Fusible Inertinites in Coking Coals

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ABSTRACT

The reflectance boundary between fusible and infusible-inertinites has been indirectly determined for 62 western Canadian coal samples, for which coke stability data were also available. The location of this boundary is a function of both rank and the vitrinite content of the coals. Among isorank coals, the position of the reflectance boundary varies inversely with vitrinite content, so that in vitrinite-rich coals, the boundary is at a lower reflectance, and it migrates to higher reflectances in inertinite-rich coals. Thus, two inertinites, possessing the same reflectance, but accompanied by different amounts of vitrinite, behave differently in carbonization. Either the reactivity of fusible inertinite is suppressed by an excess of vitrinite, or it is greater among inertinite-rich coals.

1. INTRODUCTION

Reactivities of coal macerals were originally described as fusible or infusible[1], and later as either reactive or inert[2], depending upon their response in the coke oven. It was noted that vitrinite and exinite would thermally dissociate, and that some portion of the inertinite maceral, semifusinite, would also soften. This material is now called fusible inertinite. It was concluded that among Carboniferous-age coals in the United States, one-third of the total semifusinite was actually reactive, and calculations of coke stability using this level of reactivity, yielded good correlations between predicted and actual values[2]. Subsequent work with geologically younger coals by many authors has questioned this level of reactivity of the inertinite, and among some western Canadian coking coals, for example, 50% has been an assumed value of reactivity for many years[3].

Instead of using the traditional fixed level of inertinite reactivity in coke stability predictions, alternative methods have been proposed that use a reflectance threshold (or cut-off) to identify the boundary between fusible and infusible inertinite. In an earlier study of the same coal samples used in these experiments, no fixed proportion of reactive inertinite was found[4]. Instead, a correlation was made between Romax (mean maximum reflectance of vitrinite), and the location of the reflectance cutoff. Another approach used the presence or absence of the weak inertinite I450-fluorescence to predict whether or not an individual inertinite would soften[5]. A formula relating the fluorescence to the random reflectance of the accompanying vitrinite allows the distinction to be made in white light.

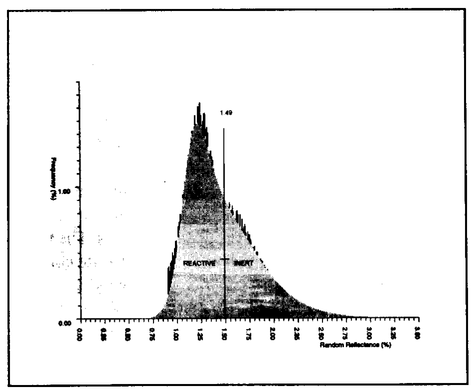
The absence of a fixed level of reactivity led to provincial modifications of the original method of coke stability calculation[6], and has caused some to question the value of predictive petrography altogether[7].

2. EXPERIMENTS

Automated petrographic analyses were run on 62 single-seam (non-blended) western Canadian coking coals which were also carbonized in the late 1970's and early 1980's at CANMET (Canada Centre for Mining & Metallurgical Research). Despite the age of the pellets, unoxidized coal surfaces were exposed by deep grinding of the epoxy binding material. The petrographic apparatus consisted of a Zeiss Universal microscope with a two-axis scanning stage and autofocus, and a 12-bit digital camera and frame grabber, controlled by a 133MHz, Pentium-based computer with Windows NT operating system. As described, the system collects reflectance data at 9 million readings per minute, and, for each sample, raw data from 200 images were collected in about 6 minutes.

The data were assembled in the form of reflectance-frequency histograms (reflectogram), and probability plots,[8,9] which were conditioned to remove reflectance values from mineral-matter and pellet-binder. A numerical model of coal reflectance was then used to replicate the reflectance distribution. A movable cursor bisects the reflectogram into two parts. This was manoeuvred to provide the reflectance cutoff value about which the proportions of reactive macerals to the left and inert macerals to the right, correctly predicted the actual coke strength obtained, (Fig. 1). The proportion of vitrinite, the mean random reflectance of vitrinite, and the proportion of reactive inertinite were recorded from the modeled replicate. It is assumed that this reflectance cutoff value is the upper reflectance limit of softening among the inertinites, and defines, for each coal, the fusible inertinite boundary.

Fig. 1.



3. RESULTS

Fig. 1 is an example of a reflectogram of an inertinite-rich coal constructed from 41 million reflectance values, overlain by the modeled replicate. The coincidence of the reflectance data and the model agrees to within less than 0.1% frequency for most of the 0.01% histogram cells. The random reflectance of the model is 1.16%, with a vitrinite content of 35%. But the coal produced an ASTM coke strength of 49.9, and modeling indicates this requires approximately

60% reactives. To contribute this additional reactive material requires that the reflectance cutoff, or, fusible inertinite boundary, be located at a random reflectance of 1.49%.

Fig. 2.

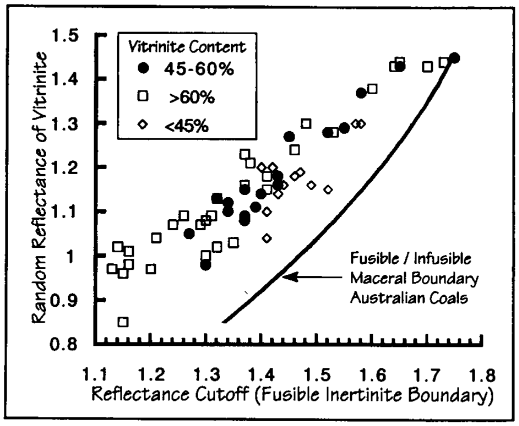
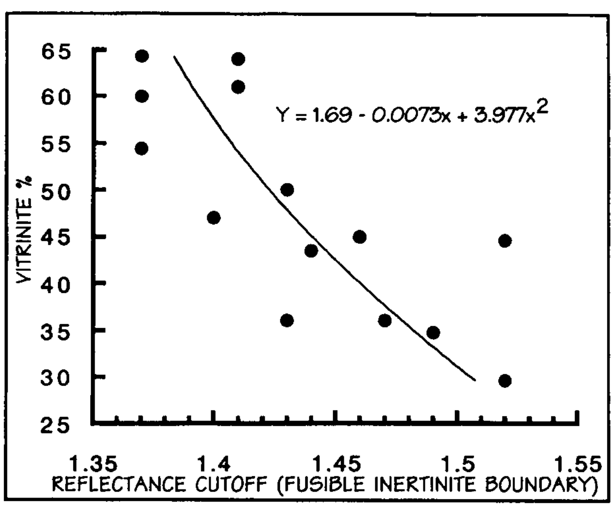


Fig. 2 shows the location of the reflectance cutoff (fusible inertinite boundary) versus the mean random reflectance of vitrinite for each of the samples examined. The samples have also been assigned to three categories of vitrinite content. The solid line in the figure is the most-recently determined boundary between fusible and infusible macerals determined for Australian Permian coals by Diessel (pers. Comm. 1997). There is a very strong linear relationship between the random reflectance (rank), and the reflectance cutoff, (correlation coefficient =0.92), given by the formula:

cutoff = 0.99(Rrt) + 0.24, where Rrt is random vitrinite reflectance.

Fig. 3 shows the inverse relationship between the reflectance cutoff values (fusible inertinite boundary) and the percentage of vitrinite for fourteen isorank coals. The diagram is a cross section through Fig. 2, at a random reflectance of 1.16% ñ 0.03%. The relationship shows the value of the reflectance cutoff increases as the percentage of vitrinite in the coal decreases.

Fig. 3.



4. DISCUSSION

The strong linear dependence of the reflectance cutoff on rank, which was established in an earlier study using the same sample-set, is confirmed4. However, an examination of the distribution of vitrinite contents shows that there is a strong compositional bias among the high volatile coals, (random reflectance values less than 1.10%). Seventeen of twenty-one samples have vitrinite contents greater than 60%, and only one less than 40%. Evidently, inertinite-rich, high volatile coals were not prime candidates for carbonization tests in the 1970's and early 1980's. This bias skews the regression line, and obscures the far more important observation, shown in Fig. 2, that the cutoff is also dependant on the vitrinite content of the coals.

Fig. 3 is a cross section through Fig.2 at 1.16% random vitrinite reflectance, and shows that, contrary to earlier belief, coals of equal rank do not have a common reflectance cutoff, but that it varies from 0.21% to 0.36% above the mean random vitrinite reflectance at this rank. The figure also shows that inertinites of the same reflectance but accompanied by different amounts of vitrinite behave differently in carbonization. Consider, for example, inertinites of 1.45% random reflectance. In a vitrinite-rich coal (÷60% vitrinite content), with a cutoff of 1.38%, they would be infusible. However, in an inertinite-rich coal (÷30% vitrinite content), with a cutoff of 1.51%, they would be fusible inertinites! This observation can be interpreted in at least two ways. It may be that either an excess of vitrinite suppresses the reactivity of fusible inertinite, or, the fusible inertinites of high-inertinite coals possess a higher degree of reactivity. The latter view has been suggested for Australian Permian coals[5]. That the reactivity of a maceral may be influenced by its association with neighbouring macerals is a phenomenon observed previously, "two particles of identical composition can behave differently during carbonization by virtue of the other macerals in the neighbourhood[10]."

Canadian and Australian coals generally contain less vitrinite than their iso-rank Carboniferous equivalents, but despite this apparent imperfection, they make strong cokes with excellent CSR's. This alone suggests that they contain more fusible inertinite than the Carboniferous-age coals, and this may explain why application of a predictive petrographic technique designed for vitrinite-rich coals has required substantial modification prior to its acceptable application.

Not all vitrinites are the same. Those with suppressed reflectance (known as saprovitrinite), and possessing unusually-high coking, and swelling characteristics have been known for some time[10]. Similarly, it now appears that not all fusible inertinites are alike. Could it be that the presence of the higher-reactivity, (and apparently fluorescing), fusible inertinite is responsible for elevated CSR's found among cokes made from the inertinite-rich coals? It is known, for example, that fusible inertinite produces anisotropic carbon, a form that is more resistant to carbon dioxide reactivity[11]. The recognition of different reactivities among fusible inertinite (caused by different vitrinite contents) may also explain why two coals of the same rank, could produce the same strength coke, but have markedly different CSR's. (In this case, the amount of reactives would be about the same, hence the same strength coke, but the different proportions of fusible inertinite impart to the coke a greater, or lesser, resistance to CO_2).

5. CONCLUSIONS

1. Iso-rank coals do not have a common reflectance cutoff.
2. Inertinites with the same reflectance but accompanied by different amounts of vitrinite behave differently in carbonization.
3. Either an excess of vitrinite suppresses the reactivity of fusible inertinite, or, the fusible inertinites of high-inertinite coals possess a higher degree of reactivity.

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Fig. 1. Reflectogram of inertinite-rich coal, with overlying modelled replicate.

Fig. 2. Scatter diagram demonstrating the dependance of reflectance cutoff (Fusible Inertinite Boundary) on vitrinite content and rank (mean random vitrinite reflectance).

Fig. 3. Relationship between Reflectance Cutoff (Fusible Inertinite Boundary), and vitrinite content.