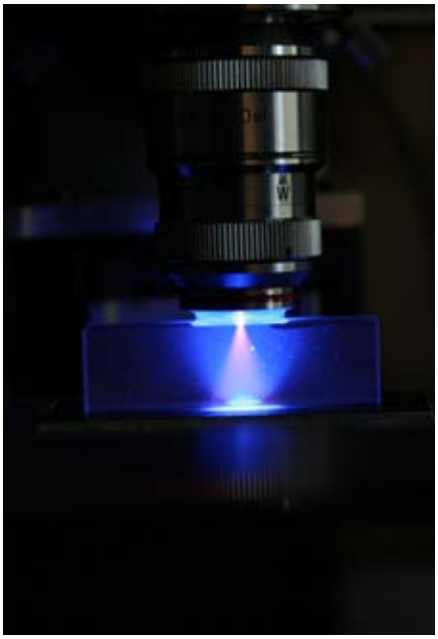
Coal Quality from Automated Fluorescence Imaging Microscopy

Photo credit: Don Farrall/Photodisc/Getty Images

Pearson Coal Petrography

Fluoresence - Coal's Third Dimension

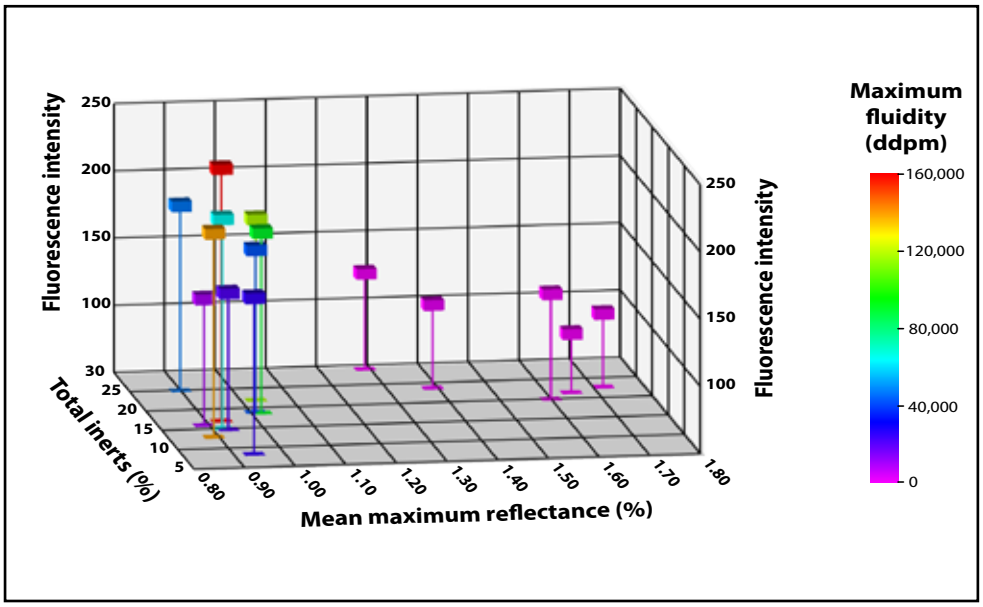
In 1852, Sir George Stokes recognized that when invisible UV light was shone on the mineral fluorspar, it emitted longer wavelength visible light. He named this phenomenon fluorescence. Most coals fluoresce to greater or lesser amounts, and among coking coals, we have discovered that the intensity of Vitrinite fluorescence correlates with Gieseler fluidity, and is independent of both coal rank and coaltype. As illustrated below, fluorescence is the third dimension in coal petrography, capable of separating coals of similar white light petrography but dissimilar Gieseler fluidity. The well-known deficiencies of the Schapiro-Grey coke strength prediction method may be caused by the inability of white light petrography to adequately characterize, and discriminate between higher- and lower-fluidity high-volatile components.



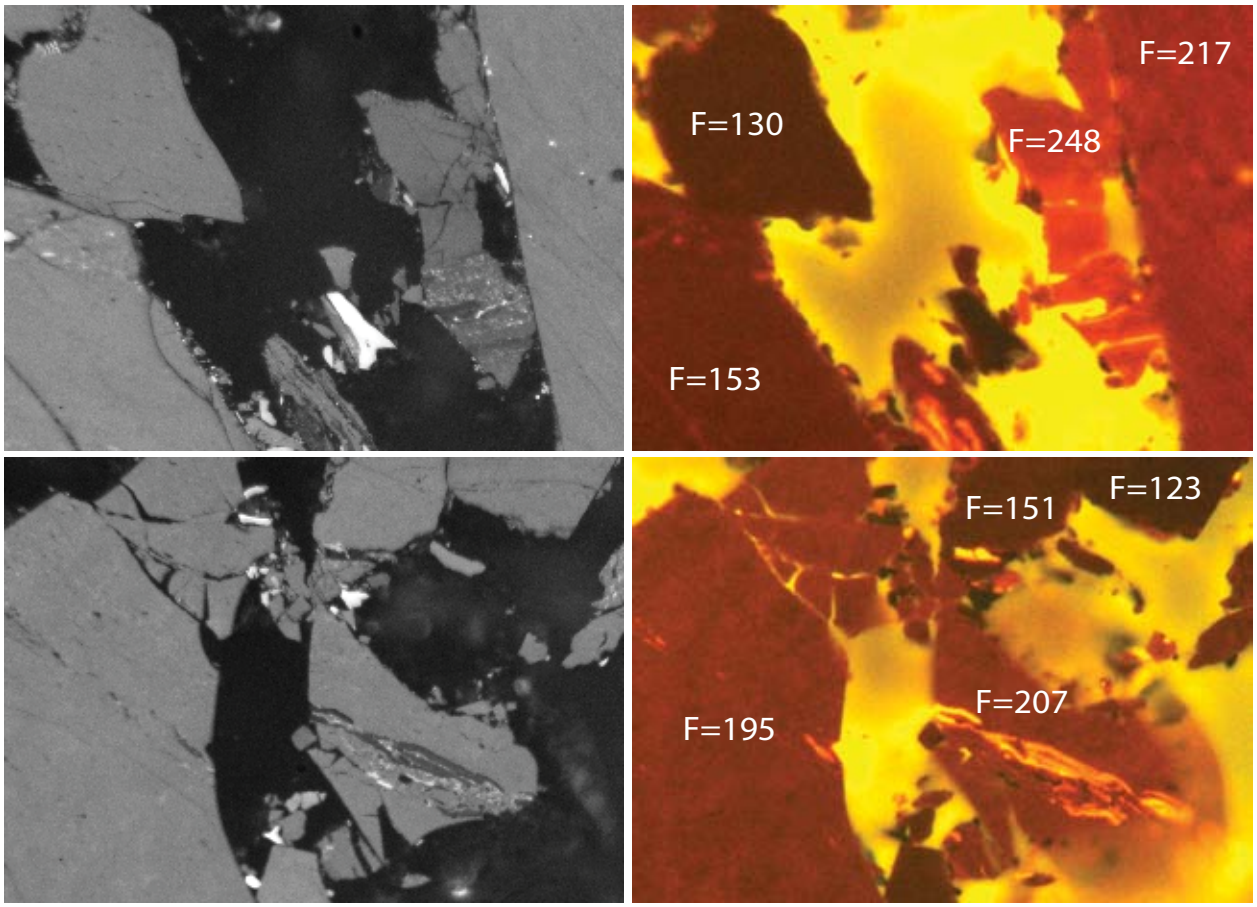
NIST Fluorescence Standard

Our fluorescence analysis is comprised of two parts. First, Fluorescence Imaging is done by Zeiss Universal microscope, using a robotic platform of a scanning stage, auto focus, excitation and emission filter wheels, and a digital sensor. An orange-emission NIST relative intensity correction standard for fluorescence spectrometry is used, whilst flat fielding and white light reflectance standardization is done by Klein & Becker YAG. Later, interpretive analysis and measurements of the images is done.

The three dimensions of coal petrography - Rank, Coaltype & Fluoresence



Vitrinite Fluorescence Intensity



These two sets of images of a commercial coking coal blend illustrate what this brochure is about. On the left are several isorank vitrinite grains, all displaying essentially the same vitrinite reflectance, (Ro-max about 0.92%), with similar imaged grayscales. However, on the right, in blue light excitation and orange emission, 470nm-520nm, the grains show markedly different levels of fluorescence, as indicated by the 8-bit values of F=0 to F=256, measured in green excitation and red emission, 559nm-630nm.

In situations where the white light petrography of the components is identical, identification of coal mixing, that is, blending, is by identifying different populations of fluorescing Vitrinites. These different populations of vitrinite possess different levels of Gieseler fluidity.

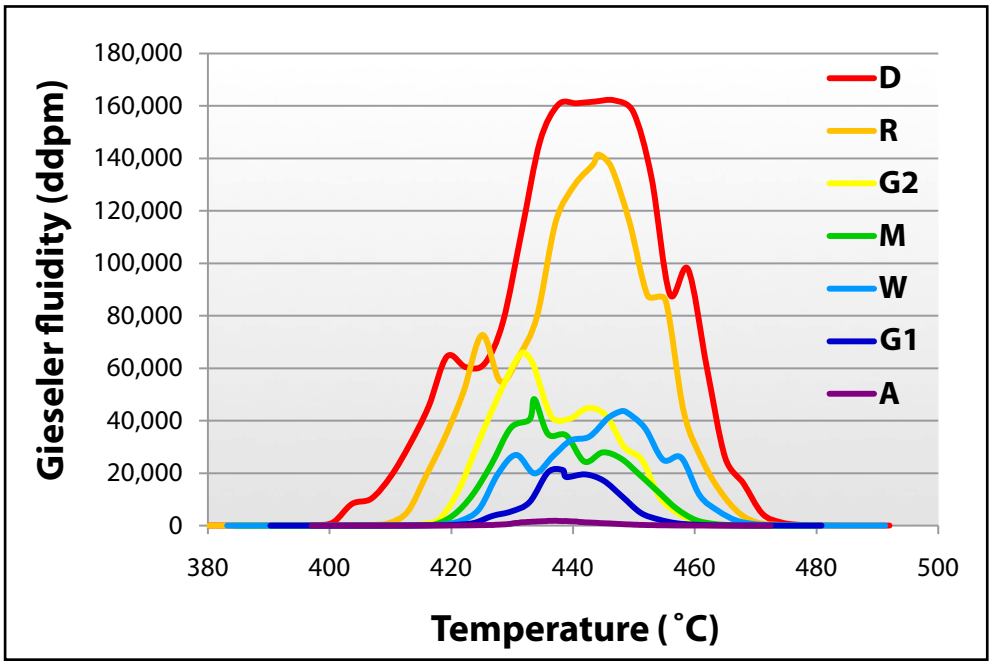
On the following pages we demonstrate that several carefully chosen coals possess the following:

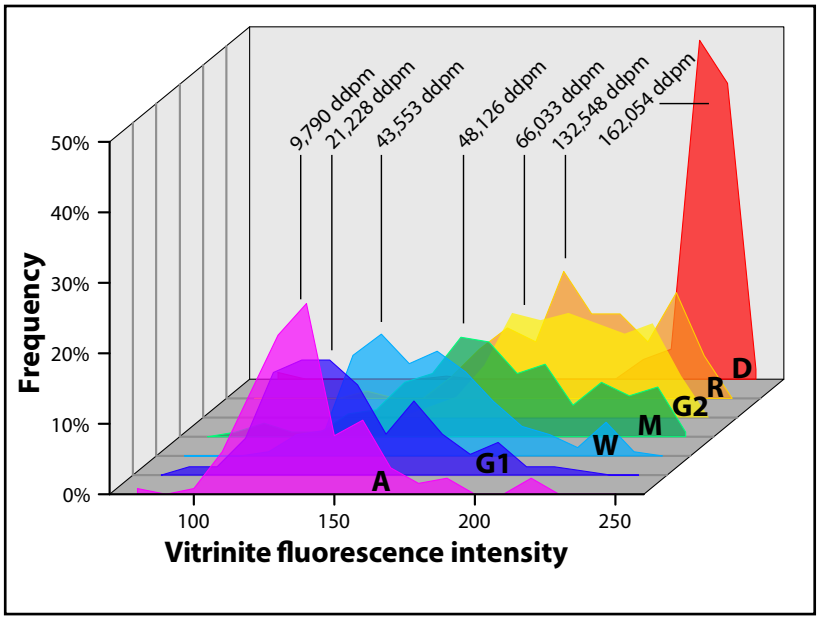
1. Markedly different Gieseler fluidities.
2. Mean Vitrinite fluorescence intensities that follow the trend of Gieseler fluidities.
3. Essentially the same white light petrographic characteristics.

Gieseler Fluidity of Coals

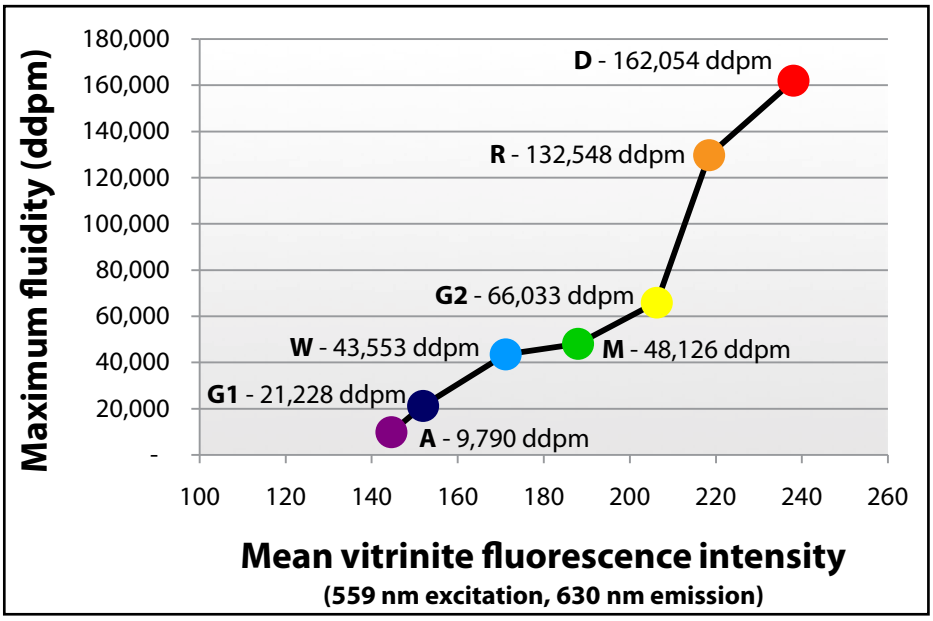
Fluidity is the term used to describe a coking coal's ability to soften and to be stirred by a torqued rod during the process of heating in a plastometer. Until recently, Gieseler plastometer motors were limited to 300 RPM, and with 100 divisions per single rotation, the units were only capable of measuring to 30,000 DDPM (**D**ial **D**ivisions **P**er **M**inute). Newer instruments are capable of measuring to 180,000 DDPM, and it comes as no surprise that many coals come closer to reaching this new upper threshold value. Gieseler maximum fluidity is an important parameter of coal quality, extensively used in the design of coke oven blends, but a predictive technique relating maximum fluidity to white-light petrography has never been demonstrated.

In the image below, an increasing colour sequence from violet to red emphasizes the Gieseler fluidities of the coals, and at the bottom of the page, fence diagrams with the same colour order show increasing fluidity versus Vitrinite Fluorescence Intensity.



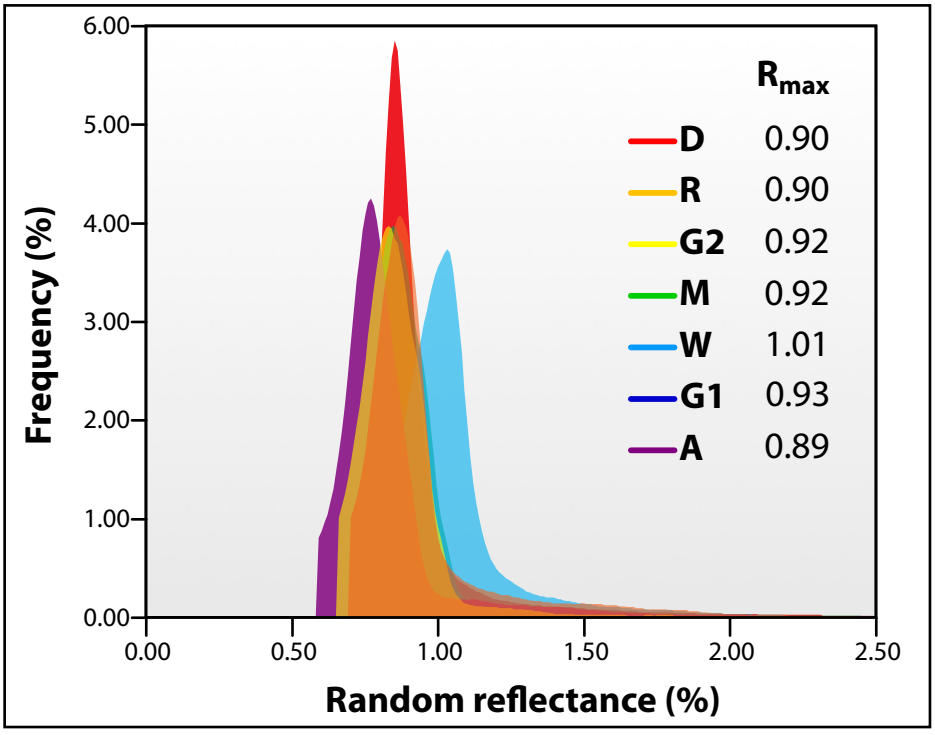


Vitrinite Fluorescence Intensity



The increasing colour sequence from violet to red is mirrored by increasing Gieseler fluidity, and Vitrinite fluorescence intensity for the seven coals.

Fingerprints of Coals

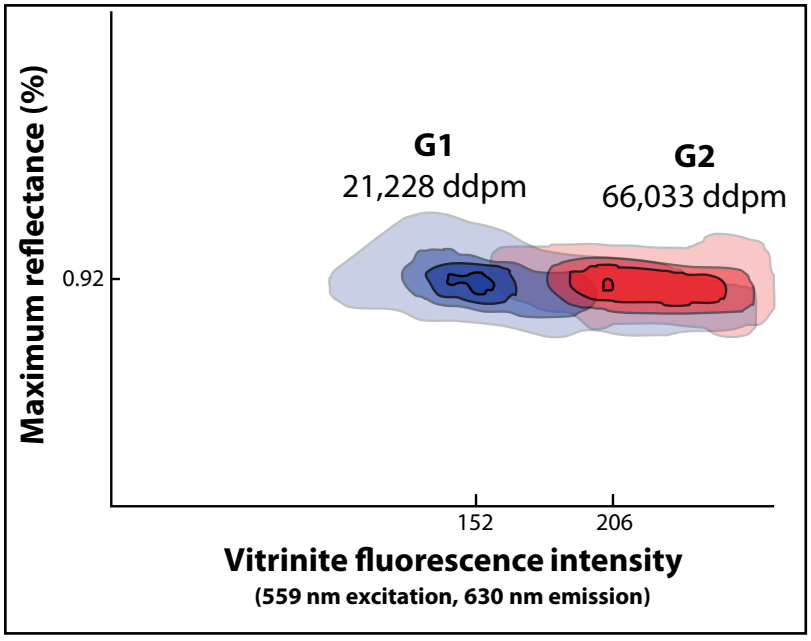


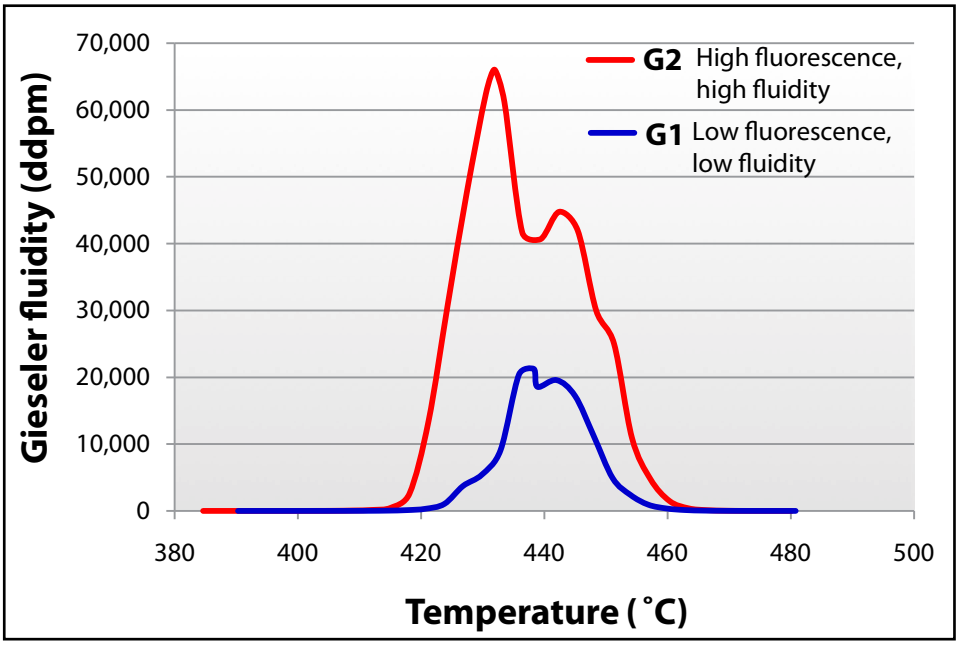
Six of the study coals possess Romax values of about 0.90% (G1, G2, M, R, D & A), W is 1.03%. All seven have vitrinite contents of 85-90%. W, G1 & G2 & M are blends , D is drill core, A and R are single seams. Reflectance Fingerprints of the coals are shown above.

Monitoring of coal variation

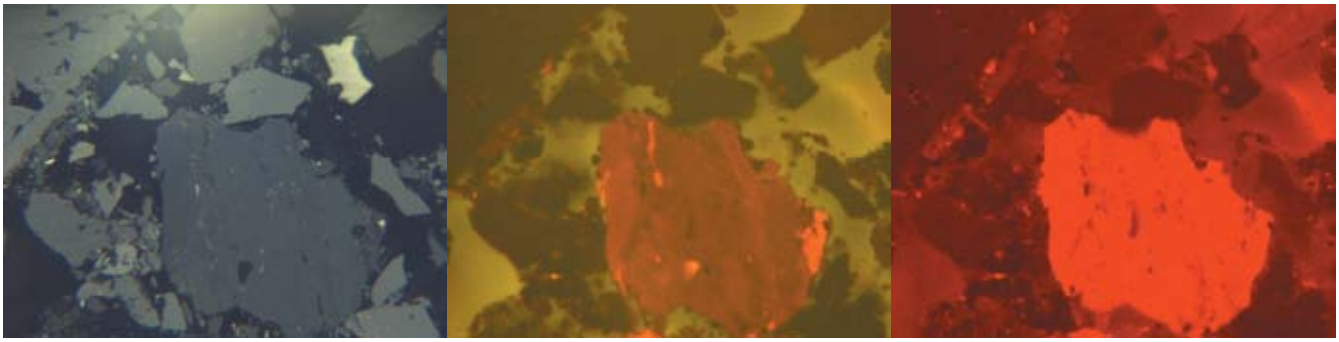
The graphs below show the effect of Vitrinite Fluorescence Intensity on the Fluidity Profiles for two examples of a commercial binary blend. Samples G1 & G2 are shown in cross plot of Romax reflectance (Y-axis), and Fluorescence intensity (X-axis), measured in green excitation and red emission, 559nm-630nm. The observed variance confirms that the coal is a blend, and also that as the proportion of the very fluorescent vitrinite is reduced, there is a corresponding drop in fluidity shown by the profile (G1). In the fluorescence profile of G2, an increase in the highly fluorescent vitrinite causes an increase in the fluidity of this high volatile blend.

Product variations of the type documented here probably impact coke quality, but these observations were not possible until the Fluorescent Imaging technology could be used in conjunction with fluidity data from high-reading plastometers.



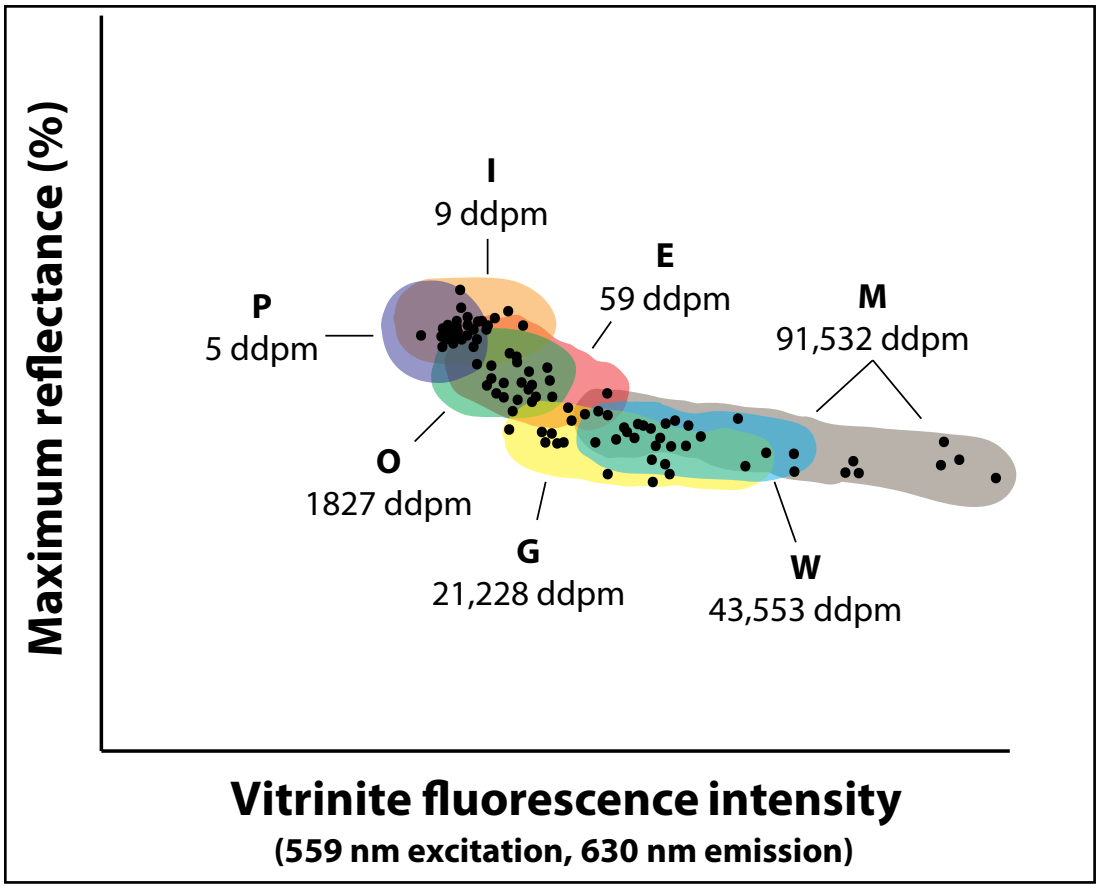


Fluorescence of blended coals



Images of an industrial blend of coking coals are shown above. Various ranks of vitrinite can be discerned in the white light image on the left; the blue light excitation and orange emission, 470nm-520nm, image in the centre shows how the different rank vitrinites can be easily separated on the basis of their fluoresence. Measurements are made in green excitation and red emission, 559nm-630nm from the image shown on the right. A scattergram of Romax reflectance (Y-axis) versus Fluorescence intensity (X-axis), of vitrinites from this industrial blend is shown below. A similar analysis of the component coals in the blend shows the populations from whence these vitrinites came. The elongated nature of some of these populations confirms that more than a few are at least binary blends (M, W, G & E, for example), when compared to the tighter distribution displayed by single seams (I, P & O).

Pattern of an industrial blend



Pearson Coal Petrography, with four laboratories on two continents, is the undisputed leader in industrial coal petrographic innovation.

Contact us, or visit us, because your problem may be our next research adventure!

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