Geochemistry of Some Rocks, Mine Spoils, Stream Sediments, Soils, Plants, and Waters in the Western Energy Region of the Conterminous United States

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1237

Geochemistry of Some Rocks, Mine Spoils, Stream Sediments, Soils, Plants, and Waters in the Western Energy Region of the Conterminous United States

By RICHARD J. EBENS and HANSFORD T. SHACKLETTE

With sections on FIELD STUDIES

By BARBARA M. ANDERSON, JOSEPHINE G. BOERNGEN, JON J. CONNOR, WALTER E. DEAN, JAMES A. ERDMAN, GERALD L. FEDER, LARRY P. GOUGH, JAMES R. HERRING, TODD K. HINKLEY, JOHN R. KEITH, RONALD W. KLUSMAN, JAMES M. MCNEAL, CHARLES D. RINGROSE, RONALD C. SEVERSON, and RONALD R. TIDBALL

STATISTICAL STUDIES IN FIELD GEOCHEMISTRY

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Geochemical summaries for natural materials from areas having important deposits of fossil fuels

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GEOCHEMISTRY OF SOME ROCKS, MINE SPOILS, STREAM SEDIMENTS, SOILS, PLANTS, AND WATERS IN THE WESTERN ENERGY REGION OF THE CONTERMINOUS UNITED STATES

By RICHARD J. EBENS AND HANSFORD T. SHACKLETTE

ABSTRACT

Geochemical summary statistics for 59 elements in rocks, soils, stream sediments, mine tailings, and native and cultivated plants are given for 25 study areas having important deposits of coal or oil shale. Each study area is briefly described as to location, study objectives, and kind of material sampled, and references are given to published reports of the study. The concentrations of elements in the sampling media are given for suites of samples as summary data that include detection ratios, means, deviations, laboratory error, and observed ranges of concentration. Studies of certain elements in soils that exist in forms available to plants were conducted using several extraction procedures, and element concentrations as well as other parameters of the extracts were determined. The concentrations of as many as 40 elements were determined in samples of surface waters, in addition to the gross alpha and beta counts, and measurements of alkalinity, dissolved solids, hardness, pH, sodium-adsorption ratios, and specific conductance of these samples. The mineralogy is summarized for outcrop samples of shale and sandstone; of core samples of fine-grained rocks, sandstone, siltstone plus shale, and dark shale; of stream sediments; and of soils used in extraction studies. This report emphasizes changes in the geochemical environment that have accompanied coal mining in arid regions and suggests, through estimates of background element abundances, the geochemical effects to be expected in areas not yet mined. The elements in plants that grow on mine spoil and reclaimed soil of mined areas indicate that care should be taken to insure proper utilization of these areas.

INTRODUCTION

The necessity of increasing domestic energy production in the United States led to greater exploitation of fossil fuels in the 1970's, particularly in some of the Western States. In such exploitation, a wide range of environmental effects was inevitable, and studies of the known or anticipated landscape changes that would attend mining operations were begun by many State and Federal agencies. One effect believed certain to follow these operations was an alteration of the geochemical environment in or near the disturbed areas. Data on the geochemical regimes that existed before disturbances occurred at the mining sites—that is, background geochemistry—are important for identifying and evaluating the changes that occur during mining and landscape restoration.

During the last two decades the U.S. Geological Survey has investigated landscape geochemistry in order to estimate natural background concentrations of elements in rocks, soils, and plants. Some studies were "large-scale" or national, such as one in which the concentrations of a large number of chemical elements were determined in surficial materials over the United States that were but little altered from their natural condition (Shacklette and others, 1970). Other geochemical investigations concerned particular areas of the country. One concerted study was made of the State of Missouri, in which the background geochemistry of rocks, soils, plants, and waters was determined (Miesch, 1976; Tidball, 1976; Erdman and others, 1976a and 1976b; Feder, 1979; Connor and Ebens, 1980 and Ebens and Conner, 1980). Tourtelot (1973) studied soil geochemistry of the Front Range Urban Corridor, Colo. Other studies were centered on small areas exhibiting geochemically related environmental problems, or were of cultivated soils and plants considered to be normal if not natural (Shacklette and others, 1970; Connor and others, 1971; Ebens and others, 1973; and Erdman and others, 1976b). Data from these studies, insofar as they represented natural or normal geochemical environments, were summarized in a geochemical compilation of landscape units of the conterminous United States (Connor and Shacklette, 1975). Geochemical summaries were published for fruits and vegetables and their associated soils from 11 areas of commercial production in the United States (Shacklette, 1980).

By building on these baseline studies and the experience in sampling and data analysis gained in their accomplishment, studies that concentrated on the geochemistry of the western energy regions were begun in 1973. These studies focused on areas where surface or underground mines for coal and oil shale were scheduled or were likely, as well as on the geochemical effects on the environment of existing coal mines and coal-fired plants that generated electricity. The investigations in areas where mining had not yet begun were essentially regional background studies that included the geochemistry of rocks and soils likely to be disturbed during mining and of native plants, stream sediments, and surface waters. Studies conducted around existing mines and power plants were more restricted in area; they investigated the effects on the geochemistry of soils, native plants, and surface waters by land-surface disturbances, stack emissions, fly ash, and mine spoil. Reclaimed land that consisted largely of spoil material was examined to identify changes in the element content of native plants and cultivated crops, and to measure the availability of chemical elements in the soil that might lead to levels of accumulation by plants that would affect the health of both plants and the animals that eat the plants. Details of these studies were described in a series of limited-distribution annual progress reports (U.S. Geological Survey, 1974a, 1975, 1976, 1977, 1978) and in many journal and conference publications.

Although these studies were in widely scattered areas and concerned many different kinds of materials, they were unified by some common characteristics: All studies followed well-defined sampling plans designed to clearly identify the sample populations and to reduce sampling bias. The samples were submitted in a randomized order that was unknown to the analysts and were analyzed in that order so that the effects of laboratory bias or analytical drift on interpretation of the data could be circumvented. The interpretation of results of all studies was based on rigorous statistical analysis of the chemical data.

The present report gives, in summary form, the results of these studies of the Western Coal Region, which were conducted over a period of 7 years; it parallels in scope, format, and data presentation the earlier publication of geochemical summaries by Connor and Shacklette (1975).

ACKNOWLEDGEMENTS

The accomplishment of the studies described in this report depended on the assistance and cooperation of many other persons and organizations. Permission to conduct studies on private property by land owners, mining and power plant companies, and tribal councils was essential and was greatly appreciated. The assistance of many State and Federal agencies in providing guidance and advice on field studies was also of great value. Within our own organization, the services of computer programmers, specialists in data handling, and assistants in the field, laboratory, and office were invaluable. Special acknowledgment and appreciation are extended to the chemists, spectrographers, and other laboratory personnel who catalogued and prepared the samples and measured element concentrations in the many kinds of materials collected in these studies. They are James W. Baker, P. R. Barnet, A. J. Bartel, B. L. Bolton, Leon A. Bradley, E. L. Brandt, P. H. Briggs, William Cary, J. G. Crock, Isabelle Davidson, J. J. Dickson, Andrew Drenick, C. M. Ellis, Jeffrey England, I. C. Frost, Johnnie M. Gardner, Carol Gent, Michele Goff, Patricia G. Guest, J. C. Hamilton, Thelma F. Harms, Raymond G. Havens, J. P. Hemming, Kathryn E. Horan, Claude Huffman, Jr., J. O. Johnson, R. J. Knite, Lorraine Lee, R. M. Lemert, Fred E. Lichte, M. J. Malcolm, J. C. McDade, C. McFee, R. E. McGregor, Violet M. Merritt, H. T. Millard, Jr., Wayne Mountjoy, Harriet G. Nieman, M. Panter, Clara S. E. Papp, Farris D. Perez, S. E. Prelipp, G. O. Riddle, Van E. Shaw, George D. Shipley, V. Smith, M. W. Solt, Arthur L. Sutton, Jr., James A. Thomas, Michele L. Tuttle, Richard E. Van Loenen, R. J. Vinnola, James S. Wahlberg, W. J. Walz, R. J. White, and Thomas L. Yager.

METHODS OF STUDY

OBJECTIVES

The studies described in this report were planned to investigate the geochemical character of the rocks, soils, stream sediments, native plants, and surface waters at representative locations overlying major coal and oil shale resources of the northern Great Plains and Rocky Mountain Provinces. (figs. 1 and 4). By selecting areas for study in which coal mines were operating, or locations where future mining of coal or oil shale was probable, the current geochemical impact of these operations could be measured, and the probable effects of mining at new locations could be estimated. An objective that also influenced the selection of studies to be undertaken was estimation of geochemical baselines applicable to large areas in these provinces, as well as in contiguous provinces lying to the west (fig. 15), where changes in the geochemical environment attributable to energy resources develop-

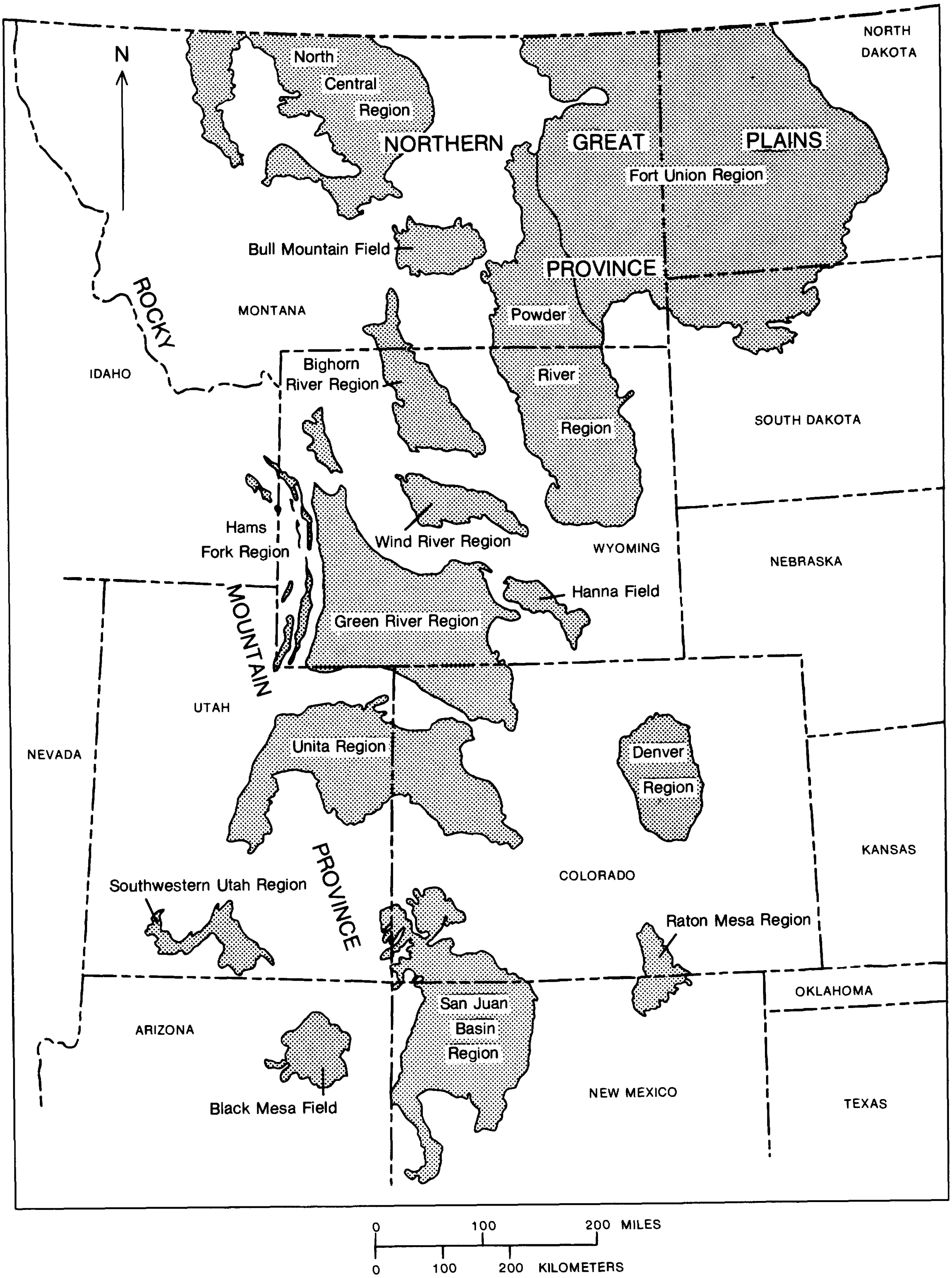

FIGURE 1.—Major coal resources of the northern Great Plains Province and the Rocky Mountain Province, Western United States. Map modified from Trumbull (1960) and U.S. Geological Survey (1970).

ment may be expected. A further objective was the unification of methodology in sampling, chemical analysis, and statistical interpretation of data for the diverse types of sampling media so that coordinated evaluations of the geochemical attributes of these provinces could be made.

COLLECTION PROCEDURES

Sampling in most studies was based on a design intended to quantify the effects of "regional" variation and the factors underlying such variation by collecting samples following hierarchical designs. By this method sample sites were "nested" at various geographic scales in order to assess the proportion of geochemical variation exhibited at each scale. Krumbein and Slack (1956) discussed in detail such designs and the requisite mathematics. In some studies, especially those in which the geochemical effects of interest originated at a point source such as a mine or power plant, samples were collected at randomly selected sites, or at sites of geometrically increasing distances from the point source. In studies of rock cores, some samples were made of the core at uniform distances within the sections of interest, others at geometrically decreasing levels in the formation. The particular sampling design used for each field study is given under the description of that study in the following section.

Sample collection procedures in the field generally were consistent for each kind of material that was sampled. Outcrop samples of rock weighing a few kilograms were collected from natural as well as artificial exposures; they were trimmed in the field or laboratory to remove visible weathering rinds and surface effects. Each stream-sediment sample was a composite of five to six grab samples at a site and consisted of fine particles taken from the beds of flowing streams or from dry streambeds, taking care to avoid material from the streambanks. Soil samples of about 1 kg each were collected from various soil horizons, depending on objectives of the study, using soil augers or spades. Rock particles larger than 2 mm were removed by hand sorting in the field or while soil was being pulverized in a ceramic mortar. Plant sampling was of two main types: by species of plant, or plant biomass. In the first type, a sample consisted of various parts of a single species collected from one or more individual plants. In biomass sampling, the above-ground parts of all plants of various species that grew in a quadrat were clipped near ground level and composited as one sample. If the plants were excessively contaminated with dust, the samples were washed in distilled water. The part of the plant that was collected depended on the objectives of the study; generally, the terminal part of woody plants, which included several years of stem growth, and the above-ground parts of forbs and grasses were collected. Cereal grains were sampled from farm storage bins by using a grain probe, which provided a composite sample of grain that had been harvested from many hectares. All water samples were collected from wells, following procedures described by Skougstad and Feder (1976).

DESCRIPTIONS OF FIELD STUDIES

The locations of the individual field studies on which the data in this report are based are shown in figures 2–16. They are briefly described below by the principal investigators who provided the data given in tables 3–77.

STUDY NO.1

Shale and sandstone of the Fort Union Formation in the Northern Great Plains

By Richard J. Ebens and James M. McNeal

A suite of shale and sandstone samples was collected from outcrops of the Fort Union Formation throughout the northern Great Plains Coal Province during the summer of 1975 for chemical and mineralogical studies. Samples were collected according to a staggered, nested, analysis-of-variance design (Leone and others, 1968). Sampling localities are shown in figure 2; each consists of a randomly selected outcrop of the Fort Union Formation within a 5-km cell. At 12 of the 48 localities shown, two samples of each rock type (shale and sandstone) were collected from a stratigraphic section in order to estimate stratigraphic variability. Geographic variability was estimated by nesting 5-km cells within 25-km cells, 25-km cells within 50-km cells, 50-km cells within 100-km cells, and 100-km cells within 200-km cells. Laboratory error was estimated by splitting 20 of the 60 samples into two parts, resulting in a total analytical load of 80 samples. The two sample groups, shale and sandstone, were each submitted to the laboratories in randomized sequence. Each sample was crushed in a jaw crusher and then ground in a vertical Braun pulverizer with ceramic plates set to pass 100 mesh. Preliminary chemical results of this work were published in Ebens and McNeal (1976, 1977), and preliminary mineralogical studies of the shale were published in McNeal and Ebens (1978). The shale mineralogy is given in table 71, and the sandstone mineralogy in table 72.

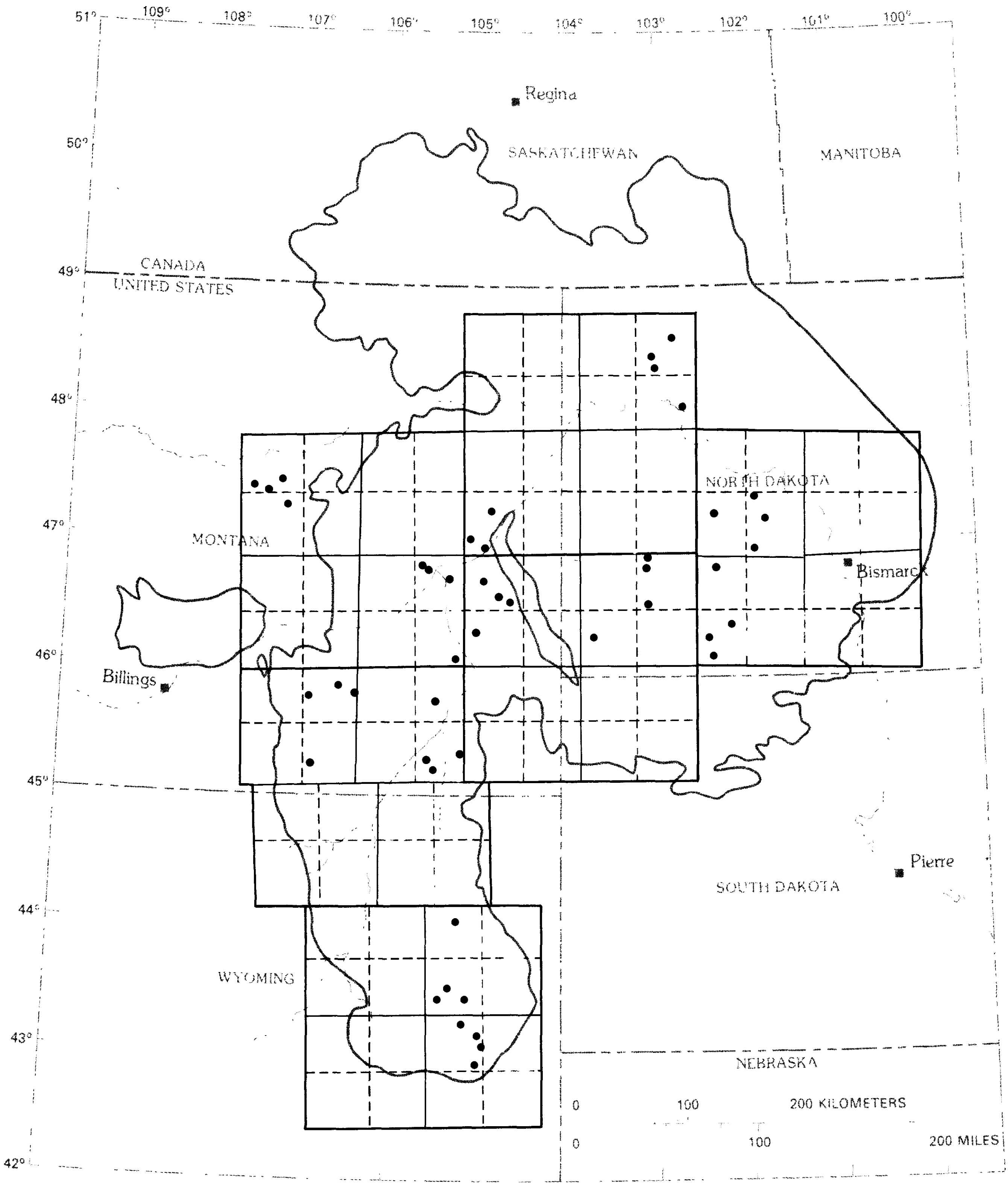

FIGURE 2.—Sampling localities of shale and sandstone of the Fort Union Formation in the northern Great Plains Coal Province used in Study No. 1. Large squares are 200 km on a side (heavy solid line); intermediate squares, 100 km (light solid line); and smaller squares, 50 km (dashed lines). Dots indicate sampling localities. Map modified from Whitaker and Pearson (1972) and U.S. Geological Survey (1974b).

STUDY NO. 2

Chemical and mineralogical analyses of core samples from Hanging Woman Creek, Montana

By Todd K. Hinkley and Richard J. Ebens

Cored overburden rock of the Fort Union Formation at the Hanging Woman Creek potential coal mine site, Big Horn County, Mont., was collected in 1976-77 and was analyzed for bulk chemistry and mineralogy (fig 3). Cores (size "NX") from the five holes, drilled through all overburden and the thick Anderson coal (one deeper hole was drilled through the lower Dietz coal), ranged in length from 130 to 260 ft (40 to 80 m). Holes were spaced so that the minimum and maximum distances between holes were about 1 km and 4 km, respectively. Four samples of each of three rock types were taken from four of the holes, and some "special" samples were taken from all five holes. The following rock types were sampled: (1) sandstone, (2) siltstone and shale, and (3) very dark colored or black shale. This classification was chosen because the three groups were expected to be chemically and mineralogically distinct. Results of this study were reported by Hinkley and others, (1978). The pH determinations for these core samples are given in table 67, and the mineralogy is given in table 74.

STUDY NO. 3

Geochemistry of fine-grained rocks in cores of the Fort Union Formation

By Todd K. Hinkley and Richard J. Ebens

Samples were taken in 1976 from each of five widely separated sites (⩾50 km): two in southeastern Montana, two in southwestern North Dakota, and one in southeastern Saskatchewan (fig. 3). Four rock samples were taken at each site from each of two drill holes that were separated by 1-2 km. The samples taken from each core were separated by a vertical distance of 0-100 m, and each sample consisted of 30 cm of a homogeneous stratum of shale or mudstone. Only three samples were collected from each of the two drill holes at Estevan, Saskatchewan, because of the paucity of fine-grained horizons in these cores. In all, 38 samples were collected. Twelve samples were split and submitted in duplicate to estimate analytical precision, as distinct from geographical variability, bringing the number of samples to 50. All samples were analyzed in a randomized sequence. Results of this study were reported by Hinkley and Ebens (1977). The mineralogy of these rock samples is given in table 73.

STUDY NO. 4

Geochemistry of sandstones from the Fort Union Formation, Northern Great Plains

By James R. Herring, Todd K. Hinkley, and Richard J. Ebens

Localities, sites, and sample design used for this study, which was conducted in 1976, are the same as those of Study No. 3, except that no samples were taken from Saskatchewan (fig. 3). Therefore, four samples were taken from each hole of a pair at four sites. Ten of the samples, split into duplicates, provided a measure of analytical precision. The total of 42 samples was analyzed in a random sequence. Each sample consisted of a section, 30 cm in length, of a relatively homogeneous sandstone. The pH determinations for these core samples are given in table 67.

STUDY NO. 5

Geochemistry of an oil shale core, Piceance Creek Basin, Colorado

By Walter E. Dean

U.S. Geological Survey oil shale core CR-2 was drilled in the northern part of the Piceance Creek Basin, in the southeast corner of T. 1 N., R. 97 W. (fig. 4). Chemical analyses of the core were obtained in three stages over a period of about 3 years (1976-79). The lower 300 m of the core is in the Garden Gulch Member, which is the oldest lithologic unit of the Eocene Green River Formation in the Piceance Creek Basin of western Colorado. The Garden Gulch Member contains more clay and less carbonate, and generally has lower oil yields than does the overlying Parachute Creek Member that forms the main body of the Green River Formation. Samples of the Garden Gulch Member in CR-2 core were collected at approximately 0.3-m intervals, crushed, and homogenized for oil-yield determinations and chemical analyses. Each analysis, therefore, represents an average for the 0.3-m sample interval. Concentrations of Al, Fe, Mg, Ca, K, Ti, B, Cr, Cu, Ga, Mn, Mo, Ni, Pb, Sc, Sr, V, Yb, and Zr were measured by semiquantitative optical emission spectroscopy in 264 samples. More complete quantitative analyses were also obtained for Si, Al, Fe, Mg, Ca, Na, K, Ti, S, Li, Rb, Hg, U, and Th in 32 of the samples, representing approximately every tenth 0.3-m sample from the Garden Gulch Member.

The interval between about 230 and 320 m in the CR-2 core contains the so-called Mahogany zone of the Parachute Creek Member of the Green River Formation, which is the part of this formation that is richest

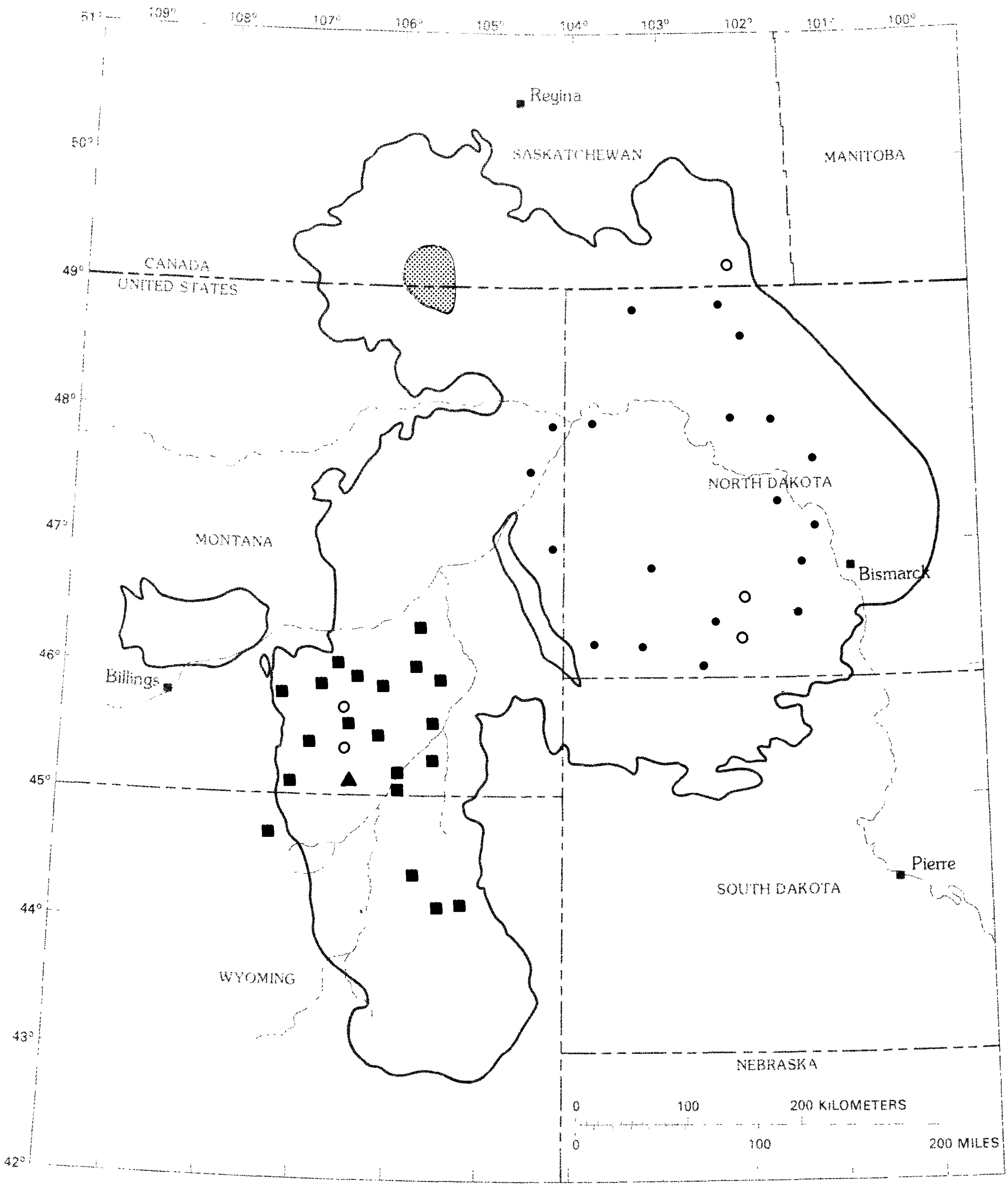

FIGURE 3—Rock core and ground-water sampling localities in the northern Great Plains Coal Province. Fine-grained rock and sandstone localities are indicated by open circles (Studies No. 3 and 4). The location of Hanging Woman Creek, where overburden rocks (Study No. 2) and soils (Study No. 14) were sampled, is indicated by a triangle. Ground-water sampling locations in Fort Union coal region (Study No. 25) are indicated by squares, and in the Powder River coal region (Study No. 28), by solid circles. The patterned area is the Poplar River Basin (Study No. 27). Parameters measured for water samples are given in tables 68–70.

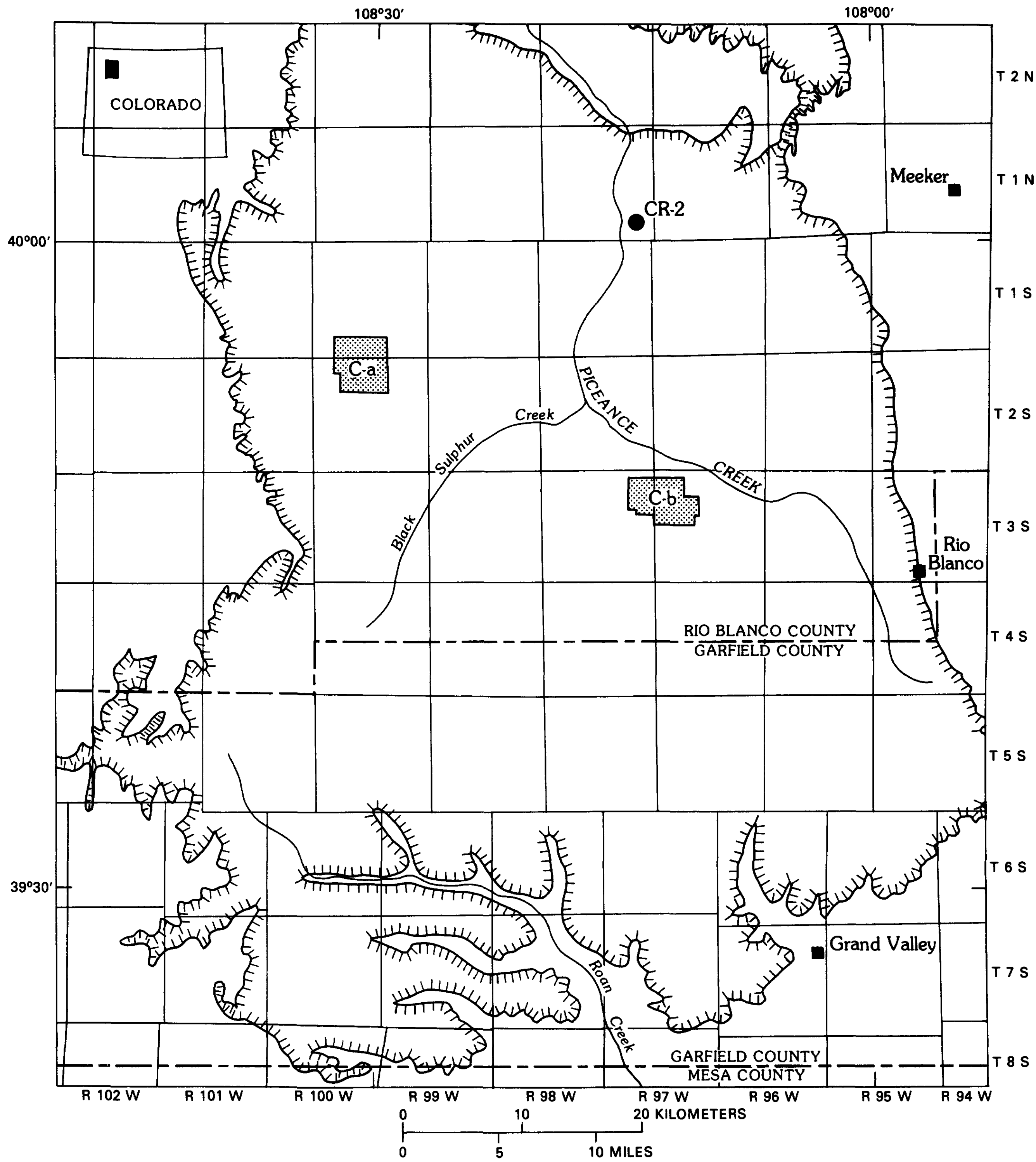

FIGURE 4—Sample localities of oil-shale-core (CR-2, Study No. 5), stream-sediment (Roan and Black Sulphur Creeks, Study No. 9), and soil (C-a and C-b, Study No. 15) samples in the Piceance Creek Basin, Colorado. Hachured line enclosed Piceance Creek Basin.

in oil. A total of 74 samples was collected within this 90-m interval according to a nested analysis-of-variance design. The 90-m interval was subdivided into three 30-m intervals, each 30-m interval was subdivided into ten 3-m intervals, and each 3-m interval was subdivided into ten 0.3-m intervals. From each 30-m interval, two 0.3-m samples (the first and sixth) were collected from each of the ten 3-m intervals. Each of the 0.3-m samples was crushed and homogenized for analysis in the same manner as were the 0.3-m samples from the Garden Gulch Member. Every fifth sample was replicated in analysis in order to determine the analytical variance.

The 300-m interval between the bottom of the Mahogany zone and the top of the Garden Gulch Member in the CR-2 core contains most of the Parachute Creek Member of the Green River Formation. This interval also contains the saline facies of the Parachute Creek Member, as indicated by the presence of the evaporite minerals nahcolite and dawsonite. The middle 300 m was also sampled according to a nested analysis-of-variance design in order to examine geochemical variability at the 30-, 3-, and 0.3-m levels. The same basic design used for the Mahogany zone was used for the middle 300 m except that two 0.3-m samples were collected from only two (first and sixth) of the ten 3-m intervals. This design resulted in the collection of 53 samples for analysis (including analytical replicates).

STUDY NO. 6

Stream-sediment chemistry in the northern Great Plains

By James M. McNeal

The objectives of this study, made in 1975, were (1) to determine if stream order and size of drainage basin are important parameters in defining different populations of sediments, and (2) to determine the magnitude of the regional geochemical variability of the sediments. To this end, data were analyzed in two analysis-of-variance designs. Three target populations were defined—sediments in first-, second-, and third-order streams—as shown on 1:1,000,000-scale topographic maps. A first-order stream is an upstream, unbranched stream segment, a second-order stream extends downstream from the junction of two first-order streams, and a third-order stream extends downstream from the junction of two second-order streams (Strahler, 1969, p. 483). Streams larger than third order were not studied because they were too few in number. In addition to stream order, the size of the drainage basin above each sampling locality was measured in order to investigate its relationship to the element content of the sediment. Ten randomly selected 50-Km^2 areas were chosen from a total of 15 in the northern Great Plains that contained at least two streams of each of the three stream orders of interest (fig. 5). Two streams of each of three orders were then randomly selected. Further, one stream of each order was randomly selected and a second sample was taken approximately 100 m upstream from the first. In order to reduce the sampling error, all samples were composited from five to six grab samples, depending on the size of the stream. All localities were sampled as near the junction of the target stream and a stream of the next highest order as was possible, while at the same time remaining above the region of influence of the larger stream during flood conditions. Results of this study were reported by McNeal (1976). The pH determinations for these sediments are given in table 67, and the mineralogy is given in table 75.

STUDY NO. 7

Chemistry of Powder River sediments

By James M. McNeal, John R. Keith, Barbara M. Anderson, and Josephine G. Boerngen

As part of a general effort to chemically characterize the landscape of the Powder River Basin, Wyoming and Montana, samples of Powder River stream sediments were collected in 1973 according to a nested analysis-of-variance sampling design (fig. 5). The length of the river across the basin was subdivided into six segments. In each segment, two localities were selected randomly, each locality being about the size of a section (1.6 km on a side). The objective was to reach the river somewhere within each locality and randomly collect two samples of the "active" sediment from a transect across the river bottom. In practice, the transect reached only to the edge of running water on the side from which the river was approached. The levels in this design reflect geochemical variation (1) between supertownships, (2) between transects within supertownships, (3) between samples within transects, and (4) between analyses of sample splits. In general, the two samples from each transect were located about 25–100 m apart. Each sample was collected by shovel, placed in a cloth bag, and dried in the laboratory if necessary before processing. Each sample was disaggregated and passed through a 2-mm sieve. The < 2-mm fraction was further sieved into four size fractions: > 200 μm, 100–200 μm, 63–100 μm, and < 63 μm. Fifteen of the resulting 96 samples were randomly selected and split into two parts, and the entire suite of 111 samples was submitted for analysis in a randomized sequence. The results of this study were reported in Keith and others (1976).

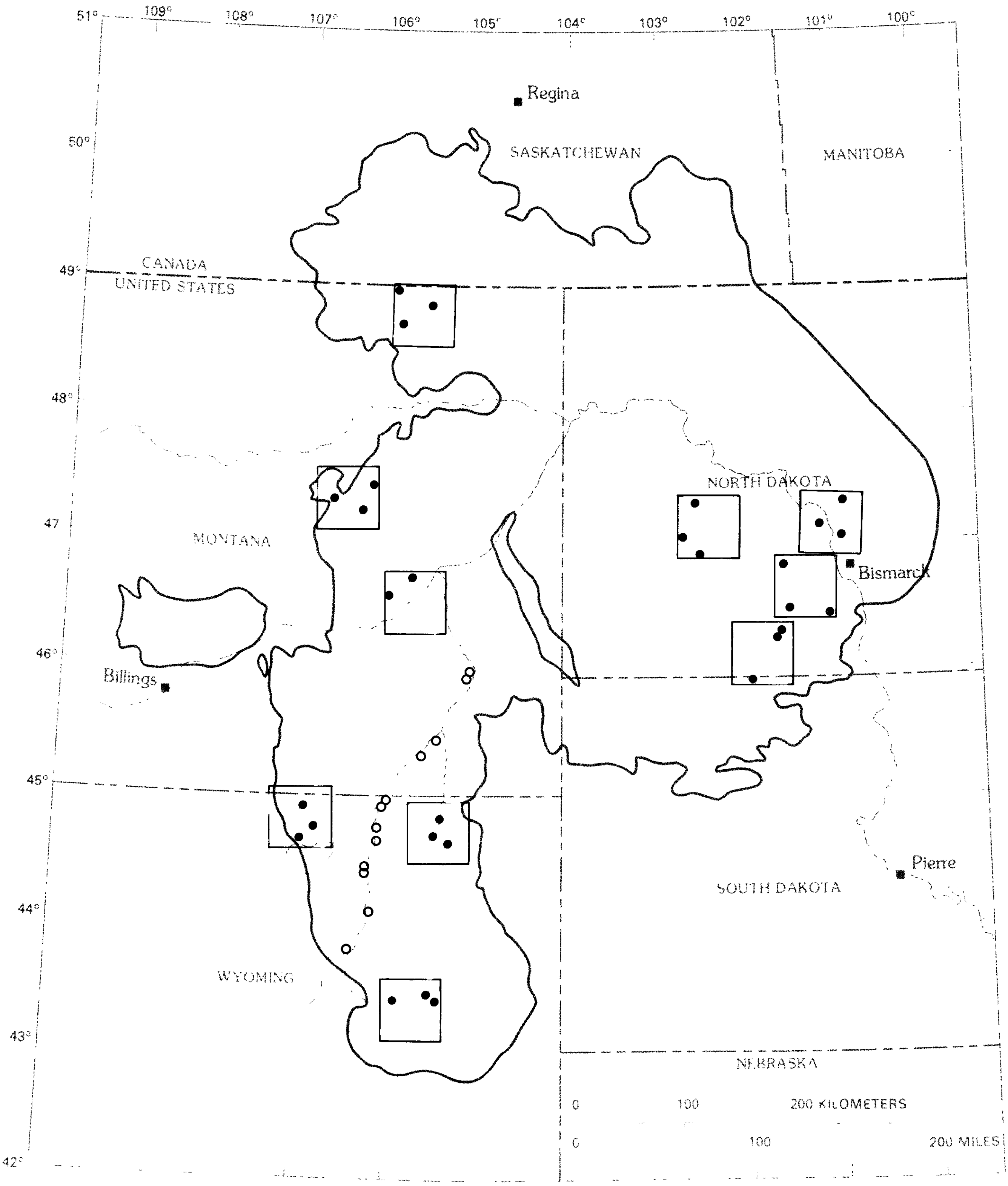

FIGURE 5—Stream-sediment sampling localities in selected areas of the northern Great Plains Coal Province (solid circles in 50-km² areas), and along the Powder River (open circles, Study No. 7).

STUDY NO. 8

Stream-sediment chemistry of the Uinta and Piceance Creek Basins, Utah and Colorado

By James M. McNeal and Gerald L. Feder

In this study two drainages in the Uinta Basin (Cottonwood Wash and Asphalt Wash) and two in the Piceance Creek Basin (Ryan Gulch and Duck Creek) were selected for sampling in 1975 (fig. 6). Each of the four stream drainages may undergo change in stream flow and sediment yield related to oil-shale mining and processing. In order to characterize each stream, eight samples were collected: three samples from random sites within three intervals of equal length along the main channel of the named stream, and five additional samples above alluvial fans at the mouths of five randomly selected tributaries entering the main stream. The resulting data were examined by a nested analysis-of-variance design containing four levels. The top level reflects differences between the two major basins (Uinta and Piceance Creek Basins); the second level reflects differences among the paired drainages within each basin; the third level reflects differences among the eight samples taken within each of the four drainages; and the lowest level reflects differences among splits of the randomly selected samples. All samples were collected from dry stream channels in areas where fine sediments had accumulated. At each locality approximately 2 kg of sediment were composited from material taken at 7 - 10 sites within 20 m of each other and at depths of no more than 3 cm. The samples were air dried at 40°, then sieved through a 150-μm stainless steel screen. Results of this study were reported by McNeal, and others (1976).

STUDY NO. 9

Geochemical variability of sediments from two streams in the Piceance Creek Basin, Colorado

By James M. McNeal, Charles D. Ringrose, and Ronald W. Klusman

This study, made in 1975, was largely aimed at quantifying the major scales of geochemical variability in sediments along two selected streams in the Piceance Creek Basin. Sediment sampling followed a six-level, nested, analysis-of-variance design. The six levels define components of geochemical variability (1) between streams, (2) between 10-km intervals, (3) between 1-km intervals, (4) between 200-m intervals, and (5) between 20-m intervals, and (6) define analytical error. The two streams chosen at the top level were Roan Creek, which flows from east to west in the southern part of the basin, and Black Sulphur Creek, which flows from north to south in the central part of the basin (fig. 4). The Roan Creek drainage crosses exposures of the lower Uinta Formation, all of the Green River Formation, and the upper Wasatch Formation. Black Sulphur Creek lies mostly in the upper Green River and the lower Uinta Formations. Two major sampling localities separated by 10 km were selected on each stream. The design was geographically balanced: in each locality two stream segments 200 m in length were randomly selected about 1 km apart. In each 200-m length, two segments about 20 m long were randomly selected, and in each 20-m segment, two sampling sites were randomly chosen. Ten samples of the 32 collected were randomly selected for duplicate analysis, and all 42 samples were placed in a random order prior to chemical analysis. Results of this study were reported by McNeal, and others (1976).

STUDY NO. 10

Sweetclover and associated spoil materials from selected coal mines in the northern Great Plains

By Richard J. Ebens and James A. Erdman

Samples of sweetclover and associated soil or spoil, or both, were collected during late summer of 1974 from 10 randomly selected sites at each of eight surface mines scattered throughout the northern Great Plains (fig. 7). In addition, three samples of alfalfa were taken from each of five mines. A sample of spoil material or a spoil-soil mixture was collected to a depth of about 20 cm. The sweetclover and alfalfa samples consisted of the above-ground portion of plants growing within 1 m of the spoil sample. Spoil materials at all mines consist of claystone and siltstone with lesser amounts of sandstone, shale, and coal of the Fort Union Formation. Glacial deposits consisting of gravel, sand, silt, and clay are important spoil materials at all mines except the Big Sky, Dave Johnston, and Hidden Valley mines. No shaping or topsoiling of the area where we sampled had been done at the Beulah North, Hidden Valley, Kincaid, and Utility mines. The Big Sky, Dave Johnston, Savage, and Velva mines were contoured and topsoiled where we sampled. Detailed descriptions of these mines are given by Erdman and Ebens (1975), Evans, Uhleman, and Eby (1978), and U.S. Environmental Protection Agency (1976). Results of this study were reported by Erdman and Ebens (1975), Erdman, Ebens, and Case (1978), and Erdman (1978). The pH determinations for these samples of mine spoil are given in table 67.

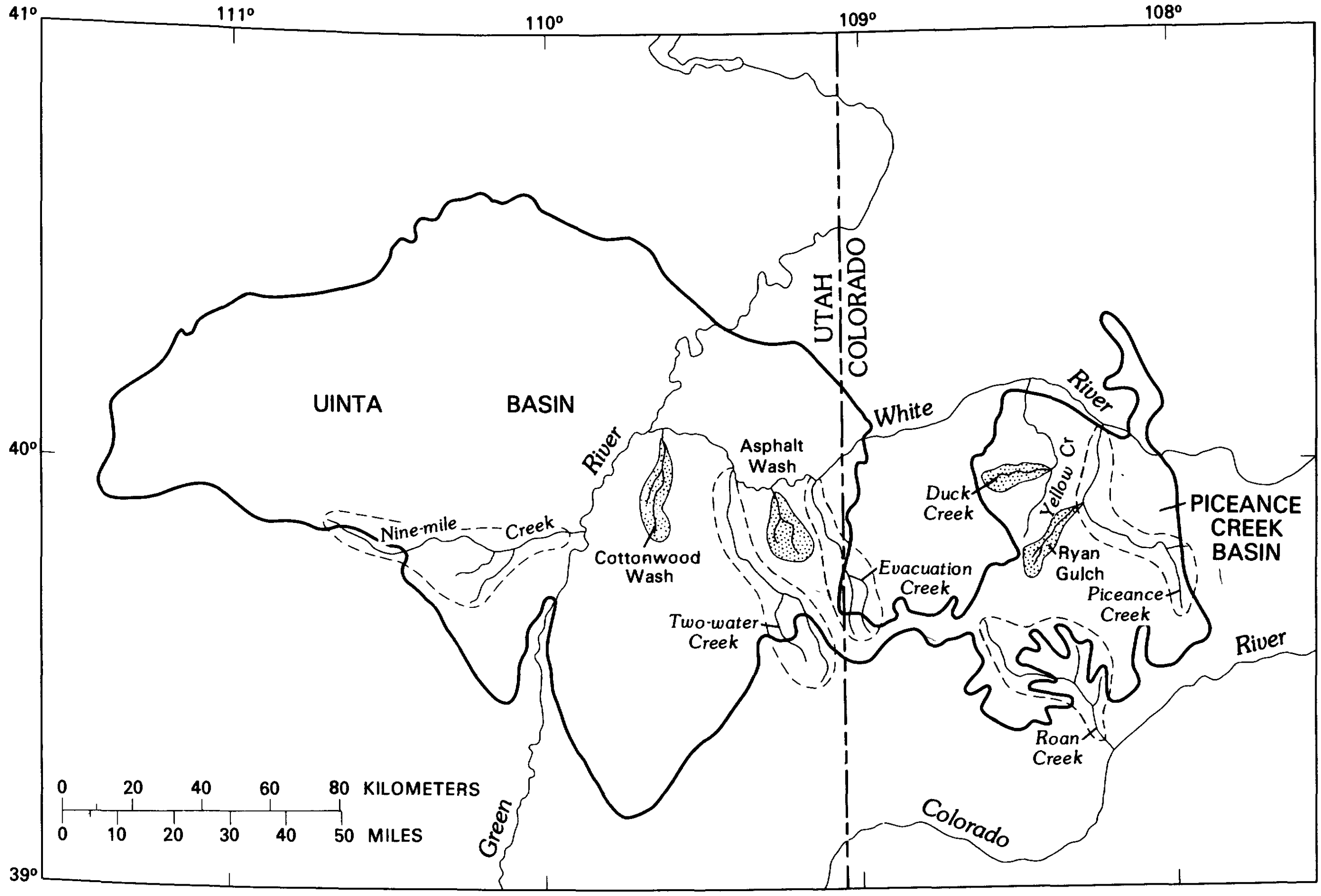

FIGURE 6—Drainage basins in which stream sediments were sampled (shaded areas, Study No. 8), and third-order watersheds in which alluvial soils were sampled (dashed lines, Study No. 12) in the Piceance Creek and Uinta Basins, Utah and Colorado (solid lines). Map modified from Oetking and others, 1967.

STUDY NO. 11

Soils, mine spoils, and native plants at the San Juan Mine, New Mexico
By Larry P. Gough and Ronald C. Severson

Samples of mine spoil, replaced topsoil, alkali sacaton (**Sporobolus airoides**), and fourwing saltbush (**Atriplex canescens**) were collected in August 1977 at the San Juan mine, located in the San Juan Basin 30 km northwest of Farmington, N. Mex. (fig. 8). Samples were collected at six randomly selected sites from an area of about 5 ha, on the basis of an unbalanced, nested, analysis-of-variance design. The area had been recontoured, topsoiled to a depth of about 20 cm, and seeded in 1974. Alkali sacaton samples consisted of the stems and leaves, usually of one grass clump, whereas the fourwing saltbush samples consisted of the young, terminal, 20- to 30-cm portion of stems (with leaves), usually from one shrub. Because alkali sacaton samples were judged to be excessively contaminated with dust, they were washed prior to chemical analysis. The purpose of this study was to quantify the variation in the element concentration of soils, mine spoils, and plant species used for revegetation at geographic scales of 100 m, 25 m, and 5 m, as well as variation due to analytical methods. This study represents a preliminary examination of both the total and extractable chemical composition of replaced topsoil and mine spoil, as well as the chemical composition of selected plants re-established on these substrates. These data may be compared with our observed concentration means and ranges for elements in similar materials collected from undisturbed sites in the San Juan Basin. (See Study No. 19.) The element content of **Atriplex** that grew under natural conditions and on mine-reclaimed land was given by Gough and Severson (1980), and the chemical character of soil useful for mine-land reclamation in the San Juan Basin was described by Severson (1981). Parameters measured in extraction studies of these soils and mine spoils are given in table 65, and pH determinations are given in table 67.

STUDY NO. 12

Alluvial soils of the Piceance Creek and Uinta Basins
By Ronald R. Tidball and Ronald C. Severson

Alluvial soils of several randomly selected watersheds within the Piceance Creek Basin, Colo., and the adjacent Uinta Basin, Utah (fig. 6), were sampled in 1975 and analyzed for total chemical composition to estimate (1) the magnitude and distribution of the variance, (2) any significant differences between watersheds, and (3) any significant differences within watersheds. A two-way factorial design (watersheds versus stream order) of the randomized-blocks type that included replication in each block was used. Channel samples of soil 0–40 cm in depth were collected from three stream orders within each of five watersheds. The analytical error was estimated from duplicate analyses of 15 samples that were randomly dispersed in the sample set. Chemical analysis was done on the < 2-mm fraction of soil. The study was described by Tidball and Severson (1977).

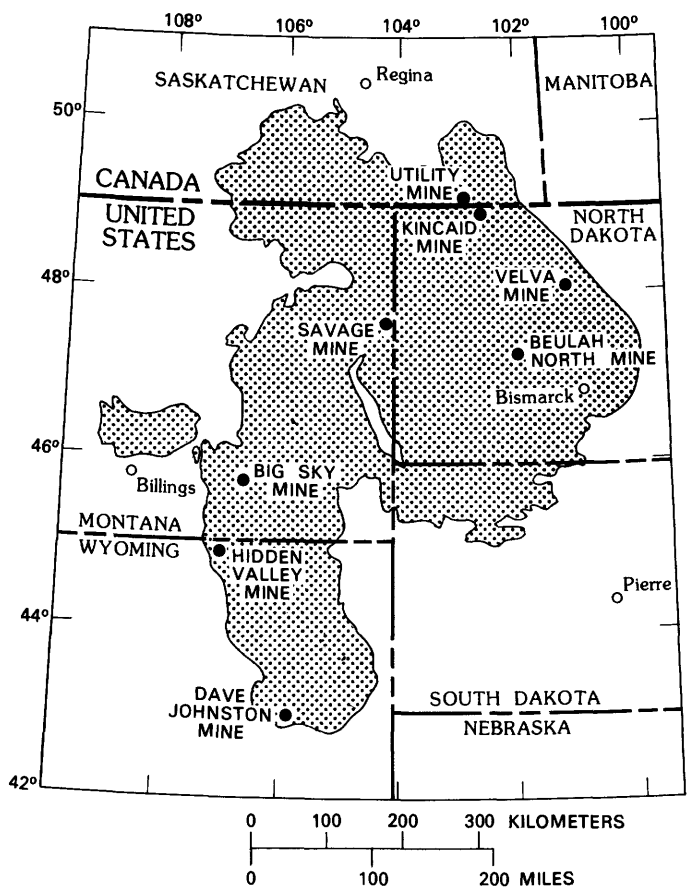

FIGURE 7.—Sampling localities for sweetclover and associated mine spoil material in the coal region, northern Great Plains (Study No. 10). Crested wheatgrass that grew on mine spoil was sampled at the Dave Johnston mine (Study No. 26).

STUDY NO. 13

Soils of the Powder River Basin, Wyoming and Montana
By Ronald R. Tidball and Richard J. Ebens

A reconnaissance-type survey of soil composition in the Powder River Basin in Wyoming and Montana was made in 1973 to estimate the magnitude and distribution of variance in these soils (fig. 9). Sample sites were selected in accordance with four barbell clusters located within each of four nearly equal quadrants. Channel samples were collected from the surface horizon (0–2 cm in depth), the B horizon (or a depth of 30–40 cm), and the C horizon (or soil parent material at 110- to 120-cm in depth) at each of 64 sites. Components of variance were estimated over distance intervals of 0–0.01 km, 0.01–1 km, 0.1–1 km, 1–10 km, and greater than 10 km. Total chemical analysis was done on the < 2 mm fraction. Analytical error was estimated from 47 duplicate analyses that were randomly distributed throughout the sample set. An account of this study was given by Tidball and Ebens (1976). The pH determinations of these soil samples are given in table 67.

STUDY NO. 14

Chemical and mineralogical evaluation of soils,
Hanging Woman Creek, Montana
By Ronald R. Tidball

The study area is one of the U.S. Bureau of Land Management's Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) sites where significant deposits of federally owned coal occur. The site is located in Big Horn County, Mont. (fig. 3). Soil samples were collected in 1975 from representative soil groups according to a hierarchical analysis-of-variance design. Channel samples of the A, or A plus B, horizon and of the C horizon from about 60- to 80-cm in depth were collected from four random sites within each of four soil groups. Total chemical composition was determined on the < 2-mm fraction of soil; each sample is a composite of corresponding horizons from two nearby profiles. The analytical error was estimated from eight randomly selected samples of the A horizon and eight samples of the C horizon. This study was described by Tidball (1978). The pH determinations of these soil samples are given in table 67, and the mineralogy is given in table 77.

STUDY NO. 15

Soils of the Piceance Creek Basin, western Colorado

By Walter E. Dean, Charles D. Ringrose, and Ronald W. Klusman

The basic sampling for the study of soils in this basin, conducted in 1975 (fig. 4), was a partially unbalanced, nested, analysis-of-variance design. The highest geographic sampling level contained nine supertownships, each of which consisted of four adjacent townships. Within each of the 36 townships, two sections were chosen at random. Within one of these two sections, two samples of soil (A horizon, or the upper 10 cm where horizons were not developed) were collected at a distance of 100 m from each other. Only one sample was collected from the other section in each township, which made a total of three samples per township. The three samples within a township were

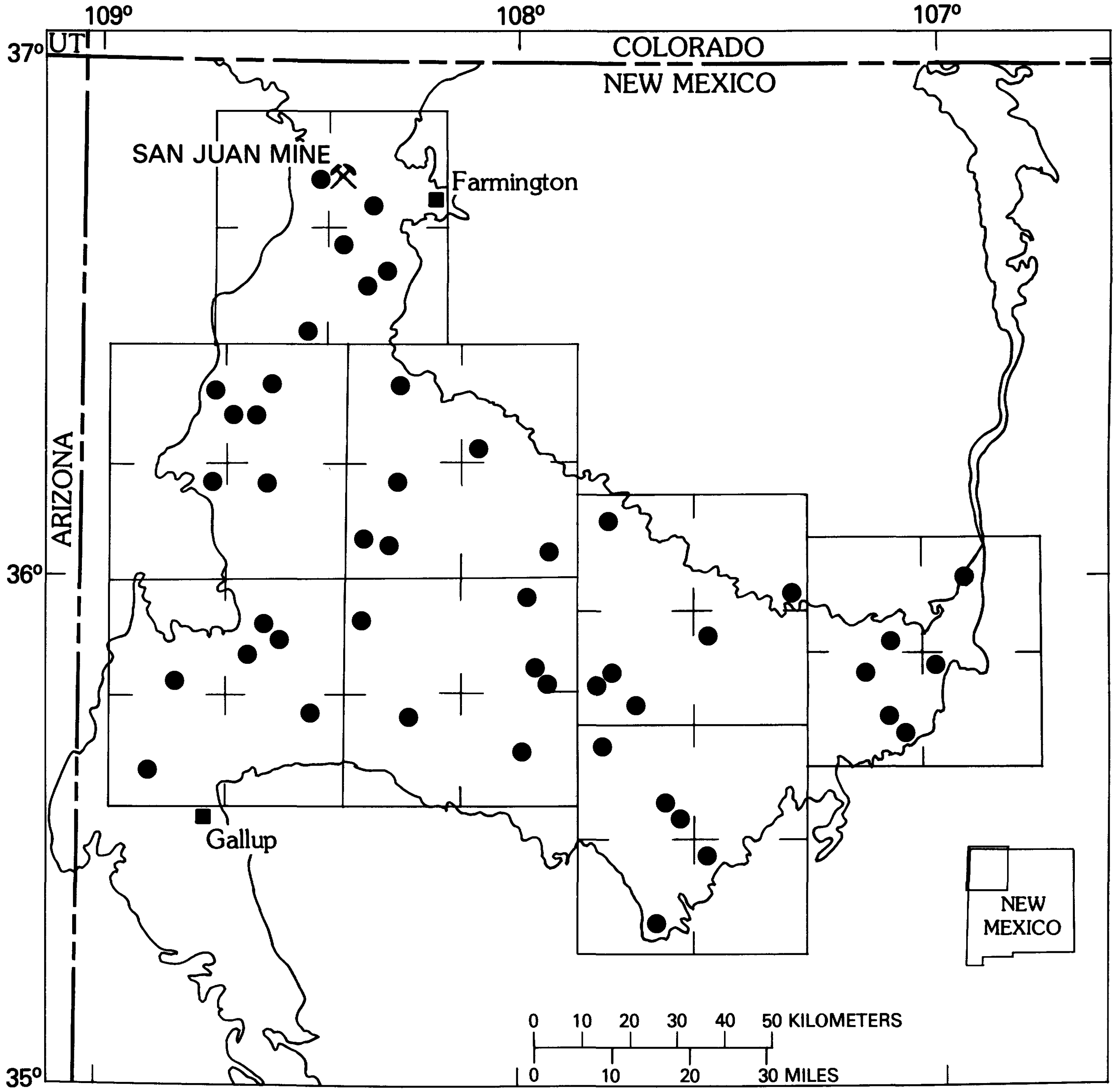

FIGURE 8.—Sampling localities (circles) within the San Juan Basin coal region, with the unbalanced, nested, analysis-of-variance sampling grid superimposed (solid line, 50 km²; dashed line, 25 km²). Soils were sampled at all locations. Study No. 11 and 19.

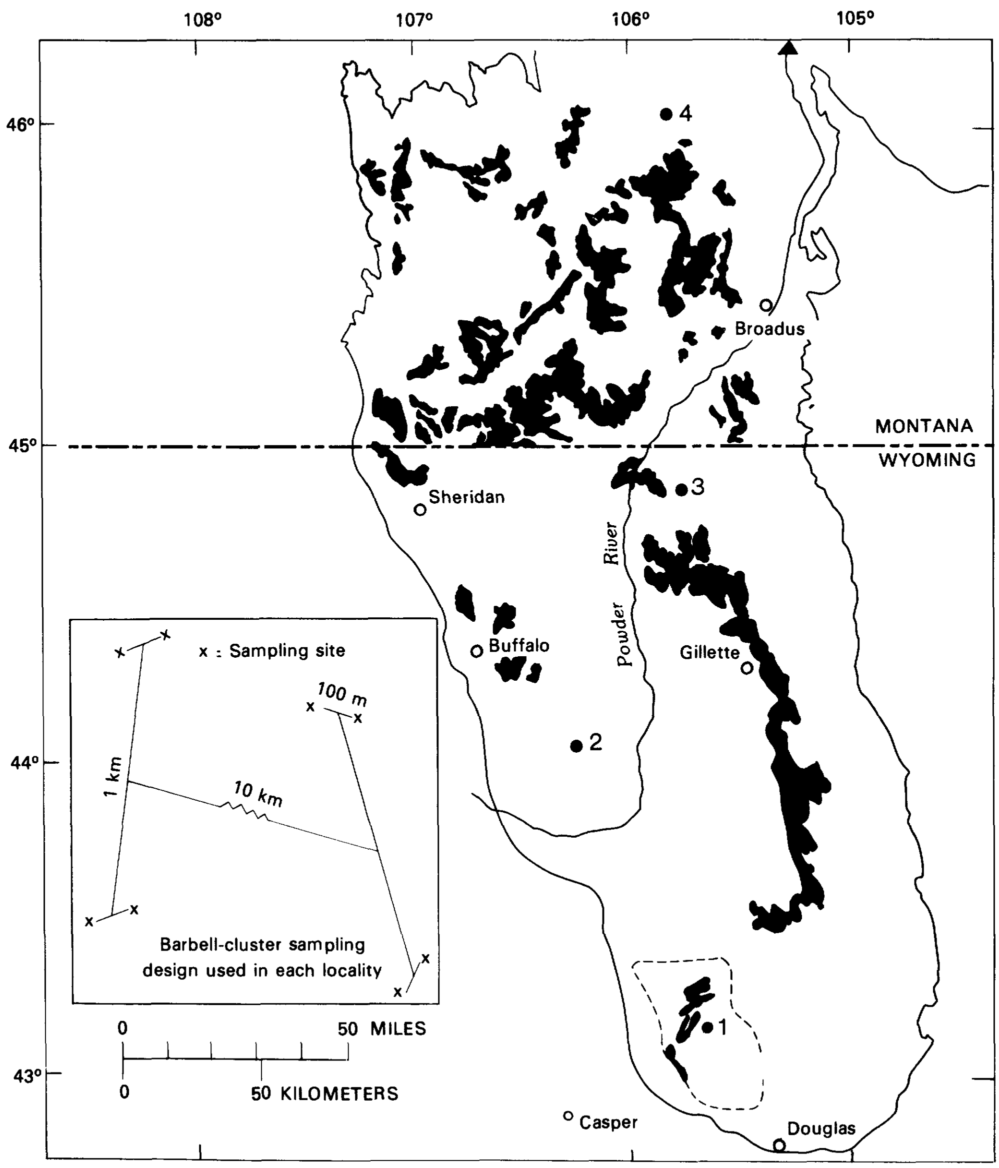

FIGURE 9.—Powder River Basin showing soil and lichen sampling localities (solid circles, numbered 1 to 4), each containing a 10-km barbell-cluster design. Channel samples of the surface horizon, the B horizon, and the C horizon of soils were collected at each of 64 sites (Study No. 13). Composite samples of a lichen were collected, where possible, at each of eight sites within a cluster (Study No. 22). Patterned areas indicated known strippable coal reserves (modified from U.S. Geological Survey, 1974c). Dashed line indicates outline of the Southern Powder River basin uranium district.

collected either from ridgetops or valley bottoms, the sampling localities alternating according to a checkerboard design. The decision as to which of the two sections in each township would have two sampling locations and which would have only one was made by a flip of a coin. From the final suite of 108 samples, 32 were chosen at random to be replicated in analysis. All 140 samples (108 samples plus 32 duplicates) were ground in a ceramic mill to pass a 100-mesh (less than 149 μm) sieve and were analyzed in a randomized sequence for 39 elements. The analytical design consisted of six levels: one physiographic (level 1, ridgetop and valley bottom); four geographic (level 2, supertownship; level 3, township; level 4, section; and level 5, the sample), and one analytical level (level 6, 32 duplicate analyses). Results of this study were published in Dean and others (1977, 1979).

STUDY NO. 16

Total soil chemistry, northern Great Plains
By Ronald C. Severson and Ronald R. Tidball

This study, conducted in the fall of 1974, represents a broad-scale inventory of total chemical composition of the A and C horizons of soils of the coal regions in the northern Great Plains Province (fig. 10). Samples were collected randomly according to an unbalanced, nested, analysis-of-variance design which was used to quantify variation in total content of elements between glaciated and unglaciated terrains at four increasingly smaller scales (100 km, 50 km, 10 km, and 1 km), as well as variation due to sample preparation and analysis. Reliable maps were prepared, based on 100-km units, for calcium, potassium, and rubidium in A and C horizons of soils; for sodium, silicon, thorium, uranium, and zinc in A horizons; and for arsenic, calcium, germanium, and magnesium in C horizons. Results of this study were reported in Tidball and Severson (1975, 1976) and in Severson and Tidball (1977, 1979). In the present report, summary statistics for elements exhibiting significant differences between terrains are given for both glaciated and unglaciated terrains. Summary statistics for elements without significant differences in concentration between terrains are reported for the region as a whole.

STUDY NO. 17

Soil geochemistry of the Wind River and Big Horn Basins, Wyoming and Montana
By Ronald C. Severson

A reconnaissance study of the element composition of soil (0- to 40-cm composite sample) was conducted in these basins in the fall of 1976 (fig. 11). Chemical variation between geologic units within a basin, within geologic units across different distances (25 km, 10 km, 5 km, and 1 km), and for sample preparation and analysis were estimated by collecting samples according to an unbalanced, nested, analysis-of-variance design. Summary statistics for element composition of the soils are reported for each basin as a whole. Results of this study were reported in Severson (1977, 1979).

STUDY NO. 18

Soils and native plants, northern Great Plains
By Larry P. Gough, Ronald C. Severson, and James M. McNeal

Samples of A and C horizons of soils, western wheatgrass (Agropyron smithii), silver sagebrush (Artemisia cana), and above-ground plant biomass were collected at 21 geochemically diverse sites in the northern Great Plains in the fall of 1976 (fig. 12). The purpose of the study was to examine functional relationships between element concentrations in native plants and supporting uncultivated soils over the unglaciated part of the northern Great Plains. A number

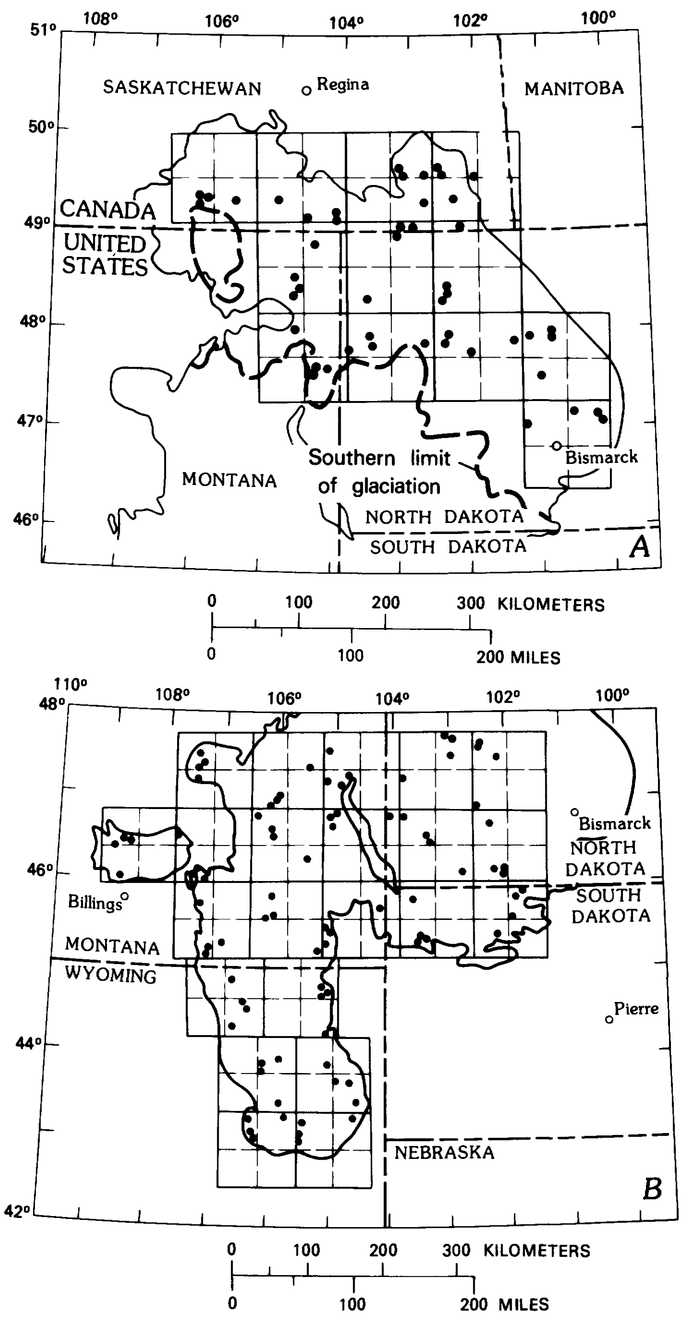

FIGURE 10.—Sampling localities (dots) in the coal regions of the northern Great Plains Province where samples of A and C soil horizons were collected. *A*, glaciated areas; *B*, unglaciated areas; large squares (solid lines) are 100 km on a side, smaller squares (dashed lines) are 50 km on a side. Study No. 16.

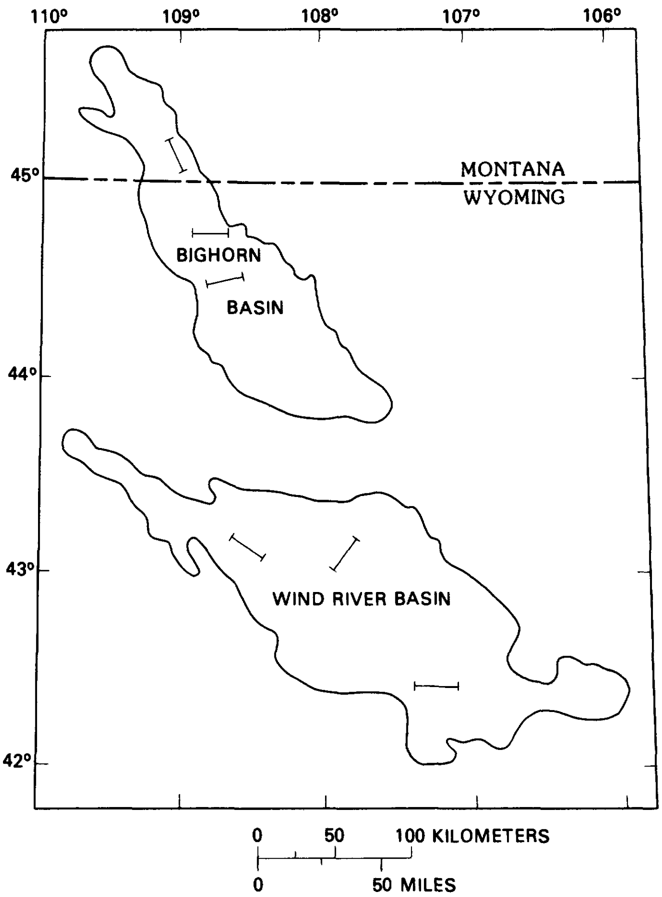

FIGURE 11.—Composite soil sampling localities (indicated by barbells) in the Bighorn and Wind River Basins. Study No. 17.

of different extracting agents for soils were used; however, only data for DTPA (0.005 M, pH 7.3) extractable elements are reported here. The soil samples consisted of the <1-cm material which was disaggregated to pass a 10-mesh sieve. Wheatgrass (aboveground parts) and sagebrush (terminal 20–30 cm of stems with leaves) samples consisted of a composite of material over about a 50-m^2 area. The biomass samples were composites of all above- ground plant material in a 3-m^2 area. Because the grass and biomass samples were judged to be excessively contaminated, they were washed prior to chemical analysis. These data provide an indication of the range in total and extractable element concentrations in soils that are favorable to native plant growth. Results of this study were presented in Gough and others (1977, 1978); Gough and others (1979); McNeal and others (1977); McNeal and others (1978); Severson and others (1977); Severson and others (1978); Severson and others (1979); Gough and others (1980); and Crock and Severson, (1980). Parameters measured in DTPA extracts of these soils are given in table 66, and the soil mineralogy is given in table 76.

STUDY NO. 19

Soils and native plants, San Juan Basin, New Mexico

By Ronald C. Severson and Larry P. Gough

Samples of the A and C horizons of soils, galleta grass (**Hilaria jamesii**), snakeweed (**Gutierrezia sarothrae**), and fourwing saltbush (**Atriplex canescens**) were collected in the summer of 1977 according to an unbalanced, nested, analysis-of-variance design from an area of the San Juan Basin, N. Mex. (fig. 8). The purpose of the study was to quantify the variation in the element concentration of these materials at geographic scales of 50 km, 25 km, 5 km, and 1 km, as well as variation due to analytical methods. This broad-scale study represents an inventory of both the total and extractable chemical composition of taxonomically defined soils likely to be impacted by the expanding development of energy-related activities in the basin. Further, the plants that were sampled are native species that are either likely to be used in reclamation efforts, or are important animal forage, or both. The A and C horizons of soils at 47 of a possible 48 sites were sampled. Owing to the sporadic distribution of the desired plant species, however, only 25, 18, and 10 sites were sampled for galleta, snakeweed, and saltbush, respectively. The galleta samples consisted of the entire plant (leaves, stems, rhizomes, and roots), whereas the snakeweed samples were of the aboveground parts (stems and leaves) and the saltbush samples were of the terminal 20 to 30 cm of stems (with leaves). Galleta samples were composited over an area of about 10 m in diameter, but the snakeweed and saltbush samples usually were from an individual plant. Because galleta and snakeweed samples were judged to be excessively contaminated with dust, they were washed prior to chemical analysis. Total element composition of the soils was reported in Severson (1978a). The biogeochemical variability of plants and the geochemistry and variability of soils from natural and reclaimed areas of the San Juan Basin were given by Severson and Gough (1981) and Gough and Severson (1981). Parameters measured in extraction studies of these soils are given in table 63, and pH determinations are given in table 67.

STUDY NO. 20

Trace-metal variation in soils and sagebrush in the Powder River Basin, Wyoming and Montana

By Jon J. Connor, John R. Keith, and Barbara M. Anderson

Samples of about 200 g of vegetation-free surface soil (0–25 cm in depth), 200 g of subsurface soil (15–20 cm in depth), and about 50 g of terminal stems and leaves of big sagebrush (**Artemisia tridentata**) were collected from the Powder River Basin of eastern Wyo-

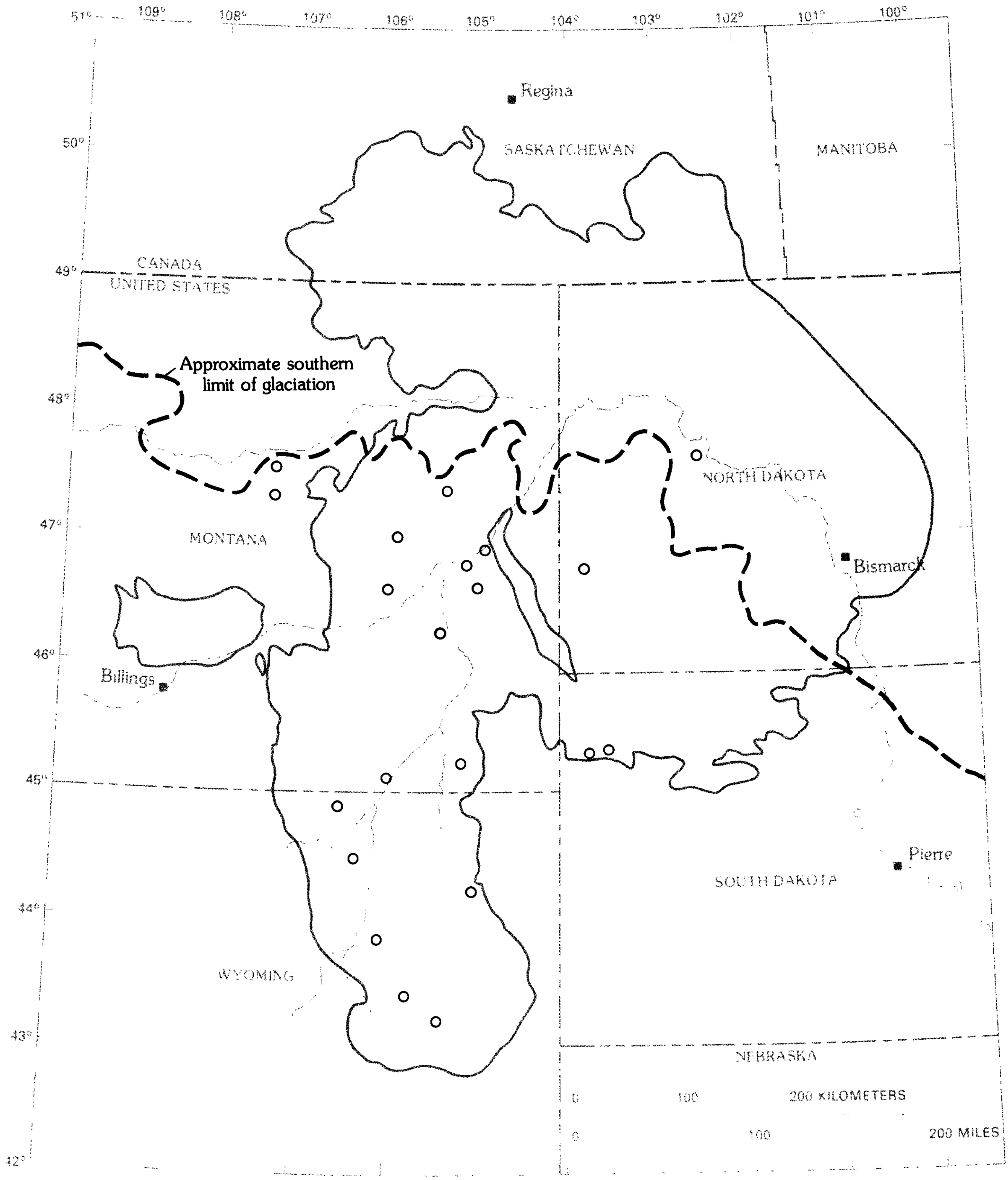

FIGURE 12.—Localities (open circles) where the A and C horizons of soil, western wheatgrass, silver sagebrush, and above-ground plant biomass were sampled in the northern Great Plains Province (Study No. 18). Extractable element concentrations in soil samples are given in table 66.

ming and southeastern Montana in May 1973 (fig. 13). The area of the basin was subdivided into 12 rectangular units between lat 43°–46° N. and long 105°–107° W. Within each rectangle, three sections (in two townships) were randomly selected for sampling. In one of the three sections, duplicate samples were collected. Eighteen soil samples of each depth category were analyzed, but due to the absence of big sagebrush in some localities, only 41 samples of this plant were collected and analyzed. Concurrently with this work, a trace-element plume downwind of the Dave Johnston powerplant on the southern edge of the basin was examined using trace-element concentrations in sagebrush. Results of these studies were given by Connor and others (1976).

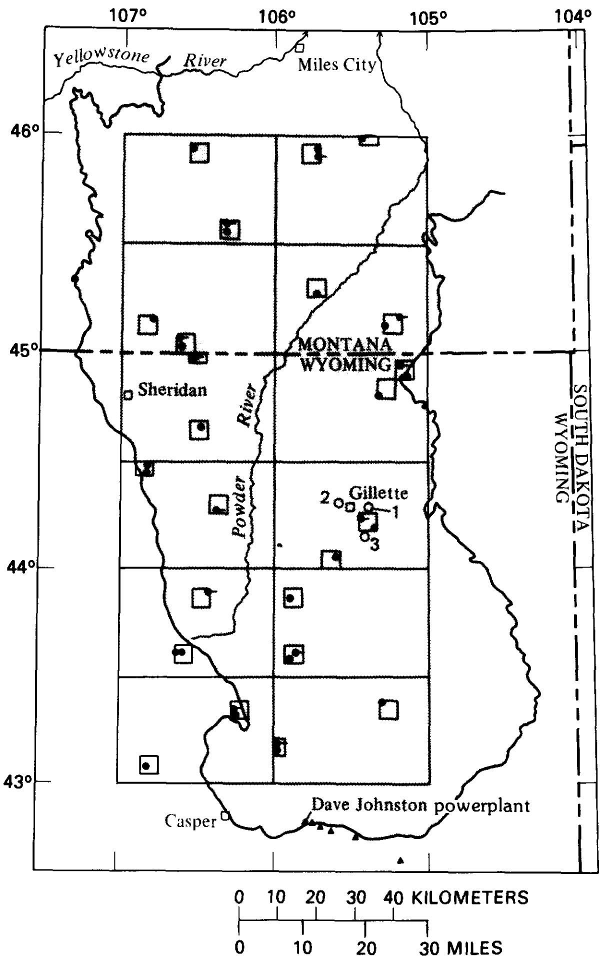

FIGURE 13.—Sampling localities for soil and big sagebrush in the Powder River Basin used in Study No. 20. Sampling localities (sections) used in the basinwide study shown by solid circles; duplicate sampling localities by solid circles with ticks; sampling localities used in the profile study by numbered open circles; sampling localities used in the powerplant study by solid triangles; "super-townships" by rectangles; and townships by squares. Study No. 20.

STUDY NO. 21

Miscellaneous small grains from the northern Great Plains

By James A. Erdman and Larry P. Gough

The effects of surface mining on agriculture in the Northern Great Plains have led to regulations requiring that reclaimed mined land be returned to its former use, which in this region is principally small grain production. In the fall of 1974, small grains, mostly hard red wheat, were sampled throughout the northern Great Plains coal province, including the southernmost part of Saskatchewan, Canada. A total of 130 grain samples was collected from storage bins located on 71 randomly selected farms (fig. 14). This total consisted of 54 samples of hard red spring wheat and 17 samples of hard red winter wheat (both **Triticum aestivum**), 21 samples of oats (**Avena sativa**), 20 samples of durum wheat (**Triticum durum**), and 18 samples of barley (**Hordeum vulgare**). Sampling was usually accomplished by using a 6-ft (1.8-m) grain probe, which provided a composite sample of the grain that had been harvested from many hectares. Such a composite sample, therefore, tended to smooth out any small-scale variability in chemical characteristics of the grain that might have occurred throughout the area represented by the sample. The purpose of the study was to develop baselines in the composition of these grains (especially wheat). These baseline values, or ranges of concentrations of environmentally important elements, can then be used in assessing the effects of the geochemically altered surface-mined lands on similar field crops after the land has been returned to agricultural production. An assessment of this type was made by Erdman and Gough (1979).

STUDY NO. 22

Soil lichens from the Powder River Basin

By James A. Erdman and Larry P. Gough

Samples of the terricolous lichen, **Parmelia chlorochroa** Tuck., were collected in the fall of 1973 in the Powder River Basin of Wyoming and Montana as part of a reconnaissance study of the landscape geochemistry (fig. 9). Twenty-two samples of this plant were collected according to a nested analysis-of-variance design. The long axis of the basin was subdivided into about 100-km intervals to establish four sampling areas nearly equal in size. With each area a barbell cluster of sampling locations was selected, using a randomization procedure. Each cluster consisted of a major axis 10 km long, an intermediate axis 1 km long, and a minor axis 100 m long. The sampling sites were then located at the ends of the 100-m axes, and samples of the lichen were collected and composited over

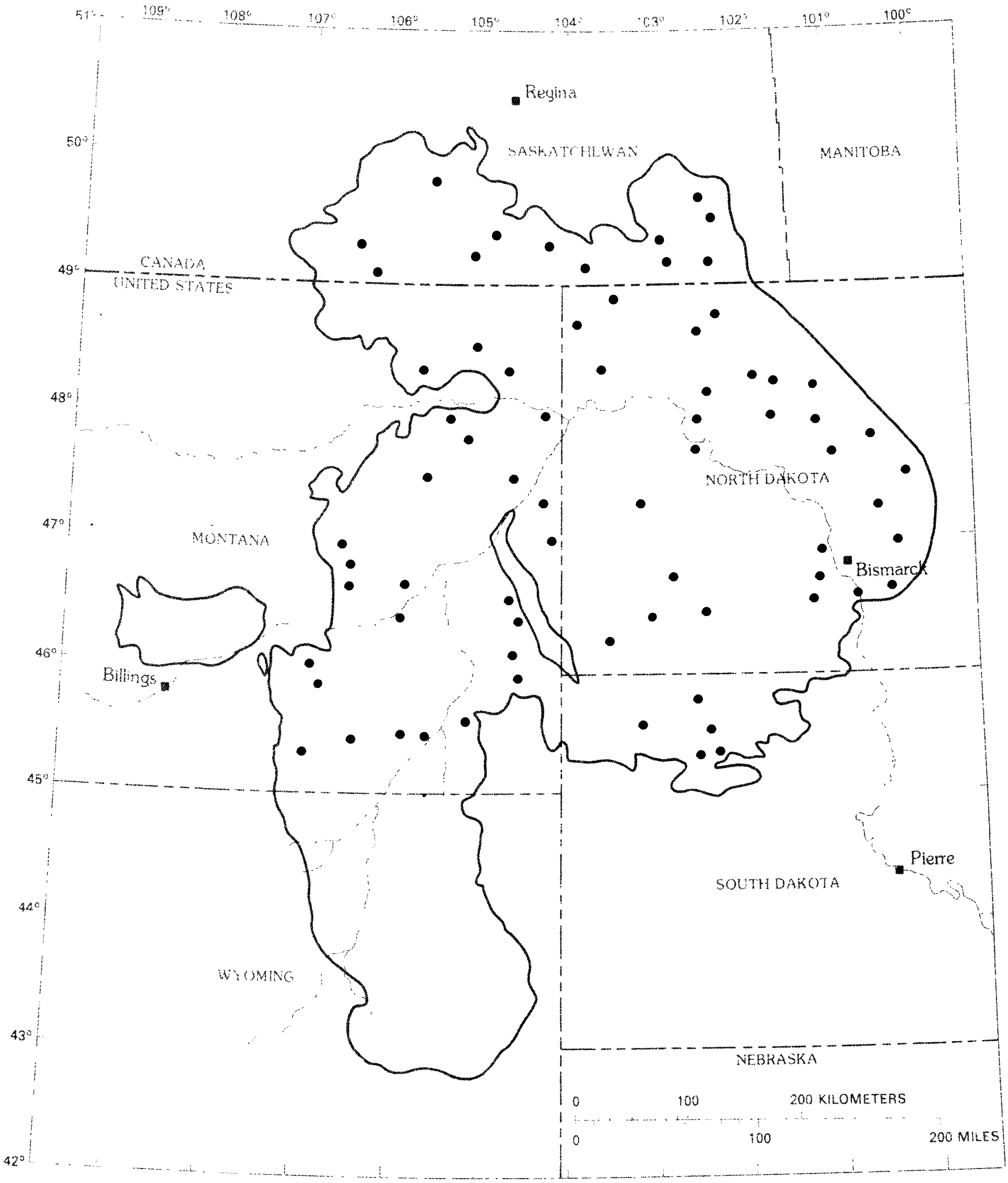

FIGURE 14.—Localities of grain sampled from farms in the northern Great Plains Province (solid circles) used in Study No. 21. The Wyoming portion of the province was excluded from the sampling design because of sparse wheat production.

an area about 10 m in diameter. Eight samples were to have been collected in each of the four localities (barbell clusters), but the absence of the lichen at many of the sites caused the design to be unbalanced in this respect. In order to estimate the analytical precision, 7 of the 22 samples were divided into equal parts prior to analysis. The sampling design permitted estimation of variation at a number of geographic scales as well as variation due to analytical procedures. Results of this study were described by Erdman and Gough (1977).

STUDY NO. 23

Big sagebrush from eight western Physiographic Provinces
By Larry P. Gough and James A. Erdman

Samples of big sagebrush (**Artemisia tridentata** Nutt.) were collected in the fall of 1975 from eight western Physiographic Provinces according to an unbalanced, nested, analysis-of-variance design (fig. 15). Thirty samples were collected from each of three very large provinces (Columbia Plateaus, Basin and Range, and Colorado Plateaus), whereas 20 samples were collected from each of the other five provinces (Great Plains, Northern Rocky Mountains, Middle Rocky Mountains, Southern Rocky Mountains, and Wyoming Basin). The purpose of the study was to quantify the variation in the element concentration of young sagebrush branches (terminal 20–30 cm of stems, including leaves and inflorescences) at geographic scales of >200 km (between provinces), 200 km, 100 km, 50 km, 25 km, and 0.1 km, as well as variation due to analytical methods and procedures. This broad-scale study provides a preliminary estimate of element-concentration ranges that are characteristic of big sagebrush throughout its distribution. Subspecies were not considered in this study—all variants were sampled as one species. The samples were not washed prior to chemical analysis. Seasonal differences in the element content of Wyoming big sagebrush were given by Gough and Erdman, 1980, and concentrations of uranium in ash of big sagebrush from three provinces were published by Erdman and Harrach (1981).

STUDY NO. 24

Total and extractable chemistry of the Sheppard-Shiprock-Doak Soil Association in the San Juan Basin that is likely to be used as topsoil in minedland reclamation.
By Ronald C. Severson

This study conducted in the fall of 1977, was designed to measure variation in total and extractable element composition of the Sheppard-Shiprock-Doak Soil Association in the San Juan Basin of New Mexico (fig. 16) The sampling localities were confined within the boundaries of the mapped occurrence of the Cretaceous Kirtland Shale and Fruitland Formations (Dane and Bachman, 1965), and also within the boundaries of the mapped occurence of the Sheppard-Shiprock-Doak Soil Association (Maker and others, 1973). Soils of this association are considered as providing prime material for stockpiling and using as topsoil in mined-land reclamation. The A and C horizons of soil were collected randomly according to an unbalanced, nested, analysis-of-variance design. The results were used to estimate variation at four distance scales (10 km, 5 km, 1 km, and 0.1 km) and the variation due to sample preparation and analysis. In addition, the taxonomic classification of each sample was identified. The total element composition of soils of this study was published in Severson (1978b). Summary statistics for extractable element composition of these soils are given in table 64, and pH determinations are given in table 67.

STUDY NO. 25

Ground-water chemistry, Fort Union coal region
By Gerald L. Feder

A reconnaissance-type survey of ground-water quality in geologic formations above the Pierre Shale in the Fort Union coal region of North Dakota and Montana was made in 1974 (fig. 3). The objectives of the study were to estimate the magnitude and distribution of variance in the quality of these ground waters. In order to estimate the regional component of variation, 19 townships were randomly chosen within the study area and a water-quality sample was collected from a well within each township. To estimate the local variation, 4 of the 19 sites were selected at random, and a second well was sampled within 10 km of the first sample site in the township. Sampling and analytical errors were estimated from three duplicate samples collected at random from the 23 sites described above. All samples were collected and analyzed according to methods described by Skougstad and Feder (1976). Results of this study are described in Feder (1975), and Feder and Saindon (1976). The geochemical summary for samples of this study is given in table 68.

STUDY NO. 26

Crested wheatgrass at the Dave Johnston mine
By James A. Erdman and Richard J. Ebens

Crested wheatgrass, *Agropyron cristatum* (L.) Gaertn., was sampled at the Dave Johnston mine, near the southern edge of the Powder River Basin in Wyoming (fig. 7), as part of a larger study whose purpose was to assess the effects of reclaimed spoils on the element concentrations in vegetation at surface coal

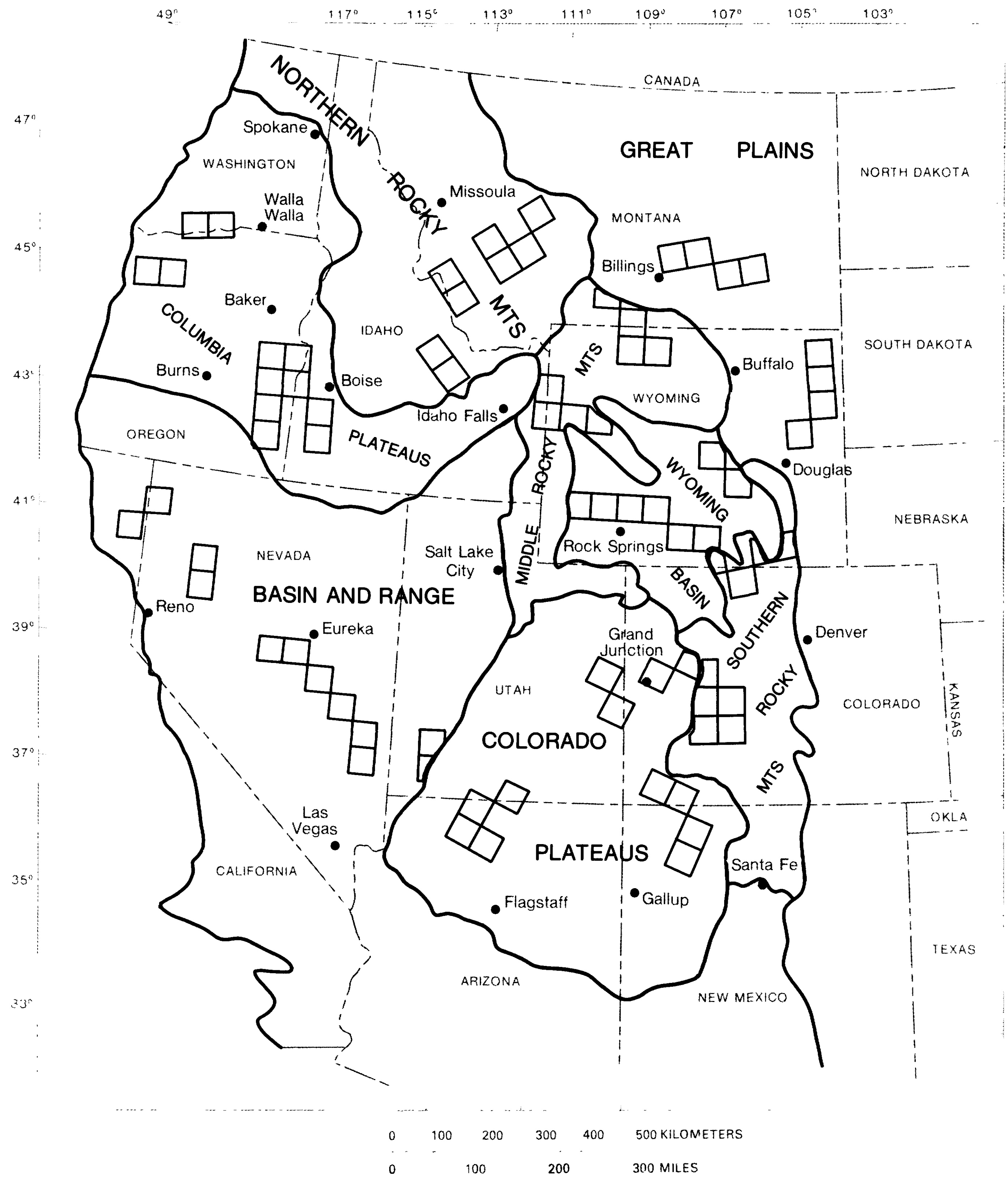

FIGURE 15.—Sampling localities used in Study No. 23, indicated by squares 50 km on a side, for big sagebrush in eight Western Physiographic Provinces. Map modified from Fenneman (1931.)

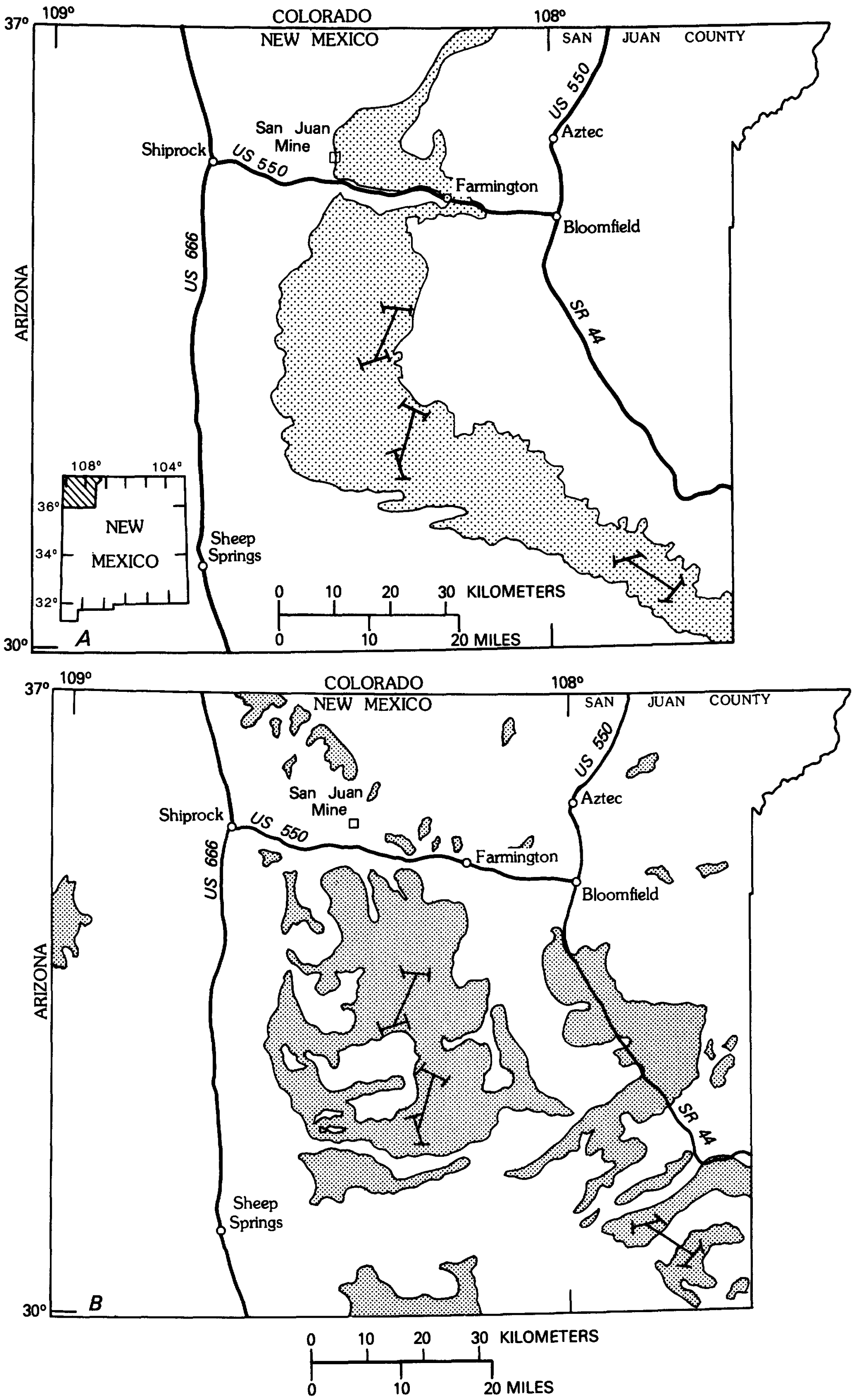

FIGURE 16.—Location of soils sampled (barbells) in San Juan County, N. Mex. used in Study No. 24. *A*, the outline of the Cretaceous Kirtland Shale and Fruitland Formations (shaded) was modified from Dane and Bachman (1965); and *B*, the distribution of the Sheppard-Shiprock-Doak Soil Association (stippled) was modified from Maker and others (1973).

mines in the northern Great Plains. This species of wheatgrass dominates the revegetated spoil banks at this mine, as it does at many of the surface mines that were sampled. Sampling was conducted July 24, 1974, when growth of wheatgrass was at the mature-seed stage of development. A three-level analysis-of-variance design was used that (1) assessed the differences in element concentrations between this grass growing on spoil materials and on soils native to the site (topsoil borrow), (2) estimated the degree of uniformity in the element contents of wheatgrass within the two substrate types, and (3) estimated the laboratory precision (reproducibility). Ten samples were collected at randomly selected locations within two tracts of reclaimed spoil piles. Ten other samples, which served as controls, were collected from two topsoil borrow areas adjoining the active mine. Each of the 20 field samples was homogenized and divided into equal portions. The number of samples for this study was, therefore, doubled from the 20 field samples to 40 laboratory samples. A report of this study was published by Erdman and Ebens (1979).

STUDY NO. 27

Ground water chemistry, Poplar River Basin,
Montana and Saskatchewan
By Gerald L. Feder

A reconnaissance-type survey was made in 1978 of ground-water quality in geologic formations above the Bearpaw Shale (named Bearpaw Formation in Canada) in the Poplar River Basin north of Scoby, Mont., including the Saskatchewan part of the basin (fig. 3). This survey was made in conjunction with a study by the Ground Water Quantity and Quality Committee of the International Poplar River Water Quality Board of the International Joint Commission. The Poplar River Basin lies in the north-western part of the Fort Union coal region. Because of the limited number of wells available for sampling, only nine sites were chosen for collecting representative samples from each of five aquifers in the area. The samples were collected and analyzed according to methods outlined in Skougstad and Feder (1976). Results of this study were described by Ground Water Quantity and Quality Committee of the International Poplar River Water Quality Board (1979). The geochemical summary for samples of this study is given in table 69.

STUDY NO. 28

Ground-water chemistry, Powder River coal region,
Montana and Wyoming
By Gerald L. Feder

A reconnaissance-type survey of ground-water quality in geologic formations above the Pierre Shale in the Powder River Basin in Wyoming and Montana (fig. 3) was made in 1975 to estimate the magnitude and distribution of variance in the quality of these ground waters. In order to estimate the regional component of variation, 20 townships were randomly chosen in the study area and a water-quality sample was collected from a well within each township. To estimate the local variation, 3 of the 20 sites were selected at random and a second well was sampled within 5 km of the first. Sampling and analytical errors were estimated from three duplicate samples collected at random from the 23 sites. All samples were collected and analyzed according to methods described by Skougstad and Feder (1976). Results of this study were described by Feder and others (1977). The geochemical summary for samples of this study is given in table 70.

METHODS OF ANALYSIS

All analytical work was performed in laboratories of the U.S. Geological Survey. The analytical technique used for each entry in the summary tables 4-77 is defined and identified by number in table 1. Fifty-six elements are listed in the summary tables. Of these, some were detected in only a relatively few samples of only a few studies. Approximate limits of determination for a variety of elements commonly looked for in spectrographic work, but seldom or never detected in earth materials and plants, are listed in table 2.

For various reasons, 21 of the 92 naturally occurring elements were never analyzed for in any of the studies. They are the six noble gases (helium, neon, argon, krypton, xenon, and radon), nitrogen, oxygen, technetium, ruthenium, rhodium, cesium, promethium, osmium, iridium, polonium, astatine, francium, radium, actinium, and protactinium.

The total element variation observed in a specific study always includes variation due to laboratory ("analytical") procedures, as well as variation due to natural effects. The inclusion of hidden and randomly sequenced sample splits in many of the laboratory sub-

TABLE 1.—*Analytical methods used*

[Number in the first column identifies the method used for determining chemical or physical properties reported in tables 2-77]

No.	Name of method	Materials analyzed, and properties commonly reported	Principal references	Remarks
1	Six-step emission spectrographic.	Stream sediments, soils, and plants: Al, B, Ba, Cr, Cu, Mg, Mn, Na, Nb, Ni, Pb, V, Y, Yb, and Zr. Stream sediments and soils: Be, Co, Ga, La, and Sc. Soils and plants: Ba, Mn, and Mo. Stream sediments only: Ca, K, and Ti. Soils only: Ce. Plants only: Al, Ge, Fe, and Ti.	Myers and others, 1961; Neiman, 1976.	Concentrations reported as midpoints of six geometric classes per order of magnitude. Method largely replaced by method No. 2.
2	Plate-reader emission spectrographic.	Rocks, stream sediments, spoil, soils, plants, and waters: Ba, Cr, Cu, Mn, Mo, Ni, Pb, Sr, V, and Zr. Rocks, stream sediments, spoil, soils, and plants: B, La, Nb, Sc, Y, and Yb. Rocks, stream sediments, spoil, soils, and waters: Be, Co, and Ga. Rocks, stream sediments, spoil, and soils: Ce. Rocks, spoil, and soils: Er and Nd. Rocks and spoil: Gd. Rocks and soils: Pr and Th. Plants and waters: Ag and Ti. Rocks and waters: Ag. Rocks only: Cd, Dy, In, and Tl. Spoil only: F and P. Soils only: Tb. Plants only: Fe. Waters only: Bi, Ge, and Sn.	Dorrzapf, 1973; Barnett, 1976.	Concentrations reported as actual values, rather than as classes of values.
3	Atomic absorption, flame.	Rocks, stream sediments, spoil, soils, plants, and waters: Li and Zn. Rocks, stream sediments, soil, plants, and waters: Mg and Na. Rocks, stream sediments, spoil, and soils: Rb. Plants and waters: As, Ca, Cd, K, and Mn. Plants only: Co, Cu, Fe, Ni, Pb, Sb, and Si. Waters only: Cr, Mo, Se, and Ti.	Ward and others, 1969; Harms, 1976; Huffman and Dinnin, 1976.	
4	Atomic absorption, flameless.	Rocks, stream sediments, spoil, soils, plants, and waters: Hg.	Vaughn and McCarthy, 1964; McHugh and Turner, 1975; Harms, 1976; Vaughn 1967.	
5	X-ray fluorescence, fusion.	Rocks, stream sediments, spoil, and soils: Al, Ca, K, S, Sb, Si, and Ti. Stream sediments, spoil, and soils: As, Se, and Sn. Rocks and soils: Br. Stream sediments and spoil: In. Spoil and soils: Mg and Na. Spoil only: I. Soils only: Cl, Mn, and P.	Wahlberg, 1976.	
6	Colorimetric	Plants only: Mo and P. Waters only: B, Br, Cl, I, Fe, P, Si, and V.	Ward and others, 1963.	
7	Turbidimetric	Plants only: S----------------------	Harms and Papp, 1975.	
8	Neutron activation	Rocks, stream sediments, spoil, and soils: Th and U.	Millard, 1975.	Used delayed-neutron technique.
9	Selective ion	Rocks, stream sediments, spoil, soils, plants, and waters: F and pH. Soils only: Chloride.	Huffman and Dinnin, 1976; Skougstad and Feder, 1976.	
10	Gasometric	Rocks, stream sediments, spoil, and soils: Carbonate C.	Huffman and Dinnin, 1976.	

TABLE 1.—*Analytical methods used*—Continued

No.	Name of method	Materials analyzed, and properties commonly reported	Principal references	Remarks
11	Calculated	Rocks, stream sediments, spoil, and soils: Organic C. Soils only: Sodium absorption ratios, exchangeable sodium percentages. Waters only: Hardness and alkalinity.	Huffman and Dinnin, 1976.	Organic C = total C minus carbonate C.
12	Combustion	Rocks, stream sediments, spoil, and soils: Total C.	Huffman and Dinnin, 1976.	
13	Fluorimetric	Plants and waters: U------------------	Harms and Papp, 1975; Thatcher and others, 1977.	
14	Gravimetric	Plants: Ash. Waters: Dissolved solids.	Ward and others, 1963; Skougstad and Feder, 1976.	Aliquots of dry plants weighed, burned to ash, and the ashed weighed and calculated as percentage of dry weight.
15	Conductivity cell	Waters only: Specific conductance-----	Skougstad and Feder, 1976.	
16	Induction-coupled plasma.	Soils only: Hot water extraction of B	Ball and others, 1978	Cited method modified by addition of a variable-speed oscillating refractor plate for background corrections.
17	Titrimetric	Waters only: Bicarbonate and carbonate	Skougstad and Feder, 1976.	
18	X-ray fluorescence, sulfide precipitation.	Rocks and stream sediments: Ge and Sn. Rocks only: As and Se.	Wahlberg, 1976------	Unpublished modification of cited method.
19	Instrumental	Waters only: Temperature--------------	Skougstad and Feder, 1976	
20	Precipation and radon emanation.	Waters only: ^{226}Ra--------------------	Thatcher, and others 1977	
21	Residue, gross emission count.	Waters only: Gross alpha and gross beta emanations.	Janzer, 1976; Thatcher and others, 1977	
22	Beta-gamma scaler	Soils only: Equivalent U.	No published reference.	Beta and gamma radiation is counted 4 minutes, compared with counts of a 0.1 percent U standard. Radioactivity of sample given as equivalent ppm U.
23	X-ray diffraction	Rocks, stream sediments, and soils: Mineral composition.	McNeal and Ebens, 1978.	Data entered on magnetic tape, then computer analyzed giving semiquantitative results.
24	2-3 diaminonaphthalene	Plants only: Se----------------------	Harms, 1976.	

TABLE 2.—Elements commonly looked for in samples of this study, but rarely or never detected by the methods listed in table 1, and their approximate lower limits of determination in parts per million

[Values apply to the methods actually used for particular samples, as given in tables 46–67. Leaders (--) in a figure column indicate that the element is commonly not detected in the sample material listed in the column heading]

Element	Material Analyzed	
	Rocks, stream sediments, mine spoil, and soils	Plant ash
Beryllium	--	0.5
Bismuth	10	20
Cereum	--	300
Dysprosium	[1]50	[1]100
Erbium	50	100
Gallium	--	5
Gold	20	50
Hafnium	100	200
Holmium	[1]20	[1]50
Indium	10	20
Lutetium	[1]30	[1]70
Neodymium	--	[2]70
Palladium	1	2
Platinum	30	70
Praseodymium	[2]100	[2]200
Rhenium	30	70
Samarium	[1]100	[1]200
Tantalum	200	500
Tellurium	2,000	5,000
Terbium	[1]300	[1]700
Thallium	50	500
Thorium	--	500
Thulium	[1]20	[1]50
Tin	--	15
Tungsten	100	300

[1]Looked for in spectrographic analysis if yttrium concentration is greater than 50 ppm.
[2]Looked for in spectrographic analysis if lanthanum or cerium is found.

mittals provided an estimation of total laboratory variance by:

$$S_a^2 = \frac{\sum_{i=1}^{n} (X_{1i}-X_{2i})^2}{2n} \qquad (1)$$

where S_a^2 represents the error variance, X_{1i} and X_{2i} represent the concentrations (or their logarithms) of an element in the two splits of the ith sample and n is the number of samples split. Where an error was not formally defined, it resides in the estimate of total variability and remains unknowable.

GEOCHEMICAL SUMMARIES

ORGANIZATION AND USE OF DATA

The geochemical summaries for elements tabulated herein (tables 4–62) are alphabetically arranged by the English spelling of each element. Summaries for each element are presented, as appropriate, for each of five broad environmental categories: rocks, stream sediments, mine spoil and associated materials, soils, and plants. Listed within each category are the summary results for one or more individual studies. Data on rocks are grouped by outcrop samples or core samples, followed by locality and gross lithologic character.

Stream sediments are arranged by locality, followed by size fraction where appropriate. Mine spoil and associated materials are subdivided into mine spoil itself, topsoil used in spoil reclamation, and plants associated with mine spoil. Soils are grouped by locality, then subdivided by soil horizon. Plants are grouped as cultivated or native species. All entries in the summary tables are given a general location, commonly the State or States.

Following the alphabetical tabulation of elements are special studies in which parameters other than element concentration in the samples were also measured. Tables 63–66 give results of soil-extraction studies, and data are grouped by the extraction method used (except in table 66, which gives elements extracted by only one method). Table 67 gives pH determinations for some of the same samples of rocks, stream sediments, mine spoil, and soil that are listed in the general tables of elements. Tables 68–70 give geochemical summaries of ground waters from three regions of the northern Great Plains Province. Tables 71–73 present shale and sandstone mineralogy of outcrop samples, and of fine-grained rocks of core samples, from the northern Great Plains Province, and table 74 gives mineralogy of three rock types from Montana. Using samples from the northern Great Plains Province, table 75 gives the mineralogy of stream sediments, table 76 gives the mineralogy of soils used in extraction studies, and table 77 gives the mineralogy of soils from Hanging Woman Creek.

Each entry in each table is identified by a study number, with which the user may find a brief description of the work in the section entitled "Descriptions of Field Studies," and a number identifying the analytical method used (from table 1). Also given are the following: a ratio, which indicates the number of samples in which the element was determined in relation to the total number analyzed; the mean, which estimates the most probable concentration to be expected in the analyzed material; the deviation, a factor which indicates the degree of variability observed; the error, a factor which indicates the reproducibility of the analytical method; and finally, the range of concentrations observed in the study.

Geometric and arithmetic means, standard deviations, standard errors, and observed ranges are given in units of percent or parts per million (ppm). Geometric deviations and geometric errors are factors.

The mean for each entry in the summary tables is commonly given to two significant figures. It is conventional in geochemical summaries to give an arithmetic average for the mean, and a few entries here do so; an example is aluminum in soils from Montana (table 4, Study No. 14). However, the tendency for elements in natural materials, particularly trace elements, to exhibit positively skewed frequency distributions suggests that the geometric mean is the more proper measure of central tendency. The geometric mean is the antilog of the arithmetic mean of the logarithmic values and, for lognormal distributions, the geometric mean is the mode.

A common problem in trace-element summaries is the necessity to summarize data that contain nonnumeric concentration values such as "trace" or "less than" some specified limit. Such data are said to be censored, and, under such circumstances, the mean has been computed using special procedures described by Cohen (1959) and applied to geochemical problems by Miesch (1967). These procedures involve an adjustment of the summary statistics computed for the noncensored part of the data. For some entries, censoring is so severe that such adjustment is unreliable or even impossible. Under these circumstances, the median of the distribution is given as the mean, or the mean is simply listed as "less than" some limiting lower value.

The use of special procedures to quantify estimates of the central tendency when part of the data is censored sometimes leads to estimates of the mean at levels below the limit of detection. For example, arsenic in fourwing saltbush from the San Juan Basin, N. Mex. (table 6, Study No. 19) is estimated to have a mean of 0.011 ppm, although the lowest measured concentration in 10 samples was 0.05 ppm. This feature of the data analysis obviously permits a greater utilization of data that may be initially viewed as rather limited because of analytical constraints.

For those rare entries for which the arithmetic average is give for the mean, it is also thought to reflect an unbiased estimate of element abundance. Where the geometric mean is given, the abundance may be estimated from the following relation:

$$t = \tau M, \qquad (2)$$

where t estimates the abundance, M is the geometric mean, and τ is an adjustment factor. (See Miesch, 1967.)

Finally, most of the element concentrations in plant tissue were summarized on an ash-weight basis. The user who wishes to convert the mean element concentration in ash to a dry-weight basis may apply the following formula:

$$M_D = (M_A \times M_P) / 100, \qquad (3)$$

where M_D approximates the mean in dry weight, M_A is the mean in ash weight, and M_P is the mean of the percent ash measured in the same plant species and study area (table 3). For example, big sagebrush from the Wyoming Basin Province exhibits a mean aluminum concentration in ash of 2.0 percent (table 4, Study No. 23) and a mean ash content (from table 3) of 4.9 percent. Based on equation 3, the approximate expected concentration of aluminum in dry weight is 0.1 percent.

Equally as important as the mean in background geochemical studies, however, is the magnitude of the scatter to be expected about the mean. A useful measure of the scatter in lognormal distributions is the geometric deviation, a factor which may be used to estimate the range of variation expected for any element in any unit. The geometric deviation is the antilog of the standard deviation of the logarithmic values. About 68 percent of the samples in a randomly selected suite should fall within the limits M/D and $M \cdot D$, where M stands for the geometric mean and D stands for the geometric deviation. For example, barium in stream sediments from the northern Great Plains (table 7, Study No. 6) has a geometric mean of 540 ppm and a geometric deviation of 1.34. Thus, the most likely concentration of barium in a suite of randomly selected stream-sediment samples from the northern Great Plains is 540 ppm; in addition, about 68 percent of the collected samples, if analyzed by the plate-reader emission spectrographic technique used by the U.S. Geological Survey laboratories, should range from about 403 (M/D) to about 724 ($M \cdot D$) ppm barium. About 95 percent will fall between 301 (M/D^2) and 970 ($M \cdot D^2$) ppm barium, and more than 99 percent between 224 (M/D^3) and 1,300 ($M \cdot D^3$).

As already stated, the deviation listed for each study includes variation arising from laboratory procedures as well as variation arising from nature. When the sampling design so permits, an estimate of that part of the total observed variation due solely to laboratory effects is given as the error, and an estimate of the variation attributed solely to natural effects may be computed from

$$D_n = \text{antilog}\,[(\log D)^2 - (\log E)^2], \qquad (4)$$

where D_n estimates the geometric deviation corrected for laboratory effects, and D and E are the geometric deviation and the standard error, respectively, taken from the summary tables. For entries consisting of the arithemtic mean, the standard deviation, and the standard error, variation due to natural effects is estimated as

$$D_n = [(D)^2 - (E)^2]^{1/2}, \qquad (5)$$

where D_n estimates the standard deviation corrected for laboratory effects and D and E are the standard deviation and the standard error, respectively.

For example, D_n for aluminum in outcrop samples of sandstone from the Fort Union Formation, northern Great Plains Province (table 4, Study No. 1), is estimated from equation 4 to be 1.48; and the expected approximate 68-, 95-, and 99.7-percent ranges corrected for analytical variation are 2.8–6.1, 1.9–9.0, and 1.3–13 percent aluminum, respectively. D_n for aluminum in C-horizon soils from Hanging Woman Creek, Mont. (table 4, Study No. 14), is estimated from equation 5 as 0.64; and the expected approximate 68-, 95-, and 99.7-percent ranges corrected for analytical variation are 4.3–5.5, 3.6–6.2, and 3.0–6.8 percent aluminum, respectively.

For some entries, the listed error is larger than the listed deviation and D_n cannot be calculated. This occurs because the deviation and the error are themselves only estimates and are each subject to errors inherent in estimation. When variation due to laboratory procedures forms a large part of the total observed variation, the estimate of the error may exceed the estimate of the total variability. In these circumstances, the only conclusion to be drawn is that the material under study is relatively uniform in composition, and further attempts to examine its natural variability must be based on laboratory procedures more precise than those used here.

All entries lacking an estimate of the error must be used judiciously. Little can be said about the natural variation of these materials without some assumptions as to the magnitude of the laboratory effects that might be present.

CONCLUDING REMARKS

In relation to geochemical characteristics of the landscape, the studies in this report have potential application to three stages of energy resource development in major areas containing coal and oil shale in the Western States. Examples of the relevance of geochemical studies to each stage of development are discussed below.

PRE-DEVELOPMENT STAGE

The geochemical input to this stage of planning is largely that of background (baseline) data on the chemical characteristics of the natural materials that will most likely be affected by the development and operation of mines and electric generating plants. Included in these materials are the rocks, soils, and

TABLE 3.—*Percentage of ash obtained by burning dry material of plants*

[Explanation of column headings: Study No. refers to study described in text. Plant parts designated as A, above-ground parts; B, stems, leaves, rhizomes, and roots; C, entire thallus; and D, grains. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available. Ash determined by method No. 14, table 1]

Common and scientific name; collection localities	Study No.	Plant part	Mean (percent)	Deviation	Error	Observed range (percent)
Alfalfa (Medicago sativa L.); Northern Great Plains						
Beulah North mine, North Dakota	10	A	7.7	1.43	--	7.2 - 11.3
Dave Johnston mine, Wyoming	10	A	10.0	1.12	--	9.5 - 11.7
Savage mine, Montana	10	A	9.5	1.10	--	8.9 - 10.6
Velva mine, North Dakota	10	A	8.1	1.23	--	7.1 - 10.3
Big Sky mine, Montana	10	A	8.1	1.10	--	7.5 - 9.0
Alkali sacaton (Sporobolus airoides (Torr.) Torr.); San Juan mine, New Mexico	11	A	5.1	1.14	--	4.1 - 5.1
Barley (Hordeum vulgare L.); northern Great Plains	21	D	2.2	1.13	1.05	1.8 - 2.9
Big sagebrush (Artemisia tridentata Nutt.); regional study						
Colorado Plateaus Province	23	A	4.7	1.11	1.03	3.8 - 5.3
Columbia Plateaus Province	23	A	5.7	1.18	1.03	4.2 - 7.9
Basin and Range Basin Province	23	A	4.8	1.13	1.03	4.1 - 5.8
Northern Great Plains	23	A	4.6	1.19	1.03	4.0 - 5.8
Northern Rocky Mountains Province	23	A	4.5	1.16	1.03	3.8 - 5.5
Middle Rocky Mountains Province	23	A	4.2	1.22	1.03	3.1 - 6.0
Southern Rocky Mountains Province	23	A	4.4	1.18	1.02	3.7 - 5.5
Wyoming Basin Province	23	A	4.9	1.53	1.03	3.9 - 5.7
Biomass above ground, mixed species; Northern Great Plains	18	A	6.7	1.20	1.13	4.8 - 9.1
Crested wheatgrass (Agropyron cristatum (L.) Gaertn.); Dave Johnston mine, Wyoming						
On mine spoil	26	A	6.0	1.14	1.01	4.7 - 7.4
Near mine spoil	26	A	6.3	1.15	1.01	5.3 - 8.0
Fourwing saltbush (Atriplex canescens (Torr.) Torr.)						
San Juan Basin, N. Mex.	19	A	12	1.22	1.04	8.4 - 16
San Juan mine, New Mexico	19	A	13	1.08	--	12 - 15
Galleta (Hilaria jamesii (Torr.) Benth.); San Juan Basin, N. Mex.	19	B	6.8	1.24	1.04	4.0 - 10
Lichen (Parmelia chlorochroa Tuck.); Powder River Basin, Wyo.	22	C	14	1.41	1.04	7.5 - 25
Oats (Avena sativa L.); northern Great Plains	21	D	3.0	1.0	1.05	1.3 - 1.8
Silver sagebrush (Artemisia cana Pursh); northern Great Plains	18	A	5.2	1.14	--	3.7 - 7.0
Snakeweed (Gutierrezia sarothrae (Pursh) Britt. and Rusby); San Juan Basin, N. Mex.	19	A	5.9	1.22	1.04	4.3 - 9.1
Western wheatgrass (Agropyron smithii Rydb.); northern Great Plains	18	A	6.6	1.24	--	4.6 - 8.8
Wheat, durum (Triticum durum Desf.); northern Great Plains	21	D	1.7	1.16	1.12	1.4 - 2.3
Wheat, hard red spring (Triticum aestivum L.); northern Great Plains	21	D	1.7	1.21	1.10	1.2 - 2.8
Wheat, hard red winter (Triticum aestivum L.); northern Great Plains	21	D	1.5	1.11	1.05	1.3 - 1.8

TABLE 3.—*Percentage of ash obtained by burning dry material of plants*—Continued

Common and scientific name; collection localities	Study No.	Plant part	Mean (percent)	Deviation	Error	Observed range (percent)
White sweetclover (Melitotus alba Desr.) Desr.); northern Great Plains						
Big Sky mine, Montana	10	A	6.7	1.11	1.03	5.9 - 8.2
Utility mine, Saskatchewan	10	A	5.0	1.07	1.03	4.4 - 5.6
Yellow sweetclover (Melilotus officinalis (L.) Lam.); northern Great Plains						
Beulah North mine, North Dakota	10	A	6.1	1.09	1.03	5.2 - 7.0
Dave Johnston mine, Wyoming	10	A	7.2	1.09	1.03	6.2 - 8.0
Hidden Valley mine, Wyoming	10	A	7.4	1.13	1.03	6.2 - 9.3
Kincaid mine, North Dakota	10	A	7.5	1.11	1.03	6.6 - 9.0
Savage mine, Montana	10	A	5.4	1.13	1.03	4.5 - 6.5
Velva mine, North Dakota	10	A	7.1	1.20	1.03	5.4 - 10

plants of the overburden material that will be removed in surface mining, the rocks from underground mining that will be brought to the surface, and the water of streams that drain the areas. These background data can be used before development is begun in judging the necessity for more detailed and intensive geochemical studies in order to predict the environmental impact of the proposed operation. If most of the variance in element concentration in soils, for example, is at the largest (regional) scale, the geochemistry of a selected development site most likely will be rather uniform. In Study No. 17, only zinc concentrations in soils of the Bighorn Basin were found to exhibit regional differences between geologic units, whereas eight elements exhibited such differences in the Wind River Basin. However, in study No. 20, little geochemical variation in the geochemistry of surface soil, subsurface soil, and big sagebrush from the Powder River Basin was found at scales greater than about 35 km (regional scale). This suggests that simple summary statistics for these materials could provide basinwide geochemical baselines. When rocks from particular geologic formations are brought to the surface by mining, their chemical features may subsequently have a pronounced effect on soil chemistry. For example, in Study No. 12 the oil shale was found to be richer in arsenic, mercury, selenium, fluorine, and molybdenum than were the soils from the same area in the Piceance Creek Basin of Colorado.

An important application of established baselines is in monitoring the effects of operating mines and power plants. If baseline element values are established, before industrial operations are begun, for a species of plant that has wide geographical distribution, as was done for sagebrush in Study No. 23, a useful biological agent is available for measuring chemical changes in vegetation that occur during the operational phase. Analysis of a lichen that grows on the soil surface showed that its element content was remarkably uniform throughout the Powder River Basin (Study No. 22), thereby suggesting its basinwide applicability for monitoring geochemical changes of airborne origin.

DEVELOPMENT AND OPERATING STAGE

In the development of mines and power plants, construction of the necessary facilities, including access and internal roads, buildings, processing plants, shipping and storage requirements, and transmission lines, causes alterations in the geochemical balances that had become established through time. In semiarid or arid regions, such as prevail in most of the Western energy regions, the development of a balanced geochemical system requires a very long period of time. Because the amount of water from precipitation generally is small, rocks and minerals in the soil weather slowly, and organic deposition from the sparse vegetation occurs at a slow rate. These factors contribute to the development of a fragile ecosystem that is susceptible to rapid degradation by the disturbances of industrial development.

The deposition of windblown soil dust from the site of a power plant in Wyoming before the plant became fully operational was found in Study No. 20 to cause trends outward from the plant in the element content of big sagebrush; these trends were imposed on trends caused by natural geologic controls on soil chemistry. This effect should be recognized and taken into account in differentiating natural geochemical trends in sagebrush and those caused by environmental disturbances. In developing surface mines, the topsoil is usually removed and stockpiled for later use in reclamation. A study of the geochemistry of a soil association likely to be used in spoil reclamation (Study No. 24) established baselines for total concentration of 38 elements in the A- and C-horizons of soil. This study found that chemical differences between taxonomically similar soils are very small at the family level; therefore, the baselines can be used as a regional characterization of soils' suitability as topsoil for mined-land reclamation.

The operation of energy-related installations produces a continuing addition of chemical elements to the surrounding area, often including those elements generally considered undesirable, or toxic if concentrated, such as mercury, arsenic, selenium, molybdenum, and sulfur. These elements are distributed in gaseous and particulate stack emissions, in fly ash recovered from the stacks and later disposed of, as spillage from transportation of fuels, and as leachates from mined coal and mine spoil. A study was made of sweetclover plants growing both spontaneously and planted on mine spoil and reclaimed spoil at eight mines in the Northern Great Plains (Study No. 10). The spoil and spoil-soil mixtures were also analyzed. Concentrations of 13 elements in sweetclover and 18 elements in spoil material from the eight mines were compared; the results indicated strong geochemical differences among mines for both plant and soil samples, which indicated the chemical distinctiveness of spoil material from each mine. Not only are the concentrations of toxic elements in spoil material of concern, but also the abundance of elements that are essential for plant growth and animal nutrition is important. Crested wheatgrass (a valuable forage plant) growing on topsoil over spoil at a mine in Wyoming (Study No. 26) contained higher concentrations of 8 of 26 elements than in control samples. Of these elements, concentrations of cobalt, manganese, and zinc—elements essential in animal nutrition—were at deficiency levels in control samples, but at marginal to adequate levels in samples from spoil material. On the other hand, the phosphorus content of the grass on spoil material was only two-thirds as much as in the control grass. In a study of power-plant stack emissions (Study No. 20) in Wyoming, big sagebrush was examined along the path of a trace-element plume. The concentrations of strontium, vanadium, and uranium in sagebrush showed statistically significant reductions eastward from the power plant.

RESTORATION AND REVEGETATION STAGE

The topography of areas severely altered by surface mining, which is affected by the spoil material from both surface and underground mining, must be restored to an acceptable degree after the site has been mined. This restoration consists of leveling and contouring the spoil material, applying the topsoil that was removed and stockpiled, and, generally, revegetating with either native plant species or agricultural crop plants. The new substrate for the plants comprises various mixtures of topsoil and subsurface rock, and the chemical nature of the rooting zone of plants is usually different from that of the original soil cover. The fresh unweathered rocks that are brought to the surface may release elements to the soil in greater concentrations than existed in the original soil and, therefore, may affect the growth of plants and the health of animals.

A measurement of the availability of certain elements, including both those that are nutritive and those that are toxic, is essential to an evaluation of the potential effects of the newly restored substrate. Geochemical studies of the rocks of the spoil material, or core samples collected before mining, can indicate the total concentrations of elements of special concern, including phosphorus, potassium, sulfur, arsenic, cadmium, mercury, molybdenum, and selenium (Studies No. 1, 2, 3, 4, 5, 10, and 11). These elements of rocks are held in minerals that are distinctive in their ratios of elements, rates of weathering, and solubility. If the mineral composition of the spoil-material rocks is known, estimates can be made of the kinds and concentrations of elements that will be released in the process of weathering. The availability of these elements to plants depends largely on their solubility in the chemical environment in which they occur and on the species of plant. The validity of using laboratory measurements of availability, such as are routinely performed on agricultural soils to determine their fertility, is not well known as applied to native plant species of potential use in revegetation. In Studies No. 11 and 19, the extractable and total soil-element concentrations favorable for native plant growth in the Northern Great Plains were studied. The plants, as well as laboratory extracts of their supporting soils obtained by three extraction procedures, were analyzed for calcium, cadmium, cobalt, copper, iron, potassium, magnesium, manganese, sodium, nickel, lead, and zinc. The ranges of the concentrations that were found, and the methods of extraction that were developed, can be used to judge the feasibility of revegetating reclaimed mine spoil with species of plants native to this region.

The suitability of the reclaimed areas for producing forage for domestic animals and cereal grains for human food depends on the effects of the chemical composition of the soil on the health and productivity of the plants and on the effects of the element composition of the plants and animals on the health of animals and man. A study of the elements in sweetclover and alfalfa plants that grew on spoil or reclaimed spoil material at eight surface mines in the Northern Great Plains (Study No. 10) revealed that the copper-to-molybdenum ratios in these plants ranged from 0.44:1 to 5:1. Ratios of 5:1 or less in forage are reported to cause molybdenosis, a serious debilitating disease, in cattle and sheep. Therefore, the possibility that the element composition of forage grown on reclaimed spoil (as determined in Studies No. 10 and 26) may be injurious to domestic as well as native animals should receive careful consideration in planning the revegetation of mined areas.

The use of reclaimed mine spoil for the production of cereal grains was examined in Study No. 21. At least one of three samples of hard red winter wheat from topsoiled spoil at a mine in Montana was found to have abnormally high levels of calcium, copper, iron, molybdenum, sulfur, and zinc, and abnormally low levels of barium, cadmium, magnesium, and phosphorus. Nickel concentrations in the samples ranged from unusually high to unusually low.

In conclusion, the geochemical data in this report can be effectively applied to the evaluation of present and future development of energy resources in the Western energy regions. These data can contribute to an understanding and appreciation of the true costs of exploiting fossil fuels to meet the energy requirements of the nation.

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TABLES 4–77

Tables giving concentrations of elements in rocks, stream sediments, mine spoil and associated materials, soils, and plants; parameters measured in extraction studies of soils; pH determinations for rocks, stream sediments, mine spoil, and soils; geochemical summaries of ground waters; and minerology of selected rocks and soils.

TABLE 4.—*Aluminum in rocks, stream sediments, mine spoil and associated materials, soils, and plants.*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterick are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (5)	80:80	4.1	1.49	1.08	1.8 - 7.7
Shale	1 (5)	80:80	7.0	1.31	1.05	1.4 - 13
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (5)	24:24	4.6	1.36	1.14	2.0 - 8.2
Siltstone and shale	2 (5)	24:24	7.0	1.19	1.04	5.1 - 8.8
Dark shale	2 (5)	23:23	7.8	1.13	1.06	6.1 - 9.7
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (5)	50:50	15	1.20	1.04	7.4 - 22
Sandstone	4 (5)	42:42	5.9	1.20	1.05	4.0 - 8.5
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)	5 (5)	74:74	3.6	1.34	1.08	1.6 - 6.6
Middle 300 m	5 (5)	51:51	3.8	1.39	1.05	.74 - 6.8
Garden Gulch Member (lower 100 m)	5 (5)	32:32	5.5	1.41	--	1.7 - 7.7
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (5)	60:60	5.0	1.19	1.12	3.4 - 7.9
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 μm	7 (5)	19:19	3.1	1.34	1.13	2.2 - 6.4
100-200 μm	7 (5)	24:24	2.6	1.34	1.14	1.8 - 5.8
63-100 μm	7 (5)	24:24	2.9	1.21	1.02	2.2 - 5.8
<63 μm	7 (5)	24:24	3.7	1.18	1.07	2.8 - 6.4
Uinta Creek and Piceance Creek Basins, Colo. and Utah	8 (5)	32:32	4.3	1.30	1.30	2.5 - 5.9
Piceance Creek Basin, Colo.						
Roan Creek	9 (1)	16:16	6.0	1.32	1.22	3 - 7
Black Sulphur Creek	9 (1)	16:16	7.6	1.20	1.22	7 - 10
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	7.6	1.08	--	7.0 - 8.7
Dave Johnston mine, Wyoming	10 (5)	10:10	6.5	1.15	--	5.3 - 8.4

TABLE 4.—*Aluminum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—**Continued**

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Hidden Valley mine, Wyoming----------	10 (5)	10:10	7.4	1.24	--	4.7 - 9.9
Kincaid mine, North Dakota-----------	10 (5)	10:10	6.7	1.21	--	4.7 - 8.7
Savage mine, Montana-----------------	10 (5)	10:10	6.0	1.13	--	4.7 - 7.1
Velva mine, North Dakota-------------	10 (5)	10:10	6.2	1.09	--	5.5 - 7.4
Big Sky mine, Montana----------------	10 (5)	10:10	5.9	1.12	--	4.6 - 6.7
Utility mine, Saskatchewan-----------	10 (5)	10:10	5.7	1.19	--	4.7 - 8.9
San Juan mine, New Mexico--------------	11 (5)	12:12	6.1	1.11	1.03	5.1 - 6.9
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (5)	12:12	2.9	1.53	1.37	1.0 - 4.7
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (2)	10:10	.054	1.61	1.20	.021 - .11
Dave Johnston mine, Wyoming--------	10 (2)	10:10	.10	1.51	1.20	.053 - .18
Hidden Valley mine, Wyoming--------	10 (2)	9:10	.42	1.53	1.20	.27 - >.76
Kincaid mine, North Dakota---------	10 (2)	10:10	.16	2.06	1.20	.041 - .40
Savage mine, Montana---------------	10 (2)	10:10	.047	1.74	1.20	.021 - .14
Velva mine, North Dakota-----------	10 (2)	10:10	.079	2.09	1.20	.035 - .40
White sweetclover						
Big Sky mine, Montana--------------	10 (2)	10:10	.11	1.36	1.20	.060 - .17
Utility mine, Saskatchewan---------	10 (2)	10:10	.069	1.53	1.20	.039 - .14
Alfalfa						
Beulah North mine, North Dakota----	10 (2)	3:3	.077	2.85	--	.028 - .23
Dave Johnston mine, Wyoming--------	10 (2)	3:3	.23	1.90	--	.14 - .48
Savage mine, Montana---------------	10 (2)	3:3	.044	--	--	.0053 - .18
Velva mine, North Dakota-----------	10 (2)	3:3	.062	4.13	--	.021 - .31
Big Sky mine, Montana--------------	10 (2)	3:3	.095	1.43	--	.063 - .12
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil--------------	26 (2)	20:20	.11	1.89	1.39	.041 - .37
Growing near mine spoil------------	26 (2)	20:20	.069	1.74	1.39	.030 - .27
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (2)	6:6	.12	1.36	--	.088 - .17
Alkali sacaton-----------------------	11 (2)	6:6	.050	1.93	--	.025 - .10
SOILS						
Piceance and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (5)	30:30	*4.6	*0.61	*0.11	2.1 - 6.8
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (5)	64:64	5.0	1.26	1.07	3.3 - 8.2
B horizon------------------------------	13 (5)	64:64	5.6	1.24	1.05	3.5 - 8.7
C horizon------------------------------	13 (5)	64:64	5.5	1.28	1.09	3.7 - 9.4
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (5)	16:16	*5.4	*.65	*.12	4.5 - 6.6
C horizon------------------------------	14 (5)	16:16	*4.9	*.73	*.36	3.1 - 5.9

TABLE 4.—*Aluminum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—**Continued**

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Piceance Creek Basin, Colo.,						
0- to 5-cm depth	15 (5)	108:108	5.5	1.17	--	3.4 - 7.8
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon	16 (5)	88:88	5.8	1.18	1.09	3.7 - 12
C horizon	16 (5)	88:88	5.9	1.22	1.06	3.4 - 10
Glaciated area						
A horizon	16 (5)	48:48	5.3	1.17	1.09	3.4 - 7.1
C horizon	16 (5)	48:48	5.3	1.22	1.06	2.9 - 7.7
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	136:136	5.6	1.19	1.09	3.4 - 12
C horizon	16 (5)	136:136	5.7	1.23	1.06	2.9 - 10
Big Horn Basin, Wyo.,						
0- to 40-cm depth	17 (5)	36:36	4.0	1.32	1.09	2.1 - 6.3
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	5.0	1.19	1.08	3.3 - 6.9
San Juan Basin, N. Mex.						
A horizon	11 (5)	47:47	4.7	1.27	1.04	2.4 - 7.7
C horizon	11 (5)	47:47	5.0	1.30	1.04	2.3 - 8.0
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	30:30	4.4	1.12	1.08	3.4 - 5.7
B horizon	24 (5)	30:30	4.4	1.21	1.12	2.9 - 6.1
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (1)	18:18	0.0044	1.50	1.27	0.0026 - 0.0130
Oats	21 (1)	21:21	.0057	1.28	1.22	.0040 - .0092
Wheat, durum	21 (1)	19:20	.0025	1.48	1.48	<.0017 - .0041
Wheat, hard red spring	21 (1)	54:54	.0020	1.73	1.35	.0008 - .0110
Wheat, hard red winter	21 (1)	17:17	.0012	1.46	1.23	.0006 - .0020
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	.097	1.75	1.23	.025 - .26
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	.053	1.49	1.16	.03 - .098
Snakeweed, San Juan Basin	19 (2)	18:18	.083	1.76	1.24	.023 - .19
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo.	22 (1)	29:29	3.8	1.35	1.15	2 - 5
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	30:30	1.1	1.94	1.13	.5 - 3
Columbia Plateaus Province	23 (1)	30:30	2.8	1.58	1.13	1.5 - 7
Basin and Range Province	23 (1)	30:30	1.7	1.59	1.13	1 - 3
Northern Great Plains	23 (1)	20:20	1.2	2.19	1.24	.5 - 5
Northern Rocky Mountains Province	23 (1)	20:20	1.4	1.85	1.24	.5 - 5
Middle Rocky Mountains Province	23 (1)	20:20	1.5	1.61	1.24	.7 - 3
Southern Rocky Mountains Province	23 (1)	20:20	1.1	2.18	1.24	.3 - 3
Wyoming Basin Province	23 (1)	20:20	2.0	1.58	1.24	1 - 3

TABLE 5.—*Antimony in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parantheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
Sandstone	4 (5)	34:42	0.41	2.2	2.04	<0.20 - 3.2
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (5)	37:42	.97	2.34	--	<.16 - 3.9
Middle 300 m	5 (5)	47:48	.96	1.65	1.26	<.2 - 2.9
Garden Gulch Member (lower 100 m)	5 (5)	16:16	.20	1.49	--	.60 - 2.8
STREAM SEDIMENTS						
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (5)	12:14	0.54	3.12	2.18	<0.1 - 1.2
100-200 μm	7 (5)	19:20	.45	2.86	1.97	<.1 - 1.5
63-100 μm	7 (5)	15:16	.45	3.06	2.89	<.1 - 1.4
<63 μm	7 (5)	16:16	.99	2.50	1.34	.34 - 3.0
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	0.89	2.40	--	0.15 - 2.0
Dave Johnston mine, Wyoming	10 (5)	10:10	.88	2.95	--	.19 - 3.8
Hidden Valley mine, Wyoming	10 (5)	10:10	1.2	2.94	--	.18 - 5.3
Kincaid mine, North Dakota	10 (5)	10:10	1.5	2.04	--	.39 - 3.5
Savage mine, Montana	10 (5)	9:10	.86	2.62	--	<.1 - 2.2
Velva mine, North Dakota	10 (5)	9:10	.94	2.69	--	<.1 - 2.5
Big Sky mine, Montana	10 (5)	9:10	.88	2.70	--	<.1 - 2.6
Utility mine, Saskatchewan	10 (5)	9:10	.94	3.01	--	<.1 - 4.6
SOILS						
Hanging Woman Creek, Mont.						
A horizon	14 (5)	2:16	<1.0	--	--	<1.0 - 1.3
B horizon	14 (5)	1:16	<1.0	--	--	<1.0 - 1.4
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (5)	103:108	.90	2.70	2.52	<.14 - 4.6
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	96:136	.86	2.42	3.88	<.10 - 24
B horizon	16 (5)	107:136	.91	2.25	3.15	<.10 - 4.9
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (5)	15:36	.16	3.14	3.03	<.10 - 2.3
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	15:36	--	--	--	<.10 - 2.8

TABLE 5.—*Antimony in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
San Juan Basin, N. Mex.						
A horizon	11 (5)	29:47	0.30	2.84	--	<0.20 - 1.6
C horizon	11 (5)	33:47	.40	2.57	--	<.20 - 1.8
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	13:30	.18	2.55	--	<.20 - .90
B horizon	24 (5)	9:30	.13	2.39	--	<.20 - .70
		PLANTS				
Native species (ash weight basis)						
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	11:30	0.012	3.62	--	<.02 - .25
Columbia Plateaus Province	23 (3)	2:30	<.02	--	--	<.02 - .04
Basin and Range Province	23 (3)	25:30	.035	2.36	--	<.02 - .20
Northern Great Plains	23 (3)	10:20	.022	3.38	--	<.02 - .20
Northern Rocky Mountains Province	23 (3)	20:20	.080	1.94	1.29	.04 - .25
Middle Rocky Mountains Province	23 (3)	18:20	.040	2.48	1.29	<.02 - .15
Southern Rocky Mountains Province	23 (3)	14:20	.021	2.39	--	<.02 - .10
Wyoming Basin Province	23 (3)	13:20	.025	2.29	--	<.02 - .10

TABLE 6.—*Arsenic in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (18)	80:80	4.4	1.95	1.12	0.80 - 25
Shale	1 (18)	80:80	5.1	2.21	1.25	1.3 - 39
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (18)	23:24	3.8	3.19	2.65	<.1 - 49
Siltstone and shale	2 (18)	24:24	6.1	1.99	1.36	2.7 - 62
Dark shale	2 (18)	23:23	7.6	1.89	1.87	1.7 - 27
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (18)	49:50	3.6	2.74	1.30	<.38 - 16
Sandstone	4 (18)	42:42	5.4	1.80	1.26	1.7 - 40
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)	5 (18)	42:42	13	1.60	--	4.3 - 29
Middle 300 m	5 (18)	48:48	11	1.87	1.32	1.7 - 29
Garden Gulch Member (lower 100 m)	5 (18)	16:16	12	1.78	--	4.5 - 40

TABLE 6.—*Arsenic in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (5)	60:60	5.5	1.53	1.34	1.7 - 22
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 μm------------------------------	7 (5)	16:19	4.9	--	--	<.1 - 24
100-200 μm---------------------------	7 (5)	24:24	5.7	1.45	1.17	2.9 - 14
63-100 μm----------------------------	7 (5)	24:24	4.9	1.34	1.08	3.5 - 13
<63 μm-------------------------------	7 (5)	24:24	7.7	1.23	1.08	5.4 - 13
Uinta and Piceance Creek Basins, Colo. and Utah--------------------------	8 (5)	32:32	6.5	2.00	1.15	1.0 - 20
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (5)	10:10	2.5	4.22	--	0.12 - 8.3
Dave Johnston mine, Wyoming----------	10 (5)	9:10	2.8	4.05	--	<.1 - 7.3
Hidden Valley mine, Wyoming----------	10 (5)	10:10	6.5	1.56	--	3.5 - 12
Kincaid mine, North Dakota-----------	10 (5)	9:10	3.5	3.92	--	<.1 - 8.3
Savage mine, Montana-----------------	10 (5)	10:10	4.9	2.58	--	.40 - 10
Velva mine, North Dakota-------------	10 (5)	10:10	5.7	1.68	--	1.4 - 8.6
Big Sky mine, Montana----------------	10 (5)	10:10	3.9	2.56	--	.57 - 9.0
Utility mine, Saskatchewan-----------	10 (5)	10:10	4.7	1.85	--	1.2 - 8.5
San Juan mine, New Mexico-------------	11 (5)	12:12	4.3	1.22	1.10	3.0 - 6.1
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (5)	12:12	2.9	1.53	1.37	1.0 - 4.7
Plants (dry-weight basis)						
Northern Great Plains						
Alfalfa						
Beulah North mine, North Dakota----	10 (3)	3:3	.11	2.24	--	.05 - .25
Dave Johnston mine, Wyoming--------	10 (3)	3:3	.17	1.18	--	.15 - .20
Savage mine, Montana---------------	10 (3)	3:3	.21	1.34	--	.15 - .25
Velva mine, North Dakota-----------	10 (3)	3:3	.09	2.53	--	.05 - .25
Big Sky mine, Montana--------------	10 (3)	3:3	.17	1.18	--	.15 - .20
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (3)	10:20	.047	1.61	--	<.05 - .09
Growing near mine spoil----------	26 (3)	1:20	<.05	--	--	<.05 - .05
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (3)	6:6	.24	1.23	--	.20 - .30
Alkali sacaton-----------------------	11 (3)	6:6	.12	1.28	--	.10 - .15
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (5)	30:30	9.3	1.63	1.11	4.2 - 23
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (5)	16:16	7.6	1.34	1.10	3.9 - 12
C horizon------------------------------	14 (5)	16:16	7.3	1.47	1.15	3.5 - 13
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------	15 (5)	107:108	6.2	2.01	--	<2.0 -21

TABLE 6.—*Arsenic in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	135:136	7.1	1.69	1.19	<.10 - 26
C horizon------------------------	16 (5)	135:136	6.8	1.90	1.18	<.10 - 76
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	4.7	1.94	1.82	.38 - 8.2
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (5)	36:36	3.6	1.90	1.39	.35 - 11
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (5)	47:47	5.4	1.52	1.20	2.5 - 19
C horizon------------------------------	11 (5)	47:47	5.4	1.46	1.14	2.1 - 15
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (5)	30:30	3.3	1.22	1.22	2.1 - 4.8
C horizon----------------------------	24 (5)	30:30	3.7	1.39	1.26	1.7 - 7.6
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (3)	25:25	0.16	1.43	1.10	0.10 - 0.30
Saltbush, fourwing, San Juan Basin-----	19 (3)	6:10	.011	1.19	1.05	<.05 - .10
Snakeweed, San Juan Basin--------------	19 (3)	18:18	.13	1.53	1.13	.05 - .20
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (3)	29:29	.92	1.32	1.27	.5 - 1.8
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (3)	30:30	.085	1.92	1.24	.05 - .20
Columbia Plateaus Province-----------	23 (3)	30:30	.19	1.74	1.24	.05 - .60
Basin and Range Province-------------	23 (3)	28:30	.12	1.87	1.24	<.05 - .30
Northern Great Plains----------------	23 (3)	20:20	.16	1.68	1.25	.10 - .35
Northern Rocky Mountains Province----	23 (3)	20:20	.97	4.72	1.25	.20 - 20
Middle Rocky Mountains Province------	23 (3)	20:20	.14	2.04	1.25	.05 - .45
Southern Rocky Mountains Province----	23 (3)	19:20	.077	1.69	1.25	<.05 - .15
Wyoming Basin Province---------------	23 (3)	20:20	.16	1.78	1.25	.05 - .30

TABLE 7.—*Barium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	700	1.71	1.44	210 - 1,900
Shale	1 (2)	80:80	940	1.42	1.11	210 - 2,100
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	410	1.39	1.16	260 - 830
Siltstone and shale	2 (2)	24:24	500	1.29	1.15	340 - 880
Dark shale	2 (2)	23:23	450	1.28	1.18	240 - 660
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	420	1.30	1.11	220 - 650
Sandstone	4 (2)	42:42	630	1.30	1.06	380 - 1,200
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	390	1.34	1.22	150 - 690
Middle 300 m	5 (2)	53:53	280	1.63	1.30	36 - 810
Garden Gulch Member (lower 100 m)	5 (2)	263:263	400	1.49	--	200 - 1,500
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	540	1.34	1.19	260 - 1,000
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (1)	24:24	870	1.39	1.21	500 - 1,500
100-200 μm	7 (1)	24:24	870	1.47	1.31	500 - 1,500
63-100 μm	7 (1)	24:24	930	1.36	1.02	500 - 2,000
<63 μm	7 (1)	24:24	1,030	1.44	1.35	500 - 1,500
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (2)	8:8	810	1.16	--	680 - 1,000
Cottonwood Creek, Utah	8 (2)	8:8	1,100	1.28	--	680 - 1,500
Duck Creek, Colo.	8 (2)	8:8	940	1.14	--	750 - 1,200
Ryan Gulch, Colo.	8 (2)	8:8	720	1.20	--	600 - 1,100
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	940	1.35	--	700 - 2,000
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	1,200	1.73	--	570 - 2,600
Dave Johnston mine, Wyoming	10 (2)	10:10	890	1.36	--	450 - 1,200
Hidden Valley mine, Wyoming	10 (2)	10:10	640	1.63	--	310 - 1,200
Kincaid mine, North Dakota	10 (2)	10:10	920	1.52	--	590 - 1,800

TABLE 7.—*Barium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Savage mine, Montana	10 (2)	10:10	880	1.45	--	520 - 1,400
Velva mine, North Dakota	10 (2)	10:10	990	1.42	--	560 - 1,600
Big Sky mine, Montana	10 (2)	10:10	830	1.42	--	470 - 1,300
Utility mine, Saskatchewan	10 (2)	10:10	920	1.56	--	490 - 1,500
San Juan mine, New Mexico	11 (2)	12:12	590	1.46	1.61	310 - 1,100
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	450	1.37	1.36	330 - 1,100
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	26	2.30	1.11	5 - 85
Dave Johnston mine, Wyoming	10 (2)	10:10	39	1.26	1.11	32 - 59
Hidden Valley mine, Wyoming	10 (2)	10:10	49	1.44	1.11	35 - 99
Kincaid mine, North Dakota	10 (2)	10:10	65	1.74	1.11	32 - 155
Savage mine, Montana	10 (2)	10:10	32	1.19	1.11	24 - 41
Velva mine, North Dakota	10 (2)	10:10	40	2.79	1.11	3 - 156
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	63	1.36	1.11	41 - 103
Utility mine, Saskatchewan	10 (2)	10:10	52	1.47	1.11	21 - 94
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	10	1.75	--	6 - 17
Dave Johnston mine, Wyoming	10 (2)	3:3	17	1.15	--	14 - 19
Savage mine, Montana	10 (2)	3:3	17	1.61	--	11 - 27
Velva mine, North Dakota	10 (2)	3:3	12	2.33	--	7 - 31
Big Sky mine, Montana	10 (2)	3:3	15	1.09	--	14 - 16
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (1)	20:20	10	1.44	1.15	6 - 22
Growing near mine spoil	26 (1)	20:20	12	1.44	1.15	6 - 22
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	26	1.56	--	17 - 42
Alkali sacaton	11 (2)	5:5	19	1.24	--	11 - 17
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	1,200	1.37	1.28	710 - 1,900
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1	64:64	670	1.28	1.15	300 - 1,000
B horizon	13 (1)	64:64	660	1.28	1.20	300 - 1,500
C horizon	13 (1)	64:64	630	1.40	1.20	300 - 1,500
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	48:48	740	1.36	1.28	500 - 3,000
Soil, 15- to 20-cm depth	20 (1)	48:48	720	1.36	1.20	300 - 1,500
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	450	1.13	1.12	340 - 560
C horizon	14 (2)	16:16	480	1.16	1.10	360 - 660
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	1,400	1.50	--	600 - 13,000

TABLE 7.—*Barium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (2)	136:136	1,100	1.33	1.33	420 - 2,320
C horizon------------------------	16 (2)	136:136	1,000	1.47	1.62	140 - 3,400
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	1,300	1.16	1.46	920 - 1,800
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (2)	36:36	1,600	1.19	1.20	1,100 - 2,200
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (2)	47:47	570	1.41	1.13	230 - 1,800
C horizon------------------------------	11 (2)	47:47	570	1.52	1.16	210 - 3,000
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (2)	30:30	620	1.24	1.28	330 - 970
C horizon----------------------------	24 (2)	30:30	690	1.34	1.17	330 - 1,200
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley--------------------------------	21 (1)	15:18	2.3	1.31	1.30	<1.5 - 3.4
Oats----------------------------------	21 (1)	10:21	3.1	1.24	1.24	<2.0 - 4.2
Wheat, durum--------------------------	21 (1)	19:20	2.7	1.40	1.29	<1.4 - 4.4
Wheat, hard red spring---------------	21 (1)	54:54	2.6	1.38	1.14	1.4 - 5.9
Wheat, hard red winter---------------	21 (1)	17:17	3.3	1.23	1.09	2.1 - 4.3
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (2)	25:25	20	1.57	1.22	8.6 - 48
Saltbush, fourwing, San Juan Basin-----	19 (2)	10:10	18	1.44	1.17	10 - 30
Snakeweed, San Juan Basin--------------	19 (2)	18:18	44	1.93	1.33	8.8 - 98
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (1)	29:29	370	1.56	1.21	150 - 500
Sagebrush, big; Powder River Basin, Wyo. and Mont.------------------------	20 (1)	41:41	500	1.71	1.26	150 - 1,500
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (1)	30:30	320	1.68	1.20	150 - 700
Columbia Plateaus Province-----------	23 (1)	30:30	380	1.74	1.20	150 - 700
Basin and Range Province-------------	23 (1)	30:30	340	1.74	1.20	150 - 1,500
Northern Great Plains----------------	23 (1)	20:20	440	2.10	1.24	150 - 1,000
Northern Rocky Mountains Province----	23 (1)	20:20	370	2.04	1.24	200 - 1,500
Middle Rocky Mountains Province------	23 (1)	20:20	460	2.15	1.24	150 - 1,500
Southern Rocky Mountains Province----	23 (1)	20:20	560	2.43	1.24	200 - 2,000
Wyoming Basin Province---------------	23 (1)	20:20	440	1.94	1.24	200 - 1,000

TABLE 8.—*Beryllium in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	1.4	1.74	1.18	0.50 - 4.2
Shale	1 (2)	80:80	3.3	1.84	1.16	.48 - 6.7
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	1.4	1.40	1.12	.80 - 2.6
Siltstone and shale	2 (2)	24:24	2.6	1.27	1.10	1.7 - 3.6
Dark shale	2 (2)	23:23	3.2	1.20	1.14	2.1 - 5.1
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	2.0	1.38	1.27	1.1 - 3.6
Sandstone	4 (2)	19:42	.96	1.50	1.82	<1.0 - 2.5
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	2.0	1.56	1.43	0.53 - 4.6
Powder River Basin, Wyo. and Mont. Size fraction, <63 μm	7 (1)	17:24	1	1.49	1.39	<1 - 2
Uinta and Piceance Creek Basins, Colo. and Utah	8 (2)	32:32	3.3	1.53	1.26	1 - 5
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	2.4	1.30	--	1.4 - 3.6
Dave Johnston mine, Wyoming	10 (2)	10:10	2.2	1.55	--	1.1 - 4.0
Hidden Valley mine, Wyoming	10 (2)	10:10	2.6	1.45	--	1.3 - 3.9
Kincaid mine, North Dakota	10 (2)	10:10	2.4	1.35	--	1.3 - 3.4
Savage mine, Montana	10 (2)	10:10	2.1	1.34	--	1.2 - 3.5
Velva mine, North Dakota	10 (2)	10:10	1.8	1.22	--	1.2 - 2.3
Big Sky mine, Montana	10 (2)	10:10	2.5	1.27	--	1.8 - 3.5
Utility mine, Saskatchewan	10 (2)	10:10	1.8	1.34	--	1.1 - 2.6
San Juan mine, New Mexico	11 (2)	12:12	2.7	1.11	1.10	2.2 - 3.2
Topsoil used in spoil reclamation San Juan mine, New Mexico	11 (2)	12:12	2.4	1.10	1.08	2.1 - 2.7
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	2.0	1.48	1.21	0.84 - 4.5

TABLE 8.—*Beryllium in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	30:64	0.85	1.35	1.30	<1 - 1.5
B horizon	13 (1)	43:64	1.1	1.37	1.37	<1 - 2
C horizon	13 (1)	38:64	1.0	1.40	1.32	<1 - 2
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	32:48	.87	1.55	1.16	<1 - 1.5
Soil, 15- to 20-cm depth	20 (1)	37:48	.99	1.47	1.16	<1 - 1.5
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	1.9	1.41	1.20	.93 - 2.9
C horizon	14 (2)	16:16	1.8	1.33	1.30	1.2 - 3.2
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	2.4	1.45	--	.88 - 4.4
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon	16 (2)	88:88	1.7	1.38	1.27	.70 - 3.5
Glaciated area						
A horizon	16 (2)	47:48	1.5	1.46	1.27	<.22 - 2.5
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	135:136	1.6	1.42	1.27	<.22 - 3.5
C horizon	16 (2)	136:136	1.6	1.44	1.23	.41 - 3.0
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	2.0	1.40	1.23	.85 - 3.3
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	2.4	1.29	1.23	1.3 - 3.6
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	1.5	1.20	1.17	1.0 - 2.3
B horizon	11 (2)	47:47	1.5	1.24	1.18	1.1 - 2.8
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	1.3	1.13	1.14	1.1 - 1.7
C horizon	24 (2)	30:30	1.3	1.16	1.13	1.0 - 1.8

TABLE 9.—*Boron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	51	1.69	1.15	15 - 140
Shale	1 (2)	77:80	98	1.39	1.19	52 - >150

TABLE 9.—*Boron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	26	1.59	1.12	11 - 49
Siltstone and shale	2 (2)	24:24	58	1.14	1.06	44 - 70
Dark shale	2 (2)	23:23	64	1.11	1.09	50 - 77
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	59	1.32	1.26	30 - 110
Sandstone	4 (2)	42:42	42	1.50	1.07	15 - 78
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	71:74	99	1.92	1.68	<13 - 400
Middle 300 m	5 (2)	32:53	24	3.24	1.31	<10 - 230
Garden Gulch Member (lower 100 m)	5 (2)	262:264	150	1.33	--	<70 - 300
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	56	1.29	1.24	25 - 82
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 µm	7 (1)	13:24	14	1.55	1.32	<15 - 50
100-200 µm	7 (1)	13:24	14	1.38	1.36	<15 - 50
63-100 µm	7 (1)	24:24	32	1.69	1.65	20 - 50
<63 µm	7 (1)	24:24	55	1.40	1.18	30 - 70
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	44	1.39	1.25	30 - 70
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	49	1.74	--	13 - 92
Dave Johnston mine, Wyoming	10 (2)	10:10	50	1.26	--	36 - 72
Hidden Valley mine, Wyoming	10 (2)	10:10	57	1.43	--	26 - 91
Kincaid mine, North Dakota	10 (2)	10:10	44	1.44	--	22 - 70
Savage mine, Montana	10 (2)	10:10	64	1.34	--	36 - 91
Velva mine, North Dakota	10 (2)	10:10	46	1.44	--	21 - 74
Big Sky mine, Montana	10 (2)	10:10	70	1.56	--	35 - 130
Utility mine, Saskatchewan	10 (2)	10:10	55	1.44	--	34 - 83
San Juan mine, New Mexico	11 (2)	12:12	13	1.52	1.41	7.3 - 25
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	8:12	6.9	1.84	1.59	<5.0 - 23
Plants (dry-weight basis)						
Northern Great Plains						
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	61	1.27	--	50 - 79
Dave Johnston mine, Wyoming	10 (2)	3:3	92	1.49	--	67 - 144
Savage mine, Montana	10 (2)	3:3	59	1.28	--	46 - 74
Velva mine, North Dakota	10 (2)	3:3	57	1.23	--	50 - 72
Big Sky mine, Montana	10 (2)	3:3	57	1.10	--	53 - 63

TABLE 9.—*Boron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)--Continued						
Northern Great Plains--Continued						
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	17	1.61	1.29	11 - 48
Growing near mine spoil	26 (2)	20:20	15	1.34	1.29	11 - 28
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	4:6	57	1.40	--	40 - >65
Alkali sacaton	11 (2)	6:6	9.1	1.30	--	7.8 - 12
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	25:30	74	1.47	1.10	24 - >100
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	57:64	30	1.50	1.21	<20 - 70
B horizon	13 (1)	57:64	30	1.56	1.28	<20 - 70
C horizon	13 (1)	54:64	29	1.58	1.24	<20 - 70
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	44:48	29	1.54	1.23	<20 - 70
Soil, 15- to 20-cm depth	20 (1)	44:48	26	1.51	1.23	<20 - 70
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	43	1.17	1.11	33 - 55
C horizon	14 (2)	16:16	41	1.28	1.21	25 - 54
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	61	1.35	--	25 - 102
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 2)	135:136	41	1.59	1.27	<2.2 - 99
C horizon	16 (2)	136:136	43	1.61	1.14	11 - 120
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	50	1.33	1.14	31 - 83
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	28	1.38	1.15	14 - 60
San Juan Basin, N. Mex.						
A horizon	11 (2)	39:47	16	2.20	1.81	<5.0 - 41
C horizon	11 (2)	36:47	15	2.59	2.29	<5.0 - 43
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	16	1.42	1.45	6.4 - 27
C horizon	24 (2)	26:30	11	1.83	1.40	<5.0 - 25
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (1)	18:18	1.6	1.22	1.22	.9 - 2.3
Oats	21 (1)	21:21	2.2	1.28	1.23	1.6 - 3.8
Wheat, durum	21 (1)	20:20	1.0	1.29	1.29	.7 - 1.8
Wheat, hard red spring	21 (1)	54:54	1.9	1.60	1.60	.8 - 4.3
Wheat, hard red winter	21 (1)	17:17	1.8	1.73	1.73	.8 - 3.5

TABLE 9.—*Boron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANTS--Continued						
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (2)	25:25	5.1	1.61	1.29	1.4 - 24
Saltbush, fourwing, San Juan Basin-----	19 (2)	9:10	27	1.46	1.23	17 - >70
Snakeweed, San Juan Basin--------------	19 (2)	13:18	24	1.48	1.24	12 - >36
Native species (ash-weight basis)						
Sagebrush, big; Powder River Basin, Wyo. and Mont.-----------------------	20 (1)	41:41	270	1.33	1.18	200 - 500
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (1)	30:30	510	1.67	1.19	300 - 1,000
Columbia Plateaus Province-----------	23 (1)	30:30	480	1.67	1.19	200 - 1,000
Basin and Range Province-------------	23 (1)	28:30	550	1.64	1.19	300 - 1,500
Northern Great Plains----------------	23 (1)	20:20	530	1.59	1.20	300 - 1,000
Northern Rocky Mountains Province----	23 (1)	20:20	480	1.61	1.20	300 - 700
Middle Rocky Mountains Province------	23 (1)	20:20	450	1.59	1.20	300 - 700
Southern Rocky Mountains Province----	23 (1)	20:20	320	1.56	1.20	200 - 700
Wyoming Basin Province---------------	23 (1)	20:20	380	1.49	1.20	300 - 500

TABLE 10.—*Bromine in rocks, stream sediments, mine spoil, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	4 (5)	37:42	0.72	1.80	1.85	<0.3 - 2.0
STREAM SEDIMENTS						
Powder River Basin, Wyo. and Mont						
Size fractions						
>200 µm----------------------------	7 (5)	6:6	0.62	1.58	--	0.4 - 1.3
100-200 µm-------------------------	7 (5)	9:9	.42	1.69	--	.2 - .9
63-100 µm--------------------------	7 (5)	10:10	.48	1.25	--	.3 - .6
<63 µm-----------------------------	7 (5)	6:6	.83	1.56	--	.5 - 1.5
MINE SPOIL						
San Juan mine, New Mexico----------------	11 (5)	6:12	0.51	1.28	--	<0.50 - 0.74
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (5)	21:30	0.62	1.49	1.19	<0.53 - 1.4

TABLE 10.—*Bromine in rocks, stream sediments, mine spoil, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
Hanging Woman Creek, Mont.						
A horizon-------------------------------	14 (5)	8:16	0.51	1.43	1.10	<0.55 - .84
C horizon-------------------------------	14 (5)	7:16	.47	1.57	1.18	<.53 - 1.2
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon-------------------------	16 (5)	134:136	.63	1.77	1.47	<.050- 2.3
C horizon-------------------------	16 (5)	136:136	1.2	1.58	1.35	.20 - 3.5
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (5)	2:47	--	--	--	<.50 - 1.3
C horizon-------------------------------	11 (5)	16:47	.31	3.33	--	<.50 - 4.4
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
C horizon----------------------------	24 (5)	12:30	.38	2.99	--	<.50 - 3.6

TABLE 11.—*Cadmium in rocks, plants associated with mine spoil, and other plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Core sample						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	4 (2)	1:42	--	--	--	<10 - 18
		PLANTS ASSOCIATED WITH MINE SPOIL				
Plants (dry weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (3)	9:10	0.15	2.19	1.22	<0.04 - .48
Dave Johnston mine, Wyoming--------	10 (3)	10:10	.37	1.99	1.22	.15 - .87
Hidden Valley mine, Wyoming--------	10 (3)	10:10	.19	2.41	1.22	.06 - .84
Kincaid mine, North Dakota---------	10 (3)	5:10	.04	2.32	1.22	<.04 - .10
Savage mine, Montana---------------	10 (3)	9:10	.08	1.84	1.22	<.04 - .23
Velva mine, North Dakota-----------	10 (3)	5:10	.04	3.38	1.22	<.04 - .22
White sweetclover						
Big Sky mine, Montana--------------	10 (3)	9:10	.10	1.78	1.22	<.04 - .26
Utility mine, Saskatchewan---------	10 (3)	6:10	.05	2.91	1.22	<.04 - .33
Alfalfa						
Beulah North mine, North Dakota----	10 (3)	3:3	.16	2.79	--	.07 - .51
Dave Johnston mine, Wyoming--------	10 (3)	3:3	.32	2.02	--	.14 - .53
Savage mine, Montana---------------	10 (3)	3:3	.23	2.56	--	.13 - .69
Velva mine, North Dakota-----------	10 (3)	3:3	.07	1.20	--	.06 - .08
Big Sky mine, Montana--------------	10 (3)	3:3	.06	1.71	--	.03 - .08

TABLE 11.—*Cadmium in rocks, plants associated with mine spoil, and other plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANTS ASSOCIATED WITH MINE SPOIL--Continued						
Plants (dry-weight basis)--Continued						
Northern Great Plains--Continued						
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (3)	20:20	0.082	1.48	--	0.034- .15
Growing near mine spoil----------	26 (3)	20:20	.054	1.92	--	.016- .15
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (3)	6:6	.17	2.42	--	.052- .26
Alkali sacaton-----------------------	11 (3)	6:6	.048	2.00	--	.022- .15
OTHER PLANTS						
Cultivated plants, Northern Great Plains (dry weight basis)						
Barley-------------------------------	21 (3)	17:18	.025	2.13	1.33	<.009- .084
Oats---------------------------------	21 (3)	20:21	.018	1.40	1.40	<.012- .030
Wheat, durum-------------------------	21 (3)	19:20	.14	1.82	1.63	<.008- .22
Wheat, hard red spring---------------	21 (3)	54:54	.035	1.49	1.21	.012- .078
Wheat, hard red winter---------------	21 (3)	17:17	.035	1.47	1.20	.015- .052
Native species (dry weight basis)						
Galleta, San Juan Basin----------------	19 (3)	24:25	.064	1.78	1.29	<.025- .26
Saltbush, fourwing, San Juan Basin-----	19 (3)	10:10	.11	1.91	1.27	.048- .32
Snakeweed, San Juan Basin--------------	19 (3)	18:18	.23	1.65	1.21	.10 - .73
Native species (ash weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (3)	29:29	4.0	1.66	1.07	1.5 - 8.0
Sagebrush, big; Powder River Basin, Wyo. and Mont.-----------------------	20 (3)	41:41	5.5	1.92	1.17	1.3 - 30
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (3)	27:30	1.2	2.41	1.21	<.4 - 3.6
Columbia Plateaus Province-----------	23 (3)	30:30	1.7	2.00	1.21	.6 - 6.0
Basin and Range Province-------------	23 (3)	29:30	1.5	2.16	1.21	<.4 - 3.8
Northern Great Plains----------------	23 (3)	20:20	3.3	2.11	1.11	1.0 - 8.8
Northern Rocky Mountains Province----	23 (3)	20:20	6.1	3.62	1.11	1.3 - 80
Middle Rocky Mountains Province------	23 (3)	20:20	3.4	2.76	1.11	1.0 - 17
Southern Rocky Mountains Province----	23 (3)	20:20	3.4	2.68	1.11	.6 - 17
Wyoming Basin Province---------------	23 (3)	20:20	2.1	2.19	1.11	1.0 - 10
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry weight basis)						
Wheatgrass, western----------------	18 (3)	17:21	.03	1.94	--	<.02 - .08
Sagebrush, silver------------------	18 (3)	19:19	.30	1.90	--	.09 - .67
Plant biomass, above-ground parts--	18 (3)	19:21	.07	2.36	1.76	<.02 - .43

TABLE 12.—*Calcium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (5)	76:80	2.4	4.37	2.18	<0.73 - 24
Shale	1 (5)	80:80	1.4	4.19	1.5	.090 - 15
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (5)	24:24	3.9	2.89	1.32	.46 - 14
Siltstone and shale	2 (5)	24:24	1.7	2.75	--	.44 - 5.3
Dark shale	2 (5)	23:23	1.2	1.47	1.45	.70 - 4.4
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (5)	50:50	1.2	3.24	0	.093 - 9.4
Sandstone	4 (5)	41:42	1.6	1.20	--	<.1 - 4.9
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (5)	74:74	11	1.36	1.05	6.3 - 32
Middle 300 m	5 (5)	51:51	4.1	1.55	1.08	.8 - 7.5
Garden Gulch Member (lower 100 m)	5 (5)	32:32	5.6	1.73	--	1.4 - 15
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (5)	60:60	2.5	1.69	<1.05	0.55 - 6.1
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (5)	19:19	1.7	1.75	1.52	1.1 - 4.1
100-200 µm	7 (5)	24:24	1.3	1.35	1.04	.86 - 3.6
63-100 µm	7 (5)	24:24	1.8	1.18	1.03	1.5 - 3.6
<63 µm	7 (5)	24:24	2.7	1.12	1.01	2.4 - 3.7
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (5)	8:8	4.7	1.40	--	3.4 - 9.2
Cottonwood Creek, Utah	8 (5)	8:8	3.1	1.06	--	2.9 - 3.4
Duck Creek, Colorado	8 (5)	8:8	8.5	1.27	--	5.0 - 10.1
Ryan Gulch, Colorado	8 (5)	8:8	3.0	1.11	--	2.6 - 3.5
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	5.4	1.44	1.19	2 - 10
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	1.6	1.51	--	0.73 - 2.8
Dave Johnston mine, Wyoming	10 (5)	10:10	.45	1.52	--	.25 - .84
Hidden Valley mine, Wyoming	10 (5)	10:10	.25	1.68	--	.12 - .47

TABLE 12.—*Calcium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Kincaid mine, North Dakota-----------	10 (5)	10:10	3.2	1.35	--	2.0 - 5.5
Savage mine, Montana-----------------	10 (5)	10:10	6.4	1.26	--	5.1 - 9.7
Velva mine, North Dakota-------------	10 (5)	10:10	3.1	1.12	--	2.6 - 3.7
Big Sky mine, Montana----------------	10 (5)	10:10	2.8	1.32	--	1.8 - 4.4
Utility mine, Saskatchewan-----------	10 (5)	10:10	3.3	2.06	--	.57 - 8.0
San Juan mine, New Mexico--------------	11 (5)	12:12	1.4	1.16	1.03	1.1 - 1.8
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (5)	12:12	1.3	1.26	1.03	.96 - 1.9
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (3)	10:10	0.9	1.31	1.05	0.6 - 1.6
Dave Johnston mine, Wyoming--------	10 (3)	10:10	1.2	1.21	1.05	.9 - 1.6
Hidden Valley mine, Wyoming--------	10 (3)	10:10	.8	1.14	1.05	.6 - .9
Kincaid mine, North Dakota---------	10 (3)	10:10	1.3	1.12	1.05	1.1 - 1.5
Savage mine, Montana---------------	10 (3)	10:10	.9	1.25	1.05	.7 - 1.4
Velva mine, North Dakota-----------	10 (3)	10:10	1.4	1.30	1.05	1.0 - 2.3
White sweetclover						
Big Sky mine, Montana--------------	10 (3)	10:10	.9	1.24	1.05	.7 - 1.4
Utility mine, Saskatchewan---------	10 (3)	10:10	.8	1.22	1.05	.5 - 1.0
Alfalfa						
Beulah North mine, North Dakota----	10 (3)	3:3	1.3	1.42	--	1.0 - 1.9
Dave Johnston mine, Wyoming--------	10 (3)	3:3	1.8	1.22	--	1.4 - 2.1
Savage mine, Montana---------------	10 (3)	3:3	2.0	1.20	--	1.7 - 2.4
Velva mine, North Dakota-----------	10 (3)	3:3	1.3	1.22	--	1.1 - 1.6
Big Sky mine, Montana--------------	10 (3)	3:3	1.1	1.23	--	.9 - 1.3
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (3)	20:20	.23	1.22	1.05	.16 - .35
Growing near mine spoil----------	26 (3)	20:20	.26	1.11	1.05	.22 - .30
San Juan mine, New Mexico						
Fourwing saltbush------------------	11 (3)	6:6	1.0	1.29	--	.91 - 1.4
Alkali sacaton---------------------	11 (3)	6:6	.41	1.13	--	.36 - .46
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (5)	30:30	*5.5	*2.97	*0.19	0.72 - 13
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (5)	64:64	.56	2.78	1.97	.072 - 4.0
B horizon------------------------------	13 (5)	64:64	.87	3.17	1.83	.13 - 7.1
C horizon------------------------------	13 (5)	64:64	1.6	3.48	1.77	.09 - 11

TABLE 12.—*Calcium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Hanging Woman Creek, Mont.						
A horizon	14 (5)	16:16	*2.6	*1.74	*0.065	0.38 - 5.5
C horizon	14 (5)	16:16	*3.8	*1.44	*.13	1.4 - 6.2
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (5)	108:108	1.9	2.51	0	.46 - 9.8
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
C horizon	16 (5)	88:88	2.5	2.09	1.05	.34 - 10
Glaciated area						
C horizon	16 (5)	48:48	4.4	1.63	1.05	.60 - 8.2
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	135:136	.97	2.30	1.06	<.014 - 7.0
C horizon	16 (5)	136:136	3.0	2.04	1.05	.34 - 10
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	3.0	1.78	1.03	.86 - 9.7
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	2.2	1.93	1.04	.68 - 8.8
San Juan Basin, N. Mex.						
A horizon	11 (5)	47:47	.55	2.12	1.05	.15 - 4.5
C horizon	11 (5)	47:47	1.1	2.13	1.03	.097 - 4.5
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	30:30	.64	1.26	1.30	.45 - 1.1
C horizon	24 (5)	30:30	1.0	1.77	1.16	.40 - 3.4
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (3)	18:18	0.035	1.15	1.04	0.026 - 0.046
Oats	21 (3)	21:21	.053	1.14	1.06	.036 - .066
Wheat, durum	21 (3)	20:20	.031	1.20	1.20	.024 - .048
Wheat, hard red spring	21 (3)	54:54	.030	1.25	1.11	.020 - .053
Wheat, hard red winter	21 (3)	17:17	.029	1.15	1.07	.021 - .036
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (3)	25:25	.35	1.34	1.03	.23 - .65
Saltbush, fourwing, San Juan Basin	19 (3)	10:10	1.4	1.30	1.03	1.0 - 2.7
Snakeweed, San Juan Basin	19 (3)	18:18	1.0	1.40	1.03	.56 - 1.7
Native species (ash-weight basis)						
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	30:30	11	1.36	1.05	5.6 - 15
Columbia Plateaus Province	23 (3)	30:30	9.1	1.32	1.05	5.6 - 13
Basin and Range Province	23 (3)	30:30	11	1.18	1.05	7.8 - 15
Northern Great Plains	23 (3)	20:20	11	1.27	1.05	7.0 - 14
Northern Rocky Mountains Province	23 (3)	20:20	11	1.36	1.05	6.8 - 16
Middle Rocky Mountains Province	23 (3)	20:20	11	1.27	1.05	8.0 - 15
Southern Rocky Mountains Province	23 (3)	20:20	11	1.24	1.05	8.8 - 16
Wyoming Basin Province	23 (3)	20:20	10	1.32	1.05	7.4 - 14

TABLE 12.—*Calcium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANTS--Continued				
Availability studies; samples from Montana, North Dakota, South Dakota, and Wyoming (dry-weight basis)						
Wheatgrass, western------------------	18 (3)	21:21	0.23	1.30	--	0.11 - 0.38
Sagebrush, silver--------------------	18 (3)	19:19	.57	1.33	--	.57 - 1.33
Plant biomass, above-ground parts----	18 (3)	21:21	.40	1.50	1.11	.23 - .91

TABLE 13.—*Carbon (carbonate) in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed Range (percent)
		ROCKS				
Core samples						
Hanging Woman Creek, Mont.						
Sandstone----------------------------	2 (10)	24:24	1.3	3.13	1.12	0.13 - 6.1
Siltstone and shale------------------	2 (10)	17:24	.11	--	1.12	<.01 - 1.6
Dark shale---------------------------	2 (10)	17:23	.07	--	--	<.01 - .77
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)--------	5 (10)	71:71	4.7	1.65	1.47	<1.9 - 14
Middle 300 m-----------------------	5 (10)	51:51	3.5	1.57	1.21	.78 - 7.9
		STREAM SEDIMENTS				
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah-------------------	8 (10)	8:8	0.96	1.65	--	0.55 - 2.7
Cottonwood Creek, Colo.--------------	8 (10)	8:8	.23	1.66	--	.09 - .53
Duck Creek, Colo.--------------------	8 (10)	8:8	2.0	1.45	--	1.06 - 2.9
Ryan Gulch, Colo.--------------------	8 (10)	8:8	.41	1.48	--	.18 - .60
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
San Juan mine, New Mexico-------------	11 (10)	12:12	0.23	1.63	1.43	0.07 - 0.42
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (10)	12:12	.28	1.39	1.20	.19 - .47

TABLE 13—*Carbon (carbonate) in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		SOILS				
Powder River Basin, Wyoming and Montana						
A horizon	13 (10)	44:64	--	--	1.90	<0.01 - 1.2
B horizon	13 (10)	53:64	--	--	1.05	<.01 - 2.2
C horizon	13 (10)	62:64	--	--	2.03	<.01 - 3.2
Hanging Woman Creek, Mont.						
A horizon	14 (10)	15:16	0.43	4.12	1.34	<.13 - 1.8
C horizon	14 (10)	16:16	.89	1.83	1.20	.26 - 2.6
San Juan Basin, N. Mex.						
A horizon	11 (10)	30:47	--	--	--	<.010 - 1.6
C horizon	11 (10)	43:47	.18	3.7	1.37	<.010 - 1.1
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (10)	3:30	--	--	--	<.010 - .14
C horizon	24 (10)	26:30	.10	3.91	1.50	<.010 - .82

TABLE 14.—*Carbon (organic) in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (11)	24:24	0.41	2.72	2.54	0.03 - 2.4
Siltstone and shale	2 (11)	24:24	.85	1.30	1.17	.55 - 1.4
Dark shale	2 (11)	24:24	4.6	2.94	2.35	.18 - 25
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)	5 (11)	71:74	4.8	2.42	1.46	<.024 - 16
Middle 300 m	5 (11)	51:51	8.5	1.61	1.112	13 - 23
		STREAM SEDIMENTS				
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (11)	8:8	0.87	1.44	--	0.48 - 1.5
Cottonwood Creek, Utah	8 (11)	8:8	.27	1.82	--	.08 - .31
Duck Creek, Colorado	8 (11)	8:8	1.41	1.56	--	.64 - 2.9
Ryan Gulch, Colorado	8 (11)	8:8	1.31	1.44	--	.95 - 2.3

TABLE 14.—*Carbon (organic) in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
San Juan mine, New Mexico	11 (11)	12:12	2.3	2.59	1.05	0.89 - 13.6
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (11)	12:12	.44	2.91	1.17	.19 - 4.1
SOILS						
Powder River Basin, Wyo. and Mont.						
A horizon	13 (11)	64:64	1.1	2.01	1.23	0.1 - 3.7
B horizon	13 (11)	64:64	.56	1.76	1.23	.1 - 1.6
C horizon	13 (11)	64:64	.33	2.10	1.60	.1 - 2.1
Hanging Woman Creek, Mont.						
A horizon	14 (11)	16:16	1.2	1.34	1.09	.73 - 1.9
C horizon	14 (11)	16:16	.59	2.41	1.35	.05 - 2.5
San Juan Basin, N. Mex.						
A horizon	11 (11)	47:47	.37	1.86	1.35	.060 - 1.6
C horizon	11 (11)	47:47	.27	2.24	1.46	.010 - 1.1
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (11)	30:30	.35	1.39	1.17	.19 - .64
C horizon	24 (11)	29:30	.10	2.65	2.02	<.010 - .40

TABLE 15.—*Carbon (total) in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (12)	80:80	1.1	--	--	0.020 - 8.6
Shale	1 (12)	80:80	.93	3.31	1.78	.08 - 5.2
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (12)	24:24	2.1	2.19	--	.38 - 6.4
Siltstone and shale	2 (12)	24:24	1.4	1.60	--	.68 - 2.5
Dark shale	2 (12)	23:23	5.6	1.95	--	2.5 - 25

TABLE 15.—*Carbon (total) in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS--Continued						
Core Samples--Continued						
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (12)	50:50	2.1	1.90	1.14	0.57 - 11
Sandstone	4 (12)	42:42	1.0	2.30	1.08	.15 - 3.1
STREAM SEDIMENTS						
Northern Great Plains regional study						
First-order streams	6 (12)	20:20	2.3	1.87	<1.06	0.84 - 9.8
Second-order streams	6 (12)	20:20	2.6	1.47	<1.04	1.4 - 5.5
Third-order streams	6 (12)	20:20	1.8	1.39	<1.03	.93 - 3.5
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (12)	23:23	.77	2.20	1.31	.26 - 19
100-200 μm	7 (12)	24:24	.54	1.85	1.31	.24 - 2.8
63-100 μm	7 (12)	24:24	.72	1.33	1.23	.50 - 1.6
<63 μm	7 (12)	24:24	1.22	1.27	<1.02	.57 - 1.8
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (12)	10:10	1.7	2.45	--	0.29 - 8.7
Dave Johnston mine, Wyoming	10 (12)	10:10	1.3	3.64	--	.38 - 19
Hidden Valley mine, Wyoming	10 (12)	10:10	2.4	2.96	--	.27 - 11
Kincaid mine, North Dakota	10 (12)	10:10	4.3	2.09	--	1.8 - 18
Savage mine, Montana	10 (12)	10:10	2.9	1.37	--	1.3 - 3.8
Velva mine, North Dakota	10 (12)	10:10	2.1	1.70	--	1.2 - 8.1
Big Sky mine, Montana	10 (12)	10:10	4.2	1.98	--	1.6 - 16
Utility mine, Saskatchewan	10 (12)	10:10	3.5	1.80	--	1.5 - 9.6
San Juan mine, New Mexico	11 (12)	12:12	2.6	2.45	1.03	1.1 - 13.8
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (12)	12:12	.78	2.29	1.02	.40 - 4.5
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (12)	30:30	2.8	1.69	1.06	0.95 - 7.4
Powder River Basin, Wyo. and Mont.						
A horizon	13 (12)	64:64	1.3	1.84	1.26	.1 - 3.7
B horizon	13 (12)	64:64	.88	1.78	1.12	.18 - 3.0
C horizon	13 (12)	64:64	.87	2.19	1.27	.19 - 3.6
Hanging Woman Creek, Mont.						
A horizon	14 (12)	16:16	1.9	1.37	1.01	1.1 - 2.8
C horizon	14 (12)	16:16	1.6	1.49	1.06	.71 - 2.6

TABLE 15.—*Carbon (total) in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (12)	108:108	3.0	1.71	1.18	0.87 - 12
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon	16 (12)	88:88	1.7	1.55	1.04	.48 - 4.9
C horizon	16 (12)	88:88	1.2	2.08	1.06	.20 - 4.4
Glaciated area						
A horizon	16 (12)	48:48	2.3	1.44	1.04	.69 - 5.6
C horizon	16 (12)	48:48	2.0	1.48	1.06	.33 - 3.5
Combined data, unglaciated and glaciated areas						
A horizon	16 (12)	136:136	1.96	1.56	1.04	.48 - 5.6
C horizon	16 (12)	136:136	1.4	1.98	1.06	.20 - 4.4
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (12)	36:36	1.5	1.72	1.17	.36 - 4.5
Wind River Basin, Wyo., 0- to 40-cm depth	17 (12)	36:36	.85	1.62	1.17	.42 - 3.2
San Juan Basin, N. Mex.						
A horizon	11 (12)	47:47	.51	1.80	1.02	.11 - 2.1
C horizon	11 (12)	47:47	.54	2.01	1.01	.090 - 1.5
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (12)	30:30	.36	1.36	1.06	.20 - .64
C horizon	24 (12)	30:30	.27	1.95	1.05	.080 - 1.1

TABLE 16.—*Cerium in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	78:80	55	1.77	1.39	<22 - 170
Shale	1 (2)	77:80	67	2.18	1.51	<22 - 250
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	52	1.64	1.62	22 - 100
Siltstone and shale	2 (2)	22:23	54	1.89	1.73	14 - 120
Dark shale	2 (2)	22:22	79	1.58	1.31	44 - 170

TABLE 16.—*Cerium in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS--Continued				
Core Samples--Continued						
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	65	1.55	1.63	22 - 160
Sandstone	4 (2)	42:42	113	1.20	1.11	75 - 160
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (2)	58:60	57	1.92	1.80	<22 - 180
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
San Juan mine, New Mexico	11 (2)	10:12	55	1.20	--	<46 - 76
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	5:12	45	1.18	--	<46 - 60
		SOILS				
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	52	1.45	1.45	25 - 110
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	4:64	<150	--	--	<150 - 200
B horizon	13 (1)	3:64	<150	--	--	<150 - 150
C horizon	13 (1)	2:64	<150	--	--	<150 - 150
Hanging Woman Creek, Mont.						
A horizon	14 (2)	15:16	56	1.59	1.49	<36 - 110
C horizon	14 (2)	16:16	58	1.45	1.45	28 - 93
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	99:136	38	2.08	--	<22 - 130
C horizon	16 (2)	91:136	32	2.31	--	<22 - 660
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	57	1.38	1.35	25 - 110
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	55	1.53	2.26	26 - 160
San Juan Basin, N. Mex.						
A horizon	11 (2)	10:47	35	1.48	--	<46 - 76
C horizon	11 (2)	16:47	38	1.59	--	<46 - 97
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	18:30	47	1.37	--	<46 - 89
C horizon	24 (2)	18:30	52	1.30	--	<46 - 92

TABLE 17.—*Chlorine in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	15:136	1,600	1.51	--	<1,000 - 4,000
C horizon------------------------	16 (5)	124:136	810	--	--	<1,000 - 15,000

TABLE 18.—*Chromium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	1 (2)	80:80	45	1.98	1.27	11 - 160
Shale------------------------------	1 (2)	80:80	84	1.40	1.15	38 - 170
Core samples						
Hanging Woman Creek, Mont.						
Sandstone----------------------------	2 (2)	24:24	59	1.55	1.18	27 - 110
Siltstone and shale------------------	2 (2)	24:24	96	1.15	1.09	68 - 130
Dark shale---------------------------	2 (2)	23:23	110	1.25	1.07	66 - 250
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (2)	50:50	72	1.39	1.10	29 - 120
Sandstone--------------------------	4 (2)	42:42	46	1.50	1.19	24 - 240
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)--------	5 (2)	74:74	34	1.42	1.16	16 - 72
Middle 300 m-----------------------	5 (2)	53:53	38	2.26	1.17	7.0 - 410
Garden Gulch Member (lower 100 m)--	5 (2)	264:264	49	1.40	--	15 - 100
		STREAM SEDIMENTS				
Northern Great Plains regional study-----	6 (2)	60:60	72	1.63	1.32	22 - 300
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 µm----------------------------	7 (1)	24:24	26	2.59	1.90	7 - 100
100-200 µm-------------------------	7 (1)	24:24	18	2.12	1.18	10 - 150
63-100 µm--------------------------	7 (1)	24:24	31	1.75	1.15	15 - 100
<63 µm-----------------------------	7 (1)	24:24	79	1.74	1.20	30 - 200

TABLE 18.—*Chromium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
STREAM SEDIMENTS--Continued						
Uinta and Piceance Creek Basins, Colo. and Utah	8 (2)	32:32	61	2.05	1.74	30 - 290
Piceance Creek Basin, Colo. Roan and Black Sulphur Creeks	9 (1)	32:32	56	2.11	1.25	30 - 200
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	58	1.48	--	27 - 90
Dave Johnston mine, Wyoming	10 (2)	10:10	38	1.39	--	19 - 65
Hidden Valley mine, Wyoming	10 (2)	10:10	40	1.60	--	17 - 75
Kincaid mine, North Dakota	10 (2)	10:10	50	1.63	--	27 - 110
Savage mine, Montana	10 (2)	10:10	36	1.50	--	17 - 71
Velva mine, North Dakota	10 (2)	10:10	46	1.43	--	22 - 78
Big Sky mine, Montana	10 (2)	10:10	37	1.44	--	18 - 55
Utility mine, Saskatchewan	10 (2)	10:10	38	1.29	--	26 - 54
San Juan mine, New Mexico	11 (2)	12:12	14	1.26	1.14	10 - 22
Topsoil used in spoil reclamation San Juan mine, New Mexico	11 (2)	12:12	22	1.41	1.41	10 - 29
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	6:10	.35	2.05	1.32	<.29 - 1.12
Dave Johnston mine, Wyoming	10 (2)	4:8	.29	1.31	1.32	<.29 - .44
Hidden Valley mine, Wyoming	10 (2)	10:10	1.54	1.53	1.32	.65 - 2.65
Kincaid mine, North Dakota	10 (2)	7:9	.60	2.07	1.32	<.29 - 1.41
Savage mine, Montana	10 (2)	2:10	<.29	--	1.32	<.29 - .35
Velva mine, North Dakota	10 (2)	4:8	.31	2.72	1.32	<.29 - 1.29
White sweetclover						
Big Sky mine, Montana	10 (2)	5:10	.30	1.53	1.32	<.29 - .50
Utility mine, Saskatchewan	10 (2)	5:10	.29	2.05	1.32	<.30 - .91
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	.55	2.65	--	.28 - 1.69
Dave Johnston mine, Wyoming	10 (2)	3:3	.91	1.32	--	.67 - 1.17
Savage mine, Montana	10 (2)	3:3	.69	1.83	--	.45 - 1.36
Velva mine, North Dakota	10 (2)	3:3	.53	3.81	--	.14 - 2.06
Big Sky mine, Montana	10 (2)	3:3	.46	1.22	--	.38 - .56
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	.40	1.71	1.37	.16 - 1.1
Growing near mine spoil	26 (2)	20:20	.27	1.78	1.37	.11 - .60
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	2.1	1.17	--	1.8 - 2.5
Alkali sacaton	11 (2)	6:6	.71	1.46	--	.47 - .91

TABLE 18.—*Chromium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS				
Piceance Creek and Uinta Basins, Colo. and Utah: alluvial, 0- to 40-cm depth	12 (2)	30:30	50	1.37	1.13	20 - 98
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	43	1.73	1.29	15 - 70
B horizon	13 (1)	64:64	46	1.56	1.22	15 - 70
C horizon	13 (1)	64:64	46	1.78	1.22	10 - 70
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	48:48	45	1.49	1.28	20 - 100
Soil, 15- to 20-cm depth	20 (1)	48:48	49	1.43	1.35	20 - 100
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	63	1.31	1.10	33 - 86
C horizon	14 (2)	16:16	57	1.49	1.25	22 - 87
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	59	1.63	1.39	12 - 110
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	45	1.56	1.48	11 - 160
C horizon	16 (2)	136:136	42	1.66	1.35	12 - 180
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	59	1.55	1.15	23 - 350
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	44	1.59	1.11	16 - 94
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	18	1.45	1.51	7.6 - 42
C horizon	11 (2)	47:47	18	1.51	1.32	6.3 - 47
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	20	1.54	1.46	9.8 - 40
C horizon	24 (2)	30:30	13	1.50	1.46	5.5 - 40
		PLANTS				
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	1.0	1.38	1.17	0.56 - 1.8
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	1.1	1.32	1.14	.81 - 1.9
Snakeweed, San Juan Basin	19 (2)	18:18	.85	1.32	1.19	.47 - 1.5
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	33	1.57	1.15	20 - 50
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	18	1.74	1.33	5 - 150
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	28:30	4.6	2.00	1.34	<2 - 10
Columbia Plateaus Province	23 (1)	30:30	12	1.59	1.34	5 - 20
Basin and Range Province	23 (1)	30:30	6.0	1.86	1.34	2 - 15
Northern Great Plains	23 (1)	20:20	6.3	2.60	1.38	1 - 30
Northern Rocky Mountains Province	23 (1)	20:20	6.6	2.44	1.38	2 - 30
Middle Rocky Mountains Province	23 (1)	20:20	11	1.89	1.38	5 - 30
Southern Rocky Mountains Province	23 (1)	20:20	5.7	2.27	1.38	2 - 15
,oming Basin Province	23 (1)	20:20	9.5	1.83	1.38	3 - 20

TABLE 19.—*Cobalt in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	79:80	5.4	1.99	1.20	<1 - 16
Shale	1 (2)	80:80	9.1	1.90	1.24	3.3 - 42
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	6.9	2.13	1.11	1.5 - 16
Siltstone and shale	2 (2)	24:24	13	1.29	1.10	7.4 - 19
Dark shale	2 (2)	23:23	16	1.20	1.05	12 - 21
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	8.7	1.61	1.17	2.3 - 36
Sandstone	4 (2)	42:42	11	1.50	1.06	4.7 - 36
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	10	1.24	1.18	6.3 - 16
Middle 300 m	5 (2)	53:53	9.4	1.76	1.17	1.1 - 41
Garden Gulch Member (lower 100 m)	5 (2)	117:264	9.0	1.36	--	<10 - 20
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	7.3	1.34	1.15	3.3 - 14
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (1)	24:24	6	1.67	1.45	3 - 15
100-200 μm	7 (1)	23:24	4	1.50	1.34	<2 - 7
63-100 μm	7 (1)	24:24	3	1.35	1.22	2 - 7
<63 μm	7 (1)	24:24	6	1.28	1.13	3 - 10
Piceance Creek Basin, Colo. Roan and Black Sulphur Creeks	9 (1)	32:32	8.0	1.48	1.17	5 - 15
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	9.4	1.17	--	7.3 - 11
Dave Johnston mine, Wyoming	10 (2)	10:10	5.0	1.36	--	3.0 - 6.6
Hidden Valley mine, Wyoming	10 (2)	10:10	6.8	1.43	--	2.8 - 10
Kincaid mine, North Dakota	10 (2)	10:10	6.8	1.47	--	3.6 - 11
Savage mine, Montana	10 (2)	10:10	6.8	1.35	--	4.3 - 13
Velva mine, North Dakota	10 (2)	10:10	6.6	1.28	--	4.1 - 10
Big Sky mine, Montana	10 (2)	10:10	5.4	1.36	--	3.5 - 8.3
Utility mine, Saskatchewan	10 (2)	10:10	6.1	1.30	--	4.0 - 9.3

TABLE 19.—*Cobalt in rocks, stream sediments, mine spoil and associated materials, soils and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
San Juan mine, New Mexico	11 (2)	12:12	8.5	1.22	1.10	5.8 - 12
Topsoil used in spoil reclamation San Juan mine, New Mexico	11 (2)	12:12	6.0	1.14	1.11	4.9 - 7.4
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (3)	9:10	.23	2.40	1.58	<.03 - .54
Dave Johnston mine, Wyoming	10 (3)	10.10	.40	1.80	1.58	.20 - 1.4
Hidden Valley mine, Wyoming	10 (3)	10:10	.53	1.90	1.58	.23 - 1.22
Kincaid mine, North Dakota	10 (3)	9:10	.15	2.21	1.58	<.03 - .43
Savage mine, Montana	10 (3)	10:10	.15	2.59	1.58	.04 - .85
Velva mine, North Dakota	10 (3)	8:10	.09	2.69	1.58	<.03 - .25
White sweetclover						
Big Sky mine, Montana	10 (3)	10:10	.27	1.78	1.58	.12 - 1.02
Utility mine, Saskatchewan	10 (3)	10:10	.13	1.57	1.58	.05 - .31
Alfalfa						
Beulah North mine, North Dakota	10 (3)	2:3	.15	3.16	--	<.07 - .45
Dave Johnston mine, Wyoming	10 (3)	3:3	.21	2.02	--	.09 - .35
Savage mine, Montana	10 (3)	3:3	.35	2.24	--	.18 - .85
Velva mine, North Dakota	10 (3)	1:3	--	--	--	<.07 - .31
Big Sky mine, Montana	10 (3)	3:3	.10	1.49	--	.08 - .16
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (3)	15:20	.099	2.26	--	<.058 - .44
Growing near mine spoil	26 (3)	10:20	.069	1.34	--	<.054 - .13
San Juan mine, New Mexico						
Fourwing saltbush	11 (3)	6:6	.47	1.47	--	.28 - .65
Alkali sacaton	11 (3)	6:6	.23	1.40	--	.16 - .34
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	7.3	1.29	1.14	4 - 12
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	60:64	6.9	1.70	1.23	<3 - 30
B horizon	13 (1)	61:64	7.6	1.64	1.25	<3 - 20
C horizon	13 (1)	59:64	7.3	1.66	1.17	<3 - 20
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	46:48	6.3	1.37	1.09	<3 - 10
Soil, 12- to 20-cm depth	20 (1)	45:48	6.3	1.56	1.09	<5 - 20
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	9.7	1.41	1.18	3.9 - 16
C horizon	14 (2)	16:16	9.3	1.41	1.25	5.0 - 16
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	7.9	1.78	1.33	1.2 - 16

TABLE 19.—*Cobalt in rocks, stream sediments, mine spoil and associated materials, soils and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (2)	135:136	6.4	1.48	1.24	<1.0 - 23
C horizon------------------------	16 (2)	136:136	6.6	1.49	1.21	1.9 - 16
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	6.3	1.33	1.14	3.0 - 10
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (2)	36:36	5.5	1.49	1.16	2.1 - 16
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (2)	47:47	5.7	1.44	1.14	2.1 - 11
C horizon------------------------------	11 (2)	47:47	5.7	1.62	1.09	1.3 - 15
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (2)	30:30	4.9	1.28	1.21	3.1 - 11
C horizon----------------------------	24 (2)	30:30	4.4	1.37	1.09	2.6 - 8.9
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley-------------------------------	21 (3)	15:18	0.028	1.24	1.24	<0.028 - 0.044
Oats---------------------------------	21 (3)	17:21	.041	1.39	1.32	<.024 - .078
Wheat, durum-------------------------	21 (3)	14:20	.024	1.40	1.40	<.014 - .040
Wheat, hard red spring---------------	21 (3)	35:54	.020	1.37	1.32	<.012 - .048
Wheat, hard red winter---------------	21 (3)	17:17	.019	1.48	1.41	.014 - .051
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (3)	25:25	.26	1.57	1.19	.072 - .52
Saltbush, fourwing, San Juan Basin-----	19 (3)	10:10	.11	1.91	1.27	.048 - .32
Snakeweed, San Juan Basin--------------	19 (3)	18:18	.18	1.86	1.20	.051 - .35
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (3)	29:29	3.5	1.53	1.24	2 - 7
Sagebrush, big; Powder River Basin, Wyo. and Mont.-----------------------	20 (3)	37:39	2.0	1.97	1.46	<1 - 6
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (3)	24:30	1.2	1.91	1.30	<1 - 3
Columbia Plateaus Province-----------	23 (3)	30:30	2.9	1.66	1.30	1 - 7
Basin and Range Province-------------	23 (3)	30:30	1.8	1.62	1.30	1 - 3
Northern Great Plains----------------	23 (3)	20:20	2.3	2.76	1.55	1 - 18
Northern Rocky Mountains Province----	23 (3)	19:20	1.5	2.15	1.55	<1 - 40
Middle Rocky Mountains Province------	23 (3)	15:20	1.2	2.14	1.55	<1 - 3
Southern Rocky Mountains Province----	23 (3)	16:20	1.2	1.89	1.55	<1 - 3
Wyoming Basin Province---------------	23 (3)	20:20	2.1	2.31	1.55	1 - 6
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry-weight basis)						
Wheatgrass, western---------------	24 (3)	17:21	.11	1.94	--	<.04 - .39
Sagebrush, silver-----------------	24 (3)	16:19	.12	1.99	--	<.05 - .29
Plant biomass, above-ground parts-	24 (3)	15:21	.11	3.17	2.39	<.04 - .43

TABLE 20.—*Copper in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	13	2.31	1.23	2.3 - 61
Shale	1 (2)	80:80	34	2.14	1.52	4.5 - 110
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	13	1.96	1.09	5.8 - 62
Siltstone and shale	2 (2)	24:24	51	1.52	1.23	19 - 80
Dark shale	2 (2)	22:22	54	1.48	1.41	18 - 94
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	38	1.64	1.40	15 - 92
Sandstone	4 (2)	42:42	14	2.20	1.33	3.1 - 58
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	45	1.58	1.51	15 - 120
Middle 300 m	5 (2)	264:264	40	2.85	1.28	1.5 - 520
Garden Gulch Member (lower 100 m)	5 (2)	264:264	58	1.56	--	20 - 150
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	22	1.43	1.13	7.4 - 50
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (1)	24:24	18	2.70	2.20	5 - 100
100-200 μm	7 (1)	24:24	9	1.96	1.21	3 - 50
63-100 μm	7 (1)	24:24	10	1.44	1.22	7 - 20
<63 μm	7 (1)	24:24	34	2.56	1.15	10 - 200
Uinta and Piceance Creek Basins, Colo. and Utah	8 (2)	32:32	31	1.34	1.11	20 - 93
Piceance Creek Basin, Colo. Roan and Black Sulphur Creeks	9 (1)	32:32	17	1.37	1.15	10 - 30
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	24	1.87	--	5 - 41
Dave Johnston mine, Wyoming	10 (2)	10:10	16	1.30	--	12 - 29
Hidden Valley mine, Wyoming	10 (2)	10:10	18	1.37	--	9.6 - 26
Kincaid mine, North Dakota	10 (2)	10:10	24	1.64	--	8.8 - 47
Savage mine, Montana	10 (2)	10:10	20	1.50	--	7.6 - 29
Velva mine, North Dakota	10 (2)	10:10	19	1.30	--	12 - 28
Big Sky mine, Montana	10 (2)	10:10	19	1.45	--	12 - 34
Utility mine, Saskatchewan	10 (2)	10:10	17	1.24	--	11 - 23
San Juan mine, New Mexico	11 (2)	12:12	18	1.58	1.50	6.0 - 28

TABLE 20.—*Copper in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—**Continued**

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	10	1.48	1.15	6.6 - 24
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	5.5	1.14	1.04	4.4 - 6.7
Dave Johnston mine, Wyoming	10 (2)	10:10	7.0	1.19	1.04	5.2 - 9.5
Hidden Valley mine, Wyming	10 (2)	10:10	8.0	1.27	1.04	5.6 - 11.4
Kincaid mine, North Dakota	10 (2)	10:10	9.0	1.20	1.04	6.7 - 12.6
Savage mine, Montana	10 (2)	10:10	5.9	1.27	1.04	4.1 - 9.3
Velva mine, North Dakota	10 (2)	10:10	7.2	1.18	1.04	5.9 - 9.5
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	8.2	1.16	1.04	6.5 - 9.8
Utility mine, Saskatchewan	10 (2)	10:10	6.9	1.14	1.04	5.3 - 9.0
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	6.3	1.11	--	5.6 - 6.8
Dave Johnston mine, Wyoming	10 (2)	3:3	12.0	1.16	--	10.4 - 14.0
Savage mine, Montana	10 (2)	3:3	6.8	1.06	--	6.4 - 7.1
Velva mine, North Dakota	10 (2)	3:3	7.4	1.23	--	6.1 - 9.3
Big Sky mine, Montana	10 (2)	3:3	8.1	1.16	--	6.8 - 9.0
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	3.2	1.44	1.33	1.6 - 5.9
Growing near mine spoil	26 (2)	20:20	2.8	1.45	1.33	1.6 - 6.0
San Juan mine, New Mexico						
Fourwing saltbush	11 (3)	6:6	9.7	1.16	--	8.4 - 12
Alkali sacaton	11 (3)	6:6	2.4	1.21	--	2.0 - 2.8
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	30	1.78	1.52	12 - 85
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	15	2.20	1.25	3 - 70
B horizon	13 (1)	64:64	17	2.00	1.37	3 - 70
C horizon	13 (1)	64:64	17	2.84	1.13	2 - 100
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	48:48	14	1.63	1.15	3 - 30
Soil, 15- to 20-cm depth	20 (1)	48:48	16	1.67	1.15	5 - 50
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	36	1.44	1.31	17 - 64
C horizon	14 (2)	16:16	33	1.82	1.63	11 - 80
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	107:108	30	1.93	1.61	<8.7 - 122
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	19	1.64	1.31	4.3 - 110
C horizon	16 (2)	136:136	17	1.82	1.49	2.7 - 110

TABLE 20.— *Copper in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (2)	36:36	20	1.65	1.29	6.7 - 60
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (2)	36:36	15	1.70	1.38	4.7 - 67
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (2)	47:47	8.9	1.90	1.14	2.1 - 30
B horizon-------------------------------	11 (2)	47:47	8.7	1.94	1.42	1.7 - 28
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon-----------------------------	24 (2)	30:30	8.8	1.41	1.16	4.9 - 19
C horizon-----------------------------	24 (2)	30:30	6.3	1.73	1.42	1.6 - 17
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley---------------------------------	21 (3)	18:18	4.8	1.12	1.08	4.0 - 5.8
Oats-----------------------------------	21 (3)	21:21	4.4	1.24	1.05	2.8 - 6.7
Wheat, durum-------------------------	21 (3)	20:20	5.0	1.17	1.16	3.8 - 6.9
Wheat,hard red spring----------------	21 (3)	54:54	4.5	1.24	1.14	3.1 - 7.1
Wheat, hard red winter---------------	21 (3)	17:17	3.9	1.17	1.10	2.9 - 5.0
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (3)	25:25	2.4	1.24	1.03	1.6 - 4.0
Saltbush, fourwing, San Juan Basin-----	19 (3)	10:10	4.7	1.28	1.04	3.3 - 7.0
Snakeweed, San Juan Basin--------------	19 (3)	18:18	8.1	1.42	1.05	4.6 - 17
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (1)	29:29	70	1.44	1.26	30 - 150
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (3)	30:30	150	1.54	1.10	70 - 270
Columbia Plateaus Province-----------	23 (3)	30:30	150	1.44	1.10	90 - 300
Basin and Range Province-------------	23 (3)	30:30	120	1.37	1.10	60 - 180
Northern Great Plains----------------	23 (3)	20:20	190	1.39	1.08	110 - 240
Northern Rocky Mountains Province----	23 (3)	20:20	210	2.19	1.08	100 - 1,000
Middle Rocky Mountains Province------	23 (3)	20:20	150	1.68	1.08	70 - 280
Southern Rocky Mountains Province----	23 (3)	20:20	140	1.60	1.08	80 - 300
Wyoming Basin Province---------------	23 (3)	20:20	160	1.40	1.08	110 - 240
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry weight basis)						
Wheatgrass, western----------------	18 (3)	21:21	.56	1.57	--	.34 - 1.5
Sagebrush, silver------------------	18 (3)	19:19	5.8	1.29	--	4.0 - 9.8
Plant biomass, above-ground parts	18 (3)	21:21	1.3	1.32	1.36	.72 - 1.9

TABLE 21.—*Dysprosium in rocks and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
Sandstone	4 (2)	5:42	4.9	1.9	1.31	<10 - 18
SOILS						
San Juan Basin, N. Mex.						
A horizon	11 (2)	6:47	7.7	1.27	--	<10 - 13
C horizon	11 (2)	8:47	6.6	1.56	--	<10 - 17
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	8:30	7.8	1.52	--	<10 - 16
C horizon	24 (2)	1:30	--	--	--	<10 - 11

TABLE 22.—*Erbium in rocks, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
sandstone	4 (2)	1:42	--	--	--	<4.2 - 5.2
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
San Juan mine, New Mexico	11 (2)	12:12	7.1	1.15	1.10	5.2 - 9.1
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	6.5	1.10	1.07	5.2 - 7.5
SOILS						
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	17:30	4.9	1.31	--	<4.6 - 8.1
C horizon	24 (2)	13:30	4.5	1.37	--	<4.6 - 7.3

DYSPROSIUM, ERBIUM

TABLE 23.—*Europium in rocks, plants associated with mine spoil, and other plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
sandstone	4 (2)	33:42	2.5	1.8	2.08	<1.0 - 4.8
PLANTS ASSOCIATED WITH MINE SPOIL						
Plants (dry-weight basis)						
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	3:6	0.29	2.28	--	<0.24 - 0.74
Alkali sacaton	11 (2)	3:6	.11	2.54	--	<.082 - .33
OTHER PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	14:25	0.17	1.86	1.85	<0.080 - 0.46
Saltbush, fourwing, San Juan Basin	19 (2)	4:10	.086	4.10	3.09	<.17 - .61
Snakeweed, San Juan Basin	19 (2)	9:18	.13	2.35	1.98	<.086 - .40

TABLE 24.—*Fluorine in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (9)	54:80	370	1.50	--	<400 - 700
Shale	1 (9)	77:80	690	1.49	1.16	<400 - 1,300
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (9)	21:24	480	1.39	1.25	<400 - 900
Siltstone and shale	2 (9)	23:24	800	1.34	1.10	<400 - 1,000
Dark shale	2 (9)	23:23	800	1.26	1.17	500 - 1,000
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (9)	45:50	600	1.51	1.22	300 - 1,200
Sandstone	4 (9)	39:42	300	1.4	1.15	<200 - 600

TABLE 24.—*Fluorine in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Core samples--Continued						
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)--------	5 (9)	60:74	760	1.78	1.20	<400 - 2,300
Middle 300 m------------------------	5 (9)	53:53	740	2.45	1.16	200 - 11,000
Garden Gulch Member (lower 100 m)--	5 (9)	32:32	1,000	1.50	--	280 - 1,700
STREAM SEDIMENTS						
Powder River Basin, Wyo. and Mont.						
Size fraction, <63 µm----------------	7 (9)	17:24	0.046	1.42	1.36	<0.04 - 0.08
Uinta and Piceance Creek Basins, Colo. and Utah--------------------------	8 (9)	32:32	9.0	2.99	2.08	.50 - 31
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (9)	10:10	760	1.29	--	500 - 1,100
Dave Johnston mine, Wyoming----------	10 (9)	10:10	670	1.39	--	400 - 1,100
Hidden Valley mine, Wyoming----------	10 (9)	10:10	740	1.35	--	500 - 1,300
Kincaid mine, North Dakota-----------	10 (9)	10:10	820	1.45	--	400 - 1,600
Savage mine, Montana-----------------	10 (9)	10:10	810	1.29	--	500 - 1,200
Velva mine, North Dakota-------------	10 (9)	10:10	710	1.75	--	400 - 2,900
Big Sky mine, Montana----------------	10 (9)	10:10	830	1.40	--	600 - 1,700
Utility mine, Saskatchewan-----------	10 (9)	10:10	680	1.60	--	400 - 1,800
San Juan mine, New Mexico-------------	11 (9)	11:12	450	1.13	--	<400 - 500
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (9)	6:12	390	1.19	--	<400 - 500
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (9)	10:10	7.3	1.39	1.19	5 - 14
Dave Johnston mine, Wyoming--------	10 (9)	10:10	7.6	1.35	1.19	5 - 12
Hidden Valley mine, Wyoming--------	10 (9)	10:10	15.0	1.35	1.19	9 - 25
Kincaid mine, North Dakota---------	10 (9)	10:10	9.3	1.39	1.19	5 - 16
Savage mine, Montana---------------	10 (9)	10:10	7.0	1.32	1.19	5 - 12
Velva mine, North Dakota-----------	10 (9)	10:10	7.5	1.41	1.19	4 - 12
White sweetclover						
Big Sky mine, Montana--------------	10 (9)	10:10	8.1	1.25	1.19	6 - 12
Utility mine, Saskatchewan---------	10 (9)	10:10	7.0	1.32	1.19	6 - 12
Alfalfa						
Beulah North mine, North Dakota----	10 (9)	3:3	3.8	2.18	--	2 - 9
Dave Johnston mine, Wyoming--------	10 (9)	3:3	3.3	1.18	--	3 - 4
Savage mine, Montana---------------	10 (9)	3:3	4.0	1.63	--	3 - 7
Velva mine, North Dakota-----------	10 (9)	3:3	2.0	2.00	--	1 - 4
Big Sky mine, Montana--------------	10 (9)	3:3	2.9	1.42	--	2 - 4
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil--------------	26 (9)	20:20	6.2	1.46	1.11	3 - 10
Growing near mine spoil------------	26 (9)	20:20	4.5	1.17	1.11	3 - 6

FLUORINE

TABLE 24.—*Fluorine in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)--Continued						
San Juan mine, New Mexico						
Fourwing saltbush	11 (9)	6:6	20	1.36	--	15 - 34
Alkali sacaton	11 (9)	6:6	7.8	1.18	--	6.0 - 9.0
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (9)	27:30	610	1.46	1.07	<400 - 1,400
Powder River Basin, Wyo. and Mont.						
A horizon	13 (9)	34:64	410	1.48	1.26	<400 - 900
B horizon	13 (9)	42:64	450	1.56	1.22	<400 - 900
C horizon	13 (9)	47:64	490	1.48	1.14	<400 - 1,000
Hanging Woman Creek, Mont.						
A horizon	14 (9)	16:16	550	1.19	1.06	400 - 700
C horizon	14 (9)	16:16	580	1.26	1.05	400 - 800
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (9)	85:108	500	1.52	1.31	<400 - 1,600
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon	16 (9)	66:88	560	1.80	1.81	<400 - 2,700
Glaciated area						
A horizon	16 (9)	48:48	450	1.60	1.81	280 - 1,400
Combined data, unglaciated and glaciated areas						
A horizon	16 (9)	96:136	510	1.82	1.81	<400 - 2,700
C horizon	16 (9)	126:136	670	1.57	1.68	<400 - 2,000
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (9)	18:36	400	1.24	--	<400 - 600
Wind River Basin, Wyo., 0- to 40-cm depth	17 (9)	12:36	340	1.42	--	<400 - 700
San Juan Basin, N. Mex.						
A horizon	11 (9)	13:47	280	1.73	--	<400 - 900
C horizon	11 (9)	18:47	330	1.85	--	<400 - 1,200
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	2 (9)	9:20	<1	--	--	<1 - 2
Oats	2 (9)	15:21	<1	--	--	<1 - 2
Wheat, durum	2 (9)	13:18	<1	--	--	<1 - 2
Wheat, hard red spring	21 (9)	32:54	1.0	1.19	--	<1 - 2
Wheat, hard red winter	21 (9)	11:17	<1	--	--	<1 - 1
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (9)	25:25	8.5	1.33	1.12	4 - 14
Saltbush, fourwing, San Juan Basin	19 (9)	10:10	6.2	1.71	1.24	3 - 15
Snakeweed, San Juan Basin	19 (9)	18:18	9.4	1.36	1.13	6 - 14

TABLE 24.—*Fluorine in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANTS--Continued				
Native species (dry-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (9)	29:29	25	1.46	1.09	14 - 50
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (9)	30:30	8.1	1.29	1.15	6 - 12
Columbia Plateaus Province-----------	23 (9)	30:30	10	1.48	1.15	6 - 22
Basin and Range Province-------------	23 (9)	30:30	8.7	1.19	1.15	6 - 12
Northern Great Plains----------------	23 (9)	20:20	8.0	1.28	1.13	5 - 11
Northern Rocky Mountains Province----	23 (9)	20:20	9.6	1.64	1.13	6 - 22
Middle Rocky Mountains Province------	23 (9)	20:20	9.0	1.18	1.13	8 - 13
Southern Rocky Mountains Province----	23 (9)	20:20	8.1	1.40	1.13	5 - 13
Wyoming Basin Province---------------	23 (9)	20:20	8.9	1.20	1.13	7 - 12

TABLE 25.—*Gadolinium in rocks, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Core samples						
Northern Great Plains, Fort Union Formation sandstone--------------------------	4 (2)	24:42	3.8	3.80	2.80	<2.2 - 22
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
San Juan mine, New Mexico-------------	11 (2)	7:12	2.9	2.74	--	<2.2 - 11
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (2)	4:12	1.5	3.10	--	<2.2 - 6.9
		SOILS				
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (2)	25:47	2.8	3.35	--	<2.2 - 16
C horizon------------------------------	11 (2)	22:47	2.3	2.98	--	<2.2 - 10
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (2)	8:30	.99	3.96	--	<2.2 - 10
C horizon----------------------------	24 (2)	11:30	1.7	2.21	--	<2.2 - 9.2
		PLANTS				
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (2)	6:25	.12	3.93	--	<0.17- 1.1

TABLE 26.—*Gallium in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	11	1.69	1.18	3.2 - 23
Shale	1 (2)	80:80	26	1.50	1.19	9.7 - 46
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	12	1.50	1.19	6.1 - 22
Siltstone and shale	2 (2)	24:24	23	1.21	1.10	17 - 34
Dark shale	2 (2)	23:23	26	1.17	1.09	17 - 36
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	18	1.42	1.20	8.1 - 40
Sandstone	4 (2)	42:42	5.3	1.50	1.12	2.6 - 11
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	5.1	1.54	1.29	3.2 - 17
Middle 300 m	5 (2)	10:53	--	--	--	<4 - 5.8
Garden Gulch Member (lower 100 m)	5 (2)	264:264	22	1.34	--	10 - 70
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	11	1.45	1.26	3.5 - 20
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (1)	24:24	13	1.67	1.34	7 - 30
100-200 µm	7 (1)	24:24	10	1.44	1.16	7 - 20
63-100 µm	7 (1)	24:24	10	1.37	1.20	7 - 20
<63 µm	7 (1)	24:24	15	1.22	<1.02	10 - 30
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (1)	8:8	17	1.17	--	15 - 20
Cottonwood Creek, Utah	8 (1)	8:8	20	1.24	--	15 - 30
Duck Creek, Colo.	8 (1)	8:8	15	1.24	--	10 - 20
Ryan Gulch, Colo.	8 (1)	8:8	22	1.34	--	15 - 30
Piceance Creek Basin, Colo.						
Roan Creek	9 (1)	16:16	15	1.09	1.16	15 - 20
Black Sulphur Creek	9 (1)	16:16	20	1.19	1.16	15 - 30
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	12	1.63	--	5.8 - 22
Dave Johnston mine, Wyoming	10 (2)	10:10	13	1.31	--	7.8 - 18
Hidden Valley mine, Wyoming	10 (2)	9:10	10	1.90	--	<3.0 - 21
Kincaid mine, North Dakota	10 (2)	9:10	9.2	1.78	--	<3.1 - 18

TABLE 26.—*Gallium in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Savage mine, Montana	10 (2)	10:10	11	1.41	--	6.9 - 16
Velva mine, North Dakota	10 (2)	9:10	8.5	1.65	--	<3.0 - 18
Big Sky mine, Montana	10 (2)	10:10	9.2	1.65	--	4.2 - 17
Utility mine, Saskatchewan	10 (2)	9:10	8.0	1.54	--	<3.1 - 12
San Juan mine, New Mexico	11 (2)	10:12	3.3	1.45	--	<2.2 - 5.5
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	4:12	2.0	1.17	--	<2.2 - 2.8
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	15	1.32	1.10	7.2 - 29
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	13	1.37	1.20	7 - 30
B horizon	13 (1)	64:64	15	1.30	1.29	7 - 30
C horizon	13 (1)	64:64	15	1.50	1.21	7 - 30
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	48:48	12	1.31	1.13	7 - 20
Soil, 15- to 20-cm depth	20 (1)	48:48	13	1.28	1.13	7 - 20
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	13	1.45	1.23	5.3 - 21
C horizon	14 (2)	16:16	12	1.51	1.39	5.8 - 22
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	107:108	18	1.82	1.40	<2.2 - 39
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
C horizon	16 (2)	88:88	11	1.51	1.33	2.7 - 25
Glaciated area						
C horizon	16 (2)	48:48	10	1.58	1.33	2.8 - 22
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	11	1.44	1.30	4.2 - 29
C horizon	16 (2)	136:136	11	1.54	1.33	2.7 - 25
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	11	1.47	1.19	4.3 - 20
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	15	1.32	1.17	7.3 - 23
San Juan Basin, N. Mex.						
A horizon	11 (2)	21:47	2.0	1.82	--	<2.2 - 6.6
C horizon	11 (2)	21:47	2.0	2.06	--	<2.2 - 10
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	19:30	3.7	3.07	--	<2.2 - 13
C horizon	24 (2)	20:30	4.0	2.80	--	<2.2 - 14

TABLE 27.—*Germanium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leadere (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (18)	80:80	1.1	1.57	1.13	0.38 - 3.0
Shale	1 (18)	80:80	1.4	1.54	1.16	.75 - 5.5
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (18)	24:24	.76	1.55	1.20	.35 - 2.0
Siltstone	2 (18)	24:24	1.1	1.36	1.23	.58 - 1.7
Dark shale	2 (18)	23:23	1.3	1.51	1.39	.53 - 2.5
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (18)	49:50	1.0	1.38	1.11	<.32 - 1.6
Sandstone	4 (18)	42:42	1.1	1.30	1.54	.60 - 1.7
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (18)	38:42	.44	1.92	--	.15 - 1.9
Middle 300 m	5 (18)	9:53	--	--	--	<.9 - 2.8
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (18)	60:60	1.2	1.34	1.25	0.36 - 1.7
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (5)	16:19	.71	3.36	1.13	<.1 - 1.7
100-200 µm	7 (5)	24:24	1.2	1.20	1.07	.78 - 1.8
63-100 µm	7 (5)	24:24	1.3	1.13	1.03	1.0 - 1.6
<63 µm	7 (5)	24:24	1.4	1.10	1.08	1.1 - 1.7
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	9:10	.73	2.98	--	<0.1 - 1.8
Dave Johnston mine, Wyoming	10 (5)	9:10	.73	2.40	--	<.1 - 1.7
Hidden Valley mine, Wyoming	10 (5)	10:10	1.4	1.38	--	.92 - 2.2
Kinciad mine, Montana	10 (5)	9:10	.51	2.31	--	<.1 - 1.3
Savage mine, Montana	10 (5)	8:10	.58	3.30	--	<.1 - 1.9
Velva mine, North Dakota	10 (5)	9:10	.68	2.56	--	<.1 - 1.6
Big Sky mine, Montana	10 (5)	10:10	.77	2.05	--	.18 - 1.9
Utility mine, Saskatchewan	10 (5)	8:10	.60	3.24	--	<.1 - 1.7
San Juan mine, New Mexico	11 (5)	12:12	1.4	1.59	1.17	.50 - 2.3
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	12:12	1.3	1.31	1.31	.70 - 1.9

TABLE 27.—*Germanium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS				
Piceance Creek and Uinta Basins, Colo. and Utah;						
alluvial, 0- to 40-cm depth----------	12 (5)	30:30	1.1	1.24	1.11	0.7 - 1.9
Hanging Woman Creek, Mont.						
A horizon--------------------------------	14 (5)	16:16	1.3	1.27	1.17	.83 - 1.8
C horizon--------------------------------	14 (5)	16:16	1.3	1.27	1.17	.78 - 1.8
Piceance Creek Basin, Colo., 0- to 5-cm depth------------------------------------	15 (5)	105:108	.87	2.35	1.96	<.14 - 2.5
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon-------------------------	16 (5)	130:136	1.6	1.27	1.13	<.10 - 2.7
C horizon-------------------------	16 (5)	132:136	1.6	1.33	1.16	<.10 - 9.3
Big Horn Basin, Wyo., 0- to 40 cm depth--	17 (5)	32:36	.87	2.49	2.64	<.10 - 1.8
Wind River Basin, Wyo., 0- to 40 cm depth------------------------------------	17 (5)	32:36	.77	2.48	2.09	<.10 - 1.7
San Juan Basin, N. Mex.						
A horizon--------------------------------	11 (5)	47:47	1.4	1.22	1.24	.80 - 1.9
C horizon--------------------------------	11 (5)	47:47	1.3	1.20	1.20	.90 - 1.9
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon-----------------------------	24 (5)	30:30	1.3	1.17	1.09	.90 - 1.7
C horizon-----------------------------	24 (5)	30:30	1.2	1.20	1.31	.90 - 1.6
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley------------------------------------	21 (1)	13:18	.030	1.52	1.34	<0.019 - 0.061
Oats--------------------------------------	21 (1)	17:21	.056	1.80	1.80	<.025 - .12
Wheat, durum---------------------------	21 (1)	15:20	.026	1.96	1.96	<.013 - .11
Wheat, hard red spring----------------	21 (1)	30:54	.017	1.85	1.84	<.014 - .068
Wheat, hard red winter----------------	21 (1)	5:17	.0095	2.16	2.15	<.012 - .036

TABLE 28.—*Indium in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
C horizon-------------------------	16 (2)	1:136	--	--	--	<50 - 51

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TABLE 29.—*Iodine in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
Sandstone	4 (5)	38:42	0.71	1.4	1.70	<0.3 - 2.0
STREAM SEDIMENTS						
Powder River Basin, Wyoming and Montana						
Size fractions						
>200 µm	7 (5)	4:6	0.057	1.93	--	<0.05 - 0.15
63-100 µm	7 (5)	5:10	.052	1.86	--	<.05 - .1
<63 µm	7 (5)	5:6	.077	2.60	--	<.05 - .3
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
San Juan mine, New Mexico	11 (5)	1:12	--	--	--	<0.50 - 0.55
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	4:12	0.46	1.24	--	<.50 - .64
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah;						
alluvial, 0- to 40-cm-depth	12 (5)	24:30	0.82	1.63	1.51	<0.5 - 1.8
Hanging Woman Creek, Mont.						
A horizon	14 (5)	11:16	.63	1.64	1.22	<.56 - 1.6
C horizon	14 (5)	6:16	.44	1.54	--	<.61 - 1.1
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	115:136	.33	2.48	2.04	<.050 - 2.3
C horizon	16 (5)	92:136	.25	2.57	2.39	<.050 - 2.5
San Juan Basin, N. Mex.						
A horizon	11 (5)	7:47	.28	1.81	--	<.50 - .97
C horizon	11 (5)	26:47	.57	2.46	--	<.50 - 3.8
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
C horizon	24 (5)	10:30	.37	2.01	--	<.50 - 1.9

TABLE 30.—*Iron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (5)	80:80	1.5	1.98	<1.07	0.25 - 5.2
Shale	1 (5)	80:80	2.4	2.09	<1.08	.32 - 7.5
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (5)	24:24	2.4	1.51	1.06	1.2 - 7.1
Siltstone and shale	2 (5)	24:24	2.6	1.34	1.02	2.0 - 5.4
Dark shale	2 (5)	23:23	2.8	1.38	1.05	1.5 - 5.0
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (5)	50:50	3.0	1.54	1.03	1.1 - 7.8
Sandstone	4 (5)	42:42	1.2	1.60	1.04	.41 - 4.3
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)	5 (5)	74:74	2.2	1.29	1.06	1.1 - 3.9
Middle 300 m	5 (5)	51:51	1.5	1.34	1.05	.54 - 2.4
Garden Gulch Member (lower 100 m)	5 (5)	32:32	3.1	2.41	--	.03 - 4.6
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (5)	60:60	2.3	1.29	<1.03	1.5 - 9.1
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 μm	7 (5)	19:19	1.9	1.75	1.47	1.2 - 4.7
100-200 μm	7 (5)	24:24	1.1	1.41	<1.02	.77 - 3.4
63-100 μm	7 (5)	24:24	1.2	1.33	1.03	.91 - 3.1
<63 μm	7 (5)	24:24	1.8	1.25	1.03	1.4 - 3.4
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (5)	8:8	1.9	1.10	--	1.6 - 2.1
Cottonwood Creek, Utah	8 (5)	8:8	2.4	1.41	--	1.8 - 5.3
Duck Creek, Colo.	8 (5)	8:8	1.9	1.09	--	1.6 - 2.1
Ryan Gulch, Colo.	8 (5)	8:8	2.1	1.14	--	1.8 - 2.6
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	2.2	1.33	1.07	1.5 - 5
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	3.2	1.31	--	1.7 - 4.7
Dave Johnston mine, Wyoming	10 (5)	10:10	1.9	1.33	--	1.1 - 3.1
Hidden Valley mine, Wyoming	10 (5)	10:10	2.1	1.35	--	1.3 - 3.8
Kincaid mine, North Dakota	10 (5)	10:10	2.8	1.20	--	2.2 - 3.7
Savage mine, Montana	10 (5)	10:10	2.4	1.22	--	1.8 - 3.2
Velva mine, North Dakota	10 (5)	10:10	2.3	1.07	--	2.1 - 2.6
Big Sky mine, Montana	10 (5)	10:10	2.3	1.18	--	1.8 - 3.2
Utility mine, Saskatchewan	10 (5)	10:10	2.1	1.16	--	1.7 - 2.9

TABLE 30.—*Iron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
San Juan mine, New Mexico	11 (5)	12:12	1.7	1.17	1.08	1.3 - 2.1
Topsoil used in spoil reclamation San Juan mine, New Mexico	11 (5)	12:12	1.4	1.09	1.07	1.3 - 1.6
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	.027	1.52	1.12	.013 - .050
Dave Johnston mine, Wyoming	10 (2)	10:10	.019	1.34	1.42	.010 - .026
Hidden Valley mine, Wyoming	10 (2)	10:10	.047	1.33	1.12	.029 - .069
Kincaid mine, North Dakota	10 (2)	10:10	.043	1.58	1.12	.016 - .069
Savage mine, Montana	10 (2)	10:10	.018	1.42	1.12	.014 - .028
Velva mine, North Dakota	10 (2)	10:10	.023	1.80	1.12	.012 - .065
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	.029	1.27	1.12	.023 - .045
Utility mine, Saskatchewan	10 (2)	10:10	.019	1.37	1.12	.013 - .033
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	.024	2.26	--	.011 - .057
Dave Johnston mine, Wyoming	10 (2)	3:3	.027	1.37	--	.019 - .035
Savage Mine, montana	10 (2)	3:3	.027	1.46	--	.018 - .036
Velva mine, North Dakota	10 (2)	3:3	.022	2.80	--	.011 - .072
Big Sky mine, Montana	10 (2)	3:3	.019	1.27	--	.015 - .024
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	.027	1.67	1.24	.012 - .074
Growing near mine spoil	26 (2)	20:20	.019	1.55	1.24	.0081 - .035
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	.078	1.27	--	.062 - .11
Alkali sacaton	11 (2)	6:6	.031	1.50	--	.021 - .051
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (5)	30:30	*2.0	*0.50	*0.040	1.1 - 2.8
Powder River Basin, Wyo. and Mont.						
A horizon	13 (5)	64:64	2.0	1.49	1.12	.87 - 5.2
B horizon	13 (5)	64:64	2.2	1.43	1.09	.75 - 6.1
C horizon	13 (5)	64:64	2.1	1.67	1.12	.66 - 8.4
Hanging Woman Creek, Mont.						
A horizon	14 (5)	16:16	*2.6	*.47	*.080	1.7 - 3.4
C horizon	14 (5)	16:16	*2.5	*.67	*.15	1.3 - 3.7
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (5)	108:108	1.8	1.22	1.13	1.1 - 2.9

TABLE 30.—*Iron in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		SOILS--Continued				
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	136:136	2.1	1.41	1.02	0.26 - 6.5
C horizon------------------------	16 (5)	136:136	2.2	1.40	1.02	.64 - 7.8
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (5)	36:36	1.2	1.38	1.07	.66 - 2.9
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (5)	36:36	1.5	1.36	1.07	.98 - 2.7
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (5)	47:47	1.1	1.62	1.03	.42 - 6.0
C horizon-------------------------------	11 (5)	47:47	1.2	1.58	1.04	.41 - 2.5
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (5)	30:30	.91	1.23	1.05	.58 - 1.2
C horizon----------------------------	24 (5)	30:30	.83	1.41	1.17	.44 - 1.5
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley-------------------------------	21 (1)	18:18	0.0088	1.32	1.21	0.0053 - 0.016
Oats---------------------------------	21 (1)	21:21	.0081	1.27	1.12	.0054 - .014
Wheat, durum-------------------------	21 (1)	20:20	.0098	1.23	1.23	.0057 - .015
Wheat, hard red spring---------------	21 (1)	54:54	.0048	1.32	1.17	.0028 - .010
Wheat, hard red winter---------------	21 (1)	17:17	.0034	1.20	1.11	.0025 - .0043
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (2)	25:25	.0530	1.49	1.09	.22 - .12
Saltbush, fourwing, San Juan Basin-----	19 (2)	10:10	.0220	1.73	1.13	.0087 - .043
Snakeweed, San Juan Basin--------------	19 (2)	18:18	.0420	1.60	1.11	.019 - .082
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (1)	29:29	1.4	1.30	1.21	.7 - 2
Sagebrush, big; regional study						
Colorado Plateaus Province---------	23 (1)	30:30	.28	1.86	1.22	.15 - .7
Columbia Plateaus Province---------	23 (1)	30:30	1.1	1.60	1.22	.5 - 3
Basin and Range Province-----------	23 (1)	30:30	.44	1.98	1.22	.2 - 1
Northern Great Plains--------------	23 (1)	20:20	.33	2.19	1.27	.15 - 1
Northern Rocky Mountains Province--	23 (1)	20:20	.35	1.94	1.27	.15 - 1
Middle Rocky Mountains Province----	23 (1)	20:20	.37	1.99	1.27	.2 - 1
Southern Rocky Mountains Province--	23 (1)	20:20	.30	1.89	1.27	.15 - .70
Wyoming Basin Province-------------	23 (1)	20:20	.53	1.84	1.27	.2 - 1.5
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry-weight basis)						
Wheatgrass, western------------------	18 (3)	21:21	.0073	1.99	--	.0018 - .0320
Sagebrush, silver--------------------	18 (3)	19:19	.0120	1.85	--	.0052 - .0440
Plant biomass, above-ground parts----	18 (3)	21:21	.0120	1.94	1.10	.0052 - .0510

TABLE 31.—*Lanthanum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	35	1.48	1.30	15 - 80
Shale	1 (2)	80:80	42	1.58	1.23	13 - 150
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	29	1.30	1.16	17 - 44
Siltstone and shale	2 (2)	24:24	39	1.17	1.13	29 - 56
Dark shale	2 (2)	23:23	44	1.19	1.12	29 - 60
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	33	1.26	1.22	20 - 62
Sandstone	4 (2)	42:42	49	1.20	1.10	35 - 70
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	35	1.48	1.38	13 - 85
Middle 300 m	5 (2)	53:53	32	1.40	1.32	15 - 66
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	35	1.30	1.25	22 - 70
Powder River Basin, Wyo. and Mont. Size fraction, <63 µm	7 (1)	23:24	49	1.83	1.49	<30 - 150
Uinta and Piceance Creek Basins, Colo. and Utah	8 (1)	32:32	45	1.70	1.18	25 - 150
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil San Juan mine, New Mexico	11 (2)	12:12	32	1.21	1.21	21 - 40
Topsoil used in spoil reclamation San Juan mine, New Mexico	11 (2)	12:12	25	1.36	1.26	18 - 51
Plants (dry-weight basis)						
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	2:6	<1.1	--	--	<1.2 - 1.8
Alkali sacaton	11 (2)	4:6	0.72	2.94	--	<0.38 - 2.3
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	39	1.16	1.15	26 - 65
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	50:64	45	1.54	1.42	<30 - 100
B horizon	13 (1)	54:64	46	1.47	1.54	<30 - 70
C horizon	13 (1)	50:64	43	1.59	1.51	<30 - 150

TABLE 31.—*Lanthanum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Powder River Basin, Wyo. and Mont.						
Soil, 15- to 20-cm depth	20 (1)	39:48	28	1.79	1.34	<30 - 70
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	36	1.27	1.21	21 - 49
C horizon	14 (2)	16:16	36	1.20	1.19	26 - 50
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	128:136	23	1.47	1.39	<10 - 49
C horizon	16 (2)	127:136	23	1.55	1.38	<10 - 62
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	36	1.20	1.15	25 - 56
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	35	1.32	2.10	22 - 68
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	27	1.38	1.28	6.9 - 43
C horizon	11 (2)	47:47	30	1.35	1.21	12 - 61
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	28	1.24	1.17	18 - 43
C horizon	24 (2)	30:30	27	1.33	1.16	16 - 46
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	20:25	1.3	1.98	1.95	<0.59 - 3.8
Saltbush, fourwing, San Juan Basin	19 (2)	5:10	1.2	2.79	2.73	<1.0 - 4.8
Snakeweed, San Juan Basin	19 (2)	15:18	1.1	1.91	1.88	<.47 - 2.4

TABLE 32.—*Lead in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	72:80	5.2	2.57	1.46	<1.2 - 16
Shale	1 (2)	80:80	15	1.86	1.43	1.6 - 44

TABLE 32.—*Lead in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	17:24	3.3	2.82	1.34	0.79 - 15
Siltstone and shale	2 (2)	24:24	14	1.46	1.17	6.0 - 25
Dark shale	2 (2)	23:23	22	1.19	1.08	17 - 37
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	49:50	11	1.66	1.31	<2.8 - 29
Sandstone	4 (2)	42:42	12	1.70	1.13	5.5 - 130
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	21	1.71	1.40	3.5 - 170
Middle 300 m	5 (2)	52:53	14	1.91	1.48	<4 - 53
Garden Gulch Member (lower 100 m)	5 (2)	261:264	41	1.52	--	<20 - 150
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	57:60	5.9	2.10	1.79	<1.2 - 20
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (1)	24:24	17	1.28	1.15	10 - 30
100-200 µm	7 (1)	24:24	11	1.26	1.23	7 - 15
63-100 µm	7 (1)	24:24	11	1.23	1.23	10 - 15
<63 µm	7 (1)	24:24	16	1.23	1.23	15 - 20
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (1)	8:8	18	1.16	--	15 - 20
Cottonwood Wash, Utah	8 (1)	8:8	19	1.26	--	15 - 30
Duck Creek, Colo.	8 (1)	8:8	13	1.23	--	10 - 15
Ryan Gulch, Colo.	8 (1)	8:8	19	1.14	--	15 - 20
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	18	1.31	1.18	15 - 30
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	16	1.82	--	5.0 - 33
Dave Johnston mine, Wyoming	10 (2)	10:10	28	1.48	--	13 - 44
Hidden Valley mine, Wyoming	10 (2)	9:10	17	2.28	--	<2.1 - 35
Kincaid mine, North Dakota	10 (2)	10:10	17	2.14	--	3.2 - 36
Savage mine, Montana	10 (2)	10:10	17	1.78	--	4.2 - 35
Velva mine, North Dakota	10 (2)	10:10	14	1.90	--	3 - 24
Big Sky mine, Montana	10 (2)	10:10	17	1.75	--	6.9 - 39
Utility mine, Saskatchewan	10 (2)	10:10	16	1.71	--	5.6 - 31
San Juan mine, New Mexico	11 (2)	12:12	11	1.33	1.11	6.6 - 17
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	11	1.15	1.18	8.2 - 13
Plants (dry-weight basis)						
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	1.2	1.34	--	0.096 - 1.7
Alkali sacaton	11 (2)	6:6	1.4	1.27	--	1.0 - 1.8

TABLE 32.—*Lead in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS				
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	12	1.63	1.22	4.8 - 26
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	19	1.38	1.15	15 - 100
B horizon	13 (1)	64:64	18	1.31	1.20	10 - 30
C horizon	13 (1)	64:64	17	1.29	1.11	10 - 30
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	48:48	17	1.24	1.19	10 - 30
Soil, 15- to 20-cm depth	20 (1)	48:48	17	1.45	1.19	10 - 100
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	7.7	1.55	1.39	2.8 - 12
C horizon	14 (2)	16:16	7.1	1.65	1.62	2.9 - 13
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	107:108	26	2.09	1.73	<3.3 - 56
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	16	1.54	1.43	5.1 - 41
C horizon	16 (2)	135:136	15	1.71	1.39	<1.2 - 47
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	8.6	1.44	1.35	3.1 - 16
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	12	1.35	1.55	6.0 - 25
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	13	1.28	1.14	7.8 - 21
C horizon	11 (2)	47:47	12	1.36	1.18	5.1 - 24
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	11	1.20	1.17	8.4 - 19
C horizon	24 (2)	30:30	9.7	1.29	1.22	6.0 - 18
		PLANTS				
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	0.88	1.80	1.27	0.40 - 8.0
Saltbush, fourwing, San Juan Basin	19 (2)	6:10	.52	1.37	1.14	<.41 - .78
Snakeweed, San Juan Basin	19 (2)	18:18	1.1	1.57	1.21	.58 - 3.0
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	110	1.64	1.17	30 - 200
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	59	1.55	1.30	<30 - 150
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	25:30	23	1.52	1.19	<20 - 50
Columbia Plateaus Province	23 (1)	25:30	23	1.55	1.19	<20 - 70
Basin and Range Province	23 (1)	14:30	17	1.51	1.19	<20 - 30
Northern Great Plains	23 (1)	18:20	21	1.47	1.18	<20 - 50
Northern Rocky Mountains Province	23 (1)	19:20	50	3.72	1.18	<20 - 700
Middle Rocky Mountains Province	23 (1)	16:20	21	1.73	1.18	<20 - 50
Southern Rocky Mountains Province	23 (1)	19:20	26	2.00	1.18	<20 - 70
Wyoming Basin Province	23 (1)	18:20	22	1.36	1.18	<20 - 30

TABLE 32.—*Lead in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANTS--Continued						
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry-weight basis)						
Wheatgrass, western----------------	18 (3)	21:21	0.63	1.96	--	0.20 - 2.4
Sagebrush, silver------------------	18 (3)	19:19	1.1	1.23	--	.80 - 1.8
Plant biomass, above-ground parts--	18 (3)	21:21	1.0	1.80	1.22	.43 - 4.0

TABLE 33.—*Lithium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	1 (3)	80:80	15	1.37	1.03	8.0 - 26
Shale------------------------------	1 (3)	80:80	31	1.78	1.09	14 - 210
Core samples						
Hanging Woman Creek, Mont.						
Sandstone--------------------------	2 (3)	24:24	12	1.73	1.31	3.4 - 2.3
Siltstone and shale----------------	2 (3)	24:24	35	1.37	1.09	20 - 56
Dark shale-------------------------	2 (3)	23:23	41	1.18	1.05	32 - 51
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (3)	50:50	32	1.24	1.03	18 - 54
Sandstone--------------------------	4 (3)	42:42	20	1.20	1.40	13 - 30
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)--------	5 (3)	71:74	35	2.24	1.13	<4.8 - 140
Middle 300 m-----------------------	5 (3)	53:53	65	1.75	1.05	13 - 190
Garden Gulch Member (lower 100 m)--	5 (3)	32:32	63	1.29	--	30 - 90
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (3)	60:60	19	1.19	1.03	10 - 29
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm----------------------------	7 (3)	18:18	12	2.05	1.23	6 - 34
100-200 μm-------------------------	7 (3)	24:24	11	1.48	1.23	6 - 34
63-100 μm--------------------------	7 (3)	24:24	12	1.35	1.23	8 - 35
<63 μm-----------------------------	7 (3)	24:24	18	1.25	1.23	13 - 39
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah-----------------	8 (3)	8:8	38	1.34	--	29 - 64
Cottonwood Creek, Utah-------------	8 (3)	8:8	23	1.18	--	17 - 30
Duck Creek, Colo.------------------	8 (3)	8:8	40	1.30	--	26 - 60
Ryan Gulch, Colo.------------------	8 (3)	8:8	31	1.30	--	21 - 44

TABLE 33.—*Lithium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (3)	10.10	24	1.20	--	16 - 29
Dave Johnston mine, Wyoming----------	10 (3)	10:10	20	1.22	--	14 - 25
Hidden Valley mine, Wyoming----------	10 (3)	10:10	28	1.28	--	18 - 39
Kincaid mine, North Dakota-----------	10 (3)	10:10	23	1.31	--	14 - 32
Savage mine, Montana-----------------	10 (3)	10:10	24	1.13	--	20 - 29
Velva mine North Dakota--------------	10 (3)	10:10	24	1.14	--	21 - 33
Big Sky mine, Montana----------------	10 (3)	10:10	29	1.30	--	21 - 55
Utility mine, Saskatchewan-----------	10 (3)	10:10	23	1.17	--	18 - 29
San Juan mine, New Mexico--------------	11 (3)	12:12	22	1.10	1.03	19 - 26
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (3)	12:12	17	1.11	1.03	16 - 22
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (3)	10:10	.8	1.41	1.18	.5 - 1.5
Dave Johnston mine, Wyoming--------	10 (3)	10:10	.9	1.45	1.18	.5 - 1.6
Hidden Valley mine, Wyoming--------	10 (3)	10:10	2.0	1.90	1.18	.8 - 7.0
Kincaid mine, North Dakota---------	10 (3)	10:10	1.6	1.38	1.18	.9 - 2.7
Savage mine, Montana---------------	10 (3)	10:10	.5	1.25	1.18	.4 - .7
Velva mine, North Dakota-----------	10 (3)	10:10	1.4	1.64	1.18	.8 - 3.7
White sweetclover						
Big Sky mine, Montana--------------	10 (3)	10:10	.4	1.37	1.18	.2 - .6
Utility mine, Saskatchewan---------	10 (3)	10:10	1.2	1.69	1.18	.6 - 2.3
Alfalfa						
Beulah North mine, North Dakota----	10 (3)	3:3	2.0	3.05	--	.6 - 4.3
Dave Johnston mine, Wyoming--------	10 (3)	3:3	.7	1.30	--	.6 - 1.0
Savage mine, Montana---------------	10 (3)	3:3	1.2	1.45	--	.9 - 1.8
Velva mine, North Dakota-----------	10 (3)	3:3	4.0	1.28	--	3.1 - 5.0
Big Sky mine, Montana--------------	10 (3)	2:3	.5	1.42	--	<.5 - .7
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (3)	20:20	1.3	1.87	1.11	.58 - 4.0
Growing near mine spoil----------	26 (3)	20:20	.82	1.92	1.11	.29 - 1.8
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (3)	6:6	1.7	1.47	--	1.1 - 2.5
Alkali sacaton-----------------------	11 (3)	6:6	.29	1.72	--	.16 - .46
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (3)	30:30	37	1.64	1.04	15 - 85
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (3)	63:64	22	1.55	1.09	<10 - 43
B horizon------------------------------	13 (3)	62:64	25	1.53	1.08	<10 - 46
C horizon------------------------------	13 (3)	61:64	25	1.66	1.07	<10 - 44
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (3)	48:48	21	1.36	1.07	11 - 35
Soil, 15- to 20-cm depth---------------	20 (3)	48:48	24	1.33	1.07	14 - 47

TABLE 33.—*Lithium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Hanging Woman Creek, Mont.						
A horizon	14 (3)	16:16	25	1.16	1.03	20 - 30
C horizon	14 (3)	16:16	24	1.24	1.04	13 - 31
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (3)	108:108	34	1.55	1.10	16 - 140
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (3)	136:136	19	1.40	1.06	7.0 - 40
C horizon	16 (3)	134:136	21	1.48	1.13	<5.0 - 110
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (3)	36:36	18	1.31	1.11	10 - 32
Wind River Basin, Wyo., 0- to 40-cm depth	17 (3)	36:36	15	1.49	1.08	8.0 - 40
San Juan Basin, N. Mex.						
A horizon	11 (3)	47:47	12	1.58	1.21	5.0 - 31
C horizon	11 (3)	47:47	13	1.70	1.29	5.0 - 32
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (3)	30:30	13	1.13	1.07	11 - 18
C horizon	24 (3)	30:30	12	1.37	1.12	5.0 - 25
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Oats	21 (3)	6:21	0.10	1.48	--	<0.11 - 0.21
Wheat, durum	21 (3)	8:20	.035	2.13	--	<.060 - .16
Wheat, hard red spring	21 (3)	16:54	.037	3.16	1.56	<.068 - .32
Wheat, hard red winter	21 (3)	1:17	<.068	--	--	<.068 - .068
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (3)	21:25	.36	1.42	1.11	<.22 - .77
Saltbush, fourwing, San Juan Basin	19 (3)	5:10	.45	1.58	1.15	<.42 - .92
Snakeweed, San Juan Basin	19 (3)	18:18	.63	1.73	1.18	.26 - 1.4
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (3)	29:29	6.3	1.44	1.14	4 - 12
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (3)	41:41	10	1.78	1.18	2 - 48
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	29:30	10	2.60	1.17	<4 - 114
Columbia Plateaus Province	23 (3)	29:30	8.4	1.97	1.17	<4 - 24
Basin and Range Province	23 (3)	26:30	13	2.64	1.17	<4 - 160
Northern Great Plains	23 (3)	20:20	16	2.56	1.25	4 - 59
Northern Rocky Mountains Province	23 (3)	16:20	5.9	1.86	1.25	<4 - 14
Middle Rocky Mountains Province	23 (3)	17:20	6.8	2.37	1.25	<4 - 17
Southern Rocky Mountains Province	23 (3)	13:20	4.8	3.38	1.25	<4 - 33
Wyoming Basin Province	23 (3)	20:20	12	1.99	1.25	4 - 26

TABLE 34.—*Magnesium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (3)	80:80	1.1	3.5	<1.12	0.60 - 3.9
Shale	1 (3)	80:80	1.4	2.63	1.10	.060 - 3.3
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (3)	24:24	1.6	2.19	--	.29 - 5.1
Siltstone and shale	2 (3)	24:24	1.2	1.46	--	.67 - 1.8
Dark shale	2 (3)	23:23	.94	1.33	--	.48 - 1.3
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (3)	50:50	1.4	1.55	1.02	.47 - 2.9
Sandstone	4 (3)	42:42	1.1	2.00	1.02	.19 - 3.0
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (3)	74:74	2.9	1.45	1.06	.32 - 5.4
Middle 300 m	5 (3)	53:53	4.2	1.44	1.05	1.1 - 7.8
Garden Gulch Member (lower 100 m)	5 (3)	32:32	2.2	1.77	--	.45 - 7.2
STREAM SEDIMENTS						
Northern Great Plains regional study						
First-order streams	6 (3)	20:20	0.98	1.27	<1.02	0.61 - 1.6
Second-order streams	6 (3)	20:20	1.2	1.44	<1.04	.59 - 2.2
Third-order streams	6 (3)	20:20	.98	1.45	<1.04	.48 - 1.5
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (3)	18:18	0.61	2.52	1.18	.22 - 2.8
100-200 µm	7 (3)	24:24	.60	1.51	1.08	.35 - 1.9
63-100 µm	7 (3)	24:24	1.1	1.22	1.06	.72 - 2.0
<63 µm	7 (3)	24:24	1.8	1.08	1.03	1.6 - 2.4
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (3)	8:8	1.2	1.33	--	.98 - 2.1
Cottonwood Creek, Utah	8 (3)	8:8	.62	1.28	--	.40 - .93
Duck Creek, Colo.	8 (3)	8:8	1.0	1.19	--	.83 - 1.3
Ryan Gulch, Colo.	8 (3)	8:8	.67	1.28	--	.53 - 1.1
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	1.4	1.23	1.12	.7 - 1.5
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10.10	1.3	1.27	--	0.78 - 1.6

TABLE 34.—*Magnesium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Dave Johnston mine, Wyoming----------	10 (5)	10:10	0.36	1.44	--	0.14 - 0.49
Hidden Valley mine, Wyoming----------	10 (5)	10:10	.43	1.51	--	.25 - .99
Kincaid mine, North Dakota-----------	10 (5)	10:10	1.4	1.17	--	1.1 - 1.7
Savage mine Montana------------------	10 (5)	10:10	2.1	1.16	--	1.7 - 2.8
Velva mine, North Dakota-------------	10 (5)	10:10	1.3	1.10	--	1.1 - 1.6
Big Sky mine, Montana----------------	10 (5)	10:10	1.3	1.23	--	.81 - 1.7
Utility mine, Saskatchewan-----------	10 (5)	10:10	1.4	1.34	--	.94 - 2.7
San Juan mine, New Mexico-------------	11 (5)	12:12	.56	1.13	1.01	.45 - .67
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (5)	12:12	.42	1.05	1.01	.40 - .46
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (2)	10:10	.89	1.21	1.17	.70 - 1.13
Dave Johnston mine, Wyoming--------	10 (2)	10:10	.47	1.52	1.17	.26 - 1.01
Hidden Valley mine, Wyoming--------	10 (2)	10:10	.68	1.37	1.17	.45 - 1.18
Kincaid mine, North Dakota---------	10 (2)	10:10	.55	1.57	1.17	.22 - .94
Savage mine, Montana---------------	10 (2)	10.10	.46	1.47	1.17	.22 - .85
Velva mine, North Dakota-----------	10 (5)	10:10	.65	1.27	1.17	.46 - 1.06
White sweetclover						
Big Sky mine, Montana--------------	10 (2)	10:10	.57	1.62	1.17	.22 - 1.00
Utility mine, Saskatchewan---------	10 (2)	10:10	.38	1.48	1.17	.18 - .57
Alfalfa						
Beulah North mine, North Dakota----	10 (2)	3:3	.52	2.03	--	.25 - 1.04
Dave Johnston mine, Wyoming--------	10 (2)	3:3	.30	1.24	--	.25 - .37
Savage mine, Montana---------------	10 (2)	3:3	.53	1.31	--	.39 - .66
Velva mine, North Dakota-----------	10 (2)	3:3	.34	1.27	--	.27 - .43
Big Sky mine, Montana--------------	10 (2)	3:3	.42	1.35	--	.32 - .58
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (2)	20:20	.11	1.19	1.17	.08 - .17
Growing near mine spoil----------	26 (2)	20:20	.12	1.25	1.17	.08 - .17
San Juan mine, New Mexico						
Fourwing saltbush---------------------	11 (3)	6:6	.72	1.13	--	.061 - .84
Alkali sacaton------------------------	11 (3)	6:6	.10	1.23	--	.082 - .12
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial,						
0- to 40-cm depth--------------------	12 (3)	30:30	1.4	1.63	1.01	0.45 - 3.9
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (3)	64:64	.54	1.87	1.03	.14 - 1.5
B horizon------------------------------	13 (3)	64:64	.67	1.72	1.02	.20 - 1.7
C horizon------------------------------	13 (3)	64:64	.83	1.90	1.07	.13 - 1.7
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (3)	16:16	*1.1	*.30	*.014	.58 - 1.6
C horizon------------------------------	14 (3)	16:16	*1.3	*.49	*.020	.47 - 2.2

TABLE 34.—*Magnesium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (5)	108:108	1.9	1.48	1.14	0.51 - 2.7
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
C horizon	16 (5)	88:88	1.2	1.81	1.01	.21 - 3.5
Glaciated area						
C horizon	16 (5)	48:48	1.6	1.50	1.01	.39 - 2.6
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	136:136	.66	1.67	1.02	.18 - 2.7
C horizon	16 (5)	136.136	1.3	1.73	1.01	.21 - 3.5
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	.86	1.41	1.04	.38 - 2.6
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	.63	1.54	1.05	.32 - 1.6
San Juan Basin, N. Mex.						
A horizon	11 (5)	47:47	.33	1.64	1.03	.11 - .82
C horizon	11 (5)	47:47	.37	1.77	1.04	.096 - .97
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	30:30	.25	1.29	1.05	.17 - .44
C horizon	24 (5)	30:30	.23	1.58	1.02	.11 - .72
PLANTS						
Cultivated plants northern Great Plains (dry-weight basis)						
Barley	21 (3)	18:18	0.12	1.13	1.05	0.10 - 0.16
Oats	21 (3)	21:21	.13	1.10	1.08	.10 - .16
Wheat, durum	21 (3)	20:20	.14	1.14	1.13	.12 - .19
Wheat, hard red spring	21 (3)	54:54	.15	1.19	1.10	.11 - .27
Wheat, hard red winter	21 (3)	17.17	.14	1.09	1.05	.12 - .16
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (3)	25:25	.063	1.57	1.05	.027 - .14
Saltbush, fourwing, San Juan Basin	19 (3)	10:10	.58	1.31	1.03	.36 - .78
Snakeweed, San Juan Basin	19 (3)	18:18	.14	1.40	1.03	.067 - .36
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	.64	1.30	1.10	.3 - 1
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	30:30	3.2	1.29	1.08	2.2 - 5.8
Columbia Plateaus Province	23 (3)	30:30	2.6	1.28	1.08	1.7 - 4.6
Basin and Range Province	23 (3)	30:30	3.0	1.21	1.08	2.2 - 4.0
Northern Great Plains	23 (3)	20:20	3.6	1.43	1.11	2.2 - 6.0
Northern Rocky Mountains Province	23 (3)	20:20	3.2	1.27	1.11	1.8 - 4.0
Middle Rocky Mountains Province	23 (3)	20:20	2.7	1.40	1.11	1.8 - 4.8
Southern Rocky Mountains Province	23 (3)	20:20	2.6	1.34	1.11	1.8 - 3.3
Wyoming Basin Province	23 (3)	20:20	3.2	1.27	1.11	2.4 - 4.6
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry weight basis)						
Wheatgrass, western	18 (3)	21:21	.07	1.36	--	.04 - .14
Sagebrush, silver	18 (3)	19:19	.22	1.30	--	.14 - .33
Plant biomass, above-ground parts	18 (3)	21:21	.11	1.75	1.06	.05 - .49

TABLE 35.—*Manganese in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	79:80	280	3.55	1.20	18 - >4,600
Shale	1 (2)	80:80	320	3.90	1.27	46 - 2,700
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	17:24	450	1.54	1.41	260 - 1,000
Siltstone and shale	2 (2)	15:24	450	1.76	1.17	250 - 1,300
Dark shale	2 (2)	11:23	400	2.10	1.29	200 - 1,700
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	300	2.55	1.23	2,500 - 4,700
Sandstone	4 (2)	42:42	233	1.60	1.08	89 - 970
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	310	1.35	1.20	190 - 780
Middle 300 m	5 (2)	53:53	220	1.44	1.33	64 - 420
Garden Gulch Member (lower 100 m)	5 (2)	264:264	280	1.31	--	100 - 700
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	440	1.60	1.18	170 - 2,900
Powder River Basin, Wyo. and Mont. Size fractions						
200 µm	7 (1)	24:24	310	1.63	1.50	200 - 700
100-200 µm	7 (1)	24:24	220	1.38	1.12	150 - 300
63-100 µm	7 (1)	24:24	220	1.32	<1.01	150 - 500
<63 µm	7 (1)	24:24	300	1.49	1.15	200 - 700
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (2)	8:8	520	1.07	--	480 - 580
Cottonwood Creek, Utah	8 (2)	8:8	580	1.23	--	460 - 800
Duck Creek, Colo.	8 (2)	8:8	610	1.15	--	460 - 690
Ryan Gulch, Colo.	8 (2)	8:8	480	1.19	--	390 - 590
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	260	1.38	1.15	150 - 500
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	9:10	340	1.83	--	<110 - 790
Dave Johnston mine, Wyoming	10 (2)	1:10	--	--	--	<110 - 200
Hidden Valley mine, Wyoming	10 (2)	6:10	210	2.30	--	<100 - 1,000
Kincaid mine, North Dakota	10 (2)	10:10	390	1.27	--	310 - 560
Savage mine, Montana	10 (2)	6:10	220	2.19	--	<110 - 1,300
Velva mine, North Dakota	10 (2)	10:10	260	1.20	--	200 - 340
Big Sky mine, Montana	10 (2)	7:10	190	1.49	--	<100 - 290
Utility mine, Saskatchewan	10 (2)	9:10	240	1.57	--	<110 - 410

TABLE 35.—*Manganese in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
San Juan mine, New Mexico	11 (2)	12:12	340	1.32	1.12	190 - 430
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	260	1.36	1.26	190 - 430
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	18	1.28	1.16	11 -26
Dave Johnston mine, Wyoming	10 (2)	10:10	27	1.29	1.16	18 - 40
Hidden Valley mine, Wyoming	10 (2)	10:10	29	1.64	1.16	15 - 66
Kincaid mine, North Dakota	10 (2)	10:10	25	1.45	1.16	13 - 50
Savage mine, Montana	10 (2)	10:10	17	1.30	1.16	12 - 24
Velva mine, North Dakota	10 (2)	10:10	26	1.35	1.16	18 - 50
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	23	1.23	1.16	16 - 29
Utility mine, Saskatchewan	10 (2)	10:10	17	1.35	1.16	11 - 24
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	32	1.64	--	22 - 57
Dave Johnston mine, Wyoming	10 (2)	3:3	27	1.37	--	19 - 35
Savage mine, Montana	10 (2)	3:3	45	1.67	--	27 - 74
Velva mine, North Dakota	10 (2)	3:3	25	1.93	--	14 - 52
Big Sky mine, Montana	10 (2)	3:3	30	1.83	--	15 - 45
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	39	1.53	1.23	23 - 140
Growing near mine spoil	26 (2)	20:20	16	1.51	1.23	5.6 - 36
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	160	1.59	--	90 - 240
Alkali sacaton	11 (2)	6:6	50	1.51	--	31 - 74
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	450	1.28	1.25	190 - 740
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	250	1.86	1.18	100 - 1,500
B horizon	13 (1)	64:64	220	1.75	1.42	70 - 1,000
C horizon	13 (1)	64:64	195	2.06	1.13	30 - 1,000
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	48:48	250	1.63	<1.02	70 - 1,000
Soil, 15- to 20-cm depth	20 (1)	48:48	230	1.56	<1.02	100 - 700
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	510	1.36	1.31	330 - 1,100
C horizon	14 (2)	16:16	510	1.59	1.17	250 - 1,300
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	480	1.65	1.60	82 - 1,200
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon	16 (5)	63:88	330	2.76	1.81	<200 - 3,800
C horizon	16 (5)	45:88	180	4.20	1.79	<200 - 3,100

TABLE 35.—*Manganese in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana--Continued						
Glaciated area						
A horizon	16 (5)	46:48	720	1.83	1.81	<200 - 2,200
C horizon	16 (5)	39:48	440	2.37	1.79	<200 - 2,200
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	109:136	460	2.38	1.81	<200 - 3,800
C horizon	16 (5)	84:136	300	2.96	1.79	<200 - 3,100
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	400	1.38	1.11	140 - 710
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	330	1.43	1.15	140 - 700
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	230	1.76	1.20	73 - 1,700
C horizon	11 (2)	47:47	180	1.76	1.25	33 - 510
Sheppard-Shiprock-Doak Soil Association, N Mex.						
A horizon	24 (2)	30:30	240	1.42	1.28	120 - 470
C horizon	24 (2)	30:30	220	1.63	1.37	81 - 1,100
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	85	1.76	1.25	22 - 200
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	71	1.60	1.21	29 - 160
Snakeweed, San Juan Basin	19 (2)	18:18	50	1.29	1.11	28 - 83
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	270	1.67	1.17	100 - 500
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	480	1.52	1.18	300 - 1,500
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	30:30	700	1.84	1.22	200 - 1,500
Columbia Plateaus Province	23 (1)	30:30	850	1.45	1.22	500 - 1,500
Basin and Range Province	23 (1)	30:30	800	1.85	1.22	150 - 1,500
Northern Great Plains	23 (1)	20:20	780	1.75	1.15	300 - 2,000
Northern Rocky Mountains Province	23 (1)	20:20	1,300	2.44	1.15	500 - 7,000
Middle Rocky Mountains Province	23 (1)	20:20	680	1.91	1.15	200 - 1,500
Southern Rocky Mountains Province	23 (1)	20:20	840	1.82	1.15	300 - 2,000
Wyoming Basin Province	23 (1)	20:20	760	1.83	1.15	300 - 1,500
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry weight basis)						
Wheatgrass, western	18 (3)	21:21	19	1.51	--	7.2 - 35
Sagebrush, silver	18 (3)	19:19	38	1.46	--	15 - 69
Plant biomass, above-ground parts	18 (3)	21:21	25	1.43	1.04	9.4 - 55

TABLE 36.—*Mercury in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (4)	80:80	0.032	1.80	1.24	0.010 - 0.17
Shale	1 (4)	80:80	.060	2.02	1.10	.020 - .48
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (4)	24:24	.031	1.62	1.37	.020 - .10
Siltstone and shale	2 (4)	24:24	.063	1.25	1.15	.040 - .090
Dark shale	2 (4)	23:23	.11	1.92	1.09	.040 - .44
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (4)	50:50	.10	1.55	1.11	.030 - .24
Sandstone	4 (4)	42:42	.08	1.90	1.12	.01 - .24
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (4)	74:74	.11	1.36	1.15	.030 - .23
Middle 300 m	5 (4)	51:51	.10	1.34	1.17	.05 - .21
Garden Gulch Member (lower 100 m)	5 (4)	32:32	.088	1.43	--	.040 - .21
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (4)	60:60	0.055	1.34	1.19	0.03 - 0.12
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (4)	17:17	.041	4.16	1.24	.01 - .19
100-200 µm	7 (4)	24:24	.019	1.83	1.24	.01 - .07
63-100 µm	7 (4)	24:24	.019	1.77	1.24	.01 - .06
<63 µm	7 (4)	24:24	.030	1.42	1.24	.02 - .07
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (4)	9:10	0.055	2.19	--	<0.010 - 0.120
Dave Johnston mine, Wyoming	10 (4)	10:10	.034	1.55	-	.020 - .070
Hidden Valley mine, Wyoming	10 (4)	10:10	.074	1.53	--	.040 - .130
Kincaid mine, North Dakota	10 (4)	10:10	.058	1.58	--	.020 - .100
Savage mine, Montana	10 (4)	10:10	.052	1.43	--	.030 - .090
Velva mine, North Dakota	10 (4)	10:10	.046	1.12	--	.040 - .050
Big Sky mine, Montana	10 (4)	10:10	.055	1.93	--	.010 - .120
Utility mine, Saskatchewan	10 (4)	10:10	.062	1.61	--	.040 - .190
San Juan mine, New Mexico	11 (4)	12:12	.030	1.80	1.16	.020 - .090
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (4)	12:12	.010	2.01	1.22	.010 - .060

TABLE 36.—*Mercury in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (4)	10:10	0.011	1.25	1.22	0.01 - 0.02
Dave Johnston mine, Wyoming--------	10 (4)	9:10	.010	1.00	1.22	<.07 - .01
Hidden Valley mine, Wyoming--------	10 (4)	10:10	.015	1.53	1.22	.01 - .03
Kincaid mine, North Dakota---------	10 (4)	10:10	.015	1.43	1.22	.01 - .02
Savage mine, Montana---------------	10 (4)	10:10	.012	1.40	1.22	.01 - .02
Velva mine, North Dakota-----------	10 (4)	10:10	.010	1.00	1.22	--
White sweetclover						
Big Sky mine, Montana--------------	10 (4)	10:10	.010	1.00	1.22	--
Utility mine, Saskatchewan---------	10 (4)	8:10	.010	1.00	1.22	<.01 - .01
Alfalfa						
Beulah North mine, North Dakota----	10 (4)	3:3	.013	1.49	--	.01 - .02
Dave Johnston mine, Wyoming--------	10 (4)	1:3	<.01	--	--	<.01 - .02
Savage mine, North Dakota----------	10 (4)	2:3	.015	1.60	--	<.01 - .02
Velva mine, North Dakota-----------	10 (4)	2:3	.010	1.00	--	<.01 - .01
Big Sky mine, Montana--------------	10 (4)	3:3	.013	1.49	--	.01 - .02
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (4)	20:20	.011	1.29	1.28	.01 - .02
Growing near mine spoil----------	26 (4)	20:20	.011	1.33	1.28	.01 - .02
San Juan mine, New Mexico						
Fourwing saltbush---------------------	11 (4)	6:6	.13	1.58	--	.080 - .20
Alkali sacaton------------------------	11 (4)	6:6	.20	1.31	--	.15 - .25
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth---	12 (4)	30:30	0.027	1.31	1.24	0.02 - 0.05
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (4)	64:64	.021	1.61	1.35	.01 - .07
B horizon------------------------------	13 (4)	63:64	.022	1.80	1.23	<.01 - .09
C horizon------------------------------	13 (4)	64:64	.025	1.80	1.20	.01 - .16
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (4)	48:48	.020	1.43	1.29	.01 - .04
Soil, 15- to 20-cm depth---------------	20 (4)	48:48	.023	1.41	1.37	.01 - .04
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (4)	16:16	.027	1.28	1.24	.02 - .04
C horizon------------------------------	14 (4)	16:16	.030	1.46	1.26	.01 - .04
Piceance Creek Basin, Colorado, 0- to 5-cm depth------------------------------	15 (4)	108:108	.041	2.53	1.47	.01 - .22
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (4)	87:88	.021	1.48	1.05	<.010 - .050
Glaciated area						
A horizon--------------------------	16 (4)	48:48	.026	1.40	1.05	.010 - .070
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (4)	135:136	.023	1.68	1.05	<.010 - .07
C horizon------------------------	16 (4)	136:136	.027	1.74	1.12	.010 - .23

TABLE 36.—*Mercury in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Big Horn Basin, Wyo., 0- to 40-cm depth-	17 (4)	36:36	0.026	1.33	1.16	0.020 - 0.050
Wind River Basin, Wyo., 0- to 40-cm depth-----------------------------------	17 (4)	35:36	.020	1.45	1.28	<.010 - .030
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (4)	47:47	.020	1.49	1.56	.010 - .060
C horizon-------------------------------	11 (4)	46:47	.020	1.85	1.35	<.010 - .060
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon-----------------------------	24 (4)	29:30	.020	1.55	1.46	<.010 - .030
C horizon-----------------------------	24 (4)	25:30	.020	1.72	1.91	<.010 - .040
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (4)	25:25	0.25	1.44	1.13	0.15 - 0.50
Saltbush, fourwing, San Juan Basin-----	19 (4)	10:10	.11	1.61	1.17	.050 - .20
Snakeweed, San Juan Basin--------------	19 (4)	18:18	.19	1.51	1.15	.10 - .45
Native species (dry-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (3)	29:29	.098	1.20	1.07	.07 - .13
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (4)	30:30	.027	1.51	1.21	.02 - .04
Columbia Plateaus Province-----------	23 (4)	30:30	.032	1.40	1.21	.02 - .05
Basin and Range Province-------------	23 (4)	30:30	.030	1.35	1.21	.02 - .05
Northern Great Plains----------------	23 (4)	20:20	.025	1.48	1.34	.02 - .06
Northern Rocky Mountains Province----	23 (4)	20:20	.024	1.46	1.34	.02 - .05
Middle Rocky Mountains Province------	23 (4)	20:20	.021	1.61	1.34	.01 - .03
Southern Rocky Mountains Province----	23 (4)	20:20	.020	1.41	1.34	.01 - .03
Wyoming Basin Province---------------	23 (4)	20:20	.023	1.30	1.34	.02 - .03

TABLE 37.—*Molybdenum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (-) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone---------------------------	1 (2)	77:80	5.0	2.19	1.35	<1.4 - 21
Shale-------------------------------	1 (2)	80:80	8.1	2.16	1.28	1.2 - 26
Core samples						
Hanging Woman Creek, Mont.						
Sandstone----------------------------	2 (2)	24:24	5.0	1.82	1.36	2.0 - 13
Siltstone and shale------------------	2 (2)	24:24	8.7	1.32	1.30	5.2 - 14
Dark shale---------------------------	2 (2)	23:23	8.5	1.77	1.20	1.1 - 19

TABLE 37.—*Molybdenum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Core samples--Continued						
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (2)	50:50	6.1	1.64	1.82	2.2 - 13
Sandstone--------------------------	4 (2)	40:42	1.8	1.60	1.65	<1.0 - 7.2
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)--------	5 (2)	74:74	14	1.68	1.33	3.5 - 44
Middle 300 m-----------------------	5 (2)	52:53	8.7	1.79	1.28	<2 - 27
Garden Gulch Member (lower 100 m)--	5 (2)	243:264	19	1.97	--	<7 - 70
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (2)	54:60	4.8	1.96	1.79	<2.2 - 11
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (2)	10:10	5.5	1.69	--	2.1 - 9.3
Dave Johnston mine, Wyoming----------	10 (2)	7:10	2.0	2.17	--	<.56 - 6.2
Hidden Valley mine, Wyoming----------	10 (2)	10:10	3.8	1.73	--	1.1 - 7.8
Kincaid mine, North Dakota-----------	10 (2)	10:10	4.9	1.75	--	1.9 - 11
Ssvage mine, Montana-----------------	10 (2)	8:10	3.2	2.32	--	<.8 - 9.9
Velva mine, North Dakota-------------	10 (2)	10:10	4.4	1.30	--	2.5 - 6.1
Big Sky mine, Montana----------------	10 (2)	10:10	4.6	1.32	--	2.5 - 6.5
Utility mine, Saskatchewan-----------	10 (2)	10:10	4.1	1.56	--	2.2 - 7.6
San Juan mine, New Mexico--------------	11 (2)	12:12	2.7	1.13	1.11	2.1 - 3.2
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (2)	12:12	1.8	1.29	1.12	1.3 - 2.8
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (2)	10:10	2.6	1.60	1.15	1.2 - 8.3
Dave Johnston mine, Wyoming--------	10 (2)	10:10	3.1	2.18	1.15	1.5 - 14.0
Hidden Valley mine, Wyoming--------	10 (2)	10:10	3.4	1.68	1.15	1.9 - 9.5
Kincaid mine, North Dakota---------	10 (2)	10:10	6.5	1.84	1.15	2.8 - 18.0
Savage mine, Montana---------------	10 (2)	10:10	6.4	1.30	1.15	4.8 - 10.4
Velva mine, North Dakota-----------	10 (2)	10:10	7.9	1.25	1.15	5.3 - 11.8
White sweetclover						
Big Sky mine, Montana--------------	10 (2)	10:10	13	1.23	1.15	10 - 20
Utility mine, Saskatchewan---------	10 (2)	10:10	11	1.33	1.15	6.4 - 15.9
Alfalfa						
Beulah North mine, North Dakota----	10 (2)	3:3	2.8	1.52	--	2.2 - 4.5
Dave Johnston mine, Wyoming--------	10 (2)	3:3	4.3	1.30	--	3.5 - 5.8
Savage mine, Montana---------------	10 (2)	3:3	7.4	2.06	--	4.4 - 17.0
Velva mine, North Dakota-----------	10 (2)	3:3	5.0	1.54	--	3.1 - 7.1
Big Sky mine, Montana--------------	10 (2)	3:3	8.5	1.30	--	6.4 - 10.8
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (2)	12:20	.43	1.37	1.21	<.39 - .84
Growing near mine spoil----------	26 (2)	8:20	.39	1.24	1.21	<.38 - .58

TABLE 37.—*Molybdenum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)--Continued						
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	0.73	1.57	--	0.53 - 1.3
Alkali sacaton	11 (2)	6:6	.70	1.29	--	.48 - .90
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	5.7	1.45	1.23	2.6 - 10
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	15:64	.86	1.42	--	<2 - 7
B horizon	13 (1)	21:64	1.3	1.45	--	<2 - 7
C horizon	13 (1)	16:64	.81	1.60	--	<2 - 15
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	3:48	<3	--	--	<3 - 20
Soil, 15- to 20-cm depth	20 (1)	3:48	<3	--	--	<3 - 20
Hanging Woman Creek, Mont.						
A horizon	14 (2)	15:16	5.7	1.59	1.43	<3.3 - 10
C horizon	14 (2)	16:16	5.2	1.60	1.60	2.1 - 9.4
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	102:108	5.4	2.05	1.51	<1.04 - 14
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	118:136	3.8	1.68	1.57	<1.0 - 12
C horizon	16 (2)	120:136	4.0	1.72	1.90	<1.1 - 18
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	35:36	4.8	1.47	1.24	<2.2 - 11
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	35:36	4.7	1.55	1.23	<2.2 - 11
San Juan Basin, N. Mex.						
A horizon	11 (2)	31:47	1.2	1.71	1.37	<1.0 - 6.5
C horizon	11 (2)	47:47	1.4	1.57	1.36	1.0 - 3.6
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	13:30	.98	1.21	--	<1.0 - 1.4
C horizon	24 (2)	12:30	.86	1.81	--	<1.0 - 3.4
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (6)	18:18	0.92	1.46	1.22	0.58 - 2.4
Oats	21 (6)	21:21	.88	1.56	1.24	.28 - 1.9
Wheat, durum	21 (6)	20:20	.48	1.46	1.31	.22 - .88
Wheat, hard red spring	21 (6)	54:54	.49	1.72	1.22	.08 - 1.1
Wheat, hard red winter	21 (6)	17:17	.64	1.33	1.11	.4 - 1.1
Native species (dry-weight basis)						
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	.49	1.64	1.13	.24 - 1.5
Snakeweed, San Juan Basin	19 (2)	18:18	.54	1.27	1.06	.38 - .99

TABLE 37.—*Molybdenum in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia- tion	Error	Observed range (ppm)
PLANTS--Continued						
Native species (ash-weight basis)						
Sagebrush, big; Powder River Basin, Wyo. and Mont.------------------------	20 (1)	41:41	10	1.51	1.23	<7 - 30
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (6)	30:30	16	1.58	1.46	10 - 30
Columbia Plateaus Province-----------	23 (6)	30:30	16	2.21	1.46	4 - 50
Basin and Range Province-------------	23 (6)	30:30	21	1.80	1.46	10 - 80
Northern Great Plains Province-------	23 (6)	20:20	12	1.89	1.29	4 - 20
Northern Rocky Mountains-------------	23 (6)	20:20	13	1.98	1.29	4 - 20
Middle Rocky Mountains Province------	23 (6)	20:20	10	2.17	1.29	4 - 30
Southern Rocky Mountains Province----	23 (6)	20:20	11	1.71	1.29	4 - 30
Wyoming Basin Province---------------	23 (6)	20:20	10	2.11	1.29	10 - 40

TABLE 38.—*Neodymium in rocks, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia- tion	Error	Observed range (ppm)
ROCKS						
Core samples						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	4 (2)	35:42	69	1.60	1.30	<46 - 140
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
San Juan mine, New Mexico-------------	11 (2)	5:12	41	1.79	--	<46 - 98
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (2)	2:12	--	--	--	<46 - 53
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (2)	4:30	<53	--	--	<53 - 74
Powder River Basin, Wyo. and Mont.						
A horizon-----------------------------	13 (1)	17:64	45	1.16	--	<70 - 100
B horizon-----------------------------	13 (1)	13:63	44	--	--	<70 - 70
C horizon-----------------------------	13 (1)	11:62	42	--	--	<70 - 70
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon-----------------------	16 (2)	11:136	--	--	--	<46 - 140
C horizon-----------------------	16 (2)	4:136	--	--	--	<46 - 72

TABLE 38.—*Neodymium in rocks, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	1:36	--	--	--	<220 - 340
San Juan Basin, N. Mex.						
A horizon	11 (2)	6:47	--	--	--	<46 - 79
C horizon	11 (2)	9:47	--	--	--	<46 - 100
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	2:30	--	--	--	<46 - 100
C horizon	24 (2)	5:30	24	1.98	--	<46 - 85

TABLE 39.—*Nickel in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	79:80	16	2.65	1.15	<1.0 - 66
Shale	1 (2)	80:80	31	1.89	1.15	9.1 - 150
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	25	2.20	1.14	5.9 - 70
Siltstone and shale	2 (2)	24:24	49	1.27	1.09	33 - 68
Dark shale	2 (2)	23:23	59	1.23	1.08	37 - 78
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	49:50	30	1.72	1.11	<8.3 - 94
Sandstone	4 (2)	42:42	26	1.60	1.07	10 - 80
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	26	1.26	1.15	14 - 47
Middle 300 m	5 (2)	53:53	25	2.42	1.18	1.5 - 190
Garden Gulch Member (lower 100 m)	5 (2)	264:264	29	1.33	--	15 - 70
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	24	1.38	1.17	10 - 45
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 µm	7 (1)	24:24	13	2.12	1.70	3 - 50
100-200 µm	7 (1)	24:24	6	1.62	1.33	3 - 15
63-100 µm	7 (1)	24:24	6	1.45	1.37	3 - 15
<63 µm	7 (1)	24:24	13	1.42	1.37	10 - 30

TABLE 39.—*Nickel in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
			STREAM SEDIMENTS--Continued			
Uinta and Piceance Creek Basins, Colo. and Utah	8 (2)	32:32	43	1.76	1.63	10 - 170
Piceance Creek Basin, Colo.						
Roan Creek	9 (1)	16:16	15	1.07	1.07	15 - 20
Black Sulphur Creek	9 (1)	16:16	18	1.20	1.07	15 - 30
			MINE SPOIL AND ASSOCIATED MATERIALS			
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	31	1.28	--	22 - 42
Dave Johnston mine, Wyoming	10 (2)	10:10	15	1.46	--	8.0 - 24
Hidden Valley mine, Wyoming	10 (2)	10:10	16	1.62	--	4.6 - 25
Kincaid mine, North Dakota	10 (2)	10:10	24	1.53	--	10 - 42
Savage mine, Montana	10 (2)	10:10	18	1.34	--	11 - 28
Velva mine, North Dakota	10 (2)	10:10	21	1.27	--	15 - 29
Big Sky mine, Montana	10 (2)	10:10	14	1.42	--	8.6 - 22
Utility mine, Saskatchewan	10 (2)	10:10	20	1.38	--	11 - 29
San Juan mine, New Mexico	11 (2)	12:12	12	1.18	1.06	9.4 - 16
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	8.6	1.14	1.06	7.1 - 11
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	3.4	1.32	1.10	2.2 - 5.1
Dave Johnston mine, Wyoming	10 (2)	10:10	4.1	2.03	1.10	1.4 - 11.1
Hidden Valley mine, Wyoming	10 (2)	10:10	4.1	1.74	1.10	1.5 - 7.7
Kincaid mine, North Dakota	10 (2)	10:10	2.2	1.54	1.10	.9 - 4.0
Savage mine, Montana	10 (2)	10:10	2.8	1.58	1.10	1.7 - 6.9
Velva mine, North Dakota	10 (2)	10:10	2.2	1.52	1.10	.9 - 3.8
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	3.4	1.66	1.10	1.3 - 6.2
Utility mine, Saskatchewan	10 (2)	10:10	1.0	1.59	1.10	.6 - 2.3
Alfalfa						
Beulah North mine, North Dakota	10 (2)	10:10	1.6	2.55	--	.6 - 3.4
Dave Johnston mine, Wyoming	10 (2)	10:10	1.9	1.28	--	1.4 - 2.3
Savage mine, Montana	10 (2)	10:10	1.9	1.10	--	1.8 - 2.1
Velva mine, North Dakota	10 (2)	10:10	1.7	1.25	--	1.4 - 2.2
Big Sky mine, Montana	10 (2)	10:10	1.2	1.55	--	.8 - 1.8
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	1.9	1.62	--	1.1 - 3.4
Alkali sacaton	11 (2)	6:6	.71	1.33	--	.49 - 1.1
			SOILS			
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	20	1.42	1.19	8.9 - 35
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	15	1.81	1.38	5 - 50
B horizon	13 (1)	64:64	17	1.78	1.30	7 - 70
C horizon	13 (1)	64:64	17	2.05	1.38	5 - 70

TABLE 39.—*Nickel in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	46:48	14	1.48	1.23	<5 - 30
Soil, 15- to 20-cm depth	20 (1)	47:48	15	1.61	1.23	<7 - 50
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	31	1.40	1.13	14 - 52
C horizon	14 (2)	16:16	29	1.55	1.27	13 - 56
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	107:108	21	1.83	1.39	<3.4 - 42
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
C horizon	16 (2)	88:88	18	1.67	1.24	4.1 - 54
Glaciated area						
C horizon	16 (2)	48:48	22	1.44	1.24	9.1 - 44
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	18	1.46	1.26	4.3 - 64
C horizon	16 (2)	136:136	19	1.61	1.24	4.1 - 54
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	22	1.37	1.13	9.9 - 35
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	18	1.55	1.16	5.8 - 40
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	8.4	1.59	1.10	2.8 - 19
C horizon	11 (2)	47:47	8.6	1.67	1.10	2.3 - 22
Sheppard-Shiprock-Doak Association, N. Mex.						
A horizon	24 (2)	30:30	6.2	1.29	1.18	3.8 - 12
C horizon	24 (2)	30:30	5.4	1.53	1.09	2.2 - 12
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (1)	18:18	0.20	1.73	1.45	0.10 - 0.67
Oats	21 (1)	19:21	.53	1.46	1.46	<.27 - .94
Wheat, durum	21 (1)	20:20	.29	1.14	1.11	.20 - .36
Wheat, hard red spring	21 (1)	54:54	.32	1.42	1.20	.17 - .67
Wheat, hard red winter	21 (1)	17:17	.27	1.29	1.14	.18 - .45
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	.83	1.33	1.18	.50 - 1.8
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	1.2	1.81	1.41	.50 - 3.4
Snakeweed, San Juan Basin	19 (2)	18:18	.66	1.38	1.21	.39 - 1.4
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	10	1.44	1.20	7 - 15
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	16	1.49	1.29	<10 - 30
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	28:30	20	2.20	1.22	<10 - 50
Columbia Plateaus Province	23 (1)	30:30	33	1.91	1.22	10 - 100
Basin and Range Province	23 (1)	29:30	21	1.84	1.22	<10 - 100

TABLE 39.—*Nickel in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANTS--Continued						
Native species (ash-weight basis)--Continued						
Sagebrush, big; regional study--Continued						
Northern Great Plains----------------	23 (1)	20:20	31	2.53	1.28	10 - 150
Northern Rocky Mountains Province----	23 (1)	19:20	19	2.21	1.28	<10 - 70
Middle Rocky Mountains Province------	23 (1)	20:20	21	2.15	1.28	10 - 70
Wyoming Basin Province---------------	23 (1)	19:20	15	1.99	1.28	<10 - 50
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry weight basis)						
Wheatgrass, western----------------	18 (3)	12:21	.13	2.26	--	<.07 - .67
Sagebrush, silver------------------	18 (3)	19:19	1.1	1.51	--	.46 - 2.0
Plant biomass, above-ground parts--	18 (3)	21:21	.38	1.79	1.18	.17 - 1.2

TABLE 40.—*Niobium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	1 (2)	80:80	7.6	1.53	1.41	2.4 - 16
Shale------------------------------	1 (2)	80:80	39	1.51	1.32	17 - 81
Core samples						
Hanging Woman Creek, Mont.						
Sandstone--------------------------	2 (2)	24:24	5.4	1.51	1.39	2.2 - 11
Siltstone and shale----------------	2 (2)	24:24	7.7	1.50	1.35	4.2 - 18
Dark shale-------------------------	2 (2)	23:23	7.5	1.62	1.54	3.2 - 18
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (2)	50:50	6.8	1.51	1.38	2.6 - 19
Sandstone--------------------------	4 (2)	42:42	18	1.5	1.24	5.4 - 37
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)--------	5 (2)	64:74	11	1.87	1.90	<4.0 - 39
Middle 300 m-----------------------	5 (2)	48:53	10	2.03	1.54	<4.0 - 30
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (2)	60:60	7.2	1.67	1.58	2.2 - 17
Powder River Basin, Wyo. and Mont. Size fractions						
100-200 µm-------------------------	7 (1)	13:24	6	1.44	1.37	<7 - 10
63-100 µm--------------------------	7 (1)	20:24	10	1.47	<1.01	>7 - 20
<63 µm-----------------------------	7 (1)	24:24	14	1.43	1.37	10 - 30

TABLE 40.—*Niobium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
STREAM SEDIMENTS--Continued						
Uinta and Piceance Creek Basins, Colo. and Utah						
Ashphalt Wash, Utah	8 (1)	8:8	13	1.23	--	10 - 15
Cottonwood Creek, Utah	8 (1)	8:8	14	1.21	--	10 - 15
Duck Creek, Colo.	8 (1)	8:8	9.2	1.30	--	7 - 15
Ryan Gulch, Colo.	8 (1)	8:8	14	1.15	--	10 - 15
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	9:10	9.9	1.92	--	<2.8 - 24
Dave Johnston mine, Wyoming	10 (2)	9:10	9.9	1.91	--	<2.9 - 22
Hidden Valley mine, Wyoming	10 (2)	10:10	12	1.35	--	8.2 - 21
Kincaid mine, North Dakota	10 (2)	6:10	6.3	2.23	--	<2.5 - 24
Savage mine, Montana	10 (2)	7:10	6.9	1.88	--	<3 - 17
Velva mine, North Dakota	10 (2)	9:10	9.1	1.84	--	<3 - 25
Big Sky mine, Montana	10 (2)	9:10	9.3	1.70	--	<2.8 - 17
Utility mine, Saskatchewan	10 (2)	7:10	7.0	2.12	--	<3 - 18
San Juan mine, New Mexico	11 (2)	12:12	9.2	1.41	1.26	5.1 - 15
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	11	1.26	1.20	7.5 - 16
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	9:10	1.0	1.92	1.57	<.3 - 2.3
Dave Johnston mine, Wyoming	10 (2)	9:10	1.5	2.16	1.57	<.3 - 3.8
Hidden Valley mine, Wyoming	10 (2)	10:10	1.8	1.85	1.57	.7 - 6.7
Kincaid mine, North Dakota	10 (2)	8:10	1.0	2.58	1.57	<.3 - 2.9
Savage mine, Montana	10 (2)	8:10	.7	2.55	1.57	<.3 - 2.8
Velva mine, North Dakota	10 (2)	7:10	1.2	2.17	1.57	<.3 - 3.0
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	1.1	1.68	1.57	.6 - 2.9
Utility mine, Saskatchewan	10 (2)	10:10	1.1	1.55	1.57	.5 - 1.8
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	4:6	1.0	2.83	--	<.52 - 3.0
Alkali sacaton	11 (2)	6:6	.65	1.99	--	.26 - 1.3
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	30	1.41	1.35	15 - 57
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	32:64	6.2	1.41	--	<7 - 15
B horizon	13 (1)	35:64	6.6	1.38	--	<7 - 15
C horizon	13 (1)	27:64	5.4	1.39	--	<7 - 15
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	26:48	6.2	1.68	--	<10 - 10
Soil, 15- to 20-cm depth	20 (1)	26:48	6.2	1.68	--	<10 - 10
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	8.4	1.56	1.56	3 - 15
C horizon	14 (2)	16:16	6.4	1.73	1.72	2.3 - 16

TABLE 40.—*Niobium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	97:108	7.0	2.11	1.97	<2.2 - 21
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	133:136	4.8	1.51	1.48	<2.2 - 19
C horizon	16 (2)	131:136	4.8	1.65	1.55	<2.2 - 22
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	8.9	1.32	1.38	4.5 - 15
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	7.4	1.39	1.41	3.1 - 16
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	13	1.27	1.32	6.4 - 22
C horizon	11 (2)	47:47	12	1.32	1.18	5.0 - 21
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	10	1.26	1.15	5.6 - 15
C horizon	24 (2)	28:30	9.2	1.43	1.26	<4.6 - 15
PLANTS						
Cultivated plants, Northern Great Plains (dry-weight basis)						
Barley	21 (1)	14:18	0.33	1.53	1.53	<0.19 - 0.82
Oats	21 (1)	19:21	.53	1.46	1.46	<.27 - .94
Wheat, durum	21 (1)	33:54	.18	1.78	1.78	<.15 - .74
Wheat, hard red spring	21 (1)	11:17	.16	1.60	1.60	<.12 - .48
Wheat, hard red spring	21 (1)	16:20	.26	1.68	1.68	<.15 - .95
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	22:25	.70	2.01	1.65	<.24 - 2.0
Saltbush, fourwing, San Juan Basin	19 (2)	4:10	.41	3.23	2.31	<.36 - 2.2
Snakeweed, San Juan Basin	19 (2)	14:18	.41	1.96	1.62	<.22 - 1.2

TABLE 41.—*Phosphorus in stream sediments, plants associated with mine spoil, soils, and other plants*

[**Explanation of column headings:** Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (-) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed Range (percent)
STREAM SEDIMENTS						
Uinta and Piceance Creek Basins, Colo. and Utah	9 (2)	32:32	0.083	1.17	1.04	0.061 - 0.11

TABLE 41.—*Phosphorus in stream sediments, plants associated with mine spoil, soils, and other plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANTS ASSOCIATED WITH MINE SPOIL						
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (6)	10:10	.99	1.23	1.14	.06 - .13
Dave Johnston mine, Wyoming--------	10 (6)	10:10	.12	1.28	1.14	.09 - .18
Hidden Valley mine, Wyoming--------	10 (6)	10:10	.12	1.20	1.14	.09 - .15
Kincaid mine, North Dakota---------	10 (6)	10:10	.13	1.18	1.14	.09 - .16
Savage mine, Montana---------------	10 (6)	10:10	.09	1.33	1.14	.06 - .14
Velva mine, North Dakota-----------	10 (6)	10:10	.12	1.41	1.14	.06 - .20
White sweetclover						
Big Sky mine, Montana--------------	10 (6)	10:10	.10	1.17	1.14	.08 - .12
Utility mine, Saskatchewan---------	10 (6)	10:10	.13	1.28	1.14	.09 - .18
Alfalfa						
Beulah North mine, North Dakota----	10 (6)	3:3	.07	1.16	--	.06 - .08
Dave Johnston mine, Wyoming--------	10 (6)	3:3	.13	1.18	--	.11 - .15
Savage mine, Montana---------------	10 (6)	3:3	.08	1.12	--	.07 - .09
Velva mine, North Dakota-----------	10 (6)	3:3	.10	1.55	--	.06 - .15
Big Sky mine, Montana--------------	10 (6)	3:3	.10	1.30	--	.07 - .11
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (6)	20:20	.084	1.38	1.17	.041 - .17
Growing near mine spoil----------	26 (6)	20:20	.13	1.24	1.17	.09 - .19
San Juan mine, New Mexico						
Fourwing saltbush------------------	11 (6)	6:6	.084	1.27	--	.065 - .12
Alkali sacaton---------------------	11 (6)	6:6	.034	1.14	--	.026 - .039
SOILS						
Northern Great Plains; North Dakota South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	107:136	0.074	1.37	1.49	<0.044 - 0.13
C horizon------------------------	16 (5)	92:136	.078	1.49	1.40	<.044 - .13
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley-----------------------------	21 (6)	18:18	0.20	1.16	1.11	0.16 - 0.32
Oats-------------------------------	21 (6)	21:21	.25	1.21	1.15	.16 - .32
Wheat, durum-----------------------	21 (6)	20:20	.29	1.14	1.11	.20 - .36
Wheat, hard red spring-------------	21 (6)	54:54	.29	1.29	1.18	.15 - .50
Wheat, hard red winter-------------	21 (6)	17:17	.26	1.18	1.12	.18 - .32
Native species (dry-weight basis)						
Galleta, San Juan Basin------------	19 (6)	25:25	.056	1.52	1.11	.016 - .13
Saltbush, fourwing, San Juan Basin-----	19 (6)	10:10	.091	1.53	1.11	.059 - .17
Snakeweed, San Juan Basin----------	19 (6)	18:18	.062	1.33	1.07	.042 - .10
Native species (ash-weight basis)						
Sagebrush, big; regional study						
Colorado Plateaus Province---------	23 (6)	30:30	3.3	1.32	1.07	1.6 - 4.4
Columbia Plateaus Province---------	23 (6)	30:30	3.1	1.40	1.07	1.7 - 4.4

TABLE 41.—*Phosphorus in stream sediments, plants associated with mine spoil, soils, and other plants*—**Continued**

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANTS--Continued				
Native species (ash-weight basis)--Continued						
Sagebrush, big; regional study--Continued						
Basin and Range Province-------------	23 (6)	30:30	3.1	1.22	1.07	2.3 - 4.0
Northern Great Plains----------------	23 (6)	20:20	3.3	1.23	1.05	2.4 - 4.2
Northern Rocky Mountains Province----	23 (6)	20:20	3.6	1.25	1.05	2.4 - 4.6
Middle Rocky Mountains Province------	23 (6)	20:20	3.4	1.31	1.05	2.1 - 4.5
Southern Rocky Mountains Province----	23 (6)	20:20	3.0	1.24	1.05	2.2 - 3.9
Wyoming Basin Province---------------	23 (6)	20:20	3.7	1.13	1.05	2.8 - 4.2

TABLE 42.—*Potassium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone--------------------------	1 (5)	80:80	1.4	1.36	<1.03	0.59 - 2.2
Shale------------------------------	1 (5)	80:80	1.9	1.99	<1.07	.24 - 3.3
Core samples						
Hanging Woman Creek, Mont.						
Sandstone----------------------------	2 (5)	24:24	1.6	1.35	1.12	.91 - 2.3
Siltstone and shale------------------	2 (5)	24:24	2.2	1.18	1.03	2.0 - 5.4
Dark shale---------------------------	2 (5)	23:23	2.2	1.26	1.07	1.1 - 2.7
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (5)	50:50	2.2	1.24	1.02	1.3 - 3.2
Sandstone--------------------------	4 (5)	42:42	1.5	1.20	1.04	1.0 - 2.4
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)--------	5 (5)	74:74	1.7	1.67	1.01	.25 - 5.1
Middle 300 m-----------------------	5 (5)	51:51	1.2	1.52	1.02	.27 - 3.0
Garden Gulch Member (lower 100 m)--	5 (5)	32:32	1.9	1.33	--	.70 - 2.8
		STREAM SEDIMENTS				
Northern Great Plains regional study-----	6 (5)	60:60	1.7	1.09	1.01	1.3 - 2.2
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 μm-----------------------------	7 (5)	19:19	1.7	1.16	1.06	1.1 - 2.0

TABLE 42.—*Potassium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
STREAM SEDIMENTS--Continued						
Powder River Basin, Wyo. and Mont.--Continued						
Size fractions--Continued						
100-200 µm	7 (5)	24:24	1.5	1.18	1.03	1.1 - 2.0
63-100 µm	7 (5)	24:24	1.5	1.13	1.03	1.2 - 2.0
<63 µm	7 (5)	24:24	1.7	1.08	1.04	1.5 - 2.2
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (5)	8:8	2.2	1.04	--	2.1 - 2.4
Cottonwood Creek, Utah	8 (5)	8:8	1.6	1.12	--	1.4 - 1.9
Duck Creek, Colo.	8 (5)	8:8	1.8	1.09	--	1.8 - 2.3
Ryan Gulch, Colo.	8 (5)	8:8	2.1	1.10	--	1.8 - 2.3
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	3.1	1.09	1.01	3 - 5
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	1.8	1.10	--	1.6 - 2.1
Dave Johnston mine, Wyoming	10 (5)	10:10	2.0	1.11	--	1.6 - 2.2
Hidden Valley mine, Wyoming	10 (5)	10:10	1.3	1.14	--	1.0 - 1.6
Kincaid mine, North Dakota	10 (5)	10:10	1.7	1.16	--	1.4 - 2.1
Savage mine, Montana	10 (5)	10:10	1.9	1.09	--	1.7 - 2.2
Velva mine, North Dakota	10 (5)	10:10	1.6	1.04	--	1.4 - 1.7
Big Sky mine, Montana	10 (5)	10:10	1.9	1.10	--	1.5 - 2.0
Utility mine, Saskatchewan	10 (5)	10:10	1.5	1.05	--	1.4 - 1.6
San Juan mine, New Mexico	11 (5)	12:12	1.4	1.12	1.01	1.1 - 1.6
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	12:12	1.5	1.05	1.01	1.4 - 1.6
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (3)	10:10	1.2	1.11	1.04	1.0 - 1.4
Dave Johnston mine, Wyoming	10 (3)	10:10	1.8	1.28	1.04	1.3 - 2.5
Hidden Valley mine, Wyoming	10 (3)	10:10	1.6	1.09	1.04	1.4 - 1.8
Kincaid mine, North Dakota	10 (3)	10:10	1.6	1.15	1.04	1.2 - 1.9
Savage mine, Montana	10 (3)	10:10	1.3	1.20	1.04	1.0 - 1.9
Velva mine, North Dakota	10 (3)	10:10	1.4	1.15	1.04	1.1 - 1.7
White sweetclover						
Big Sky mine, Montana	10 (3)	10:10	1.9	1.12	1.04	1.7 - 2.5
Utility mine, Saskatchewan	10 (3)	10:10	1.2	1.11	1.04	1.1 - 1.5
Alfalfa						
Beulah North mine, North Dakota	10 (3)	3:3	1.1	1.16	--	1.0 - 1.3
Dave Johnston mine, Wyoming	10 (3)	3:3	1.5	1.19	--	1.3 - 1.9
Savage mine, Montana	10 (3)	3:3	1.0	1.17	--	.9 - 1.2
Velva mine, North Dakota	10 (3)	3:3	1.5	1.17	--	1.2 - 1.6
Big Sky mine, Montana	10 (3)	3:3	1.9	1.08	--	1.8 - 2.0

TABLE 42.—*Potassium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)--Continued						
Northern Great Plains--Continued						
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (3)	20:20	1.2	--	--	0.72 - 1.6
Growing near mine spoil----------	26 (3)	20:20	1.1	--	--	.90 - 1.4
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (3)	6:6	2.6	1.24	--	2.1 - 3.2
Alkali sacaton-----------------------	11 (3)	6:6	.24	1.34	--	.16 - .35
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth-------------------	12 (5)	30:30	*2.1	*0.45	0.028	0.96 - 3.1
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (5)	64:64	1.9	1.12	1.04	1.6 - 2.7
B horizon------------------------------	13 (5)	64:64	1.9	1.14	1.04	1.6 - 2.8
C horizon------------------------------	13 (5)	64:64	1.9	1.13	1.02	1.6 - 2.6
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (5)	16:16	*1.8	*.21	*.041	1.4 - 2.1
C horizon------------------------------	14 (5)	16:16	*1.7	*.13	*.042	1.3 - 1.8
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (5)	108:108	2.3	1.22	1.05	.77 - 3.2
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (5)	88:88	1.9	1.12	1.02	1.4 - 2.6
C horizon--------------------------	16 (5)	88:88	1.8	1.17	1.02	1.2 - 3.0
Glaciated area						
A horizon--------------------------	16 (5)	48:48	1.7	1.09	1.02	1.3 - 2.0
C horizon--------------------------	16 (5)	48:48	1.5	1.16	1.02	1.0 - 2.0
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	136:136	1.8	1.13	1.02	1.3 - 2.7
C horizon------------------------	16 (5)	136:136	1.7	1.19	1.02	1.0 - 3.0
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (5)	36:36	1.5	1.19	1.07	.97 - 2.0
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (5)	36:36	1.5	1.19	1.07	.97 - 2.0
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (5)	47:47	1.7	1.21	1.02	.85 - 2.3
C horizon------------------------------	11 (5)	47:47	1.5	1.31	1.03	.56 - 2.3
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (5)	30:30	2.1	1.05	1.09	1.8 - 2.4
C horizon----------------------------	24 (5)	30:30	2.1	1.17	1.09	1.7 - 3.1

TABLE 42.—*Potassium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (3)	18:18	0.44	1.16	1.04	0.34 - 0.64
Oats	21 (3)	21:21	.45	1.11	1.06	.40 - .54
Wheat, durum	21 (3)	20:20	.42	1.21	1.14	.25 - .60
Wheat, hard red spring	21 (3)	54:54	.39	1.24	1.13	.24 - .62
Wheat, hard red winter	21 (3)	17:17	.37	1.14	1.07	.30 - .49
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (3)	25:25	.36	1.84	1.78	.096 - 1.1
Saltbush, fourwing, San Juan Basin	19 (3)	10:10	3.0	1.56	1.53	1.0 - 4.6
Snakeweed, San Juan Basin	19 (3)	18:18	.74	1.48	1.45	.37 - 2.0
Native species (ash-weight basis)						
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	30:30	30	1.12	1.06	25 - 37
Columbia Plateaus Province	23 (3)	30:30	27	1.17	1.06	18 - 33
Basin and Range Province	23 (3)	30:30	30	1.13	1.06	23 - 34
Northern Great Plains	23 (3)	20:20	29	1.12	1.03	25 - 33
Northern Rocky Mountains Province	23 (3)	20:20	30	1.12	1.03	26 - 35
Middle Rocky Mountains Province	23 (3)	20:20	29	1.15	1.03	21 - 34
Southern Rocky Mountains Province	23 (3)	20:20	30	1.17	1.03	22 - 36
Wyoming Basin Province	23 (3)	20:20	29	1.18	1.03	22 - 34
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry-weight basis)						
Wheatgrass, western	18 (3)	21:21	.31	1.46	--	.14 - .49
Sagebrush, silver	18 (3)	19:19	1.1	1.16	--	.17 - 1.3
Plant biomass, above-ground parts	18 (3)	21:21	.29	1.54	1.04	.13 - .64

TABLE 43.—*Praseodymium in topsoil associated with mine soil and other soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		TOPSOIL ASSOCIATED WITH MINE SPOIL				
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	2:12	--	--	--	<46 - 52
		SOILS				
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	1:136	--	--	--	<22 - 54
C horizon	16 (2)	3:136	--	--	--	<22 - 43

TABLE 43.—*Praseodymium in topsoil associated with mine soil and other soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	1:36	--	--	--	<22 - 66
San Juan Basin, N. Mex.						
A horizon	11 (2)	6:47	--	--	--	<46 - 64
C horizon	11 (2)	2:47	--	--	--	<46 - 50
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	1:30	--	--	--	<46 - 48
C horizon	24 (2)	1:30	--	--	--	<46 - 47

TABLE 44.—*Rubidium in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (-) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (3)	80:80	58	1.36	1.04	25 - 100
Shale	1 (3)	80:80	110	1.85	1.06	15 - 200
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (3)	24:24	52	1.42	1.18	25 - 84
Siltstone and shale	2 (3)	24:24	90	1.34	1.27	51 - 130
Dark shale	2 (3)	23:23	88	1.47	1.14	33 - 140
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (3)	50:50	110	1.29	1.04	65 - 170
Sandstone	4 (3)	42:42	59	1.20	1.05	35 - 90
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (3)	73:74	68	1.49	2.36	<8.0 - 120
Middle 300 m	5 (3)	53:53	100	1.30	1.06	40 - 170
Garden Gulch Member (lower 100 m)	5 (3)	32:32	98	1.27	--	60 - 140
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (3)	60:60	70	1.19	1.06	50 - 100
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (3)	18:18	60	1.34	1.16	35 - 90
100-200 µm	7 (3)	24:24	49	1.36	1.16	30 - 80
63-100 µm	7 (3)	24:24	53	1.36	1.16	25 - 70
<63 µm	7 (3)	24:24	61	1.27	1.16	40 - 110

TABLE 44.—*Rubidium in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (3)	10:10	68	1.19	--	49 - 87
Dave Johnston mine, Wyoming----------	10 (3)	10:10	82	1.17	--	57 - 96
Hidden Valley mine, Wyoming----------	10 (3)	10:10	69	1.32	--	44 - 110
Kincaid mine, North Dakota-----------	10 (3)	10:10	57	1.26	--	38 - 76
Savage mine, Montana-----------------	10 (3)	10:10	72	1.15	--	64 - 89
Velva mine, North Dakota-------------	10 (3)	10:10	55	1.14	--	48 - 75
Big Sky mine, Montana----------------	10 (3)	10:10	70	1.12	--	59 - 85
Utility mine, Saskatchewan-----------	10 (3)	10:10	51	1.10	--	44 - 60
San Juan mine, New Mexico--------------	11 (3)	12:12	71	1.14	1.06	55 - 80
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (3)	12:12	70	1.05	1.04	65 - 75
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--------------------	12 (3)	30:30	*88	*12.0	*2.16	45 - 130
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (3)	64:64	*84	*13.1	*7.55	58 - 110
B horizon------------------------------	13 (3)	64:64	*87	*16.4	*16.4	13 - 120
C horizon------------------------------	13 (3)	64:64	*86	*15.1	*4.52	56 - 110
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (3)	16:16	*80	*13.6	*7.42	60 - 110
C horizon------------------------------	14 (3)	16:16	*74	--	--	46 - 95
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (3)	108:108	105	1.29	1.09	40 - 190
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (3)	88:88	77	1.20	1.07	52 - 110
C horizon--------------------------	16 (3)	88:88	75	1.29	1.09	40 - 150
Glaciated area						
A horizon--------------------------	16 (3)	48:48	65	1.18	1.07	38 - 86
C horizon--------------------------	16 (3)	48:48	58	1.29	1.09	30 - 100
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (3)	136:136	72	1.21	1.07	38 - 110
C horizon------------------------	16 (3)	136:136	69	1.32	1.09	30 - 150
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (3)	36:36	55	1.32	1.25	30 - 90
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (3)	36:36	63	1.35	1.33	30 - 110
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (3)	47:47	57	1.56	1.64	15 - 110
C horizon------------------------------	11 (3)	47:47	62	1.47	1.30	25 - 110
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (3)	30:30	83	1.15	1.08	65 - 110
C horizon----------------------------	24 (3)	30:30	86	1.22	1.16	65 - 140

TABLE 45.—*Scandium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	69:80	5.7	2.06	1.23	<3.0 - 15
Shale	1 (2)	80:80	12	1.49	1.17	4.3 - 27
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	7.4	1.52	1.22	3.3 - 15
Siltstone and shale	2 (2)	24:24	16	1.34	1.15	9.2 - 27
Dark shale	2 (2)	23:23	19	1.20	1.09	13 - 24
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	48:50	11	1.64	1.34	<3.3 - 24
Sandstone	4 (2)	42:42	10	1.50	1.16	4.6 - 28
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	6.3	1.47	1.40	2.8 - 15
Middle 300 m	5 (2)	53:53	6.3	1.37	1.18	2.0 - 11
Garden Gulch Member (lower 100 m)	5 (2)	199:264	11	1.37	--	<10 - 20
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	59:60	7.8	1.54	1.32	2.1 - >22
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (1)	15:24	3	2.28	1.52	<2 - 10
63-100 μm	7 (1)	20:24	3	1.55	1.22	<2 - 7
<63 μm	7 (1)	24:24	6	1.48	1.36	3 - 15
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (1)	8:8	12	1.33	--	7 - 15
Cottonwood Creek, Utah	8 (1)	8:8	11	1.28	--	7 - 15
Duck Creek, Colo.	8 (1)	8:8	7	1.34	--	5 - 10
Ryan Gulch, Colo.	8 (1)	8:8	12	1.33	--	7 - 15
Piceance Creek Basin, Colo. Roan and Black Sulphur Creeks	9 (1)	32:32	8.0	1.37	1.16	7 - 15
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
San Juan mine, New Mexico	11 (2)	12:12	5.4	1.33	1.09	3.6 - 9.0
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	3.9	1.14	1.10	3.1 - 5.2

TABLE 45.—*Scandium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)						
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	0.43	1.21	--	0.34 - 0.51
Alkali sacaton	11 (2)	6:6	.19	1.32	--	.14 - .24
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	7.8	1.19	1.10	3.1 - 12
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	58:64	7.5	1.49	1.24	<5 - 15
B horizon	13 (1)	62:64	8.6	1.50	1.25	<5 - 15
C horizon	13 (1)	59:64	8.5	1.63	1.24	<5 - 15
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth	20 (1)	44:48	7.9	1.32	1.18	<3 - 15
Soil, 15- to 20-cm depth	20 (1)	47:48	7.8	1.60	1.18	<3 - 15
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	10	1.45	1.23	3.8 - 16
C horizon	14 (2)	16:16	9.2	1.60	1.40	4.1 - 16
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	99:108	6.8	1.66	1.48	<2.1 - 13
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	114:136	5.4	1.67	1.57	<3.0 - 17
C horizon	16 (2)	122:136	5.7	1.75	1.70	<3.0 - 24
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	32:36	5.9	1.59	1.19	<3.0 - 12
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	34:36	5.3	1.47	1.23	<3.0 - 11
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	3.6	1.59	1.12	1.5 - 11
C horizon	11 (2)	47:47	4.0	1.61	1.15	1.5 - 11
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	2.9	1.22	1.16	2.0 - 4.3
C horizon	24 (2)	30:30	2.5	1.32	1.15	1.7 - 4.4
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	22:25	0.25	1.43	1.29	<0.13 - 0.51
Saltbush, fourwing, San Juan Basin	19 (2)	8:10	.30	1.55	1.36	<.19 - .59
Snakeweed, San Juan Basin	19 (2)	18:18	.26	1.41	1.28	.13 - .61

TABLE 46.—*Selenium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (18)	68:80	0.19	1.96	1.85	<0.10 - 0.66
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (18)	7:24	.042	2.74	--	<.10 - .29
Siltstone and shale	2 (18)	19:24	.21	2.24	2.19	<.10 - .79
Dark shale	2 (18)	20:23	.30	2.70	1.37	<.10 - .99
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (18)	35:50	.16	2.28	1.92	<.08 - .62
Sandstone	4 (18)	31:42	.31	1.80	1.90	<.2 - 1.5
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (5)	50:60	0.19	1.78	1.59	<0.11 - .46
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 μm	7 (5)	10:19	.12	2.69	2.23	<.1 - .60
100-200 μm	7 (5)	14:24	.13	2.18	1.97	<.1 - .48
63-100 μm	7 (5)	17:24	.13	1.83	1.29	<.1 - .50
<63 μm	7 (5)	18:24	.17	2.92	2.66	<.1 - .54
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	8:10	0.19	1.97	--	<0.1 - 0.41
Dave Johnston mine, Wyoming	10 (5)	9:10	.28	1.99	--	<.1 - .69
Hidden Valley mine, Wyoming	10 (5)	10:10	.31	1.45	--	.18 - .49
Kincaid mine, North Dakota	10 (5)	8:10	.22	1.90	--	<.1 - .45
Savage mine, Montana	10 (5)	8:10	.20	2.40	--	<.1 - .66
Velva mine, North Dakota	10 (5)	9:10	.21	1.78	--	<.1 - .54
Big Sky mine, Montana	10 (5)	7:10	.17	1.90	--	<.1 - .40
Utility mine, Saskatchewan	10 (5)	7:10	.17	1.94	--	<.1 - .39
San Juan mine, New Mexico	11 (5)	6:12	.19	2.40	--	<.2 - .70
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	5:12	.18	1.91	--	<.2 - .50
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (13)	10:10	.15	2.05	1.45	.08 - .60
Dave Johnston mine, Wyoming	10 (13)	10:10	.37	2.73	1.45	.10 - 3.00

TABLE 46.—*Selenium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants--Continued						
Northern Great Plains--Continued						
Yellow sweetclover--Continued						
Hidden Valley mine, Wyoming--------	10 (13)	10:10	0.53	1.85	1.45	0.15 - 1.20
Kincaid mine, North Dakota---------	10 (13)	10:10	.17	2.28	1.45	.06 - .55
Savage mine, Montana---------------	10 (13)	10:10	1.30	2.50	1.45	.60 - 6.00
Velva mine, North Dakota-----------	10 (13)	10:10	.49	2.07	1.45	.15 - 2.00
White sweetclover						
Big Sky mine, Montana--------------	10 (13)	10:10	.42	2.26	1.45	.08 - 1.00
Utility mine, Saskatchewan---------	10 (13)	10:10	.23	1.93	1.45	.06 - .50
Alfalfa						
Beulah North mine, North Dakota----	10 (13)	3:3	.18	2.66	--	.06 - .35
Dave Johnston mine, Wyoming--------	10 (13)	3:3	.34	2.11	--	.20 - .80
Savage mine, Montana---------------	10 (13)	3:3	1.10	2.09	--	.75 - 2.70
Velva mine, North Dakota-----------	10 (13)	3:3	.33	1.18	--	.30 - .40
Big Sky mine, Montana--------------	10 (13)	3:3	.22	2.13	--	.10 - .45
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (13)	20:20	.27	1.73	1.21	.10 - .70
Growing near mine spoil----------	26 (13)	20:20	.23	1.91	1.21	.10 - .60
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (13)	6:6	.22	2.10	--	.10 - .45
Alkali sacaton-----------------------	11 (13)	6:6	.096	1.13	--	.080 - .10
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (5)	12:30	0.079	2.72	--	<0.1 - 0.57
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (5)	52:64	.25	2.40	1.71	<.1 - 1.1
B horizon------------------------------	13 (5)	57:64	.30	2.27	1.69	<.1 - 2.2
C horizon------------------------------	13 (5)	49:64	.23	2.42	1.76	<.1 - 1.6
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (5)	12:16	.17	1.91	1.87	<.12 - .37
C horizon------------------------------	14 (5)	12:16	.18	2.04	2.04	<.11 - .45
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (5)	97:108	.28	2.03	1.72	<.11 - 1.2
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (5)	62:88	.43	2.93	2.18	<.10 - 20
Glaciated area						
A horizon--------------------------	16 (5)	42:48	.47	2.45	2.18	<.10 - 10
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	104:136	.45	2.72	2.18	<.10 - 20
C horizon------------------------	16 (5)	95:136	.34	2.61	2.92	<.10 - 26
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (5)	18:36	.11	3.18	--	<.10 - 1.1

TABLE 46.—*Selenium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	17:36	0.098	2.28	--	<0.10 - 0.38
San Juan Basin, N. Mex.						
A horizon	11 (5)	15:47	.14	2.35	--	<.20 - .80
C horizon	11 (5)	13:47	.13	2.25	--	<.20 - .50
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	17:30	.23	1.77	--	<.20 - .50
C horizon	24 (5)	16:30	.20	1.85	--	<.20 - .70
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (13)	18:18	0.45	1.88	1.09	0.20 - 1.8
Oats	21 (13)	21:21	.48	1.60	1.05	.15 - 1.0
Wheat, durum	21 (13)	20:20	.84	1.60	1.12	.40 - 2.2
Wheat, hard red spring	21 (13)	54:54	.64	1.85	1.11	.15 - 2.2
Wheat, hard red winter	21 (13)	17:17	.44	1.63	1.09	.15 - 1.0
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (13)	25:25	.12	1.62	1.05	.060 - .45
Saltbush, fourwing, San Juan Basin	19 (13)	10:10	.81	3.07	1.12	.15 - 4.5
Snakeweed, San Juan Basin	19 (13)	18:18	.27	1.84	1.06	.080 - 1.2
Native species (dry-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (13)	29:29	.35	1.42	1.07	.20 - .70
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (24)	41:41	.43	2.63	1.13	.08 - 4.8
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (13)	30:30	.17	3.05	1.23	.04 - 4
Columbia Plateaus Province	23 (13)	30:30	.063	2.76	1.23	.01 - .03
Basin and Range Province	23 (13)	30:30	.11	4.65	1.23	.02 - 7
Northern Great Plains	23 (13)	20:20	.29	4.36	1.37	.04 - 2
Northern Rocky Mountains Province	23 (13)	20:20	.035	2.54	1.37	.01 - .15
Middle Rocky Mountains Province	23 (13)	20:20	.093	4.49	1.39	.02 - 1.8
Southern Rocky Mountains Province	23 (13)	20:20	.078	3.15	1.37	.02 - .90
Wyoming Basin Province	23 (13)	20:20	.18	4.13	1.37	.04 - 1.6

TABLE 47.—*Silicon in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (5)	80:80	27	1.35	<1.03	12 - 41
Shale	1 (5)	80:80	27	1.16	1.02	16 - 34
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (5)	24:24	27	1.28	1.01	17 - 39
Siltstone and shale	2 (5)	24:24	29	1.08	1.02	25 - 32
Dark shale	2 (5)	23:23	25	1.12	1.05	18 - 28
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (5)	50:50	27	1.11	1.01	21 - 33
Sandstone	4 (5)	42:42	33	1.10	1.03	26 - 41
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (5)	74:74	15	1.25	1.03	6.7 - 24
Middle 300 m	5 (5)	51:51	14	1.30	1.04	4.9 - 22
Garden Gulch Member (lower 100 m)	5 (5)	32:32	22	1.59	--	2.0 - 35
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (5)	60:60	30	1.09	1.02	22 - 35
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (5)	19:19	*32	*14.79	*8.13	14 - 37
100-200 µm	7 (5)	24:24	*36	*5.76	*2.00	27 - 39
63-100 µm	7 (5)	24:24	*35	*5.25	*2.84	27 - 37
<63 µm	7 (5)	24:24	*31	*3.69	*2.96	26 - 34
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	28	1.13	--	22 - 34
Dave Johnston mine, Wyoming	10 (5)	10:10	31	1.13	--	23 - 35
Hidden Valley mine, Wyoming	10 (5)	10:10	31	1.13	--	25 - 36
Kincaid mine, North Dakota	10 (5)	10:10	26	1.11	--	20 - 29
Savage mine, Montana	10 (5)	10:10	25	1.10	--	22 - 28
Velva mine, North Dakota	10 (5)	10:10	29	1.05	--	26 - 31
Big Sky mine, Montana	10 (5)	10:10	29	1.14	--	21 - 34
Utility mine, Saskatchewan	10 (5)	10:10	28	1.09	--	32 - 35
San Juan mine, New Mexico	11 (5)	12:12	30	1.11	1.01	23 - 32
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	12:12	35	106	101	31 - 36

TABLE 47.—*Silicon in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Devia- tion	Error	Observed range (percent)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (3)	10:10	0.08	1.76	1.27	0.03 - 0.24
Dave Johnston mine, Wyoming--------	10 (3)	10:10	.10	1.51	1.27	.05 - .15
Hidden Valley mine, Wyoming--------	10 (3)	10:10	.34	1.58	1.27	.16 - .69
Kincaid mine, North Dakota---------	10 (3)	10:10	.14	1.80	1.27	.04 - .29
Savage mine, Montana---------------	10 (3)	10:10	.06	1.39	1.27	.04 - .13
Velva mine, North Dakota-----------	10 (3)	10:10	.10	1.95	1.27	.05 - .39
White sweetclover						
Big Sky mine, Montana----------------	10 (3)	10:10	.10	1.23	1.27	.07 - .13
Utility mine, Saskatchewan-----------	10 (3)	10:10	.07	1.46	1.27	.04 - .14
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil--------------	26 (3)	20:20	.98	1.46	1.15	.44 - 1.9
Growing near mine spoil------------	26 (3)	20:20	1.2	1.35	1.15	.7 - 1.9
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--------------------	12 (5)	30:30	*27	*4.10	*1.14	18 - 35
Powder River Basin, Wyo. and Mont.						
A horizon-------------------------------	13 (5)	64:64	*35	*3.78	*3.16	26 - 43
B horizon-------------------------------	13 (5)	64:64	*34	*3.55	*2.28	26 - 40
C horizon-------------------------------	13 (5)	64:64	*32	*5.24	*1.49	20 - 42
Hanging Woman Creek, Mont.						
A horizon-------------------------------	14 (5)	16:16	*29	*2.37	*.52	25 - 33
C horizon-------------------------------	14 (5)	16:16	*28	*3.50	*.50	23 - 35
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (5)	108:108	26	1.15	1.05	15 - 34
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
C horizon--------------------------	16 (5)	88:88	*29	*3.59	*1.22	22 - 39
Glaciated area						
C horizon--------------------------	16 (5)	48:48	*27	*2.74	*1.22	22 - 36
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	136:136	*31	*3.55	*1.22	22 - 38
C horizon------------------------	16 (5)	136:136	*28	*1.13	*1.22	22 - 39
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (5)	36:36	32	1.10	1.03	25 - 38
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (5)	36:36	31	1.07	1.03	27 - 36
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (5)	47:47	36	1.09	1.02	30 - 42
C horizon-------------------------------	11 (5)	47:47	34	1.10	1.03	27 - 40
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (5)	30:30	34	1.05	1.06	30 - 37
C horizon----------------------------	24 (5)	30:30	34	1.06	1.04	31 - 38

TABLE 47.—*Silicon in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley----------------------------------	21 (3)	18:18	0.24	1.19	1.10	0.18 - 0.32
Oats------------------------------------	21 (3)	21:21	.64	1.27	1.16	.43 - 1.0
Wheat, durum----------------------------	21 (3)	20:20	.0081	2.12	1.56	.0014 - .022
Wheat, hard red spring------------------	21 (3)	54:54	.0130	1.45	1.28	.0048 - .029
Wheat, hard red winter------------------	21 (3)	17:17	.0095	1.44	1.28	.0042 - .0140
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	21 (3)	29:29	9.0	1.56	1.08	4.2 - 17

TABLE 48.—*Silver in rocks, soils and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone-------------------------	1 (2)	40:80	0.16	2.73	--	<0.22 - 1.3
Shale-----------------------------	1 (2)	69:80	.36	1.71	1.42	<.22 - .87
Core samples						
Northern Great Plains, Fort Union Formation sandstone------------------	4 (2)	3:42	.23	1.6	1.15	<.46 - .60
		SOILS				
Piceance and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (2)	28:30	0.3	1.48	1.38	<0.23 - 0.84
Hanging Woman Creek, Montana						
A horizon------------------------------	14 (2)	12:16	.29	1.55	1.34	<.23 - .49
C horizon------------------------------	14 (2)	11:16	.28	1.59	1.59	<.23 - .49
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaicated areas						
A horizon------------------------	16 (2)	22:136	.14	1.58	--	<.22 - .49
C horizon------------------------	16 (2)	29:136	.13	1.90	--	<.22 - .56
Big Horn Basin, Wyo. 0-40-cm depth-------	17 (2)	19:36	.22	1.33	--	<.22 - .40
Wind River Basin, Wyo., 0-40-cm depth----------------------------------	17 (2)	7:36	.14	1.63	--	<.22 - .40

TABLE 48.—*Silver in rocks, soils and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANTS						
Native species (ash weight basis)						
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	1:41	--	--	--	<1 - 1

TABLE 49.—*Sodium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (3)	80:80	0.49	2.74	<1.11	0.037 - 1.5
Shale	1 (3)	79:80	.42	2.53	1.14	<.062 - 1.1
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (3)	24:24	.84	1.23	1.02	.55 - 1.1
Siltstone and shale	2 (3)	24:24	.64	1.75	1.05	.12 - .98
Dark shale	2 (3)	23:23	.54	1.36	1.03	.18 - .79
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (3)	50:50	.64	1.77	1.06	.18 - 1.6
Sandstone	4 (3)	42:42	.85	1.60	1.01	.26 - 1.64
Piceance Creek Basin, Colo. Green River Formation						
Mahogary zone (upper 100 m)	5 (3)	74:74	1.4	1.68	1.08	.1 - 3.7
Middle 300 m	5 (3)	53:53	3.3	1.64	1.04	.69 - 25
Garden Gulch Member (lower 100 m)	5 (3)	32:32	.82	1.28	--	.45 - 1.5
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (3)	60:60	0.71	1.91	<1.07	0.14 - 1.9
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (3)	18:18	.95	1.17	1.04	.57 - 1.36
100-200 µm	7 (3)	24:24	.72	1.18	1.08	.44 - .90
63-100 µm	7 (3)	24:24	.80	1.10	<1.01	.66 - .97
<63 µm	7 (3)	24:24	.84	1.09	<1.01	.68 - 1.0

TABLE 49.—*Sodium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
STREAM SEDIMENTS--Continued						
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (3)	8:8	2.4	1.18	--	1.8 - 3.0
Cottonwood Creek, Utah	8 (3)	8:8	2.5	1.11	--	2.1 - 2.8
Duck Creek, Colo.	8 (3)	8:8	1.8	1.52	--	.95 - 3.0
Ryan Gulch, Colo.	8 (3)	8:8	2.5	1.09	--	2.2 - 2.8
Piceance Creek Basin, Colo.						
Roan Creek	9 (1)	16:16	2.2	1.18	1.14	2 - 3
Black Sulphur Creek	9 (1)	16:16	3.0	1.09	1.14	3 - 3
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	0.87	1.38	--	0.057 - 1.5
Dave Johnston mine, Wyoming	10 (5)	10.10	.37	1.39	--	.20 - .56
Hidden Valley mine, Wyoming	10 (5)	10:10	.089	2.32	--	.059 - .95
Kincaid mine, North Dakota	10 (5)	10:10	1.1	1.16	--	.89 - 1.4
Savage mine, Montana	10 (5)	10:10	.53	1.22	--	.40 - .68
Velva mine, North Dakota	10 (5)	10:10	.95	1.35	--	.44 - 1.3
Big Sky mine, Montana	10 (5)	10:10	.51	1.74	--	.28 - 2.3
Utility mine, Saskatchewan	10 (5)	10:10	.82	1.26	--	.52 - 1.1
San Juan mine, New Mexico	11 (5)	12:12	1.7	1.22	1.02	1.2 - 2.0
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	12:12	1.2	1.04	1.02	1.1 - 1.3
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (3)	10:10	.003	1.62	1.16	.0014 - .0065
Dave Johnston mine, Wyoming	10 (3)	10:10	.003	1.74	1.16	.0012 - .0078
Hidden Valley mine, Wyoming	10 (3)	10:10	.004	1.55	1.16	.0019 - .0090
Kincaid mine, North Dakota	10 (3)	10:10	.034	2.61	1.16	.0070 - .2070
Savage mine, Montana	10 (3)	10:10	.002	1.42	1.16	.0012 - .0036
Velva mine, North Dakota	10 (3)	10:10	.003	2.09	1.16	.0012 - .0118
White sweetclover						
Big Sky mine, Montana	10 (3)	10:10	.004	1.36	1.16	.0019 - .0056
Utility mine, Saskatchewan	10 (3)	10:10	.010	2.36	1.16	.0035 - .0792
Alfalfa						
Beulah North mine, North Dakota	10 (3)	3:3	.008	3.95	--	.002 - .031
Dave Johnston mine, Wyoming	10 (3)	3:3	.013	2.91	--	.006 - .042
Savage mine, Montana	10 (3)	3:3	.009	1.57	--	.005 - .013
Velva mine, North Dakota	10 (3)	3:3	.009	2.02	--	.004 - .016
Big Sky mine, Montana	10 (3)	3:3	.006	1.19	--	.005 - .007
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (3)	20:20	.0011	1.69	1.28	.0004 - .0021
Growing near mine spoil	26 (3)	20:20	.0008	2.00	1.28	.0004 - .0022
San Juan mine, New Mexico						
Fourwing saltbush	11 (3)	6:6	.74	--	--	.054 - 2.0
Alkali sacaton	11 (3)	6:6	.15	2.21	--	.091 - .45

TABLE 49.—*Sodium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		SOILS				
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (3)	30:30	*1.1	*0.48	*0.028	0.3 - 2
Powder River Basin, Wyo. and Mont.						
A horizon	13 (3)	64:64	.48	1.42	1.05	.22 - .93
B horizon	13 (3)	64:64	.43	1.56	1.03	.13 - .93
C horizon	13 (3)	64:64	.45	1.64	1.12	.16 - 1
Hanging Woman Creek, Mont.						
A horizon	14 (3)	16:16	*.72	*.14	*.029	.53 - .92
C horizon	14 (3)	16:16	*.77	*.17	*.020	.55 - 1.1
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (3)	108:108	1.4	1.65	1.09	.18 - 3.5
Northern Great Plains: North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	136:136	*.83	*.36	*.019	.22 - 1.6
C horizon	16 (5)	136:136	*.85	*.33	*.034	.074 - 1.8
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	.53	1.53	1.03	.20 - 1.5
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	1.3	1.26	1.03	.61 - 2.1
San Juan Basin, N. Mex.						
A horizon	11 (5)	47:47	.84	1.67	1.87	.10 - 2.1
C horizon	11 (5)	47:47	.91	1.56	1.06	.19 - 2.0
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	30:30	1.1	1.17	1.03	.85 - 1.7
C horizon	24 (5)	30:30	1.1	1.23	1.06	.70 - 1.6
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (3)	18:18	0.018	2.13	1.04	0.0044 - 0.057
Oats	21 (3)	21:21	.0052	2.03	1.29	.0016 - .025
Wheat, durum	21 (3)	20:20	.0021	2.21	1.02	.0006 - .011
Wheat, hard red spring	21 (3)	54:54	.0011	1.69	1.27	.0004 - .0061
Wheat, hard red winter	21 (3)	17:17	.0009	1.45	1.19	.0006 - .0021
Native species (dry-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (3)	29:29	.040	1.37	1.14	.02 - .06
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	30:30	.067	2.18	1.13	.02 - .24
Columbia Plateaus Proince	23 (3)	30:30	.21	1.51	1.13	.12 - .45
Basin and Range Province	23 (3)	30:30	.14	2.83	1.13	.05 - 1.5
Northern Great Plains	23 (3)	20:20	.11	2.13	1.10	.06 - .40
Northern Rocky Mountains Province	23 (3)	20:20	.072	1.97	1.10	.03 - .23
Middle Rocky Mountains Province	23 (3)	20:20	.11	3.70	1.10	.05 - 1.1
Southern Rocky Mountains Province	23 (3)	20:20	.058	2.29	1.10	.03 - .22
Wyoming Basin Province	23 (3)	20:20	.19	4.55	1.10	.05 - 2.1

TABLE 49.—*Sodium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANTS--Continued						
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry-weight basis)						
Wheatgrass, western	18 (3)	21:21	0.0024	1.79	--	0.00086 - 0.0067
Sagebrush, silver	18 (3)	19:19	.0067	2.43	--	.0018 - .050
Plant biomass, above-ground parts	18 (3)	21:21	.0054	1.46	1.04	.0037 - .015

TABLE 50.—*Strontium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	160	1.96	1.14	43 - 420
Shale	1 (2)	80:80	170	1.83	1.17	27 - 550
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	240	1.25	1.12	13 - 90
Siltstone and shale	2 (2)	24:24	250	1.13	1.09	190 - 330
Dark shale	2 (2)	23:23	25	1.18	1.08	180 - 320
Northern Great Plains, Fort Union Formation						
Sandstone	4 (2)	42:42	194	1.50	1.11	100 - 350
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	72:74	540	1.38	1.34	<200 - 990
Middle 300 m	5 (2)	53:53	340	1.37	1.13	170 - 790
Garden Gulch Member (lower 100 m)	5 (2)	264:264	290	1.42	--	100 - 700
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (5)	60:60	300	1.41	1.16	140 - 650
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (1)	24:24	180	1.51	1.27	100 - 500
100-200 µm	7 (1)	24:24	130	1.32	1.26	70 - 200
63-100 µm	7 (1)	24:24	140	1.29	<1.01	100 - 200
<63 µm	7 (1)	24:24	180	1.24	1.15	100 - 300

TABLE 50.—*Strontium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
STREAM SEDIMENTS--Continued						
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (2)	8:8	310	1.32	--	240 - 500
Cottonwood Creek, Utah	8 (2)	8:8	430	1.36	--	250 - 570
Duck Creek, Colo.	8 (2)	8:8	450	1.14	--	350 - 510
Ryan Gulch, Colo.	8 (2)	8:8	220	1.28	--	170 - 380
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	520	1.13	1.12	500 - 700
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	270	1.57	--	150 - 830
Dave Johnston mine, Wyoming	10 (2)	10:10	120	1.30	--	74 - 160
Hidden Valley mine, Wyoming	10 (2)	10:10	110	1.39	--	56 - 170
Kincaid mine, North Dakota	10 (2)	10:10	250	1.19	--	180 - 320
Savage mine, Montana	10 (2)	10:10	150	1.32	--	94 - 240
Velva mine, North Dakota	10 (2)	10:10	250	1.20	--	160 - 320
Big Sky mine, Montana	10 (2)	10:10	110	1.21	--	85 - 140
Utility mine, Saskatchewan	10 (2)	10:10	200	1.46	--	120 - 400
San Juan mine, New Mexico	11 (2)	12:12	270	1.14	1.05	220 - 330
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	190	1.55	1.57	48 - 260
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	90	1.42	1.23	53 - 145
Dave Johnston mine, Wyoming	10 (2)	10:10	84	1.32	1.23	49 - 119
Hidden Valley mine, Wyoming	10 (2)	10:10	39	1.27	1.23	26 - 55
Kincaid mine, North Dakota	10 (2)	10:10	150	1.47	1.23	82 - 251
Savage mine, Montana	10 (2)	10:10	60	1.24	1.23	44 - 92
Velva mine, North Dakota	10 (2)	10:10	94	1.35	1.23	52 - 149
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	48	1.51	1.23	24 - 87
Utility mine, Saskatchewan	10 (2)	10:10	63	1.29	1.23	46 - 93
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	270	1.53	--	168 - 360
Dave Johnston mine, Wyoming	10 (2)	3:3	82	1.61	--	59 - 143
Savage mine, Montana	10 (2)	3:3	120	1.57	--	74 - 178
Velva mine, North Dakota	10 (2)	3:3	130	1.70	--	72 - 206
Big Sky mine, Montana	10 (2)	3:3	83	1.34	--	63 - 113
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	25	1.35	--	14 - 41
Growing near mine spoil	26 (2)	20:20	25	1.25	--	16 - 39
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	48	1.38	--	35 - 71
Alkali sacaton	11 (2)	6:6	21	1.24	--	17 - 27

TABLE 50.—*Strontium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (2)	30:30	370	1.41	1.10	170 - 770
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (1)	64:64	140	1.47	1.25	70 - 300
B horizon------------------------------	13 (1)	64:64	160	1.70	1.31	70 - 700
C horizon------------------------------	13 (1)	64:64	190	1.87	1.25	70 - 1,000
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (1)	48:48	160	1.53	1.23	50 - 500
Soil, 15- to 2-cm depth----------------	20 (1)	48:48	160	1.47	1.23	100 - 500
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (2)	16:16	210	1.25	1.08	140 - 320
C horizon------------------------------	14 (2)	16:16	240	1.35	1.21	140 - 350
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (2)	108:108	280	1.54	1.25	61 - 660
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (2)	88:88	150	1.54	1.18	58 - 440
C horizon--------------------------	16 (2)	88:88	190	1.56	1.14	82 - 880
Glaciated area						
A horizon--------------------------	16 (2)	48:48	180	1.24	1.18	110 - 260
C horizon--------------------------	16 (2)	48:48	240	1.24	1.14	120 - 370
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (2)	136:136	160	1.47	1.18	58 - 440
C horizon------------------------	16 (2)	136:136	210	1.48	1.14	82 - 880
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (2)	36:36	230	1.39	1.08	76 - 480
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (2)	36:36	340	1.42	1.13	190 - 690
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (2)	47:47	160	1.37	1.09	88 - 440
C horizon------------------------------	11 (2)	47:47	202	1.42	1.10	110 - 680
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (2)	30:30	220	1.21	1.07	160 - 340
C horizon----------------------------	24 (2)	30:30	210	1.25	1.22	130 - 340
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley--------------------------------	21 (1)	18:18	0.98	1.63	1.19	0.42 - 2.8
Oats----------------------------------	21 (1)	21:21	1.4	1.42	1.23	.79 - 3.0
Wheat, durum--------------------------	21 (1)	20:20	1.5	1.36	1.34	.51 - 2.0
Wheat, hard red spring---------------	21 (1)	54:54	1.2	1.63	1.41	.40 - 3.9
Wheat, hard red winter---------------	21 (1)	17:17	1.1	1.57	1.37	.60 - 2.5
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (2)	25:25	24	1.29	1.08	17 - 43
Saltbush, fourwing, San Juan Basin-----	19 (2)	10:10	87	1.70	1.18	48 - 240
Snakeweed, San Juan Basin--------------	19 (2)	18:18	74	1.57	1.15	40 - 150

TABLE 50.—*Strontium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANTS--Continued				
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (1)	29:29	350	1.82	1.20	150 - 1,000
Sagebrush, big; Powder River Basin, Wyo. and Mont.-----------------------	20 (1)	41:41	590	1.77	1.20	150 - 1,500
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (1)	30:30	1,200	3.03	1.50	300 - 3,000
Columbia Plateaus Province-----------	23 (1)	30:30	930	2.38	1.50	150 - 1,500
Basin and Range Province-------------	23 (1)	30:30	1,400	1.72	1.50	500 - 3,000
Northern Great Plains----------------	23 (1)	20:20	1,500	1.71	1.12	500 - 3,000
Northern Rocky Mountains Province----	23 (1)	20:20	1,100	2.51	1.12	200 - 2,000
Middle Rocky Mountains Province------	23 (1)	20:20	1,100	2.58	1.12	200 - 3,000
Southern Rocky Mountains Province----	23 (1)	20:20	1,100	2.54	1.12	200 - 3,000
Wyoming Basin Province---------------	23 (1)	20:20	1,500	1.60	1.12	1,000 - 3,000

TABLE 51.—*Sulfur (total) in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed Range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone---------------------------	1 (5)	26:80	0.028	--	--	<0.08 - 0.77
Shale-------------------------------	1 (5)	37:80	.055	--	--	<.08 - .87
Core samples						
Hanging Woman Creek, Mont.						
Sandstone----------------------------	2 (5)	16:24	.12	2.13	1.55	<.05 - .82
Siltstone and shale------------------	2 (5)	23:24	.17	1.66	1.32	<.05 - .40
Dark shale---------------------------	2 (5)	23:23	.32	1.33	1.29	.17 - .52
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (5)	27:50	.066	2.58	--	<.06 - .55
Sandstone--------------------------	4 (5)	28:42	.05	2.70	1.37	<.04 - .39
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)--------	5 (5)	71:74	.23	2.22	1.34	<.032 - .88
Middle 300 m-----------------------	5 (5)	51:51	.21	1.75	1.40	.049 - .71
Garden Gulch Member (lower 100 m)--	5 (5)	32:32	.53	1.68	--	.13 - 1.3

TABLE 51.—*Sulfur (total) in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (5)	46:60	0.12	1.87	1.31	<0.08 - 0.48
Powder River Basin, Wyo. and Mont.						
Size fraction, <63 μm-----------------	7 (5)	16:24	.01	1.73	1.57	<.08 - .29
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (5)	10:10	0.41	2.09	--	0.16 - 1.1
Dave Johnston mine, Wyoming----------	10 (5)	6:10	.069	2.43	--	<.03 - .20
Hidden Valley mine, Wyoming----------	10 (5)	10:10	.086	1.75	--	.046 - .20
Kincaid mine, North Dakota-----------	10 (5)	10:10	.17	3.01	--	<.03 - .46
Savage mine, Montana-----------------	10 (5)	2:10	.035	1,80	--	<.03 - .18
Velva mine, North Dakota-------------	10 (5)	8:10	.079	2.04	--	<.03 - .16
Big Sky mine, Montana----------------	10 (5)	9:10	.17	2.48	--	<.03 - .67
Utility mine, Saskatchewan-----------	10 (5)	7:10	.081	2.80	--	<.03 - .50
San Juan mine, New Mexico-------------	11 (5)	12:12	.26	1.63	1.30	.098 - .52
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (5)	12:12	.10	1.55	1.13	.060 - .24
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (7)	10:10	0.31	1.38	1.09	0.20 - 0.53
Dave Johnston mine, Wyoming--------	10 (7)	10:10	.29	1.34	1.09	.18 - .45
Hidden Valley mine, Wyoming--------	10 (7)	10:10	.32	1.30	1.09	.21 - .43
Kincaid mine, North Dakota---------	10 (7)	10:10	.44	1.34	1.09	.22 - .65
Savage mine, Montana---------------	10 (7)	10:10	.19	1.23	1.09	.14 - .27
Velva mine, North Dakota-----------	10 (7)	10:10	.29	1.42	1.09	.20 - .50
White sweetclover						
Big Sky mine, Montana--------------	10 (7)	10:10	.26	1.29	1.09	.17 - .36
Utility mine, Saskatchewan---------	10 (7)	10:10	.26	1.29	1.09	.17 - .39
Alfalfa						
Beulah North mine, North Dakota----	10 (7)	3:3	.27	1.28	--	.22 - .36
Dave Johnston mine, Wyoming--------	10 (7)	3:3	.39	1.42	--	.26 - .48
Savage mine, Montana---------------	10 (7)	3:3	.22	1.30	--	.18 - .30
Velva mine, North Dakota-----------	10 (7)	3:3	.26	1.28	--	.20 - .33
Big Sky mine, Montana--------------	10 (7)	3:3	.31	1.07	--	.29 - .33
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (7)	20:20	.18	1.45	1.05	.09 - .33
Growing near mine spoil----------	26 (7)	20:20	.17	1.29	1.05	.10 - .27
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (7)	6:6	.45	1.17	--	.40 - .52
Alkali sacaton-----------------------	11 (7)	6:6	.15	1.20	--	.12 - .18

TABLE 51.—*Sulfur (total) in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		SOILS				
Piceance and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth------	12 (5)	10:30	0.067	1.44	--	<0.08 - 0.15
Hanging Woman Creek, Mont.						
A horizon-------------------------------	14 (5)	4:16	.041	1.63	--	<.087 - .28
C horizon-------------------------------	14 (5)	10:16	.11	2.34	1.23	<.1 - .38
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon-------------------------	16 (5)	57:136	.034	2.64	--	<.040 - .62
C horizon-------------------------	16 (5)	72:136	.047	4.71	1.58	<.040 - 2.0
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (5)	8:36	--	--	--	<.080 - .96
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (5)	3:36	.15	1.82	--	<.080 - .28
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (5)	47:47	.10	1.45	1.24	.047 - .42
C horizon-------------------------------	11 (5)	47:47	.14	2.44	1.10	.057 - 3.3
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (5)	18:30	.040	1.42	--	<.032 - .065
C horizon----------------------------	24 (5)	18:30	.040	1.69	--	<.032 - .13
		PLANTS				
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley---------------------------------	21 (7)	18:18	0.15	1.16	1.08	0.12 - 0.22
Oats-----------------------------------	21 (7)	21:21	.18	1.12	1.03	.14 - .22
Wheat, durum--------------------------	21 (7)	20:20	.18	1.13	1.07	.14 - .22
Wheat, hard red spring---------------	21 (7)	54:54	.18	1.11	1.07	.14 - .22
Wheat, hard red winter---------------	21 (7)	17:17	.15	1.11	1.07	.13 - .19
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (7)	25:25	.099	1.38	1.06	.05 - .22
Saltbush, fourwing, San Juan Basin-----	19 (7)	10:10	.30	1.39	1.06	.15 - .54
Snakeweed, San Juan Basin--------------	19 (7)	17:17	.11	1.41	1.07	.05 - .24
Native species (dry-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (7)	29:29	.067	1.36	1.19	.04 - .13
Sagebrush, big; regional study						
Colorado Plateaus Province-----------	23 (7)	30:30	.15	1.29	1.08	.10 - .21
Columbia Plateaus Province-----------	23 (7)	30:30	.16	1.21	1.08	.13 - .22
Basin and Range Province-------------	23 (7)	30:30	.16	1.19	1.08	.11 - .21
Northern Great Plains----------------	23 (7)	20:20	.13	1.27	1.08	.10 - .18
Northern Rocky Mountains Province----	23 (7)	20:20	.13	1.28	1.08	.09 - .19
Middle Rocky Mountains Province------	23 (7)	20:20	.11	1.28	1.08	.08 - .16
Southern Rocky Mountains Province----	23 (7)	20:20	.12	1.29	1.08	.09 - .16
Wyoming Basin Province---------------	23 (7)	20:20	.14	1.18	1.08	.12 - .19

TABLE 52.—*Terbium in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
		SOILS				
San Juan Basin, N. Mex.						
A horizon	11 (2)	2:47	--	--	--	<22 - 29
C horizon	11 (2)	2:47	--	--	--	<22 - 38
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	3:30	--	--	--	<22 - 36
C horizon	24 (2)	6:30	17	1.37	--	<22 - 31

TABLE 53.—*Thorium in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (8)	79:80	7.1	1.46	1.21	<3.0 - 16
Shale	1 (8)	80:80	13	1.34	1.11	8.1 - 30
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (8)	24:24	6.3	1.42	1.28	3.4 - 13
Siltstone and shale	2 (8)	24:24	12	1.29	1.23	7.2 - 22
Dark shale	2 (8)	23:23	14	1.25	1.11	9.6 - 23
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (8)	50:50	13	1.46	1.31	5.4 - 29
Sandstone	4 (8)	42:42	9.3	1.3	1.14	5.5 - 15
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (8)	60:60	8.3	1.33	--	4.9 - 20
Middle 300 m	5 (8)	43:53	8.7	1.35	--	<4.4 - 23
Garden Gulch Member (lower 100 m)	5 (8)	32:32	9.0	1.64	--	4.0 - 37
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (8)	57:60	9.4	1.33	1.07	<4.0 - 17
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (8)	18:18	7.5	2.20	1.10	3.5 - 50
100-200 µm	7 (8)	23:23	7.0	1.47	1.04	4.5 - 14
63-100 µm	7 (8)	23:23	7.9	1.58	1.49	4.3 - 20
<63 µm	7 (8)	22:22	15	1.76	1.22	3.9 - 54

TABLE 53.—*Thorium in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (8)	10:10	8.7	1.23	--	5.5 - 10
Dave Johnston mine, Wyoming----------	10 (8)	10:10	12	1.23	--	9.5 - 17
Hidden Valley mine, Wyoming----------	10 (8)	10:10	12	1.22	--	7.1 - 15
Kincaid mine, North Dakota-----------	10 (8)	10:10	8.7	1.22	--	6.9 - 14
Savage mine, Montana-----------------	10 (8)	10:10	8.2	1.21	--	5.2 - 9.9
Velva mine, North Dakota-------------	10 (8)	10:10	7.1	1.13	--	5.7 - 8.3
Big Sky mine, Montana----------------	10 (8)	10:10	8.6	1.22	--	5.6 - 11
Utility mine, Saskatchewan-----------	10 (8)	10:10	7.7	1.17	--	6.3 - 11
San Juan mine, New Mexico-------------	11 (8)	12:12	9.8	1.14	1.14	7.9 - 12
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (8)	12:12	7.7	1.19	1.16	6.0 - 11
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (8)	30:30	9.3	1.30	1.16	5.4 - 30
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (8)	48:48	9.4	1.26	1.10	5.3 - 15
Soil, 15- to 20-cm depth---------------	20 (8)	48:48	9.6	1.25	1.10	5.6 - 15
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (8)	16:16	9.9	1.15	1.12	7.8 - 14
C horizon------------------------------	14 (8)	16:16	9.9	1.16	1.12	6.9 - 12
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (8)	108:108	12	1.23	1.16	6.1 - 19
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (8)	88:88	8.8	1.20	1.12	5.9 - 13
C horizon--------------------------	16 (8)	88:88	8.3	1.34	1.27	3.7 - 18
Glaciated area						
A horizon--------------------------	16 (8)	48:48	7.7	1.25	1.12	3.0 - 11
C horizon--------------------------	16 (8)	48:48	7.0	1.35	1.27	3.1 - 14
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (8)	136:136	8.4	1.23	1.12	3.0 - 13
C horizon------------------------	16 (8)	136:136	7.8	1.36	1.27	3.1 - 18
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (8)	36:36	8.5	1.27	1.13	4.3 - 14
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (8)	36:36	12	1.43	1.10	6.3 - 30
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (8)	47:47	8.2	1.35	1.18	3.9 - 15
C horizon------------------------------	11 (8)	47:47	8.3	1.38	1.12	3.9 - 16
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (8)	30:30	7.7	1.25	1.17	4.9 - 11
C horizon----------------------------	24 (8)	30:30	7.0	1.31	1.15	3.9 - 11

TABLE 54.—*Thulium in rocks and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
		ROCKS				
Core samples						
Northern Great Plains, Fort Union Formation						
Sandstone---------------------------	4 (2)	1:42	--	--	--	<2.2 - 3.8
		SOILS				
San Juan Basin, N. Mex.						
A horizon-------------------------------	11 (2)	1:47	--	--	--	<2.2 - 2.6
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon-----------------------------	24 (2)	1:30	--	--	--	<2.2 - 4.6

TABLE 55.—*Tin in rocks, stream sediments, mine spoil and associated materials, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone---------------------------	1 (18)	80:80	1.1	1.66	1.25	0.18 - 2.4
Shale-------------------------------	1 (18)	80:80	1.4	1.69	1.37	.21 - 3.3
Core samples						
Hanging Woman Creek, Mont.						
Sandstone-----------------------------	2 (18)	24:24	.72	1.89	1.69	.1 - 1.6
Siltstone and shale------------------	2 (18)	24:24	1.3	1.94	1.64	.15 - 2.3
Dark shale---------------------------	2 (18)	23:23	1.3	1.69	1.64	.42 - 2.4
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (18)	50:50	1.3	1.74	1.41	.11 - 3.1
Sandstone--------------------------	4 (18)	42:42	1.3	1.40	1.29	.50 - 3.9
Piceance Creek Basin, Colo.						
Green River Formation						
Mahogany zone (upper 100 m)--------	5 (18)	39:42	1.7	2.74	--	<.15 -16
Middle 300 m-----------------------	5 (18)	48:48	1.6	2.19	2.10	.4 -21
Garden Gulch Member (lower 100 m)--	5 (18)	16:16	1.4	1.78	--	.50 - 4.8

TABLE 55.—*Tin in rocks, stream sediments, mine spoil and associated materials, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia-tion	Error	Observed range (ppm)
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (18)	60:60	0.97	1.37	1.27	0.47 - 1.5
Powder River Basin, Wyo. and Mont.						
Size fractions						
100-200 µm---------------------------	7 (5)	14:24	.17	3.32	1.88	<.1 - 1.6
63-100 µm----------------------------	7 (5)	21:24	.36	3.73	2.87	<.1 - 1.4
<63 µm-------------------------------	7 (5)	24:24	1.2	1.77	1.14	.44 - 4.7
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (5)	8:10	0.61	3.48	--	<0.1 - 2.0
Dave Johnston mine, Wyoming----------	10 (5)	8:10	.73	3.30	--	<.1 - 2.5
Hidden Valley mine, Wyoming----------	10 (5)	10:10	1.4	1.47	--	.68 - 2.1
Kincaid mine, North Dakota-----------	10 (5)	9:10	.85	2.65	--	<.1 - 3.7
Savage mine, Montana-----------------	10 (5)	8:10	.76	3.20	--	<.1 - 2.0
Velva mine, North Dakota-------------	10 (5)	9:10	1.1	2.56	--	<.1 - 3.3
Big Sky mine, Montana----------------	10 (5)	7:10	.56	3.60	--	<.1 - 1.7
Utility mine, Saskatchewan-----------	10 (5)	7:10	.51	3.36	--	<.1 - 1.8
San Juan mine, New Mexico--------------	11 (5)	12:12	1.9	1.27	1.29	1.4 - 2.8
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (5)	11:12	1.1	2.24	1.60	<.2 - 2.6
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (5)	30:30	1.3	1.22	1.20	0.71 - 1.8
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (5)	16:16	1.1	1.40	1.34	.69 - 2.0
C horizon------------------------------	14 (5)	16:16	1.2	1.22	1.15	.67 - 1.7
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (5)	92:108	.82	3.90	2.99	<.11 -11
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (5)	129:136	.86	1.86	1.51	<.10 - 5.6
C horizon------------------------	16 (5)	128:136	.94	1.94	1.44	<.10 - 4.8
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (5)	34:36	.72	2.15	2.27	<.10 - 1.8
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (5)	32:36	.81	2.61	2.43	<.10 - 2.8
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (5)	34:47	.43	2.68	2.04	<.20 - 1.5
C horizon------------------------------	11 (5)	39:47	.62	2.55	1.66	<.20 - 2.7
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (5)	24:30	.76	3.33	2.06	<.20 - 2.7
C horizon----------------------------	24 (5)	22:30	.75	--	--	<.20 - 5.4

TABLE 56.—*Titanium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (5)	80:80	2,300	1.47	1.06	790 - 3,900
Shale	1 (5)	80:80	3,400	1.35	1.05	1,900 - 8,900
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (5)	24:24	2,900	1.29	1.08	1,900 - 4,500
Siltstone and shale	2 (5)	24:24	4,000	1.10	1.02	3,200 - 4,500
Dark shale	2 (5)	23:23	4,100	1.11	1.04	3,400 - 4,600
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (5)	50:50	3,800	1.16	1.03	2,500 - 4,700
Sandstone	4 (5)	42:42	2,600	1.20	1.04	1,700 - 4,400
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (5)	74:74	1,700	1.31	1.09	630 - 2,900
Middle 300 m	5 (5)	51:51	1,400	1.39	1.05	490 - 4,500
Garden Gulch Member (lower 100 m)	5 (5)	32:32	2,700	1.28	--	1,200 - 3,600
		STREAM SEDIMENTS				
Northern Great Plains regional study						
First-order streams	6 (5)	20:20	3,200	1.12	1.04	2,600 - 4,100
Second-order streams	6 (5)	20:20	3,300	1.17	1.04	2,700 - 4,500
Third-order streams	6 (5)	20:20	3,600	1.21	1.02	2,300 - 4,800
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (5)	19:19	1,100	1.88	1.42	500 - 3,100
100-200 μm	7 (5)	24:24	1,400	1.38	1.06	900 - 3,500
63-100 μm	7 (5)	24:24	2,400	1.49	1.05	1,400 - 7,200
<63 μm	7 (5)	24:24	4,600	1.48	1.03	2,600 -12,000
Uinta and Piceance Creek Basins, Colo. and Utah	8 (1)	32:32	2,200	1.49	1.30	1,000 - 5,000
Piceance Creek Basin, Colo. Roan and Black Sulphur Creeks	9 (1)	32:32	2,100	1.63	1.28	1,000 - 5,000
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (5)	10:10	3,400	1.07	--	3,100 - 3,700
Dave Johnston mine, Wyoming	10 (5)	10:10	2,500	1.18	--	2,000 - 3,300
Hidden Valley mine, Wyoming	10 (5)	10:10	3,800	1.15	--	2,800 - 4,400
Kincaid mine, North Dakota	10 (5)	10.10	3,000	1.22	--	2,100 - 4,000
Savage mine, Montana	10 (5)	10:10	2,500	1.10	--	2,000 - 2,700

TABLE 56.—*Titanium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Velva mine, North Dakota	10 (5)	10:10	2,700	1.07	--	2,300 - 3,000
Big Sky mine, Montana	10 (5)	10:10	2,700	1.09	--	2,300 - 3,000
Utility mine, Saskatchewan	10 (5)	10:10	2,400	1.19	--	1,700 - 3,500
San Juan mine, New Mexico	11 (5)	12:12	2,700	1.14	1.04	2,100 - 3,200
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (5)	12:12	2,300	1.05	1.04	2,100 - 2,500
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	10:10	6.5	2.36	1.62	1 - 21
Dave Johnston mine, Wyoming	10 (2)	7:7	9.6	1.66	1.62	5 - 22
Hidden Valley mine, Wyoming	10 (2)	10:10	74	1.83	1.62	28 - 202
Kincaid mine, North Dakota	10 (2)	10:10	24	1.95	1.62	5 - 50
Savage mine, Montana	10 (2)	9:9	4.4	2.80	1.62	1 - 19
Velva mine, North Dakota	10 (2)	10:10	7.5	2.48	1.62	3 - 42
White sweetclover						
Big Sky mine, Montana	10 (2)	10:10	15	1.83	1.62	6 - 29
Utility mine, Saskatchewan	10 (2)	10:10	9.2	1.92	1.62	4 - 23
Alfalfa						
Beulah North mine, North Dakota	10 (2)	3:3	24	3.08	--	8 - 79
Dave Johnston mine, Wyoming	10 (2)	3:3	43	1.45	--	29 - 59
Savage mine, Montana	10 (2)	3:3	30	1.48	--	21 - 46
Velva mine, North Dakota	10 (2)	3:3	25	3.43	--	11 - 103
Big Sky mine, Montana	10 (2)	3:3	21	1.16	--	18 - 24
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil	26 (2)	20:20	26	1.79	1.28	11 - 74
Growing near mine spoil	26 (2)	20:20	16	2.12	1.28	3 - 50
San Juan mine, New Mexico						
Fourwing saltbush	11 (2)	6:6	43	1.50	--	25 - 64
Alkali sacaton	11 (2)	6:6	16	2.59	--	5.3 - 44
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (5)	30:30	*2,700	*310	*51	700 - 4,200
Powder River Basin, Wyo. and Mont.						
A horizon	13 (5)	64:64	*2,800	*710	*290	1,300 - 4,100
B horizon	13 (5)	64:64	*2,900	*680	*200	1,200 - 4,300
C horizon	13 (5)	64:64	*2,800	*890	*260	820 - 4,200
Hanging Woman Creek, Mont.						
A horizon	14 (5)	16:16	*3,000	*370	*140	2,500 - 3,600
C horizon	14 (5)	16:16	*2,900	*480	*90	1,700 - 3,400

TABLE 56.—*Titanium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia- tion	Error	Observed range (ppm)
SOILS--Continued						
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (5)	108:108	2,800	1.20	--	1,500 - 3,800
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (5)	136:136	*2,500	*230	*200	1,100 - 3,700
C horizon	16 (5)	136:136	*2,500	*580	*140	710 - 3,800
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	2,600	1.22	1.05	1,600 - 3,800
Wind River Basin, Wyo., 0- to 40-cm depth	17 (5)	36:36	2,200	1.22	1.07	1,500 - 3,200
San Juan Basin, N. Mex.						
A horizon	11 (5)	47:47	2,100	1.38	1.06	910 - 4,000
C horizon	11 (5)	47:47	2,200	1.41	1.05	880 - 3,800
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (5)	30:30	2,200	1.23	1.06	1,500 - 3,000
C horizon	24 (5)	30:30	1,800	1.31	1.19	990 - 3,000
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (1)	17:18	0.32	2.09	1.18	<0.09 - 1.6
Oats	21 (1)	17:21	.24	2.16	1.02	<.11 - 1.4
Wheat, durum	21 (1)	20:20	.17	1.66	1.66	.079 - .40
Wheat, hard red spring	21 (1)	53:54	.20	2.03	1.33	<.07 - 1.4
Wheat, hard red winter	21 (1)	16:17	.11	1.47	1.17	<.06 - .19
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	46	2.01	1.22	8.6 - 170
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	10	2.06	1.23	3.5 - 29
Snakeweed, San Juan Basin	19 (2)	18:18	31	2.06	1.23	5.5 - 75
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	1,700	1.44	1.12	1,000 - 3,000
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	1,000	1.54	1.38	200 - 2,000
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	30:30	520	1.96	1.22	200 - 1,500
Columbia Plateaus Province	23 (1)	30:30	1,500	1.62	1.20	700 - 5,000
Basin and Range Province	23 (1)	30:30	670	1.79	1.22	300 - 1,500
Northern Great Plains	23 (1)	20:20	520	1.98	1.19	300 - 2,000
Northern Rocky Mountains Province	23 (1)	20:20	550	1.77	1.19	200 - 1,500
Middle Rocky Mountains Province	23 (1)	20:20	630	1.91	1.19	300 - 2,000
Southern Rocky Mountains Province	23 (1)	20:20	480	1.81	1.19	200 - 1,000
Wyoming Basin Province	23 (1)	20:20	750	1.76	1.19	300 - 1,500

TABLE 57.—*Uranium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (8)	80:80	2.7	1.41	1.05	1.4 - 9.0
Shale	1 (8)	80:80	4.1	1.49	<1.04	2.6 - 10
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (8)	24:24	2.2	1.30	1.09	1.6 - 3.4
Siltstone and shale	2 (8)	24:24	4.1	1.42	1.21	2.9 - 7.8
Dark shale	2 (8)	23:23	4.5	1.34	1.05	3.4 - 11
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (8)	50:50	3.7	1.31	1.08	2.4 - 9.3
Sandstone	4 (8)	42:42	2.7	1.40	1.04	1.3 - 5.5
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (8)	74:74	4.9	1.35	1.04	2.7 - 11
Middle 300 m	5 (8)	47:53	4.3	1.48	--	<1.6 - 12
Garden Gulch Member (lower 100 m)	5 (8)	32:32	5.9	1.68	--	2.0 - 15
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (8)	60:60	3.4	1.38	1.14	2.2 - 12
Powder River Basin, Wyo. and Mont. Size fractions						
>200 μm	7 (8)	19:19	3.2	1.95	1.32	1.4 - 20
100-200 μm	7 (8)	24:24	2.0	1.31	1.05	1.3 - 4.7
63-100 μm	7 (8)	24:24	2.8	1.34	1.01	1.7 - 5.5
<63 μm	7 (8)	24:24	5.6	1.88	1.02	1.7 - 22
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (8)	10:10	3.0	1.17	--	2.3 - 3.7
Dave Johnston mine, Wyoming	10 (8)	10:10	5.6	1.34	--	2.4 - 10
Hidden Valley mine, Wyoming	10 (8)	10:10	5.1	1.09	--	4.3 - 5.7
Kincaid mine, North Dakota	10 (8)	10:10	3.3	1.29	--	1.8 - 4.7
Savage mine, Montana	10 (8)	10:10	3.6	1.26	--	2.8 - 5.1
Velva mine, North Dakota	10 (8)	10:10	2.7	1.13	--	2.1 - 3.3
Big Sky mine, Montana	10 (8)	10:10	3.5	1.19	--	2.3 - 4.3
Utility mine, Saskatchewan	10 (8)	10:10	2.7	1.22	--	2.1 - 4.3
San Juan mine, New Mexico	11 (8)	12:12	4.1	1.17	1.03	3.4 - 5.6
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (8)	12:12	2.9	1.16	1.05	2.4 - 4.0

TABLE 57.—*Uranium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)						
Northern Great Plains						
Alfalfa						
Beulah North mine, North Dakota----	10 (13)	2:3	0.035	1.98	--	<0.02 - 0.068
Dave Johnston mine, Wyoming--------	10 (13)	3:3	.200	1.87	--	.133 - .403
Savage mine, Montana---------------	10 (13)	3:3	.048	1.45	--	.036 - .073
Velva mine, North Dakota-----------	10 (13)	3:3	.086	1.20	--	.071 - .103
Big Sky mine, Montana--------------	10 (13)	3:3	.037	1.27	--	.030 - .048
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (13)	19:20	.062	2.95	1.35	<.028 - .55
Growing near mine spoil----------	26 (13)	9:20	.021	1.94	1.35	<.021 - .067
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (13)	6:6	.11	1.27	--	.072 - .13
Alkali sacaton-----------------------	11 (13)	6:6	.13	1.22	--	.10 - .16
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (8)	30:30	3.5	1.22	1.12	2.4 - 6
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (22)	63:63	*20	*7.55	*7.13	10 - 40
B horizon------------------------------	13 (22)	61:64	*17	*8.12	*6.70	<10 - 40
C horizon------------------------------	13 (22)	62:64	*19	*6.50	*6.50	<10 - 40
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (8)	48:48	3.0	1.28	1.03	1.7 - 7.0
Soil, 15- to 20-cm depth---------------	20 (8)	48:48	3.0	1.28	1.03	2.2 - 7.0
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (8)	16:16	3.0	1.13	1.06	2.5 - 3.9
C horizon------------------------------	14 (8)	16:16	3.4	1.21	1.05	2.4 - 4.6
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (8)	108:108	3.3	1.21	1.05	1.9 - 5.4
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (8)	88:88	2.5	1.23	1.04	1.4 - 4.9
C horizon--------------------------	16 (8)	88:88	2.8	1.41	1.06	1.5 - 11
Glaciated area						
A horizon--------------------------	16 (8)	48:48	2.0	1.21	1.04	1.1 - 2.9
C horizon--------------------------	16 (8)	48:48	2.2	1.42	1.06	.69 - 5.2
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (8)	136:136	2.3	1.25	1.04	1.1 - 4.9
C horizon------------------------	16 (8)	136:136	2.6	1.44	1.06	.69 - 11
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (8)	36:36	2.7	1.25	1.05	1.7 - 4.5
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (8)	36:36	2.8	1.20	1.05	2.2 - 4.5
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (8)	47:47	2.5	1.30	1.06	1.3 - 5.1
C horizon------------------------------	11 (8)	47:47	2.7	1.40	1.06	1.1 - 4.9

TABLE 57.—*Uranium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (8)	30:30	2.2	1.22	1.08	1.5 - 3.2
C horizon	24 (8)	30:30	1.9	1.28	1.06	1.1 - 3.0
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (13)	25:25	0.089	1.53	1.10	0.040 - 0.19
Saltbush, fourwing, San Juan Basin	19 (13)	4:10	.044	1.36	1.07	<.034 - .072
Snakeweed, San Juan Basin	19 (13)	17:18	.11	1.66	1.12	<.029 - .21
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (13)	28:29	1.3	2.42	1.17	<.4 - 7.0
Sagebrush, big Powder River Basin, Wyo. and Mont.	20 (13)	28:41	.56	2.05	1.49	<.4 - 3.5
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (13)	10:30	.29	2.08	--	<.4 - 1.4
Columbia Plateaus Province	23 (13)	8:30	.30	1.50	--	<.4 - .8
Basin and Range Province	23 (13)	3:30	<.4	--	--	<.4 - .4
Northern Great Plains	23 (13)	8:20	.28	3.21	--	<.4 - 4.6
Northern Rocky Mountains Province	23 (13)	6:20	.24	2.25	--	<.4 - 1.4
Middle Rocky Mountains Province	23 (13)	5:20	.27	1.58	--	<.4 - .8
Southern Rocky Mountains Province	23 (13)	2:20	<.4	--	--	<.4 - .8
Wyoming Basin Province	23 (13)	11:20	.42	2.25	--	<.4 - 4.4

TABLE 58.—*Vanadium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (-) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed Range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	79:80	46	1.68	1.28	<18 - 110
Shale	1 (2)	80:80	97	1.51	1.21	39 - 230
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	59	1.50	1.09	33 - 110
Siltstone and shale	2 (2)	24:24	130	1.28	1.14	85 - 190
Dark shale	2 (2)	23:23	150	1.17	1.08	110 - 190

TABLE 58.—*Vanadium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS--Continued				
Core samples--Continued						
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	86	1.47	1.15	32 - 150
Sandstone	4 (2)	42:42	75	1.50	1.07	38 - 180
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	74	1.41	1.31	3.7 - 150
Middle 300 m	5 (2)	53:53	91	1.50	1.24	15 - 180
Garden Gulch Member (lower 100 m)	5 (2)	264:264	130	1.37	--	50 - 300
		STREAM SEDIMENTS				
Northern Great Plains regional study	6 (2)	60:60	73	1.34	1.16	27 - 140
Powder River Basin, Wyoming and Montana Size fractions						
>200 µm	7 (1)	24:24	52	2.35	1.58	15 - 200
100-200 µm	7 (1)	24:24	37	1.57	1.18	20 - 150
63-100 µm	7 (1)	24:24	54	1.41	1.29	30 - 150
<63 µm	7 (1)	24:24	92	1.46	1.24	50 - 300
Uinta and Piceance Creek Basins Colo. and Utah	8 (1)	32:32	99	1.35	1.25	70 - 200
Piceance Creek Basin, Colorado Roan and Black Sulphur Creeks	9 (1)	32:32	70	1.37	1.16	50 - 150
		MINE SPOIL AND ASSOCIATED MATERIALS				
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	78	1.28	--	50 - 110
Dave Johnnston mine, Wyoming	10 (2)	10:10	73	1.29	--	51 - 120
Hidden Valley mine, Wyoming	10 (2)	10:10	76	1.40	--	36 - 110
Kincaid mine, North Dakota	10 (2)	10:10	63	1.40	--	40 - 100
Savage mine, Montana	10 (2)	10:10	61	1.34	--	32 - 93
Velva mine, North Dakota	10 (2)	10:10	68	1.26	--	44 - 94
Big Sky mine, Montana	10 (2)	10:10	50	1.27	--	37 - 71
Utility mine, Saskatchewan	10 (2)	10:10	62	1.24	--	42 - 86
San Juan mine, New Mexico	11 (2)	12:12	56	1.26	1.06	38 - 78
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	45	1.08	1.09	40 - 50
Plants (dry-weight basis)						
Northern Great Plains Yellow sweetclover						
Beulah North mine, North Dakota	10 (2)	9:10	.38	1.45	1.25	<.27 - .76
Dave Johnston mine, Wyoming	10 (2)	9:9	.54	1.34	1.25	.34 - .74
Hidden Valley mine, Wyoming	10 (2)	9:10	1.9	2.44	1.25	<.3 - 4.9
Kincaid mine, North Dakota	10 (2)	8:8	.9	1.71	1.25	.4 - 2.0
Savage mine, Montana	10 (2)	4:9	.25	1.70	1.25	<.27 - .54
Velva mine, North Dakota	10 (2)	9:10	.44	2.28	1.25	<.27 - 2.39

TABLE 58.—*Vanadium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)--Continued						
Northern Great Plains--Continued						
White sweetclover						
Big Sky mine, Montana--------------	10 (2)	8:8	0.50	1.23	1.25	0.42 - 0.77
Utility mine, Saskatchewan---------	10 (2)	8:10	.35	1.51	1.25	<.27 - .75
Alfalfa						
Beulah North mine, North Dakota----	10 (2)	1:3	<1.4	--	--	<1.4 - 2.3
Dave Johnston mine, Wyoming--------	10 (2)	3:3	1.5	1.12	--	1.4 - 1.8
Savage mine, Montana---------------	10 (2)	1:2	--	--	--	<1.4 - 1.8
Velva mine, North Dakota-----------	10 (2)	1:3	<1.4	--	--	<1.4 - 5.2
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (2)	19:20	.82	1.36	--	<.69 - 1.5
Growing near mine spoil----------	26 (2)	14:20	.63	1.11	--	<.52 - .98
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (2)	6:6	1.9	1.27	--	1.5 - 2.7
Alkali sacaton-----------------------	11 (2)	6:6	.94	1.47	--	.62 - 1.4
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (2)	30:30	68	1.31	1.13	41 - 110
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (1)	64:64	65	1.62	1.21	30 - 150
B horizon------------------------------	13 (1)	64:64	78	1.47	1.28	30 - 150
C horizon------------------------------	13 (1)	64:64	72	1.79	1.22	30 - 200
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (1)	48:48	77	1.36	1.21	30 - 150
Soil, 15- to 20-cm depth---------------	20 (1)	48:48	87	1.39	1.23	50 - 150
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (2)	16:16	87	1.27	1.13	49 - 120
C horizon------------------------------	14 (2)	16:16	79	1.37	1.23	40 - 120
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (2)	108:108	56	1.58	1.34	7.5 - 120
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (2)	88:88	52	1.35	1.25	20 - 96
C horizon--------------------------	16 (2)	88:88	50	1.43	1.18	19 - 100
Glaciated area						
A horizon--------------------------	16 (2)	48:48	58	1.33	1.25	24 - 89
C horizon--------------------------	16 (2)	48:48	64	1.45	1.18	24 - 150
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (2)	136:136	54	1.35	1.25	20 - 96
C horizon------------------------	16 (2)	136:136	54	1.46	1.18	19 - 150
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (2)	36:36	68	1.34	1.09	40 - 110
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (2)	36:36	48	1.32	1.11	23 - 110

TABLE 58.—*Vanadium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	41	1.49	1.09	15 - 94
B horizon	11 (2)	47:47	44	1.55	1.14	15 - 97
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	28	1.21	1.09	20 - 42
C horizon	24 (2)	30:30	28	1.40	1.09	14 - 53
		PLANTS				
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	1.3	1.47	1.12	0.063 - 2.7
Saltbush, fourwing, San Juan Basin	19 (2)	10:10	.70	1.50	1.13	.40 - 1.2
Snakeweed, San Juan Basin	19 (2)	18:18	1.1	1.63	1.16	.49 - 2.1
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	58	1.31	1.15	30 - 70
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	31	1.93	1.39	15 - 70
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	14:30	8.1	1.69	1.27	<10 - 20
Columbia Plateaus Province	23 (1)	30:30	33	1.91	1.36	15 - 100
Basin and Range Province	23 (1)	19:30	12	1.86	1.27	<10 - 50
Northern Great Plains	23 (1)	7:20	8.2	1.93	1.17	<15 - 70
Northern Rocky Mountains Province	23 (1)	8:20	10	1.77	1.17	<15 - 50
Middle Rocky Mountains Province	23 (1)	10:20	12	1.75	1.17	<15 - 50
Southern Rocky Mountains Province	23 (1)	7:20	10	1.42	1.17	<15 - 20
Wyoming Basin Province	23 (1)	13:20	14	1.70	1.17	<15 - 50

TABLE 59.—*Ytterbium in rocks, stream sediments, mine spoil and associated materials, soils and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	79:80	2.1	1.97	1.24	<0.46 - 5.9
Shale	1 (2)	80:80	3.7	1.53	1.20	1.2 - 9.0

TABLE 59.--*Ytterbium in rocks, stream sediments, mine spoil and associated materials, soils and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia-tion	Error	Observed range (ppm)
ROCKS--Continued						
Core samples						
Hanging Womand Creek, Mont.						
Sandstone----------------------------	2 (2)	24:24	1.8	1.66	1.54	0.68 - 3.4
Siltstone and shale------------------	2 (2)	24:24	4.0	1.10	1.09	3.4 - 4.8
Dark shale---------------------------	2 (2)	23:23	4.0	1.10	1.09	3.4 - 4.8
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (2)	50:50	2.9	1.31	1.19	1.4 - 5.1
Sandstone--------------------------	4 (2)	42:42	2.1	1.30	1.15	1.2 - 4.3
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)--------	5 (2)	74:74	1.4	1.37	1.14	86 - 3.5
Middle 300 m-----------------------	5 (2)	52:53	1.3	1.32	1.15	<.9 - 2.3
Garden Gulch Member (lower 100 m)--	5 (2)	178:264	1.9	1.31	--	<2 - 5
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (2)	60:60	3.0	1.35	1.29	1.3 - 7.8
Powder River Basin, Wyo. and Mont. Size Fraction						
>200 µm------------------------------	7 (1)	24:24	2	1.53	1.30	1 - 3
100-200 µm---------------------------	7 (1)	24:24	2	1.45	1.18	1 - 3
63-100 µm----------------------------	7 (1)	24:24	2	1.54	<1.01	1.5 - 7
<63 µm-------------------------------	7 (1)	24:24	6	1.76	1.33	3 - 20
Uinta and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah-------------------	8 (1)	8:8	2.5	1.32	--	1.5 - 3
Cottonwood Creek, Utah---------------	8 (1)	8:8	3.1	1.53	--	2 - 5
Duck Creek, Colo.--------------------	8 (1)	8:8	2.1	1.26	--	1.5 - 3
Ryan Gulch, Colo.--------------------	8 (1)	8:8	2.9	1.15	--	2 - 3
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks----------	9 (1)	32:32	2.0	1.38	1.27	1.5 - 3
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota------	10 (2)	10:10	2.1	1.35	--	1.1 - 3.1
Dave Johnston mine, Wyoming----------	10 (2)	10:10	1.8	1.51	--	1.0 - 3.2
Hidden Valley mine, Wyoming----------	10 (2)	10:10	2.5	1.32	--	1.4 - 3.7
Kincaid mine, North Dakota-----------	10 (2)	10:10	2.0	1.33	--	1.2 - 2.7
Savage mine, Montana-----------------	10 (2)	10:10	1.8	1.41	--	.93 - 3.2
Velva mine, North Dakota-------------	10 (2)	10:10	1.4	1.44	--	.70 - 2.1
Big Sky mine, Montana----------------	10 (2)	10:10	2.7	1.75	--	1.2 - 9.5
Utility mine, Saskatchewan-----------	10 (2)	10:10	1.6	1.36	--	1.0 - 2.4
San Juan mine, New Mexico--------------	11 (2)	12:12	1.6	1.25	1.15	1.1 - 2.5
Topsoil used in spoil reclamation						
San Juan mine, New Mexico--------------	11 (2)	12:12	1.6	1.10	1.10	1.3 - 1.8

TABLE 59.—*Ytterbium in rocks, stream sediments, mine spoil and associated materials, soils and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)						
San Juan mine, New Mexico						
Alkali sacaton	11 (2)	3:6	0.046	1.51	--	<.038 - .060
SOILS						
Piceance Creek and Unita Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	2.6	1.18	1.13	1.4 - 4.6
Powder River Basin, Wyo. and Mont.						
A horizon	13 (2)	64:64	2.1	1.40	1.33	1 - 7
B horizon	13 (2)	64:64	1.9	1.37	1.37	1 - 3
C horizon	13 (2)	64:64	1.8	1.38	1.16	<1 - 3
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm	20 (1)	47:47	1.8	1.31	1.29	1 - 5
Soil, 15- to 20-cm depth	20 (1)	48:48	1.8	1.30	1.29	1 - 5
Hanging Woman Creek, Mont.						
A horizon	14 (2)	16:16	3.2	1.26	1.17	1.9 - 4.5
C horizon	14 (2)	16:16	3.0	1.29	1.29	1.7 - 4.0
Piceance Creek Basin, Colo., 0- to 5-cm depth	15 (2)	108:108	16	1.52	1.34	4.9 - 36
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon	16 (2)	88:88	2.5	1.45	1.43	.78 - 5.8
Glaciated area						
A horizon	16 (2)	48:48	2.2	1.31	1.43	1.2 - 4.6
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	2.4	1.41	1.43	.78 - 5.8
C horizon	16 (2)	136:136	2.1	1.49	1.34	.57 - 4.7
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	2.7	1.33	1.11	1.2 - 4.3
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	2.2	1.49	1.70	.80 - 6.3
San Juan Basin, N. Mex.						
A horizon	11 (2)	47:47	1.6	1.28	1.24	.84 - 2.6
C horizon	11 (2)	47:47	1.6	1.45	1.13	.69 - 5.8
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	2.0	1.41	1.37	1.1 - 4.4
C horizon	24 (2)	30:30	1.6	1.48	1.78	.57 - 3.3
PLANTS						
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	19:25	0.083	1.61	1.32	0.056 - 0.29
Snakeweed, San Juan Basin	19 (2)	14:18	.068	1.39	1.22	<.047 - .13
Native species (ash-weight basis)						
Sagebrush, big; Powder River Basin, Wyoming and Montana	20 (1)	4:41	<2	--	--	<2 - 3

TABLE 60.—*Yttrium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	79:80	17	1.73	1.22	<4.6 - 44
Shale	1 (2)	80:80	22	1.54	1.23	7.9 - 82
Core samples						
Hanging Woman Creek Mont.						
Sandstone	2 (2)	24:24	15	1.44	1.28	8.0 - 28
Siltstone and shale	2 (2)	24:24	24	1.20	1.01	17 - 33
Dark shale	2 (2)	23:23	28	1.23	1.22	22 - 41
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	19	1.33	1.27	8.5 - 35
Sandstone	4 (2)	42:42	30	1.40	1.19	13 - 52
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	14	1.42	1.19	7.5 - 40
Middle 300 m	5 (2)	52:53	13	1.61	1.27	<2 - 29
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	60:60	21	1.24	1.15	12 - 52
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (1)	24:24	18	1.56	1.31	10 - 30
100-200 µm	7 (1)	24:24	13	3.04	<1.01	10 - 20
63-100 µm	7 (1)	24:24	48	1.67	1.34	20 - 50
<63 µm	7 (1)	24:24	48	1.67	1.34	20 - 150
Uinta Creek and Piceance Creek Basins, Colo. and Utah						
Asphalt Wash, Utah	8 (1)	8:8	29	1.15	--	20 - 30
Cottonwood Creek, Utah	8 (1)	8:8	34	1.27	--	30 - 50
Duck Creek, Colo.	8 (1)	8:8	22	1.33	--	15 - 30
Ryan Gulch, Colo.	8 (1)	8:8	27	1.21	--	20 - 30
Piceance Creek Basin, Colo.						
Roan and Black Sulphur Creeks	9 (1)	32:32	22	1.31	1.21	15 - 30
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	18	1.26	--	13 - 26
Dave Johnston mine, Wyoming	10 (2)	10:10	19	1.31	--	12 - 26
Hidden Valley mine, Wyoming	10 (2)	10:10	23	1.18	--	18 - 29

TABLE 60.—*Yttrium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Mine spoil--Continued						
Northern Great Plains--Continued						
Kincaid mine, North Dakota	10 (2)	10:10	19	1.32	--	12 - 27
Savage mine, Montana	10 (2)	10:10	17	1.40	--	10 - 27
Velva mine, North Dakota	10 (2)	10:10	16	1.29	--	10 - 23
Big Sky mine, Montana	10 (2)	10:10	23	1.46	--	16 - 57
Utility mine, Saskatchewan	10 (2)	10:10	17	1.32	--	12 - 27
San Juan mine, New Mexico	11 (2)	12:12	32	1.23	1.11	22 - 41
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	12:12	27	1.11	1.08	22 - 32
Plants (dry-weight basis)						
San Juan mine, New Mexico						
Fourwing slatbush	11 (2)	6:6	.81	1.42	--	.60 - 1.3
Alkali sacaton	11 (2)	6:6	.47	1.45	--	.30 - .68
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth	12 (2)	30:30	18	1.15	1.13	11 - 29
Powder River Basin, Wyo. and Mont.						
A horizon	13 (1)	64:64	19	1.38	1.35	10 - 30
B horizon	13 (1)	62:64	17	1.38	1.34	<10 - 30
C horizon	13 (1)	62:64	17	1.40	1.23	<10 - 30
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 5-cm depth	20 (1)	48:48	17	1.28	1.18	1 - 5
Soil, 15- to 20-cm depth	20 (1)	48:48	18	1.27	1.19	10 - 30
Hanging Woman, Creek, Mont.						
A horizon	14 (2)	16:16	24	1.19	1.13	15 - 29
C horizon	14 (2)	16:16	23	1.29	1.29	15 - 38
Piceance Creek Basin, Colo. 0- to 5-cm depth	15 (2)	108:108	16	1.52	1.34	4.9 - 36
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon	16 (2)	136:136	18	1.46	1.34	3.1 - 54
C horizon	16 (2)	136:136	17	1.47	1.32	3.1 - 42
Big Horn Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	20	1.28	1.15	10 - 29
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	17	1.35	1.53	9.6 - 39
San Juan Basin						
A horizon	11 (2)	47:47	28	1.34	1.18	15 - 46
C horizon	11 (2)	47:47	29	1.45	1.19	13 - 57

TABLE 60.—*Yttrium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (2)	30:30	30	1.33	1.14	18 - 71
C horizon----------------------------	24 (2)	30:30	1.6	1.48	1.78	.57 - 3.3
		PLANTS				
Native species (dry-weight basis)						
Galleta, San Juan Basin----------------	19 (2)	25:25	0.83	1.80	1.28	0.19 - 3.7
Saltbush, fourwing, San Juan Basin-----	19 (2)	7:10	.32	1.87	1.30	<.22 - .72
Snakeweed, San Juan Basin--------------	19 (2)	18:18	.68	1.61	1.22	.26 - 1.4
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.----------------	22 (1)	29:29	32	1.43	1.21	20 - 70
Sagebrush, big; Powder River Basin, Wyo. and Mont.-----------------------	20 (1)	5:41	<20	--	--	<20 - 30

TABLE 61.—*Zinc in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation, except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures, except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone---------------------------	1 (3)	80:80	44	1.64	1.27	10 - 120
Shale-------------------------------	1 (3)	80:80	80	1.86	<1.06	12 - 220
Core samples						
Hanging Woman Creek, Montana						
Sandstone----------------------------	2 (3)	24:24	60	1.42	--	31 - 100
Siltstone and shale------------------	2 (3)	24:24	110	1.16	1.05	86 - 150
Dark shale---------------------------	2 (3)	23:23	130	1.17	1.01	80 - 140
Northern Great Plains, Fort Union Formation						
Fine-grained rocks-----------------	3 (3)	50:50	59	1.32	1.26	30 - 110
Sandstone--------------------------	4 (3)	42:42	62	1.4	1.01	33 - 117

TABLE 61.—*Zinc in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS--Continued						
Core samples--Continued						
Piceance Creek Basin, Colorado						
Green River Formation						
Mahogany zone (upper 100 m)--------	5 (3)	74:74	79	1.23	1.08	47 - 140
Middle 300 m-----------------------	5 (3)	53:53	91	1.37	1.05	30 - 200
Garden Gulch Member (lower 100 m)--	5 (3)	32:32	120	1.25	--	68 - 160
STREAM SEDIMENTS						
Northern Great Plains regional study-----	6 (3)	60:60	71	1.22	1.13	42 - 120
Powder River Basin, Wyo. and Mont.						
Size fractions						
>200 µm------------------------------	7 (3)	18:18	46	1.71	1.20	24 - 92
100-200 µm---------------------------	7 (3)	24:24	35	1.40	1.20	22 - 89
63-100 µm----------------------------	7 (3)	24:24	38	1.26	1.20	28 - 91
<63 µm-------------------------------	7 (3)	24:24	67	1.21	1.08	55 - 110
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North Mine, North Dakota------	10 (3)	10:10	87	1.14	--	68 - 100
Dave Johnston Mine, Wyoming----------	10 (3)	10:10	59	1.18	--	43 - 70
Hidden Valley Mine, Wyoming----------	10 (3)	10:10	70	1.20	--	54 - 91
Kincaid Mine, North Dakota-----------	10 (3)	10:10	74	1.32	--	43 - 110
Savage Mine, Montana-----------------	10 (3)	10:10	67	1.23	--	44 - 81
Velva Mine, North Dakota-------------	10 (3)	10:10	65	1.08	--	56 - 71
Big Sky Mine, Montana----------------	10 (3)	10:10	50	1.17	--	42 - 66
Utility Mine, Saskatchewan-----------	10 (3)	10:10	64	1.23	--	50 - 100
San Juan mine, New Mexico-------------	11 (3)	12:12	56	1.14	1.04	47 - 66
Topsoil used in spoil reclamation						
San Juan mine, New Mexico-------------	11 (3)	12:12	48	1.08	1.02	39 - 49
Plants (dry weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (3)	10:10	25	1.36	1.06	15 - 44
Dave Johnston mine, Wyoming--------	10 (3)	10:10	33	1.41	1.06	19 - 53
Hidden Valley mine, Wyoming--------	10 (3)	10:10	43	1.22	1.06	33 - 58
Kincaid mine, North Dakota---------	10 (3)	10:10	35	1.33	1.06	18 - 49
Savage mine, Montana---------------	10 (3)	10:10	18	1.56	1.06	8 - 33
Velva mine, North Dakota-----------	10 (3)	10:10	23	1.41	1.06	15 - 40
White sweetclover						
Big Sky mine, Montana--------------	10 (3)	10:10	36	1.20	1.06	26 - 49
Utility mine, Saskatchewan---------	10 (3)	10:10	22	1.46	1.06	10 - 35
Alfalfa						
Beulah North mine, North Dakota----	10 (3)	3:3	35	1.47	--	23 - 49
Dave Johnston mine, Wyoming--------	10 (3)	3:3	43	1.40	--	29 - 57
Savage mine, Montana---------------	10 (3)	3:3	35	1.45	--	25 - 52
Velva mine, North Dakota-----------	10 (3)	3:3	25	1.41	--	17 - 34
Big Sky mine, Montana--------------	10 (3)	3:3	39	1.24	--	34 - 50

TABLE 61.—*Zinc in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)--Continued						
Northern Great Plains--Continued						
Crested wheatgrass, Dave Johnston mine, Wyoming						
Growing on mine spoil------------	26 (3)	20:20	26	1.19	1.06	18 - 32
Growing near mine spoil----------	26 (3)	20:20	20	1.24	1.06	13 - 28
San Juan mine, New Mexico						
Fourwing saltbush--------------------	11 (3)	6:6	56	1.71	--	27 - 86
Alkali sacaton-----------------------	11 (3)	6:6	14	1.30	--	11 - 17
SOILS						
Piceance and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (3)	30:30	65	1.21	1.02	33 - 110
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (3)	64:64	61	1.50	1.05	20 - 130
B horizon------------------------------	13 (3)	64:64	62	1.47	1.07	19 - 130
C horizon------------------------------	13 (3)	64:64	60	1.75	1.04	15 - 140
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (3)	48:48	59	1.31	1.05	28 - 93
Soil, 15- to 20-cm depth---------------	20 (3)	48:48	61	1.35	1.05	25 - 104
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (3)	16:16	83	1.16	1.03	65 - 100
C horizon------------------------------	14 (3)	16:16	77	1.26	1.02	42 - 110
Piceance Creek Basin, Colorado, 0- to 5-cm depth------------------------------	15 (3)	108:108	80	1.23	1.05	45 - 140
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (3)	136:136	*63	*20	*7.72	14 - 170
C horizon------------------------	16 (3)	136:136	*59	*19	*7.72	18 - 120
Big Horn Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (3)	36:36	57	1.33	1.11	34 - 110
Wind River Basin, Wyo., 0- to 40-cm depth----------------------------------	17 (3)	36:36	43	1.31	1.08	28 - 83
San Juan Basin, N. Mex.						
A horizon------------------------------	11 (3)	47:47	39	1.49	1.14	18 - 84
C horizon------------------------------	11 (3)	47:47	37	1.66	1.03	12 - 91
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon----------------------------	24 (3)	30:30	31	1.18	1.07	23 - 44
C horizon----------------------------	24 (3)	30:30	26	1.36	1.05	14 - 41

TABLE 61.—*Zinc in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia- tion	Error	Observed range (ppm)
PLANTS						
Cultivated plants, northern Great Plains (dry weight basis)						
Barley	21 (3)	18:18	28	1.38	1.13	13 - 49
Oats	21 (3)	21:21	27	1.23	1.09	19 - 44
Wheat, durham	21 (3)	20:20	36	1.34	1.17	17 - 50
Wheat, hard red spring	21 (3)	54:54	38	1.33	1.12	23 - 74
Wheat, hard red winter	21 (3)	17:17	27	1.22	1.08	20 - 38
Native species (dry weight basis)						
Galleta, San Juan Basin	19 (3)	25:25	13	1.44	1.09	8.4 - 37
Saltbush, fourwing, San Juan Basin	19 (3)	10:10	19	2.37	1.09	6.8 - 77
Snakeweed, San Juan Basin	19 (3)	18:18	17	1.34	1.03	9.6 - 27
Native species (ash weight basis)						
Sagebrush, big: Powder River Basin, Wyo. and Mont.	20 (3)	41:41	410	1.29	1.09	200 - 800
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (3)	30:30	420	1.73	1.05	200 - 1,000
Columbia Plateaus Province	23 (3)	30:30	330	1.67	1.05	200 - 940
Basin and Range Province	23 (3)	30:30	350	1.56	1.05	210 - 1,380
Northern Great Plains	23 (3)	20:20	490	1.62	1.05	280 - 800
Northern Rocky Mountains Province	23 (3)	20:20	530	2.12	1.05	330 - 2,400
Middle Rocky Mountains Province	23 (3)	20:20	430	1.49	1.05	200 - 700
Southern Rocky Mountains Province	23 (3)	20:20	430	1.42	1.05	280 - 790
Wyoming Basin Province	23 (3)	20:20	380	1.33	1.05	250 - 510
Availability studies, samples from Montana, North Dakota, South Dakota, and Wyoming (dry weight basis)						
Wheatgrass, western	18 (3)	21:21	15	1.53	--	5.7 - 34
Sagebrush, silver	18 (3)	19:19	34	1.38	--	19 - 64
Plant biomass, above-ground parts	18 (3)	21:21	27	1.23	1.05	19 - 41

TABLE 62.—*Zirconium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Devia- tion	Error	Observed range (ppm)
ROCKS						
Outcrop samples						
Northern Great Plains, Fort Union Formation						
Sandstone	1 (2)	80:80	270	1.68	1.26	100 - 590
Shale	1 (2)	80:80	320	1.48	1.20	97 - 570

TABLE 62.—*Zirconium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Core samples						
Hanging Woman Creek, Mont.						
Sandstone	2 (2)	24:24	200	1.51	1.39	85 - 430
Siltstone and shale	2 (2)	24:24	250	1.25	1.18	140 - 330
Dark shale	2 (2)	23:23	220	1.30	1.16	140 - 350
Northern Great Plains, Fort Union Formation						
Fine-grained rocks	3 (2)	50:50	200	1.44	1.26	99 - 490
Sandstone	4 (2)	42:42	325	1.60	1.25	130 - 850
Piceance Creek Basin, Colo. Green River Formation						
Mahogany zone (upper 100 m)	5 (2)	74:74	75	1.44	1.20	29 - 210
Middle 300 m	5 (2)	53:53	88	1.67	1.33	9.8 - 210
Garden Gulch Member (lower 100 m)	5 (2)	32:32	120	1.25	--	68 - 160
STREAM SEDIMENTS						
Northern Great Plains regional study	6 (2)	59:60	350	1.50	1.38	150 - >970
Powder River Basin, Wyo. and Mont. Size fractions						
>200 µm	7 (1)	24:24	61	1.59	1.23	30 - 200
100-200 µm	7 (1)	24:24	76	1.42	1.27	50 - 150
63-100 µm	7 (1)	24:24	210	2.16	1.41	70 - 1,500
<63 µm	7 (1)	24:24	820	2.72	1.15	200 - 7,000
Uinta and Piceance Creek Basins, Colo. and Utah	8 (1)	32:32	220	1.52	1.19	100 - 700
Piceance Creek Basin, Colo. Roan and Black Sulphur Creeks	9 (1)	32:32	180	1.65	1.15	70 - 700
MINE SPOIL AND ASSOCIATED MATERIALS						
Mine spoil						
Northern Great Plains						
Beulah North mine, North Dakota	10 (2)	10:10	180	1.68	--	69 - 470
Dave Johnston mine, Wyoming	10 (2)	10:10	180	1.41	--	90 - 280
Hidden Valley mine, Wyoming	10 (2)	10:10	300	1.21	--	200 - 390
Kincaid mine, North Dakota	10 (2)	10:10	170	1.45	--	95 - 310
Savage mine, Montana	10 (2)	10:10	180	1.38	--	92 - 310
Velva mine, North Dakota	10 (2)	10:10	190	1.28	--	140 - 290
Big Sky mine, Montana	10 (2)	10:10	210	1.31	--	120 - 290
Utility mine, Saskatchewan	10 (2)	10:10	160	1.40	--	91 - 210
San Juan mine, New Mexico	11 (2)	12:12	300	1.35	1.37	190 - 600
Topsoil used in spoil reclamation						
San Juan mine, New Mexico	11 (2)	11:12	420	1.51	1.51	260 - >1,000

TABLE 62.—*Zirconium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
MINE SPOIL AND ASSOCIATED MATERIALS--Continued						
Plants (dry-weight basis)						
Northern Great Plains						
Yellow sweetclover						
Beulah North mine, North Dakota----	10 (2)	10:10	1.1	1.37	1.50	0.7 - 1.7
Dave Johnston mine, Wyoming--------	10 (2)	10:10	1.6	1.48	1.50	.7 - 2.7
Hidden Valley mine, Wyoming--------	10 (2)	10:10	3.9	1.75	1.50	1.8 - 9.9
Kincaid mine, North Dakota---------	10 (2)	10:10	2.6	1.42	1.50	1.7 - 4.5
Savage mine, Montana---------------	10 (2)	9:9	.9	1.26	1.50	.6 - 1.3
Velva mine, North Dakota-----------	10 (2)	9:10	.98	2.37	1.50	<.3 - 3.9
White sweetclover						
Big Sky mine, Montana--------------	10 (2)	10:10	1.5	1.40	1.50	.9 - 2.5
Utility mine, Saskatchewan---------	10 (2)	8:10	.97	2.47	1.50	<.3 - 2.6
Alfalfa						
Beulah North mine, North Dakota----	10 (2)	1:3	<1.4	--	--	<1.4 - 3.4
Dave Johnston mine, Wyoming--------	10 (2)	3:3	3.1	1.12	--	2.8 - 3.5
Savage mine, Montana---------------	10 (2)	1:3	<1.4	--	--	<1.4 - 1.8
Velva mine, North Dakota-----------	10 (2)	2:3	1.7	2.87	--	<1.4 - 5.2
San Juan mine, New Mexico						
Fourwing saltbush-------------------	11 (2)	6:6	5.1	1.61	--	3.1 - 8.6
Alkali sacaton----------------------	11 (2)	6:6	1.9	2.49	--	.54 - 5.3
SOILS						
Piceance Creek and Uinta Basins, Colo. and Utah; alluvial, 0- to 40-cm depth--	12 (2)	30:30	340	1.34	1.25	200 - 570
Powder River Basin, Wyo. and Mont.						
A horizon------------------------------	13 (1)	64:64	230	1.71	1.30	70 - 700
B horizon------------------------------	13 (1)	64:64	200	1.57	1.44	70 - 700
C horizon------------------------------	13 (1)	64:64	160	1.73	1.31	50 - 700
Powder River Basin, Wyo. and Mont.						
Soil, 0- to 2.5-cm depth---------------	20 (1)	48:48	150	1.45	1.20	70 - 500
Soil, 15- to 20-cm depth---------------	20 (1)	48:48	140	1.40	1.20	70 - 300
Hanging Woman Creek, Mont.						
A horizon------------------------------	14 (2)	16:16	300	1.29	1.29	170 - 500
C horizon------------------------------	14 (2)	16:16	300	1.25	1.25	220 - 490
Piceance Creek Basin, Colo., 0- to 5-cm depth----------------------------------	15 (2)	108:108	260	1.55	1.43	54 - 700
Northern Great Plains; North Dakota, South Dakota, Wyoming, and Montana						
Unglaciated area						
A horizon--------------------------	16 (2)	88:88	280	1.46	1.63	94 - 600
Glaciated area						
A horizon--------------------------	16 (2)	48:48	240	1.57	1.63	61 - 660
Combined data, unglaciated and glaciated areas						
A horizon------------------------	16 (2)	136:136	260	1.51	1.63	60 - 660
C horizon------------------------	16 (2)	136:136	230	1.54	1.47	59 - 810
Big Horn Basin, Wyo., 0- to 40-cm depth--	17 (2)	36:36	320	1.35	1.29	190 - 640

TABLE 62.—*Zirconium in rocks, stream sediments, mine spoil and associated materials, soils, and plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Wind River Basin, Wyo., 0- to 40-cm depth	17 (2)	36:36	240	1.40	1.41	95 - 490
San Juan Basin, N. Mex.						
A horizon	11 (2)	46:47	430	1.65	1.57	130 ->1,000
C horizon	11 (2)	46:47	330	1.64	1.33	120 ->1,000
Sheppard-Shiprock-Doak Soil Association, N. Mex.						
A horizon	24 (2)	30:30	390	1.45	1.41	210 - 970
C horizon	24 (2)	29:30	270	1.82	1.44	97 ->1,000
PLANTS						
Cultivated plants, northern Great Plains (dry-weight basis)						
Barley	21 (1)	6:18	0.09	1.49	--	<0.077 - 0.15
Oats	21 (1)	6:21	.14	1.06	--	<.11 - .16
Wheat, durum	21 (1)	17:20	.11	1.39	--	<.069 - .19
Wheat, hard red spring	21 (1)	52:54	.13	1.40	1.34	<.08 - .25
Wheat, hard red winter	21 (1)	15:17	.10	1.36	1.31	<.06 - .16
Native species (dry-weight basis)						
Galleta, San Juan Basin	19 (2)	25:25	7.5	2.15	1.32	1.5 - 20
Saltbush, fourwing, San Juan Basin	19 (2)	9:10	1.7	2.06	1.30	<.52 - 3.4
Snakeweed, San Juan Basin	19 (2)	18:18	5.2	2.10	1.31	1.2 - 23
Native species (ash-weight basis)						
Lichen (Parmelia), Powder River Basin, Wyo. and Mont.	22 (1)	29:29	77	1.39	1.28	50 - 150
Sagebrush, big; Powder River Basin, Wyo. and Mont.	20 (1)	41:41	57	1.58	1.27	20 - 150
Sagebrush, big; regional study						
Colorado Plateaus Province	23 (1)	21:30	22	1.81	1.34	<20 - 70
Columbia Plateaus Province	23 (1)	30:30	45	1.70	1.34	20 - 100
Basin and Range Province	23 (1)	22:30	22	1.79	1.34	<20 - 50
Northern Great Plains	23 (1)	16:20	24	1.74	1.44	<20 - 70
Northern Rocky Mountains Province	23 (1)	17:20	23	1.59	1.44	<20 - 50
Middle Rocky Mountains Province	23 (1)	19:20	32	2.45	1.44	<20 - 150
Southern Rocky Mountains Province	23 (1)	16:20	24	1.65	1.44	<20 - 50
Wyoming Basin Province	23 (1)	20:20	33	1.78	1.44	20 - 70

TABLE 63.—*Parameters measured in extraction studies of soils from San Juan Basin, N. Mex. (study No. 19)*

[Explanation of column headings: Analytical method refers to method listed in table 1. Ratio, number of samples in which the element or radical was found in measurable concentrations to number of samples analyzed; other parameters were measured in all 47 samples. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate column heading is not applicable, or no data available]

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Devia-tion	Error	Observed range
				DTPA EXTRACTION				
Cadmium	A	ppm	3	19:47	0.05	1.14	1.19	<0.05 - 0.08
	C	ppm	3	7:47	.05	1.00	1.13	<.05 - .05
Cobalt	A	ppm	3	46:47	.39	1.49	1.59	<.1 - .75
	C	ppm	3	43:47	.29	1.90	2.00	<.1 - .65
Copper	A	ppm	3	47:47	.70	1.67	1.20	.3 - 2.8
	C	ppm	3	47:47	.58	1.89	1.14	.19 - 3.3
Iron	A	ppm	3	47:47	9.1	1.77	1.39	2.8 - 51
	C	ppm	3	47:47	9.9	2.17	1.67	1.5 - 48
Manganese	A	ppm	3	47:47	7.7	1.57	1.24	2.3 - 20
	C	ppm	3	47:47	4.5	1.94	1.17	.6 - 15
Nickel	A	ppm	3	47:47	.45	1.61	1.32	.1 - 1.2
	C	ppm	3	47:47	.41	1.78	1.53	.1 - .9
Lead	A	ppm	3	47:47	.77	2.17	2.42	.05 - 2.2
	C	ppm	3	45:47	.52	2.45	2.27	<.1 - 2.5
Zinc	A	ppm	3	47:47	.40	1.60	1.37	.2 - 1.9
	C	ppm	3	47:47	.29	1.70	1.35	.1 - 2.1
				AMMONIUM ACETATE EXTRACTION				
Calcium	A	ppm	3	47:47	12.4	2.14	1.09	2.7 - 42
	C	ppm	3	47:47	29.5	2.02	1.06	3.2 - 230
Magnesium	A	ppm	3	47:47	1.3	1.70	1.05	.5 - 4.3
	C	ppm	3	47:47	2.5	2.04	1.03	.4 - 9.9
Potassium	A	ppm	3	47:47	1.2	2.15	2.12	.21 - 4.1
	C	ppm	3	47:47	.64	3.00	2.33	.1 - 3.6
Sodium	A	ppm	3	47:47	.25	3.17	1.60	.09 - 48
				WATER-SATURATION EXTRACTION				
Calcium	A	me/L	3	47:47	5.4	1.84	1.14	1.6 - 36.3
	C	me/L	3	47:47	5.6	2.92	1.20	.6 - 63.6
Chloride	A	me/L	9	27:47	.51	4.05	1.97	<.5 - 75
	C	me/L	9	32:47	1.4	7.92	3.04	<.5 - 75
Magnesium	A	me/L	3	47:47	1.1	1.63	1.18	.3 - 5.1
	C	me/L	3	47:47	2.1	3.53	1.28	.3 - 40.0
Potassium	A	me/L	3	47:47	1.2	1.66	2.42	.2 - 3.2
	C	me/L	3	47:47	.74	1.72	1.48	.1 - 3.1
Sodium	A	me/L	3	47:47	1.7	3.51	1.48	.2 - 680
	C	me/L	3	47:47	8.2	4.16	1.22	.5 - 440
Sulfate	A	me/L	9	25:47	--	--	--	<1.0 - 510
	C	me/L	9	32:47	--	--	--	<1.0 - 450

TABLE 63.—*Parameters measured in extraction studies of soils from San Juan Basin, N. Mex. (study No. 19)*—Continued

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
			WATER-SATURATION EXTRACTION--Continued					
Specific conductance	A	mmhos/cm	15	47:47	0.86	2.38	1.05	0.33 - 66
	C	mmhos/cm	15	47:47	1.3	3.00	1.10	.28 - 47
			HOT-WATER EXTRACTION					
Boron----------------	A	ppm	16	15:47	0.33	1.99	2.56	<0.5 - 4.0
	C	ppm	16	27:47	.52	1.95	3.16	<.5 - 3.5
			REPLACEMENT BY SODIUM					
CEC (cation exchange capacity)---------	A	me/100 g	3	47:47	10.2	2.40	1.26	0.2 - 37.3
	C	me/100 g	3	47:47	13.0	1.71	1.13	4.2 - 40.8
			CALCULATED					
SAR (sodium adsorption ratios)-------	A	--	11	47:47	0.95	3.02	1.45	0.11 - 155
	C	--	11	47:47	4.1	3.22	1.26	.30 - 96.6
ESP (exchangeable sodium percentages)	A	percent	11	47:47	1.6	2.45	1.69	.3 - 57
	C	percent	11	47:47	2.6	2.81	1.17	.5 - 56.5

[1]ppm, parts per million; me/L, milliequivalents per liter; mmhos/cm, reciprocal milliohms per centimeter; me/100 g, milliequivalents per 100 grams.

TABLE 64..—*Parameters measured in extraction studies of soil from the Sheppard-Shiprock-Doak Soil Association, San Juan Basin which is likely to be used as topsoil in mined-land reclamation (study No. 24)*

[Explanation of column headings: Analytical method refers to method listed in table 1. Ratio, number of samples in which the element or radical was found in measurable concentrations to number of samples analyzed; other parameters were measured in all 30 samples. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
			DTPA EXTRACTION					
Cadmium--------------	A	ppm	3	3:30	--	--	--	<0.05 - 0.08
	C	ppm	3	0:30	<0.05	--	--	--
Cobalt---------------	A	ppm	3	3:30	--	--	--	<.2 - .3
	C	ppm	3	6:30	.15	1.37	--	<.2 - .3
Copper---------------	A	ppm	3	30:30	.55	1.36	1.15	.3 - .95
	C	ppm	3	30:30	.35	2.45	4.15	.1 - 8.8
Iron-----------------	A	ppm	3	30:30	7.6	1.25	1.09	4.4 - 12
	C	ppm	3	30:30	7.7	1.20	1.07	5.6 - 11
Lead-----------------	A	ppm	3	26:30	.72	1.41	1.51	<.5 - 1.2
	C	ppm	3	16:30	.55	1.27	1.40	<.5 - .8
Manganese------------	A	ppm	3	30:30	10.8	1.47	1.14	5.8 - 23
	C	ppm	3	30:30	6.2	1.43	1.14	1.8 - 12

TABLE 64.—*Parameters measured in extraction studies of soil from the Sheppard-Shiprock-Doak Soil Association, San Juan Basin which is likely to be used as topsoil in mined-land reclamation (study No. 24)*—Continued

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
			DTPA EXTRACTION--Continued					
Nickel--------------	A	ppm	3	20:30	0.24	1.70	1.82	<0.2 - 0.7
	C	ppm	3	23:30	.32	1.81	1.68	<.2 - .9
Zinc----------------	A	ppm	3	30:30	.45	1.38	1.20	.3 - 1.1
	C	ppm	3	30:30	.21	1.23	1.22	.15 - .3
			AMMONIUM ACETATE EXTRACTION					
Calcium-------------	A	ppm	3	30:30	4.1	1.39	1.09	2.0 - 6.4
	C	ppm	3	30:30	4.9	2.65	1.11	1.5 - 32
Magnesium-----------	A	ppm	3	30:30	1.2	1.32	1.15	.7 - 2.1
	C	ppm	3	30:30	2.1	2.69	1.13	.6 - 23
Potassium-----------	A	ppm	3	30:30	.67	1.57	1.30	.2 - 1.5
	C	ppm	3	26:30	.20	1.95	1.65	<.1 - .6
Sodium--------------	A	ppm	3	30:30	.60	2.09	1.78	.2 - 2.8
	C	ppm	3	30:30	1.4	1.77	1.37	.55 - 4.5
			WATER-SATURATION EXTRACTION					
Calcium-------------	A	me/L	3	30:30	4.1	1.39	1.09	2.0 - 6.4
	C	me/l	3	30:30	4.9	2.65	1.11	1.5 - 32.3
Chloride------------	A	me/L	9	3:30	--	--	--	<.5 - 1.0
	C	me/L	9	25:30	2.7	6.70	1.66	<1.0 - 49.0
Magnesium-----------	A	me/L	3	30:30	1.2	1.32	1.15	.7 - 2.1
	C	me/L	3	30:30	2.1	2.69	1.13	.6 - 22.7
Potassium-----------	A	me/L	3	30:30	.67	1.57	1.30	.2 - 1.5
	C	me/L	3	26:30	.20	1.95	1.65	<.1 - .6
Sodium--------------	A	me/L	3	30:30	.60	2.09	1.78	.2 - 2.8
	C	me/L	3	30:30	8.0	2.74	1.08	.7 - 61.1
Sulfate-------------	A	me/L	9	15:30	.98	1.56	1.38	<1.0 - 2.0
	C	me/L	9	26:30	3.2	4.55	1.32	<1.0 - 65.0
Specific conductance	A	mmhos/cm	15	30:30	.53	1.29	1.07	.3 - .8
	C	mmhos/cm	15	30:30	1.2	2.24	1.07	.5 - 7.0
			HOT-WATER EXTRACTION					
Boron---------------	A	ppm	16	1:30	--	--	--	<0.5 - 0.5
	C	ppm	16	10:30	.35	2.00	--	<.5 - 2.0
			REPLACEMENT BY SODIUM					
CEC (cation exchange capacity)---------	A	me/100 g	3	30:30	10.4	1.18	1.11	7.3 - 14.3
	C	me/100 g	3	30:30	11.6	1.42	1.20	6.0 - 21.1

TABLE 64.—*Parameters measured in extraction studies of soil from the Sheppard-Shiprock-Doak Soil Association, San Juan Basin which is likely to be used as topsoil in mined-land reclamation (study No. 24)*—Continued

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
			CALCULATED					
SAR (sodium adsorption ratios)------	A	--	11	30:30	0.37	2.25	1.35	0.13 - 2.2
	C	--	11	30:30	4.2	2.25	1.08	.42 - 20.3
ESP (exchangeable sodium percentages)	A	percent	11	30:30	6.8	1.68	1.48	2.2 - 28.9
	C	percent	11	30:30	4.7	1.75	1.33	1.3 - 11.6

[1]ppm, parts per million; me/L, milliequivalents per liter; mmhos/cm, reciprocal milliohms per centimeter; me/100 g, milliequivalents per 100 grams.

TABLE 65.—*Parameters measured in extraction studies of soils and mine spoil from San Juan mine, New Mexico (study No. 11)*

[Explanation of column headings: Analytical method refers to method listed in table 1. Ratio, number of samples in which the element or radical was found in measurable concentrations to number of samples analyzed; other parameters were measured in all 12 samples. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (-) in figure column indicate no data available]

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
			DTPA EXTRACTION					
Cadmium-------------	Topsoil	ppm	3	3:12	--	--	--	<0.05 - 0.05
	Spoil	ppm	3	11:12	0.05	1.00	1.11	<.05 - .05
Cobalt--------------	Topsoil	ppm	3	2:12	--	--	--	<.1 - .1
	Spoil	ppm	3	2:12	--	--	--	<.1 - 1.4
Copper--------------	Topsoil	ppm	3	12:12	.71	1.68	1.08	.5 - 2.2
	Spoil	ppm	3	12:12	2.0	1.18	1.04	1.5 - 2.4
Iron----------------	Topsoil	ppm	3	12:12	13	2.93	1.32	6.4 - 130
	Spoil	ppm	3	12:12	61	1.98	1.13	30 - 210
Manganese-----------	Topsoil	ppm	3	12:12	8.1	1.78	1.09	5.6 - 32
	Spoil	ppm	3	12:12	12	2.32	1.06	5.4 - 55
Nickel--------------	Topsoil	ppm	3	5:12	.038	4.82	--	<.05 - .4
	Spoil	ppm	3	12:12	.20	2.23	--	.10 - .90
Lead----------------	Topsoil	ppm	3	7:12	.13	4.13	2.04	<.1 - 1.5
	Spoil	ppm	3	10:12	.45	2.74	1.45	<.10 - 1.4
Zinc----------------	Topsoil	ppm	3	12:12	.39	2.25	1.43	.2 - 2.2
	Spoil	ppm	3	12:12	1.5	1.89	1.05	.8 - 5.2
			AMMONIUM ACETATE EXTRACTION					
Calcium-------------	Topsoil	me/100 g	3	12:12	29	1.25	1.07	22 - 47
	Spoil	me/100 g	3	12:12	33	1.12	1.06	29 - 43
Magnesium-----------	Topsoil	me/100 g	3	12:12	3.5	1.24	1.02	3.0 - 5.7
	Spoil	me/100 g	3	12:12	7.3	1.50	1.05	4.3 - 15
Potassium-----------	Topsoil	me/100 g	3	12:12	.24	1.23	1.12	.2 - .3
	Spoil	me/100 g	3	12:12	.35	1.16	1.00	.3 - .4

TABLE 65.—*Parameters measured in extraction studies of soils and mine spoil from San Juan mine, New Mexico (study no. 11)*—Continued

Parameter	Soil horizon	Reporting units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
			AMMONIUM ACETATE EXTRACTION--Continued					
Sodium--------------	Topsoil	me/100 g	3	12:12	1.7	2.87	1.17	0.5 - 10
	Spoil	me/100 g	3	12:12	21	1.97	1.18	4.2 - 43
			WATER-SATURATION EXTRACTION					
Calcium-------------	Topsoil	me/L	3	12:12	11	1.96	1.13	5.9 - 30
	Spoil	me/L	3	12:12	26	1.13	1.05	23 - 33
Chloride------------	Topsoil	me/L	9	12:12	7.2	1.62	1.19	3 - 15
	Spoil	me/L	9	12:12	19	1.50	1.13	9 - 31
Magnesium-----------	Topsoil	me/L	3	12:12	4.8	2.11	1.15	2.4 - 15
	Spoil	me/L	3	12:12	27	1.68	1.11	15 - 71
Potassium-----------	Topsoil	me/L	3	12:12	.38	1.46	1.20	.2 - .7
	Spoil	me/L	3	12:12	.64	1.17	1.06	.5 - .8
Sodium--------------	Topsoil	me/L	3	12:12	21	3.15	1.10	6.5 - 120
	Spoil	me/L	3	12:12	260	1.69	1.10	97 - 500
Sulfate-------------	Topsoil	me/L	9	12:12	18	3.12	1.14	5 - 95
	Spoil	me/L	9	12:12	230	1.79	1.13	75 - 480
Specific conductance	Topsoil	mmhos/cm	15	12:12	2.8	2.37	1.15	1.3 - 11
	Spoil	mmhos/cm	15	12:12	9.6	1.70	1.45	4.0 - 17
			HOT-WATER EXTRACTION					
Boron---------------	Topsoil	ppm	16	8:12	0.60	2.56	1.10	<0.5 - 3.5
	Spoil	ppm	16	11:12	1.8	2.91	1.46	<.5 - 11.4
			REPLACEMENT BY SODIUM					
CEC (cation exchange capacity)---------	Topsoil	me/100 g	3	12:12	17	1.62	1.08	12 - 46
	Spoil	me/100 g	3	12:12	36	1.41	1.08	22 - 68
			CALCULATED					
SAR (sodium adsorption ratios)------	Topsoil	--	11	12:12	7.6	2.26	1.11	2.7 - 25
	Spoil	--	11	12:12	51	1.56	1.06	20 - 78
ESP (exchangeable sodium percentages)	Topsoil	percent	11	12:12	4.8	2.48	1.19	1.5 - 18
	Spoil	percent	11	12:12	32	1.68	1.11	9.4 - 49

[1]ppm, ppm, parts per million; me/100 g, milliequivalents per 100 grams; me/L, milliequivalents per liter; mmshos/cm, reciprocal milliohms per centimeter.

TABLE 66.—*Elements measured in DTPA extracts of soils from the unglaciated area of the northern Great Plains (study No. 18)*

[Explanation of column headings: Analytical method refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Parameter	Soil horizon	Analytical method	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
			DTPA EXTRACTION				
Cadium----------------	A	3	21:21	0.10	1.66	--	0.040 - 0.30
	C	3	19:21	.020	3.12	--	<.010 - .10
Cobalt----------------	A	3	21:21	.20	1.65	--	.060 - .40
	C	3	21:21	.20	2.28	--	.050 - .40
Copper----------------	A	3	21:21	.40	1.77	--	.10 - 1.2
	C	3	21:21	.40	1.72	--	.10 - .80
Iron------------------	A	3	21:21	11	2.13	--	2.0 - 50
	C	3	21:21	7.0	1.60	--	3.0 - 19
Lead------------------	A	3	21:21	.60	2.21	--	.20 - 2.6
	C	3	21:21	.30	1.40	--	.20 - .60
Manganese-------------	A	3	21:21	.60	1.51	--	4.0 - 15
	C	3	21:21	.30	1.87	--	1.0 - 14
Nickel----------------	A	3	21:21	.60	2.21	--	.20 - 2.6
	C	3	21:21	.50	1.96	--	.10 - 2.1
Zinc------------------	A	3	21:21	.60	2.33	--	.20 - 5.3
	C	3	21:21	.050	2.03	--	.010 - .20

TABLE 67.—*pH determinations for rocks, streams sediments, mine spoil and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Mean, arithmetic mean. Deviation, arithmetic deviation. Error, airthmetic error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Number of samples	Mean (standard units)	Devia-tion	Error	Observed range (standard units)
		ROCKS				
Core samples						
Hanging Woman Creek, Mont.						
Sandstone------------------------------	2 (9)	24	9.0	0.66	0.15	7 -10
Siltstone and shale--------------------	2 (9)	24	8.1	1.04	.21	5 - 9
Dark shale-----------------------------	2 (9)	23	7.7	.8	.44	5.4 - 8.4
Northern Great Plains, Fort Union Formation						
Sandstone------------------------------	4 (9)	12	7.8	1.1	--	4.1 - 8.9
		STREAM SEDIMENTS				
Northern Great Plains regional study----	6 (9)	60	7.7	0.34	0.14	6.1 - 8.5
		MINE SPOIL				
Northern Great Plains regional study						
Beulah North mine, North Dakota--------	10 (9)	10	7.0	0.69	--	6.2 - 8.7
Dave Johnston mine, Wyoming------------	10 (9)	10	6.2	1.6	--	4.0 - 8.5

TABLE 67.—*pH determinations for rocks, streams sediments, mine spoil and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Number of samples	Mean (standard units)	Deviation	Error	Observed range (standard units)
		MINE SPOIL--Continued				
Hidden Valley mine, Wyoming	10 (9)	10	6.6	0.96	--	5.4 - 7.8
Kincaid mine, North Dakota	10 (9)	10	7.8	.71	--	7.1 - 9.4
Savage mine, Montana	10 (9)	10	8.2	.49	--	7.0 - 8.5
Velva mine, North Dakota	10 (9)	10	7.8	.40	--	7.0 - 8.5
Big Sky mine, Montana	10 (9)	10	7.6	.53	--	6.5 - 8.5
Utility mine, Saskatchewan	10 (9)	10	7.8	1.3	--	4.4 - 9.0
San Juan mine, New Mexico	11 (9)	12	7.6	.87	.12	6.3 - 8.4
		SOILS				
Powder River Basin, Wyo. and Mont.						
A horizon	13 (9)	64	7.2	0.46	0.26	6.0 - 7.9
B horizon	13 (9)	64	7.4	.40	.36	6.7 - 8.2
C horizon	13 (9)	64	7.5	.41	.29	6.2 - 8.5
Hanging Woman Creek, Mont.						
A horizon	14 (9)	16	8.1	.34	.21	7.0 - 8.7
C horizon	14 (9)	16	8.4	.40	.25	7.5 - 9.1
Soils used in extraction studies, San Juan Basin, N. Mex.						
Regional study						
A horizon	19 (9)	47	8.1	.30	.061	7.3 - 8.6
C horizon	19 (9)	47	8.3	.81	.14	7.4 - 9.2
Sheppard-Shiprock-Doak Soil Association						
A horizon	24 (9)	30	7.9	.38	.055	7.0 - 8.4
C horizon	24 (9)	30	8.6	.29	.039	7.8 - 9.2
San Juan mine, topsoil	11 (9)	12	8.0	.67	.076	6.6 - 8.4

TABLE 68.—*Geochemical summary of ground water from North Dakota and Montana (study No. 25)*

[Explanation of column headings: Analytical method refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic means. Deviation, geometric deviation, except that values preced by asterisk are standard deviations. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Parameter	Concentration units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
Aluminum	µg/L	2	18:19	24	2.36	1.55	<5 - 90
Arsenic	µg/L	3	9:19	<1	--	--	<1 - 26
Barium	µg/L	2	19:19	50	2.58	1.09	13 - 520
Beryllium	µg/L	2	9:19	<7	--	--	--
Bicarbonate	mg/L	17	19:19	665	1.63	1.01	251 -1,160
Bismuth	µg/L	2	0:19	<14	--	--	--
Boron	µg/L	6	19:19	175	2.72	1.07	23 - 800
Bromine	mg/L	6	15:19	.21	2.87	1.33	<.1 - 1.7
Cadmium	µg/L	3	2:19	<1	--	--	<1 - 1
Calcium	mg/L	3	19:19	28	4.50	1.04	1.8 - 350
Chlorine	mg/L	6	19:19	15	3.45	1.07	1.8 - 170
Chromium	µg/L	2	0:19	<14	--	--	--
Cobalt	µg/L	2	0:19	<14	--	--	--
Copper	µg/L	2	8:19	<1	--	--	<1 - 15
Fluorine	mg/L	9	19:19	.6	3.19	--	.1 - 7.5

TABLE 68.—*Geochemical summary of ground water from North Dakota and Montana (study No. 25)*—Continued

Parameter	Concentration units[1]	Analytical method	Ratio	Mean	Deviation	Error	Observed range
Gallium---------------------	µg/L	2	0:19	<2	--	--	--
Germanium-------------------	µg/L	2	0:19	<15	--	--	--
Iodine----------------------	mg/L	6	8:19	<.01	--	--	<1 - .78
Iron------------------------	µg/L	2	19:19	427	3.88	1.11	70 -5,000
Lead------------------------	µg/L	2	0:19	<14	--	--	--
Lithium---------------------	µg/L	3	19:19	49	1.79	1.18	20 - 150
Magnesium-------------------	mg/L	3	18:19	12	--	1.11	<.1 - 240
Manganese-------------------	µg/L	2	15:19	31	3.73	1.23	<1 - 470
Mercury---------------------	µg/L	4	4:19	<.1	--	--	<.1 - .1
Molybdenum------------------	µg/L	2	7:19	<1	--	--	<1 - 30
Nickel----------------------	µg/L	2	0:19	<14	--	--	--
Potassium-------------------	mg/L	3	19:19	4.6	1.77	1.03	1.5 - 34
^{226}Radium------------------	pCi/L	20	16:19	.40	3.12	1.15	<.1 - 4.2
Selenium--------------------	µg/L	3	6:19	<1	--	--	<1 - 6
Silica----------------------	mg/L	6	19:19	14	1.61	1.03	6.2 - 27
Silver----------------------	µg/L	2	0:19	<3	--	--	--
Sodium----------------------	mg/L	3	19:19	219	2.97	1.03	23 - 760
Strontium-------------------	µg/L	2	19:19	551	2.40	1.22	110 -3,800
Sulfate---------------------	mg/L	6	19:10	128	--	1.04	4.7 -2,400
Tin-------------------------	µg/L	2	0:19	<18	--	--	--
Titanium--------------------	µg/L	2	1:19	<2	--	--	<2 - 150
Uranium---------------------	µg/L	13	18:19	.74	--	1.23	<.01 - 40
Vanadium--------------------	µg/L	2	0:19	<14	--	--	--
Zinc------------------------	µg/L	3	16:19	42	--	1.06	<10 -1,600
Zirconium-------------------	µg/L	2	0:19	<25	--	--	--
Alkalinity (as $CaCO_3$)------	mg/L	11	19:19	576	1.60	--	206 -1,070
Gross alpha (as U natural)-	µg/L	21	4:19	<4.2	--	--	<4.2 - 49
Gross beta (as Sr/Y-90)----	pCi/L	21	15:19	5.7	1.87	1.29	<2.9 - 22
Dissolved solids (residue at 180°C)----------------	mg/L	14	19:19	1,030	1.92	1.01	281 -4,140
Hardness (total as $CaCO_3$)--	mg/L	11	19:19	126	4.98	1.06	5 -1,900
pH--------------------------	s.u.	9	19:19	*7.8	*.64	1.03	6.55 - 8.89
Sodium absorption ratio----	--	11	19:19	8.5	--	1.04	.7 - 86
Specific conductance-------	mhos/cm	15	19:19	1,690	1.66	--	495 -4,300
Temperature----------------	°C	19	19:19	9.6	1.27	1.01	7.1 - 20.4

[1]µg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; s.u., standard units; µmhos/cm, reciprocal micro-ohms per centimeter; °C, degrees Celsius.

TABLE 69.—*Geochemical summary of ground water from Poplar River Basin, Saskatchewan and Montana (Study No. 27)*

[Explanation of column headings: Method of analysis refers to method listed in table 1. Ratio, number of samples in which the element or other parameter was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic means. Deviation, geometric deviation, except that values preceded by asterisk are standard deviations. Leaders (-) in figure column indicate no data available]

Parameter	Concentration units[1]	Analytical method	Ratio	Mean	Deviation	Observed range
Arsenic---------------------	µg/L	2	7:9	1.13	1.84	<1 - 3
Barium----------------------	µg/L	2	6:9	23	--	<1 - 400
Bicarbonate-----------------	mg/L	17	9:9	673	1.62	190 - 910
Boron-----------------------	µg/L	6	9:9	1,080	3.97	40 - 2,900
Bromine---------------------	µg/L	6	7:9	210	3.29	<10 - 1,600

TABLE 69.—*Geochemical summary of ground water from Poplar River Basin, Saskatchewan and Montana (Study No. 27)*—Continued

Parameter	Concentration units[1]	Analytical method	Ratio	Mean	Deviation	Observed range
Calcium	mg/L	3	9:9	46	4.53	3.4 - 440
Carbon, dissolved organic	mg/L	10	9:9	5.4	1.80	1.7 - 14
Carbonate	mg/L	17	3:9	--	--	<1 - 21
Chlorine	mg/L	6	9:9	13	4.75	1.6 - 160
Chromium	μg/L	3	0:9	<1	--	--
Copper	μg/L	3	4:9	--	--	<1 - 30
Cyanide	mg/L	6	1:9	--	--	<.01 - .03
Fluorine	mg/L	9	9:9	.4	3.07	.1 - 2.3
Iodine	μg/L	6	6:9	10	1.87	<10 - 30
Iron	μg/L	6	9:9	700	3.85	90 - 5,500
Magnesium	mg/L	3	9:9	23	--	.9 - 340
Manganese	μg/L	3	7:9	41	--	<1 - 850
Mercury	μg/L	4	0:9	<.1	--	--
Molybdenum	μg/L	3	3:9	--	--	<1 - 10
Phenols	μg/L	6	7:9	3.2	--	<1 - 40
Phosphate (as P)	mg/L	6	9:9	.03	--	.01 - .80
Phosphorus (as P)	mg/L	6	7:9	.04	--	.01 - .80
Potassium	mg/L	3	9:9	6.8	2.08	1.9 - 11
^{226}Radium	pCi/L	20	9:9	.40	2.59	.13 - 2.3
Selenium	μg/L	3	1:9	--	--	<1 - 63
Silica	mg/L	6	9:9	12	1.30	7.9 - 17
Sodium	mg/L	3	9:9	110	--	1.4 - 670
Strontium	μg/L	3	9:9	477	3.45	80 - 1,700
Sulfate	mg/L	6	9:9	186	--	10 - 1,600
Titanium	μg/L	3	0:9	<1	--	--
Uranium	μg/L	13	9:9	1.7	--	.4 - 190
Vanadium	μg/L	6	2:9	--	--	<1 - 10
Zinc	μg/L	3	8:9	44	--	<1 - 970
Dissolved solids (residue at 180°C)	mg/L	14	9:9	1,065	2.22	185 - 3,450
Hardness (total as $CaCO_3$)	mg/L	11	9:9	214	--	12 - 2,500
pH	s.u.	9	9:9	*7.8	*.66	7.2 - 8.9
Sodium absorption ratio	--	11	9:9	4.4	--	.05 - 50
Temperature	°C	11	9:9	6.4	1.66	2.1 - 10.6

[1] μg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; s.u., standard units; °C, degrees Celsius.

TABLE 70.—*Geochemical summary of ground water from the Powder River coal region, Montana and Wyoming (Study No. 28)*

[Explanation of column headings: Method of analysis refers to method listed in table 1. Ratio, number of samples in which the element or other parameter was found in measurable concentrations to number of samples analyzed. Mean, geometric mean, except that values preceded by asterisk are arithmetic means. Deviation, geometric deviation, except that values preceded by asterisk are standard deviations. Leaders (--) in figure column indicate no data available]

Parameter	Concentration units[1]	Analytical method	Ratio	Mean	Deviation	Observed range
Aluminum	μg/L	2	19:19	17	1.9	<6 - 60
Arsenic	μg/L	3	6:20	--	--	<1 - 6
Barium	μg/L	2	9:15	24	2.7	6 - 128
Bicarbonate	mg/L	17	20:20	504	1.6	195 -1,400
Boron	μg/L	6	19:19	148	2.2	32 - 422
Bromine	mg/L	6	13:20	.15	2.0	<.1 - .7
Cadmium	μg/L	3	3:20	--	--	<1 - 1
Calcium	mg/L	3	20:20	24	--	1.9 - 530
Chlorine	mg/L	6	20:20	8.7	2.1	1.9 - 47
Copper	μg/L	2	4:19	--	--	<1 - 14

TABLE 70.—*Geochemical summary of ground water from the Powder River coal region, Montana and Wyoming (Study No. 28)*—Continued

Parameter	Concentration units[1]	Analytical method	Ratio	Mean	Deviation	Observed range
Fluorine-------------------	mg/L	9	20:20	0.68	2.8	0.1 - 14
Iodine---------------------	mg/L	6	4:20	.01	1.4	<.01 - .02
Iron-----------------------	µg/L	6	20:20	170	--	7 -28,000
Lithium--------------------	µg/L	3	20:20	36	2.4	10 - 180
Magnesium------------------	mg/L	3	20:20	13	--	.6 - 150
Manganese------------------	µg/L	3	20:20	21	--	.7 - 4,800
Mercury--------------------	µg/L	4	4:20	--	--	<.1 - .2
Potassium------------------	mg/L	3	2020	3.9	2.0	1.5 - 12
^{226}Radium------------------	pCi/L	20	17:18	.23	2.0	<.1 - .8
Selenium-------------------	µg/L	3	5:20	--	--	<1 - 12
Silica---------------------	mg/L	6	20:20	11	1.6	5.8 - 26
Sodium---------------------	mg/L	3	20:20	173	3.0	24 - 1,000
Strontium------------------	µg/L	2	15:16	444	4.1	19 - 2,754
Sulfate--------------------	mg/L	6	20:20	292	--	5.5 - 1,800
Uranium--------------------	µg/L	13	16:18	.25	--	<.01 - 7.3
Zinc-----------------------	µg/L	3	20:20	50	--	.7 - 1,800
Gross beta (as Cs-137)-----	pCi/L	21	12:18	6.6	1.8	<4 - 14
Dissolved solids (residue at 180°C)----------------	mg/L	14	20:20	1,080	1.9	345 - 3,190
Hardness (total as $CaCO_3$)--	mg/L	11	20:20	112	6.9	7 - 1,900
Sodium absorption ratio----	--	11	20:20	6.9	6.0	.4 - 73
pH-------------------------	s.u.	9	20:20	*7.7	*.6	6.5 - 8.5
Specific conductance-------	mhos/cm	15	20:20	1,500	1.8	582 - 4,000

[1] µg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; s.u., standard units; µmhos/cm, reciprocal micro-ohms per centimeter; °C, degrees Celsius.

TABLE 71.—*Shale-outcrop mineralogy, Fort Uniton Formation, northern Great Plains*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Mineral	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
Calcite---------------	1 (23)	28:60	3.6	2.83	--	<0.1 - 28
Dolomite--------------	1 (23)	40:60	5.2	3.70	--	<.1 - 24
Gypsum----------------	1 (23)	11:60	2.0	2.21	--	<.12 - 7.3
Layered silicates-----	1 (23)	60:60	50	1.41	1.05	17 - 76
Microcline------------	1 (23)	56:60	3.2	1.57	1.46	<.5 - 9.8
Pyrite----------------	1 (23)	18:60	1.9	1.37	--	<.1 - 3.0
Quartz----------------	1 (23)	60:60	30	1.30	1.05	14 - 57
Siderite--------------	1 (23)	36:60	.6	1.60	--	<.1 - 1.3
Sodic plagioclase-----	1 (23)	52:60	4.2	1.96	1.90	<.5 - 11

TABLE 72.—*Sandstone outcrop mineralogy, Fort Union Formation, northern Great Plains*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Mineral	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
Calcite---------------	1 (23)	30:60	0.8	10.6	--	<0.1 - 61
Dolomite--------------	1 (23)	47:60	2.7	7.68	1.06	<.1 - 41
Layered silicates-----	1 (23)	60:60	21	1.75	1.19	4.8 - 64
Microcline------------	1 (23)	57:60	4.3	2.79	1.14	<.5 - 16
Quartz----------------	1 (23)	60:60	43	1.41	1.02	19 - 89
Sodic plagioclase-----	1 (23)	53:60	3.9	4.67	1.17	<.5 - 26

TABLE 73.—*Mineralogy of fine-grained rocks cored from the Fort Union Formation, northern Great Plains*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Mineral	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Observed range (percent)
Calcite--------------	3 (23)	17:38	0.73	3.95	<0.25 - 10
Carbonate, mixed-----	3 (23)	2:38	.31	2.77	<.25 - 22
Chlorite-------------	3 (23)	34:38	18.5	--	<.25 - 65
Clay, total----------	3 (23)	38:38	47.2	1.41	12 - 80
Dolomite-------------	3 (23)	22:38	1.56	--	<.25 - 33
Kaolinite------------	3 (23)	26:38	5.20	--	<.25 - 80
Microcline-----------	3 (23)	37:38	1.65	1.89	<.25 - 6
Quartz---------------	3 23)	38:38	25.7	1.44	14.0 - 49.0
Siderite-------------	3 (23)	16:38	.66	3.79	<.25 - 20
Sodic plagioclase----	3 (23)	38:38	3.51	1.99	1 - 10

TABLE 74.—*Mineralogy of three rock types from drill cores at the Hanging Woman Creek site, Big Horn County, Mont.*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Mineral, and rock type	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Observed range (percent)
Calcite					
Sandstone-----------	2 (23)	12:24	2.5	4.9	<0.25 - 19
Siltstone plus shale	2 (23)	11:24	1.5	1.8	<.25 - 5.5
Dark shale----------	2 (23)	1:23	--	--	<.25 - .78
Calcium-rich dolomite					
Sandstone-----------	2 (23)	10:24	14	21	<.25 - 56
Siltstone plus shale	2 (23)	4:24	.21	.64	<.25 - 2.6
Dark shale----------	2 (23)	0:23	--	--	--
Calcium-rich siderite					
Sandstone-----------	2 (23)	11:24	.89	1.8	<.25 - 8.2
Siltstone plus shale	2 (23)	8:24	.68	1.5	<.25 - 6.4
Dark shale----------	2 (23)	12:23	1.3	1.8	<.25 - 6.8
Chlorite					
Sandstone-----------	2 (23)	23:24	3.8	2.5	<.25 - 10
Siltstone plus shale	2 (23)	24:24	11	7.0	2.7 - 25
Dark shale----------	2 (23)	22:23	14	9.5	<.25 - 27

TABLE 74.—*Mineralogy of three rock types from drill cores at the Hanging Woman Creek site, Big Horn County, Mont.*—Continued

Mineral, and rock type	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Observed range (percent)
Dolomite					
Sandstone-----------	2 (23)	12:24	2.2	2.5	<0.25 - 7.1
Siltstone plus shale	2 (23)	14:24	2.3	2.3	<.25 - 6.2
Dark shale----------	2 (23)	13:23	1.0	.73	<.25 - 2.1
Gypsum					
Sandstone-----------	2 (23)	1:24	--	--	<.25 - 5.9
Siltstone plus shale	2 (23)	0:24	--	--	--
Dark shale----------	2 (23)	1:23	--	--	<.25 - 4.6
Illite					
Sandstone-----------	2 (23)	24:24	3.0	1.7	1.10 - 8.2
Siltstone plus shale	2 (23)	24:24	12	6.7	3.8 - 25
Dark shale----------	2 (23)	23:23	15	6.4	6.1 - 27
Kaolinite					
Sandstone-----------	2 (23)	22:24	8.5	7.1	<.25 - 23
Siltstone plus shale	2 (23)	23:24	12	8.4	<.25 - 33
Dark shale----------	2 (23)	23:23	8.1	17	3.8 - 32
Magnesian calcite					
Sandstone-----------	2 (23)	1:24	--	--	<.25 - .87
Siltstone plus shale	2 (23)	2:24	.11	.38	<.25 - 1.4
Dark shale----------	2 (23)	0:23	--	--	--
Marcasite					
Sandstone-----------	2 (23)	1:24	--	--	<.25 - 10
Siltstone plus shale	2 (23)	0:24	--	--	--
Dark shale----------	2 (23)	0:23	--	--	--
Microcline					
Sandstone-----------	2 (23)	16:24	4.1	4.3	<.5 - 16
Siltstone plus shale	2 (23)	13:23	2.2	2.3	<.5 - 7.0
Dark shale----------	2 (23)	11:23	1.9	2.1	<.5 - 6.9
Oligoclase					
Sandstone-----------	2 (23)	24:24	9.6	3.0	4.3 - 18
Siltstone plus shale	2 (23)	21:24	7.4	4.4	<.5 - 14.1
Dark shale----------	2 (23)	22:23	4.6	2.8	<.5 - 10.2
Pyrite					
Sandstone-----------	2 (23)	1:24	--	--	<.1 - 3.5
Siltstone plus shale	2 (23)	10:24	.88	1.1	<.1 - 3.3
Dark shale----------	2 (23)	19:23	2.6	1.9	<.1 - 6.8
Quartz					
Sandstone-----------	2 (23)	24:24	37	12	23 - 71
Siltstone plus shale	2 (23)	24:24	33	4.5	24 - 40
Dark shale----------	2 (23)	23:23	28	3.3	16 - 32
Siderite					
Sandstone-----------	2 (23)	9:24	.30	.53	<.25 - 2.1
Siltstone plus shale	2 (23)	14:24	.45	.48	<.25 - 1.5
Dark shale----------	2 (23)	4:23	.12	.29	<.25 - 22
Silicates, layered[1]					
Sandstone-----------	2 (23)	24:24	28	10	11 - 44
Siltstone plus shale	2 (23)	24:24	52	7.3	38 - 66
Dark shale----------	2 (23)	23:23	61	5.5	54 - 78
Smectite					
Sandstone-----------	2 (23)	24:24	13	8.0	1.2 - 31
Siltstone plus shale	2 (23)	24:24	17	7.7	4.8 - 36
Dark shale----------	2 (23)	20:23	15	13	<.25 - 35

[1]The category "silicates, layered" includes the following other categories that are listed individually in the tabulation: chlorite, illite, kaolinite, and smectite.

TABLE 75.—*Mineralogy of stream sediments from the northern Great Plains*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures.]

Mineral	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
Calcite	6 (23)	26:30	1.5	1.84	1.08	<0.1 - 8.7
Dolomite	6 (23)	25:30	1.7	2.29	1.04	<.1 - 8.0
Layered silicates	6 (23)	30:30	35	1.03	1.003	21 - 59
Microcline	6 (23)	30:30	5.2	1.14	1.14	2.0 - 9.8
Quartz	6 (23)	30:30	43	1.01	1.001	28 - 63
Sodic plagioclase	6 (23)	30:30	7.3	1.39	1.03	1.1 - 19

TABLE 76.—*Mineralogy of soils used in extraction studies, northern Great Plains*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, arithmetic mean. Deviation, standard deviation. Error, standard error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Mineral, and soil horizon	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
Calcite						
A horizon	18 (23)	9:21	<0.1	--	--	<0.1 - 0.7
C horizon	18 (23)	19:21	5.3	5.2	0.86	<.1 - 15
Dolomite						
A horizon	18 (23)	16:21	.75	.94	.33	<.1 - 3.5
C horizon	18 (23)	20:21	3.3	3.5	.46	<.1 - 12
Layered silicates						
A horizon	18 (23)	21:21	28	10.7	2.8	7.3 - 56
C horizon	18 (23)	21:21	30	9.1	2.8	16 - 45
Microcline						
A horizon	18 (23)	13:21	4.9	5.2	3.1	<.5 - 19
C horizon	18 (23)	13:21	3.8	4.0	1.3	<.5 - 16
Quartz						
A horizon	18 (23)	21:21	50	8.8	1.5	30 - 67
C horizon	18 (23)	21:21	47	10.7	1.7	26 - 62
Siderite						
A horizon	18 (23)	2:21	<.1	--	--	<.1 - .5
C horizon	18 (23)	2:21	<.1	--	--	<.1 - .3
Sodic plagioclase						
A horizon	18 (23)	19:21	9.6	7.9	2.3	<.5 - 33
C horizon	18 (23)	21:21	8.7	7.2	.8	.6 - 26

TABLE 77.—*Mineralogy of soils from Hanging Woman Creek, Mont.*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the mineral was found to number of samples examined. Mean, arithmetic mean. Deviation, standard deviation. Error, standard error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Mineral	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
			WHOLE SAMPLE			
Calcite----------------	14 (23)	14:16	--	--	--	<0.2 - 11
Dolomite---------------	14 (23)	14:16	--	--	--	<.2 - 3.9
Layered silicates-----	14 (23)	16:16	40	6.8	1.6	27 - 51
Microcline-------------	14 (23)	16:16	5.4	2.3	.89	2.2 - 9
Quartz-----------------	14 (23)	16:16	42	7.6	1.5	30 - 55
Sodic plagioclase-----	14 (23)	16:16	7.6	2.2	1.3	3.4 - 11
			SAND FRACTION (2 mm to 0.05 mm)[1]			
Layered silicates-----	14 (23)	15:16	8.5	4.9	1.7	<3 - 15
Microcline-------------	14 (23)	16:16	9.1	2.1	2.0	3.2 - 11
Quartz-----------------	14 (23)	16:16	74	7.1	2.5	64 - 88
Sodic plagioclase-----	14 (23)	16:16	8.6	3.0	2.3	5.7 - 18
			SILT FRACTION (0.05 mm to 0.002 mm)[1]			
Layered silicates-----	14 (23)	16:16	21	6.2	5.9	15 - 36
Microcline-------------	14 (23)	16:16	7.3	2.0	1.2	2 - 11
Quartz-----------------	14 (23)	16:16	60	5.8	5.2	49 - 67
Sodic plagioclase-----	14 (23)	16:16	12	2.0	.94	7.2 - 16
			CLAY FRACTION (<0.002 mm)[1]			
Layered silicates-----	14 (23)	16:16	81	6.4	6.4	67 - 91
Microcline-------------	14 (23)	6:16	--	--	--	<2 - 8
Quartz-----------------	14 (23)	16:16	13	3.9	3.9	9 - 24
Sodic plagioclase-----	14 (23)	14:16	4.0	3.1	2.6	<2 - 10

[1]Calcite and dolomite were removed by the dispersion treatment.

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