

A mining research contract report  
JULY 1982



# COAL WASTE DISPOSAL SURVEY. COAL REFUSE—AN INCREASINGLY SERIOUS PROBLEM FOR COLORADO PLATEAU PRODUCTION

Contract J0333931  
Plant Resources Institute

BUREAU OF MINES  
UNITED STATES DEPARTMENT OF THE INTERIOR

OFR  
84-97



U. S. Bureau of Mines  
Minneapolis, Minn.

MAR 26 1985

LIBRARY

N O T I C E

This report was completed under a contract to the U.S. Department of Energy (DOE). Responsibility for the program to which the report relates has recently been transferred to the Bureau of Mines, U.S. Department of the Interior, and the report is made public under a Bureau cover. Inquiries concerning the report should be directed to the Bureau.

The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies or recommendations of the Interior Department's Bureau of Mines or of the U.S. Government.

ERPOTRD O C U M E N T A T I O N R E P O R T N O . P A G E		2.	3. Recipient's Accession No.
4. Title and Subtitle Coal Waste Disposal Survey (Coal Refuse-An Increasingly Serious Problem for Colorado Plateau Production)		5. Report Date July 1982	
7. Author(s) Susan M. White, W. Kent Ostler and Cyrus McKell		6.	
9. Performing Organization Name and Address Plant Resources Institute 360 Wakara Way University Research Park Salt Lake City, UT 84108		8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address U.S. Bureau of Mines Pittsburgh Research Center P.O. Box 18070 Pittsburgh, PA 15236		10. Project/Task/Work Unit No.	
		11. Contract(C) or Grant(G) No. (C) J0333931 (G)	
		13. Type of Report & Period Covered Final	
15. Supplementary Notes		14.	
16. Abstract (Limit: 200 words)  Increased coal production, wider use of indiscriminate mining techniques, improved cleaning methods, and greater emphasis on clean fuels is increasing the rate at which wastes accumulate. Over the next several years, Colorado Plateau underground coal production is predicted to increase. Currently, mine refuse is deposited in canyons or lowland areas near mines. This study presents information on the nature of coal refuse and disposal practices on the Colorado Plateau. Samples were collected and analyzed to provide information to help formulate alternative methods for reclaiming refuse piles. The analyses were based on determining the capability of unmodified refuse to provide a suitable medium for plant growth. Local topsoils which would be used in reclamation were used as standards. Potential environmental hazards were assessed also. A general cost analysis was done for both surface and underground disposal and the advantages and disadvantages of each were assessed. Several problems were identified which, if solved, would increase the effectiveness of state regulatory programs.			
17. Document Analysis a. Descriptors  Coal Mining Mine Waste Disposal Colorado Plateau  b. Identifiers/Open-Ended Terms    c. COSATI Field/Group			
18. Availability Statement  Unlimited		19. Security Class (This Report) Unclassified	21. No. of Pages 64
		20. Security Class (This Page) Unclassified	22. Price

## FOREWORD

This report was prepared by the Plant Resources Institute of Salt Lake City, UT, under USBM contract number J0333931. The contract was initiated by the Department of Energy and subsequently transferred to the Bureau of Mines under the Conservation and Development program. It was administered under the technical direction of the Pittsburgh Research Center with Anthony J. Miscoe acting as Technical Project Officer. Karen S. Hatters was the Contract Administrator for the Bureau of Mines. This report is a summary of the work completed as a part of this contract during the period September 28, 1981 and September 30, 1982. This report was submitted by the authors in July 1982.

## FOREWORD

This report was prepared by the Plant Resources Institute of Salt Lake City, UT, under USBM contract number J0333931. The contract was initiated by the Department of Energy and subsequently transferred to the Bureau of Mines under the Conservation and Development program. It was administered under the technical direction of the Pittsburgh Research Center with Anthony J. Miscoe acting as Technical Project Officer. Karen S. Hatters was the Contract Administrator for the Bureau of Mines. This report is a summary of the work completed as a part of this contract during the period September 28, 1981 and September 30, 1982. This report was submitted by the authors in July 1982.

COAL REFUSE - AN INCREASINGLY SERIOUS  
PROBLEM FOR COLORADO PLATEAU COAL PRODUCTION

Prepared For:

Department of Energy  
Division of Coal Mining  
FE - 24  
Washington, D. C. 20545

Prepared by:

Susan M. White, W. Kent Ostler, and  
Cyrus McKell  
Plant Resources Institute  
360 Wakara Way  
Universtiy Research Park  
Salt Lake City, Utah 84108

July 1982

## TABLE OF CONTENTS

<u>Title</u>	<u>Page Number</u>
Introduction	1
Methods	3
Results and Discussion	7
Suitability of Refuse as a Growth Medium	7
Environmental Analysis	26
Comparison of Surface vs. Underground Disposal of Refuse	27
Alternative Methods for Reclamation	30
Analysis of Individual Mines	32
Conclusions	59
Literature Cited	61

## INTRODUCTION

Increased coal production, wider use of indiscriminate mining techniques, improved cleaning methods, and greater emphasis on clean fuels is increasing the rate at which wastes accumulate. A vivid example of this trend is a 10-fold increase in the rate at which wastes have been produced since 1940. It has been estimated that the current rate of waste production of 100 million tons per year will double by 1980 according to a National Academy of Sciences study committee (1975). Added to the present accumulation, this material can no longer be merely discarded in convenient places. Indiscriminate disposal of coal wastes will not be accepted by a concerned populace.

Over the next several years, Colorado Plateau underground coal production is predicted to increase. Refuse resulting from preparation of this coal is generally deposited on the surface in unsightly disposal piles in canyons or lowland areas near mines. Current legal environmental disposal regulations are unclear to mine operators with regard to coverage of these disposal piles and need to be reevaluated and revised. This study provides valuable information on the nature of coal refuse and disposal practices throughout the Colorado Plateau. From refuse samples collected from mines in Utah and Colorado, physical and chemical analyses were performed to provide information on which to formulate alternative methods for reclaiming refuse piles as contrasted with present regulations.

The objectives of the present study were to test the hypothesis that unmodified refuse material from underground coal processing is a suitable medium for plant growth. In order to measure refuse material suitability from a physiochemical perspective, we analyzed the new refuse and old refuse material for (1) existing macronutrients, (2) salts, (3) texture, (4) acidity

and (5) color. At each mine, topsoil which will be used in reclaiming the refuse piles was used as the standard for comparison. We also attempted to assess any potential environmental hazards associated with the refuse piles such as its potential for polluting ground and surface waters, spontaneous combustion, acid seepage, etc. Finally, we conducted a general cost analysis for surface disposal of refuse and underground disposal and the advantages and disadvantages of each.

As a result of the study, several problems were identified which, if solved, would increase the effectiveness of formulation and implementation of state regulatory programs. These problem areas were discussed with state regulatory agency personnel in Utah and Colorado prior to preparation of the final draft of this report.

## METHODS

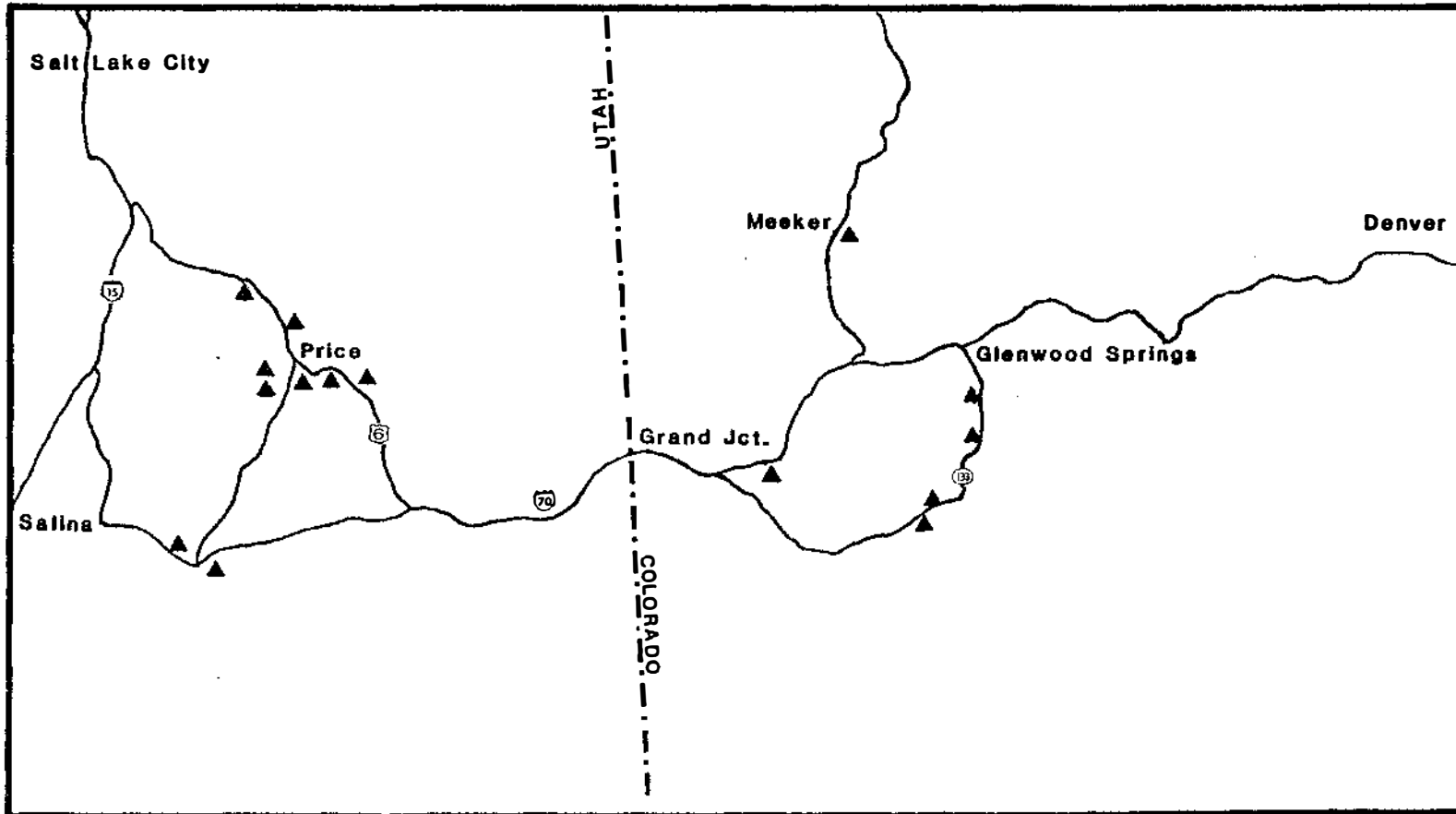
The study area included all underground mines which have coal refuse piles within the Colorado Plateau (Figure 1). The names and locations of more than 20 underground coal mines were obtained from the Department of Oil, Gas, and Mining (DOG M) in Utah and the Division of Mine Land Reclamation in Colorado. However, only 15 mines agreed to participate in this study. Three allowed sampling but requested that their company names be withheld from any publications. The non-participating mines were found to be either inactive or unwilling to allow sampling on their property.

Samples were collected from 3 representative locations at each topsoil and refuse pile. A 0-15 cm composite sample was collected at each location. In addition, a 15-30 cm composite sample was collected at each location on old refuse piles.

Each of the participating mines were visited and the refuse areas were observed for size and extent of refuse and topsoil storage piles, drainage and stream patterns surrounding the pile, rill development, sluffage, slope, and plant invasion on the refuse pile. Reclamation engineers were questioned concerning expected reclamation problems such as topsoil deficiencies and availability of water for plant establishment.

All topsoil and refuse samples were analyzed for pH, electrical conductivity (EC), and texture. Soil and refuse from 5 selected mines were also analyzed for nitrate-nitrogen ( $\text{NO}_3\text{-N}$ ), phosphorus ( $\text{PO}_4$ ), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), chlorine (Cl), sulfate ( $\text{SO}_4$ ), bicarbonate ( $\text{HCO}_3$ ), boron (B), and organic matter. Only samples from 5 selected mine sites could be analyzed for all of the above chemical parameters because of limited funding for the analysis.

Figure 1. The study area included underground mines in the Colorado Plateau. Each triangle represents a sampling location.



Topsoil and refuse analysis for K, Na, Ca, Mg, Cl, SO<sub>4</sub>, HCO<sub>3</sub>, total B and total K were performed by Western Analytical Inc., a certified laboratory located in Salt Lake City, Utah. Exchangeable K, Na, Ca, Mg, Cl, SO<sub>4</sub>, and HCO<sub>3</sub> were all analyzed by methods described in the Association of Official Agricultural Chemists (1965). Chemical analysis for B was digested by fusing sodium carbonate with sodium peroxide, and analyzed by ICP. Nitric-perchloric acid was used to digest soils for total K which was then determined by atomic absorption analysis.

Analysis for EC, NO<sub>3</sub>-N, organic matter, texture, pH and P were performed by Native Plants, Inc. Analytical Soils Laboratory. EC was determined on a 1:1, soil:water extract (Richards et al., 1954). NO<sub>3</sub>-N was analyzed by a chematropic acid procedure (Clark and Jennings, 1965). The Walkely Black method was used to determine organic matter (Allison, 1965) and P was determined by colorimetrically - NaHCO<sub>3</sub> extractable (Olsen et al., 1954). Acidity (pH) was analyzed using a 1:1, soil:water extract (Schofield and Taylor, 1955) and measured using a Corning 125 pH meter. Particle size analysis was performed on all material passing through a 2mm sieve by the hydrometer method (Day, 1965). The sodium absorption ratio (SAR) was calculated from the following equation:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

The data was summarized and a short presentation of quantitative and qualitative findings was prepared separately for each mine. The soil and refuse data were then summarized across mines by topsoil, new refuse, and old refuse (0-15 cm; 15-30 cm), with means and standard errors calculated.

Paired t-tests were conducted on all soil and refuse quantitative data (Steel and Torrie, 1960). Significance was determined at  $\alpha = .05$  level.

Linear regression analysis was conducted using age of the refuse as the dependent variable and pH as the independent variable. A second linear regression was conducted using pH of the refuse as the dependent variable and  $\text{HCO}_3$  and  $\text{SO}_4$  as the independent variable.

Surface refuse disposal costs and feasibility were compared with underground waste disposal by reviewing existing literature. Several mines that dispose of rock waste underground were contacted; however, this waste is never brought above ground. No mines within the Colorado Plateau process coal above ground and then dispose of the processed waste back underground; therefore, a literature review was used to compare underground disposal costs.

Soil spreading and hauling costs were obtained from the DOGM. These are a median value for bond estimating costs.

## RESULTS AND DISCUSSION

Each mine in this study was unique as to the varied set of circumstances under which it operates and exists. It was therefore not surprising to find a high degree of variability in sample results between mines. The range in plant nutrient values for topsoil and refuse is given in Table 1. Refuse material from the mines was produced by a number of different cleaning or processing methods such as: baths with heavy-media solutions, froth flotation, water washers, jigs, cyclones or simple crushing and sieving. Refuse was derived from different geologic strata. The mines also varied in age (4 years to over 100 years old) and subsequently the amount of refuse on the property varied greatly. Elevation at the various sites ranged from 1479m to 2440m and annual precipitation that would directly affect reclamation practices ranged from 20 cm to 64 cm. Topsoil available for use in reclamation of the refuse piles varied from a rich mountain loam to a clayey material derived from Mancos shale.

### Suitability of Refuse as a Growth Medium

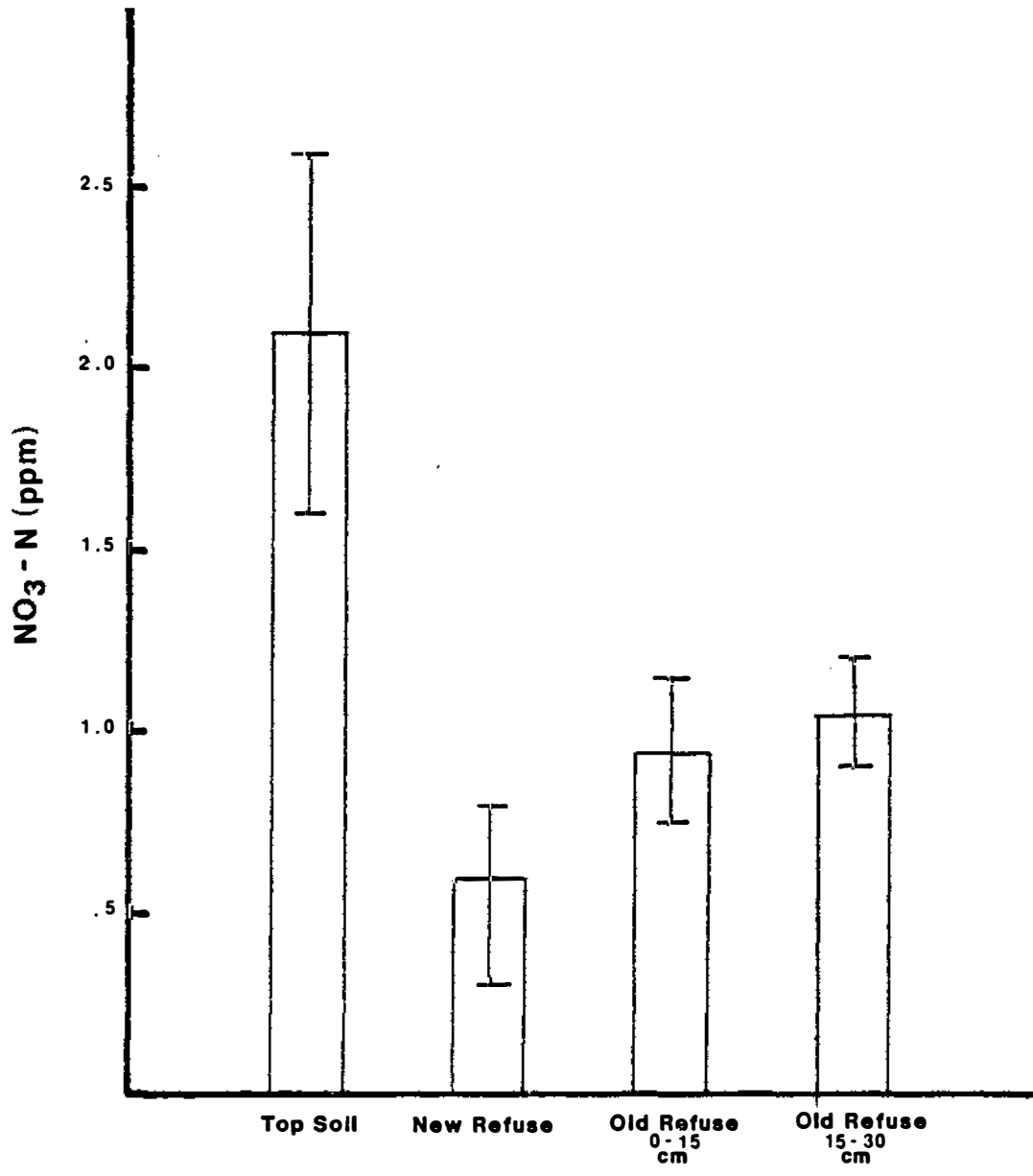
#### *Macronutrients*

Nitrate-nitrogen content of the new refuse material was significantly lower than the topsoil ( $T = 2.76$ ,  $\alpha < .05$ ). The nitrate-nitrogen content of the old refuse material was lower than the topsoil and higher than the new refuse (Figure 2); although, paired t-tests showed no significant differences. A possible explanation for this difference is the availability of nitrate at differing pH's and varying aeration regimes. Nitrogen is most available at a pH between 6.0 and 8.0. The pH of the four mines averaged 8.48 for the new refuse material and 6.89 for the older refuse, thus allowing greater availability of nitrogen at a pH of 6.89. Higher  $\text{NO}_3$  concentrations may

Table 1. The range in plant nutrient values found in topsoil, new refuse, and old refuse. Values are also given for soils on which agricultural crops are grown.

Parameter	Top Soil	New Refuse	Old Refuse	Agricultural Range
NO <sub>3</sub> -N (ppm)	1.50 - 3.95	0.70 - 0.90	0.65 - 1.50	2-60 ppm
P (ppm)	0.06 - 1.57	0.05 - 0.10	0.07 - 0.74	>5 ppm
K (meq/100g)	0.32 - 0.88	0.09 - 0.44	0.13 - 0.29	>.13
EC	0.06 - 3.0	0.2 - 1.76	0.06 - 2.86	<4
Ca (meq/100g)	14.0 - 39.9	13.0 - 46.4	20.5 - 175.0	
Na (meq/100g)	0.20 - 2.56	0.20 - 4.26	0.20 - 0.37	
Mg (meq/100g)	1.23 - 7.98	0.57 - 1.97	0.95 - 2.30	>.41
B (ppm)	22 - 66	18 - 61	26 - 224	2-100
Cl (meq/100g)	<0.001 - 0.601	<0.001 - 0.313	0.013 - 0.106	
SAR	0.23 - 1.65	0.13 - 3.62	0.07 - 0.30	<13
pH	6.43 - 9.27	7.10 - 9.92	2.94 - 9.47	5.5-8.0
HCO <sub>3</sub> (meq/100g)	0.0033 - 0.0098	0.0072 - 0.0140	0.0021 - 0.0100	
SO <sub>4</sub> (meq/100g)	0.03 - 15.70	0.62 - 26.30	0.06 - 129.80	

Figure 2. Means and standard error of nitrate-nitrogen content. Values represent 5 samples.



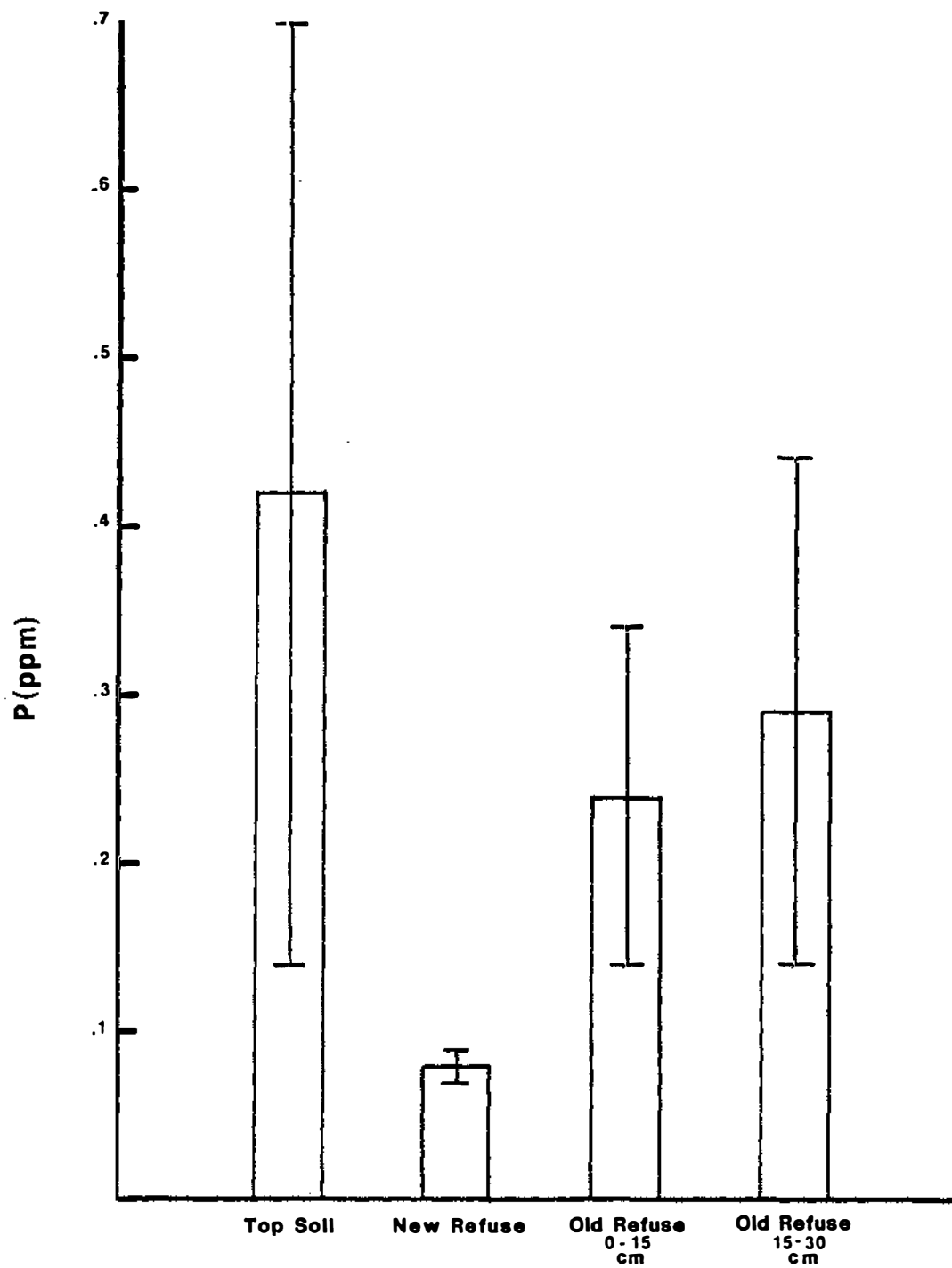
also reflect a lesser degree of compaction, which wasn't quantified in this study.

As expected, phosphorus content of the refuse material tended to be lower than levels in topsoil, although paired t-tests and ANOVA showed no significant differences (Figure 3). The lack of statistical significance was probably due to small sample size. New refuse material contained less water soluble phosphorus than the older refuse material. Again, this appears to be a function of pH. Phosphorus is more available at a pH between 6.50 and 7.50. At higher pH's typical in the new refuse, phosphorus is less available. Agricultural soils which contain less than 5 ppm soluble phosphorus are considered deficient and are generally fertilized to improve yields (Bingham, 1966). Both the topsoil and refuse materials of the study sites are below 5 ppm ( $\bar{X} = .25$  ppm) and may benefit from the addition of phosphorus fertilizer to aid plant growth.

Although the nutrient requirements of native speices is not well documented, they are generally less than that of agricultural crops and minimal levels for agriculture may be sufficient for native species. N and P nutrient deficiencies have also been reported on coal spoils in the Northern Great Plains regions (Bauer et al., 1978). Fertilization experiments on spoils for revegetation have had varied results. In one experiment, fertilization was shown to increase shrub vigor ratings but overall survival of P fertilized and nonfertilized shrubs was not statistically different. In another experiment on spoils in North Dakota, N fertilization was shown to increase grass and legume yields while P fertilization had no effect.

Agriculture crops generally show a response to potassium fertilizer on the soils containing less than 50 ppm potassium (Ulrich and Ohki, 1966). Only one sample of coal refuse analyzed indicated potassium to be under this level and this was found in a new refuse material sample (.320 meq/

Figure 3. Means and standard error of phosphorus content. Values represent 5 samples.



100g or 34 ppm). Old refuse material contained significantly less potassium than the topsoil ( $T = 3.37$ ,  $\alpha < .05$ ). New refuse material also contained less potassium than the topsoil but more than the older refuse material (Figure 4). Although potassium levels are less in the refuse materials, there still appears to be a sufficient amount to meet the requirements for native species. pH is not a factor in K availability in the range of pH's that were common to the samples.

### *Salts*

Salts, as measured by EC, calcium, sodium, magnesium, boron, chlorine, and SAR in the refuse material, all appear to be within normal plant tolerance ranges. EC values for all refuse material ranged from .06 to 3.0 (Figure 5). From an agricultural standpoint, soil is not considered saline if the EC value is below 4.0. Old refuse material in the 15-30 cm depth had a significantly greater EC value than the topsoil ( $T = 2.20$ ,  $\alpha < .05$ ); although, values are still within normal plant tolerance range. Older refuse material also had a significantly greater EC value (1.23) than the new refuse (0.71) ( $T = 2.01$ ,  $\alpha < .05$ ). Higher EC values for the older refuse material may be due to capillary rise of salts over time.

Sodium content of the topsoil and new refuse material showed a high amount of variation between the different mines (Figure 6). New refuse contained the greatest amount of sodium ( $\bar{X} = 1.68$  meq/100g) and the older refuse material contained the least ( $\bar{X} = .28$  meq/100g). Plant tolerance for sodium is indicated by the sodium absorption ratio (SAR) values. Determination of sodicity in soils of refuse is arbitrarily based on SAR. Soils are generally considered non-sodic if SAR values are below 13. The SAR equation determines the ratio of sodium to calcium and magnesium.

Figure 4. Means and standard error of potassium content. Values represent 5 samples.

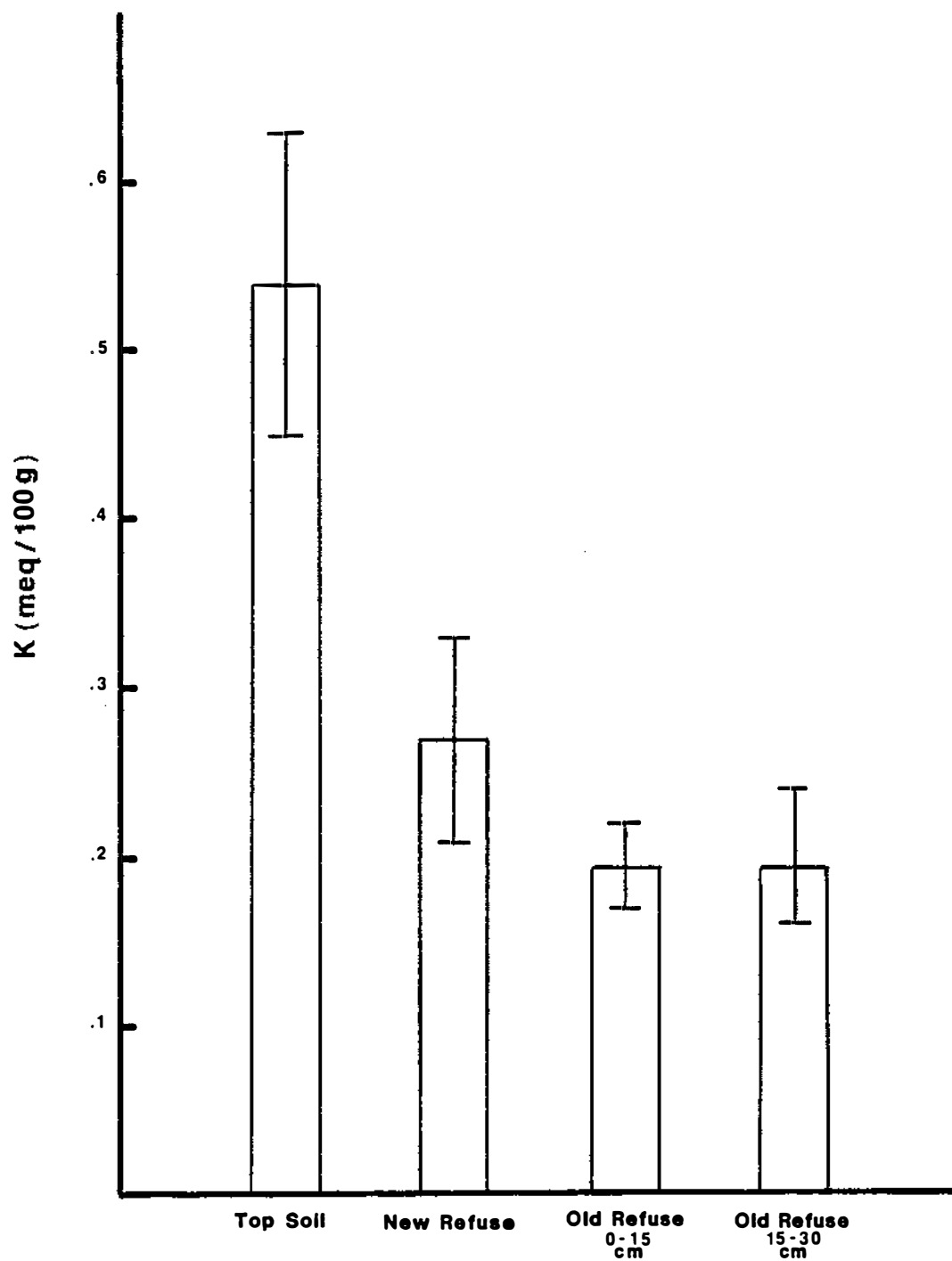


Figure 5. Means and standard error of electrical conductivity  
Values represent 15 samples.

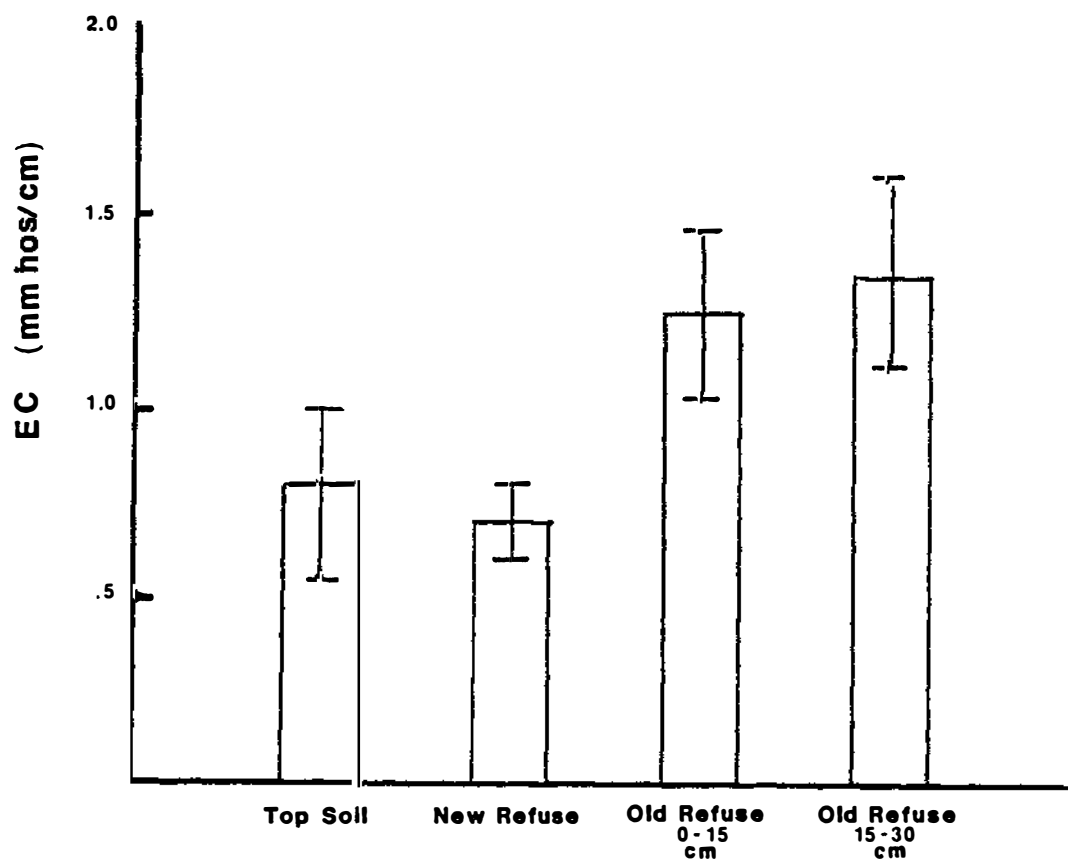
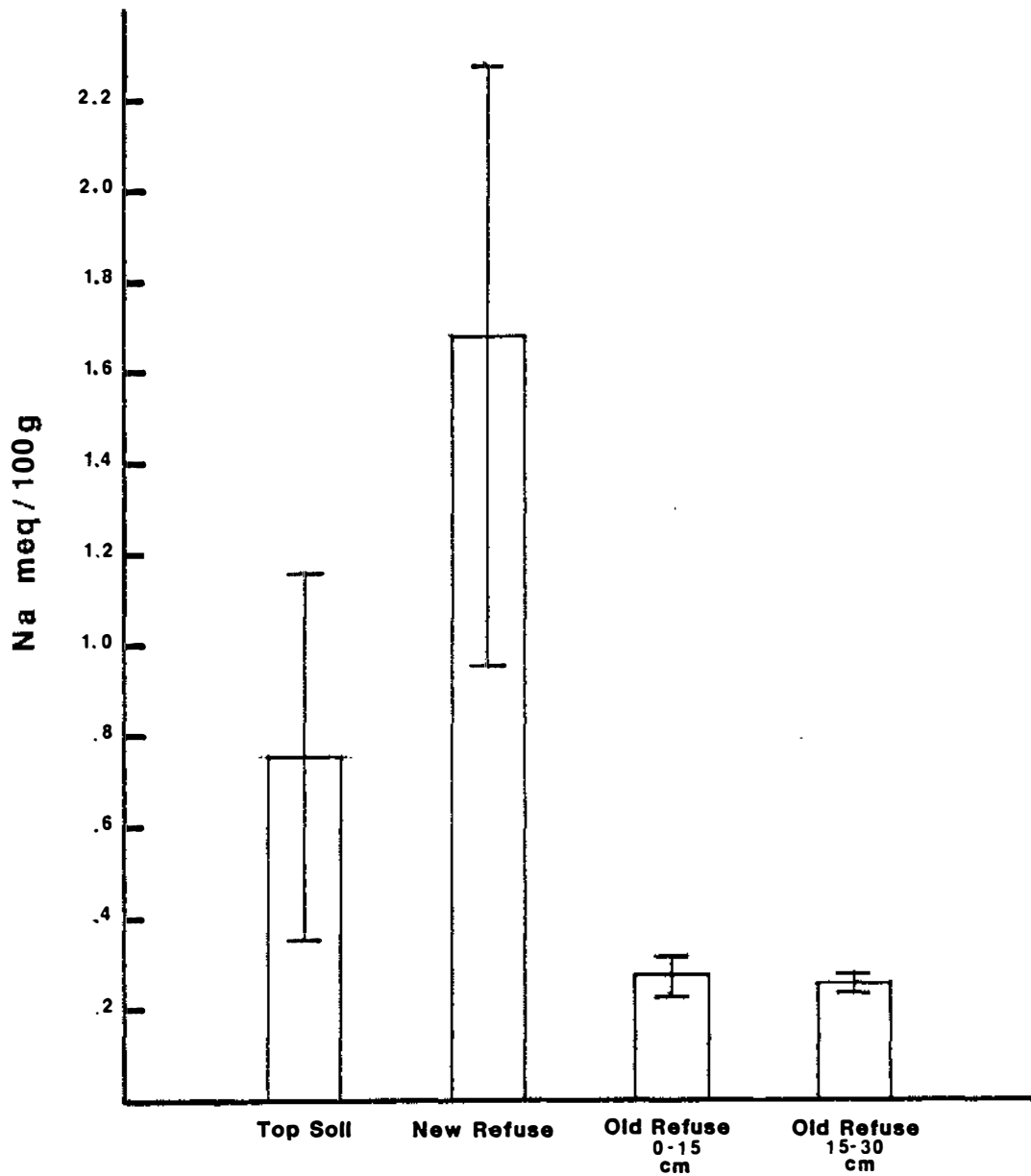


Figure 6. Means and standard error of sodium content. Values represent 5 samples.



SAR values for topsoil and refuse are well within plant tolerance ranges. New refuse had the highest SAR's (1.58) and old refuse had the lowest (0.19).

Calcium content also showed wide sample variation from 13.0 to 175.0 meq/100g (Figure 7). The old refuse material contained the highest average amount of calcium. However, the average is influenced by one mine which contained 94.8 and 175.0 meq/100g of calcium. Otherwise, calcium content of refuse material was within general ranges found in topsoil.

Magnesium content of the topsoil was significantly higher than the new refuse ( $T = 2.45, \alpha < .05$ ) and also higher than the old refuse (Figure 8). Empleton (1966) indicates that soils which contain less than 50 ppm magnesium are probably deficient. Our values for both topsoil and refuse ranged from 69.3 ppm (.57 meq/100g) to 970 ppm (7.98 meq/100g) and are in sufficient quantities for plant growth.

Boron toxicity is commonly associated with coarse soil texture and increasing pH from 7 to 9 (Peterson and Newman, 1976). Samples showed a wide range of variation in both topsoil and refuse content of boron (18.4 to 224.4 ppm). Old refuse material had a greater mean boron content than topsoil or new refuse. However, this was again due to one mine which had high boron concentration (176.4 and 224.4 ppm) (Figure 9). This high boron content in the old refuse from one mine does approach toxic levels for some plants; however, its relative insolubility at these higher pH's may prevent it from being absorbed at hazardous concentrations (pH values were 8.53 and 8.05 and texture of the refuse was a sandy loam). Bradford (1966) indicated that normal soils ranged from 2 to 100 ppm boron. Except for the old refuse material from the one mine which had a high boron content, the refuse materials from other mines were within normal range.

Figure 7. Means and standard error of calcium content. Values represent 5 samples.

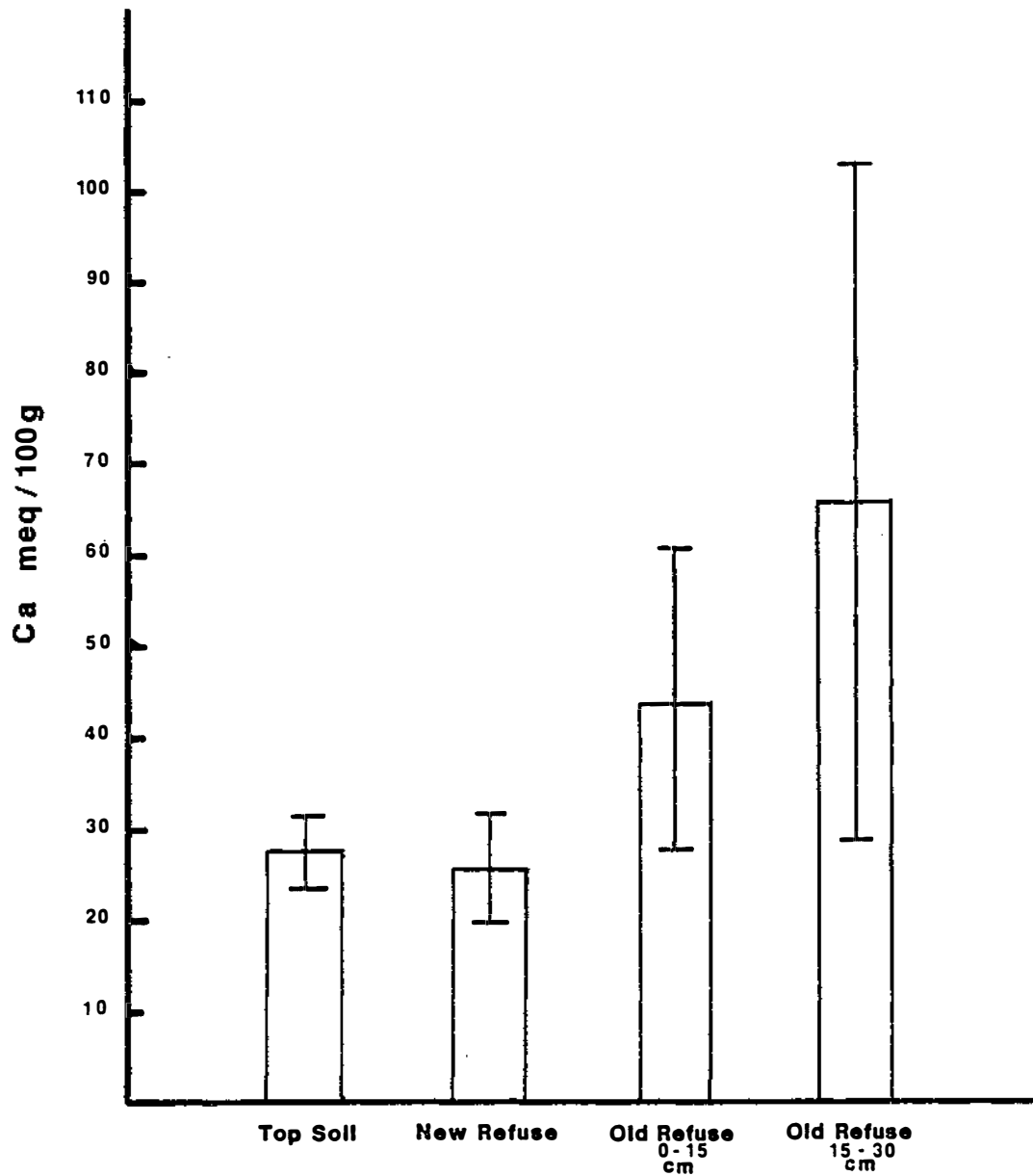


Figure 8. Means and standard error of magnesium content. Values represent 5 samples.

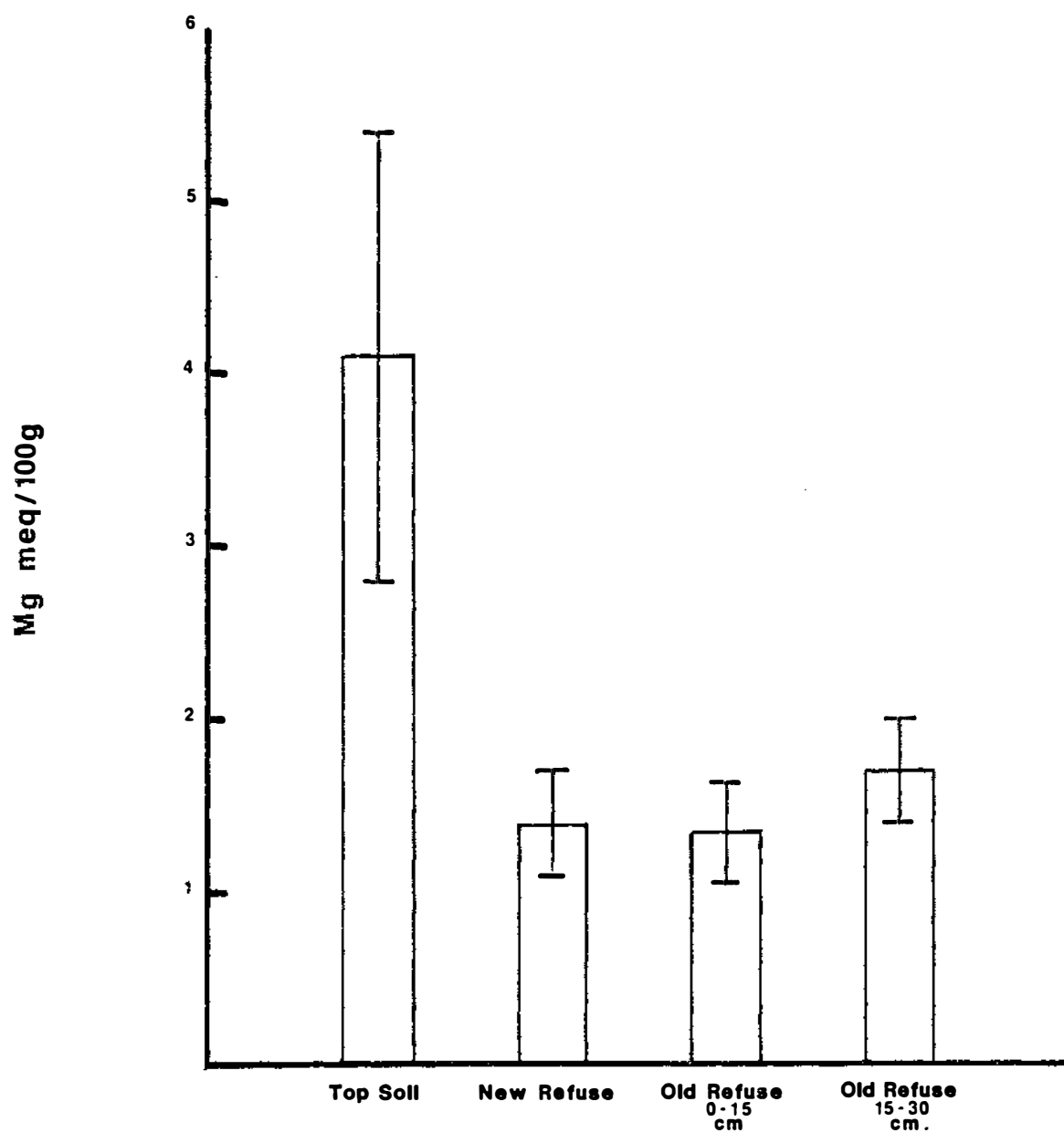
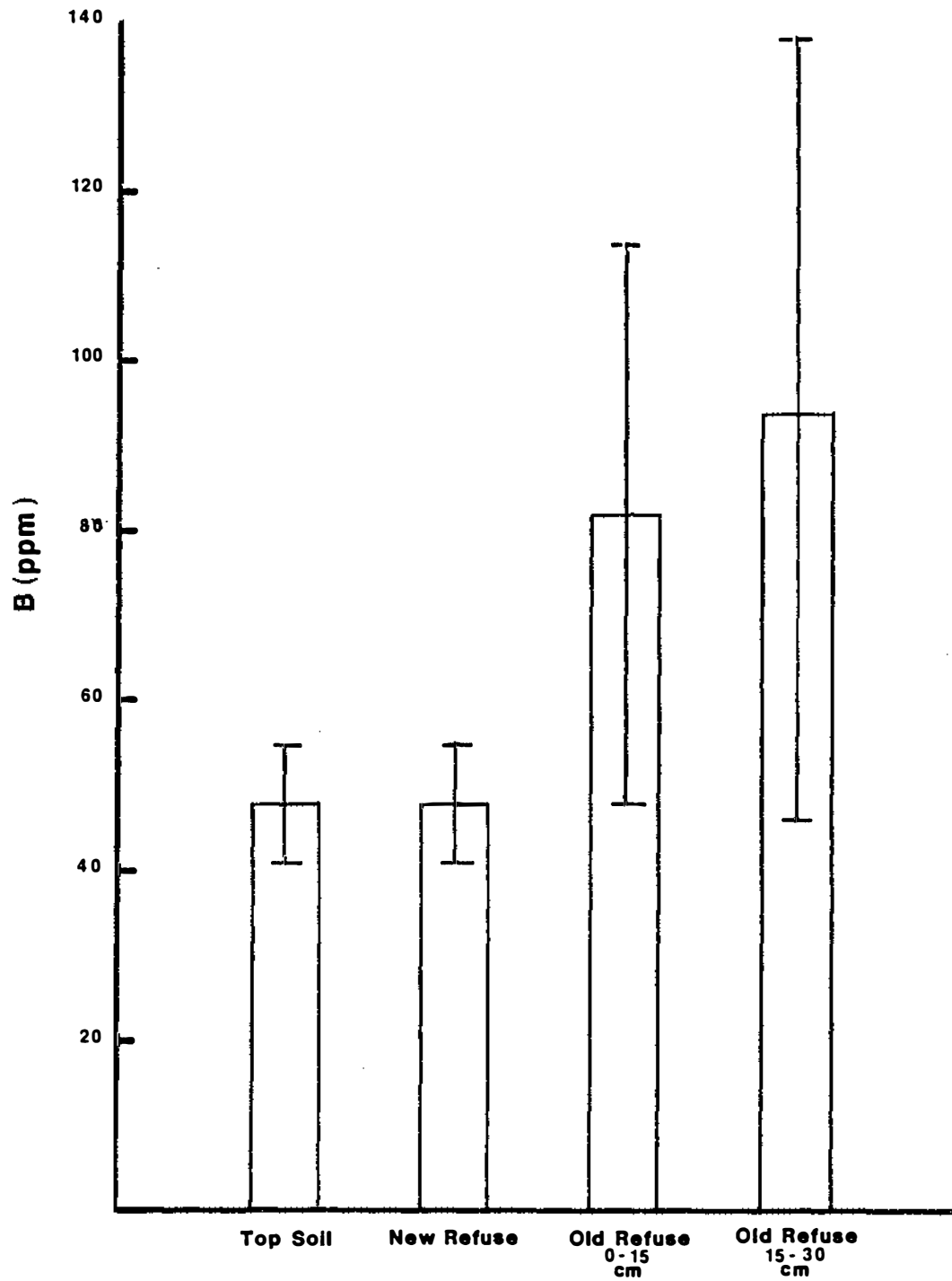


Figure 9. Means and standard error of boron content. Values represent 5 samples.



The range in chloride content of the topsoil (0.001 to 0.01 meq/100g), new refuse (.001 to .313 meq/100g), and old refuse (.001 to .120 meq/100g) shows high variability among sampling sites. A trend towards decreasing chloride content as a function of refuse material age appears to occur (Figure 10). However, small sample size and large sample variation prohibit any positive conclusions.

#### *Texture*

Sieved refuse material contained a greater percentage of sandy coarse fractions and less silt and clay than the adjacent topsoil. No difference in the distribution of soil particle fractions was found between new refuse and older refuse material. The water holding capacity of refuse material is low. Methods to increase this capacity need to be studied. Mixing refuse material with slurry on soil could possibly increase this capacity.

#### *Relative Acidity*

Statistical tests indicated no significant difference in acidity between new refuse material and topsoil; however, new refuse with an average pH of 8.65 was significantly more basic than old refuse pH ( $\bar{X} = 7.56$ ;  $T = 3.27$ ,  $\alpha < 0.01$ ). Linear regression analysis indicated a highly significant negative correlation between age of refuse material and pH (Figure 11). Only one refuse pile sampled had pH levels that could be considered toxic to plants. The pH of this 60 year old refuse pile was 2.96. However, pH exhibited variation even within data groups. For example, two 30 year old refuse piles located in the same general area had pH's of 6.24 and 8.46. This is probably due to the variation in geologic strata from which the coal material was obtained.

The potential for acid formation results from the oxidation of pyrite which is often associated with coal seams. In eastern coal spoils, acid

Figure 10. Means and standard error of chloride content. Values represent 5 samples.

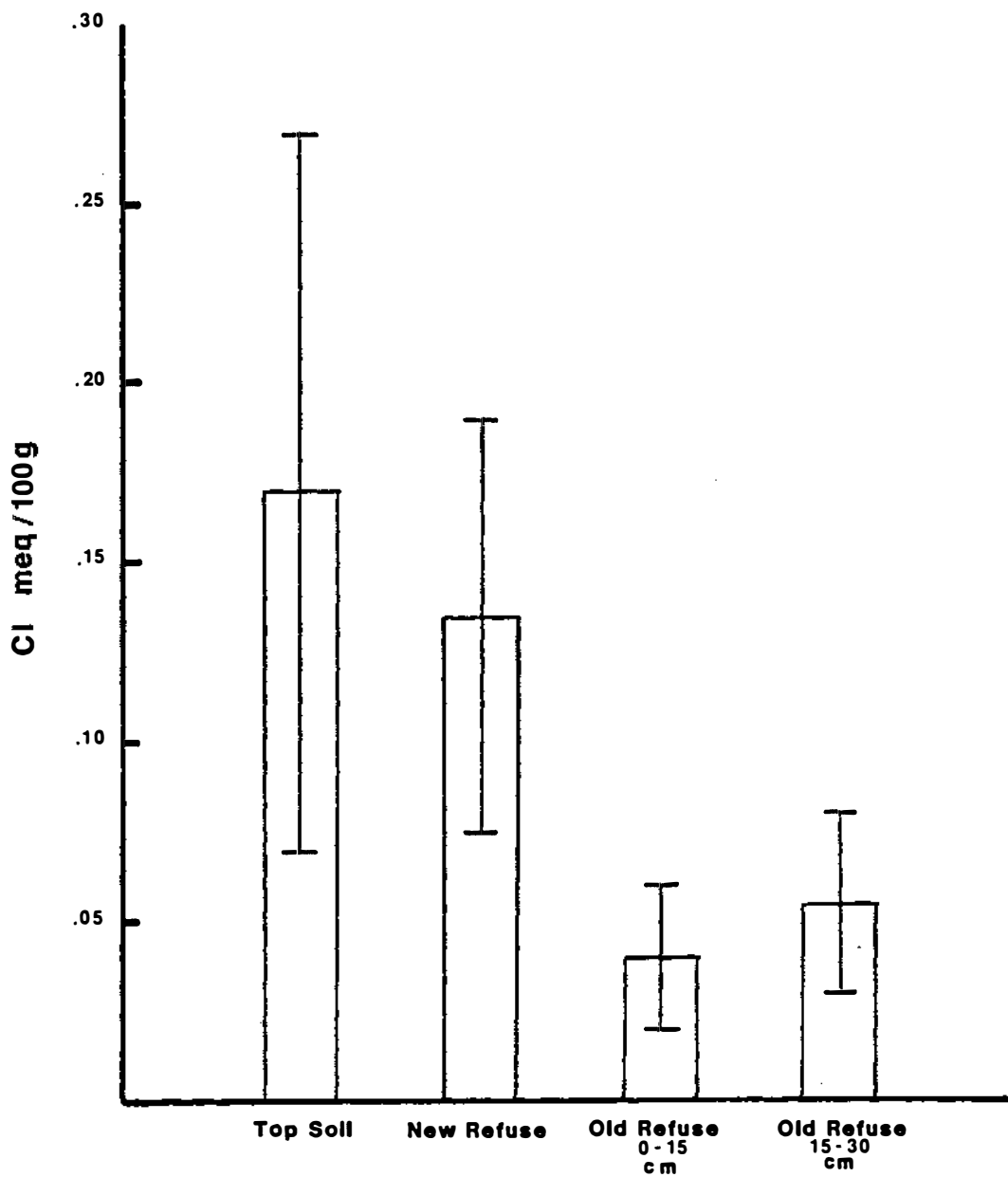
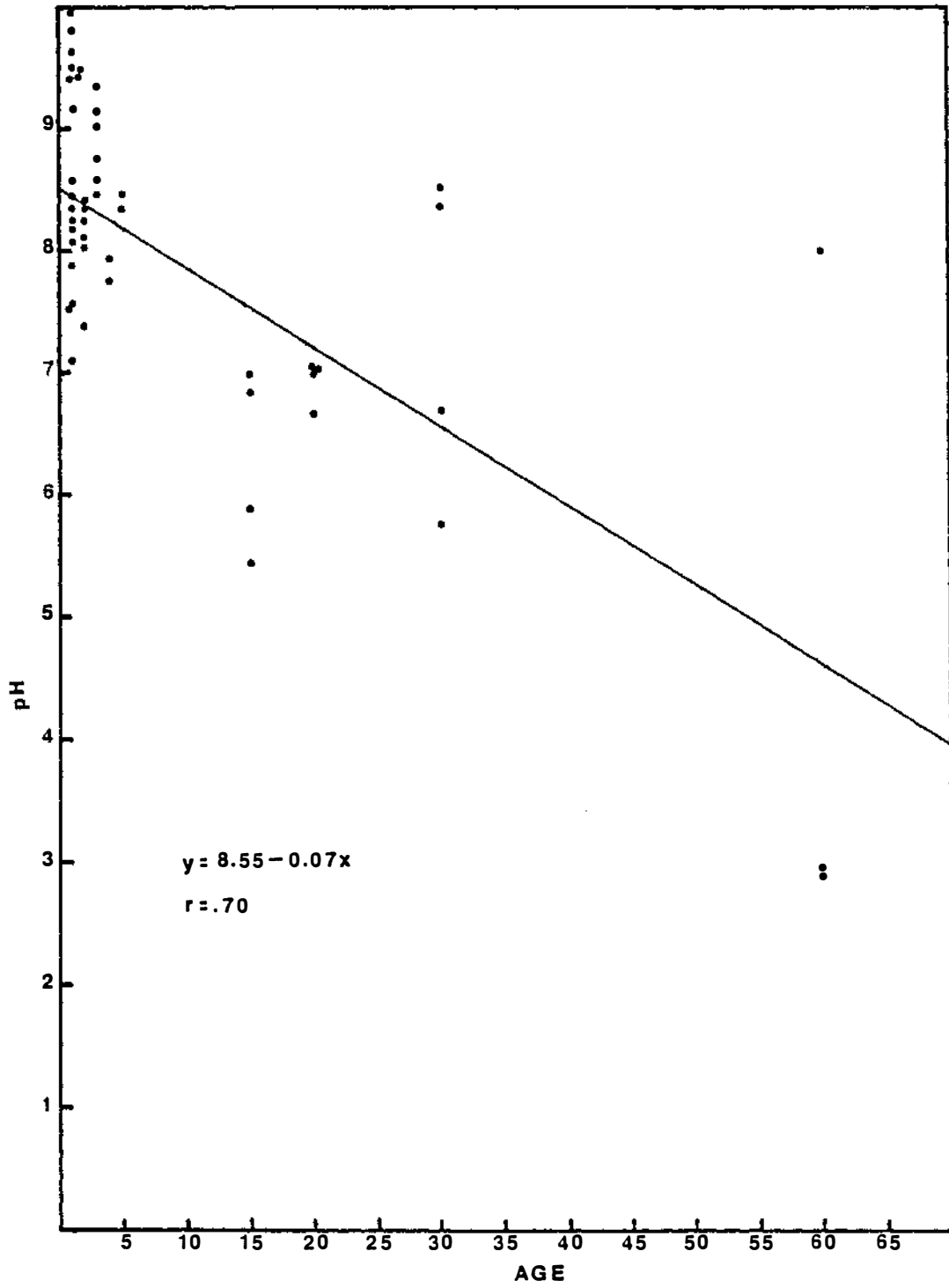
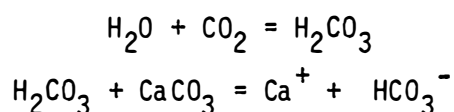


Figure 11. Regression line showing the relationship of refuse pile age and pH.



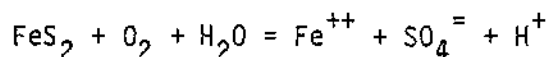
formation in the presence of certain types of iron bacteria and high precipitation often proceeds at a rapid rate. In the west, acid formation may take considerably longer since precipitation regimes are low. Acid formation is also dependent on the soils redox status. Additionally, high calcium carbonate or magnesium carbonates in the refuse material may provide enough buffering capacity to prevent acid formation.

Bicarbonate is one of the major biproducts in the weathering of carbonaceous material (Caruccio, 1978). It is produced through the dissolution of calcium carbonate in the presence of carbonic acid. The reaction is as follows:



Bicarbonate ranged from .0021 to .01 meq/100g for all material tested (Figure 12). Bicarbonate content of topsoil and refuse material increased with pH.

Sulfate is one of the primary products from pyrite oxidation (Wewerka et al., 1976). The reaction is as follows:



Sulfate was negatively correlated to pH and positively correlated with age of the refuse material (Figure 13). This again strengthens the observations that pyrite oxidation and/or some other oxidative processes are occurring in the refuse material which cause a lowering of the pH.

#### *Color - Temperature*

Refuse material for the mines is generally a dark black to grey color unless salts accumulate at the surface. This dark surface creates extreme

Figure 12. Means and standard error of bicarbonate content. Values represent 5 samples.

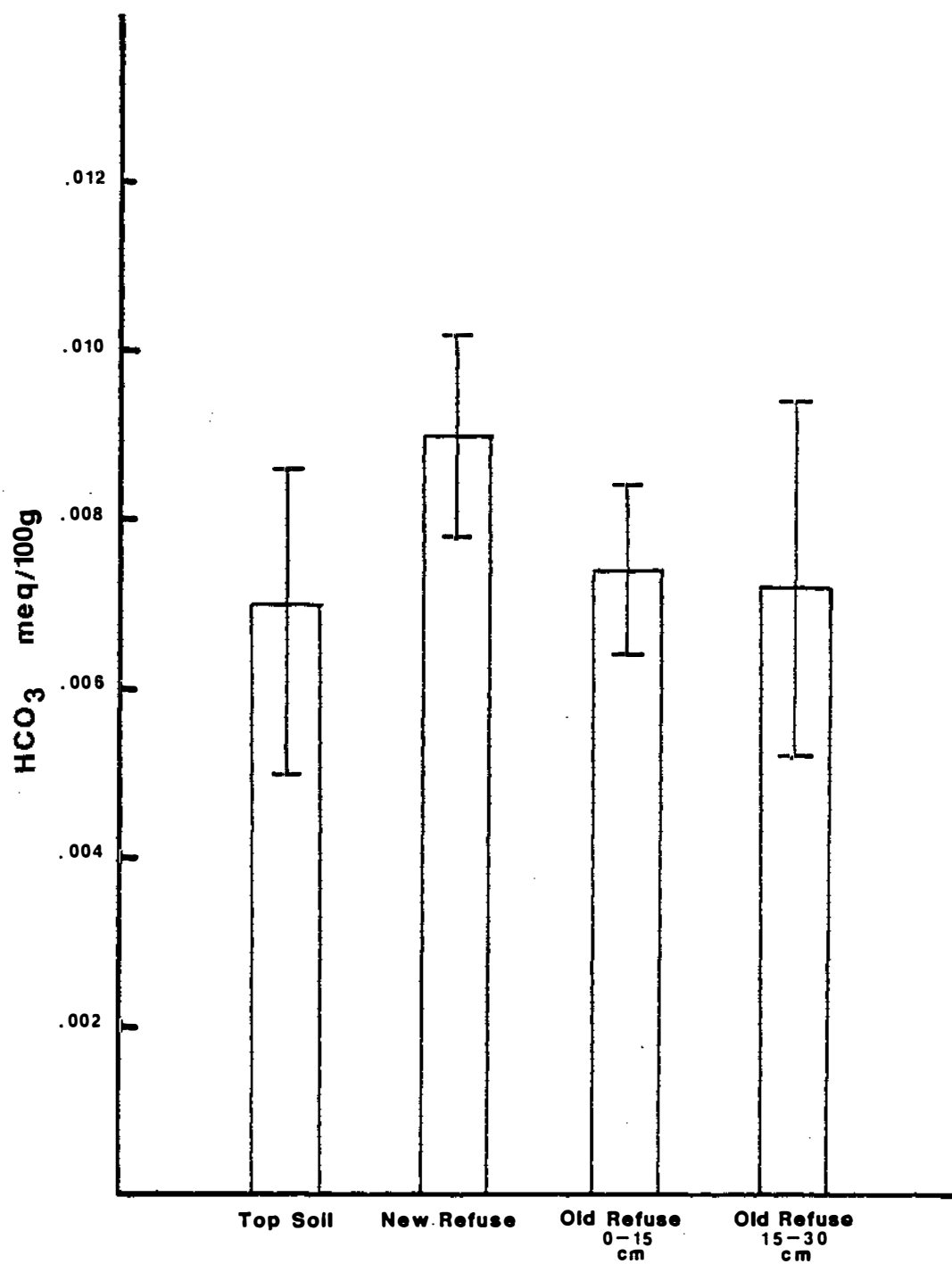
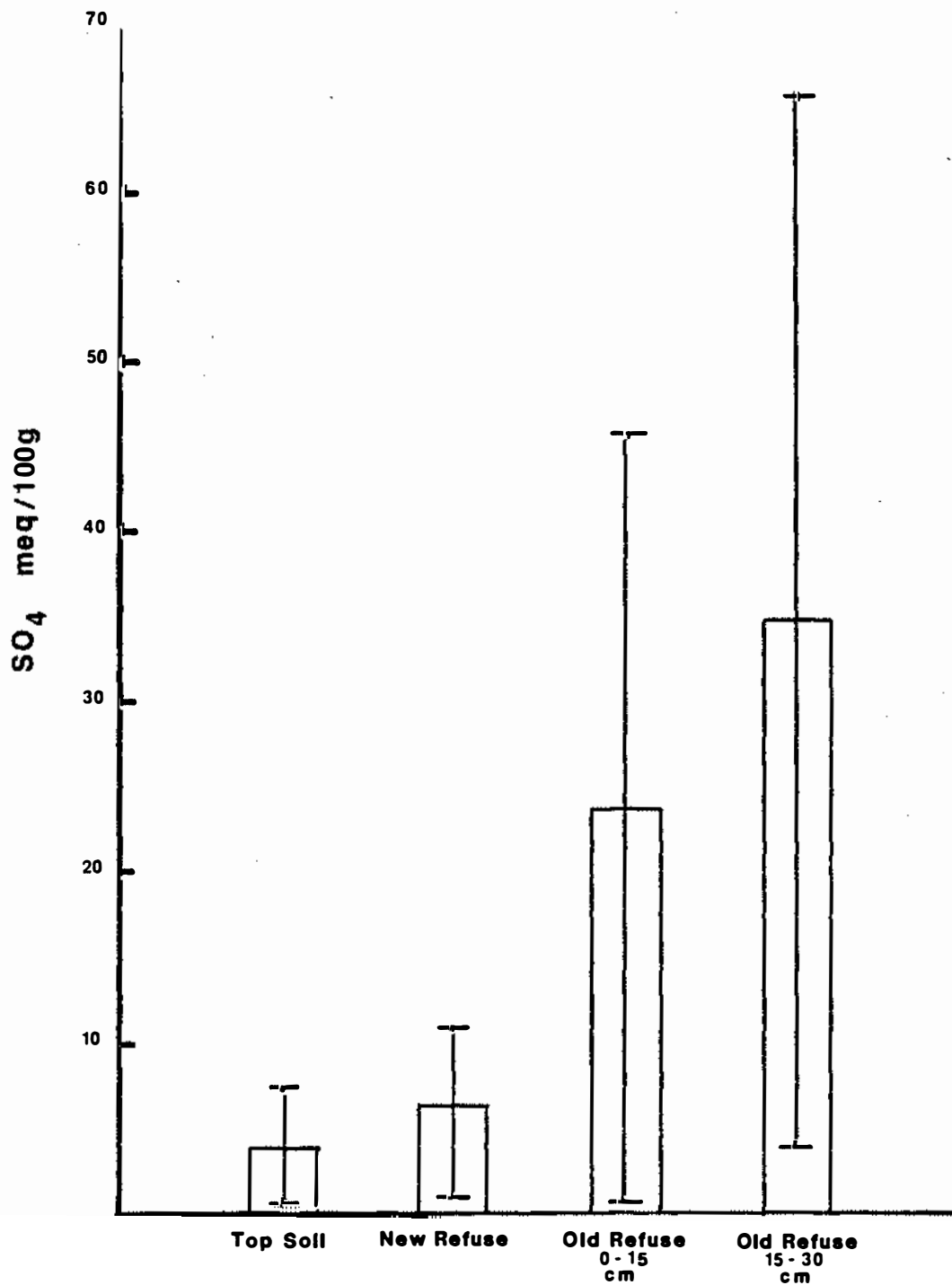


Figure 13. Means and standard error of sulfate content. Values represent 5 samples.



surface temperatures and may be a major factor in reducing seed germination and plant establishment. Furthermore, the dark color persists with time; thus, methods to decrease soil surface temperatures would probably have to be implemented for plant establishment. It was observed that on a couple of refuse piles a shallow depth of soil over the refuse reduced soil temperatures and encouraged seedling development. Mulching or other amendments may perform similar functions.

### Environmental Analysis

The environmental impacts upon the refuse piles and surrounding areas were examined. Generally, all refuse piles were constructed as to prevent mass movement. Drainage above the piles was diverted and sedimentation ponds were constructed at the base of refuse piles to prevent sediment flow into streams. Even though refuse piles have the potential for acid formation, they would probably contribute negligible runoff and ground water to the surrounding area due to the low levels of precipitation in most of the refuse areas.

Perhaps the greatest impact that refuse piles have on the environment is from an aesthetic viewpoint. Fortunately, most of these piles are in relatively remote areas. Several mines have begun covering and reclaiming the refuse piles which greatly reduces this impact. Many of the refuse piles are being shaped to the same contours as the surrounding landscape and may eventually merge with it after proper revegetation. The size and aerial extent of the exposed refuse piles from this study are as follows:

<u>Size of Refuse Pile (<math>10^3\text{m}^3</math>)</u>	<u># of Piles</u>	<u>% of Total</u>
1 - 10	2	15
10 - 100	2	15
100 - 1000	5	38
greater than 1000	4	31

Size of refuse pile was dependent on the cleaning process, age of the mine and reclamation practices.

Several old abandoned refuse dumps were observed to be unprotected near streams (Figure 14); however, water samples were not collected due to the unusually high runoff during the sampling time. Total suspended solids in these areas appear to be naturally high and any additional sediment contributed from these refuse piles would be expected to be negligible to the total amount. However, one mine did report that an abandoned refuse pile was causing a blackening of the water in a major river after rainstorms.

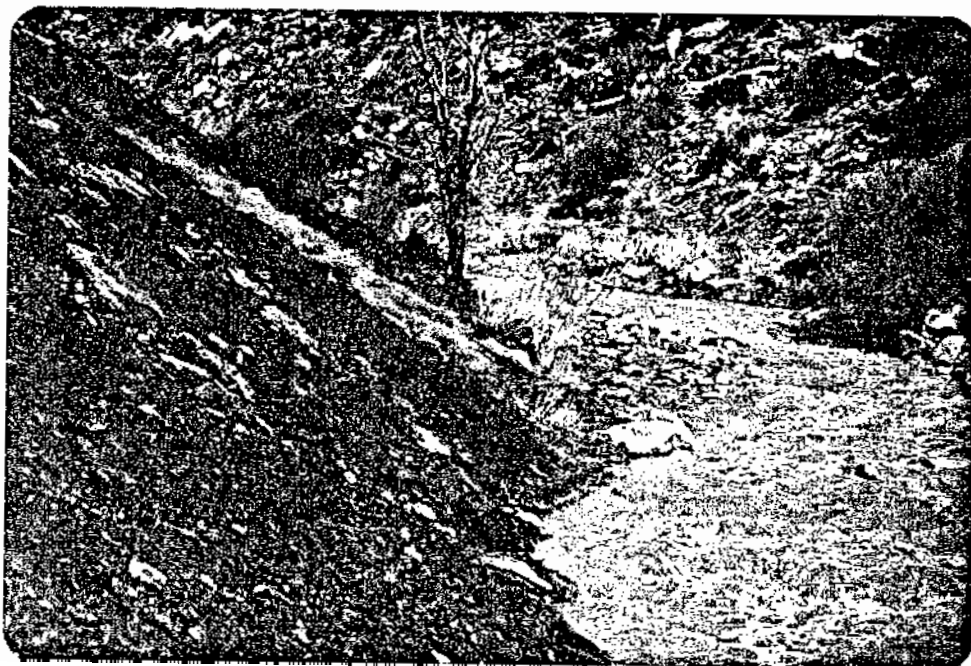
Only one mine visited had a past history of spontaneous combustion on their refuse pile. This was an old refuse pile which contained greater than 40 percent coal.

Natural invasion of plant materials has occurred on some of the refuse piles. Russian thistle, mat saltbush, rubber rabbitbrush, and prostrate kochia were some of the species observed on the pile.

#### Comparison of Surface vs. Underground Disposal of Refuse

Several mines which dispose of rock waste underground were contacted. In these mines, rock waste is never brought above ground but disposed of in mined-out cross sections. These mines are able to dispose of waste in this manner because: (1) they do not wash or process their coal; and (2) they have a thick coal seam (4.9m). The disadvantages of this type of mining are: a lower BTU coal results because no processing is done and 30 to 60 cm of coal is left remaining in the seam. These mines have indicated that in the future they may have to dispose of material outside the mine because of limited space and interference with other mining operations.

Figure 14. A stream is eroding the banks of this old abandoned refuse pile. Photo taken April 21, 1982.



Another mine investigated the feasibility of backfilling with a slurry composed of refuse material. The plan was abandoned primarily because of the capital investment required to construct a crushing facility, pipeline and distribution lines. A cost of 2.5 million dollars plus matching federal funding was the calculated price of this alternative. A more cost effective alternative was to truck material 20 miles to a disposal site.

A report by the National Academy of Sciences (1975) compares the costs of surface coal waste disposal and two backfilling methods of underground coal waste disposal. The conclusion of this report was that the cost of underground disposal will almost always be higher than that of surface disposal. The estimated costs for surface disposal (with reclamation), pneumatic backfilling behind a long wall face, or hydraulic backfilling were 0.304, 1.180, and 1.425 dollars per ton clean coal respectively.

The advantages of underground waste disposal are: the elimination of environmental and social problems associated with surface disposal; provision of lateral support to pillars; and reduced subsidence. The disadvantages of underground disposal are: increased problems associated with the health and safety of miners; loss of potentially recoverable coal; losses in overall productivity; unfavorable environmental impacts associated with the construction of roads and injection boreholes on the surface; and groundwater contamination from leaching of backfilled material.

#### Alternative Methods for Reclamation

An economic evaluation of reclamation procedures should be based on the cost needed to achieve a certain standard of success. Economics is tied directly to factors influencing successful reclamation. Factors influencing revegetation include: soil depth, soil moisture, nutrient

availability, insulation, temperature, and other biological considerations. These factors are influenced by site specific climatic conditions, soils, and cultural practices such as mulching, irrigation, fertilization, seeding, and transplanting. This study indicates that reclamation practices need to be site specific. Each mine needs to assess the reclamation alternative which is the most efficient, given their unique situation. For example, although it may appear to be too expensive to use irrigation, rather than no irrigation in reclamation, this method of reclamation may sufficiently contribute to plant establishment and the desired success standard so that only half as much topsoil as originally anticipated will need to be placed on top of the refuse material. The resultant savings in soil hauling costs could more than offset the capital outlay necessary for the irrigation systems.

The cost associated with moving and spreading soil makes this the single most expensive factor in rehabilitation of coal refuse piles. The Division of Oil, Gas and Mining in Utah bases bond costs for hauling soil from the stockpile and spreading the soil on the refuse piles at \$.92 per m<sup>3</sup> or \$.70 per yd<sup>3</sup>. Based on this rate the cost to cover a surface of 500 m x 200 m refuse pile or 1 acre would be:

<u>Depth of Cover</u>	<u>\$/500m x 200m</u>	<u>Depth of Cover</u>	<u>\$/Acre</u>
.15(m)	\$ 13,800.00	.5(ft)	\$ 564.77
.30(m)	27,600.00	1(ft)	1,128.28
.61(m)	56,120.00	2(ft)	2,256.40
.91(m)	83,720.00	3(ft)	3,387.99
1.22(m)	112,240.00	4(ft)	4,506.02

This study was not designed to assess the amount of soil required to cover the refuse piles for plant growth. We feel that some cover is necessary. From these preliminary analyses, refuse material appears to be suitable for plant root growth. However, further research is warranted.

## ANALYSIS OF INDIVIDUAL MINES

Price River Coal Company

Several coal refuse piles occur in or near the area of ownership by the Braztah Corp. or Price River Coal Co., Carbonville, Utah. Mining activities in the Price River Canyon began in the early 1900's. The mine is at 1830m (6000 ft.) elevation and receives 25 to 30 cm (10 to 12 in.) of annual precipitation. There is apparently no water available for revegetation. Topsoil will be a problem because the undisturbed adjacent sites have little soil and are composed mainly of exposed surface bedrock. Currently, Price River Coal Co. produces 1.5 million tons of coal annually and expects to produce 6.4 million tons annually in the future. Coal is separated and washed near the refuse area.

Some revegetation efforts have been made on the old pre-regulation refuse piles, although success has been limited. Several older refuse piles exist near the Price River property but their ownership is questionable. These abandoned piles have great potential for environmental pollution, particularly water pollution.

The current refuse pile is nestled in School House Canyon. Runoff water has been diverted from the top of the canyon to another canyon. The refuse pile is currently 61 m (200 ft.) high and terraces occur every 15m (50 ft.). The pile appears stable and has a 37% slope. The life of the refuse pile is three to four more years (1986) and the growth will continue in a vertical direction (Figure 15).

Analyses for several elements and compounds were done for the current refuse pile and also one of the older refuse piles (Table 2).

Figure 15. The refuse pile at Price River Coal Co. is extending up a canyon. Photo taken April 21, 1982.



Table 2.

	pH	EC	SAR	K*	Na*	Ca*	Mg*	Cl*	SO <sub>4</sub> *	HCO <sub>3</sub> *
Topsoil	8.38	0.14	0.47	0.53	0.52	23.0	1.16	<.001	0.04	0.009
New refuse (School House)	7.89	1.76	3.62	0.44	4.26	26.4	1.23	0.31	1.6	0.014
New refuse	9.43	0.73								
Topsoil	8.99	0.11								
Old refuse										
0-15 cm	6.70	0.96								
15-30 cm	5.77	1.55								
#22										
0-15 cm	8.53	0.22	0.26	0.25	0.37	36.4	2.30	0.03	1.3	0.010
15-30 cm	8.38	0.37	0.22	0.19	0.31	37.9	2.06	<.001	1.48	0.012
#23										
0-30 cm	8.05	0.40								

	ppm B	%K	ppm NO <sub>3</sub> -N	ppm P	% Organic Matter	% Sand	% Silt	% Clay	Texture
Topsoil	58.0	0.62	1.35	4.2	3.4	37	37	26	loam
New refuse (School House)	58.4	0.39				63	16	21	sandy clay loam
New refuse			0.90	2.0	6.3	63	17	20	sandy clay loam
Topsoil						35	32	33	clay loam
Old refuse									
0-15 cm						72	12	16	sandy loam
15-30 cm						70	12	18	sandy loam
#22									
0-15 cm	176.4	0.24	1.0	4.0	6.3	74	12	14	sandy loam
15-30 cm	224.4	0.18	0.7	4.2	4.5	67	19	14	sandy loam
#23									
0-30 cm						75	11	14	sandy loam

\*expressed as meq/100g.

Values for pH, EC and SAR are within normal plant tolerance ranges. The diversity of refuse piles within the Price River area allows for some quantification of the variability of the spoil materials and influence of time. One sample obtained from the new refuse had a relatively high pH (9.43); however, another new refuse sample had a lower pH (7.89). The variation in pH among the older refuse piles located in different canyons ranged from 5.77 to 8.53. This shows the need for sampling at spot locations rather than pooling samples and may also suggest the need for varying reclamation treatments within the current refuse pile.

Refuse pile #3 which is acid (pH = 6.7 and pH = 5.8) is also the oldest in this locality and may indicate a decreasing pH with age. This however, needs more data to document conclusively.

Micronutrients appear to be within normal ranges with the exception of boron which is approaching toxic levels on the older refuse pile (176 and 224 ppm). N and P may be beneficial fertilizer additions in reclamation of the refuse pile.

#### Beaver Creek Coal Co.

Beaver Creek Coal Co. washes and processes coal from three mine sites at C.V. Spur processing plant in Price, Utah. Annual precipitation at the processing site is 23 cm (9 in.) and the elevation is 1678m (5500 ft.). Soils in the area are derived from Mancos shale, are generally shallow, and have a very high salt content. Natural vegetation in the area is a salt desert shrub community.

C.V. Spur processes one million tons of coal annually. The refuse pile is constructed in 1.2 m (4 ft.) lifts and maximum height will be 36 m (100 ft.) in 20 years. Currently, the pile is 6m (20 ft.) high.

No environmental impacts on the surrounding community would be expected to occur from the refuse (Figure 16).

No revegetation has begun on the refuse pile. Topsoil and subsoil have been stockpiled and revegetated. For reclamation, 46 cm (18 in.) of subsoil and 15 cm (6 in.) of topsoil will be placed over the pile. Some temporary irrigation may be available for establishing vegetation.

pH, EC and texture were analyzed for Beaver Creek Coal (Table 3).

Table 3.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.32	1.13	7	35	58	clay
New refuse	8.08	0.47	53	16	31	sandy clay loam
Old refuse 0-15 cm	7.78	1.36	47	22	30	clay loam
15-30 cm	7.96	0.83	50	21	29	sandy clay loam

pH and EC are within normal ranges; however, a slight decline in pH is noticeable in the older refuse material although it is only three years old. Other elements are expected to be normal and N and P probably would be recommended soil additives to the refuse material in revegetation.

### King Mine

Mining began at the King Mine, Hiawatha, Utah, in the late 1800's. Annual precipitation is 30 cm (12 in.) and the refuse piles are at 2196m (7200 ft.) elevation. Vegetation in the refuse area is a mixed salt desert shrub community. The mine currently produces 900,000 tons of coal annually.

Refuse is extensive in the area with most being deposited prior to the passage of mine reclamation regulations (Figure 17). Construction of

Figure 16. Refuse pile for Beaver Creek Coal Co. at C.V. Spur Processing Plant. Photo taken April 22, 1982.

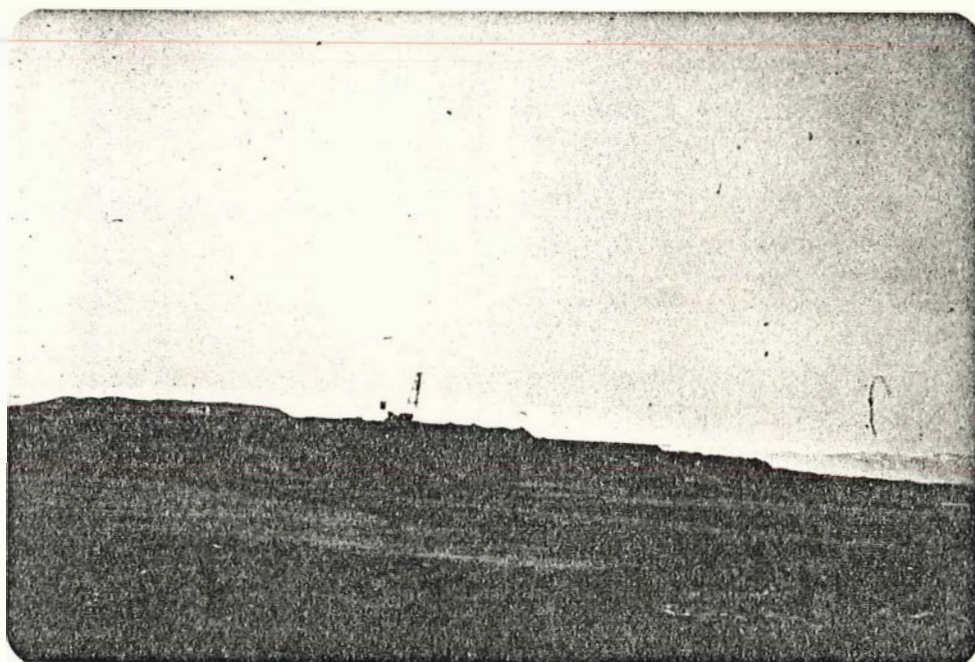
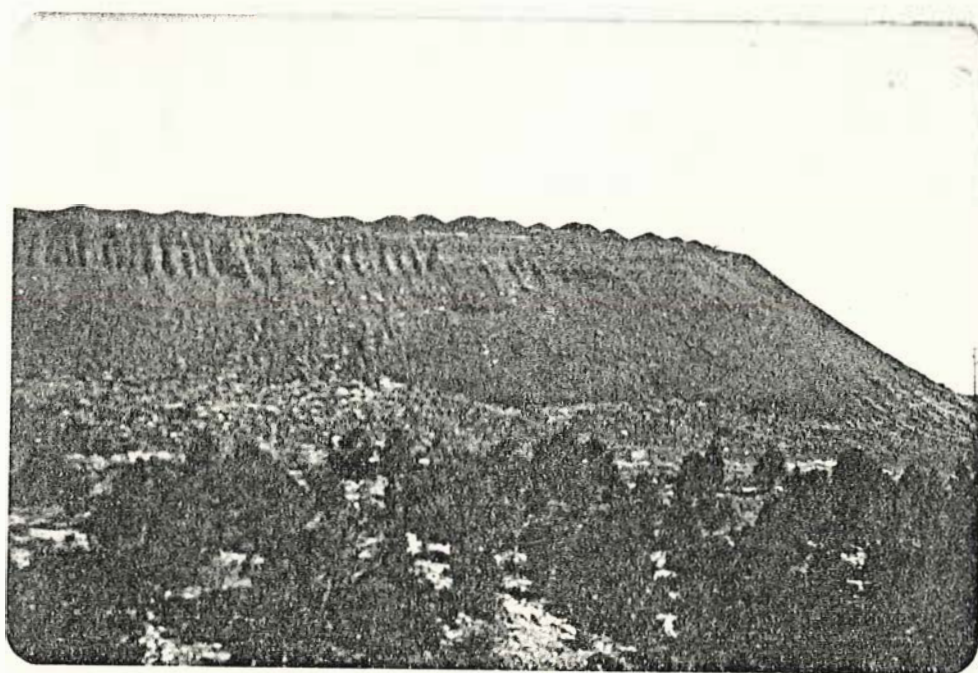


Figure 17. Refuse pile at the King Mine. Photo taken April 22, 1982.



the refuse pile began in the early 1940's and has been added to intermittently up to the present date. In addition, there are four slurry ponds with coal refuse lining the perimeter of the ponds. Slurry is currently being sold after drying.

No revegetation efforts have begun and are not expected to begin for 30 years. Material to cover the refuse site will be taken from deeper soil material nearby.

Analysis for several elements and compounds was performed for the soil and refuse material from the mine (Table 4).

Table 4 .

	pH	EC	SAR	K*	Na*	Ca*	Mg*	Cl*	SO <sub>4</sub> *	HCO <sub>3</sub> *
Topsoil	9.12	0.09	0.19	0.46	0.25	29.9	4.11	0.03	0.03	0.01
New refuse	7.54	0.71	0.13	0.32	0.20	46.4	1.97	<.001	26.3	0.007
Old refuse										
0-15 cm	2.94	2.10	0.11	0.23	0.24	94.8	1.23	.026	93.3	0.006
15-30 cm	2.98	2.31	0.07	0.18	0.20	175.0	1.15	0.03	129.8	0.002
Slurry	7.8	0.75	0.17	0.14	0.21	28.4	1.11	0.03	0.86	0.006
	ppm B	%K	ppm NO <sub>3</sub> -N	ppm P	% Organic Matter	% Sand	% Silt	% Clay	Texture	
Topsoil	22.0	0.36	1.50	4.2	1.6	35	28	37	clay loam	
New refuse	45.6	0.56	0.70	1.2	2.7					
Old refuse										
0-15 cm	56.0	1.17	1.50	10.4	6.1	60	13	27	sandy clay loam	
15-30 cm	56.8	0.97	0.95	14.8	5.1	65	11	24	sandy clay loam	
Slurry	68.8	0.23	0.60	1.2	6.1	73	11	16	sandy loam	

\*expressed as meq/100g.

The pH values of the old (approximately 40 years) refuse material (pH = 2.94 and 2.98) were the most acidic sampled in this study. The high SO<sub>4</sub> values (93.3 and 129.8 meq/100g) may indicate the oxidation of pyritic material associated with the coal seam. Spoils which have oxidized to this extent require pH reductions before plants can become established.

This could be accomplished by lime additions or adding new refuse material. The other elements analyzed are within normal ranges except possibly N should be added to the refuse for plant growth.

#### Plateau Mine

Plateau Mine at Wattis, Utah occurs at an elevation of 2257 m (7400 ft) with an annual precipitation of 36 cm (14 in.). Salt desert shrub and pinyon-juniper-sagebrush communities surround the refuse pile area.

The mine produces 1.2 million tons of coal annually; capacity is two to four million tons. Twenty percent of the material mined is processing waste. The present refuse pile has a life of eight years. A phase 2 and 3 refuse area has been proposed to extend west and southwest of the current pile. Maximum height of the piles will not exceed 46 m (150 ft.). The pile is currently 305 m x 122 m and 23 m (1000 ft. x 400 ft. x 75 ft.) tall. Side slopes on the pile are 40% to 45% and are exposed on the north, east and south (Figure 18).

Revegetation activities will proceed as each portion of the pile is completed. Life of the current pile is 8 years. Russian thistle was observed growing on the exposed refuse.

The mine does not have material to cover the refuse piles to the depth required by regulations. Therefore, they are currently involved in research to determine the minimum cover necessary on the refuse for adequate plant growth.

Only pH, EC and texture were analyzed for in the topsoil and refuse material (Table 5).

Table 5.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.46	0.14	45	28	27	clay loam
New refuse	7.56	1.17	61	15	24	sandy clay loam
Old refuse 0-15 cm	7.02	2.41	61	14	25	sandy clay loam
15-30 cm	6.86	2.22	61	13	26	sandy clay loam

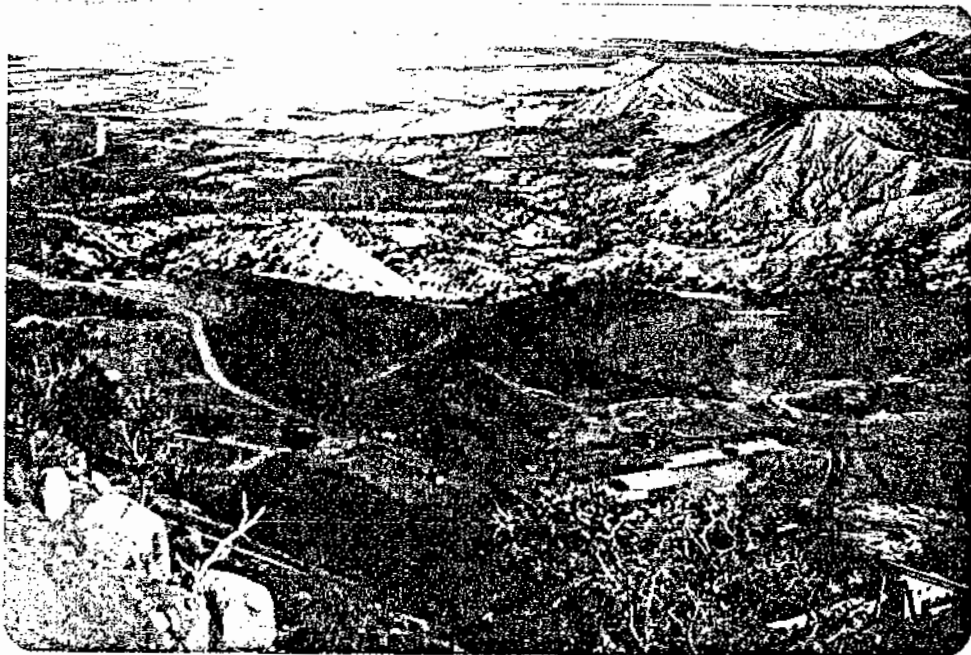
pH and EC are within normal ranges. However, the older refuse materials are more acidic than the younger ones. Trends from other mines in the area indicate that N and perhaps P should be added to the refuse material as fertilizer nutrients in reclamation.

#### Mine A

Mine A's processing plant, refuse piles, and sedimentation ponds are located in eastern Utah. This area receives 23 cm (9.3 in.) of annual precipitation at 1,678 m (5500 ft.) elevation. Vegetation surrounding the refuse area is a salt desert shrub community dominated by mat salt-bush. Soils in the area are derived from the Mancos shale formation.

Mine A has two refuse pile locations, one for rock and one for coarse and fine refuse. The first is approximately 122 m x 61 m x 4 m (400 ft. x 200 ft. x 12 ft.) in height and is composed of rock 3.5 cm (1½ in) and greater in diameter. The second refuse pile covers several acres and is 183 m x 610 m x 37 m (600 ft. x 200 ft. x 120 ft.) in height and contains the coarse refuse (less than 3.5 cm or 1½ in.) and the dredged sediment. The refuse pile is oriented in a northeast direction with 20% slopes into the sedimentation ponds while the other side meets a hill. The refuse pile is expanding northward. Sparse vegetation, such as

Figure 18. Mine and refuse pile at Plateau Mine.  
Photo taken April 22, 1982



Princess plume (Stanleyia sp.) and mat saltbush (Atriplex sp.) was observed growing on the exposed refuse. Since mining operations were initiated prior to the 1977 regulations, no topsoil has been stockpiled for reclamation.

Elemental analysis of spoil from a nearby mine may be expected to be similar to Mine A (the coal was mined from the same seam). Only pH, EC, and texture were analyzed for the refuse material from Mine A (Table 6).

Table 6.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.32	1.13	7	35	58	clay
New refuse - rock	9.66	0.46				rock
Coarse	8.47	1.23	59	13	28	sandy clay loam
Old refuse 0-15 cm	6.67	2.20	39	23	37	clay loam
15-30 cm	7.05	2.86	42	22	36	clay loam
Old coarse refuse	7.04	1.98	64	12	24	sandy clay loam
New slurry	8.74	0.50	47	33	19	loam
Old slurry	8.41	2.55	49	28	23	loam

pH and EC are within plant tolerance levels, except for the new rock refuse (pH = 9.66). It would be anticipated that the pH will lower with time as indicated by the trend in the pH of the old refuse. N fertilizer should be added to the refuse material in revegetation.

#### Mine B

Mine B is located in eastern Utah and has been in operation since 1889. Approximately one million tons of coking coal is mined annually. The mine is located at the base of the Book Cliffs at 2044 m (6700 ft.)

elevation and receives 36 to 41 cm (14 to 16 in.) of precipitation annually. The vegetation type surrounding the refuse area is representative of the salt desert shrub community with the dominant species being fourwing saltbush. Topsoil surrounding the refuse area is derived from decayed sandstone and Mancos shale.

Refuse material has nearly filled a small dry canyon and most of that material has been covered. Thus, minimal impacts to the surrounding undisturbed community would be expected from the refuse area. The active portion of the refuse pile has a 37% side slope, western aspect, and 6 m (20 ft.) benches every 24 m (80 ft.). Several large slurry ponds also exist on the property. After drying, the materials from these ponds, which contain 30 to 40% coal, are removed and placed in the refuse pile. Analyses for several elements and compounds were conducted on the soil, refuse, and slurry material (Table 7).

Table 7 .

	pH	EC	SAR	K*	Na*	Ca*	Mg*	Cl*	SO <sub>4</sub> *	HCO <sub>3</sub> *
Topsoil	8.18	1.92	1.65	0.32	2.56	39.9	7.98	0.60	15.7	0.004
New refuse	8.18	0.58	1.71	0.32	1.48	13.0	1.97	0.11	2.22	0.008
Old slurry										
0-15 cm	8.24	1.01	0.51	0.32	0.68	33.7	1.40	0.14	8.5	0.006
15-30 cm	8.10	1.13	1.13	0.32	1.35	26.9	1.89	0.15	4.8	0.005
	ppm B	%K	ppm NO <sub>3</sub> -N	ppm P	% Organic Matter	% Sand	% Silt	% Clay	Texture	
Topsoil	43.6	0.49	1.80	1.2	0.70	44	26	30	clay loam	
New refuse	60.8	0.49	0.80	1.0	2.1					
Old slurry										
0-15 cm	71.2	0.17	1.10	1.6	6.4	41	32	27	loam	
15-30 cm	69.6	0.14	0.85	2.0	6.8	44	31	25	loam	

\*expressed as meq/100g.

The analyses show that pH, EC, and SAR of all material tested are well within the normal tolerance range of native plants in the salt desert

shrub community. Nitrogen and phosphorus are relatively deficient and should be added to the refuse material for revegetation. Values for  $\text{SO}_4$  are higher than many of the other mines tested which may indicate a potential for decreases in pH over time. Microelements sampled appear to be in sufficient quantity for plant growth. Aside from this, refuse material from Mine B appears to be as good a growth medium as the existing topsoil for the soil parameters tested.

#### Western States Mineral

The J.B. King Mine, Western States Mineral, in Emery County, stopped coal production in 1981 due to the poor market. The mine is situated at the base of small cliffs. No runoff or other environmental hazards were observed around the mine area. A pinyon-juniper, mixed salt desert shrub community surrounds the mine site. The mine is old and has four slurry ponds and one refuse pile. The refuse pile has a southwest exposure with side slopes of  $47^\circ$ . The refuse pile is 183 m x 122 m and 21 m (600 ft. x 400 ft. x 70 ft.) high (Figure 19).

Natural reinvasion of rabbitbrush (Chrysothamnus) and saltbush (Atriplex) has occurred on several areas of the refuse pile where only 8cm of soil has covered the refuse. No topsoil stockpile was observed on the mine site.

Values for pH, EC and texture analyses were run for the topsoil, refuse and slurry material (Table 8).

Table 8 .

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.12	3.0	13	25	61	clay
1 year refuse						
0-15 cm	7.10	2.03	54	16	31	clay loam
15-30 cm	7.55	1.90	68	9	23	sandy clay loam
Old refuse						
0-15 cm	5.9	1.90	41	17	43	clay
15-30 cm	5.45	1.69	46	16	37	clay loam
Slurry	7.39	2.73	57	21	22	sandy clay loam

EC and pH are within tolerance levels; however, pH of the old material is again lower than the new refuse suggesting a decline in pH with age. The age of the old refuse material is unknown. The old refuse material may have to be treated or covered to a sufficient depth to allow for plant growth and root development if acidity increases. Macro soil nutrients, N and P should also be added to the topsoil and refuse material in revegetation.

#### Knight Mine

The Knight Mine, Coal Search Corporation east of Salina, Utah, began operations in 1977. Mining stopped in 1980 and will resume operation when the coal market is available. The mine area receives 30 to 36 cm (12 to 14 in.) annual precipitation and is at 2379 m (7800 ft.) elevation. Topsoil has been stockpiled and reseeded. Surrounding vegetation is a pinyon-juniper community. The mine produced 150,000 tons of coal annually. Coal was crushed at the mine but no washing operation was used. Refuse is composed of approximately one half rock and one half coal. The refuse area is small, 31 m x 31 m x 9 m (100 ft. x 100 ft. x 30 ft.) (Figure 20).

Figure 19. Mine and refuse pile of the J.B. King Mine.  
Photo taken April 23, 1982

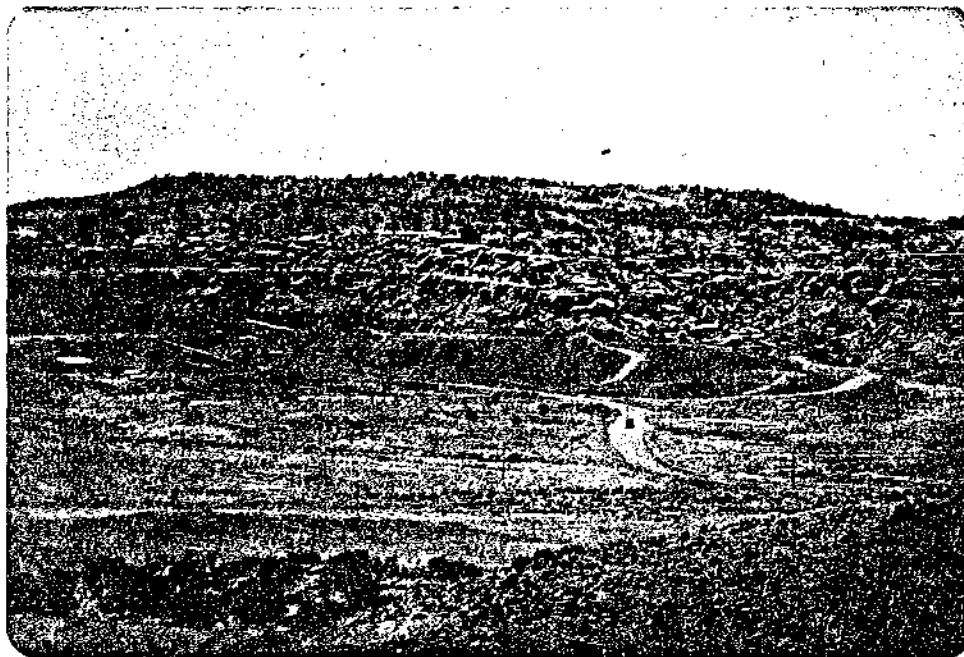


Figure 20. Refuse pile of the Knight Mine.  
Photo taken April 23, 1982.

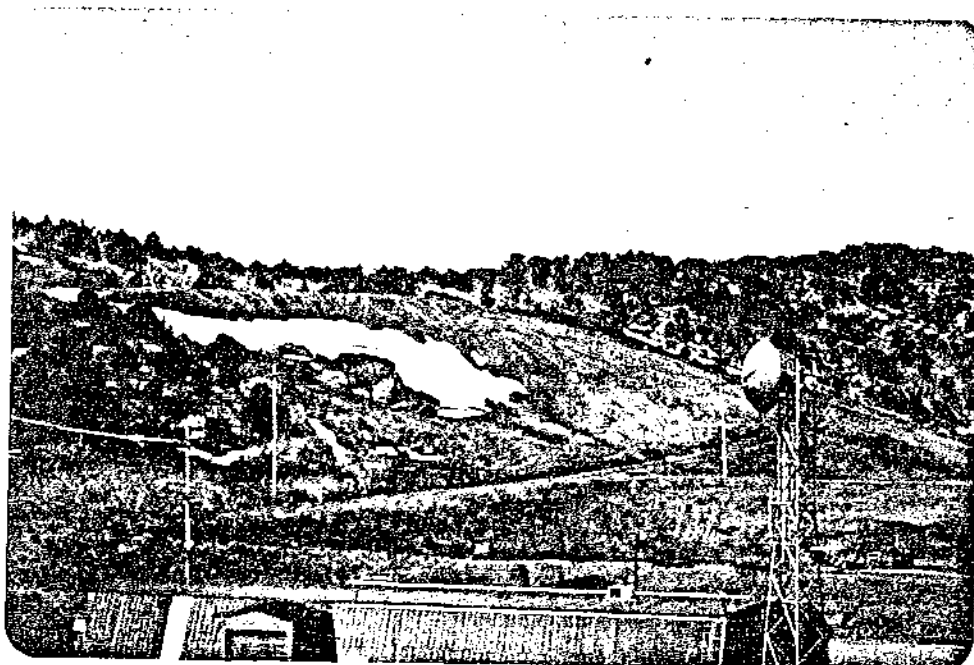


Table 9 .

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.35	0.14	42	27	31	clay loam
Refuse 0-15 cm	8.42	0.16	22	30	48	clay loam
15-30 cm	8.38	0.16	46	20	34	clay loam

Values for pH and EC are within normal tolerance levels (Table 9). Topsoil and refuse material are comparable for the elements tested. Trends from other mines indicate that N and P fertilizer amendments should be added to refuse material in revegetation.

#### Valley Camp of Utah

Valley Camp of Utah, near Schofield, currently disposes of coal refuse material (waste rock) underground. The mine produces 750,000 tons of coal annually and 1.2 million tons is the projected annual output. The mine is located at 2745 m (9000 ft.) and annual precipitation is 50 cm (20 in.). The surrounding vegetative community is composed of firs and aspen on the north slopes and sagebrush on the south and west exposures.

An old refuse pile in the general area of Valley Camp Mine was sampled. The pile was abandoned in the early 1960's and the extent of the refuse pile was difficult to determine due to slumpage from cuts above the pile and remaining snow cover (Figure 21). However, the pile is approximately 15 m x 31 m x 7.6 m (50 ft. x 100 ft. x 20 ft.). Ponding was noticed on the pile and a perennial stream runs below the pile.

Refuse and topsoil material have pH and EC values within normal range (Table 10).

Table 10.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.73	.08	19	34	47	clay
Old Refuse 0-15cm	8.40	.09	34	30	37	clay loam
15-30cm	8.38	.18	29	30	41	clay loam

#### Western Slope Carbon Co.

Hawks Nest Mine, Western Slope Carbon in Delta County, Colorado, has been in operation since the 1930's; current ownership began in 1975. The mine produces 1 million tons of coal annually. Capacity for the mine is 1.5 million tons of coal. Old refuse piles along the North Fork of the Gunnison River have been reclaimed by placing 61 cm to 91 cm (2 to 3 ft.) of gravels and 30 cm (1 ft.) of topsoil over the refuse pile and the area reclaimed to pasture. Hawks Nest Mine is currently using the Delta County Landfill to dump their refuse material. The pile is approximately 531 m x 92 m x 8 m (1700 ft. x 300 ft. x 25 ft.), and has 2:1 slopes. Slopes are being covered with soils as the refuse pile grows upward. The surrounding area is typified by badland topography and salt desert shrub vegetation (Figure 22).

The mine washes its coal by a Baum - jig washing process. Refuse material is referred to as gob. Hawks Nest also processes coal for Bear Coal Company.

Analysis indicates that gob material is alkaline (Table 11). Unfortunately, old refuse material was not accessible to evaluate if the gob has a trend towards lower acidity in older spoils. EC of the refuse is low and suitable for plant growth. Trends from other mines indicate that N and perhaps P should be added to the refuse material for revegetation.

Figure 21. An old refuse pile near Valley Camp of Utah. Currently, Valley Camp disposes of rock waste underground. Photo taken May 6, 1982.



Figure 22. Western Slope Carbon disposes of refuse at the Delta County Landfill. Photo taken April 29, 1982.

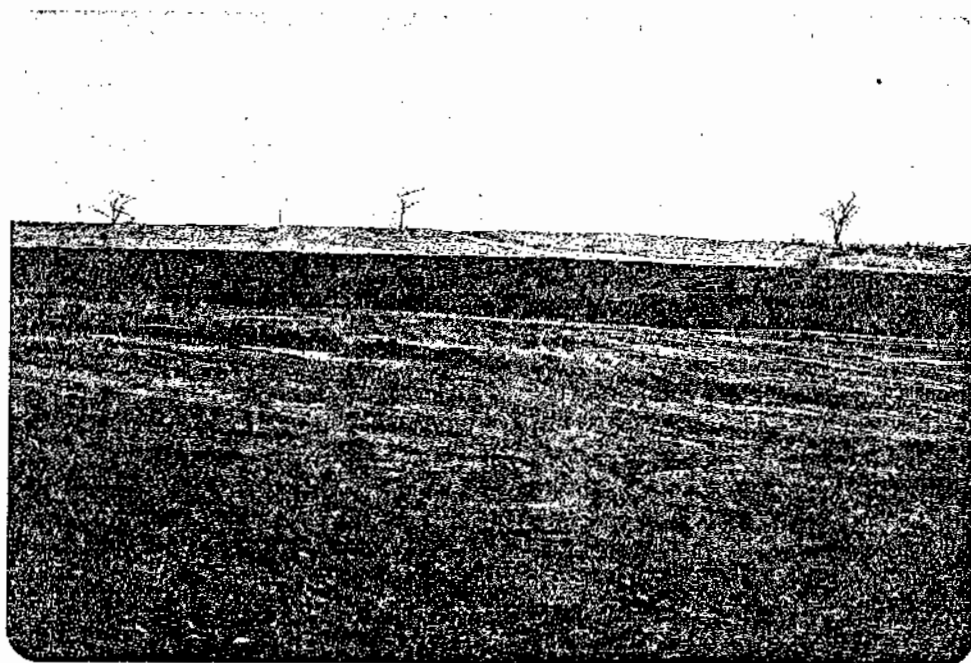


Table 11.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.01	2.24	17	30	53	clay
New refuse	9.48	1.06	48	20	32	sandy clay loam
New refuse (Bear Coal )	9.83	0.44	50	13	36	sandy clay
1 year refuse	9.47	0.89	69	8	22	sandy clay loam

### Mid-Continent Coal

Mid-Continent Coal Co., in Redstone, Colorado, began mining operations in 1956. The area receives 64 cm (25 in.) of annual precipitation and 70% of that is received as snow. Elevation at the mine is 2440 m (8000 ft.). The mine produces one million tons of coal annually, and within 10 years it is expected to produce three million tons annually. Mid-Continent produces a high quality coking coal. The mine is surrounded by a montane community of firs and aspen. A creek flows at the base of the refuse area and has been protected from the refuse by wood berms.

The refuse pile is 403 m x 153 m x 46 m (1300 ft. x 500 ft. x 150 ft.) and is extending upward. Old slopes on the site are at a ratio of one horizontal to one vertical and the new portion is at a ratio of two horizontal to one vertical. Reclamation of the refuse pile is progressing up slope, a couple of lifts behind the dumping of new refuse. Fifteen to 30 cm (6 to 12 in) of topsoil is placed over the refuse material. Although the site was visited when some snow was on the ground, greening was observed on the reclaimed area. Pine trees were planted directly on the ten year old portion of the exposed refuse pile. Many of these pines are

currently still alive. Grass stubble was also observed growing on the old exposed refuse (Figure 23.)

Analyses for several elements and compounds were done for Mid-Continent's topsoil and spoil material (Table 12).

Table 12.

	pH	EC	SAR	K*	Na*	Ca*	Mg*	Cl*	SO <sub>4</sub> *	HCO <sub>3</sub> *
Topsoil	6.43	0.06	0.23	0.88	0.20	14.0	1.64	0.12	0.04	0.003
New refuse	8.59	0.35	1.33	0.09	1.52	25.4	0.57	0.24	0.62	0.008
Old refuse										
0-15 cm	8.36	0.27	0.27	0.13	0.32	27.4	1.11	0.11	0.64	0.006
15-30 cm	8.47	0.65	0.30	0.13	0.36	27.9	1.20	0.12	0.70	0.009

\*expressed as meq/100g.

	ppm S	%K	ppm NO <sub>3</sub> -N	ppm P	% Organic Matter	% Sand	% Silt	% Clay	Texture
Topsoil	46.8	0.57	3.95	31.4	6.0	24	47	30	clay loam
New refuse	52.8	0.19	0.70	2.0	7.0	44	26	30	clay loam
Old refuse									
0-15 cm	62.4	0.29	0.65	2.2	6.8	62	17	21	sandy clay loam
15-30 cm	63.2	0.29	1.50	1.4	6.6	64	17	19	sandy loam

The analysis indicates that pH is within a normal range although the refuse material was more alkaline than the topsoil. EC, SAR, and the other salts are comparable to those found in the topsoil. Macronutrients, N and P, are low in the refuse material and would be recommended soil additives in reclamation.

#### Snowmass Coal Co.

Snowmass Coal Co. in Carbondale, Colorado has been producing 200,000 tons of coal annually until recent layoffs. Capacity is 2 million tons of coal per year. Annual precipitation at the mine is 41 cm (16 in.) with 75% of the precipitation occurring as snow. Elevation at the mine is 2318 m (7600 ft.). Southfacing slopes around the mine are sparsely vegetated

with a salt desert shrub community type and scattered juniper. North-facing slopes are vegetated by aspen and conifers.

Old refuse material was deposited along the banks of North Thompson Creek until the 1950's. Cottonwoods have established and developed suckers into the refuse material. The refuse pile is in a small, southfacing canyon and is being shaped to the same repose as the surrounding area. The pile is 153 m x 61 m (500 ft. x 200 ft.) and sloping to a height of 23 m (75 ft.). Maximum height of the refuse pile will be 61 m (200 ft.). Refuse is deposited in 12 m (40 ft.) lifts with 6 m (20 ft.) benches on a 1:3 slope. The lower portion of the pile has been covered with 0.8 m (2½ ft.) of subsoil (shale and sandstone) and 0.5 m (1½ ft.) of topsoil. Revegetation of the lower slopes will begin this year. Some temporary irrigation is available for revegetation. North Thompson Creek is below the pile. Sedimentation traps have been constructed at the base of the refuse pile to protect the stream (Figure 24).

Analysis of the topsoil and refuse material (Table 13) indicate that pH and EC are within normal range. The old refuse in the 15-30 cm depth has a higher  $SO_4$  content (9.22 meq/100g) and lower pH (7.37) than the other refuse material depths which may indicate an oxidation reaction. Other nutrients are within normal ranges compared with the topsoil material. However, N and possibly P should be added to refuse as fertilizer amendments in revegetation.

Figure 23. Refuse pile at Mid-Continent Coal Co.  
Photo taken April 28, 1982.

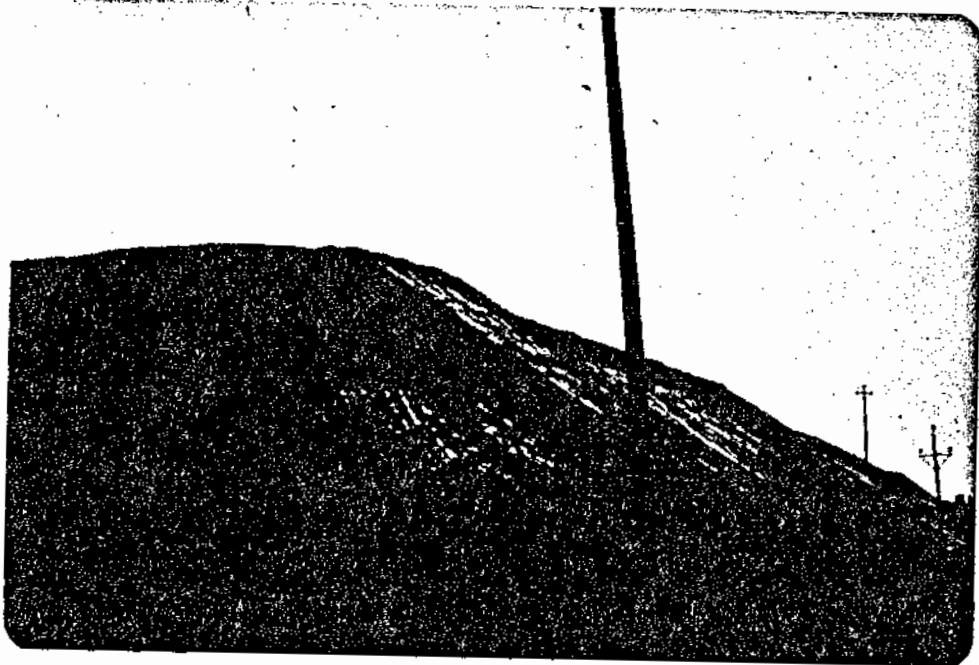


Figure 24. Refuse pile at Snowmass Coal Co. will eventually fill the canyon. Photo taken April 30, 1982.



Table 13.

	pH	EC	SAR	K*	Na*	Ca*	Mg*	Cl*	SO <sub>4</sub> *	HCO <sub>3</sub> *
Topsoil	8.27	0.45	0.23	0.52	0.33	34.9	5.76	0.11	3.20	0.009
New refuse	8.37	0.54	0.88	0.19	0.96	22.5	1.40	0.03	0.91	0.008
Old refuse										
0-15 cm	8.06	0.12	0.19	0.19	0.20	20.5	0.95	0.01	0.06	0.008
15-30 cm	7.37	1.01	0.16	0.29	0.19	24.5	2.30	0.08	9.22	0.006

	ppm B	%K	ppm NO <sub>3</sub> -N	ppm P	% Organic Matter	% Sand	% Silt	% Clay	Texture
Topsoil	65.6	1.25	1.95	1.2	2.9	29	24	48	clay
New refuse	18.4	0.18	0.65	1.6	0	58	30	12	sandy loam
Old refuse									
0-15 cm	32.0	0.23	0.65	2.2	6.0	70	12	18	sandy loam
15-30 cm	26.8	0.53	1.10	3.0	6.1				

\*expressed as meq/100g.

#### Meeker Area Mines

Mining began in the Meeker area in the 1920's. Currently, the Meeker Area Mines produce 700,000 tons of steam coal per year. Their capacity is one million tons of coal annually. The Meeker area receives 36 cm (14 in.) of annual precipitation, primarily as snow, and the elevation is 1830 m (6000 ft.). The refuse is composed of gob and fines from sedimentation ponds. The refuse pile is 15 m x 23 m x 14 m (50 ft. x 75 ft. x 45 ft.). Maximum height will be 15 m (50 ft.) as the pile spreads in an easterly direction. Life of the pile is expected to be approximately 10 years. Slopes are 4:1 and have a southern exposure. Topsoil is stockpiled (Figure 25).

Table 14.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	8.17	0.14	24	25	51	clay
New refuse (silt added)	9.18	0.20	26	28	46	clay
New refuse (rock)	9.45	0.41	51	19	30	sandy clay loam

The pH of gob material is alkaline; however, this is not expected to be a problem as the alklinity is expected to decrease with time. Salts, as indicated by EC, are low (Table 14).

#### Powderhorn Coal Co.

Powderhorn Coal Co., near Grand Junction, Colorado, contracts for 800,000 tons of steam coal annually. The mine is located at 1479 m (4850 ft.) elevation and receives an average of 20 to 24 cm (8 to 10 in.) of precipitation annually. The surrounding vegetation is of the salt desert shrub community type.

The mine has two refuse piles. One pile was completed last year. Slopes are 2½:1 with a north and northwest exposure. The pile is 153 m x 153 m x 21 m (500 ft. x 500 ft. x 70 ft.). There is a shortage of topsoil and other material to cover the pile. A small drainage area was located on the western portion of the pile and some erosion had occurred. However, the drainage has now been diverted to another area.

The mine plans to start some experimental revegetation plots in 1983 using varying amounts of topsoil to determine the minimum amount of soil cover needed for revegetaion. Mat saltbush was observed growing on the exposed refuse.

The currently used refuse pile is 610 m x 305 m x 9 m (2000 ft. x 1000 ft. x 30 ft.) high with 2½:1 slopes. Reclamation is expected for 1987 (Figure 26).

Table 15.

	pH	EC	% Sand	% Silt	% Clay	Texture
Topsoil	9.27	.46	51	23	25	sandy clay loam
New refuse	9.92	.45	58	17	25	sandy clay loam
Old refuse						
N. slope 0-15 cm	8.60	.67	58	14	27	sandy clay loam
15-30 cm	9.17	.42	54	17	29	sandy clay loam
Flat 0-15 cm	9.03	.80	59	15	26	sandy clay loam
15-30 cm	9.34	.78	64	13	24	sandy clay loam
N.W. slope						
0-15 cm	8.78	.62	57	17	27	sandy clay loam
15-30 cm	8.47	1.20	60	13	26	sandy clay loam

Refuse and topsoil material has alkaline pH (Table 15). However, native vegetation in the area should be adapted to pH. EC is within a normal range. Macronutrients, N and possibly K should be added in revegetation to the refuse material as indicated by analysis of other mines in the area.

### Mine C

Mine C produces approximately 1.3 million tons of coal annually. Capacity is approximately 1.8 million tons. Annual precipitation at the mine is 50.8 cm (20 in.) and elevation is 2074 m (6800 ft.). The surrounding vegetative type is typical of the pinyon-juniper community.

The current refuse pile is three years old. The refuse pile is small, 30 m x 50 m x 8 m (100 ft. x 164 ft. x 26 ft.) and slopes are 2:1. Reclamation has begun at the base of the pile and the grass appears to have good growth and density.

Refuse material or gob is composed of crushed rock and large pieces of coal. No washing facilities are present on the property.

Table 16.

	<u>pH</u>	<u>EC</u>	<u>% Sand</u>	<u>% Silt</u>	<u>% Clay</u>	<u>Texture</u>
Topsoil	8.26	0.26	14	29	57	clay
Gob	8.23	0.57	73	11	16	sandy loam

The pH and EC of the gob is comparable to the topsoil (Table 16). Macronutrients N and K as indicated from adjacent mines should be added to the refuse material as fertilizer amendments in revegetation.

Figure 25. Refuse pile at Meeker Area Mine. Photo Taken April 30, 1982.

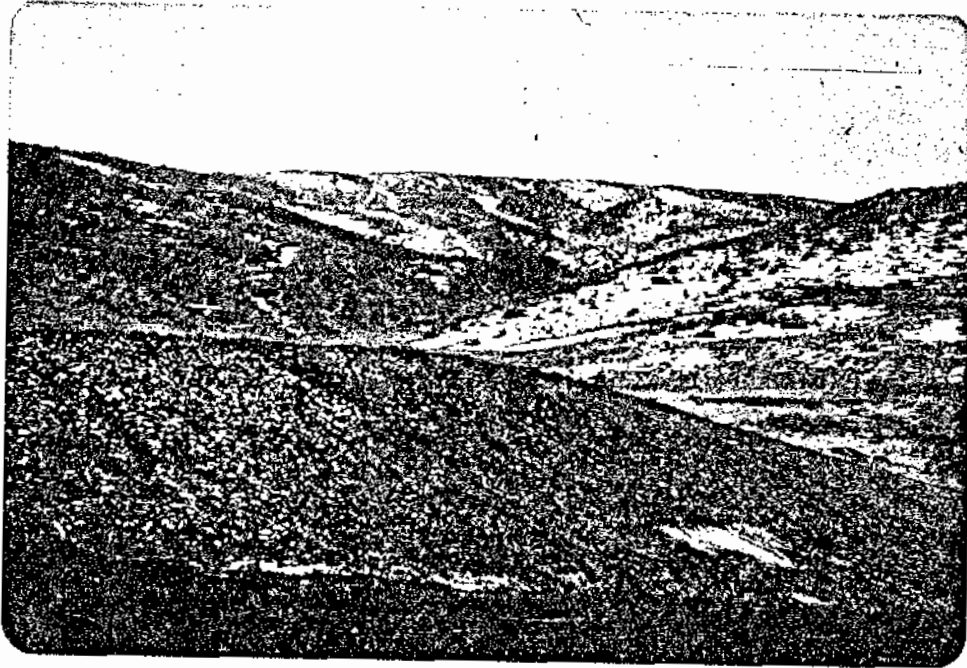
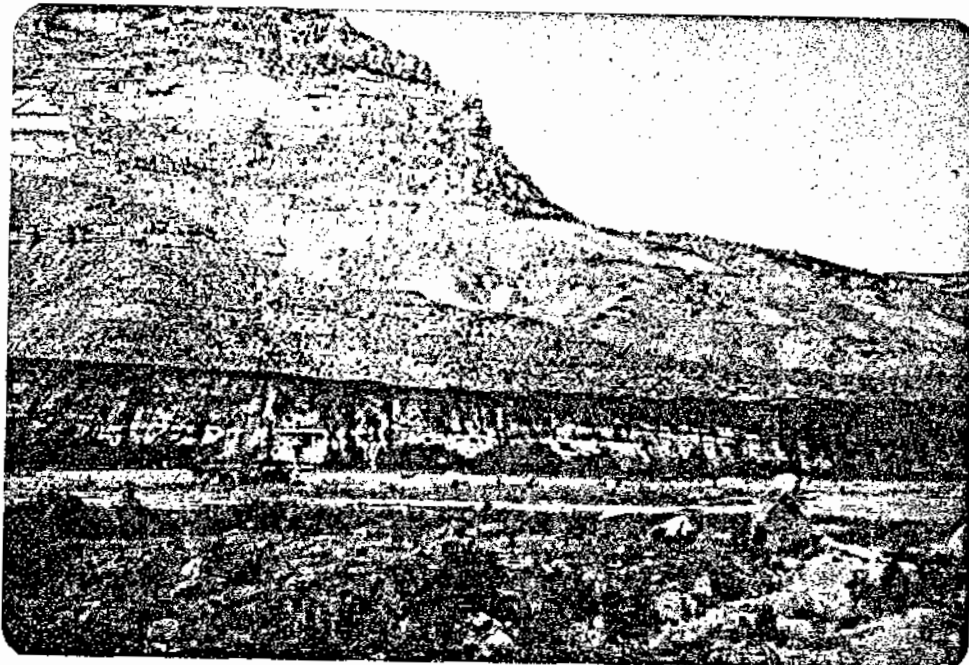


Figure 26. New refuse pile at Powderhorn Coal Co. Photo taken May 6, 1982.



## CONCLUSIONS

Several conclusions can be drawn from these studies particularly as they relate to the suitability of coal refuse material as a growth medium. This study provides a general investigation of refuse material as a growth medium, potential or current environmental impacts from refuse piles, and the feasibility of underground refuse disposal. Specific findings include:

- Overall variability of sampling results was high. Generalizations applicable to all sites are difficult due to the difference in site conditions. Recommendations and reclamation requirements must be site specific.
- Each mine needs to perform a chemical analysis of their refuse piles to determine acid-base potential, plant macronutrients, and toxicity. These test results may then be useful in determining the minimum surface coverage required on the refuse pile.
- Nitrogen and phosphorus (macronutrients) are low in refuse material. Fertilization and enhanced aeration of refuse piles appears necessary from preliminary macronutrient analyses for agricultural crops. Research is needed to determine nutrient and fertilization requirements for establishment and growth of native plant species.
- Salts are apparently low on the surface 30 cm of the refuse piles. High salinity does not appear to be a surface problem.
- From limited sampling, the possibility of boron toxicity appears in only one refuse pile. While boron toxicity need not be of primary concern, it should be monitored.

- pH of the refuse material was in the alkaline range; however, in several piles this appears to decrease as a function of time. A favorable pH range exists for a period of up to 30 or 40 years. Aging of the refuse piles appears to be favorable for potential revegetation (i.e. suitability as a media to sustain plant growth) because of the reduction of alkalinity. Some surface coverage of soil and vegetation establishment may be important to stabilize pH.
- Color of the refuse piles remained dark over time. Because of the correlation between dark color and high soil temperatures, combined with low soil moisture, some modification of the refuse pile surface appears necessary to moderate the thermal/moisture regime.
- General availability of suitable topsoil (quality and quantity) in mine vicinities is limited. Further study of alternative growth media is needed. These studies should include various depths of topsoil covers, mixing of the refuse with topsoil, or other materials.
- Vegetation is becoming established on a few of the refuse piles. Primary invasion of plants on refuse piles may have ecological value. Studies to enhance this are needed.
- Underground disposal of refuse is only economically feasible under certain geologic and mining conditions. In the future, the economics of mine design for underground refuse disposal could improve.

## LITERATURE CITED

- Allison, L. E. 1965. Organic Carbon, Chap. 90, pp. 1374-1376. In C. A. Black (ed.), *Methods of Soils Analysis*. American Society of Agronomy, Inc., Madison, Wisconsin.
- Association of Official Agricultural Chemists. 1965. *Official Methods of Analysis*. 10th Ed., p. 957. Washington, D. C.
- Bauer, A., W. A. Berg, and W. L. Gould. 1978. Correction of Nutrient Deficiencies and Toxicities in Strip-mined Lands in Semi-arid and Arid Regions. pp. 451-466. In F. W. Schaller (ed.), *Reclamation of Drastically Disturbed Lands*. Am. Soc. Agr., Crop Sc. Soc. Am., Soil Sc. Soc. Am., Madison, Wisconsin.
- Bingham, F. T. 1966. Phosphorus, Chap. 23, pp. 324-361. In H. D. Chapman (ed.), *Diagnostic Criteria for Plants and Soils*. Quality Printing Co., Inc., Abilene, Texas.
- Bradford, G. R. 1966. Boron, Chap. 4, pp. 33-61. In H. D. Chapman (ed.), *Diagnostic Criteria for Plants and Soils*. Quality Printing Co., Inc., Abilene, Texas.
- Caruccio, F. T. 1978. The Nature of Acid Mine Drainage Reactions and Their Relation to Overburden Analysis. In N. K. Wali (ed.), *Ecology and Coal Resource Development*, Pergamon Press.
- Clark, A. L. and A. C. Jennings. 1965. Spectrophotometric Estimation of Nitrate in Soil Using Chromotropic Acid. *J. Agr. Food Chem.* 13:174-176.
- Day, P. R. 1965. Particle Fractionation and Particle Size Analysis, Chap. 43, pp. 562-566. In C. A. Black (ed.), *Methods of Soils Analysis*. American Society of Agronomy, Inc., Madison, Wisconsin.
- Embleton, T. W. 1966. Magnesium, Chap. 18, pp. 225-263. In H. D. Chapman (ed.), *Diagnostic Criteria for Plants and Soils*. Quality Printing Co., Inc., Abilene, Texas.
- National Academy of Sciences. 1975. *Underground Disposal of Coal Mine Waste*. Report to the National Science Foundation, Washington, D.C.
- Olsen, S. R., C. V. Cole, F. S. Watanabe, and L. A. Dean. 1954. Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. *USDA Cir. No. 939*.
- Peterson, L. A. and R. C. Newman. 1976. Influence of Soil pH on the Availability of Added Boron. *Soil Sc. Soc. Am. Proc.* 40:280-282
- Richards et al. 1954. *Diagnosis and Improvement of Saline and Alkalai Soils*. *USDA Handb. No. 60, Method 4:89-91*.

- Schofield, R. K. and A. W. Taylor. 1955. The Measurement of Soil pH. *Soil Sci. Soc. Am. J.* 19:164-167.
- Sims, J. R. and G. D. Jackson. 1971. Rapid Analysis of Soil Nitrate with Chromotropic Acid. *Soil Sci. Soc. Am. J.* 35:605-606.
- Steel, R. G. D. and J. H. Torrie. 1960. Principles of Statistics. McGraw-Hill Book Co., Inc., New York. p. 418.
- Ulrich, A and K. Ohki. 1966. Potassium, Chap. 24, pp. 362-393. In H. D. Chapman (ed.), *Diagnostic Criteria for Plants and Soils.* Quality Printing Co., Inc., Abilene, Texas.
- West, P. W. and G. L. Lyles. 1960. A new method for the Determination of Nitrates. *Anal. Chem. Acta.* 23:227-252.
- Wewerka, E. M., J. M. Williams, P. L. Wanek, and J. D. Olsen. 1976. Environmental Contamination from Trace Elements in Coal Preparation Wastes, A Literature Review and Assessment. Los Alamos Scientific Laboratory, Los Alamos, New Mexico. ERDA LA-6600-MS, EPA-600/7-76-007.