UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY





# GEOCHEMICAL SURVEY OF THE WESTERN COAL REGIONS

Second Annual Progress Report, July 1975

By

U.S. Geological Survey
Denver, Colorado

Open-file Report 75-436
1975

## A NOTE ON THE USE OF GEOCHEMICAL SUMMARIES IN ASSESSING SUSPECTED METAL POLLUTION

An attempt to assess metal pollution requires, at the very least, some knowledge of the natural levels of metal concentration to be expected in the material of interest in the area of interest. Armed with such information, a first "cut" at assessing metal pollution can be made very simply by asking the question "Is the metal level actually observed unnaturally high?" Note that this question is focused directly on whether or not the concentration level is unusual and not on what constitutes a potentially hazardous or toxic level.

Some of the tabular geochemical summaries in this report offer the interested reader a few geochemical properties that he or she may use to determine just what level of metal concentration should be viewed as unusual. These properties are the geometric mean (GM), the geometric deviation (GD) and, if available, the geometric error (GE). The estimation of what constitutes an unusual concentration may be approached in two slightly different ways, each based on the theory of the lognormal frequency distribution. The first approach estimates a range of concentrations expected under "ordinary" conditions, as follows: Approximately two-thirds of a randomly selected set of samples are expected to exhibit concentrations between a lower level computed as GM/GD and an upper level computed as GM•GD. About 95 percent of the samples are expected to fall within the range defined as $GM/(GD)^2$ and $GM \cdot (GD)^2$, and about 99.7 percent are expected to fall within the range $GM/(GD)^3$ and $GM \cdot (GD)^3$. Clearly, if one of these ranges is used to define the ordinary range of metal concentration, samples with concentrations outside such limits must be viewed as unusual or anomalous. Such concentrations need not necessarily reflect metal pollution but they would be worthy of further investigation. The choice of which of these three ranges (or some other similar range) to use depends on the degree of certainty one wishes to attach to a declaration that a metal value is anomalous. For example, any value lying above the 95 percent range has only 2½ chances out of 100 of reflecting natural variation in the environmental material under consideration.

Conventionally, in pollution studies little interest is attached to anomalously low concentrations, and attention focuses on the upper limit alone. This suggests a second approach. The following formula may be used to determine limits above which a specified proportion of samples should fall under ordinary conditions (i.e., in the absence of metal pollution):

$$\text{Log } L = \text{Log } (GM) + f\text{Log } (GD) \qquad (1)$$

where Log L, Log (GM) and Log (GD) are logarithms of the specified upper limit, the geometric mean and the geometric deviation, respectively, and f is a multiplier. If the user wishes to define a limit above which only one sample in 10 is expected to fall under ordinary conditions, f is set equal to 1.28. If the limit is defined as that above which only about one in 20 should fall naturally, f is set to 1.65. A limiting value for one sample in 50 or one sample in 100 requires f to be equal to 2.05 and 2.33, respectively. The concentration of the chosen limit is found by computing Log L (equation 1) and taking the antilog.

(Continued on inside back cover)

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards or nomenclature.

GEOCHEMICAL SURVEY OF THE WESTERN COAL REGIONS
July 1975

Second annual progress report describing current work in a broad-scaled reconnaissance geochemical study of landscape materials in the major coal-bearing regions of the western United States

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## INTRODUCTION AND SUMMARY

by Jon J. Connor

This report is the second in an annual series describing results of studies in our geochemical survey of the western coal regions. Work described herein consists mostly of that undertaken in the Northern Great Plains Region of Wyoming, Montana, and North Dakota, with particular emphasis on the Powder River Basin (fig. 1). Most of this work has focused on the chemistry of soil material and plant tissue, although limited sampling of the stream sediments, strip mine spoil materials, potential overburden, and ground water has been completed.

The primary emphasis of this work has been on the examination of scales of trace element variation in near-surface landscape materials of the western coal region. The scale of variation is important because it is the key used to judge the cost of geochemical baseline estimation. Of particular importance is the assessment of variation at the largest scales of a study. The presence of important variation at this scale means that any attempts to describe the element distribution (which description is, in itself, a baseline) must involve sampling over large areas; this, in turn, increases cost. On the other hand, a lack of large-scale variation implies that geochemical information collected in part of the area of study may be successfully extrapolated to other parts of the area of study.

Rarely is the situation with regards to baseline estimation quite as simple as this, however, as the papers in this report make clear. Although most elements examined to date in soils and plants of the Powder River Basin and Northern Great Plains exhibit less than 20 percent of their total variability at scales larger than about 10 kilometres, a few elements of particular environmental concern do exhibit important regional effects. For example, seven elements in soil lichen in the Powder River Basin (table 2) exhibit statistically significant variation at scales greater than 10 km. Of these seven, four environmentally sensitive ones (cadmium, fluorine, lead,and selenium) have a strong regional effect accounting for nearly a fourth or more of the total observed variation. Uranium also exhibits a fairly strong regional effect although it is not quite statistically significant at the 95 percent confidence level. Similarly, eight elements in grama grass in the basin (table 4) show statistically significant variation at scales larger than 10 km, and three of these (arsenic, mercury, and lead, all of great environmental importance) exhibit about a third or more of their total observed variance at these scales. Thus, cadmium, fluorine, lead, selenium, arsenic, mercury, and perhaps uranium may be expected to show broad-scale patterns in one or more plant species in the basin. Additional work seems required if the distributions of these elements are to be properly accounted for.

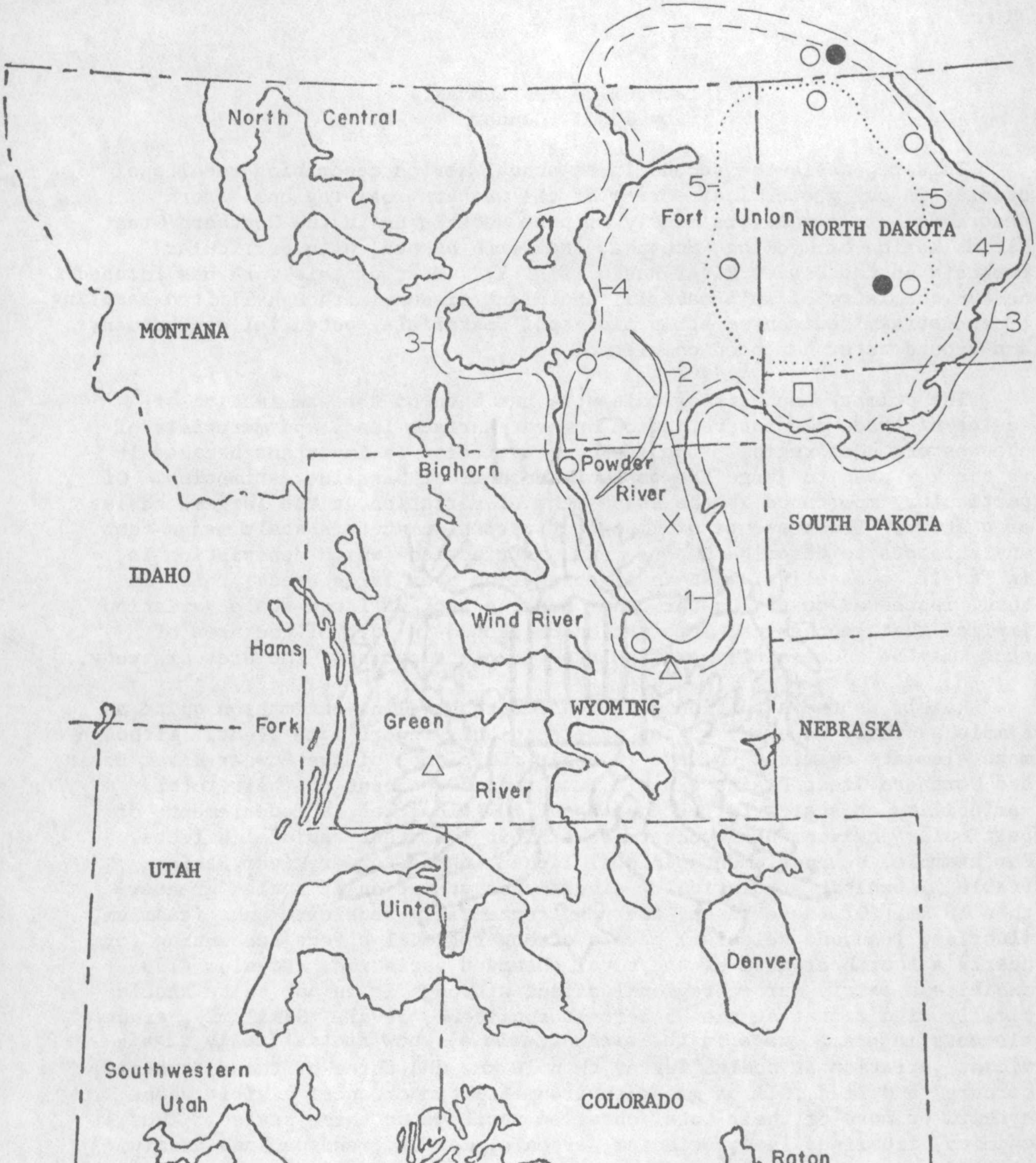



Figure 1. Location of the major coal basins in the western United States (modified from Trumbull, 1959) and of fieldwork completed to date.

EXPLANATION

| Map Unit | Material Sampled | Reference |
|---|---|---|
| **Background Geochemical Studies** | | |
| 1 | Soil, soil parent, sagebrush, lichen, and grama grass | Tidball, Erdman, and Ebens (1974); Connor, Keith, and Anderson (1976); this report. |
| 2 | Sediments (Powder River) | |
| 3 | Soil | This report. |
| 4 | Wheat | |
| 5 | Ground water | This report. |
| **Topical Geochemical Studies** | | |
| ● | Cored overburden | |
| ○ | Strip mine spoil, clover | This report. |
| □ | Mixed feed grains | |
| ╳ | Mine water (AMAX) | Feder (1974). |
| △ | Soil, sagebrush (near power plant) | Connor, Keith, and Anderson (1976); this report. |
| ▲ | Soil, grass (near power plant) | |

A smilar examination of soil in the Powder River Basin indicates that lithium and potassium in the A-horizon (table 5) exhibit more than a third of their total variation at scales above 10 km. In the Northern Great Plains as a whole, potassium and uranium in the A-horizon (table 8) have equally important components of variation at scales larger than about 100 km.

In contrast, examination of tables 2, 4, 5, 8, and 9 demonstrates that a large majority of the elements studied in both soil and plant material exhibit little or no regional variation. All such elements exhibit a variation, to be sure, but the important thing about such variation is that little, if any, of this variation occurs at scales much larger than a few tens of kilometres. Thus, samples collected hundreds of kilometres apart are expected to differ (on the average) no more than samples collected about 10-20 km apart.

Lack of important broad-scale variation indicates that data collected in only part of a region can be extrapolated to other parts of that region. But the local variation that is always present generally allows only limited successful extrapolation of individual measurements on a given sample. Such extrapolation can be undertaken, however, in the form of summary statistical properties observed on a sample suite. Thus, many of the element summaries in tables 2, 4, 6, 9, and 13 on p. 50 should prove useful in determining geochemical baselines over a broad region.

The question arises, of course, as to what summary property to extrapolate as a baseline. This, in turn, depends on the reason for the extrapolation. In the absence of regional variation, the average (mean) of a sample suite may be extrapolated to other parts of the region as the most probable or expected concentration regardless of locality. In the interest of determining a limiting value above which new data are to be judged "anomalous," however, the average is inappropriate because it would insure that approximately half of all new samples collected would be classified as anomalous. Recognizing this fact, Tidball, Erdman, and Ebens (1974) defined a geochemical baseline as a range of concentrations, so that only truly unusual samples (whether of high or low concentration) would be viewed as anomalous. The particular range or limiting value chosen is perhaps a matter of personal choice as long as the definition requires that only a small proportion of all potential samples be actually tagged as anomalous. The short discussion on the inside of the cover of this report offers the interested reader some alternatives in definition.

Many of the summaries in this report give the range of concentrations expected in about 95 percent of a suite of randomly collected samples. If interest should focus only on anomalously high concentrations, the upper limit of this range is, in fact, a concentration above which about one sample in 40 will fall due to natural causes alone. This might seem to be an unreasonably high limiting value to some, particularly in light of the fact that statisticians commonly test for unusual conditions at a probability level of "1 in 20."

As an example, the data in table 1 consist of concentrations above which about one sample in 20 of a randomly collected suite from the Powder River Basin should fall. Limiting values are given for surface soil and three native plant species and were computed according to instructions on the inside cover. Any concentrations encountered in samples of these materials in the Powder River Basin that lie much above these limits must be viewed as highly unusual.

Limits in parentheses indicate that they are expected to vary in an important way from place to place in the basin. Nevertheless, the given value may still be of use although, in fact, it is a limit above which something less than one sample in 20 is expected to fall due to natural causes alone. The second and third studies in table 1 defined regional scales as those greater than 35 km. The first, fourth, and fifth defined regional scales as those greater than 10 km. The first and second studies are two independent studies in the topmost soil layer in the basin and except for a few comparisons (such as zirconium) agreement between the two seems reasonable.

The greatest potential for change in soil chemistry of the western coal regions may result from the substitution of overburden materials for surface soil following strip mining. Some idea of this change may be seen in a comparison of the postulated upper limits for soil given in table 1 with the overburden chemistry for the Big Sky, Dave Johnston, and Welch mines (all in the Powder River Basin), given in table 7.

The average concentrations of aluminum, fluorine, mercury, and uranium in samples of overburden from the Welch mine exceed the limits for soil in table 1, as do the calcium and fluorine averages in the Big Sky overburden and the uranium average in the Dave Johnston overburden. In addition, lithium in the Welch and Big Sky overburden, magnesium in the Big Sky overburden and thorium in the Dave Johnston and Welch overburdens are near the limits for soil given in table 1.

Additional analyses of potential overburden are given in table 14. These analyses represent work undertaken in a large number of separate and independent studies conducted over an extended period. Also, different analysts used a variety of analytical procedures in generating these data. They are offered here solely to give some insight into the compositional nature of the fine-grained rocks associated with coal. The listed data are neither comprehensive nor representative and should be used with care. Even so, a comparison of table 1 with table 14 suggests something of the drastic change in total elemental composition that results from overturning the natural soil. The current practice of removing topsoil prior to stripping and replacing it upon reclamation should materially reduce the potential for such changes.

Table 1.--Approximate upper limits of element concentrations to be expected in a few ordinary near-surface materials of the Powder River Basin

[The limits are defined as those above which only about one sample in 20 of a random collection is expected to fall due to natural causes alone. Because of the presence of demonstrated regional variation, values in parentheses are expected to vary from one part of the basin to another. Values expressed as ppm (parts per million), except as indicated. Leaders (--) in figure columns mean no data available]

| Constituent | Soil, -2 mm fraction | | Plant ash | | |
|---|---|---|---|---|---|
| | A horizon, 0-2 cm depth[1] | Surface soil, 0-2.5 cm depth[2] | Sagebrush[3] | Soil lichen[4] | Grama grass[5] |
| Aluminum, percent | 7.3 | -- | -- | (5.9) | 5.0 |
| Antimony | -- | 1.9 | -- | -- | -- |
| Arsenic | -- | 12 | -- | [6]1.2 | [6](1.9) |
| Barium | 910 | 990 | 1,100 | 714 | 760 |
| Beryllium | -- | 1.7 | -- | -- | -- |
| Boron | 57 | 54 | 400 | -- | 180 |
| Cadmium | -- | -- | 16 | (9.1) | 2.0 |
| Calcium, percent | 2.3 | -- | -- | -- | 6.1 |
| Chromium | 98 | 69 | 39 | 67 | (67) |
| Cobalt | 16 | 10 | 5.1 | 6.5 | 8.6 |
| Copper | 31 | 30 | -- | (110) | 200 |
| Fluorine | 730 | -- | -- | [6](46) | [6](110) |
| Gallium | 20 | 18 | -- | -- | 17 |
| Germanium | -- | 2.2 | -- | -- | -- |
| Iodine | -- | -- | -- | [6]5.5 | -- |
| Iron, percent | 3.8 | -- | -- | 1.9 | 2.2 |
| Lead | 30 | 21 | 100 | (240) | (41) |
| Lithium | -- | 34 | 25 | 11 | 16 |
| Magnesium, percent | 1.5 | -- | -- | 1.0 | 1.5 |
| Manganese | 830 | 560 | 910 | 600 | 1,300 |
| Mercury | .041 | .024 | -- | [6].13 | [6](.035) |
| Molybdenum | -- | -- | 18 | -- | 24 |
| Nickel | 37 | 24 | 29 | 17 | 14 |
| Phosphorus, percent | -- | -- | -- | -- | 1.1 |
| Potassium, percent | -- | -- | -- | -- | 3.4 |

Table 1.--Approximate upper limits of element concentrations to be expected in a few ordinary near-surface materials of the Powder River Basin

| Constituent | Soil, -2 mm fraction | | Plant ash | | |
|---|---|---|---|---|---|
| | A horizon, 0-2 cm depth[1] | Surface soil, 0-2.5 cm depth[2] | Sagebrush[3] | Soil lichen[4] | Grama grass[5] |
| Rubidium---------- | [7]100 | -- | -- | -- | 37 |
| Scandium---------- | 14 | 11 | -- | -- | -- |
| Selenium---------- | .57 | .41 | [6]2.1 | [6](0.62) | [6].53 |
| Silicon, percent- | [7]40 | -- | 12 | (19) | 39 |
| Sodium, percent-- | .86 | -- | -- | .064 | (.10) |
| Strontium--------- | 230 | 300 | 1,100 | 900 | 290 |
| Sulfur, percent-- | -- | -- | -- | [6].10 | [6].072 |
| Thorium----------- | -- | 13 | -- | -- | -- |
| Tin--------------- | -- | 3.4 | -- | -- | -- |
| Titanium, percent | [7].39 | -- | .16 | .30 | .29 |
| Uranium----------- | -- | 4.5 | 1.4 | 5.5 | 2.0 |
| Vanadium---------- | 130 | 110 | 80 | 85 | 110 |
| Ytterbium--------- | -- | 2.1 | -- | -- | -- |
| Yttrium----------- | -- | 23 | -- | 52 | -- |
| Zinc-------------- | [7]110 | 91 | 610 | -- | (1,100) |
| Zirconium--------- | 470 | 260 | 104 | 110 | (290) |

[1] From tables 5 and 6, this report.
[2] From table 1 in Connor, Keith, and Anderson (1976) and table 9, this report.
[3] Unwashed Artemisia tridentata (from table 1 of Connor, Keith, and Anderson, (1976).
[4] Washed Parmelia chlorochroa (from table 2, this report).
[5] Washed Bouteloua gracilis (from table 4, this report); data not corrected for laboratory error.
[6] Determined on dry weight.
[7] Based on arithmetic mean and standard deviation.

Continued work on the probable effect of the Dave Johnston electric generating power plant on the trace element chemistry of the downwind landscape suggests that arsenic and antimony (fig. 16) may be building up on the surface soil near the plant. This brings to six the number of trace metals exhibiting statistically significant reductions in soil or sagebrush away from that power plant. Previous work (Connor, Keith, and Anderson, 1976; Keith, Anderson, and Connor, 1974) indicated a significant buildup of selenium, strontium, vanadium, and uranium in sagebrush downwind from the plant.

The emphasis of the geochemical survey of the western coal regions is on the distribution of a large number of elements, particularly those known to be implicated in human and animal health, in near-surface materials of the coal regions. To this end, a system of elemental analysis has been set up based on specific laboratory procedures (as well as specific laboratories) to insure a uniformity of results throughout the life of the survey. A flow chart of methods for rocks, soils, and plants are shown in figure 2. The "workhorse" of the system is emission spectrography; it not only provides semiquantitative information on as many as 30 elements but also routinely looks for another 20 or so elements (many of the rare earths) which are generally at detection levels above concentrations commonly expected in ordinary rocks, soils, and plants. Other techniques used in this survey are methods based on atomic absorption and neutron activation. Special methods are necessary for a few elements. Elements important to hydrological work are listed in table 12.

ROCKS AND SOILS
(Sample ground to pass 100 mesh)

**X-ray fluorescence**

Majors:
Al Si
Ca S
Mg Ti
Fe Mn
K Cl
P

Minors:
Se Sn
Ge As
Sb Te
Bi

**Emission spectrographic**

Common:
Fe Ni
Mg Pb
Ca Sc
Ti Sr
P V
Mn Y
B Zr
Ba Al
Co K
Cr Ga
Cu Yb

Rare:
Ag Nb
Be Ce
La Nd
Mo Sn

**Atomic absorption**

Mg Zn
Na Rb
Li Cd1/
Hg2/

**Selective ion electrode**

F

**Gasometric**

Total C

**Neutron activation**

U Th

PLANT MATERIAL

(Sample ashed at ~ 450°C)

**Atomic absorption**

Co Na
Cd Ca
Li K
Si Zn

**Colorimetric**

P

**Fluorimetric**

U

**Emission spectrographic** (→ Emission spectrographic, rocks and soils)

(Sample dried at ~ 40°C)

**Atomic absorption**

As Sb
Hg2/

**Selective ion electrode**

F

**2, 3-Diaminonaphthalene**

Se

**Turbidometric**

S

**Gravimetric**

Ash

1/ Looked for only if Zn >200 ppm.
2/ Determined by "flameless" atomic absorption.

Figure 2.--Methods of total element analysis adopted for rocks, soils, and plants in the geochemical survey of the western coal regions.

TRACE ELEMENTS IN SOIL LICHEN AND GRAMA GRASS OF THE POWDER RIVER BASIN
by James A. Erdman and Larry P. Gough

As part of a reconnaissance study of landscape geochemistry in the Powder River Basin of Wyoming and Montana initiated in the fall of 1973, samples of soil lichen (Parmelia chlorochroa) and grama grass (Bouteloua gracilis) were collected, along with sagebrush (Artemisia tridentata), to provide insight into the distribution of elements in plants. Results of the sagebrush study are given in Tidball, Erdman, and Ebens (1974) and partial results of the lichen study are given in Erdman (1974), but this report is the first to discuss the chemistry of the grama grass.

## Soil lichen

Twenty-one elements in soil lichen (Parmelia chlorochroa) from the Powder River Basin were discussed in Erdman (1974). Since that report, analyses for five more elements--arsenic, iron, manganese, silicon, and uranium--have been processed. Soil lichens were collected from four localities in the Powder River Basin (fig. 3) according to a nested analysis of variance design described in Tidball, Erdman, and Ebens (1974), except that the soil lichen samples were composited over sites 10 m on a side. An attempt was made to collect 8 samples in each of four localities, but the absence of lichen at many sites resulted in an unbalanced design. As a result, eight samples were collected in locality 1, but only five in locality 2, three in locality 3, and six in locality 4, for a total of 22 samples. Seven of these 22 were split into two parts prior to analysis, in order to estimate analytical error, and the entire group of 29 were analyzed in a randomized sequence.

The design used permits estimation of variation at a number of geographic scales, but that of greatest interest is the broad-scale or "regional" effect. In this design, the broadest-scaled effect is that between localities that reflect variation at distances greater than 10 km. Seven of the 26 elements (aluminum, cadmium, copper, fluorine, lead, selenium, and silicon) exhibit variation at these scales significant at the 95 percent confidence level (table 2).

An interesting feature of the lichen chemistry is that the highest uranium concentrations observed (up to 7 ppm in ash) were in samples collected within the Monument Hill uranium district in the southern part of the Powder River Basin. Because an attempt was made to wash all samples, it's likely that the uranium has been absorbed by the plant and is not just adhering to its surface. These data suggest a greater availability of uranium to plant tissue in the district than elsewhere but do not permit a choice between availability due to natural or manmade causes.

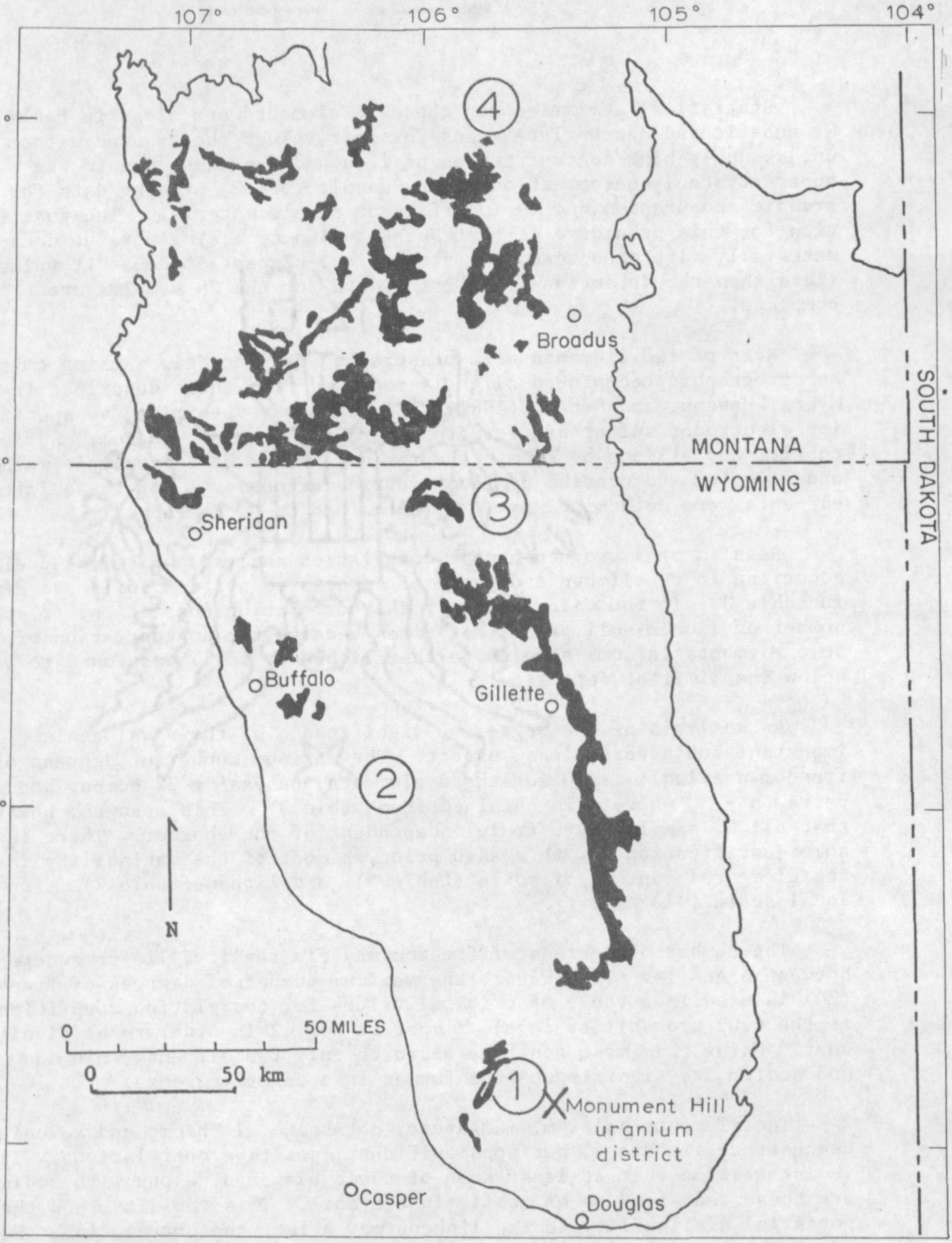



Figure 3. Sampling localities for soil lichen (Parmelia chlorochroa) and grama grass (Bouteloua gracilis) in the Powder River Basin. Solid patterns indicate known strippable coal reserves (from U.S. Geological Survey, 1974a).

Statistical summaries for these 26 elements are given in table 2. We substituted appropriate means for four values that showed either (1) unreasonably high concentrations of iron and manganese due to the apparent steel contamination of one sample, or (2) missing data for arsenic and uranium due to insufficient sample material. The justification for this procedure is that substitution of a single value does not materially alter the resulting statistics. Except for one "L" value (less than the detection limit), the data for the 29 samples are complete.

Most of the elements were measured by Harriet Neiman using emission spectrographic techniques slightly modified from those described in Myers, Havens, and Dunton (1961). Fluorine was determined by specific-ion electrode; sulfur by titration; mercury, lithium, sodium, cadmium, cobalt, and silicon by atomic absorption; iodine by a catalytic method; and selenium and uranium by fluorimetric methods. All of these latter elements were determined by T. F. Harms and C. S. E. Papp.

Results of a product-moment correlation analysis of selected elements occurring in the lichen and those of associated surface soils are given in table 3. In the calculation of the correlation coefficient (r), the number of lichen-soil pairs (n) varies, because the concentration of some elements in some samples (either lichen or soil) was found to be below the limit of detection.

An analysis of the degree of significance of the r values is important but nevertheless suspect. The maximum number of degrees of freedom available is 20 for those elements possessing 22 comparison pairs (n - 2, where n is obtained from table 3). This assumes, however, that all 22 samples were truly independent of one another. There is some justification for this assumption as most of the variability in the elemental content of soils (table 5) and lichen (table 2) is on a local scale ($<$10 km).

The number of degrees of freedom may, in reality, lie somewhere between 6 and 14. If however, the maximum number of degrees of freedom (20) is used in a table of critical values for correlation coefficients, at the 0.05 probability level, r must be $\geq$ 0.42 in order to be significant. Using this most generous approach, only two elements, aluminum and sodium, are significant--the former in a negative sense.

The elements calcium, manganese, potassium, lithium, and selenium demonstrate important, but nonsignificant, positive correlations. It is interesting that at least some of these elements, along with sodium, are those that tend to be mobile in the soil. This mobility, and thus potential availability to the lichen, may affect the correlation. However, these results demonstrate no strong relationship between the total elemental content of surface soils and that of the lichen.

Table 2.--Statistical evaluation of element concentrations in ash of soil lichens (Parmelia chlorochroa), Powder River Basin

| Element | Summary | | Logarithmic variance components | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Geometric mean, ppm (GM) | Geometric deviation (GD) | Regional[1] (>10 km) | | Local (0-10 km) | | Laboratory error[2] | |
| | | | Component | Percent | Component | Percent | ($S_E^2$) | Percent |
| Al------ | 38,000 | 1.35 | 0.0051 * | 30 | 0.084 | 49 | 0.0035 | 21 |
| As[3]----- | .92 | 1.32 | .0006 | 4 | .0030 | 21 | .0105 | 74 |
| Ba------ | 370 | 1.56 | .0060 | 16 | .0240 | 65 | .0070 | 19 |
| Cd------ | 4.0 | 1.66 | .0110 * | 23 | .0363 | 75 | .0011 | 2 |
| Co------ | 3.5 | 1.53 | .0055 | 16 | .0204 | 59 | .0084 | 24 |
| Cr------ | 33 | 1.57 | .0058 | 15 | .0291 | 76 | .0035 | 9 |
| Cu------ | 70 | 1.44 | .0082 * | 33 | .0070 | 28 | .0097 | 39 |
| F[3]------ | 25 | 1.46 | .0105 * | 39 | .0151 | 56 | .0014 | 5 |
| Fe------ | 14,000 | 1.30 | 0 | <1 | .0067 | 50 | .0067 | 50 |
| Hg[3]----- | .098 | 1.20 | .0005 | 8 | .0050 | 78 | .0009 | 14 |
| I[3]------ | 4.5 | 1.16 | .0004 | 10 | .0024 | 58 | .0013 | 32 |
| Li------ | 6.3 | 1.44 | .0006 | 2 | .0209 | 84 | .0033 | 13 |
| Mg------ | 6,400 | 1.30 | .0014 | 10 | .0100 | 76 | .0017 | 13 |
| Mn------ | 270 | 1.67 | 0 | <1 | .0453 | 91 | .0044 | 9 |
| Na------ | 400 | 1.37 | 0 | <1 | .0158 | 84 | .0030 | 16 |
| Ni------ | 10 | 1.44 | .0050 | 20 | .0142 | 56 | .0061 | 24 |
| Pb------ | 110 | 1.64 | .0122 * | 26 | .0344 | 64 | .0044 | 10 |
| S[3]------ | 670 | 1.36 | 0 | <1 | .0125 | 69 | .0057 | 31 |
| Se[3]----- | .35 | 1.42 | .0174 * | 75 | .0048 | 21 | .0010 | 4 |
| Si------ | 90,400 | 1.56 | .0165 * | 44 | .0207 | 53 | .0011 | 3 |
| Sr------ | 350 | 1.82 | 0 | <1 | .0614 | 91 | .0057 | 8 |
| Ti------ | 1,700 | 1.44 | .0040 | 16 | .0186 | 75 | .0022 | 9 |
| U------- | 1.3 | 2.42 | .0540 | 37 | .0892 | 60 | .0046 | 3 |
| V------- | 58 | 1.31 | .0003 | 2 | .0053 | 73 | .0035 | 25 |
| Y------- | 32 | 1.43 | .0019 | 8 | .0152 | 63 | .0070 | 29 |
| Zr------ | 77 | 1.39 | 0 | <1 | .0088 | 43 | .0116 | 57 |

[1] Asterisk (*) indicates component significantly different from zero at the 0.05 probability level.
[2] Based on duplicate analysis of seven samples.
[3] Values determined on dry weight.

Table 3.--Correlation coefficients of selected elements occurring in both Parmelia chlorochroa ash and associated surface soils, Powder River Basin

[r, product-moment correlation between logarithms of element concentrations (lichen ash and soil); n, number of pairs used in computation of r; asterisk (*), significantly different from zero at the 0.05 probability level]

| Element | r | n | Element | r | n |
|---|---|---|---|---|---|
| Ba---- | 0.24 | 22 | Si---- | 0.06 | 22 |
| Co---- | .08 | 20 | Ti---- | -.12 | 22 |
| Cr---- | .17 | 22 | Mn---- | .36 | 19 |
| Cu---- | -.29 | 22 | Fe---- | -.21 | 21 |
| Ni---- | -.16 | 22 | K----- | .33 | 15 |
| Pb---- | .08 | 22 | Mg---- | -.24 | 22 |
| Sr---- | .12 | 22 | Na---- | *.45 | 22 |
| V----- | .29 | 22 | Hg[1]--- | -.07 | 22 |
| Y----- | .19 | 22 | Li---- | .34 | 22 |
| Zr---- | .29 | 22 | Zn---- | -.37 | 20 |
| Al---- | *-.44 | 22 | U----- | .12 | 21 |
| Ca---- | .38 | 15 | Se[1]--- | .32 | 20 |

[1] Lichen component determined on dry weight.

## Grama grass

Grama grass (Bouteloua gracilis) forms a dense sod throughout much of the sagebrush steppe that characterizes the basin and, in contrast to the deep-rooted sagebrush, is a shallow feeder. It is an extremely valuable range grass. According to Stoddart and Smith (1955) the short-grass plains, of which the Powder River Basin is a part, are dominated almost exclusively by grama grass, which produces 50 to 95 percent of all forage on well-managed ranges. Stoddart and Smith state that the short-grass plains comprise the largest of the grazing regions of the West and produce about one-third of the range beef in the United States.

Grama grass was collected from four localities in the basin, spaced about 100 km apart (fig. 3). An attempt was made to collect a sample at 16 sites in each locality, but the absence of the grass at some of the sites resulted in an unbalanced design. In addition, an initial attempt to collect only the above-ground parts proved impractical because of the small size of the plant, and the sampling technique was changed to take the whole plant by shaving off a clump of sod with a tiling spade and shaking off the excess soil.

Forty-six whole plant samples were eventually collected from the four localities (fig. 3). Seven were collected in locality 1, 15 in locality 2, 12 in locality 3, and 12 in locality 4. Within each locality the samples were nested so as to permit estimation of the proportion of the total elemental variation existing at each of five geographic scales. Details of the design permitting this estimation are given in Tidball, Erdman, and Ebens (1974). The geographic ranges are 0-10 m, 10-100 m, 100 m-1 km, 1-10 km, and greater than 10 km (referred to here as "regional" scales). The purpose of such estimation is to define those scales in nature at which important variation in grass chemistry exists.

The samples were cleaned first in tap water and then in distilled water, using an ultrasonic probe, until the solution was clear. The cleaning procedures were not entirely successful in removing all soil constituents. Elements associated with soil, such as aluminum, chromium, iron, manganese, titanium, and zirconium, are distinctly lower in the clipped samples than in the whole samples. Also, X-ray diffraction patterns of whole-plant samples show strong quartz, clay, and feldspar peaks (fig. 4). Analyses were performed by L. A. Bradley, W. Cary, T. F. Harms, and C. S. E. Papp. In addition to the analytical techniques outlined in figure 2, molybdenum was determined colorimetrically and rubidium, by atomic absorption spectroscopy.

The statistical analysis of the chemistry of grama grass is summarized in table 4. Of 33 entries in this table, eight (arsenic, chromium, fluorine, mercury, sodium, lead, zinc, and zirconium) exhibit statistically significant variation at scales greater than 10 km. As with most other landscape materials studied in the basin, however, the largest part of the observed variation in the chemistry occurs at scales less than 1 km. The large component at the smallest

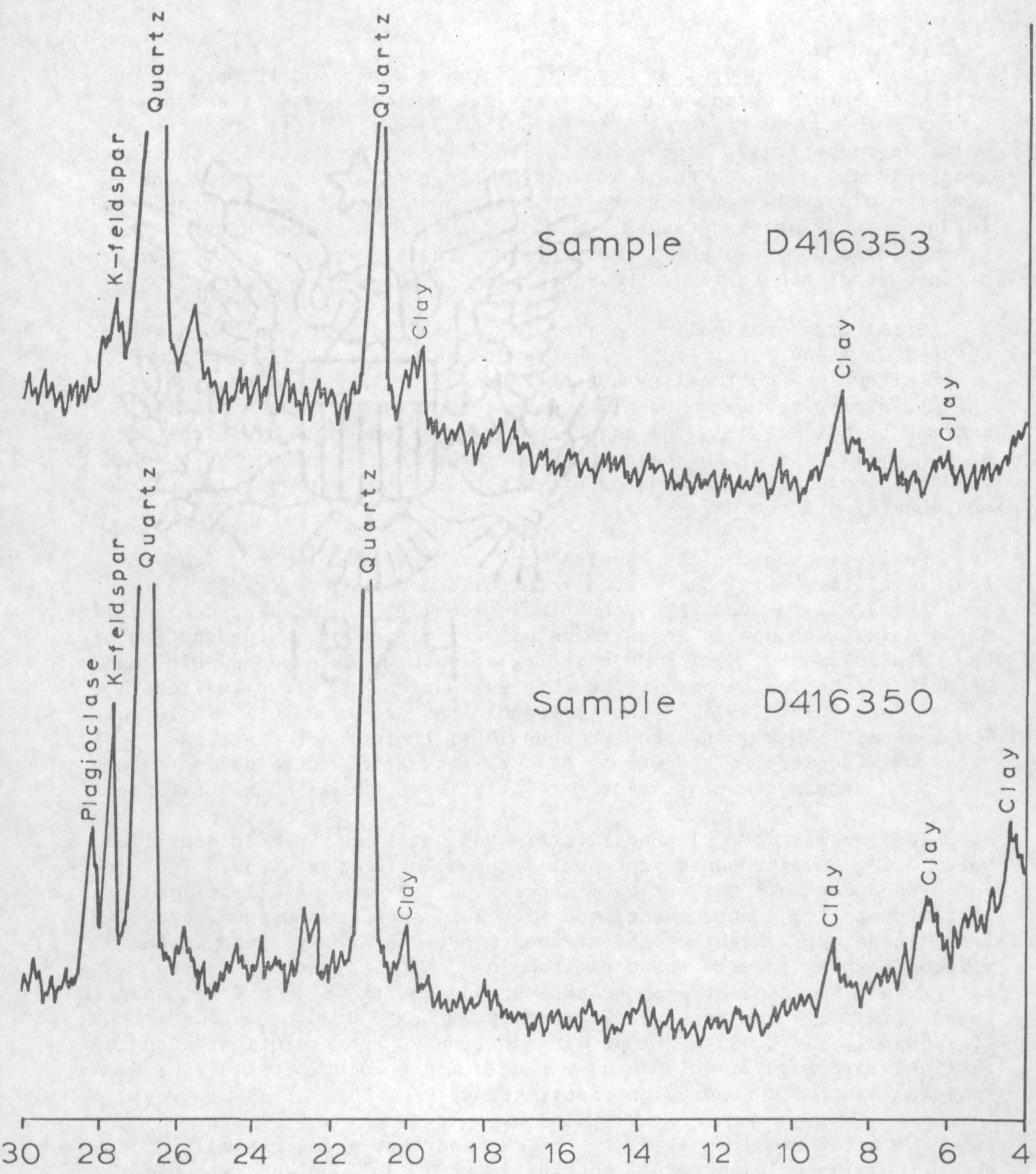



**Figure 4.** X-ray diffractograms for two samples of ash of grama grass (Bouteloua gracilis).

Table 4.--Statistical analysis of element concentrations in ash (except as noted) of grama grass from the Powder River Basin

[*, variance component significantly different from zero at the 95 percent confidence level; ppm, parts per million; detection ratio: number of samples in which constituent was measured to total number analyzed]

| Element | Detection ratio | Total $\log_{10}$ variance | Analysis of logarithmic variance: Percentage of total variance: >10 km (Regional) | 1-10 km | 0.1-1 km | 0.01-0.1 km | <0.01 km | Summary statistics: Geometric mean (GM) | Geometric deviation (GD) | Expected 95 percent range |
|---|---|---|---|---|---|---|---|---|---|---|
| Ash, percent | 46:46 | 0.02296 | <1 | 10 | 29* | <1 | 61 | 12.3 | 1.42 | 6.1 - 24.0 |
| Al, percent | 46:46 | .02065 | <1 | <1 | 30* | 19 | 51 | 2.9 | 1.39 | 1.5 - 5.6 |
| As[1], ppm[2] | 44:44 | .11857 | 41* | <1 | 8 | 9 | 42 | .51 | 2.21 | .10 - 2.5 |
| B, ppm | 46:46 | .02817 | <1 | <1 | 48* | <1 | 52 | 96 | 1.47 | 44 - 210 |
| Ba, ppm | 46:46 | .02221 | <1 | 39* | <1 | 16 | 45 | 430 | 1.41 | 220 - 850 |
| Ca, percent | 46:46 | .08526 | <1 | 30 | 31* | <1 | 39 | 2.0 | 1.96 | .52 - 7.7 |
| Cd, ppm | 44:44 | .05292 | <1 | 42* | 10 | 8 | 41 | .82 | 1.70 | .28 - 2.4 |
| Co, ppm | 44:44 | .02892 | 13 | <1 | 60* | 9 | 17 | 4.5 | 1.48 | 2.1 - 9.8 |
| Cr[1], ppm | 46:46 | .06216 | 10* | 16 | <1 | <1 | 74 | 26 | 1.78 | 8.2 - 82 |
| Cu, ppm | 46:46 | .14321 | <1 | <1 | 30* | <1 | 70 | 47 | 2.39 | 8.2 - 270 |
| F[1], ppm[2] | 40:40 | .04790 | 19* | 7 | <1 | 22 | 52 | 49 | 1.66 | 18 - 130 |
| Fe, percent | 46:46 | .02665 | <1 | 2 | 43* | 19 | 36 | 1.2 | 1.46 | .57 - 2.5 |
| Ga, ppm | 39:46 | .01469 | <1 | <1 | 31 | 31* | 38 | 11 | 1.32 | 6.3 - 19 |
| Hg[1], ppm[2] | 46:46 | .05043 | 31* | <1 | 15 | <1 | 54 | .015 | 1.68 | .0053 - .042 |
| K, percent | 46:46 | .04543 | <1 | <1 | 58* | 4 | 38 | 1.5 | 1.63 | .56 - 4.0 |
| Li, ppm | 46:46 | .03481 | <1 | <1 | 66* | 9 | 25 | 7.8 | 1.54 | 3.3 - 18 |
| Mg, ppm | 46:46 | .04553 | <1 | <1 | 59* | <1 | 41 | 6,800 | 1.63 | 2,500 - 18,000 |
| Mn, ppm | 46:46 | .07258 | <1 | 15* | 19 | 4 | 62 | 480 | 1.86 | 140 - 1,700 |
| Mo, ppm | 46:46 | .05107 | 19 | 19* | 11 | <1 | 51 | 10 | 1.68 | 3.5 - 28 |
| Na[1], ppm | 46:46 | .03315 | 30* | <1 | 3 | 26 | 40 | 510 | 1.52 | 220 - 1,200 |
| Ni, ppm | 42:46 | .03819 | <1 | 21 | 32* | <1 | 47 | 14 | 1.57 | 5.7 - 34 |
| P, ppm | 46:46 | .03188 | 6 | <1 | 25 | 1 | 68 | 5,400 | 1.51 | 2,400 - 12,000 |
| Pb[1], ppm | 46:46 | .01403 | 39* | 2 | <1 | <1 | 59 | 26 | 1.31 | 15 - 45 |
| Rb, ppm | 45:45 | .03025 | 2 | <1 | 37* | 1 | 60 | 19 | 1.49 | 8.5 - 42 |
| S, total[2], ppm | 43:43 | .00771 | <1 | 32* | <1 | 14 | 54 | 520 | 1.22 | 350 - 780 |
| Se[2], ppm | 46:46 | .06619 | <1 | 28 | 26* | <1 | 46 | .20 | 1.81 | .061 - .65 |
| Si, percent | 46:46 | .00221 | <1 | <1 | 61* | <1 | 39 | 33 | 1.11 | 27 - 41 |
| Sr, ppm | 46:46 | .02934 | <1 | <1 | 54* | <1 | 46 | 150 | 1.48 | 68 - 330 |
| Ti, ppm | 46:46 | .02480 | <1 | 11 | 30* | 19 | 41 | 1,600 | 1.44 | 770 - 3,300 |
| U, ppm | 43:46 | .05762 | 6 | <1 | 30* | 18 | 45 | .82 | 1.74 | .27 - 2.5 |
| V, ppm | 46:46 | .06242 | <1 | 4 | 44* | 12 | 39 | 44 | 1.78 | 14 - 140 |
| Zn[1], ppm | 46:46 | .08840 | 15* | <1 | 22 | <1 | 63 | 350 | 1.98 | 89 - 1,400 |
| Zr[1], ppm | 46:46 | .03871 | 9* | 8 | <1 | 22 | 61 | 140 | 1.57 | 57 - 350 |

[1] Because of the significant regional effect, the summary data given for these elements are slightly biased when applied to specific parts of the basin. They are unbiased if applied to the entire basin.

[2] Determined on dry weight.

scale includes variation due to laboratory procedures (analytical error) as well as variation over short ranges.

The component over the range 0.1-1 km is clearly very important and parallels the situation found in the chemistry of surface soils in the basin (table 5). Sampling requirements to map the chemistry of grama grass in the basin will, thus, be similar to those given on p. 32-34.

The general lack of important regional variation (except as noted above) indicates that the data of this study may be used to establish, at least provisionally, some limits as to the probable elemental concentrations in grama grass in the Powder River Basin. The geometric means in table 4 are estimates of the most probable concentrations for grass in the basin, and the expected 95 percent range (computed as outlined on the inside of the cover) is that range expected in 95 percent of a suite of randomly collected samples from the basin, if collected, prepared, and analyzed in the same fashion as the samples used here. This range has been used as a baseline by Tidball, Erdman, and Ebens (1974). The expected 95 percent ranges in table 4 may also be so used, with the exception of those ranges for the eight elements exhibiting significant regional variation. For these eight elements, the expected 95 percent range will tend to be too wide for any given subarea of the basin.

The following tabulation of geometric means for each locality gives some idea of the differences to be expected for these eight elements from place to place in the basin.

| | Locality (fig. 3) | | | |
|---|---|---|---|---|
| Element (ppm) | 1 | 2 | 3 | 4 |
| Arsenic | 0.20 | 0.48 | 0.62 | 0.83 |
| Chromium | 16 | 26 | 31 | 30 |
| Fluorine | 32 | 49 | 45 | 67 |
| Mercury | .017 | .011 | .013 | .022 |
| Sodium | 500 | 400 | 500 | 690 |
| Lead | 32 | 22 | 24 | 30 |
| Zinc | 210 | 360 | 450 | 370 |
| Zirconium | 100 | 160 | 130 | 170 |

The expected 95 percent ranges in table 4 have not been corrected for analytical error and, as a consequence, are best used in the assessment of data analyzed by the same analytical methods as were used with the data here. However, the analytical error present in the grass data (table 4) may be estimated from the laboratory error ($S_E^2$) in table 2, inasmuch as similar methods were used in the two studies. The geometric error (GE) for a given entry in table 4, then, may be computed as the antilog of the square root of the laboratory error in table 2.

All the analytical data were transformed to logarithms for the statistical analysis, because of a tendency for such transformation to "normalize" the observed frequency distributions of the data. The data for gallium, nickel, and uranium were censored (the concentrations in a few samples were below the limit of detection), and, in order to perform the analysis of variance, small arbitrary concentrations approximately equal to 0.7 of the limit of detection were assigned to such samples. The geometric mean for these elements, however, was computed using techniques described by Miesch (1976) for censored data.

SAMPLING REQUIREMENTS FOR MAPPING SOIL GEOCHEMISTRY
IN THE POWDER RIVER BASIN, MONTANA-WYOMING
by Ronald R. Tidball

## Introduction

Preliminary results of a geochemical reconnaissance of soils in the Powder River Basin based on semiquantitative spectrographic analysis were given in Tidball, Erdman, and Ebens (1974). The purpose of this report is to present the final results of the reconnaissance study and to discuss constraints on sampling directed to making regional geochemical maps of soil in the basin. Such maps will in general be expensive, because of the large number of samples that are necessary to overcome the comparatively large local variation. This supports a similar conclusion reached by Keith, Anderson, and Connor (1974). Revised estimates of geochemical baselines for soils are based on more complete chemical analyses than were available at the time of the first report.

## Components of variance

Estimates of components of variance are given in table 5 as percentages of the total variance. These estimates were derived from a nested analysis of variance sampling design (Tidball, Erdman, and Ebens, 1974, p. 9-12) in which the geochemical variability of soil was examined over five geographic ranges, 0-0.01 km, 0.01-0.1 km, 0.1-1 km, 1-10 km, and greater than 10 km. Significance tests at the 0.05 probability level show that the most important components are associated with distances from 0.1-1 km. For the most part a significant component at this level in the A-horizon is paralleled by significant components in the B- or C-horizons as well. In this work, the A-horizon refers to the 0-2 cm depth of the mineral soil with most of the plant debris removed; B-horizon is used either in the conventional sense or refers to a sampling depth of 30-40 cm where the horizon is absent; C-horizon is used either in the conventional sense or refers to soil material at a depth of 110-120 cm.

Significant regional components were found for potassium in all soil horizons, and in various soil horizons for boron, organic carbon, and lithium. Fluorine and sodium in soil B-horizons have borderline significance, that is, they are significant at a probability level of 0.1. Overall, only 10 of 105 entries in table 5 exhibit a regional component equal to or greater than 20 percent of total observable variance. Thus, for the most part there is little regional geochemical variation in soils of the basin. More than 50 percent of the total variance for most elements is associated with distances of 1 km or less. This accords with a great deal of previous experience demonstrating that a very important part of the geochemical variance of soils generally occurs at local scales.

The Powder River Basin is large--about 50,000 $km^2$--and attempts to map geochemical properties of its soil must balance cost, generally expressed in numbers of laboratory analyses, against information, expressed as the percent of mappable variance (table 5). Maps may be constructed by

Table 5.--Variance analysis of soil geochemistry in the Powder River Basin, Montana-Wyoming

[Total variance computed on logarithms of data, except as noted; $n_r$, number of randomly selected samples required to obtain stable mean in an area 100 m on a side; *, component significantly different from zero; estimate based on analyses of 64 samples]

| Constituent | Soil Horizon | Total Variance | Percentage of total variance | | | | | | $n_r$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | >10 km (Regional) | 1-10 km | 0.1-1 km | 0.01-0.1 km | 0-0.01 km | Analytical error | |
| Al--------- | A | 0.0091 | 2.2 | 15.3 | 36.4* | 24.0* | 12.4 | 9.7 | 5 |
| | B | .0075 | 18.6 | 0 | 61.7* | 0 | 7.9 | 11.8 | 3 |
| | C | .0116 | 0 | 29.7 | 37.5* | 7.5 | 17.7 | 7.6 | 4 |
| B---------- | A | .0381 | 17.2 | 0 | 49.7* | 0 | 5.3 | 27.8 | 4 |
| | B | .0433 | 19.4 | 6.7 | 30.2* | 0 | 19.3 | 24.4 | 4 |
| | C | .0468 | 44.0* | 0 | 23.3* | 2.5 | 7.6 | 22.6 | 4 |
| Ba--------- | A | .0116 | 0 | 10.2 | 8.4 | 0 | 34.8 | 46.6 | 15 |
| | B | .0116 | 0 | 3.0 | 19.8 | 4.0 | 26.7 | 46.5 | 12 |
| | C | .0214 | 0 | 48.7* | 2.0 | 0 | 24.1 | 25.2 | 5 |
| C, total--- | A | .0706 | 1.7 | .7 | 25.9* | 0 | 61.8 | 9.9 | 9 |
| | B | .0629 | 12.0 | 0 | 26.4 | 10.5 | 40.0 | 11.1 | 7 |
| | C | .1152 | 0 | 41.7* | 15.6 | 9.7 | 26.9 | 6.1 | 4 |
| C, organic- | A | .0927 | 7.5 | 2.5 | 18.4* | 0 | 54.5 | 17.1 | 9 |
| | B | .0600 | 13.8* | 0 | 19.8 | 32.6* | 7.3 | 26.5 | 8 |
| | C | .1039 | 6.0 | 5.0 | 3.3 | 3.4 | 67.1 | 15.2 | 19 |
| C, carbonate | A | .6824 | 9.5 | 30.7 | 23.8* | 6.5 | 19.7 | 9.8 | 4 |
| | B | .7295 | 6.5 | 8.2 | 34.6* | 16.5 | 25.0 | 9.2 | 5 |
| | C | .6794 | 0 | 37.7 | 22.2* | 6.5 | 23.8 | 9.8 | 4 |
| Ca-------- | A | .1974 | 1.0 | 44.6* | 17.9* | 8.2 | 0 | 28.3 | 4 |
| | B | .2504 | 0 | 28.8 | 20.6 | 7.5 | 14.0 | 29.1 | 5 |
| | C | .2932 | 0 | 0 | 72.0* | 13.0* | 0 | 15.0 | 3 |
| Co--------- | A | .0579 | 0 | 42.0 | 22.4* | 11.6 | 8.1 | 15.9 | 4 |
| | B | .0616 | 9.2 | 14.5 | 43.6* | 0 | 17.8 | 14.9 | 4 |
| | C | .0511 | 0 | 22.8 | 38.8* | 7.7 | 12.7 | 18.0 | 4 |
| Cr--------- | A | .0571 | 0 | 27.4 | 46.1* | 0.1 | 10.7 | 15.7 | 3 |
| | B | .0371 | 0 | 16.3 | 35.1* | 19.5* | 5.0 | 24.1 | 5 |
| | C | .0629 | 0 | 14.7 | 58.0* | 10.7* | 2.4 | 14.2 | 3 |
| Cu--------- | A | .1178 | 2.0 | 34.7 | 35.1* | 15.6* | 2.5 | 10.1 | 3 |
| | B | .0899 | 0 | 20.9 | 50.8* | 9.9* | 5.2 | 13.2 | 3 |
| | C | .2055 | 0 | 11.4 | 73.4* | 3.3 | 6.1 | 5.8 | 3 |
| F---------- | A | .0287 | 21.7 | 0 | 24.9* | 4.1 | 24.5 | 24.8 | 5 |
| | B | .0373 | 15.9 | 0 | 62.2* | 7.5* | 0 | 14.4 | 3 |
| | C | .0290 | 0 | 12.2 | 66.4* | 2.1 | 0 | 19.3 | 3 |
| Fe--------- | A | .0309 | 8.8 | 26.0 | 43.8* | 8.9* | 5.9 | 6.6 | 3 |
| | B | .0237 | 1.3 | 7.8 | 63.8* | 7.2 | 11.4 | 8.5 | 3 |
| | C | .0499 | 0 | 37.6 | 40.1* | 7.1 | 11.1 | 4.1 | 3 |

Table 5.--Variance analysis of soil geochemistry in the Powder River Basin, Montana-Wyoming (cont.)

| Constituent | Soil Horizon | Total Variance | Percentage of total variance >10 km (Regional) | 1-10 km | 0.1-1 km | 0.01-0.1 km | 0-0.01 km | Analytical error | $n_r$ |
|---|---|---|---|---|---|---|---|---|---|
| Ga-------- | A | .0185 | 0 | 0 | 47.8* | 16.6 | 0 | 35.6 | 5 |
| | B | .0160 | 5.5 | 0 | 23.1 | 5.3 | 11.1 | 55.0 | 9 |
| | C | .0310 | 0 | 14.8 | 28.6* | 3.8 | 24.4 | 28.4 | 6 |
| Hg-------- | A | .0360 | 5.8 | 0 | 20.7 | 20.2 | 24.1 | 29.2 | 9 |
| | B | .0648 | 0 | 41.0* | 13.2 | 2.6 | 26.9 | 16.3 | 5 |
| | C | .0648 | 2.1 | 12.3 | 19.1 | 42.2* | 8.0 | 16.3 | 8 |
| K--------- | A | .0030 | 43.5* | 0 | 25.3* | 19.8* | 4.6 | 6.8 | 4 |
| | B | .0033 | 40.5* | 1.4 | 8.3 | 14.9 | 28.6 | 6.3 | 5 |
| | C | .0028 | 32.5* | 4.0 | 0 | 0 | 56.0 | 7.5 | 8 |
| La-------- | A | .0877 | 0 | 1.0 | 10.9 | 23.1 | 10.8 | 54.2 | 24 |
| | B | .0749 | 2.0 | 0 | 0 | 12.5 | 22.0 | 63.5 | >60 |
| | C | .1938 | 0 | 40.9* | 0 | 25.7* | 8.9 | 24.5 | 6 |
| Li-------- | A | 84.61[1/] | 38.0* | 0 | 22.9* | 7.0 | 28.8 | 3.3 | 4 |
| | B | 100.8[1/] | 12.6 | 0 | 69.6* | 7.9* | 7.1 | 2.8 | 3 |
| | C | 112.1[1/] | 0 | 0 | 72.7* | 15.5* | 9.3 | 2.5 | 3 |
| Mg-------- | A | .0744 | 9.3 | 18.7 | 50.6* | 10.7* | 10.4 | .3 | 6 |
| | B | .0555 | 3.1 | 0 | 75.0* | 5.2 | 16.3 | .4 | 3 |
| | C | .2152 | 0 | 28.2 | 62.2* | 4.0* | 5.4 | .2 | 3 |
| Mn-------- | A | .0849 | 0 | 45.2 | 34.8* | 3.0 | 5.7 | 11.3 | 3 |
| | B | .0860 | 0 | 56.7* | 15.4* | 4.9 | 11.9 | 11.1 | 3 |
| | C | .1196 | 0 | 56.2* | 2.0 | 0 | 33.8 | 8.0 | 4 |
| Na-------- | A | .0237 | 28.8 | 19.1 | 26.4* | 9.0* | 13.2 | 3.5 | 3 |
| | B | .0377 | 44.8 | 0 | 33.1* | 9.8* | 10.1 | 2.2 | 3 |
| | C | .0463 | 33.9 | 12.2 | 27.1* | 0.4 | 24.6 | 1.8 | 3 |
| Ni-------- | A | .0668 | 0 | 44.2 | 21.2* | 18.0* | 0 | 16.6 | 4 |
| | B | .0631 | 0 | 24.3 | 25.7* | 0 | 21.7 | 28.3 | 5 |
| | C | .0973 | 0 | 28.7 | 36.2* | 0 | 16.7 | 18.4 | 4 |
| Pb-------- | A | .0199 | 0 | 22.6 | 16.3 | 0 | 38.1 | 23.0 | 7 |
| | B | .0135 | 0 | 20.1 | 0 | 14.4 | 31.5 | 34.0 | 14 |
| | C | .0113 | 0 | 31.4* | 3.0 | 0 | 25.2 | 40.4 | 8 |
| Rb-------- | A | 186.0[1/] | 9.7 | 0 | 27.1 | 23.8* | 0 | 39.4 | 7 |
| | B | 268.9[1/] | 6.7 | 3.9 | 0 | 0 | 24.0 | 65.4 | 25 |
| | C | 227.0[1/] | 0 | 19.3 | 6.7 | 0 | 0 | 74.0 | 10 |
| Sc--------- | A | .0354 | 5.5 | 7.9 | 34.4* | 8.5 | 15.5 | 28.2 | 5 |
| | B | .0333 | 10.6 | 5.6 | 23.8 | 1.4 | 28.6 | 30.0 | 6 |
| | C | .0607 | 0 | 15.4 | 45.6* | 0 | 22.5 | 16.5 | 4 |

Table 5.--Variance analysis of soil geochemistry in the Powder River Basin, Montana-Wyoming (cont.)

| Constituent | Soil Horizon | Total Variance | Percentage of total variance | | | | | | $n_r$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | >10 km (Regional) | 1-10 km | 0.1-1 km | 0.01-0.1 km | 0-0.01 km | Analytical error | |
| Se-------- | A | .1153 | 0 | 11.1 | 34.5* | 0 | 8.5 | 45.9 | 6 |
| | B | .1134 | 0 | 15.9 | 9.3 | 0 | 28.2 | 46.6 | 11 |
| | C | .1396 | 8.8 | 3.3 | 11.2 | 12.0 | 26.8 | 37.9 | 12 |
| Si-------- | A | 13.01 1/ | 6.6 | 17.5 | 38.6* | 4.5 | 0 | 32.8 | 4 |
| | B | 12.63 1/ | 7.4 | 6.0 | 32.1* | 10.6 | 0 | 43.9 | 6 |
| | C | 27.46 1/ | 2.7 | 0 | 76.9* | 1.2 | 0 | 19.2 | 3 |
| Sr-------- | A | .0284 | 0 | 4.5 | 28.0 | 22.6* | 5.8 | 39.1 | 8 |
| | B | .0529 | 0 | 14.1 | 30.3* | 3.2 | 31.4 | 21.0 | 6 |
| | C | .0739 | 0 | 0 | 58.9* | 12.7 | 13.4 | 15.0 | 4 |
| Ti-------- | A | .0051 1/ | 16.7 | 12.4 | 52.8* | 0 | 4.7 | 13.4 | 3 |
| | B | .0046 1/ | 0.4 | 21.9 | 36.9* | 20.4* | 5.5 | 14.9 | 4 |
| | C | .0080 1/ | 0 | 28.4 | 40.7* | 10.5* | 11.9 | 8.5 | 7 |
| eU 2/ ------ | A | 44.28 1/ | 0 | 0 | 25.6 | 22.6 | 0 | 51.8 | 10 |
| | B | .0404 | 6.8 | 0 | 0 | 0 | 7.9 | 85.3 | 36 |
| | C | 37.31 1/ | .2 | 2.1 | 13.2 | 0 | 0 | 84.5 | 18 |
| V--------- | A | .0439 | 0 | 19.9 | 42.3* | 11.8 | 5.2 | 20.8 | 4 |
| | B | .0284 | 10.1 | 14.1 | 28.1* | 0 | 15.4 | 32.3 | 5 |
| | C | .0638 | 0 | 19.9 | 41.0* | 14.2* | 10.6 | 14.3 | 4 |
| Y--------- | A | .0196 | 0 | 2.2 | 23.2 | 4.2 | 0 | 70.4 | 11 |
| | B | .0215 | 0 | 11.6 | 0 | 0 | 6.3 | 82.1 | 24 |
| | C | .0226 | 0 | 16.5 | 18.5 | 0 | 0 | 65.0 | 7 |
| Yb-------- | A | .0214 | 1.2 | 7.3 | 15.9 | 0 | 0 | 75.6 | 11 |
| | B | .0188 | 0 | 22.7 | 0 | 17.6 | 0 | 59.7 | 12 |
| | C | .0211 | 0 | 15.4 | 22.9* | 0 | 0 | 61.7 | 7 |
| Zn-------- | A | 663.4 1/ | 19.6 | 23.6 | 33.3* | 11.6* | 10.4 | 1.5 | 6 |
| | B | 552.5 1/ | 13.3 | 14.9 | 53.9* | 0 | 16.1 | 1.8 | 3 |
| | C | 1026 1/ | 0 | 45.3 | 38.4* | 0 | 15.3 | 1.0 | 3 |
| Zr-------- | A | .0541 | 0 | 32.5 | 8.4 | 11.7 | 13.8 | 33.6 | 6 |
| | B | .0382 | 6.2 | 0 | 0 | 15.6 | 30.6 | 47.6 | 42 |
| | C | .0571 | 1.5 | 0 | 27.3* | 0 | 39.4 | 31.8 | 9 |
| pH | A | .0214 1/ | 0 | 28.5 | 25.1* | 0 | 0.8 | 45.6 | 5 |
| | B | .1621 1/ | 0 | 0 | 31.6 | 14.3 | 0 | 54.1 | 8 |
| | C | .1708 1/ | 0 | 11.5 | 0 | 17.8 | 13.6 | 57.1 | 24 |

1/ Variance computed on nontransformed data.

2/ Equivalent uranium.

subdividing the basin into cells and drawing contours on the cell means. There are 450 cells 10 km on a side in the basin, but very little mappable variation occurs at this level of the design. Mapping that is based on $1\text{-km}^2$ cells will permit considerably more variation to be mapped but at a cost of a hundred-fold increase in the number of cells. In terms of percent mappable variance, cells 0.1 km on a side would probably be most reasonable but only small areas of the basin could be mapped without generating a huge analytical need.

## A sampling design

The following details of constructing a sampling plan for mapping one or more parts of the Powder River Basin are predicated on the use of cells 100 m (0.1 km) on a side. This cell size is arbitrarily selected as one that permits a reasonable amount of variation to be mapped. Fifty-five of the 105 entries in table 5 exhibit half or more of their total observed variation at scales larger than 0.1 km. Of course, such a cell size will result in an exceedingly expensive study if the area of investigation extends many kilometres in any direction.

Given this cell size, the data in table 5 are used to estimate the number of samples required from each cell in order to obtain a reliable or stable cell mean. The calculations for this exercise are based on methods developed by Miesch (1976) that use the variance ratio, v, which is defined as:

$$v = \frac{N_v}{D_v} , \qquad (1)$$

where $N_v$ is the percentage of the total variance occurring between cells and $D_v$ is the percentage of the total variance occurring within cells. The minimum number of samples to be collected at random from within each cell is denoted as $n_r$ and is such that the value of the conventional F-statistic exceeds the critical value for 1 and $2n_r$-2 degrees of freedom at the 95 percent confidence level in the following relation:

$$F = 1 + n_r v \quad . \qquad (2)$$

The numbers of samples per cell ($n_r$), given in table 5, differ from one entry to another because of the differing magnitude of observed variation. Which constituent then should be used to determine $n_r$ for a new sampling design?

If all constituents are to be mapped, then the constituent with the largest $n_r$ must be used. This, of course, would result in over-sampling of all the constituents except the most locally variable one, and it would be justified only if there is a vital interest in that one constituent. The following table shows the number of chemical constituents that could be mapped for a given $n_r$ using A-horizon material:

| $n_r$ | number of mappable constituents | relative change |
|---|---|---|
| 3 | 7 | - |
| 4 | 16 | 9 |
| 5 | 21 | 5 |
| 6 | 24 | 3 |
| 7 | 26 | 2 |
| 8 | 27 | 1 |
| 9 | 30 | 3 |
| 10 | 31 | 1 |
| 15 | 34 | 3 |

The relative change (the increase in the number of constituents per unit increase in $n_r$) shows a point of diminishing return at about $n_r$ equal to 6. The sampling burden of a design in which $n_r$ is set equal to 6 is 600 samples per square kilometre; the analytical load would be the same if each sample is to be analyzed once and proportionately higher if some or all samples are analyzed more than once. The number of analyses can easily be reduced by compositing the 6 samples and analyzing the composite, thus reducing the number of analyses to 100 per square kilometre. A value of 6, however, appears to be insufficient to produce stable cell means for Hg ($n_r$=9) and Pb ($n_r$=7), constituents of exceptional interest. If compositing within cells is done, $n_r$ could easily be set high enough to include these two elements.

The results reported here as to optimum cell size are similar to those obtained by Keith, Anderson, and Connor (1974, p. 26), where a minimum cell size for mapping the geochemistry of surface soil in the basin was judged to be 0.3 km on a side. Because the present work suggests a range somewhere between 0.1 and 1 km, the two studies together suggest an optimum size somewhere between 0.3 and 1 km on a side. If cells 0.3 km on a side are chosen, the number of composite samples per square kilometre is reduced to about 11. The number of samples to be collected for each composite may still be judged from table 5.

The values of $n_r$ for any specific constituent are similar regardless of which soil horizon is being considered. This suggests that geochemical variation for most elements in soils could be effectively evaluated using any soil horizon. There are some exceptions to this generalization: for example, barium is more locally variable in the A-horizon than in the C-horizon, and lanthanum and rubidium are less locally variable in the A-horizon than in the B-horizon.

## Geochemical baselines

Few constituents listed in table 5 have statistically significant or important variation at scales greater than 10 km. Constituents lacking such variation are thus expected to exhibit about the same mean concentration in any part of the basin, which encompasses an area larger than about 100 $km^2$. Data on such constituents from this study may be used to characterize soil geochemistry over the entire basin, as was done in Tidball, Erdman, and Ebens (1974). That report listed a set of geochemical baselines defined as the central 95 percent range of the frequency distribution of constituent concentrations in a specified sampling medium. Table 6 is a tabulation of revised baselines for soils, some of which are based on newer analyses.

Only soil constituents lacking significant regional variation are listed in table 6. Those constituents exhibiting regional variation should not be described by a single grand mean (and expected range), because there are important differences from one area to another. The expected range based on such data would tend to overestimate the range for any given locality. Data from a given area or locality would provide more proper representation. Boron in the C-horizon, organic carbon in the B-horizon, potassium in the A-, B-, and C-horizon, and lithium in the A-horizon all exhibit significant regional variation at the 0.05 probability level.

In addition, an analytical variance equal to more than 50 percent of the total observed variance is considered to be excessive. More precise analytical methods should be used to establish baselines for gallium in B-horizon; lanthanum in the A- and B-horizon; rubidium in the B- and C-horizon; equivalent uranium, yttrium, and ytterbium in all horizons; and pH in B- and C-horizons.

## Chemical analyses

The <2-mm size fraction of the mineral soil was ground to -100 mesh in a ceramic mill and analyzed for total composition in laboratories of the U.S. Geological Survey by the following methods. Semi-quantitative emission spectrographic analysis by Nancy Conklin and Leon Bradley was used for boron, barium, chromium, cobalt, copper, gallium, lanthanum, lead, nickel, scandium, strontium, vanadium, yttrium, ytterbium, and zirconium. Atomic absorption was used for the following elements by the named analysts: lithium and zinc were analyzed by G. T. Burrow; magnesium, rubidium, and sodium were analyzed by Violet Merritt; and mercury was analyzed by J. A. Thomas. Total carbon was determined by V. E. Shaw using a combustion method; carbonate carbon was determined by T. L. Yager and Charles Freeman by a gasometric method; and organic carbon was determined by difference. Natural radioactivity was determined by Lorraine Lee using a beta-gamma counter; the results are expressed as equivalent uranium. X-ray fluorescence was used by J. S. Wahlberg and

Table 6.--Statistical summary of element concentrations in soils of the Powder River Basin, Montana-Wyoming.

[Mean values given in percent except where ppm (parts per million) is indicated; mean is geometric mean except as noted; deviation is geometric deviation except as noted; estimates based on analyses of 64 samples]

| Constituent | Soil Horizon | Mean | Deviation | Expected 95% Range (baseline) | Constituent | Soil Horizon | Mean | Deviation | Expected 95% Range (baseline) | Constituent | Soil Horizon | Mean | Deviation | Expected 95% Range (baseline) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Al------------ | A | 5.1 | 1.25 | 3.3-7.9 | F------------ | A | .038 | 1.56 | .016-.092 | Rb, ppm 1/ --- | A | 85 | 13.6 | 58-110 |
| | B | 5.6 | 1.24 | 3.7-8.6 | | B | .042 | 1.51 | .018-.095 | Sc, ppm----- | A | 7.5 | 1.54 | 3.2-18 |
| | C | 5.5 | 1.28 | 3.3-9.1 | | C | .047 | 1.44 | .023-.097 | | B | 8.6 | 1.52 | 3.7-20 |
| B, ppm-------- | A | 30 | 1.57 | 12-74 | Fe----------- | A | 2.0 | 1.50 | .89-4.5 | | C | 8.5 | 1.76 | 2.7-26 |
| | B | 30 | 1.62 | 11-78 | | B | 2.2 | 1.43 | 1.1-4.5 | Se, ppm----- | A | .22 | 2.19 | .046-1.1 |
| Ba, ppm------- | A | 670 | 1.28 | 410-1,100 | | C | 2.2 | 1.67 | .79-6.2 | | B | .28 | 2.17 | .059-1.3 |
| | B | 660 | 1.28 | 400-1,100 | Ga, ppm------ | A | 13 | 1.37 | 6.9-24 | | C | .19 | 2.36 | .034-1.1 |
| | C | 630 | 1.40 | 320-1,200 | | C | 15 | 1.50 | 6.7-34 | Si 1/ -------- | A | 35 | 3.61 | 28-42 |
| C,total------- | A | 1.3 | 1.84 | .38-4.4 | Hg, ppm------ | A | .022 | 1.55 | .0091-.053 | | B | 34 | 3.55 | 27-41 |
| | B | .88 | 1.78 | .28-2.8 | | B | .022 | 1.78 | .0069-.070 | | C | 32 | 5.24 | 22-42 |
| | C | .87 | 2.18 | .18-4.2 | | C | .025 | 1.80 | .0079-.081 | Sr, ppm----- | A | 140 | 1.47 | 64-300 |
| C,organic----- | A | 1.1 | 2.01 | .27-4.5 | La, ppm------ | C | 43 | 1.67 | 15-120 | | B | 160 | 1.70 | 55-460 |
| | C | .33 | 2.10 | .075-1.5 | Li, ppm 1/ ---- | B | 27 | 10.0 | 6.9-47 | | C | 190 | 1.87 | 54-660 |
| C,carbonate--- | A | .033 | 11.0 | .00027-4.0 | | C | 27 | 10.6 | 5.8-48 | Ti 1/ -------- | A | .28 | .071 | .14-.42 |
| | B | .098 | 8.73 | .0013-7.5 | Mg----------- | A | .54 | 1.87 | .15-1.9 | | B | .29 | .068 | .15-.43 |
| | C | .30 | 5.42 | .010-8.8 | | B | .67 | 1.72 | .23-2.0 | | C | .28 | .089 | .10-.46 |
| Ca------------ | A | .56 | 2.78 | .072-4.3 | | C | .83 | 1.90 | .23-3.0 | V, ppm------ | A | 65 | 1.62 | 25-170 |
| | B | .87 | 3.17 | .087-8.7 | Mn----------- | A | .029 | 1.96 | .0076-.11 | | B | 78 | 1.47 | 36-170 |
| | C | 1.6 | 3.48 | .13-19 | | B | .027 | 1.96 | .0070-.10 | | C | 72 | 1.79 | 23-230 |
| Co, ppm------- | A | 6.9 | 1.74 | 2.3-21 | | C | .023 | 2.15 | .0050-.11 | Zn, ppm 1/ ---- | A | 65 | 25.8 | 13-120 |
| | B | 7.6 | 1.77 | 2.4-24 | Na----------- | A | .48 | 1.43 | .24-.98 | | B | 66 | 23.5 | 19-110 |
| | C | 7.3 | 1.68 | 2.6-21 | | B | .43 | 1.56 | .18-1.1 | | C | 66 | 32.0 | 2.0-130 |
| Cr, ppm------- | A | 43 | 1.73 | 14-130 | | C | .45 | 1.64 | .17-1.2 | Zr, ppm----- | A | 230 | 1.71 | 79-670 |
| | B | 46 | 1.56 | 19-110 | Ni, ppm------ | A | 15 | 1.81 | 4.6-49 | | B | 200 | 1.57 | 81-490 |
| | C | 46 | 1.78 | 14-150 | | B | 17 | 1.78 | 5.3-54 | | C | 160 | 1.73 | 53-480 |
| Cu, ppm------- | A | 15 | 2.20 | 3.1-73 | | C | 17 | 2.05 | 4.0-72 | pH 1/ -------- | A | 7.2 | .462 | 6.3-8.1 |
| | B | 17 | 2.00 | 4.3-68 | Pb, ppm------ | A | 19 | 1.38 | 9.9-36 | | | | | |
| | C | 17 | 2.84 | 2.1-140 | | B | 18 | 1.31 | 11-31 | | | | | |
| | | | | | | C | 17 | 1.28 | 10-28 | | | | | |

1/ Arithmetic mean and standard deviation given.

J. W. Baker to analyze for aluminum, calcium, iron, manganese, potassium, selenium, silicon, and titanium. Selective ion-electrode was used by Johnnie Gardner and Patricia Guest to analyze for fluorine, and pH was determined by J. A. Erdman.

A VARIANCE ANALYSIS OF THE ELEMENT COMPOSITION OF SWEETCLOVER AND ASSOCIATED SPOIL MATERIALS FROM SELECTED COAL MINES IN THE NORTHERN GREAT PLAINS

by James A. Erdman and Richard J. Ebens

Surface mining of coal deposits in the Northern Great Plains is destined to assume an important role in the traditionally agricultural economy of that region. Future plans for much of the mined land, however, are to rehabilitate it for eventual "wheat and meat" production. In part, because of our former experience with side effects of a mining operation on cattle in Missouri (Ebens and others, 1973), we set out to examine potential geochemical changes in sweetclover (*Melilotus officinalis* or *M. alba*) that may reflect the effects of surface mining in this major segment of America's grainbelt. Previous studies (Sandoval and others, 1973; Wali and Freeman, 1973) have shown that such mining can indeed alter the chemical character of the plant substrate to a remarkable degree. These same studies also demonstrated important geochemical differences in spoil from mine to mine.

The primary objective in our study is to investigate the trace element differences, if any, in sweetclover found growing on spoil banks of different strip mines in the Northern Great Plains. Secondarily we wished to assess in a gross way the potential for element uptake by sweetclover from this modified "soil". The study is based on a collection of sweetclover and the associated spoil bank substrate taken from 10 randomly selected sites (in which sweetclover could be found) at each of eight surface mines scattered throughout the Northern Great Plains from Wyoming to eastern Montana, western North Dakota, and southern Saskatchewan (fig. 5).

## Mined areas do differ

Table 7 lists the summary statistics for those elements for which we currently have data. More than half of the variation in element concentrations in dry weight of sweetclover for five of the 13 elements listed occurs between mines, and all 14 properties exhibit statistically significant differences at the 95-percent confidence level. There is a strong hint in these data that the chemistry of sweetclover is reflecting in a fairly strong way its local (or mine-area) environment.

Product moment correlation coefficients were calculated for the concentrations of nine elements in common between the spoil material and sweetclover. Taken as a group, significant positive correlations were found at the 95-percent confidence level only for sodium and sulfur, but only 10-15 percent of the variation of these two elements in sweetclover is accounted for by their differences in spoil material. Sodium concentrations of spoil material and sweetclover are high at the Kincaid mine and sulfur concentrations in the two materials are low at the Savage mine (table 7). When correlations were calculated on a mine by mine basis we obtained the following significantly positive correlations

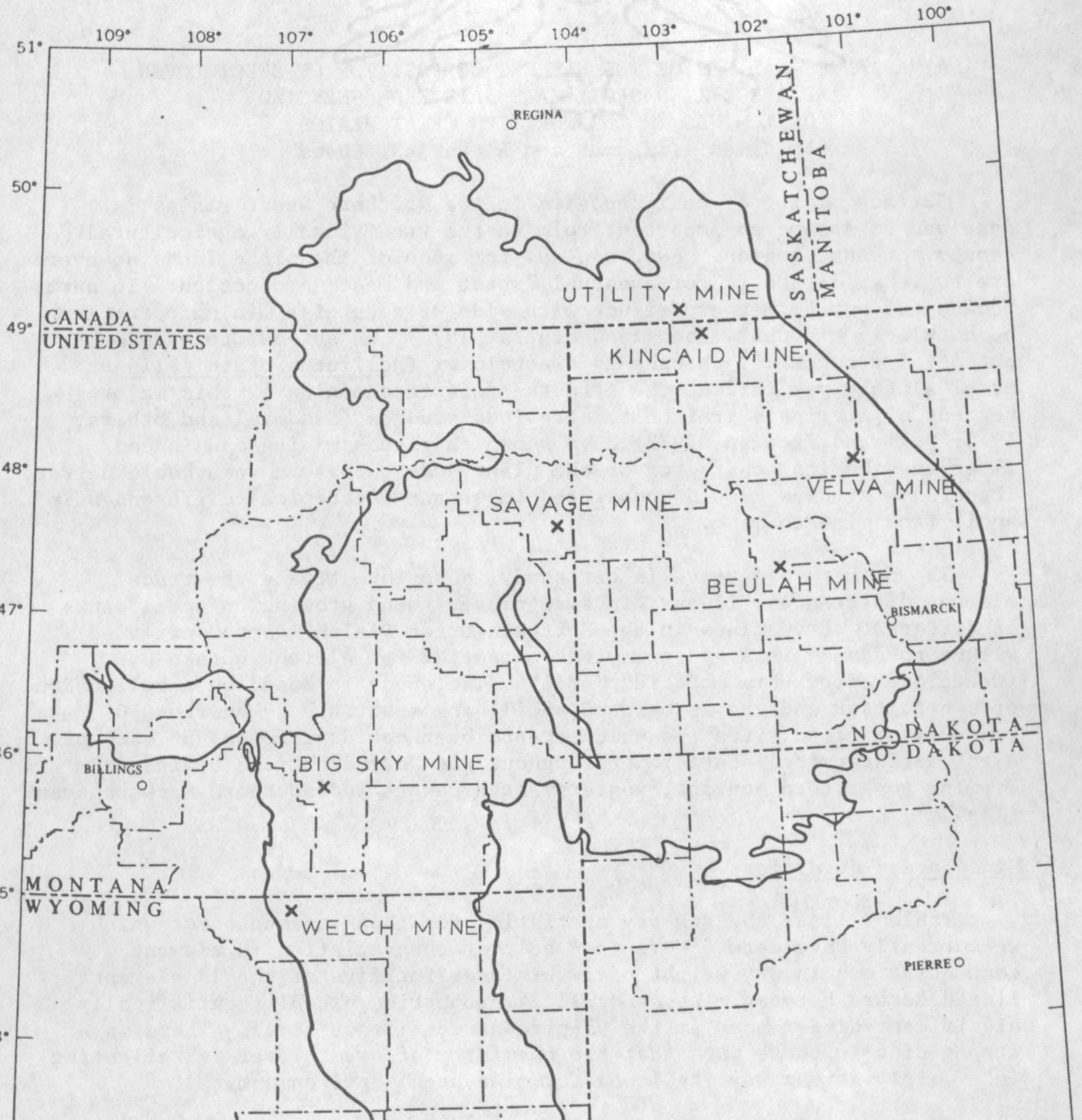



Figure 5. The Northern Great Plains Coal Province, showing locations of the eight surface mines sampled in this study. Map adapted from U.S. Geological Survey (1974a) and Whitaker and Pearson (1972).

(γ >0.7): potassium at the Beulah mine, sulfur at the Kincaid mine, calcium at the Utility mine, and lithium at the Welch mine. Because previous work (Erdman, Shacklette, and Keith, 1976) suggests that in normal environments element concentrations in plants generally correlate very poorly with the total element concentrations in the underlying substrate, the significant correlations described above suggest that some of the spoil materials may constitute an unusual geochemical environment. In addition, other effects such as climate or soil pH may also be involved.

Are comparisons between mines valid when we sampled two species of sweetclover, particularly since recent studies revealed strong differences in the element concentrations of other closely-related species (Shacklette, Erdman, and Keith, 1970; Tidball, Erdman, and Ebens, 1974)? We attempted to answer this question by collecting a number of species pairs when we sampled the mines. Twelve sites were selected, three at fields along our travel route between mines, and nine at sites on spoil piles. The paired plants grew no more than 1 m apart. Results of a two-way analysis of variance showed that only the differences in concentrations of selenium and sulfur were statistically significant at the 0.05 probability level between white and yellow sweetclover. These differences are shown as follows:

| | Selenium | | Sulfur | |
|---|---|---|---|---|
| | GM | GD | GM | GD |
| White sweetclover | 0.48 | 3.12 | 0.34 | 1.37 |
| Yellow sweetclover | .30 | 2.50 | .26 | 1.48 |

The geometric mean (GM) is given as parts per million in dry material. Because these differences are well within the range of means in table 7, they should not materially alter interpretations based on that table.

Summary data on substrate (spoil material) geochemistry in the eight mined areas studied are also listed in table 7. Although strong geochemical differences are apparent between mines, they do not constitute an objective comparison because of the sampling plan. Sites were selected on the basis of whether or not sweetclover could be sampled. Those parts of the mined areas that supported no sweetclover were not included for substrate sampling. For the most part, sweetclover seemed to grow only in substrate of a compositional or structural nature that was likely to hold ground moisture better than adjacent sites.

In spite of this, geochemical differences in spoil bank material are to be expected, and the geochemical summaries do suggest that such is the case. In particular, spoil material composed largely of glacial material should differ from that composed largely of lake deposits, wind-blown material, or bedrock.

Table 7.--Statistical analysis of element concentrations in sweetclover and associated spoil materials from selected coal mines, Northern Great Plains Coal Province

[GM, geometric mean; GD, geometric deviation. Tests using analysis of variance techniques indicated that differences in extreme mean concentrations of all elements (except fluorine and mercury in spoil materials) were significant at the 0.05 probability level. The highest and lowest means are indicated by **boldface** and *italic*, respectively.]

| Constituent | Analysis of logarithmic variance: Total $log_{10}$ variance | Percent of total variance: Between mines | Percent of total variance: Between samples within mines | Beulah mine GM | Beulah mine GD | Big Sky mine GM | Big Sky mine GD | Dave Johnston mine GM | Dave Johnston mine GD | Kincaid mine GM | Kincaid mine GD | Savage mine GM | Savage mine GD | Utility mine GM | Utility mine GD | Velva mine GM | Velva mine GD | Welch mine GM | Welch mine GD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Sweetclover[1] | | | | | | | | | | | | | | | |
| Ash, percent-- | .00650 | 62 | 38 | 6.1 | 1.09 | 6.7 | 1.11 | 7.2 | 1.09 | 7.5 | 1.11 | 5.4 | 1.13 | 5.0 | 1.07 | 7.1 | 1.20 | 7.4 | 1.13 |
| Ca, percent--- | .01687 | 52 | 48 | .88 | 1.31 | .87 | 1.24 | 1.2 | 1.21 | 1.3 | 1.12 | .87 | 1.25 | .79 | 1.22 | 1.4 | 1.30 | .81 | 1.14 |
| Cd, ppm------- | .22711 | 42 | 58 | .14 | 2.42 | .097 | 2.03 | .37 | 1.99 | .043 | 2.05 | .072 | 2.11 | .049 | 2.88 | .050 | 2.59 | .19 | 2.41 |
| Co, ppm------- | .17438 | 34 | 66 | .22 | 2.66 | .27 | 1.78 | .40 | 1.80 | .15 | 2.38 | .15 | 2.59 | .13 | 1.57 | .086 | 2.70 | .53 | 1.90 |
| F, ppm-------- | .02622 | 36 | 64 | 7.3 | 1.39 | 8.1 | 1.25 | 7.6 | 1.35 | 9.3 | 1.39 | 7.0 | 1.32 | 7.7 | 1.29 | 7.5 | 1.41 | 15 | 1.35 |
| Hg, ppm------- | .01768 | 33 | 67 | .011 | 1.25 | .010 | 1.00 | .0096 | 1.12 | .015 | 1.43 | .012 | 1.40 | .0093 | 1.16 | .010 | 1.00 | .015 | 1.53 |
| K, percent---- | .00920 | 55 | 45 | 1.2 | 1.11 | 1.9 | 1.12 | 1.8 | 1.28 | 1.6 | 1.15 | 1.3 | 1.20 | 1.2 | 1.11 | 1.4 | 1.15 | 1.6 | 1.09 |
| Li, ppm------- | .09099 | 63 | 37 | .84 | 1.41 | .42 | 1.37 | .88 | 1.45 | 1.6 | 1.38 | .47 | 1.25 | 1.2 | 1.69 | 1.4 | 1.64 | 2.0 | 1.90 |
| Na, percent--- | .23789 | 69 | 31 | .0029 | 1.62 | .0036 | 1.36 | .0029 | 1.74 | .0340 | 2.61 | .0018 | 1.42 | .0099 | 2.36 | .0028 | 2.09 | .0036 | 1.55 |
| P, percent---- | .01438 | 25 | 75 | .085 | 1.23 | .10 | 1.17 | .12 | 1.28 | .13 | 1.18 | .093 | 1.33 | .13 | 1.28 | .12 | 1.41 | .12 | 1.20 |
| S, percent---- | .02430 | 37 | 63 | .31 | 1.38 | .26 | 1.29 | .29 | 1.34 | .44 | 1.34 | .19 | 1.23 | .26 | 1.29 | .29 | 1.42 | .32 | 1.30 |
| Se, ppm------- | .20008 | 40 | 60 | .15 | 2.05 | .42 | 2.26 | .37 | 2.73 | .17 | 2.28 | 1.3 | 2.50 | .23 | 1.93 | .49 | 2.07 | .53 | 1.85 |
| Si, percent--- | .09204 | 54 | 46 | .081 | 1.76 | .10 | 1.23 | .097 | 1.51 | .14 | 1.80 | .064 | 1.39 | .065 | 1.46 | .10 | 1.95 | .34 | 1.58 |
| Zn, ppm------- | .03394 | 43 | 57 | 25 | 1.36 | 36 | 1.20 | 33 | 1.41 | 35 | 1.33 | 18 | 1.56 | 22 | 1.46 | 23 | 1.41 | 43 | 1.22 |
| | | | | Spoil materials | | | | | | | | | | | | | | | |
| Al, percent--- | 0.00570 | 28 | 72 | 7.6 | 1.08 | 5.9 | 1.12 | 6.5 | 1.15 | 6.7 | 1.21 | 6.0 | 1.13 | 5.7 | 1.19 | 6.2 | 1.09 | 7.4 | 1.24 |
| C[2], percent--- | .14789 | 14 | 86 | 1.7 | 2.45 | 4.2 | 1.98 | 1.3 | 3.64 | 4.3 | 2.09 | 2.9 | 1.37 | 3.5 | 1.80 | 2.1 | 1.70 | 2.4 | 2.96 |
| Ca, percent--- | .26104 | 88 | 12 | 1.6 | 1.51 | 2.8 | 1.32 | .45 | 1.53 | 3.2 | 1.35 | 6.4 | 1.26 | 3.3 | 2.06 | 3.1 | 1.12 | .25 | 1.68 |
| F, ppm-------- | .02633 | <1 | 100 | 760 | 1.29 | 830 | 1.40 | 670 | 1.39 | 820 | 1.45 | 810 | 1.29 | 680 | 1.60 | 710 | 1.75 | 740 | 1.35 |
| Fe, percent--- | .01337 | 35 | 65 | 3.2 | 1.31 | 2.2 | 1.18 | 1.9 | 1.33 | 2.8 | 1.20 | 2.4 | 1.22 | 2.1 | 1.16 | 2.3 | 1.07 | 2.1 | 1.35 |
| Hg, ppm------- | .05235 | 10 | 90 | .055 | 2.19 | .055 | 1.93 | .034 | 1.55 | .058 | 1.58 | .052 | 1.43 | .062 | 1.61 | .046 | 1.12 | .074 | 1.53 |
| K, percent---- | .00516 | 63 | 37 | 1.8 | 1.10 | 1.9 | 1.10 | 2.0 | 1.11 | 1.7 | 1.16 | 1.9 | 1.09 | 1.5 | 1.05 | 1.6 | 1.04 | 1.3 | 1.14 |
| Li, ppm------- | .00997 | 21 | 79 | 24 | 1.20 | 29 | 1.30 | 20 | 1.22 | 23 | 1.31 | 24 | 1.13 | 23 | 1.17 | 24 | 1.14 | 28 | 1.28 |
| Mg, percent--- | .08533 | 85 | 15 | 1.3 | 1.27 | 1.3 | 1.23 | .36 | 1.44 | 1.4 | 1.17 | 2.1 | 1.16 | 1.4 | 1.34 | 1.3 | 1.10 | .43 | 1.51 |
| Mn, ppm------- | .07796 | 33 | 67 | 340 | 1.84 | 180 | 1.51 | 110 | 1.27 | 390 | 1.27 | 210 | 2.21 | 240 | 1.58 | 260 | 1.20 | 210 | 2.32 |
| Na, percent--- | .15531 | 78 | 22 | .87 | 1.38 | .51 | 1.74 | .37 | 1.39 | 1.1 | 1.16 | .53 | 1.22 | .82 | 1.26 | .95 | 1.35 | .089 | 2.32 |
| Rb, ppm------- | .01006 | 43 | 57 | 68 | 1.19 | 70 | 1.12 | 82 | 1.17 | 57 | 1.26 | 72 | 1.15 | 51 | 1.10 | 55 | 1.14 | 69 | 1.32 |
| S, percent---- | .22353 | 41 | 59 | .41 | 2.09 | .17 | 2.48 | .069 | 2.43 | .17 | 3.02 | .035 | 1.80 | .081 | 2.81 | .079 | 2.04 | .086 | 1.75 |
| Si[3], percent-- | 13.087 | 33 | 67 | 28 | 3.35 | 29 | 3.42 | 32 | 3.35 | 26 | 2.64 | 26 | 2.45 | 28 | 2.52 | 29 | 1.46 | 32 | 3.79 |
| Th, ppm------- | .01287 | 49 | 51 | 8.7 | 1.23 | 8.6 | 1.22 | 12 | 1.23 | 8.7 | 1.22 | 8.2 | 1.21 | 7.7 | 1.17 | 7.1 | 1.13 | 12 | 1.22 |
| Ti, percent--- | .00795 | 58 | 42 | .34 | 1.07 | .27 | 1.09 | .25 | 1.18 | .30 | 1.23 | .25 | 1.10 | .24 | 1.19 | .27 | 1.07 | .38 | 1.15 |
| U, ppm-------- | .02087 | 65 | 35 | 3.0 | 1.17 | 3.5 | 1.19 | 5.6 | 1.34 | 3.3 | 1.29 | 3.6 | 1.27 | 2.7 | 1.22 | 2.7 | 1.12 | 5.1 | 1.09 |
| Zn, ppm------- | .01052 | 39 | 61 | 87 | 1.14 | 50 | 1.17 | 59 | 1.18 | 74 | 1.32 | 67 | 1.23 | 64 | 1.23 | 65 | 1.08 | 70 | 1.20 |

[1] Data expressed on a dry weight basis.
[2] Total carbon.
[3] Calculations on nontransformed data; means are arithmetic, deviations are standard deviations.

The new Duncan's multiple range test (1955) was applied to those elements in table 7 for which significant differences were found between mines. The results indicate that 1) samples of spoil material from the Welch and Dave Johnston mines are distinct from those of the other mines, in that they are higher in thorium and uranium and lower in calcium and magnesium. In addition, spoil samples from the Welch mine appear to be distinctively high in sodium. Also, sweetclover from the Welch mine is high in fluorine and silicon compared to the others. 2) Samples of spoil material from the Savage mine are distinct from those of the other mines in that they are higher in calcium and magnesium. Sweetclover from the Savage mine is high in selenium and low in sulfur. 3) Sweetclover samples from the Kincaid mine are distinct from those of the other mines in that they are high in sodium and sulfur.

Experimental design

We collected spoil material and sweetclover during late summer of 1974, according to a two-level analysis of variance design. Eight mines were selected arbitrarily in order to provide a cross section of the subbituminous and lignite coal mines that occur in the Northern Great Plains. Overburden materials at all mines consist of claystone and siltstone with lesser amounts of sandstone, shale, and coal of the Fort Union Formation of Paleocene age. Glacial deposits consisting of gravel, sand, silt, and clay are important overburden materials at all mines except Big Sky, Dave Johnston, and Welch. Brief descriptions of these mines follow.

1. Beulah mine (Knife River Coal Mining Co.), Mercer County, North Dakota. Sampled August 2, 1974. No shaping or topsoiling of the area had been done where we sampled, but there were many plantings of ornamentals such as Russian olive, cottonwood, elm, ash, lilac, spruce, and pine. Spoil material is very friable. The sampled area is currently designated a wildlife refuge.

2. Big Sky mine (Peabody Coal Co.), Rosebud County, Montana. Sampled July 26, 1974. This is a fairly new mine with extensive contouring and topsoiling of the spoil piles. Russian wildrye and other perennial grasses have been drilled, plus milk vetch, sweetclover, and alfalfa. Although both yellow sweetclover and white sweetclover were common, we collected the latter because the earlier-maturing yellow sweetclover was no longer suitable for collecting.

3. Dave Johnston mine (Pacific Power and Light Co.), Converse County, Wyoming. Sampled July 24, 1974. Spoil piles here may be as much as fifteen years old. However, the tracts that we sampled had been contoured, prepared for seeding, and drilled to grass in the fall of 1969 or planted in 1972. Yellow sweetclover was sampled, although both white and yellow sweetclover grew intermixed. The dominant grass is crested wheatgrass.

4. Kincaid mine (Baukol-Noonan, Inc.), Burke County, North Dakota. Sampled July 31, 1974. The area we sampled had not been reclaimed. The spoil materials were probably 30-50 years old and are reported to be sodic (Wali and Freeman, 1973). Large areas are practically devoid of vegetation, due, in part, to the almost concrete-like surface of the spoil piles.

5. Savage mine (Knife River Coal Mining Co.), Richland County, Montana. Sampled July 30, 1974. We sampled a large reclaimed area at the north end of the mine. The spoil material included abundant glacial outwash sand and gravel and was covered by dense stands of yellow and white sweetclover with some alfalfa.

6. Utility mine (Utility Coal Co.), Saskatchewan, Canada. Sampled September 19, 1974. The unreclaimed spoil piles that we sampled were fairly well vegetated with common prairie species such as wolfberry, fringed sagebrush, and mixed grasses. Clumps of white sweetclover occurred where native vegetation was not yet established. This and the Big Sky mine were the only two mines where we collected white sweetclover in lieu of yellow sweetclover.

7. Velva mine (Consolidation Coal Co.), Ward County, North Dakota. Sampled August 1, 1974. Vegetative recovery at this mine appeared to be unusually rapid compared to that of the other mines, probably due at least in part to the relatively porous nature of the spoil material. The sample sites were less than 15 years old but were covered with perennial plants and not pioneer weeds. Both species of sweetclover, however, were still dominant.

8. Welch mine (Welch Coal Co.), Sheridan County, Wyoming. Sampled July 27, 1974. Samples were collected in an abandoned strip pit. The spoil piles are still quite steep and support very little vegetation other than some rabbitbrush, western wheatgrass, and sweetclover.

Ten sampling sites were chosen at each mine. We selected each site first by using a random procedure and second by searching for an adequate stand of sweetclover. A channel sample of spoil material or a spoil-soil mixture (where topsoiling had been attempted) was collected to a depth of about 20 cm. The sweetclover sample consisted of the above-ground portion of a plant growing within 1 m of the channel sample. If a sufficient amount of sample material was unavailable from a single plant, more was composited from an area as much as 10 $m^2$. We attempted to sample sweetclover in its flowering and early fruiting stage with abundant leaf tissue, but some samples were further developed and had a greater proportion of stem tissue.

## Analytical procedures

Samples of sweetclover were first dried in a forced-air oven at about 50°C for 48 hours, then pulverized in a Wiley mill. Wet digestion methods were used to prepare the samples for fluorine, mercury, selenium, and sulfur determinations, the results of which were reported on a dry-weight basis. For the other elements, the samples were burned to ash in an electric muffle furnace in which the temperature was increased 50°C per hour to a temperature of 450°C and held at this level for about 14 hours. Because element concentrations in plant tissue are more commonly given on a dry-weight or moisture-free basis (for example, Furr and others, 1975), we have converted the element concentrations that were reported on an ash basis by the analysts to a dry-weight basis, using the following formula:

$$X_d = (X_a \times X_p)/100 \quad ,$$

where $X_d$ is the concentration in the dry material of the sample, $X_a$ is the concentration in the ash, and $X_p$ is the percent ash in the dry material.

Samples of spoil materials were ground to pass through a 100-mesh sieve. A part of this ground material was used for the analysis of carbon, fluorine, mercury, and sulfur. Because of the relatively high content of organic carbon in some samples, which can cause problems in emission spectrographic analysis, all samples were ashed prior to analysis for all other elements. The samples were ashed in the same manner as described above for sweetclover, and the same conversion formula was used.

Element concentrations, except silicon in spoil materials, were transformed to a logarithmic scale prior to statistical evaluation, because their frequency distributions are more nearly symmetrical on a logarithmic scale than on an arithmetic scale.

All analyses of sweetclover were done by T. F. Harms, C. S. E. Papp, and W. E. Cary. The analyses of the substrate materials were done by A. F. Drenick, A. W. England, Johnnie Gardner, Patrick Guest, Claude Huffman, Jr., Lorraine Lee, Violet Merritt, V. E. Shaw, G. D. Shipley, J. A. Thomas, J. S. Wahlberg, and T. L. Yager.

## GEOCHEMICAL RECONNAISSANCE OF SOILS IN THE NORTHERN GREAT PLAINS COAL PROVINCE

by Ronald R. Tidball and Ronald C. Severson

### Introduction

A suite of soil samples was collected throughout the Northern Great Plains Coal Province during the fall season of 1974, to evaluate the magnitude and distribution of the natural variation in terms of chemical composition. At the time of this writing, the only analytical data that have been completed are those from X-ray fluorescence analysis and neutron activation analysis. This represents about 25 percent of the total analytical work to be done. The purpose of this report is to describe the sampling design, to review the progress of the field work to date, and to list some preliminary estimates of geographic variance.

### Northern Great Plains Coal Province

The location of the reconnaissance study of soils within the bounds of the Northern Great Plains Coal Province is shown in figures 6 and 7. The area sampled was outlined by the U.S. Geological Survey (1974a) for the United States portion, and the boundary in Saskatchewan is adapted from the distribution of rocks of Tertiary age as shown by Whitaker and Pearson (1972). Although soils in the Powder River Basin have been sampled previously (p. 20-28 and 50-57), the basin was also included in this new study because it forms a natural part of the Northern Great Plains.

The Northern Great Plains Coal Province includes the coal deposits in the Powder River Basin and the Bull Mountain field of eastern Montana, as well as the extensive lignite deposits of eastern Montana and North Dakota and South Dakota (Trumbull, 1959). The coals and lignites are contained in lithologic formations of Tertiary age, which are composed of nonmarine, fine-grained sediments. Most of the province is underlain by the Fort Union Formation, the only important exception being the central part of the Powder River Basin, which is underlain mostly by the Wasatch Formation.

### Sampling design

Samples for the initial reconnaissance study were collected according to an unbalanced, or staggered (Leone and others, 1968), nested analysis of variance design. This design is shown in figure 8. The top level of this design compares soils from glaciated terrain to soils from unglaciated terrain. The area of each of these terrains was subdivided into cells with a dimension of 100 km on a side. The cells were arranged within the irregular border of the Northern Great Plains Coal Province to provide maximum correspondence to the glaciated and unglaciated terrains. Each 100-km cell was subdivided into 4 cells, 50 km on a side, of which 2 were selected randomly. These 50-km cells were subdivided into 25 cells, 10 km on a side, of which 2 were randomly selected, one in one of the 50-km cells and one in the other 50-km cell.

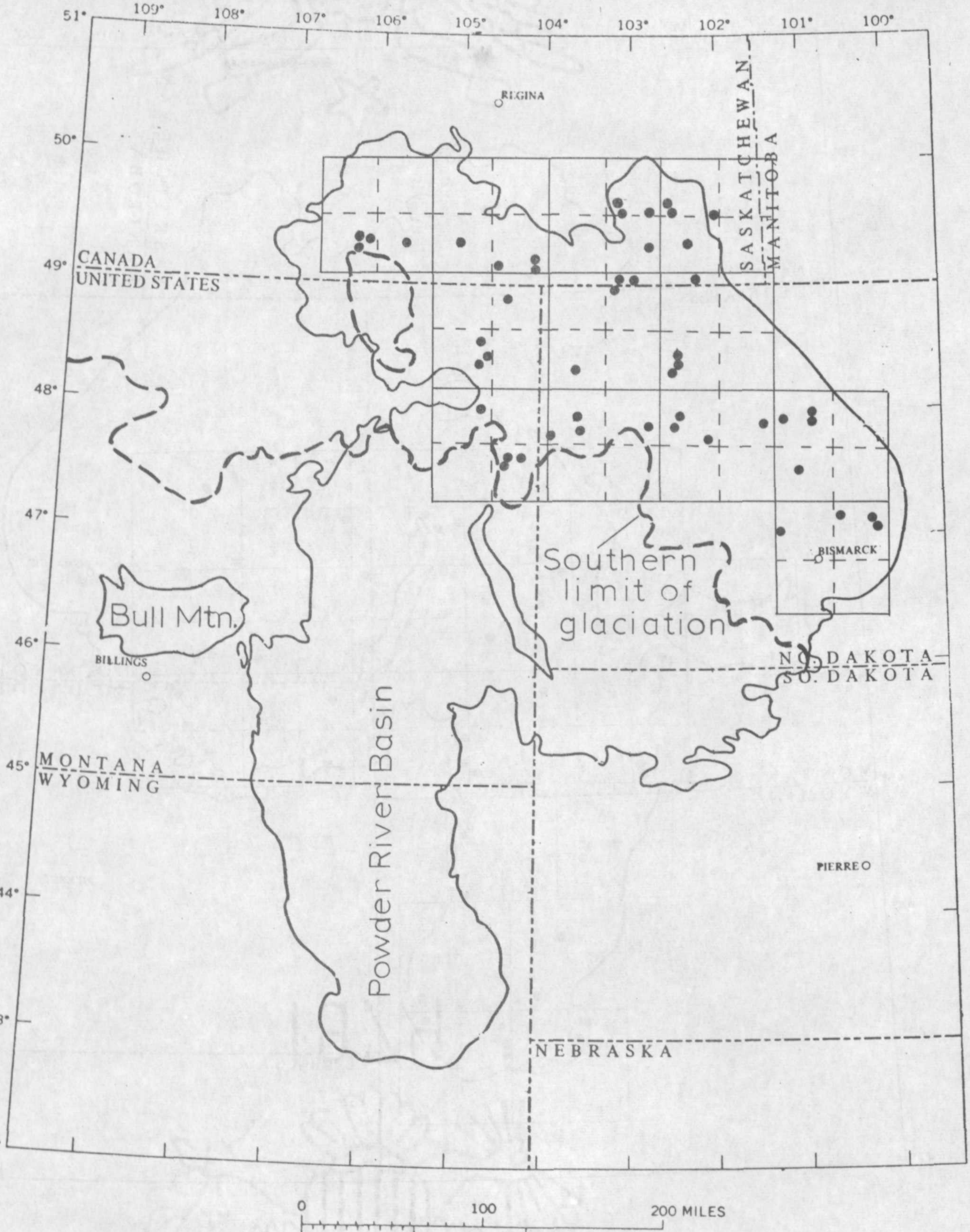



Figure 6. Soil sampling localities in glaciated terrain in the Northern Great Plains Coal Province. Large squares are 100 km on a side; smaller squares are 50 km on a side. Dots are sampling sites. The limit of glaciation is adapted from Colton, Lemke, and Lindvall (1963) for North Dakota and from Colton, Lemke, and Lindvall (1961) for Montana.

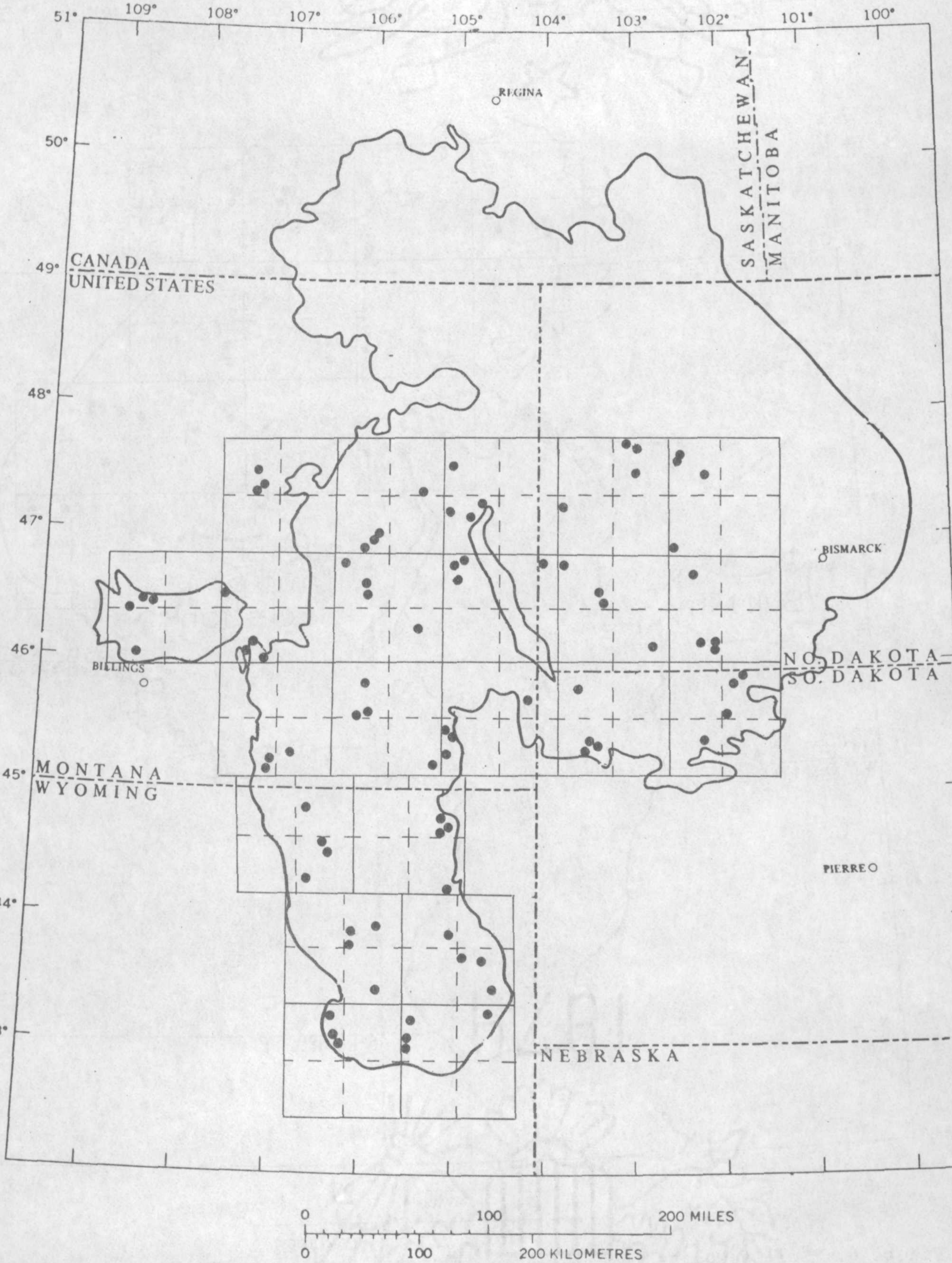
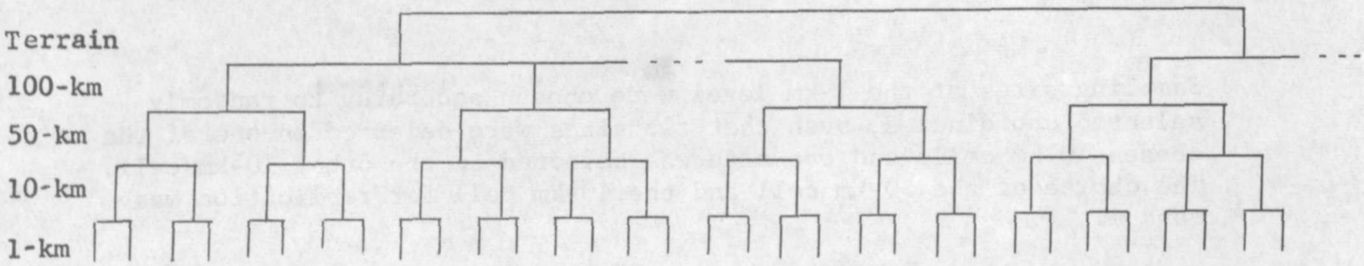



Figure 7. Soil sampling localities in unglaciated terrain in the Northern Great Plains Coal Province. Large squares are 100 km on a side; smaller squares are 50 km on a side. Dots are sampling sites.

A. NEARLY-BALANCED DESIGN

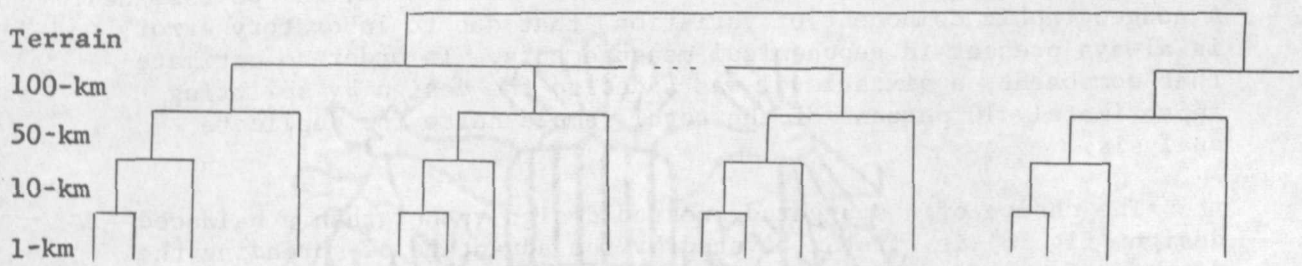



Number of units at each level

| Terrain | 100-km | 50-km | 10-km | 1-km |
|---|---|---|---|---|
| Glaciated | 12 | 24 | 48 | 96 |
| Unglaciated | 22 | 44 | 88 | 176 |
| Total | 34 | 68 | 136 | 272 = Number of samples |

| Level | Source of variance | Degrees of freedom |
|---|---|---|
| 1 | Between terrains | 2-1 = 1 |
| 2 | Between 100-km cells | 34-2 = 32 |
| 3 | Between 50-km cells | 68-34 = 34 |
| 4 | Between 10-km cells | 136-68 = 68 |
| 5 | Between 1-km cells (samples) | 272-136 = 136 |

B. STAGGERED DESIGN




Number of units at each level

| Terrain | 100-km | 0-km | 10-km | 1-km |
|---|---|---|---|---|
| Glaciated | 12 | 24 | 36 | 48 |
| Unglaciated | 22 | 44 | 66 | 88 |
| Total | 34 | 68 | 102 | 136 = Number of samples |

| Level | Source of variance | Degrees of freedom |
|---|---|---|
| 1 | Between terrains | 2-1 = 1 |
| 2 | Between 100-km cells | 34-2 = 32 |
| 3 | Between 50-km cells | 68-34 = 34 |
| 4 | Between 10-km cells | 102-68 = 34 |
| 5 | Between 1-km cells (samples) | 136-102 = 34 |

Figure 8. Comparison of a nearly-balanced design (A) with a staggered design (B). Degrees of freedom computed according to Anderson and Bancroft (1952, p. 328).

Sampling sites at the 1-km level were chosen according to randomly selected coordinates, such that two sites were selected in one of the chosen 10-km cells and one site was selected in the other 10-km cell. The choice of the 50-km cell and the 10-km cell for replication was random.

A total of 12 100-km cells (48 sites) were sampled in the glaciated terrain (fig. 6), and 22 100-km cells (88 sites) were sampled in the unglaciated terrain (fig. 7). A group of three sampling sites in the northeasternmost cell of figure 7 is located north of the mapped limit of glaciation. The soils at these sites, however, were most probably derived from sedimentary rocks of early Tertiary age, as glacial materials were not observed at the specific sampling sites. Two soil samples were collected at each of the 136 sites and include a channel composite of the A-horizon (0-10 cm in depth) and a channel composite from the C-horizon (110-120 cm in depth). If rock was encountered at a depth shallower than 110 cm, the C-horizon sample was taken from the 10 cm immediately above that point. Samples were collected at both depths by means of a 4-inch-diameter barrel-auger.

As outlined above, the sample design has five geographic "levels," each representing a range of scales and to each of which a portion of the total geochemical variability observed in the study may be assigned. A nongeographic component of variation, that due to laboratory error, is always present in geochemical measurements. In order to estimate that component, a sixth level was added to the design by splitting approximately 10 percent of the total sample suite for duplicate analysis.

The choice of a staggered, nested design rather than a balanced design (fig. 8) is first motivated by the advantage of spreading the degrees of freedom nearly evenly over all of the stages; second, the total number of samples required in the staggered design to achieve a comparable number of degrees of freedom in the upper levels is only one-half that required in the balanced design.

The soil samples were prepared for analysis by gently crushing the natural soil aggregates sufficiently to pass a 2-mm stainless steel sieve. The soil material was then ground to -100-mesh (-149-micron) size in a ceramic mill. J. W. Baker and J. S. Wahlberg analyzed the samples for aluminum, calcium, iron, potassium, silicon, and titanium by X-ray fluorescence. Andrew Drenick, Jeffery England, and H. T. Millard measured thorium and uranium by delayed neutron activation.

## Variance components

Variance components for eight elements in soils from the Northern Great Plains are given in table 8. The components are expressed as percentages of the total variance. Of the 16 entries in table 8, 10 exhibit statistically significant differences between the two terrains. These differences are:

| Element | Soil Horizon | Glaciated Terrain Mean | Glaciated Terrain Deviation | Unglaciated Terrain Mean | Unglaciated Terrain Deviation |
|---|---|---|---|---|---|
| Aluminum | A | 5.3 | 1.17 | 5.8 | 1.18 |
| | C | 5.3 | 1.22 | 5.9 | 1.22 |
| Calcium | C | 4.4 | 1.63 | 25 | 2.09 |
| Potassium | A | 1.7 | 1.09 | 1.9 | 1.12 |
| | C | 1.5 | 1.16 | 1.8 | 1.17 |
| Silicon | C | 27 | 2.74 | 29 | 3.59 |
| Thorium | A | 7.7 | 1.25 | 8.8 | 1.20 |
| | C | 7 | 1.35 | 8.3 | 1.34 |
| Uranium | A | 2 | 1.20 | 2.5 | 1.23 |
| | C | 2.2 | 1.42 | 2.8 | 1.41 |

Means are in percent, except for thorium and uranium which are in parts per million. They are geometric means, except in the case of silicon where they are arithmetic means. Deviations are geometric deviations, except in the case of silicon where they are standard deviations.

With the exception of calcium in the C-horizon, soils from the unglaciated terrain are higher in all six elements. The differences between the two terrains are not unexpected inasmuch as a compositional contrast exists in the parent materials of the two areas. These results, however, contrast with studies in Missouri (Tidball, 1972), where glaciated soils tended to have higher concentrations of most elements than did unglaciated areas. The deviations for most of the listed elements are nearly equal in the two terrains, which supports the assumption of homogeneous variance underlying the tests in table 8.

## Geochemical maps

The variance mean ratio (Miesch, 1976) was calculated to determine the feasibility of mapping elements on the basis of the means of 100-km cells. (See table 8.) This ratio is an index of the stability of a map pattern, based on means of 100-km cells, and is computed as:

$$v_m = 4(P_t + P_{100})/(2.5\ P_{50} + 1.5\ P_{10} + P_1 + P_e) \quad , \qquad (3)$$

where the subscripted P's are the percentages in table 8 corresponding to variation between terrains, 100-km cells, 50-km cells, 10-km cells,

Table 8.--Analysis of variance of soil chemistry in the Northern Great Plains Coal Province

[Asterisk (*) indicates component is significantly different from zero at the 0.05 probability level]

| Element | Soil Horizon | Total $Log_{10}$ Variance | Components as percentage of total variance | | | | | | $V_m$[2] (100-km Cells) |
|---|---|---|---|---|---|---|---|---|---|
| | | | Between Terrains | Between 100-km Cells | Between 50-km Cells | Between 10-km Cells | Between 1-km Cells (Samples) | Analytical Error | |
| Al --- | A | 0.00732 | 11.5* | 0 | 33.7* | 2.9 | 38.5 | 13.4 | 0.33 |
| | C | .01013 | 11.0* | 0 | 14.3 | 4.5 | 60.5 | 9.7 | .39 |
| Ca --- | A | .15307 | 0 | 19.0* | 0 | 17.4 | 56.7 | 6.9 | .85 |
| | C | .11258 | 26.4* | 7.5 | 0.9 | 10.1 | 45.7 | 9.4 | 1.9 |
| Fe --- | A | .01612 | 0 | 21.0* | 8.6 | 30.3* | 38.9 | 1.2 | .78 |
| | C | .03097 | 0 | 0 | 22.0* | 0 | 77.4 | 0.6 | 0 |
| K ---- | A | .00390 | 43.3* | 0 | 13.1 | 6.8 | 27.1 | 9.7 | 2.2 |
| | C | .00794 | 39.7* | 0 | 19.6 | 5.6 | 30.4 | 4.7 | 1.7 |
| Si[1] -- | A | 10.119 | 0 | 27.8* | 0 | 10.1 | 49.9 | 12.2 | 1.4 |
| | C | 13.160 | 8.4* | 9.3 | 0 | 7.5 | 65.5 | 9.3 | .82 |
| Th --- | A | .00977 | 17.7* | 6.8 | 0 | 31.3* | 4.7 | 39.5 | 1.1 |
| | C | .02146 | 12.2* | 0 | 0 | 15.9 | 53.9 | 18.0 | .51 |
| Ti[1] -- | A | .00221 | 1.9 | 7.3 | 0 | 38.8* | 17.3 | 34.7 | .33 |
| | C | .00406 | 0.6 | 0 | 8.4 | 0 | 72.1 | 18.9 | .02 |
| U ---- | A | .01367 | 32.4* | 9.9* | 0 | 18.8 | 31.2 | 7.7 | 2.5 |
| | C | .02769 | 16.7* | 4.5 | 1.4 | 12.8 | 60.8 | 3.8 | .97 |

1/ Variance computed on arithmetic basis, not logarithmic basis.

2/ Variance mean ratio for 100-km cells. See text for explanation.

1-km cells, and analytical error, respectively. A ratio of 1 is taken as the threshold above which the 100-km cell means, estimated from the data in hand (four samples per cell), are judged to be stable at the 80-percent confidence level. Maps for calcium, potassium, silicon, thorium, and uranium appear in figures 9 to 14. The map of thorium in the A-horizon is the least stable ($v_m = 1.1$), and the map of uranium in the A-horizon is the most stable ($v_m = 2.5$).

The calcium map shows one high area in eastern Montana on unglaciated terrain and another high area near the southeastern corner of Saskatchewan on glaciated terrain. The Montana area is underlain by sandstone and siltstone of Tertiary age. The samples from the Saskatchewan area are derived from glacial till; veins of calcium carbonate were visible in some of the soil profiles. Over the region as a whole, the glaciated area appears to have the higher concentrations of calcium.

The distribution of potassium is remarkably homogeneous within the two terrains. The high area in eastern Montana reflects samples formed on intermixed sandstone and shale of the Fort Union Formation; the high area in the southwestern part of the Powder River Basin reflects samples formed on sandstone and siltstone of the Wasatch Formation.

Because there is no important difference between the two major terrains (table 8), the distribution of silicon is much more erratic than that of the other elements shown.

The distribution of thorium and uranium generally parallels that of potassium. Uranium, in particular, is noticeably high in the general area of uranium mining in the southern part of the Powder River Basin.

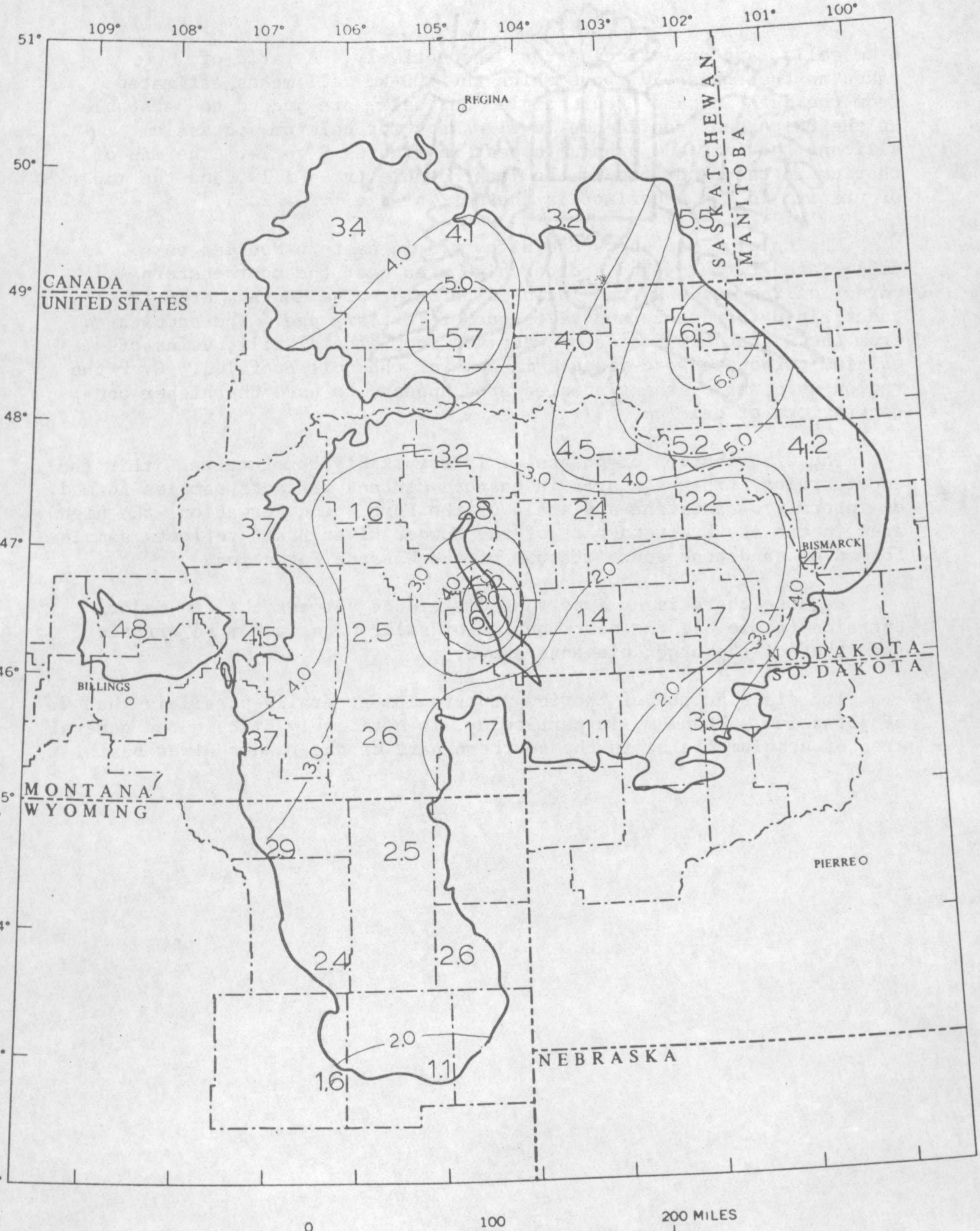



Figure 9. Regional distribution of calcium in C-horizon of soils. Values (percent) are means of 100-km cells. Stability index ($V_m$) is 1.9.

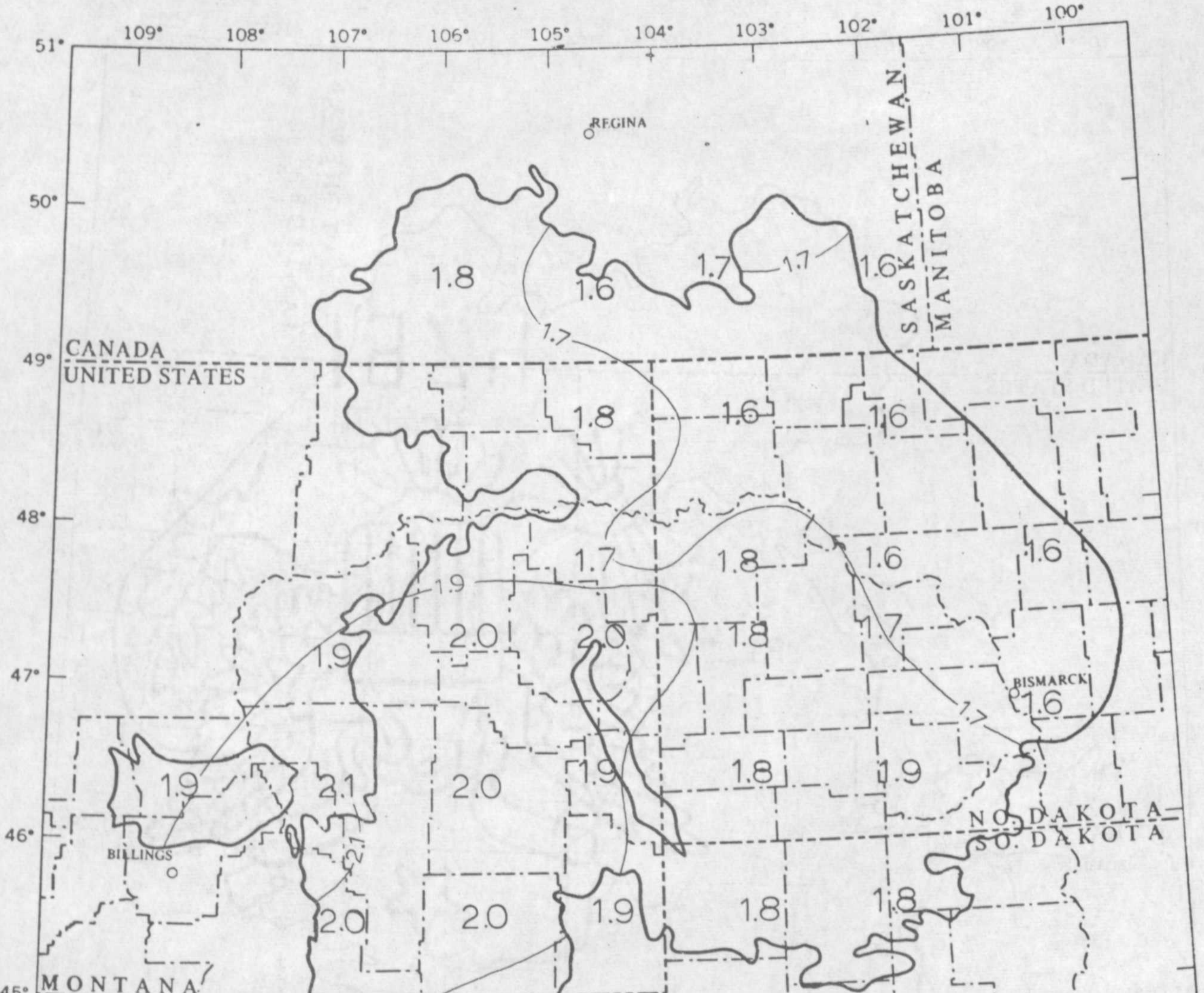



Figure 10. Regional distribution of potassium in A-horizon of soils. Values (percent) are means of 100-km cells. Stability index ($V_m$) is 2.4.

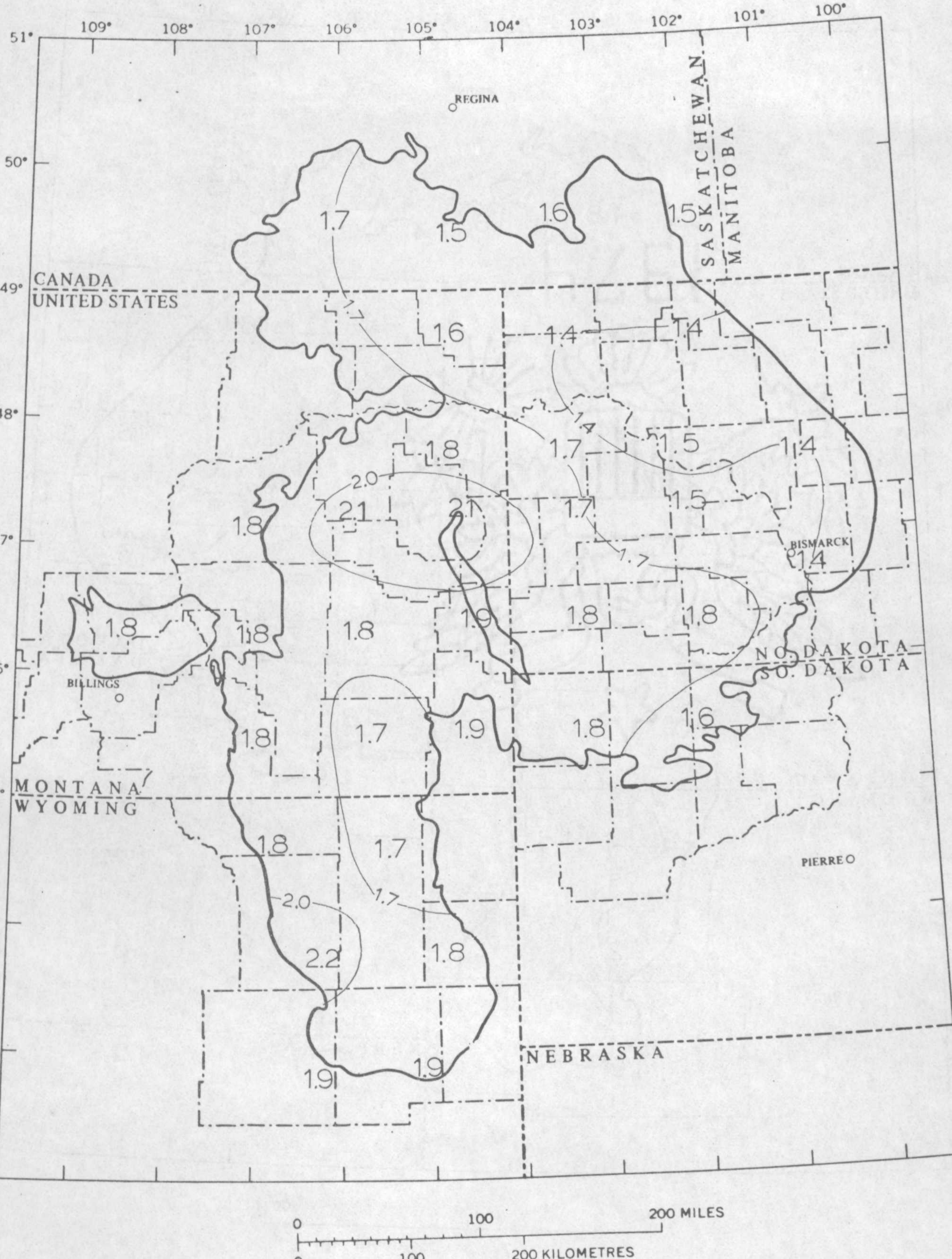



Figure 11. Regional distribution of potassium in C-horizon of soils. Values (percent) are means of 100-km cells. Stability index ($V_m$) is 1.9.


Figure 12. Regional distribution of silicon in A-horizon of soils. Values (percent) are means of 100-km cells. Stability index ($V_m$) is 1.5.

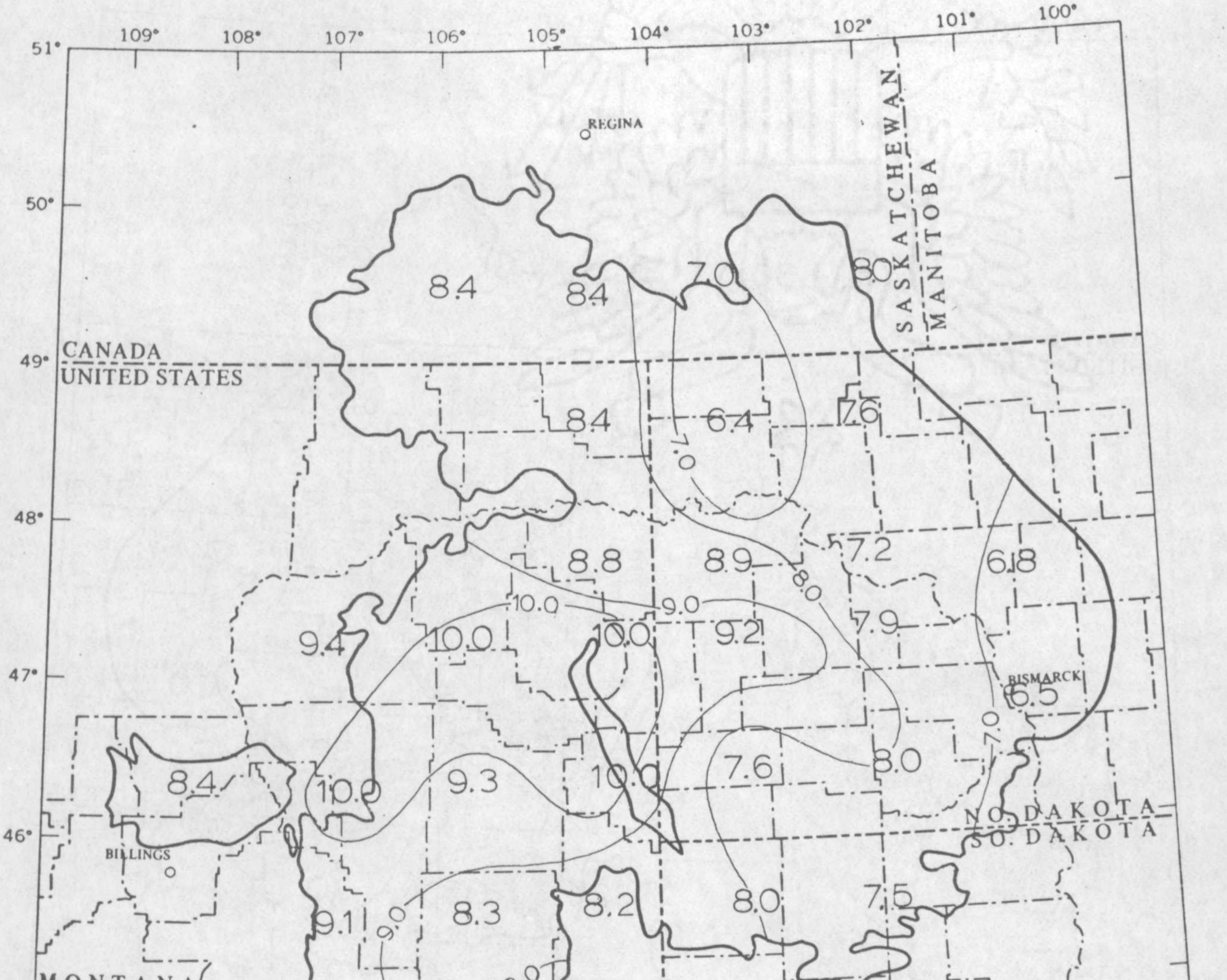



Figure 13. Regional distribution of thorium in A-horizon of soils. Values (ppm) are means of 100-km cells. Stability index ($V_m$) is 1.1.

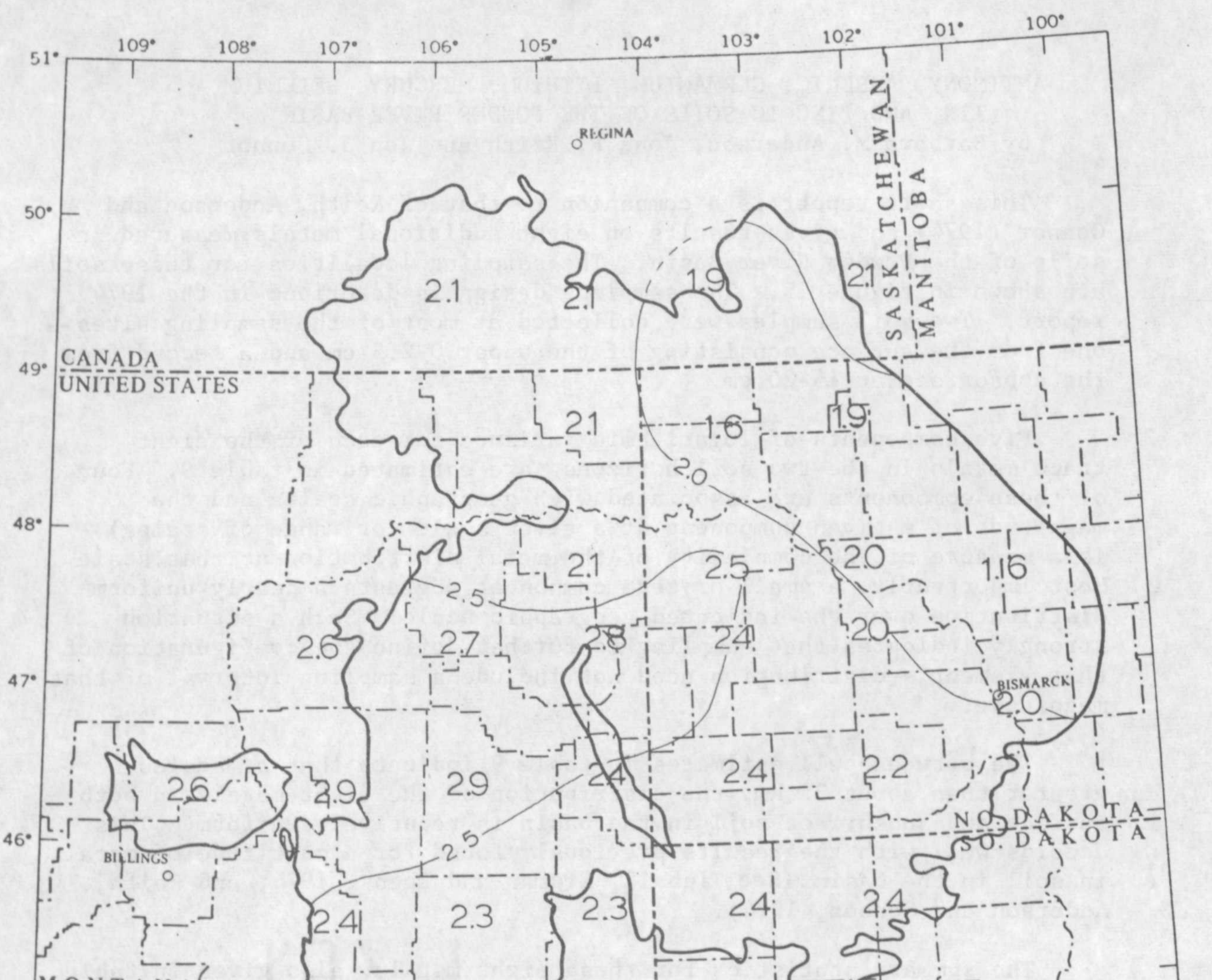



Figure 14. Regional distribution of uranium in A-horizon of soils. Values (ppm) are means of 100-km cells. Stability index ($V_m$) is 2.6.

## ANTIMONY, ARSENIC, GERMANIUM, LITHIUM, MERCURY, SELENIUM, TIN, AND ZINC IN SOILS OF THE POWDER RIVER BASIN

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

This short report is a companion to that of Keith, Anderson and Connor (1974) and gives results on eight additional metals measured in soils of the Powder River Basin. The sampling localities for these soils are shown in figure 15. The sampling design is described in the 1974 report. Two soil samples were collected at most of the sampling sites -- one from the surface consisting of the upper 0-2.5 cm and a second from the subsurface at 15-20 cm.

Five components of logarithmic variance for each of the eight trace metals in the two soil horizons are estimated in table 9. Four of these components are associated with geographic scales, and the magnitude of a given component at a given scale (or range of scales) is a measure of the complexity of the metal distribution at that scale. Most importantly, a small or zero component suggests a nearly uniform distribution over the indicated geographic scale. Such a situation strongly indicates that sampling to further define the configuration of that element's distribution need not include a sampling interval of that magnitude.

The between-cell estimates in table 9 indicate that at scales greater than about 35 km, the distribution of the eight metals in both surface and subsurface soil in the basin is relatively uniform. This accords well with the results previously found for a multitude of metals in soil in the basin. (See Tidball, Erdman and Ebens, 1974, and Keith, Anderson and Connor, 1974).

The summary statistics for these eight metals, also given in table 9 (as GM, GD and GE) may be used, at least provisionally, to establish broad-scale or regional baselines of one kind or another (see discussion on inside cover) for the basin's near-surface soil. For example, the expected 95 percent ranges in parts per million are:

| | Surface soil | Subsurface soil |
|---|---|---|
| Antimony | 0.63-2.1 | 0.60-2.1 |
| Arsenic | 2.5-14 | 2.0-21 |
| Germanium | .82-2.3 | .84-2.1 |
| Lithium | 12-38 | 14-42 |
| Mercury | .016-.026 | .020-.026 |
| Selenium | .018-.55 | .0056-.64 |
| Tin | 1.0-3.8 | 1.0-3.3 |
| Zinc | 35-100 | 34-110 |

The ranges given above for surface soil may be compared with analyses of three shallow profiles sampled near Gillette, Wyoming (fig. 15, table 10). Only 2 samples of the 24 analysed exceed the upper limit for one

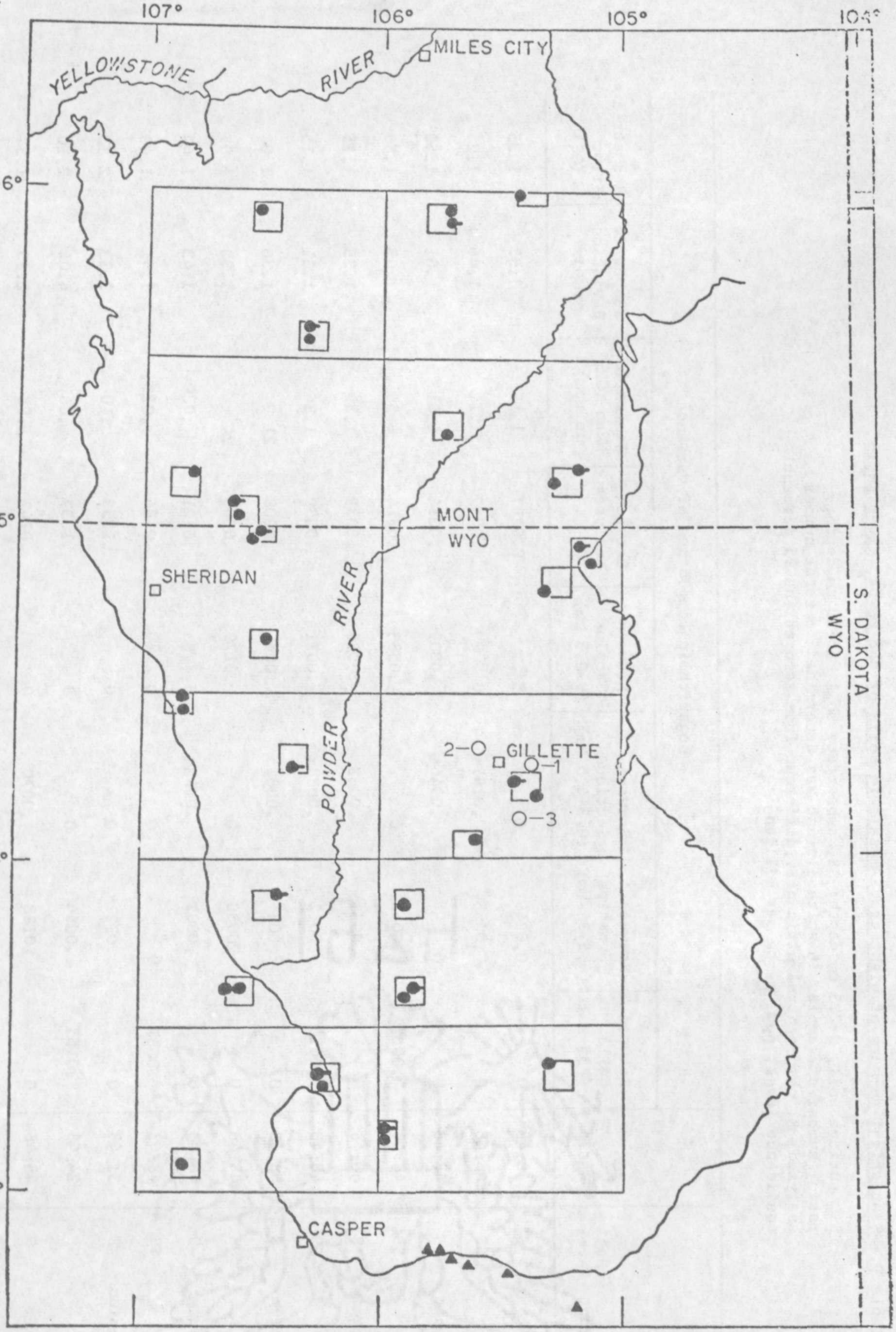



Figure 15. Sampling localities using a nested-cell design in the Powder River Basin. Solid dots are sampling localities used in the basinwide study; solid triangles are localities used in the Dave Johnston Power Plant study; open circles are localities used in the soil profile study.

Table 9.--Statistical summary of eight trace metals in soils of the Powder River Basin

[S, surface soil, 0-2.5 cm depth; SS, subsurface soil, 15-20 cm depth; ratio, number of samples in which element was determined to total number analyzed; *, component significantly different from zero at the 95 percent confidence level; ppm, parts per million]

| Element | Soil level | Ratio | Logarithmic components of variance | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Between Cells (>35 km) | Between Townships (4.5-35 km) | Between Sections (0.3-4.5 km) | Between Samples (0-0.3 km) | Between Analyses | Geometric Mean (GM, in ppm) | Geometric Deviation (GD) | Geometric Error (GE) |
| Antimony | S | 48:48 | 0 | 0.0249* | 0 | 0 | 0.0167 | 1.15 | 1.53 | 1.35 |
| | SS | 48:48 | 0 | .0063 | .0197* | 0 | .0092 | 1.11 | 1.46 | 1.25 |
| Arsenic | S | 48:48 | 0 | 0 | .0946* | .0009 | .0314 | 6.01 | 1.81 | 1.50 |
| | SS | 48:48 | .0003 | .0013 | 0 | .0383 | .0314 | 6.56 | 2.03 | 1.50 |
| Germanium | S | 48:48 | 0 | .0051 | .0043 | .0035 | .0039 | 1.39 | 1.35 | 1.15 |
| | SS | 48:48 | .0010 | .0012 | .0038 | .0071 | .0039 | 1.34 | 1.31 | 1.15 |
| Lithium | S | 48:48 | 0 | .0035 | .0081 | .0066 | .0008 | 21 | 1.36 | 1.07 |
| | SS | 48:48 | 0 | .0030 | 0 | .0179 | .0008 | 24 | 1.33 | 1.07 |
| Mercury | S | 48:48 | 0 | .0001 | .0142 | 0 | .0121 | .020 | 1.43 | 1.40 |
| | SS | 48:48 | .0067 | 0 | 0 | 0 | .0184 | .023 | 1.41 | 1.40 |
| Selenium | S | 31:48 | 0 | .0727* | 0 | 0 | .1353 | .10 | 3.33 | 2.33 |
| | SS | 24:48 | .0153 | .0064 | 0 | 0 | .1037 | .06 | 4.04 | 2.10 |
| Tin | S | 48:48 | 0 | .0188 | .0070 | 0 | .0147 | 1.98 | 1.53 | 1.32 |
| | SS | 48:48 | 0 | .0211 | .0111 | 0 | .0157 | 1.82 | 1.51 | 1.33 |
| Zinc | S | 48:48 | .0002 | .0014 | .0072 | .0051 | .0003 | 59 | 1.31 | 1.05 |
| | SS | 48:48 | 0 | .0066 | 0 | .0152 | .0003 | 61 | 1.35 | 1.05 |

Table 10.--Concentrations (in parts per million) of eight trace metals in soil profiles near Gilette, Wyoming

[Analysts: J. W. Baker, J. O. Johnson, J. A. Thomas, J. S. Wahlberg and R. J. Young]

| Depth (cm) | Lithology | Antimony | Arsenic | Germanium | Lithium | Mercury | Selenium | Tin | Zinc |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Soil Profile No. 1 | | | | | |
| 0-10 | Silt | 0.5 | 3.6 | 0.5 | 12 | 0.02 | <0.1 | 0.9 | 38 |
| 10-40 | Sand | .9 | 9.0 | 1.3 | 13 | .01 | <.1 | 1.0 | 45 |
| 40-70 | Silty sand | .8 | 3.7 | .8 | 13 | .01 | <.1 | 1.7 | 50 |
| 70-100 | Silty sand | .8 | 5.3 | .9 | 17 | .03 | .1 | .8 | 55 |
| (Base of soil?) | | | | | | | | | |
| 100-120 | Sand | .9 | 5.0 | 1.4 | 13 | .02 | <.1 | 1.5 | 30 |
| 120-150 | Sand | .6 | 5.9 | 1.3 | 12 | .02 | .1 | .6 | 29 |
| 150-190 | Conglomerate | 1.9 | 60.0 | 1.3 | 16 | .05 | .4 | 1.2 | 56 |
| 190-220 | Sandstone | .9 | 8.6 | 1.2 | 12 | .02 | <.1 | .8 | 32 |
| 220-260 | Sandstone | 1.9 | 14.0 | 1.9 | 15 | .03 | .3 | 1.9 | 45 |
| 260-360 | Conglomerate | 2.2 | 28.0 | 1.3 | 14 | .05 | .7 | 2.3 | 57 |
| 360-400 | Shale | 1.1 | 13.0 | 1.0 | 30 | .07 | .3 | 2.4 | 101 |
| | | | | Soil Profile No. 2 | | | | | |
| 0-10 | Silt | .8 | 4.2 | 1.1 | 9 | .02 | <.1 | 2.1 | 31 |
| 10-40 | Silty sand | .3 | 4.1 | .8 | 11 | .02 | .1 | .8 | 27 |
| 40-70 | Silty sand | .4 | 2.4 | .4 | 11 | .01 | .1 | .9 | 30 |
| 70-100 | Silty sand | .4 | 3.5 | 1.0 | 13 | .02 | .3 | .8 | 62 |
| (Base of soil?) | | | | | | | | | |
| 100-120 | Clayey sand | .6 | 4.4 | 1.2 | 15 | .02 | .3 | .9 | 35 |
| 120-140 | Sandstone | 1.0 | 1.3 | 1.2 | 17 | .04 | <.1 | 1.5 | 43 |
| 140-180 | Sandstone | 1.0 | 5.6 | 1.4 | 21 | .03 | <.1 | 1.3 | 47 |
| 180-240 | Sandstone | 1.0 | 2.6 | 1.1 | 21 | .03 | <.1 | 1.4 | 49 |
| | | | | Soil Profile No. 3 | | | | | |
| 0-10 | Silty sand | .5 | 3.7 | .9 | 9 | .01 | <.1 | .7 | 26 |
| 10-30 | Sand | .8 | 5.9 | .8 | 9 | .01 | <.1 | .7 | 23 |
| 30-60 | Sand | .8 | 4.1 | .8 | 9 | .02 | <.1 | .9 | 26 |
| 60-80 | Sand | .4 | 5.9 | 1.1 | 11 | .01 | <.1 | .3 | 28 |
| 80-100 | Clayey sand | .4 | 4.0 | .9 | 9 | .01 | .2 | .9 | 28 |
| (Base of soil?) | | | | | | | | | |

Table 11.--Concentrations (in parts per million) of eight trace metals in soil east of the Dave Johnston Power Plant

[Analysts: J. W. Baker, J. O. Johnson, J. A. Thomas, J. S. Wahlberg, and R. J. Young]

| Distance from power plant (km) | Field Number | Antimony | Arsenic | Germanium | Lithium | Mercury | Selenium | Tin | Zinc |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Surface Soil (0-2.5 cm) | | | | | |
| 0.8 | 1AS1 | 1.1 | 5.2 | 1.1 | 20 | 0.02 | 0.1 | 2.5 | 58.0 |
| | 1BS1 | 1.7 | 5.8 | 1.7 | 17 | .02 | < .1 | 2.4 | 47 |
| 2.6 | 2AS1 | .9 | 3.9 | .8 | 11 | .02 | < .1 | 1.0 | 28 |
| | 2BS1 | .9 | 4.2 | 1.0 | 7 | .01 | < .1 | 1.0 | 20 |
| 6.6 | 3AS1 | .8 | 6.8 | 1.5 | 27 | .02 | < .1 | 2.0 | 57 |
| | 3BS1 | .5 | 5.1 | 1.5 | 25 | .01 | .1 | 2.0 | 45 |
| 13.5 | 4AS1 | 1.2 | 2.4 | 1.2 | 17 | .02 | < .1 | 1.9 | 48 |
| | 4BS1 | .7 | 4.2 | .9 | 15 | .02 | < .1 | 1.7 | 44 |
| 26.4 | 5AS1 | .6 | 3.4 | 1.1 | 12 | .02 | .2 | 1.1 | 36 |
| | 5BS1 | 1.0 | 3.0 | 1.0 | 10 | .02 | < .1 | 2.6 | 33 |
| 53.8 | 6AS1 | .8 | 1.9 | 1.2 | 9 | .01 | < .1 | 2.7 | 33 |
| | 6BS1 | .3 | 2.7 | 1.1 | 11 | .01 | .2 | 1.1 | 33 |
| | | | | Subsurface Soil (15-20 cm) | | | | | |
| 0.8 | 1AS2 | 0.7 | 6.1 | 1.2 | 17 | .01 | 0.2 | 1.3 | 45 |
| | 1BS2 | 1.3 | 5.0 | 1.3 | 16 | .01 | < .1 | 1.7 | 43 |
| 2.6 | 2AS2 | 1.1 | 6.9 | .7 | 11 | .01 | < .1 | .9 | 26 |
| | 2BS2 | .5 | 2.9 | .9 | 8 | .01 | < .1 | 1.1 | 19 |
| 6.6 | 3AS2 | .9 | 2.8 | 1.2 | 23 | .02 | < .1 | 2.7 | 53 |
| | 3BS2 | .8 | 3.6 | .8 | 37 | .02 | .1 | 2.4 | 59 |
| 13.5 | 4AS2 | .6 | 4.4 | 1.3 | 19 | .02 | .1 | 1.2 | 48 |
| | 4BS2 | 1.1 | 1.4 | 1.4 | 20 | .02 | < .1 | 2.1 | 58 |
| 26.4 | 5AS2 | 1.4 | 5.1 | 1.0 | 23 | .01 | < .1 | 2.0 | 64 |
| | 5BS2 | 1.0 | 4.5 | 1.1 | 17 | .01 | < .1 | 1.3 | 40 |
| 53.8 | 6AS2 | 1.0 | .2 | .9 | 16 | .01 | < .1 | 2.8 | 44 |
| | 6BS2 | .8 | 4.1 | 1.0 | 8 | .01 | < .1 | 1.4 | 27 |

or more of the metals antimony, arsenic and selenium. Both are poorly sorted, calcareous conglomerates and, if such rock types were brought to the surface, the particular sites where they lay would have to be judged anomalous. The arsenic concentrations, in particular, of these two rock samples must be judged to be extremely unusual.

One part of the work in the Powder River Basin involved an examination of the potential effect of the Dave Johnston Power Plant (located on the southern edge of the basin) on the trace metal geochemistry of soils downwind from the plant. In the last report (Keith, Anderson and Connor, 1974), concentrations of 18 trace metals in surface and subsurface soils were examined by regression analysis. None were found to decrease away from the plant in a statistically significant manner.

A similar analysis was performed for the seven of the eight elements of interest here, the data on selenium being too sparse for statistical analysis. The data are given in table 11 and the resulting regression equations are:

$$^{*}\text{Log Sb} = 0.08-0.19 \text{ Log D}$$
$$\text{Log Sb} = -0.08+0.03 \text{ Log D}$$

$$^{*}\text{Log As} = 0.75-0.19 \text{ Log D}$$
$$\text{Log As} = 0.76-0.31 \text{ Log D}$$

$$\text{Log Ge} = 0.09-0.03 \text{ Log D}$$
$$\text{Log Ge} = 0.03-0.01 \text{ Log D}$$

$$\text{Log Li} = 1.23-0.09 \text{ Log D}$$
$$\text{Log Li} = 1.22-0.02 \text{ Log D}$$

$$\text{Log Hg} = -1.74-0.07 \text{ Log D}$$
$$\text{Log Hg} = -1.91+0.02 \text{ Log D}$$

$$\text{Log Sn} = 0.25-0.02 \text{ Log D}$$
$$\text{Log Sn} - 0.13+0.09 \text{ Log D}$$

$$\text{Log Zn} = 1.63-0.04 \text{ Log D}$$
$$\text{Log Zn} = 1.59-0.00 \text{ Log D}$$

An asterisk (*) indicates a statistically significant decrease in concentration with distance at the 95-percent confidence level, and D is measured in kilometres. The first equation of each pair refers to concentrations in the surface soil (0-2.5 cm depth) and the second to subsurface soil (15-20 cm depth). Arsenic in the subsurface exhibits a decrease with distance significant at the 90-percent confidence level. The relations in antimony and arsenic are shown graphically in figure 16.

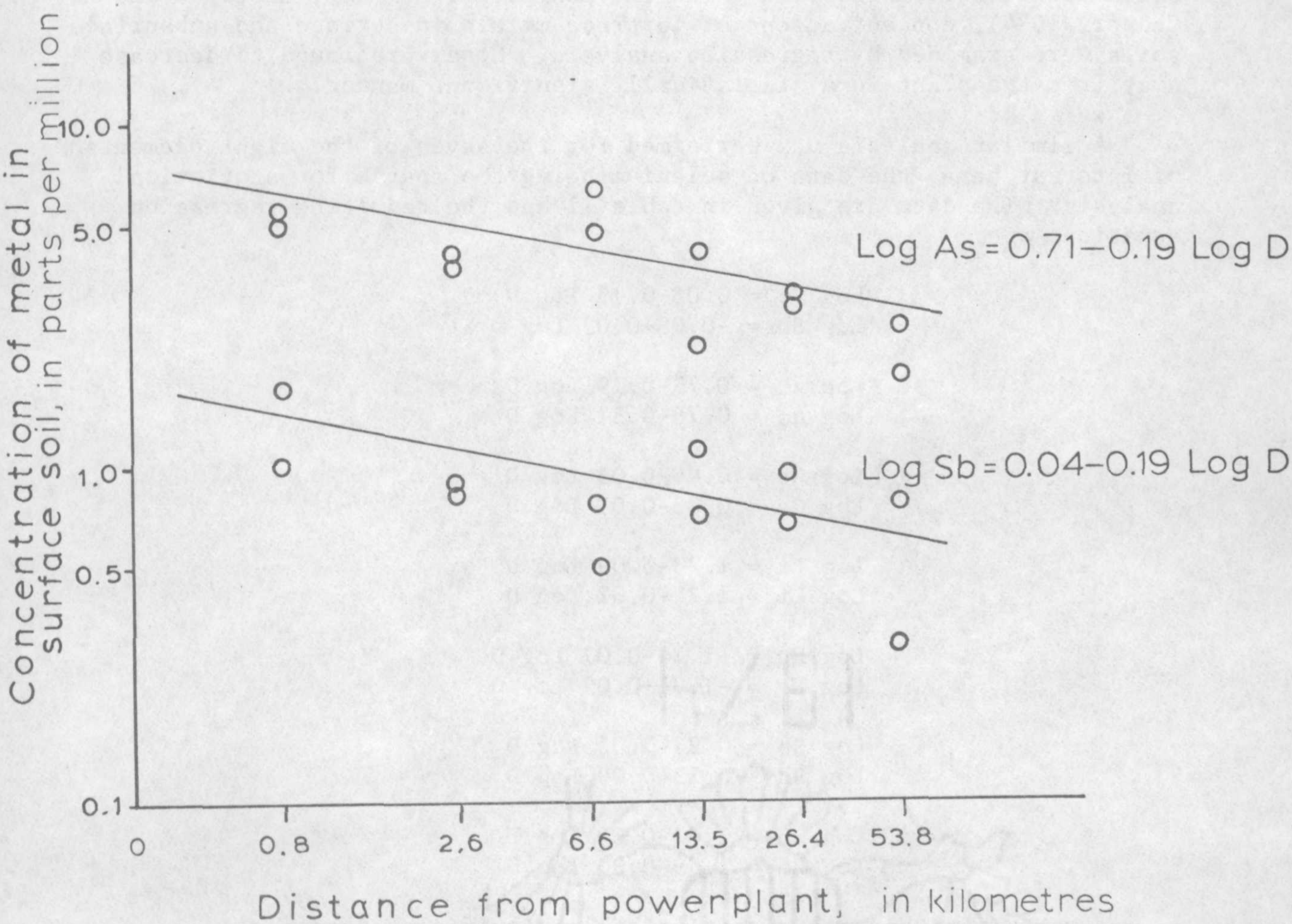



**Figure 16. Trend lines relating metal concentration in surface soil to distance from the Dave Johnston Power Plant.**

Work to date (Keith, Anderson, and Connor, 1974; Connor, Keith, and Anderson, 1976) has demonstrated that, of 15 trace metals measured in sagebrush downwind from this power plant, 4 exhibit statistically significant reductions. They are selenium, strontium, vanadium, and uranium. Their decrease with distance suggests that the power plant is acting as a point source for these four metals. It appears that antimony and arsenic should now be added to this list of metal pollutants. No data are as yet available on the concentrations of these last two metals in sagebrush near the Dave Johnston plant.

## GROUND WATERS OF THE FORT UNION COAL REGION

by G. L. Feder

Sampling of ground waters in the Fort Union coal region has been completed, and partial analytical results have been received. In addition, analytical results for three ground-water samples collected in the Fort Union coal region of Saskatchewan, Canada, are listed here and compared to the ground waters obtained in the United States part of the Fort Union coal region. Because analytical results have not been received for all the sampling sites, estimates of scale-related variance components for ground water of the Fort Union coal region cannot be made at this time. However, preliminary estimates of expected concentrations of some chemical constituents are listed for ground waters in geologic formations above the Pierre Shale.

### Sampling design

Field sampling in the Fort Union coal region was based on a Stage la nested analysis-of-variance sampling plan (Miesch, 1976),according to the model:

$$\log X_{ijk} = M + T_i + S_{ij} + E_{ijk} \quad , \qquad (4)$$

where the logarithm of the concentration of a chemical constituent for a given ground-water sample,as reported by the analyst ($\log X_{ijk}$), is assumed to deviate from the true logarithmic average for that material (M) by the cumulative effect of three independent sources of variation. $T_i$ represents broad scale differences observed between townships within the Fort Union coal region, $S_{ij}$ represents differences between wells spaced within 10 km of each other, and $E_{ijk}$ represents ever present non-geographic effect, including errors caused by sample collection, shipping procedures, and laboratory methods (analytical errors). These last effects are estimated independently by obtaining duplicate samples at randomly selected wells and analyzing them in random order. Estimates of the variance of the above effects,denoted as $S_T^2$, $S_S^2$, and $S_E^2$, respectively, can be computed using procedures given in Krumbein and Slack (1956), and their sum ($S^2_{\log X}$) represents the total observed logarithmic variance in the study area. The study in the Fort Union coal region is part of a larger study--that of ground-water chemistry in all of the western coal region. In this context, equation (4) could be expanded to include a regional effect, $S_R^2$, that of differences among coal regions in the Rocky Mountain and Northern Great Plains Provinces.

Estimates of $S_T^2$ will be obtained from 19 randomly selected townships within the study area. (See fig. 17.) To estimate $S_S^2$, 4 of these 19 wells were randomly chosen, and an additional well within 10 km was sampled.

All samples were collected from formations above the Pierre Shale, including glacial drift, and only wells used for human or livestock water supplies were chosen, regardless of depth. The average well depth is about 30 m.

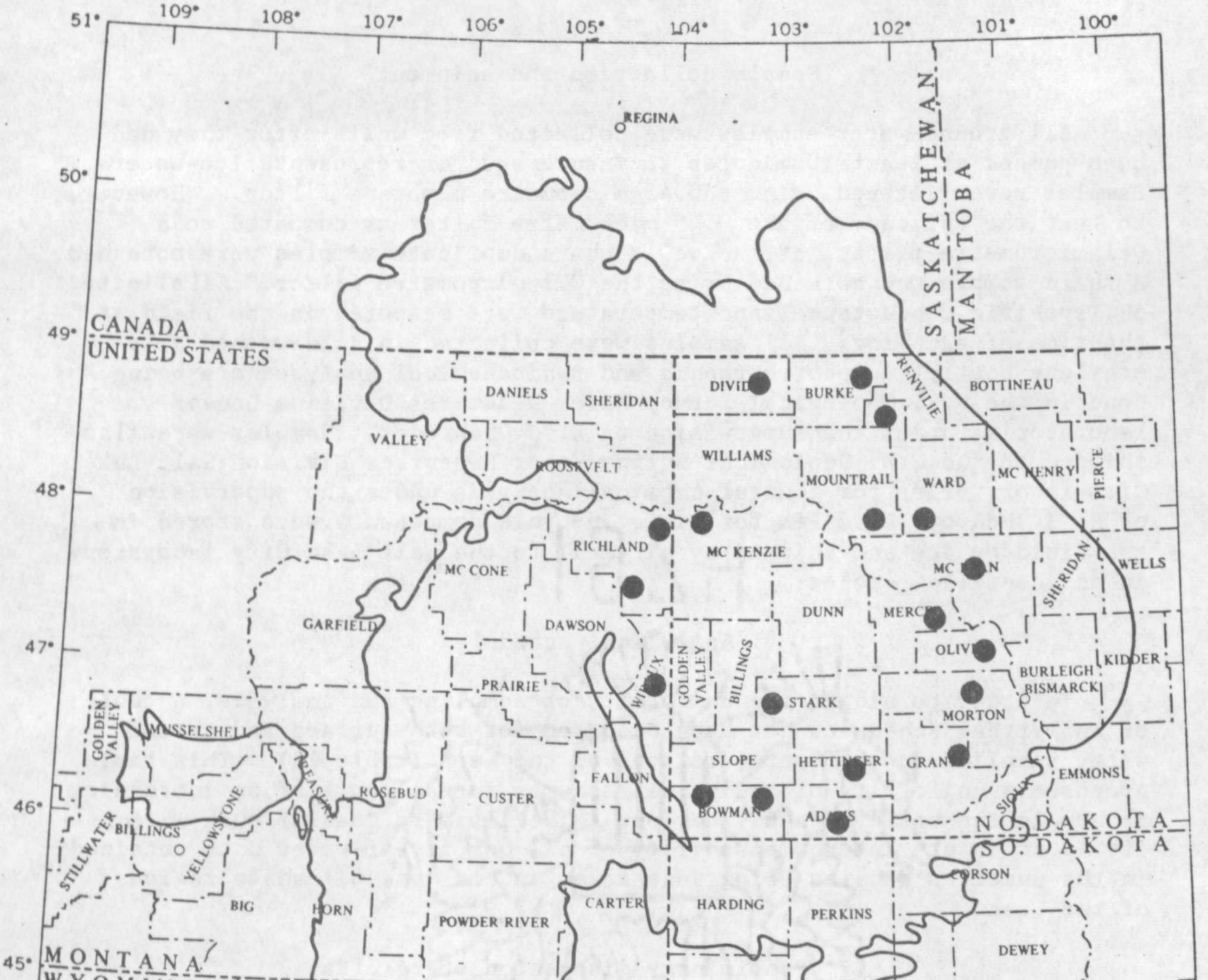



Figure 17. Locations selected for sampling well water in the Northern Great Plains.

## Sample collection and shipment

All ground-water samples were collected from wells after they had been pumped at least 10 minutes to insure aquifer-representative waters. Samples were filtered using a 0.45 micrometre membrane filter. However, to test the efficacy of the 0.45 micrometre filter as compared to a 0.1-micrometre filter, at the wells where duplicate samples were obtained, a third sample was obtained using the 0.1 micrometre filter. Alkalinity, pH, specific conductance, and temperature were measured in the field at the time of sampling. All samples were collected in acid-washed polyethylene bottles. Spectrographic and radiochemical analyses are being done in the U.S. Geological Survey Water Resources Division Denver laboratories under the supervision of L. J. Schroder. Samples were also shipped to the U.S. Geological Survey Water Resources Division Salt Lake City laboratories for general chemical analysis under the supervision of R. J. McAvoy. Samples for nitrogen-cycle components were stored in the field on ice and shipped by air mail to the Salt Lake City laboratory in an ice-filled cooler.

## Analytical schedule

In order to aid in the uniformity of sampling and analysis, a table of analytical schedules has been prepared for both surface and ground-water sampling in the energy regions of the West (table 12). This table proposes a uniformity of analytical schemes for all work of an inorganic nature in the western energy regions. The ultimate goal of such uniformity is to insure intercomparability of all quality-of-water data obtained in the numerous studies being undertaken in coal and oil shale regions of the West.

## Preliminary discussion of results

Partial laboratory analysis for 13 of the 19 townships sampled in this study have been received, and some preliminary interpretations are given below. Because data from all stations have not been received, an analysis of variance was not performed on the data. Table 13 lists the geometric mean, geometric deviation, maximum value, and minimum value for chemical constituents given in the 13 analytical results received.

Some chemical constituents, such as $NO_2$, As, Cd, Hg, I, Se, and noncarbonate hardness, were detected in such a small percentage of the samples that estimates of their geometric means and deviations were not made.

In general, chemical constituents measured in this study are highly variable among randomly selected wells throughout the Fort Union coal region, as shown by a few unusually high geometric deviations and the fact that, for most constituents, the maximum value is more than 10 times the minimum value. An examination of the scales at which this variability expresses itself must await completion of all analyses. In many of the wells sampled, ground water was collected directly from coal seams. In many areas of the Fort Union coal region, shallow coal seams are the best source of water available. In contrast to many eastern coal regions, acidic water is rarely encountered from coals in the western coal regions. Of all the samples in this study,only one had a pH below 7.0, and its pH was 6.79. However, in common with most ground waters obtained from coals, the waters in the Fort Union coal region are reducing waters (Eh less than zero), as indicated by the presence of $H_2S$ odors and relatively high concentrations of dissolved iron, ammonia, and organic nitrogen.

An interesting observation is the presence in these waters of generally much larger amounts of organic nitrogen than of ammonia, nitrate, or nitrite. Generally organic nitrogen in ground waters is associated with some form of organic pollution from human or animal activity at the ground surface. At present, an experiment is being undertaken to determine if the organic nitrogen found in ground waters of the Fort Union coal region is naturally occurring, and if it is naturally occurring, to determine what organic nitrogen compounds are present. According to J. A. Leenheer (oral commun., 1975), many stable, soluble, organic nitrogen compounds may be associated with coals. Chemical analysis of the organic nitrogen compounds will be performed by the U.S. Geological Survey Water Resources Division laboratories in Denver, Colorado,and Menlo Park, California.

In the fall of 1974, three ground-water samples were collected from the Fort Union coal region in southern Saskatchewan, Canada. These samples serve as a useful comparison to the results of the present sampling plan and are therefore included in table 13. However, because these samples were not collected as part of the present sampling design, they are not included in the statistical summaries given in table 13. The samples were collected from wells supplying municipal water supplies and by tapping ground water from the Fort Union Group or overlying glacial drift. In table 13, a comparison of the Canadian samples to the samples collected in the United States is shown. For the listed chemical constituents, the two groups of samples are very similar. Some of the differences that do exist may be due to the presence of glacial drift overlying the area where all the Canadian samples were obtained, while the samples collected in the United States were obtained from both glaciated and unglaciated areas.

One other comparison is of interest. An analysis of a water sample taken from the working face of the AMAX coal mine in Campbell County, Wyoming, was given in Feder (1974). The AMAX coal mine is in the Powder River coal region. Of all constituents measured in both that sample and the Northern Great Plains ground water, only Fe exhibits a distinct contrast. The water from the mine face contains less than 15 micrograms/litre Fe compared to an expected Fe concentration in the Northern Great Plains well water of over 300 micrograms/litre. In fact, the lowest observed concentration from the Northern Great Plains was 80 micrograms/litre.

Table 12.--*Required detection limits for constituents, recommended frequency of sampling, and possible effects of constituents on human health and agriculture for ground and surface water in the Western United States energy regions.*

[Semi-annual sampling should be done shortly after spring snowmelt and during late winter low-flow stage; quarterly sampling should be done each season. ND, not determined. Leaders (---), no data available.]

| Constituent | Recommended detection limit | | Sampling frequency | | | Possible effects | |
|---|---|---|---|---|---|---|---|
| | Ground water and surface water dissolved (0.45 um filter) | Bed material total recoverable | Ground water | Surface water: Dissolved | Surface water: Bed material | Human health | Agriculture |
| Ag | 10 µg/l | 1 ppm | ND | ND | ND | High levels may cause permanent blue-gray discoloration of skin and mucous membranes (argyria), (U.S. Public Health Service, 1962). | |
| Al | 10 µg/l | 10,000 ppm | Annual | Semi-annual | ND | | High levels may affect plant growth; toxic to plants on coal spoil piles (Sauchelli, 1969; Berg and Vogel, 1973). |
| As | 10 µg/l | 0.2 ppm | Annual | Semi-annual | Semi-annual | Poisonous at high levels; skin ulcers at intermediate levels; possibly carcinogenic (U.S. Public Health Service, 1962; Underwood, 1973). | High concentrations may poison livestock; in As-deficient areas, swine and poultry rations may be supplemented with As; high concentrations toxic to plants (Sauchelli, 1969). |
| B | 50 µg/l | 10 ppm | Annual | Semi-annual | ND | | Toxic to plants at high levels (sensitivity varies with species; low level needed; B-rich irrigation water in western coal regions may be toxic to certain plants (Sauchelli, 1969; U.S. Environmental Protection Agency, 1973). |
| Ba | 50 µg/l | 1 ppm | Annual | Semi-annual | Semi-annual | High levels may increase blood pressure; affects heart, blood vessels, and nerves (U.S. Public Health Service, 1962; U.S. Environmental Protection Agency, 1973). | |
| Be | 1 µg/l | 1 ppm | ND | ND | ND | Dust highly toxic; no known effects from presence in water; normally insoluble (U.S. Environmental Protection Agency, 1973). | |
| Bi | ------- | ----- | ND | ND | ND | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Br | 10 μg/l | ---------- | Annual | ND | ND | | |
| Ca | 1 mg/l | 1,000 ppm | Annual | Quarterly | Semi-annual | High levels may reduce incidence of heart disease and kidney stones (National Academy of Sciences, 1972). | Deficiency symptoms known (Sauchelli, 1969). |
| Cd | 1 μg/l | 1 ppm | Annual | Semi-annual | Semi-annual | High levels may cause hypertension; kidney damage (U.S. Environmental Protection Agency, 1973; National Academy of Sciences, 1972; Underwood, 1973; U.S. Public Health Service, 1962). | High levels are toxic to plants (Sauchelli, 1969). |
| Cl | 1 mg/l | ---------- | Annual | Quarterly | ND | Deficiency symptoms known (U.S. Environmental Protection Agency, 1973; U.S. Public Health Service, 1962. | Deficiency symptoms known (Sauchelli, 1969). |
| Co | 5 μg/l | 3 ppm | ND | ND | ND | Deficiency symptoms known (U.S. Environmental Protection Agency, 1973; National Academy of Sciences, 1972; Underwood, 1973). | Deficiency symptoms known (Sauchelli, 1969). |
| Cr, total (if >10 μg/l, do $Cr^{+6}$) | 5 μg/l | 1 ppm | Annual | Semi-annual | Semi-annual | Deficiency results in impaired glucose tolerance (National Academy of Sciences, 1972; Underwood, 1973). | Deficiency reduces crop yields (Sauchelli, 1969). |
| $Cr^{+6}$ | 5 μg/l | 1 ppm | ND | ND | ND | High levels may cause gastrointestinal hemorrhage and ulceration on dermal exposure (rarely occurs naturally, generally indicates man-made pollution), (U.S. Environmental Protection Agency, 1973; National Academy of Science, 1972; U.S. Public Health Service, 1962). | |
| Cu | 2 μg/l | 1 ppm | Annual | Semi-annual | Semi-annual | Gives water a foul taste. | Deficiency symptoms known; Cu/Mo ratio significant in animal diet (Sauchelli, 1969; Agarwal, 1975). |
| F | 100 μg/l | ---------- | Annual | Quarterly | ND | Reduces dental caries; excess may mottle teeth or calcify bones and joints (National Academy of Science, 1972; Agarwal, 1975; U.S. Public Health Service, 1962). | Harmful to cattle at high levels (fluorosis), (Sauchelli, 1969). |
| Fe | 20 μg/l | 500 ppm | Annual | Quarterly | Semi-annual | High levels cause laundry stains and foul taste; may aid in Fe-deficiency anemia; may stimulate pathogenic bacterial growth (U.S. Public Health Service, 1962; Hopps and Cannon, 1972.) | Deficiency diseases common; overdose can cause rickets (Sauchelli, 1969). |
| Ga | -------- | ---------- | ND | ND | ND | | |

Table 12.--*Required detection limits for constituents, recommended frequency of sampling, and possible effects of constituents on human health and agriculture for ground and surface water in the Western United States energy regions*--Continued

| Constituent | Recommended detection limit | | Sampling frequency | | | Possible effects | |
|---|---|---|---|---|---|---|---|
| | Ground water and surface water dissolved (0.45 um filter) | Bed material total recoverable | Ground water | Surface water | | Human health | Agriculture |
| | | | | Dissolved | Bed material | | |
| Ge---------- | -------- | ---------- | ND | ND | ND | | |
| Hg---------- | 0.2 µg/1 | 0.01 ppm | Annual | Semi-annual | Semi-annual | No known need; high levels toxic especially in organic forms (U.S. Environmental Protection Agency, 1973). | No known need; high levels toxic to all animals (Sauchelli, 1969; Underwood, 1973). |
| I---------- | 10 µg/1 | ---------- | Annual | ND | ND | Needed for synthesis of thyroid hormones; not known to be toxic in concentrations occurring in water supplies (National Academy of Sciences, 1972). | Some plants interfere with I utilization by animals (Sauchelli, 1969). |
| K---------- | 1 mg/1 | 100 ppm | Annual | Quarterly | ND | No reported toxic or deficiency effects due to water supply (U.S. Environmental Protection Agency, 1973). | Deficiency symptoms known (Sauchelli, 1969). |
| Li---------- | 10 µg/1 | 5 ppm | Annual | Semi-annual | ND | Large doses may reduce aggressive tendencies; may be significant in prevention of cardiovascular disease (National Academy of Science, 1972). | Plant tolerance variable among species; citrus plants especially sensitive (Sauchelli, 1969). |
| Mg---------- | 1 mg/1 | 300 ppm | Annual | Quarterly | Semi-annual | May be significant in prevention of cardiovascular disease and kidney stones (National Academy of Sciences, 1972). | Deficiency symptoms known (Sauchelli, 1969) |
| Mn---------- | 50 µg/1 | 100 ppm | Annual | Quarterly | Semi-annual | Deficiency symptoms known; causes stains and foul taste (U.S. Public Health Service, 1962). | Required; may show significant toxic and deficiency symptoms in plants and animals; important in poultry production (Sauchelli, 1969; Berg and Vogel, 1973). |
| Mo---------- | 1 µg/1 | 1 ppm | Annual | Semi-annual | Semi-annual | Deficiency symptoms known; may reduce dental caries; may increase kidney stones; causes "ginu valgum" (a crippling bone disease) (National Academy of Sciences, 1972; Agarwal, 1975). | Deficiency symptoms known; high bovine levels can cause molybdenosis, Cu/Mo ratio significant; clovers concentrate Mo (U.S. Environmental Protection Agency, 1973; National Academy of Sciences, 1972). |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ni | 1 µg/1 | 5 ppm | ND | ND | ND | Dust may be carcinogenic; no known toxicity from water source (U.S. Environmental Protection Agency, 1973). | Not required; may be toxic to some plants at low levels (Sauchelli, 1969). |
| N, total (if >5 mg/1, do $NO_3$, $NO_2$, $NH_3$, and organic N) | 0.1 mg/1 | 100 ppm | Annual | Quarterly | ND | Some forms cause methemoglobinemia in infants; may form carcinogenic nitrosamines (U.S. Environmental Protection Agency, 1973; U.S. Public Health Service, 1962). | Deficiency symptom known; high levels may be toxic to both plants and animals (Sauchelli, 1969). |
| $O_2$ | 1 mg/1 | ND | ND | Quarterly | ND | | |
| P | 0.1 mg/1 | 100 ppm | Annual | Quarterly | Semi-annual | Deficiency symptoms known; organo-phosphates toxic in water (U.S. Environmental Protection Agency, 1973). | Deficiency symptoms known; some P compounds toxic in water; important in algal growth (Sauchelli, 1969). |
| Pb | 1 µg/1 | 1 ppm | Annual | Semi-annual | Semi-annual | No known requirement; toxic--damages neural and renal systems (U.S. Environmental Protection Agency, 1973; National Academy of Sciences, 1972; Bowen, 1966; Underwood, 1973; Shakman, 1974; U.S. Public Health Service, 1962). | Not required; horses especially sensitive; may poison livestock (Sauchelli, 1969). |
| Rb | 10 µg/1 | ---------- | ND | ND | ND | | |
| $SO_4$ | 1 mg/1 | 100 ppm | Annual | Quarterly | ND | No known toxicity (U.S. Environmental Protection Agency, 1973; Shakman, 1974). | Deficiency symptoms known; no known toxicity (Sauchelli, 1969). |
| Sb | 1 µg/1 | 1 ppm | ND | ND | ND | No known effect from water; (U.S. Environmental Protection Agency, 1973). | |
| Se | 1 µg/1 | 0.1 ppm | Annual | Semi-annual | Semi-annual | Low level required, may inhibit cancer; high level toxic, may cause dental caries (U.S. Environmental Protection Agency, 1973; National Academy of Sciences, 1972; Bowen, 1966; Underwood, 1973; Shakman, 1974; U.S. Public Health Service, 1962). | Low level required; high level toxic to animals; inhibits leukemia in poultry (Sauchelli, 1969). |
| $SiO_2$ | 1 mg/1 | 10,000 ppm | Annual | Quarterly | ND | | Essential for poultry; may be essential for plants and animals (Sauchelli, 1969). |
| Sn | 1 µg/1 | 1 ppm | ND | ND | ND | | |
| Sr | 50 µg/1 | 5 ppm | Annual | ND | ND | | |
| Ti | 5 µg/1 | 10 ppm | Annual | Semi-annual | ND | | |
| Tl | 1 µg/1 | ---------- | ND | ND | ND | | |
| V | 5 µg/1 | 5 ppm | Annual | Semi-annual | Semi-annual | No known need; may cause methemoglobinemia (Shakman, 1974). | |
| Y | -------- | ---------- | ND | ND | ND | | |

Table 12.--*Required detection limits for constituents, recommended frequency of sampling, and possible effects of constituents on human health and agriculture for ground and surface water in the Western United States energy regions*--Continued

| Constituent | Recommended detection limit | | Sampling frequency | | | Possible effects | |
|---|---|---|---|---|---|---|---|
| | Ground water and surface water dissolved (0.45 um filter) | Bed material total recoverable | Ground water | Surface water: Dissolved | Surface water: Bed material | Human health | Agriculture |
| Zn------------ | 10 μg/l | 10 ppm | Annual | Semi-annual | Semi-annual | Essential nutrient; high aqueous levels may be toxic; deficiency results in growth failure, impaired would healing, delayed sexual maturity (U.S. Environmental Protection Agency, 1973; National Academy of Sciences, 1972; Bowen, 1966; Shakman, 1974; 1974; U.S. Public Health Service, 1962). | Essential; high levels may be toxic to plants and animals; deficiency symptoms known (Sauchelli, 1969). |
| Zr------------ | 5 μg/l | 10 ppm | ND | ND | ND | | |
| Specific conductance---- | -------- | ---------- | Annual | Quarterly | ND | | |
| Temperature-- | -------- | ---------- | Annual | Quarterly | Semi-annual | | |
| Total dissolved solids------ | -------- | ---------- | Annual | Quarterly | ND | | |
| Gross α------ | 10 pc/l | ---------- | Annual | Semi-annual | ND | May be carcinogenic (U.S. Environmental Protection Agency, 1973; U.S. Public Health Service, 1962). | |
| Gross β------ (if >100 pc/l, do U, Th, $^{210}Pb$, and $^{228}Ra$) | 10 pc/l | ---------- | Annual | Semi-annual | ND | May be carcinogenic (U.S. Environmental Protection Agency, 1973; U.S. Public Health Service, 1962). | |
| $^{226}Ra$-------- (if $^{226}Ra$ and gross α >5 pc/l do U and Th) | 1 pc/l | ---------- | Annual | Semi-annual | ND | Carcinogenic (U.S. Environmental Protection Agency, 1973). | |

| | | | | | |
|---|---|---|---|---|---|
| Dissolved organic carbon---------- (if >5 mg/l, do trace organics) | 1 mg/l | ---------- | Annual | ND | ND |

Note.--For aquatic organisms see U.S. Environmental Protection Agency (1973). Tolerances vary widely among aquatic organisms, and groups of constituents may show synergistic effects (i.e., a single constituent may be below the toxic level but if certain other constituents are present, also below toxic levels, the result may be toxic).

Table 13.--Chemical summary of ground water from the Northern Great Plains

[mg/l, milligrams per liter; ug/l, micrograms per liter; Leaders (---), no data available.]

| Chemical Constituent | U.S. Samples | | | | Canadian Samples | | |
|---|---|---|---|---|---|---|---|
| | Geometric Mean (GM) | Geometric Deviation (GD) | Maximum Value | Minimum Value | Sample 1 | Sample 2 | Sample 3 |
| Organic N (as N) mg/l | 2.7 | 1.26 | 3.4 | 1.6 | -------- | -------- | -------- |
| $NH_4$ (as N) mg/l | 0.16 | 5.75 | 1.30 | 0.01 | -------- | -------- | -------- |
| $NO_3$ (as N) mg/l | 0.14 | 8.13 | 4.1 | <0.01 | -------- | -------- | -------- |
| $NO_2$ (as N) mg/l | -------- | --------- | 1.2 | <0.01 | -------- | -------- | -------- |
| pH | 1/7.65 | 1/0.42 | 8.56 | 6.79 | 6.9 | 7.5 | 7.7 |
| Sp. Cond., micromhos/cm | 1,401 | 1.78 | 2,854 | 495 | 1,940 | 1,330 | 3,170 |
| Diss. solids (180°C) mg/l | 916 | 1.95 | 2,000 | 281 | 1,490 | 917 | 2,290 |
| As ug/l | -------- | --------- | 18 | <1 | <1 | 11 | 8 |
| Br ug/l | 142 | 2.88 | 1,200 | <100 | <100 | 100 | 800 |
| Ca mg/l | 49 | 2.51 | 180 | 8.9 | 200 | 81 | 88 |
| Cd mg/l | -------- | --------- | 1 | <1 | <1 | <1 | <1 |
| Cl mg/l | 11 | 3.24 | 120 | 1.8 | 4.0 | 4.4 | 130 |
| F mg/l | 0.35 | 1.95 | 1.3 | 0.1 | <0.1 | 0.3 | 0.3 |
| Fe ug/l | 346 | 3.31 | 3,600 | 80 | 830 | 2,700 | 2,100 |
| Hardness (Total as $CaCO_3$) mg/l | 221 | 2.63 | 1,000 | 42 | 880 | 380 | 380 |
| Hardness (noncarb.) mg/l | -------- | --------- | 670 | <1 | 260 | <1 | <1 |
| Hg ug/l | -------- | --------- | 0.1 | <0.1 | <0.1 | 0.1 | <0.1 |
| I ug/l | -------- | --------- | 250 | <10 | <10 | 10 | 400 |
| Mg mg/l | 25 | 2.82 | 140 | 4.8 | 93 | 43 | 38 |
| Mn ug/l | 15 | 4.37 | 150 | <1 | 390 | 180 | 120 |
| K mg/l | 5.8 | 1.95 | 34 | 2.7 | 14 | 8.1 | 7.0 |
| Na mg/l | 159 | 3.24 | 630 | 23 | 120 | 160 | 570 |
| SAR2/ | 4.7 | 4.27 | 24 | 0.7 | 1.8 | 3.6 | 13 |
| $SiO_2$ mg/l | 15 | 1.48 | 27 | 8.6 | 15 | 15 | 25 |
| Se ug/l | -------- | -------- | 6 | <1 | <1 | <1 | <1 |
| $SO_4$ mg/l | 201 | 3.02 | 830 | 36 | 540 | 250 | 910 |
| Zn ug/l | 67 | 12.59 | 2,500 | <1 | 40 | 40 | 10 |

1/ Arithmetic mean and standard deviation.

2/ Sodium absorption ratio.

## ANALYSIS OF ROCKS AND SOILS BY X-RAY FLUORESCENCE
by J. S. Wahlberg

Rocks and soils collected during the course of the geochemical survey of the western coal regions are being analyzed for the "major" rock oxides and a selected suite of minor elements by X-ray fluorescence techniques.

The basis of analysis by X-ray spectrometry is that when an X-ray of sufficient energy is absorbed by an atom, that atom re-emits an X-ray with a wavelength characteristic of the element. Using a crystal of known lattice spacing to diffract these emitted X-rays, their wavelengths can be identified from their angle of diffraction. The analogy to optical emission spectrometry is nearly perfect, with the substitution of a crystal for a diffraction grating. The intensity of the specific emitted X-ray is measured by a device such as a scintillation counter rather than a photographic plate. Useful texts on this method are those by Jenkins and de Vries (1967) and by Bertin (1970).

As in most forms of spectrometry, the concentration of an element may be obtained by comparing the intensity of the emitted rays from the sample with those from known standards. However, as in other spectrometric methods, the amount that the unknowns may differ in composition from the standards is subject to many limitations. The various methods of fluorescence analyses are largely concerned with removing or suppressing interferences, so that the concentrations of interest in the unknowns can be obtained by comparison with a limited number of standards.

Three different methods are used in the analysis of rocks and soils. A <u>fusion method</u> is used for determining "major" elements. This method overcomes most interferences by dilution. It also homogenizes the sample as the fusion is essentially a fluid solution. The remaining interferences are handled by the calculation method of Lucas-Tooth and Pyne (1964).

The fusion method is used for silica, alumina, total iron (as $Fe_2O_3$), calcium oxide, potassium oxide, magnesium oxide, phosphorus pentoxide, sulfur, titanium dioxide, manganese oxide, and chloride. These elements are generally present in major amounts and, by custom and for convenience, are expressed as percent oxides. The fusion method is relatively rapid.

In this procedure, 0.40 g of prepared sample is weighed into 6.35 g of flux and mixed. This flux consists of 450 g $Na_2B_4O_7$, 350 g $Li_2B_4O_7$, and 30 g NaBr. The mixture, in a 25-ml platinum-gold crucible, is placed in a claise fluxer, heated for about 15 minutes, and cast into a one-inch disk.

The samples are counted in a vacuum X-ray spectrometer. The percent concentrations are obtained by using the Lucas-Tooth method where the influence coefficients were obtained by counting standards of known concentrations. The following table summarizes the X-ray parameters used:

| Parameters | Elements | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mg | Al | Si | P | S | Cl | K | Ca | Ti | Mn | Fe |
| Target---- | Cr | Cr | Cr | Cr | Cr | Cr | Cr | Cr | Mo | Mo | Mo |
| Detector-- | Flow | Flow | Flow | Flow | Flow | Flow | Flow | Flow | Flow | Flow | Flow |
| Crystal--- | Rap | Pet | Pet | Pet | NaCl | NaCl | Pet | LiF | LiF | LiF | LiF |
| 2θ degrees | 44.48 | 144.67 | 109.06 | 89.40 | 144.53 | 113.91 | 50.64 | 113.08 | 86.13 | 62.97 | 57.52 |

For trace elements, dilution is obviously undesirable, whereas a <u>preconcentration</u> <u>method</u> may both remove interference and concentrate the element or elements sought to amounts more amenable to detection and estimation. In some cases a suitable matrix may also be obtained.

The determination of the traces of Ge, As, Se, Bi, Sn, Sb, and Te includes a preconcentration. A ten gram sample is decomposed with 20 ml $H_2SO_4$, 30 ml HF, and approximately 20 ml $HNO_3$. After all of the acids except $H_2SO_4$ are removed by heating to dense $SO_3$ fumes, the sample is then diluted with $H_2O$ to approximately 200 ml, and 5 mg of Cu are added. The insoluble acid sulfides are then precipitated by gassing with $H_2S$. The sample is filtered and the filtrate discarded. The precipitate is dissolved in 200 ml of 7.5% $H_2SO_4$. Approximately ½ ml of $Br_2$ is added and the sample shaken to dissolve all of the insoluble sulfides. The sample is again filtered, and the excess $Br_2$ in the filtrate is reduced with hydrazine sulfate. The acid sulfides are again precipitated by gassing with $H_2S$. This precipitate is collected on a 45-micron microporous membrane filter, dried, and placed on a one-inch Caplug for counting. A peak and off-peak count is made, and the amount of Ge, As, Se, Bi, Sn, Sb, and Te are determined by comparing the net count with that obtained from known standards similarly processed and counted. Where spectral interferences occur, these are also considered in the calculation. The method has a lower detection limit of 0.1 ppm for all of the elements. The X-ray parameters are as follows:

| Parameters | Elements | | | | | | |
|---|---|---|---|---|---|---|---|
| | Ge | As | Se | Bi | Sn | Sb | Te |
| Target---- | Mo | Mo | Mo | Mo | Cr | Cr | Cr |
| Detector-- | Scint | Scint | Scint | Scint | Flow | Flow | Flow |
| Crystal--- | LiF | LiF | LiF | LiF | LiF | LiF | LiF |
| 2θ degrees | 36.33 | 33.96 | 31.89 | 33.01 | 114.40 | 106.46 | 109.54 |
| Path------ | Air | Air | Air | Air | Vac. | Vac. | Vac. |

## ANALYSIS OF ROCKS AND SOILS FOR TOTAL CONTENT OF SODIUM, MAGNESIUM, LITHIUM, RUBIDIUM, ZINC, CADMIUM, MERCURY, FLUORINE, AND CARBON

by Claude Huffman, Jr.

Samples of rocks and soils collected during the course of the western coal regions survey are being analyzed for Na, Mg, Li, Rb, Zn, Cd, and Hg by atomic absorption spectroscopy, for F by a selective-ion electrode method, and for C by an induction-furnace gasometric determination.

### Atomic Absorption Spectroscopy

Na, Mg, Li, Rb, and Zn are determined by flame atomic absorption spectroscopy. Weigh and transfer 1 g of prepared sample to a 100-ml platinum dish. Add 10 ml demineralized water, 10 ml $HNO_3$, and 10 ml HF to the dish. Cover dish and let stand overnight. Remove cover, add 9 ml $HClO_4$, and place dish on a steam bath for 1 hr. Then place dish on a hot plate and fume off acids to near dryness. Remove dish from hot plate and wash down sides of the dish with about 10 ml water. Add 5 ml $HClO_4$ to the dish, return dish to hot plate, and fume off acids to dryness. Remove dish from the hot plate, add about 25 ml water and 5 ml HCl. Cover dish, place on a steam bath, and digest for 30 min. Remove dish from hot plate and allow contents to cool. Transfer the solution to a 100 ml volumetric flask and dilute to volume with water. Aspirate aliquots or dilutions of this sample solution into the air-acetylene flame of an atomic absorption spectrometer to determine the elements listed. The sample aliquot used for the determination of Mg was made to contain 1 percent La and the sample aliquot used for the determination of Rb was made to contain a sodium-potassium ionization buffer. The instrumental parameters used for the listed elements are those recommended by the Perkin-Elmer Corporation. Appropriate hollow cathode lamps are used for each element. Standard solutions containing known concentrations of the elements to be determined are used for calibration. The concentration of Na and Mg are reported as oxides.

Cadmium is determined only if the zinc content of the sample exceeds 200 ppm. Weigh and transfer 1.0 g of sample to a 150 ml beaker. Add 10 ml of water and 10 ml of $HNO_3$ to the beaker and cover. Place beaker on a shaking hot plate and boil until the volume of solution is reduced to about 5 ml. Remove beaker from the hot plate and allow to cool. Wash down the sides of the beaker with about 20 ml water. Place the beaker on a steam bath, cover, and digest for 1 hr. Transfer the contents of the beaker to a 50 ml volumetric flask, cool, dilute to volume with water, and mix. Allow the solids to settle overnight. Aspirate a portion of the clear sample solution into the air-acetylene flame of an atomic absorption spectrometer using deuterium background correction. The instrumental parameters used are those recommended by the Perkin-Elmer Corporation. Standard solutions containing known concentrations of cadmium are used for calibration.

Mercury is determined by the flameless atomic absorption method (Huffman, Rahill, Shaw, and Norton 1972). Weigh and transfer 0.5 g of sample to a 250 ml Erlenmeyer flask. Add 10 ml $HNO_3$, 10 ml $H_2SO_4$, and 2 ml $HClO_4$ to the flask and let stand overnight. Place flask on a Variac controlled cold hot plate. Place a watch glass and then a 150 ml beaker half filled with ice water on top of the flask. Digest the contents of the flask for about 3 hours, gradually increasing the heat to 170°C until fumes of $HClO_4$ appear. Remove the flask from the hot plate and allow the contents to cool. The sample digestion procedure is that developed by Van E. Shaw of our laboratory (oral communication, 1973). Transfer the contents of the flask to the aeration flask. Adjust the volume of the solution in the aeration flask with water to about 100 ml, and add 2 ml of 10-percent stannous-chloride solution. Details of the aeration train apparatus, aeration procedure, and instrumental parameters used are given in the paper by Huffman, Rahill, Shaw, and Norton (1972). Mercury is aerated from solution into a silver screen placed in the vapor train. This silver screen is subsequently heated and the mercury vapor is carried by air stream to an absorption cell where its concentration is measured by atomic absorption spectrometry. Known mercury standard solutions are processed through the aeration procedure for calibration.

Selective-ion electrode method for analysis of fluorine

Weigh and transfer 25 milligrams of sample to a 30 ml zirconium crucible. Add 3 pellets of NaOH (0.4 g) to the crucible. Place lid on crucible and fuse over an open burner. Allow crucible to cool and then place crucible and lid in a plastic beaker. Add water to dissolve the fused mass and filter into a 100 ml volumetric flask. Wash residue with about 5 ml of a 1 percent w/v NaOH solution, dilute to volume with water, and mix. Transfer a 20 ml portion of the sample solution to a 100 ml volumetric flask, dilute to volume with a 1 M ammonium citrate solution, and mix. Pour about 50 ml of this solution into plastic beaker and measure its potential with a pH meter equipped with a fluorine selective-ion electrode. Standard solutions of known concentration (0.02 to 20 ppm) are used for calibration.

Analysis for total carbon

Total carbon is determined by the Leco induction furnace gasometric method, a method that has been used in the steel industry for many years. Weigh and transfer 0.2 to 0.4 g of sample to a Leco ceramic crucible. Add one or more combustion accelerators (tin metal, iron chips, and tin-coated copper) to the crucible. Place the crucible in a high-frequency induction furnace within an enclosed combustion tube through which pure oxygen is passed. Heat the sample and crucible to over 1300°C for 2 or 3 min. Pass the evolved gases, which include carbon dioxide, oxides of sulfur, and possibly carbon monoxide, through a trap containing manganese dioxide to remove the sulfur oxides, then through a heated catalyst where any CO is converted to $CO_2$. Measure the amount of $CO_2$ gas evolved with the Leco WR-12-automatic determinator. Standard samples with known carbon content are used for calibration.

The lower limits of determination for the constituents analyzed by the above methods are:

| Constituent | Method | Lower limit - ppm |
|---|---|---|
| $Na_2O$ | Atomic absorption | 100 |
| MgO | Atomic absorption | 300 |
| Li | Atomic absorption | 5 |
| Rb | Atomic absorption | 20 |
| Zn | Atomic absorption | 10 |
| Cd | Atomic absorption | 1 |
| Hg | Flameless atomic absorption | .01 |
| F | Selective-ion electrode | 400 |
| C | Induction furnace-gasometric | 500 |

## ANALYSIS OF PLANTS OR PLANT ASH BY METHODS OTHER THAN EMISSION SPECTROSCOPY

by T. F. Harms and Clara S. E. Papp

Prior to analysis, the plant samples are dried at 38-40°C and ground in a Wiley mill to form a homogeneous mass. After grinding, the particle size is such that it will pass through a screen with aperture of 1.3 mm. Analyses for Hg, Se, As, Sb, F, S, and ash are made on the dried vegetation. Cd, Co, Zn, Na, Li, Ca, K, Si, P, and U are determined on the ash obtained by dry ignition of the vegetation in a furnace that is slowly heated from room temperature to 450°C.

Se and U are determined fluorimetrically, F is measured by a selective-ion electrode, P is determined by colorimetric procedures, and S is determined by a turbidimetric procedure. All of the remaining elements determined in the dried vegetation and plant ash are measured by atomic absorption spectrometry.

A brief description of the chemical methods that are used follows:

### Mercury

Dried ground vegetation is digested in nitric and sulfuric acids using a small amount of vanadium pentoxide as a digestion aid (Deitz, Sell, and Bristol, 1973). When dissolution is complete, the sample is cooled and diluted with water. The mercury is reduced to its elemental state by the addition of stannous chloride solution and is flushed by a stream of air onto gold foil, where it is amalgamated. The gold foil is then heated, and the released mercury vapor is swept into an absorption cell attached to an atomic absorption spectrophotometer. The absorbance of the mercury peak is recorded and compared to the absorbance values of known concentrations of mercury that have been similarly treated.

### Selenium

Air-dried ground vegetation is partially digested by heating with nitric acid. The solution is cooled slightly, and small amounts of hydrogen peroxide are added to help destroy the remaining organic material. The digestion is completed by adding perchloric acid to the sample solution and boiling off the nitric acid. The perchloric acid digestate is warmed with dilute hydrochloric acid to reduce the selenate ion in the solution to the selenite ion. The pH is adjusted to 2.0 with ammonium hydroxide, and the selenium is reacted with 2, 3-diaminonaphthalene to form a fluorescent complex that is extracted into cyclohexane. Known concentrations of selenium are reacted with 2,3-diaminonaphthalene, and the fluorescence is plotted against concentration to form a calibration curve. The fluorescence of the sample is measured and the selenium content established by reference to the calibration curve.

## Arsenic and antimony

For the determination of arsenic, dried ground vegetation is digested in a mixture of nitric, sulfuric, and perchloric acids. For the determination of antimony, the vegetation is decomposed with a mixture of nitric and sulfuric acids, using a small amount of vanadium pentoxide to serve as a catalyst for the digestion. After sample dissolution is complete, the digestate is heated to fumes of sulfur trioxide, cooled, and diluted with metal-free water. The arsenic or antimony in solution is reduced to its trivalent state by the addition of a mixture of potassium iodide and stannous chloride solutions and is then reacted with sodium borohydride to form gaseous arsine or stibine. The gaseous hydride is removed from solution by aeration and is swept by a flow of nitrogen into a hydrogen flame of an atomic absorption spectrophotometer. The absorbance is measured and compared to the absorbance measured from known amounts of arsenic or antimony.

## Fluorine

Air-dried ground vegetation is mixed with 50 percent sodium hydroxide solution, dried in an oven, and completely ashed at 500°C in an open nickel crucible. The ash is leached several times with hot distilled water, and the leachate is placed in a plastic petri dish that serves as a diffusion cell. Perchloric acid is added to acidify the solution, and the sample is diffused overnight using a small container of dilute sodium hydroxide to trap the hydrogen fluoride. A small amount of dilute perchloric acid is saturated with hexamethyldisiloxane and is added to the solution in the petri dish to aid in the diffusion of the fluoride ion (Taves, 1968). The sodium hydroxide solution is mixed with TISAB (total ionic strength adjustment buffer), and the fluoride ion is measured using a fluoride selective ion electrode. Known concentrations of fluoride, which have been diffused and diluted with TISAB before measurement, are used for preparing calibration curves.

## Sulfur

Sulfur is determined turbidimetrically as barium sulfate. Dried ground vegetation is mixed with fuming nitric acid, and the mixture is slowly evaporated to dryness on a steam bath. The residue is ashed at 450°C to destroy the remaining organic material. Sulfate is solubilized by repeated leaching of the ash with small volumes of hot metal-free water. An aliquot of the leachate is made slightly acid with sodium chloride-hydrochloric acid solution, and solid barium chloride is added. The turbidity caused by the barium sulfate suspension is measured in a spectrophotometer and compared to that measured from known amounts of sulfate standard to determine the sulfur content.

## Percent ash

Four grams of dried ground vegetation are weighed and placed in a crucible. The crucibles are placed in a cold muffle furnace, and the temperature of the furnace is slowly raised over a period of approximately 10 hours to 450°C. The furnace is maintained at this temperature for 12 hours and then is allowed to cool. The ash is weighed to three significant figures and the percent ash is calculated.

After the percent ash for each sample has been determined, sufficient quantities of vegetation are ashed to obtain the amount of ash required for those elements that are determined in the ash and for spectrographic analysis. A small plastic ball is added to each container of ash and the contents are shaken thoroughly to pulverize and mix the ash.

## Cadmium and cobalt

Air-dried ground vegetation is ashed at 450°C. The ash is heated with nitric and dilute hydrochloric acids. The samples are filtered to remove the insoluble materials and the pH of the filtrate is adjusted to 2.2 with ammonium hydroxide. The solubilized cadmium and cobalt are reacted with diethylammonium diethyldithiocarbamate to form complex species, which are then extracted into methyl-isobutyl ketone. The ketone is atomized into an air-acetylene flame of an atomic absorption spectrophotometer, and the absorption due to cadmium or cobalt is measured. Known concentrations of cadmium and cobalt are extracted into ketone and atomized in the same manner as the samples, and a calibration curve is established by plotting concentration of the element against absorbance.

## Zinc, lithium, sodium, calcium, potassium, and silicon

These elements are determined by atomic absorption spectrometry. Air-dried ground vegetation is ashed at 450°C. For the determination of zinc, lithium, and sodium, the ash is leached with hot 4 N nitric acid. The samples are centrifuged, and the supernatant solution is atomized directly into an acetylene-air flame. For calcium and potassium, the ash is leached with 6 N HCl on a steam bath. The sample solutions are diluted and 10 percent lanthanum solution is added to the aliquot for calcium, so that the final solution contains 1 percent lanthanum ion to mask interferences caused by aluminum, phosphate, and sulfate ions. The solution is atomized directly into an air-acetylene flame. For the determination of silicon, the ash is fused with potassium hydroxide in a nickel crucible. The melt is dissolved in water and is slightly acidified with dilute hydrochloric acid. The resulting solution is atomized directly into a nitrous-oxide-acetylene flame. Standard solutions containing known concentrations of the element to be determined are used for calibration.

## Phosphorus

Air-dried ground vegetation is ashed at 450°C, and the ash is heated with 4 N $HNO_3$. The samples are diluted and centrifuged, and an aliquot of the supernatant solution is reacted with ammonium molybdate-ammonium meta-vanadate reagent to form a yellow phosphorus complex. The yellow color is compared visually with the color of standard solutions prepared in a similar manner to determine the phosphorus concentration.

## Uranium

Uranium is determined by the procedure published by Huffman and Riley (1970). Dried ground vegetation is ashed at 450°C. The ash is leached with hot 2.5 N nitric acid, and the solution is cooled and saturated with aluminum nitrate. Uranyl nitrate is extracted into ethyl acetate, using the aluminum nitrate as a salting agent. An aliquot of the ethyl-acetate extract is evaporated, and the residue is fused with a flux composed of sodium carbonate, potassium carbonate, and sodium fluoride to form a fluorescent bead. The fluorescence of the bead--phosphor--is measured and compared to the fluorescence of phosphor containing known amounts of uranium, to determine the uranium content.

The lower limits of determination for the elements analyzed by the above methods are listed in the following table. The lower limits are based on the sample weight normally used for the determination and may vary because of limitations on the sample size.

| Element | Method | Sample Weight | Lower Limit (ppm) |
|---|---|---|---|
| Hg | Flameless AA | 1 g dry weight | 0.01 |
| Se | 2, 3-diaminonaphthalene | 2 g dry weight | .01 |
| As | Atomic absorption | 1 g dry weight | .05 |
| Sb | Atomic absorption | 1 g dry weight | .05 |
| F | Selective-ion electrode | 1 g dry weight | 1 |
| S | Turbidimetric | .5 g dry weight | 100 |
| Cd | Atomic absorption | .5 g ash | .2 |
| Co | Atomic absorption | .5 g ash | 1 |
| Zn | Atomic absorption | .05 g ash | 20 |
| Na | Atomic absorption | .05 g ash | 25 |
| Li | Atomic absorption | .05 g ash | 4 |
| Ca | Atomic absorption | .05 g ash | 100 |
| K | Atomic absorption | .05 g ash | 100 |
| Si | Atomic absorption | .025 g ash | 100 |
| P | Colorimetric | .05 g ash | 100 |
| U | Fluorimetric | .05 g ash | .4 |

## DETERMINATIONS OF URANIUM AND THORIUM IN ROCKS AND SOILS BY THE DELAYED NEUTRON TECHNIQUE

by H. T. Millard, Jr.

The basis for the analytical technique of neutron activation-delayed neutron counting (Amiel, 1962; Dyer, Emery, and Leddicote, 1962; Gale, 1967) is the emission of "delayed" neutrons by the fission daughters of uranium and thorium. These neutrons can be detected and counted with good discrimination and efficiency and thus the technique is both specific and sensitive. It allows the rapid, precise, and nondestructive determination of uranium to about 0.1 ppm and thorium to about 1 ppm in 10-gram samples of rocks and soils. Lower detection limits for uranium can be realized by recycling the same sample several times and thus improving the counting statistics.

The details of the procedure used are given elsewhere (Millard, 1975). Only a summary of that procedure will be presented here.

### Preparation of monitors and samples

A uranium standard solution (0.982 mg U/g solution) and a thorium standard solution (1.013 mg Th/g solution) were prepared and calibrated by isotope dilution-mass spectrometry. A uranium monitor (500 μg U) and thorium monitor (500 μg Th) were then prepared by adding aliquot portions of the standard solutions to dunite powder (DTS-1, 3 ppb U and 10 ppb Th). A high-level thorium monitor (10,000 μg Th) was prepared by mixing dunite powder with thorium oxide powder. These monitors were then calibrated against a set of laboratory standard rocks using the delayed neutron technique. For most of these rocks, the uranium and thorium concentrations had been determined by isotope dilution-mass spectrometry, and their homogeneity had been established by delayed neutron analysis of carefully prepared splits.

Tared 2-dram polyethylene snap-cap vials were filled with the sample powders (6 to 10 g of sample), weighed, and heat-sealed.

### Irradiation and counting procedure

The samples and monitors are first irradiated for 1 minute at a power level of 100 KW, using a bare pneumatic tube terminus in the U.S. Geological Survey TRIGA Reactor (GSTR). The activity is allowed to decay for 20 seconds, and the sample is counted for 1 minute in a $BF_3$ counter. After all samples have been run, a cadmium-lined pneumatic tube terminus is installed in the GSTR, and the samples and monitors are reirradiated at a power level of 1 MW and are counted as in the first irradiation. The cadmium reduces the flux of slow neutrons and thus increases the count rate due to thorium relative to the rate due to uranium. A timing signal for the movement of the sample into and out of the reactor is derived from the solenoid, which controls the direction of the air in the pneumatic tube. This timing signal and the counting signals are transmitted to a minicomputer that stores the data on magnetic tape and paces the operation of the system so a sample can be run every 90 seconds.

The analytical parameters for a single cycle of two irradiations and countings are as follows:

| Parameters | Reactor power level | | | |
|---|---|---|---|---|
| | 100 KW | | 1 MW (Cd-lined terminus) | |
| | U | Th | U | Th |
| Sensitivity, cps/μg ----- | 1.24 | 0.0173 | 1.00 | 0.142 |
| Counter background, cps - | 4.0±0.25 | 4.0±0.25 | 4.0±0.25 | 4.0±0.25 |
| Weight of element equivalent to counter background, μg ---------- | 3.2±0.20 | -- | -- | 2.8±1.5 |
| 3-sigma detection limits equivalent to counter background: | | | | |
| Weight of element, μg -- | .60 | -- | -- | 5.4 |
| Concentration in 1-g sample, ppm ------- | .60 | -- | -- | 5.4 |
| Concentration in 10-g sample, ppm ------ | .060 | -- | -- | .54 |

## Corrections to the data

The dead time of the counting system at high count rates is dominated by the recovery time of the $BF_3$ detectors. The correction was found (Stevenson, 1966, p. 112) to follow the relation:

$$\frac{cps_t}{cps_o} = \frac{cps_o}{1 - (t \times cps_o)} ,$$

where t is 7.8 μS, cps is counts per second, and the subscripts t and o indicate the true and observed counting rates, respectively.

The reaction $^{17}O$ (n,p) $^{17}N$ causes an interference during the second irradiation due to emission of delayed neutrons by $^{17}N$. This interference results in erroneously high values for the thorium concentration. The magnitude of this interference is equal to 0.30 cps/g oxygen, which, in turn, is equivalent to 0.89 ppm Th for a 10-g sample containing 44 percent oxygen.

## Calculations

The calculations are performed off-line by the minicomputer using the data for the two irradiations stored on magnetic tape. After the counter background has been subtracted and the dead time and oxygen corrections applied, the following simultaneous equations are solved for the weights of uranium (wt U) and thorium (wt Th):

$$(cps)_1 = (\text{wt U})\ (cps/\mu g\ U)_1 + (\text{wt Th})\ (cps/\mu g\ Th)_1,$$

and

$$(cps)_2 = (\text{wt U})\ (cps/\mu g\ U)_2 + (\text{wt Th})\ (cps/\mu g\ Th)_2\ .$$

The subscripts 1 and 2 denote the irradiation, and cps/μg U and cps/μg Th are computed from the counting data for the U and Th monitors, respectively. In addition, the standard deviations for wt U and wt Th are computed from the counting statistics, and the results are then reduced to (ppm U) $\pm$ $C.V._{cs}$ and (ppm Th) + $C.V._{cs}$, where $C.V._{cs}$ is the coefficient of variation based on the counting statistics.

The precision of this method in soil material is quite good. The geometric error for U and Th in soils of the Powder River Basin, found by Keith, Anderson, and Connor (1974, p. 19), was 1.03 and 1.10, respectively. Tidball (table 8, this report) estimates the same errors as 1.08 and 1.15, respectively. This indicates that a reported value for U should fall within 10-20 percent of the true value about 95 percent of the time and that a reported value for Th should fall within 20-30 percent of the true value about 95 percent of the time.

## MISCELLANEOUS GEOCHEMICAL DATA ON LATE CRETACEOUS AND EARLY TERTIARY FINE-GRAINED SEDIMENTARY ROCKS FROM THE WESTERN COAL REGIONS

by R. V. Mendes and George Van Trump, Jr.

The bulk of the western coal currently being mined or subject to mining in the near future is of Late Cretaceous or early Tertiary age. In general, it occurs above the broad expanse of carbonaceous gray marine shales, regionally referred to as the Mancos, Pierre, or Lewis Shales of Cretaceous age, and below less well bedded, generally variegated rocks of fluviatile aspect, commonly referred to the Wasatch Formation of Eocene age or its lithic equivalents.

Development of these coal resources, particularly by surface mining, will result in drastic changes in the local landscape. One of the more important of these changes could be the "substitution" of the natural soil cover with an unnatural cover composed in part of a mixed accumulation of those rocks associated with or lying above strippable coal layers.

This report lists some miscellaneous chemical analyses of a large number of such rocks already analyzed in laboratories of the U.S. Geological Survey (table 14). This list is meant to be neither final nor comprehensive but simply reports on geochemical data available in one U.S. Geological Survey analytical file as of June 30, 1975.

The results given here represent a variety of field investigations undertaken by a number of independent investigators and are not intended to be "typical" of the rocks that may eventually become part of a reclaimed landscape. Nevertheless, they do offer a good deal of insight into the wide variety of geochemical types that can be encountered in coal overburden. Insofar as possible, samples known or suspected to be metamorphically altered, hydrothermally mineralized, or similarly changed have been deleted from this list, as have samples that were leached, separated, or otherwise processed in a destructive manner prior to analysis. Some samples in this listing, however, had to be ashed prior to analysis because of a relatively high organic content. For such samples, all chemical results were obtained on an ash basis, except Hg, F, Se, As, and Sb.

Additional geochemical data on overburden in the western coal regions may be found in U.S. Geological Survey (1973, 1974b). Preliminary information on chemistry of western coal may be found in Swanson (1972) and Swanson, Huffman, and Hamilton (1974).

TABLE 14.-- Miscellaneous analytical data on fine-grained rocks of Late Cretaceous and early Tertiary age from Colorado, Montana, New Mexico, North Dakota, and Wyoming

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* THE DATA FROM WHICH THIS RETRIEVAL WAS MADE CONSTITUTE A MISCELLANEOUS COLLECTION OF ANALYSES FROM A VARIETY OF FIELD AND *
* LABORATORY INVESTIGATIONS. THE U. S. GEOLOGICAL SURVEY MAKES NO GUARANTEE OF THE ACCURACY OR COMPLETENESS OF THESE DATA. *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

THE GEOCHEMICAL DATA ARE LISTED BY THE STANDARD SYMBOLS FOR THE CHEMICAL ELEMENT OR COMPOUND IN PERCENT (%) OR IN PARTS PER MILLION (PPM). PROPERTIES NOT CHEMICAL IN NATURE ARE GIVEN IN CONVENTIONAL UNITS. PROPERTIES WHICH MAY APPEAR IN THIS LISTING, BUT WHICH ARE NOT READILY INTERPRETED ARE DEFINED HERE:

| | | | |
|---|---|---|---|
| FETO3 | = TOTAL IRON AS FERRIC OXIDE | N-TOT | = TOTAL NITROGEN |
| TOT H2O | = TOTAL WATER | N-ORG | = ORGANIC NITROGEN |
| TOT RE | = TOTAL RARE EARTHS | P-TOT | = TOTAL PHOSPHORUS |
| ORGNC C | = ORGANIC CARBON | WSSALTS | = WATER SOLUBLE SALTS |
| CRBNT C | = CARBONATE CARBON | POW DEN | = POWDER DENSITY (GRAMS PER CUBIC CENTIMETER) |
| GRPHT C | = GRAPHITIC CARBON | BULK DEN | = BULK DENSITY (GRAMS PER CUBIC CENTIMETER) |
| EQTH | = EQUIVALENT THORIUM | SP GRAV | = SPECIFIC GRAVITY |
| EQU | = EQUIVALENT URANIUM | LOI | = LOSS ON IGNITION |
| ALKL | = ALKALINITY, AS CALCIUM CARBONATE | A INSOL | = ACID INSOLUBLE |
| HRDN | = HARDNESS, AS CALCIUM CARBONATE | OIL | = OIL BY FISCHER ASSAY |
| HD-C | = CARBONATE HARDNESS | SH | = SPENT SHALE BY FISCHER ASSAY |
| HD-NC | = NON-CARBONATE HARDNESS | GAS | = GAS PLUS LOSS BY FISCHER ASSAY |
| DSOL | = DISSOLVED SOLIDS | OIL GAL | = OIL, GALLONS PER TON BY FISCHER ASSAY |
| SSOL | = SUSPENDED SOLIDS | H2O GAL | = H2O, GALLONS PER TON BY FISCHER ASSAY |
| SP CNDCT | = SPECIFIC CONDUCTANCE, MICROMHOS PER CENTIMETER | OIL GRAV | = SPECIFIC GRAVITY OF OIL |
| DOXY | = DISSOLVED OXYGEN | COKING | = TENDENCY TO COKE; 1=NONE, 2=SLIGHT, 3=MEDIUM, 4=HEAVY |

A LABEL ENDING IN "-S" MEANS THE ELEMENT CONCENTRATION WAS MEASURED BY EMISSION SPECTROGRAPHY. A LABEL CONTAINING A "/A" MEANS THE SAMPLE WAS ASHED PRIOR TO ANALYSIS. SOME OF THE DATA LISTED HEREIN MAY CARRY WITH IT SPECIAL SYMBOLS WHOSE MEANINGS ARE:

N = CONSTITUENT NOT DETECTED AT LOWER LIMIT OF DETERMINATION
H = CONSTITUENT NOT DETERMINED BECAUSE OF INTERFERENCE
L = CONSTITUENT LESS THAN GIVEN VALUE, OR IF GIVEN VALUE IS ZERO, CONSTITUENT LESS THAN LOWER LIMIT OF DETERMINATION
G = CONSTITUENT GREATER THAN GIVEN VALUE, OR IF GIVEN VALUE IS ZERO, CONSTITUENT GREATER THAN UPPER LIMIT OF DETERMINATION
B = BLANK, NO DATA AVAILABLE
T = CONSTITUENT PRESENT IN TRACE AMOUNTS

IF ALL DATA FOR A SAMPLE ARE QUALIFIED BY THE SYMBOL B, IT MEANS THAT THE SAMPLE HAS BEEN SUBMITTED BUT NOT YET ANALYZED. VERY LIKELY, MUCH OF THE DATA IN THIS LISTING WILL CONSIST OF A NUMBER IN THE ASCENDING SERIES 0.0001, 0.00015, 0.0002, 0.0003, 0.0005, 0.0007, 0.0010, 0.0015, 0.0020, ..., 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, 1.5, 2.0, 3.0, 5.0, 7.0, 10.0, 15.0, 20,0, ..., 10,000, 15,000, 20,000, 30,000, 50,000, 70,000, AND 100,000. THESE NUMBERS REPRESENT APPROXIMATE MIDPOINTS OF GEOMETRIC CLASSES DEVISED FOR A SEMI-QUANTITATIVE SCHEME OF SPECTROGRAPHIC ANALYSIS DESCRIBED IN U.S. GEOLOGICAL SURVEY BULLETIN 1084-T (MYERS, HAVENS AND DUNTON, 1961). THE ANALYTICAL PRECISION MAY VARY FROM CONSTITUENT TO CONSTITUENT. REGARDLESS OF THE APPARENT NUMBER OF SIGNIFICANT DIGITS GIVEN, ALL DATA SHOULD BE ROUNDED TO ONE OR TWO SIGNIFICANT DIGITS, AND NEVER MORE THAN THREE.

THE SAMPLE LOCATION IS GIVEN BY LATITUDE AND LONGITUDE IN DEGREES, MINUTES, AND SECONDS. SOME OR ALL OF THE GIVEN LOCATIONS MAY BE APPROXIMATE. ZERO LATITUDES AND LONGITUDES MEAN NO SUCH INFORMATION WAS SUPPLIED. THE AREA OF COLLECTION IS GIVEN AS THE STATE IF THE SAMPLE WAS COLLECTED IN THE UNITED STATES AND AS THE GENERAL PART OF THE WORLD IF THE SAMPLE WAS COLLECTED OUTSIDE OF THE UNITED STATES. SAMPLES COLLECTED FROM THE OCEANS ARE IDENTIFIED BY OC AS, FOR EXAMPLE, "PACIFIC OC".

MINERAL NAMES LISTED UNDER "SAMPLE MATERIAL" ARE GIVEN AS A FIVE-LETTER CODE CONSISTING OF THE FIRST LETTER FOLLOWED BY THE NEXT FOUR CONSONANTS (EXCLUDING Y), UNLESS THE NAME HAS FIVE OR FEWER LETTERS IN WHICH CASE THE NAME IS FULLY SPELLED OUT, FOR EXAMPLE, PYROXENE IS LISTED AS "PRXN," ORTHOCLASE AS "ORTHC" AND MICA AS "MICA."

THREE ASTERISKS (***) PRECEDING SAMPLE CATEGORY MEANS SAMPLE IS MINERALIZED. TWO ASTERISKS (**) MEANS SAMPLE IS ALTERED, ONE ASTERISK (*) MEANS SAMPLE IS OTHERWISE ECONOMICALLY IMPORTANT OR WAS COLLECTED IN A MINERALIZED AREA.

| SAMPLE ID | SUBMITTER NAME | SUBMITTAL DATE | SAMPLE CATEGORY | SAMPLE MATERIAL |
|---|---|---|---|---|
| D124747 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | SILTSTONE |
| D124748 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124749 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124750 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124751 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124752 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | SILTSTONE |
| D124753 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124754 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124755 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124756 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124758 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124759 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | SILTSTONE |
| D124760 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124763 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124764 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124765 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124766 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124767 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124768 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124769 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124770 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124771 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124772 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124773 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124774 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124775 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124776 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124777 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124778 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124779 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124780 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124781 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124782 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124783 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | SILTSTONE |
| D124785 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | SILTSTONE |
| D124788 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124790 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124792 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124793 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124796 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124798 | VINE JAMES D | 66- 7-22 | SEDIMENTARY ROCK | CLAYSTONE |
| D124845 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | SILTSTONE |
| D124848 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | SHALE |
| D124850 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | SHALE |
| D124858 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | CLAYSTONE |
| D124859 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | CLAYSTONE |
| D124860 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | SILTSTONE |
| D124861 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | SILTSTONE |
| D124863 | VINE JAMES D | 66- 7-25 | SEDIMENTARY ROCK | CLAYSTONE |

| SAMPLE ID | FORMATION NAME | COMMENTS |
|---|---|---|
| D124747 | FORT UNION | DRILL HOLE #1 CARB. SILTSTONE, 125.7-126.0 FT. |
| D124748 | FORT UNION | CARB. CLAYSTONE, 131.3-131.5 FT. |
| D124749 | FORT UNION | CARB. CLAYSTONE, 134.0-134.3 FT. |
| D124750 | FORT UNION | CARB. CLAYSTONE, 136.5-136.7 FT. |
| D124751 | FORT UNION | CARB. CLAYSTONE, 138.7-139.0 FT. |
| D124752 | FORT UNION | CARB. SILTSTONE, 141.8-142.0 FT. |
| D124753 | FORT UNION | CARB. CLAYSTONE, 142.7-143.0 FT. |
| D124754 | FORT UNION | CARB. CLAYSTONE, 146.7-147.0 FT. |
| D124755 | FORT UNION | CARB. CLAYSTONE, 148.7-149.0 FT. |
| D124756 | FORT UNION | CARB. CLAYSTONE, 152.0-152.2 FT. |
| D124758 | FORT UNION | CARB. CLAYSTONE, 159.7-160.0 |
| D124759 | FORT UNION | CARB. SILTSTONE, 161.8-162.0 |
| D124760 | FORT UNION | CARB. CLAYSTONE, 165.3-165.6 |
| D124763 | FORT UNION | CLAYSTONE, CARB., 176.6-176.9 |
| D124764 | FORT UNION | CLAYSTONE, CARB., 180.0-180.3 |
| D124765 | FORT UNION | CLAYSTONE, CARB., 183.5-183.7 |
| D124766 | FORT UNION | CLAYSTONE, CARB., 185.3-185.5 |
| D124767 | FORT UNION | CLAYSTONE, CARB., 185.5-185.7 |
| D124768 | FORT UNION | CLAYSTONE, CARB., 188.0-188.5 |
| D124769 | FORT UNION | CLAYSTONE, CARB., 202.5-202.7 |
| D124770 | FORT UNION | CLAYSTONE, CARB., 204.0-204.3 |
| D124771 | FORT UNION | CLAYSTONE, CARB., 211.2-211.5 |
| D124772 | FORT UNION | CLAYSTONE, CARB., 214.0-214.2 |
| D124773 | FORT UNION | CLAYSTONE, CARB., 217.0-217.2 |
| D124774 | FORT UNION | CLAYSTONE, CARB., 223.6-223.9 |
| D124775 | FORT UNION | CLAYSTONE, CARB., 226.5-226.7 |
| D124776 | FORT UNION | CLAYSTONE, CARB., 228.8-229.0 |
| D124777 | FORT UNION | CLAYSTONE, CARB., 231.0-231.1 |
| D124778 | FORT UNION | CLAYSTONE, CARB., 236.9-237.1 |
| D124779 | FORT UNION | CLAYSTONE, CARB., 239.0-239.2 |
| D124780 | FORT UNION | CLAYSTONE, CARB., 241.7-242.0 |
| D124781 | FORT UNION | CLAYSTONE, CARB., 244.0-244.2 |
| D124782 | FORT UNION | CLAYSTONE, CARB., 247.0-247.2 |
| D124783 | FORT UNION | DRILL HOLE #2 CARB. SILTSTONE, 224.4-224.6 |
| D124785 | FORT UNION | CARB. SILTSTONE, 317.0-317.2 |
| D124788 | FORT UNION | DRILL HOLE #3 CLAYSTONE, CARB. 123.2-123.3 |
| D124790 | FORT UNION | CLAYSTONE, CARB., 175.0-175.2 |
| D124792 | FORT UNION | CLAYSTONE, 102.5-102.6 |
| D124793 | FORT UNION | CLAYSTONE, 224.5-224.6 |
| D124796 | FORT UNION | CLAYSTONE, CARB., 301.5-301.6 |
| D124798 | FORT UNION | CLAYSTONE, CARB., 177.0-177.2 |
| D124845 | FORT UNION | SILTSTONE, CALCAREOUS )COQUINA BED( |
| D124848 | FORT UNION | SILICIFIED CARB SH. IN SPRING VALLEY |
| D124850 | FORT UNION | SILICIFIED CARB. SH. ABOVE SPRING VALLEY |
| D124858 | FORT UNION | CARB. CLAY )BENTONITIC( ABOVE TAVIS CR. |
| D124859 | FORT UNION | CARB. CLAY 30 FT BELOW ROCKY RIDGE COAL |
| D124860 | FORT UNION | QUARTZITE |
| D124861 | FORT UNION | QUARTZITE |
| D124863 | FORT UNION | CARB. CLAY ABOVE SHELL BED |

| SAMPLE ID | FIELD NO. | STATE | LATITUDE | LONGITUDE | SAMPLE TYPE | SAMPLE SOURCE | GEOLOGIC AGE |
|---|---|---|---|---|---|---|---|
| D124747 | V-500A | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124748 | V-500B | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124749 | V-500C | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124750 | V-500D | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124751 | V-500E | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124752 | V-500F | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124753 | V-500G | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124754 | V-500H | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124755 | V-500I | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124756 | V-500J | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124758 | V-500L | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124759 | V-500M | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124760 | V-500N | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124763 | V-500Q | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124764 | V-500R | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124765 | V-500S | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124766 | V-500T | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124767 | V-500U | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124768 | V-500V | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124769 | V-500W | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124770 | V-500X | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124771 | V-500Y | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124772 | V-500Z | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124773 | V-500AA | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124774 | V-500AB | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124775 | V-500AC | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124776 | V-500AD | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124777 | V-500AE | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124778 | V-500AF | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124779 | V-500AG | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124780 | V-500AH | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124781 | V-500AI | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124782 | V-500AJ | N DAKOTA | 46-30- 0N | 102- 0- 0W | | DRILL CORE | PALEOCENE |
| D124783 | V-501A | N DAKOTA | 46-31- 0N | 102- 8- 0W | | DRILL CORE | PALEOCENE |
| D124785 | V-501C | N DAKOTA | 46-31- 0N | 102- 8- 0W | | DRILL CORE | PALEOCENE |
| D124788 | V-502A | N DAKOTA | 46-33- 0N | 102-12- 0W | | DRILL CORE | PALEOCENE |
| D124790 | V-502C | N DAKOTA | 46-33- 0N | 102-12- 0W | | DRILL CORE | PALEOCENE |
| D124792 | V-502E | N DAKOTA | 46-33- 0N | 102-12- 0W | | DRILL CORE | PALEOCENE |
| D124793 | V-502F | N DAKOTA | 46-33- 0N | 102-12- 0W | | DRILL CORE | PALEOCENE |
| D124796 | V-502I | N DAKOTA | 46-33- 0N | 102-12- 0W | | DRILL CORE | PALEOCENE |
| D124798 | V-503B | N DAKOTA | 46-37- 0N | 102-11- 0W | | DRILL CORE | PALEOCENE |
| D124845 | V-489B | N DAKOTA | 46-39- 0N | 102- 5- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124848 | V-491 | N DAKOTA | 46-50- 0N | 101-49- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124850 | V-492B | N DAKOTA | 46-48- 0N | 101-52- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124858 | V-495B | N DAKOTA | 46-48- 0N | 101-31- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124859 | V-496A | N DAKOTA | 46-46- 0N | 101-49- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124860 | V-496B | N DAKOTA | 46-46- 0N | 101-49- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124861 | V-497 | N DAKOTA | 46-46- 0N | 101-49- 0W | SINGLE | OUTCROP | PALEOCENE |
| D124863 | V-499A | N DAKOTA | 46-47- 0N | 101-38- 0W | SINGLE | OUTCROP | PALEOCENE |

| SAMPLE ID | FE %-S | MG %-S | CA %-S | TI %-S | MN PPM-S | AG PPM-S | AS PPM-S | AU PPM-S | B PPM-S | BA PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D124747 | 3.0000 | 1.5000 | 0.3000 | 0.2000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124748 | 2.0000 | 3.0000 | 3.0000 | 0.2000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124749 | 3.0000 | 2.0000 | 3.0000 | 0.2000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124750 | 3.0000 | 1.5000 | 0.7000 | 0.2000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 69999.0000 |
| D124751 | 5.0000 | 1.5000 | 0.3000 | 0.5000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124752 | 2.0000 | 2.0000 | 1.5000 | 0.3000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124753 | 3.0000 | 3.0000 | 3.0000 | 0.3000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124754 | 5.0000 | 3.0000 | 3.0000 | 0.3000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124755 | 5.0000 | 3.0000 | 3.0000 | 0.2000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124756 | 3.0000 | 3.0000 | 3.0000 | 0.2000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 5000.0000 |
| D124758 | 5.0000 | 3.0000 | 3.0000 | 0.1500 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124759 | 3.0000 | 3.0000 | 3.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124760 | 5.0000 | 2.0000 | 0.7000 | 0.3000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124763 | 3.0000 | 1.5000 | 0.7000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124764 | 3.0000 | 3.0000 | 2.0000 | 0.3000 | 100.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124765 | 2.0000 | 3.0000 | 2.0000 | 0.2000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124766 | 2.0000 | 3.0000 | 3.0000 | 0.2000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124767 | 3.0000 | 2.0000 | 5.0000 | 0.1500 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 200.0000 |
| D124768 | 2.0000 | 1.0000 | 0.3000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124769 | 2.0000 | 3.0000 | 3.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124770 | 3.0000 | 3.0000 | 3.0000 | 0.2000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124771 | 3.0000 | 3.0000 | 3.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 1500.0000 |
| D124772 | 5.0000 | 2.0000 | 1.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124773 | 3.0000 | 2.0000 | 2.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124774 | 3.0000 | 2.0000 | 3.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124775 | 5.0000 | 2.0000 | 3.0000 | 0.3000 | 1500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124776 | 2.0000 | 3.0000 | 5.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124777 | 3.0000 | 1.5000 | 0.1500 | 0.3000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124778 | 2.0000 | 2.0000 | 7.0000 | 0.1500 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 200.0000 |
| D124779 | 3.0000 | 2.0000 | 5.0000 | 0.1500 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D121780 | 3.0000 | 3.0000 | 5.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124781 | 3.0000 | 2.0000 | 5.0000 | 0.1500 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124782 | 3.0000 | 2.0000 | 5.0000 | 0.1000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124783 | 3.0000 | 1.5000 | 1.0000 | 0.3000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124785 | 2.0000 | 3.0000 | 5.0000 | 0.1500 | 200.0000 | 7.0000 | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124788 | 0.3000 | 0.0500 | 0.3000 | 0.0010 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 300.0000 |
| D124790 | 2.0000 | 1.0000 | 0.7000 | 0.2000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124792 | 7.0000 | 1.5000 | 0.7000 | 0.3000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 1000.0000 |
| D124793 | 5.0000 | 1.5000 | 0.5000 | 0.5000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124796 | 5.0000 | 2.0000 | 1.5000 | 0.2000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124798 | 5.0000 | 1.5000 | 0.5000 | 0.3000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124845 | 2.0000 | 1.0000 | 10.0000G | 0.0700 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124848 | 0.5000 | 0.2000 | 0.3000 | 0.0020 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 70.0000 |
| D124850 | 0.1500 | 0.0700 | 0.7000 | 0.0015 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 150.0000 |
| D124858 | 5.0000 | 2.0000 | 0.3000 | 0.3000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 1000.0000 |
| D124859 | 5.0000 | 1.5000 | 0.3000 | 0.5000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124860 | 0.1000 | 0.0700 | 0.2000 | 0.5000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 500.0000 |
| D124861 | 1.5000 | 0.3000 | 0.2000 | 0.1500 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 700.0000 |
| D124863 | 5.0000 | 3.0000 | 5.0000 | 0.5000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 1000.0000 |

| SAMPLE ID | BE PPM-S | BI PPM-S | CD PPM-S | CO PPM-S | CR PPM-S | CU PPM-S | LA PPM-S | MO PPM-S | NB PPM-S | NI PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D124747 | 1,5000 | 0,0000N | 0,0000N | 5,0000 | 50,0000 | 50,0000 | 50,0000 | 5,0000 | 0,0000N | 50,0000 |
| D124748 | 1,0000 | 0,0000N | 0,0000N | 10,0000 | 50,0000 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 15,0000 |
| D124749 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 |
| D124750 | 3,0000 | 0,0000N | 0,0000N | 15,0000 | 50,0000 | 70,0000 | 0,0000N | 10,0000 | 0,0000N | 30,0000 |
| D124751 | 1,0000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 10,0000 | 50,0000 |
| D124752 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 50,0000 | 0,0000N | 0,0000N | 0,0000N | 30,0000 |
| D124753 | 1,0000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 50,0000 |
| D124754 | 1,5000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 50,0000 |
| D124755 | 1,0000 | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 30,0000 |
| D124756 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 30,0000 |
| D124758 | 1,5000 | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 50,0000 | 0,0000N | 10,0000 | 0,0000N | 30,0000 |
| D124759 | 0,0000N | 0,0000N | 0,0000N | 7,0000 | 70,0000 | 50,0000 | 0,0000N | 0,0000N | 0,0000N | 20,0000 |
| D124760 | 2,0000 | 0,0000N | 0,0000N | 20,0000 | 70,0000 | 50,0000 | 50,0000 | 5,0000 | 10,0000 | 50,0000 |
| D124763 | 1,0000 | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 30,0000 | 30,0000 | 0,0000N | 10,0000 | 20,0000 |
| D124764 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 70,0000 | 20,0000 | 30,0000 | 10,0000 | 10,0000 | 20,0000 |
| D124765 | 1,0000 | 0,0000N | 0,0000N | 15,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 30,0000 |
| D124766 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 50,0000 | 20,0000 | 0,0000N | 3,0000 | 0,0000N | 15,0000 |
| D124767 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 |
| D124768 | 1,0000 | 0,0000N | 0,0000N | 3,0000 | 70,0000 | 30,0000 | 30,0000 | 10,0000 | 10,0000 | 15,0000 |
| D124769 | 1,0000 | 0,0000N | 0,0000N | 5,0000 | 50,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 15,0000 |
| D124770 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 30,0000 | 30,0000 | 0,0000N | 10,0000 | 15,0000 |
| D124771 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 15,0000 |
| D124772 | 1,5000 | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 20,0000 |
| D124773 | 1,0000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 30,0000 |
| D124774 | 1,0000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 70,0000 | 30,0000 | 0,0000N | 0,0000N | 30,0000 |
| D124775 | 1,0000 | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 70,0000 | 30,0000 | 0,0000N | 0,0000N | 20,0000 |
| D124776 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 15,0000 |
| D124777 | 15,0000 | 0,0000N | 0,0000N | 10,0000 | 50,0000 | 30,0000 | 50,0000 | 0,0000N | 10,0000 | 20,0000 |
| D124778 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 |
| D124779 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 15,0000 |
| D124780 | 1,0000 | 0,0000N | 0,0000N | 10,0000 | 70,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 20,0000 |
| D124781 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 15,0000 |
| D124782 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 50,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 |
| D124783 | 1,0000 | 0,0000N | 0,0000N | 7,0000 | 50,0000 | 30,0000 | 30,0000 | 0,0000N | 10,0000 | 15,0000 |
| D124785 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 50,0000 | 50,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 |
| D124788 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 1,0000 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 3,0000 |
| D124790 | 3,0000 | 0,0000N | 0,0000N | 5,0000 | 30,0000 | 70,0000 | 100,0000 | 10,0000 | 0,0000N | 20,0000 |
| D124792 | 2,0000 | 0,0000N | 0,0000N | 30,0000 | 70,0000 | 70,0000 | 30,0000 | 10,0000 | 0,0000N | 70,0000 |
| D124793 | 1,5000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 70,0000 | 50,0000 | 5,0000 | 0,0000N | 30,0000 |
| D124796 | 2,0000 | 0,0000N | 0,0000N | 15,0000 | 50,0000 | 50,0000 | 30,0000 | 10,0000 | 0,0000N | 50,0000 |
| D124798 | 2,0000 | 0,0000N | 0,0000N | 15,0000 | 70,0000 | 50,0000 | 50,0000 | 7,0000 | 0,0000N | 50,0000 |
| D124845 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 15,0000 | 10,0000 | 30,0000 | 0,0000N | 0,0000N | 20,0000 |
| D124848 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 7,0000 | 0,0000N | 0,0000N | 0,0000N | 3,0000 |
| D124850 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 7,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N |
| D124858 | 3,0000 | 0,0000N | 0,0000N | 20,0000 | 100,0000 | 70,0000 | 50,0000 | 0,0000N | 15,0000 | 70,0000 |
| D124859 | 2,0000 | 0,0000N | 0,0000N | 10,0000 | 100,0000 | 70,0000 | 50,0000 | 0,0000N | 15,0000 | 70,0000 |
| D124860 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 10,0000 | 0,0000N | 0,0000N | 20,0000 | 5,0000 |
| D124861 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 30,0000 | 10,0000 | 0,0000N | 0,0000N | 0,0000N | 3,0000 |
| D124863 | 2,0000 | 0,0000N | 0,0000N | 20,0000 | 150,0000 | 70,0000 | 50,0000 | 0,0000N | 10,0000 | 70,0000 |

| SAMPLE ID | PB PPM-S | PD PPM-S | PT PPM-S | SB PPM-S | SC PPM-S | SN PPM-S | SR PPM-S | TE PPM-S | U PPM-S | V PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D124747 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124748 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124749 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124750 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 700.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124751 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124752 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124753 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 200.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124754 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 200.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124755 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124756 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 200.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124758 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124759 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 50.0000 |
| D124760 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 200.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124763 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124764 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124765 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124766 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124767 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124768 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124769 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124770 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124771 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124772 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124773 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124774 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124775 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124776 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124777 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124778 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124779 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124780 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124781 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124782 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124783 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 100.0000 | 0.0000B | 0.0000B | 100.0000 |
| D124785 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 70.0000 |
| D124788 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 30.0000 | 0.0000B | 0.0000B | 0.0000N |
| D124790 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 300.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124792 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 300.0000 | 0.0000B | 0.0000B | 200.0000 |
| D124793 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 200.0000 | 0.0000B | 0.0000B | 200.0000 |
| D124796 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 200.0000 |
| D124798 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 200.0000 | 0.0000B | 0.0000B | 150.0000 |
| D124845 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 1000.0000 | 0.0000B | 0.0000B | 30.0000 |
| D124848 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 20.0000 | 0.0000B | 0.0000B | 0.0000N |
| D124850 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 15.0000 | 0.0000B | 0.0000B | 0.0000N |
| D124858 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 300.0000 |
| D124859 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 200.0000 |
| D124860 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 15.0000 | 0.0000B | 0.0000B | 20.0000 |
| D124861 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 30.0000 |
| D124863 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000N | 150.0000 | 0.0000B | 0.0000B | 200.0000 |

| SAMPLE ID | W PPM-S | Y PPM-S | ZN PPM-S | ZR PPM-S | SI %-S | AL %-S | NA %-S | K %-S | P %-S | CE PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D124747 | 0.0000N | 30.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124748 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124749 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 5.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124750 | 0.0000N | 30.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124751 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124752 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124753 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124754 | 0.0000N | 30.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124755 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124756 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124758 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124759 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124760 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124763 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124764 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124765 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124766 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 5.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124767 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 5.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124768 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124769 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124770 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124771 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124772 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124773 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124774 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124775 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124776 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124777 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124778 | 0.0000N | 15.0000 | 0.0000N | 0.0000B | 10.0000G | 5.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124779 | 0.0000N | 15.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124780 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124781 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124782 | 0.0000N | 15.0000 | 0.0000N | 0.0000B | 10.0000G | 5.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124783 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124785 | 0.0000N | 15.0000 | 0.0000N | 0.0000B | 10.0000G | 5.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124788 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 10.0000G | 0.0300 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124790 | 0.0000N | 30.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124792 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124793 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124796 | 0.0000N | 15.0000 | 0.0000N | 0.0000B | 10.0000G | 7.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124798 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124845 | 0.0000N | 20.0000 | 0.0000N | 0.0000B | 7.0000 | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124848 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 10.0000G | 0.0700 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124850 | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 10.0000G | 0.0700 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124858 | 0.0000N | 50.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124859 | 0.0000N | 50.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124860 | 0.0000N | 50.0000 | 0.0000N | 0.0000B | 10.0000G | 0.5000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124861 | 0.0000N | 10.0000 | 0.0000N | 0.0000B | 10.0000G | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D124863 | 0.0000N | 30.0000 | 0.0000N | 0.0000B | 10.0000G | 10.0000G | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | GA PPM-S | GE PPM-S | HF PPM-S | IN PPM-S | LI PPM-S | RE PPM-S | TA PPM-S | TH PPM-S | TL PPM-S | YB PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D124747 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124748 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124749 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124750 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124751 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124752 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124753 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124754 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124755 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124756 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124758 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124759 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124760 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124763 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124764 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124765 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124766 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124767 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124768 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124769 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124770 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124771 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124772 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124773 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124774 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124775 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124776 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124777 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124778 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124779 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124780 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124781 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124782 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124783 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124785 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124788 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124790 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000T | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124792 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124793 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124796 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124798 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124845 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124848 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124850 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124858 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124859 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124860 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124861 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |
| D124863 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B | 0.0000N | 0.0000B |

| SAMPLE ID | PR PPM-S | ND PPM-S | SM PPM-S | EU PPM-S | HG PPM-S | TOTAL C% | ORGNC C% | CRBNT C% | ASH |
|---|---|---|---|---|---|---|---|---|---|
| D124747 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 6.0100 | 6.0000 | 0.0200 | 84.0000 |
| D124748 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.2100 | 0.1000 | 2.1100 | 95.0000 |
| D124749 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.9400 | 0.1000 | 1.8800 | 94.0000 |
| D124750 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 21.8000 | 21.8000 | 0.0800 | 60.0000 |
| D124751 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.0400 | 1.0000 | 0.0200 | 92.0000 |
| D124752 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.3200 | 0.5000 | 0.8200 | 95.0000 |
| D124753 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.3800 | 0.6000 | 1.8100 | 93.0000 |
| D124754 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.2600 | 0.4000 | 1.8200 | 92.0000 |
| D124755 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.1100 | 0.4000 | 1.7300 | 93.0000 |
| D124756 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.2900 | 0.5000 | 1.7800 | 94.0000 |
| D124758 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.4400 | 0.5000 | 1.9400 | 92.0000 |
| D124759 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.4900 | 0.5000 | 1.9700 | 93.0000 |
| D124760 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 12.2000 | 12.1000 | 0.1200 | 73.0000 |
| D124763 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.9800 | 1.5000 | 0.4500 | 91.0000 |
| D124764 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.9200 | 0.6000 | 1.3200 | 93.0000 |
| D124765 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.0300 | 0.2000 | 1.8100 | 95.0000 |
| D124766 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.9700 | 0.4000 | 2.5900 | 95.0000 |
| D124767 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.8400 | 0.2000 | 3.6300 | 92.0000 |
| D124768 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.3500 | 0.3000 | 0.0100 | 94.0000 |
| D124769 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.4100 | 0.7000 | 1.7300 | 95.0000 |
| D124770 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.7000 | 0.3000 | 2.4200 | 95.0000 |
| D124771 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.2000 | 0.4000 | 1.8000 | 95.0000 |
| D124772 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.6800 | 0.7000 | 0.9800 | 92.0000 |
| D124773 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.6700 | 0.6000 | 1.0300 | 92.0000 |
| D124774 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 4.9600 | 3.7000 | 1.2100 | 88.0000 |
| D124775 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.4100 | 0.8000 | 1.6100 | 92.0000 |
| D124776 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.7300 | 0.3000 | 2.3900 | 95.0000 |
| D124777 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.5800 | 0.5000 | 0.0600 | 94.0000 |
| D124778 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 4.1800 | 0.3000 | 3.8700 | 94.0000 |
| D124779 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.0500 | 0.4000 | 2.6800 | 93.0000 |
| D124780 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.2700 | 0.3000 | 1.9300 | 93.0000 |
| D124781 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.6800 | 0.5000 | 2.2200 | 94.0000 |
| D124782 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 4.5300 | 0.6000 | 3.9400 | 93.0000 |
| D124783 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.7800 | 0.1000 | 0.7200 | 95.0000 |
| D1247[illegible]5 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 6.4900 | 2.9000 | 3.5900 | 91.0000 |
| D1247[illegible]8 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 9.9600 | 9.9000 | 0.0300 | 82.0000 |
| D124790 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 19.7000 | 19.7000 | 0.0200 | 63.0000 |
| D124792 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 7.7200 | 7.7000 | 0.0300 | 81.0000 |
| D124793 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 7.1800 | 7.2000 | 0.0100L | 83.0000 |
| D124796 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 8.6800 | 0.3000 | 0.3200 | 82.0000 |
| D124798 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 6.4400 | 6.4000 | 0.0100L | 74.0000 |
| D124845 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 8.8000 | 0.0000B | 0.0000B | 0.0000B |
| D124848 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.6800 | 0.0000B | 0.0000B | 0.0000B |
| D124850 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.1700 | 0.0000B | 0.0000B | 0.0000B |
| D124858 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.5800 | 0.0000B | 0.0000B | 0.0000B |
| D124859 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.7300 | 0.0000B | 0.0000B | 0.0000B |
| D124860 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.2900 | 0.0000B | 0.0000B | 0.0000B |
| D124861 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 0.1400 | 0.0000B | 0.0000B | 0.0000B |
| D124863 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.6800 | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | SUBMITTER NAME | SUBMITTAL DATE | | SAMPLE CATEGORY | SAMPLE MATERIAL |
|---|---|---|---|---|---|
| D126720 | CULLINS HENRY L | 66-11- 7 | | SEDIMENTARY ROCK | SHALE |
| D127825 | PILLMORE C L | 66- 2-21 | | SEDIMENTARY ROCK | SILTSTONE |
| D127826 | PILLMORE C L | 66- 2-21 | | SEDIMENTARY ROCK | SILTSTONE |
| D127827 | PILLMORE C L | 66- 2-21 | | SEDIMENTARY ROCK | SILTSTONE |
| D127828 | PILLMORE C L | 66- 2-21 | | SEDIMENTARY ROCK | SHALE |
| D127832 | PILLMORE C L | 66- 2-21 | | SEDIMENTARY ROCK | CLAYSTONE |
| D129441 | VINE JAMES D | 67- 9- 7 | | SEDIMENTARY ROCK | SILTSTONE |
| D129501 | MEREWETHER E A | 67- 9-26 | | SEDIMENTARY ROCK | SHALE |
| D129503 | MEREWETHER E A | 67- 9-26 | | SEDIMENTARY ROCK | SHALE |
| D129504 | MEREWETHER E A | 67- 9-26 | | SEDIMENTARY ROCK | SHALE |
| D129505 | MEREWETHER E A | 67- 9-26 | | SEDIMENTARY ROCK | SHALE |
| D129506 | MEREWETHER E A | 67- 9-26 | | SEDIMENTARY ROCK | SHALE |
| D129507 | MEREWETHER E A | 67- 9-26 | | SEDIMENTARY ROCK | SHALE |
| D129680 | VINE JAMES D | 67-10- 6 | | SEDIMENTARY ROCK | SILTSTONE |
| D132649 | BACHMAN GEORGE O | 68- 6-24 | | SEDIMENTARY ROCK | SHALE |
| D132651 | BACHMAN GEORGE O | 68- 6-24 | | SEDIMENTARY ROCK | SHALE |
| D137660 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137662 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | SILTSTONE |
| D137681 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137682 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137683 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137684 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137685 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137686 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D137687 | BARCLAY C S V | 69- 2-28 | | SEDIMENTARY ROCK | CLAYSTONE |
| D138690 | BACHMAN GOERGE | 69- 5-31 | | SEDIMENTARY ROCK | CLAYSTONE |
| D138696 | BACHMAN GOERGE | 69- 5-31 | | SEDIMENTARY ROCK | CLAYSTONE |
| D138697 | BACHMAN GOERGE | 69- 5-31 | | SEDIMENTARY ROCK | CLAYSTONE |
| D138700 | BACHMAN GOERGE | 69- 5-31 | | SEDIMENTARY ROCK | SHALE |
| D139927 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139928 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139929 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139930 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139931 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139932 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139933 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139934 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139935 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139937 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SILTSTONE |
| D139938 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SILTSTONE |
| D139939 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139940 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139941 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139942 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139943 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139945 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139946 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139947 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D139948 | BARCLAY C S V | 69- 8-15 | | SEDIMENTARY ROCK | SHALE |
| D141326 | BACHMAN GEORGE O | 69-12- 2 | * | SEDIMENTARY ROCK | SHALE |

| SAMPLE ID | FORMATION NAME | COMMENTS |
|---|---|---|
| D126720 | MESAVERDE | DARK GRAY SUBFISSLE NONCALCAREOUS SHALE |
| D127825 | VERMEJO | MUDSTONE |
| D127826 | RATON | MUDSTONE--1,000; |
| D127827 | RATON | MUDSTONE--760; |
| D127828 | RATON | SHALE PARTING IN YORK CANYON COAL SEAM |
| D127832 | RATON | UNDER CLAY, BENEATH COAL |
| D129441 | TORREJON | MUDSTONE, GRAY |
| D129501 | FERRIS )LOWER( | SHALE, MD.GY., CARBONACEOUS - CRETACEOUS |
| D129503 | FERRIS )UPPER( | SHALE, DARK GRAY BROWN, CARBONACEOUS, COALY - PALEOCENE |
| D129504 | FERRIS )UPPER( | SHALE, CARBONACEOUS - PALEOCENE |
| D129505 | FERRIS )UPPER( | SHALE, CARBONACEOUS - PALEOCENE |
| D129506 | FERRIS )UPPER OR MIDDLE( | SHALE, CARBONACEOUS - PALEOCENE |
| D129507 | FERRIS )UPPER( | SHALE, CARBONACEOUS - PALEOCENE |
| D129680 | RATON | SILTSTONE |
| D132649 | MESAVERDE | SHALE |
| D132651 | MESAVERDE | SHALE |
| D137660 | FORT UNION | CLAYSTONE, CARBONACEOUS, SILTY |
| D137662 | FORT UNION | SILTSTONE, CARBONACEOUS, CLAYEY |
| D137681 | FORT UNION | CLAYSTONE, CARBONACEOUS |
| D137682 | FORT UNION | CLAYSTONE, CARBONACEOUS |
| D137683 | FORT UNION | CLAYSTONE |
| D137684 | FORT UNION | CLAYSTONE, CARBONACEOUS |
| D137685 | FORT UNION | CLAYSTONE, VERY CARBONACEOUS |
| D137686 | FORT UNION | CLAYSTONE, CARBONACEOUS |
| D137687 | FORT UNION | CLAYSTONE, SLIGHTLY CARBONACEOUS |
| D138690 | MESA VERDE | SHALY, COALY-CARBONACEOUS |
| D138696 | MESAVERDE | CLAYSTONE, CARBONACEOUS |
| D138697 | MESAVERDE | CLAYSTONE, CARBONACEOUS |
| D138700 | MESAVERDE | CLAYSTONE,- SHALE |
| D139927 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139928 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139929 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139930 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139931 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139932 | SENTINEL BUTTE MEMBER FORT UNION FM | CARB.SHALE)SUBFISSILESILTSTONE(,AL.LIGNITIC,IRREG.BLACKISHBROWN&BROWN |
| D139933 | SENTINEL BUTTE MEMBER FORT UNION FM | CARB. SHALE )SUBFISSILE CLAYSTONE(, BLACKISH BROWN. |
| D139934 | SENTINEL BUTTE MEMBER FORT UNION FM | CARB. SHALE, PLANT FRAGMENTS, LIGHT GRAYISH BROWN. |
| D139935 | SENTINEL BUTTE MEMBER FORT UNION FM | CARB.SHALE)SUBFISSILECLAYSTONE(,PLANTFRAGMENTSVERYLIGHTGRAYISHBROWN. |
| D139937 | SENTINEL BUTTE MEMBER FORT UNION FM | SILTSTONE, CARBONACEOUS, SLIGHTLY SILICIFIED. |
| D139938 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED MUDSTONE. |
| D139939 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139940 | SENTINEL BUTTE MEMBER FORT UNION FM | CARBONACEOUS SHALE )SUBFISSILE CLAYSTONE(, BROWN. |
| D139941 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139942 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139943 | SENTINEL BUTTE MEMBER FORT UNION FM | SILICIFIED CARBONACEOUS SHALE. |
| D139945 | TONGUE RIVER MBR. FT. UNION FM. | CARBONACEOUS SHALE )TO SUBFISSILE CARBONACEOUS MUDSTONE(, BROWN. |
| D139946 | TONGUE RIVER MBR. FT. UNION FM. | CARBONACEOUS SHALE, VERY FLAKY, BLACKISH BROWN. |
| D139947 | SENTINEL BUTTE MBR. FT. UNION FM. | CARBONACEOUS SHALE, PLANT FRAGMENTS, GRAYISH BROWN. |
| D139948 | SENTINEL BUTTE MBR. FT. UNION FM. | CARBONACEOUS SHALE, SLICKENSIDES, PLANT FRAGMENTS, GRAYISH BROWN. |
| D141326 | MESAVERDE | COAL, RADIOACTIVE, RADIOACTIVE |

| SAMPLE ID | FIELD NO. | STATE | LATITUDE | LONGITUDE | SAMPLE TYPE | SAMPLE SOURCE | GEOLOGIC AGE |
|---|---|---|---|---|---|---|---|
| D126720 | R-1-66 | COLORADO | 40- 0- 0N | 108-45- 0W | | OUTCROP | CRETACEOUS |
| D127825 | P6 1A | NEW MEXICO | 36-52- 0N | 104-53- 0W | SINGLE | DRILL CORE | CRETACEOUS |
| D127826 | P6 1B | NEW MEXICO | 36-52- 0N | 104-53- 0W | SINGLE | DRILL CORE | CRETACEOUS |
| D127827 | P6 1C | NEW MEXICO | 36-52- 0N | 104-53- 0W | SINGLE | DRILL CORE | PALEOCENE |
| D127828 | P6 55 | NEW MEXICO | 36-52- 0N | 104-53- 0W | SINGLE | UNDERGROUND MINE | PALEOCENE |
| D127832 | P5 47A | NEW MEXICO | 36-56- 0N | 104-57- 0W | SINGLE | OUTCROP | PALEOCENE |
| D129441 | CL-48 | COLORADO | 37- 2- 0N | 107- 8- 0W | SINGLE | | PALEOCENE |
| D129501 | U-1 67-EAM | WYOMING | 41-52- 0N | 106-48- 0W | | OUTCROP | CRETACEOUS |
| D129503 | U-3 67-EAM | WYOMING | 41-55- 0N | 106-46- 0W | | OUTCROP | PALEOCENE |
| D129504 | U-4 67-EAM | WYOMING | 41-57- 0N | 106-45- 0W | | OUTCROP | PALEOCENE |
| D129505 | U-5 67-EAM | WYOMING | 42- 1- 0N | 106-44- 0W | | OUTCROP | PALEOCENE |
| D129506 | U-6 67-EAM | WYOMING | 42- 1- 0N | 106-45- 0W | | OUTCROP | PALEOCENE |
| D129507 | U-7 67-EAM | WYOMING | 41-52- 0N | 106-37- 0W | | OUTCROP | PALEOCENE |
| D129680 | CH-37 | COLORADO | 37-43- 0N | 104-54- 0W | SINGLE | | PALEOCENE |
| D132649 | 6/7/68/1 | NEW MEXICO | 35-26- 0N | 106- 0- 0W | SINGLE | OUTCROP | CRETACEOUS |
| D132651 | 6/7/68/3 | NEW MEXICO | 35-26- 0N | 106- 9- 0W | SINGLE | OUTCROP | CRETACEOUS |
| D137660 | DC-2-1A | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137662 | DC-2-1C | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137681 | D-1-20 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137682 | D-1-21 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137683 | D-1-75 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137684 | D-1-76 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137685 | D-1-77 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137686 | D-1-78 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D137687 | D-1-79 | N DAKOTA | 46-45- 0N | 101-40- 0W | | DRILL CORE | PALEOCENE |
| D138690 | 5/19/69/1 | NEW MEXICO | 32-22- 0N | 106- 7- 0W | SINGLE | OUTCROP | CRETACEOUS |
| D138696 | 5/26/69/3 | NEW MEXICO | 32-22- 0N | 106- 7- 0W | SINGLE | OUTCROP | CRETACEOUS |
| D138697 | 5/26/69/5 | NEW MEXICO | 32-22- 0N | 106- 7- 0W | SINGLE | OUTCROP | CRETACEOUS |
| D138700 | 5/26/69/10 | NEW MEXICO | 32-22- 0N | 106- 7- 0W | SINGLE | OUTCROP | CRETACEOUS |
| D139927 | D-9A | N DAKOTA | 46-47-11N | 101-42-43W | SINGLE | OUTCROP | PALEOCENE |
| D139928 | D-9B | N DAKOTA | 46-47-11N | 101-42-43W | SINGLE | OUTCROP | PALEOCENE |
| D139929 | D-12 | N DAKOTA | 46-46-51N | 101-40-56W | SINGLE | OUTCROP | PALEOCENE |
| D139930 | D-13A | N DAKOTA | 46-46-59N | 101-41- 9W | SINGLE | OUTCROP | PALEOCENE |
| D139931 | D-13B | N DAKOTA | 46-46-59N | 101-41- 9W | SINGLE | OUTCROP | PALEOCENE |
| D139932 | GU-58 | N DAKOTA | 46-46- 7N | 101-49-11W | SINGLE | OUTCROP | PALEOCENE |
| D139933 | GU-67 | N DAKOTA | 46-46- 7N | 101-49-11W | SINGLE | OUTCROP | PALEOCENE |
| D13993[illegible] | GU-69 | N DAKOTA | 46-46- 7N | 101-49-11W | SINGLE | OUTCROP | PALEOCENE |
| D139935 | GU-70 | N DAKOTA | 46-46- 7N | 101-49- 8W | SINGLE | OUTCROP | PALEOCENE |
| D139937 | GU-132 | N DAKOTA | 46-45-15N | 101-46-29W | SINGLE | OUTCROP | PALEOCENE |
| D139938 | GU-141B | N DAKOTA | 46-45-15N | 101-46-29W | SINGLE | OUTCROP | PALEOCENE |
| D139939 | GU-143 | N DAKOTA | 46-49-52N | 101-45-52W | SINGLE | OUTCROP | PALEOCENE |
| D139940 | GUP-4 | N DAKOTA | 46-48-20N | 101-48-34W | SINGLE | OUTCROP | PALEOCENE |
| D139941 | D-14A | N DAKOTA | 46-47-11N | 101-42-43W | SINGLE | OUTCROP | PALEOCENE |
| D139942 | D-14B | N DAKOTA | 46-47-11N | 101-42-43W | SINGLE | OUTCROP | PALEOCENE |
| D139943 | D-14C | N DAKOTA | 46-47-11N | 101-42-43W | SINGLE | OUTCROP | PALEOCENE |
| D139945 | GU-15 | N DAKOTA | 46-48-20N | 101-48-34W | SINGLE | OUTCROP | PALEOCENE |
| D139946 | GU-16 | N DAKOTA | 46-48-20N | 101-48-34W | SINGLE | OUTCROP | PALEOCENE |
| D139947 | GU-49 | N DAKOTA | 46-48-13N | 101-48-27W | SINGLE | OUTCROP | PALEOCENE |
| D139948 | GU-56 | N DAKOTA | 46-46- 7N | 101-49-11W | SINGLE | OUTCROP | PALEOCENE |
| D141326 | 9/16/69/3 | NEW MEXICO | 35-26- 0N | 106-10- 0W | SINGLE | UNDERGROUND MINE | CRETACEOUS |

| SAMPLE ID | MGO % | CAO % | NA2O % | K2O % | FE %-S | MG %-S | CA. %-S | TI %-S | MN PPM-S | AG PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D126720 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D127825 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 5.0000 | 0.5000 | 0.3000 | 0.3000 | 200.0000 | 0.0000N |
| D127826 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 5.0000 | 0.5000 | 0.2000 | 0.3000 | 150.0000 | 0.0000N |
| D127827 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 7.0000 | 0.5000 | 2.0000 | 0.2000 | 1000.0000 | 0.0000N |
| D127828 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.5000 | 0.3000 | 0.1500 | 0.2000 | 30.0000 | 0.0000N |
| D127832 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.0000 | 0.5000 | 0.1000 | 0.5000 | 20.0000 | 0.0000N |
| D129441 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 7.0000 | 2.0000 | 1.5000 | 0.5000 | 500.0000 | 0.0000N |
| D129501 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 3.0000 | 3.0000 | 0.7000 | 100.0000 | 0.0000N |
| D129503 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.5000 | 0.3000 | 0.1500 | 0.3000 | 20.0000 | 0.0000N |
| D129504 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 2.0000 | 0.7000 | 0.3000 | 0.5000 | 50.0000 | 0.0000N |
| D129505 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.5000 | 1.0000 | 0.1500 | 0.7000 | 30.0000 | 0.0000N |
| D129506 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.5000 | 0.7000 | 0.1500 | 0.3000 | 30.0000 | 0.0000N |
| D129507 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 5.0000 | 7.0000 | 0.3000 | 0.5000 | 70.0000 | 0.0000N |
| D129680 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 0.3000 | 2.0000 | 0.3000 | 70.0000 | 0.0000N |
| D132649 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D132651 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D137660 | 1.7100 | 0.8700 | 1.4400 | 2.4800 | 3.0000 | 2.0000 | 0.7000 | 0.5000 | 300.0000 | 0.0000N |
| D137662 | 0.7500 | 0.5500 | 0.7800 | 1.2300 | 1.5000 | 0.7000 | 0.3000 | 1.0000 | 70.0000 | 0.0000N |
| D137681 | 2.0700 | 0.6400 | 0.7500 | 3.1600 | 5.0000 | 2.0000 | 0.3000 | 0.5000 | 300.0000 | 0.0000N |
| D137682 | 2.4300 | 0.6400 | 1.3700 | 3.1800 | 3.0000 | 3.0000 | 0.3000 | 0.3000 | 300.0000 | 0.0000N |
| D137683 | 3.0800 | 2.0000 | 1.9800 | 3.2600 | 5.0000 | 2.0000 | 1.5000 | 0.5000 | 1000.0000 | 0.0000N |
| D137684 | 2.7400 | 1.1400 | 1.7000 | 3.1000 | 3.0000 | 1.5000 | 0.7000 | 0.3000 | 500.0000 | 0.0000N |
| D137685 | 2.0800 | 1.2200 | 1.5400 | 2.2900 | 5.0000 | 2.0000 | 0.7000 | 0.5000 | 300.0000 | 0.0000N |
| D137686 | 2.5000 | 0.6000 | 1.5000 | 3.0600 | 7.0000 | 2.0000 | 0.3000 | 0.5000 | 300.0000 | 0.0000N |
| D137687 | 2.8400 | 1.0100 | 2.0400 | 3.2200 | 5.0000 | 2.0000 | 0.5000 | 0.3000 | 300.0000 | 0.0000N |
| D138690 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138696 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138697 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138700 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D139927 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1500 | 0.0700 | 0.2000 | 0.0050 | 30.0000 | 0.0000N |
| D139928 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1000 | 0.1000 | 0.7000 | 0.0020 | 2.0000 | 0.0000N |
| D139929 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.2000 | 0.1000 | 0.3000 | 0.0030 | 5.0000 | 0.0000N |
| D139930 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1000 | 0.1500 | 0.3000 | 0.0020 | 7.0000 | 0.0000N |
| D139931 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1500 | 0.1500 | 0.2000 | 0.0015 | 1.0000 | 0.0000N |
| D139932 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.0000 | 0.5000 | 0.1500 | 0.3000 | 100.0000 | 0.0000N |
| D139933 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 0.7000 | 0.1500 | 0.3000 | 70.0000 | 0.0000N |
| D139934 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 0.7000 | 0.1500 | 0.3000 | 70.0000 | 0.0000N |
| D139935 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 0.7000 | 0.1500 | 0.3000 | 70.0000 | 0.0000N |
| D139937 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.7000 | 0.5000 | 0.3000 | 0.3000 | 50.0000 | 0.0000N |
| D139938 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.0000 | 0.7000 | 0.2000 | 0.3000 | 70.0000 | 0.0000N |
| D139939 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0700 | 0.0500 | 0.2000 | 0.0030 | 3.0000 | 0.0000N |
| D139940 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.5000 | 0.7000 | 0.2000 | 0.3000 | 70.0000 | 0.0000N |
| D139941 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.2000 | 0.0100 | 3.0000 | 0.0050 | 5.0000 | 0.0000N |
| D139942 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0500 | 0.0300 | 1.5000 | 0.0015 | 70.0000 | 0.0000N |
| D139943 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.3000 | 0.0300 | 0.2000 | 0.0150 | 70.0000 | 0.0000N |
| D139945 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 2.0000 | 1.0000 | 0.3000 | 0.3000 | 70.0000 | 0.0000N |
| D139946 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 0.7000 | 0.7000 | 0.2000 | 100.0000 | 0.0000N |
| D139947 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 3.0000 | 1.0000 | 0.1500 | 0.3000 | 150.0000 | 0.0000N |
| D139948 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 1.0000 | 0.7000 | 0.0700 | 0.2000 | 100.0000 | 0.0000N |
| D141326 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | AS PPM-S | AU PPM-S | B PPM-S | BA PPM-S | BE PPM-S | BI PPM-S | CD PPM-S | CO PPM-S | CR PPM-S | CU PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D126720 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D127825 | 0.0000N | 0.0000N | 20.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 7.0000 | 30.0000 | 70.0000 |
| D127826 | 0.0000N | 0.0000N | 20.0000 | 1000.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 30.0000 | 50.0000 |
| D127827 | 0.0000N | 0.0000N | 15.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 7.0000 | 30.0000 | 50.0000 |
| D127828 | 0.0000N | 0.0000N | 20.0000 | 150.0000 | 1.0000 | 0.0000N | 0.0000N | 3.0000 | 30.0000 | 70.0000 |
| D127832 | 0.0000N | 0.0000N | 20.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 3.0000 | 50.0000 | 30.0000 |
| D129441 | 0.0000N | 0.0000N | 70.0000 | 1500.0000 | 1.0000 | 0.0000N | 0.0000N | 15.0000 | 15.0000 | 30.0000 |
| D129501 | 0.0000N | 0.0000N | 50.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 100.0000 |
| D129503 | 0.0000N | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 30.0000 | 150.0000 |
| D129504 | 0.0000N | 0.0000N | 30.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 200.0000 |
| D129505 | 0.0000N | 0.0000N | 50.0000 | 1000.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 50.0000 | 100.0000 |
| D129506 | 0.0000N | 0.0000N | 30.0000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 70.0000 | 150.0000 |
| D129507 | 0.0000N | 0.0000N | 30.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 70.0000 | 100.0000 |
| D129680 | 0.0000N | 0.0000N | 0.0000N | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 7.0000 | 15.0000 |
| D132649 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D132651 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D137660 | 0.0000N | 0.0000N | 200.0000 | 1500.0000 | 2.0000 | 0.0000N | 0.0000N | 20.0000 | 100.0000 | 70.0000 |
| D137662 | 0.0000N | 0.0000N | 150.0000 | 300.0000 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 30.0000 |
| D137681 | 0.0000N | 0.0000N | 150.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 150.0000 | 70.0000 |
| D137682 | 0.0000N | 0.0000N | 100.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 100.0000 | 70.0000 |
| D137683 | 0.0000N | 0.0000N | 70.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 100.0000 | 70.0000 |
| D137684 | 0.0000N | 0.0000N | 100.0000 | 1000.0000 | 2.0000L | 0.0000N | 0.0000N | 30.0000 | 100.0000 | 100.0000 |
| D137685 | 0.0000N | 0.0000N | 150.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 30.0000 | 70.0000 | 70.0000 |
| D137686 | 0.0000N | 0.0000N | 100.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 150.0000 | 100.0000 |
| D137687 | 0.0000N | 0.0000N | 70.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 150.0000 | 150.0000 |
| D138690 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138696 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138697 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138700 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D139927 | 0.0000N | 0.0000N | 20.0000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.5000 | 50.0000 |
| D139928 | 0.0000N | 0.0000N | 30.0000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 1.0000 | 20.0000 |
| D139929 | 0.0000N | 0.0000N | 20.0000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.0000 | 20.0000 |
| D139930 | 0.0000N | 0.0000N | 50.0000 | 100.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.0000 | 20.0000 |
| D139931 | 0.0000N | 0.0000N | 30.0000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.0000 | 20.0000 |
| D139932 | 0.0000N | 0.0000N | 100.0000 | 500.0000 | 1.5000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 70.0000 |
| D139933 | 0.0000N | 0.0000N | 70.0000 | 700.0000 | 2.0000 | 0.0000N | 0.0000N | 7.0000 | 70.0000 | 50.0000 |
| D139934 | 0.0000N | 0.0000N | 100.0000 | 700.0000 | 2.0000 | 0.0000N | 0.0000N | 15.0000 | 70.0000 | 50.0000 |
| D139935 | 0.0000N | 0.0000N | 100.0000 | 700.0000 | 1.5000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 70.0000 |
| D139937 | 0.0000N | 0.0000N | 70.0000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 30.0000 | 20.0000 |
| D139938 | 0.0000N | 0.0000N | 50.0000 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 30.0000 | 20.0000 |
| D139939 | 0.0000N | 0.0000N | 30.0000 | 700.0000 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 2.0000 | 10.0000 |
| D139940 | 0.0000N | 0.0000N | 100.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 7.0000 | 70.0000 | 20.0000 |
| D139941 | 0.0000N | 0.0000N | 0.0000L | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.5000 | 20.0000 |
| D139942 | 0.0000N | 0.0000N | 0.0000L | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.0000 | 10.0000 |
| D139943 | 0.0000N | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.0000 | 15.0000 |
| D139945 | 0.0000N | 0.0000N | 100.0000 | 500.0000 | 1.5000 | 0.0000N | 0.0000N | 7.0000 | 70.0000 | 20.0000 |
| D139946 | 0.0000N | 0.0000N | 70.0000 | 500.0000 | 2.0000 | 0.0000N | 0.0000N | 15.0000 | 70.0000 | 50.0000 |
| D139947 | 0.0000N | 0.0000N | 70.0000 | 1000.0000 | 1.5000 | 0.0000N | 0.0000N | 7.0000 | 100.0000 | 150.0000 |
| D139948 | 0.0000N | 0.0000N | 150.0000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 100.0000 |
| D141326 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | LA PPM-S | MO PPM-S | NB PPM-S | NI PPM-S | PB PPM-S | PD PPM-S | PT PPM-S | SB PPM-S | SC PPM-S | SN PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D126720 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D127825 | 30.0000 | 0.0000N | 10.0000 | 7.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N |
| D127826 | 70.0000 | 0.0000N | 10.0000 | 15.0000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D127827 | 50.0000 | 0.0000N | 10.0000 | 10.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D127828 | 30.0000 | 0.0000N | 10.0000 | 7.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N |
| D127832 | 30.0000 | 0.0000N | 10.0000 | 5.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D129441 | 70.0000 | 0.0000N | 0.0000N | 10.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D129501 | 30.0000 | 0.0000N | 10.0000 | 20.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D129503 | 0.0000N | 0.0000N | 0.0000N | 3.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000L | 0.0000N |
| D129504 | 30.0000 | 10.0000 | 10.0000 | 20.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D129505 | 50.0000 | 0.0000N | 10.0000 | 15.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D129506 | 30.0000 | 10.0000 | 10.0000 | 20.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D129507 | 30.0000 | 10.0000 | 10.0000 | 10.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 0.0000N |
| D129680 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D132649 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D132651 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D137660 | 70.0000 | 7.0000 | 20.0000 | 70.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 30.0000 | 0.0000N |
| D137662 | 0.0000N | 15.0000 | 30.0000 | 10.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D137681 | 70.0000 | 7.0000 | 20.0000 | 50.0000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 0.0000N |
| D137682 | 0.0000N | 0.0000N | 20.0000 | 30.0000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 0.0000N |
| D137683 | 0.0000N | 0.0000N | 20.0000 | 50.0000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 0.0000N |
| D137684 | 70.0000 | 0.0000N | 20.0000 | 100.0000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D137685 | 70.0000 | 7.0000 | 30.0000 | 150.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D137686 | 0.0000N | 10.0000 | 20.0000 | 100.0000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 0.0000N |
| D137687 | 70.0000 | 0.0000N | 20.0000 | 70.0000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 0.0000N |
| D138690 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138696 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138697 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138700 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D139927 | 0.0000N | 0.0000N | 0.0000L | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139928 | 0.0000N | 0.0000N | 0.0000L | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139929 | 0.0000N | 0.0000N | 0.0000L | 7.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139930 | 0.0000N | 0.0000N | 0.0000L | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139931 | 0.0000N | 0.0000N | 0.0000L | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139932 | 100.0000 | 0.0000L | 10.0000 | 30.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139933 | 50.0000 | 3.0000 | 10.0000 | 30.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139934 | 50.0000 | 5.0000 | 10.0000 | 30.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139935 | 50.0000 | 0.0000N | 10.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139937 | 30.0000 | 0.0000N | 10.0000 | 15.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N |
| D139938 | 50.0000 | 0.0000N | 10.0000 | 15.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N |
| D139939 | 0.0000N | 0.0000N | 0.0000L | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139940 | 70.0000 | 0.0000N | 10.0000 | 15.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D139941 | 0.0000N | 0.0000N | 0.0000L | 5.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139942 | 0.0000N | 0.0000N | 0.0000L | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139943 | 0.0000N | 0.0000N | 0.0000L | 7.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139945 | 70.0000 | 0.0000N | 10.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139946 | 50.0000 | 3.0000 | 0.0000L | 70.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139947 | 30.0000 | 7.0000 | 0.0000L | 30.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N |
| D139948 | 30.0000 | 0.0000N | 0.0000L | 7.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N |
| D141326 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | SR PPM-S | TE PPM-S | U PPM-S | V PPM-S | W PPM-S | Y PPM-S | ZN PPM-S | ZR PPM-S | SI %-S | AL %-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D126720 | 0,0000B | 0,0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0,0000B | 0.0000B | 0.0000B | 0.0000B |
| D127825 | 200,0000 | 0,0000N | 0.0000N | 70,0000 | 0.0000N | 15.0000 | 0.0000N | 150.0000 | 10.0000G | 10.0000G |
| D127826 | 150,0000 | 0.0000N | 0.0000N | 70,0000 | 0.0000N | 30,0000 | 0.0000N | 150.0000 | 10.0000G | 10.0000G |
| D127827 | 200.0000 | 0.0000N | 0.0000N | 70,0000 | 0.0000N | 50,0000 | 0.0000N | 100,0000 | 10.0000G | 7,0000 |
| D127828 | 100,0000 | 0.0000N | 0.0000N | 70,0000 | 0.0000N | 10,0000 | 0.0000N | 70,0000 | 10.0000G | 7,0000 |
| D127832 | 70,0000 | 0,0000N | 0,0000N | 100,0000 | 0,0000N | 15,0000 | 0.0000N | 200,0000 | 10,0000G | 10,0000G |
| D129441 | 300,0000 | 0,0000N | 0,0000N | 100,0000 | 0.0000N | 20,0000 | 0.0000N | 100,0000 | 10,0000G | 10,0000 |
| D129501 | 300,0000 | 0.0000N | 0.0000N | 70,0000 | 0.0000N | 30,0000 | 0.0000N | 200,0000 | 10,0000G | 7,0000 |
| D129503 | 50,0000 | 0,0000N | 0.0000N | 30,0000 | 0.0000N | 10,0000 | 0.0000N | 150,0000 | 10,0000G | 7,0000 |
| D129504 | 150,0000 | 0.0000N | 0.0000N | 100,0000 | 0.0000N | 20,0000 | 0.0000N | 200,0000 | 10,0000G | 10,0000 |
| D129505 | 100,0000 | 0.0000N | 0.0000N | 200,0000 | 0.0000N | 20,0000 | 0.0000N | 300,0000 | 10,0000G | 10,0000 |
| D129506 | 70,0000 | 0,0000N | 0.0000N | 200,0000 | 0.0000N | 30,0000 | 0.0000N | 150,0000 | 10,0000G | 7,0000 |
| D129507 | 150,0000 | 0,0000N | 0,0000N | 150,0000 | 0.0000N | 20,0000 | 0.0000N | 150,0000 | 10,0000G | 10,0000 |
| D129680 | 700,0000 | 0.0000N | 0.0000N | 30,0000 | 0.0000N | 15,0000 | 0.0000N | 300,0000 | 10,0000G | 7,0000 |
| D132649 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0,0000B | 0.0000B | 0.0000B | 0.0000B |
| D132651 | 0,0000B | 0,0000B | 0.0000B | 0.0000B | 0.0000B | 0,0000B | 0,0000B | 0.0000B | 0.0000B | 0,0000B |
| D137660 | 300,0000 | 0,0000N | 0.0000N | 150,0000 | 0.0000N | 50,0000 | 0,0000N | 300,0000 | 0,0000B | 10,0000 |
| D137662 | 200,0000 | 0,0000N | 0.0000N | 150,0000 | 0.0000N | 50,0000 | 0,0000N | 300,0000 | 0,0000B | 7,0000 |
| D137681 | 300,0000 | 0,0000N | 0.0000N | 300,0000 | 0.0000N | 20,0000 | 0.0000N | 150,0000 | 0,0000B | 10,0000 |
| D137682 | 300,0000 | 0,0000N | 0,0000N | 200,0000 | 0.0000N | 20,0000 | 0,0000N | 100,0000 | 0,0000B | 10,0000 |
| D137683 | 300,0000 | 0,0000N | 0.0000N | 200,0000 | 0.0000N | 30,0000 | 0,0000N | 150,0000 | 0,0000B | 10,0000 |
| D137684 | 300,0000 | 0.0000N | 0,0000N | 150,0000 | 0.0000N | 30,0000 | 0,0000N | 150,0000 | 0,0000B | 7,0000 |
| D137685 | 300,0000 | 0.0000N | 0,0000N | 150,0000 | 0,0000N | 30,0000 | 0,0000N | 200,0000 | 0,0000B | 7,0000 |
| D137686 | 300,0000 | 0.0000N | 0,0000N | 300,0000 | 0,0000N | 30,0000 | 0,0000N | 150,0000 | 0,0000B | 10,0000 |
| D137687 | 300,0000 | 0,0000N | 0,0000N | 300,0000 | 0,0000N | 30,0000 | 0,0000N | 100,0000 | 0,0000B | 10,0000 |
| D138690 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D138696 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D138697 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D138700 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D139927 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000G | 0,3000 |
| D139928 | 70,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 0,0000N | 10,0000G | 0,1000 |
| D139929 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 0,0000N | 10,0000G | 0,1500 |
| D139930 | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000G | 0,0300 |
| D139931 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000G | 0,0500 |
| D139932 | 700,0000 | 0,0000N | 0,0000N | 70,0000 | 0,0000N | 30,0000 | 0,0000N | 20,0000 | 10,0000G | 5,0000 |
| D139933 | 300,0000 | 0,0000N | 0,0000N | 100,0000 | 0,0000N | 30,0000 | 0,0000N | 150,0000 | 10,0000G | 7,0000 |
| D139934 | 300,0000 | 0,0000N | 0,0000N | 150,0000 | 0,0000N | 30,0000 | 0,0000N | 150,0000 | 10,0000G | 7,0000 |
| D139935 | 300,0000 | 0,0000N | 0,0000N | 150,0000 | 0,0000N | 20,0000 | 0,0000N | 150,0000 | 10,0000G | 7,0000 |
| D139937 | 150,0000 | 0,0000N | 0,0000N | 30,0000 | 0,0000N | 10,0000 | 0,0000N | 150,0000 | 10,0000G | 3,0000 |
| D139938 | 150,0000 | 0,0000N | 0,0000N | 50,0000 | 0,0000N | 20,0000 | 0,0000N | 150,0000 | 10,0000G | 5,0000 |
| D139939 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 15,0000 | 10,0000G | 0,1500 |
| D139940 | 300,0000 | 0,0000N | 0,0000N | 70,0000 | 0,0000N | 30,0000 | 0,0000N | 150,0000 | 10,0000G | 7,0000 |
| D139941 | 100,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000G | 0,2000 |
| D139942 | 70,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000G | 0,1000 |
| D139943 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000G | 0,3000 |
| D139945 | 300,0000 | 0,0000N | 0,0000N | 70,0000 | 0,0000N | 30,0000 | 0,0000N | 150,0000 | 10,0000G | 7,0000 |
| D139946 | 300,0000 | 0,0000N | 0,0000N | 100,0000 | 0,0000N | 30,0000 | 0,0000N | 150,0000 | 10,0000G | 5,0000 |
| D139947 | 300,0000 | 0,0000N | 0,0000N | 150,0000 | 0,0000N | 20,0000 | 0,0000N | 70,0000 | 10,0000G | 7,0000 |
| D139948 | 150,0000 | 0,0000N | 0,0000N | 150,0000 | 0,0000N | 0,0000L | 0,0000N | 70,0000 | 10,0000G | 7,0000 |
| D141326 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |

| SAMPLE ID | NA %-S | K %-S | P %-S | CE PPM-S | GE PPM-S | HF PPM-S | IN PPM-S | LI PPM-S | RE PPM-S |
|---|---|---|---|---|---|---|---|---|---|
| D126720 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D127825 | 0.7000 | 2.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D127826 | 0.3000 | 3.0000 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D127827 | 1.0000 | 3.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D127828 | 0.2000 | 3.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D127832 | 0.3000 | 3.0000 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129441 | 3.0000 | 3.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129501 | 0.5000 | 3.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129503 | 0.1000 | 2.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 100.0000L | 0.0000N |
| D129504 | 0.5000 | 5.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129505 | 0.3000 | 3.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129506 | 0.3000 | 3.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129507 | 0.7000 | 5.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D129680 | 2.0000 | 3.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D132649 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D132651 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D137660 | 0.0000B | 3.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137662 | 0.0000B | 2.0000 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137681 | 0.0000B | 7.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137682 | 0.0000B | 7.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137683 | 0.0000B | 2.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137684 | 0.0000B | 3.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137685 | 0.0000B | 3.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137686 | 0.0000B | 5.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D137687 | 0.0000B | 7.0000 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D138690 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138696 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138697 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D138700 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D139927 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139928 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139929 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N |
| D139930 | 0.1500 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139931 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139932 | 1.0000 | 3.0000 | 0.0000N | 200.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139933 | 1.5000 | 3.0000 | 0.0000N | 150.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139934 | 1.5000 | 3.0000 | 0.0000N | 150.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139935 | 1.5000 | 3.0000 | 0.0000N | 150.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139937 | 0.7000 | 2.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139938 | 0.7000 | 2.0000 | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139939 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139940 | 1.5000 | 3.0000 | 0.0000N | 150.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139941 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139942 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139943 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139945 | 2.0000 | 3.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139946 | 3.0000 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139947 | 3.0000 | 5.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D139948 | 0.5000 | 3.0000 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D141326 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | TA PPM-S | TH PPM-S | TL PPM-S | YB PPM-S | PR PPM-S | ND PPM-S | SM PPM-S | EU PPM-S | HG PPM-S | U PPM |
|---|---|---|---|---|---|---|---|---|---|---|
| D126720 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D127825 | 0,0000N | 0,0000N | 0,0000N | 2,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D127826 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D127827 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D127828 | 0,0000N | 0,0000N | 0,0000N | 1,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D127832 | 0,0000N | 0,0000N | 0,0000N | 2,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D129441 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D129501 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B |
| D129503 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B |
| D129504 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B |
| D129505 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B |
| D129506 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B |
| D129507 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B |
| D129680 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B |
| D132649 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 10,0000L |
| D132651 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 10,0000L |
| D137660 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D137662 | 0,0000N | 0,0000N | 0,0000N | 7,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D137681 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D137682 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D137683 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D137684 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D137685 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D137686 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D137687 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D138690 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 500,0000 |
| D138696 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D138697 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D138700 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D139927 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139928 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139929 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139930 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139931 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139932 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139933 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139934 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139935 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139937 | 0,0000N | 0,0000N | 0,0000N | 1,5000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139938 | 0,0000N | 0,0000N | 0,0000N | 2,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139939 | 0,0000N | 0,0000N | 0,0000N | 1,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139940 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139941 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139942 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139943 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B | 0,0000B | 0,0000N | 0,0000B | 0,0000B |
| D139945 | 0,0000N | 0,0000N | 0,0000N | 3,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139946 | 0,0000N | 0,0000N | 0,0000N | 2,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139947 | 0,0000N | 0,0000N | 0,0000N | 2,0000 | 0,0000N | 0,0000L | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D139948 | 0,0000N | 0,0000N | 0,0000N | 1,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000B | 0,0000B |
| D141326 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |

| SAMPLE ID | EQU PPM | ASH % | U/A PPM |
|---|---|---|---|
| D126720 | 0.0000B | 0.0000B | 0.0000B |
| D127825 | 0.0000B | 0.0000B | 0.0000B |
| D127826 | 0.0000B | 0.0000B | 0.0000B |
| D127827 | 0.0000B | 0.0000B | 0.0000B |
| D127829 | 0.0000B | 0.0000B | 0.0000B |
| D127832 | 0.0000B | 0.0000B | 0.0000B |
| D129441 | 0.0000B | 0.0000B | 0.0000B |
| D129501 | 20.0000 | 0.0000B | 0.0000B |
| D129503 | 20.0000 | 0.0000B | 0.0000B |
| D129504 | 20.0000 | 0.0000B | 0.0000B |
| D129505 | 30.0000 | 0.0000B | 0.0000B |
| D129506 | 20.0000 | 0.0000B | 0.0000B |
| D129507 | 30.0000 | 0.0000B | 0.0000B |
| D129680 | 0.0000B | 0.0000B | 0.0000B |
| D132649 | 20.0000 | 0.0000B | 0.0000B |
| D132651 | 10.0000 | 0.0000B | 0.0000B |
| D137660 | 10.0000 | 79.9000 | 0.0000B |
| D137662 | 10.0000 | 83.2000 | 0.0000B |
| D137681 | 20.0000 | 85.6000 | 0.0000B |
| D137682 | 20.0000 | 93.0000 | 0.0000B |
| D137683 | 20.0000 | 93.4000 | 0.0000B |
| D137684 | 20.0000 | 89.8000 | 0.0000B |
| D137685 | 10.0000 | 75.4000 | 0.0000B |
| D137686 | 20.0000 | 87.2000 | 0.0000B |
| D137687 | 10.0000 | 93.6000 | 0.0000B |
| D138690 | 160.0000 | 87.2000 | 0.0000B |
| D138696 | 10.0000L | 0.0000B | 0.0000B |
| D138697 | 20.0000 | 0.0000B | 0.0000B |
| D138700 | 10.0000 | 0.0000B | 0.0000B |
| D139927 | 10.0000L | 97.3000 | 0.0000B |
| D139928 | 10.0000L | 87.3000 | 0.0000B |
| D139929 | 10.0000L | 91.3000 | 0.0000B |
| D139930 | 10.0000L | 90.7000 | 0.0000B |
| D139931 | 10.0000L | 96.7000 | 0.0000B |
| D139932 | 20.0000 | 79.7000 | 0.0000B |
| D139933 | 20.0000 | 86.3000 | 0.0000B |
| D139934 | 20.0000 | 89.7000 | 0.0000B |
| D139935 | 20.0000 | 93.7000 | 0.0000B |
| D139937 | 10.0000 | 95.7000 | 0.0000B |
| D139938 | 10.0000 | 96.7000 | 0.0000B |
| D139939 | 10.0000 | 96.3000 | 0.0000B |
| D139940 | 30.0000 | 87.3000 | 0.0000B |
| D139941 | 10.0000 | 97.3000 | 0.0000B |
| D139942 | 10.0000L | 94.3000 | 0.0000B |
| D139943 | 10.0000L | 97.7000 | 0.0000B |
| D139945 | 30.0000 | 86.7000 | 0.0000B |
| D139946 | 30.0000 | 67.7000 | 0.0000B |
| D139947 | 50.0000 | 80.3000 | 0.0000B |
| D139948 | 40.0000 | 83.7000 | 0.0000B |
| D141326 | 10.0000L | 5.2000 | 10.0000 |

| SAMPLE ID | SUBMITTER NAME | SUBMITTAL DATE | | SAMPLE CATEGORY | SAMPLE MATERIAL |
|---|---|---|---|---|---|
| D160961 | SWANSON VERNON E | 73- 2-23 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D163021 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163022 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163023 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163024 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163025 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163026 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163027 | SWANSON VERNON E | 73- 7-11 | * | SEDIMENTARY ROCK | SILTSTONE |
| D163188 | SWANSON VERNON E | 73- 7-31 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D163189 | SWANSON VERNON E | 73- 7-31 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D163192 | SWANSON VERNON E | 73- 7-31 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D163193 | SWANSON VERNON E | 73- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D163194 | SWANSON VERNON E | 73- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169014 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169015 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169016 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169017 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169018 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169019 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169020 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169021 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169022 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | MUDSTONE |
| D169023 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169024 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169025 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169026 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169027 | SWANSON VERNON E | 74- 7-31 | * | SEDIMENTARY ROCK | SHALE |
| D169421 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169422 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169423 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169424 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169425 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169426 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169427 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SHALE |
| D169428 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169429 | HATCH JOSEPH R | 74- 9- 3 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169435 | HATCH JOSEPH R | 74- 8-30 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D169436 | HATCH JOSEPH R | 74- 8-30 | * | SEDIMENTARY ROCK | SHALE |
| D169726 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169728 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D169729 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | CLAYSTONE |
| D169730 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169734 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169735 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169737 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169738 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169739 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169741 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169742 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169743 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |

| SAMPLE ID | FORMATION NAME | COMMENTS |
|---|---|---|
| D160981 | FORT UNION | WYODAK MINE, CLAYSTONE, 26: 5'-27:FROM BASE |
| D163021 | FRUITLAND | SILTSTONE, BED 0,8 FT THICK ABOVE SAN JUAN COAL |
| D163022 | FRUITLAND | SILTSTONE, SAMPLE OF NINE PARTINGS IN COAL BED 'SAN JUAN' |
| D163023 | FRUITLAND | SILTSTONE, BED 0,6 FT THICK ABOVE SAN JUAN COAL |
| D163024 | FRUITLAND | SILTSTONE, SAMPLE OF EIGHT PARTINGS IN SAN JUAN COAL BED |
| D163025 | FRUITLAND | SILTSTONE, BED 1,9 FT THICK ABOVE SAN JUAN COAL |
| D163026 | FRUITLAND | SILTSTONE, SAMPLE OF SEVEN PARTINGS IN SAN JUAN COAL BED |
| D163027 | FRUITLAND | SILTSTONE, UPPER 0,4 FT OF SEAT-ROCK, SAN JUAN COAL BED |
| D163188 | FORT UNION | CLAYSTONE, ROSEBUD COAL BED, 12.5-12.6 FT FROM TOP |
| D163189 | FORT UNION | CLAYSTONE ROOFROCK, 0.4 FT THICK ABOVE ROSEBUD |
| D163192 | FORT UNION | CLAYSTONE W COAL STREAKS, 24.7-25.2 FT, ROSEBUD |
| D163193 | FORT UNION | PYRITIC SHALE, 0.2 FT THICK, BASE OF ROSEBUD COAL |
| D163194 | FORT UNION | CARB. SHALE, 0.3 FT THICK, BASE OF MCKAY COAL |
| D169014 | RATON | SILTY, CARB, SHALE AT BASE OF COAL, YORK CANYON BED, YORK CANYON MINE |
| D169015 | RATON | CARBONACEOUS SHALE PARTING, 3' THICK, YORK CANYON BED |
| D169016 | RATON | BASAL CARB. SHALE & MUDSTONE, 4' THICK, YORK CANYON BED, KAISER MINE |
| D169017 | RATON | CARB. SHALE PARTING, 10' THICK, YORK CANYON BED |
| D169018 | RATON | CARB. SHALE & MUDSTONE )ROOF(, 4' THICK |
| D169019 | RATON | BASAL CARB. SHALE & MUDSTONE, 4' THICK, YORK CANYON BED, KAISER MINE |
| D169020 | RATON | COALY SHALE & SHALY COAL, 10' THICK, YORK CANYON BED, KAISER MINE |
| D169021 | RATON | CARBONACEOUS SHALE, 7' THICK, YORK CANYON BED, KAISER MINE |
| D169022 | RATON | MUDSTONE, CARBONACEOUS, )ROOF( 6' THICK |
| D169023 | RATON | CARBONACEOUS SHALE, 3' THICK, UPPER LEFT FORK BED, LEFT FORK MINE |
| D169024 | RATON | CARBONACEOUS SHALE PARTING, 5' THICK, LEFT FORK MINE |
| D169025 | RATON | COALY SHALE PARTING, 3' THICK, LEFT FORK MINE |
| D169026 | RATON | CARBONACEOUS SHALE )ROOF(, 6' THICK, LEFT FORK MINE |
| D169027 | VERMEJO | CARBONACEOUS SHALE )BASE OF COAL( RATON BED, OUTCROP SAMPLE, 3' THICK |
| D169421 | FORT UNION | SH, CARB., ROOF ABOVE A CHANNEL, NE1/4 NE1/4 SEC. 19, T21N, R100W |
| D169422 | FORT UNION | SH, CARB., .1:PARTING, BASE UPPER BENCH, NE 1/4 NE 1/4 SEC. 19, T21N, |
| D169423 | FORT UNION | SH, CARB., .05: PARTING 7.5 FROM TOP NE1/4 NE1/4 SEC. 19, T21N,R100W |
| D169424 | FORT UNION | SH, CARB., .1: PARTING BASE UPPER BENCH, NE1/4 NE1/4 SEC.19, T21N,R100 |
| D169425 | FORT UNION | SH, CARB, .05: PARTING BASE OF JB-C-1, NE1/4 NE1/4 SEC. 19, T21N,R100W |
| D169426 | FORT UNION | SH, CARB., .4: PARTING 9.3: FROM TOP, NW1/4 NW1/4 SEC.20,T21N,R100W |
| D169427 | FORT UNION | SH, CARB., ROOF SAMPLE OF SHALE 1 FT THICK, NW1/4 NW1/4 SEC. 20, T21N |
| D169428 | FORT UNION | STS, ARGILL., LIGHT GRAY 'REP. SAMPLE' OF 30-40 FT OVERBURDEN )TM( |
| D169429 | FORT UNION | STS, ARGILL., LIGHT GRAY 'REP. SAMPLE' OF 30-40 FT OVERBURDEN )HR( |
| D169435 | DENVER | CLAYSTONE, 15' THICK KAOLINITE RICH BED ABOVE COM. COAL OTCP GRB SMPL |
| D169436 | DENVER | CARB. SHALE-BONE COAL PARTING, COAL BED AM OTCRP FACE CHNL SMP 21' THK |
| D169726 | TONGUE RIVER MEMB. FT. UNION FM. | STS. OVER KNOBLOCK BED, CORE INT. >0.5-5.6 FT. |
| D169728 | TONGUE RIVER MEMB. FT. UNION FM. | CLAYST, OVER KNOBLOCK BED, CORE INT 14.4-30.9 FT. |
| D169729 | TONGUE RIVER MEMB. FT. UNION FM. | CLAYST, OVER KNOBLOCK BED, CORE INT 30.9-41.9 FT. |
| D169730 | TONGUE RIVER MEMB. FT. UNION FM. | SH STS OVER KNOBLOCK BED, CORE INT 41.9-74 FT. |
| D169734 | TONGUE RIVER MEMB. FT. UNION FM. | STS, SANDY, OVER KNOBLOCK BED, CORE, INT>164.6-168.0 FT. |
| D169735 | TONGUE RIVER MEMB. FT. UNION FM. | STS, CLAYEY, OVER KNOBLOCK BED, CORE, INT>168.0-198.4 FT. |
| D169737 | TONGUE RIVER MEMB. FT. UNION FM. | SH, SILTY, OVER KNOBLOCK BED, CORE, INT.>3.5-16.0 FT. |
| D169738 | TONGUE RIVER MEMB. FT. UNION FM. | STS, OVER KNOBLOCK BED, CORE, INT>16.0-17.2 FT. |
| D169739 | TONGUE RIVER MEMB. FT. UNION FM. | SH, SILTY OVER KNOBLOCK BED, CORE, INT. 17.2-23.7 FT. |
| D169741 | TONGUE RIVER MEMB. FT. UNION FM. | STS, SANDY OVER KNOBLOCK BED, CORE, INT 89.7-110.7 FT. |
| D169742 | TONGUE RIVER MEMB. FT. UNION FM. | STS, CLAYEY, OVER KNOBLOCK BED, CORE, INT 110.7-126.1 FT. |
| D169743 | TONGUE RIVER MEMB. FT. UNION FM. | SH, CARB, STS, CORE BELOW KNOBLOCK BED, INT 185.2-192.4 FT. |

| SAMPLE ID | FIELD NO. | STATE | LATITUDE | LONGITUDE | SAMPLE TYPE | SAMPLE SOURCE | GEOLOGIC AGE |
|---|---|---|---|---|---|---|---|
| D160981 | L73-1F | WYOMING | 44-15- 0N | 105-22-30W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D163021 | 1-SJ-A | NEW MEXICO | 36-45- 0N | 108-22-30W | CHANNEL | OPEN PIT MINE | CRETACEOUS |
| D163022 | 1-SJ-B | NEW MEXICO | 36-45- 0N | 108-22-30W | COMPOSITE | OPEN PIT MINE | CRETACEOUS |
| D163023 | 2-SJ-A | NEW MEXICO | 36-45- 0N | 108-22-30W | CHANNEL | OPEN PIT MINE | CRETACEOUS |
| D163024 | 2-SJ-B | NEW MEXICO | 36-45- 0N | 108-22-30W | COMPOSITE | OPEN PIT MINE | CRETACEOUS |
| D163025 | 3-SJ-A | NEW MEXICO | 36-45- 0N | 108-22-30W | CHANNEL | OPEN PIT MINE | CRETACEOUS |
| D163026 | 3-SJ-B | NEW MEXICO | 36-45- 0N | 108-22-30W | COMPOSITE | OPEN PIT MINE | CRETACEOUS |
| D163027 | 3-SJ-D | NEW MEXICO | 36-45- 0N | 108-22-30W | CHANNEL | OPEN PIT MINE | CRETACEOUS |
| D163188 | BSM-3 | MONTANA | 45-45- 0N | 106-30- 0W | SINGLE | OPEN PIT MINE | PALEOCENE |
| D163189 | BSM-4 | MONTANA | 45-45- 0N | 106-30- 0W | COMPOSITE | OPEN PIT MINE | PALEOCENE |
| D163192 | BSM-10 | MONTANA | 45-45- 0N | 106-30- 0W | COMPOSITE | OPEN PIT MINE | PALEOCENE |
| D163193 | BSM-12 | MONTANA | 45-45- 0N | 106-30- 0W | COMPOSITE | OPEN PIT MINE | PALEOCENE |
| D163194 | BSM-15 | MONTANA | 45-45- 0N | 106-30- 0W | COMPOSITE | OPEN PIT MINE | PALEOCENE |
| D169014 | 741A | NEW MEXICO | 36-52-13N | 104-53-34W | CHANNEL | UNDERGROUND MINE | PALEOCENE |
| D169015 | 741C | NEW MEXICO | 36-52-13N | 104-53-34W | CHANNEL | UNDERGROUND MINE | PALEOCENE |
| D169016 | 746A | NEW MEXICO | 36-52-13N | 104-55-14W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169017 | 746C | NEW MEXICO | 36-52-13N | 104-55-14W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169018 | 746E | NEW MEXICO | 36-52-13N | 104-55-14W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169019 | 747A | NEW MEXICO | 36-52-38N | 104-55-17W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169020 | 747C | NEW MEXICO | 36-52-38N | 104-55-17W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169021 | 747E | NEW MEXICO | 36-52-38N | 104-55-17W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169022 | 747G | NEW MEXICO | 36-52-38N | 104-55-17W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169023 | 742A | NEW MEXICO | 36-56-25N | 104-58- 1W | CHANNEL | UNDERGROUND MINE | PALEOCENE |
| D169024 | 742C | NEW MEXICO | 36-56-25N | 104-58- 1W | CHANNEL | UNDERGROUND MINE | PALEOCENE |
| D169025 | 742E | NEW MEXICO | 36-56-25N | 104-58- 1W | CHANNEL | UNDERGROUND MINE | PALEOCENE |
| D169026 | 742G | NEW MEXICO | 36-56-25N | 104-58- 1W | CHANNEL | UNDERGROUND MINE | PALEOCENE |
| D169027 | 744A | NEW MEXICO | 36-55-30N | 105- 1-10W | CHANNEL | OUTCROP | CRETACEOUS |
| D169421 | JB-A-A | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169422 | JB-A-P | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169423 | JB-B-MP | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169424 | JB-B-P | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169425 | JB-C-P | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169426 | JB-D-P | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169427 | JB-O-OL | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169428 | JB-O-M | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169429 | JB-O-R | WYOMING | 41-45- 0N | 108-45- 0W | CHANNEL | OPEN PIT MINE | PALEOCENE |
| D169435 | STA.CK.#2K | COLORADO | 39-15- 0N | 104- 7-30W | CHANNEL | OUTCROP | PALEOCENE |
| D169436 | JH7402 | COLORADO | 39-37-30N | 104-45- 0W | CHANNEL | OUTCROP | PALEOCENE |
| D169726 | 74-101-A | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169728 | 74-101-C | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169729 | 74-101-D | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169730 | 74-101-E | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169734 | 74-101-I | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169735 | 74-101-J | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169737 | 74-102-2 | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169738 | 74-102-3 | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169739 | 74-102-4 | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169741 | 74-102-6 | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169742 | 74-102-7 | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169743 | 74-102-8 | MONTANA | 45-30- 0N | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |

| SAMPLE ID | SIO2 % | AL2O3 % | FETO3 % | MGO % | CAO % | NA2O % | K2O % | P2O5 % | SO3 % | F % |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0200 |
| D163021 | 64.7010 | 19.3330 | 2.7746 | 1.4300 | 1.4491 | 1.8300 | 0.4215 | 0.0500L | 2.2991 | 0.0600 |
| D163022 | 44.5910 | 25.5540 | 1.1955 | 0.3300 | 2.4903 | 0.6000 | 0.4557 | 0.0500L | 1.3696 | 0.0300 |
| D163023 | 62.6180 | 14.3200 | 2.6640 | 1.0000 | 0.1358 | 0.9000 | 2.0298 | 0.0500L | 1.3645 | 0.0500 |
| D163024 | 42.1500 | 24.9030 | 0.6699 | 0.4400 | 1.4173 | 0.4400 | 0.4550 | 0.0500L | 0.6093 | 0.0400 |
| D163025 | 44.0230 | 10.5110 | 3.9855 | 0.7300 | 2.1869 | 1.0300 | 1.4015 | 0.0500L | 6.6207 | 0.0400 |
| D163026 | 47.5980 | 27.8390 | 0.7771 | 0.3500 | 1.3500 | 0.3800 | 0.4045 | 0.0500L | 0.5381 | 0.0300 |
| D163027 | 60.9150 | 14.9120 | 4.7498 | 1.0300 | 0.1000L | 1.2000 | 2.8629 | 0.0500L | 6.1516 | 0.0900 |
| D163188 | 61.3370 | 8.1507 | 1.0461 | 0.4300 | 0.3009 | 0.0800 | 2.8407 | 0.0500L | 0.3663 | 0.0600 |
| D163189 | 72.2470 | 14.1540 | 3.5251 | 1.9000 | 0.2486 | 0.5400 | 4.0484 | 0.1283 | 1.0867 | 0.1000 |
| D163192 | 36.5000 | 13.4240 | 0.2429 | 0.5500 | 0.5177 | 0.1000 | 0.1000L | 0.0500L | 0.4616 | 0.0100 |
| D163193 | 43.5720 | 10.2320 | 16.1700 | 1.6000 | 0.1951 | 0.0900 | 3.1304 | 0.0956 | 28.0220 | 0.0900 |
| D163194 | 39.6680 | 9.3943 | 0.9747 | 1.3000 | 0.6334 | 0.1700 | 0.8378 | 0.0500L | 0.5168 | 0.0300 |
| D169014 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0716 |
| D169015 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0176 |
| D169016 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0764 |
| D169017 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0488 |
| D169018 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0552 |
| D169019 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0680 |
| D169020 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0476 |
| D169021 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0604 |
| D169022 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0632 |
| D169023 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0752 |
| D169024 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0640 |
| D169025 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0304 |
| D169026 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0760 |
| D169027 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0440 |
| D169421 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0195 |
| D169422 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1100 |
| D169423 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0020 |
| D169424 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0960 |
| D169425 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0020 |
| D169426 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0075 |
| D169427 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.2760 |
| D169428 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1640 |
| D169429 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.1640 |
| D169435 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0310 |
| D169436 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0500 |
| D169726 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0710 |
| D169728 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0935 |
| D169729 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0785 |
| D169730 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0710 |
| D169734 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0540 |
| D169735 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0825 |
| D169737 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0830 |
| D169738 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0525 |
| D169739 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0935 |
| D169741 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0695 |
| D169742 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0720 |
| D169743 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0880 |

| SAMPLE ID | TOTAL S% | FE %-S | MG %-S | CA %-S | TI %-S | MN PPM-S | AG PPM-S | AS PPM-S | AU PPM-S | B PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 0.0000B | 1.0000 | 0.7000 | 0.3000 | 0.5000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D163021 | 0.8500 | 1.5000 | 0.7000 | 0.7000 | 0.1500 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 30.0000 |
| D163022 | 0.5600 | 0.7000 | 0.1500 | 0.7000 | 0.1500 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 30.0000 |
| D163023 | 0.6400 | 1.5000 | 0.5000 | 0.1000 | 0.2000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D163024 | 0.2800 | 0.3000 | 0.1500 | 0.7000 | 0.2000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 30.0000 |
| D163025 | 2.4100 | 1.5000 | 0.3000 | 1.5000 | 0.2000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D163026 | 0.2700 | 0.5000 | 0.1000 | 0.7000 | 0.1500 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 30.0000 |
| D163027 | 2.2700 | 1.5000 | 0.7000 | 0.0700 | 0.2000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D163188 | 0.2000 | 0.7000 | 0.7000 | 0.2000 | 0.3000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D163189 | 0.5600 | 2.0000 | 1.0000 | 0.2000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D163192 | 0.2900 | 0.3000 | 0.5000 | 0.5000 | 0.5000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D163193 | 11.4000 | 10.0000 | 1.0000 | 0.1000 | 0.1500 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D163194 | 0.2700 | 1.0000 | 0.7000 | 0.7000 | 0.7000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 100.0000 |
| D169014 | 0.0600 | 1.5000 | 1.0000 | 0.1000 | 0.5000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169015 | 0.3200 | 1.5000 | 1.0000 | 10.0000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169016 | 0.2200 | 1.5000 | 1.0000 | 0.3000 | 0.3000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169017 | 0.3300 | 2.0000 | 1.5000 | 3.0000 | 0.3000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169018 | 0.5400 | 1.5000 | 0.7000 | 0.3000 | 0.3000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169019 | 0.4400 | 1.5000 | 0.7000 | 0.2000 | 0.3000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169020 | 0.1700 | 1.5000 | 1.0000 | 0.2000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169021 | 0.2300 | 2.0000 | 1.5000 | 0.3000 | 0.5000 | 100.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169022 | 0.2800 | 1.5000 | 1.0000 | 0.1500 | 0.5000 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169023 | 0.2500 | 1.0000 | 0.5000 | 0.1500 | 0.3000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169024 | 0.1300 | 1.5000 | 1.0000 | 0.2000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169025 | 0.3900 | 1.5000 | 0.7000 | 0.3000 | 0.5000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169026 | 0.3300 | 1.5000 | 1.0000 | 0.3000 | 0.3000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L |
| D169027 | 0.2300 | 1.5000 | 0.3000 | 0.3000 | 0.3000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169421 | 0.1600 | 0.3000 | 0.1000 | 0.0300 | 0.5000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169422 | 0.1600 | 1.5000 | 1.5000 | 0.2000 | 0.5000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 100.0000 |
| D169423 | 0.2900 | 1.0000 | 0.0700 | 0.3000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 150.0000 |
| D169424 | 0.2500 | 1.5000 | 1.0000 | 0.2000 | 0.5000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 100.0000 |
| D169425 | 0.4200 | 0.2000 | 0.3000 | 1.0000 | 1.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 150.0000 |
| D169426 | 0.0600 | 0.0700 | 0.0300 | 0.1500 | 1.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 100.0000 |
| D169427 | 0.3000 | 1.5000 | 1.0000 | 0.0300 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169428 | 0.0200 | 3.0000 | 1.5000 | 2.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169429 | 0.0100 | 1.5000 | 1.0000 | 1.0000 | 0.3000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169435 | 0.0300 | 0.5000 | 0.1500 | 0.1500 | 0.7000 | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169436 | 0.1200 | 1.5000 | 0.7000 | 1.0000 | 0.3000 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169726 | 0.1100 | 3.0000 | 2.0000 | 7.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169728 | 0.3300 | 3.0000 | 2.0000 | 5.0000 | 0.3000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169729 | 0.4700 | 3.0000 | 1.5000 | 5.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169730 | 0.3700 | 3.0000 | 1.5000 | 1.5000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169734 | 0.0100 | 3.0000 | 2.0000 | 7.0000 | 0.1500 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169735 | 0.0400 | 2.0000 | 3.0000 | 5.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169737 | 0.0100L | 3.0000 | 2.0000 | 7.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169738 | 0.0100L | 1.0000 | 1.5000 | 7.0000 | 0.2000 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 |
| D169739 | 0.0500 | 5.0000 | 2.0000 | 2.0000 | 0.2000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169741 | 0.0300 | 2.0000 | 2.0000 | 7.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169742 | 0.0300 | 2.0000 | 2.0000 | 1.5000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |
| D169743 | 0.0600 | 1.5000 | 2.0000 | 1.0000 | 0.3000 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 |

| SAMPLE ID | BA PPM-S | BE PPM-S | BI PPM-S | CD PPM-S | CO PPM-S | CR PPM-S | CU PPM-S | LA PPM-S | MO PPM-S | NB PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000L | 70.0000 | 70.0000 | 100.0000L | 7.0000L | 30.0000 |
| D163021 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 7.0000 | 70.0000 | 0.0000N | 10.0000 |
| D163022 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.0000 | 10.0000 | 0.0000L | 0.0000N | 10.0000 |
| D163023 | 500.0000 | 1.5000 | 0.0000N | 0.0000N | 5.0000 | 30.0000 | 50.0000 | 70.0000 | 3.0000 | 0.0000N |
| D163024 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.0000 | 20.0000 | 0.0000L | 0.0000N | 0.0000N |
| D163025 | 500.0000 | 1.5000 | 0.0000N | 0.0000N | 7.0000 | 20.0000 | 50.0000 | 50.0000 | 5.0000 | 0.0000L |
| D163026 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.0000 | 15.0000 | 0.0000L | 0.0000N | 0.0000N |
| D163027 | 1500.0000 | 1.5000 | 0.0000N | 0.0000N | 10.0000 | 30.0000 | 50.0000 | 0.0000L | 0.0000N | 10.0000 |
| D163188 | 500.0000 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 7.0000 | 70.0000 | 15.0000 | 15.0000 |
| D163189 | 700.0000 | 2.0000 | 0.0000N | 0.0000N | 7.0000 | 70.0000 | 30.0000 | 70.0000 | 3.0000 | 15.0000 |
| D163192 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 30.0000 | 70.0000 | 0.0000N | 10.0000 | 0.0000N |
| D163193 | 300.0000 | 1.5000 | 0.0000N | 0.0000N | 10.0000 | 30.0000 | 30.0000 | 0.0000L | 0.0000N | 0.0000L |
| D163194 | 300.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 100.0000 | 0.0000N | 7.0000 | 20.0000 |
| D169014 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 50.0000 | 70.0000 | 0.0000N | 30.0000 |
| D169015 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 50.0000 | 0.0000N | 0.0000N | 20.0000 |
| D169016 | 700.0000 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 50.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169017 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 30.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169018 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 70.0000 | 50.0000 | 0.0000N | 0.0000N | 20.0000 |
| D169019 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 50.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169020 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169021 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 50.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169022 | 700.0000 | 3.0000 | 0.0000N | 0.0000N | 20.0000 | 70.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169023 | 3000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 30.0000 | 30.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169024 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169025 | 1500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 150.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169026 | 5000.0000 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 70.0000 | 70.0000 | 0.0000N | 20.0000 |
| D169027 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 50.0000 | 0.0000N | 0.0000N | 0.0000L |
| D169421 | 200.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 70.0000 | 0.0000N | 7.0000 | 0.0000L |
| D169422 | 1000.0000 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 70.0000 | 70.0000 | 0.0000N | 0.0000L |
| D169423 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000L |
| D169424 | 700.0000 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 70.0000 | 70.0000 | 70.0000 | 0.0000N | 0.0000L |
| D169425 | 3000.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 200.0000 | 0.0000N | 10.0000 | 50.0000 |
| D169426 | 150.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 20.0000 | 70.0000 | 0.0000N | 0.0000L | 50.0000 |
| D169427 | 700.0000 | 3.0000 | 0.0000N | 0.0000N | 0.0000L | 70.0000 | 70.0000 | 0.0000N | 0.0000N | 0.0000L |
| D169428 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 30.0000 | 15.0000 | 70.0000 | 0.0000L | 0.0000N |
| D169429 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000L |
| D169435 | 500.0000 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 70.0000 | 0.0000N | 0.0000N | 30.0000 |
| D169436 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 70.0000 | 70.0000 | 0.0000N | 0.0000N | 20.0000 |
| D169726 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 50.0000 | 30.0000 | 70.0000 | 0.0000N | 0.0000L |
| D169728 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 50.0000 | 50.0000 | 70.0000 | 0.0000N | 0.0000L |
| D169729 | 1000.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 70.0000 | 30.0000 | 70.0000 | 0.0000L | 0.0000L |
| D169730 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 70.0000 | 50.0000 | 70.0000 | 0.0000L | 0.0000L |
| D169734 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N |
| D169735 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 50.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N |
| D169737 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N |
| D169738 | 300.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 20.0000 | 15.0000 | 0.0000L | 0.0000N | 0.0000N |
| D169739 | 700.0000 | 0.0000L | 0.0000N | 0.0000N | 10.0000 | 50.0000 | 30.0000 | 0.0000L | 0.0000N | 0.0000L |
| D169741 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 30.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N |
| D169742 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 50.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000L |
| D169743 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000L |

| SAMPLE ID | NI PPM-S | PB PPM-S | PD PPM-S | PT PPM-S | SB PPM-S | SC PPM-S | SN PPM-S | SR PPM-S | TE PPM-S | U PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D163021 | 0,0000N | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 5,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D163022 | 0,0000N | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 70,0000 | 0,0000N | 0,0000N |
| D163023 | 10,0000 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D163024 | 0,0000N | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 70,0000 | 0,0000N | 0,0000N |
| D163025 | 10,0000 | 10,0000 | 0,0000N | 0,0000N | 0,0000N | 7,0000 | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D163026 | 0,0000N | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 70,0000 | 0,0000N | 0,0000N |
| D163027 | 20,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D163188 | 3,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D163189 | 15,0000 | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D163192 | 0,0000N | 50,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D163193 | 30,0000 | 15,0000 | 0,0000N | 0,0000N | 0,0000N | 7,0000 | 0,0000N | 50,0000 | 0,0000N | 0,0000N |
| D163194 | 7,0000 | 100,0000 | 0,0000N | 0,0000N | 0,0000N | 20,0000 | 0,0000N | 500,0000 | 0,0000N | 0,0000N |
| D169014 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169015 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 2000,0000 | 0,0000N | 0,0000N |
| D169016 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 20,0000 | 150,0000 | 0,0000N | 0,0000N |
| D169017 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 200,0000 | 0,0000N | 0,0000N |
| D169018 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D169019 | 20,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169020 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169021 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169022 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 30,0000 | 200,0000 | 0,0000N | 0,0000N |
| D169023 | 0,0000N | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 200,0000 | 0,0000N | 0,0000N |
| D169024 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D169025 | 0,0000L | 50,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169026 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169027 | 0,0000N | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D169421 | 0,0000N | 0,0000L | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 0,0000N |
| D169422 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 20,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D169423 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 30,0000 | 0,0000N | 0,0000N |
| D169424 | 0,0000L | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D169425 | 0,0000N | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169426 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 30,0000 | 0,0000N | 0,0000N |
| D169427 | 10,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 50,0000 | 0,0000N | 0,0000N |
| D169428 | 15,0000 | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D16942[illegible] | 15,0000 | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D16943[illegible] | 0,0000N | 70,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000L | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D169436 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 500,0000 | 0,0000N | 0,0000N |
| D169726 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 200,0000 | 0,0000N | 0,0000N |
| D169728 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 150,0000 | 0,0000N | 0,0000N |
| D169729 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 300,0000 | 0,0000N | 0,0000N |
| D169730 | 30,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 200,0000 | 0,0000N | 0,0000N |
| D169734 | 15,0000 | 0,0000L | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D169735 | 15,0000 | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N |
| D169737 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D169738 | 0,0000L | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 0,0000N | 70,0000 | 0,0000N | 0,0000N |
| D169739 | 20,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 15,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D169741 | 15,0000 | 0,0000L | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 100,0000 | 0,0000N | 0,0000N |
| D169742 | 15,0000 | 20,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N |
| D169743 | 15,0000 | 30,0000 | 0,0000N | 0,0000N | 0,0000N | 10,0000 | 0,0000N | 70,0000 | 0,0000N | 0,0000N |

| SAMPLE ID | V PPM-S | W PPM-S | Y PPM-S | ZN PPM-S | ZR PPM-S | SI %-S | AL %-S | NA %-S | K %-S | P %-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 150.0000 | 0.0000N | 20.0000L | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 1.5000 | 0.0000N |
| D163021 | 30.0000 | 0.0000N | 15.0000 | 0.0000N | 70.0000 | 10.0000G | 10.0000G | 3.0000 | 0.7000 | 0.0000N |
| D163022 | 15.0000 | 0.0000N | 0.0000L | 0.0000N | 70.0000 | 10.0000G | 10.0000 | 1.0000 | 0.7000 | 0.0000N |
| D163023 | 150.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 10.0000 | 2.0000 | 3.0000 | 0.0000N |
| D163024 | 15.0000 | 0.0000N | 0.0000L | 0.0000N | 70.0000 | 10.0000G | 10.0000G | 0.5000 | 0.7000 | 0.0000N |
| D163025 | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 150.0000 | 10.0000G | 7.0000 | 2.0000 | 3.0000 | 0.0000N |
| D163026 | 10.0000 | 0.0000N | 0.0000L | 0.0000N | 30.0000 | 10.0000G | 10.0000G | 0.5000 | 0.7000 | 0.0000N |
| D163027 | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 10.0000 | 1.5000 | 3.0000 | 0.0000N |
| D163188 | 50.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 10.0000G | 7.0000 | 0.0700 | 2.0000 | 0.0000N |
| D163189 | 150.0000 | 0.0000N | 15.0000 | 0.0000N | 150.0000 | 10.0000G | 10.0000G | 0.5000 | 3.0000 | 0.0000N |
| D163192 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 300.0000 | 0.0000B | 10.0000G | 0.0000B | 0.0000N | 0.0000N |
| D163193 | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 50.0000 | 10.0000G | 7.0000 | 0.1500 | 5.0000 | 0.0000N |
| D163194 | 100.0000 | 0.0000N | 50.0000 | 0.0000N | 300.0000 | 0.0000B | 10.0000G | 0.0000B | 1.5000 | 0.0000N |
| D169014 | 150.0000 | 0.0000N | 30.0000 | 0.0000N | 200.0000 | 0.0000B | 10.0000G | 0.0000B | 3.0000 | 0.0000N |
| D169015 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 1.5000 | 0.0000N |
| D169016 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 3.0000 | 0.0000N |
| D169017 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 2.0000 | 0.0000N |
| D169018 | 150.0000 | 0.0000N | 30.0000 | 0.0000N | 300.0000 | 0.0000B | 10.0000 | 0.0000B | 2.0000 | 0.0000N |
| D169019 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 2.0000 | 0.0000N |
| D169020 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 2.0000 | 0.0000N |
| D169021 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 1.5000 | 0.0000N |
| D169022 | 100.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 3.0000 | 0.0000N |
| D169023 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 5.0000 | 0.0000N |
| D169024 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 1.5000 | 0.0000N |
| D169025 | 200.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 1.5000 | 0.0000N |
| D169026 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 0.0000B | 10.0000G | 0.0000B | 2.0000 | 0.0000N |
| D169027 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 3.0000 | 0.0000N |
| D169421 | 20.0000 | 0.0000N | 20.0000 | 0.0000N | 200.0000 | 0.0000B | 3.0000 | 0.0000B | 0.0000N | 0.0000N |
| D169422 | 100.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000G | 0.0000B | 7.0000 | 0.0000N |
| D169423 | 15.0000 | 0.0000N | 20.0000 | 0.0000N | 500.0000 | 0.0000B | 0.7000 | 0.0000B | 0.0000N | 0.0000N |
| D169424 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 7.0000 | 0.0000N |
| D169425 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 700.0000 | 0.0000B | 3.0000 | 0.0000B | 0.0000N | 0.0000N |
| D169426 | 15.0000 | 0.0000N | 20.0000 | 0.0000N | 500.0000 | 0.0000B | 0.7000 | 0.0000B | 0.0000N | 0.0000N |
| D169427 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 7.0000 | 0.0000N |
| D169428 | 50.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B | 3.0000 | 0.0000N |
| D169429 | 70.0000 | 0.0000N | 30.0000 | 0.0000N | 200.0000 | 0.0000B | 7.0000 | 0.0000B | 5.0000 | 0.0000N |
| D169435 | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 200.0000 | 0.0000B | 10.0000G | 0.0000B | 0.0000N | 0.0000N |
| D169436 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 1.5000 | 0.0000N |
| D169726 | 70.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B | 7.0000 | 0.0000N |
| D169728 | 100.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 5.0000 | 0.0000N |
| D169729 | 150.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 10.0000 | 0.0000B | 3.0000 | 0.0000N |
| D169730 | 150.0000 | 0.0000N | 30.0000 | 0.0000N | 200.0000 | 0.0000B | 10.0000 | 0.0000B | 3.0000 | 0.0000N |
| D169734 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 5.0000 | 0.0000B | 2.0000 | 0.0000N |
| D169735 | 70.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B | 5.0000 | 0.0000N |
| D169737 | 70.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B | 7.0000 | 0.0000N |
| D169738 | 30.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 5.0000 | 0.0000B | 3.0000 | 0.0000N |
| D169739 | 100.0000 | 0.0000N | 30.0000 | 0.0000N | 100.0000 | 0.0000B | 10.0000 | 0.0000B | 5.0000 | 0.0000N |
| D169741 | 70.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B | 5.0000 | 0.0000N |
| D169742 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B | 7.0000 | 0.0000N |
| D169743 | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 0.0000B | 7.0000 | 0.0000B | 7.0000 | 0.0000N |

| SAMPLE ID | CE PPM-S | GA PPM-S | GE PPM-S | HF PPM-S | IN PPM-S | LI PPM-S | RE PPM-S | TA PPM-S | TH PPM-S | TL PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163021 | 0.0000L | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163022 | 0.0000L | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163023 | 0.0000L | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163024 | 0.0000L | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163025 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163026 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163027 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163188 | 150.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163189 | 150.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163192 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163193 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D163194 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169014 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169015 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169016 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169017 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169018 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169019 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169020 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169021 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169022 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169023 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169024 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169025 | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169025 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169027 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169421 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169422 | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169423 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169424 | 0.0000N | 50.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169425 | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169426 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169427 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169428 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169429 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169433 | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169436 | 0.0000N | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169726 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169728 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169729 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169730 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169734 | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169735 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169737 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169738 | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169739 | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169741 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169742 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169743 | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |

| SAMPLE ID | YB PPM-S | PR PPM-S | ND PPM-S | SM PPM-S | EU PPM-S | TOTAL C% | ORGNC C% | CRBNT C% | AS PPM | CD PPM |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000B | 0.0000B | 0.0000B | 2.0000 | 0.0000B |
| D163021 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.4200 | 0.4000 | 0.0100L | 2.0000 | 1.0000L |
| D163022 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 5.6100 | 5.0000 | 0.6500 | 2.0000 | 1.0000L |
| D163023 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 6.8000 | 6.8000 | 0.0100L | 5.0000 | 1.0000L |
| D163024 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 8.2800 | 7.9000 | 0.4000 | 1.0000 | 1.0000L |
| D163025 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 11.2000 | 11.2000 | 0.0100 | 12.0000 | 1.0000L |
| D163026 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.3900 | 2.1000 | 0.3100 | 2.0000 | 1.0000L |
| D163027 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 6.9000 | 6.9000 | 0.0400 | 20.0000 | 1.0000L |
| D163188 | 3.0000 | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 0.0000B | 0.0000B | 0.0000B | 1.0000 | 1.0000L |
| D163189 | 3.0000 | 0.0000N | 70.0000 | 0.0000N | 0.0000N | 0.0000B | 0.0000B | 0.0000B | 4.0000 | 1.0000L |
| D163192 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 29.1000 | 29.1000 | 0.0100 | 2.0000 | 0.0000B |
| D163193 | 0.0000B | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 7.6600 | 7.7000 | 0.0100L | 20.0000 | 1.0000L |
| D163194 | 5.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 30.3000 | 30.3000 | 0.0100L | 4.0000 | 0.0000B |
| D169014 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.8300 | 2.8000 | 0.0200 | 2.0000 | 0.0000B |
| D169015 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 52.2000 | 51.2000 | 0.9600 | 5.0000 | 0.0000B |
| D169016 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.4900 | 3.5000 | 0.0100L | 3.0000 | 0.0000B |
| D169017 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 8.2200 | 7.4000 | 0.8300 | 5.0000 | 0.0000B |
| D169018 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 12.0000 | 12.0000 | 0.0100L | 4.0000 | 0.0000B |
| D169019 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 13.4000 | 13.4000 | 0.0100L | 8.0000 | 0.0000B |
| D169020 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 9.4500 | 9.4000 | 0.0100L | 4.0000 | 0.0000B |
| D169021 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 8.9900 | 8.5000 | 0.5000 | 5.0000 | 0.0000B |
| D169022 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 8.0300 | 8.0000 | 0.0100L | 3.0000 | 0.0000B |
| D169023 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.0200 | 2.0000 | 0.0100L | 1.0000 | 0.0000B |
| D169024 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 6.5200 | 6.4000 | 0.1200 | 3.0000 | 0.0000B |
| D169025 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 39.8000 | 39.8000 | 0.0100L | 2.0000 | 0.0000B |
| D169026 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.0900 | 3.1000 | 0.0100L | 1.0000 | 0.0000B |
| D169027 | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 24.4000 | 24.4000 | 0.0100L | 1.0000 | 0.0000B |
| D169421 | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 10.7000 | 10.7000 | 0.0100L | 3.0000 | 0.0000B |
| D169422 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 7.9600 | 8.0000 | 0.0100L | 5.0000 | 0.0000B |
| D169423 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 32.7000 | 32.7000 | 0.0100L | 1.0000 | 0.0000B |
| D169424 | 3.0000 | 0.0000N | 0.0000L | 0.0000N | 0.0000N | 12.4000 | 12.4000 | 0.0100L | 5.0000 | 0.0000B |
| D169425 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 33.8000 | 33.8000 | 0.0100L | 4.0000 | 0.0000B |
| D169426 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 8.5900 | 8.6000 | 0.0100L | 2.0000 | 0.0000B |
| D169427 | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.2200 | 1.2000 | 0.0100L | 15.0000 | 0.0000B |
| D169428 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.9500 | 0.2000 | 0.7300 | 5.0000 | 0.0000B |
| D169429 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.7200 | 0.2000 | 0.5200 | 5.0000 | 0.0000B |
| D169435 | 0.0000N | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.8600 | 1.8000 | 0.0100 | 2.0000 | 0.0000B |
| D169436 | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 13.7000 | 13.7000 | 0.0100L | 2.0000 | 0.0000B |
| D169726 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.3700 | 0.1000L | 2.3800 | 5.0000 | 0.0000B |
| D169728 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.8500 | 0.2000 | 1.6700 | 8.0000 | 0.0000B |
| D169729 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.6800 | 1.4000 | 1.3000 | 12.0000 | 0.0000B |
| D169730 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.8500 | 2.0000 | 0.8500 | 12.0000 | 0.0000B |
| D169734 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.0800 | 0.1000L | 3.1600 | 5.0000 | 0.0000B |
| D169735 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.7800 | 0.3000 | 2.5000 | 12.0000 | 0.0000B |
| D169737 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.4000 | 0.1000L | 2.3500 | 8.0000 | 0.0000B |
| D169738 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.1900 | 0.1000 | 2.0700 | 5.0000 | 0.0000B |
| D169739 | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.7900 | 0.5000 | 2.3200 | 25.0000 | 0.0000B |
| D169741 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.9500 | 0.3000 | 2.6900 | 8.0000 | 0.0000B |
| D169742 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.3800 | 0.3000 | 2.1000 | 5.0000 | 0.0000B |
| D169743 | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.6800 | 0.9000 | 1.8000 | 20.0000 | 0.0000B |

| SAMPLE ID | CU PPM | HG PPM | LI PPM | PB PPM | SB PPM | SE PPM | TE PPM | TH PPM | TL PPM | U PPM |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 0.0000B | 0.1500 | 0.0000B | 0.0000B | 0.5000 | 0.5838 | 0.2000 | 7.8740 | 0.2000N | 3.1540 |
| D163021 | 10.0000 | 0.1000 | 18.0000 | 25.0000 | 1.0000 | 0.2377 | 0.0000B | 34.0600 | 0.0000B | 11.1400 |
| D163022 | 16.0000 | 0.0800 | 80.0000 | 50.0000 | 0.4000 | 2.0724 | 0.0000B | 21.0100 | 0.0000B | 6.0410 |
| D163023 | 38.0000 | 0.0800 | 28.0000 | 25.0000L | 1.1000 | 0.9912 | 0.0000B | 9.8550 | 0.0000B | 7.0530 |
| D163024 | 18.0000 | 0.0700 | 96.0000 | 35.0000 | 0.4000 | 1.2238 | 0.0000B | 14.2400 | 0.0000B | 5.9810 |
| D163025 | 45.0000 | 0.2500 | 26.0000 | 25.0000L | 1.8000 | 1.9268 | 0.0000B | 11.8400 | 0.0000B | 6.3880 |
| D163026 | 14.0000 | 0.0700 | 76.0000 | 25.0000L | 0.4000 | 2.5105 | 0.0000B | 20.2100 | 0.0000B | 5.4920 |
| D163027 | 34.0000 | 0.1800 | 28.0000 | 25.0000L | 1.8000 | 2.0679 | 0.0000B | 12.3800 | 0.0000B | 4.2150 |
| D163188 | 15.0000 | 0.0200 | 18.0000 | 25.0000L | 0.5900 | 0.1000L | 0.0000B | 4.9470 | 0.0000B | 1.8830 |
| D163189 | 48.0000 | 0.0500 | 42.0000 | 40.0000 | 1.1400 | 1.1129 | 0.0000B | 4.6930 | 0.0000B | 3.2020 |
| D163192 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 0.5400 | 2.3999 | 0.0000B | 3.9740 | 0.0000B | 1.5140 |
| D163193 | 42.0000 | 0.4400 | 34.0000 | 40.0000 | 4.3000 | 2.0737 | 0.0000B | 4.1770 | 0.0000B | 2.0920 |
| D163194 | 0.0000B | 0.2000 | 0.0000B | 0.0000B | 2.1600 | 3.5801 | 0.0000B | 6.9140 | 0.0000B | 4.5990 |
| D169014 | 0.0000B | 0.0400 | 0.0000B | 0.0000B | 0.6000 | 0.9519 | 0.0000B | 16.2500 | 0.0000B | 6.6130 |
| D169015 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 0.6000 | 2.0891 | 0.0000B | 6.0350 | 0.0000B | 2.8420 |
| D169016 | 0.0000B | 0.0600 | 0.0000B | 0.0000B | 0.7000 | 1.9937 | 0.0000B | 13.5800 | 0.0000B | 4.6320 |
| D169017 | 0.0000B | 0.1200 | 0.0000B | 0.0000B | 0.6000 | 2.5828 | 0.0000B | 13.3800 | 0.0000B | 5.5190 |
| D169018 | 0.0000B | 0.2000 | 0.0000B | 0.0000B | 0.4000 | 1.4872 | 0.0000B | 11.5900 | 0.0000B | 4.9990 |
| D169019 | 0.0000B | 0.1800 | 0.0000B | 0.0000B | 0.9000 | 3.1607 | 0.0000B | 14.6200 | 0.0000B | 6.6870 |
| D169020 | 0.0000B | 0.0700 | 0.0000B | 0.0000B | 0.6000 | 2.1284 | 0.0000B | 15.1300 | 0.0000B | 5.5690 |
| D169021 | 0.0000B | 0.0900 | 0.0000B | 0.0000B | 0.8000 | 2.0236 | 0.0000B | 13.9800 | 0.0000B | 5.5130 |
| D169022 | 0.0000B | 0.1700 | 0.0000B | 0.0000B | 0.5000 | 1.9837 | 0.0000B | 10.6600 | 0.0000B | 5.4620 |
| D169023 | 0.0000B | 0.0300 | 0.0000B | 0.0000B | 0.4000 | 1.4268 | 0.0000B | 12.7500 | 0.0000B | 5.5810 |
| D169024 | 0.0000B | 0.0600 | 0.0000B | 0.0000B | 0.6000 | 2.0115 | 0.0000B | 13.3900 | 0.0000B | 4.3120 |
| D169025 | 0.0000B | 0.0800 | 0.0000B | 0.0000B | 0.9000 | 5.0039 | 0.0000B | 10.7200 | 0.0000B | 5.6250 |
| D169026 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 0.5000 | 1.6670 | 0.0000B | 15.8600 | 0.0000B | 4.9820 |
| D169027 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 0.4000 | 0.8574 | 0.0000B | 8.1760 | 0.0000B | 4.2020 |
| D169421 | 0.0000B | 0.0400 | 0.0000B | 0.0000B | 0.7000 | 1.8385 | 0.0000B | 12.3000 | 0.0000B | 4.2540 |
| D169422 | 0.0000B | 0.1700 | 0.0000B | 0.0000B | 1.0000 | 6.0730 | 0.0000B | 13.9200 | 0.0000B | 5.2140 |
| D169423 | 0.0000B | 0.0700 | 0.0000B | 0.0000B | 0.3000 | 0.5190 | 0.0000B | 3.6030 | 0.0000B | 1.6290 |
| D169424 | 0.0000B | 0.1700 | 0.0000B | 0.0000B | 1.2000 | 3.4735 | 0.0000B | 16.4900 | 0.0000B | 5.8990 |
| D169425 | 0.0000B | 0.1300 | 0.0000B | 0.0000B | 0.6000 | 6.7128 | 0.0000B | 13.8300 | 0.0000B | 4.8020 |
| D169426 | 0.0000B | 0.0800 | 0.0000B | 0.0000B | 1.0000 | 1.2995 | 0.0000B | 10.0000 | 0.0000B | 6.6420 |
| D169427 | 0.0000B | 0.1200 | 0.0000B | 0.0000B | 2.0000 | 2.0109 | 0.0000B | 15.2800 | 0.0000B | 5.9970 |
| D169428 | 0.0000B | 0.0300 | 0.0000B | 0.0000B | 1.1000 | 0.1624 | 0.0000B | 9.8170 | 0.0000B | 3.7750 |
| D169429 | 0.0000B | 0.0300 | 0.0000B | 0.0000B | 1.2000 | 0.7623 | 0.0000B | 11.2400 | 0.0000B | 3.7610 |
| D169435 | 0.0000B | 0.2300 | 0.0000B | 0.0000B | 0.3000 | 3.1046 | 0.0000B | 30.2500 | 0.0000B | 6.1020 |
| D169436 | 0.0000B | 0.2000 | 0.0000B | 0.0000B | 1.0000 | 2.3626 | 0.0000B | 13.3700 | 0.0000B | 4.0740 |
| D169726 | 0.0000B | 0.0200 | 0.0000B | 0.0000B | 1.1000 | 0.1021 | 0.0000B | 9.2320 | 0.0000B | 4.3640 |
| D169728 | 0.0000B | 0.0300 | 0.0000B | 0.0000B | 1.6000 | 0.2095 | 0.0000B | 12.0300 | 0.0000B | 3.7980 |
| D169729 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 1.6000 | 0.2602 | 0.0000B | 12.1800 | 0.0000B | 4.1310 |
| D169730 | 0.0000B | 0.0700 | 0.0000B | 0.0000B | 1.4000 | 0.1866 | 0.0000B | 9.9280 | 0.0000B | 4.5320 |
| D169734 | 0.0000B | 0.0300 | 0.0000B | 0.0000B | 1.4000 | 0.1000L | 0.0000B | 8.2790 | 0.0000B | 3.3940 |
| D169735 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 2.3000 | 0.1000L | 0.0000B | 11.5500 | 0.0000B | 3.5540 |
| D169737 | 0.0000B | 0.0300 | 0.0000B | 0.0000B | 1.6000 | 0.1000L | 0.0000B | 10.2700 | 0.0000B | 3.4660 |
| D169738 | 0.0000B | 0.0200 | 0.0000B | 0.0000B | 1.3000 | 0.1000L | 0.0000B | 9.3900 | 0.0000B | 3.0780 |
| D169739 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 1.8000 | 0.1139 | 0.0000B | 10.3400 | 0.0000B | 3.6660 |
| D169741 | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 1.7000 | 0.1000L | 0.0000B | 11.8300 | 0.0000B | 3.3180 |
| D169742 | 0.0000B | 0.0700 | 0.0000B | 0.0000B | 1.4000 | 0.1598 | 0.0000B | 10.7700 | 0.0000B | 3.7960 |
| D169743 | 0.0000B | 0.0800 | 0.0000B | 0.0000B | 1.7000 | 0.1556 | 0.0000B | 10.7200 | 0.0000B | 3.5660 |

| SAMPLE ID | ZN PPM | ASH % | CA/A % | MG/A % | LI/A PPM | NA/A % | K/A % | P/A PPM | CL/A % | CD/A PPM |
|---|---|---|---|---|---|---|---|---|---|---|
| D160981 | 0.0000B | 84.9000 | 0.3570 | 0.4800 | 53.0000 | 0.1000 | 1.3972 | 301.3300 | 0.0000B | 1.0000L |
| D163021 | 62.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163022 | 28.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163023 | 50.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163024 | 18.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163025 | 52.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163026 | 12.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163027 | 54.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163188 | 9.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163189 | 76.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163192 | 0.0000B | 51.7000 | 0.0000B | 0.3300 | 236.0000 | 0.0700 | 0.0000B | 0.0000B | 0.0000B | 1.0000L |
| D163193 | 58.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D163194 | 0.0000B | 54.2000 | 0.0000B | 0.7800 | 73.0000 | 0.1300 | 0.0000B | 0.0000B | 0.0000B | 1.0000L |
| D169014 | 0.0000B | 91.3000 | 0.1137 | 0.5900 | 42.0000 | 0.6400 | 1.8414 | 436.4000L | 0.1000L | 1.0000L |
| D169015 | 0.0000B | 36.9000 | 8.5314 | 0.7500 | 46.0000 | 0.3600 | 0.9510 | 436.4000L | 0.1000L | 1.0000L |
| D169016 | 0.0000B | 88.0000 | 0.3729 | 0.7200 | 42.0000 | 0.1100 | 2.0437 | 436.4000L | 0.1000L | 1.0000L |
| D169017 | 0.0000B | 83.6000 | 3.4633 | 0.8100 | 42.0000 | 0.0700 | 1.5615 | 436.4000L | 0.1000L | 1.0000L |
| D169018 | 0.0000B | 80.5000 | 0.2390 | 0.8000 | 66.0000 | 0.7000 | 1.9746 | 436.4000L | 0.1000L | 1.0000L |
| D169019 | 0.0000B | 76.9000 | 0.1879 | 0.7100 | 50.0000 | 0.1300 | 1.7172 | 436.4000L | 0.1000L | 1.0000L |
| D169020 | 0.0000B | 81.7000 | 0.2156 | 0.6900 | 52.0000 | 0.2000 | 1.2380 | 436.4000L | 0.1000L | 1.0000L |
| D169021 | 0.0000B | 82.7000 | 0.4444 | 0.9000 | 50.0000 | 0.2700 | 1.2224 | 436.4000L | 0.1000L | 1.0000L |
| D169022 | 0.0000B | 85.4000 | 0.1655 | 0.7700 | 77.0000 | 0.6900 | 1.6298 | 436.4000L | 0.1000L | 1.0000L |
| D169023 | 0.0000B | 93.1000 | 0.1129 | 0.4800 | 28.0000 | 0.1300 | 2.5912 | 436.4000L | 0.1000L | 1.0000L |
| D169024 | 0.0000B | 74.1000 | 0.2664 | 0.8400 | 52.0000 | 0.0500 | 1.0033 | 436.4000L | 0.1000L | 1.0000L |
| D169025 | 0.0000B | 47.4000 | 0.3983 | 0.8000 | 82.0000 | 0.0700 | 0.9172 | 436.4000L | 0.1000L | 1.0000L |
| D169026 | 0.0000B | 87.2000 | 0.3058 | 0.8000 | 46.0000 | 0.0700 | 1.7693 | 436.4000L | 0.1000L | 1.0000L |
| D169027 | 0.0000B | 64.4000 | 0.3793 | 0.4400 | 10.0000 | 0.0600 | 3.4203 | 436.4000L | 0.1000L | 1.0000L |
| D169421 | 0.0000B | 82.5000 | 0.0391 | 0.1300 | 34.0000 | 0.0500 | 0.4731 | 436.4000L | 0.1000L | 1.0000L |
| D169422 | 0.0000B | 86.7000 | 0.1631 | 0.8100 | 27.0000 | 0.0700 | 4.7165 | 436.4000L | 0.1000L | 1.0000L |
| D169423 | 0.0000B | 47.1000 | 0.2196 | 0.0900 | 14.0000 | 0.0200 | 0.0345 | 436.4000L | 0.1000L | 1.0000L |
| D169424 | 0.0000B | 81.8000 | 0.2100 | 0.8200 | 28.0000 | 0.0700 | 4.8225 | 436.4000L | 0.1000L | 1.0000L |
| D169425 | 0.0000B | 47.1000 | 0.8854 | 0.3300 | 54.0000 | 0.0400 | 0.0216 | 436.4000L | 0.1000L | 1.0000L |
| D169426 | 0.0000B | 88.1000 | 0.0819 | 0.0400 | 12.0000 | 0.0200 | 0.0166L | 436.4000L | 0.1000L | 1.0000L |
| D169427 | 0.0000B | 95.8000 | 0.0297 | 0.7700 | 34.0000 | 0.1100 | 3.9496 | 436.4000L | 0.1000L | 1.0000L |
| D169428 | 0.0000B | 98.2000 | 1.7710 | 0.9200 | 18.0000 | 0.6500 | 2.1494 | 436.4000L | 0.1000L | 1.0000L |
| D169429 | 0.0000B | 97.5000 | 1.0373 | 1.0000 | 20.0000 | 0.6900 | 2.4391 | 436.4000L | 0.1000L | 1.0000L |
| D169435 | 0.0000B | 86.6000 | 0.2175 | 0.1500 | 166.0000 | 0.1900 | 0.3841 | 436.4000L | 0.1000L | 1.0000L |
| D169436 | 0.0000B | 69.8000 | 1.3050 | 0.5900 | 78.0000 | 0.0700 | 1.1893 | 436.4000L | 0.1000L | 1.0000L |
| D169726 | 0.0000B | 97.7000 | 5.7029 | 2.1400 | 30.0000 | 0.7800 | 2.1186 | 436.4000L | 0.1000L | 1.0000L |
| D169728 | 0.0000B | 95.4000 | 3.9667 | 2.2300 | 46.0000 | 0.5300 | 2.7910 | 436.4000L | 0.1000L | 1.0000L |
| D169729 | 0.0000B | 96.2000 | 2.9024 | 1.6800 | 46.0000 | 0.4200 | 2.3571 | 436.4000L | 0.1000L | 1.0000L |
| D169730 | 0.0000B | 92.0000 | 1.8721 | 1.2600 | 42.0000 | 0.6700 | 2.2293 | 436.4000L | 0.1000L | 1.0000L |
| D169734 | 0.0000B | 99.4000 | 6.8603 | 2.5300 | 42.0000 | 0.6600 | 1.6701 | 436.4000L | 0.1000L | 1.0000L |
| D169735 | 0.0000B | 99.0000 | 4.9699 | 2.4400 | 40.0000 | 0.4000 | 2.6551 | 436.4000L | 0.1000L | 1.0000L |
| D169737 | 0.0000B | 96.9000 | 5.0596 | 2.2300 | 34.0000 | 0.5300 | 2.5867 | 436.4000L | 0.1000L | 1.0000L |
| D169738 | 0.0000B | 98.4000 | 5.0814 | 2.0800 | 24.0000 | 0.6200 | 1.8151 | 436.4000L | 0.1000L | 1.0000L |
| D169739 | 0.0000B | 94.9000 | 3.5454 | 2.1700 | 44.0000 | 0.4300 | 3.0216 | 436.4000L | 0.1000L | 1.0000L |
| D169741 | 0.0000B | 97.1000 | 5.9962 | 2.3200 | 30.0000 | 0.5900 | 2.2820 | 436.4000L | 0.1000L | 1.0000L |
| D169742 | 0.0000B | 97.3000 | 3.5348 | 2.4100 | 30.0000 | 0.5100 | 2.2962 | 436.4000L | 0.1000L | 1.0000L |
| D169743 | 0.0000B | 98.2000 | 2.9564 | 2.2300 | 32.0000 | 0.3000 | 2.6864 | 436.4000L | 0.1000L | 1.0000L |

| SAMPLE ID | CU/A PPM | MN/A PPM | PB/A PPM | ZN/A PPM | FE/A PPM | SI/A PPM | AL/A % | S/A % | TI/A % |
|---|---|---|---|---|---|---|---|---|---|
| D160981 | 60,0000 | 0,0000B | 50,0000L | 30,0000 | 11659,0000 | 295120,0000 | 13,5220 | 0,1114 | 0,0000B |
| D163021 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163022 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163023 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163024 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163025 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163026 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163027 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163188 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163189 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163192 | 83,0000 | 0,0000B | 70,0000 | 44,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163193 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D163194 | 136,0000 | 0,0000B | 85,0000 | 107,0000 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169014 | 46,0000 | 154,8000L | 30,0000 | 82,0000 | 16910,0000 | 305180,0000 | 12,4140 | 0,0400L | 0,5584 |
| D169015 | 54,0000 | 154,8000L | 35,0000 | 46,0000 | 21009,0000 | 231250,0000 | 10,0450 | 0,1734 | 0,4551 |
| D169016 | 50,0000 | 154,8000L | 25,0000 | 36,0000 | 17899,0000 | 298950,0000 | 12,7340 | 0,0400L | 0,4793 |
| D169017 | 78,0000 | 295,8700 | 30,0000 | 74,0000 | 30300,0000 | 266640,0000 | 11,4240 | 0,0400L | 0,4678 |
| D169018 | 62,0000 | 154,8000L | 25,0000L | 194,0000 | 26121,0000 | 300490,0000 | 11,9610 | 0,0400L | 0,5346 |
| D169019 | 84,0000 | 154,8000L | 35,0000 | 46,0000 | 18064,0000 | 292570,0000 | 13,6870 | 0,0400L | 0,5071 |
| D169020 | 60,0000 | 154,8000L | 25,0000 | 206,0000 | 16546,0000 | 296660,0000 | 13,5830 | 0,0400L | 0,5366 |
| D169021 | 68,0000 | 154,8000L | 30,0000 | 93,0000 | 32549,0000 | 285850,0000 | 12,1100 | 0,0400L | 0,5256 |
| D169022 | 62,0000 | 154,8000L | 25,0000L | 224,0000 | 23591,0000 | 294530,0000 | 12,2190 | 0,0400L | 0,5625 |
| D169023 | 36,0000 | 154,8000L | 25,0000L | 28,0000 | 12735,0000 | 323550,0000 | 10,4720 | 0,0400L | 0,5066 |
| D169024 | 60,0000 | 154,8000L | 30,0000 | 96,0000 | 25731,0000 | 294020,0000 | 13,3460 | 0,0400L | 0,5253 |
| D169025 | 130,0000 | 154,8000L | 40,0000 | 78,0000 | 22917,0000 | 273470,0000 | 15,7260 | 0,0400L | 0,6848 |
| D169026 | 50,0000 | 154,8000L | 30,0000 | 41,0000 | 20257,0000 | 281280,0000 | 13,3850 | 0,0400L | 0,4879 |
| D169027 | 40,0000 | 154,8000L | 25,0000L | 60,0000 | 20758,0000 | 307550,0000 | 11,3330 | 0,0400L | 0,5374 |
| D169421 | 39,0000 | 154,8000L | 25,0000L | 19,0000 | 4631,6000 | 404250,0000 | 3,1450 | 0,1354 | 0,4924 |
| D169422 | 66,0000 | 154,8000L | 35,0000 | 28,0000 | 17615,0000 | 297680,0000 | 10,7300 | 0,1851 | 0,5083 |
| D169423 | 26,0000 | 154,8000L | 25,0000L | 10,0000 | 14918,0000 | 420550,0000 | 0,3187 | 0,3554 | 0,5365 |
| D169424 | 80,0000 | 154,8000L | 25,0000 | 28,0000 | 18271,0000 | 306230,0000 | 10,0660 | 0,1898 | 0,5388 |
| D169425 | 184,0000 | 154,8000L | 25,0000L | 15,0000 | 2450,0000 | 374040,0000 | 2,2617 | 1,0267 | 1,2698 |
| D169426 | 53,0000 | 154,8000L | 25,0000L | 15,0000 | 896,6800 | 421030,0000 | 0,2656 | 0,0603 | 1,0497 |
| D169427 | 60,0000 | 154,8000L | 25,0000 | 90,0000 | 17450,0000 | 299870,0000 | 11,0260 | 0,2548 | 0,3856 |
| D169428 | 26,0000 | 404,3000 | 25,0000L | 87,0000 | 30880,0000 | 312850,0000 | 6,0265 | 0,0673 | 0,2494 |
| D169429 | 26,0000 | 154,8000L | 25,0000 | 77,0000 | 17683,0000 | 332620,0000 | 7,1232 | 0,0670 | 0,2792 |
| D169435 | 68,0000 | 154,8000L | 50,0000 | 69,0000 | 7583,5000 | 233700,0000 | 23,2610 | 0,0993 | 0,7790 |
| D169436 | 70,0000 | 154,8000L | 35,0000 | 68,0000 | 20217,0000 | 279060,0000 | 14,9760 | 0,1604 | 0,5232 |
| D169726 | 26,0000 | 645,9100 | 25,0000L | 64,0000 | 29975,0000 | 278490,0000 | 6,6837 | 0,0785 | 0,3055 |
| D169728 | 36,0000 | 652,7300 | 25,0000L | 94,0000 | 31022,0002 | 269739,9960 | 9,4264 | 0,3588 | 0,3441 |
| D169729 | 32,0000 | 451,8800 | 25,0000L | 100,0000 | 28523,0000 | 274790,0000 | 9,7084 | 0,4021 | 0,3417 |
| D169730 | 36,0000 | 385,7800 | 25,0000 | 114,0000 | 26258,9998 | 295680,0000 | 10,0290 | 0,3602 | 0,3803 |
| D169734 | 16,0000 | 466,5200 | 25,0000L | 51,0000 | 35053,9995 | 297390,0000 | 5,5771 | 0,0400L | 0,2040 |
| D169735 | 28,0000 | 574,7700 | 25,0000L | 82,0000 | 29486,9998 | 291290,0000 | 9,2750 | 0,0400L | 0,2825 |
| D169737 | 24,0000 | 552,9100 | 25,0000L | 76,0000 | 32202,0002 | 305260,0000 | 8,7856 | 0,0400L | 0,2800 |
| D169738 | 18,0000 | 184,3000 | 25,0000L | 62,0000 | 12530,0000 | 344830,0000 | 6,6697 | 0,0400L | 0,2426 |
| D169739 | 26,0000 | 1011,0000 | 25,0000L | 88,0000 | 62430,0005 | 278929,9960 | 10,3000 | 0,0400L | 0,2830 |
| D169741 | 24,0000 | 525,9900 | 25,0000L | 70,0000 | 23927,0000 | 304910,0000 | 8,3631 | 0,0400L | 0,2732 |
| D169742 | 30,0000 | 417,7000 | 25,0000L | 70,0000 | 25998,0000 | 294530,0000 | 7,7356 | 0,0400L | 0,3106 |
| D169743 | 24,0000 | 360,0800 | 25,0000L | 80,0000 | 25536,9998 | 279859,9960 | 9,6012 | 0,0618 | 0,3433 |

| SAMPLE ID | SUBMITTER NAME | SUBMITTAL DATE | | SAMPLE CATEGORY | SAMPLE MATERIAL |
|---|---|---|---|---|---|
| D169745 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169747 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169748 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169749 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SILTSTONE |
| D169750 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169751 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169753 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169755 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D169759 | HATCH JOSEPH R | 74- 9-30 | * | SEDIMENTARY ROCK | SHALE |
| D170634 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SILTSTONE |
| D170635 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SILTSTONE |
| D170638 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SILTSTONE |
| D170639 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170640 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170641 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170642 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170643 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SILTSTONE |
| D170644 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170645 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170648 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170649 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170650 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SILTSTONE |
| D170652 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170655 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |
| D170657 | HATCH JOSEPH R | 74-12-18 | * | SEDIMENTARY ROCK | SHALE |

| SAMPLE ID | FORMATION NAME | COMMENTS |
|---|---|---|
| D169745 | TONGUE RIVER MEMB, FT. UNION FM, | SH, CARB., OVER KNOBLOCK BED, INT>201.1-202.4 FT. |
| D169747 | TONGUE RIVER MEMB, FT. UNION FM, | SH, SILTY, OVER KNOBLOCK BED, CORE, INT>212.9-234.7 FT. |
| D169748 | TONGUE RIVER MEMB, FT. UNION FM, | STS, SANDY, OVER KNOBLOCK BED, CORE, INT.>234.7-289.2 FT. |
| D169749 | TONGUE RIVER MEMB, FT. UNION FM, | STS, SANDY, OVER KNOBLOCK BED, CORE, INT.>299.7-329.3 FT. |
| D169750 | TONGUE RIVER MEMB, FT. UNION FM, | SH, SILTY, OVER KNOBLOCK BED, CORE, INT.>329.3-334.2 FT. |
| D169751 | TONGUE RIVER MEMB, FT. UNION FM, | SH, SILTY, OVER KNOBLOCK BED, CORE, INT.>259.4-260.2 FT. |
| D169753 | TONGUE RIVER MEMB, FT. UNION FM, | SH, SILTY, OVER KNOBLOCK BED, CORE, INT.>286.7-298.7 FT. |
| D169755 | TONGUE RIVER MEMB, FT. UNION FM, | SH, SILTY, OVER KNOBLOCK BED, CORE, INT.>302.0-312.2 FT. |
| D169759 | TONGUE RIVER MEMB, FT. UNION FM, | SH, SILTY, OVER KNOBLOCK BED, CORE, INT.>401.5-407.4 FT. |
| D170634 | TONGUE RIVER MEM FORT UNION FM, | SILTSTONE, CLAYEY, CORE GRAB SAMPLE, INTERVAL =0-9. FT. |
| D170635 | TONGUE RIVER MEM FORT UNION FM, | SILTSTONE, SANDY, CORE GRAB SAMPLE, INTERVAL =14.5-28.2 FT. |
| D170638 | TONGUE RIVER MEM FORT UNION FM, | SILTSTONE, SNDY, CLY, CORE GRAB SAMPLE, INTERVAL =34.8-44.0 FT. |
| D170639 | TONGUE RIVER MEM FORT UNION FM, | SHALE, CARB., CORE GRAB SAMPLE, INTERVAL =44.0-48.0 FT. |
| D170640 | TONGUE RIVER MEM FORT UNION FM, | SHALE, CORE GRAB SAMPLE, INTERVAL =54.2-65.2 FT. |
| D170641 | TONGUE RIVER MEM FORT UNION FM, | SHALE, SILTY, CORE GRAB SAMPLE, INTERVAL =65.2-72.2 FT. |
| D170642 | TONGUE RIVER MEM FORT UNION FM, | SHALE, SILTY, CORE GRAB SAMPLE, INTERVAL =72.2-117.7 FT. |
| D170643 | TONGUE RIVER MEM FORT UNION FM, | SILTSTONE, CLY-SNDY., CORE GRAB SAMPLE, INTERVAL =120.2-135.9 FT. |
| D170644 | TONGUE RIVER MEM FORT UNION FM, | SHALE, CORE GRAB SAMPLE, INTERVAL =135.9-146.2 FT. |
| D170646 | TONGUE RIVER MEM FORT UNION FM, | SHALE, CORE GRAB SAMPLE, INTERVAL =177.0-181.6 FT. |
| D170648 | TONGUE RIVER MEM FORT UNION FM, | SHALE, CORE GRAB SAMPLE, INTERVAL =192.7-194.2 FT. |
| D170649 | TONGUE RIVER MEM FORT UNION FM, | SHALE, CARB., CORE GRAB SAMPLE, INTERVAL =194.2-201.0 FT. |
| D170650 | TONGUE RIVER MEM FORT UNION FM, | SILTSTONE, SNDY, CORE GRAB SAMPLE, INTERVAL =265.3-277.0 FT. |
| D170652 | TONGUE RIVER MEM FORT UNION FM, | SHALE, SILTY, CARB., CORE GRAB SAMPLE, INTERVAL =297.0-328.0 FT. |
| D170655 | TONGUE RIVER MEM FORT UNION FM, | SHALE, SILTY, CORE GRAB SAMPLE, INTERVAL =368-376 FT. |
| D170657 | TONGUE RIVER MEM FORT UNION FM, | SHALE, SILTY, CORE GRAB SAMPLE, INTERVAL =381-413.8 FT. |

| SAMPLE ID | FIELD NO. | STATE | LATITUDE | LONGITUDE | SAMPLE TYPE | SAMPLE SOURCE | GEOLOGIC AGE |
|---|---|---|---|---|---|---|---|
| D169745 | 74-102-10 | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169747 | 74-102-12 | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169748 | 74-102-13 | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169749 | 74-102-14 | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169750 | 74-102-15 | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169751 | 74-101-K | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169753 | 74-101-M | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169755 | 74-101-O | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D169759 | 74-101-S | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170634 | 74-105-A | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170635 | 74-105-B | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170638 | 74-105-E | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170639 | 74-105-F | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170640 | 74-105-G | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170641 | 74-105-H | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170642 | 74-105-I | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170643 | 74-105-J | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170644 | 74-105-K | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170646 | 74-105-M | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170648 | 74-105-O | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170649 | 74-105-P | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170650 | 74-105-Q | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170652 | 74-105-S | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170655 | 74-105-V | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |
| D170657 | 74-105-X | MONTANA | 45-30- ON | 106- 7-30W | COMPOSITE | DRILL CORE | PALEOCENE |

| SAMPLE ID | SIO2 % | AL2O3 % | FETO3 % | MGO % | CAO % | NA2O % | K2O % | TIO2 % | P2O5 % | MNO % |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169747 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169748 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169749 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169750 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169751 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169753 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169755 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D169759 | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B | 0,0000B |
| D170634 | 53,8010 | 12,4240 | 5,4590 | 2,8000 | 5,0276 | 1,1700 | 2,1239 | 0,4772 | 0,1431 | 0,0200L |
| D170635 | 56,0730 | 9,4024 | 3,5688 | 3,2000 | 9,7273 | 0,8400 | 2,4157 | 0,4127 | 0,1443 | 0,0200L |
| D170638 | 48,1430 | 8,4491 | 3,0600 | 3,4500 | 12,8160 | 0,6900 | 2,3161 | 0,4163 | 0,1743 | 0,0200L |
| D170639 | 45,6180 | 13,3160 | 4,8210 | 1,8000 | 0,3510 | 0,1700 | 3,1833 | 0,4651 | 0,1276 | 0,0200L |
| D170640 | 53,3060 | 14,8670 | 6,3448 | 2,2000 | 1,9483 | 0,4400 | 2,5249 | 0,6160 | 0,1825 | 0,0200L |
| D170641 | 60,2640 | 14,7720 | 5,8719 | 1,9500 | 2,1160 | 0,8200 | 2,5361 | 0,5886 | 0,1647 | 0,0200L |
| D170642 | 58,7000 | 14,6250 | 4,9415 | 2,0500 | 2,8416 | 0,8300 | 2,6757 | 0,5862 | 0,2224 | 0,0200L |
| D170643 | 66,1360 | 10,7200 | 3,6062 | 2,1500 | 2,9714 | 0,8500 | 2,2282 | 0,4796 | 0,2206 | 0,0200L |
| D170644 | 53,5000 | 13,4090 | 7,4783 | 2,2500 | 3,4480 | 0,8100 | 2,5134 | 0,5452 | 0,2576 | 0,0616 |
| D170646 | 57,6910 | 14,7790 | 4,1149 | 2,1500 | 2,5445 | 0,8700 | 2,8235 | 0,6066 | 0,1903 | 0,0200L |
| D170648 | 61,3180 | 16,0130 | 3,4608 | 1,5500 | 1,1015 | 0,7300 | 2,7769 | 0,6448 | 0,1553 | 0,0200L |
| D170649 | 76,5710 | 12,7670 | 1,4542 | 0,7800 | 0,0583 | 0,1800 | 3,6602 | 0,8917 | 0,1000L | 0,0200L |
| D170650 | 70,1460 | 11,5120 | 2,4188 | 2,7500 | 3,1897 | 0,4700 | 2,5657 | 0,5330 | 0,1216 | 0,0200L |
| D170652 | 52,3530 | 13,0900 | 3,4640 | 3,8500 | 6,7780 | 0,6100 | 2,8612 | 0,4985 | 0,1161 | 0,0200L |
| D170655 | 55,2100 | 11,6520 | 3,0712 | 3,6500 | 8,6419 | 0,7600 | 2,4326 | 0,4906 | 0,1093 | 0,0418 |
| D170657 | 52,2270 | 11,4360 | 3,6717 | 4,5500 | 8,6002 | 0,7200 | 2,5161 | 0,4709 | 0,1000L | 0,0431 |

| SAMPLE ID | CL % | F % | TOTAL S% | FE %-S | MG %-S | CA %-S | TI %-S | MN PPM-S | AG PPM-S | AS PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 0.0000B | 0.0760 | 0.4100 | 1.5000 | 2.0000 | 2.0000 | 0.3000 | 150.0000 | 0.0000N | 0.0000N |
| D169747 | 0.0000B | 0.0920 | 0.4200 | 2.0000 | 2.0000 | 7.0000 | 0.3000 | 500.0000 | 0.0000N | 0.0000N |
| D169748 | 0.0000B | 0.0535 | 0.0200 | 2.0000 | 3.0000 | 7.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D169749 | 0.0000B | 0.0520 | 0.0300 | 1.5000 | 3.0000 | 7.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D169750 | 0.0000B | 0.0772 | 0.0400 | 5.0000 | 2.0000 | 7.0000 | 0.3000 | 1000.0000 | 0.0000N | 0.0000N |
| D169751 | 0.0000B | 0.1010 | 0.0200 | 2.0000 | 1.0000 | 0.2000 | 0.5000 | 150.0000 | 0.0000N | 0.0000N |
| D169753 | 0.0000B | 0.0736 | 0.1100 | 2.0000 | 2.0000 | 10.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N |
| D169755 | 0.0000B | 0.0855 | 0.1200 | 2.0000 | 2.0000 | 5.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N |
| D169759 | 0.0000B | 0.0825 | 0.0300 | 5.0000 | 3.0000 | 7.0000 | 0.1500 | 700.0000 | 0.0000N | 0.0000N |
| D170634 | 0.1000L | 0.0865 | 0.4789 | 2.0000 | 1.0000 | 3.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N |
| D170635 | 0.1000L | 0.0785 | 0.1103 | 2.0000 | 1.0000 | 7.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D170638 | 0.1000L | 0.0745 | 0.0492 | 1.5000 | 1.5000 | 7.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D170639 | 0.1000L | 0.1200 | 0.5762 | 1.0000 | 0.7000 | 0.2000 | 0.2000 | 70.0000 | 0.0000N | 0.0000N |
| D170640 | 0.1000L | 0.0975 | 0.3956 | 1.0000 | 0.7000 | 0.7000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N |
| D170641 | 0.1000L | 0.0750 | 0.2248 | 3.0000 | 0.7000 | 1.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D170642 | 0.1000L | 0.0880 | 0.2784 | 2.0000 | 0.7000 | 2.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D170643 | 0.1000L | 0.0595 | 0.0711 | 2.0000 | 1.0000 | 2.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D170644 | 0.1000L | 0.0665 | 0.1259 | 5.0000 | 0.7000 | 3.0000 | 0.2000 | 500.0000 | 0.0000N | 0.0000N |
| D170646 | 0.1000L | 0.0920 | 0.0624 | 2.0000 | 1.0000 | 2.0000 | 0.3000 | 200.0000 | 0.0000N | 0.0000N |
| D170648 | 0.1288 | 0.1385 | 0.3202 | 1.5000 | 0.7000 | 0.5000 | 0.3000 | 150.0000 | 0.0000N | 0.0000N |
| D170649 | 0.1000L | 0.1225 | 0.0400L | 0.7000 | 0.5000 | 0.0300 | 0.5000 | 20.0000 | 0.0000N | 0.0000N |
| D170650 | 0.1000L | 0.1350 | 0.0971 | 1.0000 | 1.0000 | 2.0000 | 0.2000 | 100.0000 | 0.0000N | 0.0000N |
| D170652 | 0.1000L | 0.1070 | 0.1379 | 1.5000 | 1.0000 | 5.0000 | 0.2000 | 200.0000 | 0.0000N | 0.0000N |
| D170655 | 0.1000L | 0.0630 | 0.0400L | 1.5000 | 1.5000 | 5.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |
| D170657 | 0.1000L | 0.0800 | 0.0562 | 2.0000 | 2.0000 | 5.0000 | 0.2000 | 300.0000 | 0.0000N | 0.0000N |

| SAMPLE ID | AU PPM-S | B PPM-S | BA PPM-S | BE PPM-S | BI PPM-S | CD PPM-S | CO PPM-S | CR PPM-S | CU PPM-S | LA PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 0.0000N | 50.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 70.0000 | 30.0000 | 0.0000N |
| D169747 | 0.0000N | 70.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 30.0000 | 0.0000N |
| D169748 | 0.0000N | 50.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 15.0000 | 0.0000N |
| D169749 | 0.0000N | 50.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 30.0000 | 20.0000 | 0.0000N |
| D169750 | 0.0000N | 50.0000 | 700.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 30.0000 | 0.0000N |
| D169751 | 0.0000N | 70.0000 | 700.0000 | 0.0000L | 0.0000N | 0.0000N | 0.0000L | 70.0000 | 50.0000 | 70.0000 |
| D169753 | 0.0000N | 70.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 30.0000 | 0.0000N |
| D169755 | 0.0000N | 70.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 30.0000 | 0.0000L |
| D169759 | 0.0000N | 70.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 50.0000 | 30.0000 | 0.0000N |
| D170634 | 0.0000N | 20.0000 | 500.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 50.0000 | 30.0000 | 30.0000 |
| D170635 | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 30.0000 | 15.0000 | 50.0000 |
| D170638 | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 50.0000 | 20.0000 | 0.0000N |
| D170639 | 0.0000N | 50.0000 | 1000.0000 | 1.5000 | 0.0000N | 0.0000N | 7.0000 | 50.0000 | 70.0000 | 30.0000 |
| D170640 | 0.0000N | 20.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 30.0000 | 30.0000 |
| D170641 | 0.0000N | 20.0000 | 500.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 30.0000 | 0.0000N |
| D170642 | 0.0000N | 20.0000 | 1000.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 50.0000 | 30.0000 |
| D170643 | 0.0000N | 15.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 50.0000 | 15.0000 | 30.0000 |
| D170644 | 0.0000N | 20.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 7.0000 | 70.0000 | 50.0000 | 30.0000 |
| D170646 | 0.0000N | 20.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 50.0000 | 50.0000 |
| D170648 | 0.0000N | 20.0000 | 700.0000 | 1.0000 | 0.0000N | 0.0000N | 10.0000 | 70.0000 | 50.0000 | 50.0000 |
| D170649 | 0.0000N | 100.0000 | 700.0000 | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 50.0000 | 7.0000 | 30.0000 |
| D170650 | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 50.0000 | 15.0000 | 30.0000 |
| D170652 | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 50.0000 | 20.0000 | 0.0000N |
| D170655 | 0.0000N | 30.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 5.0000 | 70.0000 | 30.0000 | 0.0000N |
| D170657 | 0.0000N | 50.0000 | 500.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 50.0000 | 30.0000 | 30.0000 |

| SAMPLE ID | MO PPM-S | NB PPM-S | NI PPM-S | PB PPM-S | PD PPM-S | PT PPM-S | SB PPM-S | SC PPM-S | SN PPM-S | SR PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 7.0000 | 0.0000N | 30.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 100.0000 |
| D169747 | 0.0000N | 0.0000N | 15.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 150.0000 |
| D169748 | 0.0000N | 0.0000N | 10.0000 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 150.0000 |
| D169749 | 0.0000N | 0.0000N | 10.0000 | 0.0000L | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 100.0000 |
| D169750 | 0.0000N | 0.0000N | 15.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 150.0000 |
| D169751 | 0.0000N | 0.0000L | 10.0000 | 30.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 70.0000 |
| D169753 | 0.0000N | 0.0000N | 15.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 150.0000 |
| D169755 | 0.0000N | 0.0000N | 10.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 100.0000 |
| D169759 | 0.0000N | 0.0000N | 10.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000L | 0.0000N | 150.0000 |
| D170634 | 0.0000N | 5.0000 | 20.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 300.0000 |
| D170635 | 0.0000N | 5.0000 | 10.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 200.0000 |
| D170638 | 0.0000N | 0.0000N | 10.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 200.0000 |
| D170639 | 5.0000 | 5.0000 | 20.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 100.0000 |
| D170640 | 0.0000N | 5.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 300.0000 |
| D170641 | 0.0000N | 5.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 300.0000 |
| D170642 | 0.0000N | 5.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 500.0000 |
| D170643 | 0.0000N | 5.0000 | 20.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 200.0000 |
| D170644 | 0.0000N | 5.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 300.0000 |
| D170646 | 0.0000N | 5.0000 | 30.0000 | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 300.0000 |
| D170648 | 0.0000N | 7.0000 | 30.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 200.0000 |
| D170649 | 0.0000N | 15.0000 | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 70.0000 |
| D170650 | 0.0000N | 5.0000 | 15.0000 | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 70.0000 |
| D170652 | 0.0000N | 5.0000 | 15.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 100.0000 |
| D170655 | 0.0000N | 0.0000N | 15.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 150.0000 |
| D170657 | 0.0000N | 5.0000 | 15.0000 | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 7.0000 | 0.0000N | 150.0000 |

| SAMPLE ID | TE PPM-S | U PPM-S | V PPM-S | W PPM-S | Y PPM-S | ZN PPM-S | ZR PPM-S | SI %-S | AL %-S | NA %-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 30.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B |
| D169747 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 70.0000 | 0.0000B | 7.0000 | 0.0000B |
| D169748 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 0.0000L | 0.0000N | 100.0000 | 0.0000B | 7.0000 | 0.0000B |
| D169749 | 0.0000N | 0.0000N | 30.0000 | 0.0000N | 0.0000L | 0.0000N | 150.0000 | 0.0000B | 5.0000 | 0.0000B |
| D169750 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 0.0000B | 7.0000 | 0.0000B |
| D169751 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 150.0000 | 0.0000B | 7.0000 | 0.0000B |
| D169753 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 0.0000B | 5.0000 | 0.0000B |
| D169755 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 0.0000B | 5.0000 | 0.0000B |
| D169759 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 0.0000L | 0.0000N | 100.0000 | 0.0000B | 5.0000 | 0.0000B |
| D170634 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 10.0000G | 7.0000 | 2.0000 |
| D170635 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 5.0000 | 1.0000 |
| D170638 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 5.0000 | 1.0000 |
| D170639 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 70.0000 | 10.0000G | 10.0000 | 0.3000 |
| D170640 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 70.0000 | 10.0000G | 7.0000 | 0.7000 |
| D170641 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 7.0000 | 0.7000 |
| D170642 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 70.0000 | 10.0000G | 10.0000 | 1.0000 |
| D170643 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 150.0000 | 10.0000G | 5.0000 | 0.7000 |
| D170644 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 70.0000 | 10.0000G | 7.0000 | 1.0000 |
| D170645 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 70.0000 | 10.0000G | 10.0000 | 1.0000 |
| D170648 | 0.0000N | 0.0000N | 100.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 10.0000 | 0.7000 |
| D170649 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 200.0000 | 10.0000G | 7.0000 | 0.2000 |
| D170650 | 0.0000N | 0.0000N | 50.0000 | 0.0000N | 15.0000 | 0.0000N | 200.0000 | 10.0000G | 7.0000 | 0.7000 |
| D170652 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 5.0000 | 1.0000 |
| D170655 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 20.0000 | 0.0000N | 100.0000 | 10.0000G | 5.0000 | 1.0000 |
| D170657 | 0.0000N | 0.0000N | 70.0000 | 0.0000N | 15.0000 | 0.0000N | 100.0000 | 10.0000G | 5.0000 | 1.0000 |

| SAMPLE ID | K %-S | P %-S | CE PPM-S | GA PPM-S | GE PPM-S | HF PPM-S | IN PPM-S | LI PPM-S | RE PPM-S | TA PPM-S |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 7.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169747 | 7.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169748 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169749 | 3.0000 | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169750 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169751 | 7.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169753 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169755 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D169759 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170634 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170635 | 3.0000 | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170638 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170639 | 5.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170640 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170641 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170642 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170643 | 2.0000 | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170644 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170646 | 5.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170648 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170649 | 3.0000 | 0.0000N | 0.0000N | 20.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170650 | 3.0000 | 0.0000N | 0.0000N | 10.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170652 | 5.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170655 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |
| D170657 | 3.0000 | 0.0000N | 0.0000N | 15.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.0000N |

| SAMPLE ID | TH PPM-S | TL PPM-S | YB PPM-S | PR PPM-S | ND PPM-S | SM PPM-S | EU PPM-S | TOTAL C% | ORGNC C% | CRBNT C% |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 0.0000N | 0.0000N | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 2.9400 | 1.0000 | 1.9400 |
| D169747 | 0.0000N | 0.0000N | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 4.6900 | 2.0000 | 2.6400 |
| D169748 | 0.0000N | 0.0000N | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.3300 | 0.1000L | 3.3300 |
| D169749 | 0.0000N | 0.0000N | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.0000 | 0.1000L | 2.9900 |
| D169750 | 0.0000N | 0.0000N | 3.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.4600 | 0.1000 | 3.3300 |
| D169751 | 0.0000N | 0.0000N | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.5400 | 0.4000 | 0.1100 |
| D169753 | 0.0000N | 0.0000N | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 4.2100 | 0.1000L | 4.1400 |
| D169755 | 0.0000N | 0.0000N | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.2000 | 0.7000 | 2.5200 |
| D169759 | 0.0000N | 0.0000N | 0.0000L | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.7500 | 0.1000L | 3.7500 |
| D170634 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.4800 | 0.2000 | 1.2900 |
| D170635 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.9900 | 0.2000 | 2.7100 |
| D170638 | 0.0000N | 0.0000N | 1.5000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 4.0100 | 0.4000 | 3.6000 |
| D170639 | 0.0000N | 0.0000N | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 9.9800 | 9.9000 | 0.1000 |
| D170640 | 0.0000N | 0.0000N | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.0700 | 1.0000 | 1.1000 |
| D170641 | 0.0000N | 0.0000N | 1.5000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 1.7000 | 0.6000 | 1.1400 |
| D170642 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.1200 | 1.0000 | 1.0900 |
| D170643 | 0.0000N | 0.0000N | 2.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.7100 | 0.4000 | 1.2700 |
| D170644 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 2.8500 | 1.1000 | 1.7800 |
| D170646 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.7100 | 0.7000 | 1.0100 |
| D170648 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.0900 | 0.8000 | 0.3300 |
| D170649 | 0.0000N | 0.0000N | 3.0000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 0.1900 | 0.2000 | 0.0100L |
| D170650 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 1.7200 | 0.4000 | 1.2900 |
| D170652 | 0.0000N | 0.0000N | 1.5000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.2000 | 0.7000 | 2.5100 |
| D170655 | 0.0000N | 0.0000N | 2.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000N | 3.1600 | 0.4000 | 2.7300 |
| D170657 | 0.0000N | 0.0000N | 1.5000 | 0.0000N | 0.0000N | 0.0000N | 0.0000N | 3.5600 | 0.5000 | 3.0600 |

| SAMPLE ID | AS PPM | CD PPM | CU PPM | HG PPM | LI PPM | PB PPM | SB PPM | SE PPM | TH PPM | U PPM |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 20.0000 | 0.0000B | 0.0000B | 0.1700 | 0.0000B | 0.0000B | 2.2000 | 0.3265 | 10.8300 | 7.4390 |
| D169747 | 30.0000 | 0.0000B | 0.0000B | 0.1300 | 0.0000B | 0.0000B | 3.0000 | 0.2592 | 8.5980 | 3.9920 |
| D169748 | 5.0000 | 0.0000B | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 1.1000 | 0.1000L | 9.2160 | 3.1300 |
| D169749 | 5.0000 | 0.0000B | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 1.2000 | 0.1000L | 9.1870 | 3.4850 |
| D169750 | 8.0000 | 0.0000B | 0.0000B | 0.0700 | 0.0000B | 0.0000B | 1.2000 | 0.1000L | 11.7400 | 3.0680 |
| D169751 | 8.0000 | 0.0000B | 0.0000B | 0.1200 | 0.0000B | 0.0000B | 1.2000 | 0.9378 | 14.0900 | 4.6200 |
| D169753 | 12.0000 | 0.0000B | 0.0000B | 0.0900 | 0.0000B | 0.0000B | 1.6000 | 0.1000L | 9.2150 | 3.4070 |
| D169755 | 20.0000 | 0.0000B | 0.0000B | 0.0800 | 0.0000B | 0.0000B | 1.9000 | 0.1272 | 12.3900 | 3.6260 |
| D169759 | 5.0000 | 0.0000B | 0.0000B | 0.0500 | 0.0000B | 0.0000B | 1.3000 | 0.1000L | 10.1400 | 3.3530 |
| D170634 | 5.0000 | 1.0000L | 30.0000 | 0.1100 | 28.0000 | 25.0000L | 1.1000 | 0.4108 | 10.8200 | 5.5710 |
| D170635 | 5.0000 | 1.0000L | 16.0000 | 0.0500 | 28.0000 | 25.0000L | 1.0000 | 0.1000L | 6.9650 | 3.3060 |
| D170638 | 8.0000 | 1.0000L | 24.0000 | 0.0800 | 24.0000 | 25.0000L | 1.4000 | 0.1113 | 9.5160 | 2.9560 |
| D170639 | 40.0000 | 1.0000L | 52.0000 | 0.1300 | 50.0000 | 30.0000 | 4.5000 | 1.4843 | 10.5900 | 8.4840 |
| D170640 | 12.0000 | 1.0000L | 26.0000 | 0.1500 | 55.0000 | 25.0000 | 1.0000 | 0.5693 | 11.5300 | 4.4260 |
| D170641 | 8.0000 | 1.0000L | 24.0000 | 0.1300 | 36.0000 | 25.0000L | 0.9000 | 0.1000L | 7.8750 | 3.9710 |
| D170642 | 15.0000 | 1.0000L | 26.0000 | 0.1100 | 35.0000 | 25.0000 | 1.2000 | 0.4453 | 8.5840 | 4.0560 |
| D170643 | 5.0000 | 1.0000L | 12.0000 | 0.0900 | 22.0000 | 25.0000L | 0.5000 | 0.1946 | 7.5290 | 3.2520 |
| D170644 | 8.0000 | 1.0000L | 26.0000 | 0.1100 | 34.0000 | 25.0000L | 0.7000 | 0.4123 | 8.3390 | 4.0840 |
| D170646 | 5.0000 | 1.0000L | 30.0000 | 0.1000 | 32.0000 | 25.0000L | 0.7000 | 0.4517 | 12.2700 | 4.1640 |
| D170648 | 15.0000 | 1.0000L | 26.0000 | 0.1500 | 50.0000 | 25.0000L | 1.0000 | 0.4491 | 10.6900 | 5.2800 |
| D170649 | 3.0000 | 1.0000L | 10.0000L | 0.1500 | 30.0000 | 25.0000L | 1.1000 | 0.1906 | 11.1200 | 5.3720 |
| D170650 | 10.0000 | 1.0000L | 16.0000 | 0.1300 | 22.0000 | 25.0000L | 0.9000 | 0.7094 | 8.7110 | 4.3610 |
| D170652 | 15.0000 | 6.0000 | 24.0000 | 0.1300 | 30.0000 | 25.0000L | 1.3000 | 0.2459 | 10.0200 | 3.9720 |
| D170655 | 8.0000 | 1.0000L | 28.0000 | 0.1100 | 24.0000 | 25.0000L | 1.0000 | 0.2085 | 9.8690 | 3.1150 |
| D170657 | 8.0000 | 1.0000L | 24.0000 | 0.0800 | 28.0000 | 25.0000L | 1.1000 | 0.2744 | 10.5100 | 3.6600 |

| SAMPLE ID | ZN PPM | ASH % | CA/A % | MG/A % | LI/A PPM | NA/A % | K/A % | P/A PPM | CL/A % | CD/A PPM |
|---|---|---|---|---|---|---|---|---|---|---|
| D169745 | 0.0000B | 97.7000 | 3.6840 | 2.3500 | 30.0000 | 0.4500 | 2.3135 | 436.4000L | 0.1000L | 1.0000L |
| D169747 | 0.0000B | 95.7000 | 5.9071 | 2.4100 | 36.0000 | 0.4200 | 2.7730 | 436.4000L | 0.1000L | 1.0000L |
| D169748 | 0.0000B | 97.5000 | 6.6405 | 2.7100 | 24.0000 | 0.5600 | 1.8130 | 436.4000L | 0.1000L | 1.0000L |
| D169749 | 0.0000B | 98.1000 | 5.8592 | 2.7100 | 24.0000 | 0.5900 | 1.7313 | 436.4000L | 0.1000L | 1.0000L |
| D169750 | 0.0000B | 95.4000 | 6.0580 | 2.5900 | 32.0000 | 0.5100 | 2.3680 | 436.4000L | 0.1000L | 1.0000L |
| D169751 | 0.0000B | 95.8000 | 0.2602 | 0.9600 | 42.0000 | 0.2500 | 3.1672 | 781.8400 | 0.1000L | 1.0000L |
| D169753 | 0.0000B | 97.4000 | 9.3891 | 2.8600 | 32.0000 | 0.3900 | 2.3632 | 436.4000L | 0.1000L | 1.0000L |
| D169755 | 0.0000B | 95.7000 | 5.2345 | 2.3200 | 32.0000 | 0.4800 | 2.5569 | 436.4000L | 0.1000L | 1.0000L |
| D169759 | 0.0000B | 96.3000 | 7.4037 | 3.1000 | 32.0000 | 0.5900 | 2.3766 | 436.4000L | 0.1000L | 1.0000L |
| D170634 | 104.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170635 | 56.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170638 | 55.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170639 | 112.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170640 | 130.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170641 | 93.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170642 | 115.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170643 | 74.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170644 | 112.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170646 | 125.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170648 | 136.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170649 | 31.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170650 | 53.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170652 | 74.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170655 | 68.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170657 | 65.0000 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

| SAMPLE ID | CU/A PPM | MN/A PPM | PB/A PPM | ZN/A PPM | FE/A PPM | SI/A PPM | AL/A % | S/A% | TI/A % |
|---|---|---|---|---|---|---|---|---|---|
| D169745 | 28.0000 | 154.8000L | 25.0000L | 140.0000 | 18942.9998 | 279250.0000 | 9.1803 | 0.1871 | 0.3103 |
| D169747 | 30.0000 | 645.1100 | 25.0000L | 86.0000 | 30966.0000 | 241059.9980 | 9.2891 | 0.3591 | 0.3118 |
| D169748 | 20.0000 | 374.2600 | 25.0000L | 50.0000 | 21373.9998 | 266570.0000 | 6.5234 | 0.0400L | 0.2654 |
| D169749 | 24.0000 | 307.2200 | 25.0000L | 58.0000 | 17300.0000 | 284680.0000 | 6.5828 | 0.0400L | 0.2677 |
| D169750 | 26.0000 | 1280.5000 | 25.0000L | 82.0000 | 50507.0000 | 257239.9980 | 8.7376 | 0.0400L | 0.3081 |
| D169751 | 38.0000 | 189.5700 | 25.0000L | 94.0000 | 21777.0000 | 318870.0000 | 10.5740 | 0.0724 | 0.4157 |
| D169753 | 26.0000 | 496.0200 | 25.0000 | 82.0000 | 29808.0000 | 226809.9980 | 8.1998 | 0.0405 | 0.2946 |
| D169755 | 29.0000 | 527.1800 | 25.0000L | 88.0000 | 31600.9998 | 279430.0000 | 9.0826 | 0.1015 | 0.3363 |
| D169759 | 30.0000 | 698.1900 | 25.0000L | 78.0000 | 35784.0000 | 233650.0000 | 7.5051 | 0.0400L | 0.2849 |
| D170634 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170635 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170638 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170639 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170640 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170641 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170642 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170643 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170644 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170646 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170648 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170649 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170650 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170652 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170655 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |
| D170657 | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B | 0.0000B |

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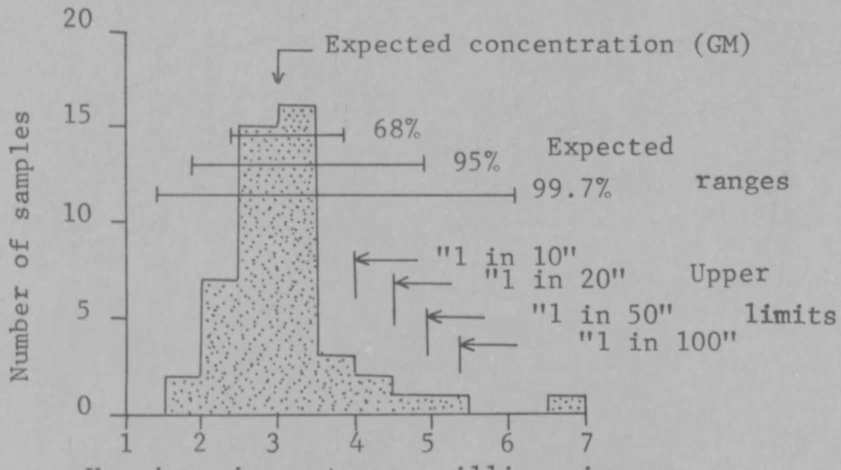
(Continued from inside front cover)

The GE, if available, can be used to correct for laboratory error hidden in GD. Where possible, GD prior to undertaking any of the above calculations should be replaced by $GD_n$, computed as follows:

$$GD_n = \sqrt{(\text{Log GD})^2 - (\text{Log GE})^2} \qquad (2)$$

Although the use of logarithms and square roots may be bothersome, reasonably-priced hand calculators are available for solution of such functions.

The following example will help clarify the ideas expressed above. Forty-eight samples of about 200 grams each collected from the top 2.5 centimetres of soil in the Powder River Basin of Wyoming and Montana were analyzed for uranium. The frequency distribution of these samples is given below. The asymmetry of the distribution suggests that the properties of the distribution should be summarized on a logarithmic basis. The expected value (GM) is computed as 3.0 parts per million (ppm). The GD for this study is 1.28 and the GE is 1.04. The correction of GD (equation 2) gives a $GD_n$ of 1.276. Based on this value, the 68 percent range (to two significant figures) is estimated as 2.4 to 3.8 ppm uranium, the 95 percent range is estimated as 1.8 to 4.9 ppm and the 99.7 percent range as 1.4 to 6.2 ppm. The limit above which one sample in 10 of a random selection is expected to fall (equation 1) is 4.1 ppm, the limit for "1 in 20" is 4.5, for "1 in 50" is 4.9, and for "1 in 100" is 5.3 ppm. Conceivably, any of these upper limits may be acceptable as an upper level of uranium for "ordinary" surface soil in the basin, depending on the reason for the study and the reasonings of the investigator.




Uranium, in parts per million, in surface soil, Powder River Basin