

MINERAL MATTER IN COAL

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Summary

Mineral matter in coal includes minerals and other inorganic materials in, and associated with, macerals. There are more than 150 species of minerals already identified in coal. However, the species of common minerals found in most coals are few. Clay minerals are spread most widely and are of the highest content. Relatively common minerals found are quartz, pyrite, calcite, dolomite, siderite, and ankerite, etc. Other minerals are seldom found in coal. The occurrence of minerals and mineral aggregates in coal seam appears in the modes of dispersed grains, nodules, lenticles, and bands. Mineral particles smaller than several microns may scatter in macerals. The elements identified in coal number 86 and include many inorganic elements, ions, and compounds that may be associated with organic matter, dissolved in pore water, or mixed with coalbed gas. During the coalification process, mineral matter can be

transferred into or out of coal bed. Some of these minerals are no doubt terrigenous detritus, and some are chemical and biochemical authigenic minerals. The minerals of other origins are few. Minerals of different origins, or which formed in different ages, often co-exist in the same seam. Besides traditional chemical, mineralogical, and petrographic methods, to identify the minerals in coal, it is useful first to obtain the low temperature ash, and then to separate the mineral content from it. Suitable instrumental and chemical analytical methods as well as microbeam analytic technique should be adopted to analyze the trace elements in coal. The mineral matters in coal are the geochemical indicators of coal. The minerals and other inorganic matters in coal are the important factors for assessing the coal quality in coal mining, preparation, storage, coking, gasification, liquefaction, and other applications. Environmental problems caused by mineral matter are being given greater and greater attention. Coals with high contents of some mineral matter are the noticeable source of metals and nonmetals.

1. Introduction

Mineral matter in coal includes five kinds of material. They are:

- (a) Crystalline mineral particles and aggregates;
- (b) Non-crystalline mineral detritus and aggregates;
- (c) Inorganic elements and compounds associated with the organic molecules of macerals;
- (d) Inorganic elements and compounds dissolved in the pore water and surface water in coal;
- (e) Inorganic constituents in coalbed gas.

Of all the above, minerals are the most important, since other inorganic elements are few in number although they are numerous in species. Those elements, with content below 1000 ppm in most dry coal, are called trace elements.

Mineral matter in coal can reflect the geochemical characteristics of coal and has a great influence on coal processing and utilization. Some of the trace elements in coal may result in pollution to the environment, or the mineral matter in coal may indeed be a mineral resource. Therefore, the study of mineral matter in coal is very important.

2. Minerals in coal

2.1 Minerals identified in coal

Following the development of analytical techniques, more and more kinds of minerals have been identified from coal. The names listed in Table 1. are the minerals identified and reported from the coal of various countries around the world. The total number of species of minerals in coals is more than 150. It must be pointed out that mineral species in most coals are not frequently seen. In Table 1, minerals are distinguished as being: abundant, common, rare, and seldom seen in most coals. Some minerals occur only in coals formed under special geological conditions. Most sulfates, nitrates, and halides exist only in weathered coal.

Mineral group	Minerals
Native element	Platinum, gold, mercury, sulfur, selenium, graphite
Intermetallic compound	Ferroplatinum
Arsenide	Lolingite
Sulfide	Pyrite**, marcasite**, galena*, sphalerite*, melnikovite*, cooperite, siegenite, pyrrhotite, chalcopyrite, bornite, tetrahedrite, tennantite, argentite, chalcocite, realgar, ferroselite, ullmannite, platarsite, arsenopyrite, glaucodot, stibnite, bismuthinite, millerite, cinnabar, orpiment, herzenbergite, covellite
Selenide	Penroseite, clausthalite, hakite
Oxide	Quartz**, chalcedony*, hematite*, cristobalite, uraninite, ilmenite, corundum, spinel, chromite, magnetite, hetaerolite, anatase, rutile, brookite, cassiterite, columbite
Hydroxide	Limonite**, bauxite**, goethite, lepidocrocite, diaspore, boehmite, gibbsite, brucite, portlandite, chalcophanite
Silicate	Kaolinite***, illite**, sericite**, montmorillonite**, mixed-layer clay minerals**, dickite*, halloysite*, chlorite*, ferrihalloysite*, muscovite*, hydromuscovite*, feldspar*, zircon*, leucite, zeolite, tourmaline, coffinite, andalusite, garnet, olivine, kyanite, topaz, staurolite, sphene, epidote, allanite, pyroxene, actinolite, hornblende, chloritoid, talc, serpentine, pyrophyllite, glauconite, biotite, gadolinite, barytolamprophyllite, fenaksite, canasite
Carbonate	Calcite***, siderite***, dolomite**, ankerite**, magnesite, rhodochrosite, aragonite, strontianite, witherite, alstonite, barytocalcite, azurite, dawsonite, schrockingerite
Vanadate	Carnotite, tyuyamunite
Phosphate	Apatite*, phosphorite*, xenotime, monazite, svanbergite, berlinite, florencite, crandallite, gorceixite, autunite, torbernite, vivianite, goyazite
Tungstate	Scheelite
Sulfate	Barite*, gypsum*, anhydrite, celestite, linarite, alunite, natrojarosite, jarosite, alunogen, epsomite, kieserite, melanterite, szomolnokite, mirabilite, polyhalite
Nitrate	Nitronatrite
Halide	Halite, sylvine, bischofite, fluorite
Amorphous mineral	Opal, volcanic glass

***— abundant; **— common; *— rare; no *— seldom seen.

Table 1. Minerals identified in coal

2.2 Occurrence of minerals in coal

The macroscopic occurrences of minerals in coal are in the shapes of rounded pellets, nodules, lenticles, bands, etc. and sometimes in dispersed crystals, while the microscopic occurrences are of isolated euhedral crystals, broken crystal fragments,

microscopic nodules, and submicroscopic crystalline aggregates. Minerals may also be the infillings in the cell cavities of macerals, cleats, or other fractures. It is necessary to point out that some fine grains of mineral are often found in coal, with the diameter not exceeding several microns, and dispersed in macerals, especially in desmocollinite. They can be identified only through electron microscopy. These fine grains closely associated with macerals are difficult to separate.

2.3 Modes of formation for minerals in coal

The minerals in coal may be classified into the following groups according to genesis:

- (a) Plant-origin minerals
- (b) Terrigenous detrital minerals
- (c) Chemical and biochemical minerals (authigenic minerals)
- (d) Minerals formed during diagenetic alteration

According to their formation stages, the minerals may be classified into two kinds: syngenetic minerals and epigenetic minerals.

“Syngenetic” means that they were formed at the same time during the accumulation of the plant debris. “Early diagenetic” means that they were formed shortly after being buried by more peat or other sediment. “Late diagenetic” means the processes associated with the deepened buried depth and advanced coalification. “Epigenetic” means formed after the coal reached its present rank.

However, the minerals occurred in a same coal bed, such as clay minerals, quartz, calcite, pyrite, etc., may have different origins. They may be formed either in the syngenetic or in the epigenetic stage. Since minerals with different origins may occur in the same coal seam, it is quite difficult to identify their origins. Study and analysis of all aspects of this problem are necessary.

2.4 Common minerals in coal

Although the mineral species in coal may be more than a hundred, the common minerals are mainly the following.

2.4.1 Clay minerals

These are always the main minerals in all kinds of coal, over 60% in total, in which, kaolinite is the most widespread, with a well-crystallized or vermicular shape. The second most widespread mineral is the illite-sericite. Other kinds of clay minerals are seldom seen. Clay minerals may originate from detritus material or from syngenetic as well as epigenetic origins. In high rank coal, mixed-layer clay minerals, dickite and chlorite formed during diagenesis may occur. The clay minerals in coal occur mainly as dispersed inclusions such as grains, nodular masses, lenticles, and bands as well. They can also fill in cell cavities and cleats. Usually the partings in coal seam consist mainly of clay minerals. When kaolinite is the main component of the parting, it is named “tonstein.”

2.4.2 Oxide and hydroxide minerals

Quartz is the common oxide mineral in coal, but its content in coal varies greatly. Quartz is mainly from detrital origin, but some quartz of a finely crystalline structure is from authigenesis. Chalcedony may also occur in coal, but opal is seldom found. Biogenic silica has been found in modern peat. Certain plants, e.g. calamites, may contain quartz. The rutile, although common in coal, is present only in tiny amounts. It is the same for hematite and magnetite. Limonite and goethite are the products of oxidation, existing only in weathered coal.

2.4.3 Sulfide minerals

Pyrite, the most common sulfide minerals in coal, is the main carrier both of sulfur and some harmful trace elements. However, hydrothermal pyrite contains much more varied trace elements. Pyrite in coal has different states and shapes, such as euhedral crystals, nodules, framboids, veins, cleat coatings, and infillings or replacements of some plant textures. Pyrite in coal is mainly authigenetic, but may also be syngenetic or epigenetic. There is much abundant pyrite in coal seams influenced by marine transgressions during their formation. Besides, marcasite and melnikovite distribute also widely. If there is hydrothermal veins near the coal beds, the sulfide minerals are likely to occur as galena, sphalerite, and chalcopyrite. Since pyrite is easy to oxidize, some sulfate minerals in coal may be the sub-products of the pyrite oxidation.

2.4.4 Carbonate minerals

The most common carbonate mineral in coal is calcite, which frequently occurs in veins or as cleat infillings and can also fill in the cell cavities of macerals, sometimes as their replacements. Second most common of the carbonate mineral is siderite, which occurs as spheroidal nodules or mosaic aggregates of fine crystals, after which come ankerite and dolomite, which occur either in the form of idiomorphic crystals or impregnated into plant material to form the so-called “coal balls.” Carbonate minerals are all from authigenetic origin. However, they may be syngenetic or epigenetic. Siderite and dolomite are likely to be from syngenetic origin, while calcite and ankerite are likely to be epigenetic.

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Biographical Sketch

Tang Xiuyi, a 1955 graduate from China University of Geosciences. A Ph. D. post graduate from Moscow Institute of Geology and Exploration in 1960. A professor at Hefei University of Technology and Huainan Institute of Technology. A long-time researcher in coal petrology, coalbed gas and trace elements in coal. Published works include “Trace elements in Chinese coal.”