Gamma-ray spectrometric and semiquantitative spectrographic analytical data of the thorium and rare-earth disseminated deposits in the southern Bear Lodge Mountains, Wyoming.

by

Mortimer H. Staatz, Nancy M. Conklin, Carl M. Bunker,
and Charles A. Bush

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

The purpose of this report is to present analytical data on 343 samples taken in the thorium and rare-earth disseminated deposits in the southern Bear Lodge Mountains. The results obtained from some or all of these data have been used first in resource calculations made on these deposits (Staatz and others, 1979, p. 23-27) and second in an overall description of these deposits and their surrounding geology (Staatz, in press).

The southern Bear Lodge Mountains occupy an area of approximately 110 km$^2$ just north of the town of Sundance in Crook County, Wyoming. The Bear Lodge dome underlies most of this area. It consists of a core of Tertiary intrusive rocks that has domed up the surrounding sedimentary rocks of Paleozoic and Mesozoic age. The central core of Tertiary intrusive rocks, mainly trachyte and phonolite, was formed by multiple intrusions of alkalic igneous rocks, during a period of at least 20 million years. This alkalic igneous core has an oval outcrop pattern and is exposed over an area about 8.8 km long by 3.5 km wide. Separate, smaller intrusive bodies also intrude the sedimentary rocks along the flanks of the dome. In the southern half of the core, isolated bodies of granite of Precambrian age are surrounded by the Tertiary alkalic rocks. After most of the igneous rocks were intruded the rocks in the central and north-central parts of the core were fractured, altered, and many of the fractures filled with sanidine-rich vein material. The greater part of this material occurs in thin veinlets that, with their surrounding host rock, make up the disseminated deposits. Most of the veinlets range from fracture coatings to veins as much as 0.6 cm thick. The fractures and the emplaced veinlets are numerous, crisscrossing, and strike in many directions. Dips are variable. Some 26 veins, ranging in thickness from 5 cm to 1.7 m, are also found in the area, but they are not included in the disseminated deposits.
The resources of these veins are small, and their description and chemistry have been reported elsewhere (Staatz and others, 1979, p. 17-18; Staatz, in press). Data in table 1 are entirely on samples taken from the disseminated deposits.

The veinlets in the disseminated deposits are brown, black, or gray. The color generally depends on the abundance of various iron and manganese oxides. Goethite tends to color the veinlets shades of brown; the presence of pyrolusite, cryptomelane, or finely disseminated specular hematite gives the veinlets a black color. Only where these oxides are lacking, or present in only small amounts does a vein show the color of the other minerals present. The principal thorium and rare-earth minerals are brockite and monazite. In addition, rare earths also occur in bastnaesite and weinschenkite. Sanidine is the principal gangue mineral. Common accessory minerals include magnetite, barite, rutile, and brookite.

The size and boundaries of the deposits, may be sharp or gradational. Most of the alkalic rocks have been altered after their emplacement and neither the outline nor relative grade is visually determinable. The position and grade of the disseminated deposits can be determined by either chemical or radiometric analyses. In order to determine the general outline of the disseminated deposits, radiometric readings were taken over the entire igneous central core of the Bear Lodge dome, an area of approximately 30 km$^2$, with a Mount Sopris scintillation counter. A contour map made from some 537 readings was compiled. Individual readings in this survey ranged from 125 to 2,000 counts per second. The area of principal interest, however, lies within the 400 counts-per-second contour. This contour, shown on figure 1, was used to select the area to be sampled in detail.
Methods of present study

All samples analyzed were taken either of bed rock or of dump material that had been dug out of bed rock. The greater part of the alkalic intrusive rocks is covered by several centimeters to a few meters of overburden. Outcrops are common along ridges. Many bulldozer trenches were made in the area in the early 1950's during exploration for rare earth-veins. In addition, there are scattered hand-dug pits that were made in prospecting for other metals during the first part of the twentieth century. Our sampling was done principally in the bulldozer trenches, either along the sides of the trenches or from the dumps. In addition we also sampled outcrops exposed in small hand-dug pits, along ridges, and in road cuts. All samples were chip samples and were taken so as to represent the average disseminated deposit at the sample locality. Veins 5 cm or more thick are widely scattered, few in number, and were not included in sampling. Although these veins would undoubtedly be mined along with the smaller veinlets in any mining operation, their relatively small volume and much higher grade would disproportionately affect the grade of the disseminated deposits. Most of the samples lie within the 400 count-per-second contour. The locations of all the samples taken are shown on figure 1.

The samples weighed 2 to 3 kg, and were ground to -20 mesh. A 600-gm split was measured out of every sample and used by Bunker and Bush to analyze for thorium (Th), radium equivalent uranium (RaeU), and potassium (K) on a gamma-ray spectrometer. From a total of about 340 samples, 192 samples were chosen for semiquantitative spectrographic analyses by Conklin. These samples were selected to give a representative geographic coverage. A split of approximately 150 g was taken for this purpose and ground to -150 mesh. In addition, the various mineral components of some samples were separated by a
heavy liquid and a magnetic separator. The various minerals were identified by X-ray diffraction, and the results of the mineralogic work are given in a separate report (Staatz, in press).
Chemical Analyses

The results of the chemical analyses are given in table 1. Thorium, uranium, and potassium were analyzed by a quantitative gamma-ray spectrometer that measures over 512 channels with a 12.7 cm diameter by 10.2 cm thick NaI crystal. This method has a precision of ±3 percent. Thorium content of the 343 samples ranges from 9.3 to 990 parts per million (ppm). Of these samples, 265 contained at least 50 ppm thorium. The uranium content of these same samples ranges from 1.8 to 346 ppm. Only five samples, however, contained as much as 80 ppm uranium and only one sample contained more than 120 ppm.

All other elements analyzed were done by semiquantitative spectrographic analyses. Results were grouped into several levels bracketed by 1.2, 0.83, 0.56, 0.38, 0.26, 0.18, 0.12, and so forth, and then reported as mid-values between these brackets. Thus, the numbers reported would be 1, 0.7, 0.5, 0.3, 0.2, 0.15, 0.1, and so forth. The precision of a reported value is approximately plus or minus one level. The lower limit of detection varies from element to element. This lower limit is generally a constant for any specific element, but in some samples large amounts of another element will produce interfering lines on the spectrographic plate and raise the limit of detection. This accounts for the variation in the lower limit of detection shown for some elements in table 1. The original semiquantitative spectrographic analyses furnished data on 57 elements. We have reported on 34 of these elements (table 1). We have eliminated a few like silicon and aluminum, which occur in all samples in amounts greater than 10 percent, as well as many elements, such as arsenic, boron, gold, antimony, and tungsten, which occur in insignificant amounts in all samples. In addition we give a value for total rare earths, which is the sum of all individual rare earths whose values lay above the limit of detection. Rare earths are probably the
most economically significant metals in these deposits. The total rare earth content of the 192 samples ranges from 47 to 27,145 ppm. Of these samples, 171 contain in excess of 500 ppm total rare earths, and 54 contain in excess of 5,000 ppm.
Present work and acknowledgments

The first 38 samples listed in table 1 were collected by Staatz between 1974 and 1977, while he was making a geologic map of the area. The rest of the samples were taken during the summer of 1979 during a detailed study of the disseminated deposits. During the summer of 1979, Staatz was assisted in the sampling program for various periods by Russell F. Dubiel, Timothy E. Mower, and David F. Piske, Jr. Sample preparation was carried out by Isabelle K. Brownfield, Timothy E. Mower, and William F. Robinson IV.
References cited


Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains.

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2 Analyzed by semi-quantitative six-step spectrographic method by N. M. Conklin.
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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In percent

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<th>Magnesium²</th>
<th>Phosphorus²</th>
<th>Potassium¹</th>
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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

[Symbols: N.D. = not determined; < = less than value indicated; > = greater than value indicated]

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<td>In percent</td>
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<td>&lt;100</td>
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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass
in the southern Bear Lodge Mountains. — Continued
[Symbols: N.D. — not determined; < − less than value indicated; > − greater than value indicated]

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| In percent |
| Calcium²     | N.D. | .07 | N.D. | .1 | .15 | .3 | N.D. | .3 |
| Iron²        | N.D. | 3 | N.D. | 7 | 3 | 10 | N.D. | 7 |
| Magnesium²   | N.D. | .07 | N.D. | .15 | .3 | .15 | N.D. | .07 |
| Phosphorus²  | N.D. | <.2 | N.D. | <.2 | <.2 | <.2 | N.D. | <.2 |
| Potassium¹   | 11.5 | 11.8 | 11.3 | 6.5 | 6.3 | 10.4 | 9.8 | 9.4 | 11.5 |
| Sodium²      | N.D. | .7 | N.D. | 5 | 3 | .7 | N.D. | .7 |
| Titanium²    | N.D. | .3 | N.D. | .7 | .3 | 1.5 | N.D. | .7 |
Table 1—Chemical analyses of samples from the principal Tertiary intrusive mass

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<td>MHS-</td>
<td>MHS-</td>
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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. —Continued

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Symbols: N.D. - not determined; < - less than value indicated; > - greater than value indicated.
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. - Continued

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| In percent |           |           |           |           |           |           |           |           |           |           |
| Calcium     | .07       | N.D.      | N.D.      | .3        | N.D.      | .3        | N.D.      | N.D.      | N.D.      | N.D.      |
| Iron        | >10       | N.D.      | N.D.      | 7         | N.D.      | 7         | N.D.      | N.D.      | N.D.      | N.D.      |
| Magnesium   | .3        | N.D.      | N.D.      | .7        | N.D.      | .7        | N.D.      | N.D.      | N.D.      | N.D.      |
| Phosphorus  | <.2       | N.D.      | N.D.      | .3        | N.D.      | <.2       | N.D.      | N.D.      | N.D.      | N.D.      |
| Potassium   | 10.4      | 10.0      | 11.2      | 11.0      | 11.2      | 11.2      | 9.1       | 9.9       |           |           |
| Sodium      | .7        | N.D.      | N.D.      | .7        | N.D.      | 1.5       | N.D.      | N.D.      | N.D.      | N.D.      |
| Titanium    | .3        | N.D.      | N.D.      | .7        | N.D.      | .7        | N.D.      | N.D.      | N.D.      | N.D.      |
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass
in the southern Bear Lodge Mountains. - Continued

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In percent

<p>| Calcium       | .07 | .07 | N.D. | N.D. | .07 | .07 | N.D. | N.D. | 5  |
| Iron          | &gt;10 | 7 | N.D. | N.D. | 7 | 7 | N.D. | N.D. | &gt;10 |
| Magnesium     | .7 | .3 | N.D. | N.D. | .15 | .03 | N.D. | N.D. | .7 |
| Phosphorus    | &lt;.2 | &lt;.2 | N.D. | N.D. | &lt;.2 | &lt;.2 | N.D. | N.D. | &lt;.2 |
| Potassium     | 7.8 | 11.6 | 10.3 | 12.1 | 10.6 | 10.0 | 10.9 | 8.7 | 8.6 |
| Sodium        | .7 | .7 | N.D. | N.D. | .7 | .7 | N.D. | f N.D. | .7 |
| Titanium      | .7 | .7 | N.D. | N.D. | .7 | .7 | N.D. | N.D. | .7 |</p>
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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

(Symbols: N.D. - not determined; < - less than value indicated; > - greater than value indicated)

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<th>136</th>
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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains—Continued

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<td>In percent</td>
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| Magnesium²   | .7 | N.D. | N.D. | N.D. | N.D. | N.D. | N.D. | .15 | N.D. |
| Phosphorus²  | &lt;.2 | N.D. | &lt;.2 | N.D. | N.D. | N.D. | N.D. | &lt;.2 | N.D. |
| Potassium¹   | 10.8 | 8.8 | 10.5 | 8.9 | 10.4 | 10.4 | 10.4 | 9.9 | 10.4 |
| Sodium²      | 1.5 | N.D. | 3 | N.D. | N.D. | N.D. | N.D. | .7 | N.D. |
| Titanium²    | .7 | N.D. | .7 | N.D. | N.D. | N.D. | N.D. | .7 | N.D. |</p>
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### Table 1: Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. - Continued

(Symbols: N.D. = not determined; < - less than value indicated; > - greater than value indicated)

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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass
in the southern Bear Lodge Mountains. — Continued

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In percent

| Calcium      | .15  | .3   | .3   | N.D. | .3   | .07  | .15  | N.D. | .07  |
| Iron         | 7    | 7    | 7    | N.D. | 7    | 7    | 7    | N.D. | 7    |
| Magnesium    | .7   | 1.5  | 1.5  | N.D. | 1.5  | .03  | .07  | N.D. | .07  |
| Phosphorus   | <.2  | <.2  | <.2  | N.D. | <.2  | <.2  | <.2  | N.D. | <.2  |
| Potassium    | 10.4 | 10.8 | 10.9 | 9.5  | 9.9  | 9.2  | 9.9  | 10.7 | 11.1 |
| Sodium       | 1    | .7   | 3    | N.D. | 3    | 1.5  | .7   | N.D. | .7   |
| Titanium     | .7   | .7   | .7   | N.D. | .3   | .3   | 1    | N.D. | .7   |
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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<td>In parts per million</td>
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<td>In parts per million</td>
<td>In parts per million</td>
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<td>In parts per million</td>
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<td>&lt;10</td>
<td>&lt;10</td>
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<th>Magnesium²</th>
<th>Phosphorus²</th>
<th>Potassium¹</th>
<th>Sodium²</th>
<th>Titanium²</th>
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**Element**

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<td>183  78  79  116  123 272  116  83  55</td>
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<tr>
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<td>15   22  11  13  13  21  27  33  11</td>
</tr>
<tr>
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<tr>
<td>Cerium²</td>
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</tr>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
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<tr>
<td>Thulium²</td>
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<tr>
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<td>7    N.D. N.D. N.D. 7   15 N.D. N.D. 7</td>
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<tr>
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</tr>
<tr>
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<tr>
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<tr>
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**In percent**

<table>
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<th>Element</th>
<th>In percent</th>
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<td>Calcium²</td>
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<tr>
<td>Iron²</td>
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<tr>
<td>Element</td>
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<td>Thorium(^1)</td>
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<td>Praseodymium(^2)</td>
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<td>Samarium(^2)</td>
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<td>Europium(^2)</td>
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<td>Strontium(^2)</td>
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<td>Tin(^2)</td>
<td>N.D.</td>
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<td>Vanadium(^2)</td>
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<td>Zinc(^2)</td>
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<td>Zirconium(^2)</td>
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**In percent**

| Calcium\(^2\) | N.D. | .07 | .07 | 1.5 | N.D. | .15 | .15 | N.D. | .15 |
| Iron\(^2\) | N.D. | 3 | 7 | 7 | N.D. | 7 | 7 | N.D. | 7 |
| Magnesium\(^2\) | N.D. | .03 | .07 | .07 | N.D. | .7 | .3 | N.D. | .7 |
| Phosphorus\(^2\) | N.D. | <.2 | <.2 | <.2 | N.D. | <.2 | <.2 | N.D. | <.2 |
| Potassium\(^1\) | 6.2 | 6.2 | 11.1 | 11.1 | 11.2 | 11.5 | 11.9 | 10.0 | 10.9 |
| Sodium\(^2\) | N.D. | 3 | .3 | .7 | N.D. | .7 | .7 | N.D. | 1.5 |
| Titanium\(^2\) | N.D. | .15 | .7 | .7 | N.D. | .7 | .7 | N.D. | .7 |
### Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. - Continued

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<td>13</td>
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<td>16</td>
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<td>500</td>
<td>300</td>
<td>N.D.</td>
<td>N.D.</td>
<td>1,500</td>
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<tr>
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<td>N.D.</td>
<td>1,500</td>
<td>700</td>
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<td>N.D.</td>
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<td>200</td>
<td>150</td>
<td>&lt;100</td>
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<td>N.D.</td>
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<td>N.D.</td>
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<tr>
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<td>1,500</td>
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<td>N.D.</td>
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<td>2,000</td>
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<tr>
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<td>300</td>
<td>150</td>
<td>150</td>
<td>N.D.</td>
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**In percent**

<p>| Calcium      | 0.1 | N.D. | 0.3 | 0.3 | 0.3 | N.D. | N.D. | 0.15 | N.D. |
| Iron         | 7   | N.D. | 10  | 7   | 7   | N.D. | N.D. | &gt;10  | N.D. |
| Magnesium    | 0.07| N.D. | 0.7 | 0.7 | 0.7 | N.D. | N.D. | 0.15 | N.D. |
| Phosphorus   | &lt;.2 | N.D. | &lt;.2 | &lt;.2 | &lt;.2 | N.D. | N.D. | &lt;.2  | N.D. |
| Potassium    | 10.6| 10.6| 10.3| 10.6|10.8 | 10.4| 11.3| 11.1| 11.2 |
| Sodium       | 1.5 | N.D. | 1   | 0.7 | 0.7 | N.D. | N.D. | 0.3  | N.D. |
| Titanium     | .7  | N.D. | .3  | .3  | .3  | N.D. | N.D. | .3   | N.D. |</p>
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Cerium
Europium
Thorium
Samarium
Lutecium
Ytterbium
Thulium
Dysprosium
Yttrium

| Total rare earths | 3,377 | N.D. | 9,135 | 5,227 | N.D. | N.D. | 673 | N.D. | 10,585 |
| Beryllium         | 7,000 | N.D. | 3,000 | 7,000 | N.D. | N.D. | 3,000 | N.D. | 15,000 |
| Bismuth           | 3     | N.D. | 3     | N.D. | 3     | N.D. | 1.5 | N.D. | 30 |
| Copper            | 7     | N.D. | 150   | 150   | N.D. | N.D. | 70  | N.D. | 100 |
| Lead              | 7     | N.D. | 1,000 | 700   | N.D. | N.D. | 15  | N.D. | 1,000 |
| Manganese         | 2,000 | N.D. | 15,000| 15,000| N.D. | N.D. | 1,500| N.D. | 3,000 |
| Molybdenum        | 5     | N.D. | 30    | 70    | N.D. | N.D. | <3  | N.D. | 300 |
| Niobium           | 150   | N.D. | 100   | 70    | N.D. | N.D. | 15  | N.D. | 300 |
| Strontium         | 1,500 | N.D. | 1,500 | 3,000 | N.D. | N.D. | 1,500| N.D. | 1,500 |
| Tin               | <10   | N.D. | <10   | <10   | N.D. | N.D. | <10 | N.D. | 30 |
| Vanadium          | 300   | N.D. | 700   | 300   | N.D. | N.D. | 300 | N.D. | 1,500 |
| Zinc              | 300   | N.D. | 700   | 700   | N.D. | N.D. | <200| N.D. | 300 |
| Zirconium         | 70    | N.D. | 70    | 70    | N.D. | N.D. | 70  | N.D. | 700 |

| In percent |

| Calcium         | 0.07  | N.D. | 0.3 | 0.3 | N.D. | N.D. | 0.7 | N.D. | 0.7 |
| Iron            | 7     | N.D. | 10  | 7   | N.D. | 5    | N.D. | 10  |
| Magnesium       | 0.3   | N.D. | 0.7 | 0.7 | N.D. | 1.5  | N.D. | 1   |
| Phosphorus      | <0.2  | N.D. | <0.2| <0.2| N.D. | <0.2 | N.D. | <0.2| |
| Potassium       | 11.2  | 11.3 | 10.6| 10.3| 10.0| 11.8 | 12.0| 10.0| 9.5 |
| Sodium          | 0.3   | N.D. | 0.3 | 0.3 | N.D. | 0.7  | N.D. | 0.7 |
| Titanium        | 0.3   | N.D. | 0.3 | 0.3 | N.D. | 0.3  | N.D. | 0.7 |
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. - Continued

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| In percent |
| Calcium     | 2          | .3         | .3         | N.D.       | 1.5        | .5         | 1          | 1.5        | .7         | .05        |
| Iron        | 2          | 7          | 7          | N.D.       | 7          | 5          | 7          | 7          | 7          | 3          |
| Magnesium   | 2          | .7         | .3         | N.D.       | .05        | .7         | .03        | .07        | .07        | .1         |
| Phosphorus  | 2          | <.2        | <.2        | N.D.       | <.2        | <.2        | <.2        | <.2        | <.2        | <.2        |
| Potassium   | 1          | 11.0       | 12.2       | 7.1        | 11.3       | 9.6        | 11.7       | 11.0       | 7.6        | 5.9        |
| Sodium      | 2          | 1.5        | .3         | N.D.       | .7         | 3          | .7         | 1.5        | 3          | 3          |
| Titanium    | 2          | .7         | .7         | N.D.       | .7         | .3         | .3         | .3         | .3         | .07        |
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. - Continued

(Symbol: N.D. - not determined; < - less than value indicated; > - greater than value indicated)

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In percent:
- Calcium: .15
- Iron: 7
- Magnesium: .3
- Phosphorus: <.2
- Potassium: 11.6
- Sodium: .7
- Titanium: .3

Table 1.—Chemical analysies of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains—Continued.

*Symbols: N.D. = not determined; < - less than value indicated; > - greater than value indicated*
### Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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<tr>
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<td>N.D.</td>
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<td>&lt;20</td>
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<td>N.D.</td>
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<tr>
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<td>&lt;20</td>
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<td>N.D.</td>
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<td>N.D.</td>
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<tr>
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<td>Lutetium(^2)</td>
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<td>N.D.</td>
<td>&lt;30</td>
<td>&lt;30</td>
<td>N.D.</td>
<td>N.D.</td>
<td>&lt;30</td>
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<td>N.D.</td>
<td>150</td>
<td>70</td>
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<td>N.D.</td>
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<tr>
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<td>5,000</td>
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<td>N.D.</td>
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<tr>
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<td>N.D.</td>
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<td>1.5</td>
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<tr>
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<td>&lt;10</td>
<td>&lt;10</td>
<td>N.D.</td>
<td>N.D.</td>
<td>&lt;10</td>
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<tr>
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<td>Copper(^2)</td>
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<td>N.D.</td>
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<td>N.D.</td>
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<td>150</td>
<td>200</td>
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<td>N.D.</td>
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<td>70</td>
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<td>N.D.</td>
<td>1,000</td>
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<td>N.D.</td>
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<td>N.D.</td>
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<td>Niobium(^2)</td>
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<td>N.D.</td>
<td>70</td>
<td>70</td>
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<td>N.D.</td>
<td>15</td>
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<td>Strontium(^2)</td>
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<td>N.D.</td>
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<td>N.D.</td>
<td>3,000</td>
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<td>&lt;10</td>
<td>N.D.</td>
<td>N.D.</td>
<td>&lt;10</td>
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<td>300</td>
<td>N.D.</td>
<td>N.D.</td>
<td>700</td>
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<td>N.D.</td>
<td>N.D.</td>
<td>&lt;200</td>
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<td>Zirconium(^2)</td>
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<td>150</td>
<td>N.D.</td>
<td>N.D.</td>
<td>300</td>
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| In percent | Calcium\(^2\) | .3        | N.D.       | N.D.       | .07        | .07         | N.D.       | N.D.       | N.D.       | 2          |
|            | Iron\(^2\) | 7         | N.D.       | N.D.       | 7          | 3           | N.D.       | N.D.       | N.D.       | 3          |
|            | Magnesium\(^2\) | .3        | N.D.       | N.D.       | .15        | .05         | N.D.       | N.D.       | N.D.       | .7         |
|            | Phosphorus\(^2\) | <.2       | N.D.       | N.D.       | <.2        | <.2         | N.D.       | N.D.       | N.D.       | <.2        |
|            | Potassium\(^1\) | 10.7      | 10.9       | 11.3       | 10.6       | 12.0        | 10.2       | 6.8        | 8.7        | 9.4        |
|            | Sodium\(^2\) | .7        | N.D.       | N.D.       | .3         | .3          | N.D.       | N.D.       | N.D.       | 1.5        |
|            | Titanium\(^2\) | .3        | N.D.       | N.D.       | .3         | .3          | N.D.       | N.D.       | N.D.       | .3         |
Table 1. — Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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<th>Locality No.</th>
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<th>270</th>
<th>271</th>
<th>272</th>
<th>273</th>
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<th>275</th>
<th>276</th>
<th>277</th>
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</table>

<table>
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<tr>
<th>Element</th>
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<tr>
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<tr>
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<tr>
<td>Lanthanum²</td>
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<tr>
<td>Cerium²</td>
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</tr>
<tr>
<td>Prasodymium²</td>
<td>&lt;100 N.D.</td>
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<tr>
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</tr>
<tr>
<td>Samarium²</td>
<td>&lt;100 N.D.</td>
</tr>
<tr>
<td>Europium²</td>
<td>&lt;100 N.D.</td>
</tr>
<tr>
<td>Terbium²</td>
<td>&lt;300 N.D.</td>
</tr>
<tr>
<td>Dysprosium²</td>
<td>&lt;50 N.D.</td>
</tr>
<tr>
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</tr>
<tr>
<td>Erbium²</td>
<td>&lt;50 N.D.</td>
</tr>
<tr>
<td>Thulium²</td>
<td>&lt;20 N.D.</td>
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<tr>
<td>Ytterbium²</td>
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<tr>
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<tr>
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<tr>
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<td>Beryllium²</td>
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<td>Bismuth²</td>
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<td>Copper²</td>
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<td>Lead²</td>
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<td>Manganese²</td>
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<tr>
<td>Molybdenum²</td>
<td>5 N.D.</td>
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<tr>
<td>Niobium²</td>
<td>15 N.D.</td>
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<tr>
<td>Strontium²</td>
<td>3,000 N.D.</td>
</tr>
<tr>
<td>Tin²</td>
<td>&lt;10 N.D.</td>
</tr>
<tr>
<td>Vanadium²</td>
<td>500 N.D.</td>
</tr>
<tr>
<td>Zinc²</td>
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<td>Zirconium²</td>
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<table>
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<td>Iron²</td>
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<td>Magnesium²</td>
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<td>Sodium²</td>
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<td>Titanium²</td>
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**Table 1**—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains.  [Continued]

(Symbols:  N.D. = not determined;  < - less than value indicated;  > - greater than value indicated)

<table>
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<th>Locality No.</th>
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<th>280</th>
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<th>282</th>
<th>283</th>
<th>284</th>
<th>285</th>
<th>286</th>
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<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Thorium&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>179</td>
<td>58</td>
<td>131</td>
<td>.69</td>
<td>123</td>
<td>73</td>
<td>45</td>
<td>42</td>
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<td>34</td>
<td>28</td>
<td>21</td>
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<td>700</td>
<td>150</td>
<td>150</td>
<td>N.D.</td>
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<td>3,000</td>
<td>N.D.</td>
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<td>1,500</td>
<td>150</td>
<td>300</td>
<td>N.D.</td>
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<tr>
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<td>500</td>
<td>N.D.</td>
<td>150</td>
<td>&lt;100</td>
<td>&lt;100</td>
<td>N.D.</td>
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<tr>
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<td>700</td>
<td>150</td>
<td>150</td>
<td>N.D.</td>
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<tr>
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<td>300</td>
<td>N.D.</td>
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<td>&lt;100</td>
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<td>N.D.</td>
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<td>&lt;100</td>
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<td>&lt;100</td>
<td>&lt;100</td>
<td>&lt;100</td>
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<td>&lt;50</td>
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<td>&lt;20</td>
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<td>&lt;30</td>
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<td>N.D.</td>
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<td>N.D.</td>
<td>70</td>
<td>150</td>
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<td>3,000</td>
<td>700</td>
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<td>&lt;10</td>
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<td>1,500</td>
<td>700</td>
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<td>N.D.</td>
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<tr>
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<td>70</td>
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<td>3,000</td>
<td>N.D.</td>
<td>3,000</td>
<td>N.D.</td>
<td>1,500</td>
<td>700</td>
<td>3,000</td>
<td>N.D.</td>
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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass
in the southern Bear Lodge Mountains. — Continued

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Tab. 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains — Continued

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| Element      | In percent | |
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| Iron²        | 7 | N.D. | 3 | N.D. | 7 | N.D. | N.D. | 3 | N.D. |
| Magnesium²   | .3 | N.D. | .3 | N.D. | .3 | N.D. | N.D. | .15 | N.D. |
| Phosphorus²  | <.2 | N.D. | <.2 | N.D. | <.2 | N.D. | N.D. | <.2 | N.D. |
| Potassium¹   | 6.4 | 8.7 | 9.7 | 7.3 | 7.5 | 8.1 | 8.8 | 7.0 | 5.0 |
| Sodium²      | 3 | N.D. | 3 | N.D. | 3 | N.D. | N.D. | 3 | N.D. |
| Titanium²    | .5 | N.D. | .3 | N.D. | .7 | N.D. | N.D. | .3 | N.D. |
Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued
[Symbols: N.D. = not determined; < - less than value indicated; > - greater than value indicated]

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Table 1.—Chemical analyses of samples from the principal Tertiary intrusive mass in the southern Bear Lodge Mountains. — Continued

[Symbols: N.D. = not determined; < = less than value indicated; > = greater than value indicated]

<table>
<thead>
<tr>
<th>Locality No.</th>
<th>Sample No.</th>
<th>MHS-</th>
<th>MHS-</th>
<th>MHS-</th>
<th>MHS-</th>
<th>MHS-</th>
<th>MHS-</th>
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</table>

<table>
<thead>
<tr>
<th>Element</th>
<th>In parts per million</th>
</tr>
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<tbody>
<tr>
<td>Thorium</td>
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</tr>
<tr>
<td>Uranium</td>
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<tr>
<td>Lanthanum</td>
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</tr>
<tr>
<td>Cerium</td>
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</tr>
<tr>
<td>Praseodymium</td>
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</tr>
<tr>
<td>Neodymium</td>
<td>150</td>
</tr>
<tr>
<td>Samarium</td>
<td>&lt;100</td>
</tr>
<tr>
<td>Europium</td>
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<tr>
<td>Gadolinium</td>
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<tr>
<td>Terbium</td>
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<tr>
<td>Dysprosium</td>
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<tr>
<td>Erbium</td>
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<tr>
<td>Thulium</td>
<td>&lt;20</td>
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<tr>
<td>Ytterbium</td>
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<tr>
<td>Lutetium</td>
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<td>Yttrium</td>
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<tr>
<td>Total rare earths</td>
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<tr>
<td>Beryllium</td>
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</tr>
<tr>
<td>Bismuth</td>
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<tr>
<td>Copper</td>
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<tr>
<td>Lead</td>
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<tr>
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<tr>
<td>Calcium</td>
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<td>Iron</td>
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<td>Magnesium</td>
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<tr>
<td>Sodium</td>
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<tr>
<td>Titanium</td>
<td>.2</td>
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</tbody>
</table>

In percent

<table>
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<tbody>
<tr>
<td>Calcium</td>
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<td>5</td>
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