Chemical Character of Minesoils at one Alaskan and twelve western conterminous United States coal-stripmines

by

R. C. Severson and L. P. Gough

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ERRATA

Page 42. Middle of page. "The highest average Zn level measured in topsoil was at the Seneca No. 2 mine (table 6), and in spoil at the Energy Fuels mine (table 7). Corrections are underlined.

Pages 60 and 61. In tables 6 and 7, the columns of data for the Energy Fuels and Seneca No. 2 mines are reversed.

Page 64. The reference should be, "Severson and others, 1981." Correction is underlined.

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INTRODUCTION

Current regulatory guidelines for rehabilitation of strip-mined land require assessment of the soil and spoil chemical quality both before and after mining to determine its suitability for plant growth. In the past, many methods have been used to characterize samples for the same chemical and physical properties (Bauer and others, 1978, p. 453), and many methods of sample preparation have similarly been used (Berg, 1978, p. 656). Sandoval and Power (1977) have attempted to standardize sample preparation and analysis for mined-land spoils in the western United States by writing a handbook of recommended laboratory methods. However, published reports, concerning rehabilitation of strip-mined lands, contain little consistency in their sample preparation or analytical methods. Studies, such as those by Jacober and Sandoval (1971), Severson and others (1979), and Soltanpour and others (1976), indicate that deviations in sample preparation, soil-extraction technique, and analysis may be serious enough to markedly affect results and interpretations. In addition, samples collected by several individuals, at different times of the year, with contrasting objectives, and analyzed in various laboratories, would not provide data that are readily comparable. Should such comparisons be made and differences in chemistry be found, it would be extremely difficult to determine whether such differences were indeed real, or merely the results of varying sampling and laboratory technique. It is, therefore, generally not feasible to use much of the published data on soil or spoil chemistry for making comparisons between mining districts, between states, between mines, or even between studies conducted by different individuals within a single mine, if the objective is to make rigid statistical assessments of variation in chemical character of soils or spoil.

The present study was undertaken in order to obtain extractable element composition data of topsoil and spoil material from a number of coal mine rehabilitated areas. The mines studied were: Dave Johnston, Seminoe No. 2, and Jim Bridger (Wyoming); Seneca No. 2 and Energy Fuels (Colorado); South Beulah, Velva, and Husky (North Dakota); and Big Sky, Decker, and Absaloka, (Montana) (fig. 1). All samples at these 11 mines were collected within a relatively short time span by one individual, they received the same preparation, they were analyzed by one laboratory using consistent methods, and they were prepared and analyzed in a randomized sequence so that any systematic error in preparation and analysis would be converted to a random error. Therefore, these data are useful for evaluating differences in the chemical composition of topsoil and spoil material between states and between mines, and should also indicate the amount of variability to be expected when small rehabilitated areas are sampled within a single mine. Similar information exists for the variability of natural soils in the northern Great Plains (Severson and Tidball, 1979) and in the San Juan Basin (Severson and Gough, 1980), for Fort Union Formation rocks in the northern Great Plains (Ebens and McNeal, 1977; Hinkley and Ebens, 1977), and for stream sediments in the northern Great Plains (McNeal, 1977). This information is useful for evaluating the background amounts of elements in these different natural materials. In conjunction with the present study, samples of rehabilitation plant species were also collected.

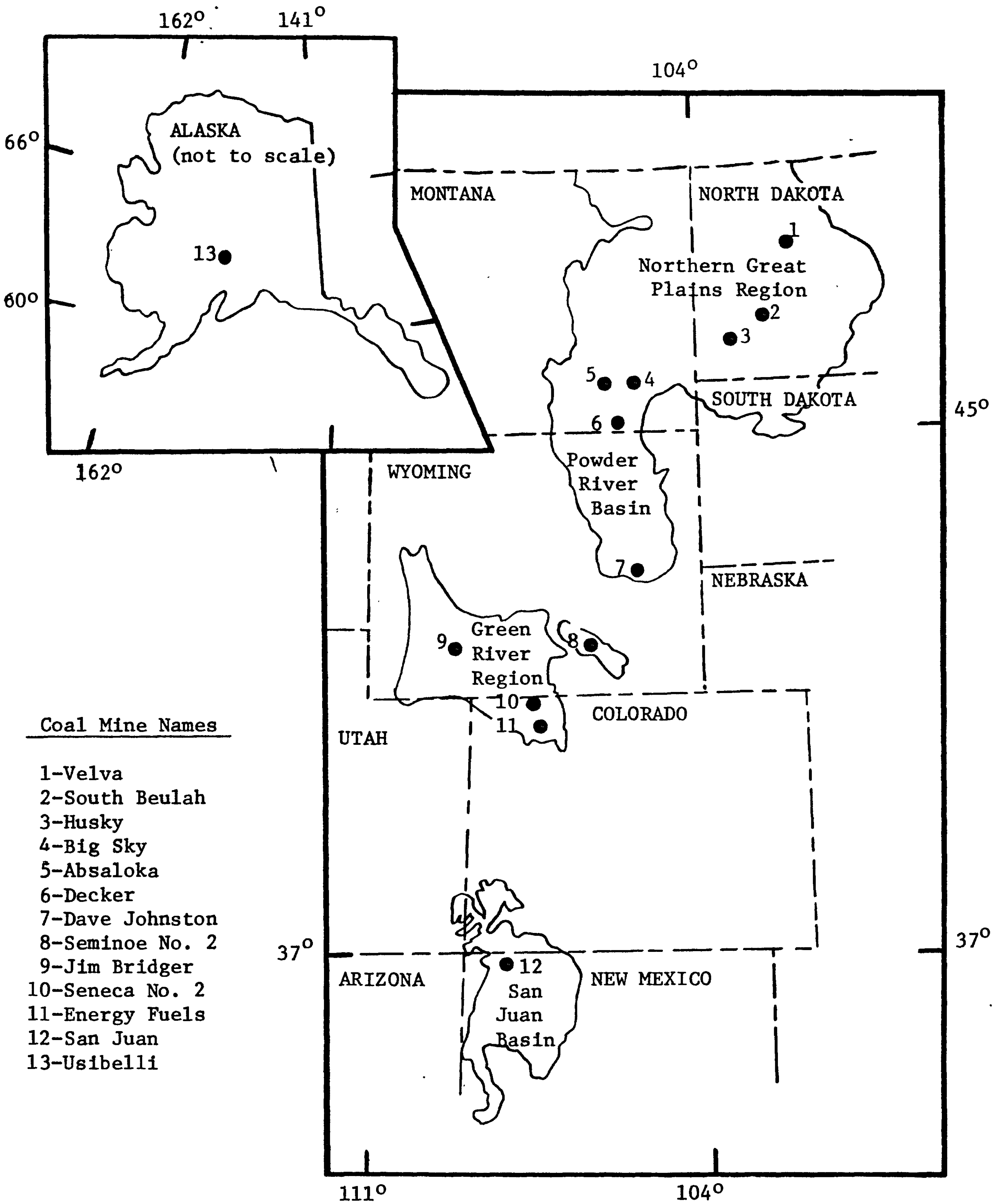

Figure 1. General locations of the coal strip mines sampled in this study.

The results of the biogeochemical variability between mines, between species, and between individuals of the same species within a mine are still being tabulated.

In addition to the mines listed above, samples of topsoil and spoil were collected at the San Juan Mine in New Mexico, and samples of natural soil and spoil were collected at the Usibelli Mine in Alaska (fig. 1). Even though these samples were collected by the same individual and prepared and analyzed by the same laboratory using the same methods as for the 11 mines listed above, continuity between these samples and those described above is lacking because the samples were collected with different objectives and at diffent seasons of the year. Therefore, comparisons between the chemistry of the soil and spoil materials at the San Juan Mine, the Usibelli Mine, and the 11 western mines should be made only with these qualifications in mind.

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The following persons were most cooperative in either granting us permission to collect samples of plant, soil, and spoil materials; or in spending time in the field showing and explaining their rehabilitation efforts: D. Elberg and D. Bennick (Husky Mine, Husky Industries, Inc.); G. Bierei, G. Herold, and T. Forney (Seminoe No. 2 Mine, Arch Minerals Corp.); H. P. Meuret (Jim Bridger Mine, Northern Energy Resources Co.); D. G. Deveraux, G. Peters, and J. R. Phillips (Dave Johnston Mine, Northern Energy Resources Co.); A. F. Grandt and R. Karo (Seneca No. 2 Mine, Peabody Coal Co.); W. L. Noud and K. A. Crofts (Energy Fuels Mine, Energy Fuels Corp.); C. L. Blohm and D. Morman (South Beulah Mine, Knife River Coal Mining Co.); J. D. Kirchmeier D. Hartwig, and L. Meira (Velva Mine, Consolidation Coal Co.); G. M. L. Robinson and R. Hoff (Big Sky Mine, Peabody Coal Co.); E. G. Robbins and D. Layton (Decker Coal Mine, Peter Kiewit Sons' Co.); D. W. Simpson and W. Sullivan (Absaloka Mine, Westmoreland Resources Inc.); R. W. Allen (San Juan Mine, Western Coal Co.); C. P. Boddy (Usibelli Mine, Usibelli Coal Mine Inc.); and Stan Weston (Usibelli Mine, Weston Agricultural Consultants Limited). Preparation and analyses of all samples were done in the U.S. Geological Survey Laboratories in Denver by J. W. Baker, A. J. Bartel, P. H. Briggs, J. G. Crock, C. M. Ellis, Carol Gent, B. Hatfield, K. E. Horan, R. G. Havens, Claude Huffman, Jr., T. Law, F. E. Lichte, J. G. McDade, C. McFee, R. E. McGregor, H. T. Millard, Jr., V. Merritt, Harriet Neiman, J. Peard, F. D. Perez, S. E. Prelipp, George Riddle, V. E. Shaw, K. Smith, A. L. Sutton, Jr., J. A. Thomas, M. L. Tuttle, R. E. VanLoenen, J. S. Wahlberg, and W. J. Walz.

FIELD SAMPLING

General Methods

Based on the tabular information provided by Evans and others (1978) for surface mined lands, we selected 11 mines that met their criteria which suggested that rehabilitation had been successful and would meet the demand of current regulations. These criteria were, (1) the area had been rehabilitated in the past 3 - 5 years, (2) topsoil had been used in the rehabilitation process, and (3) a wheatgrass and a legume had been included in the seeding mixture. By limiting our sampling using these criteria, we provided a basis for making comparisons between rehabilitated areas. At each mine, the rehabilitation specialist was most cooperative in helping select a suitable site of about 5 - 10 ha (hectares). We found that it was not possible to locate rehabilitated areas meeting all of the criteria at all of the mine sites. Most commonly, in order to meet criteria (1) above, criteria (2) and/or (3) were lacking. Therefore, criteria (1) and (3) were given priority and criteria (2) was satisfied if at all possible. Once a site had been selected, plants and soils were collected as follows: A random traverse across the site was made and at 10 locations, topsoil, spoil, and plant samples were collected. The actual sampling locations were dictated by the presence of acceptable plant material. Where grasses were sampled, the topsoil sample was obtained by digging around the plant clump to a depth of about 10 cm, extracting the plant clump with soil attached to the roots, and collecting the soil particles (topsoil, spoil, or a combination of both) adhering to the roots of the plant. Where a legume or plant other than a grass was sampled the topsoil material to a depth of about 10 cm was collected within a radius of about 20 cm of the plant. At each location where topsoil was collected, a second sample of material (called spoil material) was also collected. Because the "spoil" sample consisted of the material found between 20 to 30 cm directly below where the plant clump and topsoil had been removed, true spoil material was sampled only at some mines where topsoil was shallow or altogether absent. The spoil material was sifted through a stainless steel screen with 1 cm openings and material larger than 1 cm was discarded. In order to determine what approximate percentage of the spoil material was greater than 2 mm in diameter, samples of about 2 to 3 kg were collected at four sites at each mine where spoil material was within 50 cm of the surface.

A rehabilitated area at the San Juan Mine was sampled in the summer of 1977. Six samples each of topsoil and spoil material were collected in the general vicinity of where plants were collected, but not directly below where they were growing as described above. The topsoil samples consisted of only topsoil material and the spoil samples consisted of only spoil material. A discussion of differences between chemistry of natural soils and these mine-rehabilitated soils is given in Severson and Gough (1980).

A rehabilitated site and an adjacent undisturbed site were sampled in the spring of 1979 at the Usibelli Mine. Three samples each of undisturbed mineral soil material and spoil material were collected, but not in any particular location with respect to the plant samples. At the undisturbed site, mineral soil was collected from directly below a 15 to 20 cm mat of organic material. At the rehabilitated site, no topsoil had been applied and, therefore, the top 15 to 20 cm of spoil material was collected.

SITE CHARACTER

Dave Johnston Mine

This mine is located in Converse County, Wyoming, at approximately lat 43° 03' N. and long 105° 50' W. The rehabilitated area sampled was mined in 1968 and then, in 1972 it was recontoured, topsoiled, and seeded. Topsoil consisted generally of a noncalcareous sandy loam material that ranged in depth from 0 to 30 cm (table 1). Initally, a 15-to-30 cm veneer of topsoil was applied (J. R. Phillips, oral commun., September 1978) but subsequent erosion redistributed this material leaving some steep slopes bare of topsoil and some drainages containing 100 cm or more. The spoil material was quite variable in its lithologic composition between sampling sites (table 1). It ranged from sandstone to dark shale with some samples consisting of an estimated 60 percent coal fragments. It also ranged from noncalcareous (most common) to moderately calcareous. Most of the spoil fragments were less than 2.5 cm in diameter and about 50 to 75 percent of the spoil material was less than 2 mm in diameter (fig. 2).

Figure 2. Particle size distribution of four samples of spoil collected at the Dave Johnson Mine.

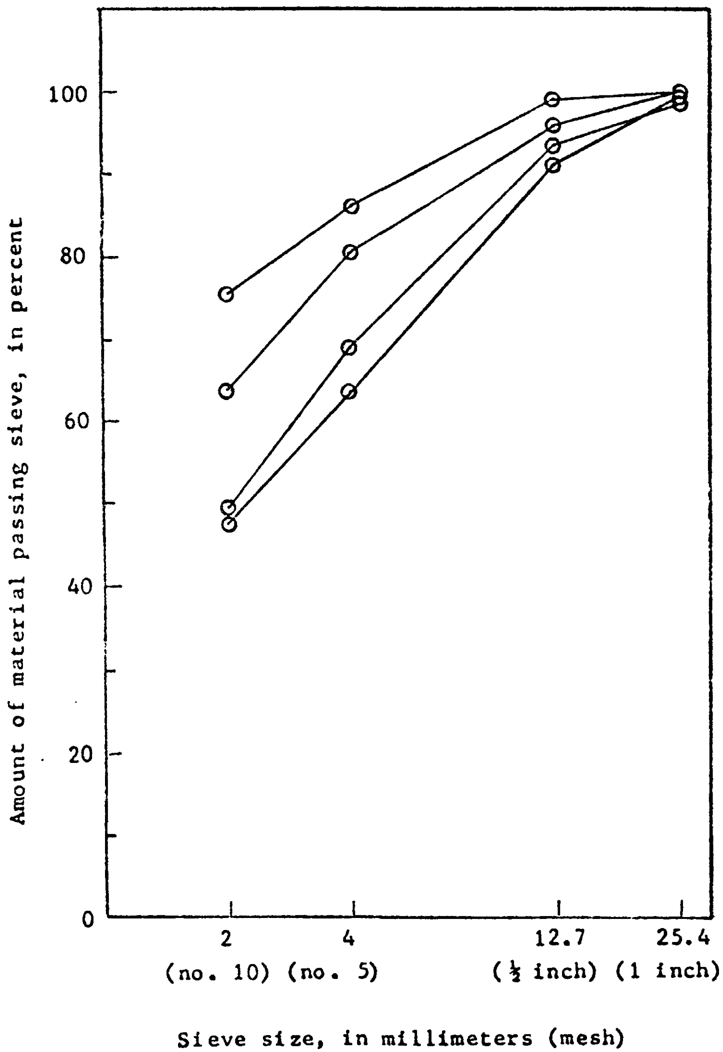
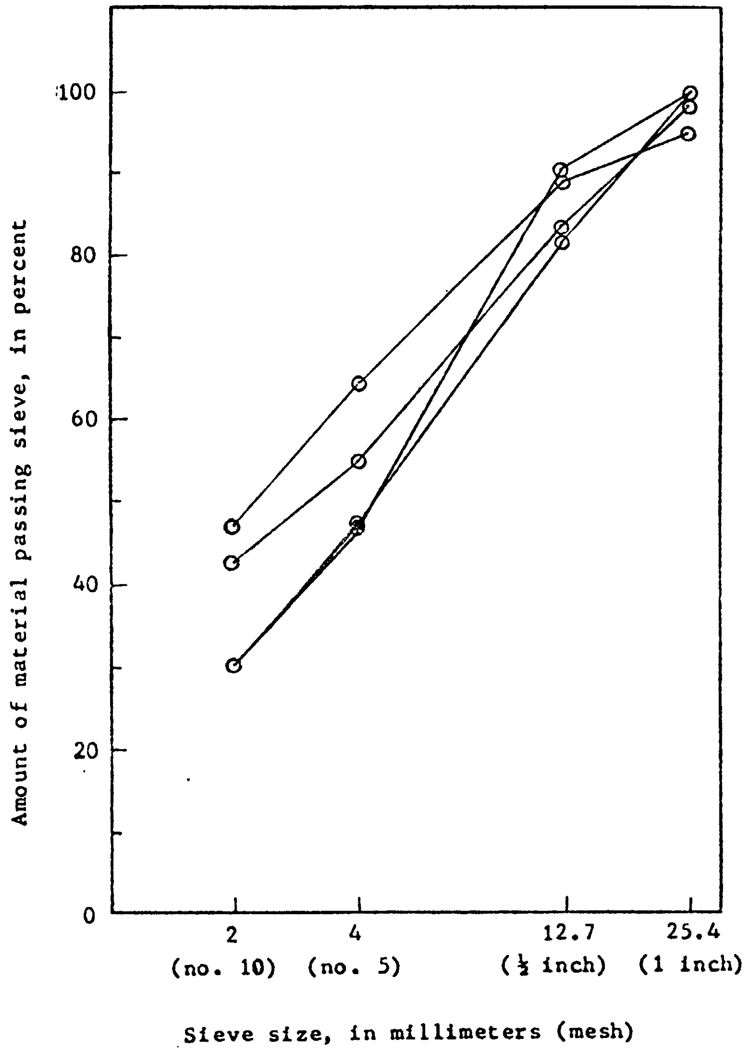


Figure 3. Particle size distribution of four samples of spoil collected at the Seminoe No. 2 Mine.



Seminoe No. 2 Mine

This mine is located in Carbon County, Wyoming, at approximately lat 41° 53' N. and long 106° 33' W. The area sampled was mined, regraded, and seeded in 1976 (Gary Herold, oral commun., September 1978). In this area, no topsoil was applied; therefore, both the "topsoil" and spoil samples are of spoil material, differing only in the depth from which they were collected. The spoil material consists of a diverse mixture of lithologies; however, fragments of coal were very sparse in this material (table 1). Consolidated sandstone fragments about 10 to 15 cm in diameter were present on the surface and throughout the mine-soil profiles. These fragments were not included in the samples collected for chemical analyses or for particle size analysis; however, they are estimated to be about 5 to 10 percent of the spoil volume. Very friable calcareous siltstone and weakly calcareous to noncalcareous shale was the major matrix of the samples collected. Very little erosion of regraded spoil was observed, probably because of the mixture of lithologies and particle sizes present. From 30 to 50 percent of the spoil material was less than 2 mm in diameter (fig. 3).

Jim Bridger Mine

This mine is located in Sweetwater County, Wyoming, at approximately lat 41° 46' N. and long 108° 45' W. In 1975, coal was strip mined from the rehabilitation area we chose for sampling (Area No. 302). The area was regraded in 1976. In the fall of 1976, native soil was removed from an unmined site and spread over the area--no stockpiling of topsoil was involved (Harley P. Meuret, oral commun., September 1978). The area was also seeded at this time. The topsoil material consisted of a noncalcareous to weakly calcareous, yellowish-brown, silt loam material (table 1). It ranged in thickness from 10 to 25 cm. The spoil material contained very few coal fragments (table 1) and consisted of a a noncalcareous to weakly calcareous, gray, brown, and reddish-brown silt loam matrix. Fragments of well-consolidated siltstone and very fine grained sandstone, which were less than 2.5 cm in diameter, accounted for about 20 percent of the spoil material volume. No shale material was found. From about 50 to 60 percent of the spoil material was less than 2 mm in diameter (fig. 4).

Figure 4. Particle size distribution of four samples of spoil collected at the Jim Bridger Mine.

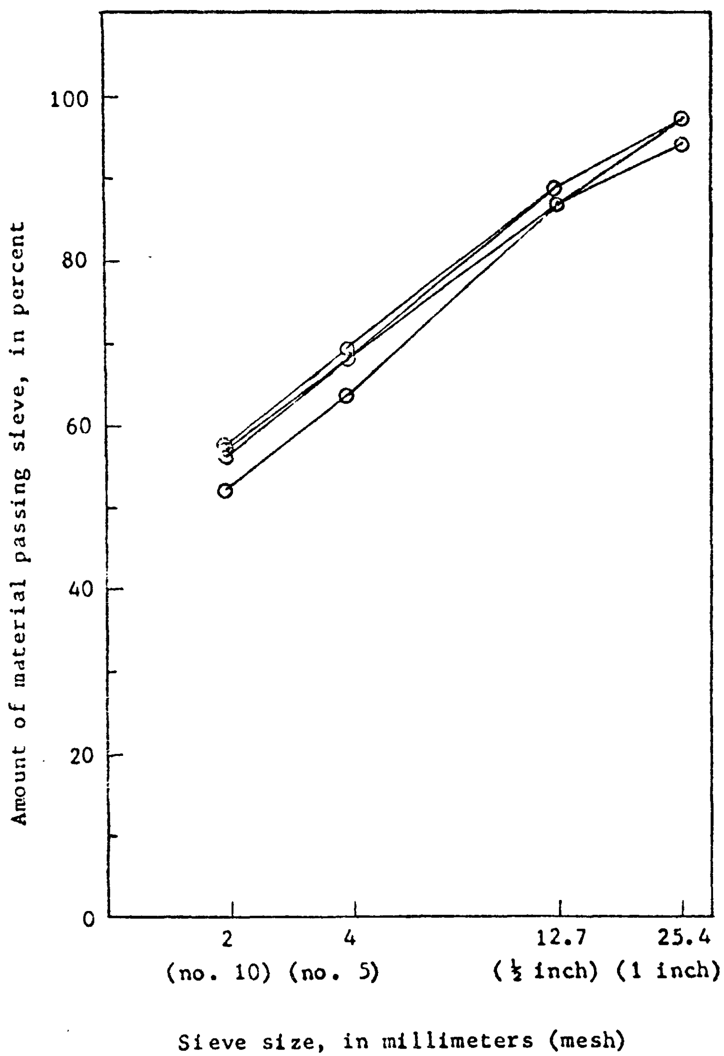
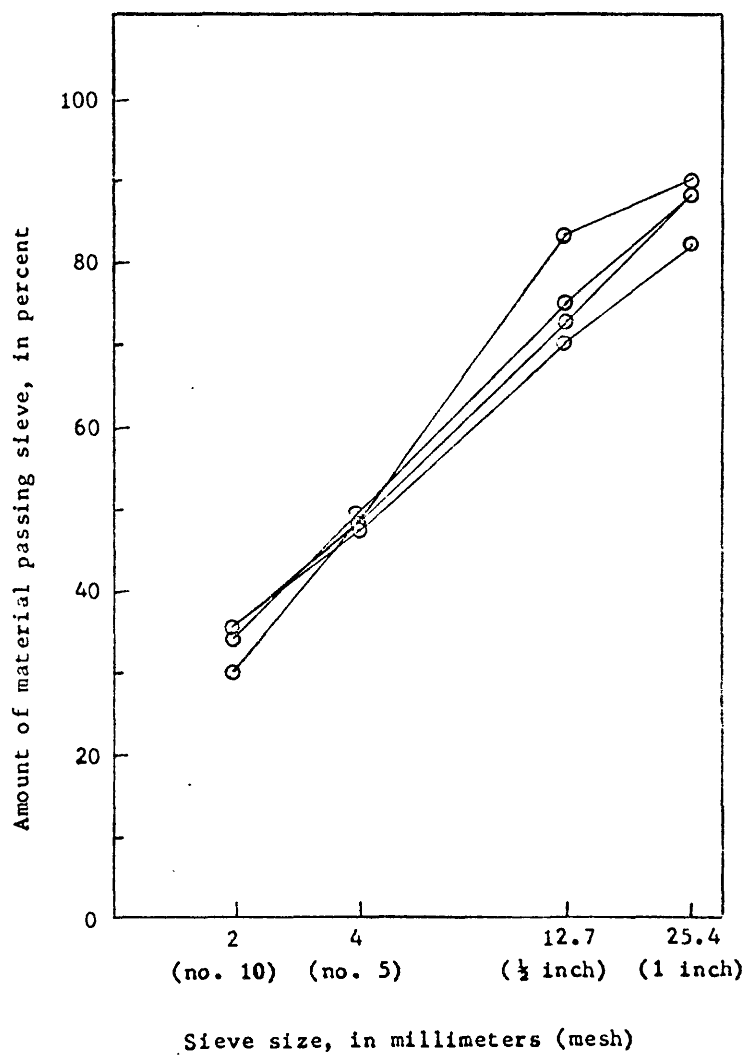


Figure 5. Particle size distribution of four samples of spoil collected at the Seneca No. 2 Mine.



Seneca No. 2 Mine

This mine is located in Routt County, Colorado, at approximately lat 40° 26' N. and long 107° 06' W. The rehabilitated area we sampled was mined, regraded, and seeded in 1975 (Roy Karo, oral commun., September 1978). No topsoil was applied to this area. Therefore, both "topsoil" and spoil samples are of spoil material differing only in the depth from which they were collected. The area contains many large consolidated pieces of sandstone (up to 0.5 m in diameter) both on the surface and within the mine-soil profile. Similar large pieces of friable black shale were also observed. Together they constituted an estimated maximum of 25 percent of the spoil material volume. Pieces of rock larger than 10 cm in diameter were not included in the samples for particle size analysis. The matrix of the spoil material consists of weakly to moderately calcareous, brown to black loam and finer textured materials (table 1). Small fragments of coal were commonly persent in the samples collected. From about 30 to 40 percent of the spoil material (not including fragments greater than 10 cm in diameter) was less than 2 mm in diameter (fig. 5).

Energy Fuels Mine

This mine is located in Routt County, Colorado, at approximately lat 40° 20' N. and long 107° 04' W. The area we sampled was mined in 1968. In late 1975 the spoil piles were graded and 20 to 25 cm of topsoil was applied. In early 1976 the area was seeded (Kent Crofts, oral commun., September 1978). At our sampling locations the topsoil ranged in thickness from 20 to 40 cm and consisted of a non-calcareous, dark brown and black, clay and silty clay material (table 1). The spoil material consisted of coarse fragments (about 10 to 15 percent were greater than 2.5 cm in diameter) of brown and black shale and siltstone, and gray sandstone (table 1). The sandstone was massive and well consolidated, and the shale and siltstone fractured easily into plates about 1 cm thick and 5 cm in length. The matrix of the spoil consisted of a noncalcareous, black, silty material, probably from the physical disintegration of the shale and siltstone, and a small amount of coal fragments (estimated to be less than 5 percent of the spoil volume). From about 35 to 50 percent of the spoil material was less than 2 mm in diameter (fig. 6).

Figure 6. Particle size distribution of four samples of spoil collected at the Energy Fuels Mine.

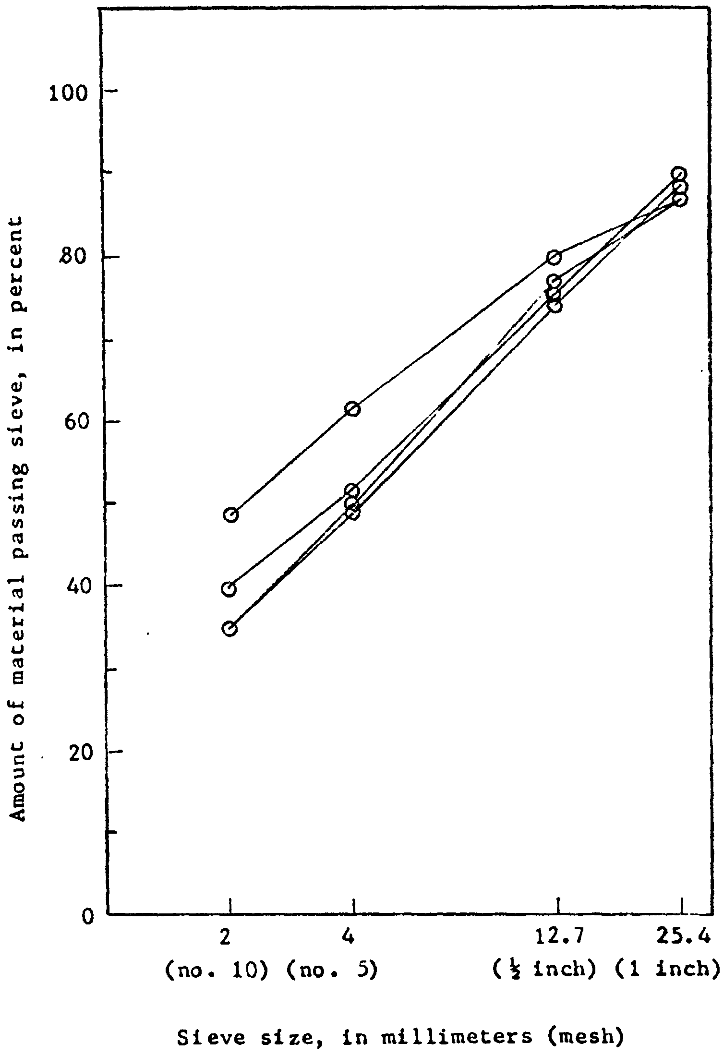
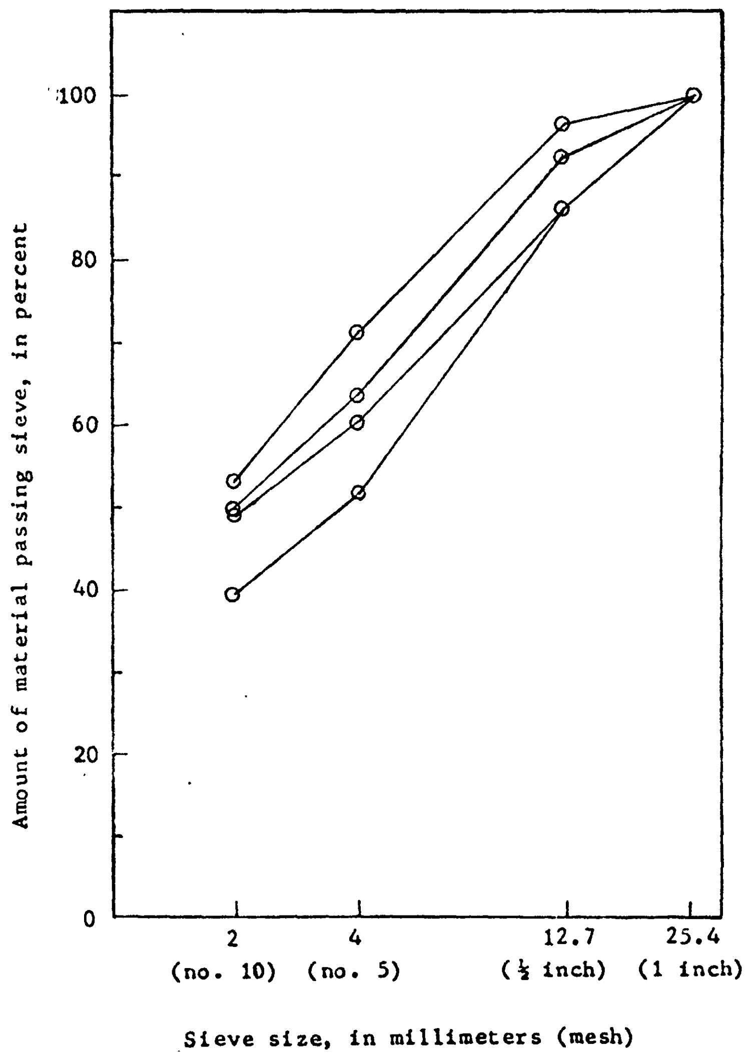


Figure 7. Particle size distribution of four samples of spoil collected at the South Beulah Mine.



South Beulah Mine

This mine is located in Oliver County, North Dakota, at approximately lat 47° 14' N. and long 101° 46' W. In the area we studied, coal was extracted in about 1972, spoil piles were graded in 1973, and 15 to 20 cm of topsoil was then applied (Dale Morman, oral commun., September 1978). The area was first seeded in 1974 and reseeded in late 1976. At the location sampled, the topsoil ranged in thickness from 10 to 20 cm and consisted of a moderately calcareous, dark-brown, silt loam material (table 1). The spoil material contained no fragments of rock larger than 2.5 cm in diameter. This is because the area has only 3 to 4 m of overburden, and all of this material has probably been physically and chemically weathered. Erratics were observed on the land surface indicating the area has also been glaciated; however the mantle of glacial till was very thin and almost completely removed. The spoil material is noncalcareous to moderately calcareous and consists of gray, brown, and black, weakly consolidated siltstone and shale (table 1). The spoil matrix is a silt loam and finer in texture. Very little coal was observed in the samples of spoil material. From about 40 to 55 percent of the spoil material was less than 2 mm in diameter (fig. 7).

Velva Mine

This mine is located in Ward County, North Dakota, at approximately lat 47° 57' N. and long 101° 00' W. The mine has been operating since 1929 under various owners and therefore mining and rehabilitation records are not readily available (Dwayne Hartwig, oral commun., September 1978). However, in the area we sampled, the spoil piles were graded, topsoiled, and seeded in 1973 or 1974. It is difficult to distinguish the topsoil material from the spoil material because both appear to be of glacial till (table 1). The material identified as spoil does, however, contain a moderate amount of coal fragments and a very small amount of weakly consolidated black shale. Evidently, this material now nearest the surface was the last overburden to be strip mined before the coal seam was encountered. The topsoil material, containing no coal, ranged from 5 to 25 cm in depth. The matrix of both the topsoil and spoil is a moderately calcareous, yellowish-brown, clay loam. Only about 20 to 30 percent of the spoil material was less than 2 mm in diameter (fig. 8). However, virtually 100 percent of this material was weakly consolidated and less than 2.5 cm in diameter and, with a moderate disaggregation force, would be broken down to much smaller aggregates. Because disaggregation was used to prepare the samples for chemical analyses, it is estimated that greater than 90 percent of the material was actually included for the analyses.

Figure 8. Particle size distribution of four samples of spoil collected at the Velva Mine.

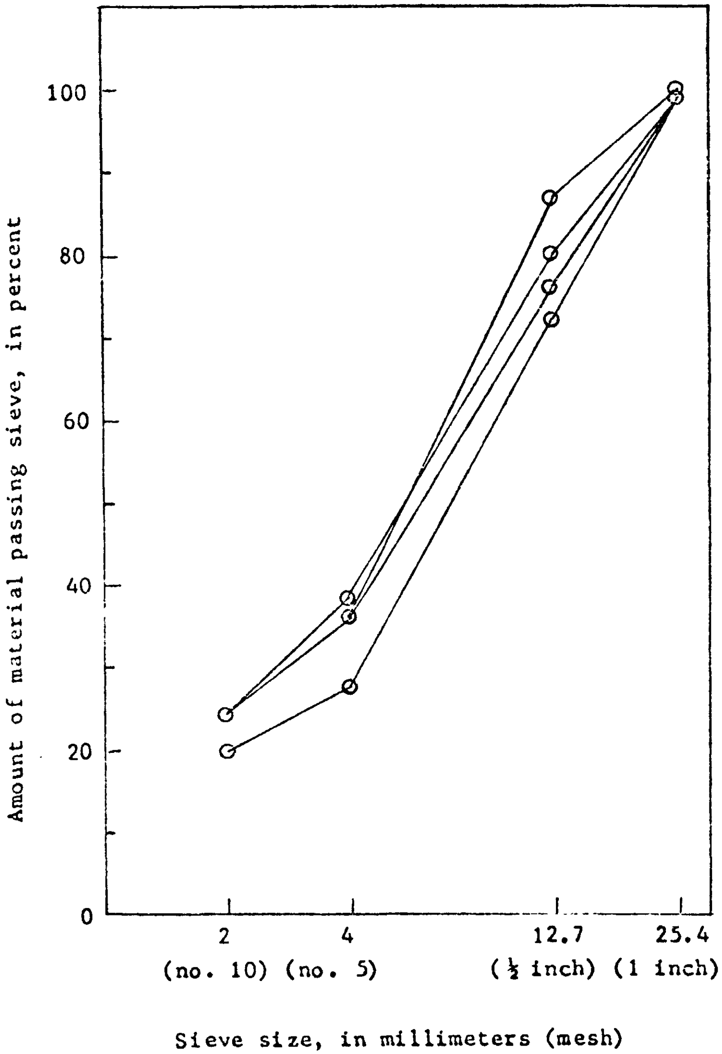
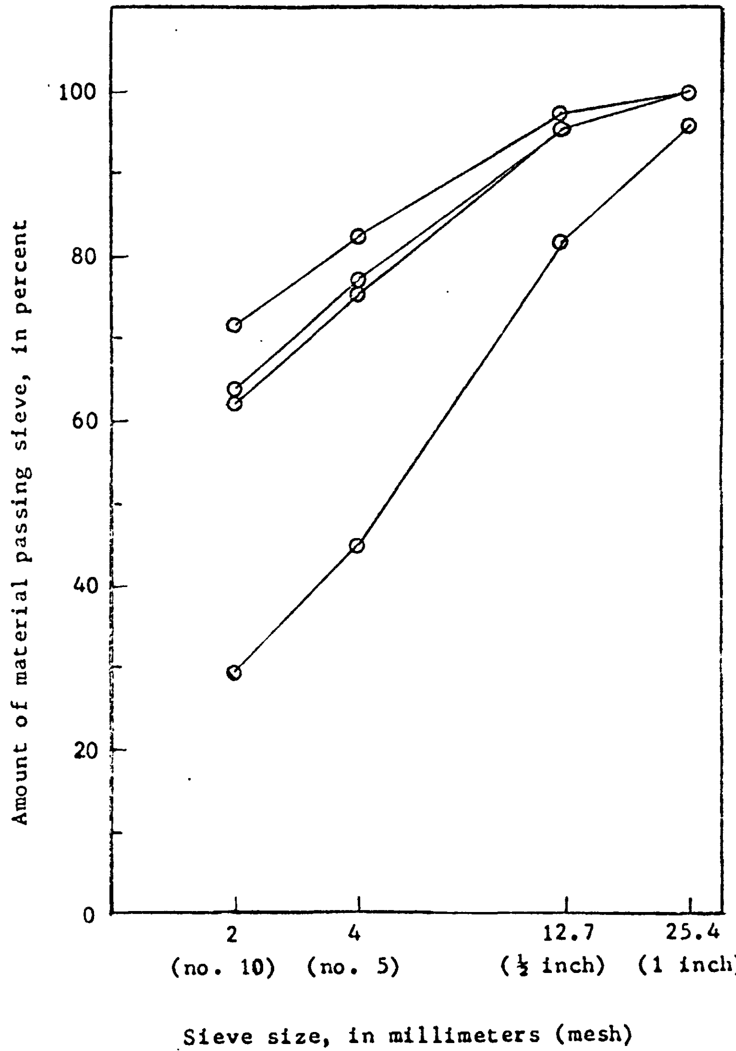


Figure 9. Particle size distribution of four samples of spoil collected at the Husky Mine.



Husky Mine

This mine is located in Stark County, North Dakota, at approximately lat 46° 51' N. and long 102° 41' W. The rehabilitated area we sampled was graded, subsoil and topsoil applied, and seeded in 1975 (Dale Elberg, oral commun., September 1978). The area is reported to have 30 cm of topsoil over 120 cm of subsoil. Where we sampled, the topsoil ranged from 15 to 50 cm in thickness and the subsoil was always greater than 70 cm (table 1). The topsoil consisted of a noncalcareous to weakly calcareous, dark-brown, clay loam material. The spoil material consisted of replaced subsoil rather than fresh, fragmented, sedimentary rock. This material was noncalcareous to weakly calcareous and ranged from a dark-brown, clay loam (similar to the topsoil) to a yellow-brown, very fine sandy loam. Almost all coarse fragments in the "spoil" material were less than 2.5 cm in diameter (fig. 9). The fraction of the spoil material less than 2 mm in diameter was from 60 to 70 percent; however, one sample was only 30 percent. These coarse fragments were weakly consolidated and most would be easily disaggregated to less than 2 mm.

Big Sky Mine

This mine is located in Rosebud County, Montana, at approximately lat 45° 49' N. and long 106° 36' W. Grading of the spoil piles, application of 60 cm of topsoil, and seeding were done in 1974 (Reg Hoff, oral commun., September 1978). This area was also reseeded in 1975. In the area we sampled, topsoil was from 10 to 30 cm deep and consisted of a moderately calcareous, yellowish-brown, silt loam and very fine sandy loam material (table 1). The spoil material was noncalcareous to weakly calcareous, gray, silty clay material (table 1). Little or no coal was observed in samples of this spoil material. Most of the coarse fragments (estimated as greater than 90 percent) in the spoil were less than 2.5 cm in diameter and were weakly consolidated. From 20 to 40 percent of the spoil material was less than 2 mm in diameter (fig. 10); however, upon disaggregation most aggregates were reduced in size to less than 2 mm.

Figure 10. Particle size distribution of four samples of spoil collected at the Big Sky Mine.

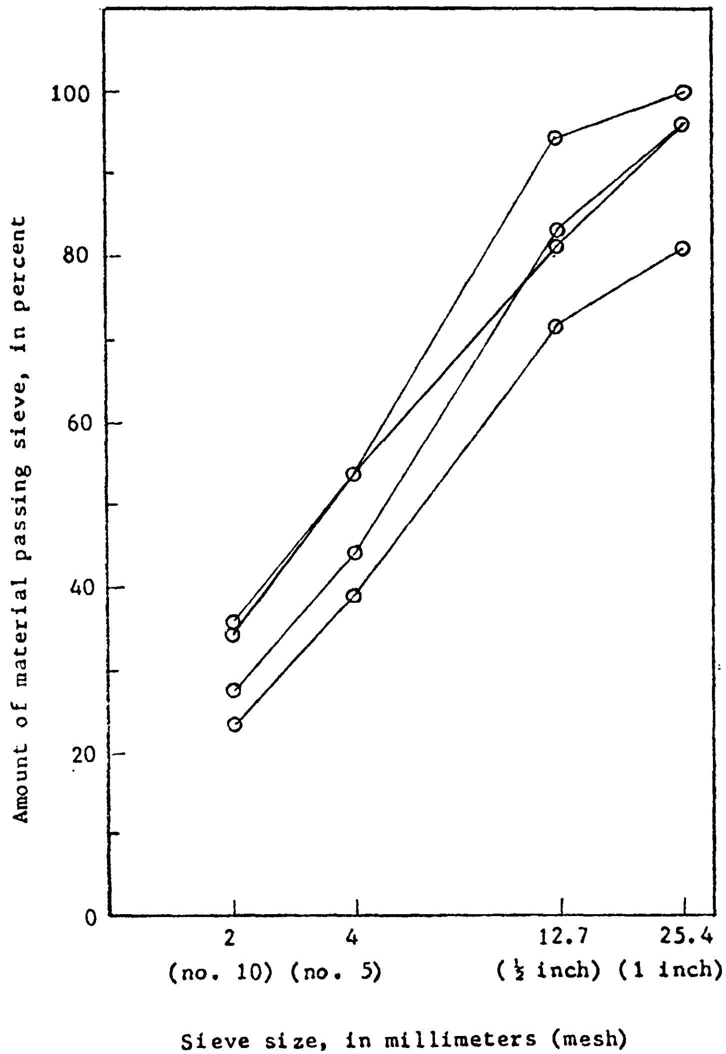
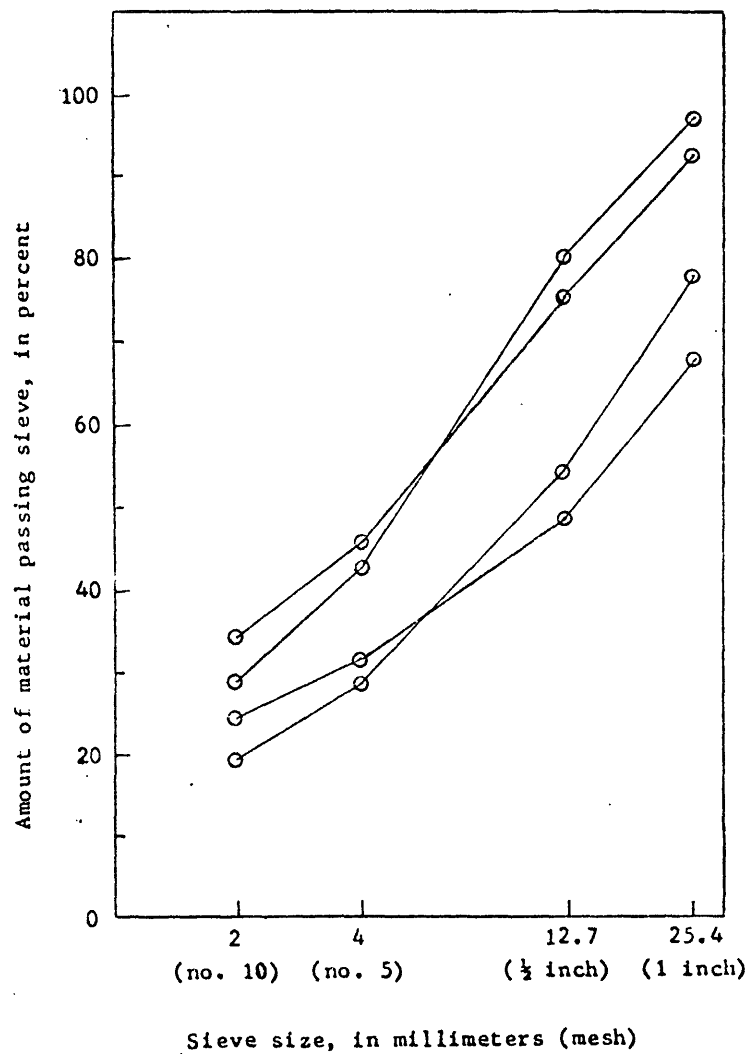


Figure 11. Particle size distribution of four samples of spoil collected at the Absaloka Mine.



Decker Mine

This mine is located in Big Horn County, Montana, at approximately lat 45° 03' N. and long 106° 03' W. The area in which samples were collected was regraded, topsoiled, and seeded in 1976. Before mining, the upper 15 cm of soil material (topsoil) was stockpiled as well as all soil material below this depth (which was considered nontoxic for plant growth) (Dwight Layton, oral commun., September 1978). Where we sampled, there was very little visible difference between the topsoil and subsoil. Their cumulative depth exceeded 90 cm. This material consisted of a yellowish-brown, calcareous, clay loam with some lenses of fine sand intermixed (table 1). At some sampling locations, the material below 30 cm was mottled with orange and gray colors, indicating it was largely unoxidized. No fragments of coal, and very few coarse fragments (greater than 2.5 cm in diameter) of sedimentary rocks, were found in any sample. No bulk samples were collected for particle size analysis because of the fineness and uniformity of the material.

Absaloka Mine

This mine is located in Big Horn County, Montana, at approximately lat 45° 49' N. and long 107° 06' W. Samples were collected from an area that was regraded, topsoiled, and seeded in 1975 (David Simpson, oral commun., September 1978). Topsoil consisted of a brown, calcareous, sandy loam material with a few segregated clayey aggregates less than 3 cm in diameter (table 1). The topsoil ranged in thickness from 25 to 40 cm. Marcasite concretions coated with carbonate (2 to 8 cm in diameter) were found on the surface at infrequent intervals. Screening of bulk samples of spoil material showed it to be quite variable in particle size. From about 70 to 90 percent of the spoil material was less than 2.5 cm in diameter and about 20 to 35 percent was less than 2 mm in diameter (fig. 11). The spoil material consisted of a mosaic of colors and textures--fragments of coal, shale, clinker, sandstone, and siltstone were common, and the matrix was largely a sandy loam material high in organic matter other than coal fragments (table 1).

San Juan Mine

This mine is located in San Juan County, New Mexico at approximately lat 36° 45' N. and long 108° 23' W. Samples were collected from an area that was regraded, topsoiled, and seeded in 1974 (R. W. Allen, oral commun., August 1977). The topsoil was uniformly about 20 cm deep and consisted of a moderately calcareous, yellowish-brown, fine and medium loamy sand (table 1). The spoil material was a weakly to moderately calcareous, loam to clay loam material containing small amounts of coal (table 1). Coarse fragments of sedimentary rock were present but they were not described or their abundance estimated. No data were collected on the spoil particle size distribution.

Usibelli Mine

This mine is located near Healy, Alaska (about 150 km south of Fairbanks) at approximately lat 63° 53' N. and long 148° 45' W.. The rehabilitated area sampled was regraded and seeded, but not topsoiled, in 1972 (C. P. Boddy, oral commun., June 1979). The spoil material was a neutral, dark-brown, silt loam and very fine sandy loam material (table 1) that appeared to be derived from a mica schist. Coarse fragments made up about 20 percent of the spoil volume. The natural soil material sampled was from below a 15 to 20 cm organic mat and was a noncalcareous, light-brown, medium to coarse loamy sand (table 1).

LABORATORY METHODS

Sample Preparation

All samples were air dried at ambient temperature. The dry samples were disaggregated in a motor-driven mortar and pestle and the fraction passing a 2-mm (10 mesh) sieve was saved. Greater than about 90 percent of all samples of topsoil material passed the 2-mm sieve after disaggreating, except for samples collected at the Jim Bridger Mine (about 80 percent). For spoil material samples, the fraction passing the 2-mm sieve was quite variable from site to site. Figures 2 through 11 show the particle size distribution of the true spoil material (sampled at sufficient depths so that no topsoil material was included) at various mine sites. The data used to construct the figures were obtained by dry sieving an approximate 2-to-3 kg sample of the air-dried spoil material which had not been previously disaggregated. The percentages passing the 2-mm sieve, therefore are less than the amount of material passing the sieve after disaggregating. However, many samples labelled as being of spoil material are actually mixtures of topsoil and spoil (table 2) because of the sampling criteria used. These samples, therefore, have varying amounts of material passing the 2-mm sieve after disaggregating and the amount is somewhat greater than the values indicated in figures 2 through 11 for each mine.

After the samples had been disaggregated, the fraction saved was split into two parts. One split was ground in a ceramic mill to pass a 100-mesh sieve (less than 149 um), and the other part received no further processing. All samples were processed in a random sequence so that any systematic bias would be converted to random error.

Chemical Analyses

The unground (less than 2 mm) material was used for all extractable element content determinations. Organic matter content was determined on the ground (less than 149 um) material as weight loss on ignition (Dean, 1974). Methods for extractable element determinations are described in Crock and Severson (1980) where Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn were determined in a DTPA extract; B was determined from a hot water extract; and pH was determined on a 1:1 soil to water paste. Extractable element content was determined on samples from the Usibelli Mine using the DTPA-NH_4HCO_3 extract of Soltanpour and Schwab (1977) as described in Severson and others (1980).

STATISTICAL ANALYSES

Estimates of variance components for states, mines, samples, and analyses were computed as shown in figure 12. These estimates are based on a four-level, unbalanced, nested, analysis-of-variance design. The samples of topsoil and spoil included in this analysis represent only the 11 western mines described previously (Field Sampling section). Figure 12 shows that unbalancing did not create any large differences in the coefficients used to compute mean-square estimates for the different levels. Therefore, the F-ratio used to test for significant differences between levels should reflect differences in natural variation and not differences in the coefficients used to estimate the mean-square values. The last level of the design, between analyses, estimates that part of the total observed variation which is due to sample preparation and analysis. When this variation is large (greater than 50 percent) relative to the natural variation, it is judged to be excessive and interpretations of such results are qualified.

Determinations of elements present in trace quantities commonly result in censored data--concentrations are reported as less than the lower limit of determination for the analytical method used. Statistical tests require completely numeric data sets; therefore, these censored values were replaced by small arbitrary values equal to 0.7 times the lower limit of determination. The small number of replaced values (tables A through D) should not significantly alter the statistical tests. Elements occurring in trace quantities tend to exhibit positively skewed frequency distributions. Therefore, a logarithmic transformation of the data prior to statistical analysis improves the estimates of central tendency because the frequency distribution of the log-transformed data is more nearly normal.

Some elements were approximately normally distributed, however statistical tests based on transformed and original data were similar. Therefore, all statistical results are based on log-transformed data unless otherwise stated.

Figure 12. Analysis-of-variance design used to estimate variation for districts, mines, samples, and analyses.

Source of variation	Degrees of freedom	Mean-square estimate	F-ratio	Variance component
Between districts (α)	3	$MS_1 = s_{\varepsilon}^2 + 1.2s_{\gamma}^2 + 10.4s_{\beta}^2 + 27.2s_{\alpha}^2$	MS_1/MS_2	$s_{\alpha}^2 = \frac{MS_1 - MS_2}{27.2} = \sigma_{\alpha}^2$
Between mines (β)	7	$MS_2 = s_{\varepsilon}^2 + 1.2s_{\gamma}^2 + 9.8s_{\beta}^2$	MS_2/MS_3	$s_{\beta}^2 = \frac{MS_2 - MS_3}{9.8} = \sigma_{\beta}^2$
Between samples (γ)	89	$MS_2 = s_{\varepsilon}^2 + 1.1s_{\gamma}^2$	MS_3/MS_4	$s_{\gamma}^2 = \frac{MS_3 - MS_4}{1.1} = \sigma_{\gamma}^2$
Between analyses (ε)	10	$MS_4 = s_{\varepsilon}^2$	[1]-----	$s_{\varepsilon}^2 = \sigma_{\varepsilon}^2$

[1]No F-ratio exists

Theoretical and observed frequency distributions for the data are given in figures 13 and 14. Figure 13 shows that all metals measured in the DTPA extract are log-normally distributed. (A possible exception is Mn, which may be approximated by either a normal or log-normal distribution). Boron and organic matter are also log-normally distributed, and pH is best described by a normal distribution (fig. 14).

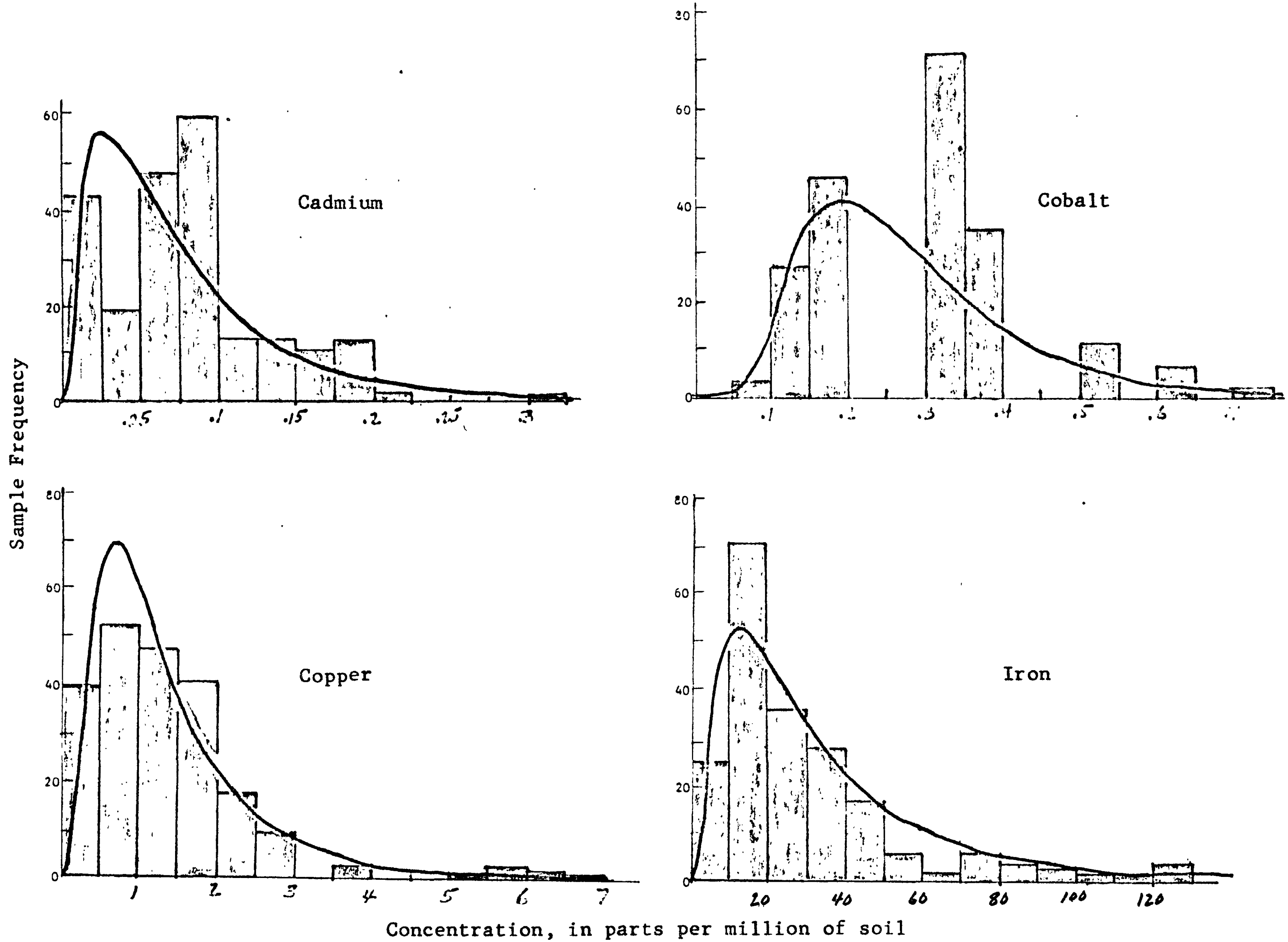


Figure 13. Theoretical log-normal (solid line) and normal (dashed line) and observed (bar graphs) frequency distributions for variables measured in DTPA extracts.

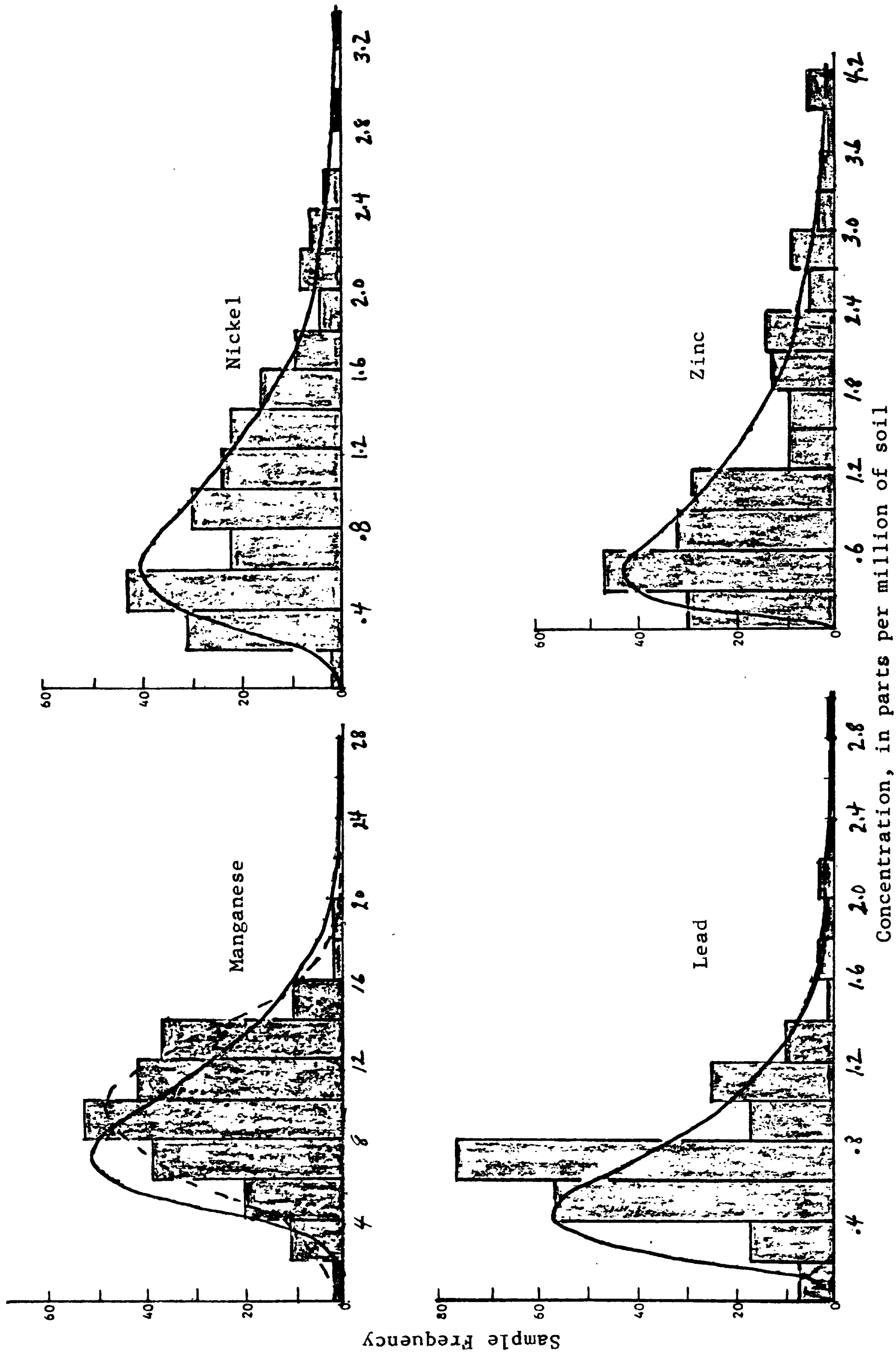


Figure 13. cont.

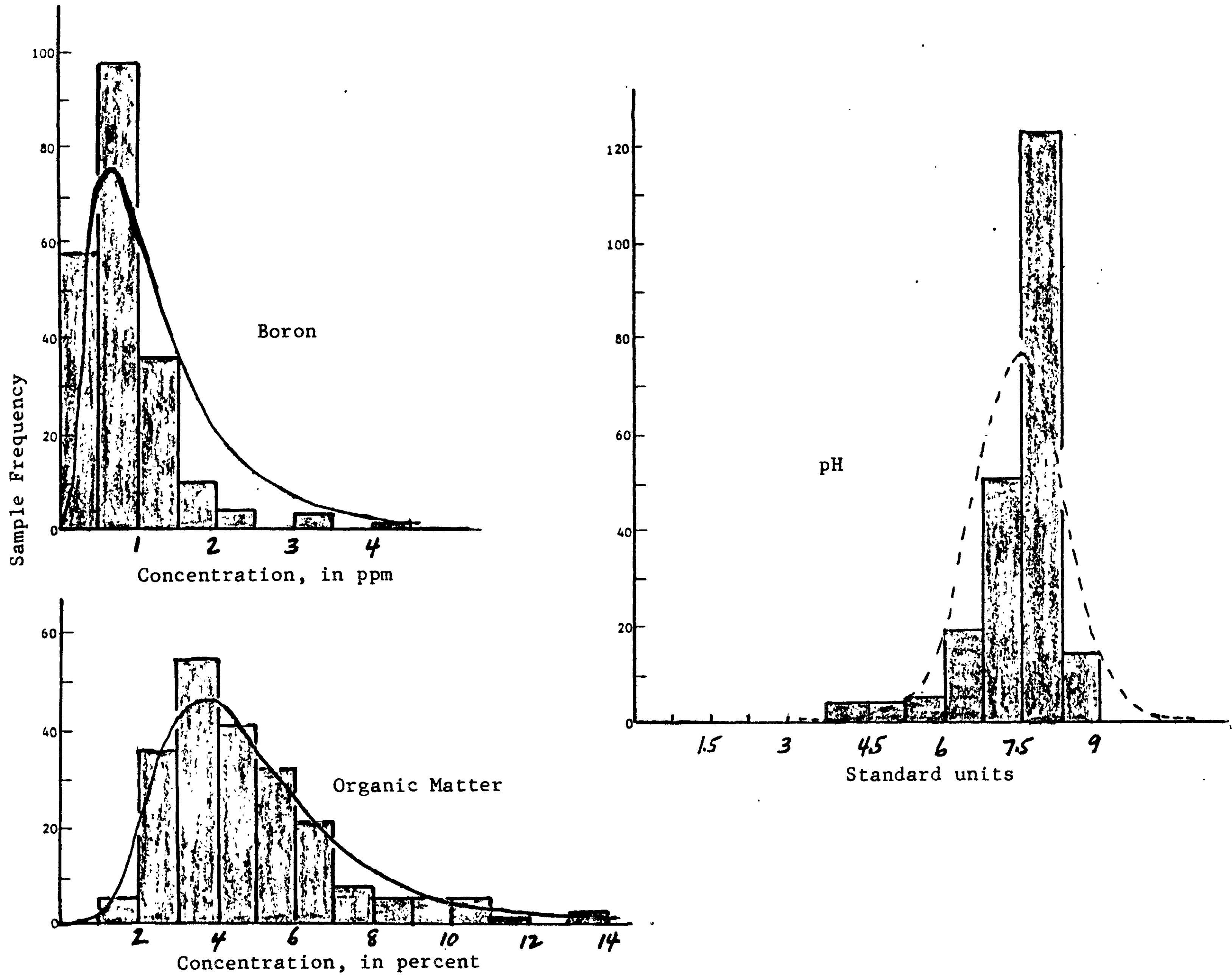


Figure 14. Theoretical log-normal (solid line) and normal (dashed line) and observed (bar graphs) frequency distributions for variables determined by various methods.

RESULTS AND DISCUSSION

A brief guide to the way in which the results are summarized and presented may aid the reader in evaluating the results and forming independent conclusions. Variation between states, mines, samples, and analyses is presented for topsoil and spoil material in tables 2 and 3, respectively. For variables exhibiting significant variation between states, a geometric mean and deviation was computed for each state and differences in these means are shown in table 4 for topsoil and in table 5 for spoil material. Means for variables exhibiting significant variation between mines are similarly presented in tables 6 and 7 for topsoil and spoil material, respectively. For variables showing significant variation between samples, summary statistics (geometric mean, geometric deviation, and observed range) for all topsoil and all spoil samples are presented in tables 8 and 9, respectively, and the results of individual analyses are given in appendix tables A-D.

The discussion of results given in the following section is only preliminary at this writing and is, therefore, subject to further interpretation.

Metals in DTPA Extracts

Components of variation are given for topsoil and spoil samples in tables 2 and 3, respectively. The metals showing the largest total variation, and therefore, those exhibiting the widest range in concentration in both topsoil and spoil material, are Cd, Cu, Fe, and Zn. Those metals exhibiting the smallest amount of total variation, and therefore the smallest range in concentration measures, are Co and Mn. A large portion of the total variation in Co and Pb is between analyses, or analytical error. Data for these metals are reliable for providing information on average amounts, but not as reliable for assessing variability.

A comparison of the average concentration of elements exhibiting significant variation between districts is given in table 4 for topsoil, and in table 5 for spoil material. For Cd, Cu, and Fe in topsoil, more than 40 percent of the variation was estimated to be between States (table 2). The mines sampled in Montana appear to have much lower mean levels of these metals than do mines in the other three States (table 4). For Co in topsoil, analytical error is high and total variation is low (table 2), and the differences in average concentration between states are small (table 4). More than 40 percent of the total variation for Cd, Fe, and Ni in spoil material (table 3) was estimated to be between states. Again, the mines sampled in Montana appear to have much lower mean levels of these metals than do mines in the other states (table 5). The average levels of Cd are highest in the Colorado mines, and the average levels of Fe and Zn are highest in the North Dakota mines (table 5). As in topsoil, analytical error for Co in spoil (table 3) is high and total variation is low and the differences in average concentration between states are small (table 5).

Comparisons of average concentrations of elements showing significant differences in variability between mines for topsoil and spoil material are given in tables 6 and 7. All elements, except Co (which has high analytical error), show significant variation between mines in both topsoil (table 2) and spoil material (table 3). More than 40 percent of the total variation in Zn in both topsoil and spoil material, and Cu in spoil material, was estimated to be between mines. Mines located in Montana have the lowest mean levels of Zn in topsoil (table 6) and two of these mines also have the lowest mean levels in spoil material (table 7). The highest average Zn level measured in topsoil was at the Energy Fuels Mine (table 6), and in spoil material at the Seneca No. 2 Mine (table 7). The highest average Cu level measured in spoil material was at the South Beulah Mine (table 7). Most of the DTPA extractable metals show no consistent pattern for high or low levels at any single mine or within mines in any single State. Therefore, useful generalizations on average metal levels based on State units or on mines within a State would be fortuitous, except perhaps for those elements exhibiting a large part of their variation between States.

Summary statistics for elements showing significant variation between samples are given for topsoil in table 8 and for spoil material in table 9. For Mn, more than 50 percent of the total variation (table 2) in topsoil, and more than 80 percent of the total variation in spoil (table 3) were estimated to be between samples. In tables 8 and 9 summary statistics are provided for all topsoil or spoil samples as a group. The between-sample-within-mine variability can best be observed by examining the individual analysis values given in appendix table A. Elements with small between-sample variability exhibit similar concentration levels from sample to sample within a mine (table A). Elements with large between-sample variability exhibit a wide range in concentration from sample to sample within a mine (table A). For some elements with large between-sample variability, the range in concentration measured for samples from a single mine may be nearly as wide as the range observed for all samples from all mines (Mn, for example at the Dave Johnston and Seneca No. 2 Mines, table A). When such large variation is measured locally within a single mine, valid generalizations on average metal levels for that mine may be fortuitous.

There appears to be no clear pattern for differences in levels of many DTPA extractable metals based on State units, mines, or even samples within a single mine. The mining and rehabilitation process, which mixes lithologic units and also includes various amounts of coal, may explain the great heterogeneity in our data on extractable concentrations of elements. Other soil variables, such as pH or organic matter content, may generally be more useful indicators of expected metal levels than are geographic divisions. The following table shows the simple correlations between pH and metal concentration, and between organic matter and metal concentration for the 110 samples of topsoil and spoil material.

SIMPLE CORRELATION COEFFICIENTS

	pH		log-organic matter	
	topsoil	spoil	topsoil	spoil
log-Cd	-.37	-.39	.68	.50
log-Co	-.46	-.38	.34	.28
log-Cu	-.43	-.41	.67	.36
log-Fe	-.69	-.69	.39	.51
log-Mn	-.28	-.07	.43	.20
log-Ni	-.32	-.52	.50	.44
log-Pb	-.14	.04	.48	.36
log-Zn	-.49	-.44	.65	.55

With this number of samples, a correlation coefficient of about 0.3 is considered significant at the 0.0001 probability level. From the table it can be seen that concentrations of many metals are directly related to organic matter content, and inversely related to pH. Admittedly, the amount of variation explained (r^2) by the simple correlation coefficients (r) is less than 50 percent in all cases. However, further interpretations using these two properties, and some other as yet undefined properties, to generate multiple-regression equations may enhance the prediction of metal concentrations in topsoil and spoil material samples from rehabilitated areas of coal-strip mines.

Other Variables

Boron

Greater than 60 percent of the variation measured for hot water extractable B in both topsoil and spoil samples was estimated to be at the between-mines level (tables 2 and 3). The Jim Bridger Mine has the highest concentration of B in both topsoil and spoil (tables 6 and 7). All other mines have similar levels (the lowest-to-highest values differing by a factor of about two) in both topsoil and spoil. The significant variation between samples of spoil (table 3) is also largely a result of the wide range in values measured at the Jim Bridger Mine (tables 9 and H). Simple correlations between log-B and pH in topsoil (r= .08), and in spoil (r= -.31) indicate that pH has little value for predicting B levels in topsoil, but may be important in combination with other as yet undefined variables for spoil. Simple correlations between log-B and log-organic matter in topsoil (r= .37) and in spoil (r= .47) indicate that organic matter (possibly coal fragments) may be more useful than pH as a component of a prediction equation, when combined with other variables.

pH

Variation between States, mines, and samples for both topsoil (table 2) and spoil material (table 3) is approximately the same for each of the three analysis of variance levels. This indicates that similar ranges in pH were measured between samples representing each level and, for samples from each of the levels, pH differed by a similar amount. In both topsoil and spoil pH was lowest for samples from Wyoming and highest for samples from Montana (tables 4 and 5). (In table 4, mean pH values for topsoil are included because of their relatively large variance component (table 2). They are not statistically compared, however, because they do not show significant variation at the between-state level.) Significant variation between mines and between samples for both topsoil (table 2) and spoil (table 3) indicates that generalizations at these levels may be inaccurate. Topsoil at the Dave Johnson Mine had the lowest mean pH measured (except for the Usibelli Mine) and the highest mean pH was measured at all Montana mines and the San Juan Mine (table 6). The lowest DTPA extractable metal levels were measured for the mines having the highest average pH, but the highest average metal levels were not consistently associated with those mines having the lowest average pH. In spoil material (table 7), the lowest average pH was measured at the Dave Johnston Mine and the highest average pH in the Montana mines. A similar relation between pH and DTPA extractable metals was observed for spoil as for topsoil. Significant variation between samples for both topsoil and spoil (tables 2 and 3) suggest that even within a single mine site a wide range in pH is to be expected. In table C, pH values for samples of topsoil from a single mine are shown to range as much as 2.5 units (Dave Johnston Mine) or as little as 0.3 units (Jim Bridger Mine). Similar ranges are shown for samples of spoil material within a single mine (table D). In table 1, from observations on topsoil samples from the Dave Johnston and Jim Bridger Mines, one would expect that the Dave Johnston Mine samples would be more uniform in their composition than Jim Bridger Mine samples. The opposite relation was observed, however. Therefore, basing chemical extrapolations on field observations of physical characteristics may be misleading, especially when estimates of chemical homogeneity (variability) are being made.

Organic Matter

Significant variation in topsoil (table 2) and spoil (table 3) organic matter content was estimated to occur between mines and between samples, but not between states. In both topsoil and spoil, the samples with high amounts of organic matter probably reflect the amount of coal intermixed with the mineral fraction (table 1). However, some samples at the South Beulah, Energy Fuels, and Absaloka Mines (table 1) contained organic matter that was not coal. As discussed previously (Field Sampling--General Methods section) the designations "topsoil" and "spoil" refer to the depth at which the samples were taken and, in some cases, are not good descriptors of the type of material that was actually sampled (table 1). In tables 6 and 7, the mines showing the highest amounts of organic matter in both topsoil and spoil material are from samples of true spoil material and these high values do reflect mainly coal fragments (table 1). Samples of both topsoil and spoil which are lowest in organic matter (tables 6 and 7) are samples of natural soil material applied to the regraded overburden as topsoil or subsoil (table 1). In the section on DTPA extractable metals, it was shown that simple correlations between organic matter and most of these metals may be useful in predicting their levels in topsoil and spoil. Even better predictions may result if those samples containing coal fragments, and those samples without coal fragments, are segregated for prediction purposes because coal and soil organic matter have differing properties.

PRELIMINARY CONCLUSIONS

Extractable elements composition data was obtained for topsoil and spoil samples from rehabilitated areas of the following coal-strip mines: Dave Johnston, Seminoe No. 2, and Jim Bridger (Wyoming); Seneca No. 2 and Energy Fuels (Colorado); South Beulah, Velva, and Husky (North Dakota); Big Sky, Absaloka, and Decker (Montana); San Juan (New Mexico); and Usibelli (Alaska). Differences in levels of many DTPA-extractable metals could not be consistantly related to States or mines. For some metals, the range in concentration measured within a small rehabilitated area at a single mine was nearly as large as the range measured at all mines. Generally, topsoil and spoil material appeared uniform in physical properties from sample site to sample site at any single mine; extractable metals, however, did not show similar uniformity. Broad-scale regulations for "suspect" or "toxic" levels based on a DTPA-soil extracts may be inappropriate because the data presented here show that large differences can be expected to occur between States, between mines, and even between small areas within a single mine. Rather than specific "suspect" or "toxic" levels for a metal based on DTPA extract of a few samples, it may be more realistic to evaluate areas using multiple prediction equations which include measurements of soil pH, organic matter and coal content, with other soil physical and chemical properties.

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Table 1. Field observations on samples of topsoil and spoil collected from rehabilitated areas of coal strip mines

[Because of the methods used to collect the samples, each sample may be a mixture of topsoil, subsoil, and spoil, the ratio value in the table (in percent) indicates the amount of topsoil in the sample--the remaining portion is spoil unless indicated as being subsoil material by an "S" enclosed in parenthesis, All data include in the table are based on field observations and should, therefore, be used as semi-quantitative estimates only; ---, no data available]

Sample type and field number	Ratio of topsoil to spoil in sample	Depth to spoil (cm)	Amount of coal in sample (percent)	Fine earth matrix (less than 2 mm) Reaction	Fine earth matrix (less than 2 mm) Description	Coarse Fragments (greater than 1 cm) Amount (percent)	Coarse Fragments (greater than 1 cm) Description
Dave Johnston Mine[1]							
Topsoil							
DJAC01	100	15	0	neutral	yellowish brown, sandy loam to loam	0	---
DJAC03	100	12	0	neutral	brown, fine sand to loamy fine sand	0	---
DJAC05	100	15	0	neutral	yellowish brown, sandy loam	0	---
DJAC07	100	>90	0	neutral	yellowish brown, sandy loam to loam	0	---
DJAC09	100	20	0	neutral	yellowish brown, sandy loam to loam	0	---
Spoil							
DJAC01	10	15	3	neutral	clay loam to silty clay loam	5	very friable shale
DJAC03	10	12	3	neutral	sandy loam to loamy sand	5	very friable shale
DJAC05	10	15	3	neutral	sandy loam to loamy sand	5	very friable shale
DJAC07	100	>90	0	neutral	yellowish brown, sandy loam to loam	0	---
DJAC09	10	20	0	neutral	sandy loam to loamy sand	5	very friable shale
Seminoe No. 2 Mine							
Topsoil							
SMAC01	0	0	1	weak to moderately calcareous	sandy loam to loamy sand	15	consolidated sandstone weak to moderately calcareous friable shale, moderately calcareous friable gra[y] siltstone
SMAC03	0	0	1	do.	do.	15	do.
SMAC05	0	0	1	do.	do.	15	consolidated sandstone weak to moderately calcareous friable shale, moderately calcareous dark brown siltstone
SMAC07	0	0	1	do.	do.	15	consolidated sandstone weak to moderately calcareous friable shale, moderately calcareous friable gra[y] siltstone
SMAC09	0	0	1	do.	do.	15	do.
Spoil							
SMAC01	0	0	1	do.	do.	15	do.
SMAC03	0	0	1	do.	do.	15	do.
SMAC05	0	0	1	do.	do.	15	consolidated sandstone weak to moderately calcareous friable shale, strongly calcareous friable light gray siltstone
SMAC09	0	0	1	do.	do.	15	consolidated sandstone weak to moderately calcareous friable shale, moderately calcareous friable gray siltstone
Jim Briger Mine							
Topsoil							
JBFS01	100	20	0	neutral to weakly calcareous	yellowish brown silt loam	5	very friable siltstone
JBFS03	90	12	0	do.	do.	30	do.
JBFS05	100	25	0	do.	light yellowish brown silt loam	15	do.
JBFS07	100	25	0	do.	do.	15	do.
JBFS09	100	25	0	do.	do.	15	do.

Table 1. Field observations on samples of topsoil and spoil collected from rehabilitated areas of coal strip mines. (Continued)

Sample type and field number	Ratio of topsoil to spoil in sample	Depth to spoil (cm)	Amount of coal in sample (percent)	Fine earth matrix (less than 2 mm) Reaction	Description	Coarse Fragments (greater than 1 cm) Amount (percent)	Description
				Jim Briger Mine, (continued)			
Spoil							
JBFS01	20	20	5	neutral to weakly calcareous	brown silt loam	20	consolidated fine grained sandstone, neutral to weakly calcareous consolidated siltstone
JBFS03	10	12	10	neutral	gray silt loam	50	consolidated fine grained sandstone, neutral consolidated siltstone
JBFS05	20	25	5	neutral to weakly calcareous	reddish brown silt loam	25	consolidated fine grained sandstone, neutral to weakly calcareous consolidated siltstone
JBFS07	20	25	20	do.	dark brown silt loam	15	do.
JBFS09	20	25	5	neutral	gray silt loam	25	consolidated fine grained sandstone, neutral consolidated siltstone
				Seneca No. 2 Mine[1]			
Topsoil							
SEAC01	0	0	0	weakly calcareous	brown laom	15	consolidated sandstone, friable black shale
SEAC03	0	0	5	moderately calcareous	dark brown loam	15	do.
SEAC05	0	0	0	do.	brown loam	25	do.
SEAC07	0	0	5	do.	dark brown loam	35	do.
SEAC09	0	0	0	neutral	reddish brown loam	15	do.
Spoil							
SEA01	0	0	0	weakly calcareous	brown loam	15	do.
SEAC03	0	0	5	moderately calcareous	dark brown loam	15	do.
SEAC05	0	0	0	do.	brown loam	25	do.
SEAC07	0	0	0	do.	dark brown loam	35	do.
SEAC09	0	0	0	neutral	reddish brown loam	15	do.
				South Beulah Mine[1]			
Topsoil[2]							
SBAI01	100	[3]---	0	moderately calcareous	dark brown very fine sandy loam to silt loam, high in organic matter	0	---
Spoil							
SBAI01	10	20	0	neutral	dark brown silt loam	1	very friable siltstone and shale
SBAI03	20	15	0	moderately calcareous	gray and brown silt loam	1	do.
SBAI05	20	15	5	neutral	reddish brown silt loam	1	do.
SBAI07	20	12	5	neutral	dark brown to black silt loam	1	do.
SBAI09	10	20	5	neutral	yellowish brown silt loam	1	do.
				Energy Fuels Mine[1]			
Topsoil[2]							
ENAC01	100	[4]---	0	neutral	[5]dark brown to black silty clay and silty clay loam	5	very firm aggregates of clayey soil material
Spoil							
ENAC01	20	25	0	neutral	brown and black silty clay loam	35	consolidated sandstone, friable black shale, friable gray siltstone
ENAC03	90	40	0	neutral	gray silt loam	20	do.
ENAC05	10	20	0	neutral	brown silt loam	20	do.
ENAC07	10	20	5	neutral	gray, brown, and black silt loam	30	do.
ENAC09	10	20	5	neutral	gray silt loam	35	do.

Table 1. Field observations on samples of topsoil and spoil collected from rehabilitated areas of coal strip mines. (Continued)

Sample type and field number	Ratio of topsoil to spoil in sample	Depth to spoil (cm)	Amount of coal in sample (percent)	Fine earth matrix (less than 2 mm) Reaction	Fine earth matrix (less than 2 mm) Description	Coarse Fragments (greater than 1 cm) Amount (percent)	Coarse Fragments (greater than 1 cm) Description
				Velva Mine			
Topsoil[6]							
VEMS01	100	[7]---	0	moderately calcareous	yellowish brown clay loam glacial till	0	---
Spoil							
VEAI01	20	25	0	moderately calcareous	yellowish brown clay loam glacial till	2	very friable black shale
VEAI03	20	10	20	do.	do.	2	do.
VEAI05	20	25	20	do.	do.	2	do.
VEAI07	20	25	10	do.	do.	2	do.
VEAI09	10	15	10	do.	do.	2	do.
VEMS01	10	20	10	do.	do.	2	do.
VEMS03	10	8	10	do.	do.	2	do.
VEMS05	10	8	0	do.	do.	2	do.
VEMS07	10	12	0	do.	yellowish brown clay loam glacial till, loamy sand lenses	2	do.
VEMS09	10	10	0	do.	yellowish brown clay loam glacial till	2	do.
				Husky Mine			
Topsoil[6]							
HUMS01	100	[8]---	0	neutral	dark brown clay loam	0	---
Spoil[9]							
HUAI01	0(S)	40	0	neutral	brown sandy clay loam	0	---
HUAI03	0(S)	40	0	neutral	do.	0	---
HUAI05	0(S)	55	0	neutral	do.	0	---
HUAI07	0(S)	40	0	neutral	do.	0	---
HUAI09	0(S)	30	0	neutral	do.	0	---
HUMS01	0(S)	30	0	neutral	brown clay loam	0	---
HUMS03	0(S)	30	0	neutral	brown clay loam, yellowish brown loamy sand	0	---
HUMS05	0(S)	30	0	neutral	do.	0	---
HUMS07	0(S)	30	0	neutral	do.	0	---
HUMS09	0(S)	15	0	weakly calcareous	yellow brown very fine sandy loam and silt loam	0	---
				Big Sky Mine[1]			
Topsoil							
BSMS01	100	25	0	moderately calcareous	yellowish brown silt loam	0	---
BSMS03	100	15	0	do.	lighty yellowish brown very fine sandy loam	0	---
BSMS05	100	25	0	do.	do.	0	---
BSMS07	100	15	0	do.	do.	0	---
BSMS09	100	30	0	do.	do.	0	---
Spoil							
BSMS01	50	25	0	neutral	gray silty clay loam	3	very friable gray shale
BSMS03	0	15	0	neutral	do.	3	do.
BSMS05	80	25	0	neutral	do.	3	do.
BSMS07	0	15	0	neutral	do.	3	do.
BSMS09	90	30	0	neutral	do.	3	do.
				Decker Mine			
Topsoil[6]							
DEAE01	100	>90	0	moderately calcareous	yellow brown loam to clay loam with up to 30 percent of loamy fine sand lenses	0	---
Spoil[6,9]							
DEAE01	0(S)	>90	0	do.	do.	0	---

Table 1. Field observations on samples of topsoil and spoil collected from rehabilitated areas of coal strip mines. (Continued)

Sample type and field number	Ratio of topsoil to spoil in sample	Depth to spoil (cm)	Amount of coal in sample (percent)	Fine earth matrix (less than 2 mm) Reaction	Fine earth matrix (less than 2 mm) Description	Coarse Fragments (greater than 1 cm) Amount (percent)	Coarse Fragments (greater than 1 cm) Description
				Absaloka Mine[1]			
Topsoil[2]							
SCAE01	100	[10]---	0	moderately calcareous	brown sandy loam, few dark brown silty clay aggregates	0	---
Spoil							
SCAE01	70	25	5	moderately calcareous	dark brown to black sandy loam high in organic matter other than coal	20	friable shale and siltstone of many colors, clinker
SCAE03	100	30	0	do.	do.	0	---
SCAE05	100	40	0	do.	do.	0	---
SCAE07	100	40	0	do.	do.	0	---
SCAE09	60	25	5	do.	do.	20	friable shale and siltstone of many colors, clinker
				San Juan Mine			
Topsoil[2]							
SJ01	100	20	0	moderately calcareous	yellowish brown fine and medium loamy sand	---	---
Spoil[2]							
SJ01	0	20	3	weakly to moderately calcareous	loam to clay loam	---	---
				Usibelli Mine			
Natural Soil[2,11]							
UM01	100	---	---	neutral	light brown medium and coarse loamy sand	0	---
Spoil[2]							
UM01	0	0	---	neutral	dark brown silt loam and very fine sandy loam	20	schist

[1]Samples were collected at locations adjacent to one another and therefore, the description of the topsoil and spoil samples is similar

[2]Material is uniform in composition from site to site.

[3]Topsoil ranges in depth from site to site as follows: SBAI01, 20 cm; SBAI03, 15 cm; SBAI05, 15 cm; SBAI07, 12 cm; SBAI09, 20 cm.

[4]Topsoil ranges in depth from site to site as follows: ENAC01, 25 cm; ENAC03, 40 cm; ENAC05, 20 cm; ENAC07, 20 cm; ENAC09, 20 cm.

[5]Topsoil has characteristics of natural soils of alluvial valley floors.

[6]The two plant species were sampled at separate sites, however, the soil material is uniform in composition throughout the area sampled.

[7]Topsoil ranges in depth from site to site as follows: VEAI01, 25 cm; VEAI03, 10 cm; VEAI05, 25 cm; VEAI07, 25 cm; VEAI09, 15 cm, VEMS01, 20 cm; VEMS03, 8 cm; VEMC05, 8 cm; VEMS07, 12 cm; VEMC09, 10 cm.

[8]Topsoil ranges in depth from site to site as follows: HUAI01, 40 cm; HUAI03, 40 cm; HUAI05, 55cm; HUAI07, 40 cm; HUAI09, 30 cm; HUMS01, 30 cm; HUMS03, 30 cm; HUMS05, 30 cm; HUMS07, 30 cm; HUMS09, 15 cm.

[9]Soil material is replaced subsoil and not typical spoil material composed of fresh, fractured, sedimentary rock.

[10]Topsoil ranges in depth from site to site as follows: SCAE01, 25 cm; SCAE03, 30 cm; SCAE05, 40 cm, SCAE07, 40 cm; SCAE09, 25 cm; SCSF01, 30 cm; SCSF03, 30 cm; SCSF05, 40 cm; SCSF07, 40 cm; SCSF09, 25 cm.

[11]Samples from an area which has not been stripmined or reclaimed.

Table 2. Variance components for variables measured in topsoil from eleven western coal strip mines

[*, variance components signficant at the 0.05 probability level]

Variable	Total $\log_{10}$ variance	Percentage of total variation between;			
		States	Mines	Samples	Analyses
		Based on DTPA extract			
Cd	0.1665	*63.3	*19.8	7.8	9.1
Co	.0503	*24.0	0	11.1	64.9
Cu	.0885	*68.4	*8.5	*18.2	4.9
Fe	.1452	*40.3	*18.8	*23.6	17.3
Mn	.0204	13.3	*20.9	*53.7	12.1
Ni	.0716	32.5	*32.2	6.7	28.6
Pb	.0803	14.8	*14.6	16.8	53.8
Zn	.1202	7.5	*54.3	*33.3	4.9
		Based on hot water extract			
B	.0758	0	*62.1	19.9	18.0
		Measured by specific ion electrode			
pH	[1].7444	30.5	*43.6	*21.8	4.1
		Based on calculated parameters			
O.M.[2]	.0292	11.7	*44.9	*27.9	15.5

[1]Arithmetic variance

[2]Organic matter

Table 3. Variance components for variables measured in spoil from eleven western coal strip mines

[*, variance components signficant at the 0.05 probability level]

Variable	Total $\log_{10}$ variance	Percentage of total variation between; States	Mines	Samples	Analyses
		Based on DTPA extract			
Cd	0.1386	*52.6	*15.5	*28.1	3.8
Co	.0460	*31.4	2.0	4.7	61.9
Cu	.1128	11.5	*49.8	*37.7	1.0
Fe	.2223	*40.3	*30.0	*27.2	2.5
Mn	.0460	4.8	*12.8	*80.9	1.5
Ni	.0833	*62.4	*16.9	*12.8	7.9
Pb	.0552	2.0	*24.9	33.8	39.3
Zn	.2284	32.1	*40.9	*25.6	1.4
		Based on hot water extract			
B	.1336	0	*71.0	*24.4	4.6
		Measured by specific ion electrode			
pH	[1].9078	*37.8	*22.4	*31.1	8.7
		Based on calculated parameters			
O.M.[2]	.0599	20.4	*36.4	*42.4	0.8

[1]Arithmetic variance

[2]Organic matter

Table 4. Multiple-mean comparison of variables measured in topsoil that exhibit significant variation between States

[Values for a variable preceded by the same letter superscript are not signigicantly different from on another at the 0.05 probability level]

Variable	States: North Dakota	Montana	Wyoming	Colorado
		Based on DTPA extract		
Cd	^{a}.10	^{c}.02	^{b}.07	^{b}.08
Co	^{b}.2	^{b}.2	^{a}.3	^{a}.3
Cu	^{a}1.5	^{c}.4	^{a}1.1	^{b}1.1
Fe	^{a}37	^{c}10	^{a}33	^{b}24

Table 5. Multiple-mean comparison of variables measured in spoil that exhibit significant variation between States

[Values for a variable preceded by the same small letter superscript are not significantly different from one another at the 0.05 probability level]

Variable	States: North Dakota	Montana	Wyoming	Colorado
		Based on DTPA extract		
Cd	^{b}.10	^{d}.03	^{c}.08	^{a}.14
Co	^{b}.3	^{c}.2	^{a}.4	^{b}.3
Fe	^{a}81	^{d}14	^{b}43	^{c}27
Ni	^{a}1.5	^{d}.5	^{c}.9	^{b}1.2
		Measured by specific ion electrode		
pH	^{c}7.1	^{a}8.1	^{d}6.4	^{b}7.6

Table 6. Multiple-mean comparison of variables measured in topsoil that exhibit significant variation between coal strip mines

[Values for a variable preceded by the same small letter superscript are not significantly different from one another at the 0.05 probability level]

	North Dakota Mines			Montana Mines			Wyoming Mines			Colorado Mines		New Mexico	Alaska
Variables	Velva	South Beulah	Husky	Big Sky	Absaloka	Decker	Dave Johnston	Seminoe Number 2	Jim Bridger	Energy Fuels	Senca Number 2	San Juan	Usibelli
							Based on DTPA extract						
Cd	^{c}.08	^{b}.11	^{b}.10	^{f}.01	^{e}.02	^{e}.02	^{c}.07	^{c}.08	^{c}.07	^{a}.14	^{d}.04	.05	0.05
Cu	^{ab}1.5	^{c}1.2	^{a}1.8	^{e}.4	^{e}.5	^{e}.5	^{c}1.2	^{ab}1.6	^{d}.8	^{bc}1.4	^{d}.9	.7	1.5
Fe	^{c}32	^{b}44	^{bc}36	^{e}10	^{e}11	^{e}10	^{a}70	^{d}24	^{e}12	^{d}24	^{d}24	13	40
Mn	^{c}9.8	^{de}8.6	^{b}11	^{e}8.0	^{e}8.0	^{c}9.9	^{cd}9.2	^{ab}12	^{f}6.4	^{a}14	^{b}11	8.1	29
Ni	^{cd}.9	^{a}1.6	^{ab}1.4	^{g}.3	^{f}.5	^{e}.7	^{cd}.9	^{b}1.3	^{g}.3	^{c}1.0	^{de}.8	.05	.6
Pb	^{c}.6	^{d}.3	^{c}.5	^{d}.3	^{c}.5	^{c}.5	^{c}.6	^{ab}.9	^{ab}.9	^{a}1.0	^{bc}.7	.1	1.4
Zn	^{c}1.2	^{c}.9	^{c}1.0	^{de}.5	^{e}.4	^{e}.4	^{b}1.6	^{d}.7	^{c}1.0	^{a}2.3	^{e}.4	.4	2.0
							Based on hot water extract						
B	^{bc}1.1	^{cd}.9	^{b}1.2	^{de}.8	^{de}.8	^{de}.8	^{de}.8	^{bc}1.1	^{a}5.4	^{b}1.0	^{e}.6	.6	.05
							Measured by specific-ion electrode						
pH[1]	^{bc}7.7	^{bc}7.7	^{e}7.2	^{ab}8.0	^{ab}8.0	^{a}8.1	^{f}5.4	^{cde}7.4	^{cd}7.5	^{cd}7.5	^{de}7.3	8.0	4.9
							Based on calculated parameters						
O.M.[2]	^{c}5.0	^{c}5.0	^{c}5.1	^{e}3.2	^{de}3.5	^{e}3.1	^{d}3.8	^{a}7.8	^{c}4.9	^{b}6.9	^{e}3.3	[3]1.2	2.4

[1]Arithmetic mean, all others are geometric means
[2]Organic matter
[3]Estimated by multiplying organic carbon by 2.72

Table 7. Multiple-mean comparison of variables measured in spoil that exhibit significant variation between coal strip mines

[Values for a variable preceded by the same small letter superscript are not significantly different from one another at the 0.05 probability level]

	North Dakota Mines			Montana Mines			Wyoming Mines			Colorado Mines		New Mexico	Alaska
Variables	Velva	South Beulah	Husky	Big Sky	Absaloka	Decker	Dave Johnston	Seminoe Number 2	Jim Bridger	Energy Fuels	Senca Number 2	San Juan	Usibelli
							Based on DTPA extract						
Cd	^{c}.09	^{b}.13	^{c}.09	^{d}.06	^{e}.03	^{f}.02	^{c}.09	^{e}.04	^{c}.09	^{a}.15	^{b}.13	.05	0.10
Cu	^{bc}2.0	^{a}4.2	^{e}1.2	^{b}2.1	^{f}.6	^{f}.5	^{cd}1.6	^{de}1.3	^{e}1.2	^{de}1.3	^{bc}1.7	2.0	12
Fe	^{b}42	^{a}250	^{b}48	^{e}23	^{f}14	^{f}10	^{b}52	^{cd}31	^{bc}40	^{d}24	^{cde}30	61	200
Mn	^{c}8.2	^{e}5.7	^{a}12	^{de}6.8	^{e}5.6	^{d}6.9	^{de}6.9	^{bc}9.7	^{cd}8.2	^{ab}10	^{bc}9.6	12	30
Ni	^{cd}1.1	^{a}2.1	^{b}1.4	^{e}.5	^{e}.4	^{e}.5	^{bc}1.3	^{d}1.0	^{e}.5	^{cd}1.1	^{cd}1.2	.2	2.7
Pb	^{bc}.6	^{b}.7	^{cd}.5	^{a}.9	^{b}.7	^{cd}.5	^{d}.4	^{bc}.6	^{a}.9	^{a}1.1	^{b}.7	.5	3.8
Zn	^{de}1.2	^{b}2.3	^{e}1.0	^{cd}1.6	^{f}.4	^{f}.3	^{cd}1.6	^{f}.4	^{b}2.2	^{bc}2.1	^{a}5.4	1.5	2.9
							Based on hot water extract						
B	^{bc}1.3	^{bcd}1.1	^{bc}1.3	^{b}1.4	^{e}.7	^{e}.7	^{cd}1.0	^{de}.9	^{a}14	^{e}.7	^{bcd}1.1	.8	<.05
							Measured by specific-ion electrode						
pH[1]	^{c}7.5	^{e}6.6	^{d}7.1	^{bc}7.8	^{ab}8.1	^{a}8.4	^{f}5.7	^{c}7.6	^{e}6.7	^{c}7.6	^{c}7.6	7.6	6.9
							Based on calculated parameters						
O.M.[2]	^{e}3.9	^{b}7.4	^{d}5.1	^{ef}3.4	^{f}3.1	^{fg}2.9	^{g}2.8	^{bc}6.9	^{a}9.5	^{cd}6.0	^{b}7.6	[3]6.2	4.0

[1]Arithmetic mean, all others are geometric

[2]Organic matter

[3]Estimated by multiplying organic carbon by 2.72

Table 8. Average values, and observed ranges, for variables measured in topsoil which exhibit significant variation between samples collected at eleven western coal strip mines

[Detection ratio, number of samples in which the variable was detected relative to the total number of samples analyzed]

Variable	Geometric mean	Geometric deviation	Observed range	Detection ratio
		Based on DTPA extract		
Cu	0.9	1.86	.2 - 2.8	110:110
Fe	23	2.28	6.7 - 190	110:110
Mn	9.8	1.38	4.0 - 27	110:110
Zn	.8	2.16	.2 - 9.5	110:110
		Measured by specific ion electrode		
pH[1]	7.5	.81	4.1 - 8.5	110:110
		Based on calculated parameters		
O.M.[2]	4.4	1.46	1.6 - 19.5	110:110

[1]Arithmetic mean and deviation

[2]Organic matter

Table 9. Average values, and observed ranges, for variables measured in spoil which exhibit significant variation between samples collected at eleven western coal strip mines

[Detection ratio, number of samples in which the variable was detected relative to the total number of samples analyzed]

Variable	Geometric mean	Geometric deviation	Observed range	Detection ratio
		Based on DTPA extract		
Cd	.07	2.30	.01 - .22	104:110
Cu	1.4	2.11	.2 - 6.7	110:110
Fe	34	2.76	6.6 - 490	110:110
Mn	7.9	1.63	1.4 - 24	110:110
Ni	.9	1.83	.2 - 2.9	110:110
Zn	1.3	2.81	.1 - 9.0	110:110
		Based on hot water extract		
B	1.1	2.20	.5 - 26	110:110
		Measured by specific ion electrode		
pH[1]	7.4	.90	3.9 - 8.9	110:110
		Based on calculated parameters		
O.M.[2]	4.7	1.71	1.6 - 33.5	110:110

[1]Arithmetic mean and deviation

[2]Organic matter

APPENDIX TABLES

In each table, for SAMPLE, the eight character identifier, the first two characters indicate the coal mine name, the second two characters indicate the type of plant sampled (AC, crested wheatgrass; AE, slender wheatgrass; AI, intermediate wheatgrass; BI, smooth brome; FS, fourwing saltbush; MS, alfalfa; SF, sandfain) at that location, the third two characters indicate the sample sequence, the seventh character, if a number 2, indicate a repeated analysis of the preceding sample with a number 1 in the seventh position, the eighth character indicates topsoil (A) or spoil (C), except for the San Juan and Usibelli Mines where only mine name, sample sequence, and repeated analysis are indicated. The letters L and G in the body of the tables indicate that value to be less than (L) or greater than (G) the detection limit of the analytical method used. In tables A and B, the values reported for all mines except the Usibelli mine are based on a DTPA-calcium chloride extract as described in Severson and Crock (1980). At the Usibelli Mine, a DTPA-ammonium bicarbonate extract was used and the relation between these two DTPA-extraction methods for all metals in tables A and B is discussed in Severson and others (1980).

Table A. Variables measured on DTPA extracts of topsoil samples.

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Velva Mine				
VEAI011A	0.07	0.1	1.3	24.0	8.7	0.8	0.7	0.9
VEAI031A	0.07	0.2	1.2	25.0	8.5	0.8	0.4	0.8
VEAI051A	0.07	0.2	1.4	44.0	9.2	0.9	0.5	0.9
VEAI071A	0.07	0.1	1.3	22.4	8.7	0.8	0.7	0.8
VEAI091A	0.06	0.4	1.1	23.0	9.5	1.0	0.8	0.8
VEMS011A	0.10	0.4	1.9	42.0	10.9	1.0	1.0	1.7
VEMS031A	0.10	0.2	2.1	41.5	11.1	0.9	0.7	2.2
VEMS051A	0.10	0.4	1.9	46.0	11.8	1.0	0.9	2.1
VEMS071A	0.07	0.3	1.7	24.8	10.9	1.0	0.3	1.2
VEMS091A	0.07	0.1	1.5	40.0	8.9	0.8	0.7	1.2
				South Beulah Mine				
SBAI011A	0.10	0.3	1.1	18.2	8.3	1.3	0.4	0.6
SBAI031A	0.14	0.1L	1.4	45.0	8.2	1.8	0.6	1.4
SBAI051A	0.10	0.2	1.0	21.9	6.6	1.4	0.4	0.6
SBAI052A	0.11	0.3	1.2	22.6	7.6	1.6	0.1L	0.7
SBAI071A	0.12	0.2	1.0	50.0	8.0	1.9	0.4	1.0
SBAI091A	0.13	0.2	1.1	26.5	13.9	1.6	0.6	1.0
SBMS011A	0.13	0.2	1.0	178.0	8.4	1.3	0.1L	0.5
SBMS031A	0.15	0.3	1.7	83.0	8.6	2.4	0.5	2.0
SBMS051A	0.09	0.3	2.0	160.0	5.9	1.6	0.6	1.1
SBMS071A	0.10	0.4	1.3	38.0	12.0	2.1	0.7	1.3
SBMS091A	0.10	0.2	0.8	21.9	9.2	1.2	0.4	0.7
				Husky Mine				
HUAI011A	0.12	0.1	1.8	110.0	10.3	2.2	0.5	1.7
HUAI031A	0.19	0.2	2.0	83.4	12.6	0.9	0.5	1.9
HUAI051A	0.10	0.3	0.9	36.0	8.0	1.0	0.1	0.7
HUAI071A	0.10	0.3	0.8	24.0	6.9	1.0	0.1	0.6
HUAI091A	0.10	0.2	1.7	120.0	11.2	1.8	0.8	3.1
HUMS011A	0.10	0.4	2.7	17.3	10.1	1.4	0.5	0.6
HUMS031A	0.10	0.4	2.3	21.0	13.2	1.6	0.6	0.8
HUMS051A	0.10	0.4	2.8	26.0	13.9	1.8	0.9	1.0
HUMS071A	0.10	0.3	1.9	22.0	11.8	1.3	0.6	0.7
HUMS072A	0.05	0.2	1.5	22.0	10.3	1.3	0.8	0.6
HUMS091A	0.13	0.3	2.5	29.0	15.0	2.1	0.9	1.0

Table A. Variables measured on DTPA extracts of topsoil samples.-continued

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Big Sky Mine				
BSAE011A	0.10L	0.3	0.4	8.3	7.1	0.3	0.8	0.6
BSAE031A	0.02L	0.1	0.3	10.5	4.8	0.2	0.1	0.4
BSAE051A	0.01L	0.1	0.4	11.3	8.8	0.3	0.1L	0.4
BSAE071A	0.02	0.2	0.3	12.0	10.2	0.5	0.3	0.7
BSAE091A	0.10L	0.3	0.4	10.8	12.4	0.4	0.7	0.9
BSMS011A	0.02L	0.2	0.3	10.1	5.9	0.3	0.3	0.3
BSMS031A	0.02L	0.1	0.4	10.2	4.8	0.3	0.1	0.6
BSMS051A	0.10L	0.3	0.5	11.1	11.6	0.4	0.8	0.6
BSMS071A	0.02L	0.2	0.3	9.1	8.3	0.3	0.4	0.5
BSMS091A	0.10L	0.2	0.5	10.1	9.8	0.4	0.5	0.6
				Absaloka Mine				
SCAE011A	0.02	0.1L	0.4	11.9	8.2	0.4	0.6	0.2
SCAE031A	0.02	0.1	0.5	11.3	8.0	0.5	0.5	0.4
SCAE051A	0.04	0.2	0.9	16.5	9.4	0.5	0.9	0.9
SCAE071A	0.10L	0.3	0.4	7.2	5.6	0.4	0.3	0.3
SCAE091A	0.04	0.2	0.6	11.1	10.9	0.5	0.6	0.4
SCSF011A	0.02	0.2	0.3	11.1	9.0	0.4	0.4	0.3
SCSF031A	0.10L	0.2	0.5	9.1	7.8	0.5	0.6	0.6
SCSF051A	0.10L	0.2	0.7	11.2	7.4	0.4	0.7	0.4
SCSF071A	0.05	0.2	0.3	8.2	6.3	3.3	0.5	0.3
SCSF091A	0.03	0.1	0.3	10.1	8.8	0.4	0.5	0.4
				Decker Mine				
DEAE011A	0.10L	0.3	0.3	8.6	9.6	0.6	0.8	0.5
DEAE031A	0.03	0.2	0.3	11.7	8.8	0.8	0.5	0.3
DEAE051A	0.10L	0.3	1.0	13.3	12.4	0.9	0.9	0.6
DEAE071A	0.02	0.1	0.4	9.3	7.4	0.5	0.5	0.3
DEAE091A	0.02	0.1	0.5	13.5	9.7	0.7	0.6	0.4
DEAE092A	0.02L	0.2	0.3	13.5	10.6	0.6	0.4	0.4
DEFS011A	0.03	0.2	0.8	11.5	11.0	0.6	0.4	0.9
DEFS012A	0.03	0.2	0.8	9.8	10.5	0.6	0.8	0.7
DEFS031A	0.03	0.2	0.2	8.7	8.3	0.5	0.4	0.3
DEFS051A	0.01	0.2	0.4	8.2	8.4	0.6	0.4	0.4
DEFS071A	0.02	0.2	0.5	6.7	10.3	1.3	0.3	0.4
DEFS091A	0.10L	0.3	0.5	8.5	12.9	0.8	0.8	0.4

Table A. Variables measured on DTPA extracts of topsoil samples.-continued

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Dave Johnston Mine				
DJAC011A	0.10	0.6	2.1	130.0	14.2	1.0	0.8	2.9
DJAC031A	0.12	0.2	0.8	77.0	13.5	1.0	0.7	1.6
DJAC051A	0.10	0.7	2.3	180.0	14.6	1.8	0.5	4.2
DJAC071A	0.05	0.2	0.6	21.8	4.0	0.5	0.4	1.1
DJAC091A	0.02	0.3	0.8	39.8	6.6	0.5	0.5	0.7
DJBI011A	0.07	0.2	1.3	71.0	6.1	0.7	0.7	1.1
DJBI031A	0.05	0.4	0.7	36.9	13.5	0.6	0.4	1.0
DJBI051A	0.10	0.5	1.7	190.0	12.9	1.2	0.8	2.4
DJBI071A	0.07	0.2	1.2	45.0	4.8	0.7	0.4	1.9
DJBI091A	0.10	0.6	1.3	78.0	11.2	2.2	0.6	1.9
				Seminoe No. 2 Mine				
SMAC011A	0.07	0.5	1.8	120.0	11.8	1.4	1.0	0.8
SMAC031A	0.08	0.4	1.5	13.7	12.4	1.2	0.8	0.6
SMAC051A	0.09	0.3	1.4	16.8	12.9	1.3	1.1	0.6
SMAC071A	0.08	0.3	1.5	19.0	11.1	1.3	0.6	0.6
SMAC091A	0.10	0.4	1.7	16.5	13.8	1.2	1.1	0.7
				Jim Bridger Mine				
JBFS011A	0.04	0.2	0.6	11.4	7.8	0.3	0.6	0.7
JBFS031A	0.06	0.3	1.0	21.3	8.0	0.5	1.0	0.8
JBFS051A	0.10L	0.4	0.9	11.2	4.9	0.4	1.0	1.2
JBFS052A	0.10L	0.4	0.8	13.6	4.9	0.4	0.9	1.2
JBFS071A	0.10L	0.4	0.6	10.6	7.8	0.4	1.0	1.1
JBFS091A	0.10	0.3	1.4	9.6	5.9	0.5	1.0	0.9
				Seneca No. 2 Mine				
SEAC011A	0.22	0.3	1.6	13.5	13.9	0.3	0.4	2.9
SEAC012A	0.16	0.2	1.5	15.7	11.3	1.2	0.9	2.7
SEAC031A	0.11	0.3	1.5	21.6	15.9	1.0	0.8	2.6
SEAC051A	0.10	0.5	0.8	12.0	18.1	0.9	1.2	0.6
SEAC071A	0.30	0.5	1.9	60.0	13.1	2.4	2.3	9.0
SEAC091A	0.10	0.3	1.2	15.9	13.1	1.0	1.0	1.2
SEMS011A	0.20	0.3	1.6	15.9	8.9	1.3	1.0	2.8
SEMS031A	0.30	0.6	2.0	190.0	27.0	2.0	2.0	9.5
SEMS051A	0.07	0.3	1.3	33.0	13.5	0.8	1.0	1.0
SEMS052A	0.10	0.4	1.2	11.1	12.9	0.8	0.9	0.9
SEMS071A	0.13	0.2	1.3	59.0	13.9	1.1	1.2	2.5
SEMS072A	0.12	0.2	1.1	18.2	12.3	0.9	0.9	2.3
SEMS091A	0.14	0.1	1.6	16.3	10.1	1.2	0.8	2.4

Table A. Variables measured on DTPA extracts of topsoil samples.-continued

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Energy Fuels Mine				
ENAC011A	0.04	0.3	1.0	26.3	13.1	0.9	0.9	0.3
ENAC031A	0.07	0.3	0.7	20.5	13.0	0.9	0.2	0.2
ENAC051A	0.04	0.3	1.0	24.0	12.0	0.7	0.9	0.2
ENAC071A	0.05	0.3	0.8	34.6	12.8	0.9	0.7	0.5
ENAC091A	0.05	0.3	1.0	19.8	12.6	0.9	0.6	0.4
ENAC092A	0.03	0.1	0.8	19.0	8.8	0.6	0.7	0.2
ENMS011A	0.02L	0.2	0.7	37.0	10.2	0.7	0.8	0.3
ENMS031A	0.04	0.4	1.0	23.8	16.8	1.6	1.0	0.4
ENMS051A	0.03	0.2	0.8	32.0	7.8	0.5	1.0	0.3
ENMS071A	0.02L	0.3	0.7	31.0	11.9	0.9	0.8	0.3
ENMS091A	0.10	0.3	1.0	15.8	10.2	0.6	0.6	0.9
ENMS092A	0.05	0.1	1.1	17.3	8.7	0.6	0.5	0.8
				San Juan Mine				
SJ011	0.05L	0.1L	0.5	7.2	6.6	0.05L	0.2	0.4
SJ012	0.05L	0.1L	0.5	7.2	6.4	0.05L	0.1	0.2
SJ021	0.05L	0.1L	0.5	11.6	6.8	0.05L	0.1L	0.4
SJ022	0.05L	0.1L	0.6	6.8	7.2	0.05L	0.1L	0.4
SJ031	0.05	0.1L	0.7	16.2	5.6	0.1	0.1L	0.4
SJ032	0.05L	0.1L	0.7	7.4	5.8	0.05L	0.3	0.2
SJ041	0.05L	0.1L	0.5	7.4	5.8	0.1	0.1L	0.2
SJ042	0.05L	0.1L	0.6	8.2	6.4	0.05L	0.2	0.4
SJ051	0.05	0.1	2.0	111.8	24.2	0.4	0.9	2.2
SJ052	0.05	0.1	2.2	125.8	31.6	0.4	1.5	1.6
SJ061	0.05L	0.1L	0.6	6.8	6.6	0.1	0.1L	0.2
SJ062	0.05L	0.1L	0.6	6.4	6.6	0.05L	0.3	0.2
				Usibelli MIne				
US011	0.15	0.4	4.3	580.0	5.7	1.6	2.8	1.9
US021	0.02	0.4	0.8	270.0	1.5	0.4	0.6	2.0
US031	0.05	0.2	0.9	410.0	2.8	0.4	1.6	2.0

Table B. Variables measured on DTPA extracts of spoil samples.

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Velva Mine				
VEAI011C	0.10	0.5	1.8	24.0	7.9	1.2	0.5	0.7
VEAI031C	0.10	0.3	2.2	44.5	10.2	1.5	0.6	1.1
VEAI051C	0.10	0.4	2.2	34.7	9.6	1.5	0.3	1.0
VEAI071C	0.11	0.4	2.3	34.8	8.9	1.5	0.4	1.0
VEAI091C	0.07	0.2	1.5	76.0	10.2	1.1	0.7	0.9
VEMS011C	0.08	0.2	2.4	60.0	6.4	0.8	0.7	1.7
VEMS031C	0.08	0.2	2.2	53.0	7.3	0.7	0.6	1.5
VEMS051C	0.10	0.4	2.0	48.0	8.1	1.0	0.6	1.2
VEMS071C	0.10	0.3	1.6	30.4	4.8	0.9	0.4	1.0
VEMS091C	0.08	0.4	1.8	41.0	10.4	1.2	1.3	2.2
				South Beulah Mine				
SBAI011C	0.18	0.4	3.9	342.0	11.0	2.6	0.4	2.3
SBAI031C	0.10	0.5	6.7	420.0	3.9	2.9	1.1	5.5
SBAI051C	0.10	0.4	2.6	130.0	7.1	1.7	0.6	1.3
SBAI052C	0.09	0.3	2.8	98.2	7.5	1.8	0.4	1.1
SBAI071C	0.20	0.3	2.8	115.0	8.5	1.9	0.4	2.0
SBAI091C	0.10	0.3	3.6	280.0	11.3	1.6	0.8	1.9
SBMS011C	0.19	0.4	3.0	409.0	1.5	2.4	0.4	2.4
SBMS031C	0.16	0.3	6.2	148.0	3.8	2.6	1.0	3.6
SBMS051C	0.12	0.3	5.7	490.0	5.0	2.3	1.0	2.9
SBMS071C	0.14	0.3	5.9	340.0	3.6	2.5	1.0	2.8
SBMS091C	0.10	0.1	6.1	450.0	9.2	1.6	1.2	2.4
				Husky Mine				
HUAI011C	0.10L	0.3	0.9	24.0	8.7	1.1	0.5	0.5
HUAI031C	0.06	0.1	1.2	67.0	9.8	1.7	0.4	0.7
HUAI051C	0.09	0.1	0.9	95.0	11.2	1.3	0.4	1.9
HUAI071C	0.10	0.2	0.8	44.0	11.3	1.2	0.3	1.8
HUAI091C	0.13	0.2	1.0	51.2	11.4	1.2	0.4	2.8
HUMS011C	0.09	0.3	2.8	97.6	12.5	2.1	0.8	1.2
HUMS031C	0.07	0.2	0.3	31.8	12.7	1.4	0.4	0.8
HUMS051C	0.12	0.3	2.2	55.8	12.8	1.4	0.7	1.0
HUMS071C	0.10	0.3	2.2	50.0	15.6	2.0	0.9	1.0
HUMS072C	0.17	0.3	2.2	37.9	15.8	2.1	0.5	1.0
HUMS091C	0.06	0.3	1.5	25.2	12.2	0.9	0.4	0.4

Table B. Variables measured on DTPA extracts of spoil samples.-continued

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Big Sky Mine				
BSAE011C	0.04	0.1	3.0	39.0	4.3	0.5	1.2	1.9
BSAE031C	0.11	0.4	5.8	35.9	6.3	0.8	2.9	3.9
BSAE051C	0.02	0.1	0.7	17.5	5.5	0.3	0.2	0.6
BSAE071C	0.11	0.3	3.0	34.4	13.9	0.3	1.7	2.8
BSAE091C	0.10L	0.3	1.7	22.0	7.2	0.5	0.8	1.5
BSMS011C	0.05	0.1	2.7	24.0	3.6	0.6	1.0	1.9
BSMS031C	0.13	0.3	5.3	23.8	7.6	1.3	2.1	4.1
BSMS051C	0.10L	0.2	0.8	13.7	6.5	0.4	0.4	0.6
BSMS071C	0.03	0.2	1.7	18.0	10.8	0.4	0.7	1.3
BSMS091C	0.04	0.1	1.4	17.1	7.1	0.4	0.8	1.0
				Absaloka Mine				
SCAE011C	0.05	0.2	1.5	36.1	5.6	0.5	1.9	1.3
SCAE031C	0.10L	0.2	0.3	7.7	4.6	0.3	0.6	0.2
SCAE051C	0.10	0.3	1.0	17.9	12.8	0.6	1.5	0.8
SCAE071C	0.10L	0.2	0.4	11.2	3.2	0.3	0.6	0.5
SCAE091C	0.02L	0.2	0.5	14.7	6.7	0.5	0.6	0.2
SCSF011C	0.03	0.1	0.4	10.2	5.2	0.4	0.5	0.4
SCSF031C	0.02L	0.1	0.4	8.9	4.1	0.2	0.4	0.1
SCSF051C	0.10L	0.2	1.0	15.1	6.8	0.4	0.7	0.3
SCSF071C	0.02L	0.1	0.3	8.1	3.1	0.3	0.3	0.2
SCSF091C	0.03	0.1	0.6	32.0	9.4	0.4	0.9	0.4
				Decker Mine				
DEAE011C	0.02	0.2	0.2	8.6	6.3	0.5	0.5	0.3
DEAE031C	0.10L	0.3	0.4	7.9	6.5	0.5	0.3	0.3
DEAE051C	0.02L	0.2	1.0	19.0	11.4	0.9	0.7	0.3
DEAE071C	0.02L	0.2	0.6	6.6	3.9	0.3	0.6	0.1
DEAE091C	0.08	0.2	0.5	9.7	6.0	0.5	0.2	0.2
DEAE092C	0.10L	0.2	0.6	7.8	6.7	0.5	0.5	0.3
DEFS011C	0.02	0.1L	0.8	12.9	8.9	0.5	0.7	0.3
DEFS012C	0.02	0.2	0.7	10.0	8.4	0.5	0.5	0.4
DEFS031C	0.10L	0.3	0.3	7.7	6.9	0.5	0.7	0.4
DEFS051C	0.02L	0.2	0.7	8.7	6.1	0.4	0.6	0.5
DEFS071C	0.02	0.2	0.5	9.4	6.8	0.5	0.5	0.3
DEFS091C	0.01	0.4	0.4	12.5	7.4	0.6	0.3	0.3

Table B. Variables measured on DTPA extracts of spoil samples.-continued

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Dave Johnston Mine				
DJAC011C	0.09	0.2	2.1	81.0	7.3	1.2	0.5	2.1
DJAC031C	0.06	0.4	1.6	75.5	5.5	1.7	0.4	2.3
DJAC051C	0.10	0.3	0.9	24.0	6.6	1.0	0.6	0.7
DJAC071C	0.10	0.4	1.3	47.0	3.3	0.8	0.6	1.5
DJAC091C	0.17	0.3	1.6	71.0	8.0	2.1	0.7	2.2
DJBI011C	0.08	0.3	2.0	160.0	7.3	1.1	0.4	1.6
DJBI031C	0.06	0.5	1.8	45.9	15.7	1.3	0.2	2.5
DJBI051C	0.11	0.6	3.7	157.0	9.4	1.8	0.3	4.2
DJBI071C	0.10L	0.4	0.9	12.4	3.7	0.6	0.4	0.6
DJBI091C	0.15	0.4	1.1	21.9	8.4	2.1	0.2	1.3
				Seminoe No. 2 Mine				
SMAC011C	0.07	0.4	1.8	18.4	11.5	1.0	0.7	0.6
SMAC031C	0.09	0.4	1.5	130.0	12.2	1.4	0.8	0.5
SMAC051C	0.03	0.2	1.2	13.4	6.5	0.8	0.4	0.2
SMAC071C	0.01	0.5	1.2	67.5	12.5	1.1	0.5	0.6
SMAC091C	0.05	0.3	1.1	12.5	7.6	0.8	0.6	0.5
				Jim Bridger Mine				
JBFS011C	0.10	0.4	0.9	14.8	5.6	0.5	1.1	1.6
JBFS031C	0.15	0.5	1.7	83.0	24.1	0.7	2.0	2.4
JBFS051C	0.10	0.5	1.1	19.6	3.4	0.5	0.7	1.6
JBFS052C	0.10L	0.4	1.1	19.4	3.2	0.5	0.9	1.7
JBFS071C	0.07	0.3	1.0	220.0	18.0	0.5	1.2	3.4
JBFS091C	0.09	0.5	1.6	38.7	11.1	0.5	0.4	3.3
				Seneca No. 2 Mine				
SEAC011C	0.19	0.3	1.9	17.6	15.0	1.3	1.0	3.6
SEAC012C	0.20	0.4	1.9	15.0	15.4	1.4	1.3	4.1
SEAC031C	0.14	0.3	2.1	28.0	8.0	1.3	0.9	4.1
SEAC051C	0.09	0.2	1.0	39.0	12.0	0.7	0.9	0.8
SEAC071C	0.20	0.3	1.7	37.0	11.7	1.6	1.6	5.3
SEAC091C	0.13	0.3	1.3	18.2	15.6	1.1	1.0	1.0
SEMS011C	0.18	0.1	1.8	36.0	10.2	1.2	1.0	2.7
SEMS031C	0.22	0.6	0.2	126.0	1.4	1.6	1.7	0.7
SEMS051C	0.10	0.1	1.2	12.2	12.4	0.6	1.2	1.0
SEMS052C	0.11	0.3	1.3	13.7	13.6	1.1	0.8	1.2
SEMS071C	0.14	0.2	1.5	20.9	9.8	1.1	1.0	3.0
SEMS072C	0.10	0.3	1.2	22.6	10.3	1.1	1.2	3.1
SEMS091C	0.17	0.3	1.6	16.0	10.9	1.3	0.6	2.4

Table B. Variables measured on DTPA extracts of spoil samples.-continued

SAMPLE	Cd, ppm	Co, ppm	Cu, ppm	Fe, ppm	Mn, ppm	Ni, ppm	Pb, ppm	Zn, ppm
				Energy Fuels Mine				
ENAC011C	0.07	0.3	1.3	20.6	8.9	0.9	0.8	1.9
ENAC031C	0.13	0.3	1.7	47.4	16.1	1.1	1.2	4.0
ENAC051C	0.07	0.2	1.1	18.1	8.3	1.0	0.6	2.0
ENAC071C	0.18	0.3	2.1	33.4	11.3	1.6	0.8	8.9
ENAC091C	0.16	0.2	2.0	39.0	7.4	1.5	0.7	8.1
ENAC092C	0.15	0.3	1.9	31.4	8.4	1.6	0.6	8.9
ENMS011C	0.10	0.4	2.0	25.0	9.6	1.1	1.1	6.5
ENMS031C	0.20	0.4	2.3	45.0	9.2	1.2	1.1	7.7
ENMS051C	0.10	0.3	1.2	16.3	9.8	0.9	0.9	2.8
ENMS071C	0.18	0.3	2.1	32.8	9.0	1.5	0.7	9.0
ENMS091C	0.18	0.2	1.6	44.0	9.3	1.4	0.6	6.5
ENMS092C	0.17	0.3	1.8	27.4	10.7	0.8	0.3	6.9
				San Juan Mine				
SJ011	0.05	0.1L	2.4	64.8	10.2	0.1	0.6	1.2
SJ012	0.05	0.1L	2.3	64.4	10.2	0.1	0.4	1.4
SJ021	0.05L	1.4	2.0	206.8	54.8	0.9	1.4	5.2
SJ022	0.05	1.4	1.9	210.1	54.4	0.9	1.4	5.2
SJ031	0.05	0.1L	2.3	36.6	6.8	0.2	0.4	1.2
SJ032	0.05	0.1L	2.4	43.6	7.6	0.2	0.5	1.2
SJ041	0.05	0.1L	2.1	44.2	6.2	0.2	0.1L	1.0
SJ042	0.05	0.1L	1.9	30.6	5.4	0.1	0.1L	1.0
SJ051	0.05	0.1L	1.5	87.2	19.6	0.2	1.0	1.8
SJ052	0.05	0.1L	1.5	85.2	19.2	0.2	0.3	1.8
SJ061	0.05	0.1L	2.1	30.4	5.4	0.1	0.7	0.8
SJ062	0.05	0.1L	2.2	31.0	6.0	0.1	0.8	0.8
				Usibelli Mine				
US011	0.21	0.3	14.0	210.0	43.0	3.6	4.7	3.3
US021	0.10	0.2	12.0	210.0	25.0	2.4	3.3	2.7
US031	0.11	0.2	11.0	190.0	24.0	2.3	3.4	2.6

Table C. Boron, pH, and organic matter content of samples of topsoil.

SAMPLE	B, ppm	pH	O.M., %
		Velva Mine	
VEAI011A	1.0	7.9	5.0
VEAI031A	1.0	7.9	4.9
VEAI051A	1.0	7.9	4.6
VEAI071A	1.0	7.8	5.7
VEAI091A	1.0	7.7	6.3
VEMS011A	1.0	7.6	4.5
VEMS031A	1.5	7.1	6.5
VEMS051A	1.0	7.7	4.1
VEMS071A	1.5	7.6	3.6
VEMS091A	1.5	7.6	5.7
		South Beulah Mine	
SBAI011A	1.0	8.0	4.8
SBAI031A	1.0	7.8	5.8
SBAI051A	1.0	7.8	4.6
SBAI052A	0.5	7.7	5.2
SBAI071A	1.0	7.8	4.4
SBAI091A	1.0	7.3	5.3
SBMS011A	0.5	7.8	3.6
SBMS031A	1.0	7.3	5.2
SBMS051A	1.5	7.5	8.1
SBMS071A	1.0	7.5	5.4
SBMS091A	1.0	7.7	4.0
		Husky Mine	
HUAI011A	1.0	6.7	5.2
HUAI031A	0.5	6.2	4.9
HUAI051A	1.0	7.3	3.3
HUAI071A	1.0	7.3	3.1
HUAI091A	1.0	6.4	4.7
HUMS011A	2.0	7.7	6.3
HUMS031A	2.0	7.7	6.2
HUMS051A	1.5	7.3	6.4
HUMS071A	1.5	7.8	5.1
HUMS072A	1.5	7.8	5.3
HUMS091A	1.0	7.1	7.6

Table C. Boron, pH, and organic matter content of samples of topsoil.-continued

SAMPLE	B, ppm	pH	O.M., %
		Big Sky Mine	
BSAE011A	3.0	7.8	3.8
BSAE031A	1.0	8.2	2.1
BSAE051A	1.0	7.8	2.8
BSAE071A	0.5	8.2	3.0
BSAE091A	1.5	7.7	4.3
BSMS011A	1.5	7.9	2.8
BSMS031A	1.0	8.1	2.7
BSMS051A	1.5	7.7	5.7
BSMS071A	1.0	8.0	2.5
BSMS091A	1.0	8.2	3.8
		Absaloka Mine	
SCAE011A	0.5	8.1	3.3
SCAE031A	1.0	8.1	3.5
SCAE051A	1.0	7.9	3.7
SCAE071A	1.0	8.3	2.9
SCAE091A	0.5	8.0	3.3
SCSF011A	1.0	8.1	3.2
SCSF031A	1.0	7.9	3.6
SCSF051A	1.0	7.9	4.3
SCSF071A	0.5	7.9	3.2
SCSF091A	0.5	8.0	4.2
		Decker Mine	
DEAE011A	1.0	8.1	2.7
DEAE031A	0.5	8.2	2.8
DEAE051A	0.5	8.1	3.8
DEAE071A	0.5	8.5	3.1
DEAE091A	0.5	8.3	3.6
DEAE092A	1.0	8.2	2.9
DEFS011A	1.0	8.1	3.5
DEFS012A	1.0	7.9	3.3
DEFS031A	0.5	8.1	2.8
DEFS051A	1.0	8.2	2.9
DEFS071A	1.5	8.0	3.3
DEFS091A	1.0	7.8	2.9

Table C. Boron, pH, and organic matter content of samples of topsoil.-continued

SAMPLE	B, ppm	pH	O.M., %
		Dave Johnston Mine	
DJAC011A	1.0	4.7	5.4
DJAC031A	1.0	6.3	4.7
DJAC051A	1.0	4.1	4.8
DJAC071A	1.0	6.8	3.4
DJAC091A	0.5L	5.3	2.0
DJBI011A	1.0	6.3	3.8
DJBI031A	0.5	5.7	4.1
DJBI051A	1.0	4.6	4.2
DJBI071A	1.0	6.5	4.3
DJBI091A	0.5	4.3	2.5
		Seminoe No. 2 Mine	
SMAC011A	1.0	7.5	7.8
SMAC031A	1.5	7.6	7.0
SMAC051A	1.0	7.2	7.8
SMAC071A	1.0	7.5	7.3
SMAC091A	1.0	7.3	9.5
		Jim Bridger Mine	
JBFS011A	2.5	7.5	4.3
JBFS031A	4.5	7.4	5.0
JBFS051A	9.5	7.5	5.5
JBFS052A	9.5	7.5	5.4
JBFS071A	7.0	7.6	4.9
JBFS091A	3.5	7.8	4.2
		Seneca No. 2 Mine	
SEAC011A	0.5	7.4	6.3
SEAC012A	1.0	7.9	6.5
SEAC031A	0.5	7.8	6.9
SEAC051A	1.0	7.6	4.8
SEAC071A	1.5	6.7	13.6
SEAC091A	1.0	7.6	4.9
SEMS011A	2.0	8.1	5.6
SEMS031A	2.0	6.0	19.5
SEMS051A	1.0	7.7	4.7
SEMS052A	1.0	7.9	4.2
SEMS071A	1.5	7.7	8.7
SEMS072A	1.5	7.7	8.8
SEMS091A	0.5	7.9	5.1

Table C. Boron, pH, and organic matter content of samples of topsoil.-continued

SAMPLE	B, ppm	pH	O.M., %
		Energy Fuels Mine	
ENAC011A	0.5	7.3	3.1
ENAC031A	0.5	6.9	3.9
ENAC051A	0.5	7.4	3.3
ENAC071A	0.5	7.0	3.4
ENAC091A	0.5	7.4	3.2
ENAC092A	0.5	7.5	1.7
ENMS011A	1.0	7.5	3.5
ENMS031A	0.5	7.1	3.6
ENMS051A	1.0	7.7	3.0
ENMS071A	1.0	7.2	3.9
ENMS091A	0.5	7.0	3.8
ENMS092A	0.5	7.5	3.7
		San Juan Mine	
SJ011	0.1L	8.4	1.8
SJ012	0.1L	8.3	1.5
SJ021	0.1L	8.4	1.5
SJ022	0.1L	8.3	1.6
SJ031	1.0	8.3	1.3
SJ032	1.0	8.4	1.4
SJ041	0.5	8.2	2.0
SJ042	0.5	8.4	1.9
SJ051	3.5	6.6	8.2
SJ052	2.5	6.6	11.0
SJ061	0.5	8.2	2.0
SJ062	0.5	8.2	1.9
		Usibelli Mine	
US011	0.1L	5.1	5.1
US021	0.1L	5.0	1.6
US031	0.1L	4.7	1.7

Table D. Boron, pH, and organic matter content of samples of spoil.

SAMPLE	B, ppm	pH	O.M., %
		Velva Mine	
VEAI011C	1.0	7.6	3.6
VEAI031C	1.5	7.1	6.6
VEAI051C	1.5	7.4	4.5
VEAI071C	1.0	7.4	3.8
VEAI091C	2.0	7.3	8.5
VEMS011C	1.5	7.6	3.9
VEMS031C	1.0	7.8	2.4
VEMS051C	1.5	7.7	3.0
VEMS071C	0.5	7.7	1.6
VEMS091C	2.0	7.4	5.2
		South Beulah Mine	
SBAI011C	0.5	6.2	6.8
SBAI031C	2.0	7.0	9.1
SBAI051C	0.5	7.3	5.2
SBAI052C	0.5	7.3	4.7
SBAI071C	2.5	6.6	10.4
SBAI091C	1.0	6.7	5.6
SBMS011C	1.5	5.5	12.0
SBMS031C	1.5	6.4	10.5
SBMS051C	1.5	6.9	7.8
SBMS071C	2.0	6.9	7.6
SBMS091C	1.0	6.5	5.4
		Husky Mine	
HUAI011C	2.0	7.5	3.4
HUAI031C	1.0	6.9	3.3
HUAI051C	1.5	6.5	5.7
HUAI071C	1.5	6.5	5.6
HUAI091C	1.5	6.2	7.0
HUMS011C	1.0	6.8	6.4
HUMS031C	1.0	7.7	5.4
HUMS051C	1.0	7.7	4.6
HUMS071C	1.5	7.2	5.9
HUMS072C	1.5	7.3	5.7
HUMS091C	1.0	7.9	4.3

Table D. Boron, pH, and organic matter content of samples of spoil.-continued

SAMPLE	B, ppm	pH	O.M., %
		Big Sky Mine	
BSAE011C	3.5	7.7	4.0
BSAE031C	2.0	7.4	4.3
BSAE051C	1.0	8.3	2.7
BSAE071C	1.5	7.7	3.5
BSAE091C	1.0	7.6	3.7
BSMS011C	3.5	7.7	3.9
BSMS031C	2.5	7.4	3.7
BSMS051C	1.0	8.1	2.7
BSMS071C	0.5	7.9	2.6
BSMS091C	0.5	7.8	3.3
		Absaloka Mine	
SCAE011C	1.0	7.7	3.6
SCAE031C	1.0	8.1	2.2
SCAE051C	1.5	8.0	5.2
SCAE071C	0.5	8.1	2.2
SCAE091C	0.5	8.1	2.8
SCSF011C	1.0	8.2	2.8
SCSF031C	0.5	8.2	3.1
SCSF051C	1.0	7.9	3.4
SCSF071C	0.5	8.3	2.7
SCSF091C	0.5	8.1	3.3
		Decker Mine	
DEAE011C	0.5	8.2	2.5
DEAE031C	1.0	8.5	2.5
DEAE051C	1.0	8.3	2.9
DEAE071C	1.0	8.4	2.9
DEAE091C	0.5	8.7	2.8
DEAE092C	0.5	8.7	2.8
DEFS011C	0.5	8.7	3.6
DEFS012C	1.0	8.6	3.7
DEFS031C	0.5	8.1	2.7
DEFS051C	1.0	8.9	2.9
DEFS071C	0.5	8.2	3.1
DEFS091C	0.5	8.0	2.3

Table D. Boron, pH, and organic matter content of samples of spoil.-continued

SAMPLE	B, ppm	pH	O.M., %
	Dave Johnston Mine		
DJAC011C	1.0	5.0	4.3
DJAC031C	1.0	4.8	1.9
DJAC051C	1.0	6.8	2.8
DJAC071C	1.0	7.1	2.3
DJAC091C	1.0	5.9	1.8
DJBI011C	1.0	6.2	3.4
DJBI031C	1.0	4.0	4.5
DJBI051C	1.0	3.9	4.4
DJBI071C	1.0	7.8	2.3
DJBI091C	1.0	7.5	2.0
	Seminoe No. 2 Mine		
SMAC011C	1.0	7.8	8.3
SMAC031C	1.0	7.4	7.0
SMAC051C	1.0	7.9	6.2
SMAC071C	0.5	7.4	6.3
SMAC091C	1.0	7.7	6.8
	Jim Bridger Mine		
JBFS011C	9.5	7.4	5.5
JBFS031C	8.0	6.1	15.7
JBFS051C	20.0	7.3	6.0
JBFS052C	22.0	7.4	6.4
JBFS071C	26.0	5.3	33.5
JBFS091C	8.5	7.2	6.6
	Seneca No. 2 Mine		
SEAC011C	0.5	8.0	5.0
SEAC012C	0.5	7.9	5.0
SEAC031C	0.5	7.9	5.8
SEAC051C	0.5	7.9	4.5
SEAC071C	1.5	7.0	9.8
SEAC091C	0.5	7.8	4.0
SEMS011C	0.5	8.0	5.4
SEMS031C	1.5	6.3	18.2
SEMS051C	0.5	7.4	5.3
SEMS052C	0.5	7.8	4.8
SEMS071C	1.0	7.8	6.5
SEMS072C	1.0	7.5	6.9
SEMS091C	0.5	8.0	4.3

Table D. Boron, pH, and organic matter content of samples of spoil.-continued

SAMPLE	B, ppm	pH	O.M., %
		Energy Fuels Mine	
ENAC011C	0.5	7.5	3.9
ENAC031C	1.5	7.3	6.4
ENAC051C	0.5	7.7	3.2
ENAC071C	1.5	7.9	13.7
ENAC091C	1.0	7.8	9.8
ENAC092C	1.0	7.5	10.2
ENMS011C	2.5	7.4	5.8
ENMS031C	1.5	7.3	12.7
ENMS051C	1.0	7.4	4.3
ENMS071C	1.5	7.4	10.6
ENMS091C	1.0	8.8	10.3
ENMS092C	1.5	7.7	9.2
		San Juan Mine	
SJ011	2.0	8.3	2.5
SJ012	2.0	8.1	2.7
SJ021	11.4	6.5	24.0
SJ022	11.4	6.5	23.0
SJ031	1.5	8.4	4.2
SJ032	2.0	8.4	4.4
SJ041	0.1L	7.9	4.0
SJ042	1.0	8.1	4.0
SJ051	2.5	6.3	9.0
SJ052	2.0	6.6	7.8
SJ061	1.0	8.3	4.3
SJ062	0.5	8.3	4.2
		Usibelli Mine	
US011	0.1L	7.1	4.8
US021	0.1L	6.9	3.6
US031	0.1L	6.8	3.6