Chapter 9. Strengths and Weaknesses of Acid-Base Accounting Data

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History and Development of the Acid-Base Accounting (ABA) Technique

Much has been written in the past 30 years on the development, applications and interpretation of the ABA method of mine drainage prediction, but for purposes of this report, most of it can be summarized from several chapters by Kania (1998a), Perry (1998) and Skousen et al., (2000) in two familiar books on mine drainage prediction, while additional information on the relationship of ABA to other prediction techniques is also found in chapters by Kania (1998b) and Perry (2000) in the same books.

Acid-Base Accounting was developed at West Virginia University by Richard M. Smith and co-workers (Skousen et al., 1990). The approach grew from early attempts at classifying mine spoils for revegetation potential, based principally on acidity or alkalinity, and rock type. From these broad classifications, the need for lime and suitability for plant species could be assessed. For example, the Neutralization Potential (NP) component of ABA was adapted from the work of M.L. Jackson (1958) as a measure of lime requirements for soil chemical analysis and plant growth.

According to Kania (1998, p. 6-1):

> Laboratory methods for performing acid-base accounting overburden analysis (ABA) have been thoroughly detailed in previous publications. Sobek et al., (1978) formally presented a step-by-step laboratory protocol for performing ABA on mine overburden and is frequently cited as the source document. However, earlier publications described the application of ABA principles to mine overburden testing (West Virginia University, 1971; Grube et al., 1973; Smith et al., 1974; Smith et al., 1976).… ABA is based on the premise that the propensity for a site to produce acid mine drainage can be predicted by quantitatively determining the total amount of acidity and alkalinity the strata on a site can potentially produce.

ABA, as originally developed, consists of measuring the acid generating and acid neutralizing potentials of a rock sample. These measurements of Maximum Potential Acidity (MPA) and Neutralization Potential (NP) are subtracted to obtain a Net Neutralization Potential (NNP), or net Acid-Base balance for the rock as follows in equation 9.1:

$$\text{Net Neutralization Potential (NNP)} = NP - MPA \qquad (9.1)$$

The results are customarily reported in tons per thousand tons of overburden or parts per thousand…

The measurements and calculations of NP, MPA, and NNP are based on the following assumed stoichiometry (Cravotta et al., 1990):

$$FeS_2 + 2CaCO_3 + 3.75O_2 + 1.5H_2O \rightarrow 2SO_4^{2-} + Fe(OH)_3 + 2Ca^{2+} + 2CO_2 \quad (9.2)$$

For each mole of pyrite that is oxidized, two moles of calcite are required for acid neutralization. On a mass ratio basis, for each gram of sulfur present, 3.125 grams of calcite are required for acid neutralization. When expressed in parts per thousand of overburden, for each 10 ppt of sulfur (equal to 1 percent sulfur content) present, 31.25 ppt of calcite is required for acid neutralization.

Cravotta et al., (1990) noted that the stoichiometry in Equation 9.2 is based on the exsolving of carbon dioxide gas out of the spoil system. They suggested that in a closed spoil system, carbon dioxide is not exsolved, and additional acidity from carbonic acid is generated. Cravotta et al., (1990) proposed that up to four moles of calcite might be needed for acid neutralization as follows:

$$FeS_2 + 4CaCO_3 + 3.75O_2 + 3.5H_2O \rightarrow 2SO_4^{2-} + Fe(OH)_3 + 4Ca^{2+} + 4HCO_3 \quad (9.3)$$

The stoichiometry of Equation 9.3 shows that twice as much calcite would be required for acid neutralization. On a mass basis, for each 10 ppt of sulfur present, 62.5 tons of calcite is needed for acid neutralization in one thousand tons of overburden. (from Perry (1998) p. 11-2).

Some problems with the literal interpretation of some ABA results are described in Perry (1998) and Hornberger and Brady (1998). For example, the MPA is a surrogate measure of potential acidity based on total sulfur present, rather than an actual acidity concentration, and the NP test is a surrogate measure of potential alkalinity, based upon estimated calcium carbonate content, rather than an actual alkalinity concentration. Therefore, there may be some missing elements in the direct comparison of potential acidity and potential alkalinity, including kinetic factors in the mine drainage chemistry.

Modifications and Improvements to Acid-Base Accounting Procedures

The two biggest problems found in the use of the original ABA test methods specified in Sobek et al., (1978) and other publications are with the NP test, including:

- a potential siderite interference problem and,
- accuracy and precision problems in NP test results related to the subjectivity of the fizz rating step in the NP test procedure.

Both of these problems were addressed and essentially resolved in a revised NP test method published by Skousen et al., (1997).

The potential for the presence of the carbonate mineral siderite to produce misleading alkalinity predictions in mine drainage has been recognized for about 40 years in a series of publications including Barnes and Romberger (1967), Meek (1981) and Morrison et al., (1990).

According to Skousen et al., (2000, p. 82):

> Siderite ($FeCO_3$), when present in the overburden, reacts quickly with HCI in the standard NP procedure in ABA and falsely indicates that the rock will behave as a net alkaline contributor after weathering (Cargeid, 1981; Morrison et al., 1990; Wiram, 1991). Continued weathering of $FeCO_3$ actually produces a neutral (Meek, 1981; Shelton et al., 1984) to slightly acid solution (Cravotta, 1991; Doolittle et al., 1992; Frisbee and Hossner, 1989). If insufficient time is allowed for complete iron oxidation and precipitation of ferric hydroxide during back titration, erroneously high NP values can be generated on samples containing $FeCO_3$, yielding misleading NP information. Such an analytical oversight can lead to incorrect post-mining water quality predictions and produce costly, long-term reclamation liabilities (Wiram, 1992).
>
> Meek (1981) and Morrison et al., (1990) suggested adding a small quantity of 30% H_2O_2 to the filtrate of an overburden sample to oxidize ferrous iron to ferric iron before back-titration is initiated. Leavitt et al., (1995) proposed a modified NP procedure that includes boiling a 2-gram overburden sample for 5 minutes after the acid is added, filtering the suspension, and adding 5 ml of 30% H_2O_2, then boiling for an additional 5 minutes. Significant reductions in NP values were found for $FeCO_3$ samples using the modified NP method compared to the standard Sobek et al., (1978) method (Table 4.4, Skousen et al., 1997). Variations in NP determinations among laboratories were also dramatically reduced by using this modified method compared to the standard NP method on $FeCO_3$ samples (Table 4.5) (p. 83).

Magnitude of the siderite effect on NP is strongly influenced by mineralogy. Skousen et al., (1997) classified their samples as Fe rich, Ca rich, S rich and Si rich rocks. The Fe rich rocks had the largest change in NP when siderite was accounted for by modified test methods. The sulfur rich rocks also showed a significant decline in NP when analyzed by modified test methods. This may result from more complete oxidation of soluble Fe in the modified test. High grade limestones (Ca rich group) showed little change in NP, since their neutralizing value is derived mainly from calcite. Si rich rocks with a high proportion of clay mineral and quartz showed some decline in NP when subjected to the modified test method.

Skousen et al., (1997) essentially solved the siderite interference problem. It is unfortunate that many commercial laboratories do not use the improved NP procedures, because they are either unaware of the modification, or they have not received technical guidance or requirements from regulatory agencies to implement the modified 1997 NP method. Concerning the problems with fizz ratings, Skousen et al., (2000, p. 84) state:

> Fizz ratings are done to asses the relative amount of carbonate present in a rock sample, which are then used to determine the amount and strength of acid to use in the NP digestion process. Conflicting NP values were found when overburden samples were assigned different fizz ratings and thereby

digested in different amounts of acid (Table 4.6) [Skousen et al., 1997, Table 4.6]. At higher fizz ratings (more acid added), the NP values increased substantially. Since the subjective fizz rating was not found to be repeatable among laboratories and not reflective of the carbonate content of a rock, a quantitative and repeatable method to determine carbonate content was proposed (Skousen et al., 1997). The method uses the percent insoluble residue after acid digestion to assign a carbonate rating (Table 4.7) [Skousen et al., 1997, Table 4.7], and has been found to accurately determine the amount and strength of acid to add for NP determination.

The fizz rating problems described in Skousen (2000) above are very relevant to the NP data from the rock sample splits used by the eight participating labs in the present ADTI-WP2 interlaboratory study. The insoluble residue/carbonate rating step in the revised NP method described in Skousen et al., (1997, 2000) would essentially resolve these fizz rating problems. It is unfortunate that most commercial laboratories doing ABA work have not adopted this NP method improvement, reportedly due to cost increases in conducting the ABA test methods. The cost increases are no doubt a real factor which can be quantified, but the relative costs to the mining industry and regulatory agencies in using inaccurate and imprecise NP data cannot be underestimated or overlooked.

Basic Usefulness of ABA Data in Typical Mine Drainage Prediction Work

ABA is the most commonly used mine drainage prediction method used in Pennsylvania, West Virginia and other states in surface mining permit reviews, and ABA or some use of its components (i.e. NP) has worked relatively well in correctly predicting mine drainage quality. ABA and mine drainage quality relationships have been evaluated in Pennsylvania and northern Appalachia in studies by Brady et al., (1994), Perry and Brady (1995) and diPretoro and Rauch (1998) which are all summarized in Perry (1998). Skousen et al., (2002) also reported a comparison of ABA and water quality data for mines in West Virginia.

In addition, a detailed evaluation of mining permitting from 1987 to 1996 in Pennsylvania was performed as a post mortem study of permits resulting in acid mine drainage. It is contained in Smith et al., (2000) and a PA DEP report by the same title, dated March 1999. That study showed that only one percent of the 1,699 permits issued in that 10 year period resulted in post-mining water quality problems precluding bond release. The high level of success in preventing AMD was attributed to advances in the science of prevention and prediction, which included the use of ABA data. However, of the 50 sites where detailed post mortem reviews were performed, 17 sites had post-mining AMD liability. This was attributed to:

- inadequate information in the permit application on which to make a sound judgment and;
- interpretation error in issuing the permit if viewed in the context of the state of improved prediction knowledge at the time of the post mortem study.

While ABA data have been found to be very useful in mine drainage prediction work in many cases, as described above, a major problem occurs in what is referred to as the “gray zone” or the “uncertain zone” as shown on Figure 9.1 and in Geidel et al., (2000). In comparing NP values to

MPA values in this figure and the accompany text, Geidel et al., (2000) use this concept as some criteria for determining whether to conduct kinetic testing. Nevertheless, ABA should still be used as a primary mine drainage prediction tool, and as a companion, screen or precursor to kinetic tests like the ADTI-WP2 Leaching Column Method.

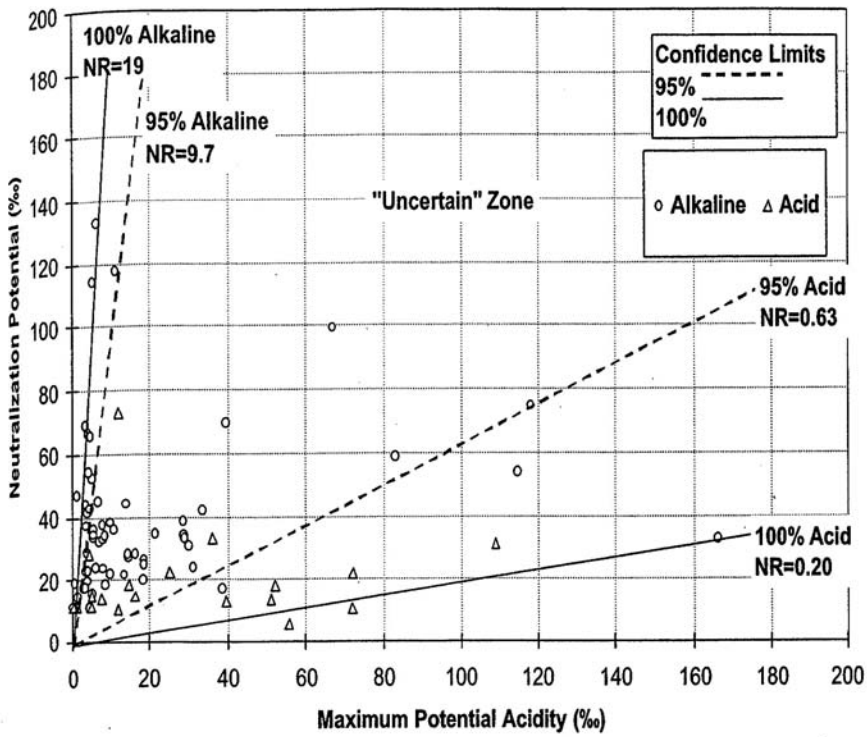

Figure 9.1 The "Gray Zone" of NP and MPA (from Geidel et al., 2000)

Problems with the Neutralization Potential and Total Sulfur Data used in the Interlaboratory Study

The five rock samples used in the ADTI-WP2 interlaboratory validation study have been described in preceding chapters of this report. The total sulfur and neutralization potential data for the original rock splits used to confirm homogenization of the large sample volumes were generated by a single laboratory using the standard and modified method for NP. Subsequently, splits were sent to the eight participating laboratories. The initial characterization and splits analyses are summarized in Tables 9.1 through 9.4 and Tables 9.8 through 9.12. Some significant and troubling variation in results were observed. These problems do not imply that this overall study of leaching column performance and related mineralogical and kinetic interpretations is seriously flawed. However, these data tables demonstrate that there may be significant accuracy and precision problems with conventional ABA data that are used in many mining permit applications. These findings lead to legitimate questions on the usefulness of some portion of conventional (i.e. 1978) ABA method data in routine mine permitting, and also strongly encourage the full implementation of the improved 1997 NP method, and perhaps further improvements in ABA testing procedures.

Summary ABA data for the Brush Creek Shale samples are shown in Table 9.1. Detailed data for all splits and replicates are included in Table 9.8.

Brush Creek Shale

The summary test results for the Brush Creek shale are shown in Table 9.1 and the raw data are in Table 9.8. The first four splits (i.e. 2, 6, 10 & 15) are the original randomly selected splits tested on July 14, 2005 to confirm the homogenization of the large volume of rock sample, which totaled about 25 buckets of five-gallon size. These four splits are very consistent in percent total sulfur, NP by the original 1978 method and by the revised 1997 method. The most remarkable observation of these original splits is that the NP values by the revised method are approximately half the magnitude of the 1978 method, presumably due to siderite interference or other factors related to the carbonate mineralogy. The big problems with this data set come in the subsequent testing and retesting of the splits sent to the participating labs. For example, original split 15 was sent to Lab 2 where the unweathered sample tested on January 19, 2005 had an NP of only 37.7 and the weathered material from the end of the leaching test had NP's of 91.09 and 96.47 from the two columns.

Table 9.1 Brush Creek Shale Summary ABA Data

Sample Treatment		N	%S			NP		
			Min	Mean	Max	Min	Mean	Max
BCS3-PA	Initial Standard NP	4	0.56	0.58	0.59	96.96	96.97	96.98
BCS3-PA	Initial Modified NP	4	0.56	0.58	0.59	47.07	48.42	49.68
BCS3-PA	Splits Before Leaching	6	0.59	0.63	0.75	21.13	44.66	89.30
BCS3-PA	Splits After Leaching	25	0.44	0.59	1.09	3.99	57.43	106.05

Overall the total sulfur percentages in the splits at the various labs are much more consistent than the NP values, but some unweathered splits have greater sulfur content than the weathered samples (i.e. Labs 3, 5 and 7) as would be expected, but some weathered material had higher sulfur values than the unweathered sample (i.e. Lab 2). Some differences in sulfur content by particle size were also observed with the fines having the higher sulfur values, as expected, at Lab 1 and in Column 1 at Lab 6.

The most troubling aspect of this Brush Creek data set is the tremendous variation in NP values, (as shown in Table 9.8), which appears to be related to differences in fizz ratings on the splits of the same homogenous sample, tested on different dates, and maybe not by the same lab analyst. The unweathered splits at the participating labs range from 21.13 (Lab 5) to 89.30 (Lab 4) and the fizz ratings of the entire Brush Creek data set range from 0 to 3. There is no consistency to the unweathered and weathered sample fizz ratings, for example in Labs 3 and 4, where the unweathered samples have lower fizz ratings than the weathered samples. In summary, no lab shows weathered NP values consistently lower than the unweathered sample, as would have been expected.

Houchin Creek Shale

Of the four shale samples used in the study, the Houchin Creek shale has the highest sulfur content. This shale sample was collected from a surface mine in Indiana by OSM staff from the Mid Continent office. The summary ABA data are contained in Table 9.2 and the raw data are found in Table 9.9. The first four samples in Table 9.9 are the original splits from the homogenization of the large sample volume. The sulfur and NP values for these four samples are consistent, but with two curiosities: Split 16 has a sulfur content about a half a percent less than the other three splits, and three of the four NP values from the revised 1997 method are slightly higher than those for the original method. In most of the labs, except Lab 2, the weathered samples from the columns have less sulfur than the unweathered samples, as would be expected. There is also a large variation in sulfur content by particle size classes in Lab 6, with the fines having the highest sulfur, as reported in previous studies.

The unweatherd NP values of the splits sent to the participating labs are only about half the magnitude of the original splits, and all of these fizz ratings are 0. The most encouraging element of this NP data is that the weathered NP values are substantially less than their unweathered counterparts, reflecting a loss of NP due to the weathering of the samples during the leaching column study.

Table 9.2 Houchin Creek Shale Summary ABA Data

Sample Treatment		N	%S			NP		
			Min	Mean	Max	Min	Mean	Max
HCS-IN	Initial Standard NP	4	4.73	5.08	5.27	41.29	44.14	47.53
HCS-IN	Initial Modified NP	4	4.73	5.08	5.27	41.05	45.54	48.27
HCS-IN	Splits Before Leaching	6	4.93	5.25	5.53	19.61	23.52	26.53
HSC-IN	Splits After Leaching	25	2.99	4.70	5.98	-17.82	13.96	34.69

Kanawha Black Flint Shale

The Kanawha Black Flint shale sample was collected from a roadcut near Charleston, WV in a terrain where selenium concentrations were a concern. However, this rock sample has relatively low total sulfur content and relatively low NP, as shown in Tables 9.3 and 9.10. These types of ABA analyses are sometimes difficult to interpret. The original splits from the homogenization of the sample, tested on June 24, 2005 have relatively consistent sulfur contents and NP values, as shown in Table 9.10, except for the 0.21 percent sulfur in Split 11. The NP values by the 1997 method are slightly lower than the 1978 method values in these 4 splits, as might be expected. The original Split 4 was used by Lab 4 in the weathering study and was retested to have 0.11% less sulfur than the original. Original Split 11 was sent to Lab 2 for the weathering study, and upon retesting the unweathered split is only 0.03% different from the original test value. However, the sulfur contents of the weathered material from both leaching columns had higher sulfur contents than the unweathered sample as shown in Table 9.10. It is curious that the sulfur contents of all of the particle size classes from the two columns at Lab 6 are only about one third to one half of the sulfur contents of the original splits, indicating a greater degree of weathering than at most of the other labs.

With this rock sample, there are again numerous inconsistencies and questions about the NP values and fizz ratings. Many of the unweathered and weathered samples from the participating labs are considerably higher to several times higher than the original homogenization splits. Also, there is one anomalous weathered sample from Lab 5 with an NP of 315.62 and a fizz rating of 2. The other fizz ratings in Table 9.10 are about evenly divided as 0 or 1.

Finally, one observation of the NP values is that the weathered NP values for numerous labs (Labs 3, 4, 7 and 8) especially Lab 4, are considerably less than the unweathered samples from these labs.

Table 9.3 Kanawha Black Flint Shale Summary ABA Data

Sample Treatment		N	%S			NP		
			Min	Mean	Max	Min	Mean	Max
KBF-WV	Initial Standard NP	4	0.21	0.30	0.35	15.17	16.95	18.69
KBF-WV	Initial Modified NP	4	0.21	0.30	0.35	13.17	13.61	14.26
KBF-WV	Splits Before Leaching	6	0.24	0.27	0.39	14.05	18.56	21.49
KBF-WV	Splits After Leaching	24	0.05	0.17	0.31	10.62	37.77	315.62

Lower Kittanning Shale (LKFC-PA)

The Lower Kittanning shale from the Falls Creek site exhibits consistency in the sulfur and NP values of the original homogenization splits in Tables 9.4 and 9.11, however, 3 of the 4 NP values from the 1997 method are slightly higher than those from the 1978 method. Split 3 from the original July 14, 2005 tests was weathered in Lab 4, and the retested unweathered sample had an almost identical sulfur content, but a slightly higher NP. The unweathered sulfur contents for Labs 3, 4, 5, 7 and 8 were higher than the weathered samples from the leaching columns, as would be expected, especially in the samples from Lab 7. However in the particle size classes shown for the two columns at Lab 6, the highest sulfur contents are not in the fines.

This Lower Kittanning shale sample has the most consistent and reasonable NP values of the five rock samples shown in Tables 9.8 through 9.12. For example, the weathered NP samples from the columns at Labs 3 and 4 are less than the unweathered sample NP values, especially at Lab 4. The fizz ratings are also consistent, as they are all 0, even within the different particle size classes.

Table 9.4 Lower Kittanning Shale Summary ABA Data

Sample Treatment		N	%S			NP		
			Min	Mean	Max	Min	Mean	Max
LKFC-PA	Initial Standard NP	4	0.89	0.91	0.93	12.41	13.54	16.47
LKFC-PA	Initial Modified NP	4	0.89	0.91	0.93	15.63	15.93	16.36
LKFC-PA	Splits Before Leaching	6	0.88	0.98	1.13	9.58	12.84	17.20
LKFC-PA	Splits After Leaching	25	0.63	0.84	1.17	4.83	12.94	17.18

This Lower Kittanning shale sample was collected from an active surface mine highwall in the Redbank Creek Watershed in Jefferson County, Pennsylvania. ABA data are available in the DEP public files for this site and adjacent sites in the watershed. Fortunately (through the assistance of Joe Tarantino and Tim Gillen from the DEP Knox Office), the overburden analysis data was compiled and some field water quality data were available to compare to the ABA and leaching test data from this project. In one overburden drill hole for the Falls Creek mine site the total sulfur of the shale overlying the coal as 0.93% with an NP of 9.70 which is very similar to the data in Tables 9.4 and 9.11. In another drill hole from this mine site the overlying shale had sulfur contents of 4.32, 1.84 and 1.10% with NP values of 1.0, 3.75 and 4.75 respectively. In overburden drill holes from adjacent mine sites the Lower Kittanning shale had total sulfur of 1.70% (NP = 17.15) and 0.95% (NP = 12.64), as shown in Table 9.5.

Table 9.5
Sulfur and NP Content of Lower Kittanning Shale Field Site

Location	%S	NP
Falls Creek Mine	0.93	9.7
Falls Creek Mine	4.32	1.0
Falls Creek Mine	1.84	3.75
Falls Creek Mine	1.10	4.75
Adjacent Mining	1.70	17.15
Adjacent Mining	0.95	12.64

Some field water quality data was also available in the public file and is summarized in Table 9.6. The mine site named the “Roy Mine” is the Falls Creek Energy Co., Inc. permit where our LKFC-PA shale sample was collected. An Original Fuels, Inc. site located 3,000 feet north of the Roy Mine has a post-mining discharge from the toe of spoil. The discharge monitoring data from 19 water samples collected from December 1999 to May 2006 are summarized in Table 9.6. Alkalinity exceeded acidity in all 19 samples and the median alkalinity is 108 mg/l while

the median acidity is 11 mg/l. The spoil discharge quality in Table 9.6 is a product of leaching the Lower Kittanning shale and other rocks disturbed by mining. However, the overall field water quality displays characteristics similar to the column leach results, with the exception of iron. The field concentrations of Fe are greater than in the leach column.

Table 9.6 Postmining Spoil Water Quality From the Lower Kittanning Shale Sample Site(1)

Sample	Flow (gpm)	pH	Acidity	Alkalinity	Iron	Manganese	Aluminum
Post mining Minimum	0.3	5.7	0	62	6.99	22.6	<0.5
Post mining Maximum	0.8	6.8	89	258	24.3	52.9	0.66
Post mining Median			11	108			

(1) pH in S.U, Acidity and Alkalinity in mg/L $CaCO_3$ Eq, all others in mg/L.

Middle Kittanning Sandstone

The Middle Kittanning sandstone was known to have negligible sulfur content and relatively low NP, and hence was selected to serve as a "blank" in this interlaboratory study. The summary ABA data are contained in Table 9.7 and the raw data are found in Table 9.12. The first four splits in Table 9.12 were from the homogenization of the sample tested on January 16, 2003, and are relatively consistent in sulfur percent and NP. The highest sulfur content in Tables 9.7 and 9.12 is 0.15 and many of the unweathered and weathered samples are less than 0.10 percent. The only odd observation of the sulfur contents is in Lab 2 where the weathered sample had 0.15 percent, which is greater than the unweathered sample at 0.05 percent, and not plausible. In most cases there was little difference between the sulfur contents of the unweathered and weathered samples, or the different particle size classes. However, in Lab 7 the unweathered sample had 0.11 percent and the weathered sample had only 0.06 percent sulfur, indicating that about half of the sulfur was removed by weathering in the leaching column. The modified NP test was not done on these sample splits.

Table 9.7 Middle Kittanning Sandstone Summary ABA Data

Sample Treatment		N	%S			NP		
			Min	Mean	Max	Min	Mean	Max
MKSS-PA	Initial Standard NP	4	0.03	0.07	0.11	14.30	19.37	24.58
MKSS-PA	Splits Before Leaching	6	0.05	0.09	0.11	8.10	22.55	44.52
MKSS-PA	Splits After Leaching	16	0.02	0.09	0.15	0.00	31.30	72.25

The NP and fizz ratings for this relatively inert sandstone are very inconsistent and vary in ways that are not readily explainable. For example, original Split 2 was used in Lab 8 and when retested, the unweathered sample had less than half the NP of the original split. The fizz ratings range from 0 to 2, and the highest NP for the coarse size class at Lab 1 is 72.25, with a fizz rating of 1. The samples from Lab 5 show the biggest rational difference of NP depletion due to weathering, where the unweathered sample has an NP of 44.52 and the weathered sample has a NP of 12.77, but the NP of that unweathered sample is more than twice the magnitude of the original homogenization splits. Conversely, the unweathered sample used in Lab 3 had an unweathered NP of 8.10 when tested on January 24, 2006, and a weathered NP of 26.85 at the conclusion of the leaching column study when tested on May 4, 2006.

Summary and Conclusions

The ABA data discussed in this chapter show major differences in the total sulfur content and neutralization potential (NP) of the five rock samples used in the interlaboratory validation study of the ADTI-WP2 leaching column method. However, the problems with the NP and fizz rating data, in particular, and some of the total sulfur data demonstrate:

- the use of the conventional ABA method is not an exact science, and interpretive skills are still necessary to utilize ABA data for prediction,
- that the improved NP method should be fully implemented including the use of the insoluble residue test in place of the subjective fizz ratings,
- and that static test methods (e.g. ABA) need to be augmented by kinetic test methods in some cases to get better measures of expected acidity, alkalinity and metals concentrations and fluxes, and other relevant mine drainage data.

The difficulties noted with obtaining reproducible NP analysis are serous enough to affect the reliability of mine drainage quality prediction.

Supplemental Raw Data Tables

The raw data used in constructing Tables 9.1, 9.2, 9.3, 9.4 and 9.7 are contained in the following tables.

Table 9.8 Test results for Brush Creek Shale.

Rock Samples for ADTI-WP2 Interlaboratory Study							
Rock ID	**Split**	**Lab No. / Col No.**	**Total Sulfur %**	**NP (1978)**	**NP (1997)**	**Test date**	**Partical Size/ notes**
BCS3-PA	2		0.59	96.97	49.68	7/14/2005	original splits
BCS3-PA	6		0.59	96.96	49.31	7/14/2005	original splits
BCS3-PA	10		0.56	96.98	47.61	7/14/2005	original splits
BSC3-PA	15		0.59	96.97	47.07	7/14/2005	original splits
BSC3-PA		1 - unw					
BCS3-PA		1	0.64	78.67		6/30/2006	composite fizz 2
BCS3-PA		1	0.68	106.05		6/30/2006	3/8 to #4 fizz 2
BSC3-PA		1	1.09	55.03		6/30/2006	<#60 fizz 2
BCS3-PA	15	2 - unw	0.59	37.7		1/19/2006	
BCS3-PA	15	2 - 1	0.64	91.09		4/27/2006	fizz 3
BCS3-PA	15	2 - 2	0.61	96.47		4/27/2006	fizz 3
BCS3-PA	9	3 - unw	0.75	35.62		1/24/2006	fizz 1
BCS3-PA	9	3 - 1	0.67	48.64		5/4/2006	fizz 3
BCS3-PA	9	3 - 2	0.67	88.81		5/4/2006	fizz 3
BCS3-PA	14	4 - unw	0.60	89.30		1/6/2006	fizz 2
BCS3-PA	14	4 - 1	0.61	92.70		4/26/2006	fizz 3
BCS3-PA	14	4 - 2	0.57	67.98		4/26/2006	fizz 3
BCS3-PA	3	5 - unw	0.61	21.13		1/30/2006	fizz 0
BCS3-PA	3	5 - 1	0.48	29.03		6/7/2006	fizz 1
BCS3-PA	3	5 - 2	0.44	3.99		6/7/2006	fizz 1
BCS3-PA		6 - unw					
BCS3-PA		6 - 1	0.48	51.04		6/8/2006	#4 fizz 1
BCS3-PA		6 - 1	0.47	40.17		6/8/2006	#16 fizz 1
BCS3-PA		6 - 1	0.48	36.55		6/8/2006	#40 fizz 1
BCS3-PA		6 - 1	0.58	66.25		6/8/2006	#60 fizz 2
BCS3-PA		6 - 1	0.63	56.77		6/8/2006	<#60 fizz 2
BCS3-PA		6 - 2	0.48	44.51		6/8/2006	#4 fizz 1
BCS3-PA		6 - 2	0.46	42.89		6/8/2006	#16 fizz 1
BCS3-PA		6 - 2	0.51	39.54		6/8/2006	#40 fizz 1
BCS3-PA		6 - 2	0.63	42.27		6/8/2006	#60 fizz 1
BCS3-PA		6 - 2	0.56	38.24		6/8/2006	<#60 fizz 1
BSC3-PA	17	7 - unw	0.61	42.76		1/12/2006	fizz 1
BCS3-PA	17	7 - 1	0.52	51.02		6/9/2006	fizz 1
BCS3-PA	17	7 - 2	0.50	51.02		6/9/2006	fizz 1
BCS3-PA	12	8 - unw	0.63	41.43		1/12/2006	
BCS3-PA	12	8 - 1	0.63	64.51		6/26/2006	fizz 2
BCS3-PA	12	8 - 2	0.64	52.49		6/26/2006	fizz 2

Table 9.9. Test results for Houchin Creek Shale.

Rock Samples for ADTI-WP2 Interlaboratory Study							
Rock ID	Split	Lab No. / Col No.	Total Sulfur %	NP (1978)	NP (1997)	Test date	Partical Size/ notes
HCS-IN	5		5.27	41.85	41.05	7/14/2005	
HCS-IN	9		5.21	41.29	45.27	7/14/2005	
HCS-IN	16		4.73	45.87	47.55	7/14/2005	
HSC-IN	23		5.10	47.53	48.27	7/14/2005	
HSC-IN		1 - unw					
HCS-IN		1	5.74	34.69		6/30/2006	composite
HCS-IN		1	4.16	27.10		6/30/2006	3/8 to #4
HCS-IN		1	4.64	27.16		6/30/2006	< #60
HCS-IN	2	2 - unw	4.93	19.61		1/19/2006	
HCS-IN	2	2 - 1	5.38	9.92		4/27/2006	fizz 0
HCS-IN	2	2 -2	5.01	6.90		4/27/2006	fizz 0
HCS-IN	4	3 - unw	5.19	24.73		1/24/2006	
HCS-IN	4	3 - 1	5.31	2.30		5/4/2006	fizz 0
HCS-IN	4	3 - 2	5.09	5.32		5/4/2006	fizz 0
HCS-IN	1	4 - unw	5.38	22.20		1/6/2006	
HCS-IN	1	4 - 1	4.83	-8.06		4/26/2006	fizz 0
HCS-IN	1	4 - 2	4.87	-17.82		4/26/2006	fizz 0
HCS-IN	5	5 - unw	5.35	22.59		1/30/2006	
HCS-IN	5	5 - 5	5.00	-12.35		6/7/2006	fizz 0
HCS-IN	5	5 - 6	4.69	-13.46		6/7/2006	fizz 0
HCS-IN		6 - unw					
HCS-IN		6 - 5	5.05	15.60		6/8/2006	#4 fizz 0
HCS-IN		6 - 5	3.56	1.95		6/8/2006	#16
HCS-IN		6 - 5	3.37	-1.65		6/8/2006	#40
HCS-IN		6 - 5	4.12	-3.37		6/8/2006	#60
HCS-IN		6 - 5	5.81	-8.95		6/8/2006	<#60 fizz 0
HCS-IN		6 - 6	5.04	-7.07		6/8/2006	#4 fizz 0
HCS-IN		6 - 6	3.71	1.69		6/8/2006	#16 fizz 0
HCS-IN		6 - 6	2.99	-6.50		6/8/2006	#40 fizz 0
HCS-IN		6 - 6	3.53	-6.84		6/8/2006	#60 fizz 0
HCS-IN		6 - 6	5.98	-12.44		6/8/2006	<#60 fizz 0
HCS-IN	3	7 - unw	5.53	25.43		1/12/2006	
HCS-IN	3	7 - 5	4.88	13.03		6/9/2006	fizz 0
HCS-IN	3	7 - 6	4.61	17.65		6/9/2006	fizz 0
HCS-IN	15	8 - unw	5.14	26.53		1/12/2006	
HCS-IN	15	8 - 1	5.12	16.63		6/26/2006	fizz 0
HCS-IN	15	8 - 2	4.92	15.44		6/26/2006	fizz 0

Table 9.10 Test results for Kanawha Black Flint Shale.

Rock Samples for ADTI-WP2 Interlaboratory Study							
Rock ID	**Split**	**Lab No. / Col No.**	**Total Sulfur %**	**NP (1978)**	**NP (1997)**	**Test date**	**Partical Size/ notes**
KBF-WV	4		0.35	15.17	13.17	6/24/2005	
KBF-WV	7		0.30	16.76	13.34	6/24/2005	
KBF-WV	11		0.21	17.17	13.65	6/24/2005	
KBF-WV	14		0.32	18.69	14.26	6/24/2005	
KBF-WV		1 - unw					
KBF-WV		1	0.24	36.32		6/30/2006	composite fizz 1
KBF-WV		1	0.21	43.91		6/30/2006	3/8 to #4 fizz 1
KBF-WV		1	0.24	29.39		6/30/2006	< #60 fizz 1
KBF-WV	11	2 - unw	0.24	14.05		1/19/2006	
KBF-WV	11	2 - 1	0.31	14.85		4/27/2006	fizz 0
KBF-WV	11	2 - 2	0.29	10.62		4/27/2006	fizz 0
KBF-WV	6	3 - unw	0.39	17.28		1/24/2006	
KBF-WV	6	3 - 1	0.26	15.01		5/4/2006	fizz 0
KBF-WV	6	3 - 2	0.30	12.76		5/4/2006	fizz 0
KBF-WV	4	4 - unw	0.24	21.05		1/6/2006	
KBF-WV	4	4 - 1	0.24	12.14		4/26/2006	fizz 0
KBF-WV	4	4 - 2	0.26	11.44		4/26/2006	fizz 0
KBF-WV	10	5 - unw	0.27	16.09		1/30/2006	
KBF-WV	10	5 - 3	0.05	-39.21		6/7/2006	fizz 0
KBF-WV	10	5 - 4	0.08	315.62		6/7/2006	fizz 2
KBF-WV		6 - unw					
KBF-WV		6 - 3	0.12	32.23		6/8/2006	#4 fizz 1
KBF-WV		6 - 3	0.12	22.17		6/8/2006	#16 fizz 0
KBF-WV		6 - 3	0.10	20.43		6/8/2006	#40 fizz 0
KBF-WV		6 - 3	0.13	23.36		6/8/2006	#60 fizz 0
KBF-WV		6 - 3	0.11	20.16		6/8/2006	<#60 fizz 0
KBF-WV		6 - 4	0.13	54.35		6/8/2006	#4 fizz 1
KBF-WV		6 - 4	0.13	37.39		6/8/2006	#16 fizz 1
KBF-WV		6 - 4	0.10	34.00		6/8/2006	#40 fizz 1
KBF-WV		6 - 4	0.10	34.07		6/8/2006	#60 fizz 1
KBF-WV		6 - 4	0.13	32.45		6/8/2006	<#60 fizz 1
KBF-WV	12	7-unw	0.24	21.49		1/12/2006	
KBF-WV	12	7 - 3	0.12	19.87		6/9/2006	fizz 0
KBF-WV	12	7 - 4	0.16	19.99		6/9/2006	fizz 0
KBF-WV	9	8 - unw	0.25	21.39		1/12/2006	
KBF-WV	9	8 - 1	0.25	16.23		6/26/2006	fizz 0

Table 9.11 Test results for the Lower Kittanning Shale.

Rock Samples for ADTI-WP2 Interlaboratory Study							
Rock ID	Split	Lab No. / Col No.	Total Sulfur %	NP (1978)	NP (1997)	Test date	Partical Size/ notes
LKFC-PA	3		0.93	12.71	15.63	7/14/2005	
LKFC-PA	8		0.90	16.47	16.36	7/14/2005	
LKFC-PA	11		0.89	12.57	15.65	7/14/2005	
LKFC-PA	16		0.92	12.41	16.06	7/14/2005	
LKFC-PA		1 -unw					
LKFC-PA		1	1.04	16.15		6/30/2006	composite
LKFC-PA		1	1.17	16.59		6/30/2006	3/8 to #4
LKFC-PA		1	0.89	14.97		6/30/2006	< #60
LKFC-PA	14	2 - unw	0.88	12.86		1/19/2006	
LKFC-PA	14	2 - 1	0.96	17.18		4/27/2006	fizz 0
LKFC-PA	14	2 - 2	1.12	8.29		4/27/2006	fizz 0
LKFC-PA	2	3 - unw	1.00	9.74		1/24/2006	
LKFC-PA	2	3 - 1	0.99	5.84		5/4/2006	fizz 0
LKFC-PA	2	3 - 2	0.91	7.26		5/4/2006	fizz 0
LKFC-PA	3	4 - unw	0.94	17.20		1/16/2006	
LKFC-PA	3	4 - 1	0.85	4.83		4/26/2006	fizz 0
LKFC-PA	3	4 - 2	0.89	7.13		4/26/2006	fizz 0
LKFC-PA	13	5 - unw	0.97	9.58		1/30/2006	
LKFC-PA	13	5 - 7	0.74	16.87		6/7/2006	fizz 0
LKFC-PA	13	5 - 8	0.77	5.19		6/7/2006	fizz 0
LKFC-PA		6 - unw					
LKFC-PA		6 - 7	0.81	15.62		6/8/2006	#4 fizz 0
LKFC-PA		6 - 7	0.79	15.77		6/8/2006	#16 fizz 0
LKFC-PA		6 - 7	0.71	12.72		6/8/2006	#40 fizz 0
LKFC-PA		6 - 7	0.69	15.08		6/8/2006	#60 fizz 0
LKFC-PA		6 - 7	0.68	13.91		6/8/2006	<#60 fizz 0
LKFC-PA		6 - 8	0.81	16.50		6/8/2006	#4 fizz 0
LKFC-PA		6 - 8	0.75	14.14		6/8/2006	#16 fizz 0
LKFC-PA		6 - 8	0.69	14.81		6/8/2006	#40 fizz 0
LKFC-PA		6 - 8	0.70	15.90		6/8/2006	#60 fizz 0
LKFC-PA		6 - 8	0.63	13.36		6/8/2006	<#60 fizz 0
LKFC-PA	7	7 - unw	1.13	14.41		1/12/2006	
LKFC-PA	7	7 - 7	0.85	13.80		6/9/2006	fizz 0
LKFC-PA	7	7 - 8	0.70	12.95		6/9/2006	fizz 0
LKFC-PA	6	8 - unw	0.96	13.25		1/12/2006	
LKFC-PA	6	8 - 1	0.91	14.14		6/26/2006	fizz 0
LKFC-PA	6	8 - 2	0.88	14.37		6/26/2006	fizz 0

Table 9.12. Test results for the Middle Kittanning Sandstone.

Rock Samples for ADTI-WP2 Interlaboratory Study							
Rock ID	**Split**	**Lab No. / Col No.**	**Total Sulfur %**	**NP (1978)**	**NP (1997)**	**Test date**	**Partical Size/ notes**
MKSS-PA	2		0.08	20.90		1/16/2003	
MKSS-PA	8		0.04	17.70		1/16/2003	
MKSS-PA	12		0.03	14.30		1/16/2003	
MKSS-PA	6		0.11	24.58		1/6/2006	
MKSS-PA		1 - unw					
MKSS-PA		1	0.07	47.30		6/30/2006	composite fizz 1
MKSS-PA		1	0.10	72.25		6/30/2006	3/8 to #4 fizz 1
MKSS-PA		1	0.12	38.84		6/30/2006	< #60 fizz 1
MKSS-PA	4	2 - unw	0.05	26.76		1/19/2006	
MKSS-PA	4	2 - 1	0.15	28.45		4/27/2006	fizz 2
MKSS-PA	7	3 - unw	0.11	8.10		1/24/2006	
MKSS-PA	7	3 - 1	0.09	26.85		5/4/2006	fizz 2
MKSS-PA	6	4 - unw	0.11	24.58		1/16/2006	
MKSS-PA	6	4 - 1	0.11	28.85		4/26/2006	fizz 2
MKSS-PA	3	5 - unw	0.07	44.52		1/30/2006	
MKSS-PA	3	5 - 9	0.08	12.77		6/7/2006	fizz 1
MKSS-PA		6 -unw					
MKSS-PA		6 - 9	0.05	0.00		6/8/2006	3/8 no fizz/no NP?
MKSS-PA		6 - 9	0.05	41.76		6/8/2006	#4 fizz 1
MKSS-PA		6 - 9	0.06	27.99		6/8/2006	#16 fizz 1
MKSS-PA		6 - 9	0.00	39.00		6/8/2006	#40 fizz 2
MKSS-PA		6 - 9	0.14	35.33		6/8/2006	#60 fizz 1
MKSS-PA		6 - 9	0.02	33.18		6/8/2006	<#60 fizz 1
MKSS-PA	1	7 - unw	0.11	21.18		1/12/2006	
MKSS-PA	1	7 - 9	0.06	26.40		6/9/2006	fizz 1
MKSS-PA	2	8 - unw	0.10	10.13		1/12/2006	
MKSS-PA	2	8 - 1	0.09	-0.19		6/26/2006	fizz 0
MKSS-PA	2	8 - 2	0.08	10.50		6/26/2006	fizz 0