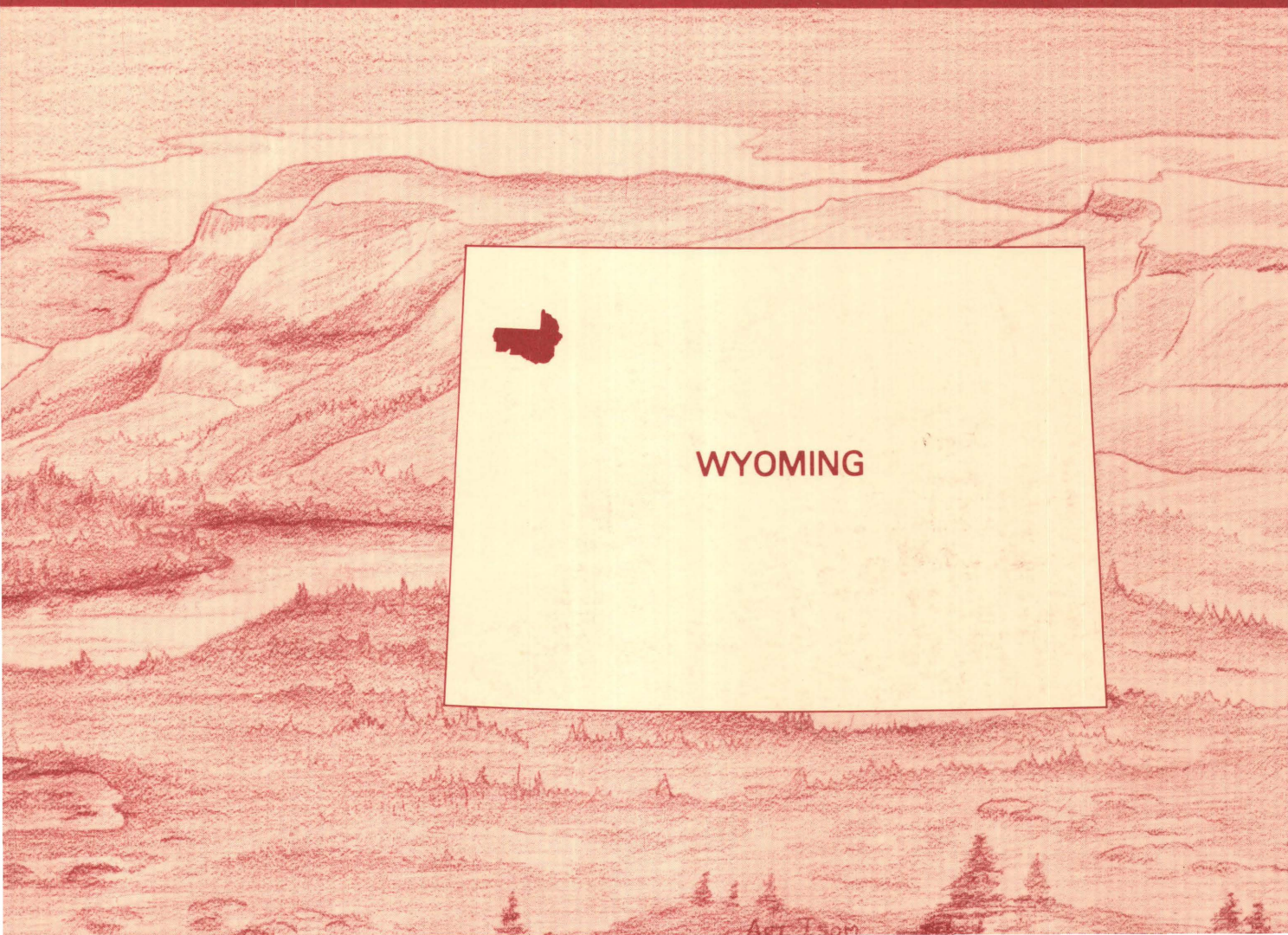
# Mineral Resources of the Teton Wilderness and Adjacent Areas, Teton, Fremont, and Park Counties, Wyoming

U.S. GEOLOGICAL SURVEY BULLETIN 1781



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By J.C. ANTWEILER, J. D. LOVE, HAROLD J. PROSTKA, DOLORES M. KULIK, and LENNART A. ANDERSON
U.S. Geological Survey, and

FRANK E. WILLIAMS, JIMMIE E. JINKS, and THOMAS D. LIGHT
U.S. Bureau of Mines

An evaluation of the mineral potential of the area

U.S. GEOLOGICAL SURVEY BULLETIN 1781

STUDIES RELATED TO WILDERNESS—WILDERNESS AREAS

DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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UNITED STATES GOVERNMENT PRINTING OFFICE: 1989

For sale by the
Books and Open-File Reports Section
U.S. Geological Survey
Federal Center
Box 25425
Denver, CO 80225

**Library of Congress Cataloging-in-Publication Data**

Mineral resources of the Teton Wilderness and adjacent areas, Teton, Fremont, and Park Counties, Wyoming.

Studies related to wilderness—wilderness areas)
(U.S. Geological Survey bulletin ; 1781)
Bibliography: p.
Supt. of Docs. no.: I 19.3:1781
1. Mines and mineral resources—Wyoming—Teton Wilderness. 2. Geology—Wyoming—Teton Wilderness. 3. Teton Wilderness (Wyo.) I. Antweiler, J. C., 1918– . II. Geological Survey (U.S.) III. Series. IV. Series: U.S. Geological Survey bulletin ; 1781.
QE75.B9 557.3 s 87-600065
[TN24.W8] [553'.09787'55]

## STUDIES RELATED TO WILDERNESS
## WILDERNESS AREAS

In accordance w th the provisions of the Wilderness Act (Public Law 88–577, September 3, 1964) and the Conference Report on Senate Bill 4, 88th Congress, the U.S. Geological Survey and the U.S. Bureau of Mines made mineral surveys of wilderness and wilderness study areas. The results of these surveys are made available to the public and are submitted to the President and Congress. This report discusses the results of a mineral survey of the Teton Wilderness and some adjoining roadless lands in the Bridger-Teton National Forest, Wyo. The area studied is south and east of Yellowstone National Park and east of Grand Teton National Park.

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# Mineral Resources of the Teton Wilderness and Adjacent Areas, Teton, Fremont, and Park Counties, Wyoming

*By* J. C. Antweiler, J. D. Love, Harold J. Prostka, Dolores M. Kulik, *and* Lennart A. Anderson
U.S. Geological Survey, *and*
Frank E. Williams, Jimmie E. Jinks, *and* Thomas D. Light
U.S. Bureau of Mines

**Summary**

The Teton Wilderness has a moderate potential[1] for oil and gas resources in two anticlines in the western part of the wilderness, and in the postulated Younts basin(?) in the eastern part of the wilderness. The wilderness also has a moderate to low potential for a gold resource in conglomerates and related alluvium in the western part, and copper in Late Archean rocks in the south-central part of the wilderness. No evidence was found of other mineral resources in the Teton Wilderness.

These conclusions are based on field investigations of the Teton Wilderness conducted during the summers of 1972 to 1974 by the U.S. Geological Survey and the U.S. Bureau of Mines, and on aeromagnetic and gravity surveys conducted by the U.S. Geological Survey in 1967 and 1974, respectively. Field investigations included analysis for various elements of more than 4,000 bedrock, stream-sediment, and panned-concentrate samples by the U.S. Geological Survey, and analysis for gold of 221 stream-sediment samples and 124 channel samples by the U.S. Bureau of Mines.

A search of county, State, and Federal records by the U.S. Bureau of Mines disclosed no currently active mines that produce metallic or nonmetallic minerals from the Teton Wilderness except one small gold-placer mine. Two copper mines operated during the early 1900's near the southeast margin of the wilderness, and gold-placer deposits have been worked from time to time along major drainages in the southwestern part of the wilderness.

The Teton Wilderness lies south and southeast of Yellowstone National Park in Teton, Fremont, and Park Counties, Wyo. It consists of 563,000 acres (2,280 km$^2$) entirely within the Bridger-Teton National Forest. The wilderness was designated by the U.S. Forest Service in 1955 and was added to the National Wilderness Preservation System by Act of Congress in 1964.

The rocks in the Teton Wilderness range in age from Late Archean to Quaternary. They are primarily sedimentary, but crystalline and igneous rocks also occur. The Teton Wilderness comprises two different geologic segments. In the eastern part of the wilderness, great thicknesses of stratified volcanogenic rocks of Eocene age originated mainly from volcanic centers outside the wilderness. The western part of the wilderness consists chiefly of Mesozoic sedimentary rocks folded into northwest-trending anticlines that were subsequently overlapped by middle and upper Cenozoic rocks. These were then tilted westward and faulted in late Cenozoic time. The Eocene volcaniclastic rocks that compose the Absaroka Range buried the Late Archean and Paleozoic core of the Laramide Washakie Range. Subsequent erosion has exposed some of that range. The exposed Late Archean rocks are gneisses and schists, and the Paleozoic rocks are of marine sedimentary origin. Because most of the rocks in the Teton Wilderness are sedimentary, mineral resources are most likely to be associated with sedimentary processes rather than igneous activity.

Two episodes of tectonic movements, separated by about 65 m.y. (million years), have affected even the youngest rocks of the Teton Wilderness. These episodes are of two types: the first comprising folding, faulting, and uplifting near the close of Cretaceous time (about 66 m.y. ago), and the second comprising several igneous events during late Pliocene or Pleistocene time (ending about 1.62 m.y. ago).

During the first episode of tectonic movements, a series of northwest-trending anticlines and synclines, broken and overridden in places by thrust or reverse faults, developed in Cretaceous and underlying rocks. At about the same time, the Basin Creek uplift developed along the northwest border of the wilderness, largely in Yellowstone National Park.

During the second episode of tectonic movements, rhyolitic tuffs, later welded, flowed south from one or more huge calderas in Yellowstone National Park across the western margin of the wilderness, partially burying some of the older anticlines and conglomerate beds that might have some

[1]Resource potential in this report is classified as moderate if, on the basis of geologic, geochemical, and geophysical evidence, a reasonable chance exists for the discovery of mineral resources. Areas with low mineral resource potential lack evidence to support a favorable genetic model, lack indicators of currently economic mineralization, and have no favorable combination of geologic, geochemical, and geophysical factors.

resource potential. At about the same time, pyroxene andesite and basalt intruded along the one major thrust fault in the north-central part of the wilderness. After emplacement of these igneous rocks, renewed movement along the Teton normal fault (west of the Teton Wilderness) caused the western part of the wilderness to be tilted westward and downward several thousand feet. During and perhaps following the westward tilting, the welded tuff and underlying rocks were broken by a series of northwest-trending normal faults which have a few tens to a few hundreds of feet displacement.

All but the highest parts of the Teton Wilderness were glaciated one or more times, and as a result, bedrock is, in places, covered with extensive deposits of glacial debris, especially along the major drainage systems. Meltwater saturated thick sequences of plastic shale and caused enormous landslides that further obscure the bedrock.

Aeromagnetic positive anomalies (highs) in the vicinity of Thunder Mountain and Younts Peak appear to be related to granodiorite intrusives that are exposed at the surface in only very small outcrops. Another positive magnetic anomaly may be related to a basic intrusive with surface expression on Soda Mountain. Two anomalies with negative polarity located near the headwaters of the Yellowstone River may be related to silicic intrusives that do not have surface expression. Major gravity low anomalies are associated with the intrusive granodiorite bodies on Thunder Mountain and Younts Peak. A gravity anomaly also occurs near the headwaters of the Yellowstone River and coincides with the aeromagnetic low that occurs there. Interpretations of the gravity data suggest that thick sections of Cretaceous strata, including source and reservoir rocks which produce hydrocarbons in other areas of Wyoming, are present in the Box Creek downwarp in the western segment of the wilderness and in a postulated basin (Younts basin?) in the eastern segment. In summary, however, the geophysical data do not provide tangible evidence that mineral resources exist within the wilderness.

At three localities in the eastern part of the wilderness, weak base- and precious-metal mineralization accompanied the emplacement of intrusives that penetrated the volcanogenic sediments. Although a slight possibility exists for other types of mineral deposits, the mineral commodities most worthy of study are those in sedimentary rocks and include oil and gas, gold in placers derived from conglomerates deposited in Laramide time, phosphate, metals in black shales, coal, gypsum, building stone, sand, and gravel. Our investigation, however, indicates that the resource potential for these commodities is moderate to low.

Several anticlines, fault-trap structures, and stratigraphic traps have a low to moderate resource potential for oil and gas. Most of the anticlines and fault-trap structures have at least seven possible producing horizons within a depth range of 1,000–10,000 feet. The Wolverine anticline, in the north-central part of the area, is the largest and has the greatest resource potential. Test drilling and seismic studies would be needed to determine whether economic deposits of oil and gas are likely to occur within these structures.

Gold ranging from traces to a few tenths troy ounces per ton occurs in alluvial deposits along several major streams that drain gold-bearing conglomerates in the Harebell Formation and Pinyon Conglomerate.

There is a low to moderate potential for gold resources in the wilderness. Gold is consistently present in small amounts in the Quaternary gravels and in the parent Harebell Formation and Pinyon Conglomerate, but the gold particles are tiny, flat, and thin. Past mining attempts have not been profitable because ordinary mining methods fail to recover much of the gold, and the cost of mining exceeds the value of the gold recovered.

Copper, molybdenum, zinc, and other metals occur in small amounts in black shale at the base of the Amsden Formation, and molybdenum is present in currently uneconomic amounts in several black shales of Eocene age. Several Tertiary igneous intrusives in the eastern part of the wilderness were examined for mineralization. No deposits of economic significance were observed, but geophysical and weak geochemical anomalies are associated with the intrusives on Younts Peak and Thunder Mountain.

Copper prospects are present on South Buffalo Fork. Two small adits driven into Late Archean crystalline rocks by early prospectors show malachite and chalcopyrite of little economic significance.

A portion of the Jackson Hole coal field lies within the Teton Wilderness. Although coal beds occur at several localities in the Meeteetse, Mesaverde, and Sohare Formations, Bacon Ridge Sandstone, and Frontier Formation, they are generally thin and too remote to be of economic interest at present. Better, more accessible coal deposits occur at several localities adjacent to the wilderness. An unknown amount of coal was produced about 1910 by the U.S. Bureau of Reclamation from a mine on Pilgrim Creek which is now within the wilderness.

Bentonite, gypsum, pumicite, phosphate, glauconite, building stone, and sand and gravel deposits are present in the wilderness but are too remote, or of too low grade to be competitive with other deposits that are more accessible, of higher grade, or nearer to markets.

## INTRODUCTION

This report consists of two parts: the geological, geochemical, and geophysical investigations by the U.S. Geological Survey, including assessments of mineral resource potential, and an evaluation of mining claims and resource potential (particularly gold) by the U.S. Bureau of Mines. The investigation by the two agencies was coordinated and integrated as much as possible, and the preceding summary statement reflects the work of both agencies. The area included in this report is shown in figure 1.

The relation of the Teton Wilderness to topographic and geographic features is shown on the relief map (fig. 2). Generalized topography, elevations, drainage, boundaries, and roads are shown on the geologic map (pl. 1). The area is mountainous, with maximum relief of more than 5,000 feet (1,500 m).[1] U.S. Highway 26–287 skirts the southern margin. There are no roads within the

[1]Measurements are given in this report in English units, and the metric equivalent is included in parentheses after the English unit. The metric equivalent is given to comparable precision as the English measurement.

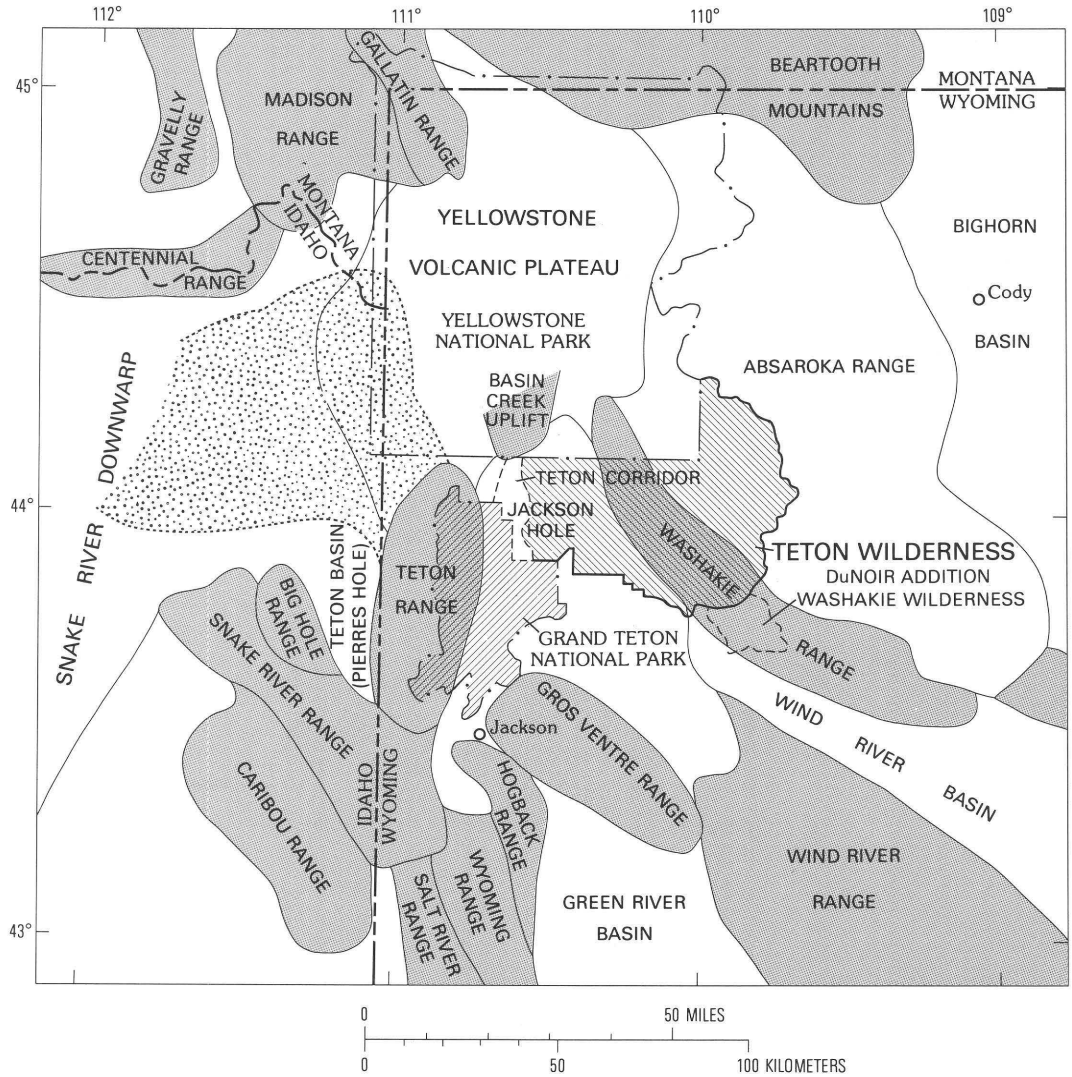



**Figure 1.** Index map showing mountains, basins, and other features surrounding the Teton Wilderness. Folded and upfaulted mountains emphasized by shading. Inferred outline of Targhee uplift in latest Cretaceous and Paleocene times shown by stipple pattern.

wilderness. No lumbering has been done. Except for one small gold-placer mine, there has been no economic exploitation of minerals.

The kind, size, and abundance of trees are closely associated with rock types, altitude, and moisture. In general, Cretaceous rocks in the central and western parts support a sparser growth than do the volcanic and crystalline rocks in the eastern parts. Forest fires burned several hundred square miles of the central and western parts during the 1930's, and regrowth has been slow.

Precipitation ranges from about 30 to 54 inches per year (Mundorff and others, 1964, pl. 2). Winters are severe. The lowest and highest temperatures recorded at an official weather station in the region were at Moran, -60 °F (-51 °C) and 92 °F (33 °C), 4 miles south of the Teton Wilderness. Even in mid-July, winter snow remains in many areas above 9,000 feet (2,700 m).

## Previous Studies

Geologic mapping was begun in the area included in the Teton Wilderness by J. D. Love in 1945 as a part of the U.S. Geological Survey's Fuels Program. The Wildcat, Whetstone, Hancock, and Wolverine anticlines were mapped, detailed stratigraphic sections were measured, and extensive fossil collections were made (Love, Hose, and others, 1951). Generalized versions of the geologic mapping were published later (Love, Weitz, and Hose, 1955; Love, 1956d, Love and Christiansen, 1985). Additional mapping and stratigraphic studies were made as a part of the U.S. Geological Survey's Gold Program between 1965 and 1971 (Antweiler and Love, 1967; Love, 1973a; Lindsey, 1972). An aeromagnetic survey was made in 1967 and a gravity survey in 1974, both by the U.S. Geological Survey. An unpublished geologic map




**Figure 2.** Relief map showing relation of Teton Wilderness (solid outline), mountains, basins, and drainage systems in northwestern Wyoming. Dashed lines show approximate boundaries of the Teton Corridor (west) and Du Noir Addition to Washakie Wilderness (southeast). Volcanic areas not shown.

was made of the Two Ocean Pass quadrangle, the south half of which lies in the Teton Wilderness, by H. W. Smedes and H. J. Prostka as part of the Yellowstone National Park research program. The stratigraphy of the Eocene volcanic rocks in the region was likewise described (Smedes and Prostka, 1972). Rhyolitic welded tuffs in the western part of the wilderness were mapped and classified by Christiansen and Blank (1972) in connection with the Yellowstone National Park research program. Their classification was used without change. Oligocene and Miocene rocks and fossils in the north-central part of the wilderness were studied by Love, McKenna, and Dawson (1976).

A geologic reconnaisance map of Teton County (Love, 1956d) covers all but the extreme eastern and northeastern part of the wilderness. A block diagram and cross sections (Love, Reed, and others, 1973) show the general structure of the western part of the wilderness. The Teton Corridor geologic map (Love, Antweiler, and Williams, 1975) bounds the west side of the wilderness. The geology of Yellowstone National Park, directly north of the western part of Teton Wilderness, is published (U.S. Geological Survey, 1972). A more detailed map of prevolcanic rocks in the southern part of the park was made by Love and Keefer (1969).

## Present Studies

Field investigations funded by the Wilderness Program were conducted during the summers of 1972, 1973, and 1974. Primary emphasis was on obtaining adequate samples for chemical and spectrographic analyses from all mappable rock and alluvial units (pl. 1), and from springs that were suspected of having unusual mineral content. Special attention was given to areas where geologic mapping and stratigraphic studies were incomplete. Details of the sampling and analytical program are discussed under that heading. Completion of a final report was delayed by fire in the Denver offices in March 1976, resulting in destruction of field notes, map compilations, analytical data, and rock and mineral specimens.

## Acknowledgments

Volunteer geologic field assistance was provided by Ron Antweiler and John Antweiler (1972–74). Geologic assistants were Gregory K. Lee (1973–74), David Phelps (1973), Dan Fuqua (1974), and J. L. Weitz (1973–74). Emil Feuz and Bob Johnson furnished horses and greatly aided the work with their wrangling expertise and assistance with camp chores and sampling. Helicopter pilots Roman Ochotsky, Tom Rice, and Virgil Jones provided safe and efficient service in remote portions of the area.

Ann Christiansen contributed most significantly in painstakingly editing the geologic maps and tables. We are indebted to W. B. Hall and Helaine Walsh for providing low-level stereo air-oblique color photography that greatly facilitated advance planning of the field program, locating the best stratigraphic sections, and giving a different perspective to the intricate structure of many parts of the Teton Wilderness.

Most of the samples were analyzed in mobile field laboratories of the U.S. Geological Survey by J. G. Viets, R. T. Hopkins, Jr., E. P. Welsch, G. W. Day, and W. D. Crim. Some nonroutine analyses, such as determination of phosphate content, organic content, and coal quality, were made by personnel of laboratories as noted in the tables.

## GEOLOGY

By J. D. Love and Harold J. Prostka,
U.S. Geological Survey

### Geologic Setting

The Teton Wilderness comprises two very different geologic segments. The western segment consists chiefly of Mesozoic rocks folded into northwest-trending anticlines that were subsequently overlapped by middle and upper Cenozoic rocks. These were then tilted westward and faulted in late Cenozoic time. The eastern segment consists chiefly of nearly flat-lying Eocene volcaniclastic rocks of the Absaroka Range. These rocks bury the Late Archean and Paleozoic core of the Laramide Washakie Range. Thus, the Absaroka Range is largely an erosional remnant of Eocene strata that once extended west across the remainder of the Teton Wilderness and east and south across the Bighorn, Wind River, and Green River basins. Some of the high peaks in the Absaroka Range are resistant cores of late Eocene intrusive igneous rocks that cut the older volcaniclastic strata.

### Rocks

Descriptions and thicknesses (where determinable) of sedimentary rocks, welded tuffs, intrusive and extrusive igneous rocks, and unconsolidated mappable alluvial units are given on plate 1. Details of some rock units are discussed in connection with mineral resource assessment. Some of the Cretaceous rocks are shown in figures 3 and 26, some of the Paleozoic rocks are shown in figures 4 and 5, and volcaniclastic rocks of the Wiggins Formation are shown in figure 6. (See also Love, Antweiler, and Williams, 1975, fig. 4).

### Structure and Geologic History

A major structural feature of the Teton Wilderness is the Buffalo Fork thrust fault, which divides the wilderness into the geologically different eastern and western segments. The Buffalo Fork fault is a Laramide thrust or high-angle reverse fault along which Late Archean and Paleozoic rocks of the Washakie Range rode up and over Mesozoic rocks to the southwest. In early Eocene time, partial reversal of the Laramide displacement raised the southwest block, which limited the present distribution of the basal volcanic units—the Wapiti Formation and Trout Peak Trachyandesite—to the northeast side of the fault. However, the next younger volcanic unit, the Langford Formation, was deposited extensively on both sides of the fault. Continued rise of the southwest

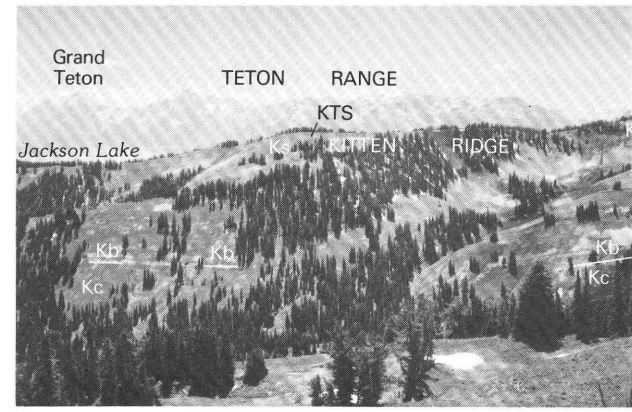



**Figure 3.** View southwest from Wildcat Peak in Teton Wilderness across southern part of the Teton Corridor toward the Teton Range. Kc, Cody Shale; Kb, basal sandstones in Bacon Ridge Sandstone; Ks, Sohare Formation, several thousand feet thick; KTS, Kitten triangulation station. The Cretaceous strata dip westward (away from the camera) on the west flank of the Wildcat anticline. Photograph by J. D. Love, July 16, 1972 (Love, Antweiler, and Williams, 1975, fig. 4).

block in post-Eocene to late Pliocene time resulted in widespread stripping of the Langford Formation, so that now only scattered patches remain. The terrane west of the Buffalo Fork thrust fault was block-faulted and tilted westward, as is indicated by westward dips in the Langford Formation of 10° on Pinyon Peak and as much as 65° in the Wolverine Creek-Coulter Creek area.

The Aycross Formation, a fine-grained volcaniclastic sequence of middle Eocene age, is present only along the southeast margin of the report area. The strata lap northward onto the Paleozoic core of the Washakie Range and are not recognizable farther north in the localities of the coarse-grained Trout Peak Trachyandesite of the Sunlight Group and the Longford and Two Ocean Formations of the Thorofare Creek Group. In this report, the Aycross Formation is not assigned to either group nor is it considered part of the Absaroka Volcanic Supergroup.

Several small remnants of Oligocene White River Formation and Miocene Colter Formation, as well as Pliocene and Pleistocene basalts, were preserved by late Cenozoic downfaulting in the Emerald Lake area along the Buffalo Fork thrust fault. Pliocene basalts near the southeastern part of the wilderness are remnants of dikes, lava flows, and cones that formerly covered large areas of a late Tertiary erosion surface developed on the early Eocene volcanic plateau. The Huckleberry Ridge Tuff, a Pliocene welded ash-flow tuff, is present in the western part of the wilderness, as outliers of the rhyolitic Yellowstone Plateau volcanic field.

The generalized distribution pattern of the major Cretaceous rock units in the Teton Wilderness prior to deposition of the Harebell Formation are shown in figure 7. This map shows the regional pattern of

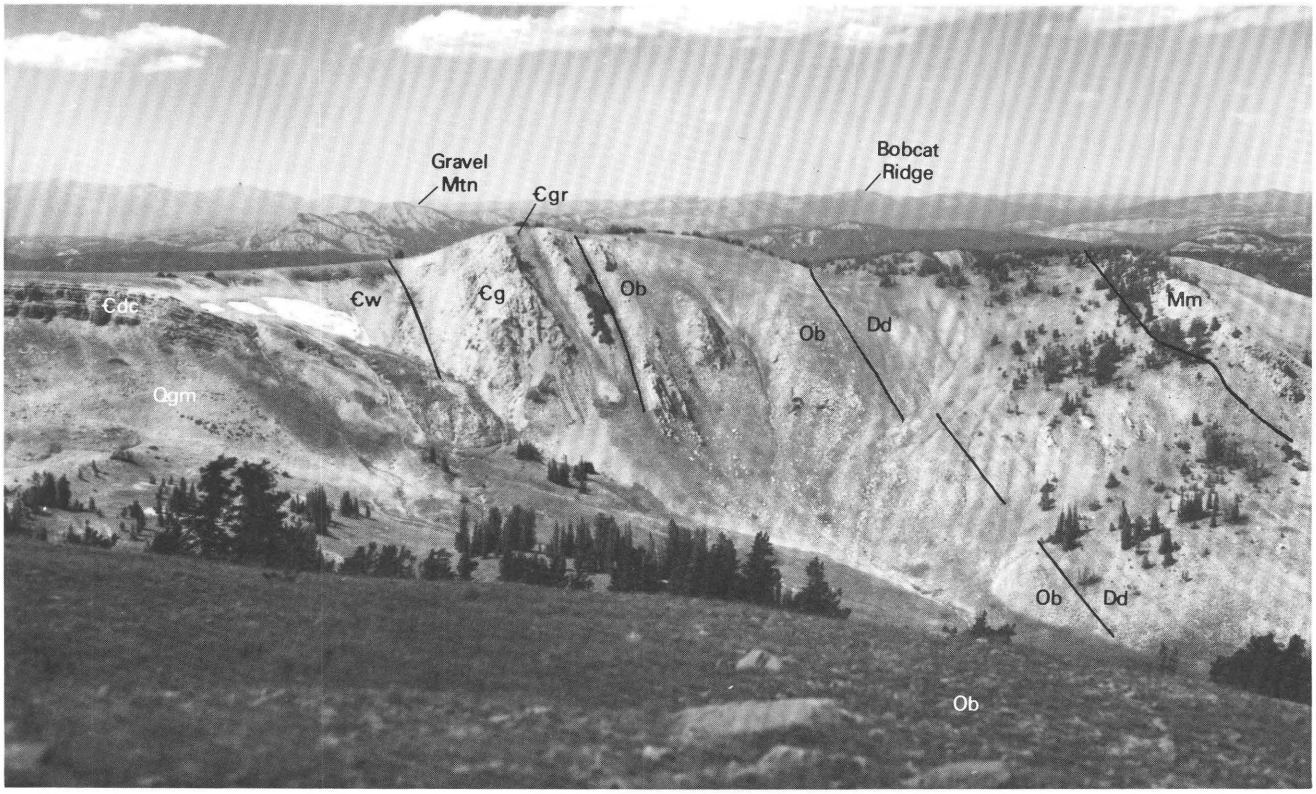



**Figure 4.** View west across Teton Wilderness from Terrace Mountain at triangulation station and BM 10,258 feet, showing Paleozoic rocks. Cw, Wolsey Shale Member, and Cdc, Death Canyon Limestone Member of Gros Ventre Formation; Cg, Gallatin Limestone; Cgr, red limestone overlain by green shale in Gallatin Limestone; Ob, Bighorn Dolomite; Dd, Darby Formation; Mm, Madison Limestone; Qgm, glacial moraine. Photograph by J. D. Love, August 24, 1973.

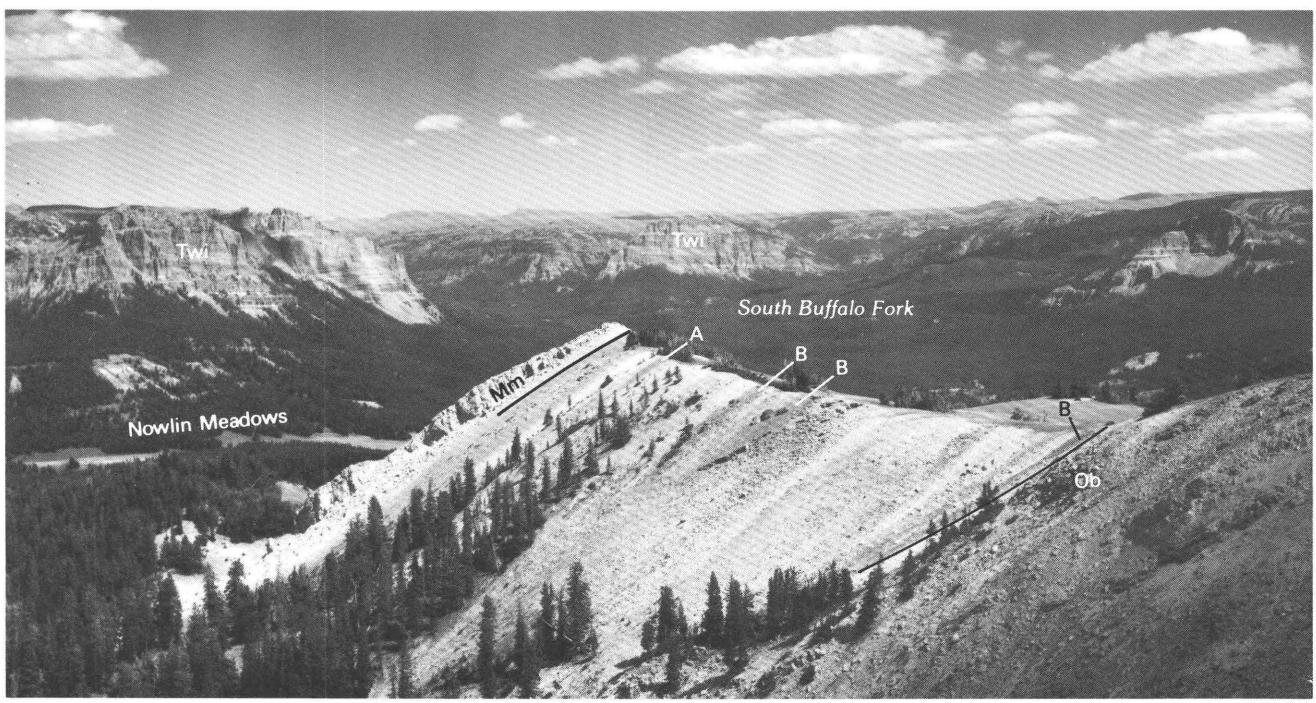



**Figure 5.** View east across mountainous southeastern part of Teton Wilderness from about 300 feet (90 m) northwest of triangulation station and BM 10,258 feet on Terrace Mountain. Ob, Bighorn Dolomite; Dd, Darby Formation; Mm, Madison Limestone; Twi, Wiggins Formation. A, red zone, and B, dark-brown fetid dolomite in Darby Formation. Flat skyline is crest of Absaroka Range. Photograph by J. D. Love, Aug. 24, 1973.

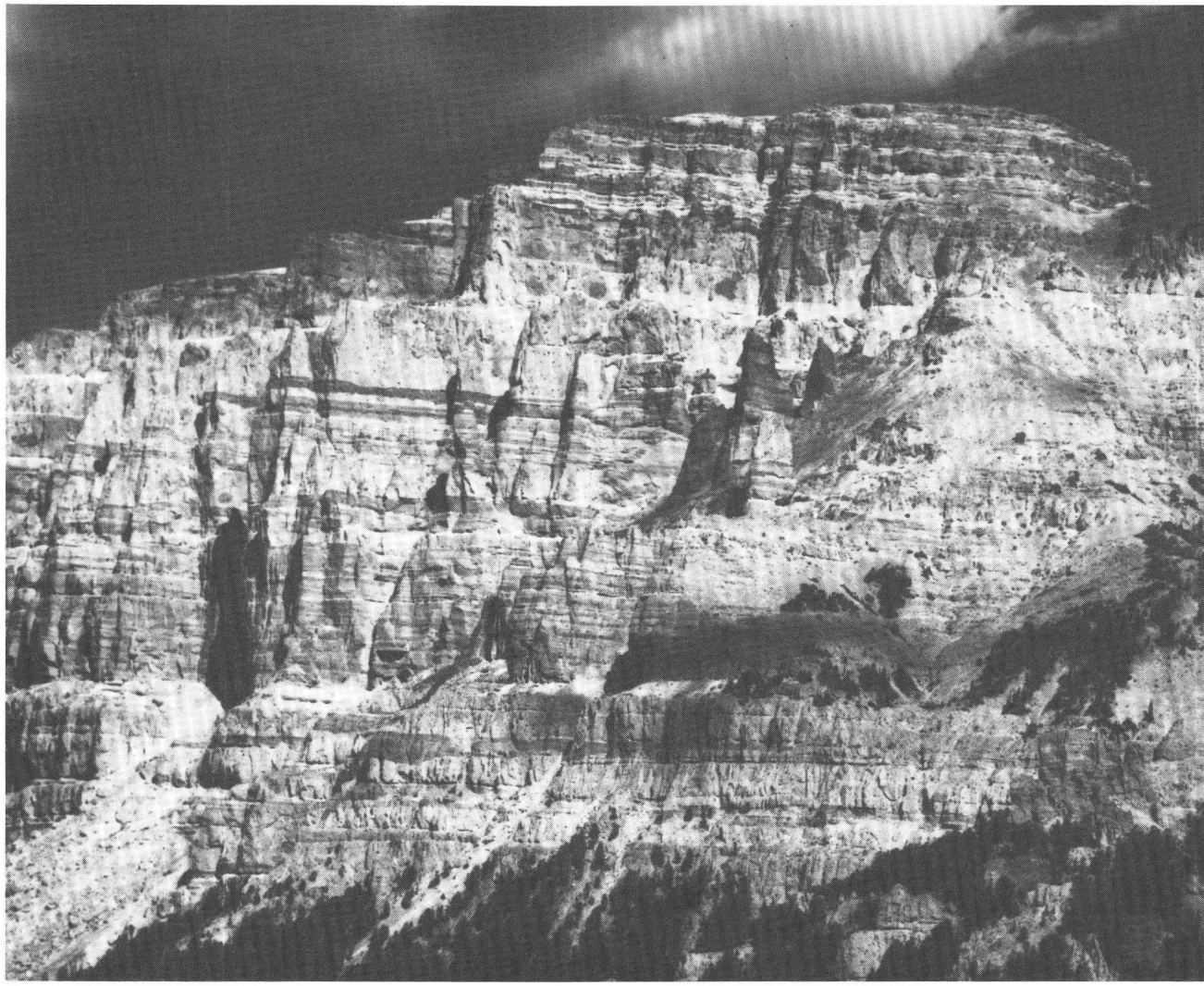


**Figure 6.** Layered volcaniclastic rocks in the Wiggins Formation exposed on the south face of Pinnacle Buttes, about 2 miles (3 km) east of Brooks Lake. Dark beds are volcanic conglomerate; white beds, tuff. Thickness of rocks shown is about 800 feet (250 m). The upper part has a K-Ar age of 45 m.y. Note cross sections of huge dark irregular blocks in upper center. Photograph by J. D. Love, Sept. 16, 1969 (Love and Love, 1980, fig. 12).

intra-Cretaceous tectonism, which is significant for oil and gas evaluation. Descriptions of the rock units are summarized on plate 1.

Two very different types of major structural episodes involved rocks of the Teton Wilderness. The first, and most important for oil and gas potential, was Laramide compressional folding. The age of this folding has been determined within narrow limits on Gravel Peak, in the west-central part of the wilderness. Here the folding occurred about 70 m.y. ago. The sequence of events, all in Maestrichtian (latest Cretaceous) or late Campanian time, has been reconstructed as follows (Love, 1977; fig. 8):

1. Deposition of 10,000 feet (3,000 m) of the Harebell Formation, which contains many fossiliferous marine or brackish-water horizons throughout and thick quartzite-boulder gold-bearing conglomerates in its upper half. Fossils at this locality are of early Maestrichtian or late Campanian age.
2. Uplift of the Washakie Range, a fold that extends southeastward from Yellowstone Lake for 75 miles (120 km) (fig. 2). The southwest margin of this fold is bounded by a thrust fault that put Paleozoic rocks on Upper Cretaceous.
3. Erosion accompanied and followed the uplifting until the Paleozoic core was exposed. This meant that about 25,000 feet (7,600 m) of rock was removed from the uplift before the next depositional event.
4. Deposition of the Pinyon Conglomerate, 4,000–5,000 feet (1,200–1,500 m) thick, laid down above a 90° unconformity across the overturned and eroded strata of the Harebell Formation. The basal part of

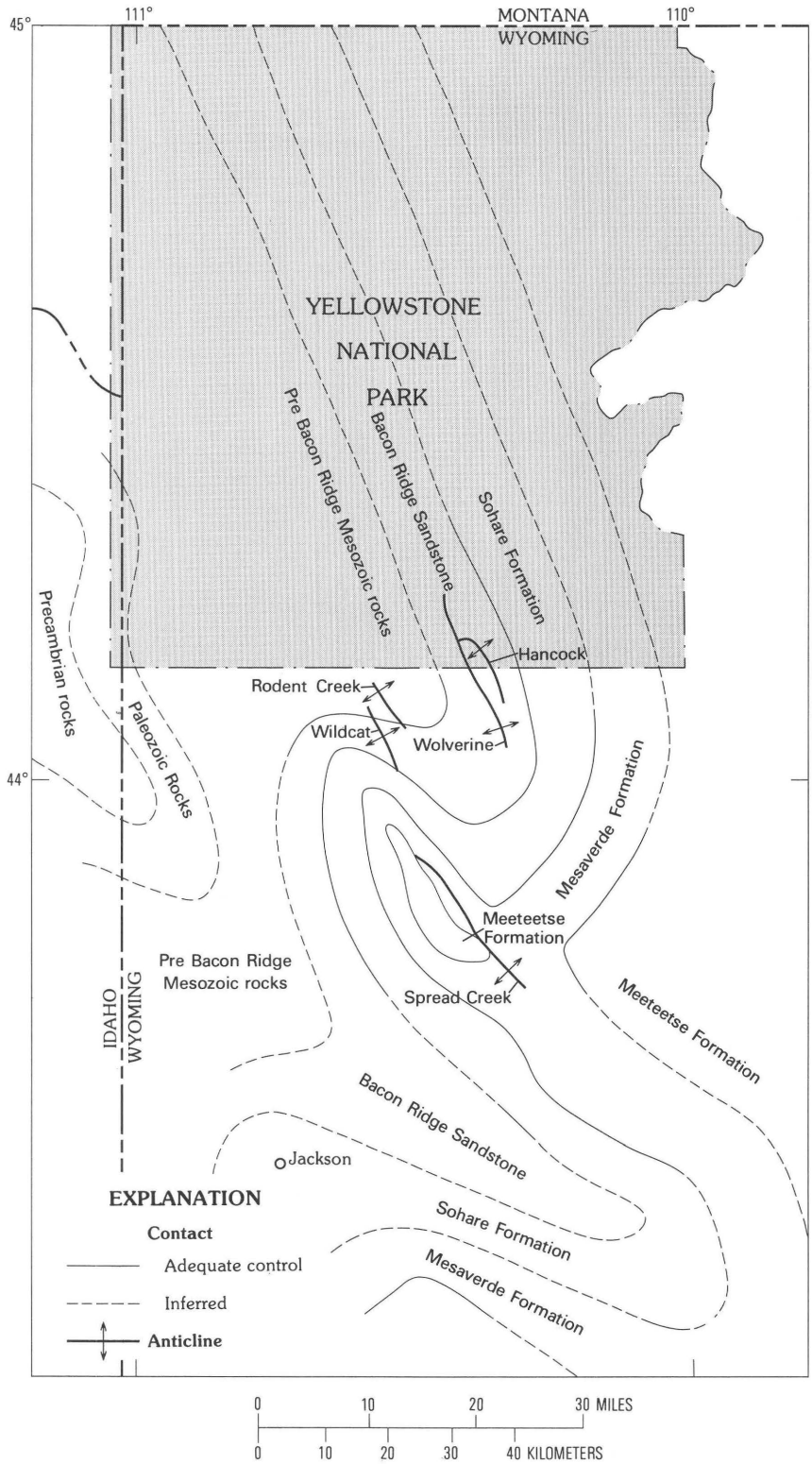



**Figure 7.** Map showing postulated areas of outcrop of Cretaceous and older rocks at beginning of deposition of Harebell Formation. Modified from Love (1973a).

the Pinyon contains a 100-foot (30-m) bed of biotite-rich tuff on which J. D. Obradovich (oral commun., 1974) obtained a K-Ar age of 68.6±0.7 m.y.

Inasmuch as the Maestrichtian Stage began about 70 m.y. ago, all four events must have occurred during a time span of about 3–6 m.y. A somewhat comparable

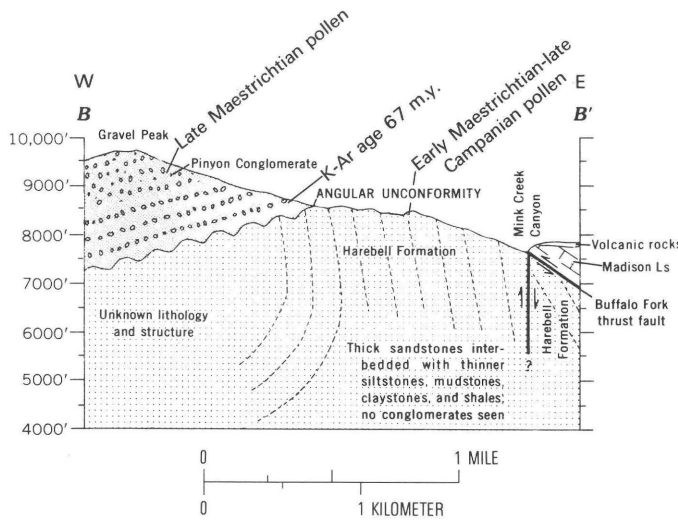



**Figure 8.** Relation of dated Pinyon Conglomerate to dated Harebell Formation and to Washakie Range. Modified from Love (1973a, fig. 33).

reconstruction of events has been made for the Basin Creek uplift along and within the northwest margin of the Teton Wilderness (Love and Keefer, 1969) and on the Spread Creek anticline south of the wilderness (Love, 1973a, fig. 21).

The structures of the individual anticlines are discussed in the section on oil and gas potential in this report. The structure of the northern part of the Washakie Range has been described elsewhere (Love and Keefer, 1975; Love, McKenna, and Dawson, 1976). The structure of the southern part of the range was described by Bengtson (1956) and Love (1956a); it has been somewhat revised by the present mapping (pl. 1).

The record of events during the earlier part of Cenozoic time in the northern Teton region was summarized by Love, Leopold, and Love (1978). The western part of the Teton Wilderness was described in connection with the Teton block diagram (Love, Reed, and others, 1973), and in the central part of the wilderness by Love, McKenna, and Dawson (1976). The Eocene record in the eastern part was discussed by Smedes and Prostka (1972).

The second major structural episode involving the Teton Wilderness occurred during late Cenozoic time. Before emplacement of the Huckleberry Ridge rhyolite welded tuffs slightly more than 2 m.y. ago (Christiansen and Blank, 1972) in the western and northern parts of the Teton Wilderness, the Laramide anticlines were eroded, but not below the Cretaceous rocks (except for the Washakie Range). Next, Pliocene and Pleistocene welded tuffs, chiefly the Huckleberry Ridge Tuff, flowed southward from a source in Yellowstone National Park and buried valley areas in the western and northwestern parts of the wilderness to a depth of 365 feet (110 m) or more. At the base of these tuffs is a profound angular unconformity, in places more than 90°. After emplacement of the Huckleberry Ridge Tuff, the Jackson Hole structural block, which includes the southwestern part of the Teton Wilderness, hinged down several thousand feet. The Huckleberry Ridge Tuff was broken by many normal faults, most with a few tens to a few hundreds of feet displacement. The Pilgrim Creek fault, however, may have as much as 10,000 feet (3,000 m) displacement, although some of this movement could have been prior to deposition of the Huckleberry Ridge Tuff.

The normal fault that coincides roughly with part of the trace of the Buffalo Fork thrust across the central part of the Teton Wilderness probably developed, at least in part, prior to 2 m.y. ago. The fault plane was intruded by pyroxene andesite and basalt having a K-Ar age of 2 m.y. (Love, McKenna, and Dawson, 1976). Displacement on this fault may be several thousand feet (fig. 8), with the east block downdropped.

The westward tilting and tension faulting during Quaternary time significantly distorted the much older Laramide structures. To obtain their original conformation, they now need to be rotated upward and clockwise (if reconstructions are oriented northward) as much as 20° to 30°. The effect of this secondary tilting on oil and gas accumulation, and on possible tilted water tables and water drive, is discussed in the mineral-resources section of this report.

The eastern segment of the Teton Wilderness has been mildly deformed into broad upwarps and downwarps, whose axes trend parallel to the structural grain of the underlying Washakie Range. A central downwarp, with a complex grabenlike axial fault zone, extends from Yellowstone River valley southeastward through Ferry Lake to Buffalo Plateau and eastward into an unnamed late Tertiary syncline, mapped by Fisher and Ketner (1968), through the southern Absaroka Range. Northeast of this axial zone, the volcanic strata rise toward the intrusive centers beyond the northeastern wilderness boundary. Dips are from 3° to 10° SW., but locally they are as much as 15° SW. around the domed intrusive complex on Yellow Mountain. No appreciable doming or structural disruption was noted around any of the other intrusive bodies in the Teton Wilderness.

Along the ragged southwest margin of the volcanic plateau is a gentle upwarp, whose axis trends parallel to the arcuate trace of the Buffalo Fork thrust fault and is about 4 miles (6 km) northeast of it. This upwarp is the locus of a broad zone of normal faults of small displacement and diverse trends. Dips in the volcanics along the limbs of this upwarp are less than 7°. The southwest limb is cut by the Buffalo Fork thrust fault.

After emplacement of the Huckleberry Ridge Tuff slightly more than 2 m.y. ago, and after its subsequent tilting and faulting, came several episodes of glaciation.

The glacial deposits in the northern part of the Teton Wilderness were mapped by Richmond and Pierce (1971a, b) and Richmond (1973) as part of the Yellowstone National Park research program. The glacial deposits in the southern part of the wilderness were mapped in connection with the present study. The older and larger ice masses moved southward across the Teton Wilderness from centers of accumulation in Yellowstone National Park, and westward from centers in the Absaroka Range. The ice in some parts of the Teton Wilderness must have been more than 2,000 feet (610 m) thick. The distribution of the ice has a significant bearing on the mineral evaluation of the Teton Wilderness because, in many places, the ice picked up quartzite roundstones and finer grained gold-bearing sandstone associated with quartzite clasts, and scattered and concentrated this debris along many major drainages. These occurrences are discussed in the section on gold deposits in this report.

The glacial debris obscures bedrock geology in large parts of the Teton Wilderness. Another effect of the extensive glaciation was the development of enormous landslides where soft Cretaceous shales, tilted and faulted in Pleistocene time, were scoured by ice and then saturated with glacial meltwater.

Continued deformation of the Jackson Hole region is indicated by numerous Holocene faults to the north and west of the wilderness (Howard and others, 1978; Love and Reed, 1968; U.S. Geological Survey, 1972), and by abundant seismic activity within this part of the Intermountain seismic belt (Smith and Sbar, 1974). The large number of landslides in the Yellowstone-Teton region is undoubtedly in part due to relatively intense seismic activity.

## AEROMAGNETIC AND GRAVITY STUDIES

By Dolores M. Kulik and Lennart A. Anderson, U.S. Geological Survey

### Introduction

Aeromagnetic and gravity surveys were made of the Teton Wilderness as part of the mineral resource assessment. No detailed geophysical studies had previously been made in the wilderness. Localized magnetic anomalies, not related to topography, are of principal interest because they may indicate buried rock masses often associated with minerals of economic importance. The gravity data provide information on structural relationships and the subsurface distribution of rock types.

### Methods of Study

The aeromagnetic map (pl. 1) was compiled from data obtained by the U.S. Geological Survey on two surveys. The area west of long. 110°15′ W. was flown in 1962 at a constant barometric elevation of 12,000 feet (3,658 m); the section east of long. 110°15′ W. was flown at an elevation of 13,000 feet (3,963 m) in 1969. Flightlines on both surveys were oriented east-west and spaced approximately 1 mile (1.6 km) apart. A fluxgate magnetometer was used to measure the total magnetic intensity along the traverses, and these data, which include the regional gradient, were compiled and contoured at a 20 nT (nanotesla) interval on the aeromagnetic map. Areas east and west of long. 110°15′ W. were manually adjusted to the 13,000-foot (3,963-m) level.

The gravity survey was made during the summer of 1974. Approximately 185 gravity stations were established in and adjacent to the wilderness. Because of rugged terrain, the stations within the wilderness were established using a helicopter; those adjacent to the wilderness were reached on foot and with a 4-wheel-drive vehicle. Observations were made with LaCoste and Romberg[1] gravity meter G131, and were tied to the Defense Mapping Agency Gravity Base Stations at Dubois and Cody, Wyo. (Defense Mapping Agency Aerospace Center, 1974). A secondary base was established at Teton Trails Lodge (Togwotee Lodge on the Angle Mountain 7 ½-minute topographic quadrangle), 7 miles (11 km) west of Togwotee Pass. Station elevations were obtained from benchmarks, spot elevations, and contour interpolations on U.S. Geological Survey 1:24,000- and 1:62,500-scale topographic maps. Elevations are accurate to 3–6 feet (1–2 m) in areas of low relief, but may be in error by 16–33 feet (5–10 m) in more rugged terrain. The resultant error in the Bouguer anomaly is less than 2 mGal (milligals). Data for 85 stations southeast of the wilderness were obtained from the Defense Mapping Agency.

Field measurements were reduced by a digital computer program by R. H. Godson and D. A. Dansereau, U.S. Geological Survey (unpub. data), which incorporates corrections for tidal and Earth curvature effects and linear instrument drift. Gravity meter readings were converted to observed gravity using the 1971 base values of the International Gravity Standardization Net (Defense Mapping Agency Aerospace Center, 1974). The Geodetic Reference System, 1967 formula (International Association of Geodesy, 1967), was used to compute theoretical gravity. The data were reduced to Bouguer anomaly values using an assumed average rock density of 2.67 g/cm$^3$. Terrain corrections were made by hand template through Zone H of Hammer (1939) and to 167 km (104 mi) by digital computer (Plouff, 1966). The corrections ranged from less than 1 mGal in the Dubois and Cody areas to more than 20 mGal in the mountains of the Teton Wilderness.

### Aeromagnetic Interpretations

The rocks in the Teton Wilderness belong to two distinct geologic segments. In the western segment, the sedimentary rocks of Pinyon Peak and the highlands to the south have little, if any, magnetic expression whereas the volcaniclastic deposits of the Absaroka Range, which cover the eastern two-thirds of the wilderness, produce a substantial number of low-amplitude magnetic anomalies. The volcaniclastic rocks cover the Paleozoic rocks of the northwest-trending Washakie Range located in the central part of the wilderness. The Paleozoic rocks produce a subtle increase in the magnetic field which follows the trace of the Buffalo Fork thrust fault. Some of the Late Archean rocks within the Washakie Range cause magnetic anomalies of appreciable amplitude, depending on their composition.

Magnetic anomalies—localized disturbances of the Earth's magnetic field—result from variations in the magnetic mineral content of the rock. To determine the magnetic mineral content of the rock, representative samples of major rock units were collected and analyzed in the laboratory for their magnetic susceptibility.

Samples from the sedimentary formations of the western highlands ranged in magnetic susceptibility from less than $1.0\times10^{-5}$ to $1.0\times10^{-2}$ SIU (Standard International Units), but despite this variation, the magnetic field associated with these rocks is uniformly distributed. Of these sedimentary rocks, the Pinyon Conglomerate,

[1]The use of trade names in this report is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

which covers a large area and is about 3,300 feet (1,000 m) thick, had the highest magnetic susceptibility, yet this formation has no apparent magnetic expression. Evidently the magnetic minerals within the rock are unevenly distributed, but on a regional scale, from a sensing distance of approximately 0.6 mile (1 km), the sedimentary rocks appear to be magnetically uniform.

Not until the north-trending Buffalo Fork thrust fault and associated parallel faults are intersected do the magnetic gradients begin to show a significant increase (pl. 1). East of the fault system, the Paleozoic rocks of the Washakie Range are in contact with and largely covered by volcanic deposits originating from the Absaroka Range. The Paleozoic rocks are chiefly limestones and consequently are magnetically inert; therefore, the source causing the increase in magnetic gradient is probably the Late Archean crystalline core of the Washakie Range.

The magnetic characteristics of the Late Archean core of the Washakie Range are unknown, and no samples were obtained for magnetic-property determination at the two sites where Late Archean rocks outcrop. A positive magnetic anomaly (pl. 1, anomaly A) is associated with one outcrop but not the other. The anomaly-producing outcrop, composed primarily of gneiss (Bengtson, 1956), is bisected by South Buffalo Fork south of Terrace Mountain within an area of low relative elevation. Because topography does not contribute to the amplitude of the anomaly, it is assumed that the magnetite content of the gneiss is substantially greater than that of the surrounding rock. A secondary magnetic peak exists to the southeast within the main anomaly, which may indicate a domelike upward projection of the gneissic rock into the covering volcanics. In that event, the site of the smaller anomaly would be favorable for the formation of metalliferous deposits; however, the source of the anomaly can also be attributed to the surface rock.

The second exposure of Late Archean rock is near the confluence of North Buffalo Fork and Soda Fork. The rock is granite gneiss and schist and has no associated magnetic anomaly. If the outcrops are representative of the Washakie core, then the magnetic character of that rock must be highly variable.

Thirteen samples of the volcanic rock covering the eastern part of the wilderness were analyzed for their magnetic susceptibility. Susceptibility values ranged from $2.4\times10^{-3}$ to $1.9\times10^{-2}$ SIU, with a mean of $1.0\times10^{-2}$ SIU. This implies a variation in the magnetite content of 0.15 to 0.6 percent within the rock (Grant and West, 1965, p. 367). A component of magnetization not considered here is that of remanent or permanent magnetization which, in some instances, can be appreciable. Volcanic rock, upon cooling, will take on the direction and polarity of the Earth's magnetic field. If deposition took place over a long period of geologic time, the orientation of the remanent component would differ within intervals of the volcanic section, thereby altering the total magnetization vector so as to add another variable to the magnetization of the rock.

Some examples of good correlation between magnetic anomalies and topography in the Wiggins environment can be seen in the east-central part of the wilderness at Thorofare Plateau and Thunder Mountain. With the exception of anomaly B (pl. 1) associated with Younts Peak, virtually all positive anomalies south of Thunder Mountain along the wilderness boundary to the southwest can be attributed to high topography. Conversely, the broad, low-amplitude, negative anomaly on the southern edge of the wilderness conforms to the Brooks Lake Creek valley.

Anomaly B, although concordant with high topography, may be partially or totally influenced by the presence of a Tertiary intrusive exposed along the west flank of Younts Peak. Evidence that the intrusive is somewhat magnetic can be found in the area directly northeast of Younts Peak, where intrusives of the same age and composition are enfolded by magnetic contours which cut across local topography. Based on the apparent effect the intrusions have on the magnetic field in anomaly C (pl. 1), it may be inferred that anomaly B is caused primarily by the intrusive. Thunder Mountain also has associated exposures of intrusive rocks, and from the magnetic intensity of its anomaly relative to Younts Peak, it seems reasonable to speculate that the intrusive on Thunder Mountain is similar to that at Younts Peak. The significance of the intrusives on Younts Peak and Thunder Mountain is that magmatic emanations acting on older dolomite included in the Langford Formation, where present, may have produced mineral resources.

An east-northeast alignment of topographic highs in the northern panhandle of the wilderness from the Trident Plateau on the west to Overlook Mountain on the eastern boundary produces only one localized anomaly (pl. 1, anomaly D). This anomaly is confined to an unnamed feature in the central part of the panhandle and may be caused by an intrusive of unknown origin. Southeast of anomaly D, a magnetic low over a region of lower elevation may signify an intrusive of differing composition.

A very narrow positive anomaly (pl. 1, anomaly E) follows the wilderness boundary from Ishawooa Cone on the southeast end northwest to Chaos Mountain, transecting the high topographic trend extending northeast beyond Overlook Mountain. The source of anomaly E has not been identified but may possibly be a linear vent system containing trapped basalt.

West of long 110° W., a ridgelike magnetic feature which terminates in a positive anomaly (pl. 1, anomaly F) located over high topography between Falcon and Atlantic Creeks, generally conforms to the topographic

outline of the Two Ocean Plateau. The correspondence between intensity and topography is not exact, but rather the source of anomaly F appears to be positioned nearer the east edge of the plateau. The source rock is probably a near-surface volcanic section which is thickest along the east edge of the plateau. A corresponding low exists in conjunction with the adjoining Yellowstone River valley.

South of and in a line with the ridgelike anomaly, a broad, low-level, positive anomaly is affiliated with Soda Mountain. The smaller anomaly (pl. 1, anomaly G) to the north straddles a zone of low elevation and may indicate an intrusive within the western flank of the adjacent hill.

Two interesting anomalies (pl. 1, anomalies H and I) are located near the headwaters of the Yellowstone River. Both are negative in polarity and are offset from the highest point of the topographic feature with which they are affiliated. These anomalies are probably caused by silicic intrusions, which contain relatively few magnetic minerals, or which possibly have a reversed remanence so as to produce a negative anomaly.

Two small positive anomalies (J and K, pl. 1) are located near the northwest boundary of the wilderness at the junction of Harebell, Wolverine, and Coulter Creeks. These anomalies identify remnants of andesitic breccia of the Langford Formation overlying the western sedimentary rocks. Adjoining rhyolite flows of Yellowstone origin have no apparent magnetic expression.

**Table 1.** Densities for rock samples from the Teton Wilderness and adjacent areas

| Sample No. | Formation | Age | Density ($g/cm^3$) |
|---|---|---|---|
| Localities on plate 2. Analyses by D. M. Kulik | | | |
| T123 | Wiggins Formation-- | Tertiary------ | 2.51 |
| T124 | -----do---------- | -----do------- | 2.57 |
| T74 | -----do---------- | -----do------- | 2.50 |
| T54 | Frontier Formation- | Cretaceous---- | 2.51 |
| T52 | Mesaverde Formation | -----do------- | 2.49 |
| T131 | Madison Limestone-- | Mississippian- | 2.66 |
| Samples from Hurich (1979) Density measurements are averages | | | |
| ---- | Tertiary and Cretaceous sedimentary rocks at 3,000- to 5,000-ft (1,000- to 1,750-m) depth---------- | | 2.43 |
| ---- | Tertiary and Cretaceous sedimentary rocks at 5,000- to 23,000-ft (1,750- to 7,000-m) depth---------- | | 2.54 |
| ---- | Jurassic through Cambrian sedimentary rocks---------- | | 2.65 |
| ---- | Monzonite, granodiorite, and granite--- | | 2.70 |
| ---- | Granitic gneiss---------- | | 2.72 |
| ---- | Migmatite---------- | | 2.73 |
| Sample from Clark (1966, p. 20)--Average | | | |
| ---- | Granodiorite---------- | | 2.73 |

## Gravity Interpretations

Qualitative analysis of subsurface structure was made by examination of gradients and configuration of gravity anomalies (pl. 2). Quantitative estimates of depth to structural features were made from two-dimensional mathematical models of gravity profiles using a computer program by Lindrith Cordell (U.S. Geological Survey, unpub. data).

Density measurements were made for six rock samples from the wilderness to aid in the interpretation of the gravity data. Density measurements from adjacent areas were also considered in calculating the gravity models. The density data are summarized in table 1.

The gravity pattern in the Teton Wilderness exhibits a northwesterly trend paralleling Laramide structures. A -205 to -230 mGal high gravity anomaly in the central part of the wilderness reflects the relatively high density of the near-surface Late Archean crystalline core of the Washakie Range (table 1). Associated low gravity anomalies occur northeast and southwest of the high and reflect the sedimentary rocks on the flanks of the range (table 1). The high gravity trend continues northwestward along Big Game Ridge and the Wolverine anticline to the northern boundary of the wilderness. The south part of the major high gravity anomaly coincides with the crest of the Washakie Range and is inferred to continue to the southeast where anticlinal structures have been mapped in the Du Noir area (Keefer, 1957).

A low-gravity anomaly lies southwest of the Washakie Range and extends both southeast and northwest beyond the boundaries of the wilderness. The anomaly reflects a sedimentary basin, termed the Box Creek downwarp (Love, 1973a), that appears from the gravity data to increase in size southwest of the wilderness boundary. In the northwest part of the wilderness the anomaly is bounded on the west by a gravity gradient associated with normal and reverse faults. The steep gradient between the low anomaly and the high Bouguer values over the Washakie Range is associated with the Buffalo Fork thrust fault, which has brought Late Archean and Paleozoic rocks to the surface. South of Gravel Peak, however, the gravity contours turn west at right angles to the Buffalo Fork thrust fault before turning sharply north again along the axis of Big Game Ridge. This departure from the northwest gravity trend is unexplained by surface geologic data. A vertical to overturned section of Upper Cretaceous Harebell Formation and the overlying Upper Cretaceous and Paleocene Pinyon Conglomerate crops out west of the Buffalo Fork thrust fault,

and Mississippian and Devonian rocks crop out east of the fault. No evidence of faulting that would account for the gravity expression has been observed in these formations. The gravity data may, however, reflect faulting below the surface outcrops or relief on the basement surface as discussed later. The high gravity anomaly over the Washakie Range is deflected by this change in trend, and then continues northward reflecting anticlinal structures exposed in Cretaceous rocks.

The northeast flank of the Washakie Range is covered by Tertiary volcanics that obscure the underlying geologic structures. A major low gravity anomaly extends across that portion of the wilderness, indicating a thick section of relatively low density material between the Washakie Range and the Absaroka Range to the east. The gravity gradient over the Absaroka Range, east of the low anomaly, increases gradually to the northeast. The gradient is interpreted to reflect the rise of the Late Archean basement. Two additional low gravity anomalies are superimposed on the major gravity low, increasing the total relief between these anomalies and the high gravity anomaly over the Washakie Range to 30 mGal. Additional gravity data collected in the adjacent Washakie Wilderness (C. A. Long, oral commun., 1980) indicate that the south half of the low anomaly extends another 3 to 4 mi (5 to 6 km) eastward with similar gravity relief.

The undulations in the contours along the gradient on the east side of the major gravity low are associated with altered andesite rocks and intrusive granodiorite bodies exposed on the southwestern part of Thunder Mountain and northwest of Younts Peak.

The small, 10-mGal low gravity anomaly north of Hawks Rest may be caused by a large alluvial deposit of several hundred feet of loosely consolidated material derived largely from the Wiggins Formation. The anomaly could reflect a small, buried intrusive, but there is no surface geologic evidence to support this possibility, and the aeromagnetic data do not clearly indicate such a body.

## Interpretation of Gravity Models

A two-dimensional gravity model (fig. 9) was calculated for profile *A–A′* (pl. 2) southeast of the Teton Wilderness, where structural cross sections were available for control (Keefer, 1957), to determine suitable density contrasts. An average density of 2.73 g/cm$^3$ was assumed for Late Archean rocks, 2.66 g/cm$^3$ for Paleozoic rocks, 2.54 g/cm$^3$ for Mesozoic rocks, and 2.53 g/cm$^3$ for Tertiary rocks in modeling profile *A–A′*. Measured densities of Tertiary rocks (table 1; Hurich, 1979) are lower than that assumed for the models, but the Tertiary rocks in the Teton area are lithologically more similar to the Cretaceous rocks of the Teton area than to the Tertiary rocks in the area from which Hurich's data are taken (J. D. Love, oral commun., 1980). These density contrasts yielded a fit to the gravity profile *A–A′* by assuming a thickness of 1,000 feet (300 m) of Tertiary rocks, 6,000 feet (1,800 m) of Mesozoic rocks, and 4,000–5,000 feet (1,200–1,500 m) of Paleozoic rocks above the Late Archean basement rocks. Keefer (1957, pl. 26) estimated approximately 1,000 feet (300 m) of Tertiary rocks and 4,000–5,000 feet (1,200–1,500 m) each of Cretaceous and Paleozoic rocks in the area of profile *A–A′*.

A second model was computed for profile *B–B′* (fig. 9) across the northern part of the low gravity anomaly to evaluate the source of the anomaly. The same rock densities were assumed as for profile *A–A′*. A thickness of 4,000–5,000 feet (1,200–1,500 m) was again assumed for Paleozoic rocks. A computed profile was fitted to the observed gravity profile *B–B′* by assuming that 4,000 feet (1,200 m) of Tertiary rocks and as much as 12,000 feet (3,700 m) of Mesozoic rocks overlie the Paleozoic rocks. The relative thickness of Tertiary and Mesozoic rocks cannot be determined by the gravity data because the assumed densities are similar.

The structure represented by the model across gravity profile *B–B′* is hypothetical, but it is consistent with that at profile *A–A′* as interpreted by Keefer (1957). Other configurations are possible, but considerable relief on the Late Archean surface is required to fit the observed gravity data. Two interpretations of the gravity data are possible: the anomaly may reflect a down-faulted section of basement rock—a half-graben—which subsequently was filled with sediment from the eroding Washakie Range or with volcanics; or, the anomaly may reflect a collapsed caldera beneath the volcanic debris. The density of such material would be substantially lower than that assumed in the model, and the total relief on the structure probably would not exceed 10,000 feet (3,000 m). The elongate and asymmetric shape of the body does not favor this interpretation.

The trend of the body parallels the Box Creek downwarp and other sedimentary basins in northern Wyoming. Thickness of sedimentary rocks derived from the gravity modeling are similar for profile *B–B′* and for profile *C–C′* (fig. 9) across the Box Creek downwarp where a thick Cretaceous section is exposed at the surface.

These correlations strongly suggest that the interpretation of a sedimentary basin overlain by Tertiary volcanic rocks is valid, and we shall refer to it as Younts basin(?).

A third gravity model was computed for profile *C–C′* (fig. 9) to determine structural relationships between the Box Creek downwarp and the Buffalo Fork thrust fault. The same density contrasts were used as in modeling profiles *A–A′* and *B–B′*. The model indicates that the Buffalo Fork thrust fault overrides the sedimentary rocks of the Box Creek downwarp at an angle of

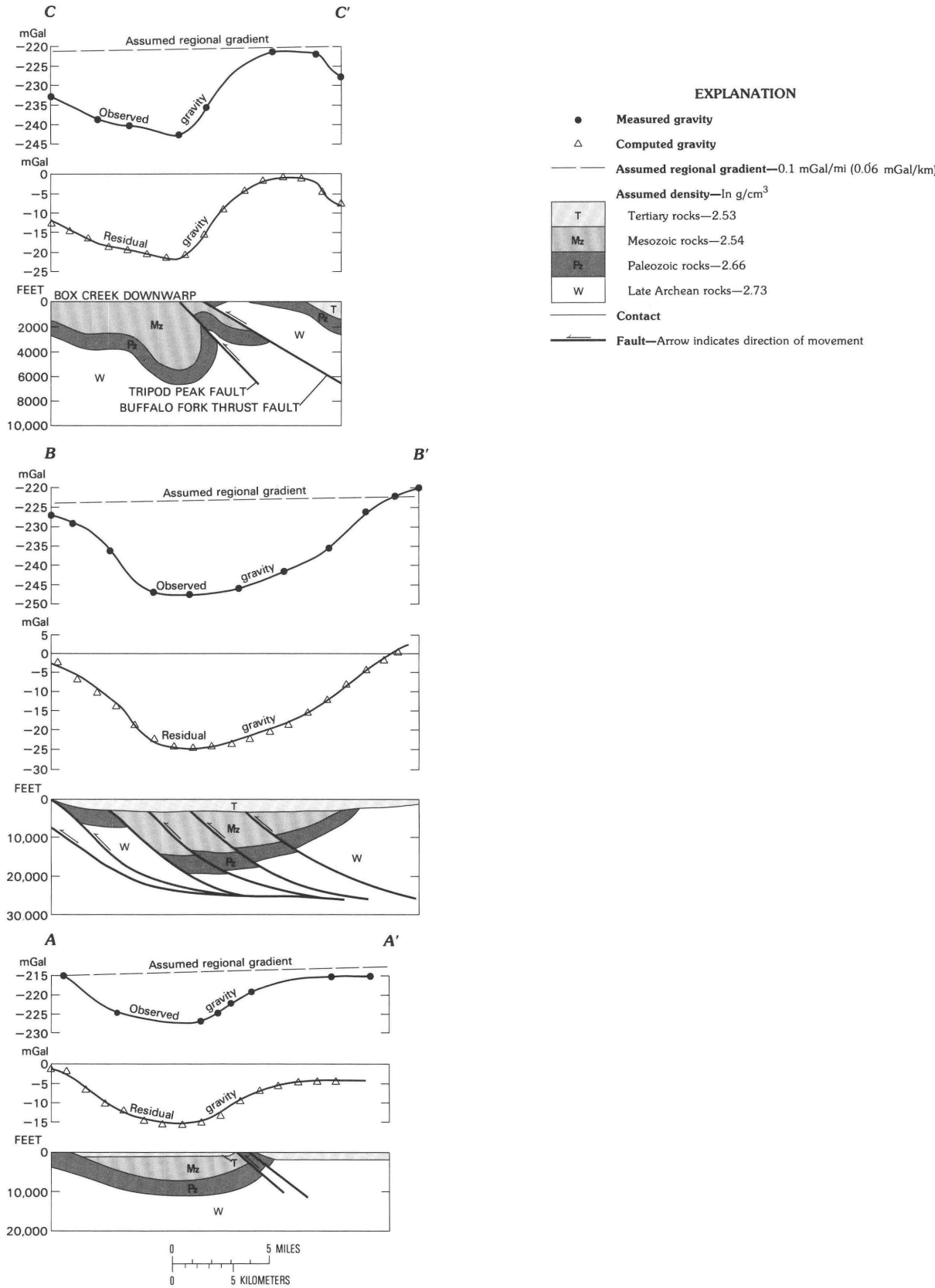



**Figure 9.** Computed gravity models and hypothetical structure along profiles *A–A'*, *B–B'*, and *C–C'* across the Teton Wilderness and adjacent areas. Lines of sections shown on plate 2.

about 30°. The configuration of the Paleozoic strata required to fit the gravity data indicates that the Tripod Peak fault is continuous across the area of the gravity model although it is obscured at the surface. The gravity model indicates about 16,000 feet (5,000 m) of Cretaceous rocks in the trough of the Box Creek downwarp, and about 5,000–8,000 feet (1,500–2,400 m) of Cretaceous rocks west of the trough.

## Hydrocarbon Potential Interpreted from Gravity Data

Interpretations of the gravity data suggest that thick sections of Cretaceous strata, including source and reservoir rocks which produce hydrocarbons in other areas of Wyoming, are present in the Box Creek downwarp in the western part of the Teton Wilderness, and in Younts basin(?), overlain by volcanic rocks, in the central part of the wilderness.

Thrust faulting appears to account for the distribution of Mesozoic, Paleozoic, and Late Archean rocks in Younts basin(?). However, structures on the east flank of the basin appear from the gravity data to be minor, and further geophysical exploration would be required to identify and define them.

Structural traps may be present at the postulated fault boundary on the western flank of Younts basin(?), the western flank of the Box Creek downwarp, areas where sedimentary strata abut the Tripod Peak and Buffalo Fork faults in the Box Creek downwarp, and in the fold structures interpreted from gravity data in the Tripod Peak fault block.

An elongate trend of high gravity values extends northeast beyond the Teton Wilderness along the South Fork Shoshone River. The trend seems to bifurcate as it approaches the east boundary of the wilderness and appears as two relatively high areas on the major negative gravity anomaly. The northeast-trending positive anomaly may indicate a structural high on the basement surface. Such a proposed basement structure may trap hydrocarbons where sedimentary rocks of the basin wedge out in depositional unconformity against the flanks of the structure. A similar northeast-trending positive gravity anomaly southwest of Gravel Peak transects the negative gravity anomaly over the north end of the Box Creek downwarp. A similar basement structure may be the cause of the westward deflection of the gravity contours from the northwest-trending anomaly over the Buffalo Fork thrust fault, Big Game Ridge, and Wolverine anticline; and similar hydrocarbon traps may be present in the Box Creek downwarp.

## Conclusions

The significant variations in the magnetic field in the Teton Wilderness are largely confined to the eastern part and are influenced principally by surface deposits derived from the Absaroka volcanic centers. Most anomalies can be correlated with variations in topography, whereas others may relate to changes in the composition of the rock.

The large-scale structural features of the wilderness are delineated by the gravity data. An unexpected result of the survey is recognition of a probable structural basin located between the Washakie and Absaroka Ranges. This is an area of relatively high elevation completely covered by pyroclastic materials. Evidence of its existence heretofore has only been speculative.

There is a mutual correspondence in the magnetic and gravity response over the Hawks Rest area. Each data set indicates relatively low values, suggesting that the probable source of the anomalies is a silicic intrusive. South of Hawks Rest, a negative magnetic anomaly (pl. 1, anomaly H) coincides with Yellowstone Point. On the basis of magnetics alone, it may be inferred that anomaly H stems from the same variety of silicic rock as does the Hawks Rest anomaly. The gravity data, however, show a positive anomaly associated with the plateau area. A density difference of about 0.3 g/cm$^3$ between the two intrusive bodies is required to produce the observed gravity change. Although the magnetic data may imply that the inferred intrusive bodies are derived from the same source, the gravity data signify that the intrusives must be different in composition.

Other correlations between the magnetic and gravity data cannot be made except that a negative gravity anomaly exists over the east side of Two Ocean Plateau where a positive magnetic ridgelike anomaly is located. This correspondence may be fortuitous in that the magnetic disturbance is caused by the surface rock, whereas the gravity is controlled by a source at depth.

These geophysical data give no positive evidence of mineral resources within the wilderness. Possible exploration targets may be in the area of the negative magnetic anomalies located near the headwaters of the Yellowstone River and south of Overlook Mountain in the northeastern part of the wilderness. Another site that may have mineral resources is indicated by the small positive magnetic anomaly southeast of anomaly A.

If sedimentary sequences cause the negative gravity anomalies over the Box Creek downwarp and Younts basin(?), they would contain strata which have significant oil and gas potential elsewhere in Wyoming. Structural traps may exist within the basins and at the bounding structures. The northeast-trending basement structures suggested by the gravity data in South Fork Shoshone River and in the northern part of Box Creek downwarp could also produce structural traps for hydrocarbon accumulation within the basins.

## GEOLOGIC AND GEOCHEMICAL APPRAISAL

By J. C. Antweiler and J. D. Love,
U.S. Geological Survey

### Mineral Resource Exploration and Development in the Teton Wilderness

As of 1985, there were no active mines that produced metallic or nonmetallic materials from the rocks exposed in the Teton Wilderness. One small gold-placer operation has been conducted intermittently on Pacific Creek, near the southwest corner of the wilderness. Gold-placer prospects have been worked from time to time elsewhere in the western and southern parts of the Teton Wilderness; attempts to develop these deposits were summarized by Hayden (1956, p. 11–12). (See section on economic appraisal, this report.)

The U.S. Bureau of Reclamation operated a coal mine, about 1910, in the Mesaverde Formation on Pilgrim Creek within the boundary of the Teton Wilderness. The coal was used to power equipment for construction of the Jackson Lake dam, 5 miles (8 km) south of the wilderness. Later, the U.S. Bureau of Reclamation and private individuals also opened coal mines in the Bacon Ridge Sandstone, north of Buffalo Fork near Lava Creek, 2 miles (3 km) south of the wilderness.

Two mines were established about 1905 on South Buffalo Fork in some copper-bearing Late Archean rocks. A uranium prospect was located at the Soda Springs on Soda Fork in 1955, and drilling was done with a portable rig. There was no further exploration work. Also, during the 1950's, uranium claims were staked west of Two Ocean Pass, along outcrops of the Phosphoria Formation, which is weakly radioactive. Samples of high-grade uranium ore from Pumpkin Buttes in northeastern Wyoming (and reported to have come from Two Ocean Pass) were passed around the bars in Jackson to stir excitement and to raise additional money for further exploration. A few prospect pits were dug, but no ore was found.

Mineral commodities and nonmetallic materials whose resource potential in the Teton Wilderness was investigated are grouped into four categories: (1) oil and gas; (2) metallic mineral deposits, particularly Au, Ag, Cu, Pb, Zn, and Mo, in bedrock as well as in placers; (3) sedimentary deposits of coal, bentonite, gypsum, phosphorite, uranium, and building stone; and (4) surficial deposits of sand and gravel. In addition, the geothermal resource potential of the area was evaluated, particularly that of springs on Soda Fork, one of which is conspicuously radioactive.

### Oil and Gas

By J. D. Love

Possible oil and gas source and reservoir rocks in the western one-fourth of the Teton Wilderness are at least 4,500 feet (1,370 m) thick, have an areal extent of 270 $mi^2$ (700 $km^2$), and have a volume of 230 $mi^3$ (960 $km^3$). These strata are chiefly marine and nonmarine sandstones and shales; some limestones and dolomites are in the lower part. They are folded into a series of anticlines and synclines, en echelon, trending north or northwest. Subsurface closure, and definition of other types of traps, if present, cannot be proved without detailed geophysical surveys (table 2). No boreholes have tested any of the anticlines within the Teton Wilderness, and no geophysical surveys (other than airborne magnetometer and gravity traverses) have been made within the wilderness, so the subsurface structure is unknown.

Table 2 gives estimated depths to potential reservoir rocks in six major anticlines in the wilderness; six other anticlines (Bailey, Arizona Creek, Lizard Creek, Kitten, Reid, and Onion Flats) are not listed because they are too small, poorly defined, or too highly faulted to have significant oil and gas potential. All these except Onion Flats were described by Love, Antweiler, and Williams (1975). Surface closure is slight or nonexistent at the north ends but adequate at the south ends.

There has been no drilling for oil and gas in the Teton Wilderness, although several anticlines (pl. 1) have been known for many years. One small flammable gas seep is present on the Whetstone anticline and another is on the east flank of the Bailey anticline. The nearest oil and gas test well, True-Travis Govt. No. 1 (pl. 1; fig. 12), is 2.2 miles (3.5 km) south of the wilderness, in sec. 29, T. 45 N., R. 113 W. It was drilled in 1958 to a depth of 4,367 feet (1,331 m) in the Cloverly-Morrison(?) sequence and encountered no major shows of oil or gas. Older potential producing horizons listed in table 2 were not penetrated.

Large volumes of oil and gas have been produced from many anticlines similar to those in the Teton Wilderness and from correlative strata in the Bighorn basin 40–50 miles (62–80 km) to the east. This does not mean that oil and gas may necessarily be present in the anticlines in the Teton Wilderness. Even larger anticlines lie directly south of the western part of the Teton Wilderness in Jackson Hole. Many of these were drilled prior to 1982. The northeast flank of the largest, the Spread Creek anticline, extends into the southwest corner of the wilderness. This anticline has more closure and more potential producing horizons than most anticlines in the wilderness and, in addition, has some of the largest natural gas seeps in Wyoming (fig. 11). The anticline has

**Table 2.** Depths to potential oil and gas reservoir rocks in subsurface parts of major anticlines in the Teton Wilderness

[Figures on thicknesses of rock units in subsurface and depths to possible reservoir rocks are tentative estimates; subsurface dips are not known, so intervals listed must be considered minimal. Intervals represent stratigraphic thickness at crestline of fold, and arbitrary assumption is that no flowage or faulting of incompetent beds has occurred. Depth figures are computed at structurally highest visible part of anticline. Small, poorly defined, or highly faulted anticlines are not listed. These include Bailey, Arizona Creek, Lizard Creek, Kitten, Reid (all previously described by Love, Antweiler and Williams, 1975), and Onion Flats. Thicknesses and depths are given in feet because all well logs, isopach maps, and structure-contour maps in the region use feet. To convert to meters, multiply feet by 0.3048. Nearest local variations in thickness are used in depth estimates]

| Formation [1] | Thickness (ft) | Anticlines<br>Possible depth to top (to nearest 50 ft) of reservoir rocks | | | | | |
|---|---|---|---|---|---|---|---|
| | | Wildcat | Whetstone[2] | Spread Creek[3] | Wolverine[4] | Hancock | Rodent Creek[5] |
| Mesaverde Formation..... | 1,000 | Exposed | 500 | Exposed | ----- | No north | Eroded away. |
| Bacon Ridge Sandstone.... | 1,600 | Exposed | 3,500 | Exposed | 1,200 | closure | Eroded away. |
| Frontier Formation..... | 1,000 | Exposed | 6,800 | [6]2,400 | 4,500 | south of | Exposed. |
| Thermopolis Shale[7]..... | 50 | 1,400 | 8,450 | [6]3,900 | 6,150 | Yellowstone | 300 |
| Cloverly Formation..... | 150 | 1,550 | 8,650 | [6]4,100- | 6,300 | National Park. Depth | 450 |
| Chugwater Formation[8]..... | 85 | 2,750 | 10,000 | 5,300 | 7,600 | estimates | 1,750 |
| Phosphoria Formation and other rocks of of Permian age..... | 200 | 3,850 | 11,200 | 6,400 | 8,650 | similar to | 2,850 |
| Tensleep Sandstone..... | 380 | 4,050 | 11,400 | 6,600 | 8,850 | those for | 3,050 |
| Amsden Formation[9]..... | 50 | 4,600 | 11,950 | 7,150 | 9,400 | Wolverine | 3,450 |
| Madison Limestone..... | 1,100 | 4,650 | 12,000 | 7,200 | 9,450 | anticline. | 3,500 |

[1]Devonian, Ordovician, and Cambrian rocks, having a combined thickness of 1,650 ft (500 m), are not included because their reservoir characteristics are variable and their production is small in the Bighorn basin. This does not imply that these rocks have no oil and gas potential in the Teton Wilderness.

[2]This is a long anticline. On the basis of surface data, the structurally highest part of the crest cannot be determined. Therefore, the depths listed are generalized estimates.

[3]Surface crestline entirely outside Teton Wilderness; depths estimated on crestline; only oil and gas potential in wilderness is on northeast flank of anticline.

[4]No north closure is certain. Site of estimated apex (if present) of crestline is approximately 4,200 ft (1,280 m) southeast along the crestline from where it crosses the Yellowstone National Park boundary.

[5]Weak east flank.

[6]Intervals interpreted from Travis-True well 2 mi (3 km) south of wilderness boundary.

[7]Muddy Sandstone Member.

[8]Crow Mountain Sandstone Member.

[9]Darwin Sandstone Member.

been tested by seven drill holes, some of which were apparently well located structurally, and although several encountered oil and gas shows, only one was capable of small gas production as of 1980. The reasons for the lack of success at the drill sites are not known, but new reflection seismic data suggest that large bedding-plane thrust faults (discussed in the following section on anticlines), not previously recognized, may have displaced stratigraphic and structural traps.

Vitrain reflectance studies of many black shales (see description of map units, pl. 1) of various ages in and near the Teton Wilderness show that these strata have been subjected to temperatures sufficient to promote maturation of hydrocarbons but not high enough to result in metamorphism. Therefore, these shales, aggregating a total thickness of several thousand feet (pl. 1), can be considered source rocks for oil and gas.

The oil and gas potential of the anticlines within the western one-fourth of the Teton Wilderness and of the presently unproductive anticlines to the south in Jackson Hole is probably comparable, because the rocks, structural patterns, and geologic history are approximately the same. If, after thorough surface and geophysical studies and adequate new drilling, the anticlines south of the Teton Wilderness remain unproductive, those in the wilderness can also probably be considered as unfavorable

prospects. On the other hand, if anticlines to the south yield oil and gas in economic volumes, the potential of those in the wilderness should be reevaluated.

### Anticlines with Possible Oil and Gas Potential

Twelve anticlines which may entrap oil and gas lie entirely or partly within the Teton Wilderness. The Bailey, Arizona Creek, Kitten, Reid, and Lizard Creek anticlines were described by Love, Antweiler, and Williams (1975). The presence of several major anticlines was the basis for the U.S. Geological Survey fuels investigations of this general area in 1945, 1948, and 1949. Table 2 summarizes the most promising oil and gas reservoir rocks, their thicknesses, and rough estimates of their depths on the structurally higher parts of each anticline.

In evaluating the oil and gas resource potential of these anticlines, many variables must be considered, such as:

1. Age of folding. In general, throughout intermontane basins of the Rocky Mountain region, the old folds (early Laramide) tend to be more prolific producers than the younger. Available data suggest that the anticlines in the Teton Wilderness were formed during the early part of Laramide deformation, near the end of the Cretaceous Period. Specific supporting data are present on the east flank of Gravel Peak near the southeast end of the Wolverine anticline, on the Basin Creek uplift along the north margin of the wilderness (Love and Keefer, 1969), and on the Spread Creek and adjacent anticlines south of the wilderness (Love, Keefer, and others, 1951; Love, 1973a).
2. Effects of later tilting. The western part of the wilderness was, in some places, tilted westward 10°–30° in Pleistocene time. To determine the original site of oil and gas accumulation, which is generally on the apex of an anticline, each fold in this area must be rotated upward and clockwise (in a model oriented in the conventional northward direction). The amount of tilting of the original water-oil interface (if any), the distance and magnitude of oil and gas migration after Pleistocene tilting, and the nature and effects of water drive cannot be determined in an undrilled area. Further complicating the evaluation is the effect of two very different types of tectonism (early Laramide compression and late Cenozoic tension) widely separated in time (see discussion in section on structure and geologic history). It is not known whether this time interval was sufficient to stabilize the sites of any oil and gas accumulation that may have occurred and to prevent any Pleistocene migration. Borehole data on these subjects is necessary to evaluate the oil and gas potential of the anticlines.
3. Depth of erosion. None of these anticlines is eroded so deeply that the lowest possible reservoirs have been breached.
4. Competence of folds. In some parts of the Cordilleran thrust belts to the west and southwest, oil- and gas-producing anticlines are formed in incompetent Mesozoic rocks, whereas the underlying Paleozoic rocks may be undeformed and have no oil and gas potential. It is assumed that Paleozoic rocks in the Teton Wilderness could contain oil and gas accumulations on these anticlines, for the following reasons: the reverse faults all have displacements of only a few hundred to a few thousand feet; the Basin Creek uplift to the north has exposed roots; the northern extension of the Wolverine anticline in southern Yellowstone National Park has Lower Cretaceous rocks exposed in its core (Love and Keefer, 1975); and all the anticlines in Jackson Hole south of the wilderness that have been drilled have Paleozoic rocks in their cores. Without drilling, the presence or absence of roots to the anticlines in the wilderness cannot be determined for certain.
5. Possible bedding plane-thrust faults. Sophisticated modern seismic data across and along the Spread Creek, Sohare, and several other major anticlines south of the Teton Wilderness indicate or suggest the presence of bedding-plane thrust faults subparallel to bedding and with major displacements in incompetent strata, chiefly of Mesozoic age. These thrusts apparently offset westward the Mesozoic rocks on and near the crests of the sharply asymmetric anticlines. In addition, the faults may create traps on the gentle flanks of the anticlines. Similar faults may affect the comparable anticlines in the Teton Wilderness, and detailed seismic surveys may be necessary to adequately evaluate the oil and gas potential of these structures.
6. Source rocks. Devonian, Mississippian, and Permian carbonate rocks and shales exposed on the south flank of the Basin Creek uplift and on the Washakie Range are fetid and contain conspicuous amounts of hydrocarbons. Especially important are black shales in the Amsden and Phosphoria Formations. Black shales in Cretaceous rocks likewise have a hydrocarbon content adequate for them to be classed as source rocks. Representative of these are thick sections of marine gray Cody Shale (pl. 6) and thinner shales in the Mowry, Frontier, Bacon Ridge, and Harebell Formations. As mentioned in the preceding section, vitrain-reflectance data indicate favorable thermal maturation of hydrocarbons, so these shales can be considered good source rocks.
7. Adequate structural traps. Surface closure is slight or nonexistent at the north ends of all anticlines listed in table 2 except Spread Creek and those whose north ends are covered by volcanic rocks. The west flanks

of most anticlines are the steepest, and some are cut by exposed reverse faults. Others may be cut by thrusts at depth. South and east closures are generally adequate.

8. Effects of igneous intrusions and local metamorphism. Eocene basalts are present in the southwestern part of the wilderness. These rocks are several miles south of the nearest anticlines. Elsewhere, intrusive igneous rocks are small thin dikes with little or no destructive effect on the oil or gas potential of the anticlines.

The characteristics and oil and gas possibilities of 9 of the 12 anticlines are summarized in the assumed order of significance (Arizona Creek, Reid, and Lizard Creek are discussed in Love, Antweiler, and Williams, 1975).

*Whetstone.*—This anticline has the best oil and gas possibilities. The surface trace is about 8 miles (13 km) long (fig. 10; Love, 1975a). The northern half trends north and the southern half northwest. Strata dip 6°–12° E. on the eastern flank and 6°–20° W. on the western flank. Other than a small Holocene(?) fault, there are no visible structural complications. The fold plunges moderately southward and gently (if at all) to the north. North closure may be present at depth. The apex, if any, of the anticline is arbitrarily taken to be where the crestline crosses Pacific Creek. This is the site used in computation of depths shown in table 2. About 3,800 feet (1,150 m) upstream from this point, a small explosively flammable gas seep emerges from a sandstone ledge under water in Pacific Creek. Details of structure of the anticline at depth and amount of closure can be determined only by geophysical studies.

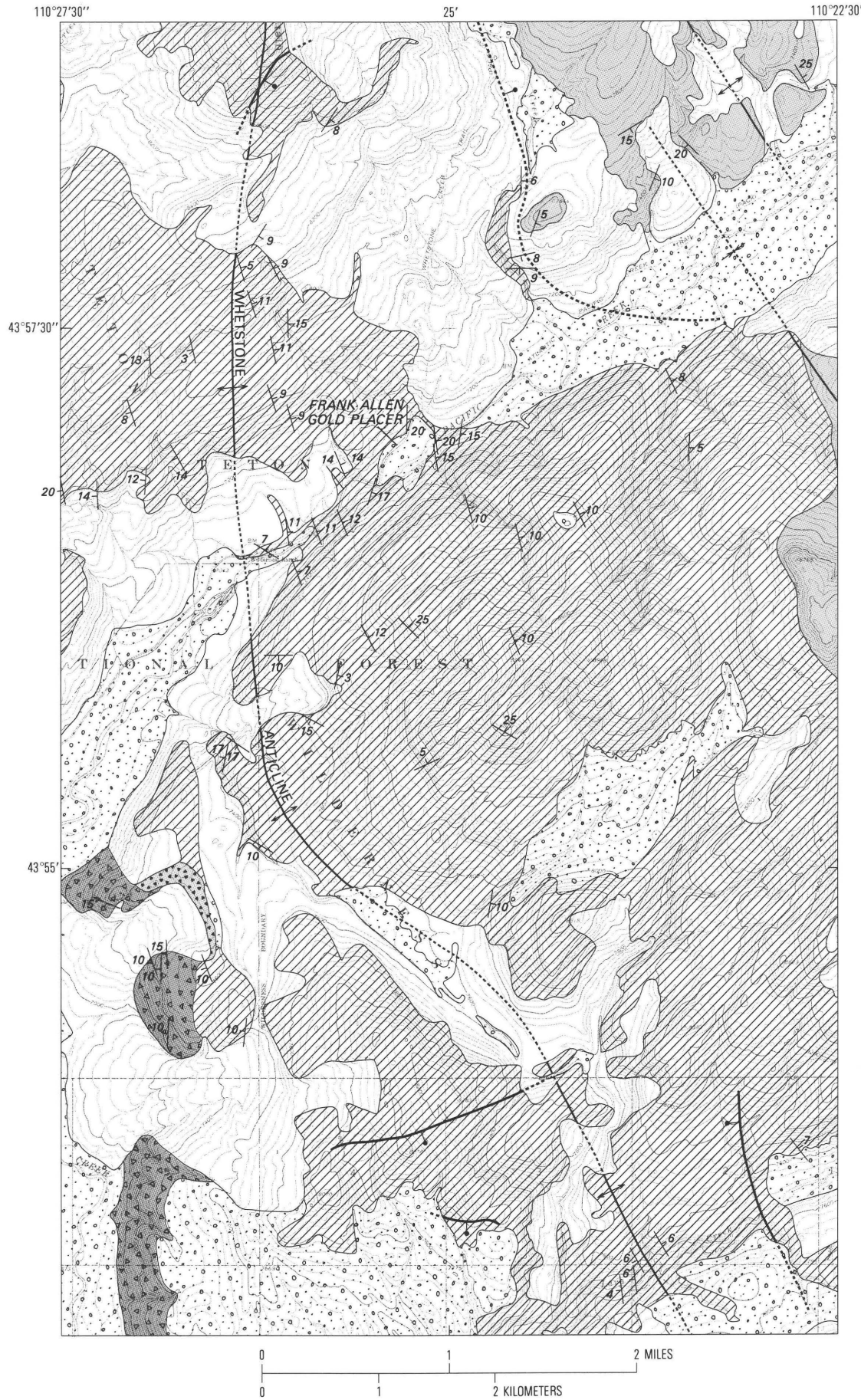
*Spread Creek.*—The Spread Creek anticline is by far the largest and potentially one of the most significant for oil and gas in the Jackson Hole region. It is about 19 miles (30 km) long and has about 6,000 feet (1,830 m) of closure. Cody Shale is exposed on the apex of the crestline. One of the largest gas seeps in Wyoming emerges from the Bacon Ridge Sandstone east of the crest 7,500 feet (5,335 m) south of the Teton Wilderness (fig. 11). Many additional gas seeps are present near the crest farther southeast for the next 8 mi (13 km). The crest of the Spread Creek anticline is exposed within 10,000 feet (3,000 m) of one of the southwest corners of the Teton Wilderness. Therefore, possible entrapment of oil and gas in this structure within the wilderness may be confined to a small part of the northeast flank. Surface geology of this part of the anticline nearest to the wilderness is shown in figure 12. The Mesaverde Formation on this part of the northeast flank dips 30° NE., but inasmuch as the overlying Colter Formation (Miocene) dips 35° SW., the original dip on the Mesaverde was probably about 65° NE. Estimated depths of the potential oil- and gas-bearing formations near the northwest end of the anticline are given in table 2.

*Bailey.*—Fair oil and gas possibility. The Bailey anticline is exposed for about 11,000 feet (3,350 m). A northern hypothetical projection, based on adjacent outcrops, extends for an additional 14,000 feet (4,270 m) under unfolded Pliocene welded tuff (Huckleberry Ridge Tuff). The anticline trends northwest, and the visible part is very tightly, almost isoclinally, folded. Details of surface geology are shown in Love (1974b). The Bailey thrust fault bounds the southwest flank and disappears beneath the unfaulted Huckleberry Ridge Tuff. The south end of the anticlinal crest merges with a high-angle fault, down on the west. The Frontier Formation crops out along the entire exposed crest. Because this is such a tight fold with thick sequences of incompetent beds at depth, rock flowage was probably considerable, and realistic estimates of depths to potential oil and gas reservoirs are not possible. These potential producing zones are probably about the same as those listed for the Wildcat anticline (table 2). Geophysical studies would be needed to determine the structure under and east of the surface crest of the anticline.

*Hancock.*—Fair to poor oil and gas possibility. The Hancock anticline is a southeastward-plunging fold that diverges from the Wolverine anticline in southern Yellowstone National Park (fig. 13; Love and Keefer, 1975, pl. 1, sec. *A–A′*) and extends about 9,000 feet (2,750 m) into the Teton Wilderness. The surface geology of the part of the anticline within the wilderness is entirely in the Harebell Formation and is shown in Love (1974a). Dips are gentle, 10°–20° on both flanks. There is no evidence of closure within the wilderness. If geophysical studies are made of the adjacent Wolverine anticline, they could be expanded to include Hancock, as well. Depths to potential oil- and gas-producing zones are about the same for both anticlines (table 2).

*Wildcat.*—Fair oil and gas possibility. Figures 14–16 show the surface expression of the Wildcat anticline. Details of surface geology are shown in Love (1974b). The south end of the anticline is obscured by landslide debris and apparently is cut off by a major normal fault (the Pilgrim Creek fault), down on the east side. The crest of the anticline is exposed for about 5.5 miles (8 km), and near Browns Meadow disappears under west-dipping unfolded Tertiary and Quaternary volcanic rocks and undeformed landslide and glacial debris. A covered northwest extension of the anticline is projected for about 3.7 miles (6 km) on the basis of sparse outcrops of Lower Cretaceous rocks near Flagg Ranch. The position of the apex of the crestline is not known, but for the computations shown in table 2, it is arbitrarily assumed to be directly west of Browns Meadow.

The anticline is asymmetric, with dips of 5°–15° on the northeast flank steepening near the southeast end to 45°. The southwest flank is steeper, 40° SW. near the southeast end and vertical to overturned along Arizona


110°27′30″
25′
110°22′30″
43°57′30″
43°55′
WHETSTONE
FRANK ALLEN
GOLD PLACER
ANTICLINE
T I O N A L F O R E S T
0 1 2 MILES
0 1 2 KILOMETERS

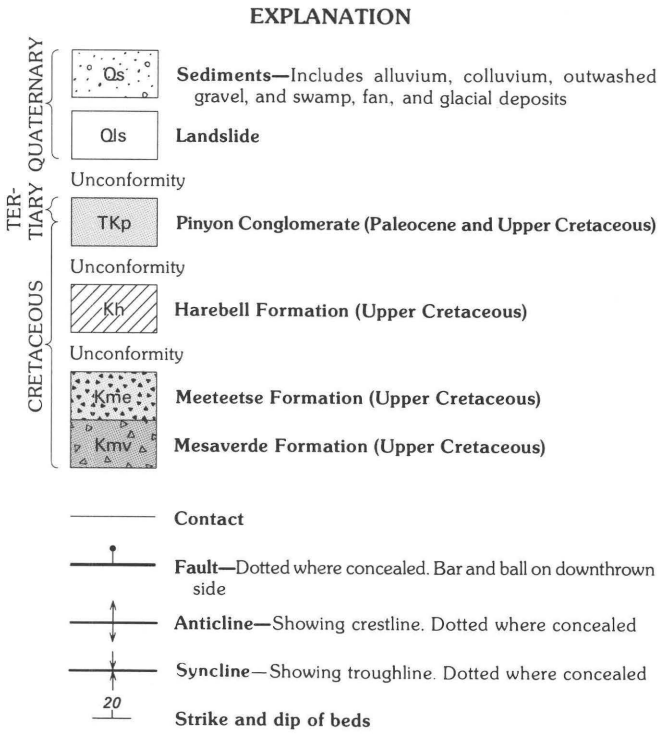



**Figure 10** (above and facing page). Geologic map of the Whetstone anticline. Modified from Love (1975a). Base from U.S. Geological Survey Whetstone Mountain topographic quadrangle, 1965, scale 1:24,000.

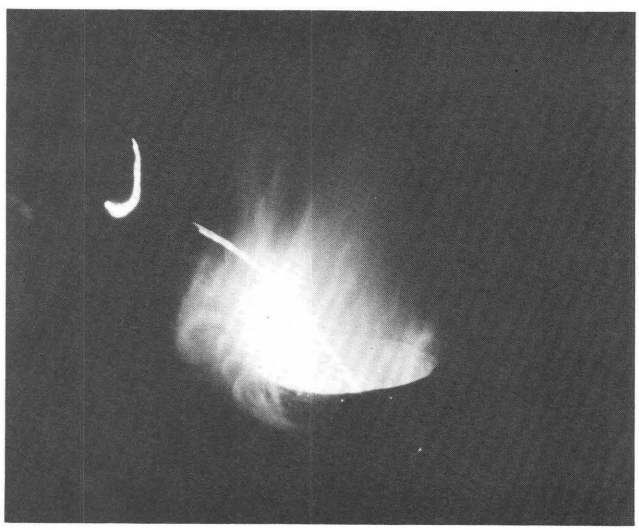


**Figure 11.** Flare from ignited gas seep emerging from Bacon Ridge Sandstone on Spread Creek anticline south of Halfmoon Lake. For location see figure 12. Width of barrel is about 12 inches (37 cm). Photograph by Roger Matson, November 1977 (Love and Love, 1980, fig. 9).

Creek, west of Browns Meadow. The anticline was shoved southwestward along the Wildcat thrust fault which is exposed about 4,000–5,000 feet (1,200–1,500 m) west of the exposed crestline. The amount of displacement along this fault is not known, nor whether, at depth, it beheads any of the potential oil- and gas-bearing zones listed in table 2 along their crestlines. On some similar structures, the faults are conduits for upward or lateral migration of oil and gas from overridden source or reservoir rocks.

The anticline plunges southeastward from a point west of Wildcat Peak at the rate of about 1,320 feet (400 m) in a horizontal distance of 9,000 feet (2,745 m). The northwestward plunge, if any, of the northwestern covered part of the anticline is not known. Details of structure within the anticline at depth can be determined only by geophysical studies.

*Kitten.*—Questionable oil and gas possibility. The Kitten anticline (figs. 14, 16) is a small fold, en echelon to, and southwest of the Wildcat anticline. Details of surface geology are shown in part in Love (1974b) and in part in Love (1973b). The surface trace of the anticline is about 12,000 feet (3,660 m) long and is entirely within the Sohare Formation and Bacon Ridge Sandstone. No faults were observed. The anticline is moderately asymmetric, with dips as much as 50° on the southwest flank and 10° on the northeast flank. Both ends disappear into monoclinal dips. The apex of the crestline has not been determined. The potential oil and gas zones are the same as those for the Whetstone anticline listed in table 2, but depths are probably slightly shallower. Geophysical studies would be needed to determine the configuration of potential producing zones.

*Rodent Creek.*—Questionable oil and gas possibility. This is a small, poorly exposed, northwest-trending asymmetric anticline about 13,000 feet (3,960 m) long, eroded down to the Mowry Shale. Details of surface geology are shown on figure 14. The northeast flank has poor closure and gentle dips; the southwest flank is overturned and is cut by the Rodent Creek thrust fault. The southeast end is cut off at the junction of several normal faults. The northwest end disappears into or near a small normal fault. The amount of displacement on the Rodent Creek thrust fault is not known, nor whether, at depth, it displaces any of the potential oil- and gas-bearing zones listed in table 2 along their crestlines.

*Onion Flats.*—Poor oil and gas possibility. This is a small, poorly defined, poorly exposed, north-trending anticline near the south boundary of the Teton Wilderness. Surface geology is shown in Love (1975b). Dips on the east flank are about 10° and on the west flank about 40°. Nowhere was the crestline observed. The north end is projected under Quaternary deposits, and the south end disappears in the Harebell Formation. More detailed surface and geophysical work would be needed in order to define the anticline precisely and to determine its oil and gas potential. The Harebell Formation is present at or near the surface. Depths to possible oil and gas zones are probably about the same as, or slightly greater than, those listed in table 2 for the Whetstone anticline.

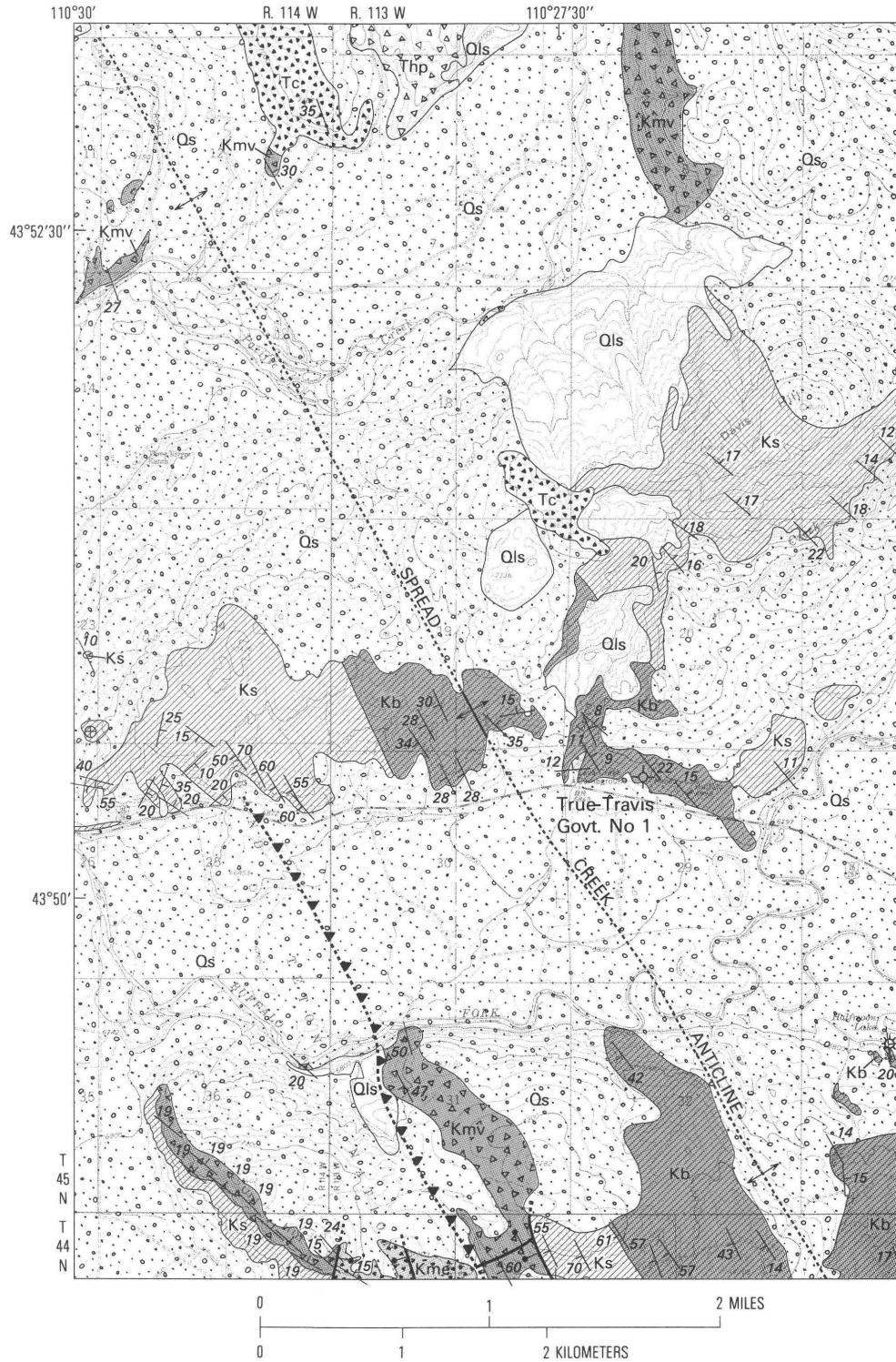
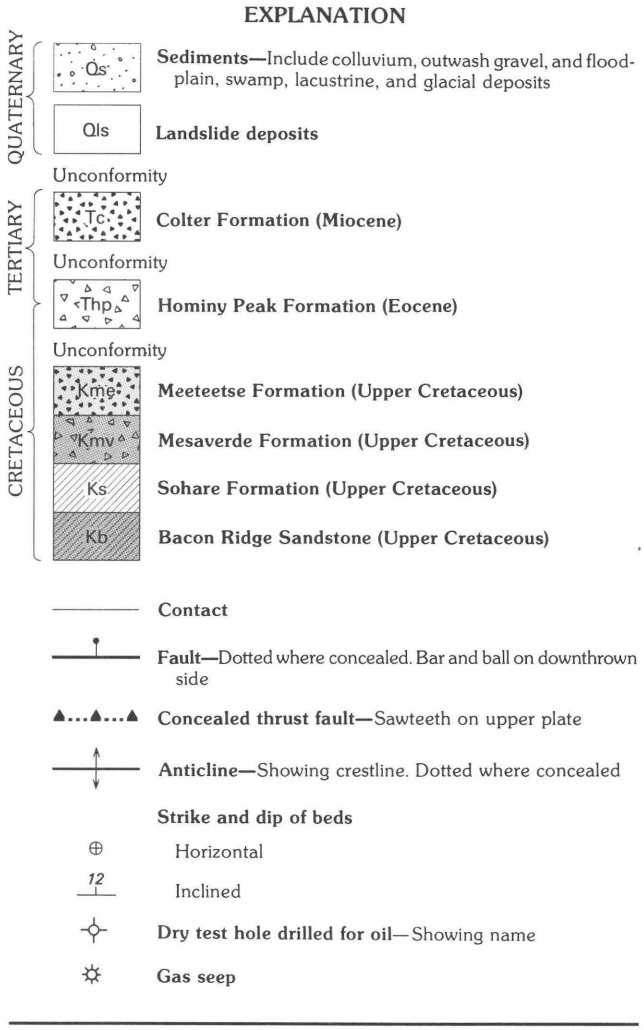



**Figure 12** (above and facing page). Geologic map of northern part of Spread Creek anticline. Modified from Love (1975a) and J. D. Love (unpublished mapping, 1945–83). Base from U.S. Geological Survey Whetstone Mountain and Davis Hill topographic quadrangles, 1965, scale 1:24,000.

*Wolverine.*—Poor oil and gas possibility. Detailed geology is shown on figure 13. The surface trace of the entire anticline is about 16.3 miles (26.2 km) long. Of this, 8.3 miles (13.3 km) is inside the Teton Wilderness, and 8 miles (13 km) is north of the wilderness in Yellowstone National Park. The northern half of the anticline has been




described in detail and a cross section presented (Love and Keefer, 1975, p. D46–D47, pl. 1, sec. *A–A'*). Inside the wilderness, the east flank dips 7°–22° E. (fig. 17) and the west flank 13°–30° W. The southern end involves the Pinyon Conglomerate, which is gently folded so this part, at least, is post-Pinyon. The Harebell Formation is at the surface on the remainder of the anticline, as far north as the park boundary. No fault was observed along the anticline. The apex of the fold is poorly defined. If the apex is present outside the park, it is probably about 4,200 feet (1,280 m) southeast along the crestline from where it crosses the park boundary, and is at an elevation of about 9,000 feet. This possible apex is used for depths shown on table 2. Where the anticline crosses the Snake River in the park, the Cloverly and Morrison(?) Formations are exposed at an elevation of 7,400 feet. This is about 4,700 feet (1,430 m) higher than the projected depth of this sequence at the inferred apex (table 2). Thus, the anticline has a southward plunge of about 940 feet (286 m) per mile. As a result of this lack of closure, oil and gas traps are unlikely in post-Cloverly rocks south of the park boundary on the Wolverine anticline. Geophysical studies would be needed to determine the configuration of deeper horizons and whether there is fold or fault closure south of the park boundary.

### Subthrust Traps

Between 1975 and 1981, many new concepts pertaining to the relation of oil and gas accumulation to thrust faults were developed as a result of major discoveries of oil and gas in the Thrust Belt of Wyoming and Utah. Another major discovery of gas beneath a 9,000-foot- (2,740-m-) thick thrust plate of Precambrian rocks on the Casper arch of central Wyoming further substantiates the economic potential of this kind of trap (Gries, 1981).

Within the Teton Wilderness there are nine high-angle reverse or thrust faults involving thick sequences of Paleozoic and Mesozoic rocks (pl. 1). The largest and longest of these is the Buffalo Fork thrust fault. Others previously named are the Box Creek, Rodent Creek, Wildcat, Bailey, and Arizona Creek thrusts. The last four are discussed in connection with the adjacent anticlines of the same names. The unnamed thrusts are smaller and not important to the present evaluation.

Cross sections of the Buffalo Fork thrust fault, in which Paleozoic and Archean rocks overrode the entire Paleozoic and Mesozoic section, have been published (Love and Keefer, 1975, pl. 1; Love, 1973a, figs. 33, 34; Love, McKenna, and Dawson, 1976, fig. 12). Additional cross sections are included in this paper (figs. 8, 9). The minimum amount of displacement is 10,000 feet (3,050 m) and in most places may be several times that amount. On outcrops along the fault trace there is a zone of intense to moderate brecciation of rocks on both sides of the fault, the amount depending on the brittle or plastic nature of the rocks. Fault slices of Paleozoic and Mesozoic rocks, some several thousand feet out of stratigraphic position, have been dragged up along the major thrust (for similar phenomena, see examples described and illustrated by Gries, 1981). Where shales are involved, they could effectively seal off the main and subsidiary fault planes, thereby preventing leakage of oil and gas.

Because of the thickness and lithology of the sedimentary rocks (about 4,000 feet (1,200 m) of Paleozoic strata, 6,500 feet (1,980 m) of pre-Harebell Mesozoic rocks, and 5,000–11,000 feet (1,500–3,350 m) of Harebell Formation) overridden by Archean and lower Paleozoic rocks along the Buffalo Fork thrust fault, brecciation is likely with possible oil and gas accumulations in fracture pores sealed against the thrust. In addition, the structural patterns of many thrust blocks that have been drilled elsewhere in Wyoming show anticlines that have been overridden, and some of these contain major amounts of oil and gas. Therefore, the entire 25-mile (40-km) segment of the Buffalo Fork thrust fault within the Teton

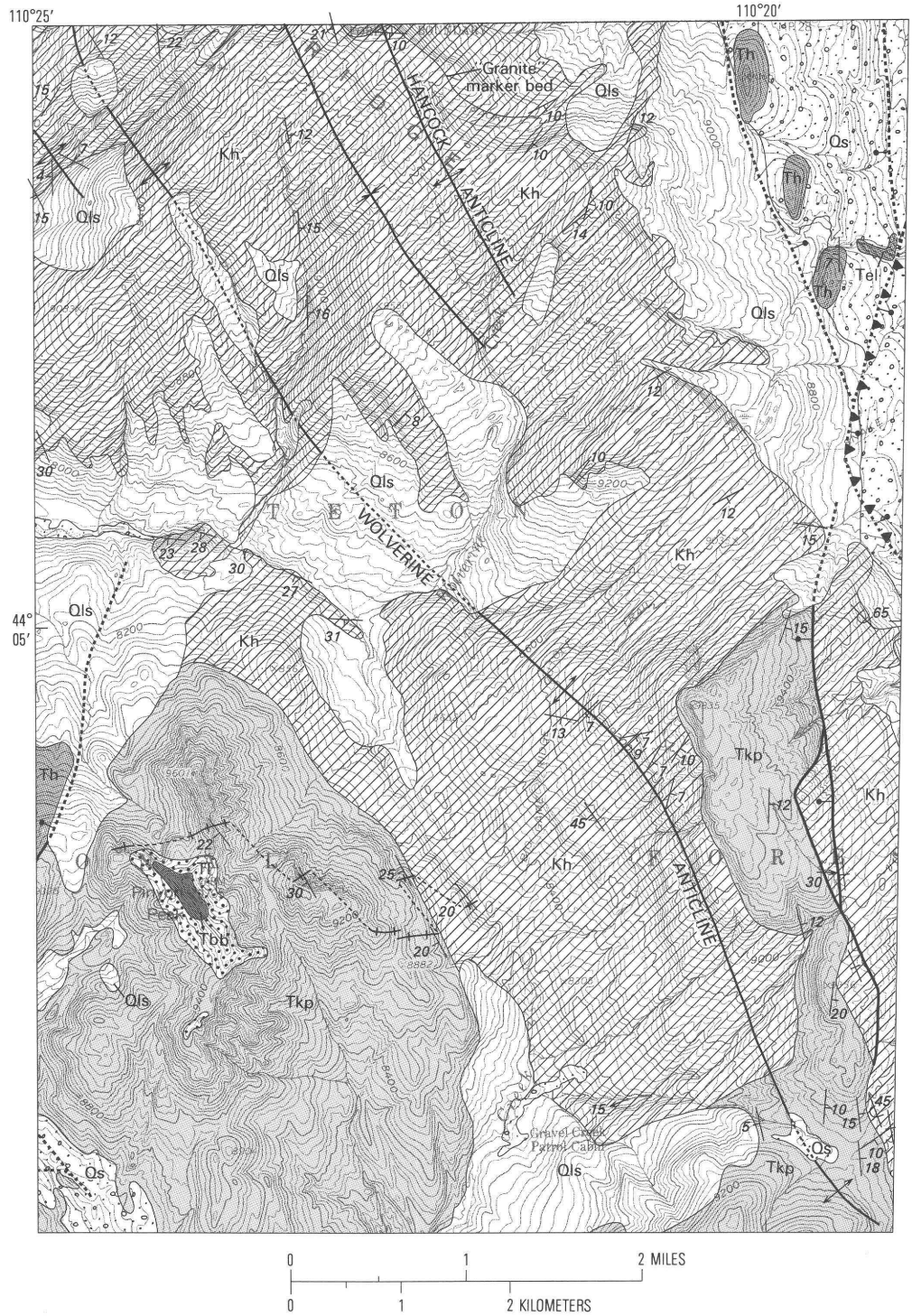
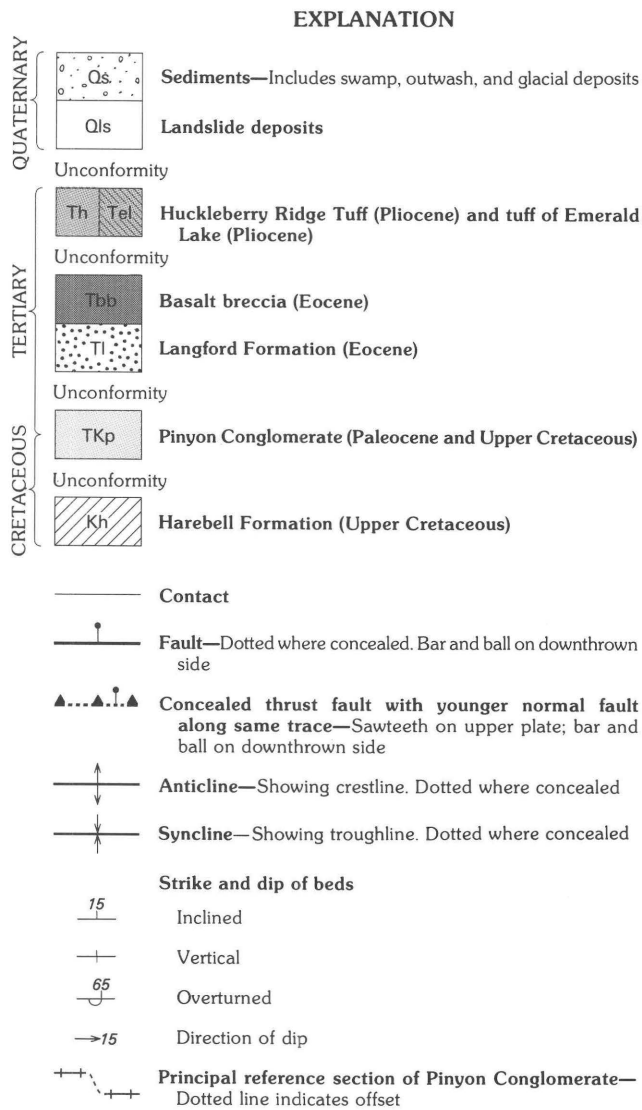



**Figure 13** (above and facing page). Geologic map of Wolverine and Hancock anticlines. Modified from Love (1974a). Base from U.S. Geological Survey Mount Hancock topographic quadrangle, 1959, scale 1:62,500.

Wilderness would require geophysical surveys to assess the oil and gas potential of subthrust traps.

### Washakie Range and Absaroka Volcanic Plateau

The Washakie Range was uplifted, folded, thrust westward along the Buffalo Fork thrust fault, and deeply eroded, all in a short interval of time (fig. 2), after deposition of the Harebell Formation and prior to deposition of the Pinyon Conglomerate (Love, 1973a). Some movement continued into middle Eocene time, as shown by the presence of giant boulders of Precambrian and




Paleozoic rocks that were carried westward from the Washakie Range during deposition of the Langford Formation. As far as we can determine from surface exposures and inferred trends of anticlines, oil and gas possibilities in the Washakie Range are minimal because lower Paleozoic and Precambrian rocks underlie the Eocene Absaroka Volcanic Supergroup, none of which is petroliferous. No oil seeps that could have come from buried source rocks have been observed in the volcaniclastic strata. Oil seeps, however, are present 20 miles (30 km) northeast and 35 miles (56 km) northwest of the Teton Wilderness, emerging from volcanic rocks of the Absaroka Range and Yellowstone rhyolite plateau (Love and Good, 1970).

### Facies and Porosity Traps

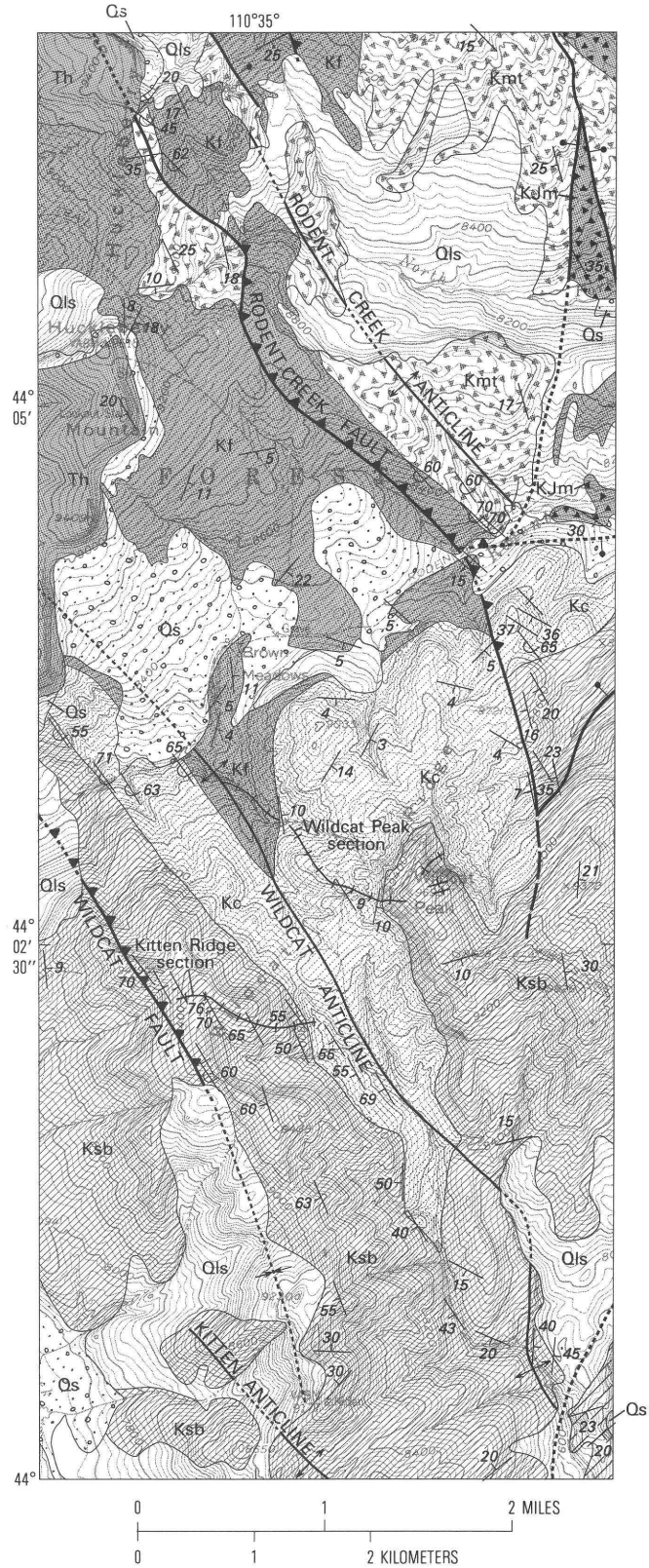
The structurally deepest part of the downwarped area in the western part of the Teton Wilderness is between Pinyon Peak and Whetstone Mountain. In this area the top of the Archean rocks may now lie as much as 13,000 feet (3,960 m) below sea level. Even in Late Cretaceous (Maestrichtian) time, about 69 m.y. ago, the uppermost strata in the Harebell Formation, northwest of Whetstone Mountain, were deposited in a semimarine environment at the same time that the basal part of this same formation in the same area was 10,000 feet (3,000 m) below sea level (Love, 1973a). This means that oil and gas may have migrated upward out of this deep during the last 69 m.y., not only into anticlines but also into fault, facies, and porosity traps.

Evaluation of possible facies and porosity traps is dependent largely on adequate regional and local data to define lateral lithologic and thickness variations in the rock units. Such data remain insufficient to permit a modern detailed evaluation of such potential traps in this 300 $mi^2$ (780 $km^2$) area or this thick a stratigraphic section. Nevertheless, available stratigraphic summaries presented elsewhere (Love and Keefer (1975); Love, Hose, and others (1951); Love, (1956c); Love (1973a); Love, Antweiler, and Williams (1975); explanations for various geologic maps (Love, 1973b, 1974a, 1974b, 1975a, 1975b)) provide sufficient data for a rough evaluation of possible facies and porosity traps. Those formations which may include facies and porosity traps are, from oldest to youngest, Bighorn Dolomite, Madison Limestone, Tensleep Sandstone, Phosphoria Formation and related rocks, Cloverly and Morrison(?) Formations, Muddy Sandstone Member of Thermopolis Shale, Frontier Formation, stray sandstones in Cody Shale, Bacon Ridge Sandstone, Sohare Formation, Mesaverde Formation, and lower part of Harebell Formation. Inclusion of the Bighorn Dolomite is unusual, but there are several places along the Buffalo Fork thrust fault where it is a soft, porous, poorly cemented limestone, rather than the typically hard, tight, siliceous dolomite.

To determine the locations of the most promising facies and porosity trends would require more detailed stratigraphic work than was possible for the wilderness evaluation and, in addition, sophisticated and expensive seismic studies, none of which has been done in the Teton Wilderness. Lacking these data, and in the absence of any drilling, all we can do is to speculate that the most promising areas are on the up-dip sides of the basin deeps centering in the Pinyon Peak-Whetstone Mountain area.

### Younts Basin(?)

The Younts basin(?) is a gravity anomaly discovered by D. M. Kulik (see section on aeromagnetic and gravity studies, this report). It suggests the presence of a major elongate structural downwarp extending south-southeast from the southeast corner of Yellowstone National Park, east of the buried east flank of the Washakie Range. Plate




## EXPLANATION

**QUATERNARY**

- Qs — **Sediments**—Include swamp, colluvial, alluvial-fan, outwash, talus, and glacial deposits
- Qls — **Landslide deposits**

Unconformity

**TERTIARY**

- Th — **Huckleberry Ridge Tuff (Pliocene)**

Unconformity

**CRETACEOUS**

- Kh — **Harebell Formation (Upper Cretaceous)**

Unconformity

- Ksb — **Sohare Formation and Bacon Ridge Sandstone (Upper Cretaceous)**
- Kc — **Cody Shale (Upper Cretaceous)**
- Kf — **Frontier Formation (Upper Cretaceous)**
- Kmt — **Mowry and Thermopolis Shales (Lower Cretaceous)**

**JURASSIC**

- Kjm — **Cloverly Formation (Lower Cretaceous) and Morrison(?) Formation (Upper Jurassic)**

- **Contact**
- **Normal fault**—Dotted where concealed. Bar and ball on downthrown side
- **Thrust or reverse fault**—Dashed where approximately located; dotted where concealed or inferred. Sawteeth on upper plate
- **Anticline**—Showing crestline. Dotted where concealed
- **Concealed syncline**—Showing troughline

**Strike and dip of beds**

- 35 — Inclined
- Vertical
- 70 — Overturned

**Figure 14.** Geologic map of Rodent Creek and parts of Wildcat and Kitten anticlines. Modified from Love (1974b). Base from U.S. Geological Survey Huckleberry Mountain topographic quadrangle, 1959, scale 1:62,500.

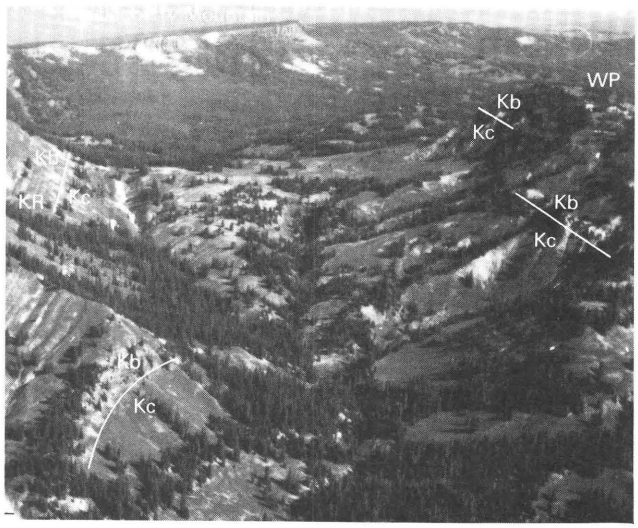



**Figure 15.** Oblique aerial view northwest along crestline of Wildcat anticline, showing contact between Cody Shale (Kc) and Bacon Ridge Sandstone (Kb) on both flanks of anticline. WP, Wildcat Peak at site of Wildcat Peak measured section (pl. 6); KR, Kitten Ridge at site of Kitten Ridge measured section (pl. 6). Huckleberry Mountain is composed of Pliocene Huckleberry Ridge Tuff, which has been tilted westward as a result of late Cenozoic down-dropping of Jackson Hole along the Teton fault (out of photograph to left). The Huckleberry Ridge Tuff extends unfolded across the truncated edges of Cretaceous rocks of the Wildcat anticline. Photograph by J. D. Love, July 31, 1965.

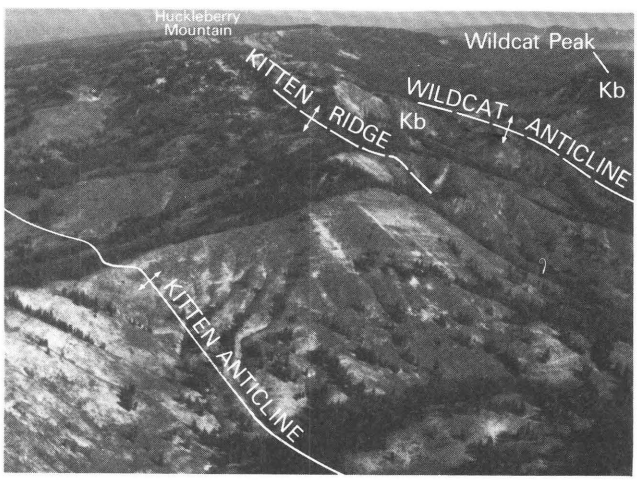



**Figure 16.** Oblique aerial view north of the Wildcat and Kitten anticlines, formed in folded Cretaceous rocks in the western part of the Teton Wilderness and the south-central part of the Teton Corridor. The crestline of the Wildcat anticline is in the Cody Shale and is flanked by the Bacon Ridge Sandstone (Kb); the Kitten anticline is entirely in the Sohare Formation. Huckleberry Mountain is composed of Pliocene Huckleberry Ridge Tuff. Photograph by J. D. Love, July 31, 1965 (Love, Antweiler, and Williams, 1975, fig. 3).

4 shows the general outline of this area and its relation to local anticlinal trends. Many oil and gas fields are on the west side of the Bighorn basin and northwest arm of the Wind River basin. The only way in which the theory of stratigraphy and structure causing this anomaly can be substantiated or disproved is by sophisticated seismic work and by drilling. If it is indeed a basin filled with 20,000 feet (6,100 m) or more of Paleozoic and Mesozoic sedimentary rocks under a relatively shallow volcaniclastic cover, it would drastically improve the possibility of oil and gas, not only in the Teton Wilderness but also in the Washakie Wilderness to the east. Along the margins of this possible downwarp, oil- and gas-bearing anticlines similar to those in the adjacent part of the Bighorn basin could be expected.

## Geochemical Studies

### Sampling and Analytical Program

Geochemical studies identified three areas in the Teton Wilderness that may have precious- and base-metal mineralization. Analysis of geochemical data also outlined the distribution and abundance of gold, phosphate, and coal in various sedimentary rocks, and metals in black shales. More than 4,000 geochemical samples were collected and analyzed as part of the resource appraisal. Stream-sediment samples were collected in all important drainages. These consisted of 660 silt-sized (minus-80-mesh) stream-sediment samples and 1,145 panned-concentrate samples (305 of which were collected solely for gold analyses). Soil samples were collected at 113 sites where no rock outcrops were present or along fault zones, altered areas, or intrusive contact zones. To complete the sampling program, 2,292 rock samples were collected which included individual fresh, unaltered rock samples to represent all the major stratigraphic and lithologic units as well as altered rock, and rock of commodity interest such as gypsum, phosphate rock, and black shales. The unaltered rock samples were used to establish a range of background values applicable to specific rock units. Most exposed rocks in the Teton Wilderness are either stratified pyroclastic rocks of Eocene age or Phanerozoic sedimentary rocks. Nonstratified igneous and metamorphic rocks occur in only a small percentage of the total area. To satisfactorily determine the mineral potential and geochemistry, extensive bedrock sampling was deemed necessary to supplement sampling of drainages and soils because mineral deposits in sedimentary rocks may not be accompanied by dispersion halos. For example, stream-sediment samples from drainages across the Phosphoria Formation do not suggest enrichment in the

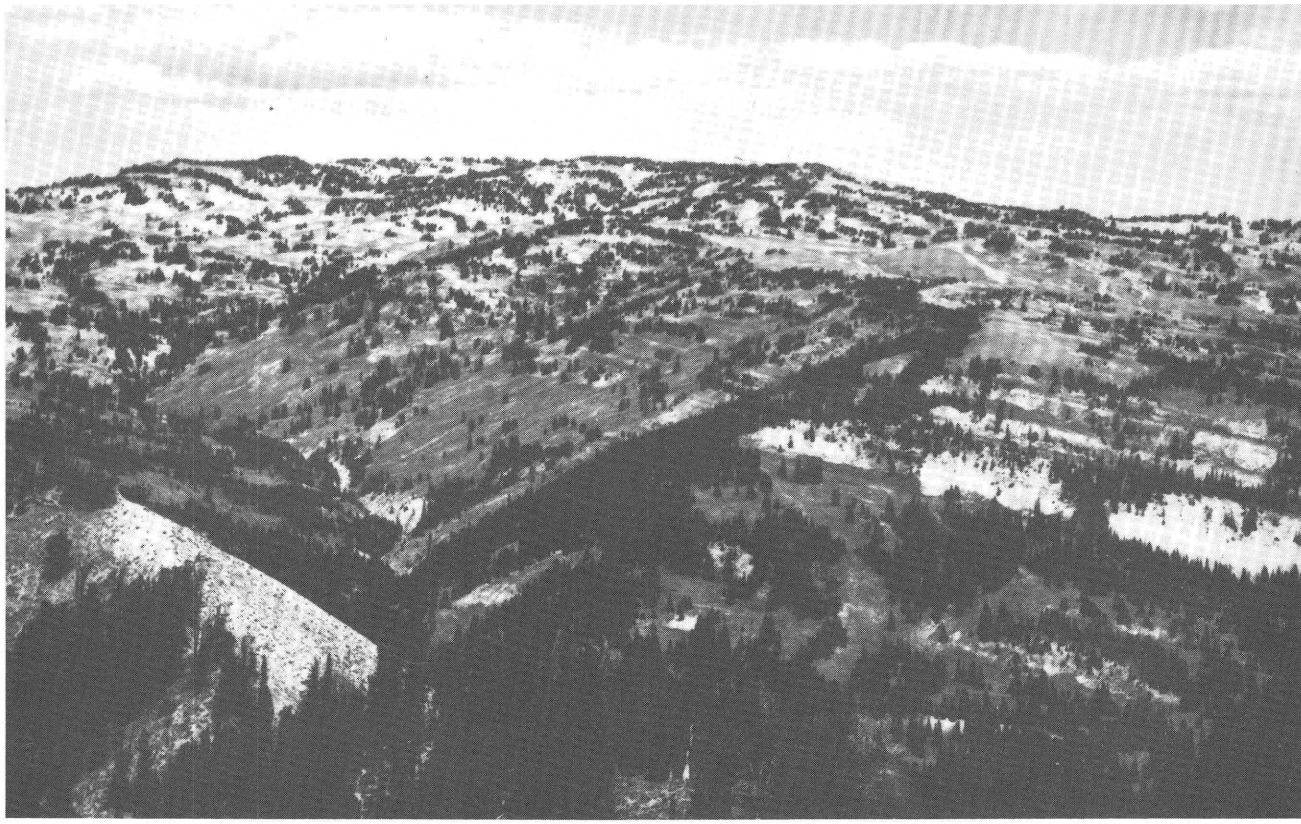


**Figure 17.** Telephoto view north-northeast from Pinyon Peak toward Wolverine anticline and Big Game Ridge (on horizon), the type area of the Harebell Formation. Dip is northeastward on northeast flank of Wolverine anticline, whose crestline is in bottom of ravine in foreground. Note scattered distribution of conifers which do not grow abundantly on the Harebell Formation. Bare exposures at lower left are in upper part of the type Pinyon Conglomerate. Photograph by J. D. Love, Aug. 24, 1969.

wide variety of elements for which the Phosphoria is noted. Small, sluggish streams that are not diluted by debris from other sources will contain those elements, but such an ideal situation is uncommon. Fresh rock-chip samples were taken of all the major rock types and stratigraphic units. Altered rock samples that might have recorded the passage of hydrothermal fluids were collected wherever found. Some bedrock samples were crushed, ground, and panned to obtain concentrates which were analyzed like those from panned alluvium. Samples of coal, gypsum, phosphorite, bentonite, and black shale were collected at several localities to provide specific resource information. Plate 2 shows the location of the sample sites.

The samples were analyzed for 31 elements by a six-step semiquantitative spectrographic procedure (Grimes and Marranzino, 1968); for gold using an atomic absorption procedure (Ward and others, 1969); for mercury using an instrumental method (Vaughn and McCarthy, 1964); and for cold-extractable heavy metals (cxHM) using the Bloom test (Bloom, 1955). All the samples were scanned for radioactivity with a scintillation counter, and those that showed more than background amounts of radioactivity were analyzed for equivalent uranium (eU); additionally, Hugh Millard analyzed about one-fifth of the samples for uranium and thorium, using a delayed neutron activation procedure.

The geochemical data and pertinent geologic data were stored on magnetic disc in the U.S. Geological Survey's computer in Denver, Colo. Computer printouts of data on several groupings of samples were studied to locate areas with mineral potential. Graphical analyses and statistical computations were also made by computer to help evaluate the mineral potential. A magnetic tape with the analytical data, together with appropriate geographic and geologic information, was prepared by McDanal and others (1983), and may be purchased from the National Technical Information Service. This tape also includes data generated in two areas contiguous to the Teton Wilderness—the Teton Corridor (Love, Antweiler, and Williams, 1975), and the Du Noir study area (Prostka and others, 1979).

### Selection of Geochemical Anomalies

Each element in each sample type of lithologic unit has a normal range of abundance in any specific area. When the amount of an element exceeds the normal range

of background values for the sample type, the abundance of that element is "anomalous"—and may indicate mineralization. Analyses of both the panned concentrates and the minus-80-mesh fraction of stream sediments were examined carefully to locate anomalous concentrations of elements. The analyses of rock and soil samples were used to establish background ranges of elements in various geologic units and to verify anomalous element concentrations in mineralized areas. Several techniques were used to recognize anomalies and to determine which indicate areas of mineral resource potential. When the field investigations were in progress, and mobile laboratories analyzed samples within a day or two after they were collected, the abundances of Cu, Pb, Co, Cr, Ni, Ti, La, Y, and Zr were considered anomalous if they were at least twice as great as the apparent average abundance, as suggested by Boyle (1971). Elements not frequently detected (Ag, As, Au, Bi, Cd, Nb, Sn, Zn) by the laboratory methods used were considered anomalous in any samples in which they were detected. Using these criteria, a field check was made and additional sampling was done to better evaluate the mineral resource potential of localities represented by analyses showing anomalous content of one or more metals. Once all the samples were collected and analyzed, a more rigorous statistical evaluation was used to determine which samples contained anomalous metal contents.

For statistical evaluation, the data were grouped into 50 sets which consisted of soils, minus-80-mesh stream sediments, panned concentrates of bedrock samples and stream sediments, and 46 classifications of rocks. Many analytical values in all data sets are qualified. To obtain geometric means, and to permit other useful statistical computations utilizing all the analytical data, qualified analytical values were replaced. Those qualified by N (not detected) were replaced by a value two reporting intervals below the lowest satisfactory measurement level. Values qualified by L (detected, but below a satisfactory measurement level) were replaced by a value one interval below the lowest satisfactory measurement level. Values qualified by G (greater than the analytical method could satisfactorily measure) were replaced by the next reporting interval above the highest level that could be satisfactorily measured. No replacements were made for values qualified by B (no analysis).

Statistical replacement information for the 50 data sets is given in table 3. The qualified values in most data sets are those with N or L, but G values appear in panned concentrates for Fe, Ti, Mn, Ba, La, Y, and Zr, and also in limestone and dolomite samples for Ca and Mg. The high values in panned concentrates reflect heavy minerals that are easily concentrated by panning such as magnetite, hematite, ilmenite, sphene, monazite, and zircon—all of which are abundant in some concentrates. Values qualified by N or L, which are prevalent in all the data sets, indicate scarcity rather than abundance. Although replacement of qualified values is desirable for statistical analysis, erroneous conclusions can result if their use is not tempered by realization of how many unqualified (valid) values are in a given data set. Any interpretation based on only a few unqualified values is subject to error but, as the percentage of unqualified values increases, the chances for error decrease. Statistical computations are meaningless when no unqualified values occur. Even if only a few unqualified values occur, however, statistical computations are desirable for the information they can disclose. In many data sets unqualified values for Ag, Au, Mo, Nb, Sn, and Zn were sparse, but those elements occur frequently enough in the study area as a whole to justify close examination of their relationship to mineral resource potential. Analyses for As, Be, Cd, Sb, Sc, and W, however, are not included in statistical computations because only a few samples had concentrations high enough to detect.

Maximum, minimum, and mean analytical values for the data sets are given in table 3 also. Most rock samples were coded according to both lithology and formation to enable computer retrieval in different data sets. Many, but not all, the rock samples are in two data sets; for example, 15 samples of gypsum are summarized in the gypsum data set, and all these samples are included in the 39 samples listed in the Gypsum Spring Formation. Similarly, most of the 119 samples of the Madison Limestone are listed in the limestone data set, which also includes limestones from other formations, such as the Gallatin Limestone. Aside from mineral resource potential, the data in table 3 are useful for geochemical studies, such as the distribution and abundance of elements in different rocks and formations of northwest Wyoming.

The geometric means show the average concentration of the analyzed elements in a variety of sample types, as well as in the major geologic formations in the wilderness. They are thus a baseline from which to identify anomalies and to evaluate their significance as indicators of mineralization. For example, the geometric mean of copper in 26 rock samples from the Two Ocean Formation is 17.5 ppm (parts per million); samples from this data set that have two or three times that abundance level might be considered anomalous. However, the geometric mean of copper for 12 samples of Trout Peak Trachyandesite is 51 ppm. A content of 50 ppm copper in a sample from the Trout Peak Trachyandesite would not be anomalous for that formation, nor indicative of mineralization, but such an amount in a sample from the Two Ocean Formation might be. Similarly, the copper content of samples of stream sediments derived from the Trout Peak Trachyandesite is likely to be greater than that of stream-sediment samples derived from the Two Ocean Formation.

Table 4 gives geometric means for selected elements using replacement statistics from table 3 for several

**Table 4.** Crustal abundance and geometric means of abundance of selected elements in various sample types, Teton Wilderness, Wyoming
[Values in parts per million]

| Sample type | Mn | Ag | Ba | Co | Cu | La | Mo | Nb | Ni | Pb | Sn | Sr | V | Zn | Au | Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crustal abundance[1]..... | 950 | 0.07 | 425 | 25 | 55 | 30 | 1.5 | 20 | 75 | 12.5 | 2 | 375 | 135 | 70 | 0.004 | 0.08 |
| Soil..... | 374 | .21 | 549 | 14 | 18 | 27 | 2.0 | 7.1 | 45 | 12 | 5.0 | 338 | 64 | 101 | .010 | .017 |
| -80 mesh stream sediment..... | 522 | .21 | 885 | 13 | 14 | 25 | 1.1 | 7.5 | 50 | 15 | 5.0 | 488 | 90 | 100 | .010 | .015 |
| Panned concentrate..... | 915 | .21 | 266 | 19 | 14 | 54 | 2.3 | 11 | 43 | 6.8 | 5.5 | 114 | 164 | 122 | .26 | .014 |
| Felsic rock..... | 255 | .22 | 692 | 6.7 | 11 | 36 | 2.6 | 13 | 17 | 18 | 6.1 | 210 | 27 | 104 | .010 | .011 |
| Intermediate rock..... | 306 | .20 | 1030 | 13 | 17 | 30 | 2.1 | 7.1 | 44 | 14 | 5.1 | 535 | 66 | 100 | .011 | .012 |
| Mafic-ultramafic rock... | 320 | .21 | 923 | 13 | 21 | 26 | 2.1 | 7.6 | 43 | 13 | 5.0 | 427 | 65 | 100 | .011 | .011 |
| Limestone..... | 122 | .21 | 34 | 2.2 | 4.0 | 13 | 2.2 | 7.0 | 3.4 | 5.5 | 9.0 | 143 | 12 | 101 | .011 | .012 |
| Dolomite..... | 72 | .22 | 19 | 2.3 | 5.4 | 12 | 2.4 | 7.0 | 3.9 | 6.3 | 5.0 | 67 | 15 | 102 | .011 | .018 |
| Shale..... | 185 | .28 | 260 | 4.6 | 13 | 26 | 3.7 | 8.0 | 21 | 15 | 5.0 | 115 | 87 | 118 | .011 | .036 |
| Phosphorite..... | 62 | .65 | 82 | 2.0 | 13 | 111 | 3.1 | 7.3 | 16 | 33 | 5.0 | 174 | 62 | 380 | .011 | .095 |
| Welded tuff..... | 281 | .25 | 790 | 5.0 | 12 | 41 | 2.5 | 11.4 | 12.1 | 20 | 5.5 | 213 | 33 | 106 | .013 | .014 |

[1]Data from Levinson (1974).

sample types of rocks and formations, and shows average crustal abundance for comparison. Its purpose is to show which sampling media or lithologies are most likely to have the highest average concentrations of the various elements. Concentrates, for example, are more likely to have higher abundances of Co, La, Mo, Nb, Sn, V, Zn, and Au than are the minus-80-mesh stream sediments. Phosphorites do not occur in many formations, but they are likely to be enriched in several elements. Shales are much more likely to be enriched in Ag, Mo, Zn, B, V, and U than are limestones, dolomites, or the volcaniclastics of the Teton Wilderness.

Additional statistical treatments were applied to the data including preparation of histograms and plots of cumulative frequency against concentration of elements. Examples are shown on plate 3 for several elements in soils, stream sediments, and concentrates. One method for selecting the threshold for anomalous values is to designate the value at two standard deviations above the geometric mean for elements whose cumulative frequency show log-normal distribution and thus indicate a single population of data (Hawkes and Webb, 1962). Single populations of data, however, are uncommon. A method useful for mixed populations of data is that of Tennant and White (1959) in which the threshold is selected at the break in slope in plots of cumulative frequency against the concentration level. The histograms on plate 3 indicate mixed populations of data for Cu and Pb in concentrates, and therefore are not desirable to select thresholds. If thresholds were to be selected from this group of histograms, however, they might be as follows (values in parts per million): Cu in soils 100, in stream sediments 50, and in concentrates 50; Pb in soils 50, in stream sediments 50, and in concentrates 100; and Zn in concentrates 1,000. Thresholds suggested from the break in slope of frequency-distribution plots are the following: Cu in soils 70, in stream sediments 100, and in concentrates 70; Pb in soils 30, in stream sediments 30, and in concentrates 80. Similar plots are shown on plate 3 for Ag, Mo, Sn, and Zn, but selection of thresholds for elements such as these whose analytical values are qualified in most samples can only be judgmental.

The thresholds used to prepare the geochemical anomaly map (pl. 3) are listed in table 5. These thresholds were selected subjectively on the basis of maximizing indications of mineralized areas, upon consideration of the geologic setting and locality where the possibility of an anomaly was indicated, and upon the statistical information. This anomaly map does not include gold, nor several elements associated with heavy mineral concentrates, nor some of the trace elements associated with the Phosphoria Formation and black shales in the Amsden Formation. Those resources will be discussed separately.

Particular attention was given to anomalies in the eastern, volcanic part of the wilderness because they might be related to mineralized areas with no geologic or geophysical expression. In the western part of the

**Table 5.** Thresholds selected for geochemical anomalies
[Values in parts per million]

| Sample medium or formation | Ag | Cu | Mo | Pb | Sn | Zn |
|---|---|---|---|---|---|---|
| Soil..... | 1 | 50 | 5 | 100 | 10 | 100 |
| Stream sediments..... | 1 | 50 | 5 | 100 | 10 | 100 |
| Panned concentrates... | 1 | 70 | 15 | 100 | 15 | 200 |
| Welded tuff..... | 1 | 30 | 15 | 100 | 15 | 200 |
| Wiggins Formation..... | 1 | 70 | 15 | 100 | 10 | 200 |
| Langford Formation.... | 1 | 70 | 15 | 100 | 10 | 200 |
| Two Ocean Formation... | 1 | 70 | 15 | 100 | 10 | 200 |
| Aycross Formation..... | 1 | 70 | 15 | 100 | 10 | 200 |
| Pinyon Conglomerate... | 1 | 50 | 15 | 100 | 10 | 200 |
| Harebell Formation.... | 1 | 50 | 15 | 100 | 10 | 200 |
| Amsden Formation..... | 1 | 50 | 15 | 100 | 10 | 200 |
| Phosphoria Formation.. | 1 | 70 | 15 | 100 | 10 | 200 |
| Late Archean rocks.... | 1 | 100 | 15 | 100 | 10 | 200 |

wilderness, many anomalies are not significant because they owe their origin to local secondary concentrations of heavy detrital minerals associated with the Harebell Formation and Pinyon Conglomerate. For example, the rather weak anomalies for Sn in concentrates are in sphene and grossularite garnet; powellite is a Mo-bearing detrital mineral; Ag can often be traced to detrital gold. Other heavy detrital minerals include ilmenite (rich in Ti), monazite (REE), and zircon (Zr). Although all these metals are of economic interest, none except gold occurs in quantities large enough to warrant study. If gold mining were to become economically attractive, however, recovery of accessory minerals should be part of a feasibility study. Because of its low crustal abundance and great value, gold was studied in detail. In the western part of the wilderness, it was studied as a potential resource, but in the eastern part as a possible indicator of mineralized areas.

As shown on plate 3, most of the mineral resource potential of the Teton Wilderness is closely linked with the sedimentary rocks, although weak geochemical anomalies are associated with granodiorite intrusions on the northwest shoulder of Younts Peak and on Yellow Mountain (pl. 1), as discussed in the following sections. Formations that often have geochemical anomalies that may suggest the possibility of resources in the rest of the wilderness are as follows: Pinyon Conglomerate, Harebell Formation, and related alluvium—gold and associated heavy minerals; Archean rocks—silver, gold, and copper; black shale of the Amsden Formation—hydrocarbons and .trace elements; Phosphoria Formation—phosphate and trace elements; and Aycross Formation—hydrocarbons and trace elements.

### Thorofare Plateau

A few weakly anomalous samples around Thorofare Plateau may be related to a granodiorite intrusive which has two small outcrops west of Thunder Mountain (pl. 1). An aeromagnetic anomaly was also identified there. (See section on aeromagnetic and gravity studies, this report, and pl. 1.) Eight bedrock samples collected from the area of intrusive outcrop (some of them with visible pyrite) show analytical values within the normal range of background (table 6). A few soil samples collected from the head of the cirque east of Thunder Mountain are weakly anomalous in Mn or Cu (samples R1026S, R1028S, R1032S, and R1004S), but bedrock samples R1025R, R1027R, R1029R, R1031R, and R1033R collected from outcrops between the soil samples (pl. 2) have analytical values within the normal range of background (table 6). Analyses of stream-sediment and panned-concentrate samples from Hidden Creek and Castle Creek, which drain part of Thorofare Plateau, suggest weak geochemical anomalies for Ag, Au, Cu, and Hg. For example, sample R1036, a stream-sediment sample at the head of Castle Creek, contained 2 ppm Ag. Several panned-concentrate samples from the Hidden Creek basin showed anomalous Hg (R404P, R406P, R408P), two had anomalous Zn (R406P, T707D), and one (R309P) showed 0.13 ppm Au. Although none of the samples is strongly anomalous in any element, they collectively may show that the area merits further exploration. Geologically, this is also true, because an intrusive body occurs nearby. Igneous activity associated with the intrusion might have left mineralized rock.

### Younts Peak

The geochemical data suggest a possible exploration target northwest of Younts Peak. Sample Y104S contains 100 ppm Cu (table 7). It was collected from a tributary to the South Fork Yellowstone River that drains the northwestern part of Younts Peak (pl. 2). A granodiorite intrusion (pl. 1) northwest of the summit of Younts Peak crops out in the drainage to the North Fork Yellowstone River, but no outcrop was observed on the South Fork drainage. Sample F3S, from a drainage that starts in the intrusive, shows no evidence of metal enrichment, but panned-concentrate sample F4P, collected at the same site as F3S, is anomalous in Cu (100 ppm) and Zn (300 ppm). Several rock samples collected on the northwest slope of Younts Peak and near the contact of the intrusive with andesites of the Wiggins Formation suggest slight enrichment in Cu, and one, Y25R, is slightly enriched in Ba and Pb. Although all the metal anomalies are weak, more detailed sampling might disclose mineralization of interest. The aeromagnetic map (pl. 1) also shows an anomaly at the intrusive.

### Yellow Mountain

Traces of gold were found in a panned concentrate from the Valley Fork Thorofare Creek, which drains part of the intrusive complex of Yellow Mountain (pl. 1). However, detailed follow-up sampling in other streams emanating from the complex and in rock outcrops on and around Yellow Mountain failed to show anomalous concentrations of any ore metals. On the drainage divide between the headwaters of Thorofare Creek and Yellowstone River, dike swarms are common, and pyrite was found near some of them, but no geochemical anomalies were associated with them.

### Other Areas

Several weak geochemical anomalies for copper and lead are suggested by the analytical data from the headwaters of South Buffalo Fork and Cub Creek (pl. 1). These anomalies are mostly in panned concentrates from drainages that are entirely within the stratified rocks of the Wiggins, Two Ocean, Langford, and Trout Peak Formations. They are believed to be nonsignificant because no

**Table 6.** Selected geochemical data on samples from Thorofare Plateau and vicinity

[Values are in parts per million; anomalous values underlined. N, not detected; L, detected but below satisfactory measurement level, given in parentheses. SS, stream-sediment sample; PC, panned-concentrate sample. For complete analytical data see McDanal and others (1983)]

| Sample No. | Description and sample locality | Mn | Ba | Ag | Cu | Pb | Zn | Hg | Au |
|---|---|---|---|---|---|---|---|---|---|
| R52R | Granodiorite intrusive..... | 1000 | 1500 | N | 20 | 15 | N | L(0.02) | N |
| R53S | Soil, same locality, light-golden..... | 700 | 700 | N | 20 | 20 | N | .02 | N |
| R54S | Soil, same locality, red..... | 1500 | 1500 | N | 30 | 20 | N | .02 | N |
| R55R | Granodiorite intrusive..... | 1000 | 1500 | N | 15 | 15 | N | L(.02) | N |
| R56R | .....do..... | 700 | 1500 | N | 20 | 20 | N | L(.02) | N |
| R57R | .....do..... | 1000 | 700 | N | 15 | 15 | N | .02 | N |
| R58R | .....do..... | 700 | 1500 | N | 10 | 15 | N | L(.02) | N |
| T707D | PC, drainage from intrusive..... | 500 | 50 | N | 15 | N | L(200) | L(.02) | N |
| T708S | SS, drainage..... | 1000 | 1500 | N | 15 | 15 | N | L(.02) | N |
| R1017R | Wiggins Fm., conglomerate, Thunder Mtn... | 700 | 2000 | N | 50 | 20 | N | L(.02) | N |
| R1018S | Soil, Thunder Mountain..... | 700 | 700 | N | 30 | 15 | N | .04 | N |
| R1019R | Wiggins Fm., conglomerate, Thunder Mtn... | 1500 | 1500 | N | 15 | 15 | N | L(.02) | N |
| R1020S | Soil, same locality..... | 1500 | 700 | N | 20 | 20 | N | .04 | N |
| R1021R | Wiggins Fm., cgl., SE. side Thunder Mtn.. | 700 | 1500 | N | 15 | 15 | N | L(.02) | N |
| R1022S | Soil, same locality..... | 700 | 700 | N | 30 | 15 | N | .04 | N |
| R1023R | Wiggins Fm., east edge Thunder Mountain.. | 1500 | 2000 | N | 15 | 15 | N | L(.02) | N |
| R1024S | Soil, east edge Thunder Mountain..... | 1500 | 1000 | N | 20 | 15 | N | L(.02) | N |
| R1025R | Wiggins Fm., rusty, Thunder Mountain..... | 1500 | 1500 | N | 20 | 20 | N | L(.02) | N |
| R1026S | Soil, same locality..... | 2000 | 1500 | N | 30 | 30 | N | .02 | N |
| R1027R | Wiggins Fm., east side Thunder Mountain.. | 1500 | 1500 | N | 15 | 15 | N | L(.02) | N |
| R1028S | Soil, east side Thunder Mountain..... | 3000 | 1500 | N | 30 | 20 | N | L(.02) | N |
| R1029R | Wiggins Fm., conglomerate, Thunder Mtn... | 1500 | 1000 | N | 20 | 20 | N | L(.02) | N |
| R1030S | Soil, same locality..... | 1500 | 1500 | N | 20 | 20 | N | L(.02) | N |
| R1031R | Wiggins Fm., conglomerate, Thunder Mtn... | 1000 | 1500 | N | 30 | 15 | N | L(.02) | N |
| R1032S | Soil, same locality..... | 1500 | 1500 | N | 70 | 20 | N | .02 | N |
| R1033R | Wiggins Formation, rusty conglomerate, east side Thunder Mountain..... | 1000 | 1000 | N | 20 | 15 | N | L(.02) | N |
| R1034S | Soil, east side Thunder Mountain..... | 700 | 700 | N | 50 | 30 | N | .04 | N |
| R1036S | SS, Castle Creek..... | 700 | 1000 | 2 | 10 | 20 | N | .02 | N |
| R404P | PC, Hidden Creek..... | 1500 | 700 | 1 | 7 | L(10) | 200 | .14 | N |
| R406P | PC, tributary to Hidden Creek..... | 1500 | 500 | N | 30 | L(10) | L(200) | .16 | N |
| R311P | PC, check sample, same locality..... | 500 | 70 | N | 7 | N | N | .02 | N |
| R408P | PC, Hidden Creek..... | 1500 | 500 | N | 50 | 15 | N | .20 | N |
| R309P | PC, check sample, same locality..... | 300 | 70 | N | 7 | N | N | L(.02) | 0.13 |

igneous intrusive rocks were found, nor were any geophysical anomalies other than the large negative gravity anomaly associated with the postulated Younts basin(?). The high zinc values in concentrates are most likely the result of concentration of zinc in ferromagnesium silicates such as pyroxenes and amphiboles and accompanying magnetite and olivine. High copper values are apparently associated with flows of andesite in the Wiggins Formation and Trout Peak Trachyandesite. These anomalies are not significant because they are not related to mineralizing processes.

## Gold

Previous studies have noted the occurrence of gold at several localities in the western segment of the Teton Wilderness (Hague and others, 1899; Love, 1956b; Antweiler and Love, 1967; Love, Antweiler, and Williams, 1975). A major objective of this study was to determine the resource potential of gold in the wilderness. Studies were made of the occurrence and distribution of gold in alluvial deposits, and in the known gold-bearing formations—the Pinyon Conglomerate and the Harebell Formation. Studies were also made of gold in other formations including the Archean rocks and the volcanic rocks in the eastern segment of the wilderness.

### Resource Potential of Gold

The ubiquitous occurrence of gold, even though in small amounts, throughout the enormous volume of the Pinyon Conglomerate, Harebell Formation, and related

**Table 7.** Selected geochemical data on samples from vicinity of granodiorite intrusion northwest of Younts Peak, Teton Wilderness
[Values in parts per million; anomalous values underlined. N, not detected. SS, stream-sediment sample; PC, panned-concentrate sample. For complete analyses see McDanal and others (1983)]

| Sample No. | Type of sample and locality | Mn | Ba | Cu | Pb | Zn |
|---|---|---|---|---|---|---|
| Y104S | SS, south of intrusive | 1500 | 1500 | 70 | 20 | N |
| Y105S | SS, South Fork Yellowstone River | 1500 | 1500 | 20 | 20 | N |
| F28S | SS, small tributary from north | 1000 | 1000 | 15 | 15 | N |
| F8S | SS, South Fork Yellowstone River | 1000 | 1000 | 10 | 15 | N |
| F9P | PC, same locality | 1500 | 1000 | 100 | 3 | N |
| F11S | SS, small tributary from east | 1500 | 1000 | 15 | 20 | N |
| F13S | SS, South Fork Yellowstone River | 1000 | 1500 | 20 | 15 | N |
| F14P | PC, same locality | 2000 | 700 | 70 | 3 | 300 |
| F15S | SS, North Fork Yellowstone River | 1000 | 1500 | 20 | 20 | N |
| F16P | PC, same locality | 2000 | 300 | 70 | 3 | N |
| F7S | SS, small tributary from south | 1500 | 1500 | 15 | 20 | N |
| F3S | SS, drainage from intrusive | 1000 | 1500 | 20 | 20 | N |
| F4P | PC, same locality | 1500 | 1000 | 100 | 3 | 300 |
| F5S | SS, North Fork Yellowstone River | 1500 | 1000 | 30 | 10 | N |
| R1S | SS, small tributary from south | 1000 | 1500 | 50 | 15 | N |
| R2S | SS, North Fork Yellowstone River | 1000 | 1500 | 10 | 15 | N |
| Y101R | Andesite, summit Younts Peak | 500 | 1000 | 20 | 15 | N |
| Y102R | .....do | 1000 | 2000 | 70 | 20 | N |
| Y103R | Andesite, Wiggins Fm., N. slope Younts Peak | 1500 | 2000 | 100 | 20 | N |
| F21R | Andesite, southwest of Younts Peak | 700 | 2000 | 15 | 20 | N |
| F22R | Rhyodacite, near intrusive | 500 | 1500 | 10 | 15 | N |
| F23R | Granodiorite, near contact | 1000 | 2000 | 50 | 50 | N |
| F24R | .....do | 500 | 1500 | 70 | 15 | N |
| F25R | Andesite, near contact | 700 | 5000 | 50 | 100 | N |
| F26R | .....do | 700 | 2000 | 70 | 50 | N |
| F27R | Altered andesite, near contact | 1000 | 2000 | 30 | 20 | N |

alluvium is difficult to relate to resource potential. Certainly the amount of gold in the formations aggregates several million ounces. However, the cost of mining, milling, and recovering gold in the Pinyon Conglomerate and Harebell Formation would exceed the value of gold contained in the formations on the basis of the gold content found by our survey. Profitable mining might be possible if concentrations of gold could be located such as those that occur on bedrock in most gold-placer mines. We did not identify any such areas either in the auriferous conglomerates or in the alluvial deposits, but they may exist. Our sampling, although detailed and extensive, was limited to outcrops of conglomerate and near-surface samples of alluvial deposits. The gigantic paleo-streams that deposited the conglomerates may have concentrated gold as they cut channels through bedrock. Those channels, however, have been buried by enormous volumes of quartzite pebbles, cobbles, and boulders. Bedrock sampling of present-day stream valleys was not possible in our survey because of the difficulties imposed by depth to bedrock and ground water. The highest gold concentrations we found were those on Frank Allen's claims on Pacific Creek, which averaged less than 0.02 troy ounces per cubic yard (575 mg/m$^3$). Mining there on a small scale was profitable to Frank Allen during and following the Depression of the 1930's (Frank Allen, oral commun. to J. C. Antweiler, Aug. 1974). However, these claims are richer than any other deposits that we sampled. The valley of Pacific Creek below the wilderness boundary has been tested in several places to determine whether

it could be mined for gold at a profit, but serious problems impede mining development. These are the difficulty of tailings disposal, depth to bedrock, water turbidity standards, lack of access except through Grand Teton National Park, and proximity to Grand Teton National Park. If mining can be profitably done on Pacific Creek south of the wilderness, further study and exploration on areas within the wilderness might be justified. On the basis of current information, however, the resource potential for gold in the Teton Wilderness appears to be moderate to low.

### Geologic Occurrence of Gold

Strong emphasis was placed on studying the distribution of gold in the Pinyon Conglomerate and Harebell Formation, and in the alluvium derived from those formations. Finely divided gold occurs throughout thick sequences of those formations (Antweiler and Love, 1967). The volume of the gold-bearing conglomerates in the Teton Wilderness is at least 50 cubic miles (208 $km^3$); several mountains (Whetstone Mountain, Gravel Peak, Gravel Mountain, and others) are composed entirely of these rocks (pl. 1; figs. 18,19). Nearly all the streams in the western segment of the wilderness have gold derived from those conglomerates. Combined computer-generated maps showing gold content of samples and areas of highest gold content (fig. 20) indicate that the distribution of gold in alluvium is closely allied to that of the two formations.

A few trace amounts of gold in the volcanic segment of the wilderness were discussed in the section on Yellow Mountain, and a few low concentrations in and near the Du Noir addition are in lenses of quartzite gravel derived from the Pinyon Conglomerate and Harebell Formation (Prostka and others, 1979). Small amounts of gold also occur in Archean rocks as discussed in the section on other gold occurrences.

#### Alluvial Deposits

Workable gold placers are more likely to occur in alluvial deposits along the main drainages than in the conglomeratic formations. First, the alluvial deposits are

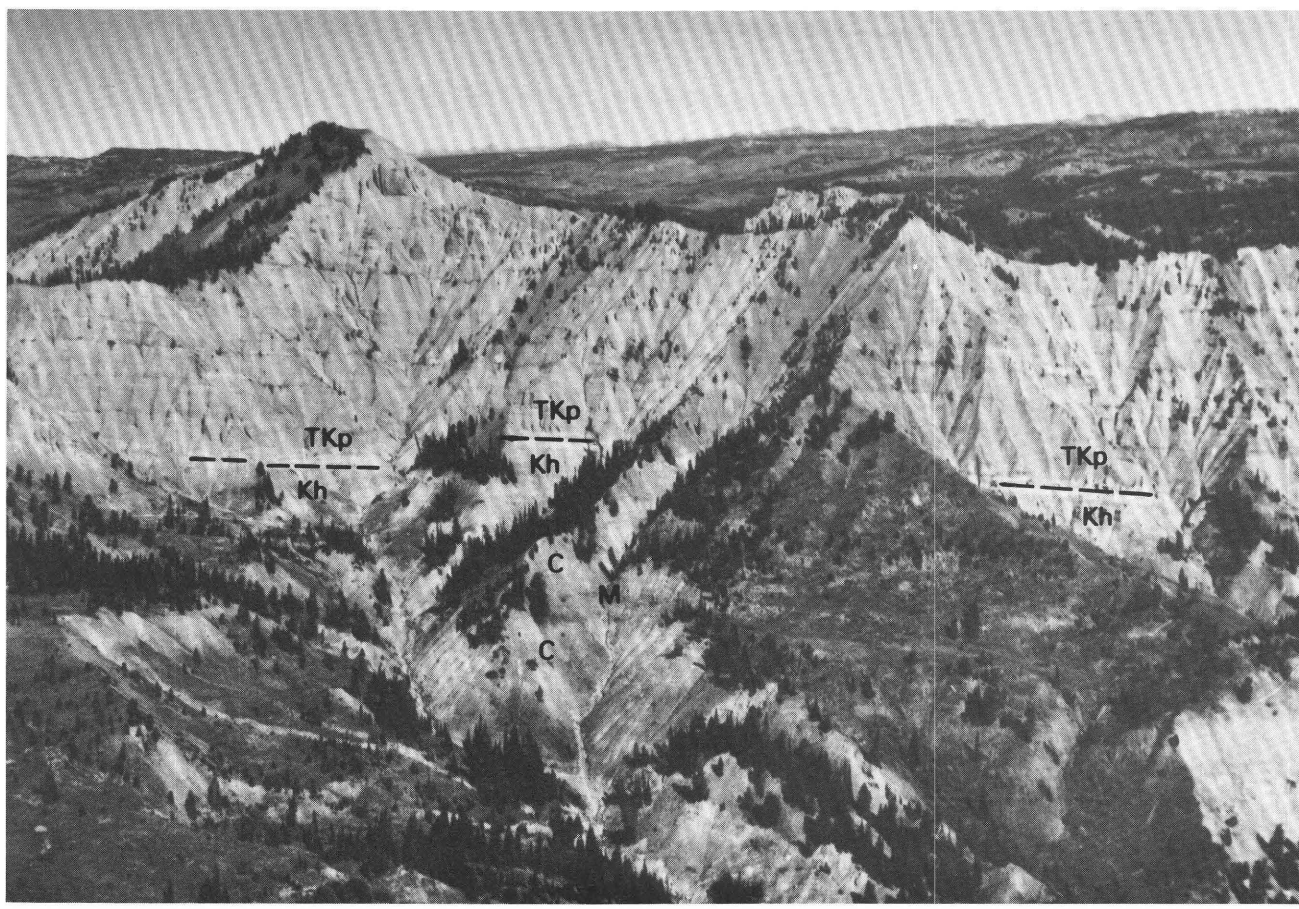



**Figure 18.** Oblique aerial view of southwest face of Gravel Mountain at stratigraphic section shown on figure 22. TKp, Pinyon Conglomerate, about 1,000 feet (300 m) thick; Kh, Harebell Formation, containing several conglomerate beds (C) nearly 100 feet (30 m) thick; M, several claystones, one of which yielded Cretaceous marine or brackish-water acritarchs. Photograph by P. E. Millward, 1955 (Love, 1973a, fig. 27).

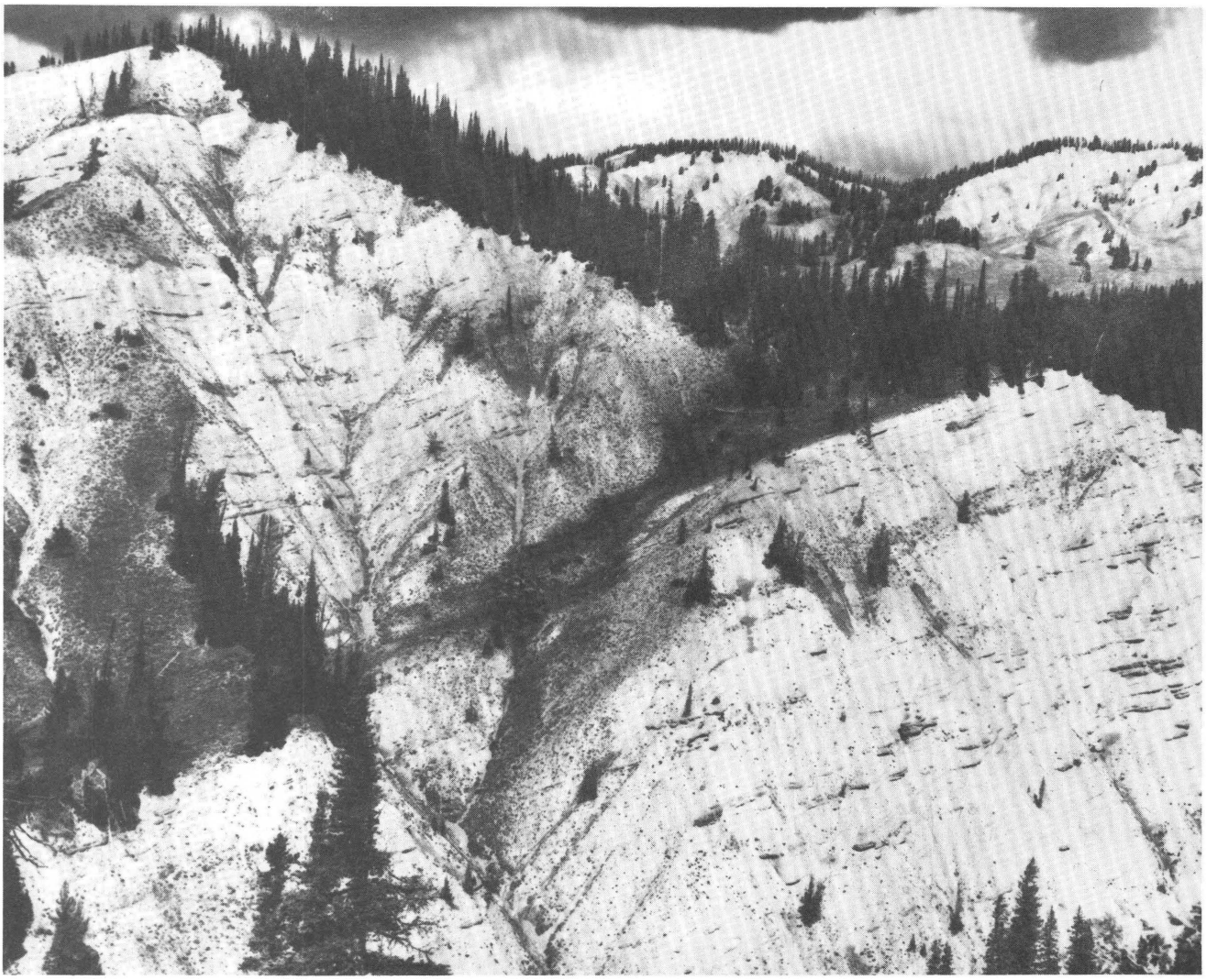


**Figure 19.** About 1,000 feet (300 m) of strata, largely quartzite conglomerate, in the Bobcat Member and underlying strata of Harebell Formation on East Fork Pilgrim Creek. Top of soft beds that form shelf extending diagonally across middle of exposure marks base of Bobcat Member. Photograph by J.D. Love (Love, 1973a, fig. 9).

loosely consolidated, whereas the conglomerates are well consolidated and in places are firmly cemented. Second, stream sorting should result in higher concentrations of gold than would be present in the older formations. Third, water is much more readily available in the alluvial deposits.

Several types of sampling were used to evaluate the gold resource potential in alluvium. In a preliminary survey, samples were taken of alluvium above the confluence of all first-order streams draining outcrops of quartzite conglomerate. Numerous additional samples were taken along drainages where gold was seen in panned concentrates by the sampler. Summaries of results are given in table 8.

Large deposits of alluvium containing quartzite clasts have accumulated in alluvial fans, landslide deposits, many flood-plain deposits along larger streams, and terrace deposits. Samples were taken at random sites in foot traverses across some of these deposits. Alluvial fans occur at the headwaters of Lava Creek for a distance of more than 5 miles (8 km) in drainages that originate on Gravel Mountain. Across one of these fans, a grid was laid out with parallel lines 200 feet apart. One sample was taken within each interval at sites determined from a table of random numbers. Using the same random site selection procedure, flood-plain deposits along Pacific Creek were sampled across the deposits at 5 different places, and across one deposit each along Lava Creek and Wolverine Creek. Results are shown in table 8. A checkerboard grid with squares 100 feet (30 m) on a side was laid out across the flood plain of Pilgrim Creek just north of its confluence with East Fork Pilgrim Creek. Samples were taken at 18 random sites in squares selected at random. A summary of analytical results is given in

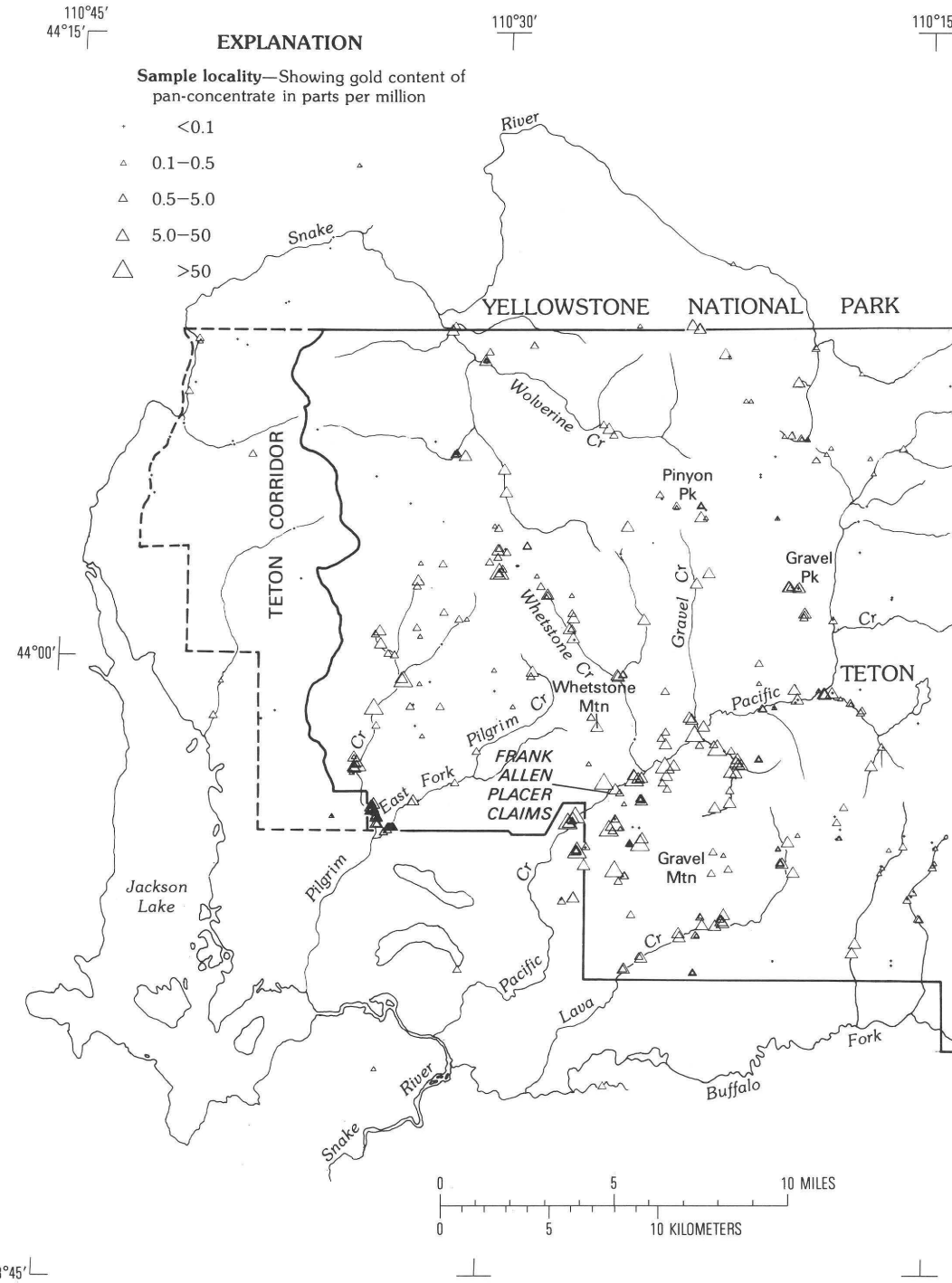



**Figure 20** (above and facing page). Map showing localities of pan-concentrate samples with anomalous gold content from Teton Wilderness and adjacent areas.

table 8. Three terrace deposits of different ages along East Fork Pilgrim Creek occur directly north of the wilderness boundary. Samples were taken at 61 sites by random selection from vertical exposures on the terraces, and from the flat tops of the terraces. The gold content of all these samples was low (table 8).

Nonrepresentative, intentionally "high-graded" samples were collected at sites thought to be favorable for gold accumulation along Pacific Creek south of the wilderness boundary and on the Frank Allen placer claims. As anticipated, these selectively taken samples were relatively high in gold content (table 8).

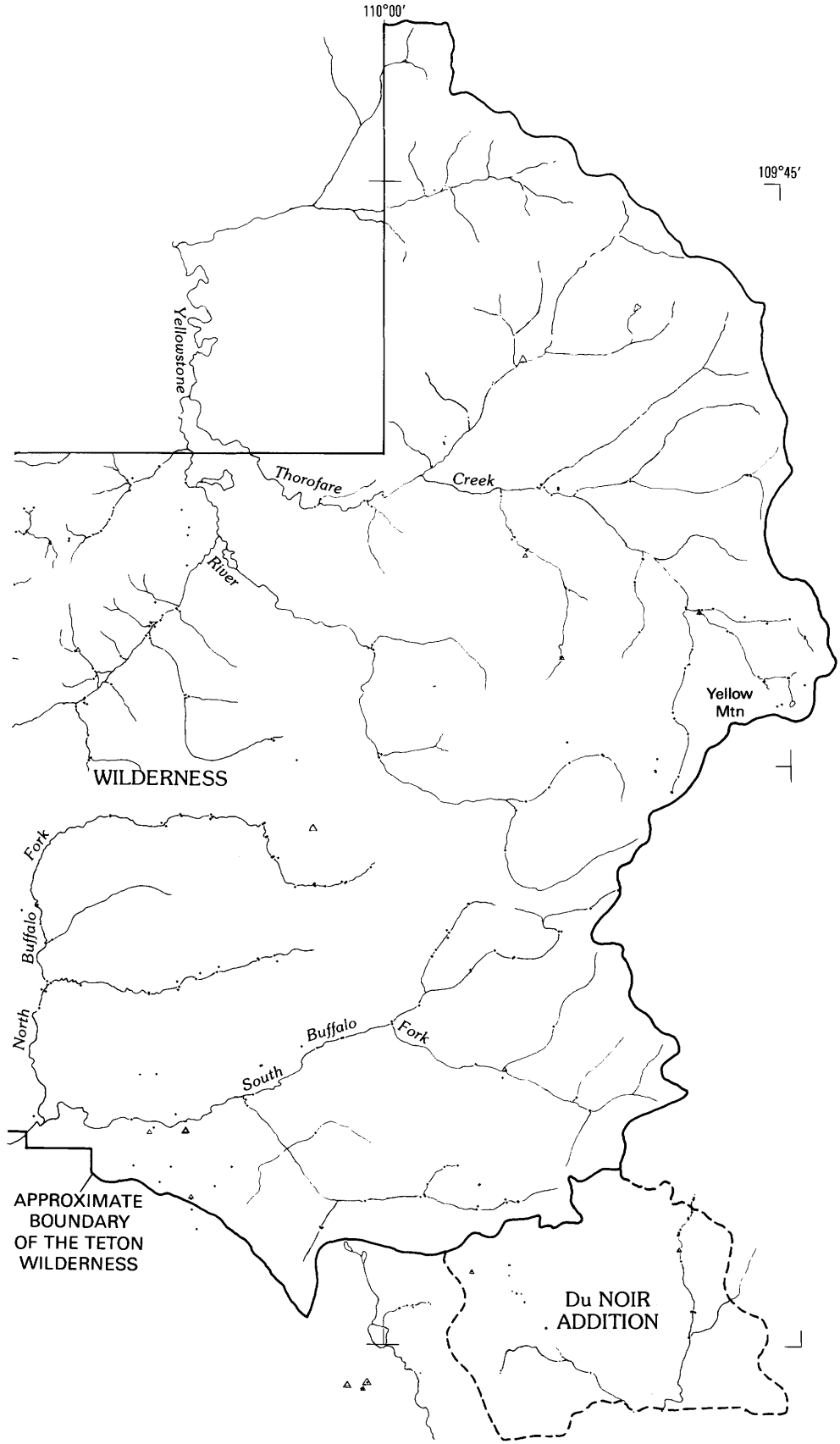

110°00′
109°45′
Yellowstone
Thorofare
Creek
River
Yellow
Mtn
WILDERNESS
Fork
Buffalo
North
Buffalo
Fork
South
APPROXIMATE
BOUNDARY
OF THE TETON
WILDERNESS
Du NOIR
ADDITION

**Table 8.** Average values of gold recovered by panning alluvial and terrace deposits in and near the Teton Wilderness
[To convert mg/yd$^3$ to troy oz/yd$^3$, multiply by $3.215 \times 10^{-5}$. For example, 127.4 mg/yd$^3$ = 0.004 troy oz/yd$^3$]

| Sample locality | Sample Nos.[1] | Average for number of samples indicated: Number of samples | Au content calculated to mg/m$^3$ | Au content calculated to mg/yd$^3$ | Value of Au in 1 yd$^3$ @$100/troy ounce | Value of Au in 1 yd$^3$ @$600/troy ounce | Sample with greatest amount of gold: Sample No.[1] | Au content mg/m$^3$ | Au content mg/yd$^3$ | Value of Au in 1 yd$^3$ @$100/troy ounce | Value of Au in 1 yd$^3$ @$600/troy ounce |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Reconnaissance sampling of alluvial deposits along main streams and tributaries draining quartzite conglomerates** | | | | | | | | | | | |
| Pilgrim Creek | A1C-A24C; B0B1C-3C | 24 | 166.6 | 127.4 | $ 0.41 | $ 2.46 | A7C | 1,863.8 | 1,425 | $ 4.58 | $ 27.49 |
| East Fork Pilgrim Creek | Varied--see pl. 2 | 40 | 376.3 | 287.7 | .93 | 5.55 | SEP13C | 8,828.3 | 6,750 | 21.70 | 130.21 |
| Pacific Creek-Wilderness Wilderness boundary to Gravel Cr... | Varied--see pl. 2 | 38 | 92.9 | 71.0 | .23 | 1.37 | FA6C | 510.1 | 390 | 1.25 | 7.52 |
| Gravel Creek to Mink Creek | Varied--see pl. 2 | 21 | 15.3 | 11.7 | .04 | .23 | H236M | 51.4 | 39.3 | .13 | .76 |
| Whetstone Creek | Varied--see pl. 2 | 17 | 59.8 | 45.7 | .15 | .88 | W39P | 307.4 | 235 | .76 | 4.53 |
| Gravel Creek | Varied--see pl. 2 | 27 | 251.1 | 192.0 | .62 | 3.70 | Au152A | 3,923.7 | 3,000 | 9.64 | 57.87 |
| "Cub creek"[2] | Varied--see pl. 2 | 14 | 67.1 | 51.3 | .16 | .99 | UCC7C | 294.3 | 225 | .72 | 4.34 |
| Lava Creek | Varied--see pl. 2 | 30 | 227.3 | 173.8 | .56 | 3.35 | LA4C | 1,471.4 | 1,125 | 3.62 | 21.70 |
| Box Creek | BCT1C-21C; also others | 15 | 29.6 | 17.3 | .06 | .33 | G501P | 170.0 | 130 | .42 | 2.51 |
| Clear Creek | VP8C-21C; SS1C-3C | 17 | 7.1 | 5.4 | .02 | .10 | VP14C | 44.6 | 34.1 | .11 | .66 |
| Fox Creek | H136P-153P; also others | 12 | 5.0 | 3.8 | .01 | .07 | H179P | 21.2 | 16.2 | .05 | .31 |
| Wolverine Creek | Varied-see pl. 2 | 29 | 53.9 | 41.2 | .13 | .79 | I9P | 310.2 | 237.2 | .76 | 4.58 |
| **Random sampling across alluvial fan** | | | | | | | | | | | |
| Lava Creek fan | G2001T-G2039T | 39 | 6.1 | 4.7 | $0.02 | $ 0.09 | G2009T | 21.8 | 16.7 | $ 0.05 | $ 0.32 |
| **Random sampling on traverses across stream valleys** | | | | | | | | | | | |
| Pacific Creek: | | | | | | | | | | | |
| 2,500 ft south of wilderness | W901-925 | 25 | 21.7 | 16.6 | $ 0.05 | $ 0.32 | W925P | 124.5 | 95.2 | $ 0.31 | $ 1.84 |
| 1,500 ft south of wilderness | W932-955 | 22 | 30.9 | 23.6 | .08 | .46 | W943P | 137.3 | 105.0 | .34 | 2.03 |
| Below confluence with Whetstone Creek | W961-993 | 32 | 12.3 | 9.4 | .03 | .18 | W976P | 57.4 | 43.9 | .14 | .85 |
| At upper meadows | G1101-1123 | 23 | 32.6 | 24.9 | .08 | .48 | G1108P | 242.5 | 185.4 | .60 | 3.58 |
| At Gravel Creek confluence | G1000-1015 | 16 | 10.2 | 7.8 | .03 | .15 | G1010P | 50.9 | 38.9 | .13 | .75 |
| Lava Creek | G3000P-G2016P | 17 | 3.1 | 2.4 | .01 | .05 | G2010P | 8.2 | 6.3 | .02 | .12 |
| Wolverine Creek | H843-847P; H1200-1213P | 19 | 4.7 | 3.6 | .01 | .07 | H1204P | 13.0 | 9.9 | .03 | .19 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Random grid sampling** | | | | | | | | | | | |
| Pilgrim Creek | I401-418P | 18 | 23.5 | 18.0 | $ 0.06 | $ 0.35 | I415P | 261.6 | 200.0 | $ 0.64 | $ 3.86 |
| **Random grid sampling of terraces** | | | | | | | | | | | |
| 3 terraces on East Fork Pilgrim Cr... | I101-161P | 61 | 5.1 | 3.9 | $ 0.01 | $ 0.08 | I116P | 14.9 | 11.4 | $ 0.04 | $ 0.22 |
| **Selective sampling of favorable sites** | | | | | | | | | | | |
| Pacific Creek: | | | | | | | | | | | |
| South of wilderness | PAC1C-PAC15C | 15 | 173.7 | 132.8 | $00.43 | $ 2.56 | PAC5C | 1,765.7 | 1,350 | $ 4.34 | $ 26.04 |
| At Allen placer claim | FA1C-FA25C; W1101-W1107C | 31 | 575.2 | 439.8 | 1.41 | 8.48 | FA15C | 4,119.9 | 3,150 | 10.13 | 60.76 |
| Silt-laden moss from Allen claim... | W1414-W1415P | 2 | 14,152.8 | 10,821.0 | 34.79 | 208.74 | W1414P | 16,839.2 | 12,875 | 41.39 | 248.36 |
| **Channel sampling** | | | | | | | | | | | |
| Vertical channel, Pacific Creek south of wilderness | W1000-1011P | 12 | 28.3 | 21.6 | $ 0.07 | $ 0.42 | W1011P | 118.5 | 90.6 | $ 0.29 | $ 1.75 |
| Vertical channel, Lava Creek south of Gravel Mountain | G2521-2532P | 12 | 15.7 | 12.0 | .04 | .23 | G2524P | 33.4 | 25.5 | .08 | .49 |
| U.S. Bureau of Mines trenches dug in terraces | W1401-1413P | 13 | 13.9 | 10.6 | .03 | .20 | W1410P | 49.4 | 37.8 | .12 | .73 |

[1]Field notes and sample descriptions for some samples were destroyed by fire at Denver Federal Center, March 19, 1976. Analytical data for individual samples are available from National Technical Information Service (McDanal and others, 1983).

[2]Local name for stream that enters Pacific Creek opposite Gravel Creek.

Channel samples were collected in shallow pits at streamside by Pacific Creek south of the wilderness boundary and on Lava Creek south of Gravel Mountain. The objective of this sampling was to determine whether an increase in gold content occurs with depth; unfortunately, the data are based on only a few feet of alluvium, and they are inconclusive. Summaries of results are in table 8. Channel samples were also taken in trenches made by the U.S. Bureau of Mines in terraces at the confluence of Pacific and Whetstone Creeks. Results are discussed in the Bureau of Mines section of this report, but summaries are given in table 8.

The highest gold concentrations found in alluvium were those from silt-laden moss on the Frank Allen placer claims on Pacific Creek. In recognition of the high gold content in moss at the edge of Pacific Creek, Mr. Allen systematically stockpiled streamside vegetation, particularly moss, in mounds along Pacific Creek. After allowing a year or two for the organic material to decay, he "harvested" the gold by shoveling and washing the silt through sluices and other gold-recovery devices (fig. 21).

Samples with high gold contents were also obtained from Gravel Creek, Lava Creek, and Pilgrim Creek and its East Fork. All these streams drain enormous volumes of quartzite conglomerate such as those on Whetstone Mountain, Pinyon Peak, Gravel Mountain, Gravel Peak, and several unnamed mountains. Mosses and other types of vegetation along all these streams trap gold particles released from weathering of the conglomerates.

The data in table 8 are arithmetic averages of samples collected at several sites. Each analytical content used in the computation of the averages was based on the analysis of a heavy mineral concentrate obtained by panning a 14-in. (35-cm) pan filled with alluvium (about 5,000 g—11 lbs.). Some tiny, flat, thin flakes are lost by panning but most are recovered in the heavy mineral fraction, which usually weighs 5–15 grams (0.2–0.5 oz) and is easily analyzed in its entirety for gold. This size sample was chosen because 5,000-g samples were the minimum size that would yield statistically meaningful results, and they could be easily and quickly concentrated by panning. Moreover, large numbers of samples could be collected and analyzed within reasonable time. Duplicate samples weighing 5,000 grams panned to heavy mineral concentrates and analyzed in their entirety yielded gold contents within 50 percent of each other most of the time, as did large samples analyzed in their entirety without panning. Analyses of the large samples made without panning usually show more gold than do their duplicates analyzed as heavy mineral concentrates, but gold lost by panning would also be lost by most commercial gold-recovery operations.

To determine the magnitude of error in our sampling and analytical procedures, we randomly selected sites where duplicate samples were taken, routinely panned, and analyzed (table 9). Table 9 shows generally good agreement for the gold content for duplicate samples. Only a few samples differ substantially from their duplicates—usually those in which very little gold is present. Duplicate samples with greater amounts of gold compare much better.



**Figure 21.** Gold placer machine designed in part and operated by Frank Allen on his claims on Pacific Creek between 1934 and 1977. This machine, powered by a gasoline washing-machine motor, pumped water and turned the trommel and centrifuge. This equipment was nearly 100-percent effective in recovering all flour gold from alluvial gravels. Photograph by J. D. Love, Aug. 27, 1972.

A further test of the sampling and analytical error is provided by comparing the results we obtained with those of the U.S. Bureau of Mines on a group of channel samples from trenches dug by the Bureau at the confluence of Pacific and Whetstone Creeks (see section on economic appraisal, this report). The Bureau of Mines sampled their trenches (B-F, table 22) with 68 one-cubic-foot (1/27-$yd^3$, 0.028-$m^3$) samples and obtained an average gold content of 9.5 mg/$yd^3$; sampling the same trenches with 13 samples, each of which was approximately 1/200 of a cubic yard, we obtained an average gold content of 10.6 mg/$yd^3$. A comparison of the data obtained on these channel samples is shown in table 10. The data for the larger and more precisely measured Bureau of Mines samples are more accurate than are the data of the Geological Survey, but the Survey data are of sufficient accuracy in reconnaissance.

### Conglomerates

Many exposures of quartzite conglomerate together with related sandstones and shales were sampled for gold. This sampling, however, was somewhat different from the sampling of alluvium. The samples usually weighed only 500–1,000 grams (1–2 pounds), and they were crushed, ground, and split to obtain 10 grams (0.35 oz)

**Table 9.** Comparison of gold data obtained on randomly taken duplicate samples, Teton Wilderness and adjacent areas

[One 14-inch pan filled with alluvium was panned to a concentrate, which was dried after estimating number of gold flakes, weighed, and analyzed for Au by atomic absorption. N, not detected. Milligrams Au per cubic yard obtained by multiplying concentrate weight by parts per million (ppm) to obtain total number of micrograms in sample; this figure was multiplied by 200 to convert to cubic yards, and divided by 1000 to convert micrograms to milligrams. To convert mg/yd$^3$ to troy ounces/yd$^3$, multiply by $3.215 \times 10^{-5}$; for example, 21.8 mg/yd$^3$ = 0.0007 troy oz/yd$^3$]

| Sample No. | Number of flakes estimated | Concentrate weight (g) | Au in concentrate (ppm) | Calculated Au (mg/yd$^3$) |
|---|---|---|---|---|
| W 901 P..... | 12-18 | 8.4 | 13.0 | 21.8 |
| Duplicate... | 30-40 | 3.0 | 40.0 | 24.0 |
| W 905 P..... | 5 | 4.0 | 1.4 | 1.1 |
| Duplicate... | 2 | 3.4 | 2.4 | 1.6 |
| W 907 P..... | 5-10 | 4.7 | 11.5 | 10.8 |
| Duplicate... | 5-15 | 2.6 | 8.0 | 4.2 |
| W 917 P..... | 0 | 3.8 | .6 | .5 |
| Duplicate... | 10-20 | 2.8 | 8.0 | 4.5 |
| W 919 P..... | 0 | 3.8 | N | N |
| Duplicate... | 3 | 2.4 | N | N |
| W 933 P..... | 4 | 4.0 | .25 | .2 |
| Duplicate... | 0 | 2.4 | N | N |
| W 934 P..... | 0 | 2.2 | N | N |
| Duplicate... | 10 | 9.0 | 4.2 | 7.6 |
| W 936 P..... | 60 | 6.6 | 36.0 | 47.5 |
| Duplicate... | 40 | 5.0 | 35.0 | 35.0 |
| W 946 P..... | 7 | 1.6 | 7.7 | 2.5 |
| Duplicate... | 20 | 3.0 | ([1]) | |
| W 947 P..... | 10 | 3.1 | 9.7 | 6.0 |
| Duplicate... | 15 | 3.7 | 6.4 | 4.7 |
| W 969 P..... | 20 | 4.9 | 12.0 | 11.9 |
| Duplicate... | 20 | 4.8 | 9.0 | 8.7 |
| W 979 P..... | 12 | 26.1 | .6 | 3.1 |
| Duplicate... | 15 | 8.1 | 8.4 | 13.5 |
| W 985 P..... | 15 | 21.9 | .35 | 1.5 |
| Duplicate... | 0 | 17.3 | .25 | .9 |
| G 1102 P.... | 10 | 3.8 | 2.3 | 1.8 |
| Duplicate... | 3 | 3.1 | 9.3 | 5.8 |
| G 1107 P.... | 10 | 1.8 | N | N |
| Duplicate... | 15 | 2.8 | 2.8 | 1.6 |
| G 1108 P.... | >100 | 5.5 | 170. | 185.4 |
| Duplicate... | >100 | 9.9 | 90. | 177.7 |
| G 1116 P.... | 7 | 5.9 | 9.6 | 11.3 |
| Duplicate... | 15 | 4.5 | 8.4 | 7.5 |
| G 1002 P.... | 0 | 2.8 | N | N |
| Duplicate... | 2 | 3.4 | .6 | .4 |
| G 1004 P.... | 15 | 2.5 | 7.8 | 4.0 |
| Duplicate... | 15 | 5.0 | 1.8 | 1.8 |
| G 1010 P.... | 25 | 7.6 | 17.0 | 25.8 |
| Duplicate... | 50 | 11.5 | 7.8 | 18.0 |
| G 2005 T.... | 7 | 4.8 | 8.8 | 8.4 |
| Duplicate... | 22 | 5.4 | 7.6 | 8.2 |
| G 2007 T.... | 12 | 5.5 | 12.0 | 13.2 |
| Duplicate... | 16 | 10.0 | 4.0 | 8.0 |
| G 2010 T.... | 3 | 3.1 | 4.5 | 2.8 |
| Duplicate... | 7 | 4.0 | 5.0 | 4.0 |
| G 2015 T.... | 4 | 3.3 | 5.1 | 3.4 |
| Duplicate... | 8 | 4.1 | 11.0 | 8.9 |
| G 2020 T.... | 1 | 1.6 | 6.9 | 2.2 |
| Duplicate... | 3 | 6.3 | 6.5 | 8.2 |
| G 2025 T.... | 4 | 6.6 | N | N |
| Duplicate... | 3 | 2.4 | N | N |
| G 2030 T.... | 0 | 5.0 | 1.0 | 1.0 |
| Duplicate... | 2 | 5.2 | N | N |
| W 1414 P.... | >300 | 23.8 | 2,705 | 12,876 |
| Duplicate... | >300 | 18.9 | 2,319 | 8,766 |
| W 1010 P.... | >100 | 8.6 | 52.7 | 90.6 |
| Duplicate... | >100 | 10.6 | 42.1 | 89.2 |
| Average 22 others..... | | | 23.6 | |
| Duplicate..... | | | 21.7 | |

[1]Sample lost.

**Table 10.** Comparison of gold content obtained by U.S. Geological Survey and U.S. Bureau of Mines on samples from channels dug by U.S Bureau of Mines at confluence of Pacific Creek and Whetstone Creek, Teton Wilderness

[To convert mg/yd$^3$ to troy ounces/yd$^3$, multiply by $3.215 \times 10^{-5}$]

| Location | U.S. Bureau of Mines | | U.S. Geological Survey | |
|---|---|---|---|---|
| | Number of samples | Average Au content (mg/yd$^3$) | Number of samples | Average Au content (mg/yd$^3$) |
| Channel B..... | 7 | 8.7 | 2 | 11.5 |
| C..... | 4 | .8 | 1 | .5 |
| D..... | 7 | 16.9 | 2 | 8.9 |
| F..... | 25 | 8.4 | 4 | 6.1 |
| Overall average all samples.... | 68 | 9.5 | 13 | 10.6 |

for analysis. These small samples gave very erratic results for gold content, and for that reason the analyses are not reported.

To obtain more meaningful data, the bulk samples from which the 10-gram split had been removed were panned to a concentrate which was analyzed in its entirety for gold. Frequently, several small samples from the same locality were combined prior to panning. The average gold content at several localities is shown in table 11. These averages were obtained by mathematical conversion of the gold content determined by atomic absorption on the panned concentrates to in-place material based on the weight of the concentrate and the weight panned.

Gold was obtained in the composite sample of every group of samples except one (L66-55). This shows that

**Table 11.** Summary of amount and value of gold recovered by crushing and panning outcrop samples from measured sections in the Pinyon Conglomerate and Harebell Formation, Teton Wilderness and vicinity, Wyoming

[Several samples at each locality were combined to obtain the summary values as described in text. Some field notes and laboratory records were destroyed by fire at Denver Federal Center, March 19, 1976. ppb, parts per billion. To convert mg/yd$^3$ to troy ounces/yd$^3$, multiply by $3.215 \times 10^{-5}$]

| Unit Nos. | Sample description | Thickness in feet (approx.) | Sample No. | Number of samples combined | Gold (ppb) | Au content converted to mg/m$^3$ | Au content converted to mg/yd$^3$ | Value of Au in 1 yd$^3$ @$100/ troy oz | Value of Au in 1 yd$^3$ @$600 troy oz |
|---|---|---|---|---|---|---|---|---|---|
| | **Big Game Ridge section 3, type Harebell Formation (Love, 1973a, p. A8-A14)** | | | | | | | | |
| | Harebell Formation: | | | | | | | | |
| 99-78 | Sandstone, siltstone, and claystone..... | 500 | L66-67 | 23 | 0.75 | 0.7 | 0.5 | <$0.01 | $0.01 |
| 72-71 | Sandstone and claystone..... | 50 | L66-66 | 4 | 37.7 | 32.8 | 25.1 | .08 | .48 |
| 70-48 | Sandstone and claystone..... | 120 | L66-65 | 5 | 1.5 | 1.3 | 1.0 | < .01 | .02 |
| 47-21 | Shale and claystone; minor conglomerate..... | 470 | W66-1 | 16 | 9.0 | 7.8 | 6.0 | .02 | .12 |
| | **Pinyon Peak section 3A, principal reference section of Pinyon Conglomerate (Love, 1973a, p. A35-A37)** | | | | | | | | |
| | Pinyon Conglomerate: | | | | | | | | |
| 30-22 | Conglomerate; minor sandstone..... | 1,000 | L66-54 | 20 | 8.7 | 7.6 | 5.8 | $0.02 | $0.11 |
| 20 | Conglomerate..... | 440 | L66-52 | 19 | 9.5 | 8.2 | 6.3 | .02 | .12 |
| 18-8 | Chiefly conglomerate; some sandstone..... | 950 | L66-51 | 21 | 23.4 | 20.4 | 15.6 | .05 | .30 |
| 7-6 | Sandstone and conglomerate..... | 210 | L66-56 | 7 | 15.0 | 13.1 | 10.0 | .03 | .19 |
| | Type Harebell Formation, upper part: | | | | | | | | |
| 4-1 | Conglomerate; minor sandstone..... | 360 | L66-55 | 7 | <.15 | <.13 | <.1 | <.01 | <.01 |
| | **Pilgrim Creek section 4, type section of Bobcat Member of Harebell Formation (Love, 1973a, p. A17-A20)** | | | | | | | | |
| ----- | Pinyon Conglomerate: | | | | | | | | |
| 41-40 | Conglomerate..... | 1,000 | L67-26 | 15 | 0.9 | 0.8 | 0.6 | <$0.01 | $0.01 |
| | Harebell Formation, Bobcat Member: | | | | | | | | |
| 38-28 | Chiefly conglomerate..... | 350 | L66-42 | 11 | 1.2 | 1.0 | .8 | <.01 | .02 |
| 26-23 | Conglomerate..... | 180 | L66-41 | 8 | 4.5 | 3.9 | 3.0 | .01 | .06 |
| | Harebell Formation, lower part of Bobcat Member and upper part of lower member: | | | | | | | | |
| 21-1 | Conglomerate, sandstone, claystone, and shale... | 585 | L66-40 | 40 | 29.1 | 25.4 | 19.4 | .06 | .37 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **East Pilgrim Creek section 5** | | | | | | | |
| | Pinyon Conglomerate: | | | | | | | |
| ----- | Quartzite conglomerate | 500-600 | L67-34 | 18 | 11.4 | 9.9 | 7.6 | $0.02 | $0.15 |
| | Harebell Formation, Bobcat Member: | | | | | | | |
| 40-37 | Conglomerate and magnetite-rich sandstone | 236 | L67-35 | 9 | 14.4 | 12.6 | 9.6 | .03 | .18 |
| 36-27 | Conglomerate, sandstone, and claystone | 450 | L67-32 | 17 | 8.6 | 7.5 | 5.7 | .02 | .11 |
| 26-22 | Sandstone and conglomerate | 170 | L67-17, 18 | 8 | 9.2 | 8.0 | 6.1 | .02 | .12 |
| 20 | Sandstone and conglomerate | 50 | L67-19 | 6 | 3.3 | 2.9 | 2.2 | .01 | .04 |
| 19 | Conglomerate | 50 | L67-20 | 2 | 5.3 | 4.6 | 3.5 | .01 | .07 |
| 17 | Sandstone | 50 | L67-21 | 2 | 3.3 | 2.9 | 2.2 | .01 | .04 |
| 16 | Conglomerate | 4-5 | L66-48 | 2 | 32.5 | 32.7 | 25.0 | .08 | .48 |
| 15-10 | Sandstone and shale | 500 | L66-44 | 7 | 15.0 | 13.1 | 10.0 | .03 | .19 |
| 9-6 | Conglomerate containing sandstone lenses | 50 | L66-47 | 5 | 52.5 | 45.8 | 35.0 | .11 | .67 |
| | Harebell Formation, lower member: | | | | | | | |
| 5-3 | Conglomerate (80 ft) and sandstone (20 ft) | 100 | L66-46 | 3 | 33.0 | 28.8 | 22.0 | .07 | .42 |
| 1 | Conglomerate, sandstone, and claystone | 350 | L66-45 | 4 | 21.0 | 18.3 | 14.0 | .04 | .03 |
| | **Pacific Creek section 7** | | | | | | | |
| | Pinyon Conglomerate: | | | | | | | |
| 53-46 | Predominantly conglomerate | 535 | L66-23 | 32 | 11.4 | 9.9 | 7.6 | $0.02 | $0.15 |
| 45-40 | Conglomerate and sandstone; samples predominantly sandstone | 750 | L66-24 | 13 | 0.5 | 0.4 | 0.3 | <.01 | .01 |
| | Harebell Formation, Bobcat Member: | | | | | | | |
| 39-26 | Predominantly conglomerate | 825 | L66-20 | 37 | 18.0 | 15.7 | 12.0 | .04 | .23 |
| | Harebell Formation, lower member: | | | | | | | |
| 21-7 | Predominantly sandstone; some conglomerate | 565 | L66-90 | 24 | 0.9 | 0.8 | 0.6 | <.01 | .01 |
| | **Gravel Mountain section 8** | | | | | | | |
| | Pinyon Conglomerate | | | | | | | |
| | Nearly all conglomerate | 1,060 | L66-80 | 27 | 5.3 | 7.2 | 5.5 | $0.02 | $0.11 |
| | Harebell Formation, Bobcat Member: | | | | | | | |
| | Conglomerate, sandstone, and siltstone | 920 | L66-81 | 31 | 43.5 | 37.9 | 29.0 | .09 | .56 |
| | Harebell Formation, lower member: | | | | | | | |
| | Siltstone, and sandstone; sparse conglomerate | 1,100 | L66-82 | 21 | 42.8 | 37.3 | 28.5 | .09 | .55 |

particulate gold occurs widely in these formations. Sampling the formations in other ways such as in traverses or at random sites in many localities also affirms the ubiquitous presence of gold in the Pinyon Conglomerate and Harebell Formation, as the summaries in table 12 show.

The gold content of the formations as indicated by the small samples that we took is too low to be economic even at a gold price of $600 per ounce, if the formations were to be mined in their entirety. However, the distribution of gold is always erratic in placer deposits, and profitable mining depends upon locating high-grade pay streaks. Much more detailed sampling than we have done would be required to determine whether such enrichments occur, as seems likely. Individual samples as small as one pound (450 g) sometimes contained several flakes of gold, but others had none. Averages of a group of samples tend to smooth out natural variations in gold content just as large samples at each site would; but they also fail to show where the highest values occur.

The data in table 11 suggest the gold content is usually greater in the lower part of the Bobcat Member which is the upper member of the Harebell Formation. Sections showing the relationship of the Harebell, Bobcat Member, and the Pinyon Conglomerate are shown in figure 22. Large units of quartzite conglomerate in the Pinyon Conglomerate such as those near the summits of Pinyon Peak and Gravel Mountain are evidently lower in gold content than sandstones and conglomerates much lower in the section. Such an observation suggests that (1) higher gold content is related to the well-known tendency of gold to be enriched at bedrock in placer deposits and (2) less gold was available from the source area when the topmost portions of the conglomerate were deposited.

The sampling discussed in the preceding sections allows an estimate of the amount of recoverable gold at the surface at several places. Experience of placer miners, however, has shown that the richest concentrations of gold usually occur on or close to bedrock. To determine whether there are richer concentrations of gold on bedrock than at the surface, we dug pits near Pacific Creek and Lava Creek, but at both places ground water entered the diggings at shallow depth and prevented us from reaching bedrock. Channel samples at intervals showed an increase in gold content with depth at the Pacific Creek pit but not at the Lava Creek pit (table 13).

Similarly, no systematic increase in the gold content with increase in depth could be observed along the sides of terraces on the East Fork Pilgrim Creek (table 8) or in the terraces sampled by the U.S. Bureau of Mines (USBM channels B–J, table 22). Terrace deposits, however, are difficult (at best) to sample as analogs to, or as substitutes for, alluvial deposits in streams. Samples from terraces almost certainly miss any natural concentrations produced by the sorting action of moving water. The reason is that geomorphic events subsequent to terrace formation remove or obscure evidence of channels favorable for gold concentrations.

**Table 12.** Summary of amount and value of gold recovered by crushing and panning outcrop samples at various localities in the Pinyon Conglomerate and Harebell Formation, Teton Wilderness, Wyoming

[Several samples at each locality were combined to obtain the summary values as described in text. ppb, parts per billion. To convert $mg/yd^3$ to troy ounces/$yd^3$, multiply by $3.215 \times 10^{-5}$]

| Locality and sample information | Sample No. | Number of samples combined | Gold (ppb) | Au content converted to | | Value of Au in 1 $yd^3$ | |
|---|---|---|---|---|---|---|---|
| | | | | $mg/m^3$ | $mg/yd^3$ | at $100/ troy oz | at $600/ troy oz |
| Whetstone Mountain and vicinity: | | | | | | | |
| Harebell Formation east of Bobcat Ridge | L66-38 | 13 | 2.7 | 5.3 | 4.0 | 0.01 | 0.08 |
| Pinyon Conglomerate landslide block, east of Bobcat Ridge | L66-39 | 15 | 5.7 | 11.1 | 8.5 | .03 | .16 |
| Harebell Formation traverse across summit of Whetstone Mountain | WM 1-22 | 20 | 6.7 | 13.2 | 10.1 | .03 | .19 |
| Harebell Formation, northeast side of Whetstone Mountain | WC 16-34 | 11 | 5.2 | 10.2 | 7.8 | .02 | .15 |
| South side of Pinyon Peak, Pinyon Conglomerate | H-806-829R | 4 | 4.5 | 8.8 | 6.7 | .02 | .13 |
| Gravel Peak, east side, Pinyon Conglomerate | H284-H310R | 5 | 3.4 | 6.7 | 5.1 | .02 | .10 |
| Near Gravel Lake, Harebell Formation | GL 4-7 | 3 | 11.0 | 16.5 | 12.6 | .04 | .24 |
| East and north of Pacific Creek, Harebell Formation | ENA,NNA | 10 | 3.7 | 7.2 | 5.5 | .02 | .11 |
| "Grey Fortress" north of Gravel Mountain, Pinyon Conglomerate | GF,HCC | 13 | 3.3 | 6.5 | 5.0 | .02 | .10 |
| Northeast of Gravel Mountain, Pinyon Conglomerate | MDL 1-14 | 14 | 4.7 | 9.3 | 7.1 | .02 | .14 |
| Box Creek area: | | | | | | | |
| Harebell Formation, head of Box Creek | BCT 1-13 | 13 | 1.8 | 3.5 | 2.7 | .01 | .05 |
| Harebell Formation, head of Box Creek | OTD 1-16 | 8 | 3.0 | 5.9 | 4.5 | .01 | .08 |
| Harebell Formation, west of Clear Creek | VP 1-5 | 5 | .8 | 1.6 | 1.2 | <.01 | .02 |
| Harebell Formation, south slope of Mount Randolph | FF 18 | 4 | 2.7 | 5.2 | 4.0 | .01 | .08 |
| Lava Creek, Harebell Formation near base | LAD | 9 | 7.2 | 14.1 | 10.8 | .03 | .20 |

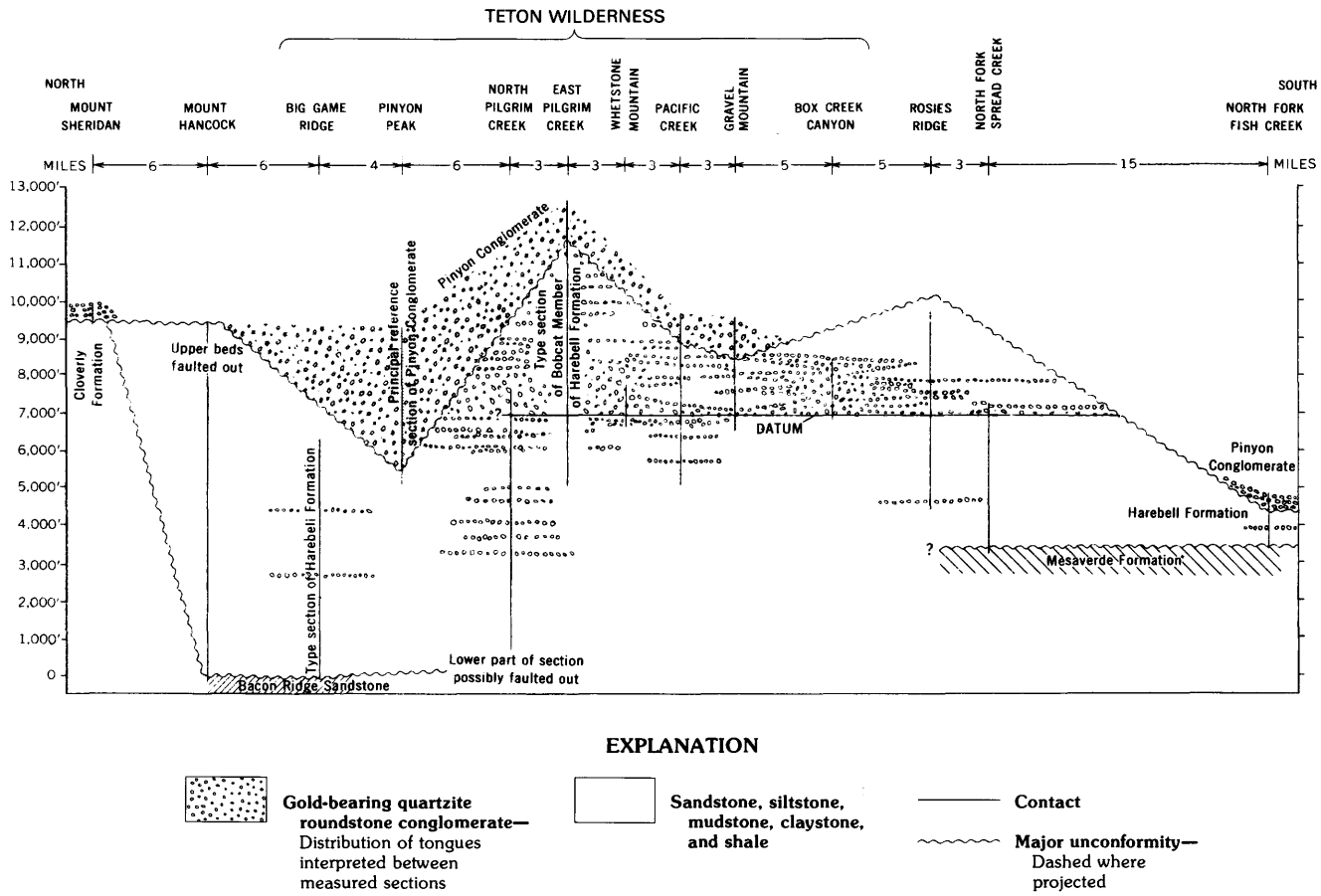



**Figure 22.** Diagrammatic section across measured sections of Pinyon Conglomerate and Harebell Formation showing distribution of gold-bearing quartzite conglomerates and the relations of the formations to each other and to older Cretaceous rocks. Reprinted, slightly modified, from Love (1973a, fig. 7; locations of sections shown on fig. 1 of that report).

Much of the gold in placer deposits for hundreds of miles downstream along the Snake River came from the Pinyon Conglomerate and Harebell Formation (Antweiler and Love, 1967), which crop out extensively in the Teton Wilderness and elsewhere in northwest Wyoming. Previous workers (Schultz, 1907; Hill, 1916) noted the apparent absence of high concentrations at bedrock in placers along the Snake River in western Wyoming and Idaho. However, gold particles on gravels in Pacific Creek are larger than those along the Snake River in Idaho (Antweiler, 1969), and they are, moreover, very near the conglomerates. Therefore, most of the larger, more dense particles should be more likely to concentrate at depth. Bedrock on the Pacific Creek flood plain about ⅓ mile (500 m) south of the wilderness boundary (where the Pacific Creek samples in table 13 were taken) was estimated to be at a depth of 146 feet (44.5 m) (Anderson, 1971). Drilling to test for bedrock concentrations of gold here or at other places in the wilderness would be desirable but was not possible for this report.

## Source of Gold

The widespread distribution of gold elsewhere in shales, claystones, siltstones, sandstones, and conglomerates suggests that it might possibly be derived from volcanic ash. The sporadic occurrence of siliceous volcanic roundstones in the conglomerates would support this possibility, but analysis failed to show any gold in those roundstones.

Tests were made to determine whether gold occurs only in the sandstone matrix in conglomerates or in quartzite roundstones or other roundstones as well. The testing consisted of thoroughly scrubbing pebbles and cobbles, followed by crushing, grinding, panning, and analysis. The only rock type that yielded gold using the procedure was quartzite. About 1,000 grams (2.2 lbs) of quartzite pebbles of different colors were crushed and ground, then panned to a concentrate which was analyzed for gold to determine whether some colors were more likely to contain gold than others. Results are shown in table 14.

**Table 13.** Gold content of samples taken at vertical intervals at two localities, Teton Wilderness and adjacent areas

[To convert mg/yd$^3$ to troy ounces/yd$^3$, multiply by $3.215 \times 10^{-5}$]

| Depth interval (in.) | Au content (mg/yd$^3$) |
|---|---|
| **Pacific Creek 1/4 mi (500 m) south of Wilderness boundary** | |
| Surface - 6 | 4.7 |
| 6 - 12 | 3.1 |
| 12 - 18 | 4.8 |
| 18 - 24 | 8.5 |
| 24 - 30 | 18.5 |
| 30 - 36 | 89.9 |
| **Upper part of Lava Creek south of Gravel Mountain** | |
| Surface - 12 | 11.3 |
| 12 - 24 | 18.9 |
| 24 - 26 | 9.6 |
| 36 - 48 | 1.4 |
| 48 - 60 | 13.0 |
| 60 - 72 | 5.0 |
| 72 - 84 | 4.8 |
| 84 - 96 | 24.1 |
| 96 - 108 | 25.5 |
| 132 - 144 | 5.8 |

**Table 14.** Gold content of roundstones from channel of Pacific Creek 1/4 mile (400 m) south of Teton Wilderness

[L, detected, but less than amount shown; N, not detected; parentheses indicate lower limit of detectability. To convert mg/yd$^3$ to troy ounces/yd$^3$, multiply by $3.215 \times 10^{-5}$]

| Description | Gold content (mg/yd$^3$) | Parts per billion |
|---|---|---|
| Quartzite pebbles: | | |
| Dark green | 6.5 | 4.3 |
| Medium tan to dark brown | 5.5 | 3.7 |
| Light tan | 3.5 | 2.3 |
| White | 1.0 | 0.7 |
| Medium light tan | .9 | 0.6 |
| Medium gray | .9 | 0.6 |
| White with siderite on fracture planes | L(.10) | L(0.07) |
| Light gray | L(.05) | L(0.03) |
| Dark purple | L(.05) | L(0.03) |
| Black | N(.05) | N(0.03) |
| Reddish purple | N(.05) | N(0.03) |
| Dark gray | N(.10) | N(0.07) |
| Light purple | N(.05) | N(0.03) |
| Sandstone--brown, probably from Harebell Formation | 5.5 | 3.7 |
| Welded tuff | N(.05) | N(0.03) |
| Andesite | N(.05) | N(0.03) |
| Rhyolite | N(.05) | N(0.03) |
| Granite | N(.05) | N(0.03) |

Flakes of gold were also recovered by slowly dissolving clean quartzite cobbles with hydrofluoric acid. Some of the recovered gold flakes were polished, examined at high magnification with a microscope, and also analyzed by electron-beam microprobe using the procedure described by Desborough (1970). One such grain was alloyed with platinum. Three other grains had approximately the same composition as other grains of placer gold recovered from Pacific Creek (88–94 percent Au, 12–6 percent Ag). Polished grains under the microscope showed nearly pure gold on the exterior of the grains, and gold-silver alloy in the interior. We conclude that most or all of the gold in the Pinyon Conglomerate and Harebell Formation was deposited in quartz-rich sands on beaches in the Belt or younger Proterozoic seas (see discussion in Love, 1973a, p. A29). These beach sands were later buried, metamorphosed to quartzites, and uncovered by erosion during deroofing of the Targhee uplift (Love and Reed, 1968, p. 83) during Late Cretaceous and Paleocene times. No evidence has been found of the lode source that contributed the large quantities of gold to the beaches of the Belt or younger Proterozoic seas.

### Other Occurrences of Gold in the Teton Wilderness

Traces of gold were detected by analysis of panned concentrates of crushed and ground rock from several sedimentary formations. Traces of gold were also in samples of dump material from prospects along South Buffalo Fork (see discussion under copper and silver). Some panned-concentrate samples from the large volumes of volcaniclastic rocks also had traces of gold, but these generally could not be related to mineralization. None of the gold occurrences except those in the conglomerates and related alluvium appear to be economically significant.

## Platinum

Rumors of platinum occurrences in or near the Teton Wilderness frequently circulate. Small amounts of platinum were recovered many years ago at Bailey Bar

on the Snake River, about 60 miles (100 km) south of the wilderness (Schultz, 1907). We collected 18 panned concentrates specifically for platinum determination by a combined fire assay-spectrographic procedure. Platinum and other platinum-group metals were detected in small amounts from samples along Pacific Creek that were rich in gold (as much as 5 ppb Pt on panned concentrates). The abundance of platinum is about 1/100 to 1/1000 that of gold, and platinum would probably be worthwhile to recover as an adjunct to gold mining if gold mining were attempted, but its recovery would be too expensive otherwise.

## Mercury

Mercury, like platinum, is frequently rumored to exist in northwestern Wyoming, and occurrences associated with Tertiary and later igneous activity are not implausible. Metallic mercury was found in a few panned concentrates along Pacific and Whetstone Creeks, and has been recovered by Frank Allen in sluice concentrates from his placer mine on Pacific Creek. This mercury may have been left on upper Whetstone Creek in the 1880's by placer miners, who brought in considerable mercury—perhaps as much as a ton (Frank Allen, oral commun. to J. C. Antweiler, 1974). They used the mercury to recover gold and, by present-day evidence of their mining, could have left that much mercury behind when they abandoned their claims. Our sampling in conglomerates or along streams where no mining had been done in the wilderness showed no indication of native mercury. However, south and southeast of the wilderness, mercury occurs in alluvial deposits not associated with placer mining and has also been found in limy concretions in the Pinyon Conglomerate.

## Rare-Earth Metals, Tin, Titanium, and Zirconium

Spectrographic analyses of concentrates of stream-sediment and bedrock samples (table 3) show high values for elements such as Fe, Ti, Sn, La, Y, and Zr that occur in magnetite, hematite, ilmenite, rutile, sphene, monazite, zircon, and other heavy minerals that tend to form placer deposits. Recovery and processing of these minerals as byproducts to placer mining for gold might be feasible, but problems of access, tailings disposal, and stream pollution within the wilderness would be severe. Larger, more accessible placer deposits occur in non-wilderness areas.

## Copper, Silver, and Gold in Archean Rocks

Rocks of Archean age crop out on both North and South Buffalo Forks and on Cub Creek above its confluence with Trail Creek and Holmes Cave Creek (pl. 1). In each of the three outcrop areas, weak geochemical anomalies were observed for one or more of the following metals: Au, Ag, Ba, Cu, Mn, Ni, Pb, or Zn. Although copper minerals and associated silver and gold occur at several places in the Archean rocks, we did not locate any definite exploration targets. Analyses of stream-sediment and panned-concentrate samples from drainages that start in or cross the Archean rocks show little or no enrichment compared to other samples.

The greatest amounts of copper that we found were in the brecciated and sheared zones where mining had been attempted early in this century by Hays and Peterson (Smith and Wynn, 1906, p. 71–72) along South Buffalo Fork. Selected specimens of copper ore on some of the dumps could be considered high grade, but the average grade of dump material is low (see section on economic appraisal, this report). Smith and Wynn's published description of this mine, however, showed considerable optimism:

> A big discovery of gold and copper ore was made by George Hays and Charles Peterson last season on the western slope of the Wind River range, on the south fork of Buffalo Fork River. Development work has been progressing ever since the discovery and some fine values have been returned by the assayer. City Marshal Grant Young is interested in several claims in the vicinity of the original discovery and he reports a recent assay as giving returns of $117.00 in gold and copper. Some twelve or fifteen men are in the camp and when spring opens up the work of development will be most vigorously prosecuted. The veins so far as they have been followed are of an extremely flattering width and give promise of the existence of large ore bodies.

Two adits were driven along a sheared and brecciated zone in the Archean rocks on opposite sides of the South Buffalo Fork canyon, 4,000 feet (1,200 m) apart but approximately on strike (N. 50° E.). Most of the mining was at the northeastern adit. Several log buildings and a shop (fig. 23) were built, but only ruins mark the site. The adit is caved, and because no mine maps or records of the underground workings remain, their extent was inferred to be at least 285 feet (87 m) on the basis of the size of the dump and the position of the mineralized vein upslope. A small trickle of water emerges from the caved portal.

Several small prospect pits, many of which expose rock coated with azurite and malachite, occur below and west of the northeastern adit in heavy second-growth timber. Gold in small amounts was recovered by panning alluvium from a spring below these workings. Gold was also recovered from dump material at workings on both sides of South Buffalo Fork. Numerous prospect pits in the timber below and west of the southwestern adit further attest to former prospecting. Rocks in these pits are stained with secondary copper minerals.

Evidence of past prospecting was also found along North Buffalo Fork in the Archean rocks. Selected analytical results are shown in table 15 for 20 of the 103



**Figure 23.** Hays and Peterson copper mine on South Buffalo Fork. Man stands at mouth of caved adit that was driven horizontally an estimated 285 feet (87 m) into Archean rocks on the mountainside. Building was probably the mine shop. Photograph by J. D. Love, Aug. 14, 1973.

Archean rock samples. Samples J101R through J109R are from the area once staked by prospectors on North Buffalo Fork, and samples S5M, S8M, A2M, and A3M are samples from the areas where mining was attempted on South Buffalo Fork. We found small amounts of gold in stream sediments below the areas of interest to prospectors. Gold was evidently the catalyst for the prospecting activity.

The rugged walls of the canyons in the Archean do not show evidence of prospecting, although minute amounts of malachite and sulfides—particularly pyrite and chalcopyrite—can be observed in rocks at several localities. Small amounts of malachite and sulfides were sampled in Archean rocks in scoured fresh exposures at river level in the "Narrows" of South Buffalo Fork canyon.

On the basis of our sampling and field observations, we conclude that the potential for the occurrence of mineral resources is low in the Archean rocks.

## Phosphorite and Associated Trace Elements in the Phosphoria Formation

The Phosphoria Formation is poorly exposed in scattered outcrops along the west flank of the Washakie Range but underlies the western third of the Teton Wilderness. No complete sections were found in the wilderness, so the detailed stratigraphy and nomenclature are based on previously described sections to the west, north, east, and south (pl. 5, fig. 24) and five new

**Table 15.** Selected analyses of Late Archean rocks, Teton Wilderness

[Values, in parts per million, by 6-step semiquantitative spectrographic analyses. N, not detected; L, detected but below satisfactory measurement level given in parentheses. Values in parentheses under element symbols are suggested thresholds of anomalous values]

| Sample No. | Description | Mn (1500) | Ag (0.5) | Ba (1000) | Cu (70) | Pb (50) | Zn (200) | Other |
|---|---|---|---|---|---|---|---|---|
| | North Buffalo Fork area | | | | | | | |
| J101R | Red-, yellow-, and green-stained schist | 1500 | N | 20 | 150 | L(10) | N | Au L(0.05) |
| J102R | Hydrothermally altered schist | 500 | 0.5 | 50 | 150 | 10 | N | |
| J103R | Unaltered schist | 1000 | N | 1000 | 70 | 10 | N | |
| J104R | Rusty schist and quartz from small pod in schist | 150 | N | 500 | 15 | L(10) | N | |
| J105R | Vuggy quartz in altered schist | 200 | N | 50 | 5 | N | N | Au L(0.05) |
| J106R | Hydrothermally altered schist | 1500 | N | 100 | 180 | N | N | |
| J107R | .....do | 1000 | 0.5 | 200 | 7 | 150 | N | |
| J108R | Fresh greenish-black schist | 1000 | N | 1000 | 100 | 70 | N | |
| J109R | Schist with disseminated pyrite | 1000 | 0.5 | 20 | 300 | N | N | |
| J1825R | Schist adjacent to quartz pegmatite | 150 | N | 200 | 20 | 200 | 500 | |
| | South Buffalo Fork area | | | | | | | |
| S5M | Specimen from dump of prospect, north side, South Buffalo Fork | 500 | N | 20 | 5,000 | N | N | |
| S8M | Vein material at adit opening above sample S5M | 200 | N | 150 | 10,000 | N | N | |
| A2M | Specimen from dump, south side, South Buffalo Fork | 15 | 1 | 50 | 7,000 | N | N | Au L(0.05) |
| A3M | Fine-grained dump material from prospect on south side of South Buffalo Fork | 100 | 2 | 100 | >20,000 | N | N | Au L(0.05) |
| A52R | Gneiss, top of Archean on Angle Mtn.; contains pyrite | 3000 | N | 200 | 300 | 50 | N | |
| A59R | Gneiss, top of Archean on Angle Mountain | 500 | N | 300 | 100 | 15 | N | |
| A1000R | Amphibolite from migmatite exposure | 2000 | N | 50 | 100 | N | N | Ni 100 |
| A1004R | Ferruginous granite gneiss, pyrite present | 100 | N | 300 | 150 | 10 | N | |
| A50R | Gneiss with abundant gossan near fault zone | 2000 | N | 200 | 700 | L(10) | N | |
| | Cub creek area | | | | | | | |
| S325R | Pegmatite in amphibolite gneiss | 70 | N | 300 | 10 | 50 | N | Au 0.20 |




**Figure 24.** Measured and sampled section of Retort Phosphatic Black Shale Member and overlying rocks in the Phosphoria Formation in Gros Ventre roadcut 17 miles (27 km) southwest of Teton Wilderness. See measured section in text for description of lithology. A, light-gray mudstone unit 11 in Retort Member; B, contact between Retort Member and Tosi Chert Tongue; C, tubular chert zone in Tosi Chert Tongue; D, upper tongue of Shedhorn Sandstone; E, base of exposed sampled section. Shovel (circled) indicates scale. Photograph by J. D. Love, July 29, 1970.

partial sections [see following sections on Northwest Enos Lake, South Enos Lake, Clear Creek Lake, and Two Ocean Pass within Teton Wilderness and the Gros Ventre Road section 17 miles (27 km) southwest of the wilderness]. The problem with all four partial sections within the wilderness is that the strata containing the phosphorite and other trace elements are soft and underlie covered intervals. Without deep trenching or drilling, these possible resources cannot be adequately evaluated.

The values of $P_2O_5$ and other trace elements in the Teton Wilderness are given in table 16. If the 6-foot (1.83-m) thickness of phosphorite in the South Enos Lake section is valid, this would constitute a significant resource but not one that is competitive with thicker and higher grade phosphorites to the southwest (Sheldon, 1963). Phosphorites in the Meade Peak Phosphatic Shale Member near the base of the Phosphoria Formation are rarely more than 2 feet (0.6 m) thick and are not economically significant.

### Northwest Enos Lake Measured Section

The Northwest Enos Lake section of the Phosphoria Formation was measured and sampled on a high knob 2,000 feet (609 m) northwest of the northwest corner of Enos Lake in the northeast corner of the Gravel Mountain quadrangle, Teton County, Wyo. The section is at field station L73–158 and was measured by J. D. Love, July 30, 1973, using steel tape and pocket transit. Geochemical samples in their stratigraphic position are listed in data set 45 together with the rest of the analytical data (McDanal and others, 1983). The location of the measured section is shown on plate 2 (sample nos. G9–18R). Unit 1 is oldest.

| Unit | Lithology | Thickness (ft) | Thickness (m) |
|---|---|---|---|
| | Dinwoody Formation (part): | | |
| 18 | Siltstone, tawny, dolomitic, thicker bedded than below. Top of exposures is at edge of timber (trees do not grow on these rocks). Sample G21R at top | 40 | 12.19 |
| 17 | Siltstone, dolomitic, tawny, slabby. Sample G20R at top | 5 | 1.52 |
| 16 | Covered interval in swale; probably all lower part of Dinwoody Formation | 80 | 24.38 |
| | Total measured part of Dinwoody Formation | 125 | 38.09 |
| | Phosphoria Formation—Approximate contact is at break in slope: | | |
| 15 | Sandstone, brown, hard; top 1 ft (0.3 m) is cherty dolomitic sandstone from which sample G19R was taken. Strike N. 30° W., dip 25° SW. on dip slope at top of unit | 20 | 6.09 |
| 14 | Dolomite and chert, interbedded, brown, hard. Sample G18R | 10 | 3.04 |
| 13 | Covered | 40 | 12.19 |
| 12 | Sandstone, cherty, phosphatic, brown, with striking tubular concretions or structures resembling "pseudocoprolites." Sample G16R is of sandstone and G17M is of the tubular structures | 10 | 3.04 |
| 11 | Dolomite and chert, brown; phosphatic brachiopods and phosphate granules in middle. Unit is highly fractured. Sight reading within this unit is strike N. 30° W., dip 27° SW. Sample G15R in phosphatic middle part | 30 | 9.14 |
| 10 | Covered interval; probably crumbly, highly fractured chert | 20 | 6.09 |
| 9 | Chert, gray, brittle, bedded. Sample G14R | 10 | 3.04 |
| 8 | Chert, gray-brown, brittle, crumbly, pulverized | 60 | 18.28 |
| 7 | Sandstone, tan, dolomitic, cherty | 5 | 1.52 |
| 6 | Sandstone, brown, hard, ledgy. Sample G13R | 10 | 3.04 |
| 5 | Covered | 40 | 12.19 |
| 4 | Sandstone, brown, phosphatic. Sample G12R | 5 | 1.52 |

**Table 16.** Selected analytical results for samples from the Phosphoria Formation in the Teton Wilderness, northwest Wyoming

[All analyses by U.S. Geological Survey: eU determined by beta-gamma scaler and $P_2O_5$ by volumetric method by G. D. Shipley; uranium determined by neutron activation by H. T. Millard, Jr.; Hg determined by chemical atomic absorption by J. G. Viets; other analyses by 6-step semiquantitative spectrographic analyses by R. T. Hopkins, Jr. Results in parts per million except $P_2O_5$ which is in percent. nd, not determined; N, not detected at level shown; L, detected but below satisfactory measurement level given in parentheses]

| Sample No. | Description | eU | U | $P_2O_5$ | Ag | Cu | Mo | Pb | V | Zn | Hg |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **South of Enos Lake** | | | | | | | | | | |
| J3M | Botryoidal nodules | L(10) | nd | 0.75 | N(.5) | 5 | N(5) | N(10) | L(10) | N(200) | 0.04 |
| J5M | 15 in. of phosphorite | 40 | nd | 17.3 | .5 | 5 | N(5) | 70 | 50 | 200 | .18 |
| J6M | 12 in. of black shale overlying J5M | 10 | nd | 1.9 | 2 | 50 | 5 | 70 | 200 | 1500 | .26 |
| J7M | 12-in. channel sample overlying J6M | 40 | 30.2 | 11.2 | 1 | 20 | 5 | 150 | 100 | 1500 | .24 |
| J8M | 12-in. channel sample overlying J7M | 40 | nd | 11.4 | 1 | 50 | 5 | 150 | 100 | 1500 | .20 |
| J9M | 12-in. channel sample overlying J8M | 30 | nd | 10.8 | 1 | 10 | N(5) | 70 | 100 | 1500 | .24 |
| J10M | 12-in. channel sample overlying J9M | 30 | nd | 2.5 | 5 | 100 | 7 | 150 | 100 | 1500 | .50 |
| J11M | 12-in. channel sample overlying J10M | 30 | nd | 13.9 | .5 | 10 | N(5) | 50 | 100 | 200 | .16 |
| J12M | 12-in. channel sample overlying J11M | 50 | nd | 17.2 | 1 | 7 | N(5) | 150 | 100 | 300 | .24 |
| J13M | 12-in. channel sample overlying J12M | 30 | nd | 11.5 | 1 | 10 | N(5) | 150 | 100 | 500 | .14 |
| J14M | 12-in. channel sample overlying J13M | 30 | nd | 6.3 | .5 | 10 | N(5) | 30 | 100 | 300 | .14 |
| J15M | 12-in. channel sample overlying J14M | 40 | nd | 16.6 | 1 | 30 | N(5) | 150 | 100 | 500 | .16 |
| J16M | 12-in. channel sample overlying J15M | 50 | nd | 16.0 | 1 | 15 | N(5) | 100 | 100 | 500 | .18 |
| J17M | 12-in. channel sample overlying J16M | 20 | nd | 2.4 | 3 | 30 | 5 | 100 | 200 | 1500 | .35 |
| J18M | 12-in. channel sample overlying J17M | 10 | nd | 1.3 | 1 | N(5) | L(5) | 20 | 100 | 500 | .20 |
| G17M | Phosphorite northwest of Enos Lake | 20 | nd | 3.9 | N(.5) | 7 | 30 | 30 | 20 | L(200) | .04 |
| | **Clear Creek Divide area** | | | | | | | | | | |
| J1124R | 12-in. channel sample underlying phosphate horizon | 8 | 9.0 | nd | N(0.5) | 5 | N(5) | 10 | 70 | 500 | 0.04 |
| J1125R | 21-in. phosphate horizon above J1125R | -- | 2.3 | nd | 1.5 | 15 | N(5) | 20 | 100 | 500 | L(.02) |
| J1126R | Black chert zone overlying J1125R | -- | nd | nd | N(.5) | N(5) | N(5) | N(10) | 30 | 300 | .08 |
| J1127R | Sandstone (similar to Shedhorn Sandstone), 15 ft | -- | nd | -- | N(.5) | N(5) | N(5) | N(10) | 20 | N(200) | .02 |
| | above J1126R | -- | 3.2 | nd | -- | -- | -- | -- | -- | -- | -- |
| J1128R | 10-in. phosphate zone overlying J1127R | 20 | 21.0 | nd | 2.0 | 10 | 50 | 50 | 150 | 300 | L(.02) |
| J1129R | 6-in. channel of phosphatic sandstone over J1127R | 7 | 7.0 | nd | N(.5) | L(5) | N(5) | N(10) | 30 | 100 | L(.02) |
| | **Southeast of Clear Creek Lake area** | | | | | | | | | | |
| J62R | Phosphoritic section of Phosphoria Formation | nd | nd | nd | N(.5) | 15 | N(5) | 10 | 30 | 1500 | 0.06 |
| | **Two Ocean Pass area** | | | | | | | | | | |
| T78M | Soft porous brown dolomite (similar to Park City Formation) | nd | nd | nd | 1 | 70 | N(5) | 70 | 100 | N(200) | 0.02 |
| T80M | 12-in. phosphorite | nd | nd | 9.6 | 1 | 7 | N(5) | 7 | 100 | N(200) | .16 |
| T79R | Dolomitic sandstone with phosphorite | nd | nd | nd | .5 | 7 | N(5) | 30 | 50 | L(200) | .04 |

| Unit | Lithology | Thickness (ft) | Thickness (m) |
|---|---|---|---|
| | Phosphoria Formation (part)—Continued | | |
| | Approximate total thickness of Phosphoria Formation. This is about 100 ft thicker than most sections so there may be duplication in the crushed parts of units 8–11 | 260 | 79.18 |
| | Tensleep Sandstone (part): | | |
| 3 | Sandstone, gray, soft | 10 | 3.04 |
| 2 | Dolomite, white, hard. Sample G11R | 10 | 3.04 |
| 1 | Sandstone, white, soft. Sample G10M for millidarcy (porosity and permeability) test. Sample G9R is from same horizon for analysis | 15 | 4.57 |
| | Total measured part of Tensleep Sandstone | 35 | 10.65 |

### South Enos Lake Measured Section

The South Enos Lake section of a part of the Phosphoria Formation was measured and sampled on an east-facing hillside 1,400 feet (427 m) south-southeast of

the outlet of Enos Lake near the northeastern margin of the Gravel Mountain quadrangle, Teton County, Wyo. The section is at field station L73–167 and was trenched, measured, and sampled by J. D. Love and J. C. and Ron Antweiler, August 1, 1973. The location of the section is shown on plate 2 (sample nos. J5–18M). Exposures are poor, and several trenches that were dug indicate much minor faulting, so this cannot be regarded as a reliable section. Nevertheless, it is the only exposed section of even a part of the black shale that was found in the Teton Wilderness. Unit 1 is oldest.

| Unit | Lithology | Thickness (ft) | Thickness (m) |
|---|---|---|---|
| | Phosphoria Formation (part): | | |
| 14 | Chert, tan, splintered and pulverized | 1+ | 0.3+ |
| 13 | Chert, black, phosphatic, splintered. Sample J18M | 1 | .3 |
| 12 | Chert, black, phosphatic, splintered. Sample J17M | 1 | .3 |
| 11 | Phosphorite, black, fetid. Sample J16M | 1 | .3 |
| 10 | Phosphorite, black, fetid. Sample J15M | 1 | .3 |
| 9 | Phosphorite, black, fetid. Sample J14M | 1 | .3 |
| 8 | Phosphorite, black, fetid. Sample J13M | 1 | .3 |
| 7 | Phosphorite, black, fetid. Sample J12M | 1 | .3 |
| 6 | Phosphorite, black, fetid. Sample J11M | 1 | .3 |
| 5 | Shale, black, soft. Sample J10M | 1 | .3 |
| 4 | Shale, black, phosphatic. Sample J9M | 1 | .3 |
| 3 | Shale, black, phosphatic. Sample J8M | 1 | .3 |
| 2 | Phosphorite, black, fetid. Sample J7M | 1 | .3 |
| 1 | Dolomite, yellow, soft | 5+ | 1.52+ |
| | Total measured part of the Phosphoria Formation in this trench | 18+ | 5.4+ |

In another trench 30 ft (9 m) to the south of the above section, the same basal units were sampled as follows:

| | | | |
|---|---|---|---|
| 3a | Shale, black, with chert geodes that have quartz(?) and calcite crystal rinds. Sample J6M | 1.7 | 0.51 |
| 2a | Phosphorite, black, coarsely granular, fetid. Sample J5M | 1.25 | .38 |
| 1a | Dolomite, yellow, soft | 5+ | 1.52+ |
| | Total measured part of the Phosphoria Formation in this trench | 7.95+ | 2.41+ |

Comments: If the main section containing 6 ft (1.83 m) of phosphorite is valid, there must be a fault 2 ft (0.61 m) southeast of the trench. It puts the yellow dolomite of unit 1 against the phosphorite section of units 6–11. More detailed trenching would be necessary to determine the economic potential of this sequence.

### Clear Creek Lake Measured Section

The Clear Creek Lake section of the Phosphoria Formation (pl. 2, sample nos. J1120–1131R), at field station L74–132, was measured by J. D. Love, Aug. 29, 1974, using steel tape and pocket transit. The section is about 3,300 feet (1,000 m) southeast of Clear Creek Lake on a high ridge, Joy Peak quadrangle, Teton County, Wyo. Unit 1 is oldest.

| Unit | Lithology | Thickness (ft) | Thickness (m) |
|---|---|---|---|
| | Phosphoria Formation: | | |
| 15 | Covered; estimated interval, to top of Phosphoria Formation | 10+ | 3.04± |
| 14 | Chert, white; interbedded with gray phosphatic sandstone. Sample J1131R is from highest exposed bed | 8 | 2.44 |
| 13 | Sandstone, tan, cherty; forming vertical wall. Strike N. 35° W., dip vertical. Sample J1130R from wall | 5 | 1.52 |
| 12 | Partly covered slope, littered with chert chips | 35 | 10.66 |
| 11 | Phosphatic sandstone, brown, fetid. Sample J1129R | 1 | .30 |
| 10 | Phosphorite, black, fetid; probably basal bed of Retort Phosphatic Shale Member; radioactive, with 0.04 mR/hr reading on scintillator. Sample J1128R | .8 | .25 |
| 9 | Chert, blue-gray; softer than below; forms slope. Partings of light-tan sandstone at top. Sample J1127R is from top 3 in. (8 cm) | 9 | 2.74 |
| 8 | Chert, light-brown, brittle, hard; forms ridge | 6 | 1.83 |
| 7 | Chert, black, brittle, breaking into chips. Sample J1126R is from basal 6 in. (15 cm) | 13 | 3.96 |
| 6 | Phosphorite, black, fetid, slightly radioactive (0.025 mR/hr). Channel sample of unit is J1125R | 1.75 | .53 |
| 5 | Chert, gray, in lower half; brown phosphatic sandstone in upper half; forms highest bare ridge on outcrop. Sample J1124R is from top 1 ft (30 cm) | 40 | 12.19 |
| 4 | Covered; swale littered with chert chips | 30 | 9.14 |
| 3 | Sandstone conglomerate; pebbles and cobbles of light-gray quartzitic sandstone; some granules of gray chert; dolomite matrix; strike N. 30° W., dip 75° SW | 7 | 2.13 |
| | Approximate total thickness of Phosphoria Formation | 167± | 50.73± |
| | Tensleep Sandstone (part): | | |
| 2 | Dolomite, chalky-white, very fine grained, brittle; light-gray chert stringers containing sparse brachiopods and endothyrids. Sample J1122R is from middle part | 8 | 2.44 |
| 1 | Sandstone, gray, medium-grained, crossbedded, nonquartzitic. Sample J1120R is from base of unit and J1121R is from top | 30+ | 9.14 |
| | Total measured part of Tensleep Sandstone | 38+ | 11.58 |

### Two Ocean Pass Measured Section

The Two Ocean Pass section of the Phosphoria Formation and Tensleep Sandstone was measured and sampled 2.8 miles (4.5 km) southwest of Two Ocean Pass on a prominent cliff on the north side of Pacific Creek, Two Ocean Pass quadrangle, Teton County, Wyo. The section is at field station L73–142 and was measured by J. D. Love, July 28, 1973, using steel tape and pocket transit. Unit 1 is oldest.

| Unit | Lithology | Thickness (ft) | Thickness (m) |
|---|---|---|---|
| | Phosphoria Formation (upper part not exposed): | | |
| 21 | Sandstone and sandy dolomite forming ragged ledges. Sample I82R is from topmost exposed ledge, probably within 10 ft (3.04 m) of top of formation | 40 | 12.19 |
| 20 | Chert, brown, forming ragged ledges | 50 | 15.24 |
| 19 | Phosphorite, black, fetid. Samples I80M and I81R | 1 | .30 |
| 18 | Sandstone, tan, ledgy, dolomitic, phosphatic; and tubular chert | 12 | 3.65 |
| 17 | Sandstone, brown, dolomitic; with phosphatic pebbles. Sample I79R | 5 | 1.52 |
| 16 | Dolomite, brown, soft, porous; strong petroliferous odor. Sample I77R is of most petroliferous part. Sample 178M is of brown crystals at top | 50 | 15.24 |
| | Total measured part of Phosphoria Formation | 158 | 48.14 |
| | Tensleep Sandstone: | | |
| 15 | Sandstone, gray, soft, porous. Sample I76R at base | 20 | 6.09 |
| 14 | Sandstone, gray, soft | 45 | 13.71 |
| 13 | Sandstone, gray, medium-grained, sparkly, highly crossbedded, poorly cemented; high porosity and permeability. Sample I75R is from base | 25 | 7.62 |
| 12 | Sandstone, gray; harder than above | 100 | 30.48 |
| 11 | Dolomite, white, chalky, brittle. Sample I74R | 1 | .30 |
| 10 | Sandstone, gray, hard | 25 | 7.62 |
| 9 | Sandstone, white, massive; strike N. 50° W., dip 12° NE. Sample I73R at top | 4 | 1.21 |
| 8 | Sandstone, gray | 20 | 6.09 |
| | Approximate total thickness of Tensleep Sandstone | 240 | 73.12 |
| | Amsden Formation (part): | | |
| 7 | Dolomite, gray, hard, brittle; and dolomitic sandstone | 20 | 6.09 |
| 6 | Shale, purple, soft. Sample I72R | .25 | .08 |
| 5 | Sandstone and dolomite, gray | 3 | .91 |
| 4 | Sandstone, red, hard. Sample I71R | 2 | .61 |
| 3 | Sandstone and dolomite, gray | 20 | 6.09 |
| 2 | Dolomite, gray, sandy. Sample I70R | 5 | 1.52 |
| 1 | Red shale scree on slope; nothing in place and no lower exposures | 20+ | 6.09+ |
| | Total measured part of Amsden Formation | 70+ | 21.4+ |

### Gros Ventre Road Measured Section of Retort Phosphatic Shale Member

The upper part of the Retort Phosphatic Shale Member of the Phosphoria Formation was measured and sampled in a fresh roadcut on the northeast side of the Gros Ventre road (fig. 24) by J. D. Love, using a steel tape, June 18, 1974. Its generalized strike is N. 65° W., dip 15 ± ° NE. This section is located 1,800 feet (550 m) south of north line, 750 feet (230 m) west of east line, sec. 6, T. 42 N., R. 114 W., Shadow Mountain quadrangle, SE. corner of quadrangle lat 43°37′30″ N., long 110°30′ W., Teton County, Wyo. This section is 17 miles (25 km) southwest of the Teton Wilderness but is better exposed than any section within the wilderness. Its stratigraphic relations to other sections south, east, and north of the wilderness are shown on plate 5. The upper part of the Retort Phosphatic Shale Member is virtually unidentifiable in the wilderness. Unit 1 is oldest.

| Unit | Sample No. | Lithology | Thickness (ft) | Thickness (cm) |
|---|---|---|---|---|
| | | Phosphoria Formation | | |
| | | Tosi Chert Tongue (part): | | |
| 19 | — | Chert, black, forms irregularly bedded ragged cliff; lesser amount of tan dolomite and sparse thin black shale partings | 20+ | 609+ |
| | | Upper part of Retort Phosphatic Shale Member: | | |
| 18 | 16 | Phosphorite, black, coarse-grained, hard; in irregular bed | .16 | 5 |
| 17 | 15 | Shale, black, fissile, hard | .75 | 23 |
| 16 | 14 | Phosphorite, black, coarse-grained, nodular, impure; in irregular bed | .08 | 2.5 |
| 15 | — | Lower half is tan cherty dolomite, and upper half is black, brittle, poorly bedded chert | 4.0 | 122 |
| 14 | 13 | Shale, black, hard; grades up to tan massive chert and dolomite | 1.17 | 35.5 |
| 13 | 12 | Shale, black, hard | 2.0 | 61 |
| 12 | 11 | Shale, black, hard, fissile; about 2-in. (5-cm) impure black phosphorite at base | 2.0 | 61 |

| Unit | Sample No. | Lithology | Thickness (ft) | Thickness (cm) |
|---|---|---|---|---|
| Upper part of Retort Phosphatic Shale Member—Continued | | | | |
| 11 | 10 | Mudstone, dark-grayish-brown, light-gray-weathering, massive, hard; forms ledge | .6 | 18 |
| 10 | 9 | Shaly mudstone, dark-brownish-black, blocky to fissile, hard; slightly radioactive | 1.75 | 48 |
| 9 | 8 | Phosphorite, black, granular; on outcrop forms a weak ledge. Radioactivity less than 0.025 mR/hr | .25 | 8 |
| 8 | 7 | Shale, black, fissile, hard; slightly rusty and silty | 2.0 | 61 |
| 7 | 6 | Shale, black, fissile, hard; slightly rusty and more silty than in underlying units | 2.0 | 61 |
| 6 | 5 | Shale, black, fissile, silty, hard; slightly more radioactive than background | 2.0 | 61 |
| 5 | 4 | Shale, black, fissile, silty, hard; slightly more radioactive than background | 2.0 | 61 |
| 4 | 3 | Shale, black, fissile, silty, hard; soft and more graphitic near top; slightly more radioactive than background | 2.0 | 61 |
| 3 | 2 | Shale, black, fissile, silty, hard; slightly more radioactive than background | 2.0 | 61 |
| 2 | 1 | Mudstone, dark-brownish-gray, massive | .5 | 15 |
| 1 | — | Covered interval; thickness estimated from adjacent Flat Creek and Crystal Creek sections | 10.00 | 300.5 |
| | | Measured and estimated total thickness of upper part of Retort Phosphatic Shale Member | 35.26 | 1,065.5 |

## Organic-Rich Metalliferous Black Shale of Mississippian Age

A petroliferous and metalliferous black shale, about 50 feet (15 m) thick, was discovered in Mississippian rocks at three localities in the wilderness. These strata were studied and sampled in detail (table 17 and pl. 2). They represent a unique shelf facies of Mississippian marine sediments that has not been recognized elsewhere in the region. They are possible source beds for oil and gas under the western half of the wilderness, and our sampling shows that locally they are enriched in several trace metals, including silver, copper, molybdenum, and zinc (table 17). Three sections of the black shale sequence were measured (pl. 2). Because of incomplete exposures and softness of the strata, precise thicknesses were not determined. The areal distribution of the black shale is not known. It is at or below the base of the Horseshoe Shale Member (Sando and others, 1975), and above the Darwin Sandstone Member of the Amsden Formation. The currently known extent of the black shale is about 10 square miles (26 km$^2$). It is not present at the north end of the Teton Range, 35 miles (56 km) to the west-northwest (J. D. Love field notes, station L55–89, Aug. 28, 1955, and July 31, 1968; quoted by Sando and others, 1975, section 49). It was not recognized along the south boundary of Yellowstone National Park, east of the South Entrance, 30 miles (8 km) to the northwest (Love and Keefer, 1975), or to the north along the west flank of the Washakie Range. It could have been missed to the north, however, because of poor exposures and lack of time to investigate in detail the stratigraphy of the Amsden Formation. Similarly, it was not observed to the south along the southwest and south flanks of the Washakie Range, but could be present. Additional work is needed to determine whether this black shale should be considered as part of the Horseshoe Shale Member of the Amsden Formation, or as a separate member.

Channel samples from a measured section (L74–51) having a thickness of about 50 feet (15 m) and from two other sections (L74–88, L74–132) were enriched (relative to other shales) most notably in Ag, Mo, Zn, Hg, and U, to a lesser extent in Cr, Cu, Ni, Pb, and V, and in B only at section L74–132. Malachite was visible in samples C1008R and C1009R (table 17). Anomalous radioactivity was detected with a scintillator at each locality. Many samples had a petroliferous odor, and several determinations of organic carbon showed that this formation may be a source rock for petroleum or other fossil fuels. Although the content of any single metal is apparently not great enough to warrant mining and milling, the content of enriched metals and organic carbon from the entire sequence is substantial.

## Black Shales in the Eocene Aycross Formation

Black shale deposits in the Aycross Formation occur near Holmes Cave in the southern part of the wilderness. Dark-gray and black shales, coaly shales, claystones, and thin beds of oil shale are interlayered with tuff pebbles, coals, and carbonaceous shales. At one locality about 600 feet (183 m) south of Holmes Cave, at an elevation of 9,600 feet, a total thickness of nearly 22 feet (7 m) was measured by J. D. Love and sampled by J. C. Antweiler (fig. 25). The trace-element content was generally low, but some of the oil shale assayed as high as 15.4 gallons per ton. Analyses of interest are in table 18.

**Table 17.** Selected analytical results for samples of black shale from the Amsden Formation and other rocks of Permian, Pennsylvanian, and Mississippian age in Teton County

[Analytical values are in parts per million unless otherwise noted. N, not detected; L, detected but below satisfactory level of measurement shown in parentheses; NA, no analyses]

| Sample No. | Description | Six-step semiquantitative spectrographic analyses[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ag | B | Cr | Cu | Mo | Ni | Pb | V | Zn |
| | Amsden Formation and Madison limestone<br>North Buffalo Fork measured section at field station L74-51 | | | | | | | | | |
| J1060R | Claystone, red, blocky; with green mottling | N | 15 | 50 | 5 | N | 30 | 10 | 20 | N |
| J1059R | Dolomite and limestone, with gray and brown brittle chert | N | L(10) | N | N | N | N | N | L(10) | N |
| J1058R | Limestone, dark-gray, silty but not fissile | N | L(10) | N | N | N | N | N | L(10) | N |
| J1057R | Shale and mudstone, black to dark-gray, limy | N | 10 | 50 | 50 | N | 15 | N | 15 | N |
| J1056R | Shale, black, fissile, hard | N | 10 | 50 | 15 | N | 30 | N | 50 | N |
| J1055R | Mudstone, bluish-gray, hard | N | L(10) | 50 | L(5) | 15 | 30 | L(10) | 50 | N |
| J1054R | Shale, black, hard, massive | 0.5 | 10 | 70 | 15 | 10 | 70 | 15 | 70 | N |
| J10534 | .....do | 1.5 | 10 | 70 | 15 | 10 | 70 | 15 | 100 | N |
| J1051R | Mudstone, gray, hard, massive | N | L(10) | 30 | L(5) | 30 | 20 | 10 | 30 | N |
| J1051R | Shale, black, platy, very slabby | N | 10 | 70 | 15 | 10 | 30 | 15 | 70 | 300 |
| J1049R | Siltstone and mudstone, interbedded | N | 10 | 50 | L(5) | 15 | 20 | 15 | 30 | L(200) |
| J1048R | Mudstone, gray, hard, massive, limy | N | 10 | 100 | L(5) | N | 15 | 15 | 20 | N |
| J1047R | Siltstone, dark-gray, slabby, interbedded with black shale | N | 10 | 70 | 5 | N | 15 | 15 | 20 | N |
| J1046R | Mudstone, gray, hard, massive | N | 10 | 50 | N | N | 10 | 10 | 20 | N |
| J1045R | Shale, black, fissile, slabby, hard | N | 20 | 100 | 15 | 5 | 30 | 20 | 70 | 200 |
| J1044R | Mudstone, gray, hard, evenly bedded, coarsely slabby | 0.5 | 15 | 50 | L(5) | 10 | 15 | 10 | 70 | N |
| J1043R | Shale, black, hard, petroliferous | .5 | 15 | 100 | 15 | 15 | 50 | 20 | 150 | 200 |
| J1042R | Mudstone, gray, limy; forms even, conspicuous rib | N | L(10) | 30 | L(5) | L(5) | 15 | N | 100 | N |
| J1041R | Shale, black, hard, slabby, petroliferous | 0.5 | 10 | 100 | 15 | 10 | 70 | 15 | 200 | 300 |
| J1040R | Mudstone, dark-gray to black | N | 15 | 70 | 7 | 10 | 30 | 10 | 100 | 300 |
| J1039R | Shale, black, hard, platy | 1.5 | 15 | 150 | 30 | 50 | 100 | 20 | 500 | 500 |
| J1038R | .....do | 1 | 10 | 100 | 15 | 10 | 70 | 20 | 150 | 200 |
| J1037R | Mudstone, gray, dense, massive | N | L(10) | 50 | L(5) | L(5) | 15 | L(10) | 100 | N |
| J1036R | Shale, black, hard, platy | 1 | 10 | 150 | 15 | 15 | 70 | 20 | 300 | 300 |
| J1034R | Shale, black, hard, platy | .7 | 10 | 150 | 15 | 50 | 100 | 20 | 300 | 300 |
| J1033R | .....do | .7 | 10 | 100 | 15 | 50 | 70 | 20 | 300 | 300 |
| J1032R | Mudstone, dark-gray, hard, massive | N | L(10) | 70 | 7 | 30 | 70 | 10 | 200 | 200 |
| J1031R | Shale, black, fissile, hard | 2 | 30 | 150 | 30 | 100 | 150 | 20 | 1,500 | 500 |
| J1030R | Mudstone, dark-gray, hard, highly petroliferous | N | L(10) | 50 | 7 | 50 | 70 | 10 | 200 | 700 |
| | Amsden Formation and other rocks of Permian, Pennsylvanian, and Mississippian age<br>Clear Creek Lake measured section at field station L74-132 | | | | | | | | | |
| J1118R | Sandstone, white, moderately pure | N | L(10) | N | N | N | N | N | 20 | N |
| J1117R | Shale, ocher and pink, soft | N | 150 | 100 | L(5) | N | 100 | 10 | 50 | N |
| J1117R | Dolomite, basal part of marker ledge | N | L(10) | N | N | N | N | 10 | 10 | N |
| J1115R | Limestone, blue-gray, cherty, top bed | N | N | N | N | 5 | N | N | 10 | N |
| J1114R | Limestone, blue-gray, basal ledge | N | L(10) | N | 20 | N | N | N | 10 | N |
| J1113R | Shale, black, uppermost exposure | N | 50 | 150 | 30 | N | 70 | N | 150 | N |
| J1112R | Shale, black, slabby, hard | 1 | 70 | 150 | 30 | 10 | 100 | 20 | 300 | N |
| J1111R | .....do | 1 | 50 | 150 | 20 | 70 | 150 | 70 | 1,000 | 700 |
| J1110R | .....do | 1.5 | 30 | 150 | 30 | 150 | 150 | 50 | 700 | 1,000 |
| J1109R | .....do | 2 | 70 | 150 | 50 | 70 | 150 | 150 | 1,000 | 1,500 |
| J1108R | .....do | 3 | 50 | 200 | 70 | 200 | 300 | 100 | 1,500 | 1,500 |
| J1107R | .....do | 5 | 70 | 200 | 70 | 150 | 300 | 70 | 1,500 | 1,500 |
| J1105R | Shale, black; radioactive part of sequence | 3 | 70 | 150 | 50 | 150 | 300 | 30 | 1,500 | N |
| J1104R | Shale at base of unit | 3 | 150 | 150 | 70 | 150 | 300 | 70 | 1,500 | N |
| J1102R | Sandstone, light-tan | N | 70 | 70 | 5 | N | 15 | 10 | 50 | N |
| J1101R | Sandstone, light-tan, soft, crossbedded | N | 50 | N | L(5) | 7 | 7 | L(10) | 20 | N |
| J1100R | Sandstone, 24 ft (7.31 m) above base | N | 50 | N | L(5) | N | 7 | N | 20 | N |
| J1099R | Sandstone, 16 ft (4.88 m) above base | N | 70 | 70 | L(5) | 5 | 10 | N | 20 | N |
| J1098R | Sandstone, 8 ft (2.44 m) above base | N | 20 | L(10) | N | N | 5 | 10 | 20 | N |
| J1097R | Sandstone at base | N | 30 | 70 | N | N | N | 10 | 30 | N |
| J1096R | Limestone, from top of Madison Limestone | N | L(10) | N | N | N | 7 | 10 | 15 | N |
| J1094R | Limestone, blue-gray, massive, hard | N | N | N | N | N | N | N | 10 | N |
| J1093R | Limestone, blue-gray | N | N | N | N | N | N | N | 10 | N |
| J1092R | .....do | N | N | N | N | N | N | N | 10 | N |
| J1091R | .....do | N | L(10) | N | N | N | N | 30 | 10 | N |
| J1090R | .....do | N | N | N | N | N | N | N | 10 | N |
| J1089R | Dolomite, light-gray to tan | N | L(10) | N | L(5) | N | N | N | 20 | N |
| J1088R | Limestone, blue-gray, fetid | N | N | N | N | N | N | N | 10 | N |
| J1087R | Limestone, "zebra" chert zone | N | N | N | N | N | N | N | 10 | N |

**Table 17.** Selected analytical results for samples of black shale from the Amsden Formation and other rocks of Permian, Pennsylvanian, and Mississippian age in Teton County—Continued

| Sample No. | Inst. Hg[2] | CxHM[2] | Ac Th[3] | Ac U[3] | Percent carbonate carbon[4] | Percent organic carbon[4] | Calculated oil (gal/ton)[5] |
|---|---|---|---|---|---|---|---|
| Amsden Formation and Madison limestone North Buffalo Fork measured section at field station L74-51 | | | | | | | |
| J1060R | L(0.02) | L(1) | NA | NA | NA | NA | NA |
| J1059R | .02 | 4 | 0.024 | 1.36 | NA | NA | NA |
| J1058R | L(.02) | 2 | NA | NA | NA | NA | NA |
| J1057R | .02 | 17 | NA | NA | NA | NA | NA |
| J1056R | .04 | 7 | NA | NA | NA | NA | NA |
| J1055R | .04 | 1 | NA | NA | NA | NA | NA |
| J1054R | .04 | 2 | 1.09 | 10.69 | NA | NA | NA |
| J10534 | .04 | 9 | 1.89 | 12.47 | NA | NA | NA |
| J1051R | .02 | 2 | .53 | 4.05 | NA | NA | NA |
| J1051R | .06 | 80 | 4.24 | 12.28 | NA | NA | NA |
| J1049R | .02 | 1 | NA | NA | 8.48 | 1.2 | 1.7 |
| J1048R | .02 | 5 | NA | NA | NA | NA | NA |
| J1047R | .02 | 5 | NA | NA | 8.00 | .09 | 1.3 |
| J1046R | .04 | 3 | NA | NA | NA | NA | NA |
| J1045R | .06 | 40 | NA | NA | NA | NA | NA |
| J1044R | .04 | 5 | 2.02 | 6.55 | NA | NA | NA |
| J1043R | .04 | 60 | NA | NA | 5.01 | 2.7 | 3.9 |
| J1042R | .04 | 7 | .03 | 3.57 | NA | NA | NA |
| J1041R | .06 | 80 | NA | NA | NA | NA | NA |
| J1040R | .02 | 60 | NA | NA | 9.27 | 1.2 | 1.7 |
| J1039R | .08 | 160 | NA | NA | NA | NA | NA |
| J1038R | .04 | 60 | .59 | 17.01 | NA | NA | NA |
| J1037R | L(.02) | 4 | .53 | 4.82 | NA | NA | NA |
| J1036R | .08 | 80 | 4.05 | 22.01 | NA | NA | NA |
| J1034R | .06 | 60 | NA | NA | NA | NA | NA |
| J1033R | .06 | 100 | NA | NA | NA | NA | NA |
| J1032R | .04 | 40 | NA | NA | NA | NA | NA |
| J1031R | .24 | 140 | NA | NA | NA | NA | NA |
| J1030R | .04 | 100 | NA | NA | NA | NA | NA |
| Amsden Formation and other rocks of Permian, Pennsylvanian, and Mississippian age Clear Creek Lake measured section at field station L74-132 | | | | | | | |
| J1118R | L(0.02) | L(1) | NA | NA | NA | NA | NA |
| J1117R | L(.02) | 1 | NA | NA | NA | NA | NA |
| J1117R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1115R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1114R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1113R | L(.02) | 3 | NA | NA | NA | NA | NA |
| J1112R | .06 | 1 | NA | NA | NA | NA | NA |
| J1111R | .14 | 40 | NA | 19 | NA | NA | NA |
| J1110R | .16 | 60 | NA | NA | NA | NA | NA |
| J1109R | .20 | 60 | NA | NA | NA | NA | NA |
| J1108R | .30 | 170 | NA | 24 | NA | NA | NA |
| J1107R | .20 | 90 | NA | NA | NA | NA | NA |
| J1105R | .22 | 3 | NA | 21 | 2.80 | 9.0 | 13.0 |
| J1104R | .28 | 7 | NA | NA | 2.26 | 9.4 | 13.5 |
| J1102R | L(.02) | 1 | NA | NA | NA | NA | NA |
| J1101R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1100R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1099R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1098R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1097R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1096R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1094R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1093R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1092R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1091R | L(.02) | 1 | 41 | 23 | NA | NA | NA |
| J1090R | L(.02) | L(1) | 33 | 86 | NA | NA | NA |
| J1089R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1088R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| J1087R | L(.02) | L(1) | NA | NA | NA | NA | NA |

**Table 17.** Selected analytical results for samples of black shale from the Amsden Formation and other rocks of Permian, Pennsylvanian, and Mississippian age in Teton County—Continued

| Sample No. | Description | Six-step semiquantitative spectrographic analyses[1] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ag | B | Cr | Cu | Mo | Ni | Pb | V | Zn |
| | Amsden Formation and Madison Limestone<br>Nowlin Meadow measured section at field station L74-88 | | | | | | | | | |
| C1021R | Shale, brick-red; Amsden Formation.... | N | 30 | 70 | 15 | N | 30 | 10 | 50 | N |
| C1020R | Shale, brick-red..... | N | 15 | 50 | 15 | N | 30 | 10 | 50 | N |
| C 212R | .....do..... | N | 50 | 100 | 10 | N | 50 | 30 | 100 | N |
| C1025R | Quartzite, red and gray..... | N | N | N | N | N | N | N | L(10) | N |
| C1019R | Limestone, purplish-gray, hard..... | N | N | N | N | N | L(5) | N | 10 | N |
| C 211R | Limestone, blue-gray; brown chert concretions..... | N | L(10) | 10 | 5 | N | L(5) | L(10) | 15 | N |
| C1024R | .....do..... | N | N | N | L(5) | N | 5 | N | L(10) | N |
| C1022R | Limestone, blue-gray, mottled..... | N | L(10) | N | N | N | N | N | L(10) | N |
| C1018R | Shale, soft, red, plastic..... | N | 50 | 150 | 7 | L(5) | 70 | 15 | 150 | N |
| C1017R | Shale, dark-gray, soft, silty..... | N | 20 | 150 | L(5) | L(5) | 70 | 20 | 200 | N |
| C1016R | Shale, dark-gray, soft; silty..... | N | L(10) | 150 | 5 | 10 | 50 | 15 | 500 | N |
| C1015R | Shale, black at base; interbedded with dolomite..... | N | 10 | 150 | 15 | 7 | 70 | L(10) | 300 | N |
| C1014R | Dolomite, dark-gray, finely crystalline..... | N | L(10) | 50 | 20 | 20 | 30 | 10 | 300 | N |
| C1013R | Shale, black, fissile..... | N | 10 | 100 | 30 | 5 | 70 | 15 | 700 | L(200) |
| C 201R | .....do..... | N | 50 | 150 | 70 | 15 | 100 | 20 | 1,500 | N |
| C 209R | .....do..... | N | L(10) | 100 | 100 | 15 | 70 | 20 | 1,000 | N |
| C1011R | Dolomite, brown, fetid, hard, ledgy..... | N | L(10) | 70 | 150 | 20 | 70 | L(10) | 700 | N |
| C 208R | 1973 sample; same locality as C1011R..... | 1.5 | L(10) | 100 | 100 | 15 | 70 | 20 | 1,000 | N |
| C1010R | Shale, black..... | 1 | 15 | 150 | 1,500 | 10 | 150 | 10 | 2,000 | N |
| C 207R | Approximate interval of 1973 sample at C1010R..... | 1.5 | L(10) | 50 | 300 | 1,000 | 100 | 20 | 700 | N |
| C1009R | Shale, black, radioactive..... | 2 | 15 | 150 | 1,500 | 100 | 100 | 10 | 5,000 | N |
| C 205R | 1973 sample; same interval as C1009R..... | 2 | 70 | 150 | 3,000 | 1,000 | 200 | 20 | 3,000 | N |
| C 206R | 1973 sample; same interval as C1009R..... | 1.5 | 70 | 150 | 1,500 | 30 | 150 | N | 2,000 | N |
| C1008R | Shale, black, hard, highly fissile.... | N | 10 | 50 | 700 | 150 | 70 | L(10) | 500 | N |
| C 204R | 1973 sample; same interval as C1008R..... | 1.5 | 70 | 150 | 2,000 | 1,000 | 150 | 20 | 2,000 | N |
| C 203R | 1973 sample; same interval as C1008R..... | N | 50 | 100 | 300 | 500 | 300 | 20 | 1,000 | N |
| C 202R | 1973 sample; same interval as C1008R..... | N | L(10) | 70 | 200 | 150 | 150 | N | 700 | N |
| C1007R | Dolomite, dark-brown, very hard..... | N | L(10) | 30 | 30 | 70 | 150 | N | 200 | N |
| C1006R | Shale, black, fissile, petroliferous.. | N | L(10) | 50 | 30 | 200 | 100 | 15 | 100 | N |
| C1005R | Dolomite, brown, fetid, hard, massive..... | N | L(10) | 50 | 10 | 70 | 100 | 10 | 300 | N |
| C1004R | Shale, black or dark-brown..... | N | 10 | 70 | 15 | 50 | 100 | 10 | 300 | N |
| C1003R | Dolomite, pink and tan, dense..... | N | 10 | 70 | 15 | 50 | 100 | 10 | 300 | N |
| C1019R | Limestone, purplish-gray, hard..... | N | N | N | N | N | L(5) | N | 10 | N |
| C1002R | Dolomite, tan, shaly, and silty..... | N | L(10) | 30 | 5 | 20 | 70 | N | 100 | N |
| C1001R | Shale, red and gray..... | N | 20 | N | 10 | 50 | 70 | L(10) | 70 | N |
| C1000R | Dolomite, yellowish-gray, massive..... | N | 10 | N | L(5) | 20 | 30 | N | 30 | N |
| C6R | Sandstone, light-pink, soft, 3.3 ft (1.2 m)..... | N | L(10) | N | N | N | N | N | L(10) | N |
| C5R | Sandstone, 1.6 ft (0.48 m) underlying C6R..... | N | L(10) | N | N | N | L(5) | N | L(10) | N |
| C4R | Sandstone, 2.5 ft (0.76 m) underlying C5R..... | N | 20 | N | N | N | N | N | L(10) | N |
| C3R | Sandstone, 2.7 ft (0.81 m) underlying C4R..... | N | L(10) | N | N | N | 5 | N | 10 | N |
| C2R | Sandstone, 0.9 ft (0.28 m) underlying C3R..... | N | L(10) | N | N | N | 5 | N | 30 | N |
| C1R | Sandstone, 1.25 ft (0.38 m) underlying C2R..... | N | L(10) | N | L(5) | N | 7 | N | 30 | N |
| C201R | Limestone and dolomite from Madison Limestone..... | N | N | 10 | 5 | N | N | L(10) | 10 | N |

[1]Analyses by R. T. Hopkins, Jr., using methods described by Grimes and Marranzino (1968).

[2]Analyses by J. G. Viets using methods described in Ward and others (1969): Inst. Hg, instrumental determination of mercury, and CxHM, cold extractable heavy metals.

[3]Activation analyses for thorium and uranium by H. T. Millard, Jr.

[4]Total carbon was determined by combustion conductometric $CO_2$ by V. E. Shaw; carbonate carbon was determined by $H_3PO_4$ digestion gasometric $CO_2$ by T. L. Yager; organic carbon is total carbon less carbonate carbon.

[5]Gallons oil per ton calculated by multiplying organic carbon by 1.44 based on assumption that organic substances in rock would convert in the same manner as Green River oil shale.

[6]Fluorimetric U determination by F. N. Ward.

**Table 17.** Selected analytical results for samples of black shale from the Amsden Formation and other rocks of Permian, Pennsylvanian, and Mississippian age in Teton County—Continued

| Sample No. | Inst. Hg[2] | CxHM[2] | Ac Th[3] | Ac U[3] | Percent carbonate carbon[4] | Percent organic carbon[4] | Calculated oil (gal/ton)[5] |
|---|---|---|---|---|---|---|---|
| | | | Amsden Formation and Madison Limestone | | | | |
| | | | Nowlin Meadow measured section at field station L74-88 | | | | |
| C1021R | L(0.02) | 1 | NA | NA | NA | NA | NA |
| C1020R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| C 212R | .18 | 3 | NA | NA | NA | NA | NA |
| C1025R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| C1019R | L(.02) | 1 | NA | NA | NA | NA | NA |
| C 211R | L(.02) | 1 | NA | NA | NA | NA | NA |
| C1024R | L(.02) | L(1) | .73 | 0.81 | NA | NA | NA |
| C1022R | L(.02) | L(1) | 1.94 | .38 | NA | NA | NA |
| C1018R | .45 | L(1) | NA | NA | NA | NA | NA |
| C1017R | .16 | 1 | NA | NA | NA | NA | NA |
| C1016R | .10 | 3 | 6.14 | 16.34 | NA | NA | NA |
| C1015R | .20 | L(1) | NA | NA | NA | NA | NA |
| C1014R | .18 | 4 | NA | NA | NA | NA | NA |
| C1013R | .12 | 20 | NA | NA | NA | NA | NA |
| C 201R | NA | NA | NA | 50 | 7.88 | 1.1 | 1.65 |
| C 209R | NA | NA | NA | [6]40 | 9.60 | .3 | .45 |
| C1011R | .22 | 40 | 9.88 | 41.48 | NA | NA | NA |
| C 208R | NA | NA | NA | [6]100 | 4.98 | 7.4 | 11.10 |
| C1010R | .14 | 450 | NA | [6]79.0 | NA | NA | NA |
| C 207R | NA | NA | NA | 40 | 10.5 | .1 | .15 |
| C1009R | .14 | 600 | NA | [6]75.0 | 4.39 | 4.8 | 6.90 |
| C 205R | NA | NA | NA | [6]110 | 4.95 | 4.7 | 7.05 |
| C 206R | NA | NA | NA | [6]100 | 5.98 | 2.5 | 3.75 |
| C1008R | .20 | 3 | 4.10 | 87.39 | NA | NA | NA |
| C 204R | NA | NA | NA | [6]100 | 5.48 | 3.8 | 5.70 |
| C 203R | NA | NA | NA | [6]60 | 6.55 | 2.5 | 3.75 |
| C 202R | NA | NA | NA | [6]50 | 9.62 | .9 | 1.35 |
| C1007R | .12 | 1 | NA | NA | NA | NA | NA |
| C1006R | .08 | 2 | NA | NA | NA | NA | NA |
| C1005R | .06 | L(1) | NA | NA | NA | NA | NA |
| C1004R | .12 | L(1) | NA | NA | 7.77 | .6 | .9 |
| C1003R | .12 | L(1) | NA | NA | 7.77 | .6 | .9 |
| C1019R | L(.02) | 1 | NA | NA | NA | NA | NA |
| C1002R | .04 | L(1) | NA | NA | NA | NA | NA |
| C1001R | .04 | L(1) | 4.74 | 6.60 | NA | NA | NA |
| C1000R | L(.02) | L(1) | NA | NA | NA | NA | NA |
| C6R | L(.02) | NA | NA | NA | NA | NA | NA |
| C5R | .02 | NA | NA | NA | NA | NA | NA |
| C4R | L(.02) | NA | NA | NA | NA | NA | NA |
| C3R | L(.02) | NA | NA | NA | NA | NA | NA |
| C2R | L(.02) | NA | NA | NA | NA | NA | NA |
| C1R | L(.02) | NA | NA | NA | NA | NA | NA |
| C201R | .04 | NA | NA | NA | NA | NA | NA |

Another locality of carbonaceous strata in the Aycross Formation is about 900 feet (275 m) west of Holmes Cave and 150 feet (40 m) stratigraphically above the Aycross at the cave mouth. Other similar deposits occur in the vicinity. The resource potential is probably low.

## Coal

All the coal beds of possible economic interest in the Teton Wilderness are in the Bacon Ridge Sandstone and in the overlying Sohare Formation in the western

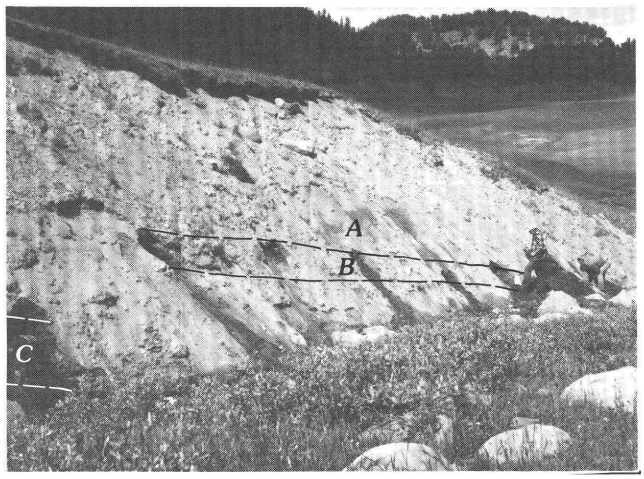



**Figure 25.** Measured and sampled section of Aycross Formation 600 feet (183 m) south of Holmes Cave, Togwotee Pass quadrangle. A, green tuffaceous claystone; B, coal and carbonaceous shale; C, radioactive (0.02 mR/hr) organic-rich shale (see table 18 for analyses). Photograph by J. D. Love, Aug. 27, 1973.

third of the wilderness. Plate 6 shows the lithologic details in five measured sections having a total stratigraphic thickness of at least 3,200 feet (975 m). In addition, thin impure coals occur in the lower part of the Frontier Formation and in the Aycross Formation near Holmes Cave as described previously. The U.S. Bureau of Reclamation operated a coal mine, about 1910, in the Mesaverde Formation on Pilgrim Creek within the boundary of the Teton Wilderness. Later, the U.S Bureau of Reclamation and private individuals also opened coal mines in the Bacon Ridge Sandstone, north of Buffalo Fork near Lava Creek, 2 miles (3 km) south of the wilderness.

The lower part of the Frontier Formation on the southeast end of the Bailey anticline has one impure coal bed 2 feet (0.6 m) thick. On Wildcat Peak, the coal-bearing Bacon Ridge Sandstone is well exposed (fig. 26), and a detailed section was measured (pl. 6, section 3). An impure coal bed 2.7 feet (0.8 m) thick occurs about 225 feet (69 m) above the base; a second, 2.5 feet (0.76 m) thick, is 260 feet (79 m) above the base; and a third, 3 feet (1 m) thick, is 580 feet (177 m) above the base. A few feet higher in the section, southeast of Wildcat Peak, is a coal bed 5.5 feet (1.7 m) thick that was sampled and analyzed (B-33A, table 19; pl. 6). The highest quality coal in this seam, sample B-33, has a thickness of 1 foot (0.3 m).

In the Kitten measured section of the Bacon Ridge

**Table 18.** Selected analytical results on samples from Eocene Aycross Formation, Togwotee Pass quadrangle, Teton Wilderness
[Analyses in parts per million unless otherwise indicated. nd, not determined; N, not detected by analytical method used; L, detected, but below satisfactory measurement level given in parentheses]

| Sample No. | Description | Six-step semiquantitative spectrographic analyses | | | | Ash[2] (pct) | X-ray $K_2O$ (pct) | Fluorescence analyses[3] (percent) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mn | Ba | Cu | Mo | | | $Na_2O$ | $P_2O_5$ | $SO_3$ | Se |
| S326M | Dark-gray shale (6 in.).... | 200 | 1000 | 100 | 7 | nd | nd | nd | nd | nd | nd |
| S327F | Coal (5 in.)..... | 3000 | 1000 | 100 | 100 | 79.7 | 2.16 | 0.68 | 1.65 | 4.24 | 3.9 |
| S331F | Coal (15 in.)..... | 300 | 1500 | 150 | 50 | 62.3 | 1.55 | .72 | .57 | 1.96 | 2.5 |
| S332M | Black shale (6 in.)..... | 200 | 1000 | 100 | 7 | nd | nd | nd | nd | nd | nd |
| S336F | Oil shale (2.5 in.)..... | 3000 | 500 | 15 | N | 90.6 | .83 | .21 | 1.87 | 2.37 | 3.3 |
| S337M | Oil shale (2.5 in.)..... | 3000 | 700 | 30 | N | nd | nd | nd | nd | nd | nd |
| S338M | .....do..... | 3000 | 500 | 30 | L(7) | nd | nd | nd | 1.20 | nd | nd |
| S339F | Dark shale (6 in.)..... | 3000 | 500 | 100 | 7 | nd | nd | nd | .65 | nd | nd |
| S340F | .....do..... | 7000 | 500 | 15 | 7 | nd | nd | nd | nd | nd | nd |
| S341F | Oil shale (6 in.)..... | 3000 | 500 | 70 | L(7) | nd | nd | nd | nd | nd | nd |
| S342F | Coaly shale (6 in.)..... | 200 | 1500 | 100 | 10 | 894 | 3.46 | .95 | .36 | 1.45 | .6 |
| S343F | Carbonaceous shale..... | 150 | 1500 | 70 | 7 | nd | 1.23 | .68 | .95 | .88 | 1.6 |
| S344F | .....do..... | 100 | 3000 | 70 | N | nd | nd | nd | nd | nd | nd |

[1]Analyses by R. T. Hopkins, Jr.

[2]Percent ash determined by gravimetric method ashed at 525°C (977°F) by A. W. Hanbert.

[3]Determinations by J. S. Wahlberg.

[4]Analyses by G. D. Shipley and Claude Huffmann, Jr.

[5]As determined spectrophotometrically by E. J. Fenelly.

[6]Total carbon determined by induction furnace, carbonate carbon determined gasometrically, and organic carbon by difference by Irving C. Frost. Hg determined by wet oxidation and atomic absorption method by J. A. Thomas.

[7]Gallons oil per ton calculated by multiplying organic carbon by 1.44 based on assumption that organic substances in rock would convert in the same manner as Green River oil shale.

**Table 18.** Selected analytical results on samples from Eocene Aycross Formation, Togwotee Pass quadrangle, Teton Wilderness—Continued

| Sample No. | Atomic absorption analyses on ash[4] | | | Analyses[5] "as received" | | Carbon[6] (percent) | | | Oil (gal/ton[7]) |
|---|---|---|---|---|---|---|---|---|---|
| | Cu | Li | Zn | As | Hg | Total | Carbonate | Organic | |
| S326M | nd | nd | nd | nd | nd | 1.24 | 0.51 | 0.7 | 1.0 |
| S327F | 92 | 26 | 88 | 15 | 0.05 | nd | nd | nd | nd |
| S331F | 134 | 46 | 62 | 15 | .05 | nd | nd | nd | nd |
| S332M | nd | nd | nd | nd | nd | 1.72 | .20 | 1.5 | 2.2 |
| S336F | 42 | 16 | 44 | 5 | nd | 12.4 | 9.34 | 3.1 | 4.5 |
| S337M | nd | nd | nd | nd | nd | 14.8 | 6.69 | 8.2 | 11.8 |
| S338M | nd | nd | nd | nd | nd | 15.1 | 6.66 | 8.4 | 12.2 |
| S339F | nd | nd | nd | nd | nd | 10.0 | 3.43 | 6.5 | 9.4 |
| S340F | nd | nd | nd | nd | nd | 11.1 | 8.52 | 2.6 | 3.7 |
| S341F | nd | nd | nd | nd | nd | 16.3 | 5.59 | 10.7 | 15.4 |
| S342F | 100 | 46 | 92 | 8 | .07 | nd | nd | nd | nd |
| S343F | 66 | 20 | 42 | 15 | .06 | nd | nd | nd | nd |
| S344F | nd | nd | nd | nd | nd | 3.1 | 0.00 | 3.1 | 4.5 |

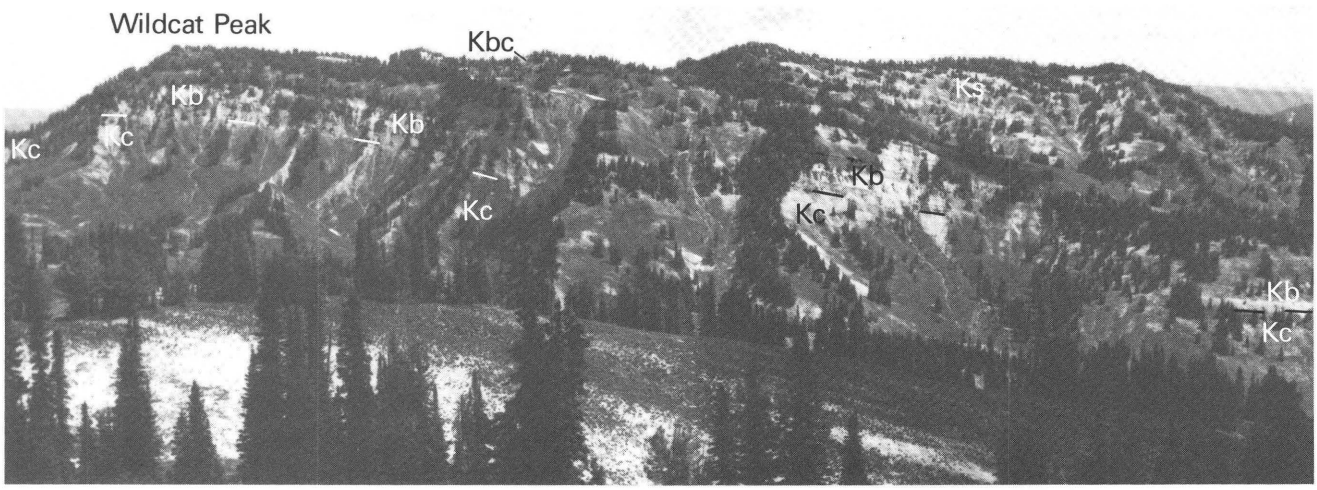



**Figure 26.** Wildcat Peak as viewed toward the east from Kitten Ridge. Deep valley extending across photograph is cut in soft Cody Shale along crest of Wildcat anticline. Kc, Cody Shale; Kb, thick cliff-forming basal sandstones in Bacon Ridge Sandstone; Kbc, coal bed 5.5 feet (1.7 m) thick in Bacon Ridge Sandstone (lines on basal contact); Ks, Sohare Formation. Thickness of visible part of section above base of Bacon Ridge Sandstone is nearly 3,000 feet (914 m). Photograph by J. D. Love, July 18, 1972 (Love, Antweiler, and Williams, 1975, fig. 7).

Sandstone (pl. 6, section 2), on the west flank of the Wildcat anticline, a coal 2.5 feet (0.8 m) thick is 207 feet (63 m) above the base of the formation. A second, 3 feet (0.9 m) thick, is 241 feet (73.5 m) above the base; and a third, 2.1 feet (0.6 m) thick, is 583 feet (178 m) above the base of the formation. These probably correlate with the lower three coals in the Wildcat Peak section.

In the section on Arizona Creek (pl. 6, section 1), several coals occur in the Bacon Ridge Sandstone as listed in table 20. It is not known how these coals correlate with the ones on Wildcat Peak and at Kitten Ridge.

Three thin coal beds in the Bacon Ridge Sandstone were sampled along Bailey Creek canyon 4 miles (6.4 km) south-southeast of the Arizona Creek coals. The lower two are each less than 1 foot (30 cm) thick, but the uppermost is 2 feet (0.6 m) of black shiny coal. Analyses are given in table 19 (first three Bacon Ridge entries).

In the Enos Creek area, a detailed section (pl. 6, section 4) containing several coals was measured in the Bacon Ridge Sandstone and the overlying Sohare Formation (table 20).

**Table 19.** Analyses of coal samples from the Teton Wilderness
[nd, not determined]

| Field No. | Locality | Thickness (in.) | Coal as received | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Percent | | | Parts per million | | |
| | | | Ash | Total S | Total C | Hg | As | Se |
| **Aycross Formation** | | | | | | | | |
| S327F | Near Holmes Cave..... | 5 | 79.7 | nd | nd | 0.05 | 15 | 3 |
| S331F | .....do..... | 15 | 62.3 | nd | nd | .05 | 15 | 2 |
| **Harebell Formation** | | | | | | | | |
| G3F | Near Pacific-Mink Cr. jct... | 15 | 11.2 | nd | nd | 0.06 | 1 | 1.4 |
| G4F | .....do..... | 15 | 33.1 | nd | nd | .09 | 2 | 2.4 |
| A618F | Buffalo Fork canyon..... | 6 | 55.4 | nd | nd | .19 | 140 | .9 |
| H52F | Near Bobcat Ridge..... | nd | 19.4 | nd | nd | .08 | 2 | 1.3 |
| H53F | .....do..... | nd | 65.8 | nd | nd | .09 | 4 | 1.8 |
| **Mesaverde Formation** | | | | | | | | |
| B-5 | Pilgrim Creek..... | nd | 8.6 | 0.34 | 53.9 | 0.06 | nd | nd |
| B-6 | .....do..... | nd | 72.7 | .15 | 16.4 | .04 | nd | nd |
| **Bacon Ridge Sandstone** | | | | | | | | |
| L72-67-1 | Bailey Creek..... | 42 | 11.5 | 1.21 | 59.6 | 0.60 | nd | nd |
| L72-67-2 | .....do..... | 42 | 12.4 | .60 | 58.9 | .05 | nd | nd |
| L72-67-3 | .....do..... | 24 | 3.5 | .72 | 66.0 | .04 | nd | nd |
| L72-40-A | West of Pilgrim Creek..... | <12 | 27.8 | 1.02 | 51.3 | .31 | nd | nd |
| B33 | Southeast of Wildcat Peak... | 12 | 6.6 | .67 | 57.4 | .14 | nd | nd |
| B33A | .....do..... | 66 | 33.4 | .77 | 37.2 | .17 | nd | nd |
| L72-42 | Kitten Ridge..... | <12 | 7.9 | .87 | 68.5 | .09 | nd | nd |
| G501F | South of Enos Creek..... | 15 | 4.3 | nd | nd | .03 | 1 | 0.7 |
| G502F | .....do..... | 21 | 5.4 | nd | nd | .03 | 2 | 1.2 |
| G503F | .....do..... | 6 | 24.1 | nd | nd | 1.0 | 100 | 4.2 |
| G506F | .....do..... | 8 | 6.8 | nd | nd | .11 | 8 | 1.2 |
| G509F | .....do..... | 9 | 3.9 | nd | nd | .03 | <1 | .6 |
| G510F | .....do..... | 9 | 3.9 | nd | nd | .05 | 1 | .7 |
| G511F | .....do..... | 9 | 4.7 | nd | nd | .05 | 2 | .8 |
| G514F | .....do..... | 15 | 6.3 | nd | nd | .03 | 2 | 1.5 |
| G515F | .....do..... | 10 | 14.8 | nd | nd | .41 | 8 | 1.6 |
| G516F | .....do..... | 3 | 30.4 | nd | nd | .12 | 10 | 2.3 |
| G518F | .....do..... | 10 | 59.1 | nd | nd | .21 | 8 | 2.7 |
| G104F | Box Creek headwaters..... | 12 | 17.1 | nd | nd | .05 | 2 | 3.3 |
| G107F | .....do..... | 11 | 8.4 | nd | nd | .08 | 5 | 1.5 |
| G110F | .....do..... | 7.5 | 28.5 | nd | nd | .07 | 1 | 3.2 |
| G111F | .....do..... | 7.5 | 8.0 | nd | nd | .03 | 1 | 1.1 |
| G114F | .....do..... | 10.5 | 16.1 | nd | nd | .05 | 1 | 1.8 |
| G115F | .....do..... | 10.5 | 18.4 | nd | nd | .04 | 1 | 1.7 |
| G118F | .....do..... | 12 | 11.6 | nd | nd | .09 | 4 | 1.7 |
| A611f | Buffalo Fork canyon..... | 12 | 28.0 | nd | nd | .08 | 8 | 2.2 |
| A612F | .....do..... | 11 | 6.5 | nd | nd | .04 | 8 | .9 |
| I38F | South of Wolverine Meadows.. | 9 | 6.1 | nd | nd | .06 | 8 | 1.2 |
| I41F | .....do..... | 12 | 61.9 | nd | nd | .06 | 1 | 5.9 |
| I42F | .....do..... | 12 | 20.9 | nd | nd | .09 | 2 | 1.9 |
| **Frontier Formation** | | | | | | | | |
| A1810F | North Buffalo Fork canyon... | nd | 9.3 | nd | nd | 0.24 | 25 | nd |
| G1021F | Enos Creek..... | 6 | 4.0 | nd | nd | .14 | 10 | nd |
| G1022F | .....do..... | 5 | 2.9 | nd | nd | .75 | 100 | nd |
| G1023F | .....do..... | 6 | 6.7 | nd | nd | .06 | 8 | nd |
| G84F | .....do..... | 6 | 82.3 | nd | nd | .09 | 5 | 0.5 |
| G85F | .....do..... | 8 | 30.8 | nd | nd | 1.1 | 400 | 3.6 |
| G86F | .....do..... | 6 | 67.2 | nd | nd | .07 | 8 | 1.4 |

**Table 19.** Analyses of coal samples from the Teton Wilderness—Continued

| Field No. | Analyses on coal ash: Percent MgO | $Na_2O$ | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | $K_2O$ | $P_2O_5$ | $SO_3$ | Parts per million Cd | Cu | Li | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Aycross Formation** | | | | | | | | | | | | | | |
| S327F | 2.92 | 0.68 | 43.6 | 12.3 | 6.4 | 14.6 | 2.2 | 1.7 | 4.2 | <1 | 92 | 26 | <23 | 88 |
| S331F | 3.74 | .72 | 58.0 | 17.6 | 6.7 | 1.6 | 2.5 | .6 | 2.0 | <1 | 134 | 46 | 25 | 62 |
| **Harebell Formation** | | | | | | | | | | | | | | |
| G3F | 0.93 | 0.36 | 49.6 | 32.1 | 4.0 | 2.7 | 1.9 | 0.15 | 4.6 | 3 | 74 | 210 | 50 | 116 |
| G4F | .46 | .14 | 58.8 | 33.2 | 1.9 | 1.4 | 1.1 | .32 | 2.3 | <1 | 36 | 166 | 35 | 20 |
| A618F | 1.54 | .76 | 69.6 | 15.2 | 5.0 | .9 | 3.9 | <.05 | 1.1 | <1 | 50 | 46 | 35 | 66 |
| H52F | .71 | .12 | 75.6 | 13.9 | 2.9 | 2.4 | .3 | .09 | 2.9 | <1 | 78 | 38 | 35 | 55 |
| H53F | .52 | .06 | 76.5 | 13.4 | 1.5 | 1.7 | 1.7 | <.05 | .6 | <1 | 50 | 36 | 50 | 50 |
| **Mesaverde Formation** | | | | | | | | | | | | | | |
| B-5 | nd | nd | 42.4 | 11.4 | 6.2 | nd | nd | 0.62 | nd | nd | nd | nd | nd | nd |
| B-6 | nd | nd | 85.9 | 6.8 | .8 | nd | nd | .05 | nd | nd | nd | nd | nd | nd |
| **Bacon Ridge Sandstone** | | | | | | | | | | | | | | |
| L72-67-1 | nd | nd | nd | 24.0 | 7.0 | 12.5 | nd | 0.10 | nd | nd | nd | nd | nd | nd |
| L72-67-2 | nd | nd | 22.0 | 6.0 | 27.6 | nd | nd | .10 | nd | nd | nd | nd | nd | nd |
| L72-67-3 | nd | nd | 35.0 | 13.0 | 12.9 | nd | nd | .20 | nd | nd | nd | nd | nd | nd |
| L72-40-A | nd | nd | 67.4 | 17.0 | 4.5 | nd | nd | .06 | nd | nd | nd | nd | nd | nd |
| B33 | nd | nd | 20.0 | 7.4 | 6.2 | nd | nd | .07 | nd | nd | nd | nd | nd | nd |
| B33A | nd | nd | 63.4 | 12.4 | 2.2 | nd | nd | .11 | nd | nd | nd | nd | nd | nd |
| L72-42 | nd | nd | 45.3 | 13.5 | 6.2 | nd | nd | 1.69 | nd | nd | nd | nd | nd | nd |
| G501F | 3.97 | 0.06 | 13.7 | 8.5 | 10.0 | 24.4 | 0.5 | .12 | 32.6 | <1 | 60 | 4 | <25 | 84 |
| G502F | 4.94 | .08 | 23.5 | 10.0 | 7.6 | 21.9 | .4 | .09 | 24.8 | <1 | 50 | 24 | <25 | 64 |
| G503F | 1.74 | .20 | 51.5 | 20.5 | 7.6 | 6.8 | 1.5 | .10 | 6.2 | <1 | 52 | 60 | 35 | 66 |
| G506F | 1.82 | .23 | 68.9 | 14.7 | 3.7 | 1.3 | 4.0 | .33 | 1.0 | 2 | 58 | 20 | <25 | 24 |
| G509F | 4.05 | .52 | 12.6 | 12.3 | 8.6 | 24.8 | .12 | .06 | 28.8 | <1 | 46 | 20 | <25 | 24 |
| G510F | 3.70 | .47 | 15.3 | 11.7 | 8.6 | 24.0 | .20 | .07 | 29.3 | <1 | 54 | 16 | <25 | 20 |
| G511F | 3.23 | .37 | 19.1 | 14.9 | 7.9 | 21.0 | .30 | <.05 | 24.8 | <1 | 64 | 40 | <25 | 30 |
| G514F | 3.63 | .45 | 35.0 | 7.7 | 5.6 | 16.6 | .8 | .15 | 22.7 | 1 | 66 | 20 | <25 | 70 |
| G515F | 3.43 | .03 | 6.3 | 2.9 | 5.8 | 43.3 | .27 | .14 | 9.9 | 10 | 140 | 4 | <25 | 540 |
| G516F | .89 | .14 | 66.1 | 15.6 | 3.8 | 3.5 | 2.8 | .18 | 4.4 | .1 | 44 | 74 | 40 | 184 |
| G518F | 1.51 | .34 | 74.9 | 12.8 | 1.7 | 3.8 | 2.2 | .10 | 4.4 | .5 | 86 | 36 | 25 | 188 |
| G104F | 4.42 | .09 | 13.5 | 9.2 | 1.9 | 37.1 | .17 | .83 | 8.2 | <1 | 42 | 20 | 25 | 32 |
| G107F | 3.75 | .09 | 27.3 | 11.5 | 6.9 | 24.2 | .9 | .46 | 13.4 | <1 | 88 | 28 | 40 | 88 |
| G110F | .94 | .11 | 54.0 | 34.5 | 1.6 | 1.9 | .34 | .05 | 2.7 | <1 | 40 | 90 | 55 | 44 |
| G111F | 3.84 | .08 | 30.5 | 19.6 | 3.5 | 16.6 | .5 | 1.5 | 15.1 | <1 | 48 | 46 | 30 | 60 |
| G114F | 3.15 | .05 | 19.9 | 15.0 | 3.4 | 32.0 | .35 | .15 | 6.7 | <1 | 34 | 46 | 30 | 22 |
| G115F | 2.48 | .05 | 27.9 | 19.5 | 2.1 | 24.9 | .39 | 1.1 | 5.7 | <1 | 30 | 74 | 25 | 20 |
| G118F | 1.08 | .53 | 50.9 | 26.1 | 6.3 | 3.5 | 2.3 | .3 | 5.5 | 3 | 186 | 82 | <25 | 144 |
| A611f | 1.78 | .39 | 62.2 | 15.8 | 4.2 | 3.3 | 3.4 | .1 | 4.3 | <1 | 64 | 40 | 30 | 126 |
| A612F | 3.31 | .62 | 47.5 | 10.0 | 7.7 | 11.9 | .3 | .3 | 12.5 | <1 | 88 | 16 | 30 | 22 |
| I38F | 4.38 | .10 | 20.0 | 12.0 | 6.5 | 26.1 | .8 | .4 | 20.7 | <1 | 68 | 20 | 30 | 62 |
| I41F | .56 | .06 | 88.5 | 7.1 | .9 | 2.1 | 1.3 | <.05 | .9 | <1 | 24 | 28 | <25 | 42 |
| I42F | 2.78 | .05 | 38.4 | 11.4 | 3.3 | 26.9 | 1.1 | .13 | 6.0 | 2 | 70 | 20 | 35 | 114 |
| **Frontier Formation** | | | | | | | | | | | | | | |
| A1810F | 0.99 | 0.33 | nd | nd | nd | nd | nd | nd | nd | nd | 56 | 70 | nd | 130 |
| G1021F | 1.13 | <.10 | nd | nd | nd | nd | nd | nd | nd | <1 | 40 | 100 | 25 | 50 |
| G1022F | 1.51 | <.10 | nd | nd | nd | nd | nd | nd | nd | <1 | 40 | 70 | 35 | 40 |
| G1023F | 1.64 | <.10 | nd | nd | nd | nd | nd | nd | nd | <1 | 40 | 120 | 90 | 15 |
| G84F | .61 | .10 | 72.8 | 17.3 | nd | nd | nd | nd | nd | <1 | 18 | 36 | 25 | 40 |
| G85F | 1.66 | .04 | 27.7 | 13.7 | 25.5 | 15.1 | 0.3 | 0.14 | 4.0 | <1 | 58 | 46 | 50 | 86 |
| G86F | .68 | .07 | 53.7 | 33.1 | 1.6 | 3.7 | .4 | .06 | .43 | <1 | 46 | 114 | 85 | 18 |

**Table 20.** Coal in the Sohare Formation and Bacon Ridge Sandstone, Teton Wilderness and vicinity
[Leaders (---), coal not present]

| Stratigraphic interval above base of Bacon Ridge Sandstone | | Thickness of coaly unit | | Thickness of coal in interval | |
|---|---|---|---|---|---|
| (ft) | (m) | (ft) | (m) | (ft) | (m) |
| Bacon Ridge Sandstone, measured section on Arizona Creek (pl. 6, section 1) | | | | | |
| 947 | 289 | --- | --- | 3.7 | 1.10 |
| 914 | 279 | --- | --- | 2.1 | .64 |
| 801 | 244 | --- | --- | 2.0 | .61 |
| 720 | 220 | --- | --- | 2.1 | .64 |
| 416 | 127 | --- | --- | 1.9 | .58 |
| 398 | 121 | --- | --- | 4.8 | 1.50 |
| Sohare Formation and underlying Bacon Ridge Sandstone south of Enos Creek, Enos Creek detailed section (pl. 6, section 4) | | | | | |
| 1,813 | 552.6 | 2.5 | 0.76 | 2.1 | 0.64 |
| 1,754 | 534.6 | 3.1 | .95 | 2.3 | .70 |
| 1,742 | 531.0 | 3.3 | 1.00 | 1.25 | .38 |
| 1,701 | 518.0 | 7.7 | 2.34 | 6.5 | 1.98 |
| 1,677 | 511.0 | 2.1 | .64 | --- | --- |
| 1,663 | 507.0 | 1.0 | .30 | --- | --- |
| 1,593 | 485.5 | .9 | .28 | --- | --- |
| 1,541 | 470.0 | .9 | .28 | --- | --- |
| 1,523 | 464.0 | 1.3 | .40 | --- | --- |
| 1,469 | 448.0 | 3.0 | .91 | --- | --- |
| 1,430 | 436.0 | 3.0 | .91 | 2.1 | 0.64 |
| 1,410 | 430.0 | .9 | .28 | --- | --- |
| 1,373 | 418.5 | 2.1 | .64 | --- | --- |
| 1,336 | 407.2 | 8.1 | 2.47 | 7.7 | 2.35 |
| 1,244 | 379.2 | 2.5 | .76 | 1.7 | .52 |
| 1,166 | 355.4 | 2.8 | .85 | --- | --- |
| 1,134 | 345.6 | 1.3 | .40 | --- | --- |
| 1,130 | 344.0 | .9 | .28 | --- | --- |
| Bacon Ridge Sandstone and Sohare Formation, Lava Creek section (pl. 6, section 5) | | | | | |
| 439 | 134 | 1.4 | 0.42 | --- | --- |
| 181 | 55 | 1.1 | .33 | --- | --- |
| 178 | 54 | 1.3 | .39 | --- | --- |
| 113 | 34 | 1.0 | .30 | --- | --- |
| 70 | 21 | 3.3 | 1.00 | --- | --- |

The Lava Creek section (pl. 6, section 5) of the Bacon Ridge Sandstone and Sohare Formation extends south-southwest down Lava Creek to U.S. Highway 26 from the top of Davis Hill, which is about 4,200 feet (1,280 m) southwest of the wilderness boundary. This section provides data on coals that dip northeastward under the southern part of the wilderness. The True-Travis oil well (dry) is 1,700 feet (518 m) east of the lowest exposures in the Lava Creek section; it encountered the base of the Bacon Ridge Sandstone at a depth of 405 feet (123 m). The depth to this contact, plus the northeast dip and the topographically higher well site, suggest that the base of the exposed section on Lava Creek is about 200 feet (61 m) above the base of the Bacon Ridge Sandstone.

Several coals in the Bacon Ridge Sandstone and Sohare Formation were measured in the Lava Creek section (table 20). None were sampled for this study, as they are outside the Teton Wilderness.

The distribution, thickness, and composition of the coals in the Teton Wilderness indicate that their resource potential is low, in comparison with other coal deposits farther south in Jackson Hole and elsewhere in Wyoming. They are too thin, too dirty, too discontinuous, and too inaccessible to compete.

## Gypsum

Gypsum crops out in only one locality in the Teton Wilderness but probably underlies the western one-third (375 $mi^2$; 975 $km^2$) of the area. The gypsum is in a single bed within the Gypsum Spring Formation of Middle Jurassic age. Along all but one part of one outcrop of the formation, the gypsum has been leached out by near-surface solution. Wells to the south, however, show it invariably present in normal subsurface sections.

The one outcrop of gypsum is on a high ridge about 5,000 feet (1,525 m) west of the north end of Enos Lake (loc. L73-176, pl. 2). The base of the Gypsum Spring Formation is marked by about 6 inches (15 cm) of pink limestone breccia (sample G82R) and above it is 13 feet (3.96 m) of red soft shale directly underlying the gypsum. The gypsum is in a bed about 50 feet (15 m) thick. It is white, moderately pure, alabaster type, bedded, with some red shale partings. The middle part is most soluble, and the outcrop is marked by a series of solution pits 6–12 feet (1.8–3.66 m) deep.

Analytical data for gypsum samples are shown in McDanal and others (1983, data set 42). The gypsum has a low resource potential because it is too thin and too inaccessible to compete with much larger deposits in the Bighorn basin to the east and the Wind River basin to the southeast.

## Bentonite

Thin beds of bentonite, generally impure, are present in the Mowry Shale, Frontier Formation, Cody Shale, Bacon Ridge Sandstone, and Harebell Formation. Although none of the bentonites is sufficiently thick, pure, or accessible to constitute a mineral resource, their trace-element content is worth noting. Some of them have concentrations of silver (as much as 5 ppm), molybdenum, and tin (table 4, data set 15, McDanal and others, 1983). Those in the Mowry Shale in the Teton Corridor have been described (Love, Antweiler, and Williams, 1975), and are generally less than 2 feet (0.6 m) thick.

Nine bentonite beds, the thickest a pale-lemon-yellow bed 3 feet (0.9 m) thick, were measured in the Frontier Formation (basal part of the Arizona Creek section; thickest beds are shown in pl. 6) near the southeast end of the exposed part of the Bailey anticline. They are associated with plastic shales and constitute an unstable zone that is marked by landslides at all outcrops. The Arizona Creek section has been extensively trampled and licked by elk and deer. In places licked holes extend as much as 2 feet (0.6 m) into the hillside. These beds contain an unidentified yellow bitter salt (O. A. Beath, University of Wyoming, written commun., 1950). Sample B–178 from the Frontier Formation is a bentonite in the basal part of the formation but from a locality east of the Teton Corridor. An impure bentonite 10.7 feet (3.3 m) thick is present in the Frontier Formation in the Enos Creek section (pl. 6).

A 2.2 foot (67-cm) bed of light-gray impure micaceous bentonite is near the base of the Cody Shale in the Arizona Creek section (pl. 6), and a few thinner beds of bentonite occur higher in the formation. A 3.3 foot (1 m) pearl-gray biotitic bentonite is present about 600 feet (180 m) above the base of the Bacon Ridge Sandstone in the Arizona Creek section (pl. 6), and is probably part of the pearl-gray marker zone that is widespread in the Bacon Ridge Sandstone of Jackson Hole (Love, Hose, and others, 1951).

Several impure bentonites 5–10 ft (1.5–3 m) thick are present in the lower and middle parts of the Harebell Formation near the southern boundary of the Teton Wilderness west of North Buffalo Fork.

## Building Stone

The Flathead Formation is a possible source of attractive building stone at several localities on the north side of Angle Mountain, along North Buffalo Fork, and on the south side of Terrace Mountain. All these localities, however, are remote; stone of comparable quality could be obtained much more cheaply at many other localities in northwestern Wyoming. The same statement applies to the Madison Limestone and Cambrian limestones on the flanks of the Washakie Range. The crystal-poor part of the Huckleberry Ridge Tuff has been used by residents of Teton County for building stone. It is colorful in some places (red, orange, pink, purple, and gray), is lightweight, easily cut and shaped, and moderately durable. No quarries have been opened in or near the wilderness; all are farther south in Jackson Hole. The largest quarry was opened by the U.S. Bureau of Reclamation at the northwest end of Signal Mountain 5 miles (8 km) south of the wilderness and produced riprap for the adjacent Jackson Lake dam. Occurrences in other parts of Jackson Hole are more accessible than those in the western part of the Teton Wilderness.

## Sand and Gravel

Sand and gravel deposits are not as plentiful in the western segment of the wilderness as they are elsewhere in Jackson Hole, and there is no unique quality that would make them particularly attractive. Most of the deposits of sand and gravel in the eastern segment of the wilderness are poorly sorted; they also contain a high proportion of soft volcanic fragments that makes them generally unsuitable for concrete and road metal.

## Radioactive Springs

Radioactive cold water has deposited moderately radioactive travertine at Soda Springs, about 1 mile (1,600 m) east-northeast, upstream, from the junction of Soda Fork and North Buffalo Fork. These springs have not previously been described, as far as we know. There are two areas of active springs. The eastern one is the largest, with cold water (50°F; 10°C) emerging from a pool 15 feet (4.57 m) across and flowing an estimated 32,000 gallons (121,600 L) per day (as of July 20, 1974). The water is highly astringent (hence the name Soda Springs) but supports algae and is drunk by elk. Nonflammable gas with a sulfur odor continually bubbles up from many orifices.

Brown, crudely stratified travertine 10 feet (3.5 m) or more in thickness has been deposited, apparently during a long period of time, around the orifice. The travertine encloses many leaf impressions and snails. Bedrock on the north side of the spring is dense Archean dark-green gneiss and greenstone, with foliation tilted steeply southeastward.

The most radioactive travertine is on the southeast margin of the pool and is stained red and black with iron- and manganese-rich layers. The maximum radioactivity

is about 1.0 mR/hr, but the average throughout the travertine deposit ranges from 0.05 to 0.2 mR/hr. A broad bare mound of red, white, and brown travertine has been built up downslope from the main orifice.

The smaller of the two springs is about 400 feet (122 m) west-northwest of the larger spring and flows about 14,000 gallons (53,200 L) per day of water (as of July 20, 1974) with a temperature of 46°F (8°C). The water is strongly astringent but not as much as that from the larger spring. This deposit is not as radioactive as the deposit at the largest spring, and less gas accompanies the water.

Samples of travertine and water showed only traces of uranium. The radioactivity is probably due to radon gas and radium.

Another area of travertine is along the Archean-swamp contact about 300 feet (90 m) west-southwest of the smaller spring. At the time of examination this site was nearly dormant, and its radioactivity was little above background.

A portable core drill was used by Lon Imeson (now deceased) to prospect the most radioactive area during the uranium boom of the 1950's. No map is available of the drill sites or of the depth of the core holes, or of the analyses of the cores. Some of the cores were observed (by J. D. Love) and were of gray coarse-grained sandstone, probably the Flathead Sandstone. Presumably, the sites were south of the springs, on the south side of the Soda Fork normal fault (pl. 1). If they had been on the north side, dark-green Archean rocks would have been encountered. The mineralized water comes up along this concealed fault, and the sources of radioactivity and soda are probably in the Archean rocks.

These radioactive springs have no resource significance, but they are a curiosity, as they are the only springs of this type in the region. It is not known if the radioactivity is sufficient to be a health hazard to people. The springs are along one of the most traveled trails in this part of the Teton Wilderness, and trail use is continually increasing. Therefore, we recommend that the possibility of a radioactive health hazard be investigated further.

## Geothermal Resources

Two parts of the Teton Wilderness are of some geothermal interest. The potential of the Teton Corridor area has been described (Love, Antweiler, and Williams, 1975). No new data have been acquired since that report was issued.

The other area of interest is in the swampy flood plain of North Buffalo Fork near its junction with Soda Fork. For a distance of about 1,500 feet (460 m), and trending in a northeasterly direction, is a series of dormant to active warm springs. Those most active and associated with the most travertine are shown at locality L74–46 on plate 2. Some mounds of calcareous travertine are as much as 4 feet (122 cm) high. Continuous streams of nonflammable gas emerge in hundreds of places. No radioactivity was observed.

Many of the hottest orifices (temperature 113°F; 45°C) flow only small amounts of water, commonly with a mildly astringent taste. One of the hottest had a flow estimated to be 300 gallons (1,140 L) per day (as of July 20, 1974). Red algae are common in the hottest water. The main stream traversing the most active thermal area had an estimated flow of 250 gallons (950 L) per minute (as of July 20, 1974).

Directly east across North Buffalo Fork from the thermal area just described, 300 feet (90 m) downstream from the junction with Soda Fork, at the edge of the river, is a warm spring that emerges from the Madison Limestone (loc. L74–49, pl. 2). The Madison strikes N. 5° W. and dips 45° W. The spring flows an estimated 20,000 gallons (76,000 L) per day of water (as of July 20, 1974) with a temperature of 92°F (33.5°C). The orifice is stained rusty brown. Nonflammable gas boils up forcefully and continuously.

A branch of the Soda Fork fault probably cuts through the warm-spring area, and meteoric water, heated by thermal gradient, comes up along this fault. These springs have little geothermal potential.

Analyses of samples of water, travertine, and gas did not disclose any suggestion of economic resources.

# ECONOMIC APPRAISAL

By Frank E. Williams, Jimmie E. Jinks, and Thomas D. Light, U.S. Bureau of Mines

## Introduction

A mineral survey of the Teton Wilderness was made by the U.S. Bureau of Mines in 1972–1974. The area was classified in 1934 as a primitive area, reclassified in 1955 as a Wilderness by the Secretary of Agriculture, and in 1964 became a unit of the National Wilderness Preservation System.

### Previous Investigations

No U.S. Bureau of Mines investigations have dealt specifically with areas within the Teton Wilderness. Some work by the Bureau under the Department of the Interior's Heavy Metals Program is relevant to this study and is referred to in the section on gold.

### Present Investigation

The U.S. Bureau of Mines began the present investigation in 1972. The work consisted of: (1) a search of county, State, and Federal records for information on mining claims, mineral leases, mineral occurrences, and mineral production within the Teton Wilderness; (2) a review of the geology, mineral exploration, and mining history of the region; (3) a reconnaissance of the wilderness in the summers of 1972 and 1973 which included searching for evidence of mineral deposits, looking for signs of activities related to mineral exploitation, and collection of stream-sediment samples; and (4) in 1974, taking cubic-foot samples of Quaternary gravels and examination of mining claims and prospects. Bureau samples were analyzed by the Reno Metallurgical Research Center, U.S. Bureau of Mines, Reno, Nev.

The Bureau of Mines' fieldwork was done by Frank E. Williams. He was assisted by Donald D. Keill in 1972, by William P. Long in 1973, and by Henry C. Meeves, Peter M. Mesard, and Mark G. Mueller in 1974. Because of incapacitating illness, Williams was unable to complete the written portion of this investigation. It was completed by Jimmie E. Jinks and Thomas D. Light.

## Mining History

There are no producing mines within the Teton Wilderness, and available data suggest that past production was minor. A small amount of gold has been won from placers along Pacific Creek and, possibly, Whetstone and Pilgrim Creeks, although no gold production has been officially reported from any of the creeks. Adits were driven in Archean rocks on South Buffalo Fork in search of copper, but no production is indicated. An unknown but probably small amount of coal has been mined approximately 1 mile (1.6 km) inside the southwest corner of the wilderness on Pilgrim Creek.

The only current mineral activity in the Teton Wilderness is a small gold placering operation by Frank Allen on unpatented mining claims on Pacific Creek (pl. 7, location L). Intermittently since 1934, Allen has worked both banks of Pacific Creek by collecting high-water deposits and silt-laden moss when the high water recedes after the spring thaw. He processes surface material only, and the amount of material available varies each year according to the height and extent of the runoff—but the amount is usually small. The amount of gold produced has not been reported.

### Mining Claims and Mineral Leases

The Bureau of Mines searched county courthouse records, State records, and Federal public land records for information on mining claims and mineral leases. Courthouse records were checked for Teton, Park, and Fremont Counties; however, only Teton County had notices of mining locations on file which were within the Teton Wilderness. The summary that follows was current as of 1974.

Approximately 50 placer mining claims were staked along Pacific and Whetstone Creeks in 1895. In the years 1905 through 1909, some 48 lode mining claims were staked along South Buffalo Fork between North Buffalo Fork and Cub creek, and about 12 lode mining claims were staked along North Buffalo Fork near the mouth of Soda Fork. Four lode mining claims were staked on North Buffalo Fork in 1919, and 14 lode mining claims were staked on South Buffalo Fork in 1930. Since 1930 some 11 lode mining claims and 104 placer mining claims have been staked within the boundaries of the present Teton Wilderness. General areas where claims have been staked are shown on plate 7. There are no patented mining claims within the Teton Wilderness.

There are no mineral leases or permits in effect within the Teton Wilderness, and public land records of the U.S. Bureau of Land Management indicate that no leases or permits have been issued in the past.

The area within the present Teton Wilderness was temporarily withdrawn from oil and gas leasing by a Secretarial Order on August 15, 1947. Consequently, no leases have been issued since, and there had been no leases issued prior to August 15, 1947. Oil and gas leases are in effect south of the Teton Wilderness, and in T. 44 N., R. 110 W., leases abut the wilderness boundary.

## Mineral Resources

The Mines and Minerals Map of Wyoming (Geological Survey of Wyoming, 1970) and Bulletin 50, Mineral Resources of Wyoming (Osterwald and others, 1966), also published by the Geological Survey of Wyoming, locate and describe the known mineral resources of Wyoming. Within the Teton Wilderness (not depicted in the report) the map shows areas containing coal, limestone, bentonite, and phosphate, one gold occurrence, and one copper-gold occurrence. Coal, limestone, bentonite, and phosphate are also shown north, west, and south of the wilderness. Outside the southwest corner of the Teton Wilderness, the map shows an open-pit gold mine, which probably represents placer mining operations on Pacific Creek, and a gold occurrence within Grand Teton National Park. The Crouch Gold prospect (gold, copper, lead, zinc) 4 miles (6.5 km) north of the northeastern tip of the Teton Wilderness and the Stinkingwater Region (molybdenum, copper, gold) 5 miles (8 km) east of the Teton Wilderness are the only mining centers reported in the vicinity of the wilderness. Both mining centers are in the Washakie Wilderness.

### Energy Resources

Several formations which produce oil and gas elsewhere in northwest Wyoming are present in the Teton Wilderness. However, no exploratory holes for oil and gas have been drilled within the wilderness. The closest holes were drilled to test the Spread Creek anticline a few miles south of the wilderness (Strickland, 1956). The Spread Creek holes were plugged and abandoned. See the detailed discussion of oil and gas in this report.

The western portion of the Teton Wilderness is underlain by the Jackson Hole coal field, which extends from Yellowstone National Park south to the Gros Ventre Range (Berryhill and others, 1950). The U.S. Bureau of Reclamation produced coal from the Mesaverde Formation at a site on Pilgrim Creek in the southwestern corner of the wilderness while an earth dam was being constructed on Jackson Lake. Coal mining was later shifted to a site outside the wilderness on Buffalo Fork near the mouth of Lava Creek. Information on the extent of the workings and the amount of coal produced from the site on Pilgrim Creek is not available, but production was apparently minor.

Although Wyoming is one of the major producers of uranium, there is no mention in the literature nor was any indication found during this investigation that uranium or other nuclear source materials occur within the wilderness. The formations from which uranium is produced in other parts of Wyoming are not present in the wilderness.

Steam vents and hot springs, indicators of geothermal resources, were not observed in the wilderness despite its proximity to Yellowstone National Park and the well-known geothermal phenomena there. See also the discussion of geothermal resources in this report.

### Nonmetallic Minerals

Limestone, phosphate, bentonite, and building stone are present in rocks that crop out within the Teton Wilderness; however, no samples were taken within the wilderness to determine quantity and quality of the materials. Information on samples from outside the wilderness suggests that the materials within the wilderness are not attractive for production because of their remoteness. As an example, Coffman and Service (1967) did not include the wilderness as having either present potential or latent (not commercially available in the foreseeable future) potential for the production of phosphate.

Sand and gravel are present along stream courses, in the Harebell Formation, and in the Pinyon Conglomerate. The amount of sand and gravel would be measured in cubic miles; however, its resource potential is low because of its distance from roads and markets.

### Metallic Minerals

The only metallic minerals reported to occur within the Teton Wilderness are copper and gold. The Bureau of Mines' investigation confirmed the presence of both metals in small quantities. No other metals were found in amounts sufficient to be of interest as possible sources of production.

#### Copper

Two adits on South Buffalo Fork (pl. 7) are believed to be copper prospects. Both adits are in contact zones between gneiss and amphibolite schist in an outcrop of Archean rocks. The eastern adit is on the north side of South Buffalo Fork on the valley floor about 5 miles (8.2 km) upstream from the junction with North Buffalo Fork. The adit is covered by a talus slide. The bearing of the adit is about N. 35° W. A 50-ton dump and the remains of a log cabin mark the site. Selected chips of copper-stained schist from the dump (sample 365) assayed 0.08 percent copper, a trace of gold, and no silver. A grab sample (366) of the dump on 5-foot centers assayed 50 ppm copper, a trace of gold, and no silver.

The western adit is on the south side of South Buffalo Fork 300 feet (100 m) above the valley floor about 1.1 mile (1.8 km) west-southwest of the eastern adit. The western adit was driven S. 47° W., 88 feet (27 m) on a shear between gneiss and amphibolite schists. The adit is partly caved. A 2- to 6-inch (5- to 15-cm) gouge zone on the footwall of the shear was sampled (367) and assayed 0.45 percent copper, a trace of gold, and no silver. See also the discussion of this prospect in the section on copper, silver, and gold in Archean rocks in this report.

The State Geologist of Wyoming in his report to the Governor for 1909 (Hall, 1910) referred to the "Buffalo Fork Mining District" and stated that copper sulfides occur in granite, schist, and diorite. Hall stated that there are several hundred feet of shafts and drifts, but the adits described were all that were found during this investigation. No other reference was found to copper prospects on Buffalo Fork.

### Gold

Gold is found in the Teton Wilderness in the Harebell Formation, the Pinyon Conglomerate, and Quaternary gravels (Antweiler and Love, 1967). (See also the U.S. Geological Survey's section on gold in this report.) This gold occurs as extremely small particles and resembles the flour gold found along the Snake River in Wyoming and Idaho. Gold in minute flakes is referred to in the literature as flour, flood, float, light, fine, powder, flake, and scale gold. The fineness (parts per thousand) of flour gold is normally higher than the fineness of regular placer gold. The following fineness values have been reported for Snake River gold: Hill (1916), 930 to 951 fine with an average of 945; Hite (1933a), 954 fine; and Hite (1933b), 943 fine. Gold recovered in this investigation from gravels of Pacific Creek has a fineness of 950. Values were calculated by the U.S. Bureau of Mines for this report using a market price of $450 per troy ounce adjusted to 950 fine gold, that is an adjusted value of $427.50 per ounce or $0.01374 per milligram.

Hague, Schultz, Hill, Wells, and others have reported on the size, distribution, character, source, and nature of the gold in the gravels of the Snake River. Hague and others (1899) wrote "For many years the gravels along Snake River and Pacific Creek in the neighborhood of Jackson Lake have been known to yield a slight amount of gold to mining prospectors, but not in remunerative quantities. Evidences of gold may be found by washing with a pan almost anywhere in the streams coming down from the conglomerate. It is quite likely that this gold has in great part been derived from the conglomerates of the Pinyon Peak Formation." The Pinyon Peak Formation referred to by Hague is now named the Harebell Formation and the Pinyon Conglomerate (Love, 1973a).

Schultz (1907) commented, "Unlike other gold placers, those of the Snake River do not increase in gold values as bed rock is approached * * *."

Hill (1916) pointed out that skim-bar gravels are the most valuable gravels found along the Snake River and stated, "The gold content of the skim bar gravels is not equally distributed over the skim bar. The richest gravels are found in the outer edges of the bars, where the gravels 'tail off', and to a depth of 6 to 8 inches only."

Wells (1973), discussing flood gold deposits, said "* * * in streams draining a gold-bearing region, seemingly rich deposits of fine-size gold may be concentrated near the upper point of the inside bars, between the high and low water marks. Good surface showings of fine-size gold are not uncommon and although they may appear to be valuable, experience has shown that in most cases the gravel a few inches beneath these surface concentrations is nearly worthless." Wells stated that the best known flood gold occurrences in the United States were those along the Snake River.

The gold-bearing sedimentary rocks in northwest Wyoming were the subject of studies by the U.S. Geological Survey (Antweiler and Love, 1967) and the U.S. Bureau of Mines in 1966 and 1967 under the Department of the Interior's Heavy Metals Program.

In the fall of 1967 the U.S. Bureau of Mines, working with the U.S. Geological Survey, carried out a reconnaissance bulk-sampling project of the Harebell Formation, the Pinyon Conglomerate, and Quaternary gravels derived from these formations on tributaries of the Buffalo Fork River directly south of the Teton Wilderness. The results are pertinent to this study only so far as they indicate sampling, value determination, and gold-recovery problems to be met in dealing with these formations within the Teton Wilderness. The Bureau reported the results of the 1967 bulk-sampling project (U.S. Bureau of Mines, 1968, p. 10) as follows: "In Wyoming, nearly 250,000 pounds of samples were cut from gravel terraces and in-place conglomerates by rotary drilling, bucket-hole drilling, and backhoe trenching at locations recommended by the Geological Survey and processed through a specially designed and assembled field concentration plant during a 3-month period. However, analytical results failed to indicate concentrations anywhere near approaching a grade that could conceivably be exploitable through improvement in technology. With few exceptions, the samples showed gold values ranging from a trace to less than 3 to 5 cents per cubic yard * * *." The 3 to 5 cents was based on a gold price of $35 per troy ounce.

## Sampling and Analytical Results

A total of 367 stream-sediment, channel, and other samples were taken by the Bureau of Mines throughout the Teton Wilderness during the period of investigation, from 1972 to 1974. In the summers of 1972 and 1973, 221 samples were taken from unconsolidated sediments along the major stream courses (pl. 7). These samples (1–221) were taken to evaluate the potential for heavy mineral deposits—especially the very fine grained (flour) gold which has been reported from the Harebell Formation, Pinyon Conglomerate, and Quaternary gravels

(Antweiler and Love, 1967)—and delineate areas for more detailed sampling.

Channel samples (222–334) were taken from 10 locations (A–J, pl. 7). These locations were selected on the major drainages west of the Continental Divide which were indicated by the stream-sediment sampling program to be the most favorable for the concentration of flour gold. None of the stream-sediment samples collected east of the Continental Divide assayed greater than 10 milligrams of gold per cubic yard, so additional sampling was not undertaken in that portion of the wilderness.

Samples (335–364) other than the stream-sediment and channel samples were taken at locations K–M (pl. 7) as part of the investigation of flour gold occurrences. In addition, three samples (365–367) were taken in an area of copper mineralization on South Buffalo Fork.

Samples 1–334, unless otherwise indicated, were amalgamated and free gold content determined. The tailings were spectrographically analyzed for: aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, gallium, gold, hafnium, indium, iron, lanthanum, lead, lithium, magnesium, manganese, molybdenum, nickel, niobium, phosphorus, platinum, rhenium, scandium, silicon, silver, sodium, strontium, tantalum, tellurium, thallium, tin, titanium, tungsten, vanadium, yttrium, zinc, and zirconium.

### Stream-Sediment Samples

All stream-sediment samples were collected and panned in two half-size (12-in.) gold pans by two panners. Before panning, samples were screened through a 0.0232-inch (28-mesh) screen to eliminate coarse material. After panning, the material from both pans was combined, and gold values were computed using a factor of 200 combined pans per cubic yard (262 combined pans per cubic meter). These factors are approximate. Different factors would change the calculated gold values.

Of the 221 panned-concentrate stream-sediment samples collected, 44 samples contained gold concentrations greater than 10 mg/yd$^3$ (8 mg/m$^3$) (table 21). Plate 7 shows the location of the stream-sediment samples and indicates those which assayed greater than 10 mg/yd$^3$. The majority of the higher concentrations occur along Pacific Creek and Pilgrim Creek, with scattered occurrences along Wolverine Creek, Rodent Creek, Lava Creek, and South Buffalo Fork.

The content of 11 milligrams gold per cubic yard (14.4 mg/m$^3$) was arbitrarily selected as the cutoff for further sampling.

Samples 128, 139, and 146 had significantly higher gold concentrations than any of the other stream-sediment samples. The gold content of sample 139 from an unpatented claim on Pacific Creek outside the wilderness boundary assayed 156 mg/yd$^3$ (205 mg/m$^3$). Sample 128 from Pilgrim Creek and sample 146 from Pacific Creek assayed 212 mg/yd$^3$ (277 mg/m$^3$) and 201 mg/yd$^3$ (263 mg/m$^3$), respectively.

The spectrographic analyses of the stream-sediment samples showed a few amounts that are considered slightly above background, but no anomalous areas were identified. Sample 201 had 0.3 percent copper, but all other samples ran 0.006 percent copper or less. Samples 72 and 75 had 0.2 percent chromium and 0.6 percent lead. Sample 114 had 0.2 percent chromium and 0.04 percent nickel.

**Table 21.** Stream-sediment samples assaying more than 10 milligrams gold per cubic yard, Teton Wilderness and adjacent areas

[Value calculated at $0.01374 per milligram, based on $450.00 per troy ounce adjusted to 950 fine gold]

| Sample No. | Drainage | Gold content (mg/yd$^3$) | Gold content (mg/m$^3$) | Value[1] (cents/yd$^3$) |
|---|---|---|---|---|
| 2 | Coulter Creek..... | 25.0 | 32.8 | 34.5 |
| 3 | Wolverine Creek..... | 19.3 | 25.3 | 26.4 |
| 5 | Rodent Creek..... | 13.3 | 17.5 | 18.3 |
| 13 | .....do..... | 13.0 | 17.0 | 18.0 |
| 26 | Wolverine Creek..... | 15.5 | 20.3 | 21.3 |
| 83 | Pilgrim Creek..... | 31.4 | 41.1 | 43.2 |
| 84 | .....do..... | 42.2 | 52.2 | 57.9 |
| 85 | .....do..... | 11.8 | 15.4 | 16.2 |
| 86 | .....do..... | 22.2 | 29.0 | 30.6 |
| 87 | .....do..... | 51.4 | 67.3 | 70.5 |
| 94 | Whetstone Creek..... | 59.8 | 78.3 | 82.2 |
| 96 | .....do..... | 50.3 | 65.9 | 69.0 |
| 97 | .....do..... | 69.2 | 90.6 | 95.1 |
| 98 | .....do..... | 30.3 | 39.6 | 41.7 |
| 125 | Pilgrim Creek..... | 17.6 | 23.1 | 24.3 |
| 127 | .....do..... | 49.2 | 64.5 | 67.5 |
| 128 | .....do..... | 211.6 | 277.2 | 290.7 |
| 131 | East Fork Pilgrim Creek | 27.0 | 28.8 | 30.3 |
| 132 | .....do..... | 24.6 | 32.2 | 33.9 |
| 134 | .....do..... | 12.6 | 16.5 | 17.4 |
| 136 | .....do..... | 23.0 | 30.1 | 31.5 |
| 138 | Pacific Creek..... | 52.4 | 68.6 | 72.0 |
| 139 | .....do..... | 156.4 | 204.9 | 214.8 |
| 141 | .....do..... | 13.1 | 17.2 | 18.0 |
| 145 | .....do..... | 65.4 | 85.7 | 90.0 |
| 146 | .....do..... | 200.8 | 263.1 | 276.0 |
| 147 | .....do..... | 75.2 | 98.5 | 103.2 |
| 148 | .....do..... | 86.8 | 113.7 | 119.4 |
| 149 | .....do..... | 15.3 | 20.0 | 21.0 |
| 150 | .....do..... | 15.6 | 20.5 | 21.3 |
| 152 | .....do..... | 14.1 | 18.4 | 19.5 |
| 154 | .....do..... | 11.0 | 14.4 | 15.0 |
| 155 | .....do..... | 14.8 | 19.3 | 20.4 |
| 156 | .....do..... | 20.1 | 26.4 | 27.6 |
| 159 | .....do..... | 14.8 | 19.4 | 20.4 |
| 161 | .....do..... | 67.5 | 88.4 | 92.7 |
| 169 | Lava Creek..... | 12.0 | 15.7 | 16.5 |
| 171 | .....do..... | 20.6 | 27.0 | 28.2 |
| 172 | .....do..... | 64.0 | 83.8 | 87.9 |
| 173 | .....do..... | 57.9 | 68.0 | 71.4 |
| 174 | .....do..... | 29.9 | 39.2 | 41.1 |
| 194 | South Buffalo Fork..... | 12.0 | 15.7 | 16.5 |
| 196 | .....do..... | 22.0 | 28.8 | 30.3 |
| 215 | Cub creek..... | 20.0 | 26.2 | 27.6 |

### Channel Samples

Areas indicated by the stream-sediment samples to be potentially favorable for gold concentration were chosen for channel-sample locations (A–J, pl. 7). Channel-sample locations were selected in places that would allow maximum horizontal and vertical control for taking samples of measured volume in order to determine gold concentrations as accurately as possible.

Channel samples, except those from channel A, were taken in 1-cubic-foot (0.03-$m^3$) volumes at 1-foot (0.3-m) vertical intervals in naturally exposed streambanks from the surface to the level of stream water saturation.

The samples, except those from channel A, were sieved through 0.25-inch, 0.094-inch (8-mesh), and 0.047-inch (16-mesh) screens. Sieving eliminated the cobbles and pebbles and allowed the finer grained material to be concentrated for analysis. In some cases the larger size fractions were also analyzed to test the possibility that gold might have been derived from quartz pebbles. The 16-mesh screen was found to be the optimum workable size for concentrating sample fines in the field.

Four of the channel samples from Pacific Creek, two from Pilgrim Creek, one from Wolverine Creek, and one from Coulter Creek were examined microscopically to determine mineralogical content. The major constituents were quartz, feldspar, lithic fragments, magnetite, and hematite. Trace amounts of sphene, zircon, apatite, ilmenite, amphibole, garnet, and mica were also observed in all samples. Monazite and tourmaline were present, but rare.

#### Lava Creek, Location A

A 6-foot (1.8-m) channel was sampled on Lava Creek in 1973 at location A (pl. 7) to check concentrations previously obtained in that area of 21–64 milligrams gold per cubic yard (27–84 mg/$m^3$). Samples were taken at 1-foot (0.3-m) vertical intervals, screened, and then concentrated by panning. The screen oversize material from the top three samples was fire-assayed for gold (table 22). The interval from 3 to 6 feet averaged 17.2 milligrams gold per cubic yard (22.5 mg/$m^3$).

#### Pacific Creek, Locations B–F

Pacific Creek and its tributaries had many more stream-sediment samples assaying greater than 10 mg/$yd^3$ than any other stream system, so five of the channels sampled were along Pacific Creek south of the Whetstone Creek confluence (B–F, fig. 27). Surface grid samples (K, fig. 27) and selected samples (L, fig. 27) were also taken along Pacific Creek. Gold content for each channel is shown in table 22.

Channel locations B, C, and D were on the south bank of Pacific Creek below the mouth of Whetstone Creek. Location C was about 150 feet (45 m) west of location B and location D was about 200 feet (60 m) west of location C. The highest gold concentrations were obtained from gravel just below a silt-gravel contact: sample 247 from channel D assayed 51.6 mg/$yd^3$ (67.4 mg/$m^3$), and sample 236 from channel B assayed 30.2 mg/$yd^3$ (39.5 mg/$m^3$). Channel C did not penetrate the gravel.

Channel-sample locations E and F (fig. 27) were on the north bank of Pacific Creek on the highest exposed streambank in the wilderness. Location E was approximately 1,000 feet (300 m) west of location D, and location F was 200 feet (60 m) west of location E. The bank was composed of poorly sorted gravel, sand, silt, and boulders that were as much as 10 inches (25 cm) in diameter. A 25-foot (8-m) vertical channel was cut at each location. Gold content of samples from channel E ranged from 1.4 mg/$yd^3$ (1.8 mg/$m^3$) to 17.6 mg/$yd^3$ (22.9 mg/$m^3$), and samples from channel F ranged from 1.9 mg/$yd^3$ (2.5 mg/$m^3$) to 28.4 mg/$yd^3$ (37.1 mg/$m^3$).

#### Pilgrim Creek, Locations G and H

On Pilgrim Creek about 3 miles (4.8 km) north of the wilderness boundary, a pair of 4-foot (1.2-m) vertical channels were sampled (location G, pl. 7). The channels were cut 30 feet (10 m) apart in an effort to obtain data which can be correlated. The material sampled can be correlated but the gold contents cannot. Gold content ranged from 0.8 mg/$yd^3$ to 39.2 mg/$yd^3$ (table 22).

Channel location H was in a 10-foot gravel bank on the west side of Pilgrim Creek about 0.7 miles (1.1 km) upstream (north) from location G (pl. 7). Ten samples were taken, each at one-foot intervals. Gold content ranged from 3.0 mg/$yd^3$ to 16.5 mg/$yd^3$ (table 22). The 3-foot (1-m) interval between 4 and 7 feet averaged 14.6 mg/$yd^3$ (19.1 mg/$m^3$).

#### Wolverine and Coulter Creeks, Locations I and J

Two gravel banks near the confluence of Wolverine and Coulter Creeks were sampled by cutting five vertical channels at two-foot intervals. Channel location I was on the north side of Wolverine Creek about 0.4 mile (0.6 km) upstream (east) from the confluence. Gold content in channel I averaged 4.0 mg/$yd^3$ (5.3 mg/$m^3$), with a maximum of 5.0 mg/$yd^3$ (7.8 mg/$m^3$) (table 22).

Channel location J was on the east bank of Coulter Creek 200 yards (60 m) upstream (south) from the confluence (pl. 7). Twelve samples were taken at 1-foot intervals; their gold content averaged 2.3 mg/$yd^3$ (2.9 mg/$m^3$) (table 22).

**Table 22.** Gold values in channel and surface samples, Teton Wilderness and adjacent areas

[Value calculated at $0.01374 per milligram, based on $450.00 per troy ounce adjusted to 950 fine gold. Channel locations shown on pl. 7]

| Sample No. | Material | Interval (ft) | Gold content (mg/yd$^3$) | Gold content (mg/m$^3$) | Value (cents/yd$^3$) |
|---|---|---|---|---|---|
| | **LAVA CREEK** | | | | |
| | **Channel A** | | | | |
| 222 | Gravel..... | 0-1 | 3.6 | 4.7 | 4.8 |
| [1]224 | .....do..... | 1-2 | 4.6 | 6.0 | 6.3 |
| [1]226 | .....do..... | 2-3 | Tr | Tr | -- |
| [1]228 | .....do..... | 3-4 | 19.0 | 24.9 | 26.1 |
| 229 | .....do..... | 4-5 | 12.6 | 16.5 | 17.4 |
| 230 | .....do..... | 5-6 | 20.0 | 26.2 | 27.6 |
| | Average..... | | 10.1 | 13.1 | 13.8 |
| | **PACIFIC CREEK** | | | | |
| | **Channel B** | | | | |
| 231 | Silt..... | 0-1 | 3.5 | 4.6 | 4.8 |
| 232 | .....do..... | 1-2 | 2.2 | 2.8 | 3.0 |
| 233 | .....do..... | 2-3 | 7.8 | 10.2 | 10.8 |
| 234 | .....do..... | 3-4 | 4.1 | 5.3 | 5.7 |
| 235 | Silt and gravel... | 4.0-4.3 | 11.9 | 15.5 | 16.5 |
| 236 | Gravel..... | 4.3-5.3 | 30.2 | 39.5 | 41.4 |
| 237 | .....do..... | 5.3-6.3 | 6.5 | 8.5 | 9.0 |
| 238 | .....do..... | 6.3-7.3 | 3.5 | 4.6 | 4.8 |
| | Average..... | | 0.8 | 1.1 | 1.2 |
| | **Channel C** | | | | |
| 239 | Silt..... | 0-1 | 1.1 | 1.4 | 1.5 |
| 240 | Silt and gravel... | 1-2 | 1.4 | 1.8 | 1.8 |
| 241 | .....do..... | 2-3 | .5 | .7 | .6 |
| 242 | .....do..... | 3-4 | .3 | .4 | .3 |
| | Average..... | | 0.8 | 1.1 | 1.2 |
| | **Channel D** | | | | |
| 243 | Silt..... | 0-1 | 0.5 | 0.7 | 0.6 |
| 244 | .....do..... | 1-2 | 4.6 | 6.0 | 6.3 |
| 245 | .....do..... | 2-3 | 1.9 | 2.5 | 2.7 |
| 246 | Silt and gravel... | 3-4 | 13.2 | 17.3 | 18.0 |
| 247 | Gravel..... | 4-5 | 51.6 | 67.4 | 71.8 |
| 248 | .....do..... | 5-6 | 25.7 | 33.5 | 35.4 |
| 249 | .....do..... | 6-7 | 20.5 | 26.8 | 28.2 |
| | Average..... | | 16.9 | 22.0 | 23.1 |
| | **Channel E** | | | | |
| 250 | Gravel..... | 0-1 | 4.1 | 5.3 | 5.7 |
| 251 | .....do..... | 1-2 | 13.8 | 18.0 | 18.9 |
| 252 | .....do..... | 2-3 | 9.7 | 12.7 | 13.2 |
| 253 | .....do..... | 3-4 | 1.4 | 1.8 | 1.8 |
| 254 | .....do..... | 4-5 | 14.6 | 19.1 | 20.1 |
| 255 | .....do..... | 5-6 | 16.5 | 21.5 | 22.8 |
| 256 | .....do..... | 6-7 | 5.7 | 7.4 | 7.8 |
| 257 | .....do..... | 7-8 | 7.8 | 10.2 | 10.8 |
| 258 | .....do..... | 8-9 | 5.9 | 7.8 | 8.1 |
| 259 | .....do..... | 9-10 | 3.0 | 3.9 | 4.2 |
| 260 | .....do..... | 10-11 | 3.2 | 4.2 | 4.5 |
| 261 | .....do..... | 11-12 | 5.4 | 7.1 | 7.5 |
| 262 | .....do..... | 12-13 | 11.9 | 15.5 | 16.5 |
| 263 | .....do..... | 13-14 | 17.7 | 22.9 | 24.3 |
| 264 | .....do..... | 14-15 | 11.1 | 14.5 | 15.3 |
| 265 | .....do..... | 15-16 | 10.3 | 13.4 | 14.1 |
| 265 | .....do..... | 15-16 | 10.3 | 13.4 | 14.1 |
| 266 | .....do..... | 16-17 | 11.3 | 14.8 | 15.6 |
| 267 | .....do..... | 17-18 | 14.3 | 18.7 | 19.5 |
| 268 | .....do..... | 18-19 | 4.6 | 6.0 | 6.3 |
| 269 | .....do..... | 19-20 | 14.9 | 19.4 | 20.4 |
| 270 | .....do..... | 20-21 | 3.8 | 4.9 | 5.1 |
| 271 | .....do..... | 21-22 | 2.41 | 3.2 | 3.3 |
| 272 | .....do..... | 22-23 | 7.8 | 10.2 | 10.8 |
| 273 | .....do..... | 23-24 | 3.2 | 4.2 | 4.5 |
| 274 | .....do..... | 24-25 | 5.9 | 7.8 | 8.1 |
| | Average..... | | 8.4 | 11.0 | 11.4 |
| | **Channel F** | | | | |
| 275 | Gravel..... | 0-1 | 9.2 | 12.0 | 12.6 |
| 276 | .....do..... | 1-2 | 1.9 | 2.5 | 2.7 |
| 277 | .....do..... | 2-3 | 10.8 | 14.1 | 14.7 |
| 278 | .....do..... | 3-4 | 11.6 | 15.2 | 15.9 |
| 279 | .....do..... | 4-5 | 6.5 | 8.5 | 9.0 |
| 280 | .....do..... | 5-6 | 7.8 | 10.2 | 10.8 |
| 281 | .....do..... | 6-7 | 5.4 | 7.1 | 7.5 |
| 282 | .....do..... | 7-8 | 15.1 | 19.8 | 20.7 |
| 283 | .....do..... | 8-9 | 10.0 | 13.1 | 13.8 |
| 284 | .....do..... | 9-10 | 4.3 | 5.7 | 6.0 |
| 285 | .....do..... | 10-11 | 23.0 | 30.0 | 31.5 |
| 286 | .....do..... | 11-12 | 11.1 | 14.5 | 15.3 |
| 287 | .....do..... | 12-13 | 42.1 | 55.1 | 57.9 |
| 288 | .....do..... | 13-14 | 28.4 | 37.1 | 39.0 |
| 289 | .....do..... | 14-15 | 7.6 | 9.9 | 10.5 |
| 290 | .....do..... | 15-16 | 5.4 | 7.1 | 7.5 |
| 291 | .....do..... | 16-17 | 4.9 | 6.4 | 6.6 |
| 292 | .....do..... | 17-18 | 7.8 | 10.2 | 10.8 |
| 293 | .....do..... | 18-19 | 2.4 | 3.2 | 3.3 |
| 294 | .....do..... | 19-20 | 2.7 | 3.5 | 3.6 |
| 295 | .....do..... | 20-21 | 7.0 | 9.2 | 9.6 |
| 296 | .....do..... | 21-22 | 9.7 | 12.7 | 13.2 |
| 297 | .....do..... | 22-23 | 5.9 | 7.8 | 8.1 |
| 298 | .....do..... | 23-24 | 4.3 | 5.7 | 6.0 |
| 299 | .....do..... | 24-25 | 12.2 | 15.9 | 16.8 |
| | Average..... | | 10.3 | 13.5 | 14.1 |

[1]Samples 223, 225, and 227 (screening rejects from samples 222, 224, and 226) were fire assayed and showed no gold.

**Table 22.** Gold values in channel and surface samples, Teton Wilderness and adjacent areas—Continued

| Sample No. | Material | Interval (ft) | Gold content (mg/yd³) | Gold content (mg/m³) | Value (cents/yd³) |
|---|---|---|---|---|---|
| | **PILGRIM CREEK** | | | | |
| | **Channel G--North-upper** | | | | |
| 300 | Silt..... | 0-1 | 13.2 | 17.3 | 18.0 |
| 301 | Clay and gravel... | 1-2 | 6.2 | 8.1 | 8.4 |
| 302 | Silt..... | 2-3 | 3.8 | 4.9 | 5.1 |
| 303 | Clay and gravel... | 3-4 | 4.1 | 5.3 | 5.7 |
| | Average..... | | 6.8 | 8.9 | 9.3 |
| | **Channel G--South-lower** | | | | |
| 304 | Silt..... | 0-1 | 0.8 | 1.1 | 1.2 |
| 305 | Clay and gravel... | 1-2 | 39.2 | 51.2 | 54.0 |
| 306 | Silt..... | 2-3 | .8 | 1.1 | 1.2 |
| 307 | Clay and gravel... | 3-4 | Lost | Lost | -- |
| | Average..... | | 13.6 | 17.8 | 18.6 |
| | **Channel H** | | | | |
| 308 | Gravel..... | 0-1 | 7.6 | 9.9 | 10.4 |
| 309 | .....do..... | 1-2 | 5.4 | 7.1 | 7.5 |
| 310 | .....do..... | 2-3 | 3.0 | 3.9 | 4.2 |
| 311 | .....do..... | 3-4 | 7.3 | 9.5 | 9.9 |
| 312 | .....do..... | 4-5 | 13.8 | 18.0 | 18.9 |
| 313 | .....do..... | 5-6 | 13.5 | 17.7 | 18.6 |
| 314 | .....do..... | 6-7 | 16.5 | 21.5 | 22.8 |
| 315 | .....do..... | 7-8 | 3.0 | 3.9 | 4.2 |
| 316 | .....do..... | 8-9 | 8.6 | 11.3 | 5.7 |
| 317 | .....do..... | 9-10 | 5.1 | 6.7 | 6.9 |
| | Average..... | | 8.4 | 11.0 | 5.4 |
| | **COULTER CREEK Channel I** | | | | |
| 318 | Gravel..... | 0-1 | 2.7 | 3.5 | 3.6 |
| 319 | .....do..... | 1-2 | 4.3 | 5.7 | 6.0 |
| 320 | Sand..... | 2-3 | 5.9 | 7.8 | 8.1 |
| 321 | Gravel..... | 3-4 | 4.3 | 5.7 | 6.0 |
| 322 | .....do..... | 4-5 | 3.0 | 3.9 | 4.2 |
| | Average..... | | 4.0 | 5.3 | 5.4 |
| | **Channel J** | | | | |
| 323 | Gravel..... | 0-1 | 1.6 | 2.1 | 2.1 |
| 324 | .....do..... | 1-2 | .5 | .7 | .6 |
| 325 | .....do..... | 2-3 | 1.6 | 2.1 | 2.1 |
| 326 | .....do..... | 3-4 | 1.1 | 1.4 | 1.5 |
| 327 | .....do..... | 4-5 | 1.9 | 2.5 | 2.7 |
| 328 | .....do..... | 5-6 | 3.5 | 4.6 | 10.8 |
| 329 | .....do..... | 6-7 | 4.6 | 6.0 | 6.3 |
| 330 | .....do..... | 7-8 | 1.6 | 2.1 | 2.1 |
| 331 | .....do..... | 8-9 | 1.4 | 1.8 | 1.8 |
| 332 | .....do..... | 9-10 | 6.2 | 8.1 | 8.4 |
| 333 | .....do..... | 10-11 | 1.4 | 1.8 | 1.8 |
| 334 | .....do..... | 11-12 | 1.6 | 2.1 | 2.1 |
| | Average..... | | 2.3 | 2.9 | 3.3 |
| | **PACIFIC CREEK Location K--Surface samples** | | | | |
| 335 | Gravel..... | 0-1 | 26.7 | 34.9 | 36.6 |
| 336 | .....do..... | 1-2 | 7.6 | 9.9 | 10.5 |
| 337 | .....do..... | 2-3 | 6.8 | 8.8 | 9.3 |
| 338 | .....do..... | 3-4 | 4.3 | 5.7 | 6.0 |
| 339 | .....do..... | 4-5 | 19.2 | 25.1 | 26.4 |
| 340 | .....do..... | 5-6 | 13.2 | 17.3 | 18.0 |
| 341 | .....do..... | 6-7 | 11.3 | 14.8 | 15.6 |
| 342 | .....do..... | 7-8 | 13.8 | 18.0 | 18.9 |
| 343 | .....do..... | 8-9 | 4.9 | 6.4 | 6.6 |
| 344 | .....do..... | 9-10 | 14.0 | 18.4 | 19.2 |
| | **PACIFIC CREEK Location K--Surface samples** | | | | |
| 345 | .....do..... | 10-11 | 18.9 | 24.7 | 26.1 |
| 346 | .....do..... | 11-12 | 5.4 | 7.1 | 7.5 |
| 347 | .....do..... | 12-13 | 2.7 | 3.5 | 3.6 |
| 348 | .....do..... | 13-14 | 6.8 | 8.8 | 9.3 |
| 349 | .....do..... | 14-15 | 12.7 | 16.6 | 17.4 |
| 350 | .....do..... | 15-16 | 17.4 | 22.9 | 24.3 |
| 351 | .....do..... | 16-17 | 39.4 | 51.1 | 54.0 |
| 352 | .....do..... | 17-18 | 7.8 | 10.2 | 3.6 |
| 353 | .....do..... | 18-19 | 15.4 | 20.1 | 21.3 |
| 354 | .....do..... | 19-20 | 21.3 | 27.9 | 29.4 |
| | Average..... | | 13.5 | 17.6 | 18.6 |

## Other Samples

Samples other than the stream-sediment and channel samples discussed above were taken on Pacific Creek and on Gravel Mountain to determine the presence and distribution of flour gold. Three samples were taken on South Buffalo Fork to check for copper, gold, and silver.

### Pacific Creek, Locations K and L

Sample location K was on the west side of Pacific Creek outside the wilderness at the head of a meadow (fig. 27). Samples 335 through 354 were 1 cubic foot (0.03 $m^3$) in volume and taken at 100-foot (30-m) intervals on a 300- by 400-foot (90- by 120-m) grid (fig. 28). These surface samples were taken to determine the grade

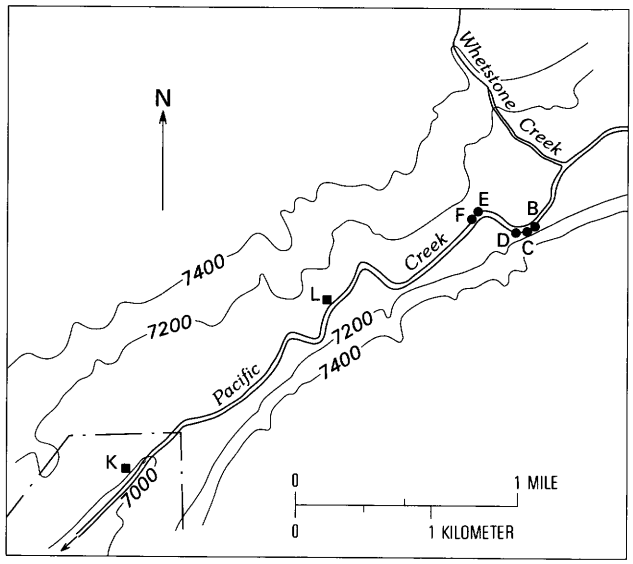



**Figure 27.** Localities of channel samples B–F and surface-and-specimen samples K and L, Pacific Creek and Teton Wilderness boundary (dot-dash line), T. 41 N., R. 113 W.

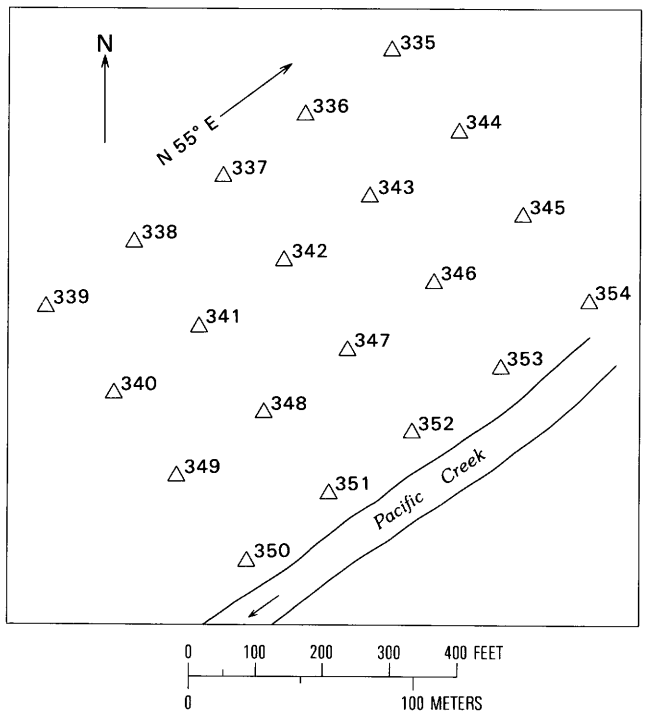



**Figure 28.** Grid showing sample localities 335–354, location K (fig. 27), Pacific Creek southwest of Teton Wilderness boundary in T. 41 N., R. 113 W.

and distribution of the flour gold in a horizontal plane in the gravels. Gold content of the samples ranged from 2.7 to 39.4 mg/yd³ (3.5 to 51.5 mg/m³), and the average for the 20 samples was 13.5 mg/yd³ (17.6 mg/m³) (table 22). The average content at sample location K was exceeded only by the average content for channel D, 16.9 mg/yd³ (22.0 mg/m³), and the average value for channel G-south, 13.6 mg/yd³ (17.8 mg/m³).

Three cubic-foot samples (355–357), consisting of approximately two-thirds silt and one-third gravel, were collected from surface material on the north bank of Pacific Creek at location L (pl. 7). These samples were taken in the area where Frank Allen intermittently conducts a small placer operation on an unpatented mining claim. Sample 355 was run through Allen's gold saver, a washing trommel, to eliminate coarse material and break up silt aggregates, then sieved through a 16-mesh screen before being assayed. Sample 356 was panned, and sample 357 was sieved through a 25-mesh screen; neither was run through the gold saver. Gold content of sample 355 was 173.6 mg/yd³ (226.9 mg/m³), sample 356, 52.7 mg/yd³ (68.8 mg/m³), and sample 357, 212.2 mg/yd³ (277.4 mg/m³). These were the highest concentrations obtained on cubic-foot samples by the Bureau during this investigation. The next lower concentration was 51.6 mg/yd³ (67.4 mg/m³) for sample 247 at location D.

### Gravel Mountain, Location M

Seven samples (358–364, pl. 7), taken on the south side of Gravel Mountain at location M, represented various lithologic components from the Pinyon Conglomerate (gold was not detected by fire assay in any of the samples:

| Sample | Description |
|---|---|
| 358 | 4-ft horizontal chip along light-colored sandstone lens. |
| 359 | Sandstone from above zone. |
| 360 | Pebbles from 25-ft (7.6-m) vertical zone. |
| 361 | Sandstone from above zone. |
| 362 | 6-ft (1.8-m) horizontal chip along dark-colored sandstone lens. |
| 363 | Randomly selected light-colored pebbles. |
| 394 | Randomly selected dark-colored pebbles. |

### South Buffalo Fork

Three samples (365–367, pl. 7) were taken in an area of copper mineralization on South Buffalo Fork. Samples 365 and 366 were taken from the dump of a caved adit (east); 365 was composed of selected rock chips stained with copper oxides and contained 0.08 percent copper; sample 366 was a grab of the entire dump on 5-foot centers and contained 0.0005 percent copper. Sample 367 was from a 2- to 6-inch (5- to 15-cm) gouge zone in a second adit (west) and contained 0.45 percent copper. The absence of alteration and the limited extent of the copper mineralization suggest that the area has little potential for the production of copper. None of the samples contained more than a trace of gold or silver.

## Conclusions

The results of the U.S. Bureau of Mines study indicate that the flour gold in the Teton Wilderness is thinly dispersed, and, where tested, the grade is far below the level needed for profitable recovery. Calculation of mining, milling, and reclamation costs was not warranted because of the extremely low grade. A study by the Bureau of Mines of similar occurrences in nearby areas reached the same conclusion in 1967 (U.S. Bureau of Mines, 1968, p. 10).

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# TABLE 3

**Table 3.** Summary of geochemical data and statistical replacement information on stream-sediment, panned-concentrate, rock, and soil samples from the Teton Wilderness, northwest Wyoming

[Gold analyses were made by atomic-absorption spectrometry (AA); mercury analyses by instrumental method (INST); other elements by six-step semiquantitative spectrographic analyses (S). Cold-extractable heavy-metals tests (CX-HM) were made by colorimetric comparison (CM). Values shown under raw-data (minimum, maximum, mean), replaced-data (geometric mean, geometric deviation), and replacement-values (N, L, G) columns are in parts per million, except iron, magnesium, calcium, and titanium, which are in percent. Columns B (not analyzed), N (not detected), L (detected but below satisfactory measurement level), and G (present in an amount greater than analytical method can satisfactorily measure) show the number of qualified analyses. The valid column shows the number of analyses not qualified by B, N, L, or G. Complete analytical data in McDanal and others (1983)]

Soils

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 15.000 | 4.3300 | 3.9200 | - | - | - | - | - | 113 | 3.1600 | 2.185 | 113 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.3000 | 3.000 | 1.7800 | 0.7480 | - | - | - | - | - | 113 | 1.6100 | 1.596 | 113 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 20.000 | 2.9700 | 2.8000 | - | - | - | 1 | - | 112 | 2.2000 | 2.446 | 113 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0200 | 0.700 | 0.2720 | 0.1560 | - | - | - | - | - | 113 | 0.2350 | 1.733 | 113 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 150.0000 | 3000.000 | 544.0000 | 538.0000 | - | - | - | - | - | 113 | 374.0000 | 2.294 | 113 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 0.7830 | 0.4020 | - | 107 | - | - | - | 6 | 0.2140 | 1.353 | 113 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 70.000 | 18.9000 | 14.7000 | - | 41 | 41 | - | - | 31 | 7.6900 | 1.728 | 113 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 1500.000 | 704.0000 | 373.0000 | - | 2 | - | - | - | 111 | 549.0000 | 2.329 | 113 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 16.4000 | 7.3700 | - | 3 | - | - | - | 110 | 14.2000 | 1.730 | 113 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 700.000 | 124.0000 | 93.4000 | - | 3 | - | - | - | 110 | 89.8000 | 2.418 | 113 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 500.000 | 26.0000 | 53.2000 | - | - | 1 | - | - | 112 | 18.2000 | 1.864 | 113 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 100.000 | 32.8000 | 17.5000 | - | 4 | 7 | - | - | 102 | 27.2000 | 1.634 | 113 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 5.000 | 5.0000 | -- | - | 112 | - | - | - | 1 | 2.0200 | 1.090 | 113 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 10.000 | 10.0000 | 0.0000 | - | 109 | - | - | - | 4 | 7.0900 | 1.063 | 113 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 63.7000 | 50.2000 | - | 1 | - | - | - | 112 | 45.2000 | 2.473 | 113 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 16.2000 | 9.8900 | - | 6 | 11 | - | - | 96 | 12.3000 | 1.766 | 113 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 113 | - | - | - | - | 5.0000 | 1.001 | 113 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1000.000 | 454.0000 | 238.0000 | - | 5 | 3 | - | - | 105 | 338.0000 | 2.151 | 113 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 76.7000 | 48.9000 | - | - | - | - | - | 113 | 64.4000 | 1.821 | 113 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 30.000 | 14.0000 | 4.8600 | - | 55 | 1 | - | - | 57 | 8.2100 | 1.717 | 113 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 300.0000 | 300.000 | 300.0000 | -- | - | 112 | - | - | - | 1 | 101.0000 | 1.109 | 113 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.000 | 95.7000 | 47.6000 | - | - | - | - | - | 113 | 84.6000 | 1.692 | 113 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 112 | 1 | - | - | - | 0.0101 | 1.090 | 113 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 1.400 | 0.0839 | 0.2360 | - | 2 | 49 | - | - | 62 | 0.0174 | 2.924 | 113 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 50.000 | 3.1800 | 8.4000 | - | - | 58 | - | - | 55 | 0.8520 | 2.237 | 113 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 5.1360 | 13.155 | 8.2500 | 2.8100 | 106 | - | - | - | - | 7 | 7.8600 | 1.393 | 7 | -- | -- | -- | 26 |
| 27 | AC-U | 1.0978 | 5.134 | 2.3900 | 1.6100 | 106 | - | - | - | - | 7 | 2.0200 | 1.832 | 7 | -- | -- | -- | 27 |

## Stream sediments

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 10.000 | 3.2900 | 1.6400 | 1 | - | - | - | - | 656 | 2.9500 | 1.604 | 656 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 10.000 | 2.0500 | 1.2600 | 1 | - | - | 1 | - | 655 | 1.6800 | 2.005 | 656 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 10.000 | 2.5200 | 1.6200 | 1 | - | - | - | - | 656 | 1.9300 | 2.325 | 656 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0200 | 1.000 | 0.2980 | 0.1330 | 1 | - | - | - | - | 656 | 0.2730 | 1.513 | 656 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 70.0000 | 2000.000 | 675.0000 | 450.0000 | 1 | - | - | 1 | - | 655 | 522.0000 | 2.163 | 656 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 0.8800 | 0.4370 | 1 | 639 | 2 | - | - | 15 | 0.2070 | 1.242 | 656 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 21.3000 | 17.2000 | 1 | 156 | 269 | - | - | 231 | 8.8000 | 1.866 | 656 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 100.0000 | 3000.000 | 985.0000 | 424.0000 | 1 | - | - | - | - | 656 | 885.0000 | 1.638 | 656 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 70.000 | 19.0000 | 11.8000 | 1 | 74 | 2 | - | - | 580 | 12.6000 | 2.373 | 656 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 1500.000 | 197.0000 | 146.0000 | 1 | 10 | - | - | - | 646 | 134.0000 | 2.797 | 656 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 700.000 | 16.8000 | 28.4000 | 1 | - | 3 | - | - | 653 | 13.8000 | 1.715 | 656 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 300.000 | 36.9000 | 27.1000 | 1 | 25 | 37 | - | - | 594 | 29.5000 | 1.685 | 656 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 10.0000 | 20.000 | 15.0000 | 5.0000 | 1 | 651 | 2 | - | - | 3 | 2.0200 | 1.146 | 656 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 50.000 | 14.7000 | 7.8800 | 3 | 569 | 41 | - | - | 44 | 7.4700 | 1.230 | 654 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 72.1000 | 46.1000 | 1 | 1 | 1 | - | - | 654 | 49.7000 | 2.823 | 656 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 16.6000 | 6.7600 | 1 | 6 | 24 | - | - | 626 | 14.8000 | 1.513 | 656 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 30.000 | 20.0000 | 14.1000 | 1 | 652 | 2 | - | - | 2 | 5.0200 | 1.080 | 656 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 729.0000 | 469.0000 | 1 | 26 | 3 | - | - | 627 | 488.0000 | 2.667 | 656 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 106.0000 | 62.4000 | 1 | - | - | - | - | 656 | 90.2000 | 1.797 | 656 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 100.000 | 18.0000 | 11.3000 | 1 | 203 | 74 | - | - | 379 | 10.1000 | 1.909 | 656 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | 1 | 649 | 7 | - | - | - | 100.0000 | 1.043 | 656 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 1000.000 | 159.0000 | 159.0000 | 1 | 1 | - | - | - | 655 | 114.0000 | 2.211 | 656 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0290 | 21.000 | 2.1500 | 5.0500 | - | 595 | 37 | - | - | 25 | 0.0122 | 2.289 | 657 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 1.500 | 0.0453 | 0.0910 | 11 | 2 | 320 | - | - | 324 | 0.0153 | 2.452 | 646 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 27.000 | 2.3800 | 3.0100 | 3 | 6 | 499 | - | - | 149 | 0.6620 | 1.864 | 654 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 3.9077 | 35.059 | 8.4500 | 5.2300 | 603 | - | - | - | - | 54 | 7.5500 | 1.544 | 54 | -- | -- | -- | 26 |
| 27 | AC-U | 0.8077 | 5.626 | 2.0700 | 1.0600 | 603 | - | - | - | - | 54 | 1.8600 | 1.588 | 54 | -- | -- | -- | 27 |

## Panned concentrates of stream sediments and rocks

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 20.000 | 8.270 | 6.0500 | 329 | - | - | 29 | - | 792 | 6.3700 | 2.432 | 821 | 0.02 | 0.03 | 30. | 1 |
| 2 | S-MG% | 0.0200 | 10.000 | 3.550 | 3.3400 | 329 | - | - | 2 | - | 819 | 1.9000 | 3.523 | 821 | 0.01 | 0.02 | 15. | 2 |
| 3 | S-CA% | 0.0500 | 15.000 | 3.040 | 3.2400 | 329 | - | 2 | 2 | - | 817 | 1.6900 | 3.336 | 821 | 0.02 | 0.03 | 30. | 3 |
| 4 | S-TI% | 0.0150 | 1.000 | 0.537 | 0.3300 | 329 | - | - | 184 | - | 637 | 0.5590 | 2.370 | 821 | 0.00 | 0.00 | 2. | 4 |
| 5 | S-MN | 15.0000 | 5000.000 | 1220.000 | 936.0000 | 329 | - | - | 10 | - | 811 | 915.0000 | 2.423 | 821 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 100.000 | 11.300 | 25.0000 | 329 | 797 | 2 | - | - | 22 | 0.2140 | 1.607 | 821 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 1500.000 | 60.700 | 159.0000 | 329 | 179 | 310 | 1 | - | 331 | 11.4000 | 2.765 | 821 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 5000.000 | 386.000 | 470.0000 | 329 | - | - | 6 | - | 815 | 266.0000 | 2.395 | 821 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 200.000 | 37.400 | 32.7000 | 329 | 74 | 11 | - | - | 736 | 19.0000 | 3.272 | 821 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 3000.000 | 612.000 | 621.0000 | 329 | 10 | - | - | - | 811 | 309.0000 | 3.999 | 821 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 2.0000 | 100.000 | 25.200 | 23.0000 | 329 | 23 | 63 | - | - | 735 | 14.0000 | 2.754 | 821 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 1000.000 | 213.000 | 244.0000 | 329 | 215 | 40 | 10 | - | 556 | 53.5000 | 4.607 | 821 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 100.000 | 17.100 | 17.6000 | 339 | 750 | 11 | - | - | 50 | 2.2500 | 1.610 | 811 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 150.000 | 33.900 | 22.5000 | 329 | 483 | 93 | - | - | 245 | 11.1000 | 2.011 | 821 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 500.000 | 95.400 | 93.4000 | 329 | 13 | 4 | - | - | 804 | 43.2000 | 4.309 | 821 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 5.0000 | 700.000 | 22.200 | 60.8000 | 329 | 272 | 161 | - | - | 388 | 6.7900 | 2.262 | 821 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 200.000 | 30.700 | 37.0000 | 329 | 761 | - | - | - | 60 | 5.5300 | 1.529 | 821 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 320.000 | 298.0000 | 329 | 353 | 34 | - | - | 434 | 114.0000 | 2.554 | 821 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 2000.000 | 238.000 | 210.0000 | 329 | - | 1 | - | - | 820 | 164.0000 | 2.515 | 821 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 500.000 | 61.500 | 76.8000 | 329 | 113 | 28 | 6 | - | 674 | 25.4000 | 3.519 | 821 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 2000.000 | 427.000 | 356.0000 | 329 | 636 | 81 | - | - | 104 | 122.0000 | 1.594 | 821 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 1000.000 | 255.000 | 308.0000 | 329 | 44 | - | 211 | - | 566 | 201.0000 | 5.451 | 821 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0100 | 1040.000 | 11.400 | 50.3000 | 7 | 361 | 68 | - | - | 714 | 0.2600 | 18.890 | 1143 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 1.300 | 0.049 | 0.0878 | 419 | 10 | 401 | - | - | 320 | 0.0138 | 2.485 | 731 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 50.000 | 2.290 | 4.8000 | 397 | 13 | 578 | - | - | 162 | 0.6270 | 1.751 | 753 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | -- | -- | -- | -- | 1150 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 26 |
| 27 | AC-U | -- | -- | -- | -- | 1150 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Felsic igneous rocks

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 7.000 | 2.180 | 1.1500 | - | - | - | - | - | 64 | 1.9400 | 1.655 | 64 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 5.000 | 0.955 | 0.8830 | - | - | - | - | - | 64 | 0.5020 | 3.996 | 64 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 15.000 | 1.890 | 2.3300 | - | - | - | - | - | 64 | 1.0800 | 3.235 | 64 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0100 | 0.700 | 0.166 | 0.1100 | - | - | - | - | - | 64 | 0.1330 | 2.109 | 64 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 100.0000 | 1500.000 | 361.000 | 387.0000 | - | - | - | - | - | 64 | 255.0000 | 2.125 | 64 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 1.170 | 0.7640 | - | 61 | - | - | - | 3 | 0.2160 | 1.440 | 64 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 30.000 | 17.800 | 6.2400 | - | 36 | 10 | - | - | 18 | 7.4000 | 1.753 | 64 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 3000.000 | 1130.000 | 580.0000 | - | 5 | - | - | - | 59 | 692.0000 | 3.834 | 64 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 9.750 | 5.2000 | - | 11 | - | - | - | 53 | 6.7000 | 2.048 | 64 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 20.0000 | 200.000 | 96.800 | 55.0000 | - | 23 | 1 | - | - | 40 | 28.4000 | 4.244 | 64 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 13.400 | 7.8100 | - | - | 1 | - | - | 63 | 11.4000 | 1.744 | 64 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 71.900 | 59.0000 | - | 6 | 11 | - | - | 47 | 35.7000 | 2.571 | 64 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 10.000 | 8.640 | 2.3400 | - | 52 | 1 | - | - | 11 | 2.5700 | 1.742 | 64 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 15.0000 | 70.000 | 36.500 | 16.8000 | - | 40 | - | - | - | 24 | 12.5000 | 2.235 | 64 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 100.000 | 33.100 | 28.1000 | - | - | 8 | - | - | 56 | 17.1000 | 3.062 | 64 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 27.400 | 23.9000 | - | 1 | 4 | - | - | 59 | 18.4000 | 2.204 | 64 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 10.900 | 2.0200 | - | 48 | - | - | - | 16 | 6.0600 | 1.412 | 64 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 489.000 | 301.0000 | - | 20 | - | - | - | 44 | 210.0000 | 3.043 | 64 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 150.000 | 40.100 | 28.3000 | - | - | 5 | - | - | 59 | 27.3000 | 2.345 | 64 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 100.000 | 50.900 | 36.9000 | - | 30 | - | - | - | 34 | 14.2000 | 3.308 | 64 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 500.000 | 350.000 | 212.0000 | - | 62 | - | - | - | 2 | 104.0000 | 1.243 | 64 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 500.000 | 111.000 | 87.8000 | - | - | - | - | - | 64 | 82.0000 | 2.333 | 64 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 62 | 2 | - | - | - | 0.0103 | 1.174 | 64 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.120 | 0.033 | 0.0226 | - | 9 | 34 | - | - | 21 | 0.0106 | 2.137 | 64 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 2.120 | 1.8000 | - | 8 | 39 | - | - | 17 | 0.6410 | 1.985 | 64 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 3.1722 | 18.742 | 7.290 | 5.0000 | 56 | - | - | - | - | 8 | 6.2400 | 1.761 | 8 | -- | -- | -- | 26 |
| 27 | AC-U | 0.6368 | 6.962 | 1.690 | 2.1300 | 56 | - | - | - | - | 8 | 1.1900 | 2.067 | 8 | -- | -- | -- | 27 |

Intermediate igneous rocks

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 15.000 | 3.530 | 2.5800 | - | - | - | - | - | 188 | 2.970 | 1.731 | 188 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 7.000 | 2.120 | 1.3800 | - | - | 1 | - | - | 187 | 1.710 | 2.075 | 188 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0700 | 20.000 | 3.150 | 2.5400 | - | - | - | - | - | 188 | 2.550 | 1.971 | 188 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0050 | 0.700 | 0.278 | 0.1400 | - | - | - | - | - | 188 | 0.244 | 1.752 | 188 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 30.0000 | 3000.000 | 423.000 | 385.0000 | - | - | - | - | - | 188 | 306.000 | 2.226 | 188 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 188 | - | - | - | - | 0.200 | 1.001 | 188 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 30.000 | 15.000 | 7.6400 | - | 115 | 66 | - | - | 7 | 5.840 | 1.277 | 188 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 30.0000 | 5000.000 | 1170.000 | 553.0000 | - | - | - | - | - | 188 | 1030.000 | 1.781 | 188 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 16.800 | 7.8200 | - | 17 | - | - | - | 171 | 12.600 | 2.075 | 188 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 1000.000 | 170.000 | 145.0000 | - | 15 | 2 | - | - | 171 | 93.700 | 3.332 | 188 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 200.000 | 22.900 | 22.7000 | - | - | 3 | - | - | 185 | 17.300 | 1.988 | 188 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 150.000 | 41.800 | 30.1000 | - | 10 | 21 | - | - | 157 | 29.800 | 1.871 | 188 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 15.000 | 9.000 | 3.5200 | - | 182 | - | - | - | 6 | 2.090 | 1.299 | 188 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.000 | 0.0000 | - | 184 | 1 | - | - | 3 | 7.130 | 1.144 | 188 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 62.000 | 47.6000 | - | 1 | - | - | - | 187 | 43.600 | 2.526 | 188 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 16.800 | 9.0600 | - | 6 | 9 | - | - | 173 | 14.000 | 1.648 | 188 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 30.0000 | 30.000 | 30.000 | -- | - | 187 | - | - | - | 1 | 5.050 | 1.140 | 188 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 150.0000 | 1500.000 | 687.000 | 355.0000 | - | 8 | 1 | - | - | 179 | 535.000 | 2.093 | 188 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 78.200 | 46.8000 | - | - | - | - | - | 188 | 66.400 | 1.789 | 188 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 30.000 | 13.300 | 4.9600 | - | 91 | 14 | - | - | 83 | 7.700 | 1.640 | 188 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 188 | - | - | - | - | 100.000 | 1.000 | 188 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 500.000 | 98.000 | 56.2000 | - | 2 | - | - | - | 186 | 83.700 | 1.760 | 188 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 182 | 6 | - | - | - | 0.010 | 1.175 | 188 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.450 | 0.051 | 0.0765 | - | 1 | 120 | - | - | 67 | 0.012 | 2.388 | 188 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 35.000 | 4.150 | 8.0800 | - | 3 | 159 | - | - | 26 | 0.600 | 1.834 | 188 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 1.9960 | 30.525 | 8.310 | 5.6500 | 156 | - | - | - | - | 32 | 7.010 | 1.777 | 32 | -- | -- | -- | 26 |
| 27 | AC-U | 0.5607 | 30.451 | 2.570 | 5.1300 | 156 | - | - | - | - | 32 | 1.700 | 1.934 | 32 | -- | -- | -- | 27 |

## Mafic and ultramafic rocks

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 15.000 | 3.530 | 2.7000 | - | - | - | - | - | 55 | 2.9400 | 1.776 | 55 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 7.000 | 1.860 | 1.1400 | - | - | - | - | - | 55 | 1.5200 | 2.165 | 55 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 10.000 | 2.660 | 1.5100 | - | - | - | - | - | 55 | 2.2300 | 1.882 | 55 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0700 | 0.700 | 0.272 | 0.1500 | - | - | - | - | - | 55 | 0.2380 | 1.675 | 55 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 100.0000 | 2000.000 | 451.000 | 417.0000 | - | - | - | - | - | 55 | 320.0000 | 2.235 | 55 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 0.500 | 0.500 | 0.0000 | - | 53 | - | - | - | 2 | 0.2070 | 1.189 | 55 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 50.000 | 18.300 | 16.0000 | - | 32 | 17 | - | - | 6 | 6.2400 | 1.483 | 55 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 50.0000 | 3000.000 | 1080.000 | 553.0000 | - | - | - | - | - | 55 | 923.0000 | 1.953 | 55 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 70.000 | 16.800 | 11.9000 | - | 2 | - | - | - | 53 | 13.0000 | 2.000 | 55 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 30.0000 | 1500.000 | 183.000 | 295.0000 | - | 5 | 1 | - | - | 49 | 102.0000 | 3.293 | 55 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 200.000 | 32.400 | 36.6000 | - | - | 1 | - | - | 54 | 21.1000 | 2.396 | 55 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 45.000 | 42.0000 | - | 4 | 13 | - | - | 38 | 26.2000 | 2.010 | 55 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 10.0000 | 10.000 | 10.000 | 0.0000 | - | 52 | 1 | - | - | 2 | 2.1400 | 1.360 | 55 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 70.000 | 27.500 | 28.7000 | - | 50 | 1 | - | - | 4 | 7.5900 | 1.412 | 55 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 500.000 | 64.900 | 71.9000 | - | - | - | - | - | 55 | 42.9000 | 2.641 | 55 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 16.500 | 8.4900 | - | 2 | 4 | - | - | 49 | 13.2000 | 1.724 | 55 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 55 | - | - | - | - | 5.0000 | 1.000 | 55 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 150.0000 | 1500.000 | 562.000 | 283.0000 | - | 3 | 1 | - | - | 51 | 427.0000 | 2.102 | 55 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 500.000 | 87.100 | 80.0000 | - | - | - | - | - | 55 | 64.6000 | 2.169 | 55 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 19.000 | 12.9000 | - | 29 | 1 | - | - | 25 | 8.6200 | 1.987 | 55 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 55 | - | - | - | - | 100.0000 | 1.000 | 55 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 300.000 | 97.600 | 60.1000 | - | 1 | - | - | - | 54 | 79.0000 | 1.938 | 55 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 51 | 4 | - | - | - | 0.0107 | 1.271 | 55 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.140 | 0.033 | 0.0287 | - | 1 | 36 | - | - | 18 | 0.0110 | 2.061 | 55 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 5.000 | 2.000 | 1.3000 | - | - | 41 | - | - | 14 | 0.6790 | 1.840 | 55 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.7771 | 18.192 | 10.200 | 4.9100 | 46 | - | - | - | - | 9 | 9.2200 | 1.635 | 9 | -- | -- | -- | 26 |
| 27 | AC-U | 0.2528 | 4.059 | 1.770 | 1.0200 | 45 | - | - | - | - | 10 | 1.4600 | 2.104 | 10 | -- | -- | -- | 27 |

## Limestone and travertine

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 20.000 | 1.0100 | 2.3800 | - | 11 | 2 | - | - | 156 | 0.3150 | 4.466 | 169 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 10.000 | 2.1200 | 2.7200 | - | - | - | - | - | 169 | 1.1000 | 3.269 | 169 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 15.3000 | 6.6800 | - | - | - | 51 | - | 118 | 15.3000 | 2.739 | 169 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.500 | 0.0520 | 0.1713 | - | 13 | - | - | - | 156 | 0.0193 | 4.461 | 169 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 5000.000 | 393.0000 | 784.0000 | - | 1 | 5 | - | - | 163 | 122.0000 | 4.553 | 169 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 5.000 | 1.6300 | 2.2500 | - | 165 | - | - | - | 4 | 0.2070 | 1.316 | 169 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 22.9000 | 37.0000 | - | 73 | 68 | - | - | 28 | 6.8100 | 1.606 | 169 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 5000.000 | 303.0000 | 653.0000 | - | 63 | 26 | - | - | 80 | 33.7000 | 4.312 | 169 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 15.000 | 8.3800 | 3.6400 | - | 156 | - | - | - | 13 | 2.2200 | 1.459 | 169 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 500.000 | 40.1300 | 93.2000 | - | 99 | 16 | - | - | 54 | 7.8900 | 2.227 | 169 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 9.5600 | 17.2000 | - | 49 | 40 | - | - | 80 | 3.9700 | 1.978 | 169 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 50.000 | 25.0000 | 10.1000 | - | 108 | 21 | - | - | 40 | 12.9000 | 1.482 | 169 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 100.000 | 41.0000 | 41.7000 | - | 164 | - | - | - | 5 | 2.1500 | 1.589 | 169 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.0000 | -- | - | 168 | - | - | - | 1 | 7.0400 | 1.084 | 169 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 17.0000 | 25.7000 | - | 83 | 42 | - | - | 44 | 3.3700 | 2.245 | 169 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 20.3000 | 24.3000 | - | 84 | 33 | - | - | 52 | 5.4700 | 2.208 | 169 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 169 | - | - | - | - | 5.0000 | 1.001 | 169 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 276.0000 | 198.0000 | - | 52 | 2 | - | - | 115 | 143.0000 | 2.322 | 169 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 1000.000 | 35.5000 | 113.0000 | - | 14 | 38 | - | - | 117 | 12.3000 | 2.284 | 169 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 20.0000 | 14.6000 | - | 113 | 6 | - | - | 50 | 7.2300 | 1.871 | 169 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 300.0000 | 300.000 | 300.0000 | -- | - | 167 | 1 | - | - | 1 | 101.0000 | 1.094 | 169 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 500.000 | 56.0000 | 73.4000 | - | 90 | 1 | - | - | 78 | 14.5000 | 2.788 | 169 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.500 | 0.2170 | 0.2470 | - | 156 | 10 | - | - | 3 | 0.0111 | 1.525 | 169 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.800 | 0.0491 | 0.1050 | - | 1 | 104 | - | - | 64 | 0.0122 | 2.318 | 169 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 25.000 | 2.4100 | 3.6800 | - | 11 | 109 | - | - | 49 | 0.6770 | 2.003 | 169 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.0241 | 14.074 | 2.8300 | 4.3100 | 155 | - | - | - | - | 14 | 1.0000 | 5.405 | 14 | -- | -- | -- | 26 |
| 27 | AC-U | 0.1919 | 4.405 | 1.0300 | 0.9260 | 146 | - | - | - | - | 23 | 0.7760 | 2.139 | 23 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Dolomite

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 20.000 | 0.7130 | 2.1000 | - | 3 | 3 | - | - | 99 | 0.2340 | 3.637 | 105 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 10.000 | 6.2300 | 3.5600 | - | - | 1 | 4 | - | 100 | 4.2200 | 3.621 | 105 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 13.9000 | 5.2000 | - | - | - | 4 | - | 101 | 12.1000 | 2.371 | 105 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.300 | 0.0344 | 0.0549 | - | 5 | 1 | - | - | 99 | 0.0117 | 4.093 | 105 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 1000.000 | 138.0000 | 200.0000 | - | 1 | - | - | - | 104 | 72.0000 | 3.082 | 105 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 0.8170 | 0.3820 | - | 99 | - | - | - | 6 | 0.2160 | 1.382 | 105 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 18.1000 | 19.5000 | - | 22 | 59 | - | - | 24 | 7.6700 | 1.578 | 105 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 143.0000 | 267.0000 | - | 59 | 14 | - | - | 32 | 19.4000 | 2.899 | 105 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 13.0000 | 8.1200 | - | 96 | - | - | - | 9 | 2.3100 | 1.664 | 105 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 150.000 | 41.4000 | 37.6000 | - | 61 | 12 | - | - | 32 | 8.8600 | 2.514 | 105 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 11.1000 | 18.8000 | - | 20 | 13 | - | - | 72 | 5.3500 | 2.192 | 105 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 100.000 | 37.0000 | 27.9000 | - | 77 | 18 | - | - | 10 | 11.9000 | 1.471 | 105 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 20.0000 | 70.000 | 38.6000 | 24.1000 | - | 97 | 1 | - | - | 7 | 2.4200 | 2.045 | 105 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 105 | - | - | - | - | 7.0000 | -- | 105 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 26.2000 | 34.4000 | - | 54 | 19 | - | - | 32 | 3.8700 | 2.833 | 105 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 16.4000 | 14.6000 | - | 32 | 33 | - | - | 40 | 6.2500 | 2.050 | 105 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 105 | - | - | - | - | 5.0000 | 1.001 | 105 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 185.0000 | 126.0000 | - | 78 | 1 | - | - | 26 | 66.9000 | 1.751 | 105 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 700.000 | 37.0000 | 86.9000 | - | - | 15 | - | - | 90 | 15.4000 | 2.529 | 105 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 100.000 | 18.5000 | 21.3000 | - | 85 | 3 | - | - | 17 | 6.0000 | 1.575 | 105 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 500.0000 | 500.000 | 500.0000 | -- | - | 103 | 1 | - | - | 1 | 102.0000 | 1.175 | 105 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 200.000 | 42.9000 | 49.3000 | - | 59 | - | - | - | 46 | 12.3000 | 2.499 | 105 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.050 | 0.0500 | -- | - | 100 | 4 | - | - | 1 | 0.0105 | 1.263 | 105 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.220 | 0.0426 | 0.0364 | - | 3 | 41 | - | - | 61 | 0.0176 | 2.514 | 105 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 40.000 | 5.3800 | 9.4700 | - | 20 | 64 | - | - | 21 | 0.6310 | 2.398 | 105 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.2995 | 9.879 | 3.8700 | 3.9000 | 99 | - | - | - | - | 6 | 1.9900 | 4.111 | 6 | -- | -- | -- | 26 |
| 27 | AC-U | 0.1924 | 41.481 | 5.3800 | 12.8000 | 95 | - | - | - | - | 10 | 0.9590 | 5.793 | 10 | -- | -- | -- | 27 |

Clay and claystone

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.1000 | 10.000 | 2.0300 | 1.6500 | - | - | - | - | - | 68 | 1.5100 | 2.272 | 68 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.2000 | 10.000 | 1.4000 | 1.6000 | - | - | - | - | - | 68 | 0.9390 | 2.353 | 68 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0700 | 20.000 | 5.9600 | 7.3400 | - | - | - | - | - | 68 | 2.0400 | 5.397 | 68 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0100 | 1.000 | 0.2280 | 0.1780 | - | - | - | - | - | 68 | 0.1610 | 2.579 | 68 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 5000.000 | 457.0000 | 794.0000 | - | - | - | - | - | 68 | 155.0000 | 4.590 | 68 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.000 | 0.7500 | 0.2890 | - | 64 | - | - | - | 4 | 0.2150 | 1.365 | 68 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 150.000 | 47.7000 | 31.8000 | - | 1 | 20 | - | - | 47 | 21.3000 | 2.843 | 68 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 375.0000 | 407.0000 | - | 1 | 3 | - | - | 64 | 168.0000 | 3.972 | 68 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 70.000 | 12.0000 | 12.9000 | - | 41 | - | - | - | 27 | 3.6600 | 2.343 | 68 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 2000.000 | 94.6000 | 259.0000 | - | 10 | 1 | - | - | 57 | 36.3000 | 3.192 | 68 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 13.4000 | 11.8000 | - | 1 | 12 | - | - | 55 | 8.1600 | 2.187 | 68 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 700.000 | 62.4000 | 109.0000 | - | 20 | 6 | - | - | 42 | 23.9000 | 2.433 | 68 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 70.000 | 23.6000 | 20.3000 | - | 53 | 4 | - | - | 11 | 2.9100 | 2.359 | 68 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 70.000 | 27.1000 | 16.5000 | - | 45 | 6 | - | - | 17 | 9.7200 | 1.798 | 63 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 100.000 | 23.6000 | 23.4000 | - | 3 | - | - | - | 65 | 14.7000 | 2.590 | 68 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 18.4000 | 13.5000 | - | 1 | 9 | - | - | 58 | 13.1000 | 1.919 | 68 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 10.000 | 10.0000 | 0.0000 | - | 65 | - | - | - | 3 | 5.1600 | 1.154 | 68 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 300.0000 | 332.0000 | - | 25 | 4 | - | - | 39 | 120.0000 | 2.426 | 68 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 83.7000 | 68.0000 | - | - | 1 | - | - | 67 | 60.4000 | 2.263 | 68 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 150.000 | 27.6000 | 24.1000 | - | 15 | 1 | - | - | 52 | 15.3000 | 2.350 | 68 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 700.000 | 417.0000 | 223.0000 | - | 62 | - | - | - | 6 | 112.0000 | 1.493 | 68 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 1000.000 | 212.0000 | 225.0000 | - | 7 | - | - | - | 61 | 95.5000 | 3.805 | 68 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.1500 | 0.150 | 0.1500 | -- | 1 | 57 | 9 | - | - | 1 | 0.0118 | 1.561 | 67 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.350 | 0.0520 | 0.0510 | - | - | 22 | - | - | 46 | 0.0234 | 2.656 | 68 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 100.000 | 11.5000 | 22.4000 | - | - | 25 | 1 | - | 42 | 1.9700 | 4.617 | 68 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.0247 | 58.140 | 13.7000 | 20.0000 | 56 | - | - | - | - | 12 | 3.2800 | 9.312 | 12 | -- | -- | -- | 26 |
| 27 | AC-U | 1.3229 | 14.918 | 7.2000 | 4.2100 | 55 | - | - | - | - | 13 | 5.9700 | 1.983 | 13 | -- | -- | -- | 27 |

## Shale

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | * REPLACED DATA * Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 10.000 | 2.2700 | 1.6300 | 4 | - | - | - | - | 197 | 1.7200 | 2.316 | 197 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 10.000 | 1.2700 | 1.5200 | 4 | - | - | - | - | 197 | 0.8380 | 2.485 | 197 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 5.7000 | 6.6500 | 4 | - | - | 3 | - | 194 | 2.0200 | 5.643 | 197 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0050 | 0.700 | 0.2370 | 0.1460 | 4 | 1 | - | - | - | 196 | 0.1810 | 2.406 | 197 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 5000.000 | 435.0000 | 820.0000 | 4 | 2 | - | 2 | - | 193 | 185.0000 | 3.824 | 197 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 5.000 | 1.3500 | 1.0700 | 4 | 159 | - | - | - | 38 | 0.2750 | 2.055 | 197 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 300.000 | 50.5000 | 43.6000 | 7 | 2 | 26 | - | - | 166 | 27.6000 | 2.752 | 194 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 2000.000 | 443.0000 | 385.0000 | 4 | 2 | 1 | - | - | 194 | 260.0000 | 3.211 | 197 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 3.0000 | 30.000 | 11.3000 | 6.1600 | 4 | 94 | - | - | - | 103 | 4.6300 | 2.419 | 197 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 2.0000 | 200.000 | 71.8000 | 44.0000 | 4 | 11 | 5 | - | - | 181 | 46.4000 | 2.702 | 197 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 1.0000 | 1500.000 | 38.2000 | 162.0000 | 4 | 2 | 10 | - | - | 185 | 13.4000 | 2.693 | 197 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 38.1000 | 26.2000 | 4 | 30 | 16 | - | - | 151 | 25.9000 | 1.865 | 197 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 200.000 | 59.0000 | 66.3000 | 4 | 143 | 9 | - | - | 45 | 3.7200 | 3.540 | 197 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 50.000 | 16.2000 | 11.1000 | 4 | 148 | 24 | - | - | 25 | 7.9900 | 1.349 | 197 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 42.5000 | 55.3000 | 4 | 7 | 3 | - | - | 187 | 21.4000 | 3.142 | 197 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 23.6000 | 21.6000 | 4 | 11 | 16 | - | - | 170 | 15.0000 | 2.199 | 197 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 10.000 | 10.0000 | 0.0000 | 4 | 195 | - | - | - | 2 | 5.0400 | 1.072 | 197 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 70.0000 | 2000.000 | 231.0000 | 221.0000 | 4 | 68 | 7 | - | - | 122 | 115.0000 | 2.175 | 197 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 7.0000 | 5000.000 | 203.0000 | 459.0000 | 4 | - | 2 | - | - | 195 | 87.4000 | 3.265 | 197 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 23.8000 | 14.0000 | 4 | 12 | 3 | - | - | 182 | 18.6000 | 1.867 | 197 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 1500.000 | 622.0000 | 477.0000 | 4 | 168 | 11 | - | - | 18 | 118.0000 | 1.655 | 197 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 1000.000 | 147.0000 | 132.0000 | 4 | 7 | - | - | - | 190 | 96.7000 | 2.655 | 197 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0300 | 0.160 | 0.1030 | 0.0476 | 1 | 185 | 9 | - | - | 6 | 0.0111 | 1.534 | 200 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.450 | 0.0769 | 0.0698 | 7 | 5 | 34 | - | 9 | 146 | 0.0360 | 3.016 | 185 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 1000.000 | 28.8000 | 108.0000 | 7 | 2 | 52 | - | 2 | 138 | 2.5700 | 5.255 | 192 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.5920 | 26.595 | 11.1000 | 6.6600 | 170 | - | - | - | - | 31 | 8.3100 | 2.498 | 31 | -- | -- | -- | 26 |
| 27 | AC-U | 0.3800 | 87.387 | 11.3000 | 19.3000 | 166 | - | - | - | - | 35 | 5.0300 | 3.433 | 35 | -- | -- | -- | 27 |

## Phosphorite

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | * REPLACED DATA * Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 3.000 | 0.9830 | 0.7970 | - | - | - | - | - | 26 | 0.7020 | 2.541 | 26 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 1.500 | 0.3190 | 0.3120 | - | - | - | - | - | 26 | 0.2320 | 2.145 | 26 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 20.000 | 8.8500 | 6.2700 | - | - | - | - | - | 26 | 6.0500 | 2.966 | 26 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0050 | 0.300 | 0.0979 | 0.0763 | - | - | - | - | - | 26 | 0.0702 | 2.571 | 26 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 700.000 | 93.8000 | 131.0000 | - | - | - | - | - | 26 | 61.6000 | 2.373 | 26 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 5.000 | 1.3600 | 1.1100 | - | 8 | - | - | - | 18 | 0.6510 | 2.598 | 26 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 32.4000 | 24.2000 | - | - | 1 | - | - | 25 | 23.5000 | 2.199 | 26 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 200.000 | 95.4000 | 50.2000 | - | - | - | - | - | 26 | 82.3000 | 1.799 | 26 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | -- | -- | -- | -- | - | 26 | - | - | - | - | 2.0000 | 1.000 | 26 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 700.000 | 270.0000 | 185.0000 | - | - | 1 | - | - | 25 | 179.0000 | 3.001 | 26 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 100.000 | 22.1000 | 24.4000 | - | 1 | 1 | - | - | 24 | 12.5000 | 2.677 | 26 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 30.0000 | 300.000 | 197.0000 | 111.0000 | - | 3 | - | - | - | 23 | 111.0000 | 3.301 | 26 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 50.000 | 15.3000 | 17.9000 | - | 17 | 2 | - | - | 7 | 3.1300 | 2.321 | 26 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.0000 | -- | - | 25 | - | - | - | 1 | 7.2900 | 1.229 | 26 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 31.2000 | 42.2000 | - | - | - | - | - | 26 | 16.1000 | 2.978 | 26 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 72.0000 | 55.4000 | - | 2 | 2 | - | - | 22 | 33.2000 | 3.672 | 26 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 26 | - | - | - | - | 5.0000 | 1.000 | 26 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 339.0000 | 221.0000 | - | 6 | 1 | - | - | 19 | 174.0000 | 2.604 | 26 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 87.2000 | 56.4000 | - | - | 1 | - | - | 25 | 61.5000 | 2.502 | 26 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 500.000 | 196.0000 | 132.0000 | - | 1 | - | - | - | 25 | 121.0000 | 3.277 | 26 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 1500.000 | 800.0000 | 564.0000 | - | 6 | 1 | - | - | 19 | 380.0000 | 2.822 | 26 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 200.000 | 65.0000 | 51.4000 | - | 2 | - | - | - | 24 | 43.2000 | 2.367 | 26 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 23 | 3 | - | - | - | 0.0111 | 1.348 | 26 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.500 | 0.1710 | 0.1110 | - | - | 3 | - | - | 23 | 0.0945 | 3.414 | 26 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 70.000 | 15.3000 | 15.4000 | - | - | 1 | - | - | 25 | 8.2300 | 3.472 | 26 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 8.9210 | 10.900 | 9.9100 | 1.4000 | 24 | - | - | - | - | 2 | 9.8600 | 1.152 | 2 | -- | -- | -- | 26 |
| 27 | AC-U | 3.1687 | 32.567 | 22.0000 | 16.3000 | 23 | - | - | - | - | 3 | 14.6000 | 3.758 | 3 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Gypsum

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 0.200 | 0.1130 | 0.0629 | - | 7 | 4 | - | - | 4 | 0.0342 | 2.094 | 15 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 10.000 | 1.3300 | 3.0650 | - | 2 | 3 | - | - | 10 | 0.1010 | 8.136 | 15 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 5.0000 | 20.000 | 10.9000 | 5.0000 | - | - | - | - | - | 15 | 9.9700 | 1.517 | 15 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0030 | 0.010 | 0.0059 | 0.0026 | - | - | 6 | - | - | 9 | 0.0032 | 2.075 | 15 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 100.000 | 25.0000 | 33.3000 | - | 8 | - | - | - | 7 | 8.6700 | 2.277 | 15 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 1.0000 | 1.000 | 1.0000 | -- | - | 14 | - | - | - | 1 | 0.2230 | 1.515 | 15 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | -- | -- | -- | -- | - | 13 | 2 | - | - | - | 5.2300 | 1.126 | 15 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 30.0000 | 30.000 | 30.0000 | -- | - | 14 | - | - | - | 1 | 10.8000 | 1.328 | 15 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | -- | -- | -- | -- | - | 15 | - | - | - | - | 2.0000 | -- | 15 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | -- | -- | -- | -- | - | 15 | - | - | - | - | 5.0000 | 1.000 | 15 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | -- | -- | -- | -- | - | 14 | 1 | - | - | - | 2.0500 | 1.110 | 15 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | -- | -- | -- | -- | - | 15 | - | - | - | - | 10.0000 | 1.000 | 15 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 15 | - | - | - | - | 2.0000 | -- | 15 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 15 | - | - | - | - | 7.0000 | 1.000 | 15 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | -- | -- | -- | -- | - | 15 | - | - | - | - | 2.0000 | -- | 15 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 15.0000 | 15.000 | 15.0000 | -- | - | 14 | - | - | - | 1 | 3.3400 | 1.515 | 15 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 15 | - | - | - | - | 5.0000 | 1.000 | 15 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1000.000 | 643.0000 | 305.0000 | - | - | - | - | - | 15 | 537.0000 | 2.069 | 15 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 10.000 | 10.0000 | 0.0000 | - | - | 8 | - | - | 7 | 8.2700 | 1.202 | 15 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | -- | -- | -- | -- | - | 15 | - | - | - | - | 5.0000 | 1.000 | 15 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 15 | - | - | - | - | 100.0000 | 1.000 | 15 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 20.000 | 11.1000 | 3.3300 | - | 6 | - | - | - | 9 | 9.0800 | 1.324 | 15 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 12 | 3 | - | - | - | 0.0120 | 1.461 | 15 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.100 | 0.0467 | 0.0327 | - | - | 9 | - | - | 6 | 0.0137 | 2.602 | 15 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 5.000 | 2.3300 | 2.3100 | - | - | 12 | - | - | 3 | 0.6390 | 1.856 | 15 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | -- | -- | -- | -- | 15 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 26 |
| 27 | AC-U | 0.4947 | 0.495 | 0.4950 | -- | 14 | - | - | - | - | 1 | 0.4950 | -- | 1 | -- | -- | -- | 27 |

Bentonite

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 7.000 | 2.6800 | 1.5200 | - | - | - | - | - | 22 | 2.3600 | 1.650 | 22 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.3000 | 2.000 | 1.1200 | 0.5310 | - | - | - | - | - | 22 | 0.9990 | 1.682 | 22 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 10.000 | 1.5900 | 2.7500 | - | - | - | - | - | 22 | 0.8230 | 2.684 | 22 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0300 | 0.300 | 0.1380 | 0.0855 | - | - | - | - | - | 22 | 0.1130 | 1.927 | 22 | 0.00 | 0.03 | 2 | 4 |
| 5 | S-MN | 20.0000 | 1000.000 | 228.0000 | 241.0000 | - | - | - | 1 | - | 21 | 175.0000 | 3.543 | 22 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 1.0000 | 0.7070 | - | 16 | 1 | - | - | 5 | 0.2810 | 1.960 | 22 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 52.9000 | 65.9000 | - | 1 | - | - | - | 21 | 24.5000 | 3.284 | 22 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 3000.000 | 761.0000 | 605.0000 | - | - | - | - | - | 22 | 593.0000 | 2.112 | 22 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 7.000 | 5.3300 | 0.8160 | - | 16 | - | - | - | 6 | 2.6100 | 1.566 | 22 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 30.0000 | 34.6000 | - | 19 | - | - | - | 3 | 6.0000 | 1.795 | 22 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 15.000 | 6.8800 | 3.7200 | - | 1 | 13 | - | - | 8 | 3.8500 | 1.581 | 22 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 62.3000 | 53.7000 | - | - | - | - | - | 22 | 47.2000 | 2.073 | 22 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 7.0000 | 20.000 | 13.0000 | 5.7200 | - | 18 | - | - | - | 4 | 2.7700 | 2.074 | 22 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 70.000 | 23.5000 | 14.2000 | - | 3 | 2 | - | - | 17 | 16.7000 | 1.823 | 22 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 13.3000 | 14.6000 | - | - | 13 | - | - | 9 | 4.7400 | 2.146 | 22 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 34.3000 | 18.1000 | - | 1 | 1 | - | - | 20 | 24.7000 | 2.235 | 22 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 11.3000 | 2.3100 | - | 14 | - | - | - | 8 | 6.6700 | 1.501 | 22 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 308.0000 | 199.0000 | - | 2 | 1 | - | - | 19 | 205.0000 | 2.258 | 22 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 27.6000 | 43.6000 | - | - | 3 | - | - | 19 | 15.3000 | 2.249 | 22 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 30.5000 | 20.1000 | - | 1 | - | - | - | 21 | 23.2000 | 2.055 | 22 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 22 | - | - | - | - | 100.0000 | 1.000 | 22 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 50.0000 | 700.000 | 193.0000 | 125.0000 | - | - | - | - | - | 22 | 170.0000 | 1.631 | 22 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 19 | 3 | - | - | - | 0.0113 | 1.380 | 22 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.160 | 0.0510 | 0.0343 | - | - | 2 | - | - | 20 | 0.0367 | 2.126 | 22 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 25.000 | 4.9500 | 6.4600 | - | 1 | 1 | - | - | 20 | 2.3500 | 3.150 | 22 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.5153 | 31.505 | 17.9000 | 14.9000 | 18 | - | - | - | - | 4 | 12.4000 | 2.856 | 4 | -- | -- | -- | 26 |
| 27 | AC-U | 1.3797 | 10.732 | 6.0800 | 4.8000 | 18 | - | - | - | - | 4 | 4.3700 | 2.745 | 4 | -- | -- | -- | 27 |

## Welded tuff

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 15.000 | 2.690 | 2.1900 | - | - | - | - | - | 79 | 2.2100 | 1.813 | 79 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 3.000 | 1.000 | 0.8180 | - | - | - | - | - | 79 | 0.5440 | 3.864 | 79 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 10.000 | 1.890 | 2.2600 | - | - | - | - | - | 79 | 0.9030 | 3.711 | 79 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0200 | 0.700 | 0.206 | 0.1360 | - | - | - | - | - | 79 | 0.1680 | 1.971 | 79 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 50.0000 | 1500.000 | 382.000 | 360.0000 | - | - | - | 1 | - | 78 | 281.0000 | 2.460 | 79 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 1.300 | 0.5340 | - | 70 | - | - | - | 9 | 0.2450 | 1.803 | 79 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 70.000 | 23.000 | 17.9000 | - | 24 | 32 | - | - | 23 | 8.3500 | 1.880 | 79 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 5000.000 | 1030.000 | 726.0000 | - | - | - | - | - | 79 | 790.0000 | 2.320 | 79 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 11.400 | 7.6800 | - | 33 | - | - | - | 46 | 5.0200 | 2.443 | 79 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 300.000 | 113.000 | 81.9000 | - | 34 | 1 | - | - | 44 | 23.8000 | 4.669 | 79 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 700.000 | 23.700 | 80.1000 | - | - | 2 | - | - | 77 | 11.6000 | 2.231 | 79 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 300.000 | 67.000 | 55.6000 | - | 6 | 6 | - | - | 67 | 40.9000 | 2.347 | 79 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 150.000 | 30.600 | 49.1000 | - | 64 | 7 | - | - | 8 | 2.5400 | 2.016 | 79 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 70.000 | 37.500 | 17.0000 | - | 55 | - | - | - | 24 | 11.4000 | 2.160 | 79 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 200.000 | 31.400 | 39.0000 | - | 1 | 15 | - | - | 63 | 12.1000 | 3.314 | 79 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 28.200 | 25.6000 | - | 1 | 4 | - | - | 74 | 19.7000 | 2.132 | 79 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 11.900 | 2.5900 | - | 68 | 3 | - | - | 8 | 5.5200 | 1.307 | 79 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 5000.000 | 570.000 | 680.0000 | - | 23 | 1 | - | - | 55 | 213.0000 | 3.268 | 79 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 56.800 | 60.2000 | - | - | 4 | - | - | 75 | 33.1000 | 2.763 | 79 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 200.000 | 44.600 | 37.0000 | - | 26 | 1 | - | - | 52 | 17.1000 | 3.057 | 79 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 500.000 | 400.000 | 173.0000 | - | 75 | 1 | - | - | 3 | 106.0000 | 1.307 | 79 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 50.0000 | 700.000 | 161.000 | 118.0000 | - | 2 | - | - | - | 77 | 122.0000 | 2.179 | 79 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.800 | 0.265 | 0.3590 | - | 63 | 12 | - | - | 4 | 0.0131 | 1.983 | 79 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.240 | 0.042 | 0.0463 | - | 6 | 35 | - | - | 38 | 0.0142 | 2.464 | 79 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 35.000 | 4.500 | 8.5400 | - | 3 | 46 | - | - | 30 | 0.8460 | 2.621 | 79 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 3.8067 | 23.544 | 13.460 | 7.8800 | 70 | - | - | - | - | 9 | 11.3000 | 1.920 | 9 | -- | -- | -- | 26 |
| 27 | AC-U | 1.3723 | 31.344 | 5.270 | 9.2300 | 69 | - | - | - | - | 10 | 2.8100 | 2.583 | 10 | -- | -- | -- | 27 |

## Jasperoid

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.1000 | 7.000 | 1.5400 | 1.6100 | - | 1 | - | - | - | 21 | 0.6940 | 4.451 | 22 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 1.500 | 0.3750 | 0.4050 | - | - | 2 | - | - | 20 | 0.1600 | 4.038 | 22 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 10.000 | 1.3100 | 2.2900 | - | - | - | - | - | 22 | 0.4080 | 4.914 | 22 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.300 | 0.0894 | 0.0817 | - | 3 | - | - | - | 19 | 0.0279 | 6.567 | 22 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 2000.000 | 223.0000 | 441.0000 | - | 1 | 1 | - | - | 20 | 70.2000 | 4.431 | 22 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 1.5000 | 1.500 | 1.5000 | -- | - | 21 | - | - | - | 1 | 0.2190 | 1.537 | 22 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 40.0000 | 41.6000 | - | 10 | 5 | - | - | 7 | 9.0000 | 2.491 | 22 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 2000.000 | 471.0000 | 530.0000 | - | 1 | - | - | - | 21 | 193.0000 | 4.674 | 22 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 15.000 | 10.0000 | 3.5400 | - | 17 | - | - | - | 5 | 2.8500 | 1.989 | 22 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 50.0000 | 28.3000 | - | 14 | 1 | - | - | 7 | 9.7000 | 2.950 | 22 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 13.2000 | 12.4000 | - | 4 | 5 | - | - | 13 | 5.6700 | 2.439 | 22 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 35.3000 | 43.2000 | - | 3 | 2 | - | - | 17 | 22.5000 | 1.873 | 22 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 15.0000 | 15.000 | 15.0000 | -- | - | 20 | 1 | - | - | 1 | 2.2300 | 1.544 | 22 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 20.000 | 16.7000 | 5.7700 | - | 19 | - | - | - | 3 | 7.8300 | 1.368 | 22 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 100.000 | 18.3000 | 26.8000 | - | 4 | 6 | - | - | 12 | 5.5900 | 2.761 | 22 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 30.000 | 15.0000 | 6.1200 | - | 13 | - | - | - | 9 | 5.6600 | 2.245 | 22 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 10.000 | 10.0000 | 0.0000 | - | 20 | - | - | - | 2 | 5.3300 | 1.226 | 22 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 371.0000 | 206.0000 | - | 13 | 2 | - | - | 7 | 92.7000 | 2.539 | 22 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 150.000 | 46.9000 | 34.6000 | - | 5 | 1 | - | - | 16 | 21.4000 | 3.011 | 22 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 200.000 | 42.2000 | 60.8000 | - | 12 | 1 | - | - | 9 | 9.6500 | 2.722 | 22 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 300.0000 | 300.000 | 300.0000 | -- | - | 21 | - | - | - | 1 | 105.0000 | 1.264 | 22 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.000 | 100.0000 | 84.8000 | - | 9 | - | - | - | 13 | 27.2000 | 3.909 | 22 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 21 | 1 | - | - | - | 0.0104 | 1.216 | 22 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.040 | 0.0300 | 0.0100 | - | - | 19 | - | - | 3 | 0.0085 | 1.663 | 22 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 6.000 | 2.8300 | 2.2300 | - | - | 16 | - | - | 6 | 0.7410 | 2.178 | 22 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 5.2977 | 14.074 | 9.4000 | 4.4200 | 19 | - | - | - | - | 3 | 8.7000 | 1.630 | 3 | -- | -- | -- | 26 |
| 27 | AC-U | 1.0776 | 8.900 | 3.8500 | 3.0600 | 17 | - | - | - | - | 5 | 3.0200 | 2.193 | 5 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Huckleberry Ridge Tuff of Yellowstone Group (Pliocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 10.000 | 2.710 | 1.8000 | - | - | - | - | - | 34 | 2.3400 | 1.677 | 34 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 2.000 | 0.331 | 0.5120 | - | - | - | - | - | 34 | 0.1460 | 3.452 | 34 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 2.000 | 0.337 | 0.3820 | - | - | - | - | - | 34 | 0.2400 | 2.127 | 34 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0200 | 1.000 | 0.139 | 0.1990 | - | - | - | - | - | 34 | 0.1400 | 2.035 | 34 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 150.0000 | 1000.000 | 401.000 | 219.0000 | - | - | - | - | - | 34 | 352.0000 | 1.676 | 34 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 1.150 | 0.5550 | - | 26 | - | - | - | 8 | 0.2940 | 2.107 | 34 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 50.000 | 20.900 | 15.1000 | - | - | 23 | - | - | 11 | 9.3700 | 1.729 | 34 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 200.0000 | 2000.000 | 1140.000 | 579.0000 | - | - | - | - | - | 34 | 972.0000 | 1.877 | 34 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 8.770 | 7.6300 | - | 21 | - | - | - | 13 | 3.2500 | 2.055 | 34 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 15.0000 | 500.000 | 146.000 | 171.0000 | - | 26 | 1 | - | - | 7 | 8.9300 | 3.495 | 34 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 18.200 | 27.3000 | - | - | 1 | - | - | 33 | 11.1000 | 2.339 | 34 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 98.800 | 48.7000 | - | 1 | - | - | - | 33 | 81.6000 | 1.908 | 34 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 30.000 | 11.400 | 9.0000 | - | 19 | 8 | - | - | 7 | 3.0100 | 1.949 | 34 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 15.0000 | 70.000 | 38.500 | 17.9000 | - | 3 | - | - | - | 31 | 30.4000 | 1.866 | 34 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 100.000 | 16.300 | 21.8000 | - | - | 15 | - | - | 19 | 6.1000 | 2.425 | 34 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 15.0000 | 200.000 | 46.500 | 43.8000 | - | - | - | - | - | 34 | 35.9000 | 1.939 | 34 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 20.000 | 13.600 | 3.2300 | - | 20 | 3 | - | - | 11 | 7.0700 | 1.603 | 34 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 240.000 | 246.0000 | - | 24 | - | - | - | 10 | 71.6000 | 2.018 | 34 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 150.000 | 30.500 | 42.2000 | - | - | 1 | - | - | 33 | 16.1000 | 2.622 | 34 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 100.000 | 58.800 | 23.8000 | - | - | - | - | - | 34 | 52.8000 | 1.690 | 34 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 200.000 | 200.000 | -- | - | 32 | 1 | - | - | 1 | 103.0000 | 1.146 | 34 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 70.0000 | 700.000 | 255.000 | 134.0000 | - | - | - | - | - | 34 | 229.0000 | 1.578 | 34 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0600 | 0.300 | 0.170 | 0.1210 | - | 25 | 6 | - | - | 3 | 0.0148 | 2.257 | 34 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.240 | 0.042 | 0.0492 | - | 5 | 10 | - | - | 19 | 0.0159 | 2.568 | 34 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 9.000 | 2.760 | 2.5400 | - | 6 | 11 | - | - | 17 | 0.8970 | 2.693 | 34 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 22.1370 | 22.187 | 22.200 | -- | 33 | - | - | - | - | 1 | 22.2000 | -- | 1 | -- | -- | -- | 26 |
| 27 | AC-U | 4.8595 | 4.859 | 4.860 | -- | 33 | - | - | - | - | 1 | 4.8600 | -- | 1 | -- | -- | -- | 27 |

Lava Creek Tuff of Yellowstone Group (Pleistocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 2.0000 | 5.000 | 2.2500 | 0.7750 | - | - | - | - | - | 16 | 2.1700 | 1.277 | 16 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0700 | 3.000 | 0.5430 | 0.9860 | - | - | - | - | - | 16 | 0.1970 | 3.564 | 16 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 15.000 | 2.3700 | 4.9700 | - | - | - | - | - | 16 | 0.6430 | 4.069 | 16 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0700 | 0.500 | 0.1270 | 0.1030 | - | - | - | - | - | 16 | 0.1100 | 1.583 | 16 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 300.0000 | 2000.000 | 463.0000 | 447.0000 | - | - | - | - | - | 16 | 376.0000 | 1.729 | 16 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 16 | - | - | - | - | 0.2000 | 1.000 | 16 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 50.000 | 17.5000 | 9.6600 | - | - | - | - | - | 16 | 15.9000 | 1.531 | 16 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 300.0000 | 2000.000 | 694.0000 | 409.0000 | - | - | - | - | - | 16 | 613.0000 | 1.641 | 16 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 5.000 | 5.0000 | 0.0000 | - | 3 | - | - | - | 13 | 4.2100 | 1.447 | 16 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 70.0000 | 150.000 | 110.0000 | 56.6000 | - | 14 | - | - | - | 2 | 7.2900 | 2.832 | 16 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 20.000 | 14.1000 | 5.7300 | - | - | 2 | - | - | 14 | 10.6000 | 1.979 | 16 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 137.0000 | 48.7000 | - | - | - | - | - | 16 | 122.0000 | 1.815 | 16 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 10.000 | 8.5000 | 2.4200 | - | 6 | - | - | - | 10 | 4.8000 | 2.111 | 16 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 70.000 | 49.3000 | 16.9000 | - | 2 | - | - | - | 14 | 36.5000 | 2.097 | 16 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 70.000 | 12.2000 | 15.7000 | - | - | - | - | - | 16 | 5.9300 | 1.944 | 16 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 30.0000 | 100.000 | 58.8000 | 23.9000 | - | - | - | - | - | 16 | 53.9000 | 1.560 | 16 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 10.8000 | 1.9500 | - | 4 | - | - | - | 12 | 8.8500 | 1.442 | 16 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 200.000 | 167.0000 | 57.7000 | - | 13 | - | - | - | 3 | 62.1000 | 1.629 | 16 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 31.5000 | 59.5000 | - | - | 6 | - | - | 10 | 11.6000 | 2.333 | 16 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 30.0000 | 100.000 | 80.6000 | 25.7000 | - | - | - | - | - | 16 | 75.4000 | 1.517 | 16 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 500.000 | 350.0000 | 212.0000 | - | 14 | - | - | - | 2 | 115.0000 | 1.533 | 16 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 150.0000 | 300.000 | 188.0000 | 50.0000 | - | - | - | - | - | 16 | 182.0000 | 1.269 | 16 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 16 | - | - | - | - | 0.0100 | 1.000 | 16 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.060 | 0.0400 | 0.0283 | - | 8 | 6 | - | - | 2 | 0.0072 | 1.942 | 16 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 4.000 | 2.4000 | 1.3400 | - | 8 | 3 | - | - | 5 | 2.6020 | 2.559 | 16 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | -- | -- | -- | -- | 16 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 26 |
| 27 | AC-U | -- | -- | -- | -- | 16 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 27 |

## Miscellaneous samples (Pleistocene and Pliocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 10.000 | 3.270 | 1.8600 | - | - | - | - | - | 28 | 2.8300 | 1.762 | 28 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 10.000 | 2.300 | 2.8600 | - | - | - | - | - | 28 | 0.9670 | 4.907 | 28 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 15.000 | 2.700 | 3.3800 | - | - | - | - | - | 28 | 1.3500 | 3.716 | 28 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0500 | 1.000 | 0.341 | 0.1980 | - | - | - | - | - | 28 | 0.2800 | 2.027 | 28 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 30.0000 | 5000.000 | 842.000 | 973.0000 | - | - | - | - | - | 28 | 517.0000 | 2.891 | 28 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 0.500 | 0.500 | -- | - | 25 | 2 | - | - | 1 | 0.2130 | 1.219 | 28 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 31.800 | 28.3000 | - | - | 14 | - | - | 14 | 12.5000 | 2.318 | 28 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 2000.000 | 1260.000 | 626.0000 | - | - | - | - | - | 28 | 995.0000 | 2.371 | 28 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 7.0000 | 70.000 | 22.800 | 19.9000 | - | 12 | 2 | - | - | 14 | 5.9800 | 3.283 | 28 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 1000.000 | 215.000 | 286.0000 | - | 4 | 1 | - | - | 23 | 56.9000 | 5.283 | 28 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 29.700 | 32.8000 | - | - | - | - | - | 28 | 18.3000 | 2.686 | 28 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 78.900 | 59.3000 | - | - | - | - | - | 23 | 59.5000 | 2.177 | 28 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 24 | 4 | - | - | - | 2.1200 | 1.155 | 28 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 30.000 | 24.000 | 5.4800 | 2 | 20 | 1 | - | - | 5 | 8.9600 | 1.633 | 26 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 56.400 | 75.3000 | - | - | - | - | - | 28 | 24.5000 | 3.840 | 28 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 20.600 | 13.1000 | - | - | 1 | - | - | 27 | 17.2000 | 1.704 | 28 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 26 | 2 | - | - | - | 5.1200 | 1.092 | 28 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 671.000 | 546.0000 | - | 4 | 3 | - | - | 21 | 267.0000 | 3.492 | 28 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 102.000 | 77.6000 | - | - | - | - | - | 28 | 70.0000 | 2.797 | 28 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 200.000 | 37.000 | 36.7000 | - | - | 1 | - | - | 27 | 27.1000 | 2.050 | 28 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 26 | 2 | - | - | - | 103.0000 | 1.112 | 28 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 70.0000 | 500.000 | 230.000 | 103.0000 | - | - | - | - | - | 28 | 208.0000 | 1.600 | 28 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0290 | 0.078 | 0.053 | 0.0346 | - | 20 | 6 | - | - | 2 | 0.0136 | 1.708 | 28 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.040 | 0.026 | 0.0081 | - | - | 17 | - | - | 11 | 0.0116 | 1.942 | 28 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 2.200 | 2.6800 | 2 | - | 21 | - | - | 5 | 0.6160 | 1.746 | 26 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 7.8088 | 18.742 | 13.000 | 4.5630 | 22 | - | - | - | - | 6 | 12.3000 | 1.437 | 6 | -- | -- | -- | 26 |
| 27 | AC-U | 1.9352 | 6.962 | 3.680 | 1.9300 | 22 | - | - | - | - | 6 | 3.3200 | 1.627 | 6 | -- | -- | -- | 27 |

## Colter Formation (Miocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 10.000 | 4.7500 | 2.9300 | - | - | - | - | - | 14 | 3.8600 | 2.028 | 14 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.3000 | 7.000 | 2.8800 | 2.1800 | - | - | - | - | - | 14 | 1.9500 | 2.787 | 14 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.3000 | 10.000 | 5.1600 | 3.4500 | - | - | - | - | - | 14 | 3.3100 | 3.439 | 14 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.1000 | 0.700 | 0.3750 | 0.2360 | - | - | - | - | - | 14 | 0.3040 | 2.012 | 14 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 300.0000 | 1500.000 | 814.0000 | 422.0000 | - | - | - | - | - | 14 | 697.0000 | 1.849 | 14 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 1.0000 | 1.000 | 1.0000 | -- | - | 13 | - | - | - | 1 | 0.2240 | 1.537 | 14 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 30.000 | 16.7000 | 8.6600 | - | 1 | 4 | - | - | 9 | 11.1000 | 1.767 | 14 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 2000.000 | 982.0000 | 653.0000 | - | - | - | - | - | 14 | 762.0000 | 2.240 | 14 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 70.000 | 23.6000 | 22.8000 | - | - | - | - | - | 14 | 14.1000 | 2.949 | 14 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 20.0000 | 2000.000 | 658.0000 | 739.0000 | - | 2 | - | - | - | 12 | 169.0000 | 7.645 | 14 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 70.000 | 26.6000 | 21.4000 | - | - | - | - | - | 14 | 18.1000 | 2.642 | 14 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 150.000 | 80.0000 | 48.8000 | - | 3 | - | - | - | 11 | 44.0000 | 2.728 | 14 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 5.000 | 5.0000 | 0.0000 | - | 12 | - | - | - | 2 | 2.2800 | 1.395 | 14 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 30.000 | 26.7000 | 5.7700 | - | 9 | 2 | - | - | 3 | 9.7700 | 1.745 | 14 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 100.000 | 50.0000 | 32.9000 | - | - | - | - | - | 14 | 36.5000 | 2.554 | 14 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 15.0000 | 500.000 | 67.1000 | 137.0000 | - | 2 | - | - | - | 12 | 23.1000 | 3.441 | 14 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 12.5000 | 3.5400 | - | 12 | - | - | - | 2 | 5.6800 | 1.398 | 14 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 150.0000 | 1000.000 | 565.0000 | 340.0000 | - | 3 | 1 | - | - | 10 | 252.0000 | 3.196 | 14 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 124.0000 | 71.3000 | - | - | - | - | - | 14 | 90.5000 | 2.779 | 14 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 100.000 | 39.2000 | 29.6000 | - | 1 | - | - | - | 13 | 27.2000 | 2.323 | 14 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 700.0000 | 700.000 | 700.0000 | -- | - | 13 | - | - | - | 1 | 115.0000 | 1.682 | 14 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 50.0000 | 500.000 | 198.0000 | 148.0000 | - | 1 | - | - | - | 13 | 127.0000 | 2.883 | 14 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.1500 | 0.200 | 0.1750 | 0.0354 | 1 | 9 | 2 | - | - | 2 | 0.0179 | 2.902 | 13 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.350 | 0.0555 | 0.0982 | - | - | 3 | - | - | 11 | 0.0226 | 2.694 | 14 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 2.2900 | 2.3600 | - | 5 | 2 | - | - | 7 | 0.7480 | 2.690 | 14 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 8.2152 | 10.672 | 9.4400 | 1.7400 | 12 | - | - | - | - | 2 | 9.3600 | 1.203 | 2 | -- | -- | -- | 26 |
| 27 | AC-U | 1.8489 | 1.884 | 1.8700 | 0.0250 | 12 | - | - | - | - | 2 | 1.8700 | 1.013 | 2 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

White River Formation (Oligocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 2.000 | 5.000 | 3.730 | 1.1000 | - | - | - | - | - | 15 | 3.580 | 1.350 | 15 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.070 | 7.000 | 1.800 | 1.6100 | - | - | - | - | - | 15 | 1.290 | 2.668 | 15 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.200 | 3.000 | 2.210 | 0.8260 | - | - | - | - | - | 15 | 1.930 | 2.002 | 15 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.100 | 0.500 | 0.327 | 0.1030 | - | - | - | - | - | 15 | 0.309 | 1.456 | 15 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 200.000 | 1500.000 | 827.000 | 432.0000 | - | - | - | - | - | 15 | 713.000 | 1.816 | 15 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 15 | - | - | - | - | 0.200 | 1.000 | 15 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.000 | 10.000 | 10.000 | 0.0000 | - | - | 12 | - | - | 3 | 7.520 | 1.159 | 15 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 1000.000 | 3000.000 | 1370.000 | 516.0000 | - | - | - | - | - | 15 | 1300.000 | 1.360 | 15 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.000 | 70.000 | 14.800 | 16.8000 | - | 1 | - | - | - | 14 | 9.430 | 2.359 | 15 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 70.000 | 700.000 | 172.000 | 169.0000 | - | 1 | 1 | - | - | 13 | 89.300 | 3.479 | 15 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.000 | 150.000 | 45.900 | 48.5000 | - | - | - | - | - | 15 | 26.700 | 3.043 | 15 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 30.000 | 100.000 | 54.700 | 25.0000 | - | - | - | - | - | 15 | 50.100 | 1.524 | 15 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 15 | - | - | - | - | 2.000 | -- | 15 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 30.000 | 30.000 | 30.000 | -- | - | 14 | - | - | - | 1 | 7.710 | 1.456 | 15 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.000 | 150.000 | 42.700 | 40.6000 | - | - | - | - | - | 15 | 27.700 | 2.753 | 15 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.000 | 50.000 | 23.300 | 11.6000 | - | - | - | - | - | 15 | 21.300 | 1.516 | 15 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 15 | - | - | - | - | 5.000 | 1.000 | 15 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 300.000 | 1500.000 | 786.000 | 296.0000 | - | 1 | - | - | - | 14 | 614.000 | 2.204 | 15 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.000 | 200.000 | 124.000 | 57.9000 | - | - | - | - | - | 15 | 104.000 | 2.131 | 15 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.000 | 70.000 | 24.300 | 17.0000 | - | - | - | - | - | 15 | 20.100 | 1.877 | 15 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 15 | - | - | - | - | 100.000 | 1.000 | 15 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 100.000 | 300.000 | 177.000 | 49.5000 | - | - | - | - | - | 15 | 170.000 | 1.332 | 15 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 15 | - | - | - | - | 0.010 | 1.000 | 15 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.020 | 0.040 | 0.024 | 0.0089 | - | - | 10 | - | - | 5 | 0.010 | 1.828 | 15 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | -- | -- | -- | -- | - | - | 15 | - | - | - | 0.500 | -- | 15 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 11.566 | 11.566 | 11.600 | -- | 14 | - | - | - | - | 1 | 11.600 | -- | 1 | -- | -- | -- | 26 |
| 27 | AC-U | 2.077 | 2.077 | 2.080 | -- | 14 | - | - | - | - | 1 | 2.080 | -- | 1 | -- | -- | -- | 27 |

Basalt of Emerald Lake (Pliocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 15.000 | 5.000 | 4.5000 | - | - | - | - | - | 8 | 3.6500 | 2.340 | 8 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.5000 | 2.000 | 1.530 | 0.6690 | - | - | - | - | - | 8 | 1.3500 | 1.770 | 8 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.5000 | 20.000 | 4.750 | 6.9000 | - | - | - | - | - | 8 | 2.1100 | 3.742 | 8 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.2000 | 0.700 | 0.329 | 0.1980 | - | - | - | 1 | - | 7 | 0.3550 | 2.130 | 8 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 300.0000 | 2000.000 | 1000.000 | 545.0000 | - | - | - | - | - | 8 | 866.0000 | 1.825 | 8 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 8 | - | - | - | - | 0.2000 | -- | 8 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 70.000 | 31.300 | 25.3000 | - | - | - | - | - | 8 | 23.3000 | 2.273 | 8 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 300.0000 | 2000.000 | 750.000 | 555.0000 | - | - | - | - | - | 8 | 621.0000 | 1.877 | 8 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 10.000 | 7.670 | 1.9700 | - | 2 | - | - | - | 6 | 5.3600 | 1.912 | 8 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 15.0000 | 300.000 | 81.900 | 92.7000 | - | - | - | - | - | 8 | 53.4000 | 2.608 | 8 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 7.0000 | 50.000 | 24.600 | 18.1000 | - | - | - | - | - | 8 | 18.8000 | 2.234 | 8 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 300.000 | 67.500 | 95.0000 | - | - | - | - | - | 8 | 41.6000 | 2.470 | 8 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 8 | - | - | - | - | 2.0000 | 1.000 | 8 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 30.0000 | 30.000 | 30.000 | 0.0000 | - | 4 | 2 | - | - | 2 | 11.0000 | 1.893 | 8 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 18.800 | 15.3000 | - | - | - | - | - | 8 | 14.0000 | 2.289 | 8 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 26.900 | 12.2000 | - | - | - | - | - | 8 | 24.3000 | 1.650 | 8 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 8 | - | - | - | - | 5.0000 | -- | 8 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 388.000 | 270.0000 | - | - | - | - | - | 8 | 298.0000 | 2.275 | 8 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 30.0000 | 300.000 | 104.000 | 89.1000 | - | - | - | - | - | 8 | 78.3000 | 2.210 | 8 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 30.000 | 20.0000 | - | - | - | - | - | 8 | 25.3000 | 1.842 | 8 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 8 | - | - | - | - | 100.0000 | 1.000 | 8 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 100.0000 | 150.000 | 136.000 | 24.4000 | - | - | - | 1 | - | 7 | 181.0000 | 2.393 | 8 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 5.5000 | 5.500 | 5.500 | -- | - | 6 | 1 | - | - | 1 | 0.0247 | 9.098 | 8 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0400 | 0.060 | 0.050 | 0.0110 | - | - | 2 | - | - | 6 | 0.0301 | 2.509 | 8 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 3.000 | 2.200 | 1.1000 | - | 1 | 2 | - | - | 5 | 1.0900 | 2.518 | 8 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | -- | -- | -- | -- | 8 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 26 |
| 27 | AC-U | -- | -- | -- | -- | 8 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 27 |

Wiggins Formation of Thorofare Creek Group (upper Eocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.1000 | 15.000 | 3.300 | 1.9400 | - | 1 | 1 | - | - | 314 | 2.730 | 2.059 | 316 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 7.000 | 1.910 | 1.1600 | - | - | 1 | 1 | - | 314 | 1.570 | 2.169 | 316 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 3.120 | 2.6100 | - | - | - | 3 | - | 313 | 2.500 | 2.264 | 316 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 1.000 | 0.279 | 0.1420 | - | 2 | - | - | - | 314 | 0.225 | 2.378 | 316 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 3000.000 | 510.000 | 430.0000 | - | 1 | 1 | - | - | 314 | 352.000 | 2.562 | 316 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 1.250 | 1.0600 | - | 314 | - | - | - | 2 | 0.202 | 1.149 | 316 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 50.000 | 15.000 | 11.6000 | - | 122 | 144 | - | - | 50 | 6.750 | 1.451 | 316 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 3000.000 | 1200.000 | 474.0000 | - | 4 | - | 2 | - | 310 | 1010.000 | 2.293 | 316 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 17.600 | 9.1300 | - | 39 | - | - | - | 277 | 12.200 | 2.239 | 316 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 1000.000 | 165.000 | 117.0000 | - | 29 | 2 | - | - | 285 | 94.400 | 3.336 | 316 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 200.000 | 22.300 | 20.3000 | - | 3 | 7 | - | - | 306 | 16.700 | 2.015 | 316 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 44.900 | 29.5000 | - | 18 | 23 | - | - | 275 | 33.000 | 1.889 | 316 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 20.000 | 12.100 | 5.6700 | - | 306 | 3 | - | - | 7 | 2.080 | 1.300 | 316 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 30.000 | 25.700 | 5.3500 | - | 298 | 11 | - | - | 7 | 7.290 | 1.222 | 316 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 67.100 | 45.2000 | - | 5 | 4 | - | - | 307 | 45.600 | 2.727 | 316 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 18.400 | 11.0000 | - | 19 | 12 | - | - | 285 | 14.300 | 1.829 | 316 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 316 | - | - | - | - | 5.000 | -- | 316 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 762.000 | 351.0000 | - | 9 | 4 | - | - | 303 | 610.000 | 2.044 | 316 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 99.400 | 62.2000 | - | 4 | 2 | - | - | 310 | 76.600 | 2.173 | 316 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 15.000 | 8.0200 | - | 120 | 23 | - | - | 173 | 8.890 | 1.759 | 316 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 316 | - | - | - | - | 100.000 | 1.000 | 316 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.000 | 110.000 | 55.3000 | - | 11 | 1 | - | - | 304 | 86.200 | 2.105 | 316 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.100 | 0.075 | 0.0354 | - | 303 | 11 | - | - | 2 | 0.010 | 1.257 | 316 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.300 | 0.035 | 0.0367 | - | - | 196 | - | - | 120 | 0.012 | 2.128 | 316 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 1.510 | 1.3100 | - | 8 | 273 | - | - | 35 | 0.547 | 1.419 | 316 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 1.9960 | 23.544 | 7.680 | 4.3300 | 272 | - | - | - | - | 44 | 6.800 | 1.629 | 44 | -- | -- | -- | 26 |
| 27 | AC-U | 0.5607 | 4.099 | 1.660 | 0.7160 | 269 | - | - | - | - | 47 | 1.540 | 1.454 | 47 | -- | -- | -- | 27 |

Trout Peak Trachyandesite of Sunlight Group (Eocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 2.0000 | 10.000 | 4.500 | 2.2400 | - | - | - | - | - | 12 | 4.080 | 1.571 | 12 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 1.0000 | 5.000 | 2.670 | 1.4600 | - | - | - | - | - | 12 | 2.340 | 1.691 | 12 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 2.0000 | 5.000 | 2.670 | 0.8880 | - | - | - | - | - | 12 | 2.560 | 1.339 | 12 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.2000 | 0.500 | 0.367 | 0.1230 | - | - | - | - | - | 12 | 0.347 | 1.425 | 12 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 150.0000 | 1500.000 | 725.000 | 437.0000 | - | - | - | - | - | 12 | 562.000 | 2.305 | 12 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 12 | - | - | - | - | 0.200 | -- | 12 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 10.000 | 10.000 | -- | - | 2 | 9 | - | - | 1 | 6.820 | 1.194 | 12 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 700.0000 | 3000.000 | 1490.000 | 642.0000 | - | - | - | - | - | 12 | 1370.000 | 1.539 | 12 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 10.0000 | 50.000 | 22.500 | 11.0000 | - | - | - | - | - | 12 | 20.500 | 1.554 | 12 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 15.0000 | 500.000 | 205.000 | 153.0000 | - | - | - | - | - | 12 | 153.000 | 2.482 | 12 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 15.0000 | 150.000 | 66.300 | 43.9000 | - | - | - | - | - | 12 | 51.100 | 2.246 | 12 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 150.000 | 58.300 | 48.2000 | - | - | - | - | - | 12 | 44.500 | 2.097 | 12 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 12 | - | - | - | - | 2.000 | -- | 12 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 11 | 1 | - | - | - | 7.210 | 1.108 | 12 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 65.400 | 45.0000 | - | - | - | - | - | 12 | 46.600 | 2.719 | 12 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 24.200 | 18.1000 | - | - | - | - | - | 12 | 20.100 | 1.809 | 12 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 12 | - | - | - | - | 5.000 | -- | 12 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 200.0000 | 1500.000 | 842.000 | 462.0000 | - | - | - | - | - | 12 | 713.000 | 1.897 | 12 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 50.0000 | 200.000 | 128.000 | 65.5000 | - | - | - | - | - | 12 | 112.000 | 1.752 | 12 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 30.000 | 19.000 | 5.6800 | - | 2 | - | - | - | 10 | 14.600 | 1.799 | 12 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 12 | - | - | - | - | 100.000 | 1.000 | 12 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 50.0000 | 200.000 | 116.000 | 44.0000 | - | - | - | - | - | 12 | 108.000 | 1.499 | 12 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 11 | 1 | - | - | - | 0.011 | 1.303 | 12 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.060 | 0.033 | 0.0231 | - | - | 9 | - | - | 3 | 0.010 | 2.004 | 12 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 35.0000 | 35.000 | 35.000 | -- | - | - | 11 | - | - | 1 | 0.712 | 3.409 | 12 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 14.3730 | 17.748 | 16.000 | 1.7000 | 9 | - | - | - | - | 3 | 15.900 | 1.112 | 3 | -- | -- | -- | 26 |
| 27 | AC-U | 1.2876 | 4.059 | 2.550 | 1.4000 | 9 | - | - | - | - | 3 | 2.290 | 1.776 | 3 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Aycross Formation of Thorofare Creek Group (Eocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 10.000 | 3.040 | 1.8300 | - | - | - | - | - | 70 | 2.5700 | 1.830 | 70 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 10.000 | 1.480 | 1.5600 | - | - | - | - | - | 70 | 0.9760 | 2.642 | 70 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0700 | 20.000 | 2.620 | 4.0500 | - | - | - | - | - | 70 | 1.2100 | 3.678 | 70 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0200 | 0.700 | 0.281 | 0.1390 | - | - | - | - | - | 70 | 0.2420 | 1.838 | 70 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 5000.000 | 570.000 | 749.0000 | - | - | - | - | - | 70 | 279.0000 | 3.686 | 70 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 1.0000 | 2.000 | 1.670 | 0.5770 | - | 67 | - | - | - | 3 | 0.2190 | 1.534 | 70 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 50.000 | 18.600 | 13.6000 | - | 2 | 36 | - | - | 32 | 9.9100 | 1.761 | 70 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 5000.000 | 1140.000 | 745.0000 | - | 1 | - | - | - | 69 | 843.0000 | 2.623 | 70 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 14.400 | 10.0000 | - | 25 | - | - | - | 45 | 6.2500 | 2.705 | 70 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 700.000 | 123.000 | 131.0000 | - | 1 | - | - | - | 69 | 77.6000 | 2.790 | 70 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 700.000 | 46.700 | 102.0000 | - | - | 1 | - | - | 69 | 18.9000 | 3.090 | 70 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 300.000 | 57.100 | 57.2000 | - | 8 | - | - | - | 62 | 35.4000 | 2.275 | 70 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 300.000 | 70.900 | 77.0000 | - | 52 | 2 | - | - | 16 | 3.9900 | 3.965 | 70 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 70.000 | 45.000 | 35.4000 | - | 62 | 6 | - | - | 2 | 7.5700 | 1.367 | 70 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 36.300 | 36.7000 | - | - | 4 | - | - | 66 | 19.5000 | 3.062 | 70 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 20.300 | 21.1000 | - | 1 | 5 | - | - | 64 | 14.8000 | 1.871 | 70 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 69 | 1 | - | - | - | 5.0200 | 1.041 | 70 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 2000.000 | 652.000 | 473.0000 | - | 6 | - | - | - | 64 | 386.0000 | 2.909 | 70 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 700.000 | 158.000 | 157.0000 | - | - | - | - | - | 70 | 107.0000 | 2.449 | 70 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 200.000 | 25.200 | 34.0000 | - | 11 | 4 | - | - | 55 | 13.5000 | 2.251 | 70 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 500.000 | 400.000 | 173.0000 | - | 67 | - | - | - | 3 | 106.0000 | 1.324 | 70 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 300.000 | 157.000 | 76.1000 | - | - | - | - | - | 70 | 136.0000 | 1.809 | 70 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | 6 | 62 | 2 | - | - | - | 0.0103 | 1.174 | 64 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.200 | 0.050 | 0.0448 | - | - | 24 | - | - | 46 | 0.0210 | 2.678 | 70 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 70.000 | 23.600 | 23.7000 | - | - | 50 | 2 | - | 18 | 1.3100 | 5.681 | 70 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.4336 | 17.572 | 8.860 | 3.5400 | 55 | - | - | - | - | 15 | 8.2700 | 1.466 | 15 | -- | -- | -- | 26 |
| 27 | AC-U | 0.6793 | 31.344 | 3.870 | 7.4100 | 54 | - | - | - | - | 16 | 2.1300 | 2.418 | 16 | -- | -- | -- | 27 |

Langford Formation of Thorofare Creek Group (Eocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.7000 | 5.000 | 2.920 | 0.9220 | - | 1 | - | - | - | 96 | 2.6400 | 1.825 | 97 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 5.000 | 1.810 | 0.8750 | - | - | - | - | - | 97 | 1.5600 | 1.890 | 97 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 20.000 | 2.900 | 2.7900 | - | - | - | - | - | 97 | 2.3300 | 1.932 | 97 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0300 | 0.500 | 0.264 | 0.0948 | - | 1 | - | - | - | 96 | 0.2310 | 2.013 | 97 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 30.0000 | 2000.000 | 473.000 | 380.0000 | - | - | - | 1 | - | 96 | 369.0000 | 2.255 | 97 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 97 | - | - | - | - | 0.2000 | 1.001 | 97 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 20.000 | 14.500 | 5.2200 | - | 48 | 38 | - | - | 11 | 6.4000 | 1.401 | 97 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 100.0000 | 2000.000 | 1120.000 | 437.0000 | - | - | 1 | - | - | 96 | 960.0000 | 1.997 | 97 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 15.300 | 5.6800 | - | 9 | - | - | - | 88 | 11.9000 | 1.971 | 97 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 500.000 | 155.000 | 99.3000 | - | 6 | 1 | - | - | 90 | 97.5000 | 3.048 | 97 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 17.600 | 9.3200 | - | 1 | 3 | - | - | 93 | 14.7000 | 1.752 | 97 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 41.000 | 27.4000 | - | 1 | 6 | - | - | 90 | 33.5000 | 1.683 | 97 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 10.0000 | 10.000 | 10.000 | -- | - | 95 | 1 | - | - | 1 | 2.0400 | 1.183 | 97 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 30.000 | 23.300 | 11.5000 | - | 92 | 2 | - | - | 3 | 7.2900 | 1.240 | 97 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 62.000 | 41.5000 | - | 1 | 2 | - | - | 94 | 40.7000 | 2.898 | 97 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 30.000 | 15.800 | 4.9000 | - | 5 | 6 | - | - | 86 | 13.0000 | 1.674 | 97 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 30.000 | 16.700 | 11.5000 | - | 94 | - | - | - | 3 | 5.1700 | 1.229 | 97 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 681.000 | 321.0000 | - | 4 | - | - | - | 93 | 533.0000 | 2.159 | 97 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 15.0000 | 300.000 | 83.600 | 49.9000 | - | - | 1 | - | - | 96 | 70.8000 | 1.779 | 97 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 15.300 | 12.9000 | - | 34 | 8 | - | - | 55 | 8.8000 | 1.790 | 97 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 97 | - | - | - | - | 100.0000 | 1.000 | 97 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 30.0000 | 500.000 | 109.000 | 67.9000 | - | 2 | - | - | - | 95 | 91.2000 | 1.820 | 97 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.300 | 0.175 | 0.1770 | 1 | 86 | 8 | - | - | 2 | 0.0114 | 1.569 | 96 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.140 | 0.031 | 0.0245 | 1 | - | 60 | - | - | 36 | 0.0116 | 2.053 | 96 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 3.000 | 1.310 | 0.7510 | 1 | - | 83 | - | - | 13 | 0.5620 | 1.392 | 96 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.5153 | 26.653 | 10.100 | 7.2800 | 82 | - | - | - | - | 15 | 8.4800 | 1.768 | 15 | -- | -- | -- | 26 |
| 27 | AC-U | 0.8050 | 5.508 | 2.200 | 1.4300 | 82 | - | - | - | - | 15 | 1.8500 | 1.799 | 15 | -- | -- | -- | 27 |

## Two Ocean Formation of Thorofare Creek Group (Eocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 15.000 | 3.670 | 2.7800 | - | - | - | - | - | 26 | 3.080 | 1.754 | 26 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 3.000 | 1.670 | 0.7470 | - | - | - | - | - | 26 | 1.390 | 2.147 | 26 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 10.000 | 2.970 | 2.1700 | - | - | - | - | - | 26 | 2.290 | 2.244 | 26 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.1500 | 0.500 | 0.279 | 0.1210 | - | - | - | - | - | 26 | 0.257 | 1.483 | 26 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 150.0000 | 2000.000 | 667.000 | 614.0000 | - | - | - | - | - | 26 | 429.000 | 2.642 | 26 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 26 | - | - | - | - | 0.200 | 1.000 | 26 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 30.000 | 20.000 | 10.0000 | - | 8 | 13 | - | - | 5 | 7.550 | 1.655 | 26 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 700.0000 | 2000.000 | 1150.000 | 379.0000 | - | - | - | - | - | 26 | 1100.000 | 1.374 | 26 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 70.000 | 22.400 | 17.3000 | - | 4 | - | - | - | 22 | 12.500 | 2.803 | 26 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 500.000 | 150.000 | 101.0000 | - | 2 | - | - | - | 24 | 87.500 | 3.469 | 26 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 27.100 | 31.5000 | - | - | - | - | - | 26 | 17.500 | 2.490 | 26 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 40.000 | 44.6000 | - | 4 | 2 | - | - | 20 | 23.900 | 2.042 | 26 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 10.0000 | 10.000 | 10.000 | -- | - | 24 | 1 | - | - | 1 | 2.160 | 1.380 | 26 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 30.0000 | 30.000 | 30.000 | -- | - | 25 | - | - | - | 1 | 7.400 | 1.330 | 26 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 56.800 | 36.2000 | - | - | - | - | - | 26 | 41.200 | 2.639 | 26 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 30.000 | 14.600 | 4.7700 | - | - | 1 | - | - | 25 | 13.400 | 1.428 | 26 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 26 | - | - | - | - | 5.000 | 1.000 | 26 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 668.000 | 333.0000 | - | 1 | - | - | - | 25 | 532.000 | 2.094 | 26 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 101.000 | 81.5000 | - | - | - | - | - | 26 | 74.600 | 2.281 | 26 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 20.800 | 16.6000 | - | 13 | - | - | - | 13 | 9.230 | 2.125 | 26 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 26 | - | - | - | - | 100.000 | 1.001 | 26 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 30.0000 | 500.000 | 108.000 | 93.3000 | - | - | - | - | - | 26 | 86.600 | 1.883 | 26 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 22 | 4 | - | - | - | 0.012 | 1.401 | 26 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.060 | 0.028 | 0.0149 | - | - | 18 | - | - | 8 | 0.010 | 1.893 | 26 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 3.000 | 1.670 | 1.1500 | - | - | 23 | - | - | 3 | 0.565 | 1.475 | 26 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 3.8067 | 7.672 | 6.110 | 1.2500 | 18 | - | - | - | - | 8 | 5.990 | 1.255 | 8 | -- | -- | -- | 26 |
| 27 | AC-U | 1.1480 | 1.778 | 1.540 | 0.1990 | 18 | - | - | - | - | 8 | 1.530 | 1.148 | 8 | -- | -- | -- | 27 |

## Unnamed sequence (lower Eocene and upper Paleocene)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 10.000 | 2.8300 | 2.3300 | - | - | - | - | - | 12 | 2.3900 | 1.713 | 12 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.5000 | 5.000 | 1.1900 | 1.2100 | - | - | - | - | - | 12 | 0.9580 | 1.766 | 12 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 20.000 | 8.6600 | 10.0000 | - | - | - | - | - | 12 | 2.2400 | 7.336 | 12 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.1000 | 1.000 | 0.3080 | 0.2270 | - | - | - | - | - | 12 | 0.2640 | 1.704 | 12 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 70.0000 | 2000.000 | 497.0000 | 652.0000 | - | - | - | - | - | 12 | 237.0000 | 3.441 | 12 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 12 | - | - | - | - | 0.2000 | -- | 12 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 20.0000 | 100.000 | 38.3000 | 27.6000 | - | - | - | - | - | 12 | 31.5000 | 1.865 | 12 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 1000.000 | 541.0000 | 339.0000 | - | - | - | - | - | 12 | 390.0000 | 2.694 | 12 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 11.3000 | 12.5000 | - | 8 | - | - | - | 4 | 3.1500 | 2.267 | 12 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 150.000 | 55.8000 | 43.4000 | - | - | - | - | - | 12 | 38.3000 | 2.701 | 12 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 70.000 | 21.7000 | 26.0000 | - | - | - | - | - | 12 | 11.8000 | 2.988 | 12 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 300.000 | 81.3000 | 91.4000 | - | 4 | - | - | - | 8 | 31.9000 | 2.934 | 12 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 12 | - | - | - | - | 2.0000 | -- | 12 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 30.0000 | 30.000 | 30.0000 | -- | - | 10 | 1 | - | - | 1 | 8.1400 | 1.527 | 12 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 14.1000 | 13.6000 | - | - | - | - | - | 12 | 10.3000 | 2.171 | 12 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 30.000 | 15.5000 | 6.1100 | - | - | 1 | - | - | 11 | 13.3000 | 1.585 | 12 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 12 | - | - | - | - | 5.0000 | -- | 12 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 150.000 | 107.0000 | 18.9000 | - | 5 | - | - | - | 7 | 77.5000 | 1.496 | 12 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 30.0000 | 500.000 | 90.0000 | 130.0000 | - | - | - | - | - | 12 | 60.6000 | 2.089 | 12 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 30.8000 | 21.5000 | - | - | - | - | - | 12 | 24.8000 | 2.011 | 12 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 200.000 | 200.0000 | -- | - | 11 | - | - | - | 1 | 106.0000 | 1.222 | 12 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 100.0000 | 1000.000 | 246.0000 | 243.0000 | - | - | - | - | - | 12 | 198.0000 | 1.779 | 12 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 10 | 2 | - | - | - | 0.0116 | 1.429 | 12 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.080 | 0.0382 | 0.0189 | - | - | 1 | - | - | 11 | 0.0301 | 1.913 | 12 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 3.000 | 2.0000 | 1.1500 | - | - | 8 | - | - | 4 | 0.7570 | 2.005 | 12 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 13.3710 | 13.371 | 13.4000 | -- | 11 | - | - | - | - | 1 | 13.4000 | -- | 1 | -- | -- | -- | 26 |
| 27 | AC-U | 2.3879 | 2.388 | 2.3900 | -- | 11 | - | - | - | - | 1 | 2.3900 | -- | 1 | -- | -- | -- | 27 |

Table 3

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Pinyon Conglomerate (Paleocene and Upper Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 20.000 | 3.4600 | 4.0500 | 111 | - | - | - | - | 219 | 2.2700 | 2.372 | 219 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 7.000 | 0.8660 | 1.0400 | 111 | - | - | - | - | 219 | 0.5910 | 2.402 | 219 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 2.1000 | 3.6700 | 111 | - | 2 | 2 | - | 215 | 0.7350 | 4.522 | 219 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 1.000 | 0.2560 | 0.2150 | 111 | - | - | 11 | - | 208 | 0.2080 | 2.569 | 219 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 15.0000 | 5000.000 | 744.0000 | 857.0000 | 111 | - | 1 | 2 | - | 216 | 438.0000 | 3.119 | 219 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 0.8640 | 0.5950 | 111 | 163 | 45 | - | - | 11 | 0.2320 | 1.396 | 219 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 28.5000 | 21.7000 | 137 | 3 | 35 | - | - | 155 | 17.9000 | 2.143 | 193 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 100.0000 | 5000.000 | 503.0000 | 419.0000 | 111 | - | - | - | - | 219 | 415.0000 | 1.824 | 219 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 3.0000 | 70.000 | 10.1000 | 10.4000 | 111 | 54 | 38 | - | - | 127 | 4.5800 | 2.220 | 219 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 3.0000 | 3000.000 | 104.0000 | 274.0000 | 111 | 9 | 2 | - | - | 208 | 36.9000 | 3.274 | 219 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 3.0000 | 100.000 | 12.4000 | 12.4000 | 111 | 3 | 12 | - | - | 204 | 8.7400 | 2.045 | 219 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 1000.000 | 74.3000 | 132.0000 | 111 | 24 | 5 | - | - | 190 | 35.3000 | 2.543 | 219 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 10.000 | 5.5000 | 1.5800 | 111 | 163 | 46 | - | - | 10 | 2.2800 | 1.238 | 219 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 30.000 | 19.1000 | 7.4300 | 157 | 113 | 26 | - | - | 34 | 8.8600 | 1.503 | 173 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 3.0000 | 200.000 | 15.9000 | 21.9000 | 111 | 2 | 1 | - | - | 216 | 10.2000 | 2.257 | 219 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 300.000 | 23.3000 | 34.1000 | 111 | 13 | 25 | - | - | 181 | 12.9000 | 2.257 | 219 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 100.000 | 45.0000 | 40.4000 | 111 | 169 | 46 | - | - | 4 | 5.5500 | 1.349 | 219 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 15.0000 | 1000.000 | 182.0000 | 178.0000 | 111 | 106 | 28 | - | - | 85 | 76.5000 | 1.922 | 219 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 7.0000 | 1000.000 | 99.4000 | 128.0000 | 111 | - | 1 | - | - | 218 | 63.5000 | 2.518 | 219 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 300.000 | 32.3000 | 35.3000 | 111 | 7 | 5 | - | - | 207 | 22.2000 | 2.103 | 219 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 1000.000 | 380.0000 | 274.0000 | 111 | 162 | 47 | - | - | 10 | 115.0000 | 1.353 | 219 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 30.0000 | 1000.000 | 257.0000 | 207.0000 | 111 | - | 1 | 42 | - | 176 | 291.0000 | 2.802 | 219 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0100 | 160.000 | 3.0000 | 14.5000 | 28 | 106 | 21 | - | - | 175 | 0.0702 | 9.112 | 302 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0150 | 0.280 | 0.0463 | 0.0390 | 192 | - | 33 | - | - | 105 | 0.0250 | 2.448 | 138 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 50.000 | 3.5700 | 6.5900 | 197 | 4 | 46 | - | - | 83 | 1.2000 | 2.700 | 133 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 3.7223 | 20.328 | 10.0000 | 6.5000 | 320 | - | - | - | - | 10 | 8.2100 | 1.942 | 10 | -- | -- | -- | 26 |
| 27 | AC-U | 1.2847 | 5.388 | 3.0700 | 1.9200 | 320 | - | - | - | - | 10 | 2.5500 | 1.901 | 10 | -- | -- | -- | 27 |

Harebell Formation (Upper Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 20.000 | 2.5800 | 2.6200 | 57 | - | - | 4 | - | 278 | 2.0800 | 2.074 | 282 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 5.000 | 0.7690 | 0.4910 | 57 | - | - | - | - | 282 | 0.6550 | 1.788 | 282 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 2.0600 | 3.3300 | 57 | - | - | 8 | - | 274 | 0.9720 | 4.113 | 282 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0150 | 5.000 | 0.2780 | 0.3270 | 57 | 1 | - | 8 | - | 273 | 0.2330 | 2.139 | 282 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 20.0000 | 5000.000 | 732.0000 | 845.0000 | 57 | - | - | 8 | - | 274 | 459.0000 | 3.185 | 282 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 0.8330 | 0.4080 | 57 | 246 | 30 | - | - | 6 | 0.2150 | 1.262 | 282 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 33.9000 | 28.8000 | 130 | 6 | 23 | - | - | 180 | 21.4000 | 2.270 | 209 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 50.0000 | 5000.000 | 699.0000 | 571.0000 | 57 | - | - | - | - | 282 | 560.0000 | 1.984 | 282 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 3.0000 | 150.000 | 9.6200 | 16.4000 | 57 | 97 | 28 | - | - | 157 | 4.0300 | 2.118 | 282 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 2.0000 | 1000.000 | 50.8000 | 86.9000 | 57 | 15 | 5 | - | - | 262 | 28.7000 | 2.516 | 282 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 1.0000 | 100.000 | 13.2000 | 14.1000 | 57 | 2 | 23 | - | - | 257 | 8.7900 | 2.129 | 282 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 700.000 | 44.0000 | 64.8000 | 57 | 56 | 3 | - | - | 223 | 26.0000 | 2.033 | 282 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 30.000 | 11.8000 | 8.4700 | 57 | 236 | 37 | - | - | 9 | 2.2200 | 1.377 | 282 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 30.000 | 13.0000 | 4.8300 | 87 | 133 | 57 | - | - | 62 | 8.7200 | 1.333 | 252 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 3.0000 | 200.000 | 13.0000 | 16.3000 | 57 | 6 | 3 | - | - | 273 | 9.4900 | 1.945 | 282 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 15.7000 | 10.9000 | 57 | 11 | 18 | - | - | 253 | 12.3000 | 1.736 | 282 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 20.000 | 12.0000 | 4.4700 | 57 | 247 | 30 | - | - | 5 | 5.2600 | 1.165 | 282 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 30.0000 | 5000.000 | 266.0000 | 452.0000 | 57 | 76 | 26 | - | - | 180 | 112.0000 | 2.311 | 282 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 7.0000 | 2000.000 | 113.0000 | 201.0000 | 57 | - | - | - | - | 282 | 72.1000 | 2.364 | 282 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 150.000 | 27.1000 | 21.2000 | 57 | 14 | 2 | - | - | 266 | 20.5000 | 1.958 | 282 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 500.0000 | 2000.000 | 840.0000 | 654.0000 | 57 | 245 | 32 | - | - | 5 | 108.0000 | 1.339 | 282 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 1000.000 | 240.0000 | 163.0000 | 57 | 5 | - | 9 | - | 268 | 201.0000 | 2.303 | 282 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0100 | 73.000 | 1.8300 | 7.6100 | 2 | 215 | 13 | - | - | 109 | 0.0234 | 5.197 | 337 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0150 | 1.300 | 0.0583 | 0.1240 | 130 | 2 | 74 | - | - | 133 | 0.0200 | 2.722 | 209 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 40.000 | 4.2000 | 7.2200 | 178 | 2 | 118 | - | 1 | 40 | 0.7300 | 2.269 | 160 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 3.6824 | 13.972 | 7.5700 | 2.6000 | 321 | - | - | - | - | 18 | 7.1500 | 1.418 | 18 | -- | -- | -- | 26 |
| 27 | AC-U | 1.3674 | 9.196 | 2.5700 | 1.7200 | 321 | - | - | - | - | 18 | 2.3100 | 1.498 | 18 | -- | -- | -- | 27 |

Meeteetse Formation (outside wilderness area) and Mesaverde Formation (Upper Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 1.0000 | 20.000 | 3.7500 | 5.630 | 1 | - | - | 1 | - | 10 | 2.7600 | 3.244 | 11 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 3.000 | 0.8450 | 0.923 | 1 | - | - | - | - | 11 | 0.4690 | 3.296 | 11 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 20.000 | 3.9600 | 5.820 | 1 | - | - | - | - | 11 | 1.4600 | 5.160 | 11 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0500 | 0.300 | 0.1950 | 0.085 | 1 | - | - | - | - | 11 | 0.1740 | 1.754 | 11 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 50.0000 | 5000.000 | 943.0000 | 1500.000 | 1 | - | - | - | - | 11 | 308.0000 | 4.918 | 11 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.000 | 0.6670 | 0.289 | 1 | 8 | - | - | - | 3 | 0.2730 | 1.759 | 11 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 20.000 | 17.1000 | 4.880 | 3 | - | 2 | - | - | 7 | 13.6000 | 1.610 | 9 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 700.000 | 336.0000 | 205.000 | 1 | - | - | - | - | 11 | 289.0000 | 1.751 | 11 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 3.0000 | 7.000 | 5.0000 | 1.070 | 1 | 3 | - | - | - | 8 | 3.8300 | 1.584 | 11 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 30.000 | 19.5000 | 7.570 | 1 | - | - | - | - | 11 | 18.2000 | 1.493 | 11 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 10.000 | 7.2000 | 2.490 | 1 | - | 1 | - | - | 10 | 6.3300 | 1.507 | 11 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 30.0000 | 30.000 | 30.0000 | 0.000 | 1 | 6 | - | - | - | 5 | 16.5000 | 1.775 | 11 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 20.0000 | 30.000 | 26.7000 | 5.770 | 1 | 8 | - | - | - | 3 | 4.0300 | 3.341 | 11 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | 1 | 8 | 3 | - | - | - | 7.7200 | 1.181 | 11 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 30.000 | 12.5000 | 9.560 | 1 | - | - | - | - | 11 | 10.1000 | 1.936 | 11 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 20.000 | 14.4000 | 3.000 | 1 | 2 | - | - | - | 9 | 10.7000 | 1.929 | 11 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | 1 | 11 | - | - | - | - | 5.0000 | -- | 11 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 15.0000 | 150.000 | 68.3000 | 68.300 | 1 | 8 | - | - | - | 3 | 52.7000 | 1.746 | 11 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 20.0000 | 100.000 | 61.8000 | 29.300 | 1 | - | - | - | - | 11 | 54.4000 | 1.772 | 11 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 30.000 | 18.0000 | 5.670 | 1 | - | 1 | - | - | 10 | 15.8000 | 1.524 | 11 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | 1 | 11 | - | - | - | - | 100.0000 | 1.000 | 11 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 30.0000 | 1000.000 | 253.0000 | 275.000 | 1 | 1 | - | - | - | 10 | 131.0000 | 3.625 | 11 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 7.300 | 2.2500 | 3.410 | - | 8 | - | - | - | 4 | 0.0400 | 10.210 | 12 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.800 | 0.1900 | 0.341 | 3 | - | 4 | - | - | 5 | 0.0236 | 4.824 | 9 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 3.0000 | 5.000 | 3.5000 | 1.000 | 3 | - | 5 | - | - | 4 | 1.1700 | 2.783 | 9 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 6.2756 | 6.276 | 6.2800 | -- | 11 | - | - | - | - | 1 | 6.2800 | -- | 1 | -- | -- | -- | 26 |
| 27 | AC-U | 3.1678 | 3.168 | 3.1700 | -- | 11 | - | - | - | - | 1 | 3.1700 | -- | 1 | -- | -- | -- | 27 |

Sohare Formation and Bacon Ridge Sandstone (Upper Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 15.000 | 2.4800 | 2.8900 | - | - | - | - | - | 58 | 1.7100 | 2.284 | 58 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 3.000 | 0.8430 | 0.6310 | - | - | - | - | - | 58 | 0.5860 | 2.684 | 58 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 4.2600 | 5.9200 | - | - | - | - | - | 58 | 0.9960 | 7.206 | 58 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.1000 | 0.500 | 0.2050 | 0.0675 | - | - | - | 1 | - | 57 | 0.1930 | 1.693 | 58 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 2000.000 | 574.0000 | 669.0000 | - | 2 | - | - | - | 56 | 217.0000 | 4.978 | 58 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 0.6310 | 0.2980 | - | 45 | - | - | - | 13 | 0.2550 | 1.619 | 58 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 26.3000 | 20.9000 | - | - | 7 | - | - | 51 | 18.0000 | 2.066 | 58 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 1000.000 | 492.0000 | 228.0000 | - | - | - | - | - | 58 | 436.0000 | 1.758 | 58 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 7.2100 | 6.0600 | - | 39 | - | - | - | 19 | 2.8900 | 1.816 | 58 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 200.000 | 32.4000 | 31.7000 | - | 1 | 3 | - | - | 54 | 22.5000 | 2.104 | 58 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 30.000 | 10.9000 | 7.0400 | - | - | 7 | - | - | 51 | 8.0300 | 1.910 | 58 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 150.000 | 29.5000 | 22.4000 | - | 18 | - | - | - | 40 | 19.3000 | 1.769 | 58 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 15.000 | 9.0000 | 5.2900 | - | 54 | 1 | - | - | 3 | 2.1600 | 1.393 | 58 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 50.000 | 16.7000 | 16.3000 | - | 41 | 11 | - | - | 6 | 7.9900 | 1.340 | 58 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 70.000 | 14.5000 | 16.6000 | - | 3 | 2 | - | - | 53 | 8.6700 | 2.362 | 58 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 15.8000 | 9.6000 | - | 1 | 7 | - | - | 50 | 12.2000 | 1.733 | 58 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 11.7000 | 2.8900 | - | 55 | - | - | - | 3 | 5.2200 | 1.209 | 58 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 500.000 | 183.0000 | 132.0000 | - | 31 | - | - | - | 27 | 83.9000 | 1.980 | 58 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 300.000 | 79.5000 | 50.9000 | - | - | - | - | - | 58 | 66.2000 | 1.875 | 58 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 500.000 | 28.0000 | 65.7000 | - | 2 | 1 | - | - | 55 | 17.1000 | 2.003 | 58 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 55 | 3 | - | - | - | 102.0000 | 1.095 | 58 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 50.0000 | 500.000 | 193.0000 | 110.0000 | - | - | - | 1 | - | 57 | 173.0000 | 1.848 | 58 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.400 | 0.1830 | 0.1890 | - | 51 | 4 | - | - | 3 | 0.0121 | 1.879 | 58 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 2.300 | 0.1890 | 0.5220 | 9 | 6 | 14 | - | - | 29 | 0.0226 | 3.998 | 49 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 11.000 | 3.8900 | 2.7000 | - | 3 | 27 | - | - | 28 | 1.1600 | 2.933 | 58 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.4040 | 26.595 | 10.9000 | 9.4300 | 53 | - | - | - | - | 5 | 8.3800 | 2.162 | 5 | -- | -- | -- | 26 |
| 27 | AC-U | 1.2793 | 5.568 | 2.8200 | 1.6300 | 53 | - | - | - | - | 5 | 2.5000 | 1.703 | 5 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Cody Shale (Upper Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.7000 | 5.000 | 2.1800 | 1.1300 | - | - | - | - | - | 21 | 1.8900 | 1.761 | 21 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.5000 | 3.000 | 1.4000 | 0.7520 | - | - | - | - | - | 21 | 1.2300 | 1.719 | 21 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.5000 | 20.000 | 5.3900 | 5.9200 | - | - | - | - | - | 21 | 3.3300 | 2.720 | 21 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0700 | 0.500 | 0.2430 | 0.1540 | - | - | - | - | - | 21 | 0.1970 | 1.986 | 21 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 30.0000 | 2000.000 | 450.0000 | 565.0000 | - | - | - | - | - | 21 | 244.0000 | 2.990 | 21 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 21 | - | - | - | - | 0.2000 | 1.000 | 21 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 300.000 | 79.7000 | 74.0000 | - | - | 5 | - | - | 16 | 30.7000 | 3.677 | 21 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 1000.000 | 572.0000 | 368.0000 | - | - | - | - | - | 21 | 428.0000 | 2.384 | 21 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 20.000 | 9.0000 | 5.0100 | - | 13 | - | - | - | 8 | 3.4000 | 2.118 | 21 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 150.000 | 68.8000 | 40.6000 | - | 4 | - | - | - | 17 | 35.6000 | 3.199 | 21 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 14.1000 | 10.3000 | - | - | 4 | - | - | 17 | 9.1500 | 2.131 | 21 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 50.000 | 29.1000 | 8.3100 | - | 2 | 8 | - | - | 11 | 20.1000 | 1.530 | 21 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 30.0000 | 30.000 | 30.0000 | -- | - | 19 | 1 | - | - | 1 | 2.3200 | 1.810 | 21 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.0000 | -- | - | 18 | 2 | - | - | 1 | 7.6100 | 1.279 | 21 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 70.000 | 27.9000 | 23.5000 | - | 1 | 1 | - | - | 19 | 16.2000 | 2.807 | 21 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 30.000 | 15.3000 | 6.2900 | - | 1 | 2 | - | - | 18 | 12.0000 | 1.748 | 21 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 21 | - | - | - | - | 5.0000 | 1.000 | 21 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 278.0000 | 177.0000 | - | 2 | 3 | - | - | 16 | 170.0000 | 2.186 | 21 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 15.0000 | 300.000 | 103.0000 | 92.7000 | - | - | - | - | - | 21 | 66.8000 | 2.695 | 21 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 50.000 | 21.5000 | 11.4000 | - | 4 | - | - | - | 17 | 14.6000 | 2.055 | 21 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 200.000 | 200.0000 | -- | - | 19 | 1 | - | - | 1 | 105.0000 | 1.187 | 21 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 30.0000 | 300.000 | 134.0000 | 89.8000 | - | - | - | - | - | 21 | 105.0000 | 2.146 | 21 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 20 | 1 | - | - | - | 0.0104 | 1.221 | 21 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.160 | 0.0493 | 0.0337 | - | - | 6 | - | - | 15 | 0.0254 | 2.577 | 21 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 5.000 | 2.0000 | 1.5300 | - | 1 | 13 | - | - | 7 | 0.7230 | 2.011 | 21 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.1063 | 11.887 | 8.7500 | 3.3000 | 17 | - | - | - | - | 4 | 8.1500 | 1.599 | 4 | -- | -- | -- | 26 |
| 27 | AC-U | 1.7293 | 3.391 | 2.9100 | 0.7930 | 17 | - | - | - | - | 4 | 2.8100 | 1.384 | 4 | -- | -- | -- | 27 |

Frontier Formation (Upper Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.3000 | 10.000 | 2.6200 | 2.2400 | - | - | - | - | - | 48 | 1.9100 | 2.227 | 48 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 2.000 | 0.5510 | 0.4320 | - | 1 | - | - | - | 47 | 0.3680 | 2.641 | 48 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 10.000 | 1.5300 | 2.7200 | - | - | - | - | - | 48 | 0.6090 | 3.601 | 48 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0150 | 0.700 | 0.2410 | 0.1650 | - | - | - | - | - | 48 | 0.1870 | 2.183 | 48 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 2000.000 | 327.0000 | 468.0000 | - | 2 | 1 | 1 | - | 44 | 113.0000 | 5.495 | 48 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 1.0000 | 0.5000 | - | 43 | - | - | - | 5 | 0.2340 | 1.630 | 48 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 52.3000 | 49.0000 | - | 1 | 5 | - | - | 42 | 26.8000 | 2.983 | 48 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 70.0000 | 2000.000 | 490.0000 | 380.0000 | - | - | 1 | - | - | 47 | 336.0000 | 2.571 | 48 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 8.3100 | 6.9100 | - | 32 | - | - | - | 16 | 3.0300 | 1.946 | 48 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.000 | 33.1000 | 29.5000 | - | 21 | 3 | - | - | 24 | 11.0000 | 2.622 | 48 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 12.5000 | 10.1000 | - | 4 | 10 | - | - | 34 | 6.7500 | 2.284 | 48 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 55.3000 | 46.8000 | - | 3 | - | - | - | 45 | 39.0000 | 2.108 | 48 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 20.000 | 11.3000 | 6.2900 | - | 43 | 1 | - | - | 4 | 2.3100 | 1.605 | 48 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 70.000 | 30.5000 | 17.9000 | - | 22 | 6 | - | - | 20 | 12.7000 | 2.060 | 48 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 12.8000 | 11.1000 | - | 5 | 11 | - | - | 32 | 6.2500 | 2.376 | 48 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 19.6000 | 11.6000 | - | 5 | 6 | - | - | 37 | 12.2000 | 2.169 | 48 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 10.000 | 10.0000 | 0.0000 | - | 44 | - | - | - | 4 | 5.3000 | 1.214 | 48 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 204.0000 | 157.0000 | - | 24 | - | - | - | 24 | 91.2000 | 2.100 | 48 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 61.3000 | 43.7000 | - | - | 2 | - | - | 46 | 44.6000 | 2.229 | 48 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 25.6000 | 17.7000 | - | - | 3 | - | - | 45 | 19.6000 | 1.915 | 48 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 46 | 2 | - | - | - | 102.0000 | 1.085 | 48 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 1000.000 | 262.0000 | 242.0000 | - | 1 | - | - | - | 47 | 169.0000 | 2.739 | 48 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.050 | 0.0500 | -- | 1 | 39 | 7 | - | - | 1 | 0.0119 | 1.481 | 47 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.900 | 0.0842 | 0.1660 | 1 | 1 | 13 | - | - | 33 | 0.0264 | 3.120 | 47 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 9.000 | 3.0000 | 2.3600 | - | 1 | 15 | - | - | 32 | 1.3600 | 2.612 | 48 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 5.5164 | 58.140 | 30.7000 | 23.1000 | 43 | - | - | - | - | 5 | 21.8000 | 2.799 | 5 | -- | -- | -- | 26 |
| 27 | AC-U | 2.3830 | 12.937 | 7.6900 | 4.9500 | 43 | - | - | - | - | 5 | 6.0300 | 2.334 | 5 | -- | -- | -- | 27 |

## Mowry Shale (Lower Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 7.000 | 2.2300 | 1.2200 | - | - | - | - | - | 48 | 1.9600 | 1.695 | 48 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 2.000 | 0.7440 | 0.4620 | - | - | - | - | - | 48 | 0.5960 | 2.172 | 48 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 10.000 | 1.1800 | 2.3400 | - | - | - | - | - | 48 | 0.5550 | 2.892 | 48 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0300 | 0.300 | 0.1670 | 0.0835 | - | - | - | - | - | 48 | 0.1450 | 1.788 | 48 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 20.0000 | 5000.000 | 490.0000 | 808.0000 | - | - | - | - | - | 48 | 232.0000 | 3.351 | 48 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.000 | 0.6690 | 0.4250 | - | 34 | 1 | - | - | 13 | 0.2720 | 1.709 | 48 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 40.0000 | 42.3000 | - | - | 5 | - | - | 43 | 22.2000 | 2.646 | 48 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 3000.000 | 824.0000 | 582.0000 | - | - | - | 1 | - | 47 | 696.0000 | 2.128 | 48 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 7.000 | 5.5700 | 0.9200 | - | 20 | - | - | - | 28 | 3.6100 | 1.678 | 48 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.000 | 29.3000 | 24.5000 | - | 19 | 1 | - | - | 28 | 11.9000 | 2.519 | 48 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 30.000 | 9.7200 | 6.1300 | - | - | 12 | - | - | 36 | 6.4400 | 1.911 | 48 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 200.000 | 46.3000 | 37.7000 | - | - | - | - | - | 48 | 37.9000 | 1.793 | 48 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 15.000 | 9.0000 | 5.2900 | - | 44 | 1 | - | - | 3 | 2.2000 | 1.438 | 48 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 50.000 | 18.6000 | 9.2500 | - | 12 | 7 | - | - | 29 | 12.5000 | 1.677 | 43 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 30.000 | 11.6000 | 7.7400 | - | - | 14 | - | - | 34 | 6.8700 | 2.079 | 48 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 23.6000 | 15.2000 | - | - | 5 | - | - | 43 | 17.3000 | 1.990 | 48 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | 10.0000 | 15.000 | 11.0000 | 2.1100 | - | 38 | - | - | - | 10 | 5.8800 | 1.386 | 48 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 2000.000 | 292.0000 | 347.0000 | - | 10 | 1 | - | - | 37 | 147.0000 | 2.475 | 48 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 150.000 | 45.9000 | 36.2000 | - | - | 2 | - | - | 46 | 30.0000 | 2.559 | 48 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 200.000 | 29.4000 | 28.2000 | - | - | - | - | - | 48 | 23.7000 | 1.832 | 48 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 48 | - | - | - | - | 100.0000 | 1.000 | 48 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 50.0000 | 500.000 | 174.0000 | 87.1000 | - | - | - | - | - | 48 | 158.0000 | 1.568 | 48 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.100 | 0.0750 | 0.0354 | 1 | 37 | 8 | - | - | 2 | 0.0127 | 1.664 | 47 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.160 | 0.0492 | 0.0293 | - | 2 | 8 | - | - | 33 | 0.0290 | 2.454 | 48 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 60.000 | 5.4300 | 9.3800 | - | - | 2 | - | - | 46 | 2.8800 | 2.731 | 48 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 5.2977 | 30.086 | 13.8000 | 11.6000 | 44 | - | - | - | - | 4 | 10.6000 | 2.288 | 4 | -- | -- | -- | 26 |
| 27 | AC-U | 2.2892 | 9.655 | 5.8500 | 3.9800 | 44 | - | - | - | - | 4 | 4.7300 | 2.130 | 4 | -- | -- | -- | 27 |

## Thermopolis Shale, including Muddy Sandstone Member at top (Lower Cretaceous)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 10.000 | 2.970 | 2.150 | - | - | - | - | - | 17 | 2.4400 | 1.921 | 17 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 2.000 | 1.240 | 0.698 | - | - | - | - | - | 17 | 0.9860 | 2.236 | 17 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 10.000 | 3.190 | 3.990 | - | - | - | 1 | - | 16 | 1.2700 | 6.310 | 17 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.1000 | 0.500 | 0.276 | 0.125 | - | - | - | - | - | 17 | 0.2500 | 1.609 | 17 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 50.0000 | 5000.000 | 1320.000 | 1620.000 | - | - | - | 2 | - | 15 | 858.0000 | 4.292 | 17 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.000 | 0.667 | 0.289 | - | 14 | - | - | - | 3 | 0.2450 | 1.604 | 17 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 20.0000 | 100.000 | 66.900 | 30.900 | - | 1 | - | - | - | 16 | 50.3000 | 2.295 | 17 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 150.0000 | 1500.000 | 597.000 | 310.000 | - | - | - | - | - | 17 | 525.0000 | 1.726 | 17 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 8.710 | 6.390 | - | 3 | - | - | - | 14 | 6.0100 | 1.962 | 17 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.000 | 51.500 | 26.000 | - | - | - | - | - | 17 | 43.1000 | 1.979 | 17 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 14.600 | 11.700 | - | - | 3 | - | - | 14 | 9.1700 | 2.263 | 17 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 70.000 | 35.000 | 17.500 | - | 1 | - | - | - | 16 | 29.5000 | 1.690 | 17 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 17 | - | - | - | - | 2.0000 | 1.000 | 17 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 10.000 | 10.000 | 0.000 | - | 10 | 3 | - | - | 4 | 8.1100 | 1.198 | 17 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 19.500 | 11.300 | - | - | - | - | - | 17 | 16.4000 | 1.906 | 17 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 30.000 | 17.300 | 6.230 | - | 1 | 1 | - | - | 15 | 13.8000 | 1.794 | 17 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 17 | - | - | - | - | 5.0000 | 1.000 | 17 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 500.000 | 146.000 | 116.000 | - | 5 | - | - | - | 12 | 95.6000 | 1.807 | 17 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 20.0000 | 200.000 | 111.000 | 63.800 | - | - | - | - | - | 17 | 90.4000 | 2.076 | 17 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 50.000 | 25.000 | 9.520 | - | - | - | - | - | 17 | 23.3000 | 1.483 | 17 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 14 | 3 | - | - | - | 107.0000 | 1.173 | 17 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.000 | 180.000 | 82.300 | - | - | - | 1 | - | 16 | 170.0000 | 2.659 | 17 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 13 | 4 | - | - | - | 0.0124 | 1.493 | 17 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.100 | 0.049 | 0.025 | - | - | 2 | - | - | 15 | 0.0352 | 2.169 | 17 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 11.000 | 3.800 | 2.600 | - | 1 | 1 | - | - | 15 | 2.4100 | 2.592 | 17 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.3092 | 17.964 | 9.770 | 5.120 | 10 | - | - | - | - | 7 | 8.6300 | 1.734 | 7 | -- | -- | -- | 26 |
| 27 | AC-U | 0.4334 | 5.752 | 3.490 | 1.700 | 9 | - | - | - | - | 8 | 2.9000 | 2.191 | 8 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Cloverly Formation (Lower Cretaceous) and Morrison(?) Formation (Upper Jurassic)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 5.000 | 1.640 | 1.080 | - | - | - | - | - | 42 | 1.2800 | 2.131 | 42 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 2.000 | 0.616 | 0.520 | - | - | 1 | - | - | 41 | 0.3580 | 3.477 | 42 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 4.820 | 6.550 | - | - | 6 | 1 | - | 35 | 0.8830 | 9.429 | 42 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0200 | 0.700 | 0.268 | 0.171 | - | - | - | - | - | 42 | 0.2100 | 2.188 | 42 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 5000.000 | 1160.000 | 1460.000 | - | - | - | 1 | - | 41 | 478.0000 | 5.446 | 42 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 5.000 | 2.130 | 2.020 | - | 38 | - | - | - | 4 | 0.2420 | 1.924 | 42 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 38.200 | 29.100 | - | - | 8 | - | - | 34 | 21.5000 | 2.527 | 42 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 50.0000 | 1500.000 | 392.000 | 398.000 | - | - | - | - | - | 42 | 265.0000 | 2.373 | 42 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 50.000 | 10.600 | 11.400 | - | 23 | 1 | - | - | 18 | 3.6700 | 2.235 | 42 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 300.000 | 36.300 | 50.600 | - | 5 | 2 | - | - | 35 | 18.4000 | 2.600 | 42 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 70.000 | 13.200 | 12.300 | - | - | 2 | - | - | 40 | 9.5300 | 2.018 | 42 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 150.000 | 29.000 | 24.700 | - | 13 | - | - | - | 29 | 18.9000 | 1.756 | 42 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 5.000 | 5.000 | -- | - | 41 | - | - | - | 1 | 2.0400 | 1.152 | 42 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 20.000 | 11.300 | 3.540 | - | 29 | 5 | - | - | 8 | 7.9500 | 1.244 | 42 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 13.200 | 23.500 | - | - | 3 | - | - | 39 | 7.8600 | 2.161 | 42 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 15.800 | 14.600 | - | 9 | 9 | - | - | 24 | 7.7300 | 2.109 | 42 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 42 | - | - | - | - | 5.0000 | -- | 42 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 248.000 | 280.000 | - | 18 | - | - | - | 24 | 107.0000 | 2.285 | 42 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 57.900 | 47.800 | - | - | - | - | - | 42 | 40.8000 | 2.428 | 42 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 25.700 | 16.800 | - | 7 | - | - | - | 35 | 17.1000 | 2.130 | 42 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 42 | - | - | - | - | 100.0000 | 1.000 | 42 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 1000.000 | 207.000 | 215.000 | - | - | - | - | - | 42 | 127.0000 | 3.120 | 42 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 41 | 1 | - | - | - | 0.0102 | 1.152 | 42 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.060 | 0.035 | 0.014 | - | 3 | 14 | - | - | 25 | 0.0172 | 2.341 | 42 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 2.410 | 1.990 | - | - | 15 | - | - | 27 | 1.1500 | 2.352 | 42 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 4.1718 | 8.821 | 6.960 | 2.170 | 38 | - | - | - | - | 4 | 6.6700 | 1.415 | 4 | -- | -- | -- | 26 |
| 27 | AC-U | 0.3735 | 3.729 | 2.320 | 1.110 | 36 | - | - | - | - | 6 | 1.9100 | 2.283 | 6 | -- | -- | -- | 27 |

Sundance Formation (Upper and Middle Jurassic)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.1000 | 10.000 | 1.6400 | 1.7200 | - | - | - | - | - | 46 | 1.1200 | 2.500 | 46 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.2000 | 10.000 | 1.3300 | 1.5300 | - | - | - | - | - | 46 | 1.0000 | 1.959 | 46 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 1.0000 | 20.000 | 14.1000 | 6.3600 | - | - | - | 14 | - | 32 | 15.8000 | 2.053 | 46 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0100 | 0.300 | 0.1080 | 0.0787 | - | - | - | - | - | 46 | 0.0787 | 2.416 | 46 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 70.0000 | 2000.000 | 595.0000 | 423.0000 | - | - | - | - | - | 46 | 440.0000 | 2.338 | 46 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.000 | 0.6750 | 0.2360 | - | 42 | - | - | - | 4 | 0.2210 | 1.412 | 46 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 150.000 | 37.3000 | 33.4000 | - | 1 | 19 | - | - | 26 | 14.8000 | 2.510 | 46 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 268.0000 | 369.0000 | - | 5 | 1 | - | - | 40 | 101.0000 | 3.891 | 46 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 9.5600 | 6.3700 | - | 30 | - | - | - | 16 | 3.2300 | 2.108 | 46 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 27.2000 | 22.5000 | - | 10 | 2 | - | - | 34 | 14.4000 | 2.398 | 46 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 10.0000 | 8.9200 | - | - | 13 | - | - | 33 | 6.1700 | 1.937 | 46 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 50.000 | 24.4000 | 8.4700 | - | 15 | 4 | - | - | 27 | 17.1000 | 1.566 | 46 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 15.0000 | 70.000 | 38.3000 | 28.4000 | - | 43 | - | - | - | 3 | 2.3900 | 2.030 | 46 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 20.000 | 15.0000 | 7.0700 | - | 44 | - | - | - | 2 | 7.2200 | 1.176 | 46 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 100.000 | 13.8000 | 17.5000 | - | 6 | 10 | - | - | 30 | 6.2200 | 2.399 | 46 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 20.6000 | 22.9200 | - | 9 | 11 | - | - | 26 | 8.4700 | 2.348 | 46 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 46 | - | - | - | - | 5.0000 | -- | 46 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 307.0000 | 163.0000 | - | 2 | - | - | - | 44 | 253.0000 | 1.806 | 46 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 500.000 | 42.3000 | 74.1000 | - | - | 1 | - | - | 45 | 25.3000 | 2.381 | 46 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 50.000 | 22.7000 | 12.1000 | - | 10 | 3 | - | - | 33 | 13.9000 | 2.079 | 46 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 45 | 1 | - | - | - | 101.0000 | 1.062 | 46 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 700.000 | 85.8000 | 120.0000 | - | 3 | 1 | - | - | 42 | 42.8000 | 2.980 | 46 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.050 | 0.0500 | 0.0000 | - | 41 | 3 | - | - | 2 | 0.0114 | 1.480 | 46 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.140 | 0.0335 | 0.0278 | - | 2 | 24 | - | - | 20 | 0.0127 | 2.203 | 46 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 2.5900 | 1.9200 | - | - | 24 | - | - | 22 | 0.9670 | 2.371 | 46 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 6.3345 | 7.585 | 6.9600 | 0.8840 | 44 | - | - | - | - | 2 | 6.9300 | 1.136 | 2 | -- | -- | -- | 26 |
| 27 | AC-U | 0.3947 | 2.489 | 1.6300 | 0.9720 | 42 | - | - | - | - | 4 | 1.3200 | 2.344 | 4 | -- | -- | -- | 27 |

## Gypsum Spring Formation (Middle Jurassic)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.1000 | 3.000 | 1.3900 | 1.050 | - | 8 | 4 | - | - | 27 | 0.2830 | 7.061 | 39 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 10.000 | 1.7200 | 2.420 | - | 2 | 3 | - | - | 34 | 0.4620 | 6.797 | 39 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.2000 | 20.000 | 9.0200 | 6.300 | - | - | - | 3 | - | 36 | 6.0900 | 4.174 | 39 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0030 | 0.500 | 0.1560 | 0.158 | - | - | 6 | - | - | 33 | 0.0320 | 3.382 | 39 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 2000.000 | 445.0000 | 493.000 | - | 9 | - | - | - | 30 | 89.2000 | 8.003 | 39 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 0.8140 | 0.376 | - | 32 | - | - | - | 7 | 0.2530 | 1.719 | 39 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 41.9000 | 31.020 | - | 18 | 3 | - | - | 18 | 12.2000 | 2.857 | 39 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 30.0000 | 5000.000 | 542.0000 | 1110.000 | - | 18 | 1 | - | - | 20 | 50.7000 | 5.939 | 39 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 10.000 | 7.3800 | 2.250 | - | 23 | - | - | - | 16 | 3.3500 | 1.930 | 39 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 37.4000 | 22.300 | - | 19 | 1 | - | - | 19 | 12.1000 | 2.795 | 39 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 12.7000 | 10.200 | - | 14 | 3 | - | - | 22 | 5.1600 | 2.529 | 39 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 30.000 | 21.9000 | 4.030 | - | 22 | 1 | - | - | 16 | 13.9000 | 1.482 | 39 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 39 | - | - | - | - | 2.0000 | -- | 39 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 10.000 | 10.0000 | 0.000 | - | 35 | - | - | - | 4 | 7.2600 | 1.116 | 39 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 30.000 | 12.1000 | 6.610 | - | 19 | 1 | - | - | 19 | 4.5700 | 2.484 | 39 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 29.5000 | 37.400 | - | 16 | 4 | - | - | 19 | 7.7600 | 2.900 | 39 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 39 | - | - | - | - | 5.0000 | -- | 39 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 2000.000 | 486.0000 | 450.000 | - | 3 | - | - | - | 36 | 278.0000 | 2.817 | 39 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 100.000 | 42.3000 | 34.600 | - | - | 6 | - | - | 31 | 21.3000 | 2.789 | 39 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 20.6000 | 13.300 | - | 21 | - | - | - | 18 | 9.1100 | 2.055 | 39 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 39 | - | - | - | - | 100.0000 | 1.000 | 39 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 500.000 | 105.0000 | 129.000 | - | 7 | - | - | - | 32 | 32.5000 | 4.348 | 39 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.050 | 0.0500 | 0.000 | - | 32 | 5 | - | - | 2 | 0.0122 | 1.574 | 39 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.100 | 0.0387 | 0.022 | - | 4 | 20 | - | - | 15 | 0.0124 | 2.382 | 39 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 5.000 | 2.2500 | 1.420 | - | - | 15 | - | - | 24 | 1.1200 | 2.264 | 39 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | -- | -- | -- | -- | 39 | - | - | - | - | - | -- | -- | 0 | -- | -- | -- | 26 |
| 27 | AC-U | 0.5544 | 0.554 | 0.5540 | -- | 38 | - | - | - | - | 1 | 0.5540 | -- | 1 | -- | -- | -- | 27 |

## Chugwater Formation (Triassic)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 7.000 | 1.4300 | 1.2800 | - | - | - | - | - | 40 | 1.1100 | 2.031 | 40 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.2000 | 7.000 | 2.0700 | 1.9200 | - | - | - | - | - | 40 | 1.3500 | 2.706 | 40 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 20.000 | 6.9300 | 6.3800 | - | - | - | - | - | 40 | 3.6500 | 4.111 | 40 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0700 | 0.700 | 0.2670 | 0.1390 | - | - | - | - | - | 40 | 0.2320 | 1.733 | 40 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 70.0000 | 5000.000 | 753.0000 | 830.0000 | - | - | - | - | - | 40 | 513.0000 | 2.428 | 40 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.500 | 0.7710 | 0.3680 | - | 33 | - | - | - | 7 | 0.2500 | 1.673 | 40 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 40.4000 | 36.0000 | - | - | 3 | - | - | 37 | 27.1000 | 2.286 | 40 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1000.000 | 228.0000 | 177.0000 | - | - | - | - | - | 40 | 184.0000 | 1.950 | 40 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 15.000 | 6.4500 | 2.7200 | - | 20 | - | - | - | 20 | 3.4800 | 1.837 | 40 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 28.1000 | 20.0000 | - | 2 | 4 | - | - | 34 | 18.8000 | 2.110 | 40 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 11.5000 | 7.8600 | - | - | 1 | - | - | 39 | 9.6400 | 1.717 | 40 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 50.000 | 29.2000 | 10.6000 | - | 16 | - | - | - | 24 | 18.4000 | 1.758 | 40 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 40 | - | - | - | - | 2.0000 | -- | 40 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 20.000 | 13.3000 | 5.7700 | - | 37 | - | - | - | 3 | 7.3200 | 1.199 | 40 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 9.3900 | 9.1800 | - | - | 2 | - | - | 38 | 7.0800 | 1.852 | 40 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 20.000 | 11.7000 | 2.8600 | - | 4 | 13 | - | - | 23 | 7.6500 | 1.686 | 40 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 40 | - | - | - | - | 5.0000 | -- | 40 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 204.0000 | 166.0000 | - | 17 | - | - | - | 23 | 98.2000 | 2.147 | 40 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 45.6000 | 40.0000 | - | - | - | - | - | 40 | 34.7000 | 2.053 | 40 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 50.000 | 24.3000 | 14.0000 | - | 1 | 4 | - | - | 35 | 17.9000 | 1.953 | 40 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 40 | - | - | - | - | 100.0000 | 1.000 | 40 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 700.000 | 210.0000 | 153.0000 | - | - | - | - | - | 40 | 154.0000 | 2.537 | 40 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 28 | 12 | - | - | - | 0.0132 | 1.530 | 40 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.030 | 0.0278 | 0.0044 | - | 7 | 24 | - | - | 9 | 0.0090 | 1.873 | 40 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 7.000 | 1.9200 | 1.7700 | - | - | 16 | - | - | 24 | 0.9580 | 2.091 | 40 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 2.8603 | 10.782 | 6.3900 | 4.0300 | 37 | - | - | - | - | 3 | 5.5400 | 1.941 | 3 | -- | -- | -- | 26 |
| 27 | AC-U | 0.9731 | 3.062 | 1.9900 | 1.0500 | 37 | - | - | - | - | 3 | 1.7900 | 1.780 | 3 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Dinwoody Formation (Lower Triassic)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.5000 | 2.000 | 1.100 | 0.513 | - | - | - | - | - | 19 | 0.999 | 1.566 | 19 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.1000 | 10.000 | 2.620 | 2.940 | - | - | - | - | - | 19 | 1.320 | 3.613 | 19 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 2.0000 | 20.000 | 11.500 | 6.580 | - | - | - | 2 | - | 17 | 10.800 | 2.092 | 19 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0100 | 0.500 | 0.127 | 0.124 | - | - | - | - | - | 19 | 0.076 | 3.098 | 19 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 150.0000 | 5000.000 | 1790.000 | 1700.000 | - | - | - | 1 | - | 18 | 1130.000 | 3.479 | 19 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.000 | 0.725 | 0.206 | - | 15 | - | - | - | 4 | 0.261 | 1.715 | 19 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 150.000 | 42.700 | 41.000 | - | 3 | 5 | - | - | 11 | 15.300 | 2.845 | 19 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 348.000 | 390.000 | - | - | - | - | - | 19 | 190.000 | 3.385 | 19 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 10.000 | 8.000 | 2.740 | - | 14 | - | - | - | 5 | 2.840 | 1.875 | 19 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.000 | 41.400 | 26.300 | - | 5 | - | - | - | 14 | 20.300 | 2.368 | 19 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 19.100 | 37.990 | - | - | 5 | - | - | 14 | 7.280 | 2.555 | 19 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 30.000 | 23.000 | 4.630 | - | 9 | - | - | - | 10 | 15.400 | 1.553 | 19 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 17 | 2 | - | - | - | 2.090 | 1.136 | 19 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 10.0000 | 10.000 | 10.000 | 0.000 | - | 16 | 1 | - | - | 2 | 7.410 | 1.143 | 19 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 20.000 | 9.450 | 6.040 | - | 1 | 7 | - | - | 11 | 5.200 | 1.980 | 19 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 20.000 | 13.000 | 4.470 | - | 9 | 5 | - | - | 5 | 4.990 | 1.359 | 19 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 19 | - | - | - | - | 5.000 | 1.000 | 19 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 263.000 | 173.000 | - | 3 | - | - | - | 16 | 174.000 | 2.190 | 19 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 100.000 | 35.000 | 31.900 | - | - | 1 | - | - | 18 | 22.600 | 2.459 | 19 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 24.700 | 16.700 | - | 3 | 1 | - | - | 15 | 15.600 | 2.172 | 19 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 19 | - | - | - | - | 100.000 | 1.000 | 19 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.000 | 129.000 | 113.000 | - | 1 | - | - | - | 18 | 66.000 | 3.657 | 19 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 16 | 3 | - | - | - | 0.012 | 1.410 | 19 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.060 | 0.029 | 0.015 | - | 7 | 5 | - | - | 7 | 0.010 | 2.227 | 19 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 9.000 | 3.140 | 2.770 | - | - | 5 | - | - | 14 | 1.490 | 2.721 | 19 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 5.5865 | 27.233 | 13.000 | 12.300 | 16 | - | - | - | - | 3 | 9.780 | 2.431 | 3 | -- | -- | -- | 26 |
| 27 | AC-U | 2.2376 | 2.576 | 2.410 | 0.239 | 17 | - | - | - | - | 2 | 2.400 | 1.105 | 2 | -- | -- | -- | 27 |

Phosphoria Formation and related rocks (Permian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 3.000 | 0.7610 | 0.6680 | - | - | 2 | - | - | 58 | 0.4790 | 2.844 | 60 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 10.000 | 0.9340 | 2.0100 | - | - | - | - | - | 60 | 0.3240 | 3.633 | 60 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 7.5900 | 6.1800 | - | - | - | - | - | 60 | 4.5900 | 3.549 | 60 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.300 | 0.0749 | 0.0738 | - | - | - | - | - | 60 | 0.0467 | 2.889 | 60 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 1000.000 | 163.0000 | 238.0000 | - | - | 1 | - | - | 59 | 81.4000 | 3.125 | 60 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 5.000 | 1.2900 | 0.9760 | - | 34 | - | - | - | 26 | 0.4140 | 2.514 | 60 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 39.4000 | 35.4000 | - | - | 7 | - | - | 53 | 24.3000 | 2.394 | 60 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 200.000 | 91.4000 | 50.0000 | - | 2 | - | - | - | 58 | 72.3000 | 2.034 | 60 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | -- | -- | -- | -- | - | 60 | - | - | - | - | 2.0000 | -- | 60 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 700.000 | 208.0000 | 186.0000 | - | 3 | 3 | - | - | 54 | 97.6000 | 3.987 | 60 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 100.000 | 16.8000 | 19.6000 | - | 4 | 1 | - | - | 55 | 9.8400 | 2.448 | 60 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 300.000 | 155.0000 | 115.0000 | - | 16 | - | - | - | 44 | 56.5000 | 3.800 | 60 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 50.000 | 14.1000 | 15.6000 | - | 48 | 3 | - | - | 9 | 2.5300 | 1.902 | 60 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.0000 | -- | - | 59 | - | - | - | 1 | 7.1200 | 1.145 | 60 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 19.9000 | 31.3000 | - | - | 2 | - | - | 58 | 10.2000 | 2.664 | 60 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 54.0000 | 52.2000 | - | 11 | 6 | - | - | 43 | 17.7000 | 3.780 | 60 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 60 | - | - | - | - | 5.0000 | 1.000 | 60 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 269.0000 | 216.0000 | - | 25 | 1 | - | - | 34 | 111.0000 | 2.436 | 60 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 64.3000 | 56.0000 | - | - | 1 | - | - | 59 | 41.5000 | 2.646 | 60 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 500.000 | 140.0000 | 121.0000 | - | 5 | 2 | - | - | 53 | 64.3000 | 3.815 | 60 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 1500.000 | 804.0000 | 563.0000 | - | 34 | 2 | - | - | 24 | 209.0000 | 2.749 | 60 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.000 | 68.8000 | 66.8000 | - | 3 | - | - | - | 57 | 42.5000 | 2.576 | 60 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.050 | 0.0500 | -- | - | 53 | 6 | - | - | 1 | 0.0113 | 1.404 | 60 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.500 | 0.1090 | 0.1080 | - | 1 | 17 | - | - | 42 | 0.0340 | 3.850 | 60 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 70.000 | 12.7000 | 16.0000 | - | - | 11 | - | - | 49 | 4.1600 | 4.296 | 60 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 1.0393 | 17.268 | 7.5400 | 6.1900 | 54 | - | - | - | - | 6 | 4.8800 | 3.188 | 6 | -- | -- | -- | 26 |
| 27 | AC-U | 1.1437 | 32.567 | 11.3000 | 13.3000 | 50 | - | - | - | - | 10 | 5.7900 | 3.331 | 10 | -- | -- | -- | 27 |

## Tensleep Sandstone (Middle Pennsylvanian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 2.0000 | 0.4060 | 0.5070 | - | - | 2 | - | - | 20 | 0.1950 | 3.184 | 22 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 10.0000 | 2.7300 | 3.9400 | - | - | - | - | - | 22 | 0.4250 | 10.140 | 22 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.0000 | 5.2800 | 6.9500 | - | - | 3 | - | - | 19 | 0.7060 | 11.000 | 22 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0100 | 0.3000 | 0.0734 | 0.0738 | - | - | - | - | - | 22 | 0.0482 | 2.575 | 22 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 500.0000 | 137.0000 | 121.0000 | - | - | 2 | - | - | 20 | 66.1000 | 3.808 | 22 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 22 | - | - | - | - | 0.2000 | 1.000 | 22 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 70.0000 | 28.3000 | 24.4000 | - | 2 | 8 | - | - | 12 | 12.1000 | 2.320 | 22 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 500.0000 | 132.0000 | 134.0000 | - | 3 | 1 | - | - | 18 | 58.4000 | 3.301 | 22 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 5.0000 | 5.0000 | 0.0000 | - | 20 | - | - | - | 2 | 2.1700 | 1.309 | 22 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.0000 | 34.3000 | 36.0000 | - | 14 | 1 | - | - | 7 | 8.1800 | 2.395 | 22 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 10.0000 | 6.0000 | 1.8400 | - | 4 | 4 | - | - | 14 | 4.2400 | 1.628 | 22 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 20.0000 | 20.0000 | 0.0000 | - | 17 | 2 | - | - | 3 | 11.4000 | 1.293 | 22 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 22 | - | - | - | - | 2.0000 | 1.000 | 22 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.0000 | 20.0000 | -- | - | 21 | - | - | - | 1 | 7.3400 | 1.251 | 22 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 20.0000 | 7.9100 | 5.1100 | - | 2 | 9 | - | - | 11 | 4.3800 | 1.808 | 22 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 15.0000 | 12.0000 | 2.7400 | - | 12 | 5 | - | - | 5 | 4.6000 | 1.769 | 22 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 22 | - | - | - | - | 5.0000 | 1.000 | 22 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 100.0000 | 100.0000 | 0.0000 | - | 19 | 1 | - | - | 2 | 54.1000 | 1.236 | 22 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 70.0000 | 18.6000 | 15.3000 | - | - | 1 | - | - | 21 | 14.7000 | 1.806 | 22 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 10.0000 | 10.0000 | 0.0000 | - | 17 | 1 | - | - | 4 | 5.7600 | 1.317 | 22 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 22 | - | - | - | - | 100.0000 | 1.000 | 22 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 500.0000 | 174.0000 | 124.0000 | - | 1 | - | - | - | 21 | 97.8000 | 3.760 | 22 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.1000 | 0.1000 | 0.1000 | -- | - | 21 | - | - | - | 1 | 0.0111 | 1.634 | 22 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.0400 | 0.0300 | 0.0100 | - | 1 | 16 | - | - | 5 | 0.0095 | 1.887 | 22 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 9.0000 | 3.6000 | 3.4400 | - | 1 | 16 | - | - | 5 | 0.7020 | 2.231 | 22 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.2995 | 0.2995 | 0.2990 | -- | 21 | - | - | - | - | 1 | 0.2990 | -- | 1 | -- | -- | -- | 26 |
| 27 | AC-U | 0.6055 | 2.3031 | 1.4900 | 0.8510 | 19 | - | - | - | - | 3 | 1.3000 | 1.988 | 3 | -- | -- | -- | 27 |

## Amsden Formation (Middle and Lower Pennsylvanian and Upper Mississippian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 7.000 | 1.1100 | 1.1500 | - | 2 | - | - | - | 102 | 0.6450 | 3.110 | 104 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 7.000 | 1.0700 | 1.5300 | - | - | 3 | 1 | - | 100 | 0.4820 | 4.170 | 104 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 20.000 | 12.9000 | 6.1800 | - | 4 | 6 | 3 | - | 91 | 5.5900 | 7.892 | 104 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.500 | 0.0933 | 0.0826 | - | - | - | - | - | 104 | 0.0631 | 2.759 | 104 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 2000.000 | 195.0000 | 342.0000 | - | 1 | 2 | - | - | 101 | 95.7000 | 3.040 | 104 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 5.000 | 1.7100 | 1.1600 | - | 79 | - | - | - | 25 | 0.3180 | 2.438 | 104 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 200.000 | 34.6000 | 37.1000 | - | 4 | 29 | - | - | 71 | 15.3000 | 2.529 | 104 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1000.000 | 101.0000 | 130.0000 | - | 3 | 13 | - | - | 88 | 52.5000 | 2.645 | 104 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 20.000 | 12.1000 | 3.4600 | - | 85 | - | - | - | 19 | 2.7600 | 2.003 | 104 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 200.000 | 88.6000 | 43.0000 | - | 31 | 1 | - | - | 72 | 32.6000 | 3.878 | 104 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 1500.000 | 78.2000 | 268.0000 | - | 23 | 15 | - | - | 66 | 8.8300 | 4.125 | 104 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 30.000 | 23.6000 | 4.8900 | - | 42 | 29 | - | - | 33 | 14.6000 | 1.452 | 104 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 200.000 | 58.1000 | 61.2000 | - | 46 | 4 | - | - | 54 | 8.4600 | 4.990 | 104 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.0000 | -- | - | 102 | 1 | - | - | 1 | 7.1000 | 1.114 | 104 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 300.000 | 70.0000 | 73.9000 | - | 18 | 3 | - | - | 83 | 22.3000 | 4.753 | 104 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 150.000 | 23.9000 | 25.4000 | - | 34 | 9 | - | - | 61 | 8.8300 | 2.673 | 104 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 104 | - | - | - | - | 5.0000 | 1.001 | 104 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 300.000 | 184.0000 | 47.4000 | - | 38 | 3 | - | - | 63 | 109.0000 | 1.911 | 104 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 5000.000 | 311.0000 | 636.0000 | - | - | 7 | - | - | 97 | 73.2000 | 5.463 | 104 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 50.000 | 16.4000 | 8.1000 | - | 45 | 1 | - | - | 58 | 9.2100 | 1.873 | 104 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 200.0000 | 1500.000 | 582.0000 | 445.0000 | - | 79 | 3 | - | - | 22 | 139.0000 | 2.003 | 104 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 1000.000 | 100.0000 | 168.0000 | - | 22 | - | - | - | 82 | 34.9000 | 3.336 | 104 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 99 | 5 | - | - | - | 0.0105 | 1.218 | 104 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.450 | 0.0997 | 0.0912 | - | - | 35 | - | - | 69 | 0.0313 | 3.688 | 104 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 1000.000 | 61.4000 | 154.0000 | - | - | 40 | - | - | 64 | 3.3600 | 8.399 | 104 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.0241 | 20.352 | 3.7700 | 4.5700 | 31 | - | - | - | - | 23 | 1.6900 | 5.241 | 23 | -- | -- | -- | 26 |
| 27 | AC-U | 0.3926 | 87.387 | 16.9000 | 22.8000 | 80 | - | - | - | - | 24 | 7.4400 | 4.091 | 24 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Madison Limestone (Upper and Lower Mississippian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 20.000 | 0.9030 | 2.8100 | - | 7 | 3 | - | - | 108 | 0.1800 | 4.498 | 118 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 10.000 | 3.8000 | 3.8700 | - | - | 1 | 1 | - | 116 | 1.7100 | 4.532 | 118 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 13.7000 | 7.0100 | - | - | - | 24 | - | 94 | 12.1000 | 3.256 | 118 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.700 | 0.0462 | 0.1010 | - | 10 | 1 | - | - | 107 | 0.0117 | 4.588 | 118 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 1000.000 | 131.0000 | 220.0000 | - | 2 | 4 | - | - | 112 | 51.4000 | 3.559 | 118 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 118 | - | - | - | - | 0.2000 | 1.001 | 118 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 25.2000 | 24.3000 | - | 61 | 35 | - | - | 22 | 7.0200 | 1.787 | 118 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 237.0000 | 383.0000 | - | 70 | 16 | - | - | 32 | 19.3000 | 3.285 | 118 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 20.000 | 11.0000 | 5.4100 | - | 109 | - | - | - | 9 | 2.2600 | 1.560 | 118 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 500.000 | 47.1000 | 85.9000 | - | 63 | 17 | - | - | 38 | 8.5700 | 2.494 | 118 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 150.000 | 9.5800 | 18.2000 | - | 31 | 22 | - | - | 65 | 4.3000 | 2.006 | 118 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 70.000 | 29.4000 | 14.3000 | - | 89 | 12 | - | - | 17 | 12.0000 | 1.469 | 118 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 7.0000 | 100.000 | 40.7000 | 51.5000 | - | 115 | - | - | - | 3 | 2.1300 | 1.520 | 118 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 20.000 | 20.0000 | -- | - | 117 | - | - | - | 1 | 7.0600 | 1.101 | 118 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 150.000 | 30.9000 | 33.0000 | - | 66 | 28 | - | - | 24 | 3.4600 | 2.680 | 118 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 100.000 | 17.7000 | 18.5000 | - | 70 | 24 | - | - | 24 | 4.5700 | 1.932 | 118 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 118 | - | - | - | - | 5.0000 | 1.001 | 118 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 1500.000 | 247.0000 | 242.0000 | - | 63 | 3 | - | - | 52 | 92.2000 | 2.183 | 118 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 1000.000 | 44.8000 | 130.0000 | - | 5 | 22 | - | - | 91 | 14.1000 | 2.635 | 118 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 50.000 | 16.9000 | 11.1000 | - | 98 | 2 | - | - | 18 | 5.9200 | 1.545 | 118 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 300.0000 | 300.000 | 300.0000 | -- | - | 117 | - | - | - | 1 | 101.0000 | 1.106 | 118 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 500.000 | 70.2000 | 100.0000 | - | 73 | - | - | - | 45 | 12.7000 | 2.872 | 118 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.500 | 0.2170 | 0.2470 | - | 105 | 10 | - | - | 3 | 0.0115 | 1.647 | 118 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.350 | 0.0377 | 0.0571 | - | - | 78 | - | - | 40 | 0.0111 | 2.090 | 118 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 3.000 | 1.5600 | 0.8820 | - | 7 | 102 | - | - | 9 | 0.5240 | 1.392 | 118 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.1879 | 6.660 | 1.3900 | 2.0400 | 109 | - | - | - | - | 9 | 0.7660 | 2.844 | 9 | -- | -- | -- | 26 |
| 27 | AC-U | 0.1919 | 1.474 | 0.7510 | 0.4020 | 102 | - | - | - | - | 16 | 0.6490 | 1.795 | 16 | -- | -- | -- | 27 |

Darby Formation (Upper and Middle Devonian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 20.000 | 1.1500 | 3.1400 | - | - | - | - | - | 40 | 0.3730 | 3.999 | 40 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.5000 | 10.000 | 6.9400 | 3.2800 | - | - | - | - | - | 40 | 5.6100 | 2.231 | 40 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.5000 | 20.000 | 12.6000 | 5.7600 | - | - | - | 2 | - | 38 | 10.5000 | 2.514 | 40 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0030 | 0.300 | 0.0575 | 0.0649 | - | 1 | - | - | - | 39 | 0.0192 | 4.403 | 40 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 1000.000 | 161.0000 | 190.0000 | - | - | - | - | - | 40 | 92.9000 | 3.034 | 40 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 1.000 | 0.7330 | 0.2520 | - | 37 | - | - | - | 3 | 0.2200 | 1.412 | 40 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 70.000 | 24.1000 | 20.8000 | - | 6 | 18 | - | - | 16 | 9.8000 | 1.995 | 40 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 500.000 | 165.0000 | 133.0000 | - | 21 | 3 | - | - | 16 | 27.2000 | 3.791 | 40 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 30.000 | 14.5000 | 9.3500 | - | 34 | - | - | - | 6 | 2.6200 | 2.001 | 40 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 44.4000 | 26.3000 | - | 21 | 3 | - | - | 16 | 11.1000 | 2.915 | 40 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 20.000 | 7.7100 | 3.9700 | - | 6 | 6 | - | - | 28 | 5.1300 | 1.829 | 40 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 70.000 | 32.0000 | 18.1000 | - | 26 | 4 | - | - | 10 | 13.5000 | 1.663 | 40 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 40 | - | - | - | - | 2.0000 | -- | 40 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 40 | - | - | - | - | 7.0000 | 1.000 | 40 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 70.000 | 21.7000 | 19.4000 | - | 16 | 9 | - | - | 15 | 4.7300 | 2.920 | 40 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 15.000 | 11.1000 | 2.1300 | - | 12 | 14 | - | - | 14 | 5.6400 | 1.720 | 40 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 40 | - | - | - | - | 5.0000 | -- | 40 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 200.000 | 117.0000 | 35.4000 | - | 30 | 1 | - | - | 9 | 60.6000 | 1.437 | 40 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 31.8000 | 41.1000 | - | - | 6 | - | - | 34 | 16.5000 | 2.496 | 40 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 20.000 | 16.5000 | 4.1200 | - | 30 | - | - | - | 10 | 6.6800 | 1.693 | 40 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 39 | 1 | - | - | - | 101.0000 | 1.066 | 40 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 500.000 | 102.0000 | 117.0000 | - | 23 | - | - | - | 17 | 17.2000 | 3.698 | 40 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.0500 | 0.050 | 0.0500 | -- | - | 36 | 3 | - | - | 1 | 0.0112 | 1.412 | 40 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.100 | 0.0424 | 0.0218 | - | - | 15 | - | - | 25 | 0.0199 | 2.504 | 40 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 5.000 | 2.5000 | 1.4100 | - | 9 | 23 | - | - | 8 | 0.5950 | 2.073 | 40 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.7044 | 6.651 | 3.8700 | 2.9900 | 37 | - | - | - | - | 3 | 2.7100 | 3.283 | 3 | -- | -- | -- | 26 |
| 27 | AC-U | 0.3176 | 1.584 | 0.6950 | 0.5510 | 35 | - | - | - | - | 5 | 0.5560 | 2.055 | 5 | -- | -- | -- | 27 |

## Bighorn Dolomite (Upper Ordovician)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 3.000 | 0.4190 | 0.6680 | - | 2 | - | - | - | 26 | 0.1810 | 3.280 | 28 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.5000 | 10.000 | 6.8000 | 2.8400 | - | - | 1 | 3 | - | 24 | 5.0900 | 3.998 | 28 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.000 | 14.1000 | 4.7200 | - | - | - | - | - | 28 | 11.5000 | 3.004 | 28 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0020 | 0.100 | 0.0228 | 0.0340 | - | 2 | - | - | - | 26 | 0.0090 | 3.586 | 28 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 20.0000 | 1000.000 | 141.0000 | 254.0000 | - | 1 | - | - | - | 27 | 66.1000 | 2.886 | 28 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 28 | - | - | - | - | 0.2000 | 1.000 | 28 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 25.0000 | 36.7000 | - | 3 | 19 | - | - | 6 | 7.9100 | 1.701 | 28 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 30.0000 | 150.000 | 75.7000 | 36.0000 | - | 17 | 4 | - | - | 7 | 17.2000 | 2.361 | 28 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 10.000 | 7.5000 | 3.5400 | - | 26 | - | - | - | 2 | 2.1900 | 1.411 | 28 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 50.000 | 27.5000 | 17.1000 | - | 20 | 4 | - | - | 4 | 6.5400 | 1.801 | 28 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 20.000 | 7.4700 | 4.5300 | - | 8 | 5 | - | - | 15 | 4.0800 | 1.897 | 28 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 20.000 | 20.0000 | -- | - | 21 | 6 | - | - | 1 | 11.2000 | 1.226 | 28 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 27 | 1 | - | - | - | 2.0300 | 1.080 | 28 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 28 | - | - | - | - | 7.0000 | 1.000 | 28 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 10.000 | 7.0000 | 2.7400 | - | 17 | 6 | - | - | 5 | 2.7000 | 1.613 | 28 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 17.5000 | 13.0000 | - | 7 | 11 | - | - | 10 | 6.4800 | 2.079 | 28 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 28 | - | - | - | - | 5.0000 | 1.000 | 28 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 300.000 | 233.0000 | 115.0000 | - | 25 | - | - | - | 3 | 56.3000 | 1.618 | 28 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 30.000 | 12.5000 | 5.0000 | - | - | 8 | - | - | 20 | 10.2000 | 1.422 | 28 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 15.000 | 11.3000 | 2.5000 | - | 24 | - | - | - | 4 | 5.6000 | 1.338 | 28 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 28 | - | - | - | - | 100.0000 | 1.000 | 28 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 200.000 | 61.9000 | 73.9000 | - | 20 | - | - | - | 8 | 10.7000 | 2.560 | 28 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 27 | 1 | - | - | - | 0.0103 | 1.189 | 28 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.100 | 0.0314 | 0.0196 | - | - | 7 | - | - | 21 | 0.0197 | 2.075 | 28 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 5.000 | 2.5000 | 1.9100 | - | 6 | 18 | - | - | 4 | 0.5450 | 1.884 | 29 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.9479 | 0.948 | 0.9480 | -- | 27 | - | - | - | - | 1 | 0.9480 | -- | 1 | -- | -- | -- | 26 |
| 27 | AC-U | 0.1924 | 0.428 | 0.2770 | 0.1310 | 25 | - | - | - | - | 3 | 0.2590 | 1.551 | 3 | -- | -- | -- | 27 |

## Gallatin Limestone (Upper Cambrian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0500 | 5.000 | 0.8180 | 1.110 | - | - | - | - | - | 29 | 0.4010 | 3.439 | 29 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.3000 | 7.000 | 1.6500 | 1.440 | - | - | 1 | - | - | 28 | 1.0600 | 3.077 | 29 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 1.5000 | 20.000 | 16.0000 | 5.860 | - | - | - | 2 | - | 27 | 14.5000 | 2.051 | 29 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0030 | 0.500 | 0.0784 | 0.135 | - | 3 | - | - | - | 26 | 0.0207 | 5.219 | 29 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 30.0000 | 1500.000 | 238.0000 | 314.000 | - | - | - | - | - | 29 | 128.0000 | 3.007 | 29 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | -- | -- | -- | -- | - | 29 | - | - | - | - | 0.2000 | -- | 29 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 100.000 | 53.3000 | 45.100 | - | 13 | 13 | - | - | 3 | 7.1500 | 1.952 | 29 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 5000.000 | 605.0000 | 1380.000 | - | 11 | 5 | - | - | 13 | 33.4000 | 5.225 | 29 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 10.0000 | 15.000 | 13.3000 | 2.890 | - | 26 | - | - | - | 3 | 2.4300 | 1.797 | 29 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.000 | 35.0000 | 32.500 | - | 17 | 4 | - | - | 8 | 8.1900 | 2.292 | 29 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 10.000 | 5.9200 | 1.560 | - | 12 | 5 | - | - | 12 | 3.3200 | 1.670 | 29 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 70.000 | 40.0000 | 27.400 | - | 22 | 2 | - | - | 5 | 12.6000 | 1.693 | 29 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 29 | - | - | - | - | 2.0000 | 1.000 | 29 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 28 | 1 | - | - | - | 7.0900 | 1.068 | 29 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 30.000 | 16.4000 | 12.500 | - | 16 | 8 | - | - | 5 | 3.0700 | 2.112 | 29 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 15.4000 | 11.300 | - | 10 | 5 | - | - | 14 | 6.7100 | 2.158 | 29 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 29 | - | - | - | - | 5.0000 | -- | 29 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 150.0000 | 500.000 | 232.0000 | 80.300 | - | 10 | - | - | - | 19 | 133.0000 | 2.129 | 29 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 200.000 | 30.4000 | 54.600 | - | 4 | 13 | - | - | 12 | 9.4300 | 2.114 | 29 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 30.000 | 15.5000 | 7.890 | - | 15 | - | - | - | 11 | 7.3900 | 1.775 | 29 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 28 | 1 | - | - | - | 101.0000 | 1.078 | 29 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 150.000 | 57.5000 | 54.400 | - | 15 | - | - | - | 14 | 15.4000 | 3.003 | 29 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 29 | - | - | - | - | 0.0100 | 1.000 | 29 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.100 | 0.0413 | 0.026 | - | - | 14 | - | - | 15 | 0.0162 | 2.497 | 29 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 3.000 | 1.3300 | 0.707 | - | 5 | 15 | - | - | 9 | 0.6040 | 1.750 | 29 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 0.5412 | 12.917 | 5.1900 | 6.740 | 26 | - | - | - | - | 3 | 2.4500 | 4.912 | 3 | -- | -- | -- | 26 |
| 27 | AC-U | 0.4493 | 1.226 | 0.7000 | 0.357 | 25 | - | - | - | - | 4 | 0.6440 | 1.565 | 4 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Gros Ventre Formation (Upper and Middle Cambrian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.1500 | 7.000 | 2.1200 | 1.6000 | - | 1 | - | - | - | 37 | 1.3000 | 3.377 | 38 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0500 | 2.000 | 1.0200 | 0.6520 | - | - | - | - | - | 38 | 0.7430 | 2.645 | 38 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.1000 | 20.000 | 4.8900 | 7.0300 | - | - | - | 5 | - | 33 | 1.9500 | 7.349 | 38 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0030 | 0.700 | 0.1880 | 0.1640 | - | - | - | - | - | 38 | 0.1040 | 3.858 | 38 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 3000.000 | 464.0000 | 642.0000 | - | - | - | - | - | 38 | 246.0000 | 3.088 | 38 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 1.0000 | 1.000 | 1.0000 | -- | - | 37 | - | - | - | 1 | 0.2090 | 1.299 | 38 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 70.000 | 30.5000 | 20.9000 | - | 6 | 11 | - | - | 21 | 13.3000 | 2.363 | 38 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 424.0000 | 399.0000 | - | 3 | - | - | - | 35 | 194.0000 | 4.162 | 38 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 20.000 | 11.5000 | 4.3900 | - | 17 | - | - | - | 21 | 5.0300 | 2.463 | 38 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 100.000 | 46.0000 | 30.5000 | - | 11 | 2 | - | - | 25 | 18.8000 | 2.999 | 38 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 100.000 | 18.4000 | 21.3000 | - | 4 | 6 | - | - | 28 | 7.9800 | 2.773 | 38 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 70.000 | 36.5000 | 19.9000 | - | 13 | 2 | - | - | 23 | 20.7000 | 1.971 | 38 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | -- | -- | -- | -- | - | 38 | - | - | - | - | 2.0000 | -- | 38 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 38 | - | - | - | - | 7.0000 | 1.000 | 38 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 50.000 | 18.4000 | 12.0000 | - | 7 | 3 | - | - | 28 | 9.0700 | 2.790 | 38 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 50.000 | 14.2000 | 8.8600 | - | 5 | 8 | - | - | 25 | 8.6700 | 1.926 | 38 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 38 | - | - | - | - | 5.0000 | -- | 38 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 243.0000 | 174.0000 | - | 17 | 7 | - | - | 14 | 88.5000 | 2.102 | 38 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 100.000 | 31.1000 | 26.5000 | - | - | 3 | - | - | 35 | 21.2000 | 2.201 | 38 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 25.4000 | 17.1000 | - | 10 | 1 | - | - | 27 | 14.4000 | 2.210 | 38 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 37 | 1 | - | - | - | 101.0000 | 1.068 | 38 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 1000.000 | 158.0000 | 136.0000 | - | 7 | - | - | - | 31 | 61.3000 | 4.000 | 38 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | -- | -- | -- | -- | - | 38 | - | - | - | - | 0.0100 | 1.000 | 38 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.800 | 0.0778 | 0.1810 | - | - | 20 | - | - | 18 | 0.0155 | 2.843 | 38 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 25.000 | 3.6400 | 7.1300 | - | 4 | 23 | - | - | 11 | 0.6800 | 2.255 | 38 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 1.2139 | 18.583 | 10.4000 | 7.2600 | 32 | - | - | - | - | 6 | 7.1600 | 3.035 | 6 | -- | -- | -- | 26 |
| 27 | AC-U | 0.2546 | 4.405 | 1.9400 | 1.3000 | 30 | - | - | - | - | 8 | 1.4900 | 2.413 | 8 | -- | -- | -- | 27 |

Flathead Sandstone (Middle Cambrian)

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.0700 | 5.000 | 0.9130 | 1.0400 | - | - | 1 | - | - | 42 | 0.4550 | 3.477 | 43 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 2.000 | 0.1450 | 0.4080 | - | 3 | 12 | - | - | 28 | 0.0272 | 3.017 | 43 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 2.000 | 0.3590 | 0.6210 | - | 1 | 25 | - | - | 17 | 0.0594 | 2.961 | 43 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.0300 | 0.500 | 0.1540 | 0.1110 | - | - | - | - | - | 43 | 0.1160 | 2.247 | 43 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 2000.000 | 199.0000 | 509.0000 | - | 4 | 2 | - | - | 37 | 24.6000 | 4.725 | 43 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 0.500 | 0.5000 | 0.0000 | - | 41 | - | - | - | 2 | 0.2090 | 1.216 | 43 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 20.000 | 16.0000 | 5.4800 | - | 7 | 31 | - | - | 5 | 7.2500 | 1.377 | 43 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 1500.000 | 230.0000 | 312.0000 | - | - | - | - | - | 43 | 140.0000 | 2.603 | 43 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 15.000 | 6.8800 | 3.7200 | - | 35 | - | - | - | 8 | 2.4700 | 1.619 | 43 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 70.000 | 25.5000 | 16.1000 | - | 13 | 10 | - | - | 20 | 10.7000 | 2.188 | 43 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 50.000 | 9.3100 | 8.2700 | - | 4 | 7 | - | - | 32 | 5.8700 | 1.958 | 43 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 150.000 | 42.9000 | 41.1000 | - | 19 | 3 | - | - | 21 | 18.2000 | 2.111 | 43 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 5.0000 | 5.000 | 5.0000 | -- | - | 42 | - | - | - | 1 | 2.0400 | 1.150 | 43 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | -- | -- | -- | -- | - | 43 | - | - | - | - | 7.0000 | 1.000 | 43 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 10.000 | 5.3400 | 1.2100 | - | 5 | 3 | - | - | 35 | 4.5100 | 1.441 | 43 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 70.000 | 20.8000 | 16.9000 | - | 27 | 4 | - | - | 12 | 5.1300 | 2.298 | 43 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 43 | - | - | - | - | 5.0000 | -- | 43 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.000 | 331.0000 | 237.0000 | - | 35 | - | - | - | 8 | 68.3000 | 2.052 | 43 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 700.000 | 40.4000 | 116.0000 | - | - | 8 | - | - | 35 | 16.0000 | 2.369 | 43 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.000 | 21.4000 | 16.4000 | - | 21 | 1 | - | - | 21 | 9.2700 | 2.132 | 43 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | -- | -- | -- | -- | - | 43 | - | - | - | - | 100.0000 | 1.000 | 43 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 20.0000 | 500.000 | 185.0000 | 130.0000 | - | - | - | - | - | 43 | 149.0000 | 1.973 | 43 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.1000 | 0.100 | 0.1000 | -- | - | 38 | 4 | - | - | 1 | 0.0115 | 1.540 | 43 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.080 | 0.0317 | 0.0186 | - | - | 19 | - | - | 24 | 0.0152 | 2.182 | 43 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 2.000 | 1.1700 | 0.4080 | - | 8 | 29 | - | - | 6 | 0.5090 | 1.477 | 43 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 2.0033 | 19.289 | 9.6400 | 7.3000 | 39 | - | - | - | - | 4 | 7.2400 | 2.604 | 4 | -- | -- | -- | 26 |
| 27 | AC-U | 0.4768 | 5.950 | 2.0700 | 2.6200 | 39 | - | - | - | - | 4 | 1.1700 | 3.294 | 4 | -- | -- | -- | 27 |

**Table 3.** Summary of geochemical data and statistical replacement information—Continued

Late Archean rocks

| Col No. | Column I.D. | RAW DATA Minimum | Maximum | Mean | Standard Deviation | B | N | L | G | Other | Valid | REPLACED DATA Geom Mean | Geom Dev | Valid | Replacement Values N | L | G | Col No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | S-FE% | 0.2000 | 20.00 | 4.3800 | 4.590 | - | - | - | 1 | - | 102 | 2.5000 | 3.348 | 103 | 0.02 | 0.03 | 30 | 1 |
| 2 | S-MG% | 0.0200 | 7.00 | 1.2200 | 1.260 | - | - | 1 | - | - | 102 | 0.6510 | 3.656 | 103 | 0.01 | 0.02 | 15 | 2 |
| 3 | S-CA% | 0.0500 | 20.00 | 2.0300 | 3.610 | - | - | 2 | - | - | 101 | 0.6190 | 5.132 | 103 | 0.02 | 0.03 | 30 | 3 |
| 4 | S-TI% | 0.002C | 1.00 | 0.1940 | 0.206 | - | 1 | 2 | - | - | 100 | 0.0922 | 4.490 | 103 | 0.00 | 0.00 | 2 | 4 |
| 5 | S-MN | 10.0000 | 3000.00 | 539.0000 | 679.000 | - | - | - | - | - | 103 | 235.0000 | 4.106 | 103 | 5.00 | 7.00 | 7000 | 5 |
| 6 | S-AG | 0.5000 | 2.00 | 0.9000 | 0.652 | - | 98 | - | - | - | 5 | 0.2130 | 1.367 | 103 | 0.20 | 0.30 | -- | 6 |
| 7 | S-B | 10.0000 | 20.00 | 10.9000 | 3.020 | - | 42 | 50 | - | - | 11 | 6.3800 | 1.281 | 103 | 5.00 | 7.00 | 3000 | 7 |
| 8 | S-BA | 20.0000 | 5000.00 | 532.0000 | 812.000 | - | 4 | - | - | - | 99 | 204.0000 | 4.212 | 103 | 10.00 | 15.00 | 7000 | 8 |
| 9 | S-CO | 5.0000 | 300.00 | 39.6000 | 60.300 | - | 38 | - | - | - | 65 | 9.0200 | 4.063 | 103 | 2.00 | 3.00 | -- | 9 |
| 10 | S-CR | 10.0000 | 1500.00 | 177.0000 | 229.000 | - | 42 | 6 | - | - | 55 | 26.2000 | 5.465 | 103 | 5.00 | 7.00 | -- | 10 |
| 11 | S-CU | 5.0000 | 10000.00 | 785.0000 | 2060.000 | - | 10 | 8 | 1 | - | 84 | 39.7000 | 11.150 | 103 | 2.00 | 3.00 | 30000 | 11 |
| 12 | S-LA | 20.0000 | 100.00 | 32.4000 | 21.600 | - | 53 | 12 | - | - | 38 | 15.3000 | 1.757 | 103 | 10.00 | 15.00 | 1500 | 12 |
| 13 | S-MO | 20.0000 | 20.00 | 20.0000 | 0.000 | - | 99 | 2 | - | - | 2 | 2.1100 | 1.381 | 103 | 2.00 | 3.00 | -- | 13 |
| 14 | S-NB | 20.0000 | 50.00 | 33.3000 | 15.300 | - | 98 | 2 | - | - | 3 | 7.3600 | 1.301 | 103 | 7.00 | 10.00 | -- | 14 |
| 15 | S-NI | 5.0000 | 700.00 | 59.9000 | 98.600 | - | 14 | 10 | - | - | 79 | 15.6000 | 4.639 | 103 | 2.00 | 3.00 | -- | 15 |
| 16 | S-PB | 10.0000 | 200.00 | 33.6000 | 39.800 | - | 41 | 15 | - | - | 47 | 8.1300 | 3.003 | 103 | 3.00 | 5.00 | -- | 16 |
| 17 | S-SN | -- | -- | -- | -- | - | 103 | - | - | - | - | 5.0000 | 1.001 | 103 | 5.00 | 7.00 | -- | 17 |
| 18 | S-SR | 100.0000 | 700.00 | 228.0000 | 176.000 | - | 56 | 6 | - | - | 41 | 86.1000 | 2.088 | 103 | 50.00 | 70.00 | -- | 18 |
| 19 | S-V | 10.0000 | 500.00 | 72.1000 | 79.400 | - | 7 | 11 | - | - | 85 | 29.9000 | 3.428 | 103 | 5.00 | 7.00 | -- | 19 |
| 20 | S-Y | 10.0000 | 70.00 | 24.0000 | 18.100 | - | 48 | 7 | - | - | 48 | 9.5600 | 2.203 | 103 | 5.00 | 7.00 | 3000 | 20 |
| 21 | S-ZN | 500.0000 | 500.00 | 500.0000 | -- | - | 101 | 1 | - | - | 1 | 102.0000 | 1.177 | 103 | 100.00 | 150.00 | -- | 21 |
| 22 | S-ZR | 10.0000 | 300.00 | 79.5000 | 58.800 | - | 21 | - | - | - | 82 | 38.3000 | 3.105 | 103 | 7.00 | 10.00 | 1500 | 22 |
| 23 | AA-AU-P | 0.2000 | 0.20 | 0.2000 | -- | - | 95 | 7 | - | - | 1 | 0.0110 | 1.448 | 103 | 0.01 | 0.03 | -- | 23 |
| 24 | INST-HG | 0.0200 | 0.10 | 0.0324 | 0.020 | - | 1 | 73 | - | - | 29 | 0.0104 | 1.985 | 103 | 0.01 | 0.01 | -- | 24 |
| 25 | CM-CX-HM | 1.0000 | 45.00 | 16.0000 | 16.300 | - | 8 | 67 | 3 | - | 25 | 1.0900 | 5.055 | 103 | 0.30 | 0.50 | 150 | 25 |
| 26 | AC-TH | 2.2893 | 36.48 | 13.5000 | 14.200 | 95 | - | - | - | - | 8 | 8.3300 | 2.854 | 8 | -- | -- | -- | 26 |
| 27 | AC-U | 0.2528 | 7.81 | 2.2800 | 2.670 | 92 | - | - | - | - | 11 | 1.3000 | 3.025 | 11 | -- | -- | -- | 27 |



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