Water-rock interactions: the formation of an unusual mineral assemblage found in a Siberian coal

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Abstract. Volcanic ash is regularly found in coal and is particularly common in the Minusinsk coal basin in southern Siberia, Russia. Ash deposits in coal are usually observed in the form of thinly bedded, kaolinite-rich layers called tonsteins. The coal we studied by scanning electron microscopy with an energy dispersive detector contained many of the minerals typically found in tonsteins: kaolinite groundmass, volcanogenic phenocrysts such as K-feldspar, quartz, apatite, and zircon, along with secondary minerals such as galena, sphalerite, and REE minerals. However, in addition to these commonly observed minerals, the groundmass contains a rare calcium-bearing magnesian siderite in roughly equal proportion to the kaolinite. Ca-Mg siderite has only been reported in a few Australian coals and never at these relatively high proportions. The relative levels of K-feldspar, apatite, and quartz are consistent with a parent magma of felsic to intermediate composition. The Ca-rich-Mg siderite appears to have developed late in the diagenetic process, likely as a result of the dissolution of calcic feldspars, micas, and mafic minerals in the acidic peat waters releasing calcium, iron, and magnesium which reacted with carbon dioxide from the decomposing plant matter.

1 Introduction

Altered volcanic ash is commonly found in coals throughout the world [1, 2]. The ash deposits in coal are usually observed in the form of thinly bedded, kaolinite-rich layers called tonsteins. Layers of altered volcanic ash are particularly common in the Minusinsk coal basin in southern Siberia, Russia. The Minusinsk coal basin is located in an intermountain trough of the same name. The trough is bounded by the Eastern Sayan Mountains in the east, by the Kuznetsky Alatau in the west, and by the Western Sayan in the south. There are four independent coal deposits within the basin: Chernogorskoe, Beiskoe, Izykhskoe, and Askizskoe deposits. The tonsteins occur throughout the whole section. More than 40 tonsteins were found in the coal seams of the Beiskoe deposit [3]. For this preliminary investigation we selected several volcanic ash layers from coal bed 19a

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in the “Arshanovsky” area Beiskoe deposit to study the mineralogy by scanning electron microscopy with an energy dispersive detector.

2 Observations

The volcanic ash zones contained many of the minerals typically found in tonsteins: kaolinite groundmass, volcanogenic phenocrysts such as K-feldspar, quartz, apatite, (Figs. 1 and 2) and zircon, along with secondary minerals such as pyrite, galena, sphalerite, rutile, ilmenite and REE minerals. However, in addition to these commonly observed minerals, the groundmass contains a rare calcium-bearing magnesian siderite in roughly equal proportion to the kaolinite (Figs. 3 and 4). Although siderite does occur in coal, Ca-Mg siderite has only been reported in a few Australian coals [4] and never at the relatively high proportions observed in this coal. The ratio of Ca, Mg, and Fe in the siderite groundmass varies only slightly throughout the sample, but the amount of Mg is consistently higher concentrations than observed in other siderites in coal (Fig. 5).

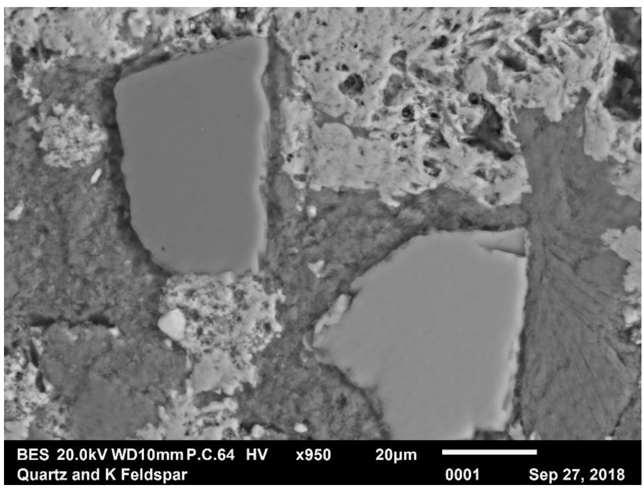

Fig. 1. Quartz (upper left) and K-feldspar (lower right) phenocrysts in Ca-Mg-siderite (lighter) and kaolinite (darker) groundmass.

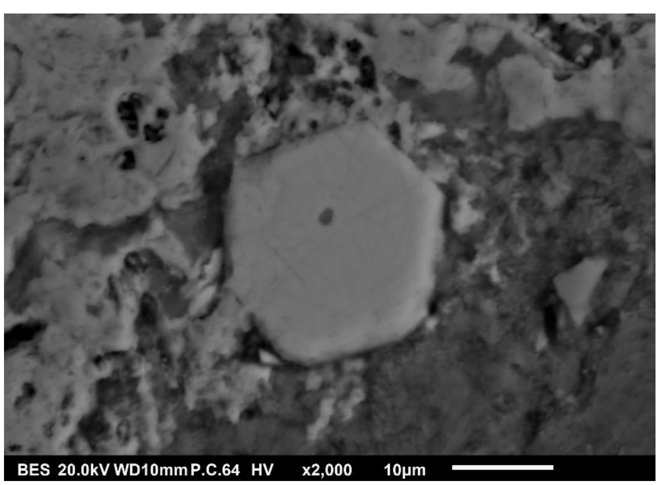

Fig. 2: Euhedral apatite in kaolinite (darker) and Ca-Mg-siderite (lighter) groundmass.

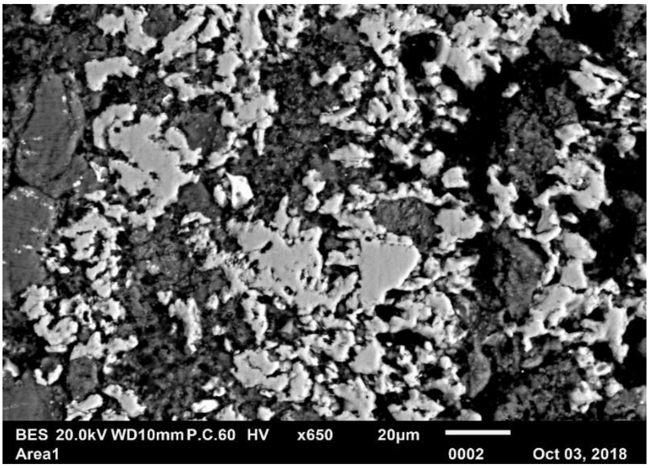

Fig. 3. Back-scattered SEM image showing relative composition of groundmass. Brighter aspect is Ca-Mg-siderite; darker is kaolinite.

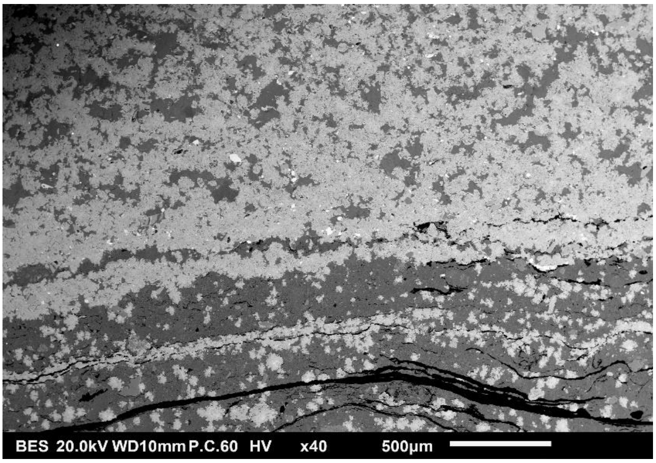

Fig. 4. Back-scattered image showing distinct layering of more Mg-siderite-rich groundmass (lighter) and more kaolinite-rich groundmass (darker). Veins of organic material visible near bottom.

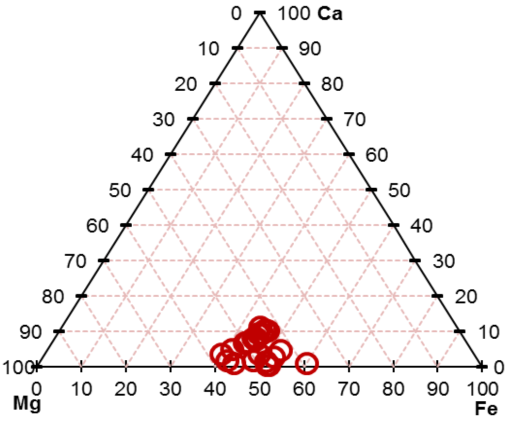

Fig. 5. Ternary diagram depicting the ratios of Mg, Fe, and Ca in siderite groundmass component.

3 Interpretation of water-rock interactions

The relative levels of K-feldspar, apatite, and quartz phenocrysts in the 19a coal are consistent with a parent magma of felsic to intermediate composition. Upon being deposited in a peat swamp the volcanic glass and metastable minerals in the ash fall quickly reacted with the acidic, organic-rich waters [1]. One of the earliest formed minerals is kaolinite. In an open, acidic environment with organic compounds present the volcanic glass would quickly be attacked by the acidic waters yielding kaolinite [5]. Siderite does occur in tonsteins [4] but is fairly rare [6]. Neither Bohor and Triplehorn [1] or Dai et al. [2] in their comprehensive discussions of tonsteins mention siderite. Patterson et al. [4] notes that iron carbonates in coal occur mostly as nodular or massive siderite grains. But in our samples the calcium-rich magnesian siderite is a dominant species. Kortenski [7] noted that the formation of siderite requires reducing conditions, high acidity and CO_2 saturation; conditions common in peat waters. The Ca-rich magnesian siderite appears to have developed in the early diagenetic process after the formation of the kaolinite, likely as a result of the dissolution of calcic feldspars, micas, and mafic minerals by the acidic waters in the peat environment thereby releasing calcium, iron, and magnesium which then reacted with carbon dioxide from the decomposing plant matter.

The observation of this unusual mineral assemblage in the Siberian coal may ultimately provide useful insights into the interactions of waters with volcanic ash in a peat environment.

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