The Origin of Quartz In Coal

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Introduction

Mineral matter in coal can originate as (1) inorganic elements from plants that were incorporated during peat formation, (2) wind- or water-borne detritus that settled in the peat-forming environment, and (3) epigenetic minerals that formed during or after burial of the peat (Stach and others, 1982). The latter two processes generally are considered to be the principal contributors to the amount and variety of minerals in coal of commercial quality. Certain physical properties, such as the shape of quartz grains, have led some workers to postulate that quartz in coal is primarily of detrital origin (Finkelman, 1981a, 1982b; Davis and others,1981); however, evidence for such a hypothesis may be highly subjective and inconclusive. In contrast, Cecil and others (1982) suggested that mineral matter in the Upper Freeport coal bed is dominantly authigenic, on the basis of statistical relationships among major-, minor-, and trace-element, maceral, and mineral data. Mineral matter in coal, exclusive of pyrite and calcite, was probably derived from plants that contributed to peat formation (Stevenson, 1913; Cecil and others, 1982).

Cathodoluminescence (CL) petrography was used in the present investigation to obtain quantitative data on the amounts of authigenic and detrital quartz in the Upper Freeport coal bed. CL is the emission of visible light during electron bombardment. It is used widely as a tool in sandstone petrology to distinquish between detrital and authigenic quartz grains. CL in quartz results from molecular or other lattice imperfections; molecular imperfections which include the addition of "activator" ions (Al^{+3} or Ti^{+3} that substitute for Si^{+4}), and other lattice imperfections are related to temperature (Zinkernagel, 1978). Zinkernagel observed three distinct types of luminescence in quartz grains that included (1) "violet" luminescing quartz (spectral peaks at 450 and 610-630 nm), (2) "brown" or orange luminescing quartz (spectral peaks at 610-630 nm), and (3) non-luminescing quartz. He examined quartz from 46 localities and ranging in age from Precambrian to Tertiary, and in all cases the CL color was dependent on the temperature of crystallization. "Violet" or blue luminescing quartz was characteristic of fast-cooled volcanic, plutonic, and high-grade metamorphic rocks that were formed at temperatures greater than 573°C. "Brown" or orange luminescing quartz was characteristic of high-grade slow-cooled metamorphic rocks formed at temperatures ranging from 573°C to 300°C. Quartz that was formed at temperatures below 300°C and that was not heat tempered did not luminesce in the visible range. The origin of quartz can be inferred from CL data because detrital quartz, which has a high- temperature origin (>300°C), luminesces in the visible range whereas authigenic quartz, formed at low temperatures (<300°C) does not luminesce.

Methodology

Both a scanning electron microscope (SEM) and an electron microprobe (EMP) were used in this study to analyze the CL properties of quartz grains in samples of the Upper Freeport coal bed because quartz grains in coal are small (silt sized) and below the resolution capabilities of a standard luminoscope. Quartz grains were identified by the detection of silicon alone with energy dispersive X-ray units attached to both the SEM and the EMP.

The SEM was used to observe and photograph the quartz grains. The EMP which was equipped with both a photomultiplier tube (spectral response 185-930 nm) and a monocrometer, was used to measure wave length and intensity of CL. The EMP, instrument conditions were calibrated using a reference sample of the upper part of the Raleigh Sandstone Member of the New River Formation (Pennsylvanian age), which contained both orange and blue luminescent detrital quartz grains and non-luminescent authigenic overgrowths of low-temperature origin (fig. 1).

Quartz grains from the Upper Freeport coal bed were analyzed in (1) ash samples that were prepared by low-temperature plasma ashing (LTA) of facies channel samples, (2) pulverized coal samples of size-gravity separates, and (3) oriented blocks of mineral-rich bands, vitrain, fusain, clay-rich parting material, and roof-shale that were each cut from a coal core. All samples were mounted in epoxy and polished prior to analysis.

Results

All the Upper Freeport coal bed samples examined contained both luminescent and non-luminescent quartz grains (table 1, fig. 2). More than 200 grains were visually examined, and 76 measured spectra were obtained.

In the LTA samples, 95 percent of the quartz particles examined were non-luminescent and 5 percent were luminescent. Most grains luminesced in the orange range.

Twenty-nine measured spectra of quartz grains were obtained from the lightest (1.275 float) and the heaviest (1.800 sink) size-gravity separates. Only nine grains were analyzed in the lightest gravity separates because of the paucity of mineral matter. All nine grains were non-luminescent and were associated with vitrain. In the heaviest gravity separates, 60 percent of the quartz was non-luminescent; this quartz is petrographically associated with both vitrain, mineral-rich bands, and shale partings. The remaining 40 percent of the quartz grains in the heavy gravity separates were luminescent and are associated with mineral-rich bands and shale parting material.

Data from CL analyses of the blocks of coal from the core revealed that luminescing quartz was relatively rare and is associated only with mineral-rich bands. Of the 29 quartz grains analyzed, only 17 percent luminesced. The non-luminescent grains are petrographically associated with both vitrain and mineral-rich bands.

Roof-shale samples from the core were also examined. Ninety-three percent of the quartz analyzed was luminescent and only 7 percent was non-luminescent. The quartz grains analyzed were similar in size to the quartz grains in coal.

Conclusions

Seventy-six percent of the quartz grains examined in the Upper Freeport coal samples are non-luminescent; therefore the quartz is interpreted to be domininantly authigenic. The authigenic quartz is petrographically associated with both vitrain and mineral-rich bands. The remaining 23 percent of the quartz analyzed luminesced in the visible range and is therefore interpreted to be detrital in origin. Detrital quartz was petrographically associated with mineral-rich bands and clay-parting material.

In contrast, quartz grains in the samples of shale directly overlying the Upper Freeport coal bed are interpreted to be predominantly detrital in origin. The quartz grains are in the same size range as quartz grains in the coal samples.

Data from CL petrography support the interpretation of Cecil and others (1982) that quartz in Upper Freeport coal bed is primarily authigenic and derived from plant ash. Although it is impossible to ascertain the ash content of Pennsylvanian plants that grew in the Upper Freeport paleo-peat forming environment, it seems reasonable that the plants did contain silica, as do most modern plants. Biogenic silica can be preserved as phytoliths (Smithson, 1956; Baker, 1960; and Jones, 1964; Andrejko and others, 1983) and quartz grains in coal are similiar in size to plant phytoliths (Wilding and Drees, 1974).

Most quartz grains in the commercial-quality Upper Freeport coal bed samples are authigenic in origin, but this interpretation does not rule out a detrital source for areas of the bed containing higher amounts of ash (approximately 20 percent) or for other high ash bituminous coal beds. The percentage of detrital quartz would be expected to increase approaching stream channels and the margins of the paleoswamp environment, but vegetal matter is probably the dominant source for quartz in interior portions of the paleoswamp.

Table 1. CATHODOLUMINESCENT AND PETROGRAPHIC CHARACTERISTICS OF QUARTZ GRAINS IN COAL AND SHALE

[Determined by using an electron microprobe (EMP). TNA, Total number of grains analyzed; Nonlum, nonluminescent grains: Lum, Luminescent grains; *, data was not obtained because coal was crushed; N/A, not applicable.]

	LOW-TEMPERATURE ASH (Facies channel samples)		SIZE-GRAVITY SEPARATES Float 1.275 (TNA = 9)		SIZE-GRAVITY SEPARATES Sink 1.800 (TNA = 20)	
	Nonlum	Lum	Nonlum	Lum	Nonlum	Lum
Number of grains	39	2	9	0	12	8
Grain size range (in µm)	*	*	6-22	N/A	5-14	9-32
Mean grain size (in µm)	*	*	9.9	N/A	8.4	18.9
Percent of total	95	5	100	N/A	60	40
Association	*	*	Vitrain	N/A	Vitrain Mineral-rich band Shale parting	Mineral-rich band Shale parting

	COAL BLOCKS (TNA = 9)		ROOF-SHALE (TNA = 15) BLOCKS	
	Nonlum	Lum	Nonlum	Lum
Number of grains	24	5	1	14
Grain size range (in µm)	8-20	7-22	N/A	6-32
Mean grain size (in µm)	12	14.8	7	13.5
Percent of total	83	17	7	93
Association	Vitrain	Mineral-rich	Shale	Shale

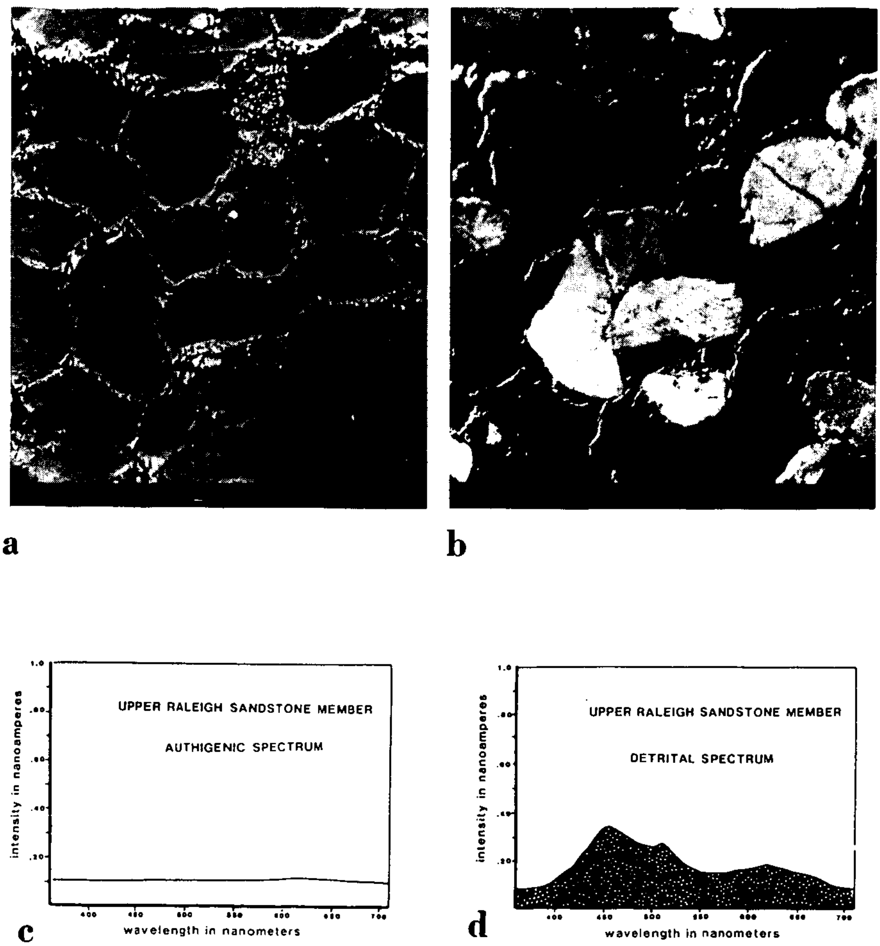

Figure 1 - Reference sample for EMP. (a) SEM backscatter electron photomicrograph,
(b) CL SEM photomicrograph. Note luminescing detrital quartz grains,
(c) EMP CL spectrum of non-luminescing authigenic overgrowth,
(d) EMP CL spectrum of blue luminescing detrital quartz grain.

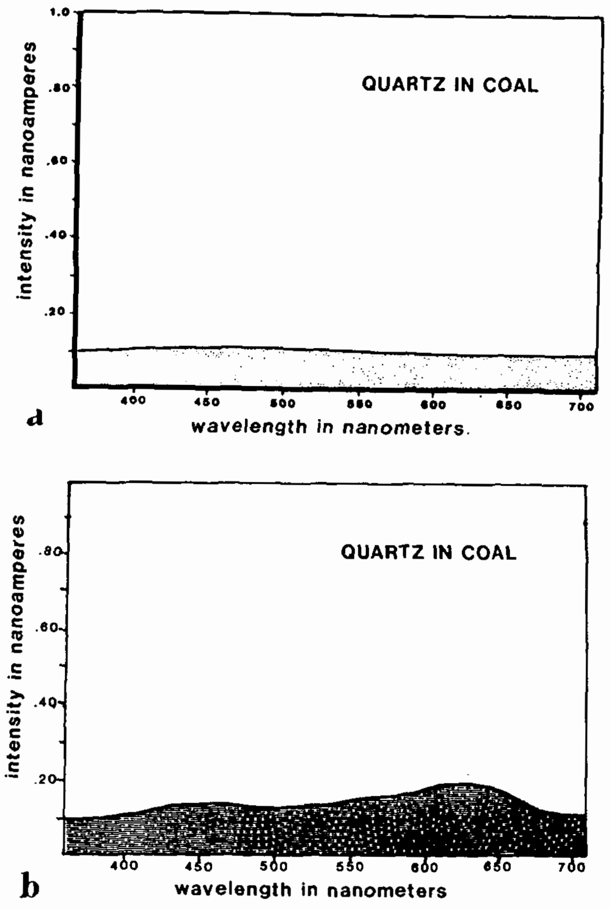

Figure 2 - EMP CL spectra of quartz in the Upper Freeport coal bed. (A) Non-luminescing authigenic spectrum, (B) Luminescing detrital spectrum.

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