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Scandium in the coals of Northern Asia (*Siberia, the Russian Far East, Mongolia, and Kazakhstan*)

S.I. Arbuzov [a,*], A.V. Volostnov [a], V.S. Mashen'kin [b], A.M. Mezhibor [a]

[a] *Tomsk Polytechnic University, pr. Lenina 30, Tomsk, 634050, Russia*
[b] *Chinggis Khaan Bank, 15 Chinggis Ave., Ulaanbaatar, Mongolia*

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Abstract

We present new original data on the geochemistry of scandium in the coals of Asian Russia, Mongolia, and Kazakhstan. In general, the studied coals are enriched in Sc as compared with the average coals worldwide. Coal deposits with abnormally high, up to commercial, Sc contents were detected in different parts of the study area. The factors for the accumulation of Sc in coals have been identified. The Sc contents of the coals depend on the petrologic composition of coal basins (composition of rocks in their framing) and the facies conditions of coal accumulation. We have established the redistribution and partial removal of Sc from a coal seam during coal metamorphism. The distribution of Sc in deposits and coal seams indicates the predominantly hydrogenic mechanism of its anomalous concentration in coals and peats. The accumulation of Sc in the coals and peats is attributed to its leaching out of the coal-bearing rocks and redeposition in a coal (peat) layer with groundwater and underground water enriched in organic acids. The enrichment of coals with Sc requires conditions for the formation of Sc-enriched coal-bearing rocks and conditions for its leaching and transport to the coal seam. Such conditions can be found in the present-day peatland systems of West Siberia and, probably, in ancient basins of peat (coal) accumulation.

Keywords: coal; metal-bearing capacity; geochemistry; scandium; accumulation factors

Introduction

Over the last few decades, extensive studies of the trace elements of coal basins and coal deposits worldwide have shown that coals accumulate many valuable metals, including rare and disseminated elements. Scandium is of particular interest as an element almost not making up commercial deposits, which is usually extracted during the recovery of ores of other metals but often makes up geochemical anomalies in coal ashes, up to commercial contents (Arbuzov and Ershov, 2007; Arbuzov et al., 2003; Kashirtsev et al., 1999; Seredin and Finkelman, 2008; Seredin et al., 2006; Valiev et al., 1993; Yudovich and Ketris, 2006).

Despite the abundance of information about the Sc content of coals, the geochemistry of this element is poorly known. The most complete overview of its geochemistry is presented in (Yudovich and Ketris, 2002, 2006). The few works concerned with the occurrence of Sc in coals (Arbuzov and Ershov, 2007; Arbuzov et al., 1996, 1997, 2000, 2003; Borisova et al., 1974; Eskenazi, 1996; Gordon et al., 1968; Guren et al., 1968; Kryukova et al., 2001; Menkovskii et al., 1968; Seredin et al., 2006; Swaine, 1964; Yudovich and Ketris, 2002, 2006; Yurovskii, 1968) deal only with some special issues of its geochemistry. Currently, there is no clear vision of the causes or conditions of accumulation of high Sc contents in coals. In consequence, no prospecting criteria for Sc-bearing coals have been developed. This is explained by the lack of interest in coals as a source of Sc in industry. The low demand for this element, mostly because of its extremely high cost, is satisfied by the available resources and does not stimulate the study of any other Sc sources. However, the ashes of some coals could compete with conventional Sc sources owing to their accessibility and high contents of the metal.

Description of the study area

The Sc geochemistry of coals was studied for Asian Russia, Mongolia, and Kazakhstan (Fig. 1). The selection of the study area was determined by the objectives of the study, which included not only the estimation of the Sc content of coals

* Corresponding author.
E-mail address: siarbuzov@mail.ru (S.I. Arbuzov)

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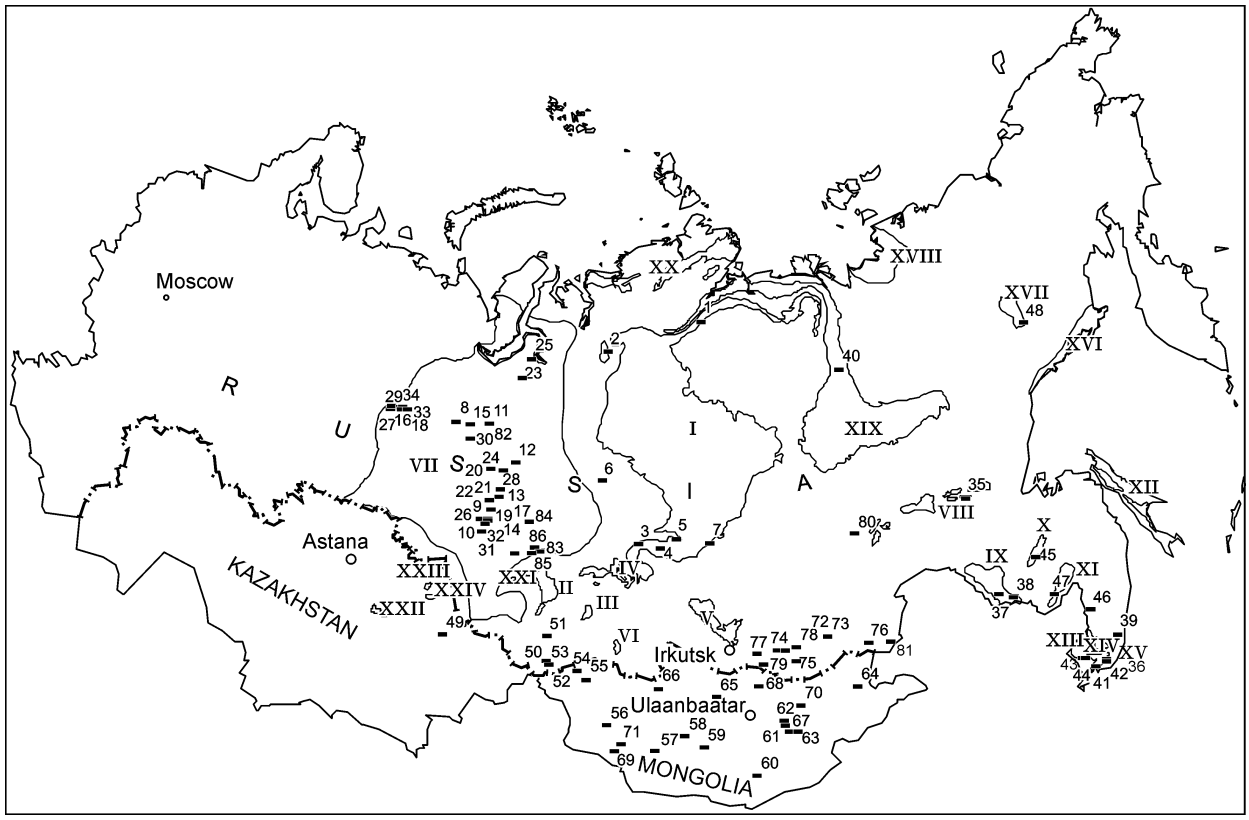

Fig. 1. Distribution of the studied coal basins and deposits in the territory of Northern Asia. Basins: I, Tunguska; II, Kuznetsk; III, Minusa; IV, Kansk–Achinsk; V, Irkutsk; VI, Ulugkhem; VII, West Siberian; VIII, South Yakutian; IX, Lower Zeya; X, Bureya; XI, Middle Amur; XII, Sakhalin; XIII, Razdol'naya; XIV, Bikin–Ussuri; XV, Partizansk; XVI, Okhotsk; XVII, Arkagala; XVIII, Yana–Omoloi; XIX, Lena; XX, Taimyr; XXI, Gorlovo; XXII, Karaganda; XXIII, Ekibastuz; XXIV, Maikube. Coal deposits and occurrences: 1, Kayak; 2, Kaierkan; 3, Kokui; 4, Gavrilovka; 5, Kodinsk; 6, Stony Tunguska; 7, Zheron; 8, Ai-Pim; 9, Archin'ya; 10, Upper Tara; 11, Upper Trom"egan; 12, East Permyaki; 13, Gerasimovka; 14, Grigor'evka; 15, Konitlor; 16, Lazarev; 17, Letnyaya; 18, Lova; 19, Luginetskii; 20, Malaya Rechka; 21, Myl'dzhino; 22, Lower Tabagan; 23, Novyi Urengoi; 24, Prigranichnoe; 25, SG-7-397; 26, North Kalinov; 27, Tal'nikovaya; 28, Trassovoe; 29, Umyt'ya; 30, Fedorovka; 31, Shirotnoe; 32, South Tabagan; 33, Yakhlya; 34, Symor'yakh; 35, El'ga; 36, Sergeevka; 37, Erkovtsy; 38, Raichikha; 39, Voznovo; 40, Zhigansk; 41, Shkotovo; 42, Avangard; 43, Lipovtsy; 44, Pavlovka; 45, Urgal; 46, Bikin; 47, Ushumun; 48, Arkagala; 49, Karazhyra; 50, Kurai; 51, Pyzhina; 52, Taldu-Dyurgun; 53, Balkhash; 54, Nuursthotgor; 55, Khartarvagatai; 56, Khundlun; 57, Zeegt; 58, Uvurchuluut; 59, Bayanteeg; 60, Tavantolgoi; 61, Baganuur; 62, Tugrugnuur; 63, Alag-Togoo; 64, Aduunchuluun; 65, Saikhan-Ovoo; 66, Mogoin-Gol; 67, Shivee-Ovoo; 68, Sharyngol; 69, Manit; 70, Chandgantal; 71, Khurengol; 72, Olon'-Shibir'; 73, Tataurovo; 74, Tarbagatai; 75, Zashulan; 76, Kharanor; 77, Zagustai; 78, Burtui; 79, Okino-Klyuchevskoe; 80, Apsat; 81, Urtui; 82, Kavrin; 83, Tugan; 84, Kolpashevo; 85, Lagernyi Sad; 86, Talovka.

but also the study of (1) regularities in the accumulation of abnormal contents of metals; (2) influence of different factors of the geologic medium on the levels of Sc accumulation in coals and coal ashes; and (3) conditions of Sc accumulation and occurrence in coals showing different degrees of metamorphism.

Nine coal basins and 14 coal deposits were studied in Siberia. The region is characterized by the presence of coals of all ranks from lignites to anthracites, within a wide age interval from Devonian to Paleogene. Detailed geochemical studies were carried out for four basins: Kuznetsk, Minusa, Irkutsk, and Kansk–Achinsk. The data on the Gorlovo, Tunguska, West Siberian, Ulugkhem, and Taimyr basins are also representative, though not so abundant. Also, contact-metamorphic graphite rocks which formed after coals are observed here. Overall, 3285 coal samples and 1927 peat samples (a total of 5212 samples) were studied for Siberia.

The knowledge of the Russian Far East is not so detailed. Late Jurassic, Cretaceous, Paleogene, and Neogene coals are observed here. The region is marked by the substantial role of volcanism in the formation of coal-bearing sediments. The numerous deposits and basins of the Russian Far East are insufficiently studied, so that the present conclusions are tentative. Part of the data were obtained from the study of the collections of coal samples provided by V.V. Ivanov, A.A. Kumar'kov, M.A. Klimin, V.N. Shvets, and V.A. Melkii. The coals of this region are represented by 291 samples from 13 deposits.

The first representative geochemical studies for Mongolia were carried out. In total, 327 coal samples were studied from 18 deposits of Carboniferous, Permian, Jurassic, and Cretaceous ages. The Mongolian coal deposits are distinguished by the wide interval of coal formation from Early Carboniferous to Cretaceous.

A small amount of data was obtained for the coal-bearing sediments of Kazakhstan. They are represented by the coals and coal-bearing rocks of the Carboniferous Ekibastuz and Karaganda basins and Jurassic Maikube basin and Karazhyra