AN APPLICATION OF ACID-BASE ACCOUNTING FOR HIGHWAY CONSTRUCTION IN EAST TENNESSEE[1]

by

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Abstract. Concern over the environmental impact of highway construction on the foothills Scenic Parkway in east Tennessee prompted the use of acid-base accounting to evaluate overburden rocks. Samples were acquired during active construction to evaluate the acid producing potential of the overburden. A core was provided representing the middle portion of the overburden for acid-base accounting and mineralogical analyses. Substantial quantities of pyrite were noted in a few zones in the overburden. Most of the overburden contained sufficient neutralizers to neutralize the potential acidity if the overburden was blended in the fill during construction. Higher neutralization potential values in the overburden were directly related to the relative proportion of dolomite detected in the samples.

Additional key words: acid-base accounting, highway construction, east Tennessee.

Introduction

The Tennessee Department of Transportation (TDOT) had expressed concern that acidity problems might be encountered during the construction of the Foothills Scenic Parkway in East Tennessee (Fig. 1). These concerns were based on sporadic vegetation failures observed on the previously completed section of the parkway.

Certain sections of the precambrian rocks of east Tennessee contain pyrite (FeS_2), (Byerly and Middleton, 1981) and the oxidation of pyrite will result in the formation of acidity. Drastic land disturbances, such as highway construction, expose iron disulfide to the air and water necessary to promote the following reaction presented in a simplified form:

$$4FeS_2 + 15O_2 + 14H_2 \text{ ----> } 4Fe(OH)_3 + 8H_2SO_4$$

The production of sulfuric acid affects water and soil quality. Minerals are dissolved in the acid environment developed during the oxidization process, and elements are mobilized in the soil which could impact water quality in the immediate watershed.

Jago and Byerly (1988) conducted a leaching study on pyritic precambrian rocks containing pyrite in east Tennessee. Using acid-base accounting, they established that the acid-producing potential for the material under evaluation was 23.7 tons per 1000 tons material ($CaCO_3$ equivalent). They concluded that additions of interlayer lime to fill material improved the leachate quality.

The objectives of this study were to identify the acid producing strata in the overburden core and to access the environmental impact for revegetation and water quality.

Materials and Methods

Several samples were analyzed from the active construction site to assess whether the overburden had acid-producing potential. An overburden core was provided by TDOT from the geologic section affected during construction. Water quality sampling stations were in place to monitor

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chemical parameters for pre-construction, active-construction, and post-construction phases of the project.

The first sampling was completed on-site during active construction. Six samples were removed at random from disposal piles. Different rock types were selected to determine if materials placed in the fill were potentially toxic. The Tennessee Department of Transportation provided a thirty-two foot section of the overburden for laboratory analyses. The upper twenty-five feet of the core was not sampled. The overburden core and the pile sample sites were located near Caylor Gap on the Wear Cove, Tennessee Geologic Quadrangle (Fig. 1).

Both overburden core and pile samples were ground to less than 60 mesh and were analyzed using acid-base accounting (Smith et al. 1974; Sobek et al. 1978). Total sulfur values were used to calculate the acid-base account. The neutralization potential followed the guidelines presented by Shelton et al. (1984).

Mineralogical analyses were conducted on the overburden core samples. Ground samples (less than 60 mesh) were placed in metal powder sample holders and scanned from 2 degrees to 60 degrees 2 theta using copper (k) alpha radiation (McMurdie et al. 1986).

Water quality has been monitored since the inception of the construction on the parkway. Station I (Fig.1) is a water monitoring sampling station in the watershed draining Caylor Gap where the overburden core and the pile samples were collected. Data reported are an average of twelve months for each year.

Results and Discussion

Preliminary sampling

Results from the pile samples obtained during active construction are reported in Table 1. The rocks were identified as part of the Anakeesta formation, Precambrian age, from the Great Smokey Mountain Group. The Anakeesta formation consists of "dark gray, bluish-gray, black slates with interbeds of fine-grain sandstone" (Hardeman 1966). Three of the pile samples were potentially toxic (Table 1). Samples showing a deficiency of 5 tons/1000 tons material ($CaCO_3$ equivalent) are considered potentially toxic (Smith et al. 1974; Sobek et al. 1978).

Overburden Analysis

All of the samples contained a significant concentration of total sulfur (>0.4%) (Table 2). In most samples, sufficient neutralizers were present to counteract potential acidity.

Potentially toxic zones were found at depths of 30 to 37 feet and 47 to 52 feet (Table 2 and Fig. 2). The potentially toxic

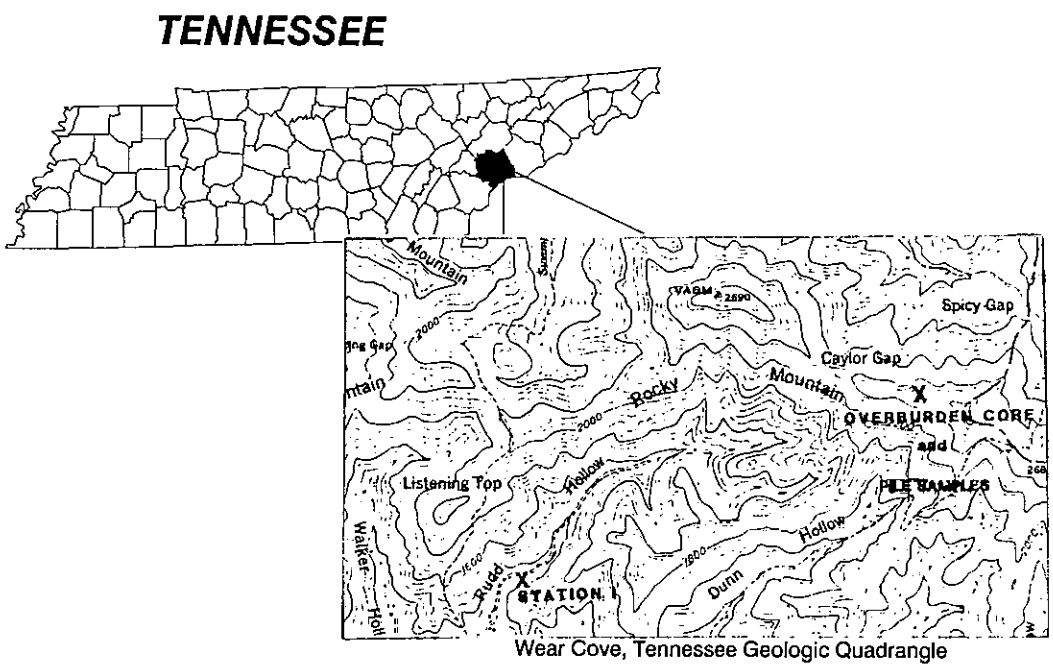

Figure 1. Location of Overburden Core, Pile Samples, and Water Monitoring Station on the Foothills Scenic Parkway.

Table 1. Acid-Base Account of Grab Samples. Foothills Scenic Parkway.

Sample Number	Paste pH	Munsell Color	Fizz	Percent Sulfur	$CaCO_3$ equivalents (tons/1000 tons material) Max From Sulfur	N.P.	Deficiency	Excess
1	5.8	2.5Y6/0	None	.063	1.98	1.03	.95	
2	5.4	5Y8/1	None	.019	.58	.11	.47	
3	7.4	5Y6/1	Slight	.031	.96	1.03		.07
4	6.2	2.5Y6/0	Slight	2.149	67.16	2.86	64.30	
5	7.3	2.5Y7/0	Slight	.684	21.38	.92	20.46	
6	7.0	2.5Y6/0	Slight	2.358	73.69	2.86	70.83	

rocks were sandstone conglomerates with a dark shale-slate intercalate. Pyrite was visually confirmed between the bands of shaly slate and the sandstone conglomerate with the aid of a 10X hand lens. Revegetation and water quality problems can be anticipated if the potentially toxic materials are deposited on the surface.

The physical stability of the pyrite containing rocks were not evaluated in this study, but the rapidity of rock disintegration in the fill indicates that water quality and revegetation may be impacted. Future studies on the Precambrian rocks in east Tennessee should include physical stability and\or weatherability evaluations. If these rocks are resistant to physical and chemical breakdown in the construction fill, products from the oxidation of pyrite will be minimized. This will enhance success of revegetation and reduce affect on water quality in the watershed. A rapid, chemical and physical breakdown may affect the stability of the fill plus increase surface area which will increase oxidation reactions in rocks containing pyrite.

Mineralogy

Primary minerals present in the overburden samples were chlorite, muscovite, orthoclase, quartz, and dolomite (Table 3). Pyrite was not detected in the x-ray analysis. Samples containing less than 10% dolomite were potentially toxic (Table 2). The presence of dolomite contributed heavily to the high NP values. In the absence of dolomite, the NP's are low. The dolomite is probably responsible for the majority of the bases in these overburden rocks.

Water Quality

Sulfate and magnesium concentrations in the water varied over the five-year period (Fig. 3), but showed a slight increase. The variation in sulfate was probably due to differences in rainfall over the five-year period. The increase in magnesium concentrations were probably related to weathering of dolomite in the fill.

Conclusions

Substantial quantities of pyritic

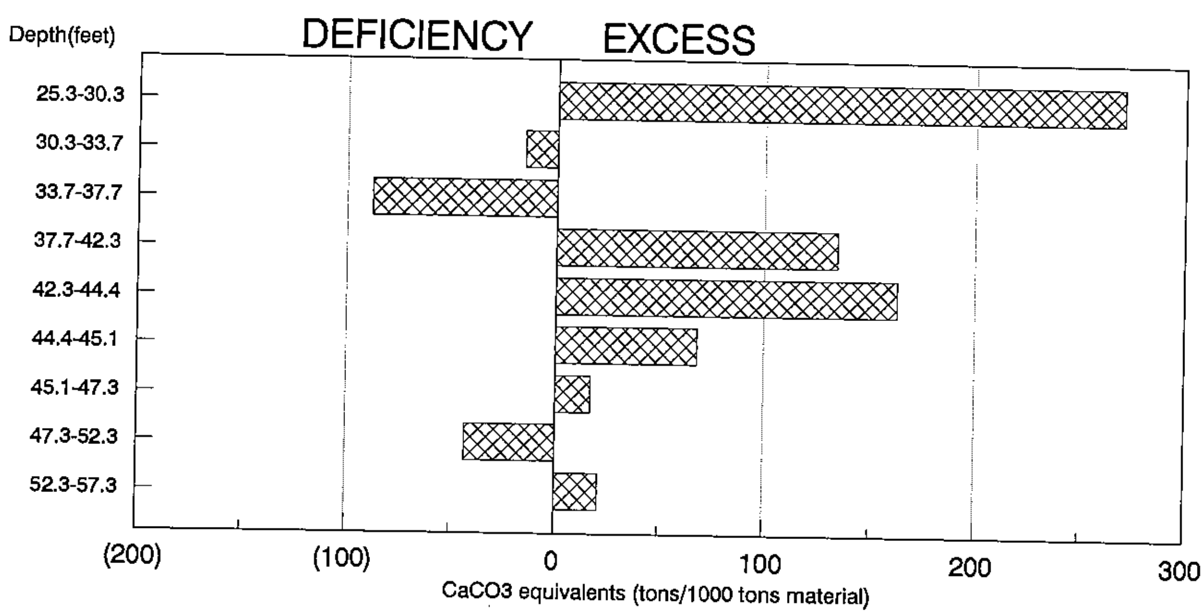

Figure 2. Acid-Base Account of Foothills Parkway Overburden Core.

Table 2. Acid-Base Account of Overburden Core. Foothills Scenic Parkway.

Sample Number	Depth	Munsell Color	Fizz	Percent Sulfur	Max From Sulfur	N.P.	Deficiency	Excess
				$CaCO_3$ equivalents (tons/1000 tons material)				
	ft							
1	25.3-30.3	N 6/0	Strong	.843	26.35	297.43		271.08
2	30.3-33.7	N 6/0	Slight	.717	22.40	7.00	15.40	
3	33.7-37.3	N 5/0	Slight	2.840	88.88	1.00	87.88	
4	37.3-42.3	N 6/0	Strong	.674	21.07	155.38		134.31
5	42.3-44.4	N 5/0	Strong	1.160	36.25	199.09		162.84
6	44.4-45.1	N 5/0	Moderate	.810	25.31	93.47		68.16
7	45.1-47.3	N 5/0	Moderate	1.443	45.09	61.90		16.81
8	47.3-52.3	N 5/0	Moderate	2.853	89.16	46.12	43.04	
9	52.3-57.3	N 5/0	Moderate	.925	28.91	49.76		20.85

Table 3. Summary of Mineralogical Analyses for Overburden Core. Foothills Scenic Parkway.

Sample	Depth	Chlorite[1]	Muscovite[2]	Orthoclase[3]	Dolomite[4]	Quartz[5]
		Minerals Present				
	ft	Approx. Percentage				
1	25.3-30.3	20-30	10-20	ND	10-30	>30
2	30.3-33.7	ND	10-20	20-30	ND	>30
3	33.7-37.3	ND	20-30	20-30	ND	>30
4	37.3-42.3	ND	10-20	20-30	10-20	>30
5	42.3-44.4	ND	20-30	20-30	20-30	>30
6	44.4-45.1	ND	20-30	10-20	10-20	>30
7	45.1-47.3	ND	20-30	10-20	10-20	>30
8	47.3-52.3	ND	20-30	10-20	10-20	>30
9	52.3-57.3	ND	20-30	10-20	<10	>30

[1] - Chlorite - $(Fe,Al,Mg)_6(Si,Al)_4O_{10}(OH)_8$

[2] - Muscovite - $KAl_2(Si_3,Al),O_{10}(OH,F)_2$

[3] - Orthoclase - $KAlSi_3O_8$

[4] - Dolomite - $Ca,Mg(Co_3)_2$

[5] - Quartz - SiO_2

materials are present in the Precambrian rocks studied on the Foothills Scenic Parkway. Byerly and Middleton (1981) reported acid-base account values for potentially deleterious rocks southwest of the Great Smoky Mountains in Monroe County, Tennessee. Values in this study ranged from a deficiency of 7.69 to 42.88 calcium carbonate equivalent (tons/1,000 tons material). This is compared to samples from the Foothills Parkway where the pile samples ranged from an excess of .07 to a deficiency 70.83 and the overburden samples ranged from an excess of 271.08 to a deficiency of 87.88 calcium carbonate equivalent (tons/1,000 tons material). Most zones in the overburden tested on the Foothills Parkway contain sufficient quantities of basic materials to neutralize potential acidity in the fill if the materials are blended. This is supported, in part, by results reported by Jago and Byerly (1988). In a pyritic material encapsulation study involving Precambrian rocks, they found the best leachate quality was achieved by interlayering limestone with the fill material.

Higher NP values in the Foothill's study are directly related to the relative proportion of dolomite detected in the samples. This is probably responsible for elevated levels of magnesium in the water quality samples.

The following are suggested guidelines to accomplish the best post-construction environmental quality:

1. Complete an overburden analysis (acid-base accounting) on the geologic section to be removed during construction.

2. During construction, monitor overburden for changes in depth or sequence of acid-toxic rocks.

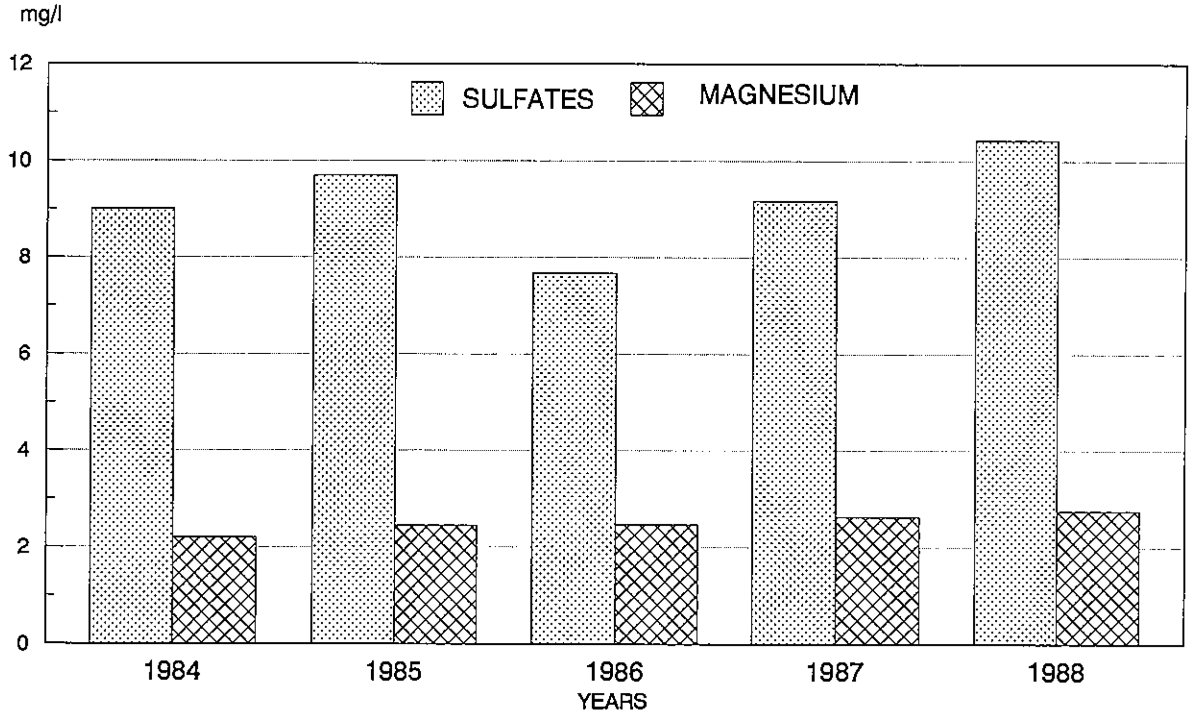

Figure 3. Five-Year Average of Sulfate and Magnesium Water Quality Data.

Station I, Foothills Scenic Parkway.

3. Examine older fills constructed from the same geologic materials for presence of acid-toxic rocks and vegetation success.

4. Study the physical stability of overburden rocks under controlled experimental conditions.

5. Monitor water quality in watersheds affected by construction activities.

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