Acid-base accounting by down-hole prompt gama ray spectroscopy wireline logging

Cecil, C. Blaine
Dulong, Frank T.

U.S. Geological Survey, Reston, VA

Renton, John J.

West Virginia University, Morgantown, WV

Lewis, Rick
Clayton, Ned

Schlumberger HydroGeological Technologies, Englewood, CO

Abstract

The U.S. Geological Survey in cooperation with the West Virginia Geological and Economic Survey, West Virginia University, and Schlumberger HydroGeological Technologies (HGT) is testing a methodology that chemically characterizes coal-bearing strata in a rapid, accurate, and cost effective manner. The methodology utilizes a prompt gamma ray spectroscopy tool in down-hole wireline logging. The spectroscopy tool routinely analyzes for the elements Ca, S, Fe, Ti, K, Gd and Si. Calcium and sulfur data can be use for acid-base accounting determinations and acid drainage prediction. The system can also detect and quantify manganese which can then be used to evaluate the potential for Mn leaching. Because the tool provides a continuous down-hole chemical analysis record of the formation surrounding the drill hole, significant errors that are otherwise introduced by sampling and standard analytical procedures can be reduced or eliminated. Comparison of data from wireline logging of two bore holes with chemical analyses of 1603 total feet of equivalent core samples indicate that the tool provides elemental concentration logs that should improve chemical characterization of coal-bearing strata.

Introduction

The U.S. Geological Survey in cooperation with the West Virginia Geological and Economic Survey (WVGES), Schlumberger HydroGeological Technologies (HGT), and West Virginia University (WVU) initiated a program to apply oil and gas industry well logging technology to the chemical characterization of coal-bearing strata. The methodology is based on chemical analyses of bore holes using prompt neutron gamma ray spectroscopy wireline logging hereinafter referred to as geochemical logging (GCL). The objective of the program is to evaluate a wireline logging methodology that chemically characterizes coal-bearing strata in a rapid, accurate, and cost effective manner. Traditional methodologies generally involve coring, core sampling, and chemical analysis of selected core samples. In contrast, the gamma ray spectroscopy technique consists of wireline logging of a drill hole. The logging provides continuous chemical analyses, top to bottom, of a 6.5 inch drill hole thereby eliminating sampling bias and error as well as other analytical error associated with sample preparation and analyses of a core. The GCL tool also interrogates a formation volume that is much larger than that analyzed by core. Data generated by wireline logging may be directly applied to the chemical characterization of coal-bearing strata including acid/base accounting of over burden.

Methods

In order to compare results from wire line logging with conventional analytical methods, two study sites were selected in an area known to have a variety of rock types and chemistries, and histories of acid mine drainage. In a collaborative effort, the participants defined the study requirements and selected sites near the eastern edge of the bituminous coal field. The first site (designated USGS-WVGES-1), in Tucker County, WV, was approximately 10 miles northeast of Davis, WV, The second site (designated USGS-WVGES-3), in Mineral County, WV, was 5 miles west of Keyser, VYTV. The region has a long history of coal production from strata that are known to have significant stratigraphic and regional variations in mineralogy, chemistry, and acid mine drainage.

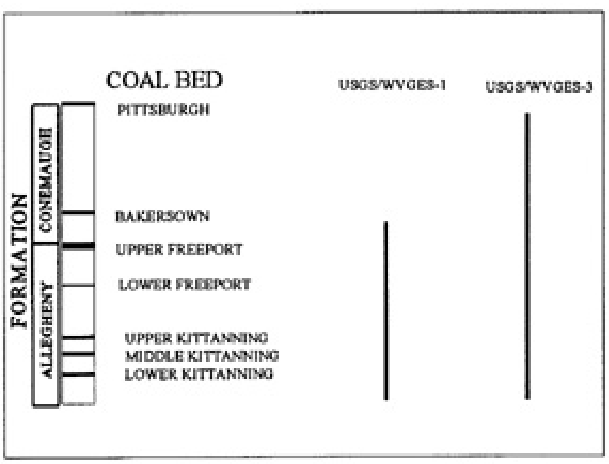

Figure 1.Geological Formations and major coal beds penetrated by core holes USGS/WVGES 1 and 3.

The top of each core hole required a few feet of casing down to bed rock. Core was then extracted from the base of the casing to the bottom of each hole. The intervals cored included Upper and Middle Pennsylvanian coal-bearing strata (Figure 1). The stratigraphic interval cored in the first hole, was from the approximate stratigraphic horizon of the Bakerstown Coal bed in the Upper Pennsylvanian Conemaugh Formation through the Middle Pennsylvanian Allegheny Formation to near the top of Pottsville Formation. Core extracted from the second hole included the entire Conemaugh and Allegheny Formations. The core was described at each well site using standard driller's log descriptions. Core from coal beds was removed, boxed, and transported to the West Virginia Geologic and Economic Survey for standard coal analyses.

The core, minus core from coal beds, was boxed and transported to core curation facilities at the West Virginia Geological and Economic Survey (WVGES). After detailed geological description by geologists from the WVGES, the cores were divided into one foot increments and each one foot increment was longitudinally cut in half. One half was archived for future reference and the other half was cut again into quarters. One complete set of one foot quarter samples from each of the two cores was submitted to West Virginia University, Department of Geology and Geography (WVDGG) analytical laboratories where each sample was ground to -200 mesh and prepared for mineralogical and chemical analyses. Mineralogical analyses was conducted by X-ray diffraction (XRD); chemical analyses included major and minor element analyses by X-ray fluorescence (XRF) and acid-base accounting was conducted using standard wet chemical procedures. The core sampling and analysis protocol was designed for a comparison of data generated from analyses of the total core using one foot increments with continuous down hole GCL analyses. Sampling and analyses of the core in one foot increments provided data for 650 samples from the first hole, and 953 samples from the second hole.

At site number one a second hole, 6.5 inches in diameter, was drilled by air rotary equipment approximately 20 feet from the core hole. This second hole was drilled in order to accommodate the size of the geochemical logging tool which has a 5 inch diameter. Both the core hole and air rotary hole were logged using density, natural gamma, and resistivity logs in order to determine if there were significant variations in lithologies between the two holes. Differences in the resistivity logs within some intervals indicated that there were variations in the composition of strata between the two holes. The 6.5 inch air rotary hole was then logged using the geochemical logging tool. To eliminate variation resulting from off-set drilling as observed in the first hole, the core hole at site two was reamed with air rotary drilling to a diameter of 6.5 inches. The reamed hole was then logged by standard tools as well as GLC.

Results

Preliminary results on the total suite of one foot increment core samples includes total sulfur by a commercial analyzer, calcium carbonate as calcite plus dolomite by X-ray diffraction (XRD), calcium calculated as CaO determined by X-ray fluorescence (XRF), and maximum potential acidity and neutralization potential determined by standard wet chemical methods. The GCL analyses consist of continuous weight percent Si, Ca, Fe, Ti, K, GD, and S determinations, top to bottom of each of the two test holes.

The chemical data from each of the two holes were compared in two ways. In the first case, data from only the Allegheny Formation were compared. Allegheny Formation samples were compared separately because these strata are known to consistently present problems in acid production when disturbed by surface mining. In the second case, data from the entire stratigraphic section penetrated by coring, which includes the Conemaugh and Allegheny Formations (minus the coal beds), were compared. The second case provided a wide range in lithologies and acid-base accounting variables. A comparison of the mean and standard deviation for the geochemical wireline log data and chemical analyses of one foot increment core data from Allegheny Formation strata is shown in Table 1.

Discussion

The numerical comparison of the results from GLC and core analyses indicates that there are some differences between the GLC data and the chemical data, particularly in USGS/WVGES-1 where there was a twenty foot off-set between the core hole and the 6.5 inch air rotary hole. Although the mean values for sulfur were equal for the Allegheny Formation between the two methods in USGS/WVGES-1, the mean values for calcite and NNP were not equal for either the entire core or the Allegheny Formation. A large part of the differences in data sets can be ascribed to differences in the amount of calcite within each of the two holes as indicated by differences in resistivity and density logs. These differences were sufficient to cause a noticeable difference in NNP values between the two holes.

There were fewer differences between the GCL and core data sets in USGS/WVGES-3. At this site, the core hole was reamed to a 6.5 inch diameter. When the data were acquired from what was essentially the same hole, the means were equal for sulfur, calcite, and NNP for both the Allegheny Formation and the Conemaugh plus the Allegheny Formations.

Conclusions

The preliminary data indicate that geochemical logging can provide a level of accuracy equivalent to chemical analyses of one foot increment samples of core. The data generated thus far in our study indicate that geochemical logging can be used in chemical characterization of coal-bearing strata. The data can address problems such as acid/base accounting in overburden characterization. Geochemical logging data allow acid/base accounting for part or all of a drill hole. The logging has the advantage of providing accurate data in a matter of minutes for an individual drill hole or any number of holes. The logging also offers a tremendous time savings since elemental concentration logs and acid/base computations could be provided at the wellsite. If further testing demonstrates that ECS logging is as accurate as conventional chemical methods of overburden characterization, then geochemical logging of air rotary holes may eliminate the need for coring. The project objectives of accuracy and rapid analysis appear to be met by geochemical logging. The industry will have to address cost effectiveness.

Table 1a. Data from Allegheny Formation samples from sites WVGES-1 and 3.

USGS/WVGES - 1, Allegheny Formation at the 95% confidence level

	Calcite		Sulfur		NNP	
	GCL	CORE	GCL	CORE	GCL	CORE
m	0.64	1.28	0.16	0.17	1.5	7.7
sd	2.41	3.92	0.46	0.34	29	42
n	453	229	453	230	453	229
	unequal means		equal means		unequal means	

USGS/WVGES-3 , Allegheny Formation at the 95% confidence level

m	1.62	1.22	0.18	0.17	11	7.0
sd	4.03	3.06	0.26	0.24	39	36
N	425	212	425	212	425	212
	equal means		equal means		equal means	

Table 1b. USGS/WVGES-1 Conemaugh and Allegheny Formations, total core analyses.

m	1.13	1.93	0.11	0.16	36	43
sd	3.14	4.91	0.35	0.33	34	51
n	1185	575	1185	575	1185	575
	unequal means		unequal means		unequal means	

USGS/WVGES-3 Conemaugh and Allegheny Formations total core analyses.

m	4.36	5.06	0.23	0.25	36	43
sd	8.81	10.2	0.46	0.80	86	105
n	1909	945	1909	945	1909	945
	equal means		equal means		equal means	