0.49
Q4A	27.89	52.44	18.78	24.31	7.92	45.73	11.25	2.74	0.50	5.11	2.37
Q4B	18.30	19.65	3.22	9.18	2.70	14.80	4.87	1.01	0.27	0.46	
Q4	96.64	14.80	11.71	38.82	6.88	30.34	11.03	2.08		9.55	4.49

All trace element data reported as ppm.

Blank spaces in the table indicate the concentration was below detection limits

ND = no data

FIGURE 1. VERTICAL DISTRIBUTION OF 10 ELEMENTS IN THE 3 LIGNITE SEAMS FROM MAE MOH, THAILAND FOR J SEAM, ONLY THOSE SEAMS DESIGNATED AS LIGNITE ARE INCLUDED

