Abundance and distribution of trace elements in Mengjiawan coal from Shaanxi, China

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Keywords: Coal, Trace Element, Distribution

Abstract. The abundance of one major and eight trace elements in 215 coal samples from the Mengjiawan exploration area, northern Shaanxi, China, were determined. As compared with Chinese coal, American coal and coal Clarke value, only Th content in the Mengjiawan coal is high. The abundance of the element is different in every coal-seam. The highest contents of Cl(43mg/kg), Ge(7mg/kg), and Th(20mg/kg) occur in the coal seam No.5-2, while the highest contents of F(108mg/kg) in coal seam No.3-1. The elements were divided into two groups based on their coal seam distribution, and the characteristics of each group were discussed.

Introduction

There are huge Jurassic coal reserves in northern Shaanxi , China. Only a few researchers studied abundance of trace elements in this district[1]. Mengjiawan exploration area is located in the middle of the northern Shaanxi Jurassic coalfield, China. The coal is bituminous, with low sulfur contents and ash yield, as well as high calorific value. The coal is mined mainly for power generation. There is little knowledge about the concentration of trace elements in the Mengjiawan coal and the concentration variation of the elements among coal seams. Therefore, it is essential to understand the abundances and distribution of the trace elements in different coal seams in the Mengjiawan exploration area. On the basis of new data of the coal geochemistry, the authors report the contents of the eight potentially hazardous trace elements and one major element (P), as well as vertical variation of the concentration of the elements in different coal seams from Mengjiawan exploration area in Shaanxi Province, China.

Geological setting

The Mengjiawan exploration area is located in Yulin, northern Shaanxi, China. The coal-bearing strata of Mengjiawa is Jurassic Yan'an Formation, which consists of coal, dark mudstone, gray sandstone and sandy mudstone. The Yan'an Formation was deposited in the lacustrine sedimentary system[2]. The rank of the study area coal is bituminous.

Sampling and analytical procedures

The 215 coal samples of eight coal seams from Mengjiawan exploration area were analyzed. All coal samples were taken from 55 boreholes during exploration. The coal samples were air-dried and ground to pass a 200-mesh sieve for chemical analysis. Fluorine and Chlorine were determined by an ion-selective electrode (ISE) method. As was analyzed by atomic fluorescence spectroscopy(AFS). The other trace elements(P, Ge, Ga, U, V and Th) were determined by inductively coupled plasma mass spectrometry(ICP-MS).

Result and discussion

Trace element concentration

The arithmetic, and the number of samples(N) for the elements in individual coal seam from Mengjiawan exploration area was tabulated in Table 1. Because of inhomogeneity of coal and the elements in horizontal and vertical oriented variations, the abundance of the elements in individual coal seam of Mengjiawan is different, but they are all in the normal ranges. The coal seam No.5-2 has the highest contents of Cl(43mg/kg), Ge(7mg/kg), and Th(20mg/kg), while coal seam No.3-1 has the highest contents of F(108mg/kg).The enrichment of different elements in different coal seam is noted, especially in coal processing.

Table 1 The number of sample and content of the nine elements in eight coal-seams(mg/kg)

Coal seam	N	F	Cl	As	Ge	Ga	U	V	Th	P
1-2	22	76	37	2	2	3	2	18	17	9
2-2	81	77	22	2	5	5	3	11	16	5
2-2U	2	86	40	1.5	5	4.5	2.5	11	16	5
3-1	29	108	32	2	4	2	2	14	16	12
3-1L	20	95	38	1	3	3	2	13	13	9
4-1	11	102	38	1	5	2	2	15	16	14
5-2	20	98	43	2	7	5	3	12	20	13
5-3L	30	93	41	2	6	4	2	14	15	12

The arithmetic (AM) value of the elements in the Mengjiawan coal were acquired directly by design formulas: $AM=\sum(C_x \times N_x)/N$ (X: every coal seam number; N: the amount of all coal samples; N_x: the amount of coal samples in coal seam NO.X; C_x: the concentration of elements in coal seam No.X). The AM and the number of samples for the elements in the Mengjiawan coal were listed in Table 2. In order to research on enrichment of the elements in Mengjiawa coal, the contents and number of Chinese coal and American coal, as well as coal Clark value and enrichment factor
(EF) also were listed in Table 2. The EF is the ratio of elemental content in coal to the coal Clarke value. It shows that the thorium is highly enriched from EF value (up to ×5.03) in Mengjiawan coal, whereas F(up to ×1.07), Ge(up to ×1.96), and U(up to ×1.32) show a moderate enrichment. In comparison with the averages of trace elements in Chinese coals, the Mengjiawan coal is only moderate enrich in Th (× 2.68-2.77), and Ge(×1.18-1.93). As compared with the averages of trace in American coals, the Mengjiawan coal is only strongly enriched in Th(5.03×), and U shows a moderate enrichments in the Mengjiawan coal.

Table 2 The average content and number of trace elements in Chinese coals, American coal and the coal Clarke value(mg/kg).

			F	Cl	As	Ge	Ga	U	V	Th
This study		AM	88	32	1.8	4.7	3.9	2.5	13.1	16.1
		N	215	215	215	185	185	185	174	174
China	[3]	AM	157	218	4.09	2.43	6.84	2.33	51.18	5.88
		N	1123	1123	1123	1123	1123	1123	1123	1123
	[4]	AM	186	260	5	4	9	3	25	6
		N	1069	311	3193	3289	3407	1383	1257	1011
	[5]	AM	131.3	264	3.8	2.97	6.52	2.41	35.05	5.81
		N	729	721	3386	3195	2334	1317	1266	1011
	[6-7]	AM	130	255	3.79	2.78	6.55	2.43	35.1	5.84
		N	1964	812	3386	3265	2451	1383	1324	1052
USA[8]		AM	98	614	24	5.7	5.7	2.1	22	3.2
		N	7376	4171	7676	5689	5689	6923	7924	6866
Clarke [9]		AM	82	340	9	2.4	6.0	1.9	28	3.2
EF		N	1.07	0.094	0.20	1.96	0.65	1.32	0.47	5.03

Spatial distribution of the elements

In this study, 215 coal samples were analyzed; 22 from coal seam No.1-2, 83 from coal seam No. 2-2 and 2-2U, 49 from coal seam No.3-1 and 3-1L, 11 from coal seam No.4-1, and 50 from coal seam No.5-2 and 5-3L. The concentration of the elements is different in every coal seam, while different elements have similarities as well as differences.

The distributions of the elemental contents along the coal seam units were made a detailed discussion by hierarchical cluster analysis. The elements in Mengjiawa coal were divided into two groups based on hierarchical cluster analysis(Fig. 1). It shows that the rescaled distance between two groups is 25 in Fig. 1. The elemental origin is associated with peat-swamp environments and post-depositional sedimentary environments. So the primal environment of Mengjiawa mining area can be inferred from the vertical variation of elemental contents, especially some elements have landmark significance[1,9].

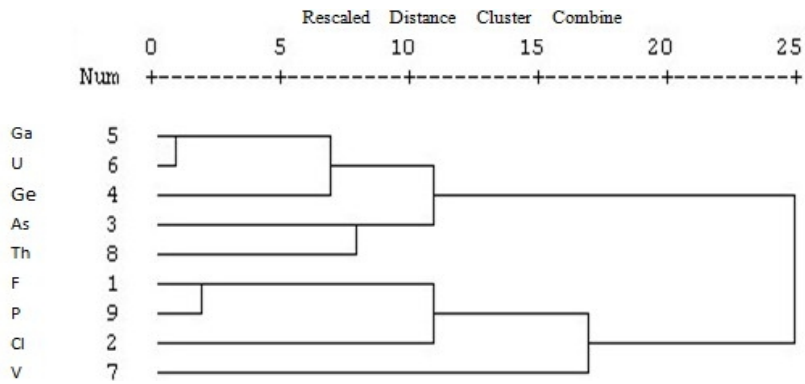

Fig. 1 The result of hierarchical cluster analysis of contents of the elements in eight coal seams.

Germanium, U, Ga, Ge, Th and As are divided into Group No.1. The highest concentrations for Ge, Ga, U, Th and As were enriched in coal seam No.5-2 and the lowest content value in the coal seam No.3-1D, except Ga. The content variation trend is more similar for Ge, Ga, U and Th than As among different coal-seam (Fig.2 A). The elements F, P, Cl, and V were classified into group No.2(Fig.2 B). For F, Cl and P, their concentration variations are irregular, but there are indistinctly increase from coal seams 1-2 to 5-3L. While, the content variation for V does not change obviously.

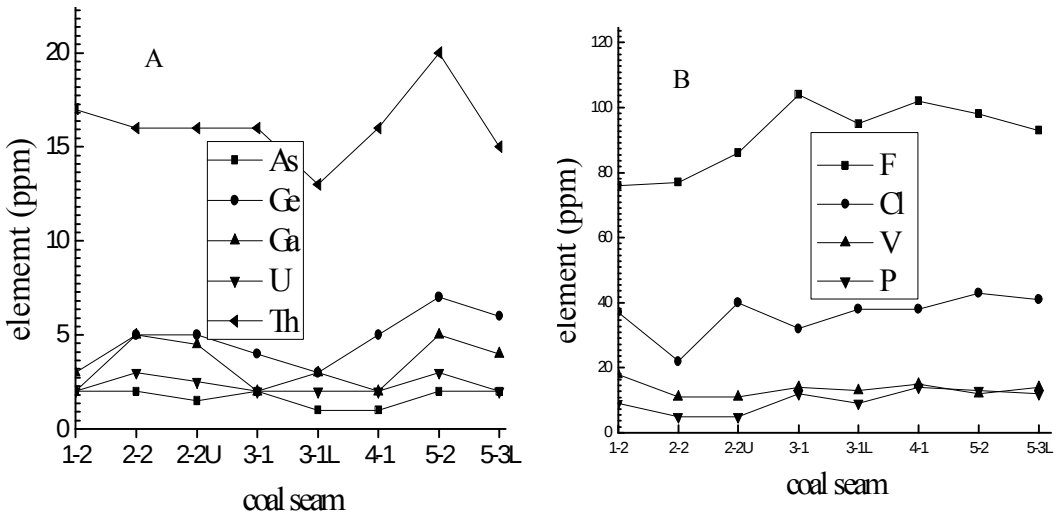

Fig.2 Vertical variations of the elemental concentration in different coal seam of the Mengjiawan exploration area

The coal affinity indexes show how efficiently coal acted as a geochemical barrier for trace elements during all its geologic history[9]. Because of a higher coal affinity index for Ge, As, Ga, U and Th, there is a greater contribution of authigenic fraction(organics, sulfides and so on). While for F, P, Cl and V, due to lower coal affinity index, they are one of a clastogenic matter (represented by macro-mineral forms). The elements are divided into two groups based on result of above hierarchical cluster analysis. The group No.1 has a higher coal affinity index than the group No.2. It can be concluded the elements in group No.1 may be major authigenic during coal-forming process, while the elements in the group No.2 may be major brought to coal from the surrounding environment during coal-forming process.

Conclusion

Compared with Chinese coal, American coal and the coal Clarke value, only Th shows a relatively strong enrichment in the Mengjiawan coal. The element distributions are different between every coal seam in Mengjiawan. There are the highest contents of Cl (43mg/kg), Ge (7mg/kg), and Th (20mg/kg) in the coal seam No.5-2, while the highest content of F(108mg/kg) in coal seam No.3-1.

The elements were classified into two groups by hierarchical cluster analysis. Group No.1 elements contain Ge, U, Ga, Th and As. Group No.2 elements include F, P, Cl, and V. In every group, elements variation trend is similar.

Acknowledgement

In this paper, the research was sponsored by the Nature Science Foundation of China (Research Project No. 201141172142) and Foundation of Yulin College under Grant No. 2013-13YK25.

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