THE AMERICAN OIL & GAS REPORTER®
JANUARY 2010
The "Better Business" Publication Serving the Exploration / Drilling / Production Industry

Automated Mineralogy Derives Key Characteristics Directly From Reservoir Rock

Using scanning electron microscopy and energy dispersive X-ray spectrometry technology, combined with sophisticated software for automation and image processing, automated mineralogy provides fully-integrated mineral and rock analysis for rapid, accurate, repeatable and statistically valid results that reduce uncertainty in reservoir engineering models.

By Alan R. Butcher and Pieter Botha

HILLSBORO, OR.–Automated mineralogy is an advanced analysis technique that provides quantitative mineral, textural and lithological data for use in developing higher-quality geological and reservoir engineering models. It helps to reduce the uncertainty in operational decisions, resulting ultimately in more successful exploration and more efficient production.

Mineralogical information is instrumental in refining and understanding geologic models, depositional environments and reservoir characteristics. These models often are built on incomplete information, making them less reliable than what they could be, and thereby increasing the economic risk in the decision-making process. Automated mineralogy provides reliable and repeatable quantitative data on specific variables such as mineralogy, texture, lithology, porosity, and density that can significantly influence the quality of, and confidence in, these models.

Conventional mineralogy methods rely on subjective interpretations. For example, in examining drill cuttings for color and texture variations that can reveal chemical and mineral properties that indicate the location, amount and recoverability of hydrocarbons, even the most expertly trained analyst cannot be 100 percent objective. The subjectivity of the analysis impacts the accuracy of the predictions, which contributes to the risks inherent in oil and gas exploration and recovery.

Automated mineralogy improves the return on investment by providing objective and quantitative answers to chemical, mineral, textural and physical properties that are calculated directly from the reservoir rock to eliminate guesswork and reduce risk. More sampling points improve texture definition, leading to digital images that are geologically accurate for both simple and highly complex rock textures. The images are reliable and allow key mineral, textural, chemical and physical parameters to be extracted without manual intervention.

Using scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDS) technology, combined with sophisticated software for image processing and automation, provides a fully-integrated mineral and rock analysis system that is rapid, accurate, repeatable and statistically valid. Automated mineralogy technology is widely used in the mining industry for ore characterization and mineral liberation analysis to optimize extraction and separation operations. And even though these systems were developed for industrial applications, there are a number of units in use by research organizations, including the Colorado School of Mines and the University of Utah's Energy & Geoscience Institute in the United States, and the Camborne School of Mines in the United Kingdom.

Among the service providers that have recognized the value of quantitative material characterization and now provide services to the oil and gas industry with automated mineralogy technologies are Fugro, Ammtec Ltd. and the SGS Group. The initial investment in automated mineralogy is offset by substantial returns on the investment, with the long-term benefits accruing for the life of the well and/or field.

Two Most Important Signals

Proprietary automation software scans a focused beam of electrons over the sample surface, measuring a variety of signals generated by electron-sample interactions and mapping that data into a high-resolution image. For automated mineralogy, the two most important signals are backscattered electrons (BSEs) and characteristic X-rays. BSEs are beam electrons that are scattered back out of the sample by collisions with sample nuclei. The intensity of the BSE signal is primarily a function of the average atomic number of the sample.

Characteristic X-rays are generated when an incident electron creates a vacancy in an inner shell of a sample atom, which is filled by an outer shell electron from the same atom. The energy released is determined by the difference between the shells and indicates the atom's elemental identity. X-ray microanalysis can provide quantitative elemental analysis with micrometer-scale spatial resolution.

The automated mineralogy analysis platform is optimized for resolution, beam stability, stage precision, vacuum conditions and chamber size. In addition to the analysis and automation software, a key technological development is using multiple, high-speed energy dispersive X-ray spectrometry detectors in combination with carefully designed data acquisition algorithms, which permit much faster data acquisition than conventional SEM configurations. The ability to load up to 14 samples at a time, all of which are measured without operator intervention, increases sample throughput and operator efficiency.

Combining EDS and BSE signals allows fast, accurate mineral identification in a wide range of sample types, including drill cuttings, polished thin-sections and drilling cores. Automatic analysis of hundreds of thousands of data points per sample generates large and statistically-valid data sets. The system combines these data points to generate digital false color mineral maps, from which it then extracts quantitative mineral and textural information for downstream applications.

Analyzing Drill Cuttings

Drill cuttings, representing material obtained directly from the drilled geologic sequence, are generally underutilized in the industry as a source of information. Advances in drilling techniques and monitoring have allowed for the accurate collection of drill cutting samples from regular drilling intervals. As such, cuttings can be used to generate highly valuable geologic information, especially in sequences where drill cores are not available, or where wireline data are inconclusive.

Cuttings analysis has traditionally been regarded as simply too cumbersome, and questions have also been raised about the statistical validity of cuttings samples. Automated mineralogy provides a method by which thousands of cuttings can be analyzed in a fraction of the time required for conventional methods, providing results that are statistically robust and representative.

Figure 1 shows a schematic representa-

FIGURE 1

Automated Mineralogy Process Schematic

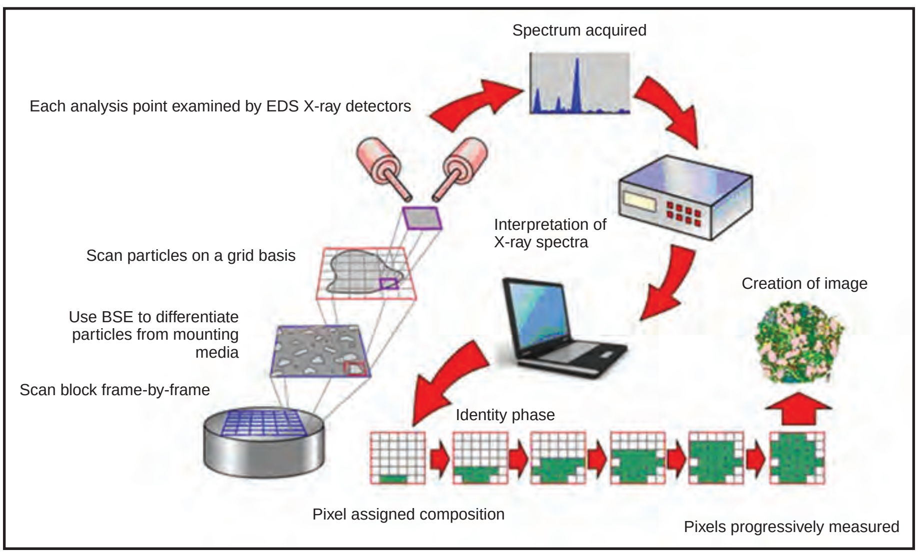
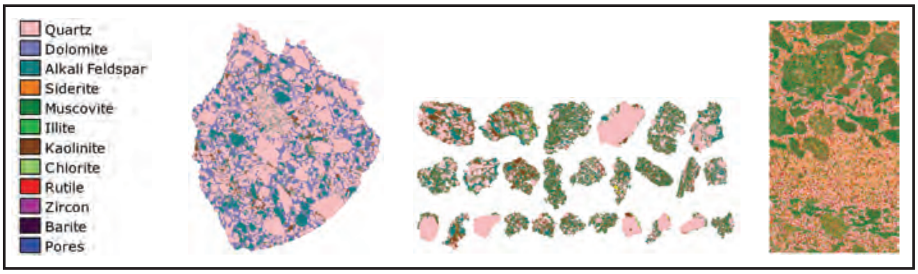


FIGURE 2

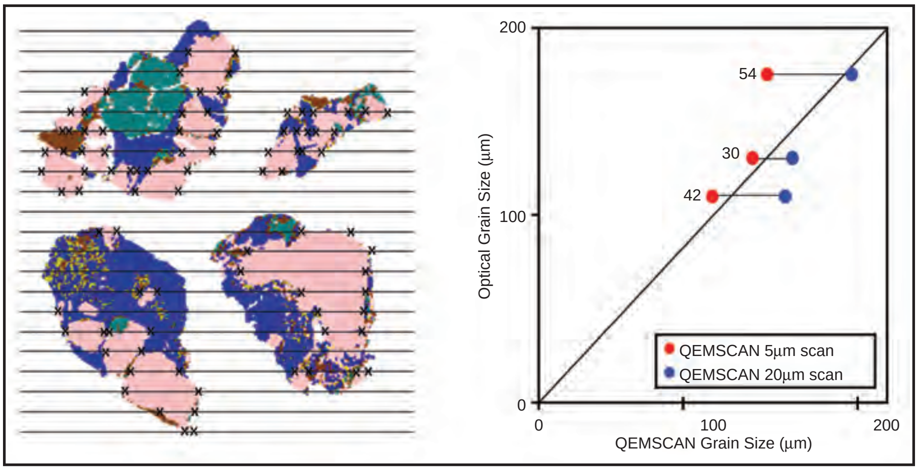
Digital Mineral Maps



Courtesy of Anzon Australia

FIGURE 3

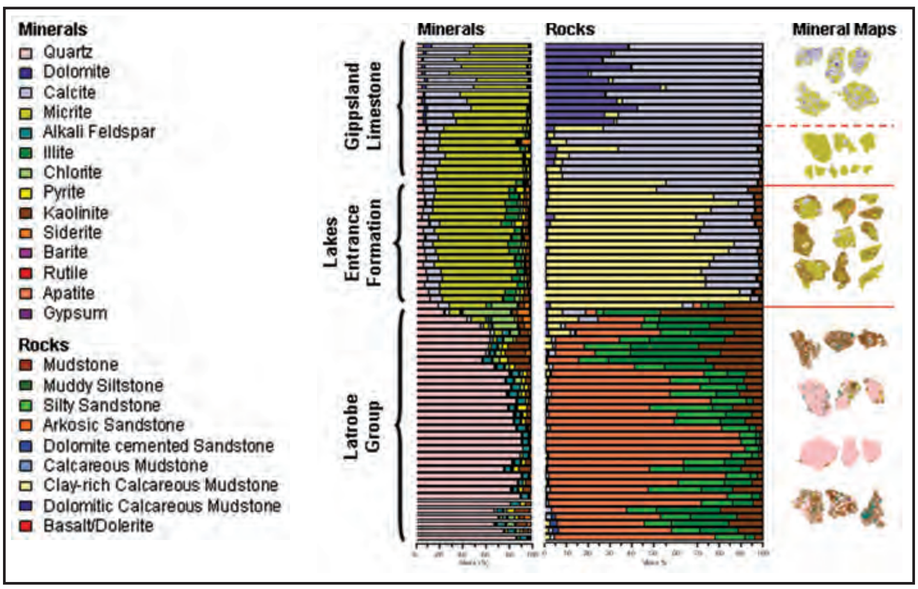
Calculating Grain Size (Automated Mineralogy versus Optical Petrography)



Courtesy of Pore Scale Solutions

FIGURE 4

Comparison of Mineral and Lithotype Logs



Courtesy of Anzon Australia

tion of the automated mineralogy process. Starting at the bottom left, the sample is mounted in epoxy and sectioned, creating a smooth, flat surface. The electron beam scans across the sample surface and identifies cuttings based on the contrast between minerals and the mounting media. The system then scans each cutting on a grid basis, and collects and interprets an X-ray spectrum for each pixel in the grid to determine its mineral phase. The results for all pixels are combined in a digital image that represents the mineralogy in the scanned particle.

Digital mineral maps provide visual representation of the mineralogy and how minerals relate to each other, providing contextual information, which is often critical in understanding depositional environments, diagenetic processes and petrophysical properties.

Grain size and shape are fundamental textural parameters in sandstones and other sedimentary rocks, where they have great impact on the interpretation of depositional environments. Grain density is a parameter used to calibrate wireline logs and to understand why certain geophysical signatures exist in certain geologic formations. The example digital mineral maps in Figure 2 provide visual representations of the mineralogy and how the different minerals relate to one another.

Automated mineralogy uses the stereological ratio of surface area-to-volume to estimate average grain size. This requires random size and orientation of the cuttings, as well as large sample sets to provide a statistically sound result. Automated mineralogy calculates the average surface area of all grains in the sample by measuring intercept lengths and boundary transitions of each individual grain, and then averages them over the entire sample. It can measure many thousands of grains in this fashion, providing a robust average grain size.

Figure 3 illustrates the method of calculating grain size and compares the grain size calculations of automated mineralogy with that of conventional optical petrography.

Lithotyping And Porosity

Digital particle classification is an interactive capability that allows the automated mineralogy system to classify cuttings into categories based on characteristics specified by the operator. Each category represents a certain rock type, defined by basic classification rules that include composition and texture. This capability is commonly used to differentiate between different rock types in cuttings samples.

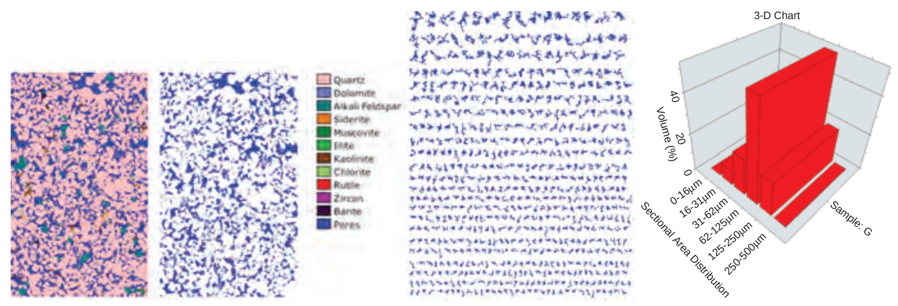
As cuttings samples are collected over regular drilling intervals, samples naturally overlap, with a single sample inevitably containing material from more than one geologic formation. Digital lithotyping allows the separation and quantification of these rock types in each sample, thereby improving stratigraphic resolution and deconvoluting "smeared" mineralogical information.

Figure 4 shows the mineral and lithotype logs next to each other, indicating the strong relationship between mineralogy, lithotypes and geologic boundaries in the presented sequence.

Similar to the way it identifies minerals, automated mineralogy also identifies and measures pore spaces (porosity) in the surface of the sample. In addition to providing a basic quantification of pore spaces, analysis software has the ability to separate and treat each area of discretely connected pore space individually. Figure 5 illustrates this capability.

FIGURE 5

Individually Separating/Treating Each Area of Discretely Connected Pore Space



Analogous to how automated mineralogy software classifies cuttings into rock types, the analysis software can be used to classify pore spaces into digital size ranges (better referred to as "sectional area" ranges). The proportion of material in each category can then be quantified.

Automated mineralogy is a high-throughput, objective and repeatable analysis solution that provides quantitative mineralogical and textural data on a wide range of sample types. Its nondestructive analysis delivers an unparalleled level of information, allowing engineers to develop highly refined geologic and reservoir models for oil and gas exploration and production. Better models reduce uncertainty in operational decisions, ultimately resulting in more successful exploration and more efficient production. ❒

ALAN R. BUTCHER

Alan R. Butcher is a geologist who has been involved with applying automated mineralogy to the oil and gas sector since 1999, first with CSIRO and then with Intellection Pty. Ltd. Since 2009, Alan has been a technical adviser to FEI, and is currently strategic marketing manager for FEI's industry market division, natural resources, based in Brisbane, Queensland, Australia.

PIETER BOTHA

Pieter Botha is an applications scientist at FEI's industry market division, natural resources, based in Hillsboro, Or. He has worked in the field of automated mineralogy for four years. Botha joined Intellection Pty. Ltd. in 2006, where he was involved in service projects using automated mineralogy for the mining industry. His responsibilities expanded toward the technical and scientific development and refinement of new application areas such as oil and gas, geoarchaeology and soil analysis. Botha holds a master's in geology.