**U.S DEPARTMENT OF THE INTERIOR**

**U.S. GEOLOGICAL SURVEY**

# PARTITIONING OF MINOR ELEMENTS AND MAJOR-ELEMENT OXIDES BETWEEN ROCK COMPONENTS AND CALCULATION OF THE MARINE DERIVED FRACTION OF THE MINOR ELEMENTS IN ROCKS OF THE PHOSPHORIA FORMATION, IDAHO AND WYOMING

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**Abstract**

Major-element-oxides from five sections of the Phosphoria Formation -- Mud Spring, Lakeridge, Wheat Creek, Fontenelle Creek, and Conant Creek -- are partitioned into normative-mineral components in order to determine the marine versus terrigenous fractions of the rocks. The components are apatite, dolomite, calcite, biogenic silica and organic matter, the marine-derived fraction of the samples, and a detrital component, the terrigenous fraction of the samples. The same proportionality constants are used in the calculation of each component for all the sections. The average sum of the components is 99.6 percent with an average standard deviation of 2.7 percent, demonstrating that the components have a relatively constant composition. The coherence of the normative scheme was also checked by comparing measured inorganic $CO_2$ to calculated $CO_2$; correlation coefficients were 0.99 or greater for all but one of the sections.

Assuming aluminum is entirely of terrigenous origin, X-Y plots of aluminum versus Ba, Li, Ga, and Sc, which show good correlations, demonstrate a relatively constant minor element content in the terrigenous fraction. The terrigenous fraction of the minor elements is determined primarily from a sample composed almost entirely of the terrigenous detrital component. There were exceptions where the terrigenous minor-element fraction was determined by the minor element content of a standard shale or by the minor-element/$Al_2O_3$ ratios extracted from a well defined minimum line formed on minor-element/$Al_2O_3$ graphs. The marine fraction of minor elements is the difference between bulk minor-element content of the samples and their terrigenous contribution of minor elements. Positive correlations exist between the marine fraction of several minor elements and the components apatite and organic matter, further validating the normative calculation.

# INTRODUCTION

Over the past few decades oceanographers have examined the behavior of minor elements in seawater and sediment from different geochemical environments of the modern ocean (Elderfield, 1970; Bertine and Turekian, 1973; Bruland, 1983; Landing and Bruland, 1987; Jacobs and others, 1987; Piper, 1988; Anderson and others, 1989; Shaw and others, 1990; Emerson and Huested, 1991; Bruland and others, 1991). From this research the marine minor elements have been used to interpret the depositional environments of ancient sedimentary deposits (Piper, 1991; Piper and Medrano, 1994; Piper and Isaacs, 1995). The Phosphoria Formation is enriched in a number of the marine derived minor elements because of the low terrigenous sedimentation rate (0.2-0.5 mg/yr/cm$^2$) and a large marine fraction, composed mainly of chert, apatite, calcite or/and dolomite, and organic matter. In this bulletin the marine fraction of minor elements and their *host* phases are calculated from major- and minor-element analyses of rock samples from the Phosphoria Formation using a normative procedure (described in detail in Medrano and Piper, 1992). In the next bulletin, the second part of this study, the *source* of the marine fraction of minor elements and their depositional environment will be discussed.

The normative procedure involves calculating the percentage of each mineral component in each sample. The components of the Phosphoria Formation are apatite, calcite, dolomite, organic matter, biogenic silica, and terrigenous detritus. Unlike the typical normative calculation these components, or minerals, are not fictitious. All have been identified in these rocks by X-ray defraction and in thin sections using a petrographic microscope (Gulbrandsen, 1960a,b; McClellan and Lehr, 1969; Murata and others, 1972). All the components are composed of a single mineral, except the terrigenous detrital component and organic matter. The terrigenous detrital component is a multi-mineral component, composed of detrital quartz, clay minerals, feldspars, mica, and accessory minerals like zircon and rutile (Gulbrandsen, 1960a). After the components are quantitatively determined, they are partitioned into either the marine and terrigenous fractions.

The minor-element content in the terrigenous fraction is determined from minor element/$Al_2O_3$ graphs. The marine minor element content of the rocks is calculated as the difference between the terrigenous minor-element content and the bulk analyses. Key to calculating the marine minor elements is: 1) evaluating the quality of the initial data; 2) evaluating the constancy of composition for components at each section; 3) determining compositional variations of components between sections; 4) determining "proportionality constants" for each rock component; 5) evaluating the terrigenous fraction for constant minor-element composition; and 6) determining minor element/terrigenous fraction proportionality constants.

## GEOLOGIC SETTING AND SAMPLING

### Geologic Setting

The Phosphoria Formation, deposited in an interior sag basin (Wardlaw and Collinson, 1986) located along the western margin of the North American craton, consists of carbonaceous and phosphatic mudstone, phosphorite with minor amounts of carbonates, and dark gray chert (McKelvey, 1959). It was deposited over approximately 10 m.y., from the middle of the Leonardian to the middle of the Guadalupian stages in Permian time (Wardlaw and Collinson, 1984; Murchey and Jones, 1992). The basin is located in the eastern half of Idaho, western Wyoming, northern Utah, northeastern Nevada and southwest Montana (fig. 1). Paleomagnetic data indicate that at the time of deposition the basin lay 3° to 9° N of the equator (Sheldon, 1964).

### Sample selection.

Rock samples from Conant Creek, Wheat Creek, Fontenelle Creek, Lakeridge, and Mud Spring (fig. 1) are described in U.S. Geological Survey publications (Sheldon and others, 1953; Sheldon and others, 1954; Smart and others, 1954; Sheldon, 1963).

Stratigraphic sections, showing sample positions, were constructed from these reports (fig. 2). These sites are located on an east-west transact of the area of deposition. Conant Creek, the easternmost site, is mainly a carbonate facies, possibly of shallow-water origin. Mud Spring, more than 500 km to the west, is a mudstone facies, possibly originating in deeper water (McKelvey 1959). The sections in between consist of these plus major phosphate and chert facies.

The Conant Creek, Fontenelle Creek, Wheat Creek, and Mud Spring samples are from surface outcrops or trenches and include mainly the Meade Peak Phosphatic Shale Member, with only a few samples from the Retort Phosphatic Shale Member and the Rex Chert Member, all of the Phosphoria Formation. The analyzed powders for these sections are aliquots of original ground powders (to 200 mesh). The samples from the Lakeridge section are from a core collected from a well deeper than 4200 m (Murata and others, 1972). Samples of Lakeridge core include all the members of the Phosphoria Formation, as well as interbedded units of the Park City Formation and Shedhorn Sandstone. (fig. 2*C*).

Figure 1. Locality map, showing sections sampled in this study, marked by small solid squares. Map is adapted from Yochelson (1968).

Figure 2. Stratigraphic columns of the Phosphoria Formation showing samples analyzed: Conant Creek (*A*), Wheat Creek (*B*), Fontenelle Creek (*B*), Mud Spring (*C*) and Lakeridge (*C*). Compiled from Smart and others, 1954, Sheldon 1963, Sheldon and others, 1953, Sheldon and others, 1954. Legend is given in figure 2*A*.

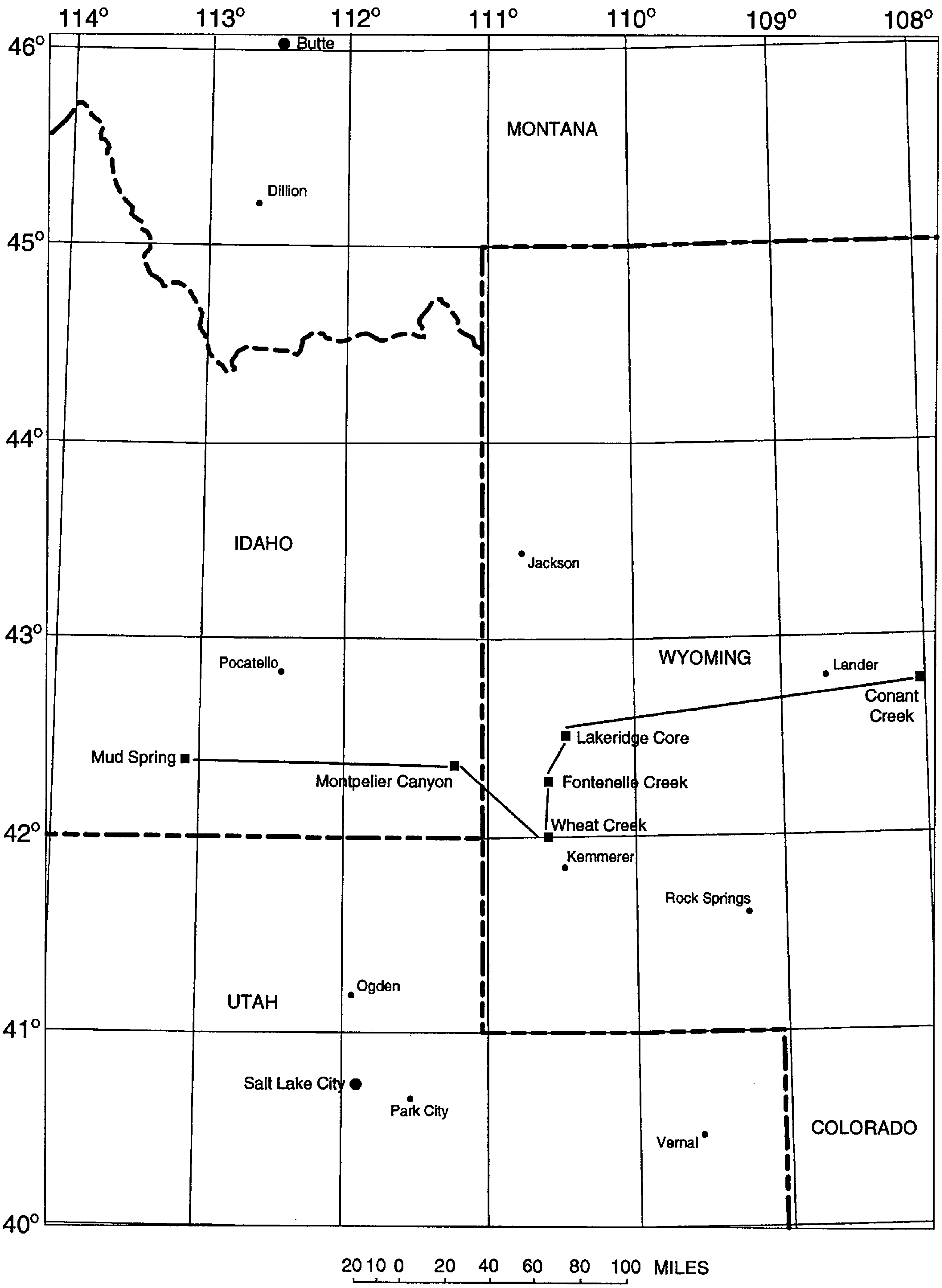

114°
113°
112°
111°
110°
109°
108°
46°
45°
44°
43°
42°
41°
40°
Butte
MONTANA
Dillion
IDAHO
Jackson
Pocatello
WYOMING
Lander
Conant Creek
Lakeridge Core
Mud Spring
Montpelier Canyon
Fontenelle Creek
Wheat Creek
Kemmerer
Rock Springs
UTAH
Ogden
Salt Lake City
Park City
Vernal
COLORADO
20 10 0 20 40 60 80 100 MILES

Figure 1

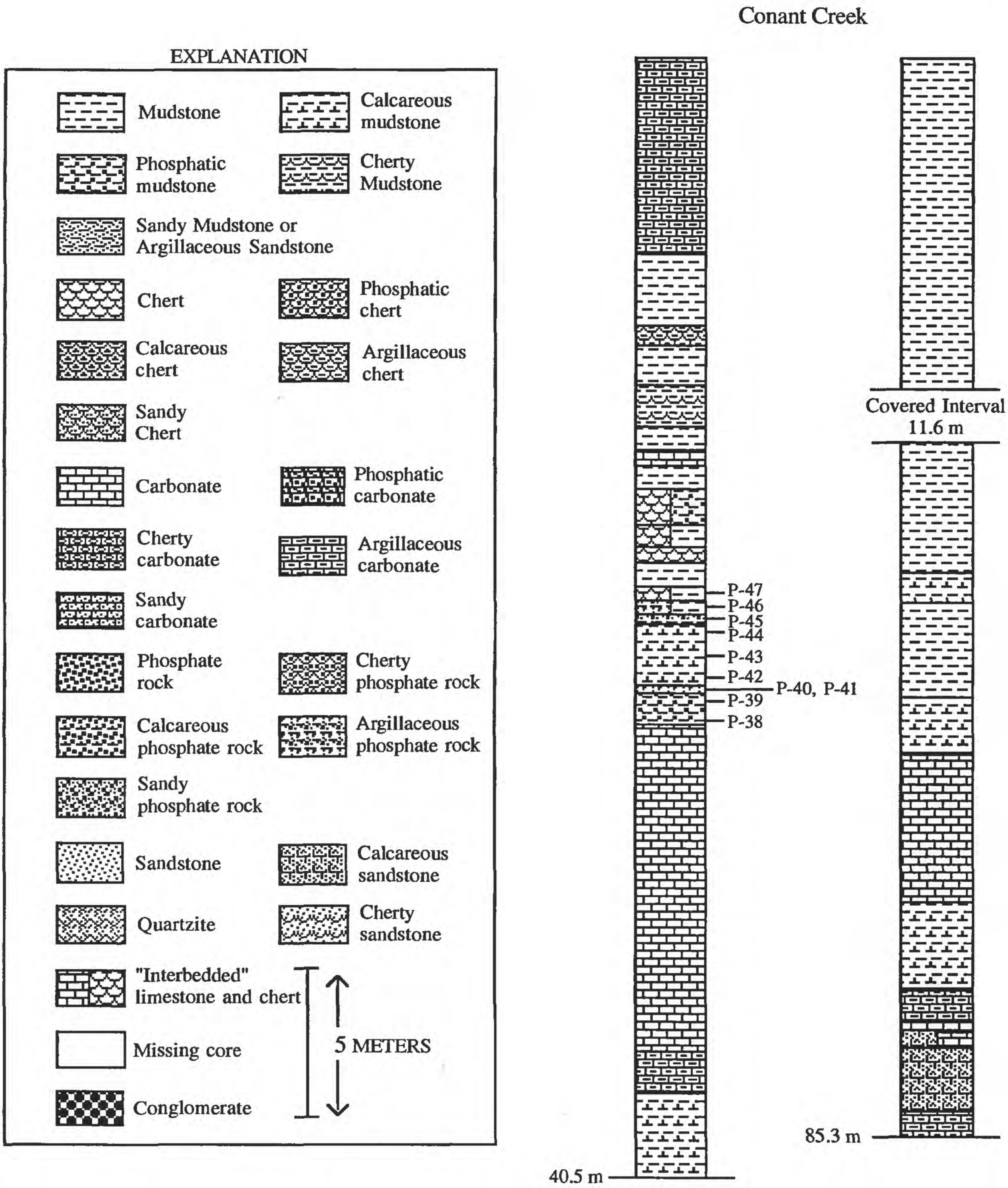
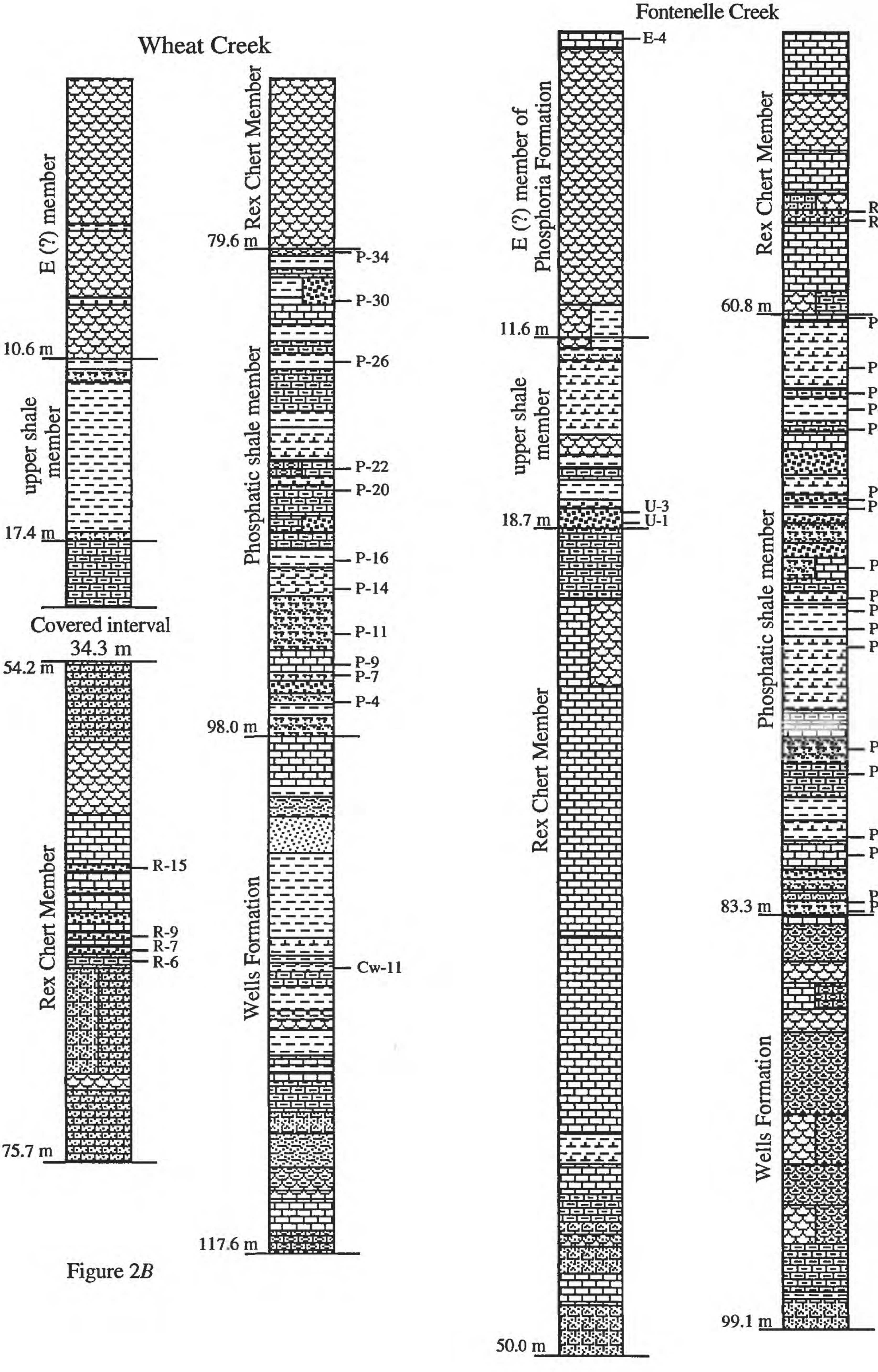
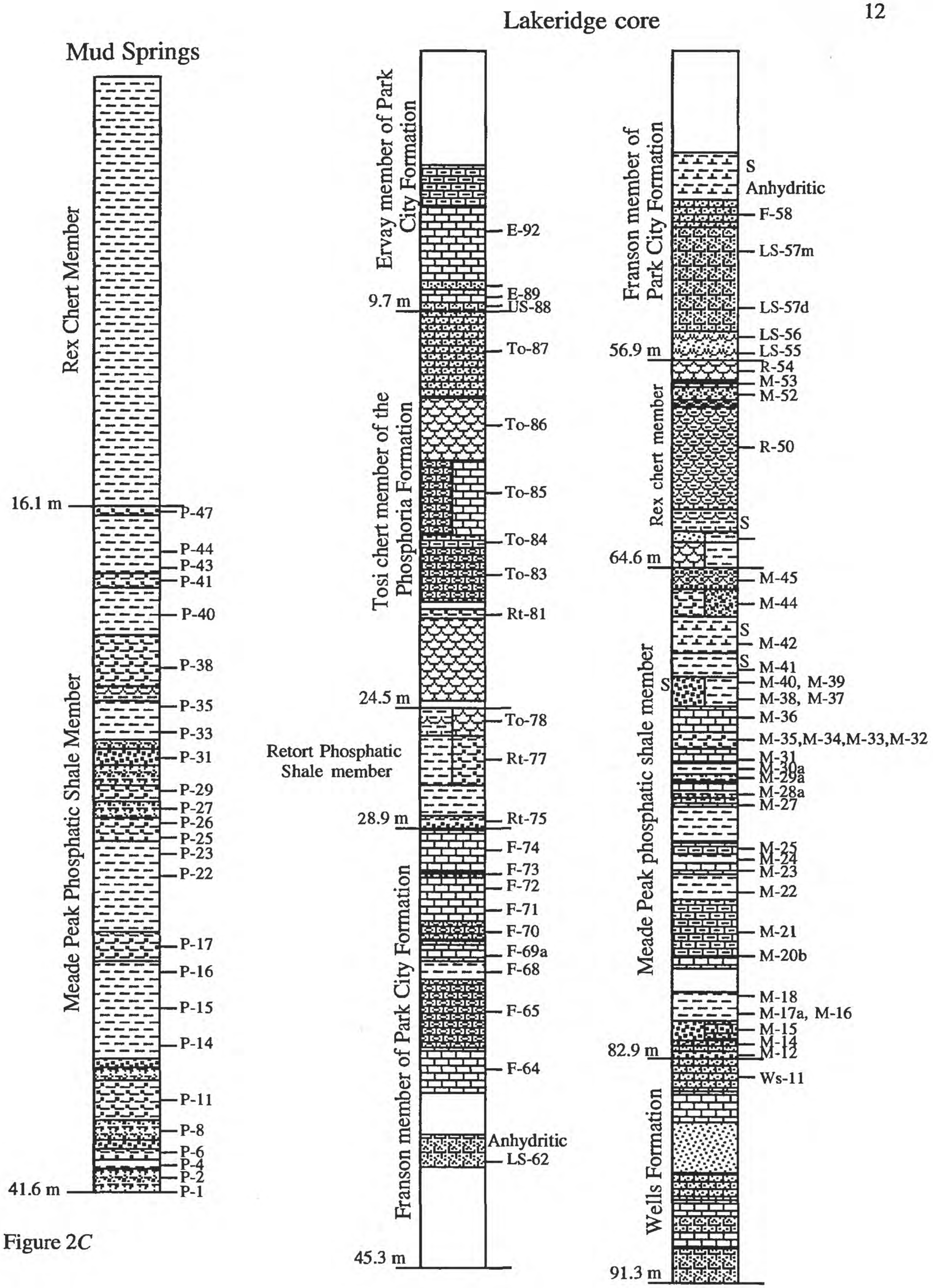

Conant Creek
EXPLANATION
Mudstone
Calcareous mudstone
Phosphatic mudstone
Cherty Mudstone
Sandy Mudstone or Argillaceous Sandstone
Chert
Phosphatic chert
Calcareous chert
Argillaceous chert
Sandy Chert
Carbonate
Phosphatic carbonate
Cherty carbonate
Argillaceous carbonate
Sandy carbonate
Phosphate rock
Cherty phosphate rock
Calcareous phosphate rock
Argillaceous phosphate rock
Sandy phosphate rock
Sandstone
Calcareous sandstone
Quartzite
Cherty sandstone
"Interbedded" limestone and chert
Missing core
Conglomerate
5 METERS
P-47
P-46
P-45
P-44
P-43
P-42
P-40, P-41
P-39
P-38
40.5 m
Covered Interval 11.6 m
85.3 m

Figure 2A



Wheat Creek
E (?) member
10.6 m
upper shale member
17.4 m
Covered interval
34.3 m
54.2 m
Rex Chert Member
R-15
R-9
R-7
R-6
75.7 m
Rex Chert Member
79.6 m
P-34
P-30
P-26
Phosphatic shale member
P-22
P-20
P-16
P-14
P-11
P-9
P-7
P-4
98.0 m
Wells Formation
Cw-11
117.6 m
Fontenelle Creek
E-4
E (?) member of Phosphoria Formation
11.6 m
upper shale member
U-3
18.7 m
U-1
Rex Chert Member
50.0 m
Rex Chert Member
R-9
R-6
60.8 m
P-45
P-43
P-40
P-39
P-37
P-31
P-32
Phosphatic shale member
P-25
P-23
P-21
P-20
P-19
P-13
P-12
P-8
P-7
P-3
83.3 m
P-1
Wells Formation
99.1 m


Figure 2*B*



Mud Springs
Rex Chert Member
Meade Peak Phosphatic Shale Member
16.1 m
41.6 m
P-47
P-44
P-43
P-41
P-40
P-38
P-35
P-33
P-31
P-29
P-27
P-26
P-25
P-23
P-22
P-17
P-16
P-15
P-14
P-11
P-8
P-6
P-4
P-2
P-1
Lakeridge core
Ervay member of Park City Formation
Tosi chert member of the Phosphoria Formation
Retort Phosphatic Shale member
Franson member of Park City Formation
9.7 m
24.5 m
28.9 m
45.3 m
E-92
E-89
US-88
To-87
To-86
To-85
To-84
To-83
Rt-81
To-78
Rt-77
Rt-75
F-74
F-73
F-72
F-71
F-70
F-69a
F-68
F-65
F-64
Anhydritic
LS-62
Franson member of Park City Formation
Rex chert member
Meade Peak phosphatic shale member
Wells Formation
56.9 m
64.6 m
82.9 m
91.3 m
S
Anhydritic
F-58
LS-57m
LS-57d
LS-56
LS-55
R-54
M-53
M-52
R-50
S
M-45
M-44
S
M-42
S
M-41
S
M-40, M-39
M-38, M-37
M-36
M-35,M-34,M-33,M-32
M-31
M-30a
M-29a
M-28a
M-27
M-25
M-24
M-23
M-22
M-21
M-20b
M-18
M-17a, M-16
M-15
M-14
M-12
Ws-11


Figure 2*C*

# ANALYTICAL TECHNIQUES AND EVALUATION OF THE DATA

## Major-element-oxide analyses

Major-element oxides, except $SiO_2$, were measured by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) after acid digestion (Lichte and others, 1987a). Selected samples were analyzed by wavelength-dispersive X-ray fluorescence spectroscopy (XRF; Taggart and others, 1987). Loss on ignition (LOI) at 925°C was measured on the samples which were analyzed by XRF. The limit of detection and the precision and accuracy of each analytical technique were determined by repeated analysis of rock standards by the Branch of Geochemistry and are given in table 1. Wet chemical analyses (for $P_2O_5$ only), originally reported in U.S. Geological Survey Circulars 307, 325, 327 (Sheldon and others, 1953; Sheldon and others, 1954; Smart and others, 1954), are listed with the ICP-AES and XRF data in table 2.

Evaluating the quality of the major-element data is important because the major element data are used to determine the normative components and with each calculation any error in the original data is compounded. Accuracy of an analysis is its deviation from its true value. Unfortunately the true value cannot be known. What is known is the "accepted value," which represents the mean of all values from several different analytical techniques. The U.S. Geological Survey Laboratory has determined accuracy for its analytical techniques by comparing its analyses with "accepted values" (table 1).

We have further evaluated the quality of these data by comparing analyses of individual elements made by more than one technique. Ideally, the analytical results of multiple techniques should agree closely. For our data, X-Y plots of individual elements, measured by two techniques, show agreement within 5 percent of the one-to-one line in 75 percent of the cases (fig. 3). This procedure does not identify which technique is in error; rather it establishes that a finite systematic error of some percent exists in one or the other, or possibly both analyses. Analytical results for $P_2O_5$ (fig. 3*A*), measured by wet chemistry and XRF (Mud Spring, Conant Creek, and Lakeridge sections) are in excellent agreement. In contrast, the ICP-AES data for the Wheat Creek and Fontenelle Creek sections are higher by approximately 13 percent and 9 percent, respectively, than the XRF data. These deviations suggest a systematic error in the ICP-AES data for a few elements.

Precision of an analytical technique is defined by the deviation of a set of determinations from their mean (table 1). The X-Y plots also provide a measure of precision (fig 3). Whereas accuracy is assumed to be represented by the approach of the correlation line to a slope of one, precision is evaluated by the degree of correlation to the line of best fit, i.e., the correlation coefficient. This is a measure of the combined precision of the two techniques. For major-element oxides used in the normative calculation ($Al_2O_3$, MgO, CaO, $P_2O_5$) the correlation coefficients are $R \geq 0.99$ (fig. 3). The precision for the ICP-AES and the XRF data is lower than the maximum reported by the U.S. Geological Survey Laboratory (table 1).

We use the ICP data for the calculation of the components because it is the technique used to measure the minor elements and we want to be consistent by using the same data set within each section and between sections. The exception to this is the following: $SiO_2$, not analyzed by ICP, is measured by XRF. In the case of Lakeridge, $SiO_2$ data is not available for all the samples, so they are calculated from the difference between the sum of all the major elements, plus a LOI term, and 100 percent.

Table 1. Detection limits, accuracy and precision for elements analyzed by the different analytical techniques were determined by repeated analysis of rock standards by the Branch of Geochemistry (Arbogast and others, 1990; Baedecker and others, 1987; Lichte and others, 1987).

| Analytical Technique | Detection Limit | Accuracy | Precision |
|---|---|---|---|
| ICP-AES | Limits of detection, in weight percent, in parentheses: $Al_2O_3$ (0.09), CaO (0.07), $Fe_2O_3$ (0.07), $K_2O$ (0.1), MgO (0.08), $Na_2O$ (0.1), $P_2O_5$ (0.02), and $TiO_2$ (0.02). Limit of detection in parts per million in parentheses: Ag (2), As (10), Au (8), Ba (1), Be (1), Bi (10), Cd (2), Ce (4), Co (1), Cr (1), Cu (1), Eu (2), Ga (4), Ho (4), La (2), Li (2), Mn (10), Mo (2), Nb (4), Nd (4), Ni (2), Pb (4), Sc (2), Sn (10), Sr (2), Ta (40), Th (4), U (100), V (2), Y (2), Yb (1), and Zn (2). | Standards analyzed varied 0.5 to 10 % from the proposed value | ±2 to 10 percent for concentrations greater than 10 times the lower limit of detection |
| XRF | Concentration Range<br>$SiO_2$ 0.10% to 99.0%<br>$Al_2O_3$ 0.10% to 28.0%<br>$Fe_2O_3$ 0.04% to 28.0%<br>MgO 0.10% to 60.0%<br>CaO 0.02% to 60.0%<br>$Na_2O$ 0.15% to 30.0%<br>$K_2O$ 0.02% to 30.0%<br>$TiO_2$ 0.02% to 10.0%<br>$P_2O_5$ 0.05% to 50.0%<br>MnO 0.01% to 15.0%<br>LOI 0.01% to 100.0% | Standards analyzed varied 0.5 to 3 % from the proposed value | Precision is better than ±5 percent and, depending on the element, as low as ±0.2 percent |
| ICP-MS | Limits of detection in parts per million: La (0.002), Ce (0.002), Pr (0.002), Nd (0.009), Sm (0.006), Eu (0.003), Gd (0.011), Tb (0.002), Dy (0.007), Ho (0.002), Er (0.007), Tm (0.002), Yb (0.006), Lu (0.002). | Accuracy similar to ICP-AES and neutron activation analysis | The average RSD for the REE is 2.5%. They range from 1.7% to 5.1%. |
| Total C by combustion | Concentration Range<br>C 0.05% to 30% | Standard: MAG-1, $\overline{X}$ = 2.28%, n = 12, s = 0.009%, proposed value: 2.15±0.40% | RSD is ≤ 5% for samples with > 0.01% C or an absolute standard deviation of 0.05% C, whichever is greater. |
| Total S by combustion | Concentration range<br>S 0.05% to 30% | Standard: SDO-1, $\overline{X}$ = 5.44%, n = 10, proposed value: 5.35±0.44% | RSD for standard is 0.2% |
| Carbonate carbon by coulometric titration | Concentration range<br>$CO_2$ 0.01% to 50.0% | Standard: GSP-1, $\overline{X}$ = 0.10±0.003%, n = 12, proposed value: 0.11% | RSD is < 5% for concentration range of 0.01% to 36%. |
| F by ion-selective electrode | Concentration range<br>F 100ppm to 2.7% | Standard: GSP-1, $\overline{X}$ = 3240 ppm, n = 23, proposed value: 3630 ppm | RSD for standard is 11%. |

**Table 2.** Major-element-oxide contents in samples of the Phosphoria Formation from Conant Creek, Wheat Creek, Fontenelle Creek, Lakeridge, Wyoming, and Mud Springs, Idaho.

[All values in weight percent, as determined by inductively coupled plasma spectroscopy (I), X-ray-fluorescence spectroscopy (X), and wet chemical analysis (W). LOI, loss on ignition]

| | Conant Creek | | | | | | | | | | Mud Springs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample---- | P-47 | P-46 | P-45 | P-44 | P-43 | P-42 | P-41 | P-40 | P-39 | P-38 | P-47 | P-44 | P-43 | P-41 | P-40 | P-38 | P-35 |
| $SiO_2$------- | 62.9 (X) | 37.4 (X) | 26.7 (X) | 40.8 (X) | 38 (X) | 38.7 (X) | 39 (X) | 55.5 (X) | 40 (X) | 27.1 (X) | 47 (X) | 69.8 (X) | 62.3 (X) | 50.4 (X) | 61.1 (X) | 47.7 (X) | 62.9 (X) |
| $Al_2O_3$------ | 2.94 (I) | 3.98 (I) | 2.15 (I) | 2.91 (I) | 5.57 (I) | 7.14 (I) | 2.88 (I) | 3.62 (I) | 4.44 (I) | 4.71 (I) | 10.77 (I) | 8.79 (I) | 11.00 (I) | 7.98 (I) | 11.09 (I) | 10.85 (I) | 7.01 (I) |
| | 2.58 (X) | 3.6 (X) | 1.8 (X) | 2.48 (X) | 4.87 (X) | 8.38 (X) | 2.28 (X) | 3.35 (X) | 3.93 (X) | 4.14 (X) | 10.3 (X) | 8.45 (X) | 10.8 (X) | 7.44 (X) | 10.8 (X) | 10.3 (X) | 6.59 (X) |
| $Fe_2O_3$------ | 2.89 (I) | 1.97 (I) | 1.26 (I) | 2.06 (I) | 2.25 (I) | 2.73 (I) | 2.23 (I) | 3.13 (I) | 2.35 (I) | 2.35 (I) | 5.03 (I) | 2.93 (I) | 3.58 (I) | 2.93 (I) | 4.58 (I) | 3.69 (I) | 2.32 (I) |
| | 2.81 (X) | 2.04 (X) | 1.22 (X) | 2 (X) | 2.12 (X) | 2.61 (X) | 2.22 (X) | 2.92 (X) | 2.27 (X) | 2.26 (X) | 4.99 (X) | 2.87 (X) | 3.55 (X) | 2.92 (X) | 4.8 (X) | 3.8 (X) | 2.27 (X) |
| MgO------- | 2.59 (I) | 3.50 (I) | 6.01 (I) | 9.15 (I) | 9.13 (I) | 7.92 (I) | 1.54 (I) | 6.54 (I) | 5.98 (I) | 7.34 (I) | 0.71 (I) | 0.71 (I) | 0.85 (I) | 0.40 (I) | 0.90 (I) | 0.80 (I) | 0.60 (I) |
| | 2.41 (X) | 3.44 (X) | 5.83 (X) | 8.44 (X) | 8.48 (X) | 7.71 (X) | 1.47 (X) | 6.12 (X) | 5.75 (X) | 7.21 (X) | 0.73 (X) | 0.72 (X) | 0.86 (X) | 0.45 (X) | 0.92 (X) | 0.83 (X) | 0.63 (X) |
| CaO------- | 13.2 (I) | 23.2 (I) | 30.2 (I) | 20.0 (I) | 18.3 (I) | 18.9 (I) | 26.7 (I) | 12.7 (I) | 20.7 (I) | 25.6 (I) | 11.81 (I) | 4.05 (I) | 4.28 (I) | 16.24 (I) | 6.59 (I) | 14.84 (I) | 10.82 (I) |
| | 12.8 (X) | 24 (X) | 30.6 (X) | 19.3 (X) | 17.8 (X) | 18.5 (X) | 26.7 (X) | 12 (X) | 20.5 (X) | 25.6 (X) | 11.8 (X) | 3.89 (X) | 4.23 (X) | 16.4 (X) | 6.56 (X) | 14.9 (X) | 10.7 (X) |
| $Na_2O$------ | 0.27 (I) | 0.61 (I) | 0.89 (I) | 0.20 (I) | 0.30 (I) | 0.26 (I) | 0.77 (I) | 0.14 (I) | 0.50 (I) | 0.57 (I) | 0.36 (I) | 0.45 (I) | 0.41 (I) | 1.20 (I) | 0.57 (I) | 0.54 (I) | 0.31 (I) |
| | 0.28 (X) | 0.61 (X) | 0.65 (X) | 0.26 (X) | 0.35 (X) | 0.33 (X) | 0.75 (X) | 0.19 (X) | 0.51 (X) | 0.8 (X) | 0.43 (X) | 0.48 (X) | 0.46 (X) | 1.21 (X) | 0.82 (X) | 0.57 (X) | 0.35 (X) |
| $K_2O$-------- | 1.33 (I) | 1.98 (I) | 0.95 (I) | 1.39 (I) | 2.80 (I) | 3.73 (I) | 1.31 (I) | 2.02 (I) | 2.36 (I) | 2.60 (I) | 1.67 (I) | 2.03 (I) | 2.38 (I) | 1.21 (I) | 2.70 (I) | 2.81 (I) | 1.86 (I) |
| | 1.21 (X) | 1.88 (X) | 0.84 (X) | 1.22 (X) | 2.49 (X) | 3.36 (X) | 1.2 (X) | 1.79 (X) | 2.15 (X) | 2.34 (X) | 1.62 (X) | 1.99 (X) | 2.38 (X) | 1.17 (X) | 2.7 (X) | 2.73 (X) | 1.81 (X) |
| $TiO_2$------- | 0.06 (I) | 0.07 (I) | 0.02 (I) | 0.07 (I) | 0.13 (I) | 0.18 (I) | 0.02 (I) | 0.10 (I) | 0.12 (I) | 0.13 (I) | 0.13 (I) | 0.22 (I) | 0.25 (I) | 0.08 (I) | 0.25 (I) | 0.13 (I) | 0.08 (I) |
| | 0.12 (X) | 0.16 (X) | 0.08 (X) | 0.14 (X) | 0.25 (X) | 0.33 (X) | 0.12 (X) | 0.21 (X) | 0.23 (X) | 0.21 (X) | 0.38 (X) | 0.51 (X) | 0.54 (X) | 0.32 (X) | 0.57 (X) | 0.48 (X) | 0.31 (X) |
| $P_2O_5$------ | 4.51 (I) | 11.5 (I) | 15.5 (I) | 2.62 (I) | 3.94 (I) | 3.27 (I) | 17.04 (I) | 1.08 (I) | 8.52 (I) | 9.71 (I) | 10.49 (I) | 3.18 (I) | 4.53 (I) | 11.89 (I) | 4.81 (I) | 10.99 (I) | 8.02 (I) |
| | 4.28 (X) | 11.4 (X) | 14.8 (X) | 2.6 (X) | 3.71 (X) | 3.12 (X) | 16.3 (X) | 0.96 (X) | 8.16 (X) | 9.21 (X) | 10.5 (X) | 3.12 (X) | 4.58 (X) | 11.9 (X) | 4.84 (X) | 11 (X) | 8 (X) |
| | 4.3 (W) | 11.6 (W) | 14.9 (W) | 2.7 (W) | 3.9 (W) | 3.2 (W) | 16.4 (W) | 0.8 (W) | 8.0 (W) | 9.2 (W) | 10.2 (W) | 2.65 (W) | 4.50 (W) | 11.8 (W) | 4.85 (W) | 10.4 (W) | 7.50 (W) |
| MnO------- | 0.02 (I) | 0.02 (I) | 0.02 (I) | 0.03 (I) | 0.02 (I) | 0.03 (I) | 0.01 (I) | 0.03 (I) | 0.02 (I) | 0.03 (I) | 0.01 (I) | 0.01 (I) | 0 (I) | 0.01 (I) | 0 (I) | 0 (I) | 0 (I) |
| LOI-------- | 8.54 | 11.4 | 15.3 | 21.9 | 20.7 | 19.9 | 7.16 | 15.2 | 14.5 | 19.2 | 10.3 | 8.5 | 8.64 | 6.17 | 6.16 | 6.6 | 5.11 |
| S--------- | 0.62 | 1.52 | 0.59 | 0.39 | 0.29 | 1.02 | 0.94 | 0.4 | 0.48 | 0.82 | 0.14 | 0.09 | 0.12 | 0.12 | 0.05 | 0.14 | 0.13 |
| C (Inorganic) | 1.77 | 2.09 | 3.67 | 5.54 | 4.86 | 4.16 | 1.05 | 3.75 | 3.40 | 4.56 | 0.12 | 0.06 | 0.05 | 0.15 | 0.05 | 0.10 | 0.08 |
| C (Organic) | 0.41 | 0.54 | 0.50 | 0.45 | 1.02 | 1.48 | 0.91 | 0.54 | 0.61 | 0.83 | 1.19 | 1.03 | 1.11 | 0.96 | 0.86 | 0.97 | 1.08 |

| | Mud Springs | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample---- | P-33 | P-31 | P-29 | P-27 | P-26 | P-25 | P-23 | P-22 | P-17 | P-16 | P-15 | P-14 | P-11 | P-8 | P-6 | P-4 | P-2 | P-1 |
| $SiO_2$------- | 58.2 (X) | 18.8 (X) | 38.5 (X) | 38.1 (X) | 41.4 (X) | 58.3 (X) | 64 (X) | 78.9 (X) | 52.6 (X) | 83.5 (X) | 85 (X) | 87.9 (X) | 59.5 (X) | 32.1 (X) | 24.8 (X) | 91.2 (X) | 51.9 (X) | 25.9 (X) |
| $Al_2O_3$------ | 11.23 (I) | 3.33 (I) | 4.95 (I) | 5.50 (I) | 7.39 (I) | 7.41 (I) | 6.41 (I) | 6.39 (I) | 10.62 (I) | 8.66 (I) | 3.78 (I) | 3.42 (I) | 6.33 (I) | 4.12 (I) | 3.10 (I) | 1.83 (I) | 6.58 (I) | 2.02 (I) |
| | 11 (X) | 3.39 (X) | 4.47 (X) | 4.41 (X) | 6.99 (X) | 7.05 (X) | 5.99 (X) | 6.09 (X) | 10.2 (X) | 8.41 (X) | 3.5 (X) | 3.18 (X) | 5.95 (X) | 3.81 (X) | 2.78 (X) | 1.63 (X) | 6.21 (X) | 1.75 (X) |
| $Fe_2O_3$------ | 4.39 (I) | 1.13 (I) | 1.53 (I) | 1.30 (I) | 2.15 (I) | 2.29 (I) | 1.77 (I) | 2.42 (I) | 3.85 (I) | 2.57 (I) | 2.43 (I) | 2.15 (I) | 1.89 (I) | 1.30 (I) | 1.07 (I) | 1.62 (I) | 1.90 (I) | 1.20 (I) |
| | 4.44 (X) | 1.4 (X) | 1.46 (X) | 1.37 (X) | 2.17 (X) | 2.29 (X) | 1.73 (X) | 2.31 (X) | 3.87 (X) | 2.54 (X) | 2.32 (X) | 2.01 (X) | 1.87 (X) | 1.35 (X) | 1.05 (X) | 1.5 (X) | 1.88 (X) | 1.22 (X) |
| MgO-------- | 0.90 (I) | 0.51 (I) | 0.56 (I) | 0.56 (I) | 0.73 (I) | 0.58 (I) | 0.37 (I) | 0.56 (I) | 0.88 (I) | 0.70 (I) | 0.23 (I) | 0.30 (I) | 0.63 (I) | 0.53 (I) | 0.71 (I) | 0.18 (I) | 0.96 (I) | 0.23 (I) |
| | 0.92 (X) | 0.81 (X) | 0.82 (X) | 0.82 (X) | 0.76 (X) | 0.63 (X) | 0.4 (X) | 0.59 (X) | 0.9 | 0.74 (X) | 0.26 (X) | 0.33 (X) | 0.67 (X) | 0.82 (X) | 0.83 (X) | 0.22 (X) | 1 (X) | 0.35 (X) |
| CaO-------- | 6.96 (I) | 37.86 (I) | 27.30 (I) | 35.42 (I) | 22.26 (I) | 13.55 (I) | 11.54 (I) | 3.28 (I) | 12.63 (I) | 9.18 (I) | 2.55 (I) | 1.47 (I) | 13.97 (I) | 30.38 (I) | 35.42 (I) | 1.50 (I) | 17.92 (I) | 36.68 (I) |
| | 6.99 (X) | 38.9 (X) | 27.4 (X) | 26.2 (X) | 23 (X) | 13.6 (X) | 11.3 (X) | 3.1 (X) | 12.8 (X) | 9.16 (X) | 2.41 (X) | 1.39 (X) | 13.9 (X) | 31.7 (X) | 37.4 (X) | 1.26 (X) | 18.3 (X) | 38.5 (X) |
| $Na_2O$------- | 0.36 (I) | 0.55 (I) | 0.70 (I) | 0.92 (I) | 0.82 (I) | 1.82 (I) | 1.67 (I) | 0.47 (I) | 0.41 (I) | 0.34 (I) | 0.14 (I) | 0.09 (I) | 1.01 (I) | 0.80 (I) | 0.59 (I) | 0.07 (I) | 0.49 (I) | 0.50 (I) |
| | 0.42 (X) | 0.8 (X) | 0.71 (X) | 0.74 (X) | 0.88 (X) | 1.79 (X) | 1.62 (X) | 0.5 (X) | 0.43 (X) | 0.39 (X) | 0.18 (X) | 0.15 (X) | 1.01 (X) | 0.82 (X) | 0.63 (X) | 0.07 (X) | 0.53 (X) | 0.51 (X) |
| $K_2O$-------- | 2.76 (I) | 0.62 (I) | 1.31 (I) | 1.72 (I) | 1.64 (I) | 1.34 (I) | 0.96 (I) | 1.72 (I) | 3.34 (I) | 2.88 (I) | 1.07 (I) | 1.08 (I) | 1.43 (I) | 1.18 (I) | 0.90 (I) | 0.34 (I) | 1.98 (I) | 0.43 (I) |
| | 2.74 (X) | 0.76 (X) | 1.23 (X) | 1.27 (X) | 1.6 (X) | 1.29 (X) | 0.91 (X) | 1.67 (X) | 3.26 (X) | 2.63 (X) | 1.03 (X) | 1.05 (X) | 1.36 (X) | 1.13 (X) | 0.87 (X) | 0.31 (X) | 1.92 (X) | 0.4 (X) |
| $TiO_2$------- | 0.20 (I) | 0.05 (I) | 0.05 (I) | 0.03 (I) | 0.07 (I) | 0.07 (I) | 0.05 (I) | 0.15 (I) | 0.20 (I) | 0.13 (I) | 0.07 (I) | 0.08 (I) | 0.13 (I) | 0.05 (I) | 0.05 (I) | 0.05 (I) | 0.05 (I) | 0.03 (I) |
| | 0.46 (X) | 0.12 (X) | 0.23 (X) | 0.24 (X) | 0.36 (X) | 0.47 (X) | 0.41 (X) | 0.33 (X) | 0.45 (X) | 0.38 (X) | 0.11 (X) | 0.11 (X) | 0.43 (X) | 0.27 (X) | 0.14 (X) | 0.08 (X) | 0.32 (X) | 0.06 (X) |
| $P_2O_5$------- | 5.91 (I) | 28.85 (I) | 20.20 (I) | 21.73 (I) | 16.26 (I) | 9.60 (I) | 7.95 (I) | 2.29 (I) | 9.32 (I) | 6.85 (I) | 1.88 (I) | 0.98 (I) | 9.69 (I) | 22.19 (I) | 26.56 (I) | 0.98 (I) | 12.57 (I) | 28.63 (I) |
| | 5.96 (X) | 27.9 (X) | 19.5 (X) | 20.1 (X) | 16.3 (X) | 9.61 (X) | 7.88 (X) | 2.18 (X) | 9.33 (X) | 6.83 (X) | 1.81 (X) | 0.97 (X) | 9.67 (X) | 22.2 (X) | 26.3 (X) | 0.85 (X) | 12.6 (X) | 27.8 (X) |
| | 5.70 (W) | 28.4 (W) | 19.2 (W) | 19.5 (W) | 16.4 (W) | 9.35 (W) | 7.75 (W) | 2.20 (W) | 9.15 (W) | 6.75 (W) | 1.80 (W) | 0.95 (W) | 9.40 (W) | 21.5 (W) | 27.1 (W) | 0.90 (W) | 12.8 (W) | 28.0 (W) |
| MnO-------- | 0 (I) | 0.01 (I) | 0.02 (I) | 0 (I) | 0.05 (I) | 0.06 (I) | 0.52 (I) | 0.01 (I) | 0 (I) | 0 (I) | 0.02 (I) | 0.01 (I) | 0.06 (I) | 0 (I) | 0 (I) | 0.02 (I) | 0.02 (I) | 0.01 (I) |
| LOI-------- | 7.48 | 4.27 | 3.87 | 3.26 | 5.05 | 3.54 | 3.5 | 3.05 | 5 | 4.34 | 1.75 | 1.78 | 4.27 | 3.86 | 3.59 | 0.96 | 4.1 | 2.04 |
| S--------- | 0.06 | 0.39 | 0.24 | 0.27 | 0.2 | 0.09 | 0.03 | 0.02 | 0.09 | 0.07 | 0.02 | 0.01 | 0.18 | 0.46 | 0.46 | 0.03 | 0.16 | 0.41 |
| C(Inorganic) | 0.06 | 0.32 | 0.23 | 0.21 | 0.21 | 0.12 | 0.16 | 0.03 | 0.09 | 0.06 | 0.04 | 0.02 | 0.14 | 0.29 | 0.31 | 0.03 | 0.23 | 0.18 |
| C (Organic) | 1.05 | 0.77 | 0.59 | 0.48 | 0.45 | 0.36 | 0.33 | 0.32 | 0.39 | 0.41 | 0.36 | 0.34 | 0.41 | 0.54 | 0.59 | 0.20 | 0.49 | 0.31 |

Table 2. continued

| Sample----- | E-4 | U-3 | U-1 | R-9 | R-6 | P-45 | P-43 | P-40 | P-39 | P-37 | P-32 | P-31 | P-25 | P-23 | P-21 | P-20 | P-19 | P-13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fontenelle Creek | | | | | | | | | | | | | | | | | |
| $SiO_2$------- | 16.3 (X) | 14.3 (X) | 11.7 (X) | 40.3 (X) | 39.4 (X) | 15.5 (X) | 61.9 (X) | 22.5 (X) | 64.4 (X) | 61.8 (X) | 5.04 (X) | 63 (X) | 32.6 (X) | 52.8 (X) | 55.8 (X) | 63.4 (X) | 46.5 (X) | 18.2 (X) |
| $Al_2O_3$------ | 2.65 (I) | 2.84 (I) | 1.34 (I) | 1.15 (I) | 3.4 (I) | 0.04 (I) | 3.02 (I) | 0.09 (I) | 3.4 (I) | 3.97 (I) | 0.72 (I) | 8.51 (I) | 5.29 (I) | 10.21 (I) | 10.02 (I) | 9.45 (I) | 6.05 (I) | 4.73 (I) |
| | 2.63 (X) | 2.61 (X) | 1.29 (X) | 1.24 (X) | 3.09 (X) | 0.73 (X) | 2.87 (X) | 0.65 (X) | 3.4 (X) | 3.9 (X) | 0.64 (X) | 8.26 (X) | 5.13 (X) | 10.2 (X) | 10.4 (X) | 9.22 (X) | 5.86 (X) | 4.55 (X) |
| $Fe_2O_3$------ | 3.00 (I) | 2.29 (I) | 2.29 (I) | 2.15 (I) | 3.58 (I) | 0.46 (I) | 2.15 (I) | 1.00 (I) | 1.86 (I) | 1.72 (I) | 0.80 (I) | 2.43 (I) | 2.43 (I) | 4.72 (I) | 3.72 (I) | 2.86 (I) | 1.72 (I) | 2.00 (I) |
| | 3.4 (X) | 2.33 (X) | 2.25 (X) | 2.13 (X) | 3.75 (X) | 0.4 (X) | 2.08 (X) | 0.91 (X) | 1.78 (X) | 1.71 (X) | 0.55 (X) | 2.45 (X) | 2.49 (X) | 4.55 (X) | 3.96 (X) | 2.87 (X) | 1.64 (X) | 1.93 (X) |
| MgO-------- | 0.45 (I) | 0.45 (I) | 3.32 (I) | 6.47 (I) | 0.51 (I) | 18.26 (I) | 5.15 (I) | 14.11 (I) | 3.98 (I) | 4.32 (I) | 0.33 (I) | 0.61 (I) | 4.32 (I) | 1.29 (I) | 0.95 (I) | 0.55 (I) | 7.80 (I) | 2.99 (I) |
| | 0.57 (X) | 0.56 (X) | 3.3 (X) | 6.36 (X) | 0.58 (X) | 16.9 (X) | 4.75 (X) | 13.7 (X) | 3.83 (X) | 4.18 (X) | 0.38 (X) | 0.64 (X) | 4.34 (X) | 1.34 (X) | 1.05 (X) | 0.8 (X) | 7.58 (X) | 3.02 (X) |
| CaO-------- | 39.2 (I) | 40.6 (I) | 40.6 (I) | 23.8 (I) | 26.8 (I) | 28 (I) | 11.2 (I) | 26.6 (I) | 9.66 (I) | 10.64 (I) | 47.6 (I) | 8.54 (I) | 23.8 (I) | 1.96 (I) | 4.76 (I) | 5.88 (I) | 13.44 (I) | 23.8 (I) |
| | 40.4 (X) | 42 (X) | 42.7 (X) | 23.5 (X) | 27.2 (X) | 26.7 (X) | 10.7 (X) | 25.8 (X) | 9.5 (X) | 10.5 (X) | 49.6 (X) | 8.28 (X) | 23.8 (X) | 1.64 (X) | 4.92 (X) | 5.82 (X) | 13.1 (X) | 24.5 (X) |
| $Na_2O$------- | 0.95 (I) | 0.63 (I) | 0.54 (I) | 0.28 (I) | 0.58 (I) | 0.05 (I) | 0.14 (I) | 0.14 (I) | 0.14 (I) | 0.14 (I) | 1.49 (I) | 1.62 (I) | 0.47 (I) | 0.12 (I) | 0.42 (I) | 1.19 (I) | 1.30 (I) | 0.43 (I) |
| | 0.91 (X) | 0.63 (X) | 0.55 (X) | 0.3 (X) | 0.59 (X) | 0.075 (X) | 0.18 (X) | 0.19 (X) | 0.2 (X) | 0.19 (X) | 1.33 (X) | 1.49 (X) | 0.54 (X) | 0.22 (X) | 0.46 (X) | 1.19 (X) | 1.19 (X) | 0.49 (X) |
| $K_2O$-------- | 0.82 (I) | 0.70 (I) | 0.44 (I) | 0.31 (I) | 0.82 (I) | 0.12 (I) | 0.80 (I) | 0.12 (I) | 0.92 (I) | 1.13 (I) | 0.24 (I) | 2.04 (I) | 1.44 (I) | 2.88 (I) | 2.76 (I) | 2.40 (I) | 1.44 (I) | 1.32 (I) |
| | 0.8 (X) | 0.86 (X) | 0.4 (X) | 0.28 (X) | 0.8 (X) | 0.11 (X) | 0.74 (X) | 0.09 (X) | 0.89 (X) | 1.09 (X) | 0.22 (X) | 2.11 (X) | 1.44 (X) | 3.16 (X) | 2.98 (X) | 2.48 (X) | 1.37 (X) | 1.35 (X) |
| $TiO_2$------- | 0.07 (I) | 0.07 (I) | 0.07 (I) | 0.05 (I) | 0.13 (I) | 0.01 (I) | 0.08 (I) | 0.01 (I) | 0.12 (I) | 0.12 (I) | 0.03 (I) | 0.33 (I) | 0.17 (I) | 0.51 (I) | 0.45 (I) | 0.42 (I) | 0.17 (I) | 0.15 (I) |
| | 0.12 (X) | 0.12 (X) | 0.05 (X) | 0.06 (X) | 0.23 (X) | 0.03 (X) | 0.18 (X) | 0.02 (X) | 0.21 (X) | 0.24 (X) | 0.02 (X) | 0.65 (X) | 0.34 (X) | 0.66 (X) | 0.69 (X) | 0.7 (X) | 0.43 (X) | 0.23 (X) |
| $P_2O_5$------- | 29.77 (I) | 32.06 (I) | 29.77 (I) | 8.70 (I) | 20.38 (I) | 0.82 (I) | 1.15 (I) | 2.29 (I) | 1.65 (I) | 2.52 (I) | 36.84 (I) | 5.95 (I) | 13.28 (I) | 0.55 (I) | 3.21 (I) | 4.35 (I) | 0.53 (I) | 14.20 (I) |
| | 27.3 (X) | 29.4 (X) | 27.1 (X) | 7.77 (X) | 18.5 (X) | 0.47 (X) | 1.02 (X) | 2.02 (X) | 1.52 (X) | 2.23 (X) | 32.1 (X) | 5.39 (X) | 12.0 (X) | 0.45 (X) | 3.18 (X) | 4.12 (X) | 0.45 (X) | 12.7 (X) |
| | 7.4 (W) | 29.2 (W) | 26.7 (W) | 7.8 (W) | 18.4 (W) | 0.5 (W) | 1.1 (W) | 1.9 (W) | 1.5 (W) | 2.2 (W) | 31.8 (W) | 5.3 (W) | 18.8 (W) | 0.2 (W) | 3.2 (W) | 3.9 (W) | 0.7 (W) | 14.4 (W) |
| MnO-------- | 0.02 (I) | 0.01 (I) | 0.01 (I) | 0.02 (I) | 0.01 (I) | 0.02 (I) | 0.02 (I) | 0.02 (I) | 0.02 (I) | 0.02 (I) | 0 (I) | 0.02 (I) | 0.02 (I) | 0.01 (I) | 0.02 (I) | 0.03 (I) | 0.04 (I) | 0.01 (I) |
| LOI---------- | 4.36 | 4.22 | 8.19 | 17 | 3.81 | 39 | 14.1 | 33.4 | 12.7 | 12.8 | 5.94 | 5.52 | 14.3 | 21.1 | 15.1 | 8.29 | 20.3 | 28.1 |
| S---------- | 1.05 | 0.94 | 0.6 | 0.27 | 0.76 | 0.1 | 0.26 | 0.16 | 0.36 | 0.34 | 1.5 | 0.46 | 0.68 | 1.9 | 0.96 | 0.49 | 1.48 | 3.9 |
| C(Inorganic) | 0.81 | 0.49 | 2.09 | 4.48 | 0.45 | 10.34 | 3.21 | 9.32 | 2.54 | 2.64 | 1.06 | 0.20 | 2.62 | 0.15 | 0.08 | 0.06 | 4.75 | 2.09 |
| C (Organic) | 0.57 | 0.84 | 0.51 | 0.54 | 0.50 | 1.06 | 1.45 | 0.78 | 1.81 | 1.55 | 1.15 | 1.39 | 1.99 | 8.65 | 5.25 | 2.64 | 1.18 | 15.51 |

| Sample----- | P-12 | P-8 | P-7 | P-3 | P-1 |
|---|---|---|---|---|---|
| | Fontenelle Creek | | | | |
| $SiO_2$------- | 16.8 (X) | 36.8 (X) | 12.3 (X) | 6.62 (X) | 26.2 (X) |
| $Al_2O_3$------ | 2.65 (I) | 8.69 (I) | 2.64 (I) | 1.53 (I) | 2.08 (I) |
| | 2.79 (X) | 8.76 (X) | 3.03 (X) | 1.29 (X) | 1.89 (X) |
| $Fe_2O_3$------ | 1.22 (I) | 3.15 (I) | 1.14 (I) | 0.97 (I) | 2.29 (I) |
| | 1.1 (X) | 3.26 (X) | 1.08 (X) | 0.94 (X) | 2.45 (X) |
| MgO-------- | 14.28 (I) | 1.06 (I) | 10.46 (I) | 0.56 (I) | 0.53 (I) |
| | 14.4 (X) | 1.04 (X) | 10.7 (X) | 0.89 (X) | 0.64 (X) |
| CaO-------- | 26.6 (I) | 10.92 (I) | 28 (I) | 44.8 (I) | 33.6 (I) |
| | 25.9 (X) | 11.6 (X) | 28.7 (X) | 47.7 (X) | 36.1 (X) |
| $Na_2O$------- | 0.08 (I) | 0.28 (I) | 0.28 (I) | 1.08 (I) | 0.57 (I) |
| | 0.19 (X) | 0.41 (X) | 0.37 (X) | 1.06 (X) | 0.81 (X) |
| $K_2O$-------- | 1.09 (I) | 2.88 (I) | 1.06 (I) | 0.52 (I) | 0.62 (I) |
| | 0.94 (X) | 3.03 (X) | 0.98 (X) | 0.49 (X) | 0.63 (X) |
| $TiO_2$------- | 0.07 (I) | 0.33 (I) | 0.10 (I) | 0.07 (I) | 0.07 (I) |
| | 0.18 (X) | 0.45 (X) | 0.14 (X) | 0.04 (X) | 0.1 (X) |
| $P_2O_5$------- | 1.69 (I) | 8.02 (I) | 8.02 (I) | 34.35 (I) | 27.48 (I) |
| | 1.36 (X) | 7.82 (X) | 7.03 (X) | 32.1 (X) | 25.4 (X) |
| | 1.7 (W) | 7.5 (W) | 6.8 (W) | 25.0 (W) | 25.2 (W) |
| MnO-------- | 0.02 (I) | 0.02 (I) | 0.03 (I) | 0 (I) | 0.01 (I) |
| LOI---------- | 35.6 | 24.6 | 32.9 | 5.96 | 4.07 |
| S---------- | 0.21 | 3.3 | 0.89 | 1.4 | 0.81 |
| C(Inorganic) | 9.07 | 0.21 | 6.88 | 0.81 | 0.39 |
| C (Organic) | 1.43 | 12.59 | 4.34 | 1.91 | 1.33 |

Table 2. continued

Wheat Creek

| Sample----- | R-15 | R-9 | R-7 | R-8 | P-34 | P-30 | P-26 | P-22 | P-20 | P-16 | P-14 | P-11 | P-9 | P-7 | P-4 | P-3 | P-1 | Cw-11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$------- | 3.7 (X) | 13.8 (X) | 16.2 (X) | 25.7 (X) | 37.3 (X) | 35.8 (X) | 60.7 (X) | 21.5 (X) | 22.9 (X) | 42.6 (X) | 37.7 (X) | 27.8 (X) | 10.3 (X) | 51.8 (X) | 32.6 (X) | 57.1 (X) | 15.8 (X) | 52.7 (X) |
| $Al_2O_3$------ | 0.86 (I) | 2.65 (I) | 1.13 (I) | 0.01 (I) | 2.08 (I) | 7.18 (I) | 10.02 (I) | 3.78 (I) | 3.59 (I) | 8.69 (I) | 8.69 (I) | 6.24 (I) | 1.64 (I) | 10.02 (I) | 4.73 (I) | 7.56 (I) | 2.46 (I) | 1.89 (I) |
| | 0.46 (X) | 2.49 (X) | 0.9 (X) | 0.12 (X) | 1.98 (X) | 7.07 (X) | 10 (X) | 3.93 (X) | 3.68 (X) | 8.46 (X) | 8.38 (X) | 6.01 (X) | 2.04 (X) | 9.78 (X) | 4.4 (X) | 7.44 (X) | 2.14 (X) | 1.99 (X) |
| $Fe_2O_3$------ | 1.09 (I) | 1.72 (I) | 0.82 (I) | 1.40 (I) | 2.00 (I) | 2.72 (I) | 1.86 (I) | 1.57 (I) | 1.04 (I) | 2.57 (I) | 2.29 (I) | 2.43 (I) | 0.64 (I) | 3.72 (I) | 1.72 (I) | 2.29 (I) | 0.89 (I) | 1.86 (I) |
| | 1.06 (X) | 1.78 (X) | 0.77 (X) | 1.36 (X) | 2.08 (X) | 2.82 (X) | 1.91 (X) | 1.45 (X) | 1.01 (X) | 2.6 (X) | 2.28 (X) | 2.51 (X) | 0.6 (X) | 3.85 (X) | 1.82 (X) | 2.18 (X) | 0.82 (X) | 1.81 (X) |
| MgO-------- | 0.35 (I) | 0.51 (I) | 0.35 (I) | 13.81 (I) | 1.06 (I) | 3.82 (I) | 1.18 (I) | 13.45 (I) | 14.11 (I) | 4.48 (I) | 4.81 (I) | 2.99 (I) | 15.80 (I) | 1.18 (I) | 0.51 (I) | 4.65 (I) | 0.37 (I) | 1.05 (I) |
| | 0.48 (X) | 0.62 (X) | 0.46 (X) | 13.5 (X) | 1.05 (X) | 3.82 (X) | 1.21 (X) | 13.3 (X) | 14 (X) | 4.35 (X) | 4.8 (X) | 3.11 (X) | 15.7 (X) | 1.15 (X) | 0.6 (X) | 4.46 (X) | 0.47 (X) | 1.13 (X) |
| CaO-------- | 47.6 (I) | 39.2 (I) | 40.8 (I) | 25.2 (I) | 29.4 (I) | 21.0 (I) | 9.24 (I) | 23.8 (I) | 22.4 (I) | 16.8 (I) | 18.2 (I) | 26.6 (I) | 29.4 (I) | 13.02 (I) | 29.4 (I) | 10.08 (I) | 40.8 (I) | 21.0 (I) |
| | 50.2 (X) | 42.2 (X) | 43.1 (X) | 25.1 (X) | 29.8 (X) | 21.8 (X) | 9.2 (X) | 23.7 (X) | 22.8 (X) | 16.8 (X) | 18.8 (X) | 27.9 (X) | 29.8 (X) | 13.0 (X) | 30.6 (X) | 9.63 (X) | 42.8 (X) | 21.4 (X) |
| $Na_2O$------- | 1.49 (I) | 1.32 (I) | 1.20 (I) | 0.09 (I) | 0.77 (I) | 0.82 (I) | 0.78 (I) | 0.46 (I) | 0.47 (I) | 0.55 (I) | 0.50 (I) | 0.74 (I) | 0.27 (I) | 0.51 (I) | 0.96 (I) | 0.89 (I) | 1.12 (I) | 0.43 (I) |
| | 1.34 (X) | 1.26 (X) | 1.13 (X) | 0.16 (X) | 0.73 (X) | 0.65 (X) | 0.81 (X) | 0.49 (X) | 0.46 (X) | 0.58 (X) | 0.52 (X) | 0.75 (X) | 0.3 (X) | 0.55 (X) | 0.83 (X) | 0.68 (X) | 1.04 (X) | 0.41 (X) |
| $K_2O$-------- | 0.12 (I) | 0.86 (I) | 0.28 (I) | 0.05 (I) | 0.52 (I) | 1.92 (I) | 2.84 (I) | 1.08 (I) | 1.06 (I) | 2.64 (I) | 2.64 (I) | 1.92 (I) | 0.94 (I) | 3.12 (I) | 1.80 (I) | 2.64 (I) | 0.84 (I) | 0.74 (I) |
| | 0.15 (X) | 0.65 (X) | 0.25 (X) | 0.03 (X) | 0.49 (X) | 1.94 (X) | 2.63 (X) | 0.94 (X) | 0.9 (X) | 2.59 (X) | 2.55 (X) | 1.88 (X) | 0.8 (X) | 3.16 (X) | 1.68 (X) | 2.52 (X) | 0.77 (X) | 0.71 (X) |
| $TiO_2$------- | 0.05 (I) | 0.12 (I) | 0.05 (I) | 0.01 (I) | 0.07 (I) | 0.17 (I) | 0.45 (I) | 0.13 (I) | 0.15 (I) | 0.33 (I) | 0.33 (I) | 0.17 (I) | 0.07 (I) | 0.33 (I) | 0.15 (I) | 0.17 (I) | 0.10 (I) | 0.07 (I) |
| | < 0.02 (X) | 0.18 (X) | 0.04 (X) | < 0.02 (X) | 0.1 (X) | 0.4 (X) | 0.69 (X) | 0.25 (X) | 0.27 (X) | 0.52 (X) | 0.48 (X) | 0.3 (X) | 0.08 (X) | 0.61 (X) | 0.24 (X) | 0.55 (X) | 0.11 (X) | 0.11 (X) |
| $P_2O_5$------- | 38.84 (I) | 29.77 (I) | 32.06 (I) | 2.52 (I) | 19.24 (I) | 12.37 (I) | 6.41 (I) | 3.21 (I) | 1.42 (I) | 8.02 (I) | 9.16 (I) | 17.63 (I) | 5.04 (I) | 8.70 (I) | 18.78 (I) | 2.29 (I) | 29.77 (I) | 9.16 (I) |
| | 32.8 (X) | 27.2 (X) | 27.8 (X) | 1.98 (X) | 17.5 (X) | 11.5 (X) | 5.67 (X) | 2.77 (X) | 1.28 (X) | 7.5 (X) | 8.39 (X) | 16.2 (X) | 4.35 (X) | 8.06 (X) | 17.1 (X) | 2.14 (X) | 25.7 (X) | 8.28 (X) |
| | 32.5 (W) | 26.9 (W) | 27.7 (W) | 1.9 (W) | 17.4 (W) | 11.4 (W) | 5.8 (W) | 2.8 (W) | 1.4 (W) | 7.6 (W) | 8.2 (W) | 16.2 (W) | 4.5 (W) | 7.9 (W) | 17.3 (W) | 2.0 (W) | 25.5 (W) | 8.4 (W) |
| MnO-------- | 0.01 (I) | 0.01 (I) | 0.01 (I) | 0.03 (I) | 0.02 (I) | 0.01 (I) | 0.01 (I) | 0.03 (I) | 0.03 (I) | 0.01 (I) | 0.01 (I) | 0.01 (I) | 0.02 (I) | 0.01 (I) | 0.01 (I) | 0.01 (I) | 0.02 (I) | 0.02 (I) |
| LOI--------- | 5.34 | 6.04 | 5.77 | 31.8 | 6.55 | 11.9 | 5.28 | 30.9 | 32.1 | 12.4 | 14 | 10.8 | 35.8 | 6.05 | 7.48 | 11.9 | 7.25 | 9.27 |
| S---------- | 1.4 | 1.4 | 1.1 | 0.04 | 0.53 | 0.38 | 0.12 | 0.13 | 0.06 | 0.26 | 0.21 | 0.56 | 0.17 | 0.32 | 0.77 | 0.09 | 1 | 0.4 |
| C(Inorganic) | 1.01 | 0.92 | 0.97 | 8.56 | 1.43 | 2.11 | 0.44 | 8.02 | 8.51 | 2.45 | 2.71 | 1.90 | 9.50 | 0.49 | 1.47 | 2.68 | 1.55 | 2.39 |
| C (Organic) | 0.39 | 0.37 | 0.34 | 0.44 | 0.44 | 0.63 | 0.30 | 0.54 | 0.46 | 0.58 | 0.76 | 0.83 | 0.60 | 0.41 | 0.58 | 0.44 | 0.64 | 0.44 |

Lakeridge

| Sample----- | E-92C | US-91B | E-90A | E-89A | US-88C | TO-87B | TO-86D | TO-85A | TO-84B | RT-81A | TO-78C | RT-77 | RT-75A | F-74 | F-73 | F-72B | F-71B | F-70E |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$------- | | 78.6 (X) | | | 44.0 (X) | | | 47.4 (X) | | | 36.6 (X) | 50.9 (X) | | 8.85 (X) | | | 9.53 (X) | |
| $Al_2O_3$------ | 0.81 (I) | 0.87 (I) | 0.74 (I) | 0.98 (I) | 0.45 (I) | 1.3 (I) | 2.1 (I) | 5.1 (I) | 2.8 (I) | 2.1 (I) | 2.1 (I) | 7.8 (I) | 3.4 (I) | 0.89 (I) | 1.8 (I) | 0.57 (I) | 0.36 (I) | 2.5 (I) |
| | | 0.96 (X) | | | 0.54(X) | | | 4.8 (X) | | | 1.99 (X) | 7.39 (X) | | 0.63 (X) | | | 0.34 (X) | |
| $Fe_2O_3$------ | 1.6 (I) | 2.2 (I) | 2.0 (I) | 2.3 (I) | 3.3 (I) | 5.8 (I) | 3.3 (I) | 4.6 (I) | 5.2 (I) | 3.0 (I) | 3.2 (I) | 7.3 (I) | 2.5 (I) | 0.99 (I) | 1.6 (I) | 0.96 (I) | 1.4 (I) | 6.7 (I) |
| | | 2.07 (X) | | | 3.13 (X) | | | 4.4 (X) | | | 2.97 (X) | 7.01 (X) | | 0.93 (X) | | | 1.35 (X) | |
| MgO-------- | 23.2 (I) | 2.2 (I) | 10.5 (I) | 18.3 (I) | 7.0 (I) | 6.1 (I) | 2.2 (I) | 7.0 (I) | 8.5 (I) | 2.2 (I) | 9.7 (I) | 2.8 (I) | 2.5 (I) | 14 (I) | 17 (I) | 21 (I) | 14.8 (I) | 7.1 (I) |
| | | 1.91 (X) | | | 6.80 (X) | | | 6.98 (X) | | | 10.2 (X) | 2.77 (X) | | 16.3 (X) | | | 17.1 (X) | |
| CaO-------- | 29 (I) | 7.8 (I) | 22 (I) | 31 (I) | 22 (I) | 13 (I) | 4.9 (I) | 14 (I) | 20 (I) | 24 (I) | 21 (I) | 11 (I) | 39 (I) | 31 (I) | 29 (I) | 32 (I) | 31 (I) | 14 (I) |
| | | 7.32 (X) | | | 21.0 (X) | | | 13.8 (X) | | | 19.3 (X) | 10.8 (X) | | 29.8 (X) | | | 29.1 (X) | |
| $Na_2O$------- | 0.32 (I) | 0.36 (I) | 0.34 (I) | 0.38 (I) | 0.27 (I) | 0.36 (I) | 0.38 (I) | 0.82 (I) | 0.57 (I) | 0.84 (I) | 0.43 (I) | 1.1 (I) | 1.5 (I) | 0.63 (I) | 0.93 (I) | 0.49 (I) | 0.38 (I) | 0.96 (I) |
| | | 0.32 (X) | | | <0.15(X) | | | 0.67 (X) | | | 0.33 (X) | 1.00 (X) | | 0.34 (X) | | | 0.16 (X) | |
| $K_2O$-------- | 0.25 (I) | 0.26 (I) | 0.22 (I) | 0.35 (I) | 0.16 (I) | 0.49 (I) | 0.70 (I) | 1.7 (I) | 0.97 (I) | 0.68 (I) | 0.74 (I) | 2.8 (I) | 0.97 (I) | 0.30 (I) | 0.47 (I) | 0.18 (I) | 0.14 (I) | 0.61 (I) |
| | | 0.24 (X) | | | 0.11 (X) | | | 1.54 (X) | | | 0.64 (X) | 2.73 (X) | | 0.18 (X) | | | 0.09 (X) | |
| $TiO_2$------- | 0.01 (I) | 0.02 (I) | 0 (I) | 0.02 (I) | 0.01 (I) | 0.02 (I) | 0.03 (I) | 0.10 (I) | 0.05 (I) | 0.05 (I) | 0.05 (I) | 0.15 (I) | 0.07 (I) | 0.01 (I) | 0.02 (I) | 0 (I) | 0.008 (I) | 0.02 (I) |
| | | 0.08 (X) | | | 0.04 (X) | | | 0.29 (X) | | | 0.11 (X) | 0.31 (X) | | 0.07 (X) | | | 0.03 (X) | |
| $P_2O_5$------- | 0.85 (I) | 3.9 (I) | 2.0 (I) | 4.1 (I) | 2.2 (I) | 1.7 (I) | 1.3 (I) | 3.0 (I) | 3.4 (I) | 15 (I) | 2.2 (I) | 5.7 (I) | 23 (I) | 4.4 (I) | 5.0 (I) | 2.8 (I) | 3.4 (I) | 2.5 (I) |
| | | 3.33 (X) | | | 1.78 (X) | | | 2.57 (X) | | | 1.68 (X) | 5.03 (X) | | 3.60 (X) | | | 2.77 (X) | |
| MnO-------- | 0.115 (I) | 0.028 (I) | 0.076 (I) | 0.101 (I) | 0.062 (I) | 0.058 (I) | 0.026 (I) | 0.052 (I) | 0.062 (I) | 0.022 (I) | 0.065 (I) | 0.031 (I) | 0.014 (I) | 0.026 (I) | 0.032 (I) | 0.036 (I) | 0.028 (I) | 0.048 (I) |
| | | 0.03(X) | | | 0.06(X) | | | 0.05(X) | | | 0.07(X) | 0.04 (X) | | 0.03 (X) | | | 0.03 (X) | |
| LOI--------- | | 4.02 | | | 20.9 | | | 13.8 | | | 22.8 | 7.92 | | 36.4 | | | 37.9 | |
| S---------- | 0.13 | 0.28 | 0.09 | 0.36 | 0.05 | 2.0 | 0.56 | 1.4 | 1.1 | 1.2 | 0.84 | 3.9 | 2.2 | 0.52 | 0.52 | 0.13 | 0.15 | 0.74 |
| C(Inorganic) | 11.0 | 1.12 | 0 | 9.93 | 5.76 | 3.85 | 1.10 | 4.07 | 5.51 | 1.84 | 6.44 | 1.38 | 2.29 | 9.93 | 8.11 | 10.3 | 10.4 | 4.15 |
| C (Organic) | 0.67 | 0.33 | 8.15 | 0.57 | 0.55 | 0.86 | 0.39 | 1.61 | 0.83 | 1.20 | 0.96 | 3.36 | 1.73 | 0.87 | 1.38 | 0.98 | 1.08 | 0.67 |
| F----------- | 0.10 | 0.34 | 0.21 | 0.39 | 0.46 | 0.19 | 0.17 | 0.37 | 0.42 | 1.7 | 0.25 | 0.67 | 2.8 | 0.54 | 0.5 | 0.44 | 0.29 | 0.28 |

Table 2. continued

Lakeridge

| Sample---- | F-69A | F-68A | F-65B | F-64A | LS-62A | F-58B | LS-57M | LS-57D | LS-56A | LS-55B | R-54C | M-53B | M-52 | R-50F | M-48B | M-47 | M-45 | M-44A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$------- | | 49.0 (X) | | | 48.2 (X) | | | 7.2 (X) | | | 52.5 (X) | 48.1 (X) | | 53.1 (X) | | | 23.3 (X) | |
| $Al_2O_3$------ | 0.55 (I) | 16.8 (I) | 0.76 (I) | 4.9 (I) | 7.2 (I) | 0.01 (I) | 0.15 (I) | 0.09 (I) | 0.08 (I) | 0.76 (I) | 0.96 (I) | 1.5 (I) | 0.83 (I) | 0.57 (I) | 11 (I) | 1.1 (I) | 0.66 (I) | 5.9 (I) |
| | | 17.2 (X) | | | 6.75 (X) | | | 0.12 (X) | | | 1.05 (X) | 1.48 (X) | | 0.70 (X) | | | 0.86 (X) | |
| $Fe_2O_3$------ | 0.45 (I) | 6.8 (I) | 2.0 (I) | 7.3 (I) | 4.4 (I) | 0.54 (I) | 3.8 (I) | 3.3 (I) | 3.5 (I) | 2.3 (I) | 4.4 (I) | 4.6 (I) | 3.0 (I) | 2.8 (I) | 4.6 (I) | 3.6 (I) | 3.2 (I) | 2.8 (I) |
| | | 6.92 (X) | | | 4.15 (X) | | | 3.00 (X) | | | 4.07 (X) | 4.46 (X) | | 2.45 (X) | | | 2.99 (X) | |
| MgO-------- | 18.3 (I) | 3.8 (I) | 20 (I) | 6.1 (I) | 4.8 (I) | 16 (I) | 13 (I) | 12.8 (I) | 0.58 (I) | 16 (I) | 6.0 (I) | 7.3 (I) | 0.32 (I) | 5.2 (I) | 1.2 (I) | 0.13 (I) | 0.17 (I) | 0.68 (I) |
| | | 3.89 (X) | | | 4.85 (X) | | | 14.4 (X) | | | 5.81 (X) | 7.35 (X) | | 4.79 (X) | | | 0.14 (X) | |
| CaO-------- | 39 (I) | 3.8 (I) | 27 (I) | 9.8 (I) | 13 (I) | 41 (I) | 25 (I) | 34 (I) | 11 (I) | 27 (I) | 18 (I) | 18 (I) | 43 (I) | 18 (I) | 2.4 (I) | 34 (I) | 39 (I) | 34 (I) |
| | | 3.53 (X) | | | 12.8 (X) | | | 32.4 (X) | | | 16.8 (X) | 17.5 (X) | | 17.5 (X) | | | 38.2 (X) | |
| $Na_2O$------- | 0.18 (I) | 1.6 (I) | 0.43 (I) | 1.4 (I) | 1.8 (I) | 0.07 (I) | 0.22 (I) | 0.24 (I) | 0.36 (I) | 0.63 (I) | 0.65 (I) | 0.82 (I) | 1.5 (I) | 0.46 (I) | 1.5 (I) | 1.1 (I) | 1.1 (I) | 1.8 (I) |
| | | 1.53 (X) | | | 1.54 (X) | | | <0.15 (X) | | | 0.48 (X) | 0.66 (X) | | 0.38 (X) | | | 0.84 (X) | |
| $K_2O$-------- | 0.19 (I) | 5.6 (I) | 0.19 (I) | 1.8 (I) | 2.0 (I) | 0.01 (I) | 0.07 (I) | 0.04 (I) | 0.04 (I) | 0.06 (I) | 0.14 (I) | 0.24 (I) | 0.48 (I) | 0.12 (I) | 3.2 (I) | 0.24 (I) | 0.18 (I) | 1.8 (I) |
| | | 5.84 (X) | | | 1.90 (X) | | | 0.03 (X) | | | 0.12 (X) | 0.21 (X) | | 0.11 (X) | | | 0.15 (X) | |
| $TiO_2$------- | 0.02 (I) | 0.48 (I) | 0.01 (I) | 0.08 (I) | 0.17 (I) | 0 (I) | 0 (I) | 0 (I) | 0 (I) | 0 (I) | 0 (I) | 0.01 (I) | 0.02 (I) | 0.01 (I) | 0.30 (I) | 0.02 (I) | 0.02 (I) | 0.08 (I) |
| | | 1.00 (X) | | | 0.41 (X) | | | <0.02 (X) | | | 0.05 (X) | 0.08 (X) | | 0.05 (X) | | | 0.05 (X) | |
| $P_2O_5$------- | 0.02 (I) | 0.23 (I) | 0.39 (I) | 0.23 (I) | 0.16 (I) | 0.39 (I) | 6.0 (I) | 2.1 (I) | 1.5 (I) | 3.4 (I) | 2.8 (I) | 5.7 (I) | 34 (I) | 8.0 (I) | 1.4 (I) | 23 (I) | 25 (I) | 22 (I) |
| | | 0.24 (X) | | | 0.14 (X) | | | 1.72 (X) | | | 2.31 (X) | 4.60 (X) | | 6.73 (X) | | | 23.9 (X) | |
| MnO-------- | 0.030 (I) | 0.022 (I) | 0.037 (I) | 0.053 (I) | 0.032 (I) | 0.036 (I) | 0.034 (I) | 0.040 (I) | 0.022 (I) | 0.028 (I) | 0.035 (I) | 0.039 (I) | 0.017 (I) | 0.026 (I) | 0.012 (I) | 0.018 (I) | 0.019 (I) | 0.009 (I) |
| | | 0.03 (X) | | | 0.04 (X) | | | 0.04 (X) | | | 0.04(X) | 0.04 (X) | | 0.03 (X) | | | 0.03 (X) | |
| LOI--------- | | 8.94 | | | 8.52 | | | 36.2 | | | 15.5 | 14.7 | | 11.1 | | | 3.65 | |
| S---------- | 0.13 | 4.7 | 0.16 | 0.41 | 5.2 | 0.82 | 0.43 | 1.1 | 1.8 | 0.74 | 0.17 | 0.45 | 1.3 | 0.72 | 2.6 | 0.81 | 0.91 | 2.2 |
| C(Inorganic) | 12.0 | 1.28 | 10.3 | 3.57 | 2.78 | 11.7 | 6.74 | 10.5 | 1.94 | 6.05 | 4.46 | 4.48 | 0.78 | 3.00 | 0.13 | 0.26 | 1.30 | 0.38 |
| C (Organic) | 1.02 | 1.92 | 0.76 | 0.58 | 2.34 | 0.87 | 0.78 | 0.77 | 2.74 | 1.02 | 0.36 | 0.34 | 0.69 | 1.29 | 1.12 | 0.60 | 0.74 | 1.20 |
| F----------- | 0.15 | 0.62 | 0.06 | 0.07 | 0.08 | 0.04 | 0.49 | 0.49 | 0.26 | 0.38 | 0.23 | 0.51 | 3.4 | 0.74 | 0.38 | 2.3 | 2.5 | 3 |

Lakeridge

| Sample---- | M-42A | M-41 | M-40 | M-39B | M-38A | M-37A | M-36B | M-35A | M-34A | M-33A | M-32A | M-31A | M-30A | M-29A | M-28A | M-27B | M-25 | M-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$------- | | 62.6 (X) | | | 35.0 (X) | | | 63.9 (X) | | | 53.3 (X) | | | 23.8 (X) | | | 49.1 (X) | |
| $Al_2O_3$----- | 3.8 (I) | 7.4 (I) | 1.3 (I) | 4.2 (I) | 8.7 (I) | 6.5 (I) | 3.8 (I) | 11 (I) | 8.1 (I) | 12 (I) | 12 (I) | 6.4 (I) | 12 (I) | 2.1 (I) | 7.2 (I) | 2.8 (I) | 12 (I) | 8.1 (I) |
| | | 7.10 (X) | | | 8.51 (X) | | | 11.6 (X) | | | 12.5 (X) | | | 1.93 (X) | | | 11.7 (X) | |
| $Fe_2O_3$----- | 2.6 (I) | 4.9 (I) | 1.1 (I) | 5.8 (I) | 10 (I) | 3.9 (I) | 1.9 (I) | 5.1 (I) | 3.3 (I) | 5.1 (I) | 4.5 (I) | 2.3 (I) | 4.4 (I) | 2.8 (I) | 3.5 (I) | 1.2 (I) | 4.5 (I) | 2.9 (I) |
| | | 4.85 (X) | | | 10.1 (X) | | | 5.01 (X) | | | 4.50 (X) | | | 2.81 (X) | | | 4.4 (X) | |
| MgO-------- | 0.25 (I) | 1.5 (I) | 0.22 (I) | 0.55 (I) | 1.1 (I) | 1.6 (I) | 18 (I) | 1.3 (I) | 1.1 (I) | 1.8 (I) | 1.8 (I) | 12 (I) | 2.0 (I) | 0.37 (I) | 1.0 (I) | 18 (I) | 2.0 (I) | 2.7 (I) |
| | | 1.43 (X) | | | 1.00 (X) | | | 1.24 (X) | | | 1.83 (X) | | | 0.31 (X) | | | 1.97 (X) | |
| CaO-------- | 38 (I) | 9.9 (I) | 48 (I) | 38 (I) | 12 (I) | 21 (I) | 22 (I) | 2.8 (I) | 25 (I) | 11 (I) | 7.4 (I) | 18 (I) | 7.1 (I) | 36 (I) | 27 (I) | 27 (I) | 9.7 (I) | 18 (I) |
| | | 9.56 (X) | | | 12.7 (X) | | | 2.71 (X) | | | 7.28 (X) | | | 35.9 (X) | | | 9.46 (X) | |
| $Na_2O$------ | 1.9 (I) | 3.0 (I) | 1.5 (I) | 1.5 (I) | 1.1 (I) | 1.6 (I) | 1.5 (I) | 1.9 (I) | 1.4 (I) | 1.4 (I) | 0.94 (I) | 1.0 (I) | 1.3 (I) | 1.2 (I) | 1.8 (I) | 1.3 (I) | 1.5 (I) | 1.5 (I) |
| | | 2.69 (X) | | | 0.96 (X) | | | 1.88 (X) | | | 0.92 (X) | | | 1.05 (X) | | | 1.43 (X) | |
| $K_2O$-------- | 0.98 (I) | 1.2 (I) | 0.42 (I) | 1.3 (I) | 2.9 (I) | 2.8 (I) | 0.73 (I) | 3.2 (I) | 2.5 (I) | 3.7 (I) | 3.8 (I) | 1.9 (I) | 3.5 (I) | 0.64 (I) | 2.3 (I) | 0.41 (I) | 3.5 (I) | 2.5 (I) |
| | | 1.20 (X) | | | 2.82 (X) | | | 3.42 (X) | | | 3.77 (X) | | | 0.58 (X) | | | 3.51 (X) | |
| $TiO_2$------- | 0.08 (I) | 0.10 (I) | 0.03 (I) | 0.10 (I) | 0.20 (I) | 0.17 (I) | 0.05 (I) | 0.25 (I) | 0.10 (I) | 0.28 (I) | 0.33 (I) | 0.17 (I) | 0.27 (I) | 0.05 (I) | 0.13 (I) | 0.03 (I) | 0.28 (I) | 0.20 (I) |
| | | 0.53 (X) | | | 0.42 (X) | | | 0.80 (X) | | | 0.56 (X) | | | 0.08 (X) | | | 0.56 (X) | |
| $P_2O_5$------- | 25 (I) | 0.57 (I) | 34 (I) | 25 (I) | 9.4 (I) | 14 (I) | 0.30 (I) | 1.2 (I) | 19 (I) | 6.9 (I) | 4.8 (I) | 1.2 (I) | 4.1 (I) | 23 (I) | 20 (I) | 0.60 (I) | 6.0 (I) | 11 (I) |
| | | 0.51 (X) | | | 8.37 (X) | | | 1.14 (X) | | | 4.23 (X) | | | 22.9 (X) | | | 5.41 (X) | |
| MnO-------- | 0.011 (I) | 0.031 (I) | 0.006 (I) | 0.007 (I) | 0.014 (I) | 0.019 (I) | 0.040 (I) | 0.027 (I) | 0.013 (I) | 0.022 (I) | 0.015 (I) | 0.030 (I) | 0.018 (I) | 0.013 (I) | 0.011 (I) | 0.027 (I) | 0.018 (I) | 0.012 (I) |
| | | 0.04 (X) | | | 0.02 (X) | | | 0.03 (X) | | | 0.02 (X) | | | 0.02 (X) | | | 0.02 (X) | |
| LOI--------- | | 6.46 | | | 18 | | | 7.47 | | | 9.65 | | | 5.40 | | | 9.76 | |
| S---------- | 1.4 | 1.0 | 1.2 | 5.4 | 9.8 | 3.5 | 0.78 | 3.2 | 3.1 | 3.7 | 3.7 | 1.8 | 3.7 | 2.0 | 3 | 0.67 | 3.7 | 3.8 |
| C(Inorganic) | 0.40 | 2.22 | 0.60 | 0.63 | 0.23 | 0.77 | 6.43 | 0.32 | 0.53 | 0.59 | 0.49 | 6.14 | 0.64 | 1.12 | 0.56 | 9.72 | 0.75 | 1.38 |
| C (Organic) | 0.60 | 1.08 | 1.22 | 3.89 | 10.4 | 3.84 | 1.49 | 3.36 | 3.40 | 3.21 | 3.96 | 2.82 | 5.38 | 2.40 | 2.95 | 1.38 | 4.48 | 7.55 |
| F----------- | 3.2 | 0.08 | 3.7 | 3.2 | 1.3 | 1.7 | 0.07 | 0.18 | 0.26 | 0.82 | 0.60 | 0.16 | 0.50 | 2.4 | 2.3 | 0.06 | 0.61 | 1.1 |

Table 2. continued

| | | | | | | | | | Lakeridge | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample---- | M-23B | M-22B | M-21A | M-20B | M-18 | M-17 | M-16 | M-15A | M-14 | M-12B | WS-11D |
| $SiO_2$------- | | 20.2 (X) | | | 20.6 (X) | | | 17.9 (X) | 12.6 (X) | | 22.8 (X) |
| $Al_2O_3$------ | 1.6 (I) | 4.9 (I) | 1.9 (I) | 10 (I) | 5.3 (I) | 5.1 (I) | 5.3 (I) | 4.9 (I) | 3.6 (I) | 0.43 (I) | 6.1 (I) |
| | | 4.63 (X) | | | 5.12 (X) | | | 4.73 (X) | 3.54 (X) | | 5.58 (X) |
| $Fe_2O_3$------ | 0.62 (I) | 1.7 (I) | 1.3 (I) | 4.2 (I) | 2.0 (I) | 2.2 (I) | 2.3 (I) | 2.0 (I) | 3.0 (I) | 2.8 (I) | 3.9 (I) |
| | | 1.68 (X) | | | 1.94 (X) | | | 2.01 (X) | 2.94 (X) | | 3.70 (X) |
| MgO-------- | 20 (I) | 9.6 (I) | 0.61 (I) | 0.68 (I) | 7.0 (I) | 3.0 (I) | 12 (I) | 2.2 (I) | 1.1 (I) | 0.46 (I) | 12 (I) |
| | | 10.6 (X) | | | 7.37 (X) | | | 2.05 (X) | 0.99 (X) | | 14.1 (X) |
| CaO-------- | 29 (I) | 21 (I) | 38 (I) | 14 (I) | 18 (I) | 18 (I) | 20 (I) | 25 (I) | 28 (I) | 48 (I) | 21 (I) |
| | | 19.9 (X) | | | 18.6 (X) | | | 25.6 (X) | 27.7 (X) | | 19.7 (X) |
| $Na_2O$------- | 0.61 (I) | 0.84 (I) | 1.1 (I) | 1.8 (I) | 0.81 (I) | 0.96 (I) | 1.2 (I) | 1.3 (I) | 0.89 (I) | 1.1 (I) | 0.49 (I) |
| | | 0.77 (X) | | | 0.79 (X) | | | 1.28 (X) | 0.94 (X) | | 0.35 (X) |
| $K_2O$------- | 0.37 (I) | 1.4 (I) | 0.65 (I) | 3.1 (I) | 1.7 (I) | 1.7 (I) | 1.6 (I) | 1.6 (I) | 1.3 (I) | 0.14 (I) | 2.4 (I) |
| | | 1.34 (X) | | | 1.62 (X) | | | 1.52 (X) | 1.28 (X) | | 2.04 (X) |
| $TiO_2$------ | 0.03 (I) | 0.12 (I) | 0.03 (I) | 0.28 (I) | 0.13 (I) | 0.13 (I) | 0.13 (I) | 0.07 (I) | 0.07 (I) | 0.02 (I) | 0.13 (I) |
| | | 0.21 (X) | | | 0.27 (X) | | | 0.25 (X) | 0.18 (X) | | 0.30 (X) |
| $P_2O_5$------ | 0.69 (I) | 2.3 (I) | 23 (I) | 11 (I) | 5.0 (I) | 9.9 (I) | 3.0 (I) | 15 (I) | 16 (I) | 30 (I) | 0.16 (I) |
| | | 1.95 (X) | | | 4.39 (X) | | | 15.1 (X) | 16.9 (X) | | 0.10(X) |
| MnO-------- | 0.015 (I) | 0.011 (I) | 0.006 (I) | 0.012 (I) | 0.017 (I) | 0.013 (I) | 0.015 (I) | 0.008 (I) | 0.005 (I) | 0.017 (I) | 0.044 (I) |
| | | 0.01 (X) | | | 0.02 (X) | | | 0.01 (X) | <0.01 (X) | | 0.05 (X) |
| LOI--------- | | 30.4 | | | 27.9 | | | 22.9 | 25 | | 27.6 |
| S--------- | 1.0 | 3.1 | 4.3 | 4.7 | 4.4 | 7.1 | 3.4 | 5.0 | 6.3 | 1.0 | 1.4 |
| C(Inorganic) | 10.8 | 6.62 | 1.26 | 0.13 | 4.69 | 1.74 | 6.03 | 1.49 | 0.93 | 1.66 | 8.08 |
| C (Organic) | 4.27 | 10.1 | 12.6 | 7.21 | 15.1 | 24.9 | 8.27 | 15.5 | 18.1 | 1.24 | 0.72 |
| F----------- | 0.07 | 0.25 | 2.5 | 1.2 | 0.61 | 1.2 | 0.38 | 2.1 | 2.6 | 3.4 | 0.14 |

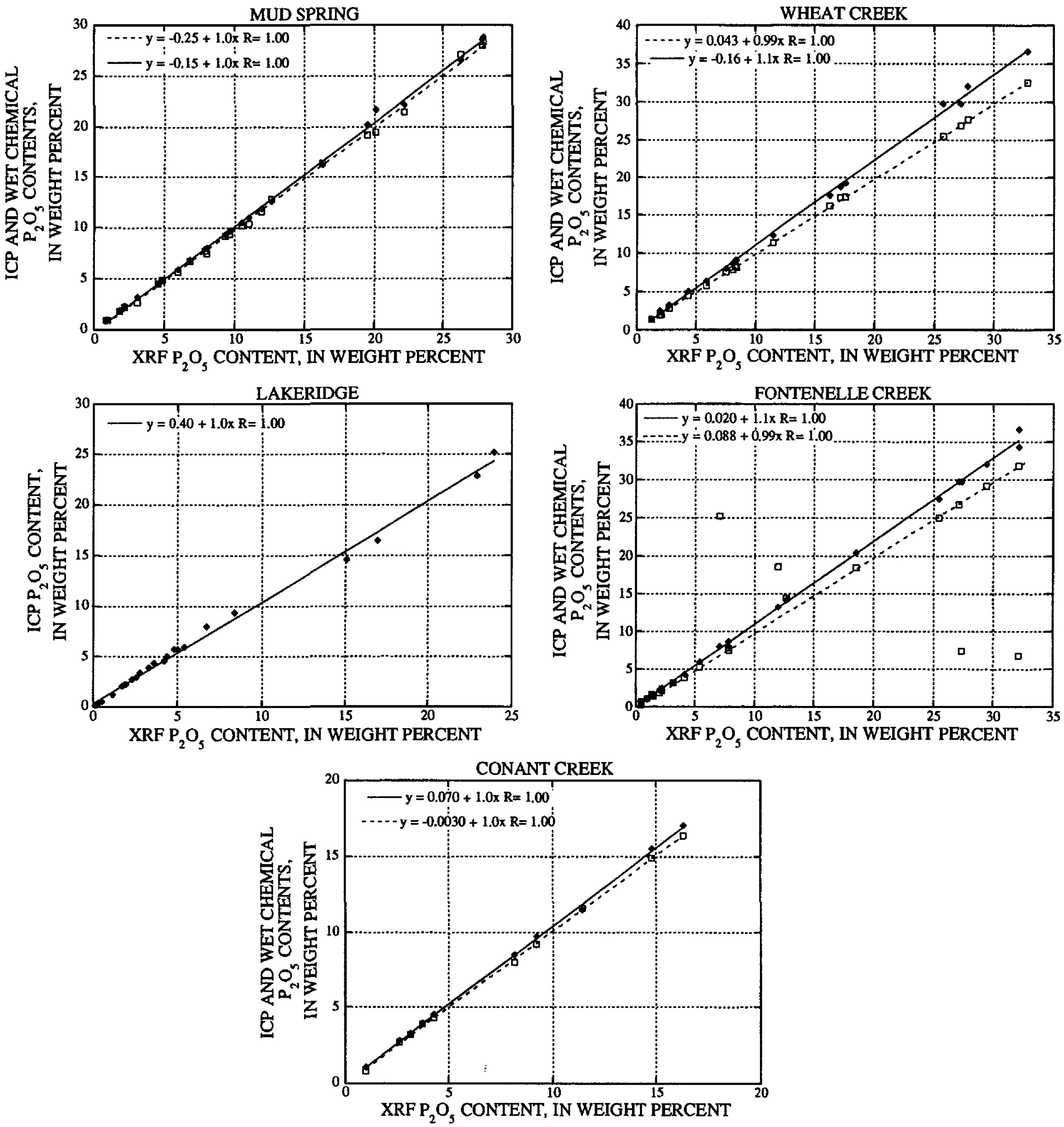



Figure 3. Comparison of measured $P_2O_5$ (*A*), $Al_2O_3$ (*B*), CaO (*C*), and MgO (*D*) contents by different analytical techniques: inductively coupled plasma-atomic emission spectroscopy (ICP), X-ray-fluorescence spectroscopy (XRF), and wet chemical analysis (WC). The open squares are the WC/XRF data and the solid diamonds are the ICP-AES/XRF data. Graphs include curves of best fit, equation for curve of best fit, correlation coefficients (R values) and the one-to-one line (the solid line). In figure 3*A*, the Fontenelle graph, the line of best fit does not include the four outlier data points.

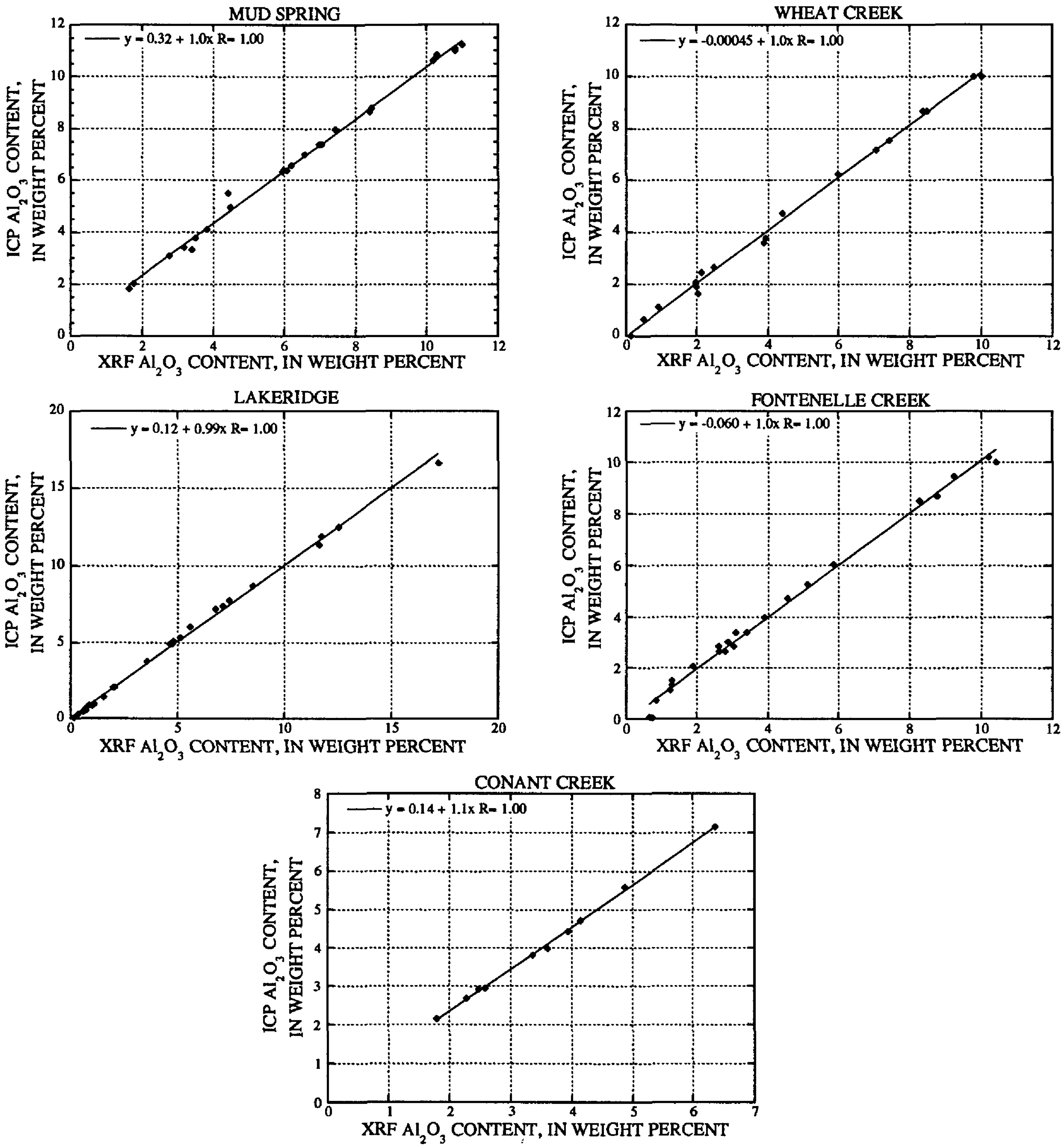



Figure 3. continued

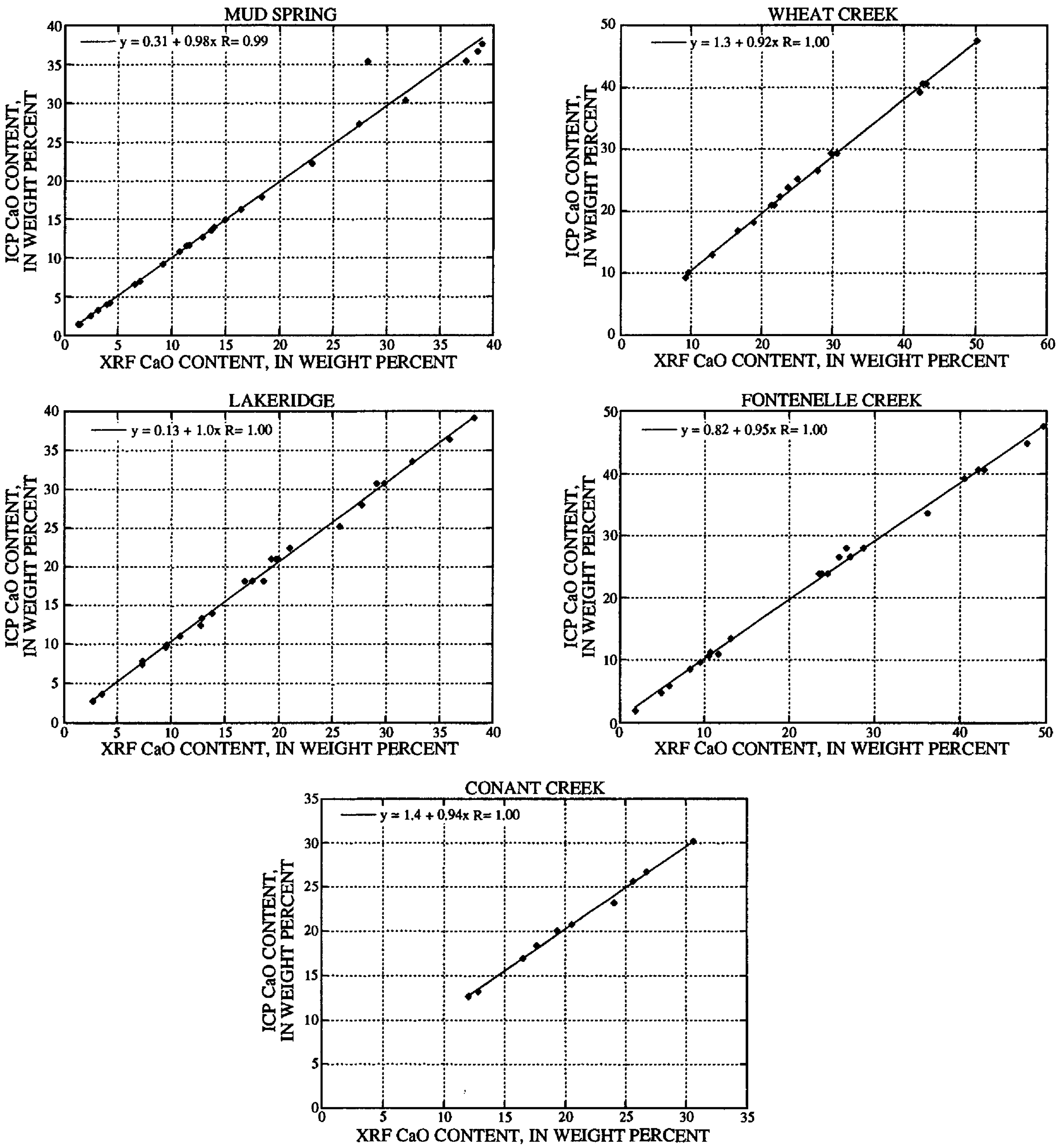



Figure 3. continued

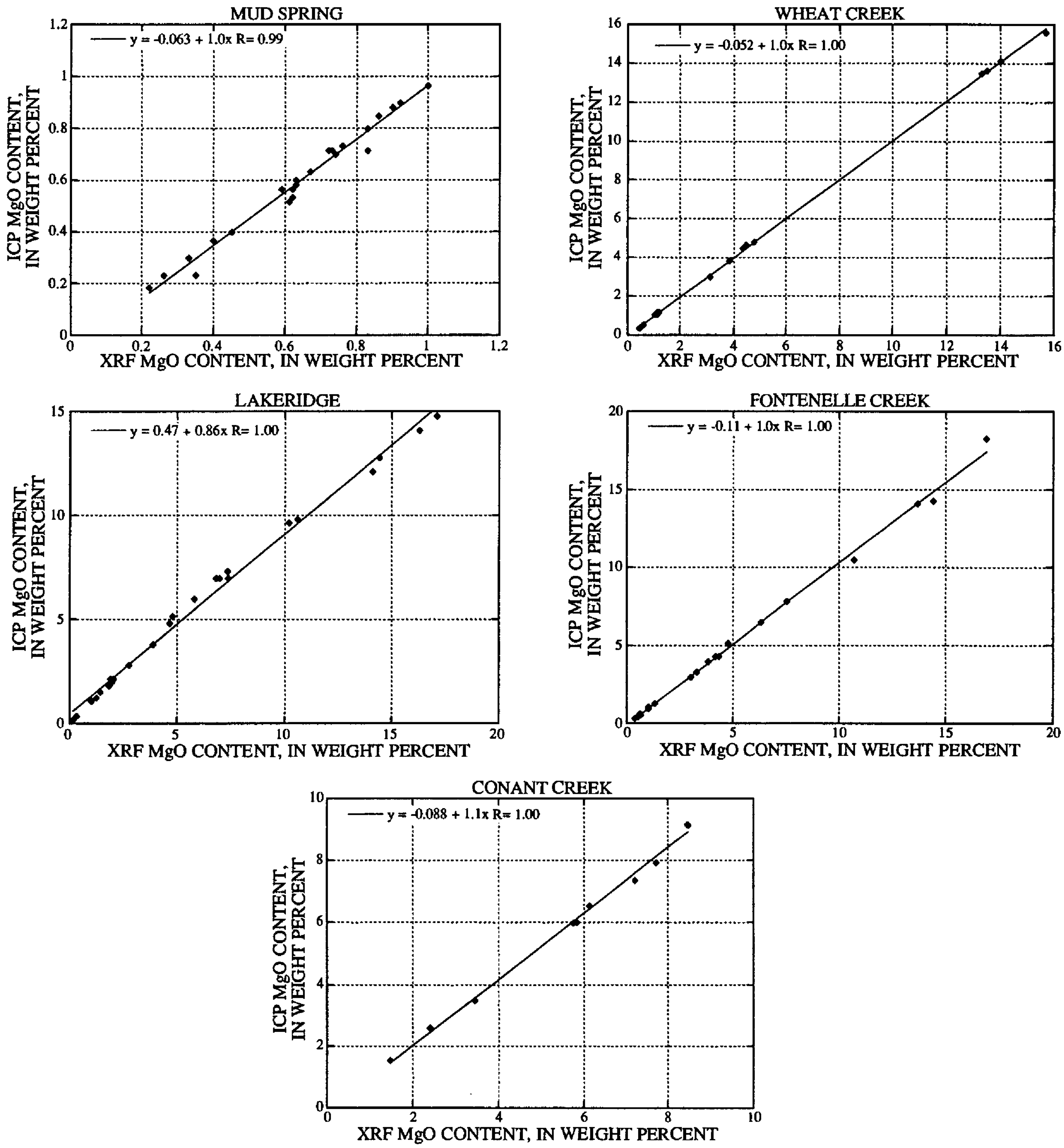



Figure 3. continued

**Minor-element analyses**

Minor elements were determined by inductively coupled plasma-emission spectroscopy (ICP-AES; table 3), and the rare earth elements (REE) by inductively coupled plasma-mass spectroscopy (ICP-MS; table 4; Lichte and others, 1987b). The range of detection, precision, and accuracy of each analytical technique is given in table 1. Minor elements that were above their detection level in only a few samples -- Bi, Nb, Sn, Ta and U -- are not reported in table 3.

La was the only minor element used to gauge the quality of minor-element data because it was analyzed by two techniques, ICP-MS and ICP-AES, and was significantly above the detection limit. X-Y plots of La (fig. 4) gave results similar to the X-Y plots for the major elements which were analyzed by both ICP-AES and XRF, $R \geq 0.98$ and deviation from the 1:1 curve of $\leq 14$ percent.

**-Miscellaneous analyses**

Total sulfur and total carbon, evolved as oxides during combustion, were measured by absorption of infrared radiation (table 2; Jackson and others, 1987). Carbonate carbon was measured as $CO_2$ by coulometric titration (Jackson and others, 1987). For the Lakeridge samples, fluorine was determined by ion-selective electrode following $LiBO_2$ fusion and $HNO_3$ dissolution (Bodkin, 1977; Cremer and others, 1984). The ranges of detection, precision, and accuracy are given in table 1.

**Table 3.** Minor-element contents in samples of the Phosphoria Formation at Conant Creek, Wheat Creek, Fontenelle Creek, and Lakeridge, Wyoming and Mud Springs, Idaho

[All values in parts per million.]

| | Conant Creek | | | | | | | | | | Mud Springs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-47 | P-46 | P-45 | P-44 | P-43 | P-42 | P-41 | P-40 | P-39 | P-38 | P-47 | P-44 | P-43 | P-41 | P-40 |
| Mn---- | 149 | 119 | 168 | 199 | 186 | 226 | 88 | 249 | 177 | 210 | 85 | 86 | 30 | 46 | 21 |
| Ag---- | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | 4 | 4 | 5 | 5 | 6 |
| As---- | 5 | 20 | 10 | 10 | 20 | 30 | 40 | 10 | 20 | 20 | 30 | 10 | 10 | 20 | 30 |
| Ba---- | 68 | 84 | 59 | 84 | 132 | 161 | 93 | 115 | 120 | 132 | 4460 | 1830 | 4860 | 1040 | 601 |
| Be---- | 1 | 2 | 1 | 0.5 | 1 | 2 | 1 | 0.5 | 1 | 2 | 3 | 1 | 2 | 2 | 2 |
| Cd---- | 1 | 1 | 1 | 1 | 5 | 6 | 1 | 1 | 2 | 6 | 9 | 6 | 4 | 8 | 3 |
| Co---- | 5 | 4 | 3 | 4 | 5 | 6 | 5 | 5 | 5 | 5 | 21 | 14 | 5 | 6 | 7 |
| Cr---- | 374 | 466 | 315 | 262 | 516 | 735 | 371 | 281 | 435 | 544 | 1970 | 1110 | 1680 | 1060 | 1420 |
| Cu---- | 37 | 19 | 8 | 17 | 18 | 11 | 11 | 20 | 22 | 10 | 225 | 221 | 255 | 169 | 126 |
| Ga---- | 2 | 5 | 2 | 2 | 8 | 9 | 2 | 4 | 5 | 6 | 14 | 12 | 13 | 6 | 11 |
| Li---- | 50 | 52 | 27 | 31 | 54 | 64 | 32 | 39 | 42 | 38 | 25 | 18 | 21 | 14 | 22 |
| Mo---- | 38 | 8 | 8 | 13 | 6 | 6 | 18 | 32 | 12 | 12 | 10 | 6 | 4 | 12 | 11 |
| Ni---- | 63 | 31 | 15 | 25 | 31 | 37 | 29 | 49 | 33 | 35 | 376 | 304 | 126 | 298 | 286 |
| Pb---- | 2 | 16 | 31 | 21 | 37 | 31 | 144 | 18 | 65 | 67 | 11 | 11 | 12 | 10 | 10 |
| Sc---- | 4 | 5 | 4 | 3 | 6 | 8 | 3 | 4 | 5 | 6 | 11 | 10 | 12 | 9 | 12 |
| Sr---- | 175 | 429 | 499 | 137 | 196 | 168 | 579 | 83 | 358 | 448 | 1170 | 254 | 393 | 470 | 338 |
| Th---- | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | 4 | 5 | 9 | 8 | < 4 | 8 |
| V---- | 54 | 69 | 40 | 41 | 69 | 91 | 44 | 48 | 58 | 72 | 145 | 114 | 149 | 118 | 170 |
| Y---- | 46 | 102 | 109 | 26 | 45 | 50 | 92 | 20 | 59 | 65 | 158 | 86 | 157 | 173 | 76 |
| Zn---- | 23 | 32 | 30 | 14 | 779 | 903 | 314 | 28 | 551 | 1080 | 1240 | 883 | 512 | 1570 | 1230 |

| | Mud Springs | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-38 | P-35 | P-33 | P-31 | P-29 | P-27 | P-26 | P-25 | P-23 | P-22 | P-17 | P-16 | P-15 | P-14 | P-11 |
| Mn---- | 21 | 13 | 20 | 98 | 176 | 21 | 361 | 442 | 4040 | 112 | 18 | 16 | 124 | 87 | 473 |
| Ag---- | 7 | 6 | 5 | 11 | 7 | 6 | 5 | 3 | 3 | 3 | 4 | 4 | < 2 | < 2 | 3 |
| As---- | 30 | 20 | 30 | 10 | < 10 | 10 | 10 | 10 | < 10 | 10 | 20 | 10 | < 10 | < 10 | 10 |
| Be---- | 569 | 336 | 534 | 292 | 230 | 219 | 276 | 219 | 821 | 253 | 867 | 1010 | 373 | 202 | 286 |
| Be---- | 2 | 2 | 3 | 1 | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | < 1 | < 1 | 1 |
| Cd---- | 3 | 2 | 2 | 13 | 18 | 9 | 29 | 11 | 55 | 3 | 7 | 5 | 3 | < 2 | 12 |
| Co---- | 5 | 3 | 6 | 13 | 9 | 4 | 9 | 10 | 108 | 5 | 3 | 5 | 7 | 4 | 20 |
| Cr---- | 1660 | 1940 | 2200 | 1750 | 904 | 1010 | 1040 | 442 | 234 | 910 | 1910 | 1740 | 570 | 570 | 542 |
| Cu---- | 200 | 143 | 258 | 179 | 94 | 80 | 78 | 61 | 96 | 49 | 197 | 195 | 96 | 74 | 113 |
| Ga---- | 12 | 11 | 11 | 5 | 5 | 8 | 8 | 6 | 6 | 7 | 13 | 11 | < 4 | < 4 | 7 |
| Li---- | 20 | 14 | 31 | 22 | 20 | 21 | 26 | 20 | 15 | 20 | 31 | 25 | 9 | 13 | 23 |
| Mo---- | 16 | 9 | 18 | 7 | 9 | 9 | 9 | 13 | 18 | 6 | 17 | 8 | 10 | 7 | 11 |
| Ni---- | 240 | 153 | 340 | 177 | 381 | 144 | 418 | 584 | 986 | 271 | 182 | 187 | 150 | 129 | 319 |
| Pb---- | 14 | 11 | 12 | 11 | 5 | 9 | 12 | 6 | 11 | 6 | 17 | 14 | 5 | 4 | 9 |
| Sc---- | 12 | 9 | 12 | 6 | 6 | 4 | 8 | 7 | 6 | 7 | 13 | 11 | 3 | 3 | 6 |
| Sr---- | 522 | 462 | 792 | 1010 | 527 | 669 | 407 | 246 | 136 | 71 | 545 | 867 | 266 | 59 | 307 |
| Th---- | 9 | 5 | 6 | < 4 | < 4 | < 4 | 6 | 5 | 8 | 7 | 8 | 4 | < 4 | < 4 | 4 |
| V---- | 155 | 141 | 222 | 830 | 203 | 296 | 229 | 143 | 109 | 110 | 223 | 173 | 62 | 60 | 159 |
| Y---- | 109 | 173 | 133 | 463 | 183 | 171 | 122 | 86 | 59 | 52 | 253 | 208 | 41 | 34 | 142 |
| Zn---- | 883 | 517 | 1320 | 874 | 1400 | 742 | 1430 | 1540 | 2110 | 903 | 534 | 613 | 506 | 364 | 1220 |

| | Mud Springs | | | | | Fontenelle Creek | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-8 | P-6 | P-4 | P-2 | P-1 | E-4 | U-3 | U-1 | R-9 | R-6 | P-45 | P-43 | P-40 | P-39 | P-37 |
| Mn---- | 25 | 23 | 170 | 121 | 104 | 160 | 43 | 95 | 150 | 110 | 170 | 150 | 160 | 120 | 120 |
| Ag---- | 3 | 5 | 3 | < 2 | < 2 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 |
| As---- | 10 | 10 | < 10 | 20 | < 10 | 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| Ba---- | 189 | 154 | 520 | 191 | 92 | 140 | 74 | 28 | 51 | 91 | 20 | 110 | 33 | 120 | 110 |
| Be---- | 2 | 2 | < 1 | 2 | < 1 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 |
| Cd---- | 31 | 29 | < 2 | 13 | 5 | < 4 | 6 | 5 | < 4 | < 4 | < 4 | 20 | 10 | 30 | 32 |
| Co---- | 3 | 3 | 4 | 4 | 5 | 4 | 5 | 5 | 4 | 5 | 2 | 5 | 4 | 5 | 5 |
| Cr---- | 1250 | 1610 | 65 | 803 | 289 | 470 | 560 | 620 | 430 | 1100 | 130 | 370 | 130 | 450 | 480 |
| Cu---- | 96 | 74 | 26 | 84 | 34 | 43 | 20 | 20 | 25 | 26 | 8 | 47 | 20 | 48 | 43 |
| Ga---- | 5 | 5 | < 4 | 9 | < 4 | < 8 | < 8 | < 8 | < 8 | < 6 | < 8 | 10 | < 8 | 10 | 10 |
| Li---- | 18 | 25 | 14 | 69 | 21 | 23 | 20 | 20 | 10 | 23 | 6 | 20 | 6 | 20 | 20 |
| Mo---- | 10 | 7 | 27 | 21 | 13 | 10 | 8 | 7 | < 4 | 4 | < 4 | 31 | 10 | 36 | 23 |
| Ni---- | 139 | 129 | 122 | 245 | 107 | 34 | 39 | 53 | 20 | 31 | 10 | 66 | 22 | 86 | 79 |
| Pb---- | 15 | 12 | < 4 | 9 | 10 | 140 | 20 | 10 | < 8 | 6 | < 8 | < 8 | < 8 | < 6 | < 8 |
| Sc---- | 6 | 5 | < 2 | 8 | 3 | 4 | 5 | 4 | < 4 | 5 | < 4 | < 4 | < 4 | < 4 | 4 |
| Sr---- | 741 | 946 | 44 | 453 | 951 | 660 | 660 | 330 | 240 | 510 | 82 | 85 | 180 | 100 | 120 |
| Th---- | < 4 | < 4 | < 4 | 4 | < 4 | < 8 | < 8 | < 8 | < 6 | < 8 | < 8 | < 6 | < 8 | < 8 | < 8 |
| V---- | 515 | 515 | 30 | 123 | 44 | 110 | 110 | 260 | 44 | 86 | 25 | 56 | 38 | 110 | 120 |
| Y---- | 429 | 501 | 22 | 195 | 347 | 170 | 570 | 260 | 81 | 250 | 10 | 26 | 10 | 26 | 31 |
| Zn---- | 552 | 493 | 214 | 823 | 298 | 160 | 640 | 540 | 200 | 290 | 89 | 420 | 120 | 610 | 770 |

| | Fontenelle Creek | | | | | | | | | | | | | Wheat Creek | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-32 | P-31 | P-25 | P-23 | P-21 | P-20 | P-19 | P-13 | P-12 | P-8 | P-7 | P-3 | P-1 | R-15 | R-9 |
| Mn--- | 38 | 120 | 160 | 72 | 120 | 210 | 330 | 74 | 170 | 120 | 210 | 35 | 84 | 81 | 72 |
| Ag---- | < 4 | < 4 | < 4 | 9 | 5 | < 4 | < 4 | 10 | < 4 | 10 | 5 | < 4 | < 4 | < 4 | < 4 |
| As---- | < 20 | < 20 | < 20 | 30 | 20 | < 20 | < 20 | < 20 | < 20 | 30 | < 20 | < 20 | < 20 | < 20 | 20 |
| Ba---- | 65 | 230 | 160 | 290 | 290 | 280 | 190 | 130 | 79 | 250 | 88 | 80 | 85 | 210 | 210 |
| Be---- | 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | 2 |
| Cd---- | 20 | 10 | 44 | 220 | 190 | 150 | 42 | 150 | 57 | 280 | 140 | 10 | 27 | 10 | 6 |
| Co---- | 4 | 8 | 8 | 4 | 9 | 10 | 10 | 5 | 6 | 7 | 7 | 4 | 4 | 4 | 4 |
| Cr---- | 1200 | 630 | 800 | 1600 | 2700 | 500 | 120 | 2500 | 270 | 2800 | 1100 | 550 | 530 | 460 | 620 |
| Cu---- | 24 | 42 | 56 | 170 | 140 | 49 | 36 | 160 | 31 | 210 | 70 | 43 | 66 | 20 | 20 |
| Ga---- | < 8 | 10 | 10 | 41 | 20 | 10 | < 8 | 10 | < 8 | 27 | 10 | 9 | 10 | < 8 | < 8 |
| Li---- | 8 | 22 | 22 | 40 | 44 | 20 | 10 | 30 | 7 | 41 | 10 | 9 | 10 | 6 | 9 |
| Mo--- | 10 | 20 | 56 | 580 | 240 | 58 | 10 | 200 | 46 | 300 | 69 | 20 | 32 | 8 | 31 |
| Ni---- | 24 | 76 | 120 | 440 | 220 | 130 | 88 | 360 | 120 | 500 | 290 | 46 | 59 | 28 | 41 |
| Pb--- | < 8 | 10 | 10 | 10 | 20 | 20 | 9 | 10 | < 8 | 20 | < 8 | < 8 | 10 | 10 | 29 |
| Sc---- | 5 | 8 | 6 | 10 | 10 | 9 | 5 | 7 | < 4 | 10 | 5 | 6 | < 4 | < 4 | 6 |
| Sr---- | 990 | 190 | 330 | 58 | 110 | 140 | 94 | 540 | 190 | 290 | 370 | 1000 | 460 | 1200 | 1100 |
| Th---- | < 8 | < 8 | < 8 | 10 | 9 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 |
| V---- | 180 | 160 | 340 | 11000 | 1700 | 740 | 140 | 2200 | 450 | 2200 | 610 | 150 | 200 | 110 | 71 |
| Y---- | 750 | 120 | 200 | 40 | 190 | 79 | 20 | 150 | 36 | 280 | 140 | 340 | 320 | 210 | 200 |
| Zn---- | 330 | 610 | 960 | 1700 | 600 | 1000 | 510 | 1600 | 890 | 2200 | 1100 | 350 | 170 | 650 | 530 |

| | Wheat Creek | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | R-7 | R-6 | P-34 | P-30 | P-26 | P-22 | P-20 | P-16 | P-14 | P-11 | P-9 | P-7 | P-4 | P-3 | P-1 |
| Mn--- | 76 | 260 | 140 | 110 | 58 | 210 | 200 | 110 | 96 | 65 | 120 | 84 | 84 | 80 | 120 |
| Ag---- | < 4 | < 4 | < 4 | 6 | < 4 | 5 | < 4 | 7 | 10 | 9 | < 4 | 9 | 9 | 7 | < 4 |
| As---- | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 | < 20 |
| Ba---- | 650 | 48 | 150 | 240 | 320 | 120 | 120 | 270 | 270 | 200 | 66 | 320 | 230 | 260 | 220 |
| Be---- | 2 | < 2 | < 2 | 2 | 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | 2 | < 2 | < 2 | < 2 |
| Cd---- | 37 | 85 | 20 | 44 | 20 | 23 | 20 | 33 | 70 | 41 | 7 | 4 | 63 | 10 | 7 |
| Co---- | 4 | 6 | 5 | 3 | 3 | 2 | 3 | 3 | 5 | 4 | 3 | 2 | 5 | 2 | 4 |
| Cr---- | 480 | 70 | 550 | 1900 | 1200 | 600 | 310 | 1900 | 1600 | 2500 | 370 | 1300 | 1100 | 170 | 660 |
| Cu---- | 21 | 22 | 52 | 80 | 27 | 51 | 36 | 69 | 84 | 88 | 20 | 86 | 46 | 27 | 28 |
| Ga---- | < 8 | < 8 | < 8 | 10 | 10 | < 8 | < 8 | 10 | 20 | 10 | < 8 | 10 | 9 | < 8 | < 8 |
| Li---- | 7 | 5 | 10 | 40 | 30 | 20 | 10 | 31 | 34 | 30 | 9 | 45 | 26 | 10 | 8 |
| Mo--- | < 4 | 5 | 10 | 27 | 10 | 20 | 10 | 8 | < 4 | 57 | 5 | 36 | 24 | 20 | 8 |
| Ni---- | 20 | 21 | 40 | 200 | 97 | 96 | 100 | 170 | 200 | 180 | 52 | 260 | 81 | 87 | 24 |
| Pb--- | 63 | 20 | 10 | 10 | 10 | < 8 | < 8 | 10 | 10 | 10 | < 8 | 24 | 20 | 10 | 9 |
| Sc---- | < 4 | < 4 | 6 | 10 | 10 | 5 | 4 | 10 | 10 | 9 | < 4 | 10 | 7 | 6 | 5 |
| Sr---- | 1100 | 110 | 620 | 430 | 230 | 210 | 130 | 360 | 360 | 610 | 220 | 300 | 600 | 110 | 810 |
| Th---- | < 8 | < 8 | < 8 | < 8 | 9 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 | < 8 |
| V---- | 160 | 42 | 110 | 350 | 350 | 150 | 140 | 440 | 1300 | 820 | 70 | 410 | 290 | 100 | 110 |
| Y---- | 350 | 40 | 280 | 270 | 170 | 58 | 22 | 190 | 220 | 250 | 43 | 180 | 300 | 38 | 190 |
| Zn---- | 540 | 230 | 330 | 1000 | 480 | 410 | 410 | 770 | 830 | 710 | 220 | 1200 | 630 | 750 | 200 |

| Wheat Creek | | Lakeridge | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Cw-11 | E-92C | US-91B | E-90A | E-89A | US-88C | TO-87B | TO-86D | TO-85A | TO-84B | RT-81A | TO-78C | RT-77 | RT-75A | F-74 |
| Mn--- | 120 | 890 | 220 | 590 | 780 | 480 | 450 | 200 | 400 | 480 | 170 | 500 | 240 | 110 | 200 |
| Ag---- | < 4 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 |
| As---- | < 20 | < 10 | < 10 | < 10 | < 10 | < 10 | 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Ba---- | 180 | 16 | 40 | 20 | 27 | 48 | 62 | 66 | 120 | 62 | 92 | 82 | 110 | 150 | 34 |
| Be---- | < 2 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | 1 | < 1 | 1 | < 1 | 1 | 1 | < 1 |
| Cd---- | 20 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | 8 | 8 | < 2 | < 2 |
| Co---- | 4 | 3 | 3 | 3 | 4 | 4 | 4 | 4 | 6 | 5 | 4 | 4 | 6 | 5 | 2 |
| Cr---- | 140 | 120 | 210 | 130 | 240 | 170 | 180 | 180 | 400 | 370 | 410 | 260 | 570 | 670 | 150 |
| Cu---- | 34 | 22 | 34 | 36 | 29 | 57 | 61 | 52 | 60 | 78 | 57 | 42 | 63 | 42 | 7 |
| Ga---- | < 8 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | 6 | 4 | < 4 | < 4 | 8 | 8 | < 4 |
| Li---- | 7 | 8 | 20 | 14 | 16 | 12 | 18 | 36 | 43 | 32 | 31 | 26 | 50 | 31 | 7 |
| Mo--- | 5 | 5 | 7 | 8 | 8 | 14 | 17 | 16 | 13 | 19 | 11 | 10 | 16 | 12 | 15 |
| Ni---- | 22 | 15 | 24 | 21 | 24 | 39 | 41 | 38 | 53 | 59 | 45 | 35 | 110 | 90 | 16 |
| Pb--- | < 8 | < 4 | 20 | 9 | 11 | 9 | 28 | 21 | 32 | 32 | 40 | 21 | 25 | 19 | 6 |
| Sc---- | < 4 | < 2 | < 2 | 2 | 3 | 2 | 2 | 2 | 6 | 4 | 3 | 3 | 7 | 7 | 2 |
| Sr---- | 460 | 74 | 99 | 96 | 140 | 130 | 100 | 73 | 150 | 190 | 700 | 160 | 340 | 1000 | 130 |
| Th---- | < 8 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | 14 | < 4 |
| V---- | 36 | 18 | 23 | 21 | 29 | 19 | 22 | 26 | 59 | 57 | 39 | 43 | 66 | 160 | 41 |
| Y---- | 120 | 20 | 84 | 29 | 62 | 59 | 25 | 16 | 40 | 31 | 78 | 26 | 110 | 460 | 50 |
| Zn---- | 180 | 3 | 8 | < 2 | 2 | 3 | 4 | 64 | 22 | 19 | 13 | 880 | 500 | 55 | 3 |

Lakeridge

| Sample | F-73 | F-72B | F-71B | F-70E | F-69A | F-68A | F-65B | F-64A | LB-62A | F-58B | LS-57M | LS-57D | LB-56A | LS-55B | R-54C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn--- | 250 | 280 | 220 | 370 | 230 | 170 | 290 | 410 | 250 | 280 | 260 | 310 | 170 | 220 | 270 |
| Ag---- | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 |
| As---- | < 10 | < 10 | < 10 | < 10 | < 10 | 32 | < 10 | < 10 | 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 |
| Ba---- | 42 | 65 | 37 | 52 | 19 | 27 | 110 | 170 | 36 | 11 | 15 | 10 | 47 | 19 | 23 |
| Be---- | < 1 | < 1 | < 1 | < 1 | < 1 | 3 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 | < 1 |
| Cd---- | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | < 2 | 2 | < 2 |
| Co---- | 3 | 2 | 2 | 6 | 3 | 20 | 4 | 9 | 10 | 2 | 4 | 4 | 3 | 3 | 5 |
| Cr---- | 170 | 130 | 130 | 380 | 10 | 140 | 74 | 210 | 120 | 20 | 200 | 130 | 110 | 150 | 250 |
| Cu---- | 21 | 15 | 25 | 120 | 8 | 55 | 36 | 130 | 51 | 12 | 79 | 60 | 69 | 42 | 79 |
| Ga---- | < 4 | < 4 | < 4 | < 4 | < 4 | 17 | < 4 | 4 | 6 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 |
| Li---- | 6 | 3 | 6 | 17 | 6 | 110 | 8 | 15 | 23 | < 2 | 4 | 2 | 11 | 7 | 9 |
| Mo--- | 10 | 9 | 15 | 37 | 2 | 27 | 11 | 27 | 8 | 2 | 15 | 13 | 13 | 10 | 16 |
| Ni---- | 18 | 14 | 29 | 75 | 5 | 59 | 23 | 84 | 36 | 5 | 38 | 35 | 36 | 36 | 49 |
| Pb--- | 8 | < 4 | < 4 | 6 | < 4 | 10 | < 4 | 9 | 14 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 |
| Sc---- | 4 | 2 | < 2 | 4 | < 2 | 15 | < 2 | 4 | 6 | < 2 | 2 | < 2 | < 2 | < 2 | 3 |
| Sr---- | 160 | 99 | 140 | 110 | 180 | 70 | 89 | 70 | 300 | 630 | 400 | 270 | 180 | 230 | 220 |
| Th---- | < 4 | < 4 | < 4 | < 4 | < 4 | 7 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 | < 4 |
| V---- | 38 | 29 | 39 | 66 | 14 | 180 | 11 | 34 | 36 | 6 | 14 | 7 | 6 | 14 | 24 |
| Y---- | 60 | 20 | 40 | 58 | 5 | 10 | 6 | 10 | 11 | 9 | 170 | 62 | 40 | 130 | 52 |
| Zn---- | 7 | 2 | 6 | < 2 | 6 | 27 | 5 | 7 | 25 | 11 | 25 | 23 | 11 | 83 | 30 |

Lakeridge

| Sample | M-53B | M-52 | R-50F | M-48B | M-47 | M-45 | M-44A | M-42A | M-41 | M-40 | M-39B | M-38A | M-37A | M-36B | M-35A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn--- | 300 | 130 | 200 | 95 | 140 | 150 | 72 | 82 | 240 | 44 | 56 | 110 | 150 | 310 | 210 |
| Ag---- | < 2 | < 2 | < 2 | 2 | < 2 | < 2 | < 2 | < 2 | 3 | < 2 | 7 | 65 | 6 | < 2 | 3 |
| As---- | < 10 | < 10 | < 10 | 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | < 10 | 76 | 20 | < 10 | 20 |
| Ba---- | 94 | 150 | 45 | 200 | 140 | 270 | 270 | 270 | 180 | 290 | 60 | 86 | 110 | 100 | 63 |
| Be---- | < 1 | 2 | < 1 | 2 | < 1 | < 1 | 4 | 2 | < 1 | 3 | 4 | 2 | 2 | < 1 | 2 |
| Cd---- | < 2 | 2 | 15 | < 2 | 4 | < 2 | < 2 | < 2 | < 2 | < 2 | 4 | 8 | 110 | < 2 | 5 |
| Co---- | 5 | 4 | 5 | 7 | 4 | 4 | 4 | 4 | 7 | 4 | 8 | 8 | 8 | 4 | 9 |
| Cr---- | 450 | 900 | 320 | 1000 | 420 | 720 | 2100 | 1200 | 240 | 630 | 1900 | 1800 | 1800 | 110 | 730 |
| Cu---- | 84 | 87 | 56 | 84 | 86 | 85 | 110 | 94 | 73 | 50 | 74 | 110 | 58 | 21 | 43 |
| Ga---- | < 4 | 4 | < 4 | 12 | < 4 | < 4 | 10 | 6 | 6 | 5 | 11 | 22 | 16 | < 4 | 12 |
| Li---- | 13 | 14 | 15 | 61 | 12 | 19 | 46 | 11 | 8 | 9 | 25 | 48 | 30 | 5 | 25 |
| Mo--- | 23 | 17 | 120 | 22 | 39 | 31 | 33 | 25 | 25 | 16 | 59 | 220 | 24 | 5 | 14 |
| Ni---- | 65 | 47 | 73 | 190 | 69 | 52 | 150 | 41 | 90 | 92 | 190 | 400 | 100 | 20 | 70 |
| Pb--- | 7 | < 4 | 10 | 20 | < 4 | < 4 | 6 | 6 | 6 | < 4 | 7 | 32 | 11 | < 4 | 13 |
| Sc---- | 3 | 5 | < 2 | 13 | 5 | 9 | 10 | 12 | 5 | 12 | 14 | 14 | 13 | 3 | 10 |
| Sr---- | 260 | 2000 | 350 | 110 | 760 | 800 | 1000 | 980 | 130 | 1500 | 1300 | 400 | 670 | 98 | 120 |
| Th---- | < 4 | 5 | < 4 | 8 | < 4 | < 4 | < 4 | 7 | < 4 | < 4 | 4 | 4 | 6 | < 4 | 5 |
| V---- | 50 | 100 | 56 | 140 | 55 | 100 | 170 | 220 | 56 | 62 | 170 | 230 | 110 | 26 | 120 |
| Y---- | 130 | 900 | 230 | 34 | 240 | 640 | 340 | 530 | 31 | 500 | 300 | 290 | 89 | 6 | 33 |
| Zn---- | 58 | 310 | 600 | 41 | 170 | 21 | 22 | 13 | 39 | 88 | 190 | 280 | 6000 | 28 | 160 |

Lakeridge

| Sample | M-34A | M-33A | M-32A | M-31A | M-30A | M-29A | M-28A | M-27B | M-25 | M-24 | M-23B | M-22B | M-21A | M-20B | M-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mn--- | 99 | 170 | 120 | 230 | 140 | 100 | 89 | 210 | 140 | 94 | 120 | 87 | 45 | 91 | 130 |
| Ag---- | 5 | 5 | 6 | 3 | 9 | < 2 | 4 | < 2 | 6 | 9 | 2 | 7 | 14 | 10 | 9 |
| As---- | 10 | 20 | 21 | 10 | 22 | 10 | 21 | 10 | 36 | 33 | < 10 | 29 | 40 | 41 | 42 |
| Ba---- | 97 | 68 | 87 | 170 | 69 | 180 | 210 | 74 | 120 | 130 | 43 | 120 | 140 | 67 | 160 |
| Be---- | 2 | 2 | 2 | 1 | 2 | < 1 | 2 | < 1 | 2 | 2 | < 1 | 2 | 3 | 5 | 3 |
| Cd---- | 24 | 15 | 20 | 11 | 66 | 52 | 30 | 5 | 63 | 260 | 20 | 210 | 540 | 360 | 160 |
| Co---- | 7 | 9 | 8 | 5 | 8 | 4 | 6 | 3 | 9 | 6 | 2 | 4 | < 1 | 10 | 3 |
| Cr---- | 1000 | 1400 | 1400 | 890 | 2100 | 740 | 1200 | 110 | 1500 | 1900 | 280 | 1200 | 950 | 950 | 2800 |
| Cu---- | 40 | 46 | 41 | 23 | 89 | 57 | 61 | 16 | 54 | 94 | 16 | 71 | 330 | 140 | 160 |
| Ga---- | 11 | 16 | 15 | 8 | 16 | < 4 | 10 | < 4 | 14 | 9 | < 4 | < 4 | < 4 | 15 | < 4 |
| Li---- | 24 | 36 | 41 | 25 | 44 | 13 | 23 | 4 | 29 | 25 | 4 | 20 | 17 | 39 | 43 |
| Mo--- | 13 | 9 | 17 | 11 | 59 | 16 | 19 | 5 | 47 | 170 | 19 | 210 | 200 | 240 | 330 |
| Ni---- | 73 | 91 | 100 | 65 | 220 | 67 | 100 | 17 | 130 | 290 | 43 | 270 | 1400 | 360 | 710 |
| Pb--- | 10 | 12 | 15 | 6 | 15 | 5 | 10 | < 4 | 10 | 17 | 5 | 12 | 23 | 16 | 14 |
| Sc---- | 8 | 14 | 13 | 8 | 14 | 8 | 10 | 3 | 13 | 10 | 2 | 6 | 6 | 11 | 8 |
| Sr---- | 800 | 350 | 230 | 140 | 200 | 940 | 860 | 120 | 290 | 500 | 140 | 220 | 1400 | 740 | 360 |
| Th---- | < 4 | 6 | 6 | < 4 | 6 | < 4 | < 4 | < 4 | 6 | < 4 | < 4 | < 4 | < 4 | 7 | < 4 |
| V---- | 150 | 140 | 180 | 95 | 180 | 76 | 140 | 32 | 220 | 770 | 250 | 1500 | 2600 | 1300 | 1500 |
| Y---- | 62 | 72 | 37 | 29 | 83 | 270 | 120 | 8 | 54 | 84 | 8 | 59 | 260 | 160 | 210 |
| Zn---- | 900 | 580 | 600 | 320 | 1500 | 1200 | 950 | 130 | 1300 | 4300 | 440 | 2800 | 9400 | 8900 | 3200 |

| | Lakeridge | | | | | |
|---|---|---|---|---|---|---|
| Sample | M-17 | M-16 | M-15A | M-14 | M-12B | WS-11D |
| Mn--- | 100 | 120 | 60 | 39 | 130 | 340 |
| Ag---- | 15 | 8 | 13 | 13 | < 2 | < 2 |
| As---- | 46 | 21 | 36 | 59 | < 10 | 10 |
| Ba---- | 100 | 160 | 240 | 150 | 290 | 210 |
| Be---- | 5 | 2 | 3 | 3 | < 1 | 1 |
| Cd---- | 590 | 360 | 190 | 110 | 29 | < 2 |
| Co---- | 2 | 5 | 3 | 2 | 4 | 8 |
| Cr---- | 3300 | 580 | 3300 | 5500 | 330 | 82 |
| Cu---- | 320 | 99 | 210 | 480 | 130 | 46 |
| Ga---- | < 4 | < 4 | < 4 | 29 | 4 | 6 |
| Li---- | 42 | 26 | 55 | 79 | 12 | 32 |
| Mo--- | 670 | 410 | 290 | 360 | 30 | 10 |
| Ni---- | 1100 | 660 | 880 | 1200 | 110 | 30 |
| Pb--- | 22 | 8 | 20 | 25 | 7 | 10 |
| Sc---- | 8 | 6 | 9 | 8 | 3 | 6 |
| Sr---- | 550 | 270 | 830 | 890 | 1900 | 100 |
| Th---- | 4 | < 4 | < 4 | < 4 | < 4 | < 4 |
| V---- | 3900 | 2400 | 1500 | 1100 | 120 | 42 |
| Y---- | 280 | 58 | 450 | 270 | 450 | 6 |
| Zn---- | 7000 | 5200 | 3700 | 4800 | 790 | 43 |

**Tabla 4.** Rare earth elements in samples from the Phosphoria Formation from Conant Creek, Fontenelle Creek, Wheat Creek, and Lakeridge, Wyoming, and Mud Spring, Idaho. [All values in parts per million.]

| | Conant Creek | | | | | | | | | | Mud Spring | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-47 | P-46 | P-45 | P-44 | P-43 | P-42 | P-41 | P-40 | P-39 | P-38 | P-47 | P-44 | P-43 | P-41 | P-40 |
| La | 33 | 71 | 74 | 19 | 34 | 36 | 62 | 14 | 37 | 41 | 91 | 71 | 110 | 120 | 68 |
| Ce | 21 | 30 | 27 | 15 | 26 | 27 | 35 | 15 | 23 | 22 | 46 | 50 | 57 | 44 | 52 |
| Pr | 4.9 | 8.9 | 8.3 | 3 | 5.3 | 5.6 | 7.8 | 2.6 | 5.1 | 5.2 | 19 | 14 | 19 | 17 | 12 |
| Nd | 22 | 41 | 37 | 13 | 22 | 25 | 33 | 11 | 22 | 23 | 83 | 59 | 79 | 71 | 53 |
| Sm | 3.5 | 6.4 | 5.6 | 2.2 | 3.8 | 4.2 | 5.2 | 2 | 3.6 | 3.7 | 13 | 9.9 | 13 | 11 | 9.0 |
| Eu | 0.81 | 1.3 | 1.2 | 0.43 | 0.84 | 0.88 | 1.3 | 0.43 | 0.83 | 0.82 | 2.9 | 2 | 2.5 | 2.5 | 1.9 |
| Gd | 4.2 | 7.2 | 6.8 | 2.7 | 3.8 | 4.3 | 6.3 | 2 | 4.4 | 4.1 | 14 | 9.2 | 14 | 13 | 9.3 |
| Tb | 0.6 | 1.1 | 1 | 0.4 | 0.87 | 0.67 | 0.96 | 0.33 | 0.63 | 0.69 | 2.1 | 1.6 | 2.1 | 1.8 | 1.4 |
| Dy | 3.9 | 7.7 | 7.4 | 2.2 | 4 | 4.5 | 6 | 2.3 | 4.1 | 4.7 | 13 | 9.1 | 13 | 12 | 8.5 |
| Ho | 0.86 | 1.7 | 1.6 | 0.46 | 0.87 | 0.93 | 1.4 | 0.43 | 0.93 | 1 | 2.9 | 1.9 | 2.9 | 2.7 | 1.7 |
| Er | 2.4 | 5 | 4.7 | 1.4 | 2.7 | 3 | 3.9 | 1.5 | 2.8 | 2.8 | 9.2 | 5.7 | 9.3 | 7.9 | 5.1 |
| Tm | 0.35 | 0.67 | 0.63 | 0.2 | 0.35 | 0.37 | 0.52 | 0.19 | 0.41 | 0.41 | 1.2 | 0.72 | 1.2 | 1.0 | 0.8 |
| Yb | 2.2 | 5 | 4.7 | 1.5 | 2.5 | 2.8 | 3.7 | 1.6 | 2.7 | 3 | 8 | 5.5 | 8.2 | 7.4 | 4.4 |

| | Mud Spring | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-38 | P-35 | P-33 | P-31 | P-29 | P-27 | P-26 | P-25 | P-23 | P-22 | P-17 | P-16 | P-15 | P-14 | P-11 |
| La | 77 | 120 | 88 | 290 | 100 | 120 | 77 | 66 | 47 | 43 | 150 | 120 | 23 | 21 | 87 |
| Ce | 50 | 42 | 43 | 57 | 36 | 42 | 46 | 51 | 44 | 30 | 57 | 42 | 13 | 14 | 42 |
| Pr | 16 | 21 | 15 | 42 | 15 | 17 | 12 | 10 | 7.6 | 8 | 29 | 22 | 4.1 | 3.9 | 13 |
| Nd | 68 | 91 | 63 | 180 | 63 | 72 | 51 | 45 | 33 | 34 | 130 | 96 | 18 | 16 | 56 |
| Sm | 11 | 14 | 9.8 | 28 | 10 | 11 | 8.4 | 7.5 | 5.4 | 5.7 | 22 | 16 | 3 | 2.9 | 8.8 |
| Eu | 2.4 | 3.2 | 2.2 | 6.3 | 2.1 | 2.4 | 1.7 | 1.6 | 1.1 | 1.1 | 4.7 | 3.6 | 0.68 | 0.56 | 2 |
| Gd | 11 | 16 | 10 | 31 | 12 | 13 | 9.2 | 7.5 | 5.3 | 5.3 | 24 | 18 | 3.4 | 3.2 | 10 |
| Tb | 1.8 | 2.3 | 1.5 | 4.7 | 1.7 | 1.9 | 1.4 | 1.2 | 0.87 | 0.81 | 3.6 | 2.7 | 0.52 | 0.42 | 1.6 |
| Dy | 11 | 14 | 9.5 | 30 | 11 | 12 | 8.9 | 7.5 | 5.4 | 5.3 | 22 | 17 | 3.3 | 2.8 | 10 |
| Ho | 2.3 | 3.1 | 2.2 | 7.1 | 2.6 | 2.8 | 2.1 | 1.7 | 1.3 | 1.1 | 4.9 | 3.7 | 0.7 | 0.65 | 2.3 |
| Er | 6.9 | 8.8 | 6.8 | 22 | 7.5 | 8.6 | 6 | 5.1 | 3.9 | 3.2 | 14 | 11 | 2 | 2 | 6.8 |
| Tm | 0.92 | 1.1 | 0.93 | 2.6 | 0.99 | 1 | 0.73 | 0.65 | 0.55 | 0.43 | 2 | 1.5 | 0.25 | 0.23 | 0.95 |
| Yb | 6.1 | 8.3 | 6.4 | 19 | 7 | 7.6 | 5.6 | 4.4 | 3.7 | 3 | 13 | 9.7 | 2.1 | 1.7 | 6.3 |

| | Mud Spring | | | | | Fontenelle Creek | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-8 | P-8 | P-4 | P-2 | P-1 | E-4 | U-3 | U-1 | R-9 | R-6 | P-45 | P-43 | P-40 | P-39 | P-37 |
| La | 220 | 240 | 15 | 110 | 210 | 110 | 360 | 150 | 45 | 160 | 6.2 | 17 | 8.5 | 19 | 22 |
| Ce | 65 | 52 | 16 | 46 | 61 | 40 | 110 | 49 | 22 | 79 | 3.7 | 16 | 5.6 | 19 | 21 |
| Pr | 30 | 29 | 2.6 | 16 | 29 | 14 | 57 | 20 | 5.7 | 20 | 0.3 | 2.7 | 0.6 | 3 | 3.2 |
| Nd | 140 | 130 | 12 | 68 | 130 | 60 | 240 | 88 | 27 | 84 | 3.6 | 13 | 5.2 | 15 | 16 |
| Sm | 22 | 21 | 1.8 | 11 | 21 | 9.4 | 41 | 15 | 4.3 | 13 | 0.62 | 2.2 | 0.99 | 2.7 | 2.7 |
| Eu | 5.1 | 4.6 | 0.39 | 2.5 | 4.8 | 2.5 | 10 | 3.5 | 0.93 | 3.4 | 0.1 | 0.47 | 0.16 | 0.56 | 0.84 |
| Gd | 30 | 26 | 2 | 13 | 26 | 11 | 47 | 19 | 6 | 17 | 1 | 2.7 | 1 | 2.7 | 3 |
| Tb | 4.2 | 3.9 | 0.32 | 2 | 3.6 | 1.7 | 7.1 | 2.6 | 0.77 | 2.5 | 0.11 | 0.34 | 0.15 | 0.4 | 0.46 |
| Dy | 29 | 29 | 2.1 | 13 | 24 | 11 | 42 | 18 | 4.6 | 16 | 0.96 | 2.4 | 1.1 | 2.5 | 3.2 |
| Ho | 7.1 | 6.6 | 0.43 | 3.1 | 5.3 | 2.5 | 9.1 | 3.8 | 1.2 | 4.2 | 0.16 | 0.58 | 0.3 | 0.65 | 0.68 |
| Er | 23 | 22 | 1.3 | 9.5 | 16 | 7.1 | 26 | 11 | 3.4 | 11 | 0.65 | 1.8 | 0.67 | 1.9 | 2.2 |
| Tm | 3 | 3 | 0.15 | 1.3 | 2.1 | 0.91 | 3.5 | 1.4 | 0.44 | 1.5 | 0.06 | 0.23 | 0.12 | 0.24 | 0.26 |
| Yb | 21 | 20 | 1.4 | 8.3 | 13 | 6 | 19 | 8.1 | 2.8 | 7.7 | 0.53 | 1.5 | 0.57 | 1.7 | 1.7 |

| | Fontenelle Creek | | | | | | | | | | | | | Wheat Creek | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-32 | P-31 | P-25 | P-23 | P-21 | P-20 | P-19 | P-13 | P-12 | P-6 | P-7 | P-3 | P-1 | R-15 | R-9 |
| La | 330 | 70 | 150 | 37 | 140 | 72 | 26 | 85 | 27 | 200 | 95 | 210 | 220 | 160 | 120 |
| Ce | 83 | 55 | 54 | 49 | 100 | 74 | 37 | 28 | 22 | 62 | 25 | 42 | 52 | 40 | 54 |
| Pr | 42 | 11 | 18 | 8.8 | 23 | 11 | 4.2 | 9.6 | 3.9 | 23 | 10 | 23 | 29 | 15 | 14 |
| Nd | 190 | 46 | 76 | 41 | 100 | 49 | 17 | 44 | 17 | 98 | 43 | 99 | 130 | 66 | 62 |
| Sm | 31 | 8.7 | 11 | 8 | 18 | 8.7 | 2.9 | 6.4 | 2.6 | 14 | 5.8 | 13 | 18 | 9.5 | 9.3 |
| Eu | 7.4 | 1.9 | 2.4 | 1.6 | 4.5 | 1.8 | 0.59 | 1.5 | 0.63 | 3.2 | 1.3 | 3.5 | 4.4 | 2.3 | 1.8 |
| Gd | 44 | 9.7 | 13 | 7.3 | 20 | 7.9 | 2.5 | 8.1 | 2.9 | 16 | 7.5 | 18 | 22 | 13 | 12 |
| Tb | 6 | 1.4 | 1.9 | 1.3 | 3.1 | 1.4 | 0.45 | 1.2 | 0.44 | 2.5 | 1 | 2.7 | 3.1 | 1.7 | 1.7 |
| Dy | 39 | 8.7 | 12 | 7 | 19 | 8.2 | 2.6 | 8.1 | 2.8 | 17 | 6.9 | 18 | 21 | 12 | 11 |
| Ho | 10 | 2.1 | 2.9 | 1.5 | 4.5 | 1.8 | 0.59 | 1.8 | 0.84 | 4 | 1.8 | 4.6 | 4.6 | 2.9 | 2.7 |
| Er | 30 | 6.7 | 8.3 | 4.3 | 13 | 5.5 | 2.1 | 5.9 | 1.8 | 12 | 5.6 | 14 | 14 | 8.8 | 8.9 |
| Tm | 3.8 | 0.93 | 1.1 | 0.63 | 1.7 | 0.63 | 0.25 | 0.72 | 0.25 | 1.6 | 0.69 | 1.9 | 1.9 | 1.2 | 1.2 |
| Yb | 23 | 5.9 | 6.1 | 3.6 | 9.6 | 4 | 2 | 4.7 | 1.7 | 11 | 5.2 | 12 | 11 | 6.7 | 7.6 |

| | Wheat Creek | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | R-7 | R-6 | P-34 | P-30 | P-26 | P-22 | P-20 | P-16 | P-14 | P-11 | P-9 | P-7 | P-4 | P-3 | P-1 |
| La---- | 230 | 22 | 210 | 220 | 150 | 54 | 19 | 140 | 160 | 160 | 27 | 110 | 210 | 35 | 130 |
| Ce---- | 59 | 7.6 | 71 | 68 | 85 | 31 | 19 | 57 | 57 | 43 | 9.6 | 54 | 53 | 46 | 32 |
| Pr--- | 26 | 3.1 | 28 | 24 | 17 | 6.4 | 2.5 | 16 | 18 | 19 | 2.9 | 14 | 21 | 6.2 | 13 |
| Nd---- | 120 | 16 | 120 | 100 | 73 | 30 | 13 | 63 | 77 | 79 | 13 | 59 | 90 | 27 | 57 |
| Sm--- | 17 | 2.8 | 17 | 14 | 11 | 4.3 | 2.2 | 9.7 | 12 | 12 | 2.3 | 10 | 14 | 5.1 | 7.8 |
| Eu---- | 3.9 | 0.56 | 3.7 | 3.2 | 2.4 | 1.1 | 0.4 | 2.6 | 2.7 | 3.2 | 0.48 | 2.4 | 3.4 | 1 | 2.1 |
| Gd---- | 23 | 3.6 | 22 | 18 | 12 | 5.3 | 1.9 | 13 | 14 | 15 | 3.1 | 12 | 19 | 5 | 12 |
| Tb---- | 3.2 | 0.47 | 3 | 2.5 | 1.9 | 0.73 | 0.36 | 1.8 | 2.1 | 2.3 | 0.4 | 1.8 | 2.6 | 0.63 | 1.6 |
| Dy--- | 22 | 3.1 | 20 | 16 | 13 | 4.7 | 1.8 | 12 | 14 | 15 | 2.6 | 11 | 18 | 4.8 | 11 |
| Ho---- | 5.2 | 0.58 | 4.3 | 3.9 | 2.8 | 1 | 0.38 | 2.6 | 3.2 | 3.5 | 0.55 | 2.6 | 4.1 | 1 | 2.4 |
| Er---- | 16 | 1.9 | 12 | 12 | 8.2 | 3 | 1.3 | 7.8 | 9.8 | 11 | 1.8 | 7.8 | 13 | 3 | 8.3 |
| Tm--- | 2.3 | 0.2 | 1.6 | 1.8 | 1.2 | 0.46 | 0.22 | 1.1 | 1.3 | 1.6 | 0.25 | 1.2 | 1.9 | 0.47 | 1.2 |
| Yb---- | 13 | 1.4 | 9.2 | 10 | 6.7 | 2.3 | 1.5 | 6.7 | 8.2 | 10 | 1.6 | 6.6 | 12 | 3.1 | 7.8 |

| Wheat Creek | | Lakeridge | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Cw-11 | E-92C | US-91B | E-90A | E-89A | US-88C | TO-87B | TO-86D | TO-85A | TO-84B | RT-81A | TO-78C | RT-77 | RT-75A | F-74 |
| La---- | 88 | 11 | 55 | 20 | 44 | 39 | 16 | 11 | 33 | 19 | 50 | 20 | 87 | 340 | 32 |
| Ce---- | 41 | 5.2 | 25 | 8.0 | 18 | 16 | 7.7 | 9.0 | 27 | 10 | 20 | 12 | 48 | 110 | 17 |
| Pr--- | 8.7 | 2.1 | 10 | 2.8 | 6.4 | 6.5 | 2.4 | 1.9 | 5.6 | 3.0 | 5.9 | 2.9 | 13 | 50 | 4.5 |
| Nd---- | 36 | 8.4 | 41 | 10 | 25 | 25 | 9.5 | 8.1 | 21 | 11 | 22 | 11 | 47 | 200 | 17 |
| Sm--- | 6 | 1.6 | 7.5 | 1.8 | 4.4 | 4.6 | 1.8 | 1.4 | 3.9 | 2.0 | 3.5 | 1.9 | 7.8 | 33 | 3.0 |
| Eu---- | 1.6 | 0.34 | 1.4 | 0.47 | 1.2 | 0.86 | 0.37 | 0.29 | 0.77 | 0.42 | 0.98 | 0.35 | 1.9 | 6.8 | 0.60 |
| Gd---- | 7.9 | 1.8 | 8.9 | 2.2 | 5.3 | 5.3 | 2.1 | 1.6 | 4.3 | 2.2 | 4.5 | 2.2 | 9.0 | 38 | 4.1 |
| Tb---- | 1.1 | 0.24 | 1.3 | 0.32 | 0.75 | 0.76 | 0.29 | 0.21 | 0.62 | 0.34 | 0.66 | 0.31 | 1.4 | 5.6 | 0.60 |
| Dy--- | 7.3 | 1.7 | 7.7 | 2.1 | 4.8 | 5.0 | 2.0 | 1.5 | 4.1 | 2.5 | 4.8 | 2.0 | 8.5 | 35 | 3.7 |
| Ho---- | 1.6 | 0.39 | 1.7 | 0.50 | 1.1 | 1.2 | 0.48 | 0.32 | 0.91 | 0.57 | 1.1 | 0.49 | 2.0 | 7.7 | 0.87 |
| Er---- | 5.1 | 1.2 | 4.5 | 1.5 | 3.2 | 3.3 | 1.4 | 1.0 | 2.6 | 1.7 | 3.6 | 1.5 | 5.8 | 22 | 2.6 |
| Tm--- | 0.6 | 0.16 | 0.56 | 0.23 | 0.40 | 0.45 | 0.20 | 0.13 | 0.36 | 0.23 | 0.48 | 0.21 | 0.80 | 2.8 | 0.36 |
| Yb---- | 3.1 | 0.96 | 3.1 | 1.4 | 2.2 | 2.6 | 1.2 | 0.78 | 2.2 | 1.5 | 2.7 | 1.3 | 4.4 | 16 | 2.2 |

| | Lakeridge | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | F-73 | F-72B | F-71B | F-70E | F-69A | F-88A | F-65B | F-64A | LB-62A | F-58B | LS-57M | LB-57D | LS-56A | LS-55B | R-54C |
| La---- | 39 | 14 | 26 | 32 | 11 | 52 | 6.5 | 13 | 21 | 5.3 | 100 | 34 | 22 | 78 | 33 |
| Ce---- | 21 | 6.1 | 12 | 19 | 7.7 | 69 | 7.3 | 23 | 39 | 5.6 | 28 | 10 | 6.1 | 29 | 11 |
| Pr--- | 5.2 | 1.8 | 5.2 | 6.8 | 1.2 | 7.5 | 1.4 | 3.1 | 4.7 | 1.2 | 16 | 5.6 | 3.6 | 13 | 5.1 |
| Nd---- | 20 | 7.1 | 21 | 28 | 3.8 | 25 | 5.6 | 12 | 18 | 5.0 | 67 | 22 | 15 | 54 | 20 |
| Sm--- | 4.0 | 1.3 | 3.7 | 5.3 | 0.80 | 4.6 | 1.1 | 2.7 | 3.3 | 1.2 | 12 | 3.7 | 2.7 | 10 | 3.3 |
| Eu---- | 0.97 | 0.31 | 0.70 | 1.1 | 0.23 | 0.75 | 0.22 | 0.51 | 0.59 | 0.17 | 2.7 | 0.77 | 0.61 | 2.1 | 0.79 |
| Gd---- | 4.3 | 1.6 | 4.7 | 5.5 | 0.7 | 4.1 | 0.9 | 2.5 | 3.1 | 1.3 | 15 | 4.6 | 3.5 | 12 | 4.1 |
| Tb---- | 0.70 | 0.22 | 0.58 | 0.86 | 0.06 | 0.72 | 0.13 | 0.36 | 0.52 | 0.19 | 2.3 | 0.71 | 0.47 | 1.8 | 0.56 |
| Dy--- | 4.7 | 1.6 | 3.8 | 5.4 | 0.60 | 4.4 | 0.83 | 2.4 | 3.2 | 1.2 | 14 | 4.7 | 3.0 | 11 | 3.6 |
| Ho---- | 1.0 | 0.38 | 0.79 | 1.2 | 0.13 | 0.95 | 0.20 | 0.50 | 0.68 | 0.26 | 3.2 | 1.2 | 0.69 | 2.4 | 0.89 |
| Er---- | 3.1 | 1.1 | 2.1 | 3.1 | 0.36 | 3.1 | 0.50 | 1.5 | 1.9 | 0.71 | 9.0 | 3.6 | 1.9 | 6.7 | 2.5 |
| Tm--- | 0.42 | 0.18 | 0.29 | 0.40 | 0.05 | 0.49 | 0.07 | 0.21 | 0.31 | 0.09 | 1.2 | 0.58 | 0.24 | 0.82 | 0.35 |
| Yb---- | 2.7 | 1.1 | 1.7 | 2.2 | 0.27 | 3.2 | 0.38 | 1.3 | 1.8 | 0.55 | 6.1 | 4.0 | 1.3 | 4.4 | 2.1 |

| | Lakeridge | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | M-53B | M-52 | R-50F | M-48B | M-47 | M-45 | M-44A | M-42A | M-41 | M-40 | M-39B | M-36A | M-37A | M-36B | M-35A |
| La---- | 70 | 600 | 140 | 46 | 220 | 420 | 270 | 430 | 35 | 410 | 230 | 220 | 80 | 12 | 47 |
| Ce---- | 22 | 150 | 49 | 44 | 59 | 85 | 100 | 260 | 44 | 140 | 90 | 70 | 41 | 18 | 62 |
| Pr--- | 12 | 86 | 24 | 7.4 | 25 | 54 | 35 | 64 | 6.1 | 44 | 25 | 27 | 9.3 | 2.3 | 9.3 |
| Nd---- | 48 | 340 | 95 | 27 | 93 | 200 | 130 | 250 | 22 | 160 | 91 | 100 | 35 | 9.2 | 34 |
| Sm--- | 8.3 | 59 | 16 | 5.3 | 15 | 30 | 22 | 43 | 4.2 | 24 | 13 | 16 | 5.5 | 1.7 | 6.3 |
| Eu---- | 1.7 | 13 | 3.2 | 0.85 | 3.7 | 5.4 | 5.1 | 9.3 | 0.64 | 5.7 | 3.2 | 3.3 | 1.2 | 0.30 | 1.1 |
| Gd---- | 10 | 76 | 19 | 4.9 | 18 | 37 | 26 | 48 | 4.0 | 32 | 17 | 20 | 6.4 | 1.4 | 5.6 |
| Tb---- | 1.5 | 11 | 2.8 | 0.76 | 2.6 | 5.5 | 3.9 | 7.1 | 0.67 | 4.6 | 2.5 | 3.0 | 0.91 | 0.20 | 0.89 |
| Dy--- | 9.5 | 68 | 17 | 4.7 | 16 | 35 | 25 | 42 | 4.3 | 29 | 17 | 19 | 6.2 | 1.5 | 5.6 |
| Ho---- | 2.3 | 16 | 3.8 | 1.0 | 3.7 | 8.5 | 5.7 | 9.0 | 0.95 | 7.0 | 4.0 | 4.7 | 1.5 | 0.32 | 1.2 |
| Er---- | 6.7 | 45 | 10 | 3.0 | 11 | 24 | 16 | 25 | 2.9 | 20 | 12 | 13 | 4.6 | 0.98 | 3.5 |
| Tm--- | 0.89 | 5.7 | 1.2 | 0.48 | 1.4 | 3.1 | 2.1 | 3.0 | 0.44 | 2.6 | 1.8 | 1.8 | 0.65 | 0.14 | 0.51 |
| Yb---- | 4.9 | 31 | 6.5 | 3.0 | 7.5 | 17 | 12 | 16 | 2.7 | 14 | 9.1 | 11 | 3.9 | 0.94 | 3.2 |

| Sample | | | | | | | | Lakeridge | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | M-34A | M-33A | M-32A | M-31A | M-30A | M-29A | M-28A | M-27B | M-25 | M-24 | M-23B | M-22B | M-21A | M-20B | M-18 |
| La---- | 73 | 78 | 54 | 28 | 71 | 190 | 110 | 10 | 60 | 74 | 8.7 | 47 | 160 | 130 | 160 |
| Ce---- | 40 | 72 | 44 | 22 | 43 | 41 | 42 | 13 | 47 | 33 | 5.3 | 20 | 30 | 110 | 46 |
| Pr--- | 7.6 | 14 | 8.0 | 4.5 | 10 | 19 | 11 | 1.9 | 9.4 | 8.9 | 1.2 | 6.2 | 16 | 20 | 19 |
| Nd---- | 27 | 50 | 28 | 17 | 40 | 73 | 44 | 7.2 | 35 | 34 | 4.6 | 23 | 62 | 73 | 72 |
| Sm--- | 4.3 | 8.8 | 4.8 | 3.0 | 6.9 | 11 | 7.0 | 1.5 | 6.0 | 5.5 | 0.88 | 3.8 | 9.5 | 13 | 11 |
| Eu---- | 0.88 | 1.9 | 0.86 | 0.65 | 1.4 | 2.4 | 1.5 | 0.26 | 1.1 | 1.2 | 0.17 | 0.74 | 2.1 | 3.0 | 2.1 |
| Gd---- | 4.6 | 8.7 | 4.4 | 3.1 | 7.4 | 14 | 7.9 | 1.3 | 5.9 | 6.0 | 0.8 | 4.2 | 12 | 14 | 13 |
| Tb---- | 0.70 | 1.4 | 0.63 | 0.46 | 1.1 | 2.1 | 1.2 | 0.18 | 0.86 | 0.92 | 0.11 | 0.61 | 2.0 | 2.2 | 1.9 |
| Dy--- | 4.6 | 8.4 | 3.8 | 2.9 | 6.9 | 14 | 7.7 | 1.2 | 5.4 | 5.7 | 0.80 | 4.1 | 13 | 14 | 13 |
| Ho---- | 1.1 | 1.8 | 0.88 | 0.68 | 1.6 | 3.5 | 1.9 | 0.26 | 1.2 | 1.4 | 0.17 | 0.99 | 3.4 | 3.1 | 3.1 |
| Er---- | 3.3 | 4.8 | 2.7 | 1.9 | 4.6 | 10 | 5.7 | 0.82 | 3.5 | 4.4 | 0.57 | 2.8 | 11 | 8.8 | 9.3 |
| Tm--- | 0.46 | 0.63 | 0.37 | 0.26 | 0.62 | 1.4 | 0.79 | 0.11 | 0.50 | 0.60 | 0.07 | 0.40 | 1.4 | 1.1 | 1.2 |
| Yb---- | 2.7 | 3.7 | 2.4 | 1.6 | 3.9 | 8.1 | 4.7 | 0.73 | 3.1 | 3.7 | 0.44 | 2.5 | 8.6 | 6.5 | 7.6 |

| | | | Lakeridge | | | |
|---|---|---|---|---|---|---|
| Sample | M-17 | M-16 | M-15A | M-14 | M-12B | WS-11D |
| La---- | 190 | 42 | 330 | 140 | 270 | 20 |
| Ce---- | 42 | 31 | 64 | 35 | 60 | 34 |
| Pr--- | 21 | 7.4 | 37 | 22 | 48 | 3.9 |
| Nd---- | 79 | 29 | 140 | 85 | 190 | 14 |
| Sm--- | 12 | 5.2 | 20 | 15 | 33 | 2.5 |
| Eu---- | 2.6 | 1.0 | 4.2 | 3.0 | 7.0 | 0.40 |
| Gd---- | 16 | 5.3 | 25 | 18 | 38 | 2.1 |
| Tb---- | 2.4 | 0.84 | 3.7 | 2.6 | 5.5 | 0.31 |
| Dy--- | 15 | 5.3 | 25 | 17 | 33 | 2.1 |
| Ho---- | 3.9 | 1.2 | 6.3 | 4.2 | 7.5 | 0.44 |
| Er---- | 12 | 3.6 | 19 | 13 | 21 | 1.3 |
| Tm--- | 1.6 | 0.49 | 2.6 | 1.7 | 2.6 | 0.21 |
| Yb---- | 9.9 | 3.0 | 16 | 11 | 14 | 1.3 |

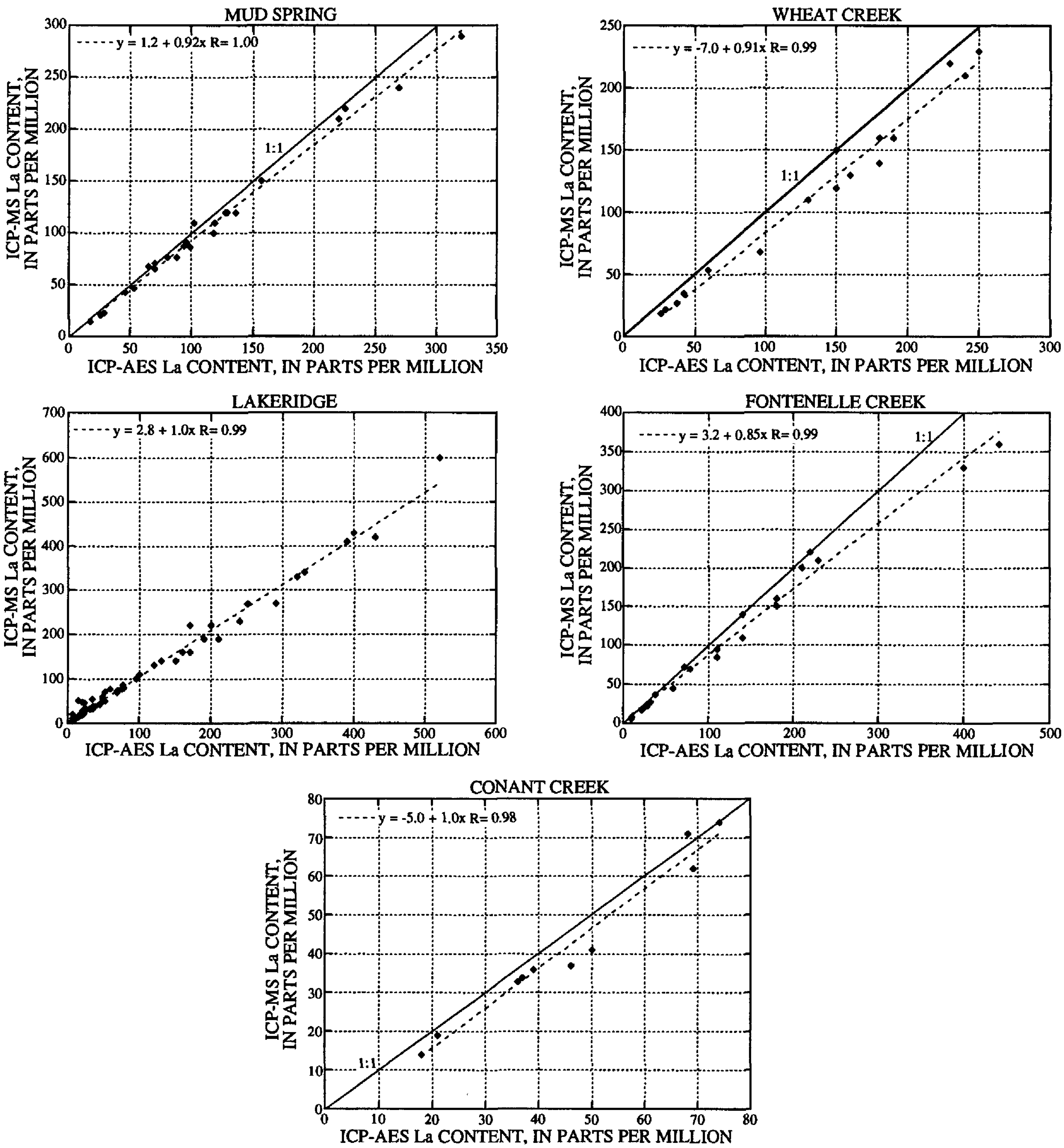



Figure 4. Graphs comparing La content analyzed by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) and by inductively coupled plasma-mass spectroscopy (ICP-MS). Graphs include line of best fit, equation for line of best fit, correlation coefficient (R values) and the one-to-one line (the solid line).

## CONSTANCY OF COMPOSITION FOR ROCK COMPONENTS

The components are assumed to have constant composition within a section. Simple x-y plots can demonstrate their constancy of composition. Our interpretation, if two elements of a graph strongly correlate and extrapolate to the origin, is 1) those two elements are almost entirely in that one component, 2) their element to element ratio in that component is relatively constant, and, therefore, the general composition of the component is also constant.

X-y plots, in which the data scatter above a well-defined minimum line that extends to the origin, indicate that one element is entirely in one component and the other element is primarily in the same component, but is also in one or more other components. We interpret the minimum line to represent a constant element to element ratio in the component they have in common, a good indication that the component itself has constant composition. We assume that the data which make up the minimum line represent samples composed of only one component. Given the ubiquitous distribution of all the components, this assumption is not likely valid. Another problem with this interpretation is that it doesn't account for the error in the analyses, which is 5 to 10 percent. Despite these problems the points must at least approach this condition (of both being solely in one component) in order to form a line.

These graphs are used to check variations in component composition between sections.

The detrital component is defined as the sum of all minerals of terrigenous origin, and is uniquely defined by $Al_2O_3$ (Isaacs, 1980). Graphs of $K_2O$, $TiO_2$ and $Fe_2O_3$ versus $Al_2O_3$ are used to evaluate the composition of the detrital component (fig. 5). A strong correlation exists within each section between $Al_2O_3$ and both $K_2O$ and $TiO_2$. The correlation coefficients for the $K_2O$-$Al_2O_3$ graph range from $R = 0.96$ to 0.99, except Mud Spring, for which $R = 0.87$. The correlation coefficients for $TiO_2$ and $Al_2O_3$ range from $R = 0.93$ to 0.97, except Mud Spring, for which $R = 0.79$. The $Fe_2O_3$-$Al_2O_3$ graph shows a well defined minimum line. All the graphs support the idea that 1) these elements are almost entirely in the detrital component and 2) relatively constant composition exists within each section. $Fe_2O_3$ data, which scatters above a minimum line, must be in another component such as pyrite or iron oxide.

Small differences in composition in the detrital component exist between sections. The most pronounced difference is represented by the $K_2O/Al_2O_3$ ratio (0.62), for Conant Creek, the easternmost section (fig. 5). It is significantly higher than at the other locations, whose $K_2O/Al_2O_3$ ratios range from 0.23 to 0.31. Small differences in the $TiO_2$ content exist between sections , represented by the $TiO_2/Al_2O_3$ ratio, which ranges from 0.018 to 0.044 (fig. 5). A couple of factors possibly cause these differences. (1) The proportions of the minerals which compose the detrital component might vary as a function of distance from source. (2) The composition of the minerals that comprise the detrital component could vary as a result of different sources (Peterson, 1980). Or (3) it could be analytical error. It is probably a result of a combination of these factors. However the variations are small.

Geologic evidence supports a constant terrigenous composition. Paleogeographic reconstructions of the area in which the Phosphoria Formation was deposited remained relatively unchanged for at least 10 m.y. years and continued unchanged into the Triassic with the depositon of the Dinwoody Formation (McKelvey, 1959). The only difference between the two formations was the lack of a significant biogenic input during the deposition of the Dinwoody (Peterson, 1980). The Phosphoria Formation, as was mentioned earlier, had a very low sedimentation rate. This was the result of being surrounded by other basins. The only sources of terrigenous detritus was the Antler Orogenic belt to the west, which had been eroded to low relief by Permian time (Cook, 1988), and the Lemhi uplift to the north, the source of the Shedhorn Sandstone (Peterson, 1980).

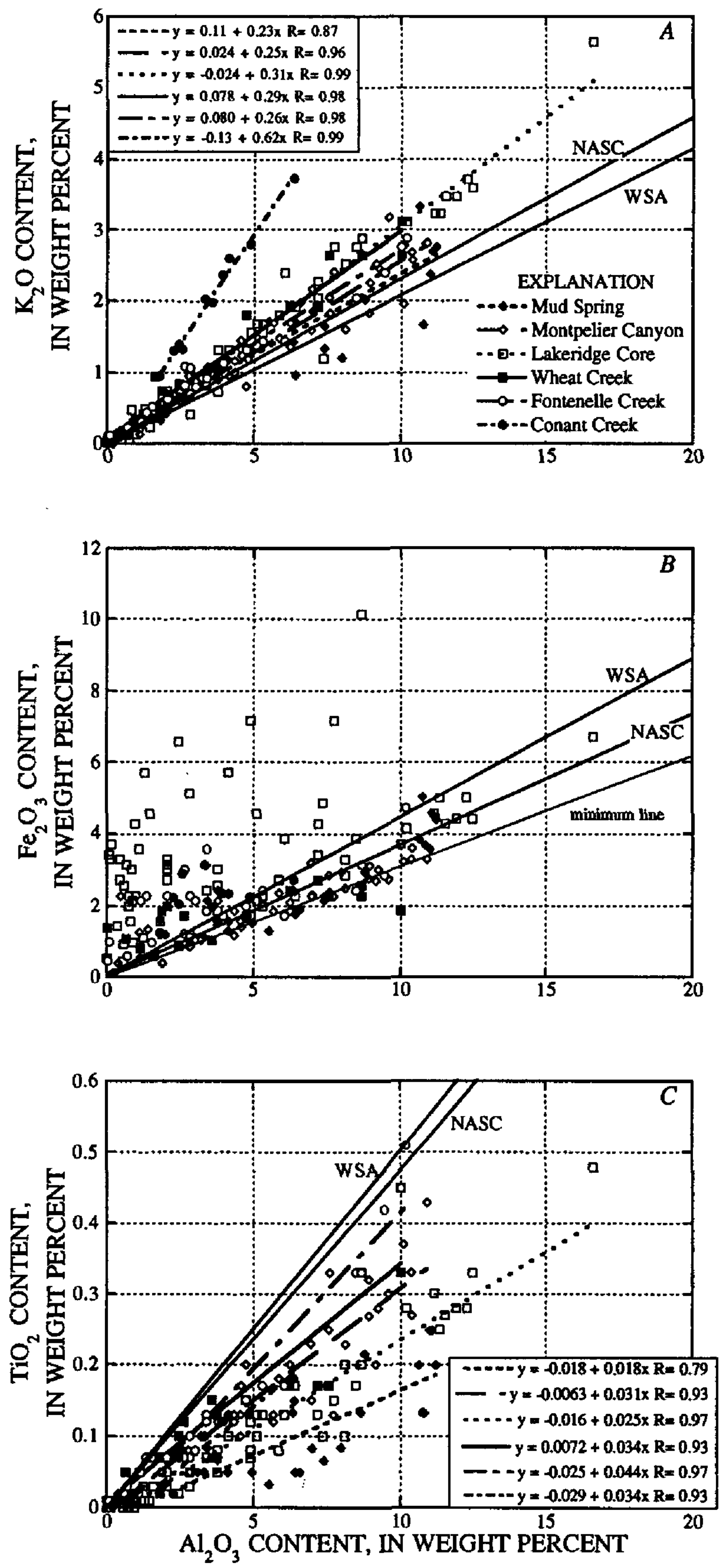



Figure 5. $TiO_2$ (*A*), $Fe_2O_3$ (*B*), and $K_2O$ (*C*) versus $Al_2O_3$ content, as determined by inductively coupled plasma-atomic emission spectroscopy. The line for the world shale average (WSA) and North American shale composite (NASC) are shown for comparison purposes. Legend shown in figure 5*A*. Note the $K_2O$ content at Conant Creek is higher than at all other sections and the Lakeridge samples have excess iron which scatters above the minima.

The graph of CaO versus $P_2O_5$, used to evaluate constancy of apatite composition, shows a well-defined minimum, which intersects the origin (fig. 6). $P_2O_5$ in the apatite fraction dominates the total $P_2O_5$ inventory in all samples. The scatter above the minimum is attributed to CaO in dolomite and calcite, and less so to CaO in the detrital component. The minimum line is essentially the same as the line representing the $CaO/P_2O_5$ ratio in stoichiometric apatite (McClellan and Lehr, 1969), an indication that the apatite component is clearly the dominant CaO-containing component in some of the rocks and that the composition of apatite is constant.

The MgO versus $CO_2$ graph shows most of the data along the line of stoichiometric dolomite ($MgCa(CO_3)_2$), demonstrating that the dolomite composition at all locations is relatively constant (fig. 7*A*). A few samples from Montpelier Canyon are exceptions. Their $CaO/CO_2$ and $MgO/CO_2$ ratios indicate they contain calcite, rather than dolomite.

Scatter of the Lakeridge data is interpreted as a result of a systematic analytical error. Data above the dolomite line were one analytical batch and those below the line another batch. The difference in MgO analyses between batches is confirmed by 35 samples that were analyzed by both XRF and ICP. The graph of ICP-AES versus XRF MgO data shows that the ICP-AES data is 13 percent lower than the XRF data (fig. 3*D*).

The graph of CaO and $CO_2$ sample data was considered as a possible gauge for the composition of calcite (fig. 7*B*). The samples with significant amounts of $CO_2$ plot either above the line for stoichiometric dolomite or below the line for stoichiometric calcite, except for the few samples from Montpelier Canyon. This observation in conjunction with the $MgO/CO_2$ graph, indicates that the bulk of the carbonates at these five sections is dolomite. As a result, calcite could not be evaluated for constancy of composition. It was assumed to be stoichiometric ($CaCO_3$), with insignificant MgO and minor-element substitution (Gulbrandsen, 1960b).

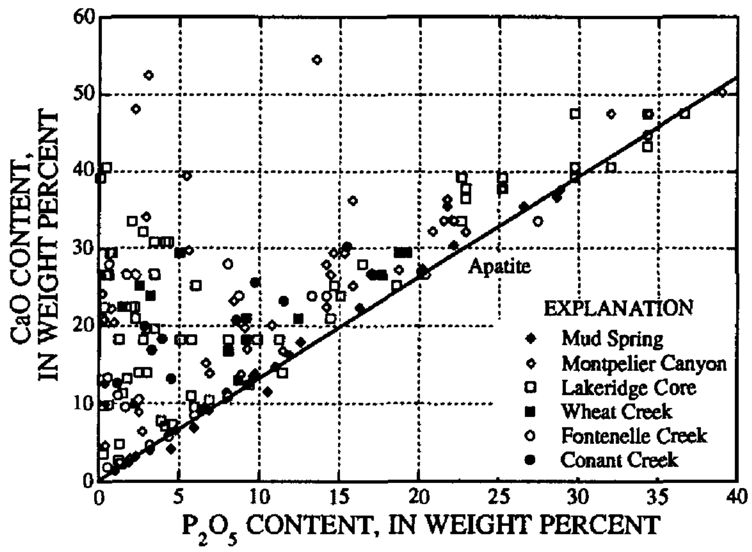



Figure 6. CaO versus $P_2O_5$ content, as determined by inductively coupled plasma-atomic emission spectroscopy.. The line represents the ratio of CaO:$P_2O_5$ in stoichiometric apatite.

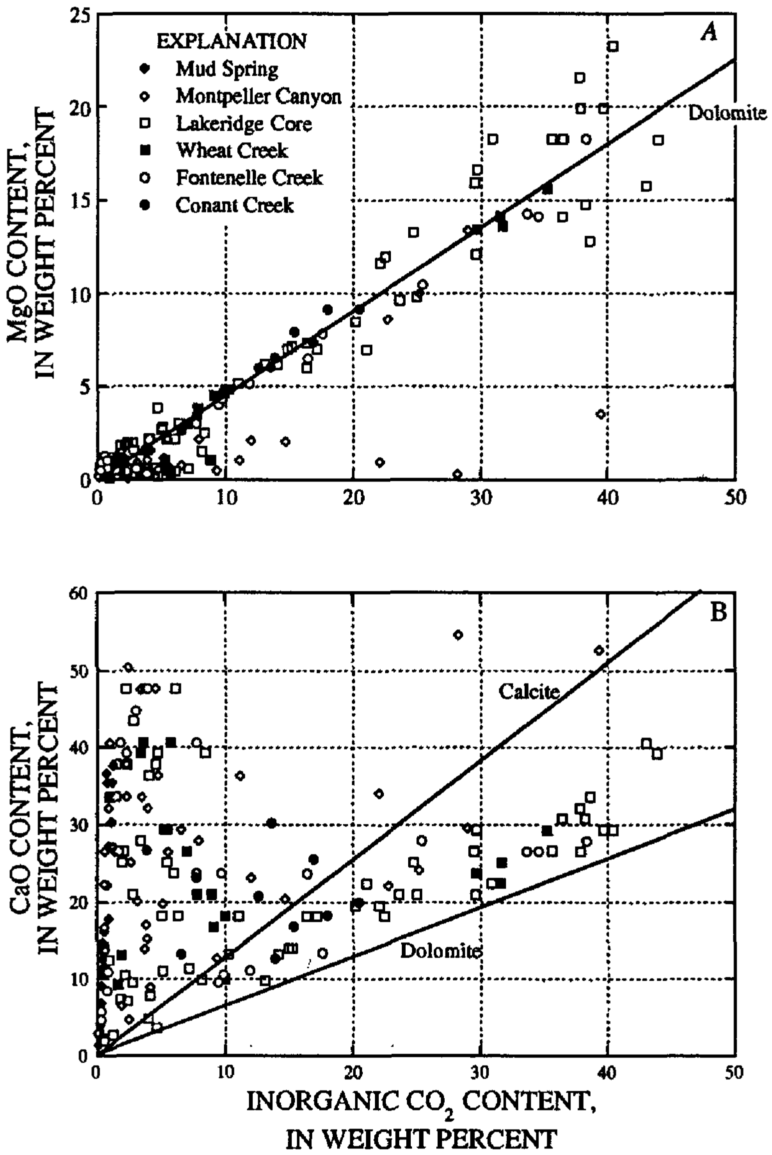



Figure 7. MgO (*A*,) and CaO (*B*) versus inorganic-$CO_2$ content. Legend shown in figure 7*A*. In figure 7*A*, the line represents the MgO:$CO_2$ ratio in dolomite with a composition of $MgCa(CO_3)_2$ and in figure 7*B*, the lines represent the CaO:$CO_2$ ratio in dolomite and calcite with a composition of: $MgCa(CO_3)_2$ and $CaCO_3$, respectively.

The composition of organic matter could not be checked, but published accounts suggest a relatively constant composition. The average C content of kerogen was 68.5 weight percent with a $\sigma = 6.0$ (Powell and others, 1975).

By graph or by published accounts, the components of the Phosphoria Formation are relatively constant in composition. Even the detrital component which is composed of several minerals shows little variation, possibly a reflection of relatively constant depositional conditions for 10 million years.

## PROPORTIONALITY CONSTANTS FOR ROCK COMPONENTS

Rock components were calculated using the formulas in table 5. The formulas differ slightly from those previously used for the Montpelier Canyon section (Medrano and Piper, 1992). These changes reflect the larger data base. The new proportionality constants were determined through an iterative process, whereby each calculated component was plotted against the sum of the components with the aim of obtaining closure for the sum of components to 100 percent and a random distribution of each component about 100 percent. The changes from the previous calculations include the following:

Table 5. Formulas used to calculate the normative components.

| Component | Formula |
|---|---|
| Detrital component | 6.0 x $Al_2O_3$ |
| Dolomite | (MgO - 0.07 x $Al_2O_3$) / 0.22 |
| Calcite | (CaO - 0.15 x $Al_2O_3$ - 0.304 x Dolomite - 0.555 x Apatite) / 0.56 |
| Biogenic silica | $SiO_2$ - 3.5 x $Al_2O_3$ |
| Apatite | ($P_2O_5$ - 0.01 x $Al_2O_3$) / 0.41 |
| Organic matter | Organic C x 1.4 |
| Calculated $CO_2$ | 0.48 x Dolomite + 0.01 x Apatite + 0.44 x Calcite |

1) The MgO and CaO content in the detrital component is 1.2 and 1.4 weight percent lower, respectively.

2) The $Al_2O_3$/detrital component proportionality constant is reduced from 6.4 to 6.0.

3) The formula for dolomite from the Lakeridge core was adjusted to account for a systematic analytical error in the MgO ICP data, as mentioned earlier. They are: (MgO - 0.1 x $Al_2O_3$) / 0.27, if the $MgO/CO_2$ ratio > 0.48; (MgO - 0.1 x $Al_2O_3$) / 0.25, if 0.48 ≥ $MgO/CO_2$ ratio > 0.41; and (MgO - 0.1 x $Al_2O_3$) / 0.23, if the $MgO/CO_2$ ratio ≤ 0.41. At Mud Spring there was no calcite and ≤ 2.3 weight percent dolomite.

4) The $SiO_2$:$Al_2O_3$ ratio in the detrital component, the proportionality constant in the formula for biogenic silica (table 5), was reduced from 3.75 to 3.5. The effect is to increase the biogenic silica.

5) The organic carbon/organic matter proportionality constant is reduced from 1.7 to 1.4. This change is based on chemical analyses of organic matter (kerogen) in Phosphoria Formation from published literature (Powell and others, 1975).

The results are listed in table 6 and are presented as bar graphs (fig. 8) to allow for comparison of the five locations.

Figure 8. Bar graphs showing calculated abundance of the terrigenous component, dolomite, calcite, biogenic/diagenetic silica, apatite and organic matter in each sample analyzed for all the sections; Mud Spring (*A*), Conant Creek (*B*), Wheat Creek (*C*), Fontenelle Creek (*D*), Lakeridge (*E*). Legend is given in figure 8*A*.

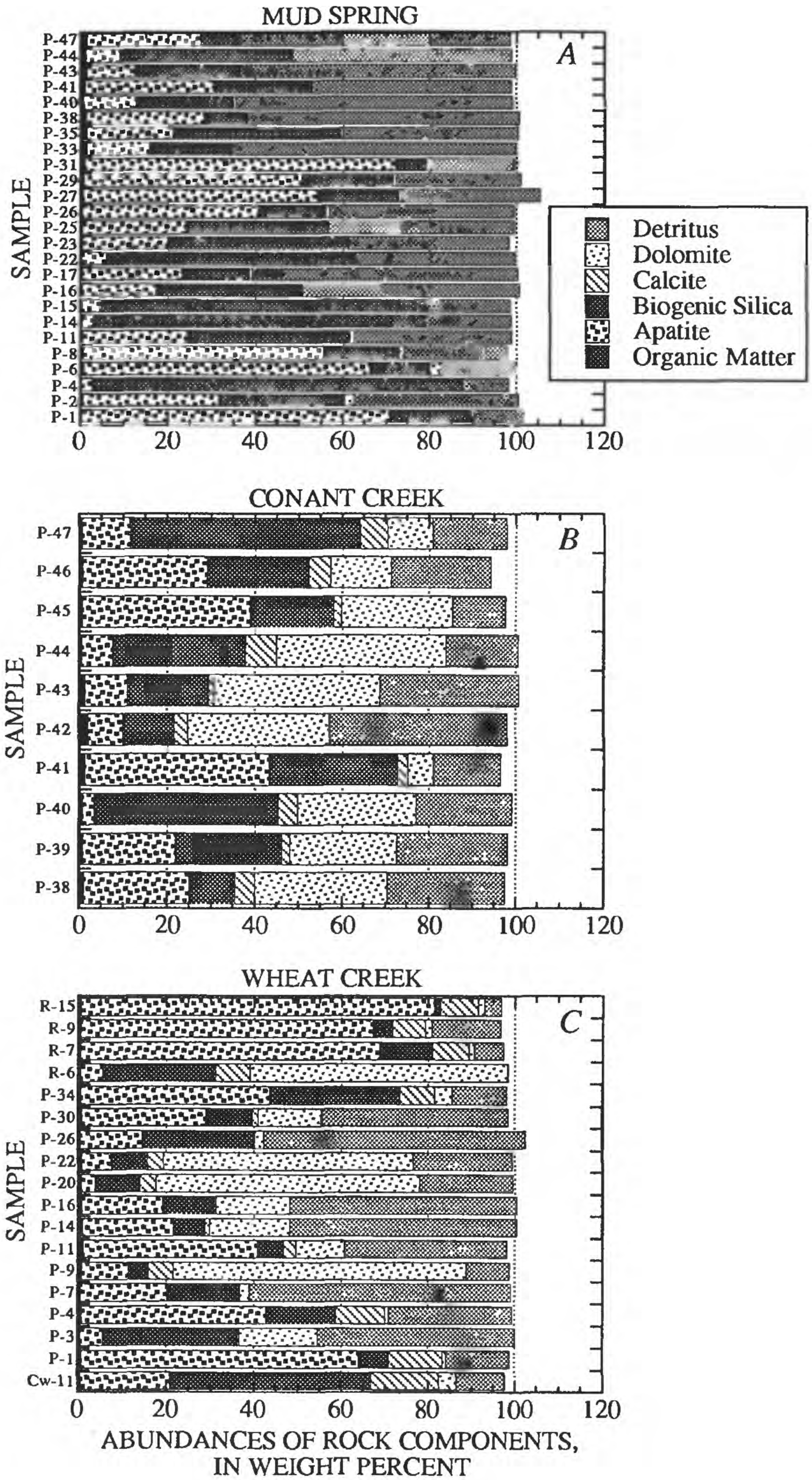

MUD SPRING
A
P-47
P-44
P-43
P-41
P-40
P-38
P-35
P-33
P-31
P-29
P-27
P-26
P-25
P-23
P-22
P-17
P-16
P-15
P-14
P-11
P-8
P-6
P-4
P-2
P-1
SAMPLE
0 20 40 60 80 100 120
Detritus
Dolomite
Calcite
Biogenic Silica
Apatite
Organic Matter
CONANT CREEK
B
P-47
P-46
P-45
P-44
P-43
P-42
P-41
P-40
P-39
P-38
SAMPLE
0 20 40 60 80 100 120
WHEAT CREEK
C
R-15
R-9
R-7
R-6
P-34
P-30
P-26
P-22
P-20
P-16
P-14
P-11
P-9
P-7
P-4
P-3
P-1
Cw-11
SAMPLE
0 20 40 60 80 100 120
ABUNDANCES OF ROCK COMPONENTS,
IN WEIGHT PERCENT

Figure 8

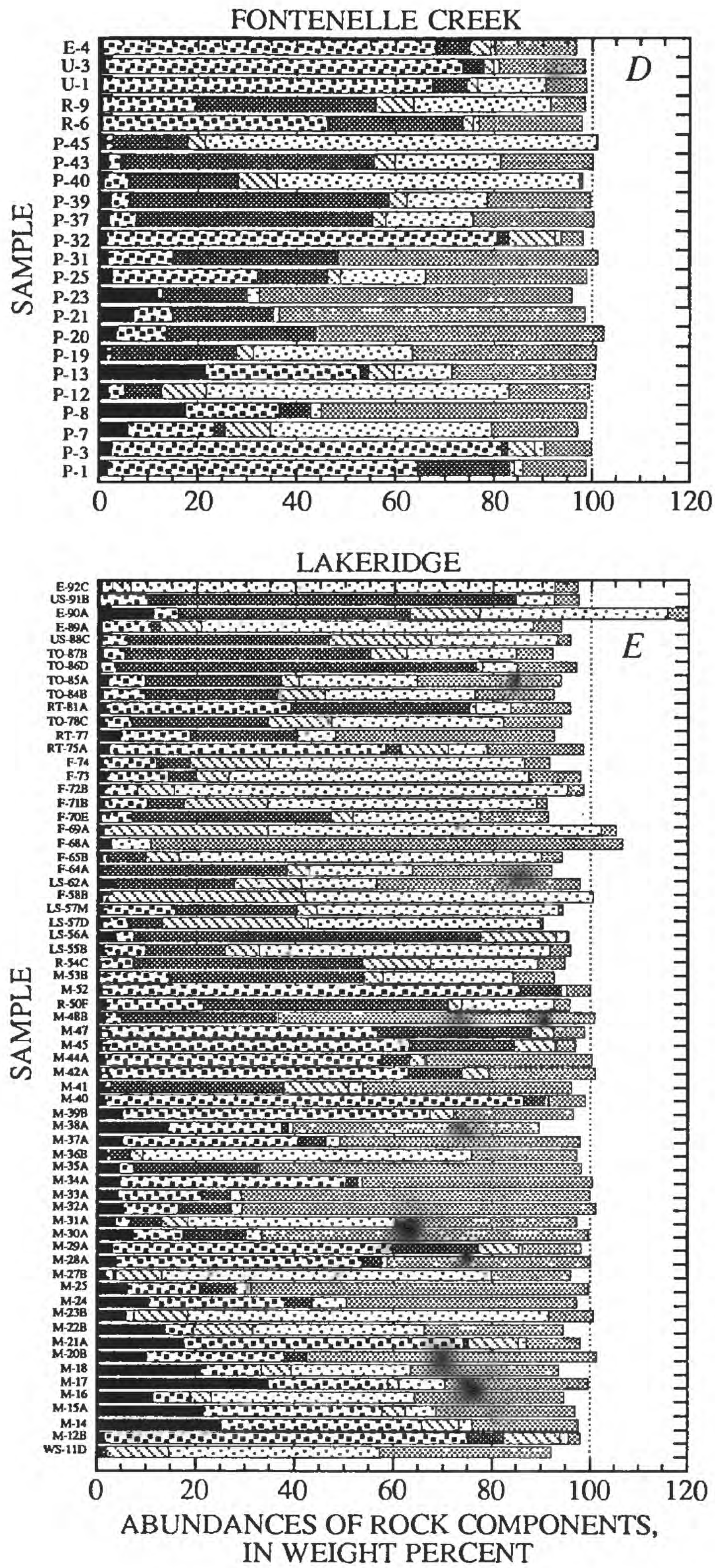



Figure 8. continued

Table 6. Component abundances in samples of the Phosphoria Formation from five sections: Conant Creek, Mud Spring, Fontenelle Creek, Wheat Creek and Lakeridge

[All values in weight percent]

Conant Creek

| Sample | Detrital component | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Total |
|---|---|---|---|---|---|---|---|
| P-47 | 18 | 11 | 6.1 | 53 | 11 | 0.6 | 99 |
| P-46 | 24 | 15 | 4.8 | 23 | 28 | 0.8 | 96 |
| P-45 | 13 | 27 | 1.5 | 19 | 38 | 0.7 | 99 |
| P-44 | 17 | 41 | 6.2 | 30 | 6.8 | 0.6 | 102 |
| P-43 | 33 | 40 | 0.3 | 18 | 9.5 | 1.4 | 103 |
| P-42 | 43 | 34 | 2.3 | 12 | 7.8 | 2.1 | 100 |
| P-41 | 16 | 6.2 | 2.6 | 30 | 42 | 1.3 | 97 |
| P-40 | 23 | 28 | 3.6 | 42 | 2.5 | 0.8 | 100 |
| P-39 | 27 | 26 | 1.3 | 24 | 21 | 0.9 | 100 |
| P-38 | 28 | 32 | 3.8 | 11 | 24 | 1.2 | 99 |

Mud Spring

| Sample | Detrital component | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Total |
|---|---|---|---|---|---|---|---|
| P-47 | 65 | 0 | 0 | 9.3 | 25 | 1.7 | 101 |
| P-44 | 53 | 0.4 | 0 | 39 | 7.5 | 1.4 | 101 |
| P-43 | 66 | 0.3 | 0 | 24 | 11 | 1.6 | 102 |
| P-41 | 48 | 0 | 0 | 22 | 29 | 1.3 | 100 |
| P-40 | 67 | 0.5 | 0 | 22 | 11 | 0.9 | 102 |
| P-38 | 65 | 0.2 | 0 | 9.7 | 27 | 1.4 | 103 |
| P-35 | 42 | 0.5 | 0 | 38 | 19 | 1.5 | 102 |
| P-33 | 67 | 0.5 | 0 | 19 | 14 | 1.5 | 102 |
| P-31 | 20 | 1.3 | 0 | 7.0 | 70 | 1.1 | 100 |
| P-29 | 30 | 1.0 | 0 | 21 | 49 | 0.8 | 102 |
| P-27 | 33 | 0.8 | 0 | 19 | 53 | 0.7 | 106 |
| P-26 | 44 | 1.0 | 0 | 16 | 39 | 0.6 | 101 |
| P-25 | 44 | 0.3 | 0 | 32 | 23 | 0.5 | 101 |
| P-23 | 38 | 0 | 0 | 42 | 19 | 0.5 | 100 |
| P-22 | 38 | 0.5 | 0 | 57 | 5.4 | 0.4 | 101 |
| P-17 | 64 | 0.6 | 0 | 15 | 22 | 0.5 | 103 |
| P-16 | 52 | 0.4 | 0 | 33 | 16 | 0.6 | 103 |
| P-15 | 23 | 0 | 0 | 72 | 4.5 | 0.5 | 99 |
| P-14 | 21 | 0.3 | 0 | 76 | 2.3 | 0.5 | 100 |
| P-11 | 38 | 0.9 | 0 | 37 | 23 | 0.6 | 100 |
| P-8 | 25 | 1.1 | 0 | 18 | 54 | 0.7 | 98 |
| P-6 | 19 | 2.3 | 0 | 14 | 65 | 0.8 | 100 |
| P-4 | 11 | 0.2 | 0 | 85 | 2.4 | 0.3 | 99 |
| P-2 | 39 | 2.3 | 0 | 29 | 31 | 0.7 | 102 |
| P-1 | 12 | 0.4 | 0 | 19 | 70 | 0.4 | 102 |

Table 6. Continued

Fontenelle Creek

| Sample | Detrital component | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Total |
|---|---|---|---|---|---|---|---|
| E-4 | 16 | 1.2 | 0 | 7.0 | 72 | 0.8 | 97 |
| U-3 | 17 | 1.1 | 0 | 4.4 | 78 | 1.2 | 102 |
| U-1 | 8.0 | 15 | 0 | 7.0 | 73 | 0.7 | 103 |
| R-9 | 6.9 | 29 | 5.4 | 36 | 21 | 0.7 | 100 |
| R-6 | 20 | 1.3 | 0 | 28 | 50 | 0.7 | 99 |
| P-45 | 0.2 | 83 | 3.4 | 15 | 1.5 | 1.5 | 105 |
| P-43 | 18 | 22 | 4.3 | 51 | 2.7 | 2.0 | 101 |
| P-40 | 0.5 | 64 | 7.1 | 22 | 5.6 | 1.1 | 101 |
| P-39 | 20 | 17 | 3.2 | 52 | 3.9 | 2.5 | 100 |
| P-37 | 24 | 18 | 2.0 | 48 | 6.0 | 2.2 | 100 |
| P-32 | 4.3 | 1.3 | 0 | 2.5 | 89 | 1.6 | 99 |
| P-31 | 51 | 0.1 | 0 | 33 | 14 | 1.9 | 101 |
| P-25 | 32 | 18 | 0 | 14 | 32 | 2.8 | 99 |
| P-23 | 61 | 2.6 | 0 | 17 | 1.1 | 12 | 94 |
| P-21 | 60 | 1.1 | 0 | 20 | 7.6 | 7.3 | 97 |
| P-20 | 57 | 0.0 | 0 | 30 | 10 | 3.7 | 101 |
| P-19 | 36 | 34 | 3.0 | 25 | 1.1 | 1.6 | 101 |
| P-13 | 28 | 12 | 0.5 | 1.6 | 34 | 22 | 99 |
| P-12 | 16 | 64 | 8.0 | 7.5 | 4.1 | 2.0 | 102 |
| P-8 | 52 | 2.1 | 0 | 6.4 | 19 | 18 | 98 |
| P-7 | 17 | 47 | 4.6 | 2.4 | 20 | 6.1 | 96 |
| P-3 | 9.2 | 2.1 | 0 | 1.3 | 84 | 2.7 | 99 |
| P-1 | 12 | 1.8 | 0 | 19 | 67 | 1.9 | 102 |

Wheat Creek

| Sample | Detrital component | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Total |
|---|---|---|---|---|---|---|---|
| R-15 | 4.0 | 1.4 | 0 | 1.4 | 89 | 0.6 | 97 |
| R-9 | 16 | 1.5 | 0 | 4.5 | 73 | 0.5 | 95 |
| R-7 | 6.8 | 1.2 | 0 | 12 | 78 | 0.5 | 99 |
| R-6 | 0.1 | 62 | 5.3 | 26 | 6.1 | 0.6 | 100 |
| P-34 | 12 | 4.2 | 3.2 | 30 | 47 | 0.6 | 97 |
| P-30 | 43 | 15 | 0 | 11 | 30 | 0.9 | 100 |
| P-26 | 60 | 2.2 | 0 | 26 | 15 | 0.4 | 104 |
| P-22 | 23 | 60 | 1.3 | 8.3 | 7.7 | 0.8 | 101 |
| P-20 | 22 | 63 | 1.5 | 10 | 3.4 | 0.7 | 100 |
| P-16 | 52 | 18 | 0 | 12 | 19 | 0.8 | 102 |
| P-14 | 52 | 19 | 0 | 7.3 | 22 | 1.1 | 102 |
| P-11 | 37 | 12 | 0 | 6.0 | 43 | 1.2 | 99 |
| P-9 | 10 | 70 | 1.7 | 4.5 | 12 | 0.8 | 100 |
| P-7 | 60 | 2.2 | 0 | 17 | 21 | 0.6 | 101 |
| P-4 | 28 | 0.8 | 5.5 | 16 | 46 | 0.8 | 97 |
| P-3 | 45 | 19 | 0.5 | 31 | 5.4 | 0.6 | 101 |
| P-1 | 15 | 0.9 | 0 | 7.0 | 73 | 0.9 | 96 |
| Cw-11 | 11 | 4.2 | 13 | 46 | 22 | 0.6 | 97 |

Table 6. Continued

Lakeridge

| Sample | Detrital component | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Total |
|---|---|---|---|---|---|---|---|
| E-92C | 4.9 | 86 | 3.7 | 0 | 2.0 | 0.9 | 97 |
| US-91B | 5.2 | 7.7 | 0.2 | 75 | 9.5 | 0.5 | 98 |
| E-90A | 4.4 | 38 | 14 | 47 | 4.7 | 11 | 120 |
| E-89A | 5.9 | 67 | 8.3 | 1.8 | 10 | 0.8 | 94 |
| US-88C | 2.7 | 26 | 21 | 41 | 5.2 | 0.8 | 96 |
| TO-87B | 7.7 | 22 | 7.2 | 50 | 4.2 | 1.2 | 92 |
| TO-86D | 12 | 7.2 | 1.2 | 73 | 3.1 | 0.6 | 97 |
| TO-85A | 31 | 24 | 3.6 | 28 | 7.1 | 2.3 | 95 |
| TO-84B | 17 | 30 | 9.6 | 27 | 8.3 | 1.2 | 93 |
| RT-81A | 12 | 7.2 | 1.5 | 36 | 37 | 1.7 | 96 |
| TO-78C | 12 | 35 | 13 | 28 | 5.4 | 1.3 | 95 |
| RT-77 | 46 | 7.6 | 0 | 22 | 14 | 4.7 | 94 |
| RT-75A | 20 | 8.0 | 10 | 3.1 | 55 | 2.4 | 99 |
| F-74 | 5.3 | 52 | 16 | 6.8 | 11 | 1.2 | 92 |
| F-73 | 11 | 61 | 6.9 | 5.6 | 12 | 1.9 | 98 |
| F-72B | 3.4 | 80 | 7.4 | 0 | 6.7 | 1.4 | 99 |
| F-71B | 2.2 | 55 | 17 | 7.5 | 8.4 | 1.5 | 91 |
| F-70E | 15 | 26 | 4.5 | 40 | 6.1 | 0.9 | 92 |
| F-69A | 3.3 | 67 | 33 | 0 | 0 | 1.4 | 105 |
| F-68A | 100 | 8.0 | 0 | 0 | 0.2 | 2.7 | 111 |
| F-65B | 4.5 | 73 | 6.5 | 7.9 | 0.9 | 1.1 | 94 |
| F-64A | 29 | 21 | 4.4 | 37 | 0.4 | 0.8 | 93 |
| LS-62A | 43 | 15 | 13 | 24 | 0.2 | 3.3 | 99 |
| F-58B | 0.1 | 58 | 40 | 0 | 0.9 | 1.2 | 100 |
| LS-57M | 0.9 | 49 | 3.9 | 25 | 15 | 1.1 | 94 |
| LS-57D | 0.6 | 47 | 29 | 7.1 | 5.1 | 1.1 | 90 |
| LS-56A | 0.5 | 2.1 | 16 | 70 | 3.6 | 3.8 | 96 |
| LS-55B | 4.5 | 59 | 7.1 | 16 | 8.4 | 1.4 | 96 |
| R-54C | 5.8 | 22 | 14 | 47 | 6.7 | 0.5 | 95 |
| M-53B | 8.7 | 27 | 3.9 | 39 | 14 | 0.5 | 93 |
| M-52 | 5.0 | 1.0 | 0 | 8.5 | 84 | 1.0 | 99 |
| R-50F | 3.4 | 19 | 2.8 | 50 | 20 | 1.8 | 96 |
| M-48B | 67 | 0.4 | 0 | 32 | 3.1 | 1.6 | 104 |
| M-47 | 6.5 | 0.1 | 4.9 | 31 | 55 | 0.8 | 99 |
| M-45 | 4.0 | 0.4 | 8.7 | 22 | 61 | 1.0 | 97 |
| M-44A | 35 | 0.4 | 3.5 | 5.8 | 55 | 1.7 | 102 |
| M-42A | 23 | 0 | 6.0 | 11 | 61 | 0.8 | 102 |
| M-41 | 44 | 2.9 | 13 | 35 | 1.2 | 1.5 | 98 |
| M-40 | 7.5 | 0.4 | 1.4 | 4.4 | 84 | 1.7 | 99 |
| M-39B | 25 | 0.6 | 5.3 | 0 | 61 | 5.4 | 98 |
| M-38A | 52 | 0.8 | 0 | 1.4 | 23 | 15 | 92 |
| M-37A | 51 | 2.7 | 0 | 5.6 | 35 | 5.4 | 100 |
| M-36B | 23 | 66 | 2.4 | 4.3 | 0.6 | 2.1 | 98 |

Table 6. Lakeridge continued

| Sample | Detrital component | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Total |
|---|---|---|---|---|---|---|---|
| M-35A | 68 | 0.4 | 0 | 25 | 2.7 | 4.7 | 101 |
| M-34A | 49 | 0.9 | 0 | 2.5 | 45 | 4.8 | 102 |
| M-33A | 74 | 2.2 | 0 | 6.0 | 16 | 4.5 | 103 |
| M-32A | 75 | 2.1 | 0 | 11 | 11 | 5.5 | 104 |
| M-31A | 39 | 42 | 5.2 | 6.5 | 2.9 | 3.9 | 99 |
| M-30A | 69 | 3.1 | 0 | 13 | 9.8 | 7.5 | 102 |
| M-29A | 12 | 0.7 | 8.8 | 17 | 56 | 3.4 | 99 |
| M-28A | 43 | 1.1 | 0 | 4.0 | 49 | 4.1 | 101 |
| M-27B | 17 | 67 | 9.2 | 0.7 | 1.4 | 1.9 | 97 |
| M-25 | 71 | 3.0 | 0 | 7.5 | 14 | 6.3 | 102 |
| M-24 | 49 | 6.8 | 0 | 5.7 | 27 | 11 | 99 |
| M-23B | 10 | 73 | 11 | 0 | 1.6 | 6.0 | 101 |
| M-22B | 29 | 34 | 12 | 0 | 5.4 | 14 | 96 |
| M-21A | 11 | 1.6 | 11 | 1.1 | 56 | 18 | 98 |
| M-20B | 61 | 0 | 0 | 4.5 | 28 | 10 | 103 |
| M-18 | 32 | 24 | 6.1 | 0 | 12 | 21 | 95 |
| M-17 | 31 | 9.2 | 2.5 | 0 | 24 | 35 | 101 |
| M-16 | 32 | 41 | 4.2 | 0.3 | 7.1 | 12 | 96 |
| M-15A | 29 | 6.2 | 5.0 | 0 | 36 | 22 | 98 |
| M-14 | 23 | 2.7 | 7.7 | 0 | 40 | 25 | 99 |
| M-12B | 2.6 | 1.7 | 12 | 7.6 | 73 | 1.7 | 98 |
| WS-11D | 36 | 43 | 12 | 1.0 | 0.2 | 1.0 | 94 |

A critical step in the process of calculating the components is the calculation of the detrital component using a proportionality constant extracted from the residual versus $Al_2O_3$ graph (fig. 9). The residual is the difference between 100 percent and the sum of the apatite, dolomite, calcite and organic matter. Therefore, the detrital component or terrigenous fraction depends on the correct calculation of the residual components. The components, apatite, dolomite, and calcite, three of the four components of the residual, were independently checked by graphing measured $CO_2$ versus calculated $CO_2$, where the calculated $CO_2$ = sum of $CO_2$ in calcite, dolomite, and apatite (fig 10; Gulbrandsen, 1960a, b, 1970). The correlation coefficient for data from all the sections is $R \geq 0.99$, except for Mud Spring, which was 0.89.

The overall calculations of the components are also checked by the approach of the sum of the components to 100 percent. The average sum for all the sections is 99.6 percent and the average standard deviation is 2.7 percent. The sum of each section is in table 7.

Table 7. The average of the sum of the rock components for each section and its standard deviation.

| Section name | Average | Standard deviation |
|---|---|---|
| Conant Creek | 99.5 | 2.2 |
| Fontenelle Creek | 99.7 | 2.4 |
| Wheat Creek | 99.3 | 2.3 |
| Lakeridge | 98.1 | 4.7 |
| Mud Spring | 101.2 | 1.7 |

The sum of the Lakeridge core components does not approach 100 percent as closely as the other sections. One possible reason is the high S (up to 10 weight percent) and Fe, which can not be completely accounted for by organic matter (Powell and others, 1975) or apatite (Compton and others, 1993), as it is at the other sections. Pyrite was identified in many of the samples, but there was no clear correlation between excess sulfur (Total S - 0.27 x Organic C - 0.077 x P) and excess Fe (Total $Fe_2O_3$ - 0.35 x

$Al_2O_3$) (fig. 11). Thus, pyrite could not be calculated as a component in the Lakeridge core. Iron and sulfur in these rocks clearly needs further study.

The small amount of scatter around 100 percent for the sum of the components and the one to one line in the graph of calculated $CO_2$ versus measured $CO_2$ indicates the validity of calculating marine and detrital components based on major-element-oxide analyses. The small amount of scatter further suggests little variation in the composition of the individual components between samples in this data set.

Figure 9. Residual versus $Al_2O_3$ content. The residual is the difference between 100 and the sum of the components: dolomite, calcite, apatite, and organic matter. The slope of the line is the proportionality constant used to determine the detrital component from $Al_2O_3$

Figure 10. Carbonate content, estimated from calculated abundance of dolomite, calcite, and apatite, versus carbonate content measured by induction-furnace carbon analysis. Shown are the best fit curves and their corresponding correlation coefficients.

Figure 11. $Fe_2O_3$ content minus that in the terrigenous component versus S content adjusted for that in organic matter and apatite for Lakeridge samples. Lines represent the $Fe_2O_3$:S ratio in amorphous FeS and pyrite.

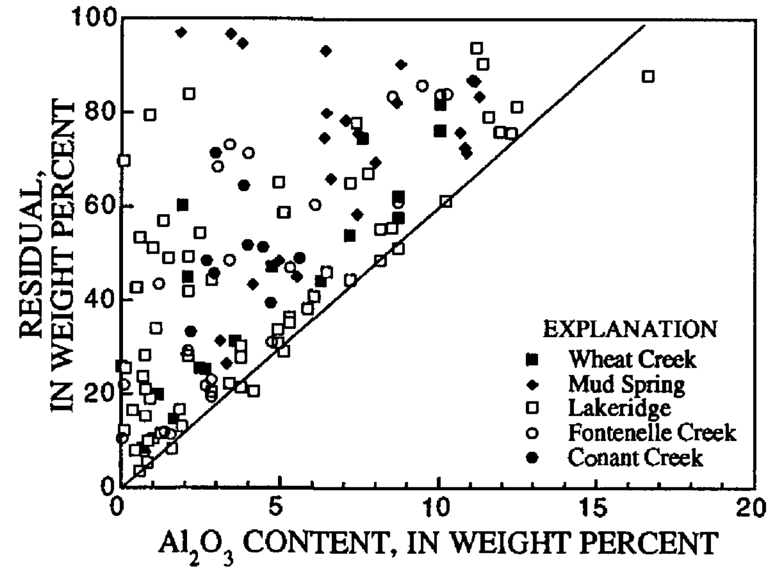



Figure 9

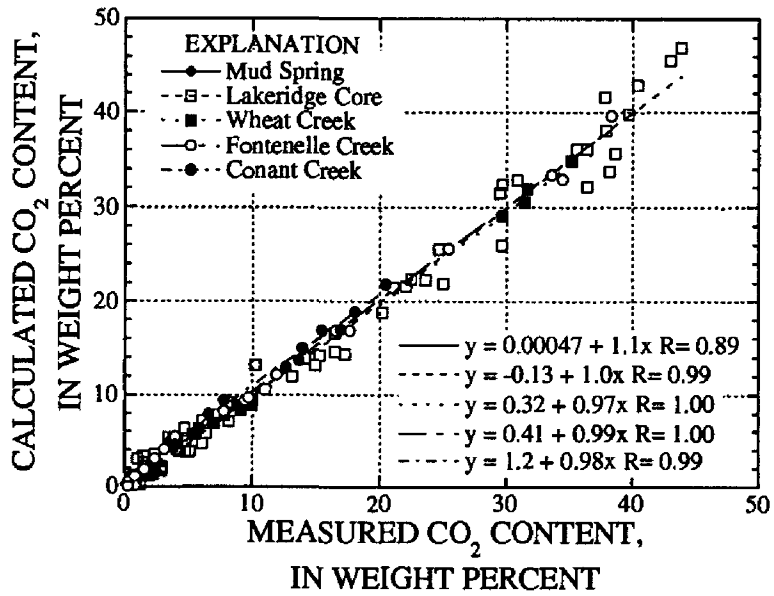



Figure 10

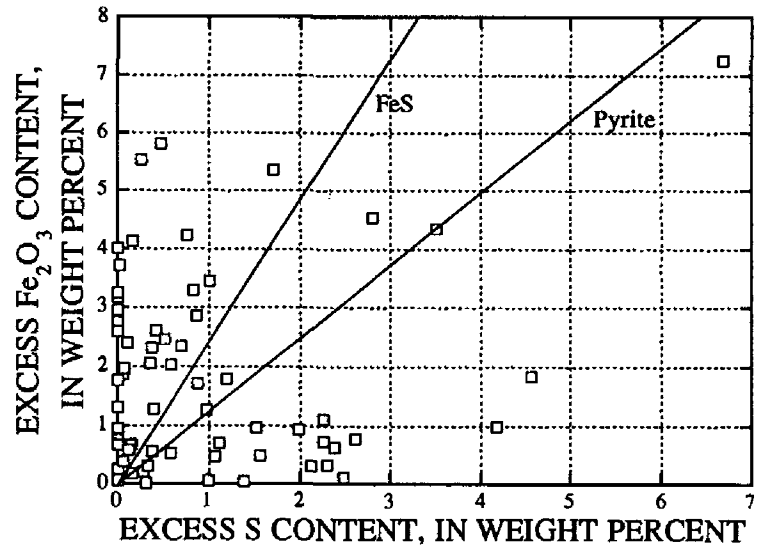



Figure 11

## DETERMINATION OF THE TERRIGENOUS MINOR ELEMENT CONTENT

Assuming all the $Al_2O_3$ in the samples is contained in the terrigenous fraction and the $Al_2O_3$ content is constant, we conclude that minor elements that correlate strongly with $Al_2O_3$ are also contained solely in the terrigenous fraction and their content constant. Samples from Conant Creek and Mud Spring show Sc correlates strongly with $Al_2O_3$, where R = 0.93 and 0.95 respectively, both having near origin intercepts (fig. 12*O*, 13*D*), despite the fact that Sc content only ranges from 2 ppm (the detection limit) to 13 ppm. The other sections have a slight scatter above the minimum line, but also correlate with $Al_2O_3$.

Ga, again, at Conant Creek and Mud Spring correlates strongly with $Al_2O_3$, where R = 0.96 and 0.91 respectively, and have near origin intercepts (fig. 12*I*, 13*B*), despite the Ga content in these samples being very close to the detection limit of 4 ppm. The other sections have a small amount of scatter above the minimum line, but also correlate with $Al_2O_3$.

Li correlates with $Al_2O_3$ at all the sections, where R ranges from 0.68 to 0.86, with the exception of Mud Spring, where R = 0.22 (fig. 12*J*, 13*C*), owing mostly to the line of best fit approaching a horizontal line. These trends closely follow the trends in the $K_2O$ versus $Al_2O_3$ graph (fig. 5*A*), where Conant Creek has the highest trend and Mud Spring the lowest. This results possibly from the substitution of Li for K in clays. The Li plot shows that, whereas the Li content is constant in the terrigenous fraction within each section, there appears to be some small variation between sections, similar to that found for $K_2O$. However, the variation is small considering the extent of the area of deposition and the time span over which the Phosphoria Formation was deposited.

The Li content of the Lakeridge samples has the greatest amount of scatter; it ranges between the Mud Spring and Conant Creek data. This greater range of values in comparison to other sections is similar for other minor elements from the Lakeridge core. It possibly results from these samples containing a wider range of lithologies and

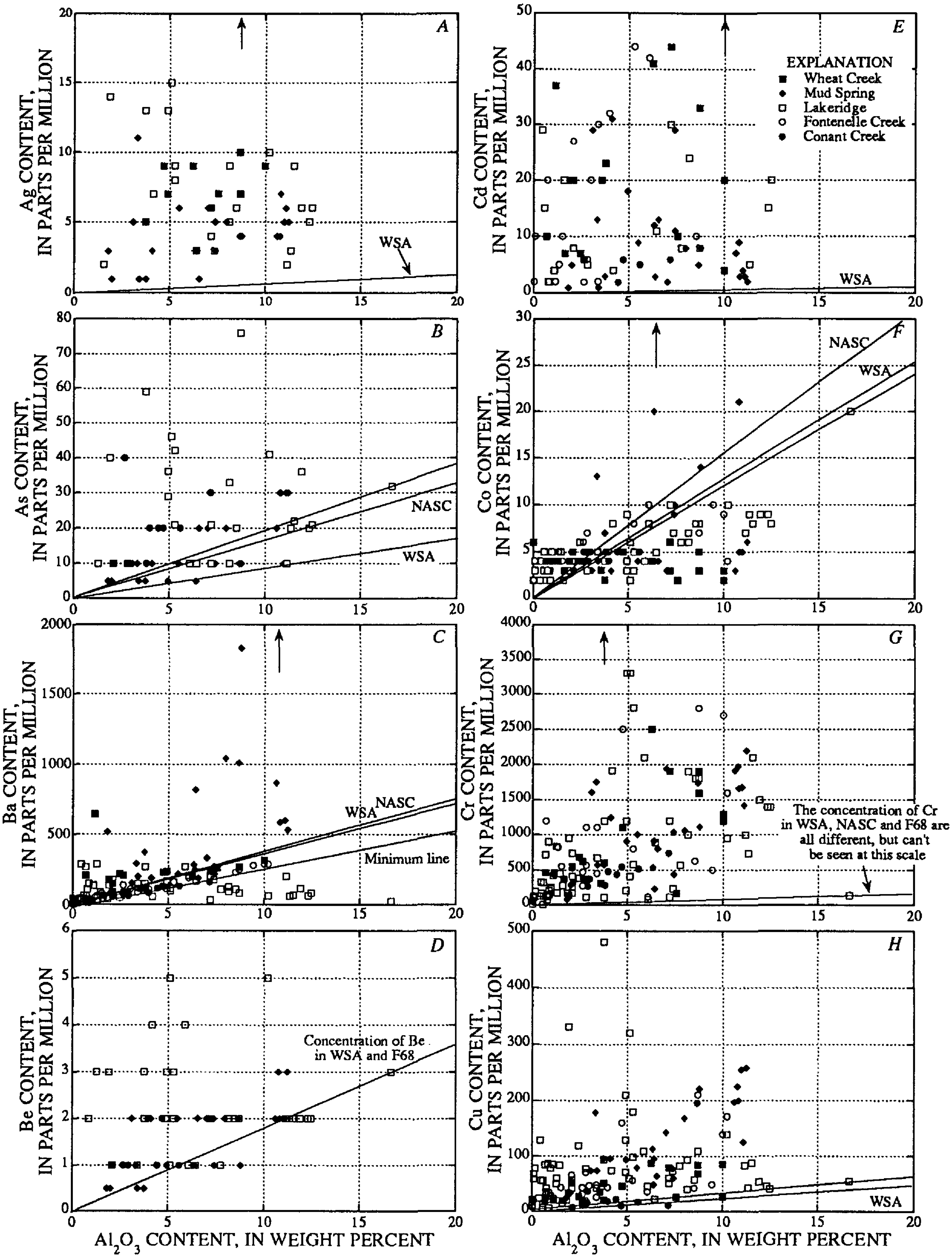

A
Ag CONTENT, IN PARTS PER MILLION
WSA
B
As CONTENT, IN PARTS PER MILLION
NASC
WSA
C
Ba CONTENT, IN PARTS PER MILLION
WSA
NASC
Minimum line
D
Be CONTENT, IN PARTS PER MILLION
Concentration of Be in WSA and F68
$Al_2O_3$ CONTENT, IN WEIGHT PERCENT
E
Cd CONTENT, IN PARTS PER MILLION
EXPLANATION
Wheat Creek
Mud Spring
Lakeridge
Fontenelle Creek
Conant Creek
WSA
F
Co CONTENT, IN PARTS PER MILLION
NASC
WSA
G
Cr CONTENT, IN PARTS PER MILLION
The concentration of Cr in WSA, NASC and F68 are all different, but can't be seen at this scale
H
Cu CONTENT, IN PARTS PER MILLION
WSA
$Al_2O_3$ CONTENT, IN WEIGHT PERCENT

Figure 12

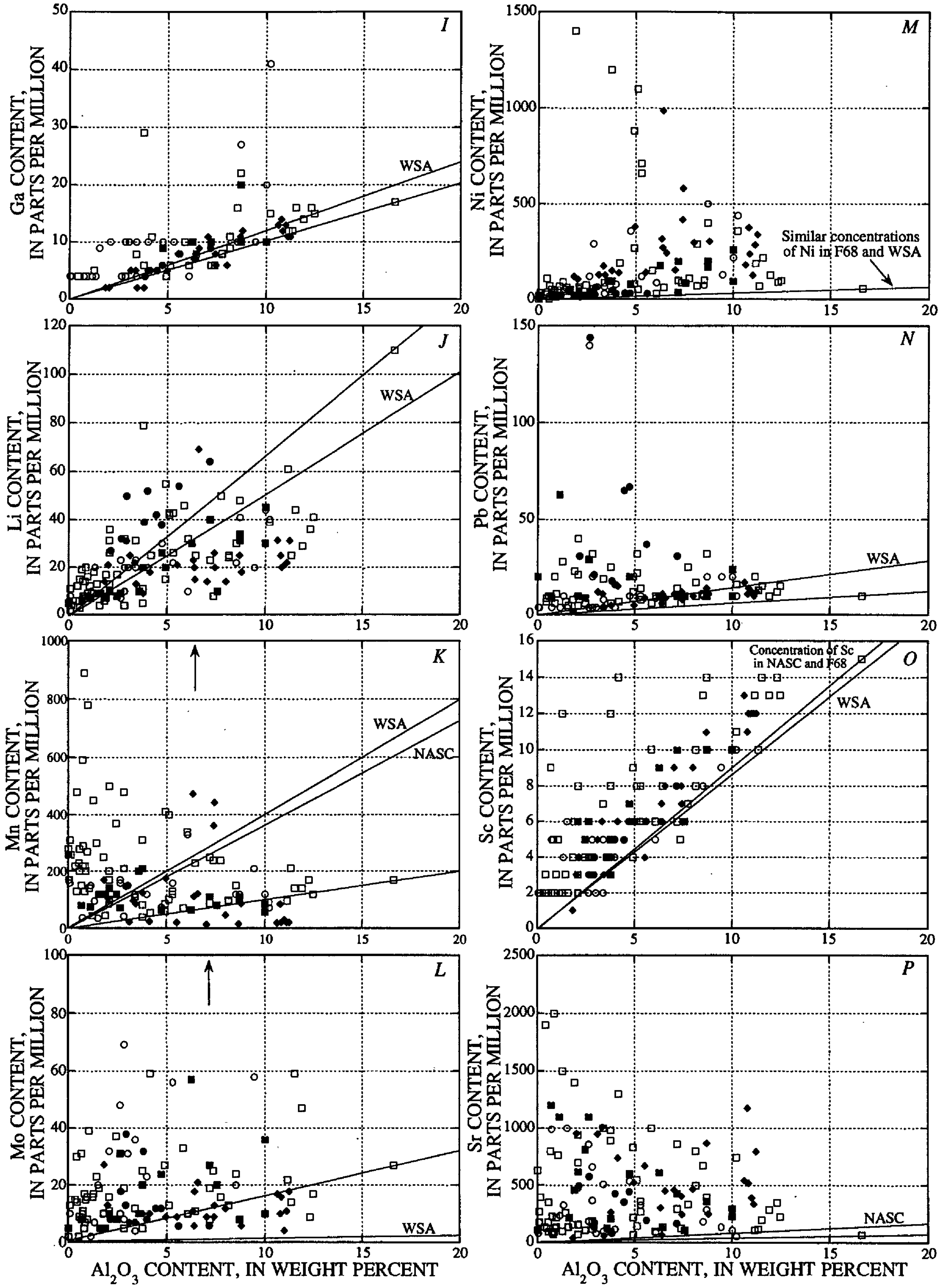



Figure 12. continued

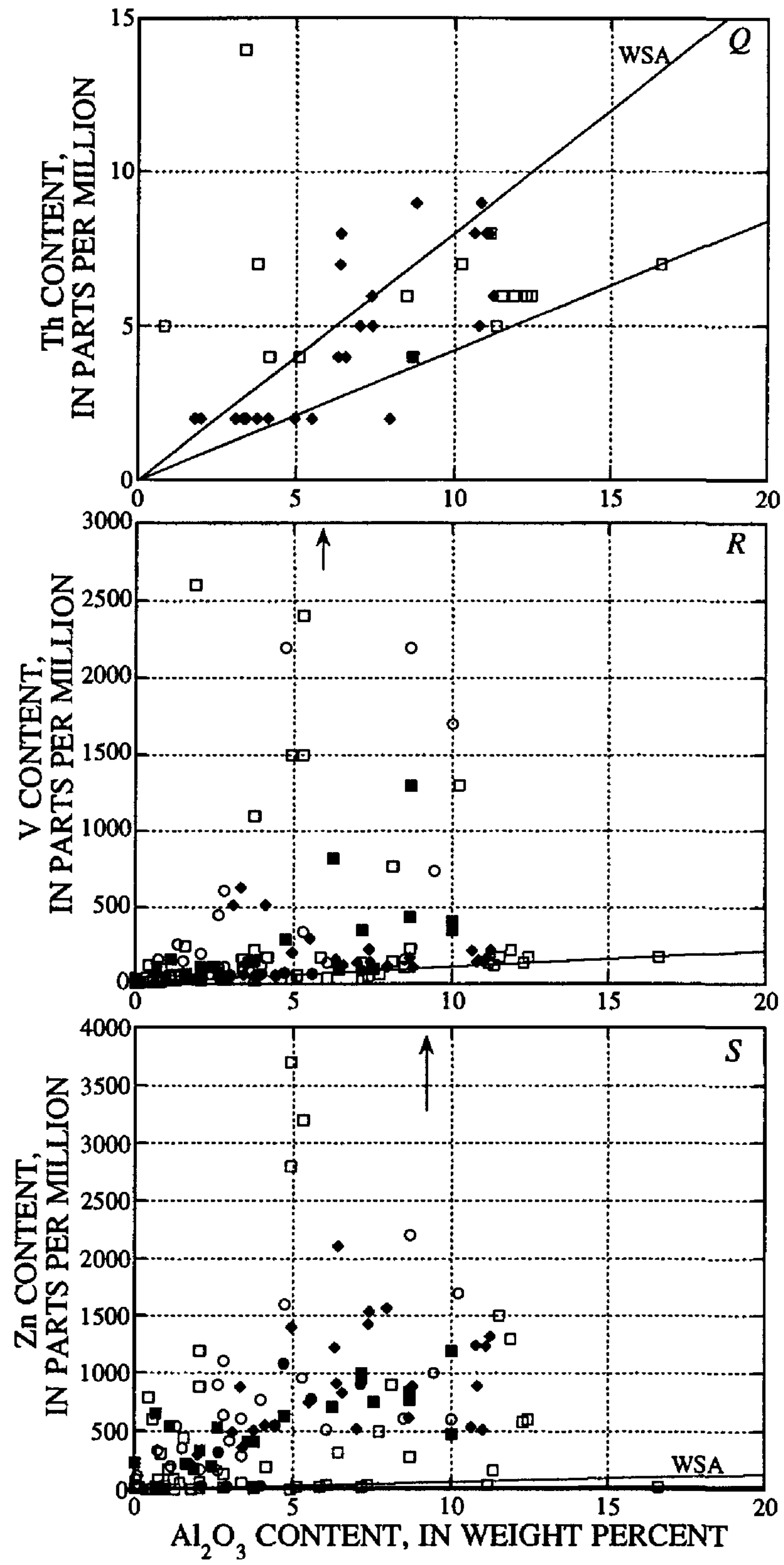



Figure 12. Minor-element versus $Al_2O_3$ content, as determined by inductively coupled plasma-atomic emission spectroscopy: *A*) Ag; *B*) As; *C*) Ba; *D*) Be; *E*) Cd; *F*) Co; *G*) Cr; *H*) Cu; *I*) Ga; *J*) Li; *K*) Mo; *L*) Ni; *M*) Pb; *N*) Sc; *O*) Sr; *P*) Th; *Q*) V; *R*) Y; *S*) Zn. Lines drawn represent the minor element:$Al_2O_3$ ratios in the world shale average (WSA) and the North American shale composite (NASC) The unmarked line is either the minimum line for this graph relative to the $Al_2O_3$ content or is a line which intersects the F68a data point. The legend is given in figure 9*E*. Samples with minor-element content below the detection limit are not included. The arrows pointing up indicate data for some samples that are outside the limits of the graph. Limits of the graphs were chosen so as to include as much data as possible, yet show the minimum relative to the $Al_2O_3$ content.

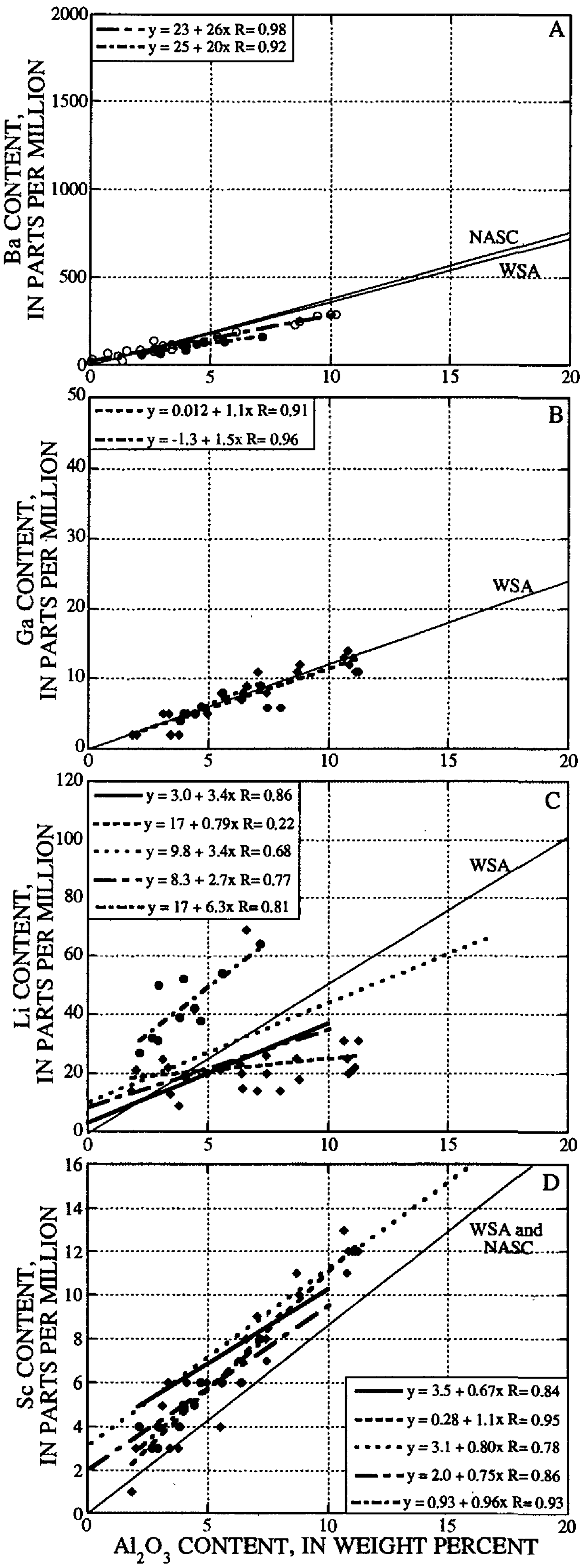



Figure 13. Selected sections of Ba, Ga, Li and Sc content versus $Al_2O_3$ content, which exhibit a strong correlation: (A) Ba content at Fontenelle Creek and Conant Creek, with their lines of best fit, and lines representing Ba content in WSA and NASC; (B) Ga content at Mud Spring and Conant Creek, with lines of best fit and line representing Ga content in WSA. C) Li content at Conant Creek and Mud Spring, with lines of best fit and equations for all sections and line representing Li content in WSA. D) Sc content at Mud Spring and Conant Creek, with lines of best fit and equations for all sections, and lines representing Sc content in WSA and NASC. Legend in figure 9*E*.

representing all the members of the Phosphoria Formation, unlike the other sections, which are primarily from the lower Meade Peak Phosphatic Shale member. Also the Lakeridge core is unweathered, which may have effected the minor element content relative to the other sections, which are from surface outcrops or trenches.

Ba and $Al_2O_3$ have correlation coefficients at Conant Creek and Fontenelle Creek of R = 0.92 and 0.98 respectively (fig. 12*C*, 13*A*). Wheat Creek scatters slightly above but has a minimum line which coincides with the line of best fit for Conant Creek and Fontenelle Creek. Some of the data from Mud Spring scatters well above the minimum line and Lakeridge has a small group of samples that lie below the minimum line.

Studies of modern sediment show strong correlations between the terrigenous fraction of the sediment and Ba, Li, Ga, and Sc, and less so Th and Co, and (Piper and Isaacs, 1995, Piper and others, in press). Here in the Phosphoria Formation, Li, Ga and Sc also show strong correlations despite some scatter from a couple of sections and despite the Ga and Sc data ranging to near the detection limit. Ba also shows a strong correlation, with the exception of Mud Spring and Lakeridge sections. Th and Co were below their detection limit in too many cases to be used as indicators of constant composition. Clearly though, for the elements, Ba, Li, Ga, and Sc, the graphs indicate they are primarily in a terrigenous fraction of relatively constant composition. We conclude from these relations that all minor elements have a constant concentration in the terrigenous fraction.

The minor-element contents in the terrigenous fraction are determined by one of three possible methods:

1) Minimum line method: the minimum line from the minor element, $Al_2O_3$ graphs, a line formed by a group of points which have the least amount of a given minor element relative to $Al_2O_3$, and which intersects the origin, can be used to determine the minor element content of the terrigenous fraction. This method is best used when the minor element has only a slight marine enrichment or forms a well defined minimum line

such is seen in the graphs of Pb and V (fig. 12*N*, *R*). However, for minor elements, like Cr, Mo, and Ni, the data forms no well defined minimum line (fig. 12*G*, *L*, *M*). One problem with this method, which was discussed earlier, is the assumption that the samples which form the minimum line have solely a terrigenous minor-element fraction. However, the fact that a group of points form a line means they at least approach this condition.

2) Single analysis method: the minor element content of a sample, in which the terrigenous fraction comprises > 95 weight percent of the rock, like sample F68A of the Lakeridge core, is taken to be the minor element content of the terrigenous fraction for all the samples. This method works well when a large portion of data shows significant marine minor element enrichment. As the $Al_2O_3$ content increases, i.e., the marine component decreases, the minor element content should approach the value in the sample with >95 detritus. A good example is Ni or Sr (fig. 12*M*, *P*). For elements that are slightly above the detection limit, yet are primarily in the terrigenous fraction, it represents a sample with the greatest amount of the minor element with the smallest amount of analytical error. An example of this is Be and Sc (fig. 12*D*, *O*). The minor element content of the 5 percent of the sample which is not terrigenous is a potential problem with this method. There could be contributions of minor elements from the marine environment, such as from the retention of organic matter in the sediment, or from the precipitation of an authigenic minerals, like Mn precipitation under bottom water oxidizing conditions, or Mo precipitation under bottom water sulfate reducing conditions. Relying on one analysis, which is bound to have certain amount of analytical error, is another problem with this technique.

3) Standard shale method: a standard shale analysis, such as the World Shale Average (WSA; Turekian and Wedepohl, 1961; Wedepohl, 1969-1978), or North American Shale Composite (NASC; Gromet and others, 1984) for the minor elements, and, for the rare earths', another WSA (Piper, 1974), or another NASC (Haskin and

Haskin, 1966), (table 8) is used for the minor element content of the terrigenous fraction. Obviously one problem with this method is the possibility of the Phosphoria's terrigenous fraction having a composition significantly different from the average shales. Major and minor elements graphed against $Al_2O_3$, that show a significant correlation, have contents similar to the values in WSA and/or NASC (fig. 5 and 12*C*, *I*, *J*, and *N*, table 8). The minor element contents of Ba, Ga, Li, and Sc in the terrigenous fraction of our samples are 429 ppm, 17 ppm, 110 ppm, and 15 ppm, respectively, as compared to 546, 18, 76, and 13 in WSA (Turekian and Wedepohl, 1961; Wedepohl, 1969-1978).

We have chosen to primarily use the single analysis method (2) for determining the minor element content of the terrigenous fraction. We took the minor element content of sample F68A to be the content of terrigenous fraction (which includes As, Be, Co, Ga, Mn, Ni, Pb, Sc, Sr, Th, V), except in the following cases.

1. If the F68A element content is below the detection limit. The Ag and Cd contents of the terrigenous fraction are determined using their contents in the standard shale (WSA).

2. If the minor-element content of sample F68A is significantly higher than the WSA and the graph of the minor element and $Al_2O_3$ forms no minimum line. Cr, Cu, Li, and Mo contents of the terrigenous fraction are determined by the standard shale method (WSA). It is suspected that the F68A values for Cr, Cu, and Mo contain a marine fraction.

3. If the minor-element content of sample F68A is significantly different from a well defined minimum line. Zn and Ba contents in the terrigenous fraction are determined by the well defined minimum line.

The REE contents of the terrigenous fraction was not determined in the same way, i.e., using the values from sample F68A. In every case sample F68A was the minimum point in rare-earth-element, $Al_2O_3$ graphs (fig. 14). However, there was for most of the graphs a well defined minimum line, which wasn't always the same value as sample

F68A. It was also noted that both the minimum line and sample F68A were unusual in that they had high La:Ce ratios compared to WSA (Piper, 1974) and NASC (Haskin and Haskin, 1966). We concluded that there must be a marine fraction of rare earth elements in these samples.

The rare earth element contents of the terrigenous fraction, in particular, the Ce and La contents of the terrigenous fraction, were calculated by forcing the data to a shale pattern. They were determined by normalizing the REE contents, attained using the minimum line from REE/$Al_2O_3$ plots, and the REE contents of sample F68A values with the WSA and NASC values. The pattern most resembling a normalized shale pattern was the minimum line values normalized to the NASC values. The fraction of the NASC values which most closely produced the minimum line values, was then used to calculate the rare earth element contents in the terrigenous fraction (table 8).

Figure 14. Rare-earth-elements versus $Al_2O_3$ content, determined by inductively coupled plasma-mass spectroscopy: *A*) La; *B*) Ce; *C*) Pr; *D*) Nd; *E*) Sm; *F*) Eu; *G*) Gd; *H*) Tb; *I*) Dy; *J*) Ho; *K*) Er; *L*) Tm; *M*) Yb.. The unmarked line represents the calculated terrigenous fraction of minor elements relative to the $Al_2O_3$ content. Legend is given in figure 12*A*.

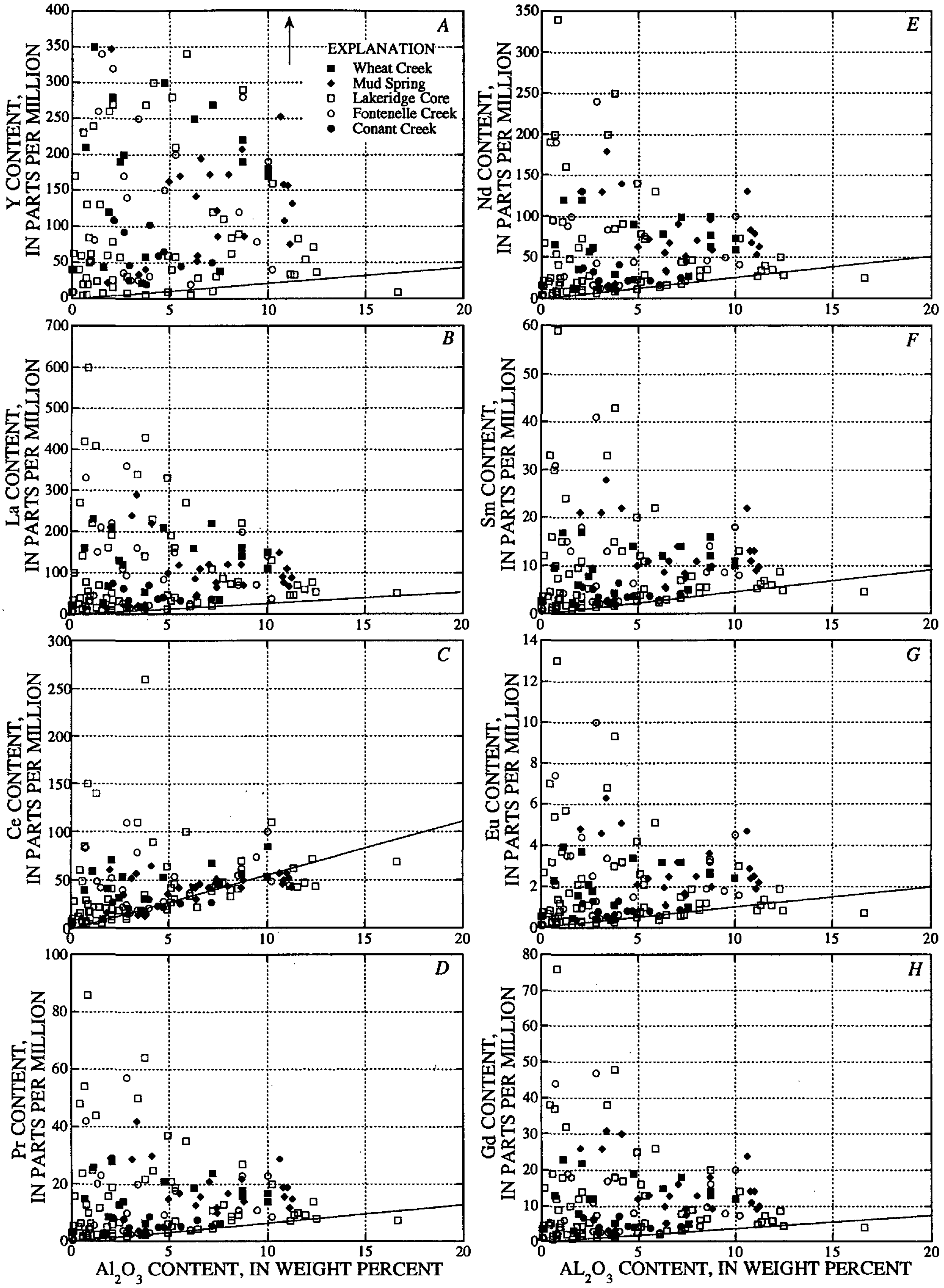

A
B
C
D
E
F
G
H
EXPLANATION
Wheat Creek
Mud Spring
Lakeridge Core
Fontenelle Creek
Conant Creek
Y CONTENT, IN PARTS PER MILLION
La CONTENT, IN PARTS PER MILLION
Ce CONTENT, IN PARTS PER MILLION
Pr CONTENT, IN PARTS PER MILLION
Nd CONTENT, IN PARTS PER MILLION
Sm CONTENT, IN PARTS PER MILLION
Eu CONTENT, IN PARTS PER MILLION
Gd CONTENT, IN PARTS PER MILLION
Al2O3 CONTENT, IN WEIGHT PERCENT
AL2O3 CONTENT, IN WEIGHT PERCENT

Figure 14

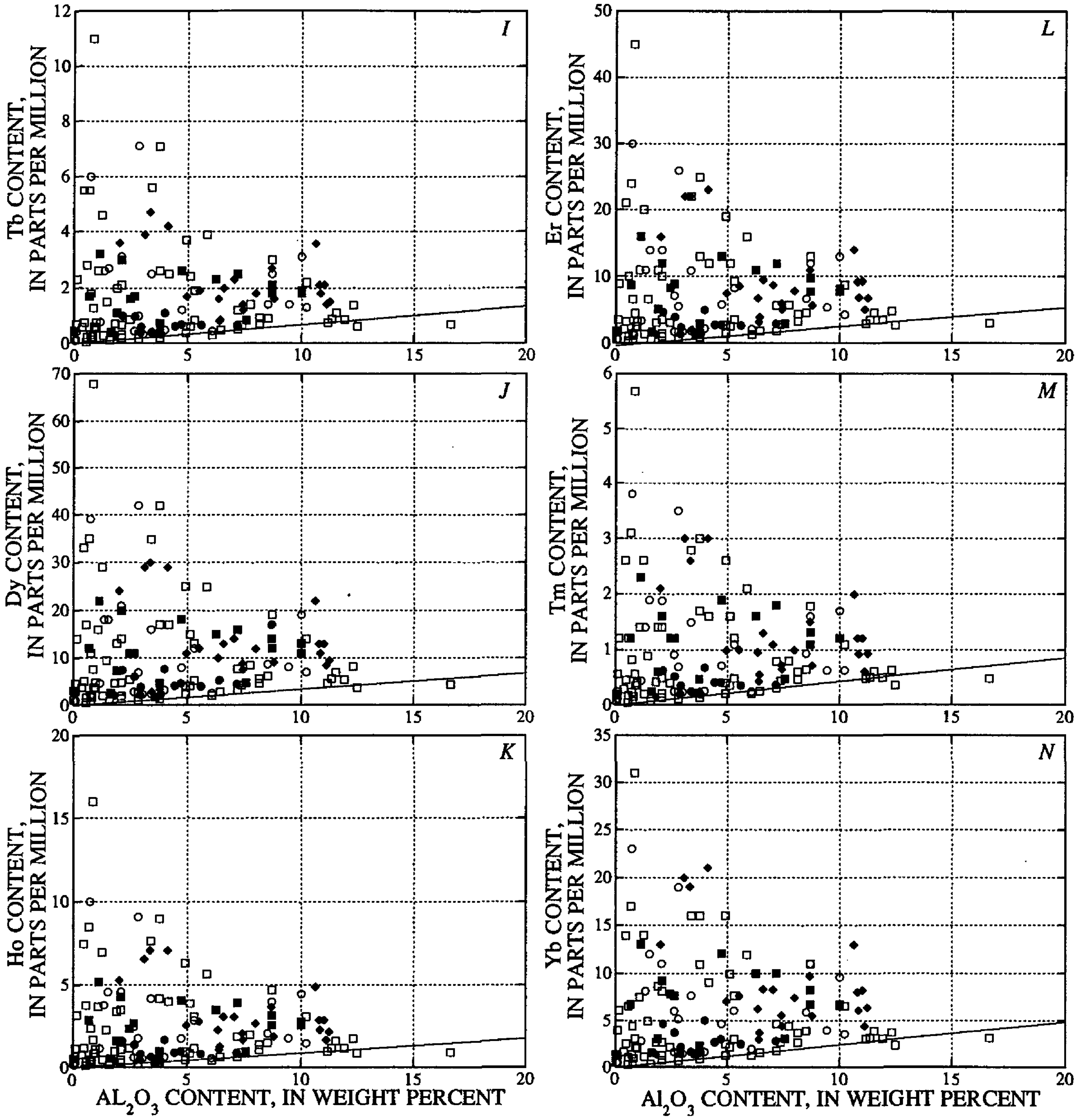



Figure 14. continued

Table 8. Major and minor-element composition of terrigenous fraction. All values are in parts per million.

| | World Shale Average[1] | North American Shale Composite[2] | Value determined from sample F68 | Value from minimum line | Value used in calculations[4] |
|---|---|---|---|---|---|
| Major-oxides | | | | | |
| $SiO_2$ | 58.4 | 64.8 | 49.0 | | 58.3 |
| $Al_2O_3$ | 15.1 | 16.9 | 16.6 | | 16.7 |
| $Fe_2O_3$ | 6.84 | 6.29 | 6.8 | 5.14 | 6.2 |
| MgO | 2.49 | 2.85 | 3.8 | 1.14 | 1.2 |
| CaO | 3.09 | 3.58 | 3.6 | 3.58 | 2.5 |
| $Na_2O$ | 1.3 | 1.13 | 1.6 | | |
| $K_2O$ | 3.19 | 3.94 | 5.6 | 4.17 | 4.2 |
| $TiO_2$ | 0.77 | 0.79 | 0.48 | 0.48 | 0.48 |
| $P_2O_5$ | 0.16 | 0.14 | 0.23 | 0.23 | 0.17 |
| $CO_2$ | 2.63[3] | – | – | | |
| Minor elements | | | | | |
| Ag | 0.05-0.90 | – | – | | 0.48* |
| As | 13 | 28.4 | 32 | | 32 |
| Ba | 546 | 636 | 27 | 429 | 429 |
| Be | 2-3 | – | 3 | 3 | 3 |
| Cd | 0.8 | – | – | | 0.8* |
| Co | 19 | 25.7 | 20 | | 20 |
| Cr | 83 | 124.5 | 140 | | 83* |
| Cu | 35 | – | 55 | 55 | 35* |
| Ga | 18 | – | 17 | 17 | 17 |
| Li | 76 | | 110 | | 76* |
| Mn | 600 | 600 | 168 | 168 | 168 |
| Mo | 0.7-2.0 | – | 27 | | 2* |
| Ni | 42 | 58 | 59 | | 59 |
| Pb | 21.6 | – | 10 | 14 | 10 |
| Sc | 13 | 14.9 | 15 | 15 | 15 |
| Sr | 24-359 | 142 | 70 | 70 | 70 |
| Th | 12 | 12.3 | 7 | | 7 |
| V | 98-2600 | – | 180 | 180 | 180 |
| Zn | 100 | – | 27 | 60 | 60 |
| Rare Earth Elements | | | | | |
| Y | 27 | 27 | 10 | | 36 |
| La | 41 | 32 | 52 | 52 | 43 |
| Ce | 83 | 70 | 69 | 60 | 93 |
| Pr | 10.1 | 7.9 | 7.5 | 10.6 | 10.5 |
| Nd | 38 | 31 | 25 | 38 | 41 |
| Sm | 7.5 | 5.7 | 4.6 | 7.8 | 7.6 |
| Eu | 1.61 | 1.24 | 0.75 | 1.25 | 1.65 |
| Gd | 6.35 | 5.21 | 4.1 | 7.35 | 6.9 |
| Tb | 1.23 | 0.85 | 0.72 | 1.19 | 1.13 |
| Dy | 5.5 | – | 4.4 | 7.2 | 5.5* |
| Ho | 1.34 | 1.04 | 0.95 | 1.62 | 1.38 |
| Er | 3.75 | 3.4 | 3.1 | 4.5 | 4.5 |
| Tm | 0.63 | 0.5 | 0.49 | 0.70 | 0.70 |
| Yb | 3.53 | 3.1 | 3.2 | 4.3 | 4.1 |

[1] World Shale Average (major-element oxides,Turekian and Wedepohl, 1961; minor elements, Wedepohl, 1969-1972; rare-earth elements, Piper, 1974)

[2] North American Shale Composite (major and minor elements on a volatile free basis: Gromet and others, 1984; rare-earth elements, Haskin and Haskin, 1966)

[3] $CO_2$, Wedepohl, 1969-1972

[4] Numbers with * in this column were taken from the World Shale Average (the first column)

## MARINE MINOR ELEMENTS CALCULATED

The marine minor elements and REEs were calculated by subtracting the fraction calculated to be contributed by the terrigenous material from the bulk content:

$$\mathbf{C = A - B \times (terrigenous\ fractional\ content\ of\ sample)}$$

Where A = total minor-element content of sample, B = minor-element content of terrigenous material, C = marine derived minor-element content in each sample (tables 9 and 10). The error in the calculation of C increases as the minor element content of the sample approaches that of the terrigenous fraction, or the error in C increases as C goes to zero. For those elements that are primarily marine in origin the error is small, for example Cr, Ni, and Sr. For those elements which are primarily terrigenous in origin the error is large, for example Ga, Sc, and Co.

A correlation table for each stratigraphic section was created for components in the marine fraction (dolomite, calcite, biogenic silica, apatite and organic matter) and the marine fraction of minor elements (table 11). These correlations provide a measure of the validity to the calculations of the marine fraction of minor elements. For example, the marine fraction of the heavy metals correlates strongly with organic matter and the marine fraction of REEs correlate with apatite. These associations have been reported in earlier studies, which examined merely the bulk composition of samples (Nissenbaum and others, 1976; Altschuler and others, 1967).

## SUMMARY

The goal of this study is to calculate the fraction of the minor elements in these rock samples that is marine derived. This is done by first calculating the components -- dolomite, calcite, apatite, organic matter, biogenic silica and the terrigenous detritus component. These components were then partitioned into marine and terrigenous fractions. The minor element content of sample F68a, a sample composed of >95 weight percent terrigenous detritus, was taken to be the minor element content of the terrigenous fraction of all the samples. There were a few exceptions, where either the minor element content of a standard shale was used or the minor element content was determined from extracting a minor element/$Al_2O_3$ ratio from a well defined minimum line from a minor element/$Al_2O_3$ graph. The rare earth element contents and, in particular, the Ce and La contents of the terrigenous fraction, were calculated by forcing the data to a shale pattern. The marine fraction of minor elements and REEs was then calculated from the difference between the bulk minor element content of each sample and the minor elements contributed by the terrigenous fraction. The interpretation, using these calculated marine derived minor elements, of the environment of deposition will be the topic of another bulletin.

**Table 9.** Calculated marine minor-element contents in samples of the Phosphoria Formation at Conant Creek, Wheat Creek, Fontenelle Creek, and Lakeridge, Wyoming and Mud Springs, Idaho

[All values in parts per million. Blank indicate element is below the detection limit.]

| | Conant Creek | | | | | | | | | | Mud Springs | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-47 | P-46 | P-45 | P-44 | P-43 | P-42 | P-41 | P-40 | P-39 | P-38 | P-47 | P-44 | P-43 | P-41 | P-40 |
| Ag----- | | | | | | | | | | | 4 | 4 | 5 | 5 | 6 |
| As----- | 0 | 12 | 6 | 4 | 9 | 16 | 35 | 3 | 11 | 11 | 9 | 0 | 0 | 5 | 9 |
| Ba----- | 0 | 0 | 4 | 9 | 0 | 0 | 24 | 17 | 6 | 11 | 4183 | 1604 | 4577 | 835 | 315 |
| Be----- | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 |
| Cd----- | 1 | 1 | 1 | 1 | 5 | 6 | 1 | 1 | 2 | 6 | 8 | 8 | 3 | 8 | 2 |
| Co----- | 1 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 8 | 3 | 0 | 0 | 0 |
| Cr----- | 359 | 446 | 304 | 248 | 488 | 699 | 358 | 262 | 413 | 521 | 1916 | 1066 | 1625 | 1020 | 1365 |
| Cu----- | 31 | 11 | 3 | 11 | 6 | 0 | 5 | 12 | 13 | 0 | 202 | 203 | 232 | 152 | 103 |
| Ga----- | 0 | 1 | 0 | 0 | 3 | 2 | 0 | 0 | 1 | 1 | 4 | 4 | 2 | 0 | 0 |
| Li------ | 37 | 34 | 17 | 18 | 29 | 31 | 20 | 22 | 22 | 17 | 0 | 0 | 0 | 0 | 0 |
| Mn----- | 119 | 79 | 146 | 170 | 130 | 154 | 61 | 211 | 132 | 163 | 0 | 0 | 0 | 0 | 0 |
| Mo----- | 38 | 8 | 8 | 13 | 5 | 5 | 18 | 32 | 11 | 11 | 9 | 5 | 3 | 11 | 10 |
| Ni------ | 53 | 17 | 7 | 15 | 11 | 12 | 19 | 35 | 17 | 18 | 338 | 273 | 87 | 270 | 247 |
| Pb----- | 0 | 14 | 30 | 19 | 34 | 27 | 142 | 16 | 62 | 64 | 5 | 6 | 5 | 5 | 3 |
| Sc----- | 1 | 1 | 2 | 0 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 2 | 2 |
| Br----- | 163 | 412 | 490 | 125 | 173 | 138 | 568 | 67 | 339 | 428 | 1125 | 217 | 347 | 437 | 291 |
| V------ | 22 | 26 | 17 | 10 | 9 | 14 | 15 | 5 | 10 | 21 | 29 | 19 | 30 | 32 | 50 |
| Zn------ | 12 | 18 | 22 | 4 | 759 | 877 | 304 | 14 | 535 | 1063 | 1201 | 851 | 472 | 1541 | 1190 |

| | Mud Springs | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-38 | P-35 | P-33 | P-31 | P-29 | P-27 | P-26 | P-25 | P-23 | P-22 | P-17 | P-16 | P-15 | P-14 | P-11 |
| Ag----- | 7 | 6 | 5 | 11 | 7 | 6 | 5 | 3 | 3 | 3 | 4 | 4 | 1 | 1 | 3 |
| As----- | 9 | 7 | 8 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ba----- | 310 | 156 | 245 | 206 | 103 | 77 | 86 | 28 | 656 | 89 | 594 | 787 | 276 | 114 | 123 |
| Be----- | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cd----- | 2 | 2 | 1 | 13 | 18 | 9 | 29 | 11 | 55 | 3 | 6 | 5 | 3 | 1 | 12 |
| Co----- | 0 | 0 | 0 | 9 | 3 | 0 | 0 | 1 | 100 | 0 | 0 | 0 | 2 | 0 | 12 |
| Cr----- | 1606 | 1905 | 2144 | 1733 | 879 | 983 | 1003 | 405 | 202 | 878 | 1857 | 1697 | 551 | 553 | 510 |
| Cu----- | 177 | 128 | 234 | 172 | 84 | 68 | 62 | 45 | 83 | 36 | 175 | 177 | 88 | 67 | 100 |
| Ga----- | 2 | 4 | 0 | 2 | 0 | 3 | 1 | 0 | 2 | 1 | 3 | 3 | 0 | 0 | 1 |
| Li------ | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mn----- | 0 | 0 | 0 | 64 | 126 | 0 | 287 | 387 | 3975 | 48 | 0 | 0 | 86 | 53 | 409 |
| Mo----- | 15 | 8 | 17 | 7 | 8 | 8 | 8 | 12 | 17 | 5 | 16 | 7 | 10 | 7 | 10 |
| Ni------ | 202 | 128 | 300 | 165 | 363 | 125 | 392 | 558 | 963 | 248 | 144 | 156 | 137 | 117 | 297 |
| Pb----- | 7 | 7 | 5 | 9 | 2 | 6 | 8 | 4 | 7 | 2 | 11 | 9 | 3 | 2 | 5 |
| Sc----- | 2 | 3 | 2 | 3 | 2 | 0 | 1 | 0 | 0 | 1 | 3 | 3 | 0 | 0 | 0 |
| Sr----- | 476 | 433 | 745 | 996 | 506 | 646 | 376 | 215 | 109 | 44 | 500 | 631 | 250 | 45 | 280 |
| V------ | 38 | 65 | 101 | 594 | 150 | 237 | 149 | 63 | 40 | 41 | 108 | 80 | 21 | 23 | 91 |
| Zn------ | 844 | 492 | 1280 | 862 | 1382 | 722 | 1403 | 1513 | 2087 | 880 | 496 | 582 | 492 | 352 | 1197 |

| | Mud Springs | | | | | Fontenelle Creek | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-8 | P-6 | P-4 | P-2 | P-1 | E-4 | U-3 | U-1 | R-9 | R-6 | P-45 | P-43 | P-40 | P-39 | P-37 |
| Ag----- | 3 | 5 | 3 | 1 | 1 | | | | | | | | | | |
| As----- | 2 | 4 | 1 | 7 | 1 | 15 | | | | | | | | | |
| Ba----- | 83 | 74 | 473 | 31 | 40 | 72 | 1 | 0 | 21 | 3 | 19 | 32 | 31 | 32 | 8 |
| Be----- | 1 | 1 | 0 | 1 | 0 | | | | | | | | | | |
| Cd----- | 31 | 29 | 1 | 13 | 5 | 2 | 6 | 5 | 2 | 2 | 2 | 20 | 10 | 30 | 32 |
| Co----- | 0 | 0 | 2 | 0 | 3 | 1 | 2 | 3 | 3 | 1 | 2 | 1 | 4 | 1 | 0 |
| Cr----- | 1229 | 1595 | 76 | 770 | 279 | 457 | 546 | 813 | 424 | 1083 | 130 | 355 | 130 | 433 | 460 |
| Cu----- | 87 | 67 | 22 | 50 | 30 | 37 | 14 | 17 | 23 | 19 | 8 | 41 | 20 | 41 | 35 |
| Ga----- | 1 | 2 | 0 | 3 | 0 | 1 | 1 | 3 | 3 | 1 | 4 | 7 | 4 | 7 | 6 |
| Li------ | 0 | 11 | 6 | 39 | 12 | 11 | 7 | 14 | 5 | 7 | 6 | 6 | 8 | 4 | 2 |
| Mn----- | 0 | 0 | 152 | 55 | 84 | 133 | 14 | 81 | 138 | 76 | 170 | 120 | 159 | 86 | 80 |
| Mo----- | 10 | 7 | 27 | 20 | 13 | 10 | 8 | 7 | 2 | 4 | 2 | 31 | 10 | 36 | 23 |
| Ni------ | 124 | 118 | 116 | 222 | 100 | 25 | 29 | 48 | 16 | 19 | 10 | 57 | 22 | 56 | 65 |
| Pb----- | 13 | 10 | 1 | 5 | 9 | 138 | 18 | 9 | 3 | 6 | 4 | 2 | 4 | 2 | 2 |
| Sc----- | 2 | 2 | 0 | 2 | 1 | 2 | 2 | 3 | 1 | 2 | 2 | 0 | 2 | 0 | 0 |
| Sr----- | 724 | 933 | 36 | 425 | 943 | 849 | 648 | 324 | 235 | 496 | 82 | 72 | 180 | 86 | 103 |
| V------ | 471 | 482 | 10 | 52 | 22 | 81 | 79 | 246 | 32 | 49 | 25 | 23 | 37 | 73 | 77 |
| Zn------ | 537 | 482 | 207 | 799 | 291 | 150 | 630 | 535 | 196 | 278 | 89 | 409 | 120 | 598 | 756 |

Table 9. continued

| | Fontenelle Creek | | | | | | | | | | | | | Wheat Creek | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-32 | P-31 | P-25 | P-23 | P-21 | P-20 | P-19 | P-13 | P-12 | P-8 | P-7 | P-3 | P-1 | R-15 | R-9 |
| Ag----- | | | | 9 | 5 | | | 10 | | 10 | 5 | | | 2 | 2 |
| As----- | | | | 10 | 1 | | | | | 13 | | | | | 15 |
| Ba----- | 46 | 11 | 24 | 27 | 32 | 37 | 34 | 8 | 11 | 26 | 15 | 41 | 31 | 193 | 142 |
| Be----- | 2 | | | | | | | | | | | | | | 2 |
| Cd----- | 20 | 10 | 44 | 220 | 190 | 150 | 42 | 150 | 57 | 280 | 140 | 10 | 27 | 10 | 6 |
| Co----- | 3 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 3 | 0 | 4 | 2 | 2 | 3 | 1 |
| Cr----- | 1196 | 588 | 774 | 1549 | 2650 | 453 | 90 | 2476 | 257 | 2757 | 1086 | 542 | 520 | 457 | 607 |
| Cu----- | 22 | 24 | 45 | 149 | 119 | 29 | 23 | 150 | 25 | 192 | 64 | 40 | 62 | 19 | 14 |
| Ga----- | 3 | 2 | 5 | 31 | 10 | 1 | 0 | 5 | 1 | 19 | 7 | 8 | 8 | 3 | 1 |
| Li------ | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 1 | 0 | 2 | 1 | 3 | 0 |
| Mn----- | 31 | 34 | 107 | 0 | 19 | 115 | 269 | 26 | 143 | 32 | 181 | 20 | 63 | 74 | 45 |
| Mo----- | 10 | 19 | 55 | 579 | 239 | 57 | 9 | 199 | 48 | 299 | 69 | 20 | 32 | 8 | 31 |
| Ni------ | 21 | 46 | 101 | 404 | 185 | 97 | 67 | 343 | 111 | 469 | 280 | 41 | 52 | 26 | 32 |
| Pb----- | 4 | 5 | 7 | 4 | 14 | 14 | 5 | 7 | 2 | 15 | 2 | 3 | 9 | 10 | 27 |
| Sc----- | 4 | 0 | 1 | 1 | 1 | 0 | 0 | 3 | 0 | 2 | 2 | 5 | 0 | 1 | 4 |
| Sr----- | 987 | 154 | 308 | 15 | 68 | 100 | 69 | 520 | 179 | 254 | 358 | 994 | 471 | 1197 | 1089 |
| V------ | 152 | 68 | 283 | 10890 | 1592 | 638 | 75 | 2149 | 421 | 2106 | 579 | 133 | 178 | 103 | 42 |
| Zn------ | 327 | 579 | 941 | 1663 | 564 | 966 | 488 | 1583 | 880 | 2169 | 1090 | 344 | 163 | 648 | 520 |

| | Wheat Creek | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | R-7 | R-6 | P-34 | P-30 | P-26 | P-22 | P-20 | P-16 | P-14 | P-11 | P-9 | P-7 | P-4 | P-3 | P-1 |
| Ag----- | 2 | 2 | 2 | 6 | 2 | 5 | 2 | 7 | 10 | 9 | 2 | 9 | 9 | 7 | 2 |
| As----- | | | | | | | | | | | | | | | |
| Ba----- | 621 | 48 | 96 | 55 | 62 | 23 | 28 | 46 | 46 | 39 | 24 | 62 | 108 | 65 | 157 |
| Be----- | 2 | | | 1 | 0 | | | | | | | 0 | | | |
| Cd----- | 37 | 85 | 20 | 44 | 20 | 23 | 20 | 33 | 70 | 41 | 7 | 4 | 63 | 10 | 7 |
| Co----- | 3 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Cr----- | 454 | 70 | 540 | 1864 | 1150 | 581 | 292 | 1857 | 1557 | 2469 | 362 | 1250 | 1076 | 132 | 668 |
| Cu----- | 19 | 22 | 46 | 65 | 6 | 43 | 28 | 51 | 66 | 75 | 17 | 65 | 38 | 11 | 23 |
| Ga----- | 3 | 4 | 2 | 3 | 0 | 0 | 1 | 2 | 12 | 4 | 2 | 0 | 4 | 0 | 2 |
| Li------ | 2 | 5 | 1 | 7 | 0 | 3 | 0 | 0 | 0 | 2 | 2 | 0 | 4 | 0 | 0 |
| Mn----- | 65 | 260 | 119 | 38 | 0 | 172 | 164 | 22 | 8 | 2 | 103 | 0 | 16 | 4 | 95 |
| Mo----- | 2 | 5 | 10 | 26 | 9 | 20 | 10 | 7 | 1 | 56 | 5 | 35 | 23 | 19 | 8 |
| Ni------ | 18 | 21 | 33 | 175 | 62 | 83 | 87 | 139 | 169 | 158 | 46 | 225 | 64 | 60 | 15 |
| Pb----- | 62 | 20 | 9 | 6 | 4 | 2 | 2 | 5 | 5 | 6 | 3 | 18 | 17 | 5 | 8 |
| Sc----- | 1 | 2 | 4 | 4 | 1 | 2 | 1 | 2 | 2 | 3 | 1 | 1 | 3 | 0 | 3 |
| Sr----- | 1095 | 110 | 611 | 400 | 188 | 194 | 115 | 323 | 323 | 584 | 213 | 258 | 580 | 78 | 800 |
| V------ | 146 | 42 | 88 | 272 | 242 | 109 | 101 | 346 | 1208 | 753 | 52 | 302 | 239 | 18 | 83 |
| Zn------ | 536 | 230 | 323 | 974 | 444 | 396 | 397 | 739 | 799 | 688 | 214 | 1164 | 613 | 723 | 191 |

| Wheat Creek | | Lakeridge | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Cw-11 | E-92C | US-91B | E-90A | E-89A | US-88C | TO-87B | TO-86D | TO-85A | TO-84B | RT-81A | TO-78C | RT-77 | RT-75A | F-74 |
| Ag----- | 2 | | | | | | | | | | | | | | |
| As----- | | 3 | | | | | 8 | | | | | | | | |
| Ba----- | 131 | 0 | 18 | 1 | 2 | 36 | 29 | 12 | 0 | 0 | 38 | 28 | 0 | 62 | 11 |
| Be----- | | | | | | | | | 0 | | 1 | | 0 | 0 | |
| Cd----- | 20 | | | | | | | | | | | 8 | 8 | | |
| Co----- | 2 | 2 | 2 | 2 | 3 | 3 | 2 | 2 | 0 | 2 | 2 | 2 | 0 | 1 | 1 |
| Cr----- | 131 | 116 | 206 | 128 | 235 | 168 | 174 | 170 | 375 | 356 | 400 | 250 | 531 | 653 | 146 |
| Cu----- | 30 | 20 | 32 | 34 | 27 | 56 | 58 | 46 | 49 | 72 | 53 | 38 | 67 | 35 | 5 |
| Ga----- | 2 | | | | | | | | 1 | 1 | | | 1 | 5 | |
| Li------ | 0 | 4 | 16 | 11 | 12 | 10 | 12 | 27 | 20 | 19 | 22 | 17 | 15 | 15 | 3 |
| Mn----- | 101 | 882 | 211 | 583 | 770 | 475 | 437 | 179 | 349 | 451 | 149 | 479 | 162 | 76 | 191 |
| Mo----- | 5 | 5 | 7 | 8 | 8 | 14 | 17 | 16 | 12 | 19 | 11 | 10 | 15 | 12 | 15 |
| Ni------ | 15 | 12 | 21 | 18 | 21 | 37 | 36 | 31 | 35 | 49 | 38 | 28 | 63 | 78 | 13 |
| Pb----- | 3 | | 19 | 9 | 10 | 9 | 27 | 20 | 29 | 30 | 39 | 20 | 20 | 17 | 5 |
| Sc----- | 0 | | | 1 | 2 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 4 | 1 |
| Sr----- | 452 | 71 | 95 | 93 | 136 | 128 | 95 | 64 | 129 | 178 | 691 | 151 | 307 | 988 | 126 |
| V------ | 16 | 9 | 14 | 13 | 18 | 14 | 8 | 4 | 4 | 26 | 17 | 21 | 0 | 123 | 31 |
| Zn------ | 173 | 0 | 5 | | 0 | 1 | 0 | 57 | 4 | 9 | 6 | 873 | 472 | 43 | 0 |

Table 9. continued

| Sample | F-73 | F-72B | F-71B | F-70E | F-69A | F-68A | F-65B | F-64A | LS-62A | F-58B | LS-57M | LS-57D | LS-56A | LB-55B | R-54C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lakeridge | | | | | | | | |
| Ag----- | | | | | | | | | | | | | | | |
| As----- | | | | | | 0 | | | 0 | | | | | | |
| Ba----- | 0 | 50 | 28 | 0 | 5 | 0 | 91 | 44 | 0 | 11 | 11 | 8 | 45 | 0 | 0 |
| Be----- | | | | | | 0 | | | | | | | | | |
| Cd----- | | | | | | | | | | | | | | 2 | |
| Co----- | 1 | 1 | 2 | 3 | 2 | 0 | 3 | 3 | 1 | 2 | 4 | 4 | 3 | 2 | 4 |
| Cr----- | 161 | 127 | 128 | 368 | 7 | 57 | 70 | 186 | 84 | 20 | 199 | 130 | 110 | 146 | 245 |
| Cu----- | 17 | 14 | 24 | 115 | 7 | 20 | 34 | 120 | 36 | 12 | 79 | 60 | 69 | 40 | 77 |
| Ga----- | | | | | | 1 | | 0 | 0 | | | | | | |
| Li------ | 0 | 0 | 4 | 6 | 4 | 34 | 5 | 0 | 0 | | 3 | 2 | 11 | 4 | 5 |
| Mn----- | 232 | 274 | 216 | 345 | 224 | 2 | 282 | 360 | 178 | 280 | 258 | 309 | 169 | 212 | 260 |
| Mo----- | 10 | 9 | 15 | 37 | 2 | 25 | 11 | 26 | 7 | 2 | 15 | 13 | 13 | 10 | 16 |
| Ni------ | 12 | 12 | 28 | 66 | 3 | 0 | 20 | 67 | 13 | 5 | 37 | 35 | 36 | 33 | 46 |
| Pb----- | 7 | | | 5 | | 0 | | 6 | 10 | | | | | | |
| Sc----- | 2 | 1 | | 2 | | 0 | | 0 | 0 | | 2 | | | | 2 |
| Sr----- | 152 | 97 | 138 | 100 | 178 | 0 | 86 | 49 | 270 | 630 | 399 | 270 | 180 | 227 | 216 |
| V------ | 18 | 23 | 35 | 39 | 8 | 0 | 3 | 0 | 0 | 6 | 12 | 6 | 5 | 6 | 14 |
| Zn----- | 0 | 0 | 5 | | 4 | 0 | 2 | 0 | 0 | 11 | 24 | 23 | 11 | 80 | 27 |

| Sample | M-53B | M-52 | R-50F | M-48B | M-47 | M-45 | M-44A | M-42A | M-41 | M-40 | M-39B | M-36A | M-37A | M-36B | M-35A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lakeridge | | | | | | | | |
| Ag----- | | | | 2 | | | | | 3 | | 7 | 65 | 6 | | 3 |
| As----- | | | | 0 | | | | | | | | 59 | 4 | | 0 |
| Ba----- | 57 | 129 | 30 | 0 | 112 | 253 | 119 | 173 | 0 | 258 | 0 | 0 | 0 | 3 | 0 |
| Be----- | | 2 | | 0 | | | 3 | 1 | | 3 | 3 | 0 | 0 | | 0 |
| Cd----- | | 2 | 15 | | 4 | | | | | | 4 | 8 | 110 | | 4 |
| Co----- | 3 | 3 | 4 | 0 | 3 | 3 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 |
| Cr----- | 443 | 896 | 317 | 944 | 415 | 717 | 2071 | 1181 | 203 | 824 | 1879 | 1757 | 1756 | 91 | 674 |
| Cu----- | 81 | 85 | 55 | 61 | 84 | 84 | 98 | 86 | 58 | 47 | 65 | 92 | 40 | 13 | 19 |
| Ga----- | | 3 | | 1 | | | 4 | 2 | 0 | 4 | 7 | 14 | 8 | | 1 |
| Li------ | 6 | 10 | 12 | 10 | 7 | 16 | 19 | 0 | 0 | 3 | 6 | 8 | 0 | 0 | 0 |
| Mn----- | 285 | 122 | 194 | 0 | 129 | 143 | 13 | 44 | 166 | 31 | 14 | 22 | 64 | 272 | 96 |
| Mo----- | 23 | 17 | 120 | 21 | 39 | 31 | 32 | 25 | 24 | 16 | 59 | 219 | 23 | 5 | 13 |
| Ni------ | 60 | 44 | 71 | 151 | 65 | 50 | 129 | 28 | 64 | 88 | 175 | 369 | 70 | 7 | 30 |
| Pb----- | 6 | | 10 | 13 | | | 2 | 4 | 2 | | 5 | 27 | 6 | | 6 |
| Sc----- | 2 | 4 | | 3 | 4 | 8 | 5 | 9 | 0 | 11 | 10 | 6 | 5 | 0 | 0 |
| Sr----- | 254 | 1997 | 348 | 63 | 755 | 797 | 975 | 964 | 99 | 1495 | 1283 | 363 | 634 | 82 | 72 |
| V------ | 34 | 91 | 50 | 20 | 43 | 93 | 107 | 179 | 0 | 49 | 125 | 136 | 18 | 0 | 0 |
| Zn------ | 53 | 307 | 598 | 1 | 166 | 19 | 1 | 0 | 12 | 84 | 175 | 249 | 5969 | 14 | 119 |

| Sample | M-34A | M-33A | M-32A | M-31A | M-30A | M-29A | M-28A | M-27B | M-25 | M-24 | M-23B | M-22B | M-21A | M-20B | M-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lakeridge | | | | | | | | |
| Ag----- | 5 | 5 | 6 | 3 | 9 | | 4 | | 6 | 9 | 2 | 7 | 14 | 10 | 9 |
| As----- | 0 | 0 | 0 | 0 | 0 | 6 | 7 | 5 | 13 | 17 | | 20 | 36 | 21 | 32 |
| Ba----- | 0 | 0 | 0 | 5 | 0 | 126 | 25 | 1 | 0 | 0 | 2 | 0 | 91 | 0 | 24 |
| Be----- | 1 | 0 | 0 | 0 | 0 | | 1 | | 0 | 1 | | 1 | 3 | 3 | 2 |
| Cd----- | 24 | 14 | 19 | 11 | 65 | 52 | 30 | 5 | 62 | 260 | 20 | 210 | 540 | 360 | 180 |
| Co----- | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| Cr----- | 960 | 1339 | 1338 | 858 | 2043 | 730 | 1164 | 96 | 1441 | 1860 | 272 | 1176 | 941 | 899 | 2774 |
| Cu----- | 23 | 20 | 15 | 10 | 65 | 53 | 46 | 10 | 29 | 77 | 13 | 61 | 326 | 119 | 169 |
| Ga----- | 3 | 4 | 3 | 2 | 5 | | 3 | | 3 | 1 | | | | 5 | |
| Li------ | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 0 | 19 |
| Mn----- | 17 | 46 | 0 | 165 | 24 | 79 | 17 | 181 | 20 | 12 | 104 | 37 | 26 | 0 | 77 |
| Mo----- | 12 | 8 | 16 | 10 | 58 | 16 | 18 | 5 | 46 | 169 | 19 | 209 | 200 | 239 | 329 |
| Ni------ | 44 | 48 | 56 | 42 | 179 | 60 | 75 | 7 | 88 | 261 | 37 | 253 | 1393 | 324 | 691 |
| Pb----- | 5 | 5 | 8 | 2 | 8 | 4 | 6 | | 3 | 12 | 4 | 9 | 22 | 10 | 11 |
| Sc----- | 1 | 3 | 2 | 2 | 4 | 6 | 4 | 0 | 2 | 3 | 1 | 2 | 4 | 2 | 3 |
| Sr----- | 766 | 298 | 178 | 113 | 152 | 931 | 830 | 108 | 240 | 466 | 133 | 199 | 1392 | 697 | 338 |
| V------ | 62 | 7 | 45 | 26 | 55 | 54 | 62 | 1 | 91 | 682 | 233 | 1447 | 2580 | 1190 | 1443 |
| Zn------ | 871 | 536 | 555 | 297 | 1458 | 1193 | 924 | 120 | 1257 | 4271 | 434 | 2782 | 9393 | 8863 | 3181 |

Table 9. continued

| | Lakeridge | | | | | |
|---|---|---|---|---|---|---|
| Sample | M-17 | M-16 | M-15A | M-14 | M-12B | WS-11D |
| Ag----- | 15 | 8 | 13 | 13 | | |
| As----- | 36 | 11 | 27 | 52 | | 0 |
| Ba----- | 0 | 24 | 114 | 53 | 279 | 54 |
| Be----- | 4 | 1 | 2 | 2 | | 0 |
| Cd----- | 590 | 360 | 190 | 110 | 29 | |
| Co----- | 0 | 0 | 0 | 0 | 3 | 1 |
| Cr----- | 3275 | 554 | 3276 | 5481 | 328 | 52 |
| Cu----- | 309 | 88 | 200 | 472 | 129 | 33 |
| Ga----- | | | | 25 | 4 | 0 |
| Li------ | 19 | 2 | 33 | 62 | 10 | 4 |
| Mn----- | 49 | 67 | 10 | 1 | 126 | 279 |
| Mo----- | 669 | 409 | 289 | 360 | 30 | 9 |
| Ni------ | 1082 | 641 | 863 | 1187 | 108 | 9 |
| Pb----- | 19 | 5 | 17 | 23 | 7 | 6 |
| Sc----- | 3 | 1 | 5 | 5 | 3 | 1 |
| Sr----- | 529 | 248 | 809 | 874 | 1898 | 75 |
| V------ | 3845 | 2343 | 1447 | 1059 | 115 | 0 |
| Zn------ | 6982 | 5181 | 3682 | 4586 | 788 | 21 |

**Table 10.** Calculated marine rare earth elements in samples from the Phosphoria Formation from Conant Creek, Fontenelle Creek, Wheat Creek, and Lakeridge, Wyoming, and Mud Spring, Idaho. [All values in parts per million.]

| | Conant Creek | | | | | | | | | | Mud Spring | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-47 | P-46 | P-45 | P-44 | P-43 | P-42 | P-41 | P-40 | P-39 | P-38 | P-47 | P-44 | P-43 | P-41 | P-40 |
| Y--- | 40 | 93 | 104 | 20 | 33 | 35 | 86 | 12 | 49 | 55 | 135 | 67 | 133 | 156 | 52 |
| La--- | 25 | 61 | 68 | 11 | 20 | 18 | 55 | 4 | 26 | 29 | 63 | 48 | 82 | 99 | 39 |
| Ce--- | 5 | 8 | 15 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Pr--- | 3.0 | 6.4 | 6.9 | 1.2 | 1.8 | 1.1 | 6.1 | 0.2 | 2.3 | 2.2 | 12.2 | 8.5 | 12.1 | 12.0 | 5.0 |
| Nd--- | 15 | 31 | 32 | 6 | 8 | 7 | 26 | 2 | 11 | 11 | 56 | 37 | 52 | 51 | 26 |
| Sm--- | 2.2 | 4.6 | 4.6 | 0.9 | 1.3 | 0.9 | 4.0 | 0.3 | 1.6 | 1.6 | 8.1 | 5.9 | 8.0 | 7.4 | 3.9 |
| Eu--- | 0.52 | 0.91 | 0.99 | 0.14 | 0.29 | 0.17 | 1.03 | 0.05 | 0.39 | 0.35 | 1.83 | 1.13 | 1.41 | 1.71 | 0.80 |
| Gd--- | 2.98 | 5.55 | 5.91 | 1.50 | 1.49 | 1.34 | 5.19 | 0.42 | 2.56 | 2.15 | 9.54 | 5.56 | 9.45 | 9.70 | 4.71 |
| Tb--- | 0.40 | 0.83 | 0.85 | 0.20 | 0.29 | 0.19 | 0.78 | 0.07 | 0.33 | 0.37 | 1.37 | 1.00 | 1.35 | 1.26 | 0.65 |
| Dy--- | 2.9 | 6.4 | 6.7 | 1.2 | 2.2 | 2.1 | 5.1 | 1.0 | 2.6 | 3.1 | 9.4 | 6.2 | 9.4 | 9.4 | 4.8 |
| Ho--- | 0.62 | 1.37 | 1.42 | 0.24 | 0.41 | 0.34 | 1.18 | 0.11 | 0.56 | 0.61 | 2.01 | 1.17 | 1.99 | 2.04 | 0.78 |
| Er--- | 1.6 | 3.9 | 4.1 | 0.6 | 1.2 | 1.1 | 3.2 | 0.5 | 1.6 | 1.5 | 6.3 | 3.3 | 6.3 | 5.7 | 2.1 |
| Tm--- | 0.23 | 0.50 | 0.54 | 0.08 | 0.12 | 0.07 | 0.41 | 0.03 | 0.22 | 0.21 | 0.75 | 0.35 | 0.74 | 0.67 | 0.13 |
| Yb--- | 1.5 | 4.0 | 4.2 | 0.8 | 1.1 | 1.0 | 3.0 | 0.7 | 1.6 | 1.8 | 5.3 | 3.3 | 5.5 | 5.4 | 1.7 |

| | Mud Spring | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-38 | P-35 | P-33 | P-31 | P-29 | P-27 | P-26 | P-25 | P-23 | P-22 | P-17 | P-16 | P-15 | P-14 | P-11 |
| Y--- | 86 | 158 | 109 | 456 | 152 | 159 | 106 | 70 | 45 | 38 | 230 | 189 | 33 | 27 | 128 |
| La--- | 49 | 102 | 59 | 281 | 87 | 106 | 58 | 47 | 30 | 27 | 123 | 98 | 13 | 12 | 71 |
| Ce--- | 0 | 3 | 0 | 38 | 8 | 11 | 7 | 10 | 8 | 0 | 0 | 0 | 0 | 0 | 7 |
| Pr--- | 9.2 | 16.6 | 7.9 | 39.9 | 11.9 | 13.5 | 7.3 | 5.3 | 3.6 | 4.0 | 22.3 | 16.5 | 1.7 | 1.7 | 9.0 |
| Nd--- | 41 | 74 | 35 | 172 | 51 | 58 | 33 | 27 | 17 | 18 | 104 | 75 | 9 | 8 | 40 |
| Sm--- | 6.1 | 10.8 | 4.7 | 26.5 | 7.7 | 8.5 | 5.0 | 4.1 | 2.5 | 2.8 | 17.2 | 12.1 | 1.3 | 1.3 | 5.9 |
| Eu--- | 1.33 | 2.51 | 1.09 | 5.97 | 1.61 | 1.86 | 0.97 | 0.87 | 0.47 | 0.47 | 3.65 | 2.74 | 0.29 | 0.22 | 1.37 |
| Gd--- | 6.51 | 13.10 | 5.35 | 29.62 | 9.95 | 10.72 | 6.14 | 4.43 | 2.65 | 2.66 | 19.60 | 14.42 | 1.84 | 1.78 | 7.38 |
| Tb--- | 1.06 | 1.82 | 0.74 | 4.47 | 1.36 | 1.53 | 0.90 | 0.70 | 0.44 | 0.38 | 2.88 | 2.11 | 0.26 | 0.19 | 1.17 |
| Dy--- | 7.4 | 11.7 | 5.8 | 28.9 | 9.4 | 10.2 | 6.5 | 5.1 | 3.3 | 3.2 | 18.5 | 14.1 | 2.1 | 1.7 | 7.9 |
| Ho--- | 1.40 | 2.52 | 1.27 | 6.82 | 2.19 | 2.34 | 1.49 | 1.09 | 0.77 | 0.57 | 4.02 | 2.98 | 0.39 | 0.37 | 1.78 |
| Er--- | 4.0 | 6.9 | 3.8 | 21.1 | 6.2 | 7.1 | 4.0 | 3.1 | 2.2 | 1.5 | 11.1 | 8.7 | 1.0 | 1.1 | 5.1 |
| Tm--- | 0.46 | 0.81 | 0.46 | 2.46 | 0.78 | 0.77 | 0.42 | 0.34 | 0.28 | 0.16 | 1.55 | 1.14 | 0.09 | 0.09 | 0.68 |
| Yb--- | 3.4 | 6.6 | 3.6 | 18.2 | 5.8 | 6.2 | 3.8 | 2.6 | 2.1 | 1.4 | 10.4 | 7.6 | 1.2 | 0.9 | 4.7 |

| | Mud Spring | | | | | Fontenelle Creek | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-8 | P-6 | P-4 | P-2 | P-1 | E-4 | U-3 | U-1 | R-9 | R-6 | P-45 | P-43 | P-40 | P-39 | P-37 |
| Y--- | 420 | 494 | 18 | 181 | 343 | 164 | 564 | 257 | 79 | 243 | 10 | 19 | 10 | 19 | 22 |
| La--- | 209 | 232 | 10 | 93 | 205 | 103 | 353 | 147 | 42 | 151 | 6 | 9 | 8 | 10 | 12 |
| Ce--- | 42 | 35 | 6 | 9 | 50 | 25 | 94 | 42 | 16 | 60 | 3 | 0 | 5 | 0 | 0 |
| Pr--- | 27.4 | 27.0 | 1.4 | 11.9 | 27.7 | 12.3 | 55.2 | 19.2 | 5.0 | 17.9 | 0.3 | 0.8 | 0.5 | 0.9 | 0.7 |
| Nd--- | 130 | 122 | 7 | 52 | 125 | 53 | 233 | 85 | 24 | 76 | 4 | 6 | 5 | 7 | 6 |
| Sm--- | 20.1 | 19.6 | 1.0 | 8.0 | 20.1 | 8.2 | 39.7 | 14.4 | 3.8 | 11.4 | 0.6 | 0.8 | 0.9 | 1.1 | 0.9 |
| Eu--- | 4.69 | 4.29 | 0.21 | 1.85 | 4.60 | 2.24 | 9.72 | 3.37 | 0.82 | 3.06 | 0.10 | 0.17 | 0.15 | 0.22 | 0.25 |
| Gd--- | 28.29 | 24.72 | 1.24 | 10.28 | 25.16 | 9.90 | 45.82 | 18.45 | 5.52 | 15.59 | 0.98 | 1.45 | 0.96 | 1.29 | 1.38 |
| Tb--- | 3.92 | 3.69 | 0.20 | 1.55 | 3.46 | 1.52 | 6.91 | 2.51 | 0.69 | 2.27 | 0.11 | 0.14 | 0.14 | 0.17 | 0.21 |
| Dy--- | 27.6 | 28.0 | 1.5 | 10.8 | 23.3 | 10.1 | 41.1 | 17.6 | 4.2 | 14.9 | 0.9 | 1.4 | 1.1 | 1.4 | 1.9 |
| Ho--- | 6.76 | 6.34 | 0.28 | 2.56 | 5.13 | 2.28 | 8.86 | 3.69 | 1.10 | 3.92 | 0.16 | 0.33 | 0.29 | 0.37 | 0.33 |
| Er--- | 21.9 | 21.2 | 0.8 | 7.7 | 15.5 | 6.4 | 25.2 | 10.6 | 3.1 | 10.1 | 0.6 | 1.0 | 0.6 | 1.0 | 1.1 |
| Tm--- | 2.83 | 2.87 | 0.07 | 1.02 | 2.02 | 0.80 | 3.38 | 1.34 | 0.39 | 1.36 | 0.06 | 0.10 | 0.12 | 0.10 | 0.09 |
| Yb--- | 20.0 | 19.2 | 0.9 | 6.7 | 12.5 | 5.3 | 18.3 | 7.8 | 2.5 | 6.9 | 0.5 | 0.8 | 0.5 | 0.9 | 0.7 |

| | Fontenelle Creek | | | | | | | | | | | | | Wheat Creek | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | P-32 | P-31 | P-25 | P-23 | P-21 | P-20 | P-19 | P-13 | P-12 | P-6 | P-7 | P-3 | P-1 | R-15 | R-9 |
| Y--- | 746 | 102 | 189 | 18 | 168 | 59 | 7 | 140 | 30 | 261 | 134 | 337 | 316 | 209 | 194 |
| La--- | 328 | 48 | 138 | 11 | 114 | 46 | 10 | 73 | 20 | 178 | 68 | 206 | 215 | 156 | 113 |
| Ce--- | 79 | 8 | 24 | 0 | 44 | 21 | 3 | 2 | 7 | 14 | 9 | 33 | 40 | 36 | 39 |
| Pr--- | 41.5 | 5.6 | 14.7 | 2.4 | 16.7 | 5.0 | 0.4 | 6.6 | 2.2 | 17.5 | 8.2 | 22.0 | 27.7 | 14.6 | 12.3 |
| Nd--- | 188 | 25 | 63 | 16 | 75 | 26 | 2 | 32 | 10 | 77 | 38 | 95 | 125 | 84 | 55 |
| Sm--- | 30.7 | 4.8 | 8.6 | 3.3 | 13.4 | 4.4 | 0.1 | 4.2 | 1.4 | 10.0 | 4.5 | 12.3 | 17.1 | 9.2 | 8.1 |
| Eu--- | 7.33 | 1.06 | 1.68 | 0.59 | 3.51 | 0.86 | 0.00 | 1.03 | 0.37 | 2.34 | 1.02 | 3.35 | 4.19 | 2.23 | 1.54 |
| Gd--- | 43.70 | 6.18 | 10.81 | 3.07 | 15.85 | 3.99 | 0.00 | 6.14 | 1.80 | 12.40 | 6.32 | 17.37 | 21.14 | 12.73 | 10.90 |
| Tb--- | 5.95 | 0.82 | 1.54 | 0.61 | 2.42 | 0.76 | 0.04 | 0.68 | 0.26 | 1.91 | 0.81 | 2.60 | 2.96 | 1.66 | 1.52 |
| Dy--- | 38.8 | 5.9 | 10.3 | 3.6 | 15.7 | 5.1 | 0.6 | 6.5 | 1.9 | 14.1 | 6.0 | 17.5 | 20.3 | 11.8 | 10.1 |
| Ho--- | 9.94 | 1.40 | 2.46 | 0.65 | 3.67 | 1.02 | 0.09 | 1.41 | 0.42 | 3.28 | 1.56 | 4.47 | 4.43 | 2.85 | 2.48 |
| Er--- | 29.8 | 4.4 | 6.9 | 1.5 | 10.3 | 2.9 | 0.5 | 4.6 | 1.1 | 9.7 | 4.8 | 13.6 | 13.4 | 8.6 | 8.2 |
| Tm--- | 3.77 | 0.57 | 0.88 | 0.20 | 1.28 | 0.23 | 0.00 | 0.52 | 0.14 | 1.24 | 0.57 | 1.84 | 1.81 | 1.17 | 1.09 |
| Yb--- | 22.8 | 3.8 | 4.8 | 1.1 | 7.1 | 1.7 | 0.5 | 3.5 | 1.0 | 8.9 | 4.5 | 11.6 | 10.5 | 6.5 | 6.9 |

Table 10. continued

| | Wheat Creek | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | R-7 | R-6 | P-34 | P-30 | P-26 | P-22 | P-20 | P-16 | P-14 | P-11 | P-9 | P-7 | P-4 | P-3 | P-1 |
| La---- | 348 | 40 | 276 | 254 | 148 | 50 | 14 | 171 | 201 | 237 | 39 | 158 | 290 | 22 | 185 |
| | 227 | 22 | 205 | 201 | 124 | 44 | 10 | 118 | 138 | 144 | 23 | 84 | 198 | 15 | 124 |
| Ce---- | 53 | 8 | 59 | 28 | 29 | 10 | 0 | 8 | 8 | 8 | 0 | 0 | 27 | 4 | 18 |
| Pr--- | 25.3 | 3.1 | 26.7 | 19.5 | 10.7 | 4.0 | 0.2 | 10.5 | 12.5 | 15.1 | 1.9 | 7.7 | 18.0 | 1.4 | 11.5 |
| Nd---- | 117 | 16 | 115 | 82 | 48 | 21 | 4 | 42 | 56 | 84 | 9 | 34 | 78 | 8 | 51 |
| Sm--- | 16.5 | 2.8 | 16.1 | 10.7 | 6.4 | 2.6 | 0.6 | 5.7 | 8.0 | 9.2 | 1.6 | 5.4 | 11.8 | 1.7 | 6.7 |
| Eu---- | 3.79 | 0.56 | 3.49 | 2.49 | 1.41 | 0.73 | 0.04 | 1.74 | 1.84 | 2.58 | 0.32 | 1.41 | 2.93 | 0.25 | 1.86 |
| Gd---- | 22.53 | 3.60 | 21.14 | 15.03 | 7.85 | 3.74 | 0.41 | 9.40 | 10.40 | 12.42 | 2.42 | 7.85 | 17.04 | 1.87 | 10.98 |
| Tb---- | 3.12 | 0.47 | 2.86 | 2.01 | 1.22 | 0.47 | 0.12 | 1.21 | 1.51 | 1.86 | 0.29 | 1.12 | 2.28 | 0.32 | 1.43 |
| Dy--- | 21.6 | 3.1 | 19.3 | 13.6 | 9.7 | 3.5 | 0.6 | 9.1 | 11.1 | 12.9 | 2.1 | 7.7 | 16.4 | 2.3 | 10.2 |
| Ho---- | 5.11 | 0.58 | 4.13 | 3.31 | 1.97 | 0.69 | 0.08 | 1.88 | 2.48 | 2.98 | 0.41 | 1.77 | 3.71 | 0.37 | 2.20 |
| Er---- | 15.7 | 1.9 | 11.4 | 10.1 | 5.5 | 2.0 | 0.3 | 5.5 | 7.5 | 9.3 | 1.4 | 5.1 | 11.7 | 1.0 | 7.6 |
| Tm--- | 2.25 | 0.20 | 1.51 | 1.50 | 0.78 | 0.30 | 0.07 | 0.73 | 0.93 | 1.34 | 0.18 | 0.78 | 1.70 | 0.15 | 1.10 |
| Yb---- | 12.7 | 1.4 | 8.7 | 8.2 | 4.2 | 1.4 | 0.6 | 4.6 | 6.1 | 8.5 | 1.2 | 4.1 | 10.8 | 1.2 | 7.2 |

| Wheat Creek | | Lakeridge | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Cw-11 | E-92C | US-91B | E-90A | E-89A | US-88C | TO-87B | TO-86D | TO-85A | TO-84B | RT-81A | TO-78C | RT-77 | RT-75A | F-74 |
| Y---- | 116 | 18 | 82 | 27 | 60 | 58 | 22 | 12 | 29 | 25 | 74 | 22 | 93 | 453 | 48 |
| La---- | 63 | 9 | 53 | 18 | 41 | 38 | 13 | 6 | 20 | 12 | 45 | 15 | 67 | 331 | 30 |
| Ce---- | 30 | 1 | 20 | 4 | 13 | 13 | 1 | 0 | 0 | 0 | 8 | 0 | 5 | 91 | 12 |
| Pr--- | 7.5 | 1.6 | 9.5 | 2.3 | 5.8 | 6.2 | 1.6 | 0.6 | 2.4 | 1.2 | 4.6 | 1.6 | 8.1 | 47.9 | 3.9 |
| Nd---- | 31 | 6 | 39 | 8 | 23 | 24 | 6 | 3 | 8 | 4 | 17 | 6 | 28 | 192 | 15 |
| Sm--- | 5.1 | 1.2 | 7.1 | 1.5 | 4.0 | 4.4 | 1.2 | 0.5 | 1.6 | 0.7 | 2.6 | 1.0 | 4.3 | 31.4 | 2.6 |
| Eu---- | 1.41 | 0.26 | 1.31 | 0.40 | 1.10 | 0.82 | 0.24 | 0.08 | 0.26 | 0.14 | 0.77 | 0.14 | 1.13 | 6.46 | 0.51 |
| Gd---- | 7.12 | 1.46 | 8.54 | 1.89 | 4.89 | 5.11 | 1.57 | 0.74 | 2.19 | 1.03 | 3.64 | 1.34 | 5.79 | 36.59 | 3.73 |
| Tb---- | 0.97 | 0.18 | 1.24 | 0.27 | 0.68 | 0.73 | 0.20 | 0.07 | 0.27 | 0.15 | 0.52 | 0.17 | 0.87 | 5.37 | 0.54 |
| Dy--- | 6.7 | 1.4 | 7.4 | 1.9 | 4.5 | 4.9 | 1.6 | 0.8 | 2.4 | 1.6 | 4.1 | 1.3 | 5.9 | 33.9 | 3.4 |
| Ho---- | 1.44 | 0.32 | 1.63 | 0.44 | 1.02 | 1.16 | 0.37 | 0.15 | 0.49 | 0.34 | 0.93 | 0.32 | 1.36 | 7.42 | 0.80 |
| Er---- | 4.6 | 1.0 | 4.3 | 1.3 | 2.9 | 3.2 | 1.1 | 0.4 | 1.2 | 0.9 | 3.0 | 0.9 | 3.7 | 21.1 | 2.4 |
| Tm--- | 0.52 | 0.13 | 0.52 | 0.20 | 0.36 | 0.43 | 0.15 | 0.04 | 0.15 | 0.11 | 0.39 | 0.12 | 0.47 | 2.86 | 0.32 |
| Yb---- | 2.6 | 0.8 | 2.9 | 1.2 | 2.0 | 2.5 | 0.9 | 0.3 | 0.9 | 0.8 | 2.2 | 0.8 | 2.5 | 15.2 | 2.0 |

| | Lakeridge | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | F-73 | F-72B | F-71B | F-70E | F-69A | F-68A | F-65B | F-64A | LS-62A | F-58B | LS-57M | LS-57D | LS-56A | LS-55B | R-54C |
| Y---- | 58 | 19 | 39 | 53 | 4 | 0 | 4 | 0 | 0 | 9 | 170 | 62 | 40 | 128 | 50 |
| La---- | 34 | 13 | 25 | 26 | 10 | 9 | 5 | 0 | 2 | 5 | 100 | 34 | 22 | 76 | 31 |
| Ce---- | 11 | 3 | 10 | 5 | 5 | 0 | 3 | 0 | 0 | 6 | 27 | 9 | 6 | 25 | 6 |
| Pr--- | 4.0 | 1.4 | 5.0 | 5.3 | 0.9 | 0.0 | 0.9 | 0.0 | 0.2 | 1.2 | 15.9 | 5.5 | 3.6 | 12.5 | 4.5 |
| Nd---- | 15 | 6 | 20 | 22 | 2 | 0 | 4 | 0 | 0 | 5 | 67 | 22 | 15 | 52 | 18 |
| Sm--- | 3.2 | 1.0 | 3.5 | 4.2 | 0.6 | 0.0 | 0.8 | 0.5 | 0.0 | 1.2 | 11.9 | 3.7 | 2.7 | 9.7 | 2.9 |
| Eu---- | 0.79 | 0.25 | 0.66 | 0.86 | 0.18 | 0.00 | 0.15 | 0.02 | 0.00 | 0.17 | 2.69 | 0.76 | 0.60 | 2.03 | 0.69 |
| Gd---- | 3.54 | 1.37 | 4.55 | 4.48 | 0.47 | 0.00 | 0.59 | 0.47 | 0.13 | 1.30 | 14.94 | 4.56 | 3.47 | 11.69 | 3.70 |
| Tb---- | 0.58 | 0.18 | 0.56 | 0.69 | 0.02 | 0.00 | 0.08 | 0.05 | 0.03 | 0.19 | 2.29 | 0.70 | 0.48 | 1.75 | 0.49 |
| Dy--- | 4.1 | 1.4 | 3.7 | 4.6 | 0.4 | 0.0 | 0.6 | 0.8 | 0.8 | 1.2 | 14.0 | 4.7 | 3.0 | 10.8 | 3.3 |
| Ho---- | 0.85 | 0.33 | 0.76 | 1.00 | 0.08 | 0.00 | 0.14 | 0.09 | 0.09 | 0.26 | 3.19 | 1.19 | 0.68 | 2.34 | 0.81 |
| Er---- | 2.6 | 0.9 | 2.0 | 2.4 | 0.2 | 0.0 | 0.3 | 0.2 | 0.0 | 0.7 | 9.0 | 3.6 | 1.9 | 6.5 | 2.2 |
| Tm--- | 0.34 | 0.16 | 0.27 | 0.30 | 0.03 | 0.00 | 0.04 | 0.00 | 0.01 | 0.09 | 1.19 | 0.56 | 0.24 | 0.79 | 0.31 |
| Yb---- | 2.2 | 1.0 | 1.6 | 1.6 | 0.1 | 0.0 | 0.2 | 0.1 | 0.0 | 0.5 | 6.1 | 4.0 | 1.3 | 4.2 | 1.9 |

| | Lakeridge | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | M-53B | M-52 | R-50F | M-48B | M-47 | M-45 | M-44A | M-42A | M-41 | M-40 | M-39B | M-38A | M-37A | M-36B | M-35A |
| Y---- | 127 | 898 | 229 | 10 | 238 | 639 | 327 | 522 | 15 | 497 | 291 | 271 | 71 | 0 | 9 |
| La---- | 66 | 598 | 139 | 17 | 217 | 418 | 255 | 420 | 16 | 407 | 219 | 198 | 58 | 2 | 18 |
| Ce---- | 14 | 145 | 46 | 0 | 53 | 81 | 67 | 239 | 3 | 133 | 67 | 21 | 0 | 0 | 0 |
| Pr--- | 11.1 | 85.5 | 23.6 | 0.4 | 24.3 | 53.6 | 31.3 | 61.6 | 1.5 | 43.2 | 22.4 | 21.5 | 3.9 | 0.0 | 2.2 |
| Nd---- | 44 | 338 | 94 | 0 | 90 | 198 | 116 | 241 | 4 | 157 | 81 | 79 | 14 | 0 | 6 |
| Sm--- | 7.6 | 58.6 | 15.7 | 0.2 | 14.5 | 29.7 | 19.3 | 41.3 | 0.8 | 23.4 | 11.1 | 12.0 | 1.6 | 0.0 | 1.1 |
| Eu---- | 1.56 | 12.92 | 3.14 | 0.00 | 3.59 | 5.33 | 4.52 | 8.93 | 0.00 | 5.58 | 2.79 | 2.44 | 0.36 | 0.00 | 0.00 |
| Gd---- | 9.40 | 75.66 | 18.77 | 0.28 | 17.55 | 36.73 | 23.57 | 46.44 | 0.95 | 31.48 | 15.28 | 16.40 | 2.88 | 0.00 | 0.91 |
| Tb---- | 1.40 | 10.94 | 2.76 | 0.00 | 2.53 | 5.46 | 3.50 | 6.84 | 0.17 | 4.52 | 2.22 | 2.41 | 0.33 | 0.00 | 0.12 |
| Dy--- | 9.0 | 67.7 | 16.8 | 1.0 | 15.6 | 34.8 | 23.1 | 40.8 | 1.9 | 28.6 | 15.6 | 16.1 | 3.4 | 0.3 | 1.9 |
| Ho---- | 2.18 | 15.93 | 3.75 | 0.08 | 3.61 | 8.45 | 5.21 | 8.69 | 0.34 | 6.90 | 3.66 | 3.98 | 0.80 | 0.01 | 0.26 |
| Er---- | 6.3 | 44.8 | 9.8 | 0.0 | 10.7 | 23.8 | 14.4 | 24.0 | 0.9 | 19.7 | 10.9 | 10.7 | 2.3 | 0.0 | 0.4 |
| Tm--- | 0.83 | 5.67 | 1.18 | 0.01 | 1.35 | 3.07 | 1.85 | 2.84 | 0.13 | 2.55 | 1.43 | 1.43 | 0.29 | 0.00 | 0.03 |
| Yb---- | 4.5 | 30.8 | 6.4 | 0.3 | 7.2 | 16.8 | 10.6 | 15.1 | 0.9 | 13.7 | 8.1 | 8.9 | 1.8 | 0.0 | 0.4 |

Table 10. continued

| | Lakeridge | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | M-34A | M-33A | M-32A | M-31A | M-30A | M-29A | M-28A | M-27B | M-25 | M-24 | M-23B | M-22B | M-21A | M-20B | M-18 |
| Y---- | 44 | 45 | 10 | 15 | 58 | 266 | 104 | 2 | 28 | 66 | 5 | 48 | 256 | 138 | 199 |
| La---- | 52 | 46 | 22 | 11 | 41 | 185 | 91 | 3 | 29 | 53 | 5 | 34 | 155 | 104 | 146 |
| Ce---- | 0 | 3 | 0 | 0 | 0 | 29 | 2 | 0 | 0 | 0 | 0 | 0 | 19 | 53 | 16 |
| Pr--- | 2.5 | 6.3 | 0.1 | 0.5 | 2.7 | 17.7 | 6.5 | 0.1 | 1.9 | 3.8 | 0.2 | 3.1 | 14.8 | 13.6 | 15.7 |
| Nd---- | 7 | 20 | 0 | 1 | 12 | 68 | 26 | 0 | 6 | 14 | 1 | 11 | 57 | 48 | 59 |
| Sm--- | 0.6 | 3.2 | 0.0 | 0.1 | 1.6 | 10.1 | 3.7 | 0.2 | 0.6 | 1.8 | 0.2 | 1.6 | 8.6 | 8.3 | 8.6 |
| Eu---- | 0.08 | 0.68 | 0.00 | 0.01 | 0.26 | 2.19 | 0.79 | 0.00 | 0.00 | 0.40 | 0.01 | 0.25 | 1.91 | 1.99 | 1.56 |
| Gd---- | 1.24 | 3.61 | 0.00 | 0.44 | 2.63 | 13.14 | 4.93 | 0.13 | 0.97 | 2.64 | 0.14 | 2.17 | 11.22 | 9.77 | 10.81 |
| Tb---- | 0.15 | 0.57 | 0.00 | 0.04 | 0.32 | 1.96 | 0.71 | 0.00 | 0.05 | 0.37 | 0.00 | 0.28 | 1.87 | 1.51 | 1.54 |
| Dy--- | 1.9 | 4.3 | 0.0 | 0.8 | 3.1 | 13.3 | 5.3 | 0.3 | 1.5 | 3.0 | 0.3 | 2.5 | 12.4 | 10.6 | 11.3 |
| Ho---- | 0.43 | 0.78 | 0.00 | 0.15 | 0.65 | 3.33 | 1.31 | 0.05 | 0.21 | 0.73 | 0.04 | 0.56 | 3.24 | 2.25 | 2.66 |
| Er---- | 1.1 | 1.5 | 0.0 | 0.2 | 1.5 | 9.4 | 3.8 | 0.1 | 0.3 | 2.2 | 0.1 | 1.5 | 10.5 | 6.0 | 7.9 |
| Tm--- | 0.12 | 0.11 | 0.00 | 0.00 | 0.14 | 1.31 | 0.49 | 0.00 | 0.00 | 0.26 | 0.00 | 0.19 | 1.32 | 0.67 | 0.98 |
| Yb---- | 0.7 | 0.7 | 0.0 | 0.0 | 1.1 | 7.6 | 2.9 | 0.0 | 0.2 | 1.7 | 0.0 | 1.3 | 8.1 | 4.0 | 6.3 |

| | Lakeridge | | | | | |
|---|---|---|---|---|---|---|
| Sample | M-17 | M-16 | M-15A | M-14 | M-12B | WS-11D |
| Y---- | 269 | 47 | 439 | 262 | 449 | 0 |
| La---- | 177 | 28 | 317 | 130 | 269 | 4 |
| Ce---- | 14 | 1 | 37 | 14 | 58 | 0 |
| Pr--- | 17.8 | 4.1 | 33.9 | 19.6 | 47.7 | 0.1 |
| Nd---- | 66 | 16 | 128 | 76 | 189 | 0 |
| Sm--- | 9.7 | 2.8 | 17.8 | 13.3 | 32.8 | 0.0 |
| Eu---- | 2.09 | 0.48 | 3.71 | 2.63 | 6.96 | 0.00 |
| Gd---- | 13.89 | 3.11 | 22.97 | 16.44 | 37.82 | 0.00 |
| Tb---- | 2.05 | 0.48 | 3.37 | 2.34 | 5.47 | 0.00 |
| Dy--- | 13.3 | 3.6 | 23.4 | 15.8 | 32.9 | 0.1 |
| Ho---- | 3.48 | 0.78 | 5.89 | 3.89 | 7.46 | 0.00 |
| Er---- | 10.6 | 2.2 | 17.7 | 12.0 | 20.9 | 0.0 |
| Tm--- | 1.39 | 0.27 | 2.39 | 1.54 | 2.56 | 0.00 |
| Yb---- | 8.6 | 1.7 | 14.8 | 10.1 | 13.9 | 0.0 |

Table 11. Components and calculated marine minor element correlation table for A) Conant Creek (R=0.71 is significant at the 1 percent level, R-values with significance at 1 percent level or better have been shaded), and B) Mud Spring (R=0.49 is significant at the 1 percent level, R-values with significance at 1 percent level or better have been shaded)

| A | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | As | Cr | Cu | Mn | Mo | Ni | Pb | Sr | V | Zn | La |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite | 1.00 | | | | | | | | | | | | | | | |
| Calcite | -0.23 | 1.00 | | | | | | | | | | | | | | |
| Biogenic $SiO_2$ | -0.47 | 0.55 | 1.00 | | | | | | | | | | | | | |
| Apatite | -0.57 | -0.25 | -0.28 | 1.00 | | | | | | | | | | | | |
| Organic matter | 0.22 | -0.50 | -0.61 | -0.08 | 1.00 | | | | | | | | | | | |
| As | -0.42 | -0.33 | -0.34 | 0.60 | 0.53 | 1.00 | | | | | | | | | | |
| Cr | 0.18 | -0.34 | -0.65 | -0.09 | 0.86 | 0.29 | 1.00 | | | | | | | | | |
| Cu | -0.42 | 0.55 | 0.88 | -0.31 | -0.61 | -0.48 | -0.43 | 1.00 | | | | | | | | |
| Mn | 0.71 | 0.06 | 0.02 | -0.66 | -0.07 | -0.64 | -0.13 | -0.10 | 1.00 | | | | | | | |
| Mo | -0.46 | 0.53 | 0.92 | -0.26 | -0.47 | -0.30 | -0.51 | 0.77 | 0.16 | 1.00 | | | | | | |
| Ni | -0.47 | 0.57 | 0.87 | -0.35 | -0.39 | -0.36 | -0.30 | 0.85 | 0.07 | 0.95 | 1.00 | | | | | |
| Pb | -0.35 | -0.37 | -0.25 | 0.64 | 0.31 | 0.89 | 0.05 | -0.42 | -0.48 | -0.17 | -0.28 | 1.00 | | | | |
| Sr | -0.52 | -0.25 | -0.36 | 0.98 | -0.04 | 0.61 | -0.01 | -0.36 | -0.64 | -0.32 | -0.37 | 0.68 | 1.00 | | | |
| V | -0.54 | 0.39 | -0.08 | 0.48 | -0.12 | 0.08 | 0.25 | 0.14 | -0.55 | -0.04 | 0.14 | -0.06 | 0.50 | 1.00 | | |
| Zn | 0.40 | -0.49 | -0.71 | -0.08 | 0.77 | 0.30 | 0.81 | -0.57 | 0.08 | -0.50 | -0.37 | 0.31 | 0.05 | -0.05 | 1.00 | |
| La | -0.57 | -0.16 | -0.23 | 0.92 | -0.15 | 0.41 | -0.06 | -0.20 | -0.69 | -0.30 | -0.32 | 0.33 | 0.87 | 0.63 | -0.24 | 1.00 |

| B | Dolomite | Biogenic $SiO_2$ | Apatite | Organic matter | Ag | Ba | Cd | Cr | Cu | Mn | Mo | Ni | Sr | V | Zn | La |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite | 1.00 | | | | | | | | | | | | | | | |
| Biogenic $SiO_2$ | -0.33 | 1.00 | | | | | | | | | | | | | | |
| Apatite | 0.55 | -0.66 | 1.00 | | | | | | | | | | | | | |
| Organic matter | -0.13 | -0.47 | -0.04 | 1.00 | | | | | | | | | | | | |
| Ag | 0.14 | -0.56 | 0.37 | 0.49 | 1.00 | | | | | | | | | | | |
| Ba | -0.32 | -0.16 | -0.25 | 0.58 | 0.04 | 1.00 | | | | | | | | | | |
| Cd | 0.29 | -0.22 | 0.39 | -0.23 | 0.00 | -0.14 | 1.00 | | | | | | | | | |
| Cr | 0.13 | -0.60 | 0.09 | 0.71 | 0.58 | 0.33 | -0.23 | 1.00 | | | | | | | | |
| Cu | -0.26 | -0.41 | -0.19 | 0.79 | 0.44 | 0.60 | -0.26 | 0.76 | 1.00 | | | | | | | |
| Mn | -0.21 | 0.13 | -0.08 | -0.26 | -0.14 | -0.04 | 0.73 | -0.39 | -0.16 | 1.00 | | | | | | |
| Mo | -0.03 | 0.21 | -0.14 | -0.30 | -0.27 | -0.27 | 0.04 | -0.31 | -0.24 | 0.25 | 1.00 | | | | | |
| Ni | -0.23 | -0.03 | -0.12 | -0.11 | -0.05 | -0.02 | 0.65 | -0.32 | -0.09 | 0.84 | 0.18 | 1.00 | | | | |
| Sr | 0.31 | -0.72 | 0.70 | 0.35 | 0.36 | 0.17 | 0.04 | 0.57 | 0.34 | -0.29 | -0.17 | -0.27 | 1.00 | | | |
| V | 0.63 | -0.44 | 0.73 | -0.01 | 0.51 | -0.25 | 0.40 | 0.30 | -0.02 | -0.12 | -0.24 | -0.20 | 0.54 | 1.00 | | |
| Zn | -0.17 | -0.28 | -0.02 | 0.13 | 0.20 | -0.01 | 0.50 | -0.10 | 0.07 | 0.57 | 0.03 | 0.87 | -0.13 | -0.12 | 1.00 | |
| La | 0.57 | -0.59 | 0.86 | 0.08 | 0.38 | -0.13 | 0.23 | 0.32 | 0.05 | -0.20 | -0.20 | -0.34 | 0.74 | 0.82 | -0.26 | 1.00 |

Table 11. (cont.) Components and calculated marine minor elements correlation table for C) Fontenelle Creek (R=0.51 is significant at the 1 percent level, R-values with significance at 1 percent level or better have been shaded) and D) Wheat Creek (R=0.56 is significant at the 1 percent level, R-values with significance at 1 percent level or better have been shaded)

| C | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Cd | Cr | Cu | Mn | Mo | Ni | Pb | Sr | V | Zn | La |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite------ | 1.00 | | | | | | | | | | | | | | | |
| Calcite-------- | 0.83 | 1.00 | | | | | | | | | | | | | | |
| Biogenic $SiO_2$ | 0.01 | 0.24 | 1.00 | | | | | | | | | | | | | |
| Apatite------- | -0.48 | -0.53 | -0.56 | 1.00 | | | | | | | | | | | | |
| Organic matter | -0.21 | -0.24 | -0.31 | -0.18 | 1.00 | | | | | | | | | | | |
| Cd------------ | -0.22 | -0.21 | -0.22 | -0.35 | 0.82 | 1.00 | | | | | | | | | | |
| Cr------------ | -0.42 | -0.44 | -0.35 | 0.02 | 0.83 | 0.78 | 1.00 | | | | | | | | | |
| Cu------------ | -0.32 | -0.30 | -0.24 | -0.19 | 0.92 | 0.89 | 0.87 | 1.00 | | | | | | | | |
| Mn------------ | 0.69 | 0.64 | 0.19 | -0.40 | -0.40 | -0.29 | -0.58 | -0.46 | 1.00 | | | | | | | |
| Mo------------ | -0.26 | -0.26 | -0.17 | -0.29 | 0.74 | 0.83 | 0.68 | 0.85 | -0.46 | 1.00 | | | | | | |
| Ni------------ | -0.16 | -0.17 | -0.31 | -0.28 | 0.91 | 0.93 | 0.78 | 0.93 | -0.31 | 0.85 | 1.00 | | | | | |
| Pb------------ | -0.24 | -0.24 | -0.22 | 0.33 | -0.09 | -0.09 | -0.04 | -0.01 | 0.07 | -0.07 | -0.10 | 1.00 | | | | |
| Sr------------ | -0.38 | -0.39 | -0.60 | 0.91 | -0.08 | -0.29 | 0.05 | -0.13 | -0.32 | -0.27 | -0.21 | 0.39 | 1.00 | | | |
| V------------- | -0.20 | -0.22 | -0.13 | -0.24 | 0.55 | 0.63 | 0.43 | 0.64 | -0.38 | 0.93 | 0.68 | -0.07 | -0.24 | 1.00 | | |
| Zn------------ | -0.22 | -0.21 | -0.24 | -0.27 | 0.85 | 0.86 | 0.67 | 0.81 | -0.33 | 0.74 | 0.93 | -0.16 | -0.22 | 0.59 | 1.00 | |
| La------------ | -0.51 | -0.55 | -0.56 | 0.85 | -0.04 | -0.08 | 0.24 | 0.00 | -0.52 | -0.12 | -0.08 | 0.09 | 0.76 | -0.17 | -0.05 | 1.00 |

| D | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Ag | Ba | Cd | Cr | Cu | Mn | Mo | Ni | Pb | Sr | V | Zn | La |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite----- | 1.00 | | | | | | | | | | | | | | | | | |
| Calcite------- | 0.05 | 1.00 | | | | | | | | | | | | | | | | |
| Biogenic $SiO_2$ | -0.15 | 0.72 | 1.00 | | | | | | | | | | | | | | | |
| Apatite------- | -0.64 | -0.21 | -0.38 | 1.00 | | | | | | | | | | | | | | |
| Organic matter | 0.16 | -0.13 | -0.39 | -0.12 | 1.00 | | | | | | | | | | | | | |
| Ag----------- | -0.17 | -0.21 | -0.15 | -0.24 | 0.58 | 1.00 | | | | | | | | | | | | |
| Ba----------- | -0.41 | -0.06 | -0.05 | 0.65 | -0.39 | -0.31 | 1.00 | | | | | | | | | | | |
| Cd----------- | 0.17 | 0.21 | 0.05 | -0.19 | 0.37 | 0.35 | -0.03 | 1.00 | | | | | | | | | | |
| Cr----------- | -0.30 | -0.41 | -0.36 | 0.01 | 0.62 | 0.69 | -0.24 | 0.26 | 1.00 | | | | | | | | | |
| Cu----------- | -0.10 | -0.12 | -0.18 | -0.14 | 0.67 | 0.72 | -0.30 | 0.32 | 0.76 | 1.00 | | | | | | | | |
| Mn----------- | 0.68 | 0.38 | 0.11 | -0.20 | -0.16 | -0.59 | -0.06 | 0.18 | -0.61 | -0.27 | 1.00 | | | | | | | |
| Mo----------- | -0.21 | -0.23 | -0.22 | 0.06 | 0.31 | 0.50 | -0.26 | -0.10 | 0.55 | 0.48 | -0.39 | 1.00 | | | | | | |
| Ni----------- | -0.03 | -0.39 | -0.25 | -0.35 | 0.48 | 0.79 | -0.41 | 0.15 | 0.77 | 0.82 | -0.49 | 0.50 | 1.00 | | | | | |
| Pb----------- | -0.29 | -0.12 | -0.10 | 0.53 | -0.41 | -0.17 | 0.88 | 0.14 | -0.17 | -0.22 | -0.01 | -0.07 | -0.26 | 1.00 | | | | |
| Sr----------- | -0.60 | -0.14 | -0.35 | 0.98 | -0.16 | -0.28 | 0.88 | -0.20 | -0.02 | -0.15 | -0.17 | 0.05 | -0.37 | 0.56 | 1.00 | | | |
| V------------ | -0.14 | -0.29 | -0.30 | -0.07 | 0.67 | 0.70 | -0.18 | 0.47 | 0.72 | 0.68 | -0.47 | 0.20 | 0.66 | -0.14 | -0.09 | 1.00 | | |
| Zn----------- | -0.35 | -0.49 | -0.25 | 0.00 | 0.15 | 0.74 | -0.06 | 0.06 | 0.62 | 0.58 | -0.67 | 0.48 | 0.82 | 0.07 | -0.02 | 0.48 | 1.00 | |
| La----------- | -0.70 | -0.19 | -0.18 | 0.68 | 0.08 | 0.14 | 0.51 | 0.20 | 0.45 | 0.30 | -0.43 | 0.10 | 0.07 | 0.43 | 0.64 | 0.28 | 0.30 | 1.00 |

Table 11. (cont.) Components and marine minor elelements correlation table for E)Lakeridge (R=0.32 is significant at the 1 percent level, R-values with a significance of 1 percent or better are shaded)

| E | Dolomite | Calcite | Biogenic $SiO_2$ | Apatite | Organic matter | Ba | Cr | Cu | Mn | Mo | Ni | Pb | Sr | V | Zn | La |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dolomite------ | 1.00 | | | | | | | | | | | | | | | |
| Calcite-------- | 0.44 | 1.00 | | | | | | | | | | | | | | |
| Biogenic $SiO_2$ | -0.23 | -0.04 | 1.00 | | | | | | | | | | | | | |
| Apatite------- | -0.56 | -0.25 | -0.23 | 1.00 | | | | | | | | | | | | |
| Organic matter | -0.24 | -0.16 | -0.33 | 0.10 | 1.00 | | | | | | | | | | | |
| Ba------------ | -0.29 | -0.01 | -0.06 | 0.73 | -0.10 | 1.00 | | | | | | | | | | |
| Cr------------ | -0.45 | -0.31 | -0.35 | 0.35 | 0.78 | 0.07 | 1.00 | | | | | | | | | |
| Cu------------ | -0.35 | -0.09 | -0.13 | 0.33 | 0.76 | 0.22 | 0.73 | 1.00 | | | | | | | | |
| Mn------------ | 0.62 | 0.32 | 0.26 | -0.43 | -0.37 | -0.17 | -0.50 | -0.28 | 1.00 | | | | | | | |
| Mo------------ | -0.20 | -0.16 | -0.29 | 0.10 | 0.91 | -0.04 | 0.68 | 0.73 | -0.34 | 1.00 | | | | | | |
| Ni------------ | -0.26 | -0.10 | -0.29 | 0.23 | 0.88 | 0.07 | 0.72 | 0.90 | -0.35 | 0.85 | 1.00 | | | | | |
| Pb------------ | -0.31 | -0.23 | 0.25 | 0.01 | 0.33 | -0.15 | 0.27 | 0.36 | 0.02 | 0.29 | 0.36 | 1.00 | | | | |
| Sr------------ | -0.49 | -0.09 | -0.28 | 0.94 | 0.15 | 0.69 | 0.33 | 0.39 | -0.40 | 0.14 | 0.30 | 0.00 | 1.00 | | | |
| V------------- | -0.14 | -0.09 | -0.30 | 0.12 | 0.85 | 0.00 | 0.52 | 0.69 | -0.30 | 0.92 | 0.87 | 0.25 | 0.19 | 1.00 | | |
| Zn------------ | -0.26 | -0.18 | -0.31 | 0.20 | 0.73 | -0.04 | 0.52 | 0.65 | -0.37 | 0.74 | 0.79 | 0.23 | 0.27 | 0.81 | 1.00 | |
| La------------ | -0.46 | -0.19 | -0.19 | 0.87 | 0.13 | 0.75 | 0.33 | 0.31 | -0.35 | 0.17 | 0.21 | -0.06 | 0.82 | 0.15 | 0.09 | 1.00 |

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