Fuel 185 (2016) 305–315

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Petrology and chemistry of sized Pennsylvania anthracite, with emphasis on the distribution of rare earth elements

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ARTICLE INFO

Article history:
Received 27 May 2016
Received in revised form 12 July 2016
Accepted 14 July 2016

Keywords:
Rare earth elements
Coal rank
Macerals
Sized coal samples

ABSTRACT

Sized samples of anthracite were obtained from three preparation plants (breakers), several beneficiating multiple coals, in the Pennsylvania Anthracite Fields. Vitrinite reflectance spans 5.07% R_{max} (anthracite, approaching meta-anthracite) in the east to 2.36% R_{max} (semi-anthracite) in the west. Maceral distributions do not show the size partitioning observed in many bituminous coals. All sites showed distinct Gd anomalies, possibly a function of hydrothermal metamorphism of the coals. The rare earth distribution pattern (L-, M-, and H-type) within the products from each breaker are similar. Principal components analysis confirmed an observation from the latter assessment that coals from the same breaker tend to cluster together, but distinct from the clusters of the other breakers.

1. Introduction

Anthracite mining in Pennsylvania has gone through many phases. In 1897, the United States produced nearly 1/3rd of the global coal production, with Pennsylvania producing over 107 Mt, responsible for 53% of the latter total and the Pennsylvania Anthracite Fields accounting for about 10% of the world's coal production [1]. Anthracite production peaked in the early part of the 20th century, with annual output reaching nearly 100 Mt (short) during World War I. Current production is about 2 Mt (short).

In most portions of the Anthracite Fields (Fig. 1), the coal veins dipped at steep angles due to the intense folding and faulting of the region. The southern limbs of synclines in the Southern Field are overturned and some coals in the Middle Fields are near vertical. Mining methods, differing greatly from mining techniques in flat-lying bituminous coal beds, or even in the flat-lying anthracites of Sullivan County, Pennsylvania, were adapted to the situation. One of the fundamental treatises on the early mining methods was written by Chance [2]. Later summaries of early-20th century methods appear in the book prepared by the Hudson Coal Company [3], Moore's textbook of coal geology [4], and Wallace [5]. By the time of the Knox Mine disaster, the January 1959 inundation of Northern Field mines due to inflow of the flood-stage Susquehanna River [6], the industry was in decline. By the 1970s, while some underground mines were still in operation, much of the production came from surface mines, often mining remnant pillars on the sites of older underground mines. Minor underground mining still exists, but much of the mining of in-place coal is in surface mining of the pillars, as above. In addition, reclamation of coal from waste (locally known as culm[1]) banks is a source of fuel for circulating fluidized bed boilers.

Throughout the history of anthracite mining in Pennsylvania, anthracite sizing took on a series of names descriptive of the sizes required [7] along with the amount of slate, or non-carbonaceous rock, and bone, a name for high-mineral matter coal, permitted in the products [9] (Table 1). While some other sizes could be in the sized products, strict guidelines for the content of out-of-size coal were enforced. Egg, Stove, and Chestnut sizes could contain no more than 5% of larger sizes; Chestnut could not contain more than 10% of Pea or 5% of Buckwheat sizes; Pea could not contain more than 15% of Buckwheat and 55% of Rice; and Buckwheat could not contain more than 15% of Rice. The price commanded for the coarser grades, Pea through Broken, was higher than for the fine sizes. Stove and Chestnut sizes were used for domestic ranges and small heaters and Egg size anthracite was used in furnaces [9]. Moore [4] did not even consider sizes below Barley. The sizes finer than No. 4, and often finer than No. 3, were more likely to be discarded than sold. In the operation of the Chance cone, a cyclone using sand as the heavy medium, heavy particles of Stove size or greater were returned to crushers in order to

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[1] "Crushed coal, more often crushed anthracite, but also applied to coal slack, shaly coal, or impure coal" [8].

http://dx.doi.org/10.1016/j.fuel.2016.07.055
0016-2361/

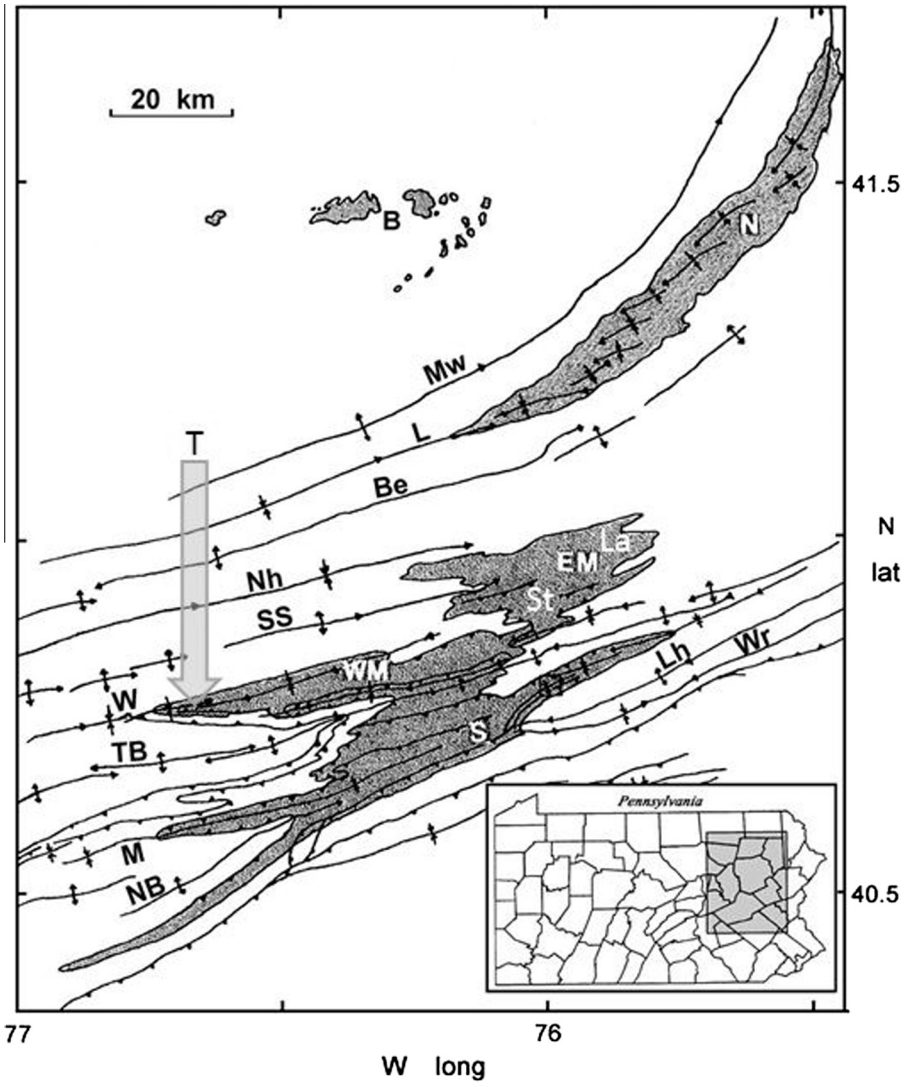

Fig. 1. Location of the study sites within the Pennsylvania Anthracite Fields: T – Treverton, St – St. Nicholas, La – Lattimer. Tectonic map of the Pennsylvania anthracite fields (modified after [17]). B = Bernice (semianthracite) Field; Be = Berwick anticlinorium; EM = Eastern Middle Field; L = Lackawana synclinorium; Lh = Lehighton anticline; M = Minersville synclinorium; Mw = Milton – White Deer anticlinorium; N = Northern Field; NB = New Bloomfield anticlinorium; Nh = Northumberland anticlinorium; S = Southern Field; SS = Shade Mountain – Selinsgrove anticlinorium; TB = Tuscarora Mountain – Broad Mountain anticlinorium; W = Western Middle Field synclinorium; WM = Western Middle Field; shaded area = Pennsylvanian age rocks.

Table 1
Traditional names for double-screened sizes of anthracite products with the amount of permissible slate and bone.

Nomenclature	Size (in.)	Top size (cm)	Bottom size (cm)	Slate permitted (%)	Bone permitted (%)
Oversize	>4.375				
Broken	4.375 to 3 or 3.25	11.113	7.62 or 8.255	1	2
Egg	3 or 3.25 to 2. 4375	7.62 or 8.255	6.191	2	2
Stove	2.4375 to 1.625	6.191	4.128	4	3
Nut (or Chestnut)	1.625 to 0.8125	4.128	2.064	5 to 7	5
Pea	0.8125 to 0.5625	2.064	1.429	8	10
No. 1 (Buckwheat)	0.5625 to 0.3125	1.429	0.794	10	10
No. 2 (Rice)	0.3125 to 0.1875	0.794	0.476		
No. 3 (Barley)	0.1875 to 0.09375	0.476	0.238		
No. 4	0.09375 to 0.046875	0.238	0.119		
No. 5	0.046875 to zero	0.119	0.000		

attempt to liberate coal from the rock. Particles finer than Stove size were sent directly to the rock pile. At the time of the greatest anthracite production, the market for the finest sizes of anthracite was limited; therefore the fine anthracite was discarded with the rock.

1.1. Chemistry

The U.S. Geological Survey [10] analyzed a number of anthracite samples from active mines. One important caveat with respect to their efforts is that the most active periods of anthracite mining,