Overview

Petrology is a branch of geology that deals with understanding the origin, occurrence, structure, and history of materials, and typically uses a combination of microscopy and chemical analyses. Naturally occurring carbon-bearing substances, like coal and petroleum source rocks, are complex mixtures of organic chemicals that retain a distant resemblance to the organisms from which they were derived. However, biological and geological processes over time alter these substances into individual resources that can have markedly different quality and commercial value.

The Coal and Organic Petrology Laboratories (COPL) employs microscopy and petrologic techniques to relate biological origin, and depositional and geologic history to the composition and structure of the resulting raw material. These analytical procedures are used in resource exploration, mine planning, resource selection, and quality control. Taken a step further, these techniques can be used to evaluate the efficiency of industrial processes and to predict the behavior of organic resources during utilization.

Key Equipment

The COPL emphasizes the reflected-light microscopy of solid, carbonaceous, natural, or man-made materials. Following procedures and classification schemes established by The American Society for Testing of Materials (ASTM), the International Standards Organization (ISO) and The International Committee for Coal and Organic Petrology, quantitative information is developed from a diversity of materials, such as coals, organic sediments, and industrial- and research-derived products and residues. COPL maintains a variety of specialized microscopes.

**The Zeiss Axiophot Microscope** with white/blue/UV- light capabilities, microprocessor photometric and photographic controls for general reflected-light microscopy at 400X and 500X magnification is used to characterize carbonaceous raw materials, petroleum source rocks, industrial residues and carbon products.

**The Zeiss Universal Microscopes** with reflected white- and blue- light illumination using a series of oil and/or air immersion objectives providing magnifications from 100X to 1000X are used for materials characterization as well as to determine organic composition following point-counting procedures.

**The Leitz Orthoplan MPV2 Microscope** with photometric capability for the quantitative measurement of reflected white-light or fluorescence emission intensity from blue- or ultraviolet-light illumination is used to determine the maturity of coals and sediments for resource utilization, petroleum exploration, basin analysis, as well as the influence of thermal processes on carbon-bearing materials.

A second MPV2 microscope provides photometric capability for spectral analysis of fluorescence emission from blue or ultraviolet light excitation. This microscope passes the filtered emission through a monochromator that divides the light into narrow bandwidths and has been used for characterization of solid-state materials such as coal, petroleum source rocks, roadway asphalts, and model compounds.

**The Leitz DM4000 Microscope** provides both transmitted and reflected-light capabilities using white/blue/UV light in the 200X to 1000X range. The instrument has a computer controlled 12 megapixel digital camera for materials characterization as well as future light density measurements for random vitrinite reflectance.

**The Nikon Microphot FXA Microscope** is available for reflected white-light illumination in a range of magnification from 50X to 1000X. This instrument has a microprocessor controlled camera system for general characterization as well as a color video camera for image capture and automated image analysis and is used for textural analysis of carbon materials employed in the production of electrodes and anodes for the steel and aluminum industries.
Equipment Capabilities

Application of Reflectance Analysis
The amount of light reflected from the surface of humic substances contained in coal or dispersed in sediments provides a sensitive measure of rank or maturity in response to regional thermal history. When the photometer system is calibrated against standards of known reflectance, a distribution of reflectance values can provide a unique mean value for a given material. Reflectance analyses are used to predict the behavior of a coal for the production of metallurgical coke; to establish the quality and uniformity of coal products; and, to establish the maturity of sediments with regard to the generation and migration of petroleum and gas. Consequently, the technique establishes a relationship between geologic history, exploration and resource assessment. Because reflectance is strongly related to the aromatic structure of organic material, the technique has been used effectively to evaluate changes in carbonaceous materials during processing and for process optimization.

Composition Analysis
Analysis of organic sediments in terms of their different plant- or organism-derived constituents has been used to reconstruct the environments of deposition and to predict the behavior of coals in industrial processes. Using a variety of classification schemes, standard point-counting techniques can be employed to determine the composition of organic materials. Compositional analysis has many applications, but the most significant is determining the relative reactivity of a bituminous coal with respect to its ability to become thermoplastic during coke making. The concept of reactive and inert macerals (presence or absence of thermoplastic properties) is an important consideration for many industrial applications. Furthermore, the types and amounts of organic material associated with sedimentary rocks dictate the quality of a source rock for the production and migration of petroleum; for example, carbon derived from terrestrial sources can be inferior to algal marine source rocks.

The point counting technique can be applied to the production of man-made materials as well, whether they are derived from petroleum or coal sources. The ability of a material to develop an ordered intermediate (mesophase) can have a profound influence on the quality of a value-added carbon. The size and shape of areas of equal molecular alignment in the resulting carbon can be determined by point counting or image analysis techniques. Those carbons having a higher concentration of elongated regions provide superior filler-materials for the production of electrodes or anodes.

Fluorescence Microscopy
Fluorescence microscopy is based upon the concept that ultraviolet or blue light is absorbed by certain organic functional groups and then readmitted at a higher wavelength. If the excitation light is filtered from the light path, then the surface can be expressed by an emission image based upon the organic chemistry of the material. This allows us to visualize fairly immature organic materials that normally would not be observed using white light illumination. Such observations are used to classify the potential quality of petroleum source rocks. Fluorescence intensity and spectral distribution are very sensitive to surface oxidation (natural, thermal or chemical). Consequently, the techniques have been used to evaluate the quality and storage deterioration of coals and the thermal sensitivity of roadway asphalts. As both of these materials become oxidized they lose their thermoplastic properties, thus effecting their quality and service life.

Key Publications