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Teaching-Aid

Notes on the relationship between microlithotype composition and Hardgrove grindability index for rank suites of Eastern Kentucky (Central Appalachian) coals

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ABSTRACT

Hardgrove grindability index (HGI) has been a standard test in the coal and coal-fired power generation industries since the 1930s. Previous studies have demonstrated the relationship between HGI and coal rank and the maceral and mineral composition. In particular, within the high volatile bituminous rank range, HGI increases with an increase in coal rank and, for any specific rank, decreases with an increase in the liptinite content. Fundamentally, the HGI test is approximately at the scale of coal microlithotypes, the microscopic assemblages of macerals. In this study, for two relatively narrow rank ranges, each spanning 0.05% R_{max}, we examined the relationship between HGI and several maceral and microlithotype ratios for Pennsylvanian eastern Kentucky coals. While some relationships do show statistically significant trends, not all were as well defined as might have been expected.

1. Introduction

Hardgrove grindability index (HGI), in various forms of its development, has been a standard procedure in the coal industry since the 1930s (Black, 1936; Hardgrove, 1931; Yancey and Geer, 1936). The current technique dates to 1951 with a modification in 1971 with the addition of four standard coals. The test is used, in part, as a guideline for coals used in pulverized coal combustion with pulverizers rated for their design throughput based on an HGI = 50. As noted by Hower (1998), the technique is not only widely used but also widely misunderstood and maligned.

As a coal rank parameter, HGI is a prime example of the interaction of coal rank (metamorphism) and coal type (macerals and minerals and, in particular, their assemblages at the scale of microlithotypes). HGI peaks in the medium volatile bituminous rank range; therefore, as long as the studied coals are on one side of the rank divide, some semblance of a correlation between coal rank, coal type, and HGI can be derived (Hower, 2008a). As with many coal properties, there is a botanical-influenced provincialism in HGI. For coals of a given rank, we should not necessarily expect to see equivalent HGI values, for example, for coals of different ages, such as the Appalachian Middle Pennsylvanian, as in this study, versus the western US Cretaceous. Such botanical provincialism can also apply to coals of the same age but originating in different floral provinces, such as the Permian Gondwana coals versus the Permian Cathaysian and Angaran coals of China.

Studies of HGI at the University of Kentucky Center for Applied Energy Research (CAER) have focused on the basic relationship between coal petrology and the grinding properties (Hower, 1998; Hower and Calder, 1997; Hower and Wild, 1988; Hower et al., 1987; Padgett and Hower, 1997; Trimble and Hower, 2003). Several of the latter studies have utilized a combined analysis of macerals and microlithotypes, such that the maceral composition of each lithotype is described (technique described by Hower and Wagner, 2012; we are using a less detailed approach here). The combined maceral/microlithotype analysis has also proven to be useful in studies of pulverization of coal-fired power plants (Hower, 2008a, 2008b). Hower and Wild (1988), working with the large set of high volatile bituminous coals from Kentucky, established a relationship between coal rank, expressed as vitrinite reflectance, the liptinite content of the coal, mineral content, and HGI.

CAER's extensive HGI + petrology + other coal quality data set has proven to be of interest in the application of neural network techniques to coal characterization data (Bagherieh et al., 2008; Chelgani et al., 2008; Jorjani et al., 2008; Modarres et al., 2009).

In this study, using data collected in a number of CAER studies, we investigate the relationship between the microlithotype content of the coal, the composition of the microlithotypes, and the HGI.

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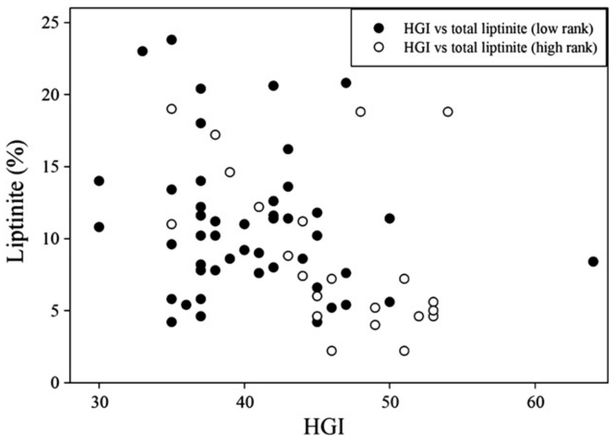

Fig. 1. HGI versus total liptinite for two isorank suites of Pennsylvanian eastern Kentucky coals. The low rank and high rank designations are relative, indicating reflectance ranges from 0.75% to 0.80% R_{max} and from 0.95% to 1.00% R_{max}, both within the high volatile A bituminous rank range. Within each rank range, the liptinite percentage is one of the determining factors in HGI.

2. Methods

The data from previous studies of the combined maceral and microlithotype composition and HGI, as noted in the Introduction, were searched for whole coals and lithotypes with high volatile A bituminous reflectances from 0.75% to 0.80% R_{max} and from 0.95% to 1.00% R_{max}. For our purposes, each group is considered to be an isorank set, thus eliminating coal rank as a variable within each set of coals while preserving a distinct rank separation between the individual sets. All of the data were generated in studies in which, in general, only the whole-coal petrology was available. All of the coals are of Pennsylvanian age, specifically within the Westphalian, from the Eastern Kentucky portion of the Central Appalachian coalfield. Ideally, this also narrows the range of variation since the botanical input to coal formation would have been similar for all of the coals. The complete data set is listed in Appendix A.

3. Results and discussion

Before discussing the microlithotypes, it is valuable to show the relationship between the HGI and the total liptinite content for the two coal rank ranges (Fig. 1). Recall that Hower and Wild (1988) found liptinite to be one of the most significant predictors of HGI for high volatile bituminous coals. The correlation for the lower rank coals is poor ($r^2 = 0.039$)

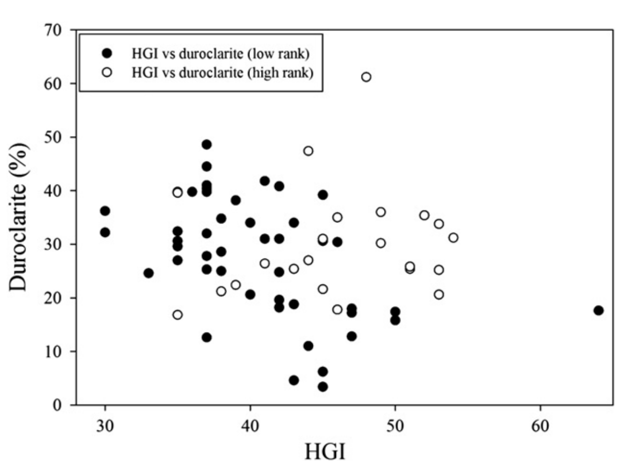

Fig. 2. HGI versus the duroclarite percentage for two isorank suites of Pennsylvanian eastern Kentucky coals.

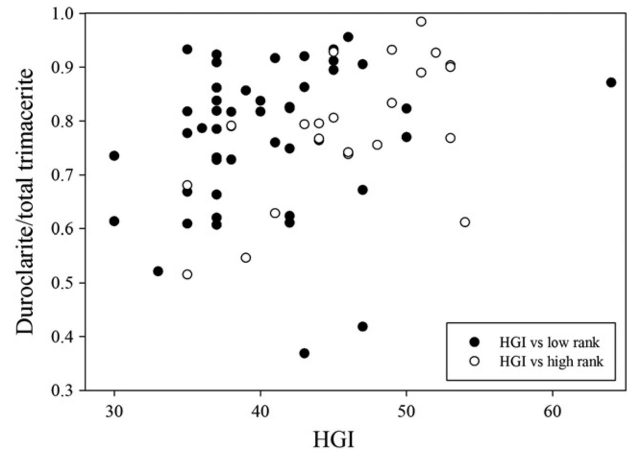

Fig. 3. HGI versus the ratio of duroclarite/total trimacerite microlithotypes for two isorank suites of Pennsylvanian eastern Kentucky coals.

owing to the significant scatter in the coals with HGI < 50. The correlation for the higher rank set is better ($r^2 = 0.23$) but not significant at the 5% level of confidence. Within the higher rank set, removal from consideration of some of the outliers, such as the 54 HGI/18.8% liptinite, 48 HGI/18.8% liptinite, and 35 HGI/11% liptinite samples, improves the correlation, but there is no compelling reason to make that adjustment.

In our previous studies, duroclarite, in general, has proven to be the most abundant trimacerite microlithotypes in the Pennsylvanian Central Appalachian coals. In the trimacerite microlithotypes, all three of the maceral groups are present in amounts >5%; duroclarite is marked by vitrinite being more abundant than liptinite or inertinite. Neither the low nor the high rank coals show any significant relationship between the amount of duroclarite and HGI ($r^2 = 0.237$ and $r^2 = 0.021$, respectively) (Fig. 2). The scatter aside, there are no discernable trends in HGI with an increase in duroclarite.

The amount of duroclarite with respect to total trimacerite (Fig. 3) has an $r^2 = 0.042$ for the low rank coals and $r^2 = 0.356$ for the high rank coals. The relationship for the high rank (0.95%–1.00% R_{max}) series is significant at the 1% level of confidence. The relationship for the low rank coals (0.75%–0.80% R_{max}) is not significant but can be improved if the outlier coal samples 2145 (47 HGI and 0.42 duroclarite/total trimacerite) and 2158 (43 HGI and 0. 37 duroclarite/total trimacerite) are removed from consideration.[1] Both of the latter coals have low amounts of vitrite (6.2% and 2%, respectively; only one other coal in the rank range has <10% vitrite). In isolation, because vitrite, along with inertite, is the most brittle microlithotype (Hower, 1998, 2008b), low vitrite would be expected to lead to a low HGI number. In contrast, duroclarite, while not the microlithotype most resistant to breakage, vitrinertoliptite would generally occupy that niche is harder to grind. Hence, looking at two distinctly different microlithotypes may not be a productive path. Considering the amount of vitrinite in duroclarite, focusing strictly on just one microlithotype is another approach (Fig. 4). In this case, neither rank range yields a significant relationship. The one sample below the vitrinite in duroclarite cluster (37 HGI and vitrinite/duroclarite = 0.20) is an outlier due to the vagaries of counting statistics. In this case, the amount of duroclarite is low and therefore, the individual numbers for specific macerals are not highly significant.

The bimaceral microlithotype durite and the trimaceral microlithotypes claroduritite and vitrinertoliptite are the microlithotypes most resistant to breakage. As such, they would be expected to contribute, both individually and collectively, to low HGI numbers. Fig. 5 illustrates the relationship between durite + clarodurite + vitrinertoliptite (the

[1] Both coals are from the Peach Orchard No. 3 coal bed, Magoffin County, Kentucky. Hower and Ruppert (2011) examined the petrology of this coal bed.